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Prezidează : G. Udubaşa.

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— Savu H., Vâjdea E., Romanescu O. — Vîrsta radiometrică (K/Ar) și originea masivului granitoid de la Săvîrșin și a altor intruziuni neokimmerice din zona Mureș (Tradusă în lb. engleză) (p. 419).

— Borcoș M., Popescu Gh., Roșu E. — Date noi privind stratigrafia și evoluția vulcanismului terțiar din Munții Metaliferi (Tradusă în lb. franceză) (D.S. 70—71/4).

— Kräutner H., Vâjdea E., Romanescu O. — Datarea K-Ar a magmatitelor banatitice din sudul munților Poiana Ruscă (bazinul Rusca Montană) (Tradusă în lb. engleză) (p. 373).

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— Pop Gr. — Formațiunile neocretacice de la Soarbele (Carpații Meridionali) (Tradusă în lb. franceză) (D.S. 70—71/4).

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— Stănoiu I. — O nouă imagine litostratigrafică şi tectonică a „seriei de Tulişa" din versantul nordic al munţilor Parîng cu implicaţii asupra conţinutului şi denumirii noţiunii de „pînză de Severin" (Nu se publică).

SESIUNE FESTIVĂ DE COMUNICĂRI ŞTIINŢIFICE DEDICATĂ CONGRESULUI AL XIII-LEA AL P.C.R.

Şedinţa din 16 noiembrie 1984

Prezidează : I. Bercia.

— Udubaşa G. — Parageneze de minerale opace în roci şi minereuri [1].

— Balintoni I. — Succesiuni şi tipuri de parageneze în unele metamorfite din Carpaţii româneşti [2].

— Hârtopanu P. — Relaţii texturale şi semnificaţia lor genetică în rocile manganifere metamorfozate din Carpaţii Meridionali [3].

— Iancu V. — Asociaţii minerale în roci metamorfice de grad scăzut din Carpaţii Meridionali [4].

— Iancu V., Balintoni I. — Asociaţii şi parageneze minerale în metamorfitele seriei de Baia de Arieş [5].

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[1,2,3,4,5] Lucrări apărute în volumul „Mineral Parageneses", Ed. Theophrastus, Atena, 1985.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

MINERALOGIE

CHEMICAL INHOMOGENEITY OF SPHALERITE FROM BAIA DE ARIEȘ. AN INVESTIGATION WITH THE ELECTRON MICROPROBE [1]

BY

CONSTANTIN LAZĂR [2], NICOLAE FARBAȘ [3]

Electron microprobe. Chemical inhomogeneity. Minor elements. Sphalerite Lead-zinc deposit. Replacement ore. Neogene metallogeny. Apuseni Mountains — Neogene eruptive — Baia de Arieș district.

Abstract

The authors proved by aid of the electron microprobe that an optical homogeneous sphalerite grain from Baia de Arieș lead-zinc ore deposit showed a microchemical heterogeneity. Within a single sphalerite grain there have been investigated the linear distributions of iron, copper and cadmium. The areal distribution of iron, illustrated by the counter map, exhibits an irregular zonal arrangement with a mosaic-like picture. Concerning this question, our results have been compared with the data obtained by other authors.

Résumé

Hétérogénéité chimique de la blende de Baia de Arieș, une investigation à microsonde électronique. Les auteurs démontrent à l'aide de la microsonde électronique que le grain de blende du gisement polymétallique de Baia de Arieș, homogène du point de vue optique, présente une hétérogénéité microchimique.

La distribution linéaire du fer, du cuivre et du cadmium a été étudiée à l'intérieur d'un grain singulier de sphalérite. La distribution aréale du fer, illustrée sur la carte de mesurage (counter map) montre un arrangement zonaire, irrégulier d'aspect mosaïqué.

Nos résultats sont comparés aux données obtenues par d'autres chercheurs concernant ce problème.

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Introduction

The lead-zinc deposit from Baia de Arieş (Apuseni Mountains) is related to Neogene subvolcanic bodies, consisting mainly of andesites. Sphalerite, pyrite and galena are by far the most common minerals of the polymetallic ore.

In the crystallization sequence of the most important ore minerals, recognized under the microscope, sphalerite is placed between the previously formed pyrite and the younger galena. The ore minerals exhibit large depositional intervals, which are partially overlapped (Lazăr, 1963, 1966).

The observations of ore-microscopy, the minor elements contents and the investigation of the fluid inclusions (Lazăr, 1967) show that the sphalerite precipitation developed over a wide range of temperature.

Sphalerite occurs commonly in the replacement ore together with other ore minerals (pyrite, galena, alabandite, fahlore, chalcopyrite, iron oxides, etc.) and "gangue minerals" (especially carbonates and/or quartz). The monomineralic aggregates, consisting exclusively of sphalerite, are less common. The concentrations of massive sphalerite usually occur within hydrothermal altered andesitic matrix of breccia pipes. As a result of successive replacements, the sphalerite grains of both kinds of occurrences are very different in size, but the coarse-grained sphalerite prevails.

Commonly the replacement sphalerite does not display crystallographic outlines. The euhedral sphalerite crystals occur in cavities.

The colour of sphalerite from Baia de Arieş ore deposit changes from yellow to dark-brown. The last one usually characterizes the sphalerite of the massive ore. The thin sphalerite fragments obtained by cleavage are quite transparent to opaque and are very often non-homogeneously coloured. Zones of various colours (yellow, greenish-yellow, brownish-yellow, reddish-yellow, reddish-brown, brown, greenish, greenish-brown, dark-brown etc.) can have either a regular distribution or especially a chaotic one.

A lamellar twinning of the coarse xenoblastic sphalerite grains may be commonly developed.

Chalcopyrite exsolution bodies, which sometimes display an oriented distribution, represent another feature of sphalerite crystals.

As it is noticed during the microscopic investigation, the sphalerite replaces pyrite and may be replaced by the subsequently formed minerals, especially by galena, carbonates and quartz.

Large development of sphalerite crystals as well as their abundance in the ore deposit has favoured the investigation of minor elements content of sphalerite. The first analytical data have been reported in some papers (Iosof, 1962 ; Lazăr, 1963 ; Lazăr, Udubaşa, 1965 ; Udubaşa, Lazăr, 1968 ; Lazăr et al., 1979).

Cu, Ag, Au, Cd, Pb, Fe and Mn were reported to be present in all spectrographic analyses of sphalerite. At the same time, In, Ga, and Sn have been found in many samples of sphalerite spectrographically analysed. The contents of Tl, Ge, As, Mo and Te are very low, being situated below the sensitivity of the quantitative spectrographic analysis.

Sphalerite from Baia de Arieş is rich in Fe, Mn, Pb, Cd, Cu and In ; the elements are given in order of decreasing their average contents (Tab. 1).

TABLE 1

Element	Sphalerite-Baia de Arieş			Sample 29 (+8 m level. Iosif mine)						
	N	Δ ppm	$\overline{X}$ ppm	sp. a.[1] ppm	ch. a. wt %	Fx wt %	Electron microprobe			
							I wt %	II	III	
Ag	46		26	10–30				+	+	(1)
As	5	<300		1000				—	—	
Au *	13		0.0845					++	+++	(3)
Bi	7			10–30				+	+	(3)
Ca								+	+	(2)
Cd	43	2800–10000	4981	>3000			0.44	++	++	(3)
Co	4		6.7	<3				—	—	
Cu	46	180–38000	4463	300–1000	0.06[2]		0.07	—	++	(3)
Fe**	27	3100–142300	30015		3.30[3] 2.86[4]	3.57	3.21	+++	+++	(3)
Ga	38	1.0–500	21.8					+	+	(3)
Ge	34	—		—				+	+	(3)
Hg								+	+	(2)
In	44	5.0–1500	194.8	30–100				—	—	
K								—	++	(3)
Mn	46	1300–32000	12638	>3000	1.40[3]		1.50	++	+++	(3)
Na								++	++	(3)
Ni	7		52.6	3				—	—	
Pb	44	7.5–39000	7834.9	3000				+	—	
S					33.40[3]			++++	++++	(3)
Sb	6			<100				—	+	(1)
Sn	34		29.4	10				+	++	(1)
Te	2	<10						++	++	(3)
Ti	9		40.1					—	—	
Tl	5	<10						—	+	(1)
Zn				>3000	60.0[2]	58		++++	++++	(3)

N = number of determinations } spectrographic analysis
Δ — concentration range } analyst A. Zămîrcă
$\overline{X}$ — average content

sp.a.[1] — spectrographic analysis. Analyst G. Lahovary
ch.a. — chemical analysis. Analyst F. Negrescu (2), S. Iliescu (3) and Al. Medeşan (4)(Udubaşa et al., 1974).
Fx — determined by X-ray fluorescence method. Analyst R. Giuşcă
I — quantitative electron microprobe analysis. Analyst J. Ottemann (Udubaşa et al., 1974).
II, III — qualitative electron probe microanalysis.
Abundance of elements : + very small amounts ; ++ small amount ; +++ high amount ; ++++ very high amount
Au * determined by neutron activation method (RNAA). Analyst Ş. Anastase (Lazăr, Anastase, 1983)
Fe ** determined by spectrographic analysis. Analyst A. Zămîrcă ; determined by X-ray fluorescence. Analyst R. Giuşcă.

The obtained data indicate no significant variations of Cd, Ni and Mn content, whereas the Ga, Bi and Ti contents show a considerable dispersion of contents. In Table 1 are also listed the concentration range of Mn, Fe, Cu, Cd, Ga, In and Pb.

Changes in the chemical composition of sphalerite characterized by wide range in minor element abundances have been also revealed by analytical data obtained on two sphalerite samples separated from the same handspecimen (Tab. 2).

TABLE 2

Sample	Cu	Ag	Cd	Ga	In	Pb	Sb	Fe	Ni	Mn
40	2850	10.5	4100	<10	100	3800	<100	40100	48	10000
40a	6000	16.0	5800	2.0	9	4100	45		<10	18500

The samples were spectrographically analysed for Cu, Ag, Cd, Ga, In, Pb, Sb, Ni and Mn (analyst A. Zămîrcă). Iron determined by X-ray fluorescence (analyst R. Giuşcă). Contents are given in ppm.

For the geochemical investigation of sphalerite, previous data obtained by different analytical methods (spectrographic analysis, chemical analysis, polarographic analysis, X-ray fluorescence and RNAA) have been compared with those obtained by electron microprobe analysis (EMA). At the same time EMA has supplemented the list of minor elements, which were found in sphalerite (Tab. 1) and, especially gives the first data regarding spatial distribution of some minor elements within sphalerite grains from the Baia de Arieş ore deposit.

These aspects represent the subject of the present paper.

Materials and methods

The sphalerite sample was collected from a lens-shaped ore pocket occurring within No. 3 ore-body of the "Iosif Nou" stockwork on the +8 m level of the Baia de Arieş mine (Fig. 1).

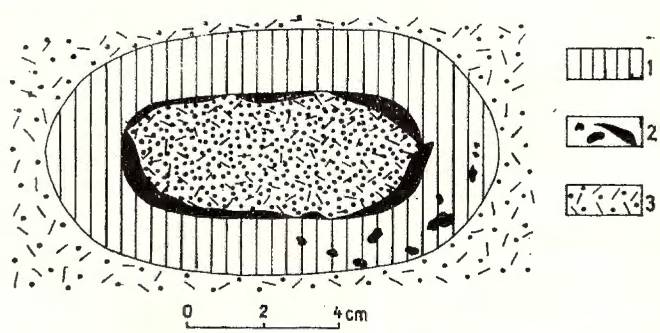

Fig. 1. — Section through a polymetallic ore lens.
1, polymetallic ore consisting mainly of sphalerite ; 2, pyrite ; 3, altered andesitic breccia.

Dark brown sphalerite is associated with pyrite, some galena and "gangue minerals". The sulphides are generally coarse-grained.

In the polished section of about 6 mm thickness, prepared for the analysis, between sphalerite and pyrite occurs a very narrow band of galena (Fig. 2). The interfaces between the areas occupied by the above mentioned ore minerals are perpendicular to the polished surface. The "gangue minerals" occur both as infiltration veinlets along the galena band and as small inclusions in the sulphides.

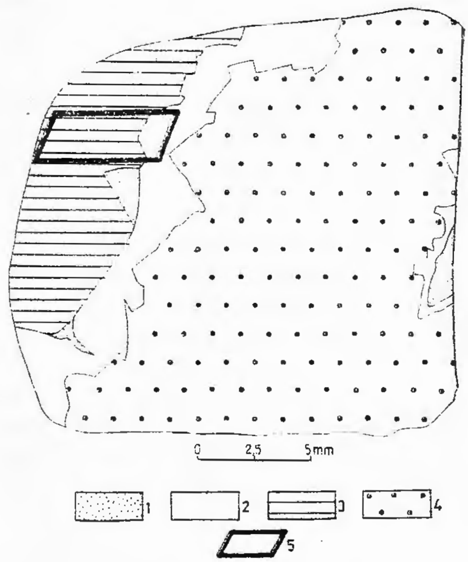

Fig. 2. — Position of investigated area on the polished section. 1, carbonates ; 2, galena ; 3, sphalerite ; 4, pyrite ; 5, investigated area.

The polished section was repolished with diamond paste.

After a careful investigation of the polished section under the ore microscope, a characteristic area of sphalerite was selected to be examined with the electron microprobe (Pl. I, fig. 1). Then the polished surface was sputtered with a carbon coat in a high vacuum chamber.

The analyses were carried out in the Laboratory for textural investigations and analyses of ISIM-Timişoara with an JEOL-JCXA-50A Electron Probe Microanalyzer.

X-ray excitation was achieved by an electron-beam, normal to the sample surface. Accelerating voltage : 25 KV for all measurements. Probe diameter : 2 µm and 100 µm for qualitative analysis and 2 µm for the investigation of linear and areal element distribution. The analyzing crystals of the two-channel EP-microanalyzer were RAP, PET and LiF.

To avoid uncertainties we did first the redetermination of the occurring minerals in the selected area. For this we compared the electron image of composition (COMPO) with the X-ray scanning pictures for Zn, Pb, S, Ca and Mg (Pl. I, Fig. 2 ; Pl. II, Fig. 1-3 ; Pl. III, Fig. 1-3).

A line scan carried out through the same site reveals the simultaneous variation of Zn, Pb, S, Ca and Mg contents (Fig. 3) as well as of Fe and Mn contents (Pl. I, Fig. 3).

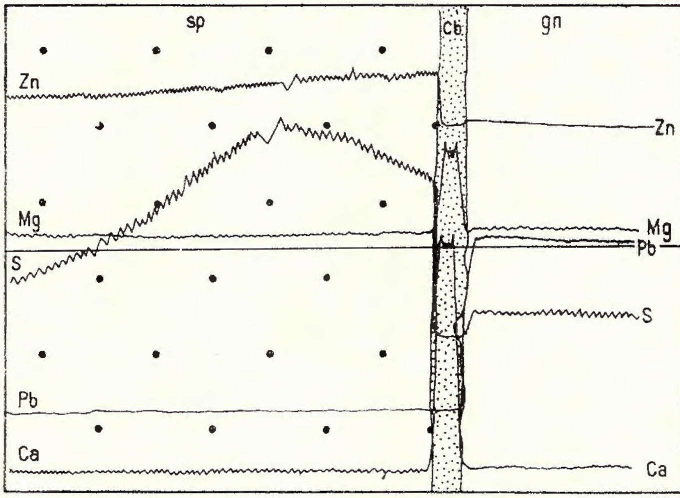

Fig. 3. — Line scans of the elements ZnK_α, PbL_α, SK_α CaK_α, and MgK_α at the boundary between sphalerite (sp) and galena (gn), where there is a narrow band of carbonates (cb). × 300.

A site within a larger sphalerite area, which is characterized by lack of inclusions of other minerals, was selected in order to prevent the influence of iron and/or copper-rich minerals (Yui, Czamanske, 1971). Here a high speed qualitative analysis, using a special program by aid of a PDP 8/m computer connected to the microanalyzer, was undertaken. To provide a representative measurement, a widely spot size (100 µm in diameter) was used. Based on the recorded CPS (counts/sec) values were determined the elements present in the sphalerite. Estimating those abundances in the mineral composition, the elements can be divided into four qualitative groups. The results are listed in Table 1 (Column II).

A second analysis was carried out using the same program. The analytical conditions were as follows : probe diameter 2 µm, counting time 1 second, accelerating voltage 25 KV and the sample current 1.10^{-7} A[4]. The measurements have been carried out along a profile in three points, situated at different distances from the margin of the sphalerite grain (Fig. 4). The movement of the specimen from one point to another was done manually. The mean value of the above mentioned three measurements is given in Column III of Table 1, in the same manner as in Column II. But before this the CPS values recorded during the measurements for each chemical element were recalculated on a common base for RAP + PET and for LiF respectively. Therefore the influence determined by the variation of current intensity during the measurements has been eliminated.

Along a second profile, which is slightly deviated from the first one and is oriented approximately perpendicular to the boundary be-

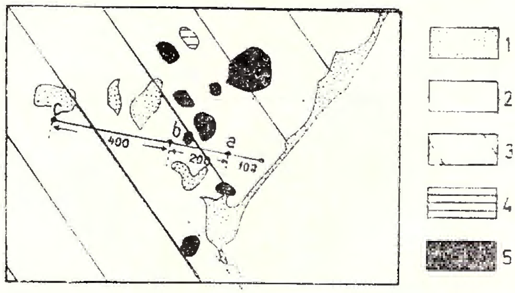

Fig. 4. — Location of microprobe traverse for the qualitative analysis on the polished section. 1, carbonates ; 2, galena ; 3, sphalerite ; 4, pyrite ; 5, vugs ; a, b, c, qualitative point analyses ; 100, 200, 400-distance in µm. For general setting see plate I, fig. 1.

tween sphalerite and galena, have been determined the uncorrected Mn-, Fe-, Cu-, Cd- and Zn- contents in sphalerite, using a program for quantitative analysis. The measurements were carried out under the following analytical conditions : electron-beam 2 µm in diameter, counting time 3×15 seconds/point, I curr. 9×10^{-8}A. Mn, Fe and Cu was simultaneously determined, whereas Cd and Zn was separately determined. The obtained results were used to draw the diagram given in Figure 5.

We have investigated the distribution of iron along a profile by means of a computer program concerning the linear element distribution. Therefore, we selected a traverse of 2500 µm oriented approximately perpendicular to the sphalerite-galena boundary. The automatic moving of the specimen by a step of 50 µm has been led to 50 pointform measurements. The electron beam was 2 µm in diameter ; counting time one second/point. The variation of iron content along the traverse in sphalerite is shown in Figure 6. The uncorrected values for iron have been obtained by means of the relation between iron concentration in the sample and pure iron from microprobe equipment.

The distribution of Cd along a profile of 3000 µm, which crosses completely the sphalerite grain along a little deviated line from those along which has been determined the Mn, Fe, Cu, Cd and Zn contents, was investigated using also the same LED-program. The results are shown in Figure 7.

We have also determined the linear distribution of copper in sphalerite on a site where occur chalcopyrite blebs (exsolution bodies)

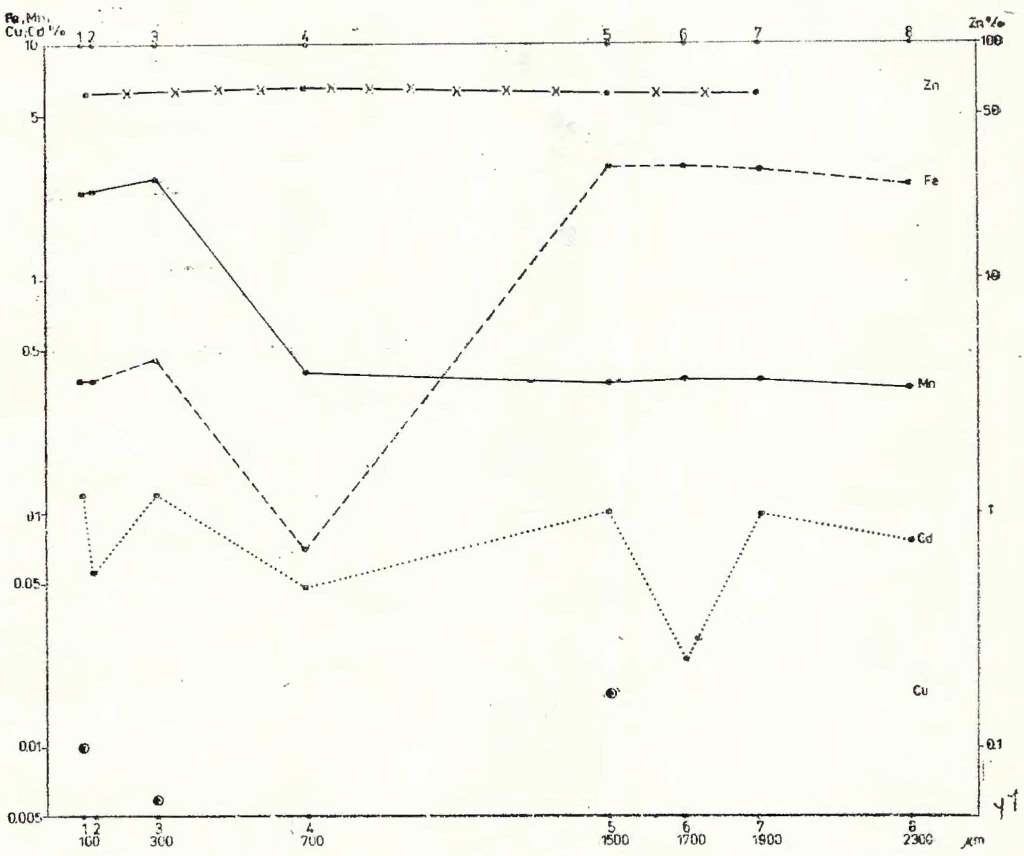

Fig. 5. — Variation diagram of Zn, Fe, Mn, Cd and Cu content within a sphalerite grain.

which have been tested before by line scan for Fe and Cu and by X-ray images for Fe, Cu, Zn and S (Pl. IV, Pl. V). Here there have been performed 50 point-by-point measurements (spot size 2 µm in diameter, counting time : one second/one point) along two traverses of 2500 µm and 250 µm oriented generally parallel to those for iron, which correspond to the intervals of 50 µm and 5 µm respectively, between two successive points. The last interval was necessary

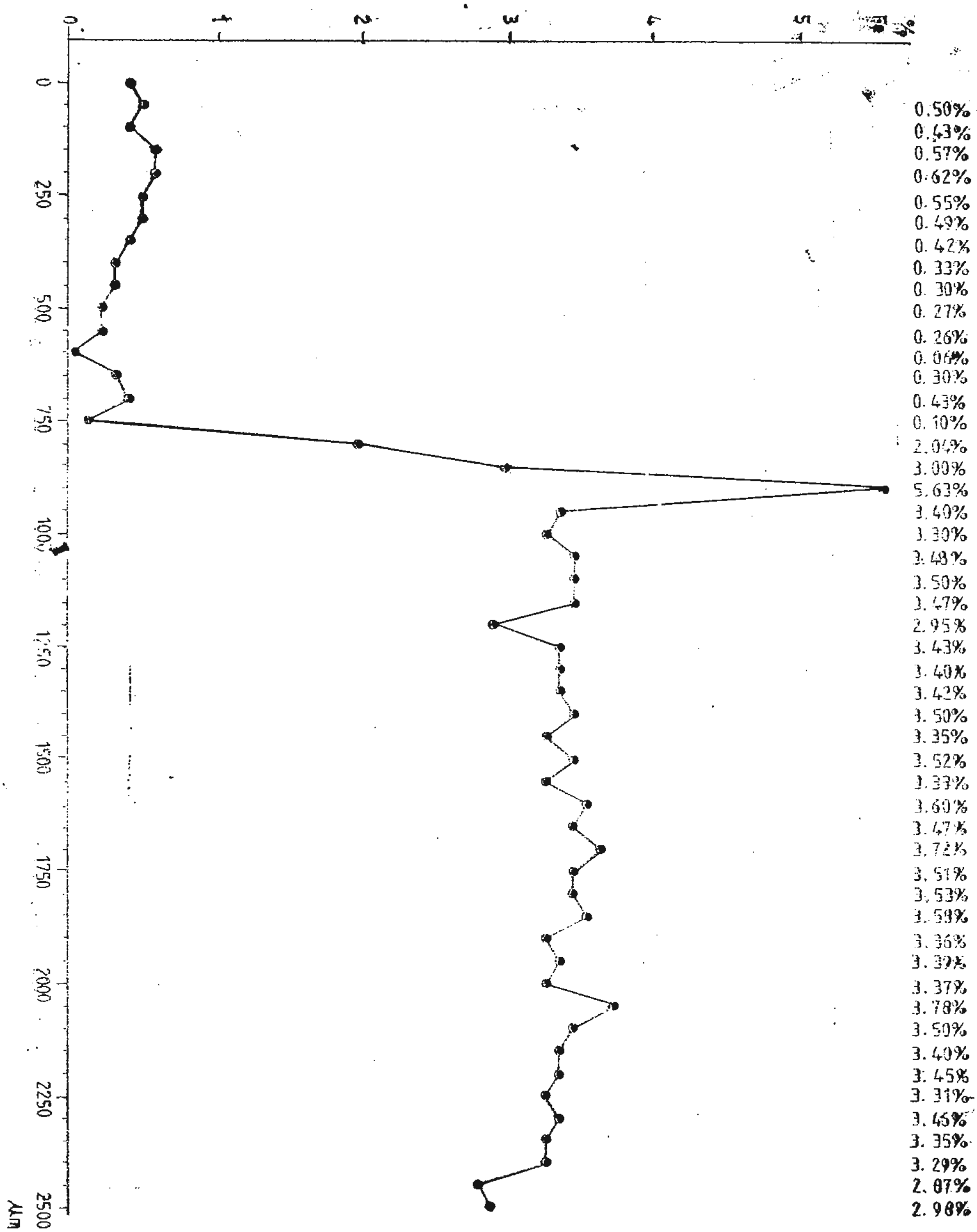

Fig. 6. — Linear iron distribution within a sphalerite grain.

because of the presence of minute exsolution bodies of chalcopyrite; in this case, Figure 8 illustrates the variation of copper content.

Taking into account the positive indications concerning the variation of the iron content of sphalerite, obtained by means of previous methods

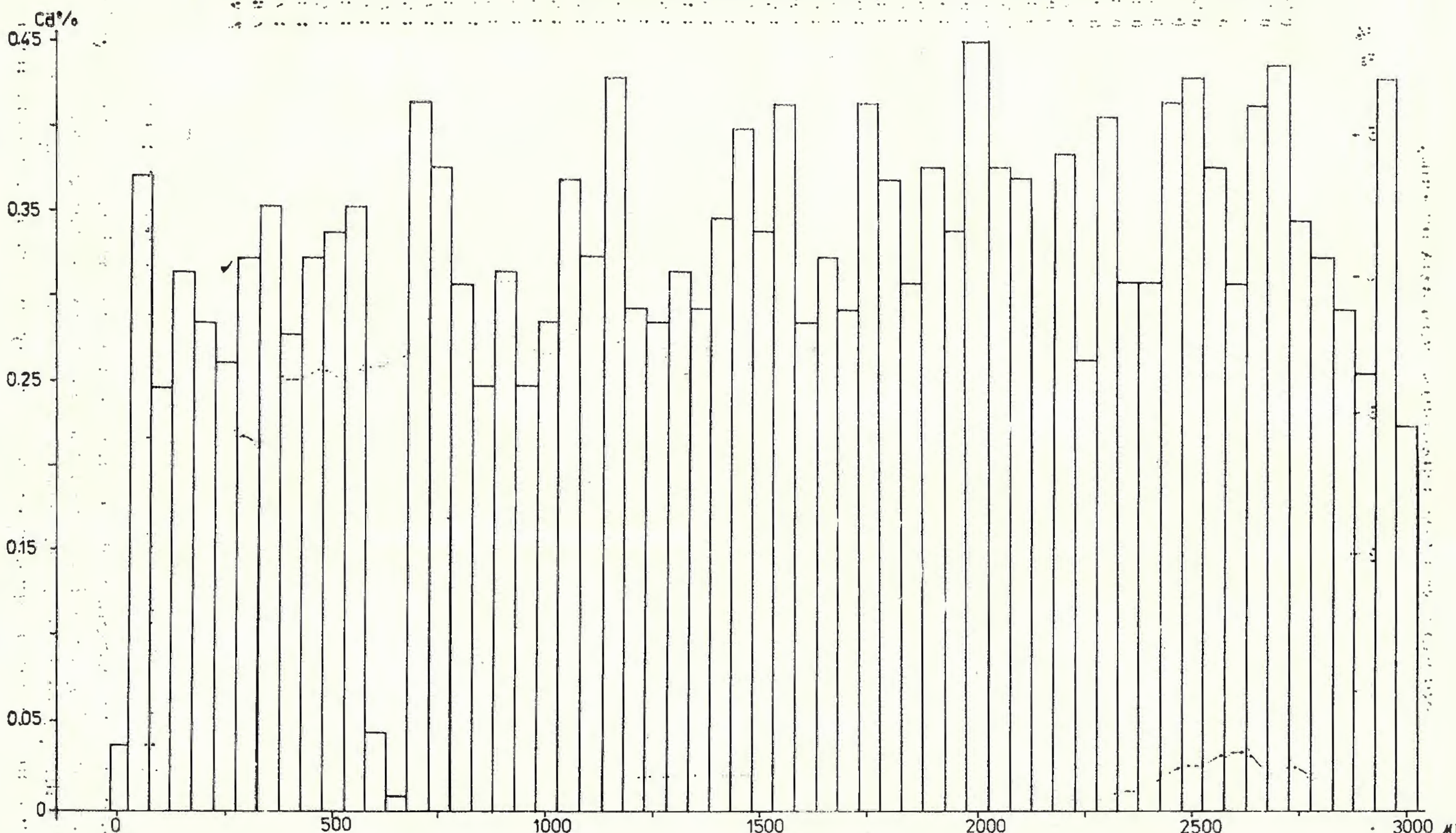

Fig. 7. — Linear distribution of cadmium within a sphalerite grain.

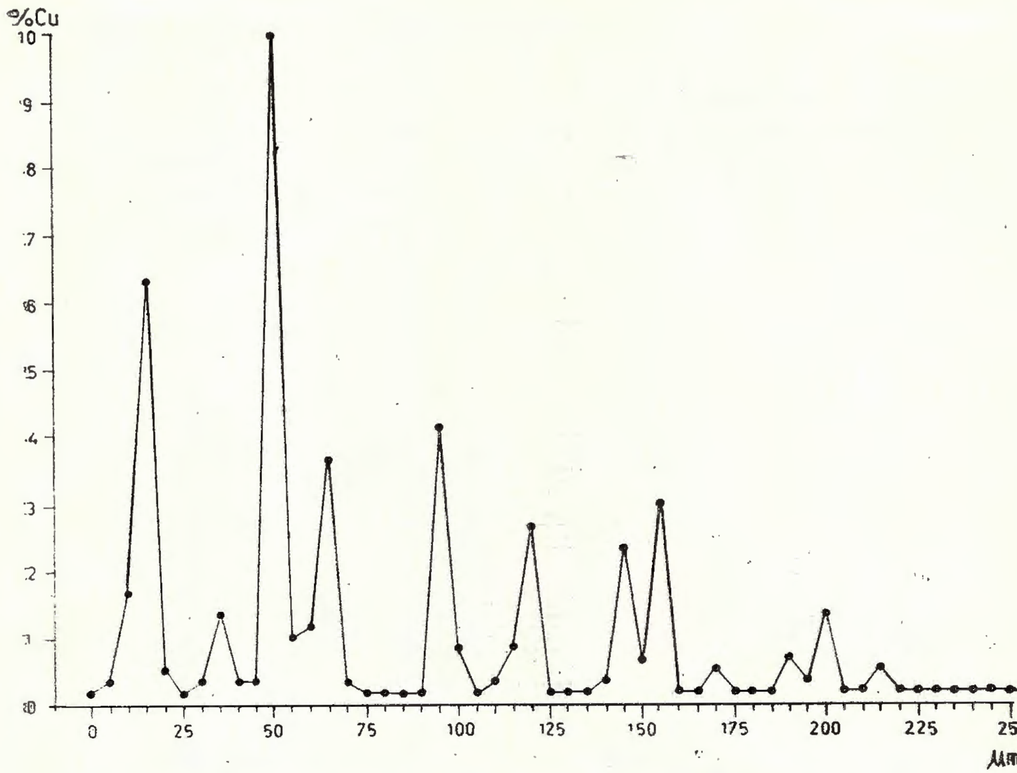

Fig. 8. — Linear distribution of copper within a sphalerite grain.

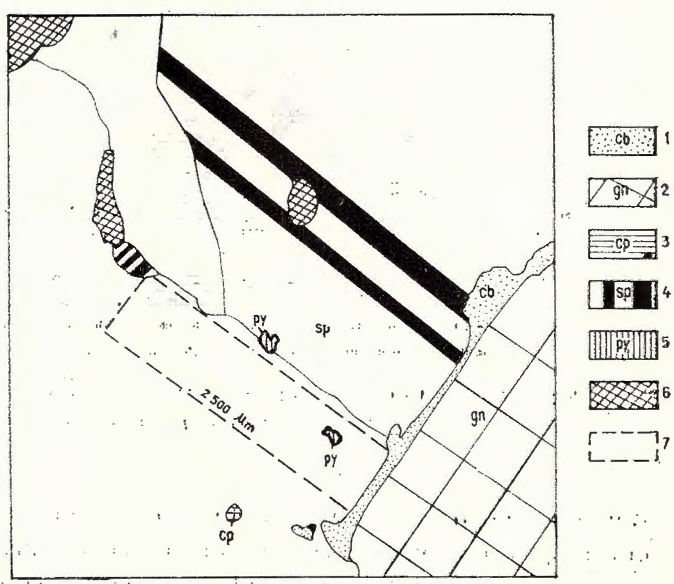

Fig. 9. — Position of counter map on the polished section. Grain boundaries developed by etching. 1, carbonates; 2, galena; 3, chalcopyrite; 4, sphalerite with twinning lamellae; 5, pyrite; 6, vugs; 7, map outline.

(line scanning, qualitative and semiquantitative analysis, linear distribution) we have undertaken the investigation of areal distribution of iron in sphalerite using a special worked out computer program. A number of 1581 measurements have been performed (spot size 2 µm in diameter, counting time 1 sec/1 point, current intensity 1.10^{-7}A) on a microarea of about 600 µm $\times$ 2500 µm, placed at the border of sphalerite grain. During the automatic moving of the specimen the y-axis was approximately perpendicular to the sphalerite-galena boundary (Fig. 9). The

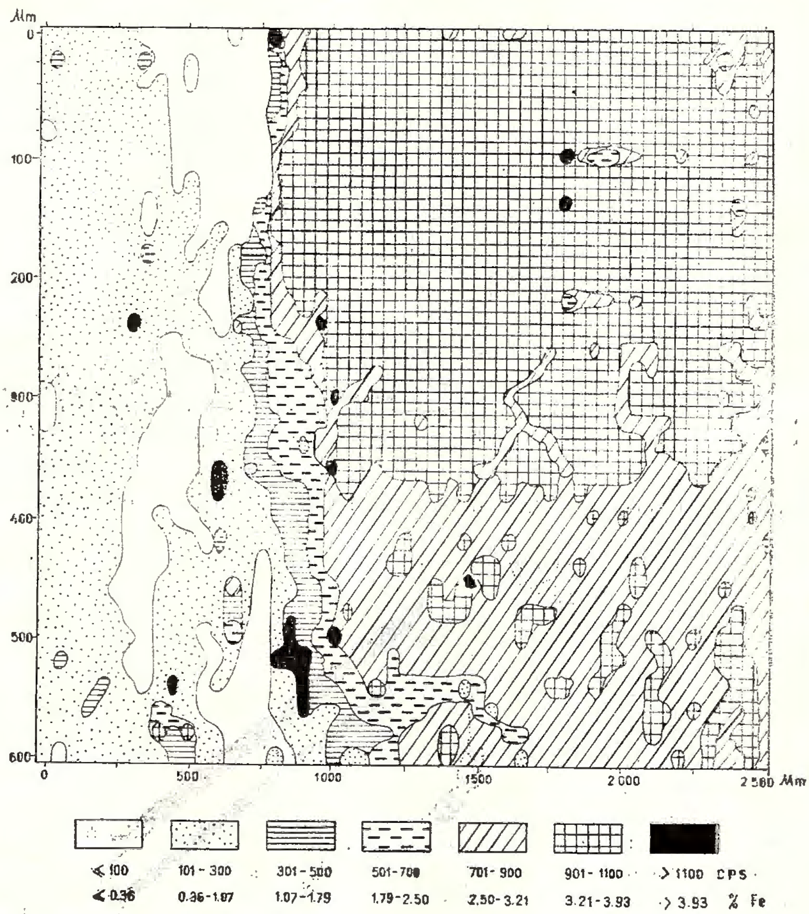

Fig. 10. — Counter map processed for areal distribution of iron within a single grain of sphalerite.

raw counter map, drawn up by the computer has been worked out outlining areas which correspond to seven arbitrarily selected CPS-values, concentration ranges of iron respectively (Fig. 10).

The internal nature of the investigated area of the sphalerite has been developed through structure etching. After removing the carbon coat, the polished section has been etched with a mixture of HCl + HNO_3 (solution in distilled water in a ratio of 1 : 3) during 15 minutes and then examined under the ore microscope.

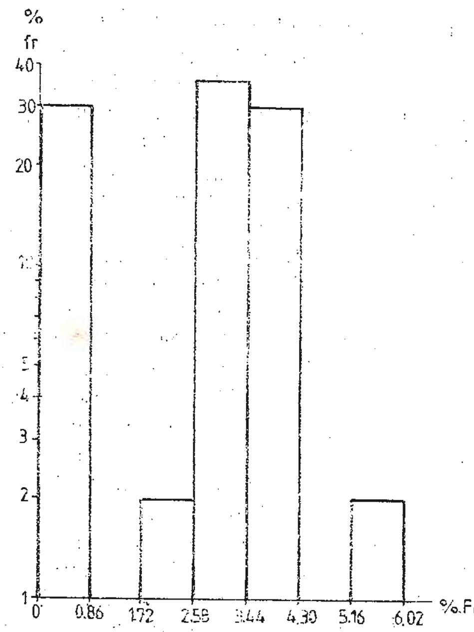

Fig. 11. — Hystogram of iron contents in sphalerite along a microprobe traverse of 2 500 µm.

Results

The main results of the electron microprobe investigation are given below.

X-ray scanning pictures of the distribution of the Zn, Pb, S, Ca and Mg in the area selected for analysis (Pl. II, Fig. 2, 3 ; Pl. III, Fig. 1-3) confirm the determinations made by the reflected light microscopy.

The line scan reveals that the variation curves for S, Zn and Pb present a minimum corresponding to the band which is placed between sphalerite and galena. At the same time, here it is noticed an increasing of the Ca, Mg and Mn content. This fact gives us indications about the complex composition of the carbonate infiltrated between sphalerite and galena aggregates. The abundance of Ca and Mg in sphalerite is the same as in galena, whereas iron and manganese contents are higher in sphalerite than in the associated galena. The iron content of sphalerite shows significant variations along the line scan direction (Pl. I, Fig. 3).

On the basis of the large spot size qualitative analysis one can indicate the presence of the following elements (divided into four groups mentioned below) : Zn and S (in appreciable amounts) ; Fe (in moderate amount) ; Na, Mn, Au, Cd and Te (in small amounts) and

Ca, Ag, Hg, Ga, Ge, Sn, Pb, Bi (in very small amounts) (Column II, Table 1).

The second type of qualitative analysis (with narrow spot) along a profile (Fig. 4) shows a few different results in comparison with previous measurements ; there occur much more elements, among these we notice the presence of copper ; other elements — Mn for instance — can be considered more abundant on account of these measurements (Column III, Table 1). In brackets is given the number of measurements in which the element has been found. If we examine the CPS values corrected for current intensity variations, we can see that some elements (Mn, Fe, Cu, Au, Ga, etc.) exhibit however obvious differences. This can suggest at least in part that the content of one and the same element is different in these three measurement points within the same sphalerite grain. This supposition has been verified and confirmed for Mn, Fe, Cu and Cd. The Cu, Fe and Mn content fluctuates whereas the cadmium concentration is relatively uniform (Fig. 5). We found that the zinc content of sphalerite varies inversely with the added contents of Fe, Mn, Cd and Cu.

It should be mentioned here that the investigation of linear iron distribution, where 50 counts were taken by step scanning at 50 μm intervals along a 2 500 μm traverse, shows a variation of iron content. Its amount ranges from 0.06% to 5.63% with an average of 2.50 weight percent (not corrected values !). By means of computer we draw up a diagram which has been worked out in Figure 6. It is possible to distinguish two zones : a low-iron zone (Fe $\leq$ 0.62%) and an iron-richer zone (2.95—3.78% Fe). Each zone presents small variations of iron content. It can be noticed an abrupt transition from one zone to another marked by maximum content of iron (5.63% Fe), determined along the traverse.

In comparison with iron, cadmium is more uniformely distributed. Its uncorrected content ranges from 0.22 to 0.45 wt.%. There are three small values (Fig. 7), corresponding to galena (the first one) and to inclusions of "gangue minerals" from sphalerite (the other two values). The average Cd-content ($\bar{x}_{60}$=0.32%) as well as Fe-content is lower than the corrected content, which was previously established (Table 1, Column I).

The electron probe microanalysis confirmed the optical determination of the exsolution bodies from sphalerite and at the same time it has permitted us to identify the minute micron-sized exsolved particles, which optically cannot be determined. One can see both a superposition of the peaks of the variation curves for iron and copper (Pl. IV, Fig. 2) and a similarity of the X-ray scanning images for FeKα and CuKα (Pl. IV, Fig. 3 ; Pl. V, Fig. 1) which are complementary to that for ZnKα (Pl. V, Fig. 2). Uniform distribution of the sulphur in the same area proves that the smallest exsolution bodies consist of an iron-copper sulphide which contains more copper than iron. On the basis of this fact we can assign to chalcopyrite the exsolved phase.

The linear distribution of copper within an area in sphalerite grain in which occur exsolution bodies of chalcopyrite is shown in

Figure 8. The automatically recorded diagram shows marked variation of the copper content. Cu poor zones (Cu-content less than 0.1%) alternate with zones showing moderate enrichment of copper in sphalerite. The higher Cu-content (about 10%) corresponds to exsolution bodies of chalcopyrite, partly included in the measurement spot surface.

In the counter map obtained by means of the computer are listed signs and numbers corresponding to 12 quantitative classes, separated on the basis of CPS-values. Examination of the raw computer map reveals a relatively irregular distribution of iron within the investigated area of sphalerite. But the worked out map exhibits that the very low and low iron contents constitute strips oriented parallel to the margin of the sphalerite grain and situated in its external part. Here can occur limited zones with moderate, high and very high iron content (Fig. 10). The inner part is much richer in iron being generally homogeneous but having a trend to develop a zoning.

We come to the conclusion that in the investigated area, sphalerite is relatively rich in iron if we take into account that more than 60% of the map surface belongs to the classes with high iron content (2.50—3.93% Fe).

Recognition of the internal texture of the investigated sphalerite aggregate was possible by structure etching. It can be seen that all measurements have been made in a single sphalerite grain (Fig. 9). Twinning lamellae are also present in other grains.

Discussion

A sphalerite sample has been selected under a binocular microscope from the same handspecimen out of which the investigated polished section was prepared too. This sample has been analysed by different methods, the analytical data being listed in Table I. Another polished section prepared from the same specimen was analysed by electron probe for Mn, Fe, Cu and Cd (Udubaşa et al., 1974). The contents are listed in Table 1 too.

The results obtained by means of microprobe analysis agree with those obtained by other analytical methods (Tab. 1).

Examining the results of qualitative analyses which were obtained through large measurement spot (Column II) and through focussed measurement spot, we can point out the following : (1) the number of chemical elements which were found is different being higher in Column III ; (2) most part of the elements (80%) is common to both kinds of measurements ; (3) 12 from 20 common elements belong to the same qualitative classes in both columns ; (4) showing a higher Mn amount and the presence of Cu and Sb, data from Column III are much closer to those obtained by other analytical methods ; (5) if we take into account the presence of Pb, Au and Sn, data listed in Column II seem to be more real.

Comparing the corrected CPS-values obtained during the three collinear point-by-point measurements, it is noticed that Cu, Ga and Fe have the highest variations. Variation of Mn abundance is less important whereas the Cd content seems to be more constant. These estimations generally agree with the conclusions which result from the spectrographic analysis (Tab. 1). Chemical elements revealing variations in the qualitative microprobe analysis along a traverse show in seven of nine cases, the same correlations which have been established by quantitative spectral analysis.

At the same time, it must be underlined that there are situations when the ratio of some microcomponents of sphalerite — calculated on account of CPS values obtained by qualitative analysis — may be misrepresented. So, the true gold content of sphalerite within the investigated sample is much lower than that of Cu and Cd. The high CPS value of gold represents in fact a second radiation of zinc (Zn $K_{\beta 2}$).

On the basis of the above facts, we can conclude that the estimation of minor elements abundances in sphalerite, established on account of qualitative analysis, must be regarded as approximations. It is closer to the true situation when one compare two successive elements in the Periodic Table, having similar X-ray fluorescence behaviour. A quantitative interpretation on the basis of CPS in qualitative analysis should be inexact because the CPS value is determined by: 1) the atomic number of the element; 2) the counted position against the position of the peak and 3) the intensity of current during the measurement.

The change of Fe-, Mn-, Cd- and Cu- contents within the sphalerite grain supposed on the basis of qualitative analysis, was confirmed for iron by quantitative analysis. The contents which are found ranging from 0.00 percent to 3.05 percent, have not compensated for absorption, fluorescence and atomic number effect. These corrections would have little effect on the recorded values when low contents are determined (Einaudi, 1968).

The negative correlation between Zn-content and Fe-, Mn-, Cd-, and Cu- contents on the other hand, clearly proves that these four elements substitute for zinc in the sphalerite structure.

Variations of Zn-, Fe-, Cu-, Mn- and Cd- content are also illustrated by the concentration curves recorded along 200 µm long traverses in sphalerites from some tin deposits in Transbaikalia, which were optically homogeneous and free of inclusions of other minerals (Dolomanova et al., 1971).

Sphalerite "in all colours" associated with pyrite, calcite, etc., has been reported from the Iosif mine of Baia de Arieş deposit during the last century (Ackner, 1855, p. 334).

Within the "ore stockwork" from limestones, Fellenberg described brown, brownish-red, greenish and oil green, black or brownish-black sphalerite (Cotta, 1862, p. 169).

The above observations refer to sphalerite occurrences at the upper part of the ore deposit. Sphalerite occurring on deeper levels of the deposit shows a large chromatic series (Lazăr, 1962, 1966, 1967).

Several authors (Kullerud, 1959; Palache et al., 1963; Ramdohr, Strunz, 1967 etc.) consider that the colour of sphalerite is a function of its iron content and changes from light yellow to black.

In Uytenbogaard's and Burke's opinion (1971), the colour of sphalerite is not always in correlation with the iron content. Roedder and Dwornik pointed out that the iron content cannot be correlated with band colour of minutely banded colloform sphalerite from Pine Point (Canada), which has been investigated by aid of EMA.

It is well-known that natural sphalerite always contains variable amount of iron substituting for zinc.

As it results from Table 3, a correlation can be established between iron content of sphalerite and its colour.

TABLE 3

Sphalerite :	1	2	3	4	5	6	7	8	9	10	11	12	13
(Fe (wt %)	0.57	1.37	12.19	12.738	14.36	0.55	1.05	2.1	3.0	3.45	5.97	3.235	2.50

1 — brown-yellow sphalerite — Capnic (Sipöcz, 1886)
2 — red-brownish sphalerite — Săcărîmb (Sipöcz, 1886)
3 — black sphalerite — Rodna (Sipöcz, 1886)
4 — black sphalerite — Rodna (Loczka, 1886)
5 — black sphalerite — Rodna (Udubaşa et al., 1974)
6 — yellow sphalerite — Baia de Arieş (Lazăr et al., 1979)
7 — yellow-brown sphalerite — Baia de Arieş (Lazăr, unpublished)
8 — brown-reddish sphalerite — Baia de Arieş (Lazăr et el., 1979)
9 — brown-reddish sphalerite — Baia de Arieş, (Lazăr, 1967)
10 — brown sphalerite — Baia de Arieş (Lazăr, unpublished)
11 — brown sphalerite — Baia de Arieş (Lazăr, 1967)
12 — brown sphalerite — Baia de Arieş (sample 29, mean value of the previous data)
13 — brown sphalerite — Baia de Arieş (sample 29, uncorrected average content, this paper).

The brownish-orange internal reflections of isotropic sphalerite from our polished section suggest a low iron content, which has been confirmed both by previous data and by our analytical data.

Lately numerous examples of chemical heterogeneity within a single crystal of some minerals have been reported using the electron probe microanalyzer : olivine and chrome spinel (Hoffman, Walker, 1978), spinels (Hollander, 1968), minerals of the tennantite-tetrahedrite series (Yui, 1971), zoning in copper-bearing pyrite (Frenzel, Ottemann, 1967 ; Einaudi, 1968) zoning in arsenic-bearing pyrite (Burkart-Baumann und Ottemann, 1971), banded sphalerite (Roedder and Dwornik, 1968), sphalerite (Dolomanova et al., 1971), silver-bearing sphalerite (Taylor and Radtke, 1969) and iron-bearing sphalerite (Pantó, Pantó, 1972).

The iron content of sphalerite from the Baia de Arieş ores ranges from 0.06 to 5.63 percent as shown by the linear distribution of the element using the electron microprobe. The highest frequency is situated between 2.58 and 3.44 percent (Fig. 11) whereas the arithmetic mean is 2.50% Fe.

The isoconcentration map, presented in the figure 10, shows a deformation of the real image, respectively of the topomicrochemical image of the sphalerite grain, which has been determined by the compressed scale on the abscissa of the typewriter. But this fact will not modify essentially the conclusions, which can be drawn on account of its examination. The most characteristic features of iron distribution within a single grain of sphalerite is the zoning. This image is more or less similar to those obtained on traverses oriented radially across the sphalerite grain (Pantó, Pantó, 1972).

By investigating the linear distribution of copper along a 250 μm traverse, the analysed part represents, as a whole, about 100 μm. Therefore, the analysis for copper can be considered to be representative for the investigated area of sphalerite. Here occur, in an irregular alternance, low and high copper contents.

Cadmium presents also a heterogeneous distribution in the analysed sphalerite.

Udubaşa and Istrate (1976) have pointed out that the inner brown zones of sphalerite from Coranda-Hondol (Metaliferi Mts) contain Sn, In, Ag and Au, which cannot be found in the external cleiophanic zones of the same sphalerite grain.

Conclusions

Electron microprobe analyser complements and extends the use of reflected light microscopy, chemical and spectrographic analysis and X-ray diffraction in mineralogy.

In order to investigate the distribution of some minor elements within individual sphalerite grains, we have used an electron microprobe analyser controlled by computer. In addition to the classical X-ray pictures and line scan the electron microprobe analyser using special programs elaborated by one of the authors of the present paper and JEOL allowed to investigate the linear and areal distribution of the elements on large areas.

Qualitative and quantitative microprobe analyses carried out in a site or along a traverse, at unequal or equidistant intervals, have demonstrated that : (1) changes concerning the minor element content in sphalerite are much more pronounced than those inferred from the heterogeneity of colour and (2) chemical and/or spectrographical data give only informations about bulk composition of the sphalerite.

The electron probe microanalysis of sphalerite from Baia de Arieş showed a small scale inhomogeneity concerning the distribution of Zn, Fe, Mn, Cd and Cu within the sphalerite grain and at the same time, its zonal microstructures with a less mosaic-like picture which is revealed by iron distribution.

To give an explanation for the distribution type of the analysed elements, first of all of iron, within the sphalerite grain, it is reasonable to admit that : (1) at the time of sphalerite precipitation, the concentration of some elements, e.g. Zn, Fe, Mn, Cd, Cu in the ore forming solutions underwent numerous changes sometimes inducing important differences of concentration between two points situated at a relatively very small distance, of a few microns and (2) the replacing power of iron (Fe^{2+}) presented variation, controlled by the physico-chemical conditions governing the precipitation of sphalerite during the metasomatic process.

The above mentioned results are comparable with those obtained by other authors concerning the distribution of individual minor elements in sphalerite.

The study of minerals with regard to their chemical inhomogeneity by electron probe should be continued using quantitative analysis ; all data obtained during these measurements must, however, be corrected.

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[4] In all measurements are given the specimen current intensities.

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NEOMOGENITATEA CHIMICĂ A BLENDEI DE LA BAIA DE ARIEŞ, O INVESTIGARE CU MICROSONDA ELECTRONICĂ

(Rezumat)

În zăcămîntul de la Baia de Arieş, blenda este, alături de pirită şi galenă, un component principal al paragenezei de sulfuri.

De obicei, blenda metasomatică este lipsită de contururi proprii, cristale idiomorfe fiind prezente în geode.

Culoarea blendei este foarte variată, de la galben-cafenie pînă la brun-închisă.

Prezenţa corpurilor de dezamestec de calcopirită şi a maclelor lamelare constituie caracteristici ale structurii interne a cristalelor de blendă.

Larga dezvoltare a granulelor de blendă, ca şi abundenţa ei în zăcămînt au favorizat cercetarea elementelor minore din blendă.

Datele anterioare, privind geochimia sfaleritului, obţinute prin diferite metode analitice, sînt sintetizate în tabelul 1.

Variaţia chimismului blendelor din zăcămîntul polimetalic, în ceea ce priveşte concentraţia microcomponenţilor, este pusă în evidenţă, de asemenea, de datele analitice, obţinute prin analiză spectrală, pe două probe monominerale de blendă, provenind din acelaşi eşantion (tab. 2).

Detalii privind proba de blendă analizată cu microsonda electronică (MSE), date sumare privind aparatura şi procedeele analitice folosite, fac obiectul capitolului „Materiale şi metode". Referitor la acestea din urmă, ţinem să precizăm că au fost executate următoarele : confirmarea mineralelor — stabilite pe cale optică — din cîmpul selectat, cu ajutorul imaginilor electronice de compoziţie şi de Rx (pl. II-V) ; determinarea variaţiei liniare a principalilor componenţi ai mineralelor din cîmp (Zn, Pb, S, Fe, Mn, Ca şi Mg) (fig. 3, p. I, fig. 3) ; analiză calitativă rapidă pe bază de program cu un spot de 100 μm şi spot focalizat (~ 2 microni) — în acest din urmă caz în 3 puncte inechidistante, situate în lungul unui profil ; stabilirea conţinutului de Mn, Fe, Cu, Cd şi Zn (valori procentuale necorectate, fig. 5) pe un profil uşor deviat faţă de precedentul, utilizînd un program pentru analiză cantitativă ; investigarea distribuţiei Fe în lungul unui profil de 2 500 μm şi stabilirea conţinuturilor (valori necorectate) prin raportare la un etalon de Fe pur (fig. 6) ; a fost urmărită variaţia conţinutului de Cd pe o traversă de 3 000 μm, pe baza aceluiaşi program LED (fig. 7) ; variaţia liniară a Cu a fost testată prin analiză punctiformă utilizînd un pas de 50 μm şi de 5 μm. Prezenţa dezamestecurilor de calcopirită în blendă ne-a determinat să optăm pentru ultima variantă, rezultatele fiind redate în figura 8 ; cercetarea distribuţiei areale a Fe — scop în care au fost executate, pe bază de program, 1 581 de măsurători pe o suprafaţă de cca 600 × 2 500 μm (fig. 10). Ulterior, prin atac structural, a fost verificată premisa că toate măsurătorile au fost executate în interiorul unui singur granul (cristal) de blendă (fig. 9).

Rezultatele tuturor acestor metode de cercetare a omogeneităţii chimice a blendei sînt prezentate în capitolul următor, iar comentarea lor în capitolul „Discuţii", principalele concluzii, care pot fi desprinse pe baza acestui studiu fiind reunite în ultimul capitol al lucrării. Vom releva, în cele ce urmează, doar cele mai semnificative aspecte prezentate în aceste ultime trei capitole.

Analizele calitative şi cantitative executate local, în lungul unui profil sau pe o suprafaţă dintr-un granul de blendă, cu ajutorul MSE comandată de calculator, utilizînd programe speciale, au arătat că :

— numărul microcomponenţilor blendei este mai mare decît acela stabilit pe baza analizei spectrale de emisie ;

— analiza spectrală, analiza chimică şi alte metode analitice (polarografie, fluorescenţă de Rx, spectrometrie de absorbţie atomică etc.) ne dau informaţii numai în ceea ce priveşte chimismul global al mineralului ;

— rezultatele analizelor cu MSE — cu toate că diferă volumul de material investigat — sînt în bună concordanţă cu cele obţinute prin alte metode analitice ;

— estimarea abundenţei elementelor chimice pe baza analizei calitative trebuie privită numai ca orientativă (informativă) ;

— modificarea concentraţiei elementelor minore din sfalerit este mult mai importantă decît aceea care rezultă din variaţiile de culoare şi heterogeneitatea chimică evidenţiată spectral ;

— analiza cu MSE a pus în evidenţă o neomogeneitate chimică în ceea ce priveşte distribuţia Zn, Fe, Mn, Cd şi Cu în interiorul granulului de blendă cercetat ;

— corelaţia negativă stabilită între concentraţia Zn şi conţinuturile de Fe, Mn, Cd şi Cu — deşi stabilită pe valori procentuale necorectate — atestă substituţia izomorfă a zincului prin elementele enumerate în cristalul de blendă cercetat ;

— harta isoconcentraţiei fierului (fig. 10) arată că sfaleritul analizat prezintă o microstructură zonară cu un aspect mozaicat subordonat, rezultatele fiind comparabile cu cele obţinute în străinătate prin altă metodă.

În încheiere, sînt schiţate ipoteze genetice ale neomogeneităţii chimice, constatată la blenda de la Baia de Arieş şi se subliniază oportunitatea continuării cercetării neomogeneităţii chimice a mineralelor cu ajutorul microsondei electronice şi necesitatea aplicării corecţiilor la toate datele analitice obţinute.

EXPLANATION OF PLATES

Plate I

Fig. 1. — Investigated polished section : white galena ; grey sphalerite ; dark grey gangue minerals ; black voids. || N, × 25.

Fig. 2. — Position of COMPO and X-ray images for ZnK_{α} PbL_{α} (great rectangle), respectively for CuK_{α} FeK_{α} (small rectangle). Carbon-coated polished section. || N, × 40.

Fig. 3. — COMPO and variation of iron and manganese in sphalerite (left side of the picture) ~ 300 : 1.

Plate II

COMPO (Fig. 1) and X-ray scanning images showing distribution of SK_{α} (Fig. 2) and Z_nK_{α} (Fig. 3). ~ 300 : 1.

Plate III

Pb L_{α} X-ray image (Fig. 1), Ca K_{α} X-ray image (Fig. 2) and Mg K_{α} X-ray image (Fig. 3) in the selected area. ~ 300 : 1.

Plate IV

Fig. 1. — Electron image of composition (COMPO) for the exsolution bodies of chalcopyrite in sphalerite. ~ 300 : 1.

Fig. 2. — COMPO and line scan for iron and copper. ~ 1000 : 1.

Fig. 3. — X-ray scanning picture showing distribution for Fe K_{α}. ~ 1000 : 1.

Plate V

X-ray scanning images showing chemical distribution for Cu K_{α} (Fig. 1), Zn K_{α} (Fig. 2) and S K_{α} (Fig. 3) in the area from Figure 2, plate IV. Each element is concentrated in bright areas of the photograph. ~ 1000 : 1.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

MINERALOGIE

MAGNESIAN SKARNS FROM ŢIBLEŞ : MINERALOGIC AND GEOCHEMICAL DATA. I. FLUORPHLOGOPITE [1]

BY

VASILE POMÂRLEANU [2], GHEORGHE UDUBAŞA [2], ELEONORA NEAGU [3]

Magnesian skarn. Mica. Fluorphlogopite. Chemical analyses. Mineralogic composition. Mineral association. Zeolites. Geothermometry. Li. Eastern Carpathians — Neogene-Quaternary Eruptive — Ţibleş. Transcarpathian flysch Zone — Ţibleş and Lăpuş Mountains.

Abstract

Chemical analyses and X ray diffraction data on phlogopite from Ţibleş magnesian skarns show that the mineral is fluorphlogopite with 4.3% F. Several diagrams show that the Ţibleş mineral has an almost similar composition with theoretical phlogopite. On the Marakushev diagram, the Ţibleş phlogopite is plotted in the extremely alkaline field which is not occupied by other mica. The alkalinity of deposition environment during the whole mineralogical process changes when the temperature decreases, namely from an alkalinity rich in K at high temperature (as phlogopite shows) to an alkalinity rich in Na at low temperature (as noticed by the presence of halite crystals in calcite fluid inclusions). Associations of skarn minerals deposited within a large interval of temperature from 700—690°C (temperature of phlogopite formation as determined by lithium-geothermometer) and up to 220—100°C (temperature of zeolite formation).

Résumé

Skarns magnésiennes de Ţibleş : données minéralogiques et géochimiques. I. Fluorphlogopite. Les analyses chimiques ainsi que les données de diffraction de rayons X sur la phlogopite des skarns magnésiennes de Ţibleş décèlent qu'il

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s'agit du fluorphlogopite. La teneur en F est de 4,3%. Grâce à plusieurs diagrammes on a montré que le minéral de Ţibleş a presque la composition du fluorphlogopite théorétique. Sur le diagramme de Marakushev, le fluorphlogopite de Ţibleş se situe sur le champ extrême d'alcalinité qui dépasse le champ des autres micas. L'alcalinité du milieu de dépôt au cours de tout le processus minéralogique change avec la baisse de la température, c'est-à-dire allant d'une alcalinité riche en K à une haute température (le cas du fluorphlogopite) à une alcalinité riche en Na à une baisse température (tel qu'on montre la présence des cristaux de halite des inclusions fluides de calcite). Les associations de minéraux de skarn se sont déposées pendant un long intervalle de température à partir de 700—690°C (température de formation du fluorphlogopite déterminée par lithium géothermomètre) jusqu'à 220—100°C (température de formation des zéolites).

Introduction

Magnesian skarns occurring within the Ţibleş Neogene subvolcanic massif, East Carpathians have been recently described (Udubaşa et al., 1982). They formed at the contact of some monzodioritic rocks with sedimentary deposits of Paleogene age. More than 40 minerals have been identified in that relatively small body and the observed and presumed relationships among them allowed five mineral associations to separate ; the association typical of the postmagmatic magnesian skarn stage includes large grains or crystals of grammatite and phlogopite ; the last mineral has been lately proved to contain high amounts of fluorine (4.3%) and thus the mineral can be characterized as fluorphlogopite. The aim of this paper is to present both detailed geochemical data concerning fluorphlogopite and some thoughts about the geochemical environment of the skarn formation.

Some Petrographic Data about the Eruptive Massif

The Ţibleş calc-alkaline eruptive complex belongs to the Neogene subvolcanic zone of the East Carpathians and intrudes the sedimentary formations of the Transcarpathian flysch. The bimodal character of the igneous complex is supported by the existence of two distinct formations, i.e. an early, acidic formation consisting mainly of dacites and granodiorites and a late, intermediate multiphase formation including monzodiorites, quartz monzogabbros, andesites etc. The central stock of the main intrusion prevailingly monzodioritic in composition is surrounded by an envelope of microdiorites and andesites (Fig. 1). Late and postmagmatic phenomena are known only in relation with the rocks of the intermediate formation ; there have been described various types of hornfelses (Edelstein et al., 1980), magnesian skarns (Udubaşa et al., 1982), as well as vein and disseminated mineralizations exhibiting a rather well developed regional zoning (Udubaşa et al., 1983 ; Pop et al., 1984).

Three phlogopite occurrences have been identified within the contact metamorphic products of the Ţibleş massif, all of them related

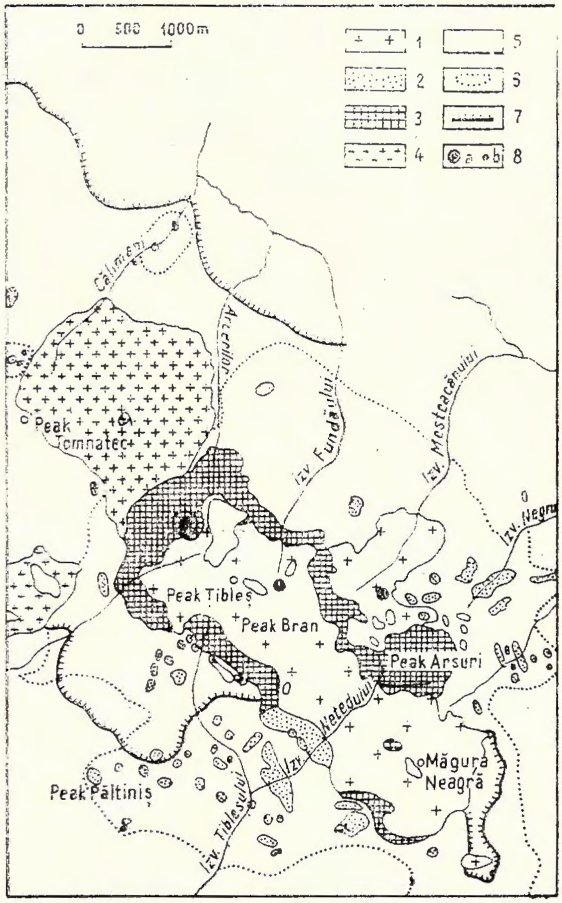

Fig. 1. — Geological map of eastern part of the Ţibleş Massif (after Edelstein et al., 1980) showing phlogopite occurrences.

1, quartz monzodiorites; 2, diorites and quartz diorites, granodiorites, andesites; 3, quartz microdiorites, pyroxene andesites; 4, microgranodiorites and dacites; 5, oligo-miocene sedimentary rocks; 6, halo of thermal contact; 7, overthrust; 8, phlogopite occurrences (a, underground; b, at the surface).

with the monzodiorites (Fig. 1). The most significant phlogopite occurrence is that of the magnesian skarn body described by Udubaşa et al. (1982) in the Izvorul Rău I gallery.

Mode of Presentation and X-Ray Data

Crystals of phlogopite up to 8-12 cm in size were found in some vugs within the skarn body. The mineral forms also lepidoblastic aggregates both within the skarns (coarse grained) and within the hornfelses (finer grained). Phlogopite is usually associated with spinel, forsterite and diopside, including them and with grammatite which, in its turn, includes phlogopite lamellae.

The Ţibleş phlogopite has a brown-yellow to pale yellow colour and thereby it is distinct from phlogopite occurring elsewhere: pale green to dark green in the Ocna de Fier (Kissling, 1967) or the Băişoara skarn deposits (Popescu et al., 1972). Optically, the Ţibleş mineral is biaxial positive, with 2V=6-12°. Gradual transformations of phlogopite grains into lamellar amesite, then into fibrous, almost colourless crysotile have been often observed.

X-ray diffraction pattern of phlogopite (Cu Kα, Ni filter) shows characteristic peaks at 9.90 (70), 3.21 (100) and 2.00 (30) ; these figures (both d values and intensities) suggest that the Ţibleş mineral is structurally more similar to the synthetic 1M phlogopite (ASTM 10-495) than to the normal phlogopite (Tab. 1). In addition, the main peaks

TABLE 1

Phlogopite and fluorphlogopite X-ray data

Phlogopite 1M ASTM 10—495	Synthetical fluorphlogopite 1 M AST M 16—344	Fluorphlogopite Ţibleş
9.94 (100)	9.96 (100)	9.90 (70)
3.35 (100)	3.33 (65)	3.31 (100)
2.61 (30)	2.61 (4)	
2.01 (3)	1.996 (16)	2.00 (30)

of the normal phlogopite migrate toward higher d-values and the 2.61 peak is of low intensity in the case of fluorphlogopite and is lacking at the Ţibleş mineral.

Chemical Data

Chemical analyses of the Ţibleş and other occurrences of phlogopites are given in the table 2. Atomic ratios have been calculated on

TABLE 2

Chemical composition of phlogopites from some occurrences

	1	2	3			24 oxygens structural formula		
						1	2	3
SiO_2	40.33	41.18	36.80		Si	5.892	6.00	5.40
TiO_2	0.56	0.04	—	Z	$Al^{(4)}$	2.108	1.82	2.60
Al_2O_3	12.60	10.37	16.19		Fe^{3+}	—	0.18	—
Fe_2O_3	0.49	4.55	3.00		Al	0.061	0.00	0.20
FeO	1.59	3.80	3.82		Ti	0.060	0.00	—
MnO	0.04	0.01	—		Fe^{3+}	0.053	0.32	0.54
MgO	28.46	24.86	25.23	Y	Fe^{2+}	0.194	0.46	0.46
CaO	1.05	0.21	—		Mn	0.004	0.00	—
Na_2O	0.60	0.56	0.04		Mg	6.197	5.40	5.52
K_2O	9.00	9.96	5.78		Li	0.009	—	—
Li_2O	0.015	—	—		Ca	0.164	0.03	—
H_2O^+	0.58	2.98	8.24	X	Na	0.169	0.16	—
H_2O^-	0.20	0.30	1.30		K	1.676	1.85	0.66
F	4.30	0.70	nd		OH	0.565	2.90	—
Total	99.795	99.76	100.40		F	1.986	0.32	—

1. Phlogopite from Ţibleş magnesian skarns ; 2, Phlogopite from Siilinjärvi carbonatite complex, Finland (Puustinen 1973) ; 3, Phlogopite from Ocna de Fier skarns (Kissling 1967).

the 24 oxygens (O,OH) basis. Z, Y and X types of cations have been separated. The amount of Z-type cations is 8, representing Si and Al in tetrahedric coordination.

The Ţibleş phlogopite has lower FeO and higher MgO contents as compared to phlogopites of other occurrences (Tab. 3). Because

TABLE 3

Fe and Mg average contents in some skarn phlogopites

Deposit	content %			Source
	Fe_2O_3	FeO	MgO	
Ţibleş	0.49	1.59	28.46	This paper
S U Aldan	2.07	3.32	24.28	Liţarev (1962)
S U Pamir	0.93	1.11	25.77	
Ocna de Fier	3.00	3.82	25.23	Kissling (1967)

of its high MgO content the Ţibleş phlogopite plots on the $FeO+MnO/MgO/Fe_2O_3+TiO_2$ diagram into the field characterizing the carbonate

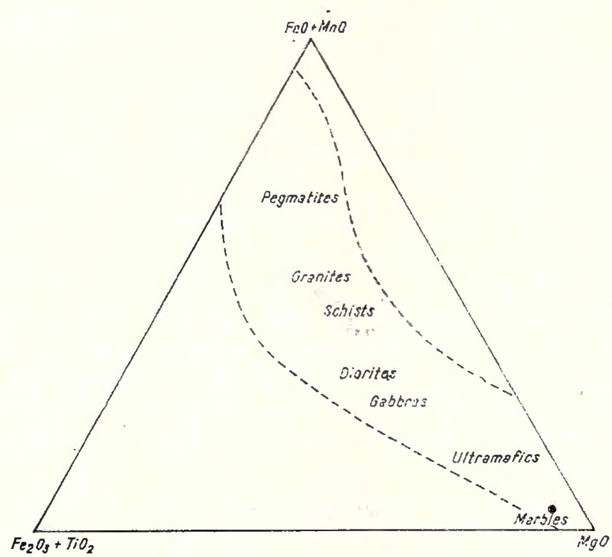

Fig. 2. — Diagram $FeO+MnO$, MgO, $Fe_2O_3+TiO_2$ with the plot of analytical data of Ţibleş fluorphlogopite according to the rock type.

rocks (Fig. 2). This fact supports the idea already expressed by Udubaşa et al. (1982) that the magnesian skarns from Ţibleş formed by metasomatic replacement of some dolomitic limestones.

The ferricity and aluminosity of minerals are chemical factors of special genetic importance in deciphering the compositions of reacting solutions and rocks, giving up micas. Thus, the phlogopite ferricity, $f(\%)=Fe_2O_3+FeO/2Fe_2O_3+FeO+MgO$, calculated using the data in the table 2 is of 8.2%. This value lies within the ferricity interval (2.8-11.8%) corresponding to the values of phlogopite occurring in magnesian skarns (Liţarev, 1962).

The phlogopite aluminosity, Al/(Si+Al+Fe+Mg), has a value of 15%. It is known that this value is dependent of the isomorphic degree $(Mg, Fe)O+SiO_2 \rightarrow Al_2O_3$ (Marakuşev, Tararin, 1965). As function of such isomorphic substitution the composition of micas continuously changes from phlogopite+annite to eastonite+siderophyllite.

Plotting these ferricity (8.2%) and aluminosity (15%) values of the Ţibleş phlogopite on the diagram in Figure 3 (after Ivanov, 1970, 1978), it becomes evident that (1) the ferricity and aluminosity values

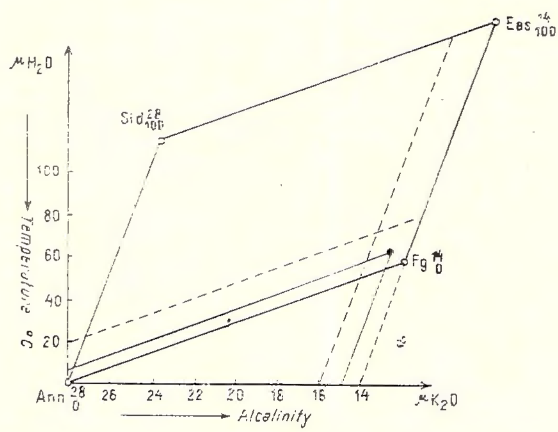

Fig. 3. — Variation diagram of ferricity and aluminosity of biotites in relation with potassium and water chemical potentials (Ivanov, 1970, 1978). Symbols: Ann $^{28}_{0}$, Fg $^{14}_{0}$ Sid $^{28}_{100}$ and Eas $^{14}_{100}$ represent theoretical composition of mica: annite, phlogopite, siderophyllite and eastonite with ferricity values (lower) and of aluminosity (upper).

of the Ţibleş mineral are close to those of the theoretical phlogopite and (2) the phlogopite and the associated minerals formed from solutions characterized by low chemical potential both of water and of potassium and high temperature and alkalinity.

High alkalinity of the fluids is also suggested by plotting the ratios Si/Al (2.7) and Mg+Fe/Al (2.9) on the Marakuşev diagram of alkalinity groups (quoted by Lazebnic, 1973). Extremely high values of these ratios exceed the limits of the IVth group; a new group, the Vth group of alkalinity seems thus to exist (Fig. 4).

The close relationship between the chemistry of the Ţibleş and the theoretical phlogopite can be also seen by taking into account the cations of the octahedric position. It is known that the Mg+Fe bearing micas (phlogopite, Mg-biotite, Fe-biotite, siderophyllite-lepidomelane) and the Li+Fe micas (lepidolite, zinnwaldite, protolithionite, siderophyllite-lepidomelane) form a continuous solid solution series. Gottesmann and Tischendorf's (1979) diagram relating the composition of this solid solution series uses Mg-Li, $Al_{(6)}+Fe^{3+}+Ti$, $Fe^{2+}+Mn$, Li-Mg as main parameters ; further on, the ratios $Fe^{2+}+Mn/(Fe^{2+}+Mn)+(Mg-Li)$ and $Fe^{2+}+Mn/(Fe^{2+}+Mn)+(Li-Mg)$ delineate some subfields. The ratio $Fe^{2+}+Mn/(Fe^{2+}+Mn)+(Mg-Li)$ of the Ţibleş phlogopite is 0.03. Plotting this value on the diagram, one can see that the Ţibleş phlogopite is chemically very or closely related to the theoretical phlogopite (Fig. 5).

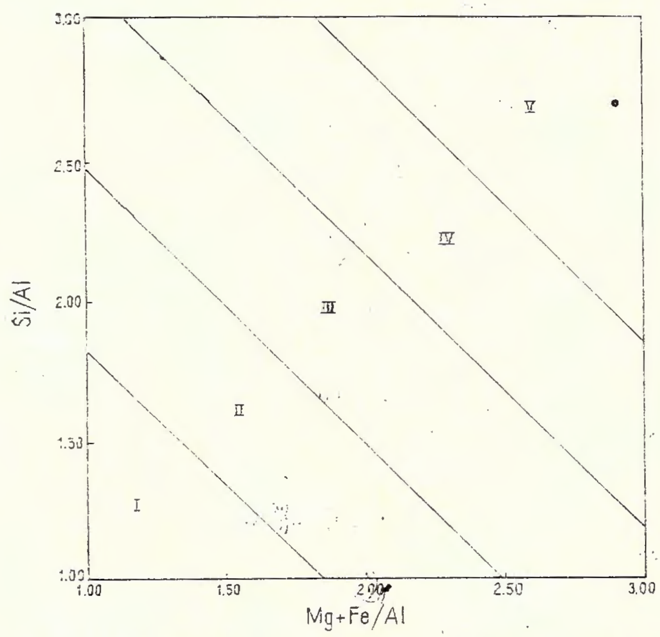

Fig. 4. — Values of ratios Si/Al and Mg+Fe/Al of fluor-phlogopite as function of alkalinity groups.

Geothermometrical Data

The geothermometry of phlogopite is based on the method using lithium in biotites (Pomârleanu, Movileanu, 1977). The Ţibleş phlogopite contains 0.015% Li_2O (Tab. 2) or 69.6 ppm Li. According to the diagram of Figure 6, the temperature formation of the Ţibleş phlogopite is about 690-700°C.

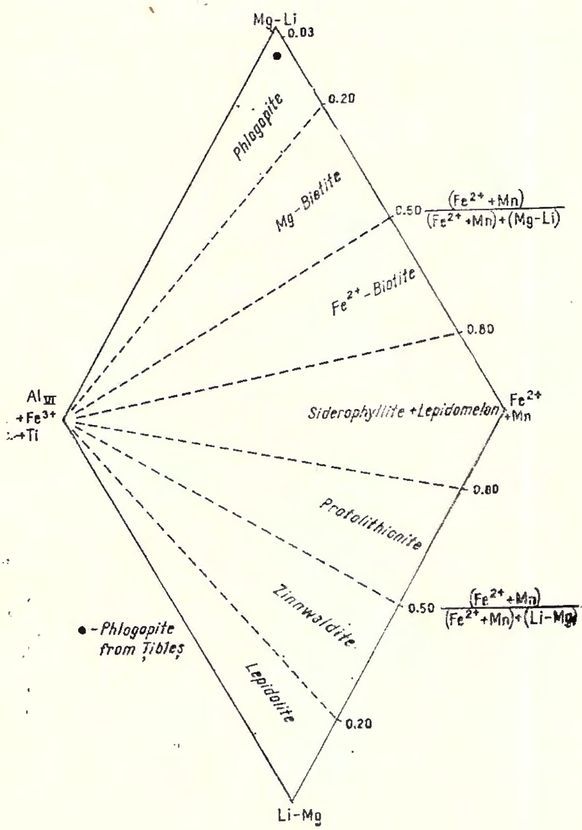

Fig. 5. — Plot of Ţibleş fluorphlogopite in bitriangular diagram of mica classification drawn according to the type and quantity of cations in octahedric position (Gottesman and Tischendorf, 1978).

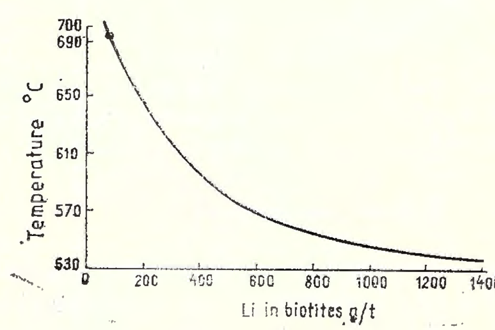

Fig. 6. — Formation temperature of Ţibleş fluorphlogopite, deduced on account of Li geothermometer in biotites (Pomârleanu, Movileanu, 1977).

Discussion

The data presented above inequivocally show that the phlogopite occurring within the magnesian skarns represents the fluorine-bearing variety of this mineral, i.e. it is actually fluorphlogopite. Its fluorine content (4.30%) is even higher than 3.5% F considered by Ivanov (1978) as the upper value of fluorphlogopites. The X_F coefficient i.e. F/F+OH, has a value by 5% higher than the average of 11 analyses of phlogopites given by Deer et al. (1962). Such data, if available for other associated minerals (pargasite, tremolite etc.), can give a quantitative basis for calculating some thermodynamic parameters (enthalpy, Gibbs energy etc.) of the deposition environment.

The local development of the Mg-rich paleosome may also explain the local development of the magnesian skarns. The high fluorine and boron contents of some associated minerals (phlogopite, apatite, tourmaline) show that the magma generating the intermediate formation has been rather rich in volatile (non-hydroxylic) compounds. The unusual occurrence of massive rutile, associated with apatite, phlogopite, pyrrhotite etc. forming nests and veinlets within the altered monzodiorites in the eastern part of the Ţibleş massif (Kovacs et al., 1985) could be easily understood by accepting the titanium transport (or partial remobilization) as $TiCl_4$ or TiF_4 compounds ; hydrolysis of these compounds can lead to the formation of rutile and the release of fluorine and boron allows their entering in the phlogopite and/or apatite lattices (apatite from the Mesteacănul Valley, east Ţibleş, contains 1.4% F and 0.3% Cl, Kovacs et al., 1985). The hydrothermal (residual) solutions have been rich in volatile compounds (Cl, CO_2 etc.) as proved by the halite crystals within the fluid inclusions in calcite.

During the formation of the magnesian skarn assemblages and of the subsequent mineral associations the mineral forming fluids were alkali-rich and changed their character from potassium-rich (during the fluorphlogopite formation, i.e. at temperatures of about 690-700°C) to sodic (to the end of mineral forming processes, i.e. at temperatures of about 290-340°C, as shown by the homogeneization of the halite-bearing inclusions in calcite, Pomârleanu et al., 1982). Laumontite and stilbite have formed at temperature of about 220-100°C ending thus mineral deposition in the area.

Conclusions

1. The phlogopite from the magnesian skarns in the Ţibleş igneous complex posses values of ferricity, aluminosity, X_F coefficient, Si/Al, Mg+Fe/Al and $(Fe^{2+}+Mn)/(Fe^{2+}+Mn)+(Mg-Li)$ ratios very close to those of the theoretical phlogopite.

2. The fluorine content (4.30%) as well as X-ray diffraction data allow to ascribe the Ţibleş mineral to the fluorphlogopite variety.

3. The phlogopite-bearing mineral association formed under the conditions of low potential of water, relatively low potential of K_2O and high alkalinity of mineral forming fluids.

4. The alkalinity of the mineral forming environment changed its character from potassic (suggested by the abundant phlogopite) to sodic (indicated by the halite crystals in the fluid inclusions in calcite).

5. The formation of the mineral associations in the magnesian skarn body covers a large temperature interval, i.e. from 700-690°C (formation temperature of phlogopite indicated by the lithium as a geothermometer according to Pomârleanu and Movileanu, 1977) to 220-100°C (formation temperature of zeolites, according to Pomârleanu and Neagu, 1983).

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SKARNELE MAGNEZIENE DIN ŢIBLEŞ: DATE MINERALOGICE ŞI GEOCHIMICE. I. FLUORFLOGOPITUL

(Rezumat)

Analizele chimice precum şi datele de difracţie raze X asupra flogopitului care se găseşte în skarnele magneziene din Ţibleş arată că mineralul este fluorflogopit care conţine 4,3% F. Prin aplicarea mai multor diagrame s-a arătat că mineralul de la Ţibleş are compoziţia aproape de flogopitul teoretic. În diagrama lui Marakuşev flogopitul de la Ţibleş se proiectează în cîmpul extrem de alcalinitate care nu-i ocupat de alte mice. Alcalinitatea mediului de depunere în timpul întregului proces mineralogic se schimbă cu descreşterea temperaturii, adică de la o alcalinitate bogată în K la temperatură înaltă (după cum arată flogopitul) la o alcalinitate bogată în Na la temperatură joasă (după cristalele de halit în incluziunile fluide din calcit). Asociaţiile de minerale de skarn s-au depus într-un interval larg de temperatură de la 700-690°C (temperatura de formare a flogopitului determinată prin geotermometrul litiu) şi pînă la 220-100 (temperatura de formare a zeoliţilor).

D. S. Inst. Geol. Geofiz. vol. 70—71/1 (1983 ; 1984), 1986, pag. 53—67

1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

BANATITIC ERUPTIVE ROCKS IN THE BOZOVICI-LIUBCOVA ZONE (BANAT)[1]

BY

ION ÎNTORSUREANU[2]

Banatites. Cretaceous. Magmas differentiation. Calc-alkali magma. Subduction. Microplates. Migration-magma. Petrogenesis. Lamprophyres. South Carpathians — Neocretaceous-Paleogene magmatites — Şopot — Semenic.

Abstract

The small-sized banatitic (laramian) eruptive rocks form intrusive bodies, intruded in metamorphic and/or Senonian deposits which they metamorphosed at the contact. They are represented by quartz monzogabbros, microdiorites, diorite porphyries, quartz monzodiorites, quartz monzodiorite porphyries, granodiorites, granodiorite porphyries, hornblende-bearing andesites, hornblende±biotite-bearing quartz andesites, biotite±hornblende dacites, granitic aplites and lamprophires, mentioned approximately in the order of their emplacement. Petrochemical data indicate their origin in calc-alkaline magmas, with slight shoshonitic tendencies, formed as a result of the subduction of the Moesian microplate on a W-WN trend, under the Transylvanian microplate. The convergent movement between the two microplates lasted about 150 m.y., from the Upper Jurassic till nowadays, in an active stage of collision. The association of banatitic eruptive rocks emplaced during four phases is explained in the Senonian-Paleocene time-span mainly by the intermittent migration of the magmas formed gradually by the progressive melting of the subducted lithosphere. It is likely that lamprophyres resulted from magmas coming from great depths in the subduction zone, through the fusion of basic restites, that was contaminated with sial during the emplacement. The magmatic differentiation processes had a rudimentary character, the products being represented by veinlets of granitic aplites and schlieren texture.

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Résumé

Roches éruptives banatitiques de la zone de Bozovici-Liubcova (Banat). Les roches éruptives banatitiques (laramiennes) forment des corps intrusifs de dimensions réduites, cantonés dans des métamorphites et/ou des dépôts sénoniens qu'ils métamorphosent au contact. Ils sont représentés par des monzogabbros quartzifères, microdiorites, porphyres dioritiques, monzodiorites quartzifères, porphyres monzodioritiques quartzifères, granodiorites, porphyres granodioritiques, andésites à hornblende, andésites quartzifères à hornblende$\pm$biotite, dacites à biotite$\pm$hornblende, aplites granitiques et lamprophyres, énumérées en ordre de leur mise en place. Les données pétrochimiques relèvent qu'elles proviennent des magmas calco-alcalins, à faibles tendances shoshonitiques, formés par subduction de la microplaque moesienne, de direction W-WN au-dessous de la microplaque transylvaine. Le mouvement convergent d'entre ces deux microplaques a duré environ 150 m.a., à compter du Jurassique supérieur jusqu'à présent, en se continuant par un stade actif de colision. L'association de roches éruptives banatitiques, mise en place pendant l'intervalle Sénonien-Paléocène, au cours de quatre phases, peut être expliquée par la migration intermittente des magmas formés successivement à la suite de la fusion progressive de la lithosphère en subduction. Les lamprophyres ont résulté, probablement, des magmas formés à des grandes profondeurs, dans la zone de subduction, par fusion des restites à caractère basique et elles ont subi un processus de contamination avec le sial durant la mise en place. Les processus de différenciation magmatique ont eu un caractère rudimentaire, les produits étant représentés par des filonets d'aplites granitiques et des textures en schlieren.

Introduction

The banatitic eruptive rocks and related mineralizations in the Bozovici-Liubcova Zone constituted the object of recent prospecting and exploration by means of drillings and mine workings which made possible a better knowledge of them. The present paper deals with the petrographic characterization of the banatitic rocks and presents a model of petrogenetic evolution based on the global tectonics concept.

The study area comprises the southern segment of the central alignment, trending NNE-SSW, including a part of the southeastern border of the Semenic Mts and the western one of the Almaș Mts, between which the Bozovici Basin interposes. The hydrographic network is represented by the Nera River with its tributaries (Pătășel, Miniș, Lăpușnic, Orăștica, Bănia, Șopot valleys) in the north, and the Oravița Valley (tributary of the Danube) with several ravines (Lilieci, Purcaru, Sișcu, Recica, Praznici, Brestelnic, etc.) in the south.

Among the previous published papers we shall mention here those referring to the banatitic rocks (Gunnesch et al., 1975) or to the related mineralizations (Întorsureanu et al., 1981) as well as the unpublished ones (reports) (Negüț, Popa, 1964; Întorsureanu et al., 1974, 1980). Mappings and studies for the elaboration of the Geological Map of SRR, sc. 1 : 50 000, have been carried out by Năstăseanu, Savu (1970) and Năstăseanu et al. (1981).

Geological Setting

The study region lies in the South Carpathians bend zone and consists mostly of crystalline formations of the Getic Nappe that thrust the metamorphites of the Danubian Domain (Plate I). Here, the Getic Nappe is represented by the Sebeș-Lotru and Miniș-Buceava series (Savu, 1979; Năstăseanu et al., 1981), formed during the Dalslandian cycle, that evolved into the Upper Precambrian A (850 m.y. Rb/Sr) (Savu, 1979).

Metamorphites of the Danubian Autochthon occur on a small area in the southeastern part and consist of the Toronița Series, Upper Precambrian A in age (Năstăseanu et al., 1981).

In the western part the Getic Nappe crystalline is pierced by the Poniasca and Sichevița pre-Alpine granitoid massifs (Savu, 1979), as well as by small basic (dolerites, anamesites, diabases) or acid (rhyolites, microdiorites, granodioritic porphyries) eruptive bodies of Upper Paleozoic age (Întorsureanu et al., 1983).

Sedimentary deposits belong to the eastern margin of the Reșița-Moldova Nouă Zone (limestones, marls, sandstones, conglomerates, of Upper Carboniferous-Albian age), to the Sopot Zone (organogenous limestones, sandstones, conglomerates, of Cenomanian-Campanian age) and to the Bozovici and Sichevița Tertiary basins with mostly Miocene detrital formations (Năstăseanu, Savu, 1970; Năstăseanu et al., 1981).

Banatitic Eruptive Rocks

In the Bozovici-Liubcova Zone, banatitic eruptive rocks belong to the central lineament (Giușcă et al., 1966) and are found only as small-sized intrusions, represented by veins, apophyses, dykes or irregular bodies. These intrusive bodies are hosted in the Getic Nappe metamorphites or in Upper Cretaceous deposits, which they affect at the contact and, only subordinate, in the crystalline formations of the Danubian Autochthon.

Among numerous intrusions consistently spread in the study zone, those occurring in the Lăpușnicu Mare (Gura Săliștei), Lilieci, Purcaru and Nasovăț are of importance; they appear as subvolcanic bodies, with sizes of some hundreds of metres, related to porphyry copper (Cu $\pm$ Mo) or skarn (Cu $\pm$ Fe) mineralizations and a wide range of hornfelses.

The banatitic eruptive rocks association formed during four stages: 1) quartz monzogabbros, microdiorites, diorite porphyries; 2) quartz monzodiorites, quartz monzodiorite porphyries, granodiorites, granodiorite porphyries); 3) hornblende$\pm$biotite-bearing andesites, biotite$\pm$hornblende-bearing dacites, granitic aplites; 4) lamprophyres.

The main banatitic rock bodies consist chiefly of quartz monzodiorites (Lilieci, Nasovăț, Bănia, Alibeg) or of quartz monzodiorite porphyries (Lăpușnicu Mare, Purcaru, Nasovăț, Lilieci, Bănia). The mineralogical compositions are represented by plagioclase (44.4-61.8%), potash feldspar (11-18.1%), quartz (12.3-16.3%), green hornblende (7-21.7%), biotite (0.2-2.3%), magnetite, apatite, sphene (0.7-1.4%). Plagioclases are characterized by contents of An (32-48%), abundant zonary structures and albite or albite + Karlsbad twins. Most of the banatitic rock occurrences are made up of hornblende-bearing andesites or hornblende± biotite-bearing quartz andesites, which form veins, apophyses or small-

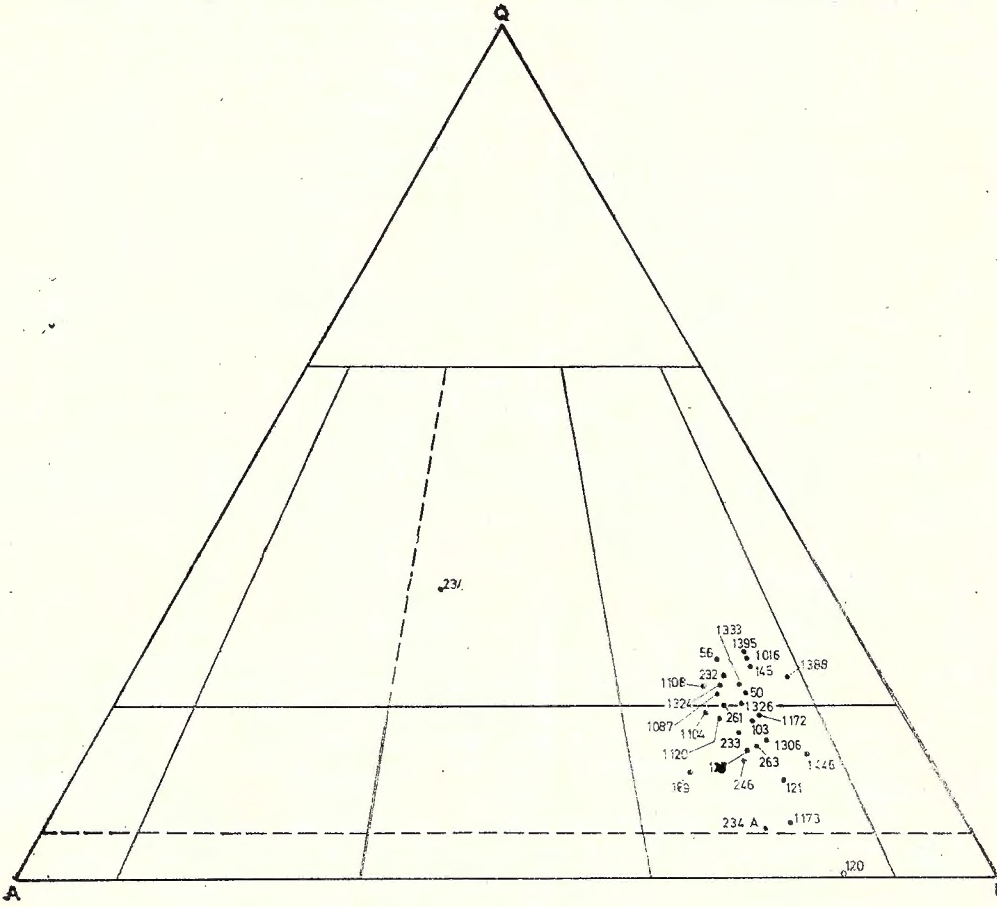

Fig. 1. — *QAP* diagram.

sized irregular bodies, some of them worked in small quarries (Nera and Pătășel valleys). Andesite veins, hosted in the quartz monzodiorite porphyry body, have been intercepted in the borehole 65,526 at Lăpușnicu Mare. Quartz monzogabbro has been identified in the borehole 61,523 (m 401,9-407,1) as enclaves in the quartz monzodiorite body in the Lilieci Ravine. The other mentioned rock types are found subordinately, as veins (dacites, granitic aplites, lamprophyres) or apophyses and separations (granodiorites, granodiorite porphyries) and they have previously been described by Întorsureanu et al. (1980). The types of banatitic rocks occurring in the study zone are represented on the *QAP* diagram (Fig. 1), on which the normative compositions (according to C.I.P.W. method) have been plotted.

For the petrochemical characterization of the banatitic rocks and the establishing of the main magma types 29 chemical analyses (Tab. 1) have been carried out, on the basis of which the standard composition (C.I.P.W.) and *QAP* parameters (Tab. 2) have been established [3].

SiO_2/K_2O diagram (Fig. 2) points out that the analysed banatitic rocks come from calc-alkaline magmas, sometimes showing shoshonitic tendencies. An exception is lamprophyre (sample 120) which possesses a more obvious shoshonitic character.

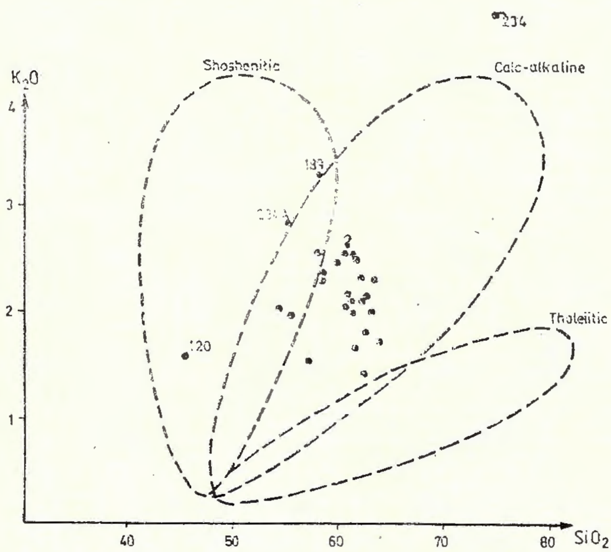

Fig. 2. — K_2O/SiO_2 diagram.

On the *QLM* diagram (Fig. 3) most of the analyses plot in the field of suprasaturated rocks, whereas lamprophyre, quartz monzogabbro and other two analyses occur under the PF line, in the field of intermediary or nonsaturated rocks.

Trace elements, spectrally determined (Tab. 3), show concentrations relatively similar to those from other banatitic rock complexes.

Petrogenetic Evolution

Petrogenesis of banatitic rocks was controlled by three main factors : conditions of magma formation, chemistry and their evolution.

Conditions of banatitic magma formation. It is well-known that at present the majority of the authors agree that the formation of the magma, from which the banatitic rocks come, took place in subduction zones (Rădulescu, Săndulescu, 1973 ; Bleahu, 1974 ; Herz, Savu, 1974). It is thus considered that in the South Carpathians bend zone (Banat)

TA

Chemical composition of banatitic

No.	Sample	Rock	Location	SiO_2	TiO_2	Al_2O_3
1	234	Granitic aplite	Gal. II Lăpușnicu Mare	75.46	0.06	13.21
2	1395	Hornblende-bearing quartz andezite	Aluniș Ravine	63.43	0.42	14.38
3	1326	Hornblende ± biotite bearing dacite	Valea Mare-Bănia	63.17	0.60	16.90
4	1772	Hornblende-bearing andesite	Nera Valley	63.00	0.30	14.69
5	50	Granodiorite porphyry	Gal. VI — Orăștica	62.58	0.40	17.63
6	1016	Granodiorite porphyry	Gal. II Lăpușnicu Mare	62.56	0.24	18.63
7	1388	Hornblende-bearing quartz andezite	Pătășel Valley	62.31	0.35	17.68
8	232	Granodiorite porphyry	Gal. II —Lăpușnicu Mare	62.20	0.49	17.04
9	1324	Granodiorite porphyry	Perilor Ravine-Bănia	62.01	0.50	15.65
10	145	Granodiorite porphyry	Nasovăț valley	61.75	0.50	18.26
11	1108	Granodiorite	B. 61521, m 650, Lilieci	61.74	0.60	16.29
12	1087	Granodiorite porphyry	B. 61521, m 402.7 — Lilieci	61.28	0.44	16.41
13	1333	Granodiorite porphyry	Valea Mică	61.22	0.76	15.20
14	56	Granodiorite porphyry	Lilieci ravine	61.02	0.43	19.81
15	1120	Quartz monzodiorite	B 61521, m 143-Lilieci	60.78	0.50	17.49
16	1306	Quartz monzodiorite	Bănia valley	60.75	0.60	17.15
17	261	Hornblende-bearing quartz andesite	Purcaru Ravine	60.59	0.47	17.87
18	1104	Quartz monzodiorite	B. 61521, m 622 — Lăpușnicu Mare	60.56	0.44	16.75
19	103	Quartz monzodioritic porphyry	Ciubera Ravine	60.55	0.46	18.36
20	263	Hornblende-bearing andesite	Purcaru Ravine	59.68	0.50	18.85
21	123	Hornblende-bearing andesite	Oravița Valley	58.35	0.55	17.62
22	223	Hornblende-bearing andesite	Lilieci Ravine	58.20	0.35	19.80
23	246	Quartz monzodiorite	Tilva Înaltă	58.12	0.68	17.98
24	189	Quartz monzodiorite	Tunești Ravine	57.75	0.66	16.81
25	1446	Quartz monzodiorite	Alibeg Ravine	57.01	0.45	16.71
26	121	Quartz monzodioritic porphyry	Ciocaru Ravine	55.80	0.55	17.52
27	234 A	Quartz monzodiorite	Bobot Ravine	54.82	0.75	18.47
28	1173	Quartz monzogabbro	B. 61523, m 403 — Lilieci	53.50	0.74	17.14
29	120	Lamprophyre (odinite)	Ciubera Ravine	45.40	0.80	17.21

Analyst : M. Dumitrescu : 1016, 145, 1108, 1087, 1120, 261, 1104, 263, 246, 189, 234 A, 1173
A. Movileanu : 1395, 1326, 1772, 1388, 1324, 1333, 1306, 1446

BLE 1

eruptive rocks in Bozovici-Liubcova zone

Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O^+	H_2O^-	CO_2	S	Total
0.18	0.35	0.01	0.21	1.05	6.49	2.45	—	0.12	0.08	—		99.66
3.15	1.52	0.10	2.18	5.86	1.73	4.28	0.15	1.02	—	2.01		100.23
1.63	2.38	0.05	1.94	5.63	2.31	3.92	0.20	—	—	—		99.92
1.96	2.09	0.10	2.02	5.64	2.01	5.03	0.13	1.73	—	1.28		99.98
2.18	2.67	0.11	2.35	5.51	2.14	3.43	0.23	0.03	0.49	—		99.74
2.11	2.33	0.04	2.22	4.86	1.78	3.45	0.07	0.85	0.79	0.18		100.11
2.18	1.46	0.08	1.64	6.53	1.42	4.35	0.13	0.63	—	1.70		100.49
2.43	3.09	0.06	3.50	4.72	2.14	3.38	0.23	0.73	0.10	0.26		100.36
2.46	2.31	0.06	1.62	5.92	2.31	4.22	0.18	0.79	—	2.06		100.09
2.52	2.45	0.10	2.09	4.72	1.71	3.72	0.23	1.18	0.38	0.15	0.02	99.78
3.14	3.29	0.10	2.41	5.60	2.58	3.00	0.15	0.90	0.22	—		100.02
3.76	3.00	0.08	2.22	5.80	2.53	3.37	0.11	0.60	0.31	0.15	0.02	100.08
2.67	2.83	0.01	2.34	6.65	2.01	3.73	0.22	0.54	—	1.44		99.68
2.73	2.32	0.10	2.25	5.67	2.14	2.76	0.31	0.21	0.34	—		100.09
2.33	3.31	0.09	2.53	5.80	2.63	3.15	0.15	0.87	0.50	0.22		100.35
2.48	2.74	0.01	2.23	7.03	2.10	3.91	0.19	0.79	—	—		100.04
2.42	2.59	0.08	1.88	5.33	2.53	3.55	0.22	1.35	0.77	0.40	0.02	100.07
3.71	3.05	0.09	2.38	6.04	2.68	3.20	0.15	0.77	0.17	—	0.28	100.27
2.61	2.80	0.11	3.00	5.77	2.14	3.42	0.26	0.85	0.24	0.10		100.67
1.82	1.80	0.08	1.83	6.14	2.45	4.00	0.23	1.24	0.56	0.68	0.19	100.05
1.35	4.25	0.35	2.65	6.35	2.35	3.45	0.60	0.44	1.40	0.40	0.20	100.34
1.15	3.60	0.30	3.45	5.75	2.30	3.35	0.50	0.30	1.25	0.55	0.15	99.75
3.35	3.13	0.08	2.74	6.96	2.53	3.31	0.24	0.25	0.28	0.11	0.01	99.73
3.70	2.96	0.07	3.14	7.14	3.29	3.15	0.28	0.70	0.30	0.19	0.05	100.19
3.96	2.89	0.12	3.04	8.74	1.53	3.72	0.13	0.60	—	1.02		99.90
3.82	3.70	0.10	5.80	6.42	1.98	2.94	0.36	1.20	0.35	—		100.53
3.56	3.62	0.15	2.75	6.93	2.81	3.88	0.30	1.12	0.43	—	0.12	99.71
3.71	4.49	0.10	5.26	8.64	2.03	2.80	0.15	0.88	0.36	—		99.80
3.82	3.95	0.11	7.23	8.40	1.61	2.81	0.40	2.42	3.18	1.75		99.09

D. Nacu : 234, 50, 232, 56, 103, 121, 120
G. Apostolescu : 123, 223

TABLE 2

C.I.P.W. normal composition and QAP values

No.	Sample no.	Q	or	ab	an	c	hd	en	fs	il	ml	fo	ap	cc	π	di	Q	A	P
1	234	33.66	38.40	20.76	5.22	0.25	—	0.52	0.41	0.11	0.26	—	—	—	—	—	34.3	39.2	26.5
2	1 395	22.38	10.33	36.59	15.07	—	—	5.36	—	0.81	4.05	—	0.38	4.61	—	0.26	26.5	12.2	61.2
3	1 326	17.28	13.65	33.17	21.69	—	1.06	3.56	1.57	1.14	2.36	—	0.51	—	—	2.75	20.1	15.9	63.9
4	1 772	15.86	12.09	43.31	11.77	—	1.50	3.03	1.15	0.58	2.89	—	0.34	2.96	—	4.51	19.1	14.6	66.3
5	50	18.68	12.65	29.03	25.59	0.29	—	6.85	2.65	0.76	3.16	—	0.58	—	—	—	21.7	14.7	63.5
6	1 016	21.86	10.61	29.44	22.64	2.83	—	5.58	2.24	0.46	3.08	—	0.11	0.41	—	—	25.9	12.5	61.6
7	1 388	20.07	8.44	37.04	20.81	1.42	—	4.19	0.46	0.67	3.18	—	0.33	3.89	—	—	23.2	9.8	67.0
8	232	19.27	12.74	28.81	20.17	1.84	—	8.78	2.99	0.94	3.55	—	0.59	0.59	—	—	23.8	15.7	60.5
9	1 324	19.20	13.76	35.99	15.12	0.71	—	4.07	1.51	0.96	3.59	—	0.46	4.72	—	—	22.8	16.4	60.8
10	145	20.96	10.23	31.86	20.97	2.73	—	5.27	1.76	0.96	3.70	—	0.59	0.34	0.04	—	24.9	12.2	62.9
11	1 108	18.99	15.38	25.62	23.58	—	0.74	5.16	2.28	1.15	4.59	—	0.38	—	—	1.93	22.7	18.4	58.9
12	1 087	17.36	15.04	28.69	22.31	—	0.85	4.15	1.35	0.84	5.48	—	0.28	0.34	0.04	3.02	20.8	18.0	61.2
13	1 333	18.78	11.94	31.73	18.90	—	0.58	4.85	1.46	1.45	3.89	—	0.56	3.29	—	2.19	16.5	15.1	68.4
14	56	21.66	12.67	23.40	25.83	3.52	—	5.62	1.49	0.82	3.96	—	0.79	—	—	—	25.9	15.2	58.9
15	1 120	15.92	15.68	26.89	26.04	—	0.11	6.25	3.47	0.96	3.41	—	0.38	0.50	—	0.24	18.8	18.5	62.6
16	1 306	13.64	12.51	33.35	23.23	—	2.02	2.64	0.96	1.15	3.62	—	0.49	—	—	6.39	16.5	15.1	68.4
17	261	17.13	15.16	30.45	22.55	1.15	—	4.75	2.12	0.90	3.55	—	0.57	0.92	0.04	—	20.1	17.8	62.1
18	1 104	16.36	15.97	27.31	23.62	—	0.74	4.31	1.02	0.84	5.42	—	0.38	—	0.53	3.59	19.6	19.2	61.2
19	103	15.78	12.75	29.19	26.24	0.89	—	7.54	2.45	0.88	3.81	—	0.67	0.23	—	—	18.8	15.2	66.0
20	263	13.60	14.67	34.29	24.74	0.68	—	4.62	0.75	0.96	2.67	—	0.59	1.56	0.36	—	15.6	16.8	67.6
21	123	12.11	13.96	29.34	24.54	0.46	—	6.63	6.05	1.05	1.97	—	1.53	0.91	0.38	—	15.1	17.5	67.4
22	223	13.20	13.64	28.44	21.32	4.02	—	8.62	5.35	0.67	1.67	—	1.27	1.25	0.28	—	17.2	17.8	65.0
23	246	11.54	14.99	28.08	26.80	—	0.86	5.28	1.54	1.29	4.87	—	0.61	0.25	0.02	3.37	14.2	18.4	67.4
24	189	9.94	19.58	26.85	22.17	—	1.03	4.63	0.78	1.26	5.40	—	0.72	0.43	0.09	7.00	12.7	24.9	62.4
25	1 446	11.37	9.04	31.67	24.55	—	1.37	3.99	0.80	0.86	5.77	—	0.33	2.33	—	7.83	14.8	11.8	73.4
26	121	8.75	11.84	25.18	29.11	—	0.04	14.51	2.93	1.06	5.60	—	0.92	—	—	0.24	11.7	15.8	72.5
27	234 A	4.04	16.80	33.22	24.97	—	1.46	4.81	1.76	1.44	5.22	—	0.77	—	0.23	4.57	5.1	21.3	73.6
28	1 173	4.65	12.10	23.90	28.46	—	2.36	9.25	2.93	1.42	5.42	—	0.38	—	—	8.55	6.7	17.5	75.8
29	120	—	9.76	24.39	28.30	0.75	—	14.94	2.48	1.56	5.68	2.92	1.04	4.08	—	—	—	15.6	84.4

TABLE 3

Trace elements (p.p.m.) in the banatitic eruptive rocks in the Bozovici-Liubcova zone

No.	Sample no.	Cu	Pb	Zn	Mo	Sn	Ga	Co	Cr	Ni	V	Zr	Sc	Y	Yb	La	Be	Ba	Sr
1	• 1 395	19	26.5	105	<2	3	12.5	6.5	3	3	80	60	7.5	12	1.9	<30	1.2	1050	560
2	• 1 326	50	13	62	2	4	18	9.5	8	8	150	135	14	17.5	2.2	<30	2	750	900
3	• 1 772	6	4	125	<2	<2	8.5	7	10	13	85	100	10	12	1.1	<30	<1	300	320
4	• 1 016	36	23	65	S.L.D.	5	20	11	S.L.D.	9	200	135	17	24	2.4	S.L.D.		635	255
5	• 1 388	11	28.5	100	<2	<2	14	7.5	6	6.5	100	90	8.5	13	1.9	<30	1.2	700	470
6	• 1 324	9	18.5	50	<2	2.5	15	8	8	8	140	135	11.5	19.5	2.2	<30	1.8	1000	1200
7	• 145	8	16	57	5	...	...	33	13	14	...	...	...	...	...	...	...	...	...
8	1 108	36	10	46	35	5.5	19	16	S.L.D.	10.5	190	135	19.5	22	2.6	S.L.D.	...	585	780
9	1 087	20	12	51.5	S.L.D.	5	21	11.5	S.L.D.	10	175	140	17	20	2.1	<30	...	675	1000
10	1 333	28	125	83	2	3	15	15	8	9	210	115	16	18	2.4	<30	2.1	620	850
11	56	9.5	26	70	2	2	15.5	14	10	8.6	255	150	16	18.5	2.3	40	...	700	920
12	1 120	16.5	11	45	S.L.D.	6	21	15	S.L.D.	11	150	155	20	21	2.5	S.L.D.	...	730	1300
13	1 306	44	100	170	2	2.5	12.5	13	6	7.5	190	110	14	18	2	<30	1.6	750	1100
14	261	36	17	31	S.L.D.	...	...	36	9	17	...	...	...	...	...	...	...	...	...
15	1 104	150	12.5	60	9	5.5	19.5	10	S.L.D.	8.5	140	125	15.5	19.5	2.1	S.L.D.	...	650	780
16	263	5	25	39	6	...	...	25	11	8	...	...	...	...	...	...	...	...	...
17	246	15	13	23	S.L.D.	...	...	33	10	8	...	...	...	...	...	...	...	...	...
18	189	45	357	117	S.L.D.	...	...	48	7	7	...	...	...	...	...	...	...	...	...
19	1 446	125	24.5	115	<2.5	2.5	17.5	19	8	11	260	90	23	19.5	2.6	<30	1.2	740	750
20	121	180	18.5	80	2	2	19	23	170	34	300	90	33	14.5	2.3	30	...	600	920
21	234 A	110	16	36	S.L.D.	...	...	29	5	6	...	...	...	...	...	...	...	...	...
22	1 173	115	18	70	S.L.D.	5	16	38	37	28	300	90	42	16	2.2	S.L.D.	...	450	650

Analyst : A. Zămârcă (sample 1395, 1326, 1772, 1388, 1324, 1333, 1306, 1446)
A. Şerbănescu (sample 1016, 1108, 1087, 1120, 1104, 1173)
N. Isipescu (sample 145, 56, 261, 263, 246, 189, 121, 234 A).
... undetermined

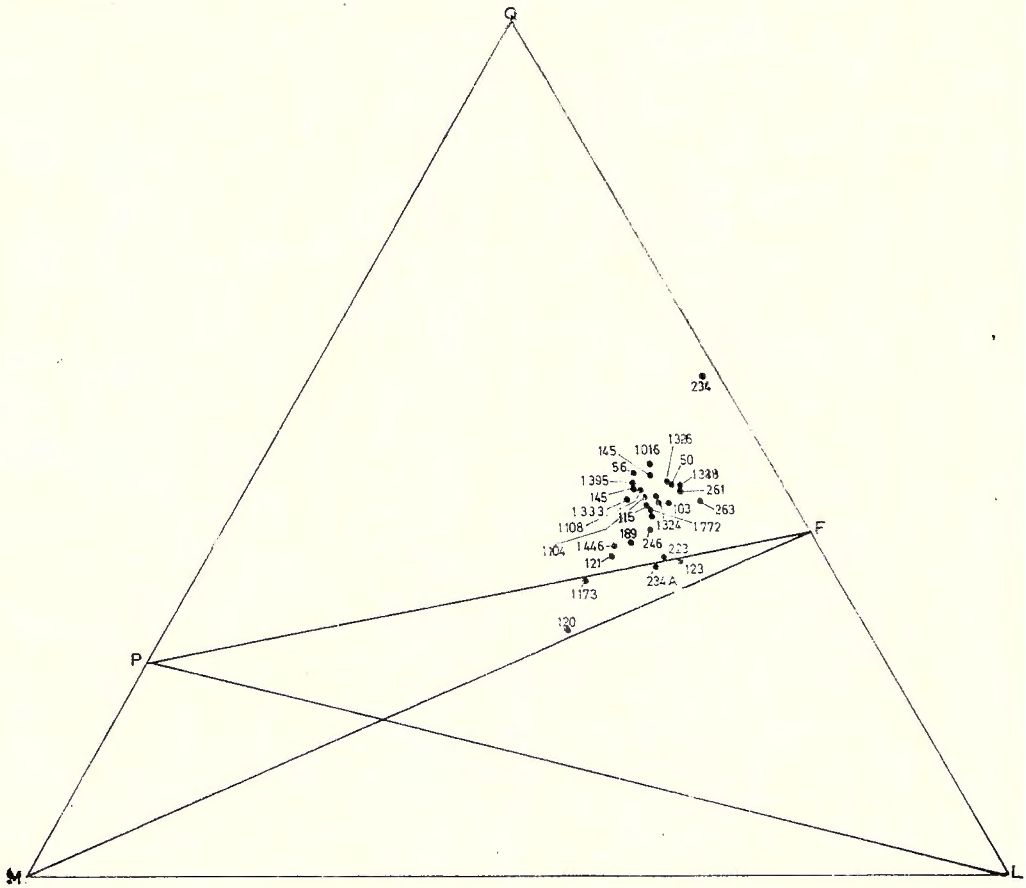

Fig. 3. — *QLM* diagram.

banatitic magmas originate in the "eastern basin" oceanic crust (Rădulescu, Săndulescu, 1973). Likewise, it is possible that the sialic cover of the oceanic crust (with variable thicknesses), subducted under the Transylvanian Microplate on a W-WN trending, might have taken part in the formation of the banatitic magmas.

The Benioff plane probably occurred in the link zone between the Moesian Platform and the Danubian Domain ; it is curved shaped and resembles the general structure of the South Carpathians. This location of the subduction zone is suggested by several elements, among which some have been mentioned by Savu (1982) : 1) the Getic Depression which probably played the part of a trough in which the Paleogene-Neogene deposits are overthrust by Mesozoic formations of the South Carpathians ; 2) the ophiolitic mélange in the Severin Nappe

(Savu 1982), as a component of a subduction complex ; 3) the banatitic intrusions in the Danubian Domain crystalline ; 4) the emergence of the Danubian Domain at the end of the Cretaceous.

The depth of the banatitic magma formation in the Bozovici-Liubcova Zone (central lineament), estimated on the basis of the

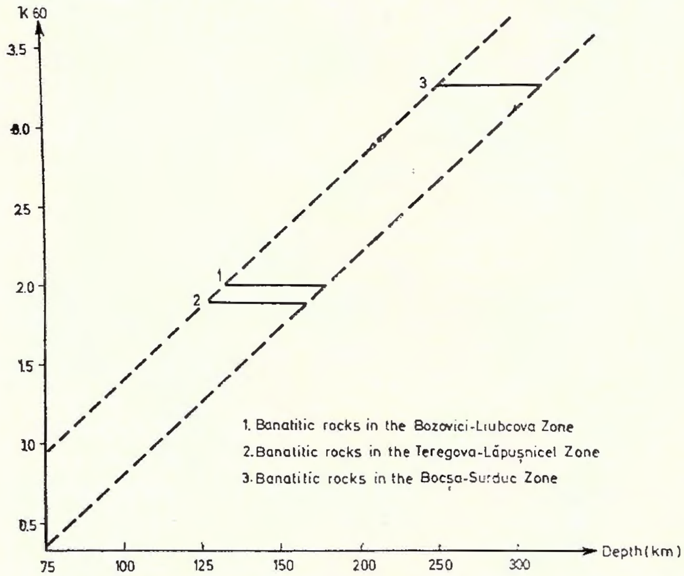

Fig. 4. — K 60/magma generation depth diagram (after Dickinson, 1968).

K_2O/SiO_2=60 ratio (Dickinson, 1968), is situated in the interval 130-185 km, close to those in the Teregova-Lăpușnicel Zone (eastern lineament 125-165 km), whereas the rocks in the Bocșa-Surduc Zone (western lineament) came from magmas formed at 250-300 km (Fig. 4). All this attests the dipping direction of the subduction plane towards west-westnorth, as already mentioned in previous papers (Rădulescu, Săndulescu, 1973 ; Herz, Savu, 1974 ; Airinei, 1981).

The duration of convergence between the two microplates is considered to be of 150 m.y., beginning in the Upper Jurassic (Savu, 1982), with a subduction stage which probably developed up to the Paleogene, followed by a collision, that is still active (Airinei, 1981).

In conclusion, considering the tectonostructural conditions one can admit that magmas formed gradually, during a long period of time and in connection with the stages or substages of the convergent movements between the Moesian and Transylvanian microplates.

Chemistry of magmas. Petrochemical data indicate that in the study region the banatitic rocks came from mostly calc-alkaline magmas, showing weak alkaline tendencies, and only lamprophyres originated in shoshonitic magmas. The chief factors that controlled the chemistry of the banatitic magmas were determined by the formation conditions.

They are mainly represented by the mineralogical and chemical composition of the subducted lithosphere, depth and degree of fusion.

The composition of the subducted and melted lithosphere plays the essential part on the determination of the magma types which form in the convergence zones. Within the same consumption zone of the lithosphere the chemism of the magmas can vary according to the stage or substage of development of the convergent movements to the depth at which the fusion took place and to its intensity. Thus, Jakeš, White (1972), Miyashiro (1974), Condie (1976) pointed out that three successive magma series could form within the island arcs or at the margin of the active continental plates ; arc tholeiites, calc-alkaline and shoshonitic or alkaline, arranged approximately in the same order as against the dipping of the Benioff plane.

The study of the available data indicates that the relation implied by the mentioned model also manifested, at least partly, in the South Carpathians bend zone. Here, during the Alpine cycle some successive magma series evolved in direct relationship with the stages and substages of compression and consumption of the lithosphere.

Thus, the widespread Senonian-Paleocene banatitic magmatites are arranged as three NNE-SSW trending alignments parallel to the Benioff plane. They are characterized by a chiefly calc-alkaline chemistry (Giușcă et al., 1966) with transition to shoshonitic composition in the Surduc-Bocșa massif, situated on the western alignment (Russo-Săndulescu, Berza, 1979). It is likely that the Senonian volcanics (andesites, pyroclastics) formed during the second subduction substage. The Paleocene intrusive bodies with a granodioritic-monzonitic composition, formed from magmas coming from a first collision stage when the participation of the sialic layer in the formation of the meltings was probably more significant. Lamprophyres also belong to the first collision substage, being emplaced during its final stage. The magma which generated the lamprophyres probably originated in basic restites coming from the selective and incongruent melting of some minerals (quartz, orthose, plagioclases) from the consumpted lithosphere. The shoshonitic character of lamprophyres can be explained in this case through the contamination of the meltings coming from basic restites with the continental crust during the emplacement on deep fractures. This hypothesis of the lamprophyres origin is consistent with both the observation data and the mechanism of the global tectonics of the experimental studies (Piwinski, Wyllie, 1968).

Evolution of the banatitic magmas. After their formation magmas underwent complex evolutive processes which finally led to the appearance of petrographic $\pm$ metalliferous associations. The control factors were represented by intermittent migration, mixture, differentiation and crystallization of the magma.

It is likely that the intermittent migration of the magma played the decisive role in explaining the association of banatitic rocks in the study area (Întorsureanu et al., 1981). The process was controlled by both the conditions of gradual or cyclic formation of the melting and the pressures exercises by the convergent movement of the microplates, by the pressure of the volatiles, by the viscosity and by the access ways. According to the local conditions the intermittent migration might occur suddenly (volcanic eruptions) or slowly (plutonism) and intermediary magmatic chambers might be formed. The intermittent migration is proved by both the field evidence on the succession of the rock types and the radiometric ages (Russo-Săndulescu et al., 1983). Thus, it is conclusive the fact that the Bocșa and Surduc banatitic plutons, made up of successive intrusions, were emplaced during a wide time-span (22 m.y. and 13 m.y., respectively). All these data indicate that the magmas which generated the successive intrusions did not coexisted only during one magmatic reservoir, as they would have consolidated during a much shorter time-span, estimated at 10^5-10^6 years (Spera, 1980, fide Gill, 1981).

The mixture of magmas at different scales is very likely in the subduction zones due to the progressive fusion of the lithosphere when meltings with a different chemism may form which cannot migrate immediately. Likewise it is not out of question that in the deeper zones of the Benioff plane deep-seated fractures might occur on which primary magmas of the upper mantle might intrude and mix with the secondary ones generated in the subduction zone.

Differentiation and crystallization are associated processes which develop in the final stage of evolution. The petrographic products resulted from magmatic differentiation are subordinate (aplite veinlets, schlieren texture) ; it points to a rudimentary differentiation under subvolcanic conditions (Giușcă et al., 1966). Post-magmatic fluids, separated from magmas during the consolidation, generated skarns $\pm$ mineralizations (Cu$\pm$Fe) and porphyry copper concentrations (Cu$\pm$Mo).

Conclusions

In the study zone the banatitic eruptive rocks formed from calc-alkaline magmas, generated by the compression of an oceanic crust in the W-WN dipping subduction zone, between the Moesian and the Transylvanian microplates. The convergent movement between the two microplates lasted about 150 m.y., beginning in the Upper Jurassic and continuing up to now, with an active stage of collision. The association of banatitic rocks, emplaced during four phases, is chiefly explained by the intermittent migration of the banatitic magma formed gradually or cyclically through the progressive melting of the subducted lithosphere. Lamprophyres resulting from magmas occurred through the fusion of restites with a basic chemism, in deep-seated zones of the Benioff plane, during the final stage of the banatitic magmatic cycle. The magmatic differentiation processes had a rudimentary character and their products are represented by schlieren textures and veinlets of granitic aplites.

[3] Analyses have been processed by the electronic computer after CAPE, FVUL and CATA programmes by P. Andăr, to whom I am greatly indebted.

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ROCILE ERUPTIVE BANATITICE DIN ZONA BOZOVICI-LIUBCOVA (BANAT)

(Rezumat)

Rocile eruptive banatitice (laramice) formează corpuri intrusive cu dimensiuni reduse, cantonate în metamorfite și/sau depozite senoniene pe care le metamorfozează la contact. Asociația de roci eruptive banatitice este alcătuită din monzogabbrouri cuarțifere, microdiorite, porfire dioritice, monzodiorite cuarțifere, porfire monzodioritice cuarțifere, granodiorite, porfire granodioritice, andezite cu hornblendă, andezite cuarțifere cu hornblendă $\pm$ biotit, dacite cu biotit $\pm$ hornblendă, aplite granitice și lamprofire, enumerate aproximativ în ordinea de punere în loc.

Datele petrochimice arată că rocile au derivat din magme calco-alcaline cu ușoare tendințe shoshonitice, formate prin subducția microplăcii moesice, în direcția V-NV, sub microplaca transilvană. Mișcarea convergentă dintre cele două microplăci a durat 150 m.a., începînd în Jurasicul superior, trecînd printr-un stadiu de subducție, urmat de o coliziune activă și în prezent (Airinei, 1981).

Asociația de roci eruptive banatitice, puse în loc în patru faze, în intervalul Senonian-Paleocen, se explică, în principal, prin migrarea intermitentă a magmelor, formate treptat prin topirea progresivă a litosferei subduse

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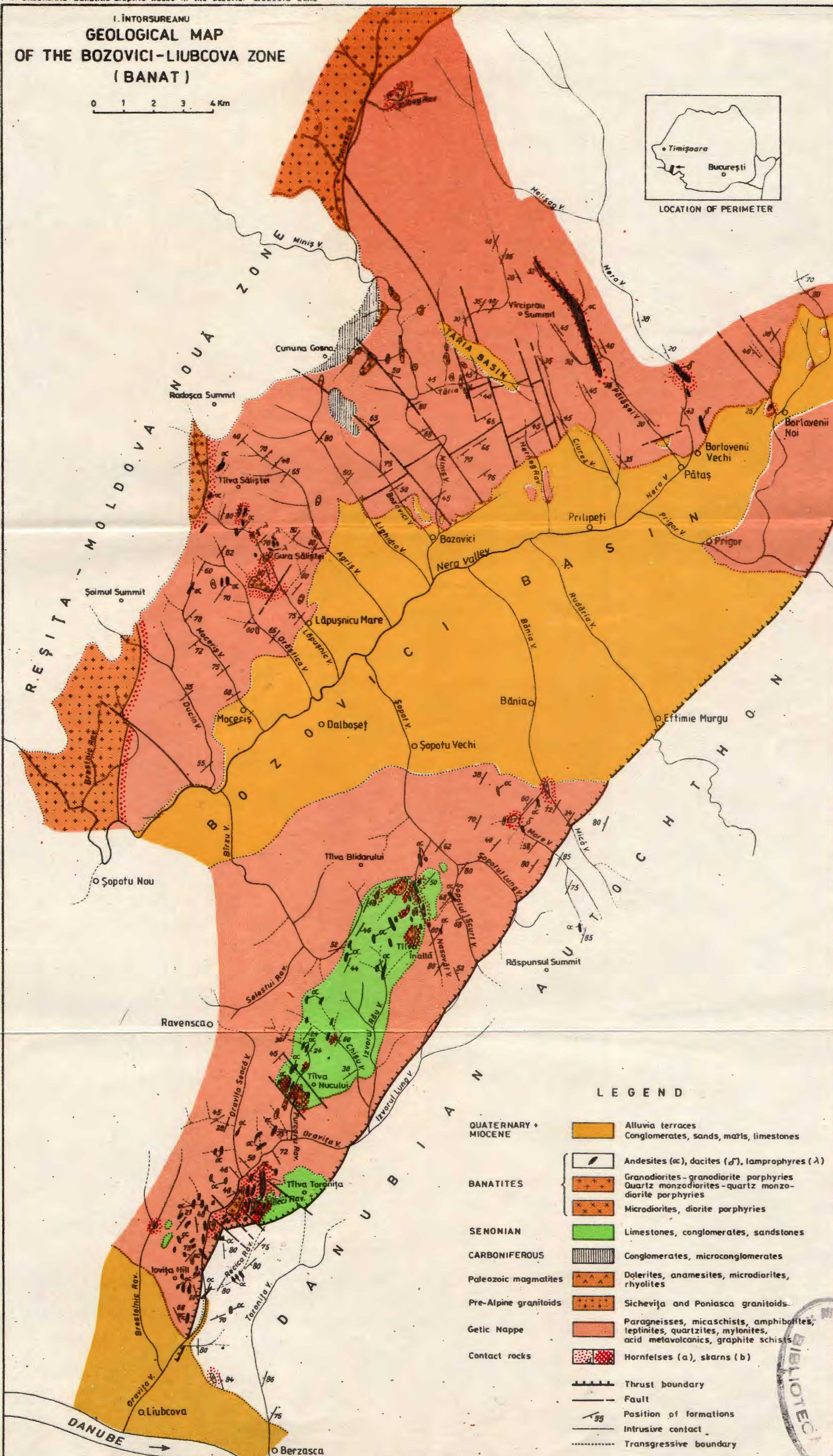

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

AURÉOLE DE CONTACT DU MASSIF ALCALIN DE DITRĂU DANS LA ZONE DE LĂZAREA (CARPATHES ORIENTALES) [1]

PAR

SILVIA MÎNZATU [2], GYULA JAKAB [3]

Alkali rocks. Syenite. Tinguaite. Bostonite. Diorite. Lamprophyre. Aureole. Retrograde metamorphism. Hydrothermal processes. Pneumatolitic activity. Tulgheș Series. Rebra Series. Biotite. Rare earths. East Carpathians — Crystalline-Mesozoic Zone — Giurgeu Mountains.

Résumé

Les aspects microscopiques mettent en évidence un contact thermique et métasomatique du massif alcalin de Ditrău (zone de Lăzarea) avec la série cristallophylienne de Rebra (Rb_2 et Rb_3). L'auréole est percée par des filons de siénites, tinguaïtes, bostonites, diorites et lamprophyres, liées génétiquement au massif de Ditrău. Les activités superposées pneumatolitiques, de rétromorphisme et hydrothermales sont relevées par l'apparition de minéraux spécifiques et par leur transformation.

Les preuves sur l'existence des phénomènes de contact suggèrent une interprétation d'ordre tectonique, à savoir que le massif alcalin de Ditrău a un caractère intrusif, affectant au contact les séries cristallines de Tulgheș et de Rebra, de sorte que le charriage de ces séries, s'il existerait, pourrait être réalisé avant la mise en place du massif de Ditrău.

Abstract

Contact Aureole of the Ditrău Alkaline Massif in the Lăzarea Zone (East Carpathians). Microscopic aspects point out a thermic and metasomatic contact of the Ditrău alkaline massif (Lăzarea Zone) with the Rebra crystalline series

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(Rb_2 and Rb_3). The aureole is intruded by syenite, tinguaite, bostonite, diorite and lamprophyre veins, genetically connected with the Ditrău massif. The superposed retromorphic and hydrothermal pneumatolitic activities are reflected by the occurrence of specific minerals and alteration of others. Evidences related to the existence of contact phenomena suggests a tectonic interpretation that is the intrusive character of the Ditrău alkaline massif affecting, at the contact, the Tulgheş and Rebra crystalline series, so that the overthrusting of these series, if it exists, might have been achieved before the emplacement of the Ditrău massif.

Au sud-ouest du massif alcalin de Ditrău, tout près de la commune de Lăzarea, on a mis en évidence par deux forages l'auréole de contact du massif avec les formations cristallines de la série de Rebra.

L'existence des enclaves de calcaires cristallins de type Rebra dans les roches siénitiques (VIII^{e} galerie de Lăzarea) a relevé l'existence des phénomènes de contact pyrométasomatique dans cette zone (Jakab, 1976).

Les forages ont traversé la série de Rebra aux caractères principalement terrigènes dans la partie supérieure — Rb_3 — (forage 142) et carbonatés dans la partie médiane — Rb_2 — (forage 141).

A la suite de l'étude microscopique on a observé quelques transformations épigénétiques de la série de Rebra traversée à la fois par des filons de siénites, de bostonites, de diorites et de lamprophyres appartenant au massif alcalin de Ditrău.

Le forage 142 a traversé jusqu'à 1394 m de profondeur des roches d'aspect microscopique monotone, à schistosité marquée, finement ondulées et injectées lit-par-lit. La poussière fine, noire, graphiteuse est fréquente dans ces roches. La présence de la magnétite finement granulaire confère aux roches des caractères magnétiques (Romanescu et al., 1981).

Prédominent les micaschistes biotitiques, les micaschistes biotito-muscovitiques+grenat passant vers des roches à caractère phylliteux, à séricite+biotite±chlorite et vers des cornéennes micacées à amphiboles et clinozoïzite ou bien vers des cornéennes biotito-muscovitiques à grenat. Des schistes et des quartzites+biotite±séricite±amphiboles (pargasite à côté d'actinote) tout comme des quartzites noirs cornifiés s'intercalent entre ces micaschistes. Les injections de quartz, de quartz+feldspath ou de calcite sont associées ou non à la minéralisation et sont concordantes, lentilliformes concordantes et discordantes. Les filons de siénites, de tinguaïtes, de diorites s'associent aux lamprophyres, mais d'une manière plus fréquente vers la base du forage.

Les micaschistes biotitiques et biotito-muscovitiques passent aux schistes micacés et aux quartzites micacés à grenats de texture plane schisteuse ou finement plissée. Le quartz pavimenteux est associé à la biotite finement écailleuse englobant de la poussière graphiteuse disposée linéairement. La biotite porphyroblastique (pl. I, figs. 1 et 2) à traces de graphite comprend des minéraux fins entourés d'auréoles pléocroïques. Elle a une orientation perpendiculaire à la schistosité. Les grenats aplatis ou fissurés sont rétromorphosés. La tourmaline verdâtre est finement cristallisée ; la pyrite hydrothermale est déposée le long des fissures ou disseminée en roche. Parfois, l'ilménite à une bordure de leucoxène.

Les schistes biotitiques à chlorite et séricite d'aspect phylliteux contiennent de la biotite souvent chloritisée et des grenats chloritisés, rétromorphosés. Les solutions hydrothermales ont déposé de la pyrite, de la chalcopyrite et des carbonates sur les plans de schistosité.

Les schistes biotito-muscovitiques à clinozoïzite (cornéennes) contiennent du clinozoïzite ayant des couleurs à biréfringence anormale, bleu-indigo.

Les intercalations de schistes quartzo-feldspathiques à biotite et muscovite±grenat comportent de l'albite maclée ou non polysynthétique, pavimenteuse, claire ou séricitisée et kaolinisée. La biotite est fréquemment chloritisée. Le feldspath en grande quantité vers la base du forage confère à la roche un caractère gneissique. L'épidote et les carbonates sphaerulitiques ont une origine hydrothermale.

Les cornéennes biotito-muscovitiques à grenats contiennent de la biotite fraîche ou chloritisée, des grenats fissurés et des nodules de muscovite en paillettes disposées d'une manière radiaire, en suggérant un type différent de pseudomorphose d'après un minéral complètement remplacé (pl. I, fig. 3).

Les quartzites à séricite et biotite intercalés à divers niveaux sont cornifiés. Le quartz pavimenteux s'associe à séricite, biotite chloritisée, zoïzite, épidote et sphène, tous imprégnés du graphite. Rarement le quartzite renferme en exclusivité du quartz, allant vers des quartzites noirs dont la couleur est due au pigment graphiteux ou manganeux. La séricite est associée à biotite verte et les carbonates à la pyrite.

Les quartzites feldspathiques (à albite) constituent très rarement des intercalations. La chlorite est sporadique, alors que la pyrite est dispersée en roche ou elle remplie les fissures.

Le forage 141 a traversé 1.100 m dans le complexe de Rebra$_2$, caractérisé par une nature surtout carbonatée et d'une manière subordonnée terrigène tout comme par la présence des orto- et des paraamphibolites. Dans sa partie supérieure apparaissent des calcaires schisteux à talc. Au-dessous de ces calcaires se développent des roches à caractère terrigène et à métamorphisme plus accentué ayant des intercalations d'aspect de cipolins et de skarns.

Les schistes de la première partie du forage contiennent de la biotite brun olivâtre tandis que les micaschistes à grenat±tourmaline± sillimanite ont de la biotite brun rouge. Vers la base apparaissent des cornéennes à biotite brun rouge±grenats±épidote±sphène.

Les filons lamprophyriques et siénitiques sont en nombre réduit.

Les calcaires dolomitiques à phlogopite sont finement marmoréens. La phlogopite à teneur réduite en fer est brun pâle jusqu'à incolore. Sa présence dans les calcaires de Lăzarea a été mise en évidence pour la première fois par Mînzatu et Ardelean (1980).

Suivent des schistes micacés biotitiques±amphiboles±muscovite± grenats semblables aux cornéennes. La biotite brun olivâtre est finement écailleuse, tandis que la muscovite et l'amphibole trémolitique ont un large développement. Bien que l'un des minéraux énumérés puisse prédominer, la biotite est constamment brun olivâtre. Harker (1960), Moorhouse (1959) et Tilley (1924) considèrent que la biotite de cette couleur est caractéristique pour l'auréole de contact thermique. Les grenats aplatis sont fissurés perpendiculairement à la schistosité.

Les schistes biotito-muscovitiques à amphiboles comportent en plus calcite, quartz, épidote, apatite, sphène et biotite vert olivâtre à sagénite. Cette association minéralogique suggère un matériel préexistant d'origine basique (orthoamphibolites ?). Les injections hydrothermales contiennent de l'épidote et de la pyrite. Le fond quartzitique des schistes à biotite et grenats contient biotite brun olivâtre+sagénite, muscovite et abondamment apatite, magnétite, épidote et sphène opacitisé et transformé finalement en ilménite.

Les schistes quartzo-feldspathiques à biotite brun olivâtre contiennent outre la biotite poïkiloblastique de la muscovite. Le quartz hydrothermal est associé avec de la pyrite le long des fissures.

Les micaschistes à biotite brun rouge+muscovite+grenats d'aspect de cornéennes comportent de la biotite porphyroblastique, disposée parfois perpendiculairement à la schistosité, renfermant de la poussière noire graphiteuse et des fins minéraux radioactifs entourés des auréoles pléocroïques. Les grenats sont parfois squelettiques (pl. I, fig. 4) substitués par le quartz ; d'autres fois comportent de la même poussière noire.

Les micaschistes à biotite brun rouge et les grenats semblables aux cornéennes contiennent de la tourmaline finement cristallisée et en grande quantité par rapport à la façon habituelle d'apparition.

Les micaschistes à sillimanite sont une variété du type antérieur. On remarque fréquemment que la biotite passe aux gerbes de sillimanite. D'autres fois, la sillimanite fibreuse est englobée dans la muscovite (pl. II, fig. 1). Les grenats ont une bordure de magnétite et de séricite.

Les gneiss à biotite brun rouge (cornéennes) ont de la biotite à structure poïkilitique et d'abondants grenats.

Les calcaires skarnifiés constituent des zones minces irrégulières. Sur un fond carbonaté, le quartz, le sphène, les amphiboles, les grenats et la pyrrhotine se trouvent dans un désordre parfait. Tout proche des injections de quartz, les amphiboles sont ouralitisés. Les roches contiennent aussi de la zoïzite, d'autres fois c'est l'amphibole qui prédomine. Le sphène idiomorphe est associé au quartz et à l'apatite idiomorphe, mais apparaît également comme des inclusions en amphiboles.

Les calcaires type cipolins apparaissent sporadiquement, ayant la texture parallèle, due à l'orientation commune des granules aplaties de dolomie et des paquets de muscovite. La chlorite vert pâle est présente seulement sur des fissures.

Généralement, les roches filoniennes, les porphyres, les aplites siénitiques, les tinguaïtes, les bostonites, les diorites et les lamprophyres (camptonites, spessartites et vogésites) ont les minéraux composants totalement transformés.

L'activité pneumatolitique est décelée par la présence des minéraux de néoformation caractéristique. L'introduction du bore a déterminé l'apparition de la tourmaline sous forme d'agglomérations le long des plans de schistosité dans les cornéennes quartzo-biotitiques à sillimanite. La couleur brun pâle à disposition zonée indique un type plus pauvre en alumine et plus riche en fer. La biotite est remplacée partiellement par la tourmaline, l'orientation étant parallèle à la schistosité, ce qui dénote que les solutions pneumatolitiques ont suivies les plans de résistence minimum. La tourmaline des schistes micacés est idiomorphe et provient probablement d'une tourmaline détritique recristallisée sous l'influence d'un apport de bore. Dans une injection granodioritique, la tourmaline a un aspect lobé-poïkiloblastique. Le contour tout à fait spécial suggère une genèse liée également à l'introduction du bore (pl. II, fig. 2).

L'introduction du fluor est un processus faiblement représenté. La phlogopite apparaît dans les calcaires métamorphosés de distribution relativement uniforme, fait relevant que la pénétration du fluor ne s'est pas faite par voies ouvertes mais par diffusion et par substitution moléculaire dans toute la masse de la roche.

L'introduction du phosphore dans le processus pneumatolitique a conduit à l'apparition de l'apatite. Celle-ci forme des agglomérations de cristaux idiomorphes, clairs et incolores (si elle est associée au quartz et au sphène bien cristallisé) et des granules xénomorphes à arrondies (si elle est en présence de l'amphibole).

Effets du métamorphisme de contact

Le métamorphisme de contact dans la zone de Lăzarea est aussi bien thermique (isochimique) que pyrométasomatique.

Le métamorphisme thermique est reconnu dans le cas du quartz recristallisé, de la sillimanite et du grenat, mais discutable dans le cas du sphène. Probablement la biotite porphyroblastique s'est développée sous des influences thermales auxquelles s'est ajoutée une métasomatose ferro-magnésienne (qui a aussi généré la cordiérite).

La biotite porphyroblastique a souvent une disposition perpendiculaire à la schistosité. Harker (1960) et Pitcher et Read (1963) la considèrent d'origine contact-métamorphique. Streckeisen (1968) affirme que la biotite porphyroblastique de l'auréole de contact du massif de Ditrău avec la série de Bistrița-Barnar est plus jeune que la structure de base de la roche et ses plissements.

Les auteurs de la présente note opinent pour l'origine de la biotite ultérieure au métamorphisme régional et aux déformations mécaniques superposées, mais liée au métamorphisme thermal, éventuellement à une métasomatose ferro-magnésienne. Nos arguments sont d'ordre microscopique : les porphyroblastes ont une position transversale sur les bandes à biotite finement cristallisée ; ils ont renfermé au cours de leur développement outre des inclusions graphiteuses linéaires ou finement plissées, des granules d'apatite et des minéraux radioactifs. Nous considérons que cette position de la biotite porphyroblastique à disposition transversale n'est pas redevable au plissement fin du plan S (plissement mis en évidence par les inclusions graphiteuses linéaires finement froncées) mais à un processus de recristallisation ultérieure aux déformations tectoniques. En échange la biotite des nids et des agglomérations linéaires le long des injections quartzo-feldspathiques a probablement recristallisée durant le processus de ségrégation des solutions qui ont circulé pendant les phases post-tectoniques.

La biotite porphyroblastique des roches du complexe de Rebra$_2$ est plus rarement discordante et sa teinte varie de brun vert olivâtre à brun rouge. Selon Tilley (1924) la biotite brun rouge en grandes paillettes caractérise la zone interne de l'auréole de contact thermique ; selon Moorhouse (1959) les biotites olivâtre et rouge ont une origine thermale.

Les arguments microscopiques sont corroborés aux arguments chimiques. Les analyses chimiques (6) sur une biotite porphyroblastique (épigénétique) et sur une biotite finement cristallisée (syngénétique du métamorphisme régional) d'une même cornéenne diffèrent par les teneurs en SiO_2, Fe total, Al_2O_3 et CaO (tabl. 1). La teneur en TiO_2 de la biotite porphyroblastique (épigénétique) pourrait être justifiée par un apport de titane dans le magma siénitique caractérisé lui-même par une teneur grande en cet élément.

TABLEAU 1

Teneur en oxydes de la biotite

	SiO_2	Al_2O_3	Fe_2O_3	FeO	TiO_2	CaO	MgO	MnO	Na_2O	K_2O
Biotite épigénétique	40,96	16,96	0,49	18,80	1,65	1,20	6,73	0,17	0,55	8,33
Biotite syngénétique	32,47	10,84	23,19		0,11	2,45	6,18	0,48	0,15	8,03

Analiste : O. Kalman, I. P.E.G. — Miercurea Ciuc.

Les microéléments (7) à valeurs plus élevées pour Gu, Ni et V en biotite épigénétique suggèrent une source d'influence d'un magma plus basique. La teneur en Ba supérieure à 1% est caractéristique pour une biotite à baryum et la teneur élevée en Sr est en accord avec l'enrichissement de cet élément dans le massif de Ditrău (tabl. 2).

TABLEAU 2

Teneur en microéléments de la biotite

	Ag	As	Co	Cr	Ge	Ga	Cu	Mn	Mo	Ni	Pb	Sn	V	Zn	In	Ba	Sr
Biotite épigénétique	0,2	30	—	30	—	10	8000	250	1	100	20	1	85	100	—	>10.000	2000
Biotite syngénétique	0,2	—	10	20	5	3	20	250	—	30	20	3	25	60	2	8000	45

Analiste : O. Kalman, I.P.E.G. — Miercurea Ciuc.

Le comportement des lantanides Sm, Eu, Tb (8) en biotite épigénétique est le même pour la biotite associée à la sodalite dans un filon de la vallée de Ditrău, relevant une origine commune, mais différente pour la biotite magmatique primaire des roches du complexe essexite-hornblenditique du massif de Ditrău (tabl. 3). L'absence de La, Ce, Nb, Dy, Yb et Lu dans les deux premières biotites témoigne la même idée.

TABLEAU 3

Teneur en lantanides de la biotite

gr/t	La	Ce	Nd	Sm	Eu	Dy	Tb	Yb	Lu
Biotite porphyroblastique (épigénétique) Lăzarea	—	—	—	<2	0,15	—	0,8	—	—
Biotite épigénétique vallée Ditrău	—	—	—	<2	0,40	—	0,6	—	—
Biotite magmatique massif Ditrău	27	69	50	6,4	1,20	7	0,33	1,1	0,36

Analiste : M. Sălăgean, I.F.I.N., București.

La muscovite dépasse rarement du point de vue quantitatif la biotite. L'aspect est porphyroblastique, poïkiloblastique, à disposition perpendiculaire ou inclinée à la schistosité de la roche. La muscovite largement feuilletée à disposition radiaire constitue des nodules qui semblent représenter des pseudomorphoses d'après andalousite. Un exemple semblable est donné par Pitcher et Read (1963) pour le massif de Donegal.

La cordiérite fraîche a des nuances bleuâtres mais apparaît aussi pigmentée avec une substance pulvérulente opaque, agglomérée au centre des granules.

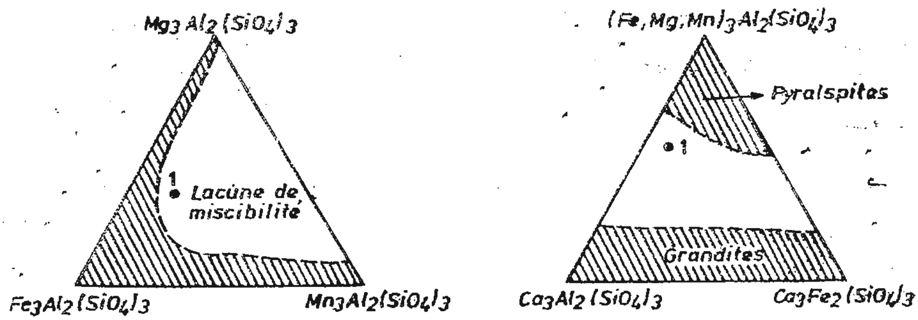
La sillimanite se développe dans les couches à biotite brun rouge, sous forme des gerbes à orientation commune ou bien perpendiculaire aux couches biotitiques. Chapman (1950) la considère comme représentant des ségrégations aux dépens de la biotite caractéristiques pour les zones du voisinage du contact. D'autre fois, les aiguilles de sillimanite apparaissent d'une manière isolée ou en gerbes noyées dans la muscovite, fait signalé aussi par Harker (1960), Chapman (1950), Moorhouse (1959) et d'autres, et interprété comme le résultat d'un haut degré de métamorphisme thermique.

Le sphène accessoire est parfois en grande quantité dans les calcaires skarnifiés où il apparaît idiomorphe ou xénomorphe-arrondi. Sa présence est redevable à l'influence thermique d'après l'opinion de Harker (1960). Le sphène des cornéennes s'est formé initialement dans les conditions du métamorphisme régional.

Le grenat d'une cornéenne micacée à amphiboles et clinozoïzite a la suivante composition chimique (9) : SiO_2 = 38,24%; Al_2O_3 = 19,83%; Fe_2O_3 = 3,20%; FeO = 12,20%; TiO_2 = 0,60%; CaO = 14,60%; MgO = 5,60%; Na_2O = 0,28%; K_2O = 0,12%; MnO = 4,70%.

Selon Hsu (1960) les grenats des cornéennes de contact ont le rapport $Mn > Fe \gg Mg$. Pour notre grenat ce rapport diffère : $Mn = Mg \ll Fe$ et la composition normative est : grossulaire = 30,82%; almandin = 28,67%; pyrope = 18,98%; spessartine = 11,22%; andradite = 10,31% en suggérant une double genèse : formé initialement pendant le métamorphisme régional. Il a recristallisé sous l'influence du métamorphisme thermique provoqué par l'intrusion du massif de Ditrău.

Les données Rx : a° = 11,64 (10) et 11,576 (11) comparables à Miheev : a° = 11,607 et ASTM : a° = 11,60 indiquent une spessartine vers grossulaire. Deer et al. (1965) citent une spessartine d'une skarn de Devonshire à valeur de a° = 11.637 très proche de la nôtre. La double genèse du grenat de l'auréole de contact thermique de Lăzarea résulte aussi du diagramme (fig.) sur laquelle il se situe dans la zone de la lacune de miscibilité entre les pyralspites et les grandites, zone qui



Diagrammes triangulaires des domaines de miscibilité des grenats pyralspitiques, granditiques.

1, grenat — Lăzarea.

sépare les grenats formés durant le métamorphisme régional de ceux formés pendant le métamorphisme thermal.

Rétromorphisme. Les aspects de rétromorphisme sont visibles dans les roches de la série de Rebra 3. Les structures de glissement (pl. II, fig. 3) observées microscopiquement sont provoquées par les déformations tectoniques ultérieures au métamorphisme régional et sont attribuées par Harker (1960) au processus de rétromorphisme. La chlorite pseudomorphose les paquets de biotite, qui pendant le glissement, se sont tournés de presque 90°, en présentant une structure hélicitique.

Les grenats sont rarement frais. L'aspect squelettique spongieux est le résultat des réactions chimiques du processus de rétromorphisme. Généralement, les grenats sont fissurés, envahis de biotite et de chlorite et ont une bordure de séricite+muscovite. Le mica blanc de la périphérie du grenat peut être redevable aux processus hydrothermaux qui ont aussi provoqué la décoloration de la chlorite en même temps avec l'introduction de la pyrite sur les fissures de ce grenat. Une telle transformation a été décrite par les auteurs de cette note (1981) pour les grenats de la zone d'Aurora, au NE du massif de Ditrău. On a imaginé un schéma d'évolution du processus de substitution de grenat à muscovite :

grenat →	biotite	→ chlorite	→ séricite muscovite
(métamorphisme régional)	(métamorphisme de contact thermique)	(rétromorphisme) température plus baissée	(activité hydrothermale)

Souvent la biotite est corrodée à la périphérie par la séricite (pl. II, fig. 4). Certaines pseudomorphoses de séricite peuvent être mises aux dépens du disthène ou de l'andalousite qui, au cours d'un stade plus avancé, se transforme en muscovite largement développée à contours lobés.

L'activité hydrothermale est représentée par des injections de quartz et de carbonates, accompagnées ou non de pyrite et de chalcopyrite ; la chlorite en rosettes est associée à l'épidote et aux minéraux ferromagnésiens qui se décolorent tout proche des fissures. Les grenats sont substitués par le quartz et réduits à des squelettes (aspect discutable dû probablement au rétromorphisme aussi).

La minéralisation de l'auréole se caractérise par deux types d'association géochimiques : l'une, avec prédominance de la chalcopyrite et de la pyrotine et avec les éléments sidérofiles (Co, Ni, Sr) légèrement élevés, est liée génétiquement aux roches basiques, respectivement aux filons de roches dioritiques; l'autre, contenant de Ag, Pb, Zn, Mo$\pm$Y etc., apparaît dans les zones de circulation hydrothermale est, probablement, liée génétiquement aux différentiés moins basiques. Une zone intensément circulée par les solutions hydrothermales a été identifiée par des méthodes radiométriques dans le forage 142 (470 m) et peut être également liée au massif de Ditrău.

Conclusions

Les données de cette note complètent celles existantes portant sur le métamorphisme de contact autour du massif de Ditrău. Les auteurs ont déjà signalé quelques aspects particuliers dûs au contact thermique et métasomatique dans la partie est du massif de Ditrău, dans la zone d'Aurora (Mînzatu et Ardelean, 1980 ; Jakab et Mînzatu, 1981).

Dans la zone de Lăzarea, la série de Rebra (Rb_2 et Rb_3) a été influencée, au contact avec le massif de Ditrău, autant thermique que métasomatique, et traversée par des filons de siénites, tinguaïtes, bostonites, diorites et lamprophyres liées génétiquement au massif.

L'étude microscopique relève dans les roches et les minéraux quelques particularités qui sont rattachées à des phénomènes essentiels : pneumatolitiques, métamorphisme thermique et métasomatique, rétromorphisme et activité hydrothermale.

Les preuves concernant l'existence des phénomènes de contact suggèrent des interprétations tectoniques. Etant argumentée l'existence de l'auréole de contact aussi bien à l'est du massif (zone d'Aurora) qu'au sud-ouest (zone de Lăzarea) on peut affirmer que le massif alcalin de Ditrău a un caractère intrusif, affectant les séries de Tulgheș et de Rebra que métamorphose au contact ; le charriage de la série de Tulgheș sur la série de Rebra, s'il existerait, s'est réalisé seulement avant la mise en place du massif de Ditrău.

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DISCUSSIONS

I. Balintoni : Le fait que la série de Rebra a été traversée par le massif de Ditrău est relevé par la présence des filons de siénites et de tinguaïtes dans les forages. La manière dont est envisagée l'association de minéraux rencontrée dans les roches de la série de Rebra est tout à fait confuse. Tous les minéraux cités en tant que minéraux de contact tels sillimanite, cordiérite, andalousite, grenat, biotite et d'autres apparaissent dans la série de Rebra à de grandes distances envers le massif de Ditrău et dans des conditions géologiques qui excluent leur attribution à un métamorphisme de contact posthercynien. Pour cela, nous considérons que les minéraux attribués par les auteurs à l'influence thermique du Ditrău peuvent être tenir pour des minéraux de métamorphisme régional, alors que les vrais minéraux de contact thermique en relation avec le Ditrău n'ont pas été pris en considération par les auteurs. Ils n'ont pas eu en vue l'information selon laquelle une paragenèse de contact thermique peut être séparée par les paragenèses de métamorphisme régional générées en des conditions de température comparables.

AUREOLA DE CONTACT A MASIVULUI ALCALIN DITRĂU ÎN ZONA LĂZAREA (CARPAȚII ORIENTALI)

(Rezumat)

Prin intermediul unor foraje a fost pusă în evidență, în partea de sud-vest a masivului alcalin Ditrău, o aureolă de contact a acestuia în seria cristalofiliană Rebra (Rb_2 și Rb_3), în zona Lăzarea.

Studiul microscopic reliefează în roci și minerale, particularități pe care le raportează la fenomene esențiale : pneumatolitice, metamorfism termic și metasomatic, retromorfism și activitate hidrotermală.

Minerale specifice ale activității pneumatolitice sînt : turmalina, flogopitul și apatitul. Metamorfismul termic a produs pe lîngă recristalizarea cuarțului și sillimanit și granați. Originea biotitului porfiroblastic este legată de metamorfismul termal și o metasomatoză feromagneziană. Muscovitul porfiroblastic, radiar poate reprezenta pseudomorfoze după andaluzit. Cordieritul rămîne rareori proaspăt. Sillimanitul este format pe seama biotitului, iar sfenul are o origine dublă : termală în skarne și metamorfică în corneene. Analizele chimice și Rx argumentează geneza dublă a unui granat din corneene. Aspecte de retromorfism sînt oglindite în structuri de alunecare, habitus scheletic la granați, în cloritizarea granaților și a biotitului — și în corodarea biotitului de către sericit. Activitatea hidrotermală a afectat majoritatea rocilor din aureolă.

Se sugerează o interpretare tectonică potrivit căreia, masivul alcalin Ditrău are caracter intrusiv și metamorfozează la contact seriile de Tulgheș și Rebra ; în consecință, șariajul seriei de Tulgheș peste seria de Rebra s-ar fi putut realiza numai înaintea punerii în loc a masivului Ditrău.

EXPLICATION DES PLANCHES

Planche I

Fig. 1. — Porphyroblastes de biotite à inclusions contourées d'auréoles pléocroïques et des traces de poussière graphiteuse. 50 ×, N ||.

Fig. 2. — Biotite à inclusions radioactives contourées d'auréoles pléocroïques noircies et à inclusions d'apatite (A) ; les porphyroblastes sont développées perpendiculairement à la schistosité de la roche. 75 ×, N ||.

Fig. 3. — Muscovite secondaire à disposition radiaire. 25 ×, N ||.

Fig. 4. — Grenats squelettiques substitués au quartz. 40 ×, N ||.

Planche II

Fig. 1. — Aiguilles de sillimanite (S). en muscovite (M) ; biotite (B), granules de magnétite (M). 80 ×, N ||.

Fig. 2. — Tourmaline d'aspect lobé, poïkiloblastique. 15 ×, N ||.

Fig. 3. — Structure de glissement dans les schistes muscovito-chloritiques.

Fig. 4. — Biotite corrodée par la séricite (S). 27 ×, N ||.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

CONTRIBUTIONS À L'ÉTUDE DE LA DACITE DE DRĂGOIASA (MONTS CĂLIMANI) — DISTRICT DE SUCEAVA [1]

PAR

EUGENIA NIȚOI [2]

Drăgoiasa Dacite. Lithofacies. Rhyodacites. Lava. Intrusive body. Petrochemistry. Magmas differentiation. East Carpathians — Neogene Quaternary eruptive — Călimani Mountains.

Résumé

La dacite de Drăgoiasa est située dans les monts Călimani du Nord à la limite entre la zone cristallino-mésozoïque et l'éruptif néogène. On a constaté que la dacite de Drăgoiasa n'est pas une formation unitaire, liée à une seule apparition mais au moins à deux émissions qui s'entrecroisent et localement se recouvrent l'une à l'autre. On a séparé dans cette formation trois types de faciès : de corps, de coulée et bréchique. Ces faciès sont séparés à partir des critères structuraux, texturaux, de l'emplacement en espace et des caractères pétrochimiques. La „dacite de Drăgoiasa" est représentée par des dacites et par des rhyodacites emplacées différemment en espace, tout en formant des corps intrusifs et des minces coulées de laves.

Abstract

Contributions to the Study of the Drăgoiasa Dacite (Călimani Mountains) — Suceava District. Drăgoiasa Dacite lies in the northern Călimani Mts at the limit between the Crystalline-Mesozoic zone and the Neogene eruptive. It is not a unitary formation related to one emission ; there are at least two emissions intruding each other and locally overlapping each other. Three facies types have been distinguished within this formation — body, flow and breccious facies —

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on the basis of structural and textural criteria, their spatial distribution and petrochemical characters. "Drăgoiasa Dacite" is represented by dacites and rhyolites with a different spatial location, forming intrusive bodies and thin lava flows.

1. Introduction

La dacite de Drăgoiasa est située dans les monts Călimani du Nord, à la limite entre la zone cristallino-mésozoïque et l'éruptif néogène. Les premières observations portant sur cette roche revient à Atanasiu (1898) qui l'a décrite comme „tuf trachytique dont l'apparition est liée à une faille profonde orientée NNO-SSE". Savul (1938) la désigne et la décrite comme „la dacite de Drăgoiasa *s.s.* à passages vers des rhyolites, située à la base des premières éruptions des monts Călimani, recouverte des coulées ultérieures d'andésites à hypersthène et à augite". Török (1954) situe „le faciès de Drăgoiasa dans la première série effusive surmontant le faciès subvolcanique". Des recherches sporadiques à caractère général sur la dacite de Drăgoiasa ont été faites par Cosma et al. (1964), Peltz et al. (1970), Peltz, Stoian (1985), Peltz et al. (1985).

Lors des recherches effectuées ces dernières années au nord des monts Călimani nous avons constaté que la dacite de Drăgoiasa n'est pas une formation unitaire liée à une seule coulée de la lave, mais il y a au moins deux émissions qui s'entrecroisent et localement se recouvrent l'une à l'autre. Nous allons essayé ci-dessous de démontrer que les trois types de faciès (de corps, de coulée et bréchique) séparés dans cette formation acide sur des critères physiographiques diffèrent aussi du point de vue des caractères chimiques. Là-dessus il s'ensuit que le magma d'où a engendré la dacite de Drăgoiasa a eu un caractère de plus en plus acide vers la fin de la période de mise en place. Comme formes de gisement les plus fréquentes sont les corps intrusifs et les laves.

Pour le moment, l'âge de cette dacite ne peut pas être établi avec précision. Savul (1938) lui attribue, à partir des données paléontologiques, l'âge helvétien-tortonien, alors que sur les cartes de la R.S.R. feuille Şarul Dornei au 1 : 50000 et feuille Topliţa au 1 : 200000 la dacite est située au niveau pannonien (au-dessous des dépôts sédimentaires pontiens).

2. Cadre géologique

2.1. *Le soubassement de la zone de Drăgoiasa,* sur lequel se sont déposées les coulées ultérieures de laves, est représenté par des roches cristallines (schistes séricito-chloriteux, paragneiss, calcaires cristallins) appartenant aux séries de Rebra et de Tulgheş (Balintoni et al., 1981). Celles-ci ont été rencontrées soit en place en tant qu'affleurements continus dans le versant gauche de la vallée Tomnatec (Pl.) et dans le versant droit de la vallée Neagra (calcaires cristallins, paragneiss biotitiques), soit en place (?) comme lambeaux dans l'aire de distribution de la formation acide, dans les vallées Fundoi, Bolovăniş et Tomnatec (calcaires cristallins).

2.2. *Complexe volcano-sédimentaire pannonien.* Dans la partie nord-ouest (au NO) de la zone étudiée, au-dessus de la dacite de Drăgoiasa, se dispose localement un complexe volcano-sédimentaire constitué d'un mélange de matériel éruptif, métamorphique et sédimentaire. Rarement, apparaît une faible stratification, là où des niveaux minces de tufs se sont développés. La puissance totale des dépôts atteignent 150 à 200 m. La distribution spatiale, les compositions pétrographique et minéralogique du complexe volcano-sédimentaire révèlent une étroite liaison entre sa formation et la mise en place de l'éruptif andésitique néogène. Eu égard aux critères pétrographiques et la distribution géographique on a pu séparer dans ce complexe des dépôts de roches voisines comme lithologie et faciès de celles de la zone Neagra Şarului-Gura Haitei. On a reconnu ainsi, même à Drăgoiasa, la série intermédiaire (II) et la série supérieure (III) séparées par Peltz, Peltz (1970) dans les formations volcano-sédimentaires des monts Gurghiu, par Rădulescu et al. (1973) dans la chaîne Călimani-Gurghiu-Harghita et par Niţoi (1982, 1984) dans les monts Călimani du Nord.

La série intermédiaire (II) est constituée de tuffites et d'agglomérats. C'est le matériel éruptif qui prédomine (andésites à pyroxènes, à pyroxène et à amphiboles) et d'une manière subordonnée le matériel sédimentaire (grès micacés, marnes, oolithes ferrugineuses) et celui métamorphique (quartzites noirs, schistes séricito-chloriteux). Le liant, de nature andésitique, encaissant tous les éléments constitutifs de cette série, les prédomine.

La série supérieure (III) n'est formée que par des agglomérats contenant surtout des fragments arrondis et subarrondis d'andésites pyroxéniques et d'andésites basaltiques englobées dans un liant légèrement développé. Sur la planche on a représenté cartographiquement les deux séries du complexe volcano-sédimentaire. Les laves andésitiques du compartiment supérieur reposent sur le complexe volcano-sédimentaire.

3. Dacite de Drăgoiasa

Surmontant directement le soubassement cristallin, elle occupe dans la zone étudiée une aire de 18 km^2 environ, à orientation NNO-SSE. Puisque les conditions géologiques n'ont pas été les mêmes sur toute l'aire d'extension de la dacite, au cours de la mise en place, on a pu séparé trois types de faciès différents structuralement et texturalement, au point de vue de la distribution géographique aussi bien que des caractères pétrochimiques.

Des roches en faciès de corps se sont développées sur les versants droit et gauche de la vallée Neagra et sur la colline Răcila-Păltiniş, zone qui pourrait être considérée comme zone d'implantation de la dacite. La dacite se caractérise par : texture massive, structure porphyrique donnée par les phénocristaux de feldspaths plagioclase et de biotite noyés dans une masse fondamentale microcristalline ou criptocristalline ; l'analyse modale (tabl. 2) montre la prédominance des phénocristaux par rapport à la masse fondamentale ; les dimensions des minéraux sont de 2 à 3 mm, étant visibles à l'oeil nu. La roche présente parfois d'intenses tectonitisations (vallée Neagra).

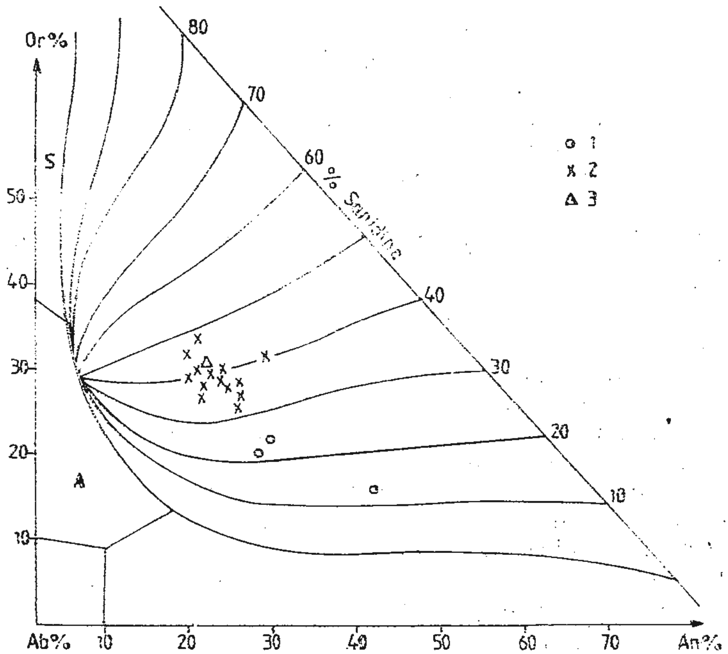

Fig. 1. — Composition calculée des feldspaths (A. Rittmann, 1973). 1, roches en faciès de coulée ; 2, roches en faciès de corps ; 3, roches en faciès bréchique.

Le calcul de la norme Rittmann (fig. 1) permet la construction d'un diagramme en vue d'apprécier la composition du feldspath de ces roches. Il est à remarquer leur caractère bifeldspathique, quoiqu'à la suite de l'étude optique ce ne soit que le feldspath plagioclase qui peut être déterminé (An = 25-30%). On a figuré sur le tableau 1 les compositions calculées des feldspaths suivant la norme Rittmann (1973) ainsi que les indices de couleur. Un phénomène à part observé dans les roches du faciès de corps est la présence des feldspaths à contours idiomorphes et à zonations fines, „développés" sur un noyau feldspathique préexistant à contours arrondis. Ce noyau représenterait, selon Rittmann (1969), un „cristalloblaste fondu hérité des anciennes roches sédimentaires soumises aux processus d'anatexie". La biotite est présente sous deux aspects. Le premier (BI) est celui des feuillets primaires de biotite, formés dans des conditions subvolcaniques, de teinte brun-rougeâtre, dépenaillés aux extrémités, corrodés par la masse fondamentale, sagenitisés, disposés d'une manière non orientée. Le deuxième aspect (BII) est celui de gerbes à couleur verdâtre, formées aux dépens d'un minéral préexistant (pyroxène ?) dans des conditions de surface après la migration du magma vers la surface. Comme minéraux accessoires notons : magnétite, apatite, zircon, hornblende, pyroxènes et grenat. L'existence des petits cristaux de grenat, transparents, à contours hipidiomorphes, renfermés dans des cristaux de biotite en développement, révèle que la dacite de Drăgoiasa a pris naissance dans le magma à une profondeur correspondant à la limite croûte inférieure/manteau supérieur (Green, Ringwood, 1968).

TABLEAU 1

Composition calculée des feldspaths d'après la norme Rittmann et l'indice de couleur des dacites et des rhyodacites

No. échant.	Indice de couleur	OR	AB	AN
17	8,56	32,07	40,66	27,27
020 V	9,97	27,19	49,84	22,97
3034	15,32	33,83	46,17	20,00
1132	11,18	24,65	50,67	24,70
1131	9,73	28,63	51,00	20,37
3012	10,06	27,98	50,97	21,05
3038	8,20	27,57	49,26	23,17
3020	9,08	29,15	50,67	21,17
3013	7,47	19,87	50,93	29,20
m296	4,26	14,69	44,21	41,09
1122	8,85	30,04	50,83	19,13
3046	8,59	28,04	49,67	22,29
3016	6,17	27,32	48,47	24,29
1123	7,16	25,87	52,48	21,64
3005	10,45	31,18	47,97	20,86
3004	8,18	29,01	48,32	22,67
3033	4,93	21,55	51,59	26,85
3041	6,01	27,53	48,80	23,67
3006	7,28	31,72	49,73	18,55

Les roches en faciès de coulée forment des niveaux minces de lave qui apparaissent dans les affleurements petits des vallées de Stînceni et de Tomnatec. Les principales caractéristiques sont : texture fluidale, structure pilotaxitique ou de dévitrification ; les minéraux de petites dimensions de 0,50 à 1 mm sont visibles rien qu'au microscope. A titre de minéraux principaux signalons : feldspath plagioclase (sur la figure 1 est illustrée la différence entre la composition de ces feldspaths et celle des feldspaths des roches des faciès de corps et bréchique), hornblende, biotite. Prédomine la masse fondamentale contenant beaucoup de verre. Les roches en faciès de coulée sont accompagnés d'un matériel ferrugineux (limonite, hématite, oolithes ferrugineuses) provenu, probablement, des formations préexistantes.

Les roches en faciès bréchique, rencontrées dans les vallées de Curmătura, de Bolovăniș et de Steji, ont une allure différente comme morphologie et structure par rapport aux deux autres types de roches. Leur surface d'affleurement a un contour presque circulaire. Nous supposons l'existence de petits corps de roches acides, mis en place dans une coulée ultérieure du magma le long d'une faille de direction

SE-NO qui traversent les roches du faciès massif. Ces petits corps sont intensément fragmentés, fissurés dans leurs parties inférieure et supérieure, acquérant un aspect bréchique. Sur ces fissures non orientées, s'est déposé un matériel de composition plus acide que le précédent. Il a imprimé à la roche un aspect tâcheté, les fragments de roche préexistante de teinte plus foncée (gris noirâtre) contrastant avec le matériel injecté de couleur plus claire (blanchâtre). Une autre caractéristique de ces roches est la présence de nombreuses enclaves de roches métamorphiques et sédimentaires, parfois de 0,30 cm de longueur, provenues des formations traversées. Par suite de l'étude microscopique on a pu déterminer quelques types de roches enclavées (la nature réelle de celles-ci est toutefois masquée, partiellement, des transformations ultérieures thermiques auxquelles elles ont été soumises) : quartzites noirs, quartzites à muscovite, schistes noirs limonitisés, schistes quartzo-feldspathiques, roches à sillimanite de néoformation, quartz roulés.

TABLEAU 2

Composition modale des roches

	Faciès de coulée	Faciès de corps	Faciès bréchique
Feldspath plg.	2,70–3,56	60,80–61,70	—
Biotite	1,00–2,60	3,80–5,60	—
Hornblende	1,00–1,90	1,00–1,30	—
Masse fondamentale	89,00–90,00	36,30–37,06	60,00–65,00
Enclaves	3,40–4,00	—	40,00–35,00

3.1. *Dans la vallée de Bolovăniș*, au-dessous des dépôts de roches pyroclastiques du complexe volcano-sédimentaire, se développe un niveau mince de tuffite grossière, de teinte blanc grisâtre, constitué de fragments arrondis et subarrondis de dacites et de roches cristallines renfermées dans une matrice litho-vitro-cristallo-clastique. Cette matrice contient des cristaux et des fragments de cristaux de plagioclase, biotite, muscovite, hornblende, toutes fraîches.

4. Composition chimique

Quant à la dacite de Drăgoiasa il y a peu de données concernant ses caractères chimiques. Le nombre réduit d'affleurements ne nous a pas permis de faire plusieurs analyses chimiques. Des données analytiques employées, 13 analyses chimiques sont nouvelles et 6 sont empruntées des ouvrages antérieurs (Mastacan, 1930 ; Seghedi in Balintoni et al., 1983). Afin d'affirmer que les trois types de faciès séparés dans la dacite de Drăgoiasa peuvent être désignés sous le nom de „dacite" ou sous d'autres noms (rhyodacites ou bien rhyolites), nous les avons représentés sur divers diagrammes basés sur une classification chimique.

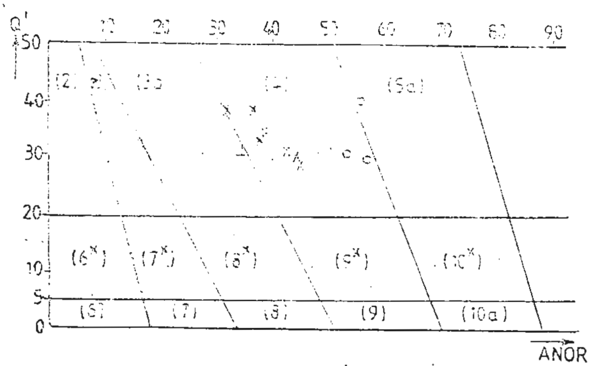

Fig. 2. — Diagramme Q'-ANOR (A. Streckeisen, R. W. Le Maître, 1979). 1, 2, 3, idem fig. 1.

Conformément au diagramme Q'-ANOR (Streckeisen, Le Maître, 1979) basé sur des données de la norme CIPW, les roches se situent dans des champs des dacites et des rhyodacites (fig. 2).

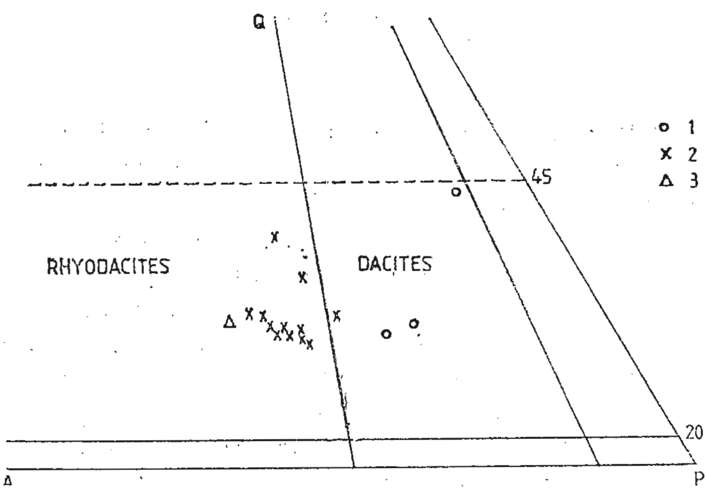

Fig. 3. — Diagramme *QAP* (Streckeisen, 1967). 1, 2, 3, idem fig. 1.

Le diagramme *QAP* (fig. 3) (Streckeisen, 1967) localise les roches acides de Drăgoiasa toujours dans le domaine des dacites et des rhyodacites (les roches du faciès de coulée se situent dans le champ des dacites, celles des faciès de corps et bréchique dans celui des rhyodacites). Si on emploie le diagramme SiO_2-K_2O (Peccerillo, Taylor, 1976), il s'agit alors des dacites et des dacites riches en K (fig. 4).

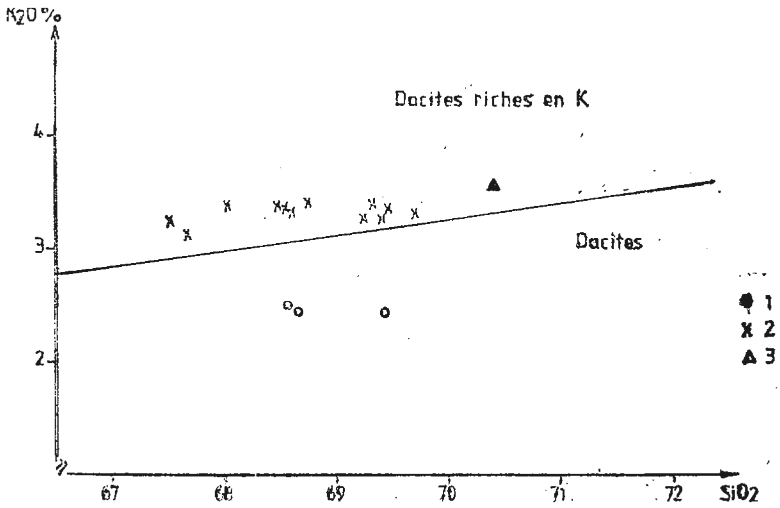

Fig. 4. — Diagramme SiO_2-K_2O (Peccerillo, Taylor, 1976). 1, 2, 3, idem fig. 1.

La variation des principaux oxydes (tabl. 3) dénote une faible non-homogénéité du matériel initial d'où ont engendré les dacites et les rhyodacites de Drăgoiasa (fig. 5).

L'acidité des roches oscille entre 66,6% et 70,41% SiO_2. Les valeurs des paramètres Niggli (tabl. 4) montrent une tendance d'évolution du magma dacitique vers des termes plus acides (fig. 6). Dans la figure 6 on remarque aussi l'allure légèrement différente de la ligne d'évolution des roches dans le faciès de coulée. La tendance vers des termes plus acides est évidente voire sur le diagramme FAM ($FeO+0,9$ Fe_2O_3/Na_2O+K_2O/MgO (fig. 7) ; on y observe un faible enrichissement en alcalis pendant les stades plus tardifs d'évolution ainsi que la diminuation de la teneur en éléments ferromagnésiens.

La relation *al-alk* (fig. 8) situe les roches acides de Drăgoiasa à la limite du domaine des magmas alcalins avec ceux relativement pauvres en alcalis. Sur le diagramme *fm-al* (fig. 9) les roches acides appartiennent au domaine des roches saliques.

TABLEAU 3

Composition chimique des roches acides de Drăgoiasa (dacites, rhyodacites)

No.	No. échantillon	Localisation	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	H_2O^-	H_2O^+	CO_2	Total	Analiste
1	17	V. Neagra	66,60	16,87	1,37	1,65	0,09	0,20	3,83	2,93	3,57	1,03	0,17	0,64	0,51	1,08	100,03	Mastacan
2	020	V. Neagra	67,53	18,12	2,27	0,22	0,04	0,45	2,85	3,46	3,21	0,24	0,04		1,19		99,62	Mastacan
3	3034	V. Stînceni	67,69	16,41	3,13	0,56	0,03	0,69	2,30	2,83	3,11	0,25	0,11		2,75		100,05	E. Călinescu
4	1132	V. Neagra Broșteni	67,77	17,06	2,05	0,60	0,03	0,48	3,07	3,37	2,57	0,18	0,12		2,23		99,63	E. Călinescu
5	1131	V. Neagra Broșteni	68,10	17,60	1,85	0,70	0,05	0,32	2,72	3,52	3,34	0,13	0,19		1,21		99,73	E. Călinescu
6	2012	V. Stînceni	68,51	17,46	1,79	0,21	0,03	0,64	2,22	2,90	3,37	0,31	0,15		2,22		99,98	E. Călinescu
7	3038	V. Neagra	68,54	16,56	1,85	0,75	0,06	0,49	3,19	3,61	3,30	0,25	0,13		1,06		99,90	E. Călinescu
8	3020	V. Curmăturii	68,58	17,13	2,17	0,61	0,04	0,29	2,53	3,46	3,33	0,23	0,08		1,43		99,83	E. Călinescu
9	3013	V. Stînceni	68,60	16,93	2,68	0,23	0,05	0,33	3,92	3,72	2,48	0,17	0,10		0,74		100,12	E. Călinescu
10	m296	V. Stînceni	68,60	17,76	1,05	0,07	0,06	0,15	4,00	2,46	2,46	0,28	0,14		1,23		99,51	E. Călinescu
11	1122	p. Curmăturii	68,82	16,85	2,13	0,43	0,04	0,28	2,76	3,76	3,38	0,15	0,16		0,83		99,59	E. Călinescu
12	3046	V. Neagra	69,19	16,59	2,11	0,31	0,03	0,54	3,02	3,60	3,24	0,22	0,11		0,86		99,94	E. Călinescu
13	3016	V. Curmăturii	69,31	16,48	1,61	0,34	0,03	0,49	3,40	3,64	3,35	0,22	0,12		0,14		100,30	E. Călinescu
14	1123	Creastă V. Tomnatic	69,37	17,05	1,31	0,34	0,03	0,35	2,58	3,33	3,18	0,22	0,15		1,70		99,61	
15	3005	V. Neagra	69,38	16,44	2,50	0,17	0,04	0,53	2,71	3,30	3,28	0,26	0,12		1,00		99,88	E. Călinescu
16	3004	V. Neagra	69,45	16,40	1,50	0,62	0,03	0,55	3,07	3,47	3,30	0,21	0,13		1,18		100,06	E. Călinescu
17	3033	V. Tomnatic	69,46	17,35	0,93	0,46	0,02	0,17	3,73	3,85	2,41	0,38	0,09		1,25		99,98	E. Călinescu
18	3041	V. Bolovăniș	69,69	16,49	1,31	0,40	0,02	0,50	3,35	3,67	3,34	0,22	0,13		0,05		100,8	E. Călinescu
19	3006	V. Curmăturii	70,41	16,51	1,31	0,16	0,02	0,48	2,50	3,55	3,58	0,18	0,11		1,05		99,99	E. Călinescu

Echantillons 3033, m 296, 3013 — faciès de coulée ; 3006 — faciès bréchique ; autres échantillons — faciès de corp.

TABLEAU 4

Paramètres Niggli

No.	No. échant.	*Si*	*al*	*fm*	c	*alk*	*k*	*mg*	*c/fm*	t	p	W	gz	*Q*	*L*	*M*
1	17	304,0	45,0	13,0	19,0	23,0	0,44	0,17	1,46	—	—	—	112,0	53,20	40,40	6,40
2	020	311,6	49,30	11,60	14,10	24,90	0,38	0,26	1,22	0,8	—	0,90	112,0	53,7	39,4	6,90
3	3034	327,98	46,85	18,33	11,93	22,89	0,42	0,27	0,65	0,91	0,28	0,82	136,40	55,98	34,29	9,78
4	1132	322,87	47,89	13,09	15,66	23,36	0,33	0,26	1,19	0,64	0,24	0,74	129,42	55,41	57,35	7,24
5	1131	320,00	48,73	11,55	13,69	26,03	0,38	0,19	1,18	0,46	0,38	0,68	115,87	53,88	39,09	7,03
6	3012	341,87	51,33	12,06	11,86	24,74	0,43	0,39	0,98	1,16	0,32	0,86	142,90	56,60	34,86	8,53
7	3038	318,52	45,34	12,75	15,88	26,03	0,38	0,27	1,24	0,87	0,26	0,66	144,39	53,37	41,02	5,61
8	3020	332,21	48,89	11,46	13,13	26,52	0,39	0,18	1,14	0,84	0,16	0,81	126,11	54,70	38,73	6,57
9	3013	311,59	45,31	12,07	19,07	23,55	0,30	0,18	1,58	0,58	0,19	0,89	117,37	54,02	40,88	5,10
10	m 296	347,39	57,99	5,31	21,69	20,01	0,40	0,21	4,08	1,07	0,30	0,87	167,34	59,53	36,95	5,52
11	1122	327,60	47,26	11,17	13,97	27,60	0,37	0,18	1,25	0,34	0,32	0,80	117,20	53,64	40,63	5,74
12	3046	326,75	46,16	12,33	15,28	28,23	0,37	0,31	1,23	0,78	0,22	0,84	121,81	54,12	40,22	5,67
13	3016	327,24	45,84	10,23	17,19	26,74	0,38	0,34	1,68	0,78	0,24	0,78	120,30	53,88	41,88	6,25
14	1123	349,62	50,63	8,97	13,93	26,48	0,39	0,29	1,55	0,83	0,32	0,75	143,70	56,37	37,44	6,18
15	3005	336,01	46,91	13,42	14,06	25,61	0,40	0,28	1,04	0,95	0,25	0,91	133,56	55,31	37,97	6,72
16	3004	333,37	46,38	11,60	15,78	26,24	0,38	0,34	1,36	0,76	0,26	0,66	128,41	54,74	39,90	5,36
17	3033	338,31	49,79	5,01	19,66	25,75	0,29	0,25	3,88	1,39	0,19	0,81	135,53	55,64	40,96	3,40
18	3041	331,64	46,23	9,64	17,07	27,06	0,37	0,37	1,77	0,79	0,26	0,73	123,41	54,15	41,72	6,13
19	3006	353,60	48,85	8,97	13,45	28,74	0,40	0,40	1,49	0,68	0,23	0,86	138,65	55,48	39,57	4,95

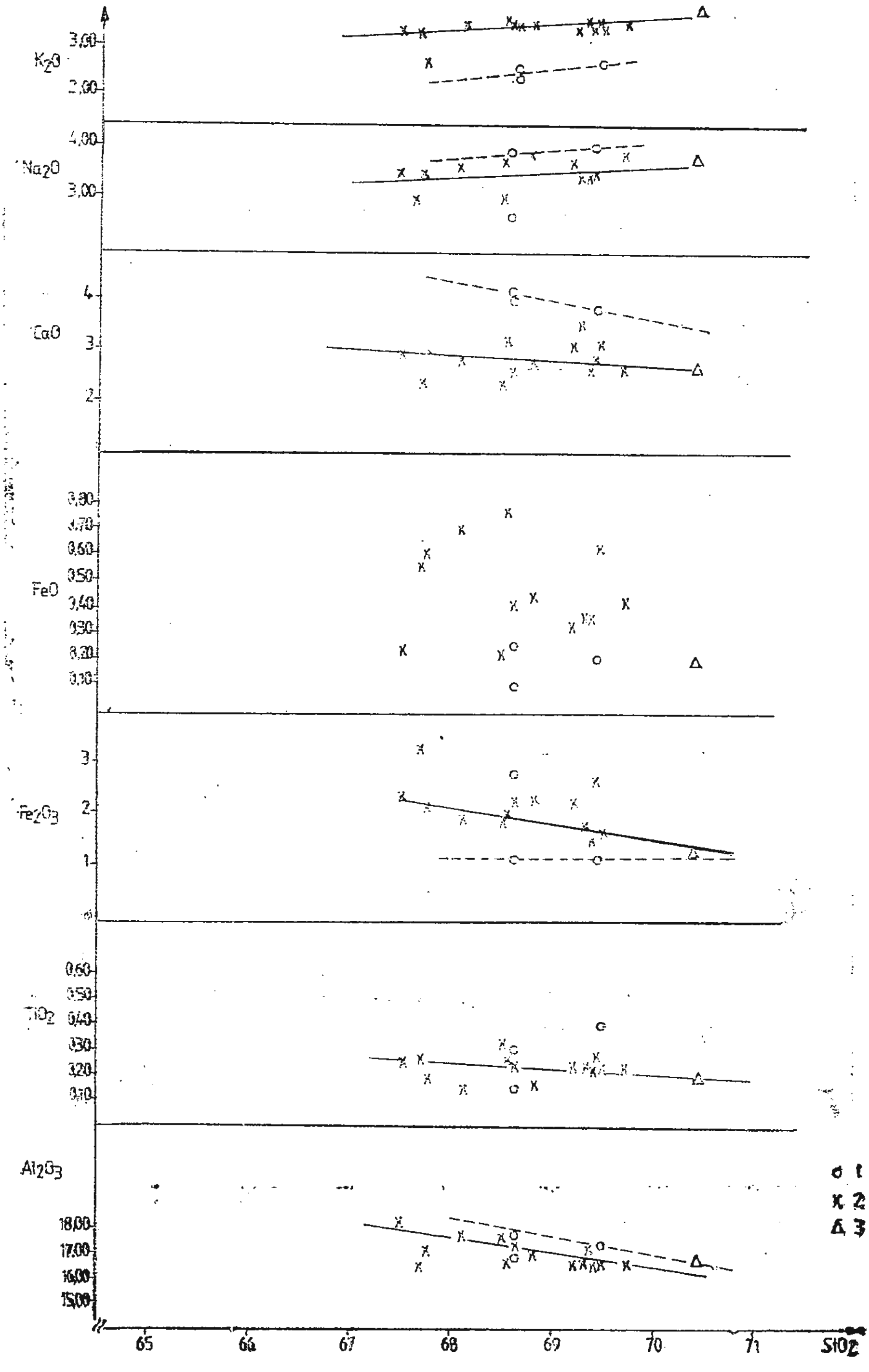

Fig. 5. — Diagramme de variation des principaux oxydes. 1, 2, 3 idem fig. 1.

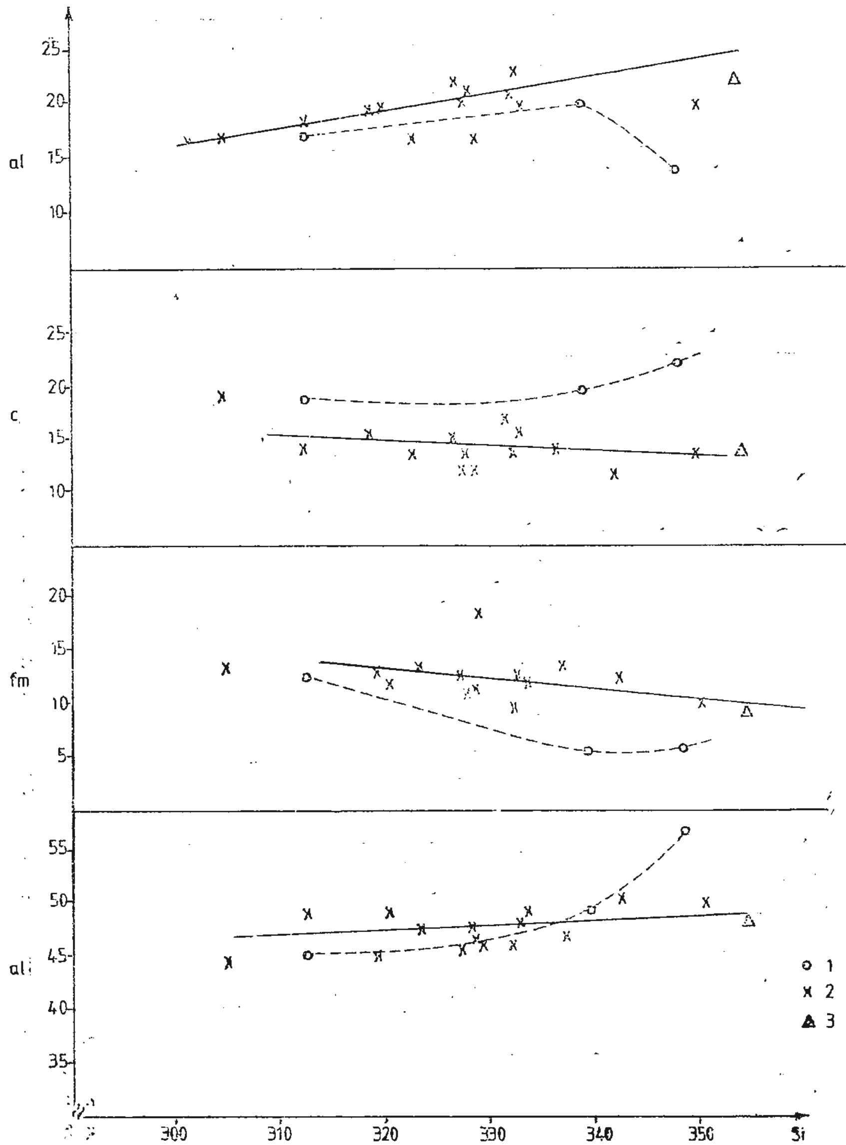

Fig. 6. — Diagramme de variation des paramètres Niggli. 1, 2, 3, idem fig. 1. 4, sens d'évolution des roches en faciès de corps et bréchique ; 5, sens d'évolution des roches en faciès de coulée.

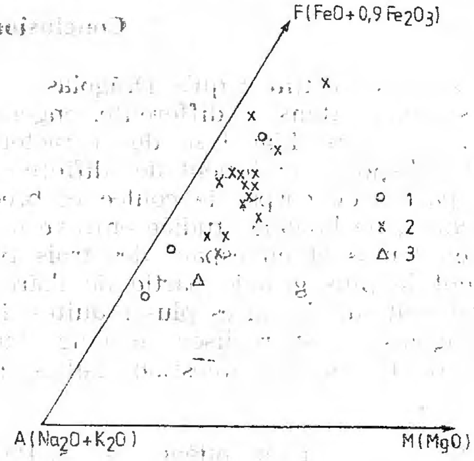

Fig. 7. — Diagramme FAM
1, 2, 3, idem fig. 1.

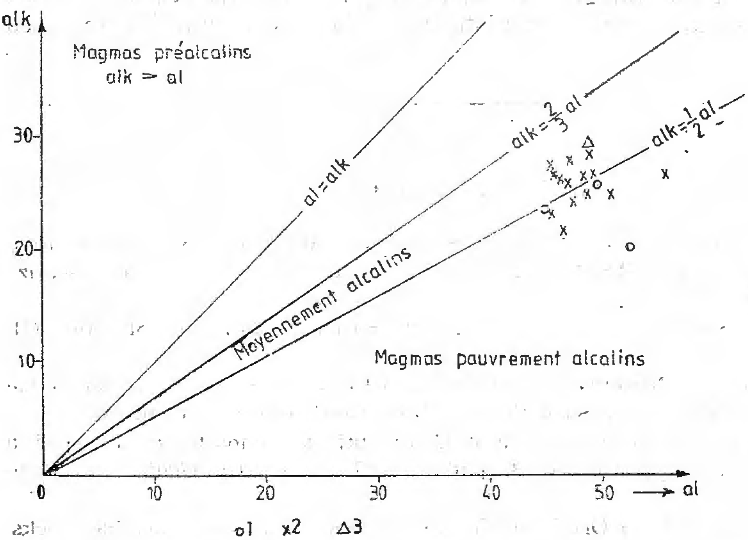

Fig. 8. — Diagramme *al-alk.*

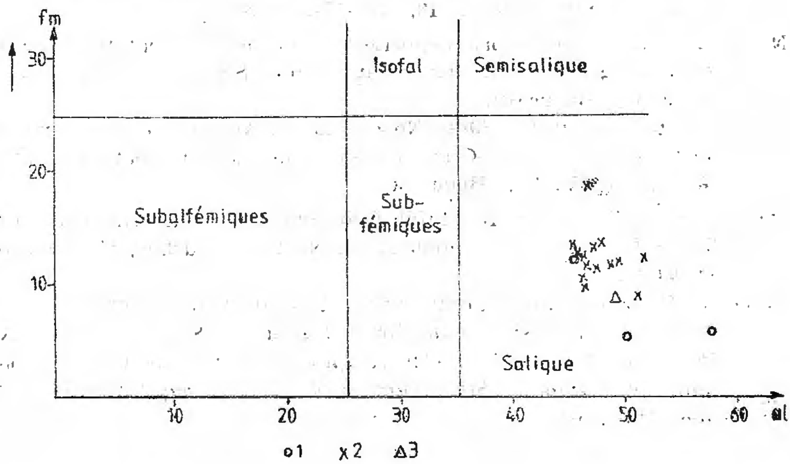

Fig. 9. — Diagramme *fm-al.*

5. Conclusions

On peut affirmer qu'à Drăgoiasa il y a des dacites et des rhyodacites d'une extension différente, engendrant des corps et des coulées de laves minces. L'analyse des caractères chimiques, pétrographiques et minéralogiques indiquent des différences entre les trois types de faciès séparés : de corps, de coulée et bréchique. Le degré élevé de recouvrement de la zone étudiée entrave la détermination exacte des relations en temps et en espace des trois types de faciès. Les rhyodacites occupent la plus grande partie de l'aire étudiée, alors que les dacites apparaissent sur des aires plus réduites. La mise en place de la „dacite" de Drăgoiasa s'est réalisée le long d'une faille située à l'est et à l'ouest de la zone en question, failles dont la direction est SSE-NNO (Pl.).

Je remercie mon collègue Dr. S. Peltz pour ses observations et ses utiles suggestions ainsi que la chimiste Erna Călinescu pour les analyses chimiques.

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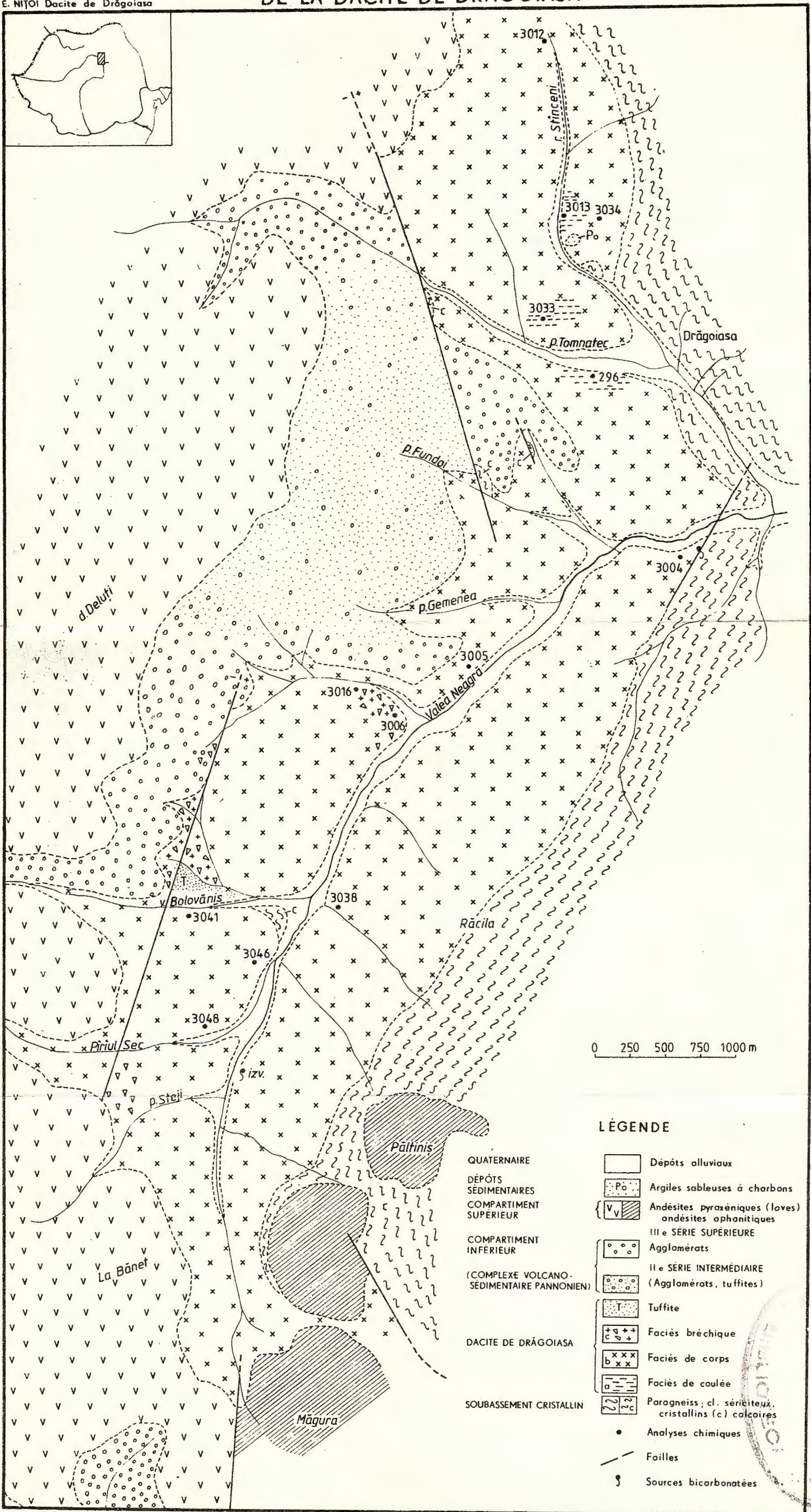
CONTRIBUȚII LA STUDIUL DACITULUI DE DRĂGOIASA (MUNȚII CĂLIMANI) — JUDEȚUL SUCEAVA

(Rezumat)

Dacitul de Drăgoiasa, situat în munții Călimani de nord, a fost studiat și delimitat de Atanasiu (1898), Savul (1938), Török (1954). În cadrul acestei formațiuni acide s-au putut separa, pe criterii fiziografice și petrochimice, trei tipuri de facies : de corp, de curgere și brecios. Ca forme de zăcămînt sînt întîlnite corpuri intrusive și curgeri subțiri de lave. Dacitul de Drăgoiasa stă direct peste fundamentul cristalin și este acoperit de complexul vulcano-sedimentar. Punerea în loc a acestei formațiuni acide s-a făcut de-a lungul unor falii situate în estul și vestul zonei cercetate, falii a căror direcție este SSE-NNV. Clasificările, pe criterii chimice, ale celor trei tipuri de facies separate, indică existența, în cadrul „dacitului de Drăgoiasa" a dacitelor și a riodacitelor.

CARTE GEOLOGIQUE DE L'AIRE DE DISTRIBUTION DE LA DACITE DE DRĂGOIASA



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

PETROCHEMICAL STUDY OF THE SURDUC BANATITIC MAGMATITES (BANAT)[1]

BY

DOINA RUSSO-SĂNDULESCU[2], IRINA BRATOSIN[2], CATRINEL VLAD[3], ROSETTE IANC[3]

Banatitic magmatites. Cretaceous. Paleocene. Intrusion. Magmas differentiation. Subduction. Calc-alkali magmas. Granodioritic magmas. South Carpathians — Neocretaceous-Paleogene magmatites — Bocşa, Ocna de Fier — Surduc.

Abstract

The Surduc massif is a banatitic pluton resulting from the emplacement of two intrusions of different age : Upper Cretaceous — Surduc 1 — and Paleocene — Surduc 2. During the first intrusion occur nodules of gabbronorites and anorthosites with cumulate structures, coming from the fractional crystallization of a basic magma. A new impulse of more potassic magma did not remelt all the material accumulated in a deep-seated, intermediary magmatic chamber. This material is represented by nodules or even crystals of cumulate type, within schlieren of gabbroic, monzodioritic or quartz monzonitic rocks with a strong potassic up to shoshonitic calc-alkaline chemism. The first intrusion, quite complex at the present level of emplacement, can suggest its appearance in a distension period. The second intrusion (Surduc 2) — calc-alkaline — shows conspicuous characteristics of the granodioritic magmas related to subduction processes.

Résumé

Etude pétrochimique des magmatites banatitiques de Surduc (Banat). Le corps de Surduc est un pluton banatitique constitue de deux intrusions d'âge différent, à savoir crétacé supérieur pour Surduc 1 et paléocène pour Surduc 2.

Une nouvelle impulsion de magma plus potassique ne réussit pas à réfondre tout le matériel accumulé, qui présente à la suite de ce phénomène une distri-

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bution non homogène des nodules ou bien des cristaux de type cumulé, dans les schlieren de roches monzodioritiques ou monzonitiques quartzifères à chimisme calco-alcalin fortement potassique jusqu'à shoshonitique. Cette première intrusion qui assez complexe au niveau actuel de mise en place s'est produite, paraît-il, au cours d'une période plutôt de distension.

L'intrusion Surduc 2 calco-alcaline tient des caractères prégnants des magmas granodioritiques liés aux processus de subduction.

Introduction

Surduc body is the westernmost intrusion known in outcrop within the "plutonic banatites" (Russo-Săndulescu, Berza, 1977) intruding the crystalline formations of the Supragetic Nappe in the South Carpathians.

Among the few geological and petrological data published or in manuscript on the Surduc body mention should be made of Constantinof's studies (1956-1972) pointing out the existence of special petrographic types as compared with other banatitic intrusions, olivine gabbros and monzonitic rocks, the former originating by magmatic differentiation.

In a general paper on the banatitic province Giușcă et al. (1966) presented the evolution of the acid magmas of granodioritic type towards weakly basic terms, on the one hand, and towards peracid terms, on the other hand, pointing out an alkaline-monzonitic or syenitic tendency in the weakly basic domain.

Taking into account the lack of chemical evidence on various petrographic types found in the Surduc pluton, a thorough geochemical study has lately been initiated, which will be presented further on.

Considerations on the Structure and Petrography of the Pluton

The shape and sizes of the pluton can hardly be estimated after the reduced outcropping area — about 15 sq.km — but the conjugation of a maximum gravimetric tendency with a major positive magnetic anomaly suggests the westward prolongation of the massif under the cover of Neogene sediments of the Pannonian Depression up to Jamu Mare (Andrei et al., 1976). After the shape of the anomaly the pluton has an elliptical contour, whose big axis with an E-W trending exceeds 12 km.

Although with a high degree of covering, the eastern part of the massif could be directly studied, so that two intrusions of different age (Russo-Săndulescu et al., 1986) — Surduc 1 (S_1) and Surduc 2 (S_2) — were differentiated. The S_1 intrusion develops in the eastern part, intruding the crystalline schists of the Bocșița-Drimoxa Formation. Its petrographic constitution is extremely complicated as compared with the S_2 intrusion, relatively homogeneous in petrographic respect, occurring in the western part of the outcropping area.

Surduc 1. This intrusion is characterized by the presence of "schlieren" differentiates of highly varied sizes and shapes (from hundreds of metres to microscopic ones), so that the limits between the petrographic types were drawn taking into account the predominance of a certain petrotype within a larger group ; in particular either the abundance of leucocrates or that of melanocrates is evidenced.

1. The group of gabbroic rocks is represented, beside homogeneous gabbros with pyroxene, biotite+hornblende, by "nodules" of variable sizes (from centimetric up to metric) of rocks with cumulate textures ; their limits are hardly traceable in fresh outcrops, but by weathering they often display rounded shapes. Cumulates generally have a planary "architecture" within which anorthosite laminas (up to 1.5 cm thick) alternate with olivine gabbros proving a primary layered texture without traces of a subsequent deformation or recrystallization. The undulations or "microfolds" visible in anorthosite laminas can be due to slumpings in the incompletely crystallized magma. Under the microscope one can sometimes observe thin pinched out bands of clinopyroxene and magnetite or clinopyroxene, olivine and subpoikilitic biotite included into gabbros called by us homogeneous in order to dfferentiate them from cumulate nodules.

2. The group of monzodioritic rocks ± quartz seem to develop around gabbroic rocks. After the presence of melanocrate minerals they are monzodiorite with pyroxene and biotite or with pyroxene, biotite and hornblende. The constant presence of potash feldspar as poikilitic masses as well as of two types of plagioclase feldspar — euhedral crystals of unzoned plagioclase or even of irregular nuclei of bitownite beside zoned plagioclase of andesine type with thin external zones reaching 30% An — is specific to monzodiorites.

3. The group of quartz monzodioritic and monzonitic rocks develops towards the interior of the massif showing numerous mineralogical or structural variations within larger schlieren. The inner structure of small-sized schlieren can be homogeneous but they often show a magmatic lamination defined by the orientation of plagioclase crystals.

The above mentioned mineralogical features of the group of monzodioritic rocks are preserved in the group of quartz monzodiorites and monzonites but attenuated by the increase of the content of potash feldspar (also of monzonitic-poikilitic type) and of quartz.

4. In the north-eastern part of the massif there is an isolated zone of monzonitic rocks and potassic syenitic segregations within which orthoclase feldspar reaches maximum values. It is worth mentioning the almost pegmatoid structure of these monzonites in which clouded grey plagioclase, with numerous corroded basic nuclei, has sizes up to 1.5/1 cm.

A mineralogical characteristic specific to the whole S_1 unit is given by the constant presence of pyroxenes (clinopyroxene and in small amounts orthopyroxene) displaying very fine exsolutions, undeterminable microscopically.

Surduc 2. It occurs in the western part of the outcropping area as an independent intrusion, with porphyric facies at the contact with Surduc 1 and with numerous enclaves (centimetric up to decimetric) among which some originate in the rocks of the first intrusion (S_1).

The characteristic features of this unit are given by its homogeneous structure mostly represented by monzogranites and less by granodiorites with hornblende and biotite. It is of note that within the hornblende crystals remnants of clinopyroxene occur and within the recurrently zoned plagioclase of "banatitic" type basic corroded nuclei are found in the centre of the crystals. Although all these features are observed in case of the S_1 unit too, the presence of porphyric facies at the contact, of the enclaves from the S_1 intrusions and of the smaller K/Ar ages (Russo-Săndulescu et al., this volume) indicate that Surduc 2 is a subsequent intrusion.

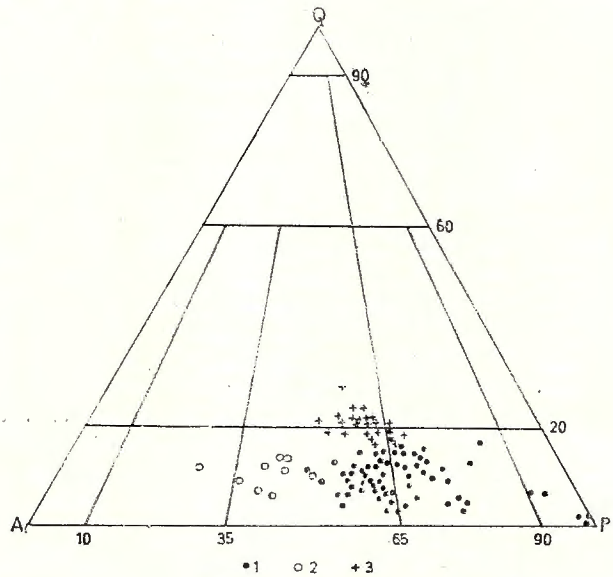

Fig. 1. — *QAP* modal diagram.
1, groups of homogeneous gabbroic, monzodioritic and monzonitic rocks (1, 2, 3 in text) within S_1 intrusion; 2, group of monzonitic rocks and potassic syenitic segregations within S_1 intrusion; 3, S_2 intrusion.

QAP modal composition of the groups of monzodioritic and monzonitic rocks from the S_1 intrusion as well as those from the S_2 intrusion is plotted on the Streckeisen diagram in Figure 1.

Geochemistry

The chemical features of the studied rocks are defined by their contents of major and trace elements presented in Tables 1-10.

According to the SiO_2 content cumulates (nos. 1-7 in Table 1) can be assigned to ultramafic rocks, like the two "erratic" nodules (nos. 8 and 9 in Table 1); the other gabbros named homogeneous can be broadly regarded as equivalents of basalts. In terms of normative constituents the group of gabbroic rocks includes nonsaturated olivine tholeiites with normative hy + ol (cumulates and gabbros 402, 407, 482), tholeiites suprasaturated with normative q + hy (the rest of gabbros) and nodule 244 — the only one with normative nepheline might be considered as alkali basalt.

Alumina, with very high fluctuations in cumulates and gabbros, shows generally high values (except for the two mentioned nodules — analyses 8 and 9) due to the accumulation of significant amounts of basic plagioclase. As a matter of fact Al_2O_3 is also variable (15-18%, predominantly 17-18%) within the groups of monzodioritic and monzonitic rocks. This fluctuation is considered by Jakeš and Smith (1970)

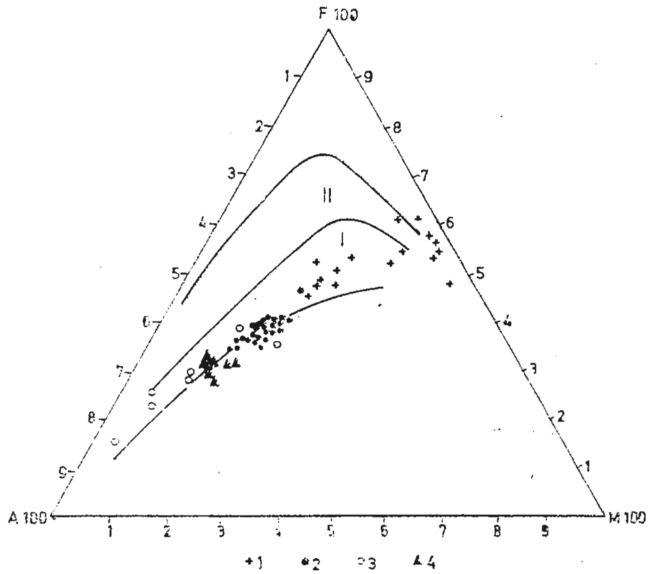

Fig. 2. — FAM diagram (A = $Na_2O + K_2O$; F = $FeO + 0.9 \times Fe_2O_3$; M = MgO). Domains I and II correspond to the hypersthene series and pigeonitic series, respectively, after Kuno.
1, group of gabbroic rocks and of cumulate nodules ; 2, group of monzodioritic and monzonitic rocks ; 3, group of monzonites and of potassic syenitic segregations (1, 2, 3 — Surduc 1 intrusion) ; 4, monzogranites (Surduc 2 intrusion).

as specific to potassium-rich calc-alkaline volcanic series and to shoshonites.

FAM diagram (Fig. 2) points out a slight tendency of iron enrichment only of cumulates from nodules as well as some discontinuities towards homogeneous gabbros and then to monzodiorites and quartz monzonites. The group of monzonites and of syenitic segregations shows a rapid increase of alkalies concomitantly with the iron decrease, a tendency typical of the calc-alkaline differentiation.

The fact that the tendency of alkali enrichment is due especially to potassium is illustrated by its plotting as compared to silica (Fig. 3). The filiation of the monzodiorites from gabbros is not too distinct due to the same lack of intermediary rocks mentioned above. The general outline at the top of the diagram is quite similar to the shoshonitic series from the Andes (Lefèvre, 1973).

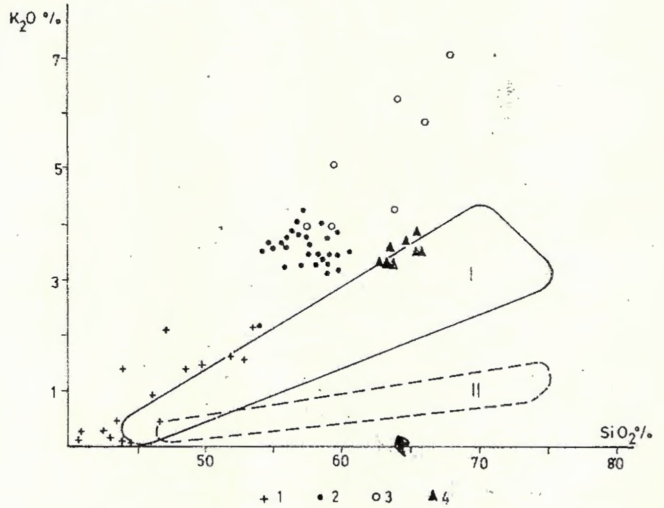

Fig. 3. — K_2O/SiO_2 diagram. Domains I and II correspond to the calc-alkaline series and island arc tholeiitic series, respectively, after Gill (1970).
1, 2, 3, 4 see Figure 2.

The relationships of the iron and magnesium oxides (Fig. 4) compared with different calc-alkaline, alkaline or tholeiitic series — presented by Brown and Schairer (1971) — point out a compositional difference between the group of gabbroic rocks, cumulate inclusive, and monzonites and monzodiorites. Thus, "erratic" cumulates and nodules are entirely different due to very high amounts of Fe total and Mg ; gabbros seem to be closer to the curve of alkali suites and monzodiorites and monzonites are clearly calc-alkaline. This difference may point to a mixing of magma as well to the fact that cumulates are not related by a fractional crystallization at the present-day emplacement level of Surduc 1 intrusion.

In order to illustrate better the existence or inexistence of a control due to the subsequent differentiation within the Surduc intrusions some major and trace elements have been plotted versus Zr.

The mafic nodules 244 and 403 are different from the group of gabbroic rocks or other cumulates due to the high content of Zr.

Two groups can be distinguished within cumulates : one belonging to the nodule with a rhythmical structure (546) and another made up of isolated nodules probably coming from other "layers" with smaller

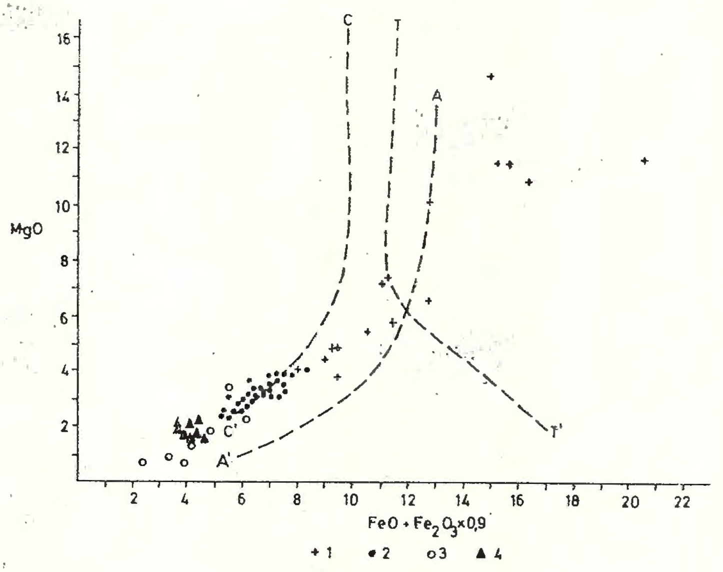

Fig. 4. — MgO/FeO + 0.9 Fe_2O_3 diagram versus A-A′ = Hawaii alkaline series, T-T′ = Hawaii tholeiitic series ; C-C′ = calc-alkaline series after Brown and Schairer (1971). 1, 2, 3, 4 see Figure 2.

amounts of Zr (405, 251, 454) ; an isolated nodule is also 404 in which olivine is totally serpentinized.

On some diagrams the gabbros in which modal olivine disappears and small orthoclase amounts appear seem to come from these nodules as if they represent the residual liquid as against cumulates but displaying a relatively wide range of compositions.

The interval between gabbros and the groups of monzodioritic and quartz monzonitic rocks is attenuated on these differentiation diagrams. The spreading of these rocks on the diagram is, however, due to the preservation of various amounts of inherited crystals (basic plagioclase and pyroxene) proper to cumulates.

On the majority of the variation diagrams monzonites and syenitic segregations can be interpreted as last products of a crystallization within Surduc 1.

Generally, the variation tendencies versus Zr at most major elements seem to increase or decrease relatively regularly from one group

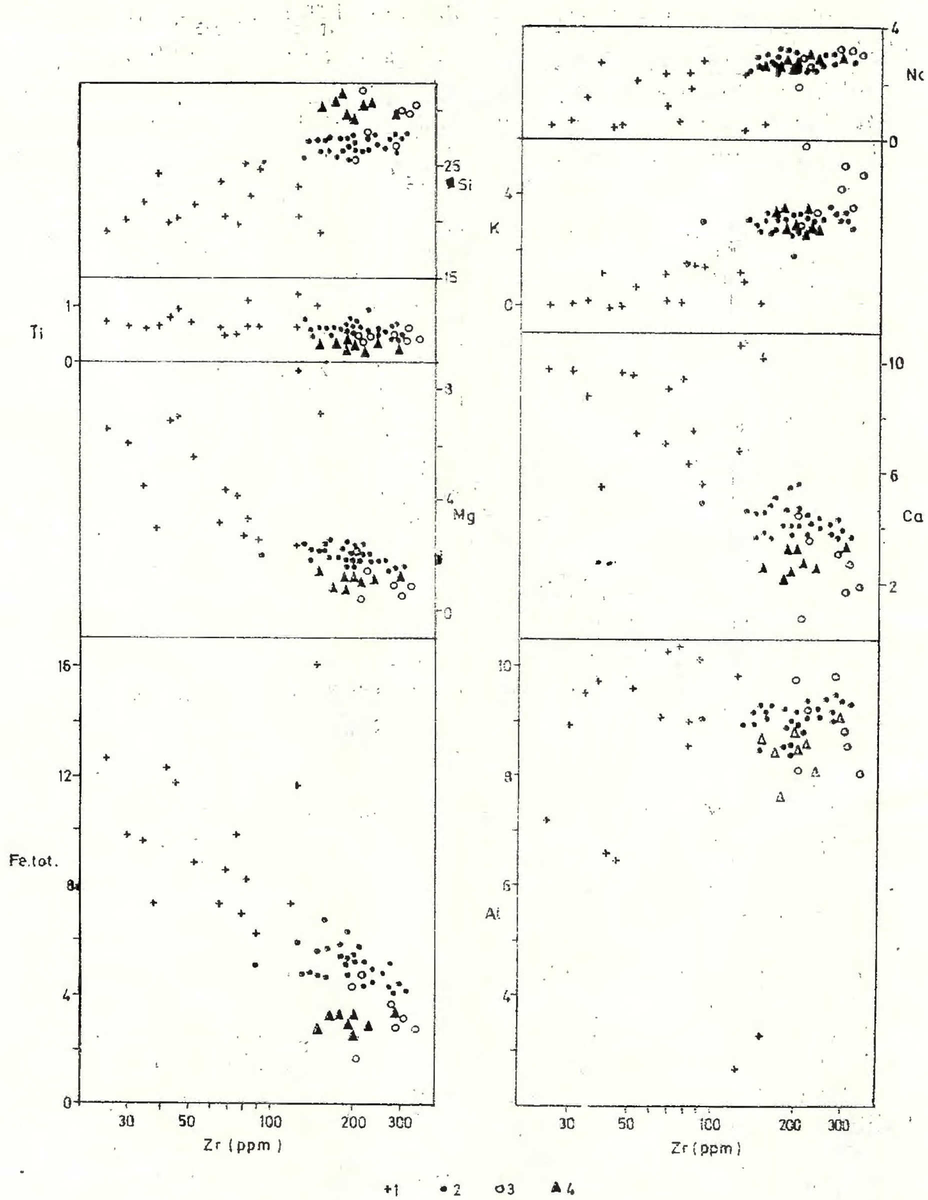

Fig. 5. — Variation of some major elements versus Zr.
1, 2, 3, 4 see Figure 2.

to another; while silica and alkalies increase, Mg, Fe total and Ca decrease and Al is relatively constant.

Trace elements show wide variation domains both within each group and from one group to another in the rocks of Surduc 1. Ni, Co, Cr (Fig. 6) and V, Sc (Fig. 7) versus Zr generally show a tendency of decrease from nodules and gabbros to monzodiorites, monzonites and

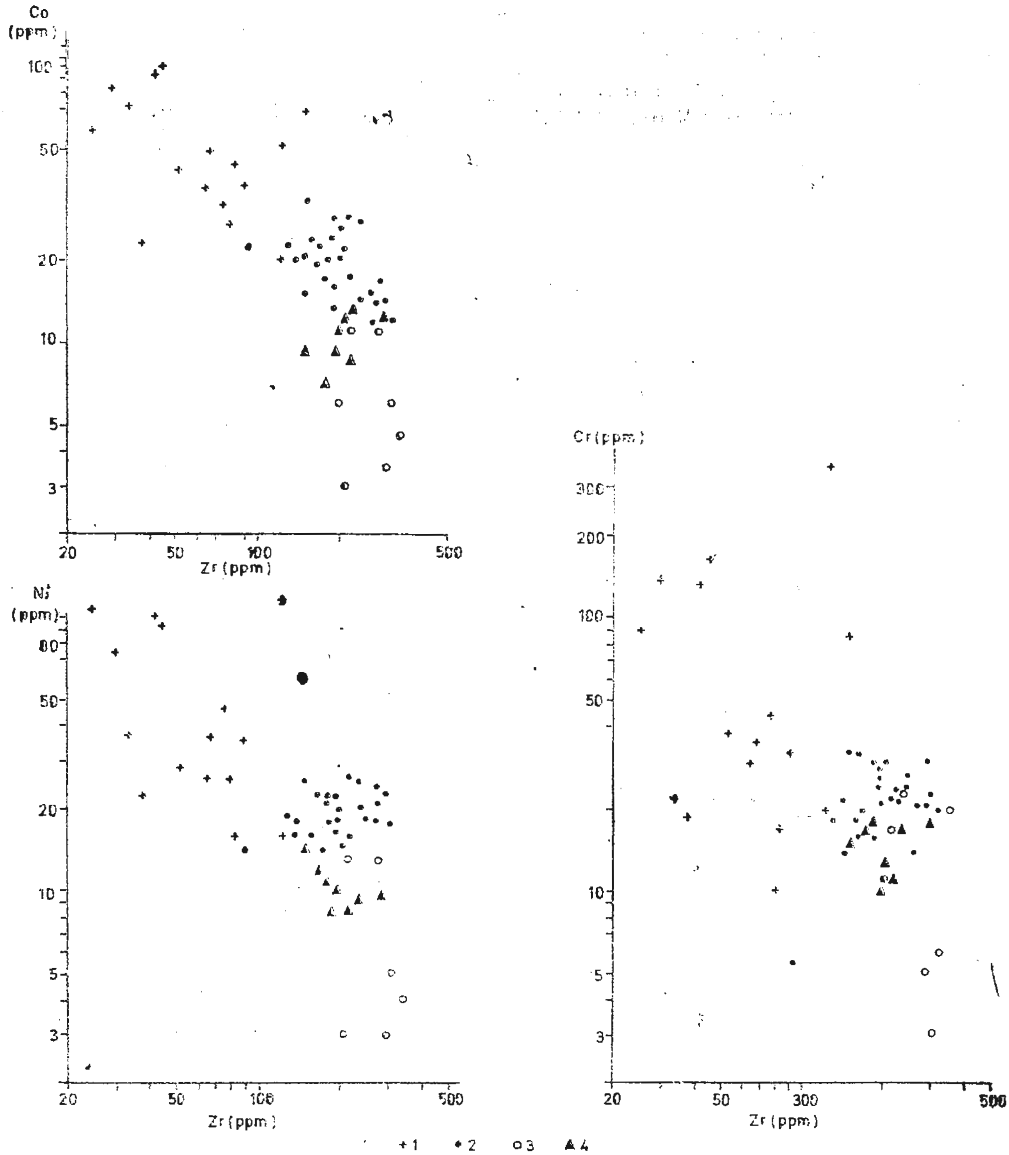

Fig. 6. — Co, Ni, Cr variation versus Zr.
1, 2, 3, 4 see Figure 2.

syenitic segregations. In isolated nodules with cumulate structure Cr and Ni decrease within a larger variation domain (22 ppm-135 ppm for Cr and 37-105 ppm for Ni) as against Co and Sc which show more grouped values. The smallest values in these elements are shown by syenitic segregations, except Sc which displays the lowest value within the Surduc 2 intrusion.

As expected, the later intrusion S_2 displaying some characters which resemble S_1, although forms a relatively unitary group of analyses, can

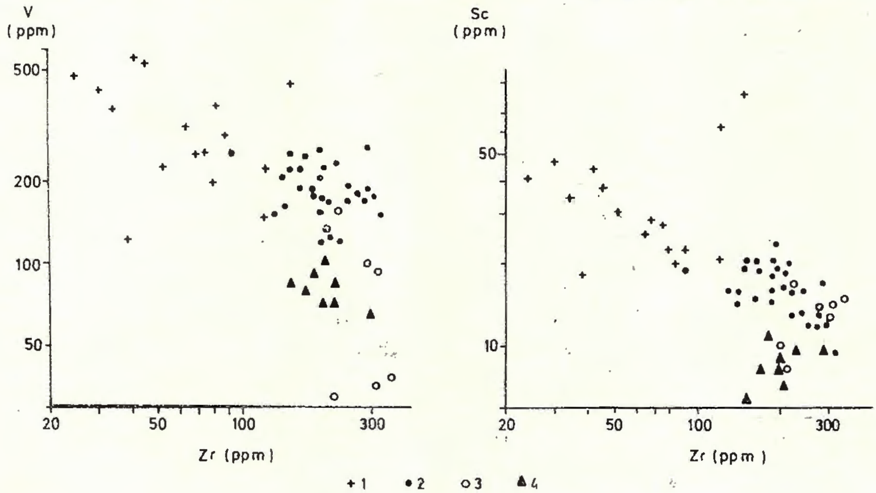

Fig. 7. — V and Sc variation versus Zr.
1, 2, 3, 4 see Figure 2.

occupy different positions after the analysed element or group of elements. Nevertheless, on most diagrams Surduc 2 cannot be the acid differentiate of Surduc 1.

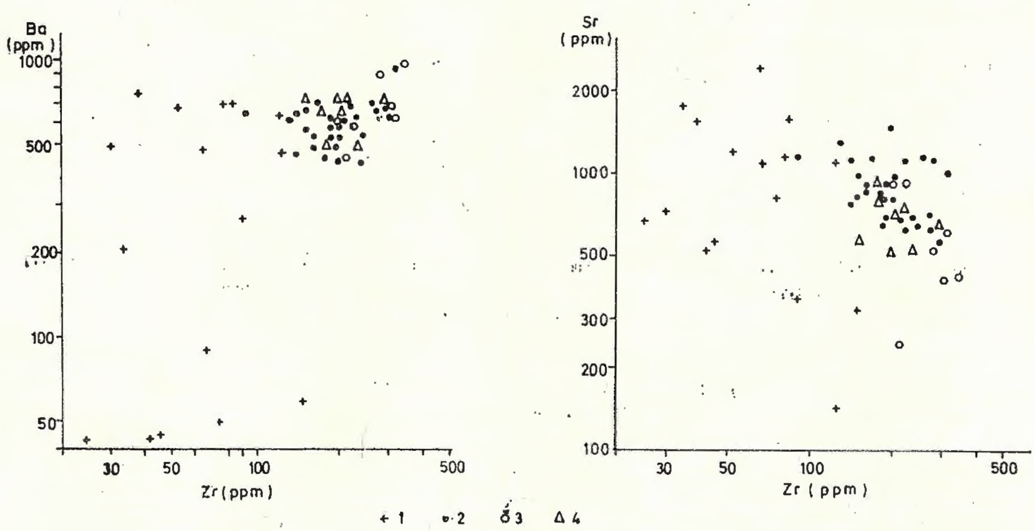

Fig. 8. — Ba and Sr variation versus Zr.
1, 2, 3, 4 see Figure 2.

A special behaviour has Sr and Ba which do not show a clear variation tendency versus Zr. In the isolated nodules 405, 251, 454 at values very similar to Zr, Ba and Sr vary very much (Ba=42-500 ppm and Sr=670-1750 ppm). These variations do not correspond to the variation of K and Ca. In nodules K and Ca grouped at relatively close values. In gabbros and then in monzodiorites and monzonites as against nodules Ba ranges within a small variation domain at higher values, whereas Sr first increases from nodules to gabbros, where it reaches the maximum values of 2450 ppm (a gabbro with poikilitic biotite) and then it decreases.

In Surduc 2, Ba and Sr occur in amounts similar to the monzonitic rocks from Surduc 1, without forming a separate group as in case of other elements, generally showing high values.

Petrogenetic Considerations

Taking into account the petrographic and chemical data on the studied rocks one might assume that within the same area — Surduc massif — occur successive intrusions coming from magmas with proper chemical and crystallization characteristics, whose petrogenetic consanguinity is not always distinct.

A study of the variation diagrams points out that the model of a fractional crystallization is preferable for the nodule. Considering the great differences between the amounts of trace elements, fluctuations as in case of Sr, as well as the discontinuities from one group of rocks to another, processes with a different degree of partial melting and mixing of magma are probably involved within the Surduc massif too.

Basic magmas generating cumulate nodules with a relatively primary chemism (low SiO_2 and high MgO) can be regarded as the less modified meltings originating in the mantle. The likeness of several structural and textural aspects from nodules with those described in the layered intrusions point to similar processes of fractional crystallization and crystal gravitational accumulation. In spite of the plagioclase abundance in these cumulates (most of them adcumulates) the presence of olivine even in the anorthosite laminas excludes the role of the plagioclase flotation the accumulation taking place rather on the margins or on the floor of the magmatic chamber (in some nodules crescumulated olivine occurs).

Most of the trace elements are compatible with this model of cumulate resulting from fractional crystallization, e.g. the highly variable values of Ni, Cr or Sr in the same decimetric nodule with rhythmical layering (546 in Table 1). The abundance of Sc, which varies in nodules from 35 to 44 ppm (except for anorthosite) is almost twice higher than in gabbros; Co behaves similarly. In nodules Cr reaches maximum values ten times higher than in the host gabbros. All this can represent proofs pointing to a repartition tendency between the accumulating minerals and the coexistent magmatic liquid which possibly generated homogeneous gabbros.

A new magma impuls, this time with a more potassic character, fails to remelt the whole crystallized material; nodules as well as inherited remnant crystals of cumulate type show a nonhomogeneous internal distribution. The fractionation of plagioclase or of other crystalline phases might have occurred under the present location of the body, and the bands, schlieren and the magmatic flow structures within the actual Surduc intrusion would represent processes of chemical differentiation of a more recent magma mixed with sequences of earlier cumulates, more or less resorbed. Thus the nodules with tholeiitic chemistry are included in calc-alkaline rocks rich in potassium or in those with a shoshonitic character ; this shoshonitic chemistry is visible on Peccerillo and Taylor's diagram (1976).

Although after some elements the calc-alkaline Surduc 2 intrusion is similar with the potassic differentiates of the Surduc 1 intrusion (monzonites and syenitic segregates), which would point to similar source materials, the K_2O differences (Fig. 3) indicate nonhomogeneous sources.

Taking into account the similar K/Ar apparent ages (Russo-Săndulescu et al., this volume) of the monzodiorites and potassic differentiates of the S_1 intrusion, but older than those of the S_2 intrusion, the matter is rather complicated. It is possible that the expulsion of a volatile-rich magma (e.g. those of shoshonitic type) might lead to a more basic resurgent magmatism, but the great time difference between the location of the two intrusions at Surduc (Lower Senonian and Paleocene, respectively) does not permit this interpretation.

Jakeš and White (1972) observed that where tholeiites occur in association with calc-alkaline rocks and shoshonites, the latter are the youngest. In the Surduc massif, within the same area these rocks are associated, and the potassic differentiates of the S_1 intrusion are prior to the calc-alkaline S_2 intrusion.

Ultrapotassic rocks are usually rare and occur in zones with an extensional tectonics. Potassic syenitic segregations of the S_1 intrusion indicate on the variation diagrams their origin by the differentiation of the monzodioritic magma. Associating these facts with the existence of cumulates, which occur usually under conditions of relative absence of tectonic stress, related with deep fractures, one might suggest that Surduc 1 appeared in a period of distension as compared with Surduc 2 which mostly displays characters of a magma connected with subduction processes. Spread on large areas in Bulgaria, a similar magmatism with strong potassic characters of Upper Cretaceous age was also connected with a period in which the distension processes predominated (Boccaletti et al., 1978).

All the above-mentioned considerations indicate that the different ages of the two successive intrusions at Surduc correspond to different geotectonic conditions. At the same time the source materials generating the magmas have probably a different degree of melting for the two intrusions.

TABLE 1

Chemical analyses in the group of gabbroic rocks

	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O	Total	FeO total /MgO
1	546/5	42.70	12.40	8.64	7.90	0.22	11.53	13.88	0.71	traces	1.40	0.06	no	0.09	0.67	100.28	1.35
2	546/2A	43.40	12.23	7.36	8.42	0.22	11.55	13.74	0.76	0.05	1.57	0.02	no	0.08	0.59	100.06	1.30
3	546/7	44.80	33.21	1.08	1.67	0.05	2.48	14.72	1.75	0.18	0.32	0.07	—	—	—	100.33	1.06
4	405	40.74	13.65	8.65	8.51	0.22	10.97	13.86	0.75	0.15	1.20	0.22	0.16	—	0.69	99.77	1.48
5	404	42.77	19.68	7.12	6.37	0.18	6.62	13.35	1.05	0.23	0.97	0.12	—	—	1.19	99.65	1.92
6	251	42.86	16.85	6.33	7.06	0.19	9.98	13.40	0.92	0.15	1.04	0.05	—	0.13	0.48	99.55	1.27
7	454	46.40	18.05	5.96	5.72	0.19	7.35	12.48	2.17	0.42	1.01	0.20	—	0.12	—	100.17	1.50
8	403	40.77	6.24	12.29	9.95	0.39	11.68	14.40	0.83	0.23	1.97	0.60	—	—	0.83	99.78	1.79
9	244	44.01	4.80	7.76	7.92	0.30	14.58	14.81	0.64	1.39	2.15	0.12	0.0	0.04	1.14	99.66	1.02
10	407	43.49	19.45	5.71	5.93	0.25	7.27	12.73	1.53	0.40	0.93	0.20	—	—	1.75	99.64	1.52
11	402	46.12	18.20	6.75	5.26	0.29	5.86	10.50	2.95	0.96	1.23	0.68	—	0.03	0.86	99.69	1.93
12	482	47.20	17.03	5.94	5.14	0.14	5.53	10.72	2.60	2.05	1.70	0.42	0.58	0.08	0.98	100.17	1.89
13	408	48.51	18.68	5.72	4.31	0.18	3.90	9.73	3.10	1.43	0.99	0.55	1.52	0.07	0.97	99.66	2.42
14	59	49.80	17.30	5.27	4.58	0.15	4.84	10.00	3.15	1.43	1.00	0.54	0.68	0.19	0.89	99.99	1.92
15	451	51.84	18.40	5.43	4.51	0.18	4.74	7.72	3.80	1.60	1.16	0.46	0.56	0.10	—	100.59	1.98
16	288	52.70	19.21	3.69	4.69	0.07	4.15	7.88	3.84	1.58	1.02	0.46	—	0.09	0.92	100.30	1.93
17	91	53.46	16.22	4.56	4.85	0.18	4.52	9.01	3.24	2.10	1.08	0.54	0.0	0.03	0.28	100.07	1.98

TABLE 2

Trace elements (p.p.m.) in the group of gabbroic rocks

	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Be	Zr	Yb	Y	La	Sr	Ba	Li
1	546/5	2	25	13	<2	100	95	130	550	44		42	1.4	17	<30	550	43	—
2	546/2A	<2	36	13	2	94	93	160	530	38		45	1.3	14	<30	570	45	
3	546/7	2	18	22	<2	2	3.5	1	6.5	<2		<10	< 0.5	<10	<30	2100	130	
4	405	3.5	38	15	5.5	105	57	90	500	40	<1	25	0.8	14	<30	670	42	6
5	404	4	28	20	6	47	32	45	250	28	<1	75	0.8	10	<30	850	50	16
6	251	3	30	16	<2	75	85	135	430	48	<1	30	1.4	14	<30	730	500	5
7	454	13	430	13	<2	37	73	22	380	35	1.2	34	1.7	19	<30	1750	200	5
8	403	5	210	19	9.5	60	70	87	450	82	<1	150	2.6	42	<30	320	60	16
9	244	3	320	13	6	118	53	350	205	63	<1	125	2.2	44	<30	140	640	43
10	407	13	17	18	5.5	37	50	35	240	28	<1	67	0.9	15	<30	1100	90	16
11	402	8	320	21	6.5	28	42	38	220	31	1	52	1.6	33	<30	1200	680	16
12	482	7	37	17	4	16	44	17	350	20	1.8	82	1	12	<30	1600	700	26
13	408	18	125	21	6.5	16	20	20	140	21	1.4	122	1.6	22	<30	1100	470	13
14	59	20	65	25	<2	26	36	30	300	26	1.6	65	2.8	22	<30	2450	480	12
15	451	15	110	22	3	22	23	19	125	18	<1	38	1.6	18	30	1550	770	9,5
16	288	20	150	26	6	35	37	32	280	22	1.9	90	25	28	33	350	270	33
17	91	14	105	25	2	26	26	10	190	22	1.2	80	1.9	30	34	1150	700	13

TABLE 3

Chemical analyses in the group of monzodioritic rocks ± quartz

	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O	Total	Fe total /MgO
1	448	54.60	16.85	3.96	4.09	0.12	3.81	6.53	3.48	3.79	1.27	0.35	0.68	0.07	0.17	99.83	2.00
2	94	54.70	17.53	3.29	4.35	0.15	3.71	7.01	3.23	3.79	0.92	0.41	0.0	0.03	0.56	99.68	1.97
3	209	55.87	17.56	3.44	4.09	0.17	3.56	6.42	3.60	3.63	0.99	0.34	—	0.01	0.58	100.26	1.99
4	30	56.18	17.20	3.30	3.95	0.14	3.87	6.55	3.36	3.83	0.95	0.39	0.0	0.03	0.64	100.39	1.78
5	139	56.27	17.56	3.03	4.14	0.14	3.60	6.62	3.44	3.72	0.89	0.37	0.0	0.03	0.45	100.26	1.90
6	146	56.43	17.81	3.40	3.62	0.13	3.02	6.06	3.57	4.05	0.96	0.39	—	0.06	0.72	100.22	2.21
7	545	56.83	17.10	3.06	4.01	0.14	3.21	5.51	3.72	3.23	0.88	0.37	0.91	0.08	—	99.12	2.10
8	249	57.45	16.85	2.85	4.11	0.13	3.08	5.85	3.60	3.77	0.92	0.33	0.69	0.09	—	99.80	2.16
9	281	57.52	17.27	3.77	3.05	0.10	3.10	5.86	3.47	3.61	0.94	0.35	—	0.06	0.50	99.60	2.07
10	423 A	54.00	16.86	5.07	3.71	0.20	4.01	7.66	3.49	2.12	0.98	0.41	0.98	0.04	0.97	100.50	2.06
11	423	54.38	17.13	4.39	3.45	0.18	3.21	6.90	3.35	3.66	0.94	0.40	0.94	0.05	1.13	100.11	2.30
12	25	55.54	18.00	4.21	3.16	0.14	3.21	6.00	3.58	3.65	0.99	0.36	0.0	0.02	0.97	99.83	2.16
13	421	55.56	17.14	3.70	3.95	0.17	3.89	6.84	3.19	3.19	0.97	0.40	0.30	0.04	0.67	100.01	1.87
14	376	55.64	16.66	3.67	4.13	0.17	3.91	6.40	3.34	3.70	0.86	0.38	—	0.05	0.71	99.62	1.90
15	85	57.18	17.83	3.77	2.86	0.12	2.89	5.72	3.70	4.28	0.86	0.42	—	0.04	0.58	100.25	2.16
16	426	58.02	16.95	3.67	3.02	0.16	3.37	6.27	3.60	3.24	0.85	0.32	0.35	0.05	0.55	100.42	1.87
17	525	58.75	16.00	3.05	3.82	0.12	3.34	5.20	3.60	4.05	1.45	0.29	—	0.04	0.74	100.48	1.96

TABLE 4

Trace elements (p.p.m.) in the group of monzodioritic rocks ± quartz

	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Be	Zr	Yb	Y	La	Sr	Ba	Li
1	448	26	85	20	4.5	19	22	18	150	16	2.3	130	1.5	24	30	1300	620	15
2	94	20	90	22	<2	21	22	20	245	19	2	165	1.7	27	34	1150	700	27
3	209	26	135	20	4	31	32	32	250	20	2.2	150	2.4	30	40	1000	670	20
4	30	21	80	24	3	16	20	12	120	16	2.4	200	2.2	27	38	800	560	33
5	139	21	80	23	2	21	20	30	155	18	2.1	185	2	30	41	800	620	33
6	146	35	95	19	4	26	28	22	230	17	2.3	220	2.7	30	47	630	630	27
7	545	36	90	36	<2	18	28	30	220	19	2.4	195	3.1	23	30	1500	560	20
8	249	32	70	22	<2	20	26	22	165	19	2.8	200	2.9	24	30	970	550	21
9	281	6.5	105	19	3.5	25	27	27	190	16	2	240	2.3	27	37	670	550	26
10	423 A	20	115	19	5	22	24	25	260	24	1.9	190	2.1	30	36	900	500	9
11	423	27	55	19	5	14	22	5.5	230	19	1.9	90	1.9	26	33	1150	650	7
12	25	22	65	21	2	24	17	21	260	17	2.2	280	2.2	24	44	1100	650	17
13	421	26	130	18	5	22	23	19	220	20	2.5	160	1.8	28	33	850	500	16
14	376	15	85	19	3.5	15	22	22	120	20	1.9	210	1.9	28	<30	680	630	26
15	85	31	100	27	2.5	18	15	14	175	12	2.4	260	1.8	22	44	1150	720	53
16	426	22	75	20	5	18	20	22	200	16	2.4	140	1.7	23	36	780	470	37
17	525	34	75	18	3.5	25	15	32	210	20	2.8	150	2.5	28	35	820	580	27

TABLE 5

Chemical analyses in the group of quartz monzodioritic and monzonitic rocks

	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O	Total	Fe total /MgO
1	486	58.10	17.30	2.97	2.85	0.12	3.18	5.45	3.67	3.45	1.63	0.36	0.80	0.05	0.49	100.46	1.73
2	44	58.35	17.37	3.46	3.08	0.14	2.83	5.27	3.85	3.35	0.83	0.48	0.26	—	0.71	99.98	2.31
3	411	58.77	17.50	3.28	3.12	0.12	3.14	5.13	3.75	3.35	0.78	0.40	0.50	—	0.57	100.41	1.93
4	11	58.86	17.37	3.29	2.89	0.14	2.78	5.94	3.78	3.16	0.81	0.31	—	0.04	0.65	100.02	2.10
5	540 A	59.25	15.90	3.37	3.89	0.12	3.11	5.72	3.65	3.72	0.97	0.27	—	0.04	0.41	100.59	2.22
6	541	59.50	16.25	3.55	2.86	0.12	2.94	5.48	4.0	3.40	1.23	0.28	—	0.08	0.27	100.03	2.05
7	538	57.50	16.15	4.85	2.98	0.13	3.01	5.65	4.12	3.40	0.95	0.35	—	0.07	0.80	100.02	2.43
8	42	59.03	17.79	3.44	2.55	0.01	2.48	5.37	3.87	3.47	0.68	0.33	0.0	0.02	0.95	99.99	2.27
9	12	59.74	17.39	3.09	2.66	0.11	2.39	5.30	3.76	3.94	0.81	0.28	—	0.02	0.70	100.19	2.27
10	47	59.76	17.68	2.95	2.70	0.18	2.64	5.23	3.34	3.15	0.79	0.30	0.0	0.03	0.81	99.56	2.02
11	6	60.58	17.17	3.15	2.43	0.13	2.44	5.31	3.62	3.50	0.78	0.37	0.0	0.01	0.49	99.98	2.15

TABLE 6

Trace elements (p.p.m.) in the group of quartz monzodioritic and monzonitic rocks

	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Be	Zr	Yb	Y	La	Sr	Ba	Li
1	486	33	45	21	3.5	16	17	23	120	13	2	220	1.8	21	<30	1100	700	26
2	44	28	70	19	5.5	16	20	14	165	14	2	140	1.8	23	40	1150	650	15
3	411	23	27	18	4	16	19	16	190	15	2.2	160	1.1	27	52	900	550	43
4	11	20	56	19	3	20	14	25	170	13	2.2	240	2	24	45	680	420	43
5	540	55	80	18	4.5	22	16	26	200	20	2.7	190	2.6	29	30	680	430	27
6	541	30	75	19	4	18	13	28	170	16	2.5	190	2.4	26	38	680	520	27
7	538	22	77	18	7.5	14	17	16	180	14	2.6	180	1.8	21	<30	820	450	10
8	42	20	28	19	<2	23	14	23	175	12	2.2	290	1.8	24	45	560	650	26
9	12	24	36	16	3	18	12	21	170	12	2.2	270	2	22	45	700	670	35
10	47	28	160	18	<2	17	12	20	150	9.5	2.2	310	1.8	19	40	1000	950	23
11	6	23	65	17	2.5	21	14	30	180	13	2.1	280	2.4	26	50	630	670	37

TABLE 7

Chemical analyses in the group of monzonitic rocks and syenitic segregations

	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O	Total	FeO total /MgO
1	267	57.39	18.60	3.11	2.73	0.12	3.47	6.11	2.65	3.83	0.88	0.47	—	0.03	0.25	99.64	1.59
2	515	58.90	17.60	3.65	2.89	0.11	2.17	5.18	3.67	3.90	0.84	0.43	—	0.04	0.92	100.33	2.84
3	286	59.10	18.79	3.24	1.83	0.10	1.63	4.26	4.31	5.08	0.87	0.42	—	0.04	0.54	100.21	2.90
4	526	63.90	16.10	2.86	1.47	0.08	1.38	3.82	4.10	4.27	0.82	0.33	—	0.06	0.53	99.77	2.92
5	287	63.95	16.68	2.53	1.55	0.11	0.73	2.50	3.91	6.24	0.77	0.40	—	—	0.34	99.71	5.23
6	523	66.0	15.85	2.44	0.98	0.11	0.86	1.83	4.12	5.85	0.92	0.26	—	0.11	0.34	99.77	3.68
7	520	67.50	15.55	2.0	0.45	0.05	0.59	1.10	4.02	7.02	0.62	0.11	—	0.04	0.68	99.76	3.81

TABLE 8

Trace elements (p.p.m.) in the group of monzonitic rocks and syenitic segregations

	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Be	Zr	Yb	Y	La	Sr	Ba	Li
1	267	18	63	16	5.5	8.5	6	12	130	10	2.7	200	2	21	30	930	600	30
2	515	175	34	21	4.5	13	11	23	150	17	3.4	220	2.9	32	42	940	600	12
3	286	26	12	21	3	13	11	5	100	14	1.5	280	3.2	33	50	530	900	30
4	526	18	12	20	4	5	6	6	95	14	4.5	310	4.7	38	58	600	630	36
5	287	22	8	18	2	3	3.5	3	35	13	3.1	300	2.4	37	32	410	970	22
6	523	42	13	19	4.5	4	3.5	20	38	15	4.4	340	4.8	42	60	420	970	10
7	520	32	13	17	2.5	3	3	17	32	8.5	4	210	4.1	26	45	240	450	5.5

TABLE 9

Chemical analyses in S_2 monzogranitic and granodioritic rocks

Sample no.		SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O	Total	FeO total /MgO
1	71	62.81	16.55	2.82	1.82	0.10	2.24	4.79	3.81	3.36	0.65	0.21	0.40	0.03	0.47	100.06	1.94
2	293	63.32	16.26	3.03	1.38	0.09	2.05	4.65	3.52	3.36	0.54	0.22	0.0	0.03	1.16	99.61	2.00
3	490	63.40	16.26	2.58	1.26	0.10	2.12	4.18	4.05	3.62	0.75	0.17	0.18	0.06	0.75	99.53	1.68
4	113	65.53	15.90	3.80	0.85	0.08	1.65	3.35	3.60	3.95	0.52	0.19	—	0.07	1.01	100.56	2.58
5	409	62.99	17.05	2.60	2.12	0.12	1.67	4.35	3.93	3.36	0.55	0.22	—	—	1.0	99.96	2.67
6	37	64.67	16.39	2.33	1.48	0.10	2.00	3.49	3.63	3.73	0.51	0.16	0.0	0.02	1.02	99.53	1.78
7	543	65.40	15.05	2.48	1.53	0.07	1.85	3.87	3.90	3.50	0.55	0.18	—	0.05	0.64	99.61	2.03
8	527	67.75	14.35	3.07	1.37	0.11	1.60	3.02	3.75	3.50	0.57	0.19	—	0.10	0.90	100.37	2.43

TABLE 10

Trace elements in S_2 monzogranitic and granodioritic rocks

Sample no.		Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Be	Zr	Yb	Y	La	Sr	Ba	Li
1	71	26	40	22	<2	10	11	12	100	9.5	2.3	200	1.9	25	41	700	620	32
2	293	29	21	20	2	8.5	9.5	10	70	9	1.8	195	1.5	22	50	530	720	32
3	490	25	38	20	4	8.5	12	11	75	7.5	3	210	1.6	16	<30	750	685	27
4	113	20	20	19	3.5	12	13	17	80	8.5	1.6	170	1.6	16	46	930	670	8
5	409	13	14	18	2	9.5	12	18	65	10	1.9	290	1.7	21	<30	660	680	14
6	37	25	95	17	<2	14	9.5	15	85	6.5	2.1	150	1.8	17	36	560	700	7
7	543	30	17	20	<2	9.5	6.5	17	85	10	2.7	230	2.4	20	30	530	530	15
8	527	31	78	18	3	11	7	18	90	11	2.8	180	2.2	22	36	800	500	18

Annexes to tables

Tabs. 1 — 2

546/5 ;/2A ;/7 = Bănii Ravine. Cumulates from a nodule with a rhythmical structure of gabbronorites and an anorthosite lamina (pl + cpy + ol + mt and pl + ol, respectively).
405 ; 404 ; 251 = Bănii Ravine. Cumulates from isolated nodules (pl + cpy + 01 + mt).
454 = Nărăştia Valley. Isolated nodules (pl + cpy + poikilitic bi).
bi + mt).
403 ; 244 = Nărăştia Valley. Isolated nodules (pl + cpy + poikilitic bi),
Gabbros with cpy + opy + pl + bi ± ho ± fk ± q.
407 = Ogaşul cu apă ; 402 = Nărăştia Valley ; 482 = Ogaşul cu skarne.
408 = Ogaşul cu apă ; 59 = Ogaşul cu apă ; 451 = Nărăştia Valley ; 288 = tributary of the Cocoroni Valley ; 91 = Nărăştia Valley.

Tabs. 3 — 4

Monzodiorites and quartz monzodiorites (pl + cpy + opy + bi + fk ± ho) :
448, 94 = Nărăştia Valley ; 209, 30 = Iepii Valley ; 139 = Cocoroni Ravine ; 146 = Surduc Valley ; 545 = Nărăştia Valley ; 249 = Bănii Ravine ; 281 = Cocoroni Ravine ; 423, 423 A = Ursului Ravine ; 25 = Iepii Ravine ; 421, 376 = Ursului Ravine ; 85 = Nărăştia Valley ; 426 = Nărăştia forest road = Ursului Ravine ; 525 = Cocoroni Hill.

Tabs. 5 — 6

Quartz monzodiorites (pl + ho + cpy + bi + fk + q) :
486 = Balosin Ravine ; 44 = Carului Ravine ; 411, 11 = Iepii Valley.
Quartz monzonites (pl + cpy + opy + bi + fk + q) :
540 A, 541 = Iepii Valley.
Quartz monzonites (pl + ho + cpy + bi + fk + q) :
538 = Miului Hill ; 42 = Balosin Ravine ; 12 = Iepii Valley ; 47 = Carului Ravine ; 6 = Iepii Valley.

Tabs. 7 — 8

Quartz monzonites and quartz syenites with pegmatoid plagioclase (pl + bi + cpy + fk + q) :
267, 286, 526 + Northern tributary of the Cocoroni Ravine ; 515 = Mieilor Ravine.
Porphyric quartz monzonites and syenites (pl + bi ± cpy as phenocrysts in a groundmass of fk + q + bi) : 287 = tributary of the Cocoroni Ravine ; 523 = Ogăşelul ; 520 = Mieilor Ravine.

Tabs. 9 — 10

Equigranular monzogranites (ho + cpy + bi + fk + pl + q) :
71 = Cernovăţ Valley ; 293 = Morii Ravine ; 490 = Surduc Quarry ; 119 = Cheii Valley.
Porphyric monzogranites (ho + bi + fk + pl + q) : 409, 543 = Iepii Valley ; 37 = Balosin Ravine ; 527 = Carului Ravine.
pl = plagioclase ; cpy = clinopyroxene ; opy = orthopyroxene ; bi = biotite ; ho = hornblende ; fk = potash feldspar ; q = quartz.

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STUDIUL PETROCHIMIC AL MAGMATITELOR BANATITICE DE LA SURDUC (BANAT)

(Rezumat)

Corpul de la Surduc este cea mai vestică intruziune cunoscută în afloriment din cuprinsul „banatitelor plutonice" (Russo-Săndulescu, Berza, 1977) care străbat formațiunile cristaline ale pînzelor supragetice din Carpații Meridionali.

Dintre puținele date geologice și petrografice publicate sau inedite (rapoarte) asupra corpului de la Surduc pot fi citate în primul rînd cele ale lui Constantinof (1956-1972), care subliniază existența unor tipuri petrografice mai deosebite față de alte intruziuni banatitice, cum sînt gabbrourile cu olivină și rocile monzonitice. Autorul afirmă că gabbrourile au luat naștere prin diferențiere magmatică. Într-o lucrare de sinteză asupra provinciei banatitice (Giușcă et al., 1966) se fac considerații asupra evoluției magmelor acide de tip granodioritic către termeni slab bazici un prim sens și către termeni peracizi un al doilea sens, arătîndu-se că în domeniul slab bazic se remarcă o tendință alcalină-monzonitică sau sienitică.

Structura și petrografia plutonului Surduc

Forma și dimensiunile plutonului sînt destul de greu de apreciat după suprafața redusă — cca 15 km^2 — de aflorare. În schimb, analiza conjugată a unei tendințe de maxim gravimetric suprapus unei importante anomalii magnetice pozitive sugerează extinderea masivului spre vest, pe sub sedimentele neogene ale depresiunii pannonice, pînă în apropiere de Jamul Mare (Andrei et al., 1976). După forma anomaliei plutonul apare cu un contur eliptic a cărui axă mare cu orientarea est-vest depășește 12 km.

Observații directe asupra părții de est a plutonului au permis deosebirea a două intruziuni de vîrstă diferită (Russo-Săndulescu et al., 1986) denumită unitatea Surduc 1 (S_1) și unitatea Surduc 2 (S_2). Prima intruziune, care se dezvoltă în partea de est străbătînd șisturile cristaline ale formațiunii de Bocșița-Drimoxa, are o alcătuire petrografică extrem de complicată față de intruziunea ulterioară S_2, relativ omogenă din punct de vedere petrografic.

Surduc 1. Se caracterizează prin prezența unor diferențiate în „șlire" de forme și dimensiuni foarte variate, de la sute de metri pînă la cele de dimensiuni microscopice. Limitele între șlire nu sînt tranșante, astfel încît în caracterizarea grupurilor de roci analizate se va ține cont de predominanța unui anume petrotip.

1. Grupul rocilor gabbroice, în care s-au deosebit pe lîngă gabbrouri omogene cu piroxeni biotit$\pm$hornblendă, „nodule" de dimensiuni variabile, centimetrice pînă la metrice de roci cu structuri de cumulate. Cumulatele au în genere o arhitectură planară în care se disting lamine cu grosimi pînă la 1,5 cm de anortozite în alternanță cu gabbrouri cu olivină, demonstrînd o structură primară de tip stratificat, fără semne ale unei deformări sau recristalizări ulterioare. Existența unor „microcute" vizibile în laminele anortozitice sînt datorate unor alunecări („slumping") în magma incomplet cristalizată. Alteori apar, doar la microscop, benzi subțiri, efilate, de clinopiroxeni și magnetit sau clinopiroxeni, olivină și biotit subpoichilitic prinse în gabbrourile pe care le-am numit omogene, spre a le diferenția de cumulatele din nodule.

2. Grupul rocilor monzodioritice $\pm$ cuarț par a se dezvolta în jurul rocilor gabbroice. După mineralele melanocrate acestea sînt cu piroxeni și biotit, sau cu piroxeni, biotit și hornblendă. Specifică pentru monzodiorite este prezența constantă a feldspatului potasic, în plaje

poichilitice, precum și a două tipuri de feldspat plagioclaz-cristale euhedrale de plagioclaz neozonat, sau doar a unor nuclee neregulate de bitownit, alături de plagioclaz zonat de tip andezin cu zone externe subțiri ce ajung pînă la 30% An.

3. Grupul rocilor monzodioritice și monzonitice cuarțifere se dezvoltă spre interiorul masivului, dovedind numeroase variații cantitativ mineralogice, sau structurale în cadrul unor șlire mai largi. Structura internă a șlirelor de dimensiuni mici poate fi omogenă, dar adesea ele arată o laminare magmatică definită de orientarea cristalelor de plagioclaz.

4. În partea de nord-est a masivului se dezvoltă destul de singulară o zonă cu roci monzonitice și segregații sienitice potasice în care participarea feldspatului ortoclaz atinge valori maxime. Interesant de semnalat este structura uneori aproape pegmatoidă a acestor monzonite în care plagioclazul fumuriu cu numeroase nuclee bazice, corodate are dimensiuni pînă la 1,5 cm.

Un caracter mineralogic specific pentru întreaga unitate S_I este dat de prezența constantă a piroxenilor (clinopiroxen și în cantități mai reduse ortopiroxen) în care au fost observate exoluții extrem de fine, nedeterminabile microscopic.

Surduc 2. Apare la vest ca o intruziune independentă, cu faciesuri porfirice la contactul cu Surduc 1 și cu numeroase enclave centimetrice pînă la decimetrice, dintre care o parte sînt provenite din rocile primei intruziuni (S_I).

Caracterele specifice ale acestei unități sînt date de structura ei omogenă predominată de prezența monzogranitelor și mai puțin a granodioritelor cu hornblendă și biotit. Interesant este faptul că în cadrul cristalelor de hornblendă se recunosc adesea resturi de clinopiroxen, iar uneori în plagioclazul zonat recurent de tip „banatitic" în centrul cristalelor pot apare nuclee corodate bazice. Deși aceste caractere amintesc de unitatea S_I, prezența faciesurilor porfirice la contact, a anclavelor amintite, precum și a vîrstelor K/Ar mai mici (Russo-Săndulescu et al., 1986) sînt argumente pentru a considera Surduc 2 ca o intruziune ulterioară.

Geochimia

Caracterele chimice ale rocilor analizate sînt definite prin conținuturile lor în elemente majore și minore prezentate în tabelele 1-10. După conținutul în silice cumulatele (nr. 1-7 în tabelul 1) pot fi încadrate la roci ultrabazice, ca și cele două nodule „eratice" (nr. 8 și 9 în tabelul 1); celelalte gabbrouri pe care le-am numit omogene pot fi considerate, în mare, ca echivalente unor bazalte. În termeni de constituenți normativi în grupul rocilor gabbroice se disting tholeiite olivinice nesaturate cu hy+ol normative, tholeiite suprasaturate cu q+hy normative restul gabbrourilor, iar nodulul 244 singurul cu nefelin normativ ar putea fi clasificat ca bazalt alcalin.

Pe diagrama FAM (fig. 2) se poate observa o tendință slabă de îmbogățire în fier doar a cumulatelor din nodule. Grupul monzonitelor și segregațiilor sienitice prezintă în schimb o creștere rapidă a alcaliilor odată cu scăderea fierului, tendință caracteristică diferențierii calco-alcaline. Faptul că tendința de îmbogățire în alcalii se datorează în special K este ilustrată în proiecția acestuia față de silice (fig. 3).

Relațiile oxizilor de fier și magneziu (fig. 4) comparate cu diverse serii calco-alcaline, alcaline sau tholeiitice — discutate de Brown și Schairer (1971) — dovedesc o distincție compozițională între grupul rocilor gabbroice, inclusiv cumulatele, față de monzonite și monzodiorite. Astfel cumulatele și nodulele „eratice" apar cu totul deosebite prin cantitățile de Fe total și Mg foarte mari, gabbrourile par a se înscrie într-o diferențiere mai apropiată de curba suitelor alcaline, iar monzodioritele și monzonitele apar net calco-alcaline. Această distincție poate indica atît un amestec de magme, cît și faptul că gabbrourile și cumulatele nu sînt înrudite printr-o cristalizare fracționată la nivelul actual de punere în loc a intruziunii Surduc 1. Pentru a ilustra mai bine existența sau inexistența unui control datorat diferențierii ulterioare în cadrul intruziunilor de la Surduc, pe diagramele de variație (fig. 5-8) au fost proiectate unele elemente majore și elemente minore față de Zr. Luate în mare, tendințele de variație față de Zr la cele mai multe din elementele majore par a crește sau a descrește relativ regulat de la grup la grup.

Elementele minore prezintă domenii largi de variație, atît în cadrul fiecărui grup cît și de la grup la grup în Surduc 1 ; intruziunea ulterioară S_2, care prezintă unele caractere ce amintesc de S_1, deși formează un grup relativ unitar de analize poate ocupa poziții diferite după elementul sau elementele analizate. Pe cele mai multe diagrame însă Surduc 2 nu pare a fi diferențiatul acid al intruziunii Surduc 1.

Considerații petrogenetice

După aspectele petrografice și datele chimice asupra rocilor studiate se poate sugera că în cadrul aceluiași spațiu — masivul Surduc — apar intruziuni succesive provenite din magme cu caractere chimice și de cristalizare proprii, a căror înrudire petrogenetică nu este întotdeauna distinctă.

Privind diagramele de variație, modelul unei cristalizări fracționate pare preferabil. Ținînd cont însă de diferențele mari între cantitățile de elemente urmă, fluctuații ca în cazul Sr, precum și de discontinuitățile de la un grup de roci la altul, în cadrul masivului Surduc sînt implicate probabil și procese de topire parțială cu un grad diferit și amestec de magme. Magmele bazice care au dat naștere nodulelor de roci cumulate cu un chimism relativ primitiv (SiO_2 mic și MgO mare) pot fi privite ca topiturile cel mai puțin modificate, provenite foarte probabil din manta. O bună parte din elementele urmă sînt compatibile cu acest model de cumulat provenit prin cristalizare fracționată, ca de pildă, valorile extrem de variabile ale Ni, Cr, sau Sr în același nodul decimetric cu stratificație ritmică (546, tabelul 1).

Un nou impuls de magmă, de data aceasta cu un caracter mai potasic, nu reușește să retopească întreg materialul cristalizat ; acesta prezintă acum o distribuție internă neomogenă ca nodule sau doar cristale de tip cumulat. Deși după unele elemente intruziunea Surduc 2 de tip calco-alcalin seamănă cu diferențiatele potasice ale intruziunii Surduc 1 (monzonitele și segregatele sienitice), fapt care ar conduce la materiale surse similare, diferențele în K_2O (fig. 3), sugerează surse neomogene. Ținînd cont atît de caracterele chimice discutate cît și de vîrstele aparente K/Ar (Russo-Săndulescu et al., 1986) mai mari în intruziunea Surduc 1 față de Surduc 2 (Senonian inferior și respectiv Paleocen) se poate conchide totuși că cele două intruziuni deosebite în plutonul compus de la Surduc nu sînt comagmatice și corespund probabil unor condiții geotectonice relativ diferite. Intruziunea S_1 cu caractere puternic potasice în care apar și roci cumulate s-a pus în loc într-o perioadă mai degrabă de distensiune față de S_2 care prezintă pregnant caracterele unei magme legată de procese de subducție.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

PETROLOGICAL STUDY OF BANATITES IN THE OCNA DE FIER-DOGNECEA ZONE (BANAT) [1]

BY

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Banatites. Cretaceous. Paleocene. Granodiorites. Dykes. Rhyolites. Andesites. Magmas differentiation. Calc-alkali magmas. South Carpathians — Neocretaceous-Paleogene magmatites — Bocşa — Ocna de Fier — Surduc.

Abstract

The petrological study of the banatites in the Bocşa-Dognecea region allowed a detailed description of the periodization of the Upper Cretaceous-Paleocene intrusions in the NW Banat. Thus, the stage during which two phases of differentiation with a potassic tendency took place was followed by a calc-alkaline one, represented by basic minor intrusions and a granodioritic major intrusion. Rhyolite and andesite dykes, later on lamprophyres (of uncertain origin) end the banatitic magmatic manifestations.

Résumé

Etude pétrologique des banatites de la région d'Ocna de Fier-Dognecea (Banat). L'étude pétrologique des banatites de la région de Bocşa-Dognecea nous a permis de détailler la succession des intrusions d'âge crétacé supérieur-paléocène du nord-ouest du Banat. Ces intrusions appartiennent à deux stades, le premier pendant lequel les intrusions sont mises en place (deux phases) des magmas différenciés à tendance potassique et un deuxième stade calco-alcalin, représenté

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par des intrusions mineures basiques et une intrusion majeure granodioritique. Les dykes de rhyolites et d'andésites, suivis des lamprophyres (dont l'origine reste toutefois un problème à résoudre) achèvent les manifestations magmatiques banatitiques.

1. Introduction

The biggest banatitic pluton (Upper Cretaceous magmatism) cropping out in Romania develops both north of the Bîrzava Valley — Bocșa massif and south of this valley, in the Ocna de Fier-Dognecea zone.

Within the Bocșa massif the existence of three distinct intrusions was proved (Russo-Săndulescu et al., 1978), denominated in the order of their succession and from west to east : Bocșa 1 (B_1), Bocșa 2 (B_2) and Bocșa 3 (B_3). B_1 and B_2 intrusions are comagmatic ; they are characterized by a chemism with a potassic tendency and, in petrographic and mineralogical respect, by the presence of basic rocks and of pyroxenes, respectively. B_3 intrusion lies in the central and eastern part of the Bocșa composite body ; it differs from the other two intrusions by its clear calc-alkaline origin and the predominance of hornblende biotite granodiorites, which contain numerous porphyric monzodioritic enclaves, rocks often found at the periphery of the main body as small dykes intruding crystalline schists and then intersected by granodiorites. Due to the lack of similarities with rocks of the B_1 and B_2 units, on the one hand, and of the clear consanguinity between small monzodioritic bodies and granodiorites of the pluton, on the other hand, it has been established (Russo-Săndulescu, Berza, 1977, 1980) that during the stage of calc-alkaline plutonic intrusion first more basic rocks were emplaced — B_3, phase 1 ($B_{3.1}$), followed by granodiorites — B_3, phase 2 ($B_{3.2}$)

More detailed studies on the banatites west of Reșița-Moldova Nouă zone, south of the Bîrzava Valley, were published by Codarcea (1931), Radu-Mercus (1962), Constantinof (1972), Vlad (1974), Gheorghiță (1975), Constantinescu (1980), Cioflica et al. (1980). Banatites in the Ocna de Fier zone were mapped and described in petrographic respect by Codarcea (1931) and that cartographic image is still used nowadays.

In order to complete the analytical data and the evolution within the banatites north of the Bîrzava Valley (Bocșa massif), the petrological study of the southern part of the Bocșa 3 intrusion was carried out in the Ocna de Fier-Dognecea area (Russo-Săndulescu et al., 1976). Chemical and spectral analyses on banatites from the Oravița-Ciclova-Sasca-Moldova Nouă zones allowed us to assign the respective bodies to the stages and phases known in the northern part of the outcrop area of the "plutonic banatites" in the west Banat (Russo-Săndulescu, Berza, 1977).

2. Petrography of Banatitic Rocks in the Ocna de Fier-Dognecea Zone

Alpine magmatites in the study area are represented by a granodioritic body extending N-S 15 km and reaching a maximum width of 5 km, by small bodies of more basic rocks occurring independently within crystalline schists and by vein rocks younger than the granodioritic massif. In some places relationships were observed which permitted the interpretation of basic rock occurrences as a previous intrusive phase. Their petrographic, mineralogical and chemical constitution differs from that of the products of the stage with a potassic tendency recognized in the western part of the Bocşa massif (B_1 and B_2 — Russo-Săndulescu et al., 1978); on the other hand they display strong similarities with granodiorites, which accounts for their interpretation as an early phase of the calc-alkaline stage — that is B_3 phase 1. On the Izvorul Negru Valley, nearby the contact with the crystalline schists, granodiorites intrude a small body of black porphyric quartz diorites. In the thalweg of the valley there are zones richer in feldspar, disposed at the border of the granodioritic intrusion, indicating centimetric infiltrations of the granodioritic magma (Fig. 1). Another outcrop lies in

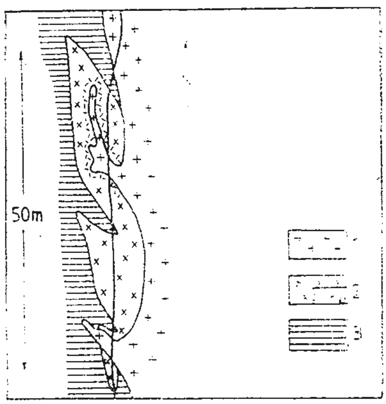

Fig. 1. — Outcrop on the Izvorul Negru Valley.
1, biotite granodiorites; 2, hornblende+biotite porphyry quartz diorites: a, high feldspar zone; 3, crystalline schists.

the left side of the Bîrzava Valley, on the highroad connecting Bocşa Montană with Bocşa Română, at about 200 m from the gas station. Here, the crystalline schists penetrated by porphyric monzodioritic dykes are intruded by the granodioritic body which, using the same access way as monzodiorites, cuts monzodioritic blocks of different sizes — metric up to decimetric — identical with enclaves whose chemical and petrographic composition will be described in the following chapters.

2.1. *Early Bodies (Bocşa 3, Phase 1)*

First described by Codarcea (1931) at Ocna de Fier and by Radu Mercus (1962) at Dognecea, the $B_{3.1}$ bodies represent several small outcrops west of the granodioritic body and more seldom east of it (Pl.). In spite of their reduced sizes (tens or hundreds of metres) there is a wide mineralogical and petrographic variability, both between them and within the same body. Monzodiorites and quartz diorites with hornblende biotite prevail ; gabbros and pyroxene diorites occur as well (Fig. 2).

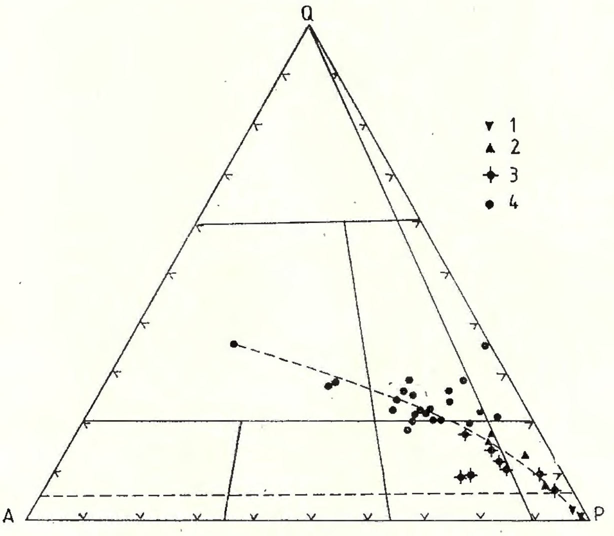

Fig. 2. — *QAP* modal diagram of banatites in the Ocna de Fier-Dognecea zone.
1, Early basic bodies east of the massif ; 2, early basic bodies west of the massif ; 3, enclaves ; 4, rocks of the Ocna de Fier-Dognecea massif.

West of the granodioritic massif, besides the hornblende biotite quartz diorite of Izvorul Negru (Fig. 1) three bodies of the same type occur nearby and a forth one more southwards, on the Biniș Valley. Farther southwards, in the Dognecea zone there are other small exposures with a composition varying from quartz monzodiorites to quartz diorites ; the body on the Vîrîți Ravine is characterized by the presence of clinopyroxene and, in places, of orthopyroxene.

East of Ocna de Fier-Dognecea granodioritic intrusion, Codarcea (1931) figured the basic bodies from Ferendia and Moravița valleys. In the Ferendia Valley plagioclase characterizes this gabbro, being found as two generations : a bytownitic one (An_{88}) forming centres on about two thirds of the crystal, and another one with 55% An, enveloping and intruding corrosively the former one. In the same body one could also observe zones within which an enrichment in potash feldspar occurs concurrently with an association of clinopyroxene with biotite, without hornblende.

2.2. *Enclaves from Granodiorites*

In the Ocna de Fier-Dognecea granodioritic body two categories of enclaves are to be found : enclaves of crystalline schists and of porphyric monzodiorites and quartz diorites. The enclaves of crystalline schists (of metric up to millimetric sizes), represented by biotite hornfelses $\pm$ andalusite $\pm$ corundum, occur only in the contact zone up to some metres from it. Locally they are intruded or enveloped by an aplitic zone rich in potash feldspar. The monzodioritic and quartz dioritic enclaves are highly abundant especially towards the periphery of the granodioritic body where they reach the maximum sizes (some square metres in exposures).

According to the amount of alkali feldspar, two kinds of enclaves were distinguished : quartz monzodioritic — the most frequent type — and quartz dioritic enclaves (Fig. 2).

Monzodioritic enclaves display usually a porphyric texture, given by 2-5 mm phenocrysts of highly zoned plagioclase (An_{50-37} with basic centres of An_{68} and thin margins of An_{24}) ; hornblende and biotite are found both as phenocrysts and as microlites in the groundmass. The colour index of the enclaves varies usually between 33 and 38.

Megaenclaves (5-8 sq.m) of monzodiorites with abundant hornblende, biotite $\pm$ clinopyroxene occur in the Izvor Ravine within an apophysis of the granodioritic massif. These enclaves have been mostly digested so that clinopyroxene xenocrysts are observed in the granodiorite surrounding them.

2.3. *Ocna de Fier-Dognecea Granodioritic Body*

The Ocna de Fier-Dognecea banatites represent the southern prolongation of the Bocșa 3 body described north of the Bîrzava Valley by Russo-Săndulescu et al. (1978). They are also monotonous, being constituted almost of granodiorites. Due to the gradual southward sinking of the B_3 pluton, in the study region prevail the porphyric facies specific to marginal zones or to apophyses, so that the rocks can be described as porphyric granodiorites ; in some cases this character is quite obvious, the groundmass displaying a granulation of only 0.1 mm, and the rocks correspond to porphyric microgranodiorites.

Both on the western margin and on the eastern one occur granodiorites within which biotite is the only mafic mineral and there are gradual transitions towards hornblende biotite granodiorites. Locally these biotite granodiorites show a decrease of the potash feldspar percentage, concomitantly with an increase of the quartz amount, so that they correspond to biotite tonalites (e.g. the apophysis on the Enășoanei Valley).

On the other hand one can observe fine-grained acid differentiates of aplitic type, poor in mafic minerals — practically only biotitic — described by Codarcea (1931) as granites. These "segregations" can, TAB

Chemical analyses in banatitic rocks

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO
1418	60.10	15.77	2.34	3.04	0.14	3.98	6.67
1358	61.80	16.28	2.66	2.06	0.15	3.17	5.25
1401	62.21	16.57	2.22	2.49	0.08	3.34	4.70
1459	62.32	16.03	2.58	2.02	0.06	2.73	6.07
1429	62.52	16.20	2.20	2.37	0.16	3.04	5.25
1344	62.91	16.69	2.54	1.99	0.12	2.62	4.90
1380	63.00	15.90	2.50	2.10	0.09	2.78	5.04
1420	63.06	16.04	1.96	2.50	0.09	2.99	4.68
1474	63.26	16.22	1.24	2.93	0.03	3.10	4.47
1494	63.29	16.26	2.72	2.45	0.12	1.59	5.33
1351	63.35	16.48	2.45	1.88	0.09	1.98	4.98
1512	63.53	15.54	2.63	2.13	0.10	2.67	5.25
1593	63.77	15.90	2.25	2.16	0.13	2.42	4.83
1375	63.86	16.67	2.16	2.31	0.08	1.78	4.27
1532	64.07	16.03	2.14	2.15	0.05	2.49	4.89
1444	64.15	15.87	2.11	2.31	0.09	2.58	4.97
1525	64.93	15.51	1.99	2.21	0.09	2.41	4.19
1602	64.96	15.92	2.48	1.88	0.09	1.65	4.38
1531	65.06	15.90	1.70	2.02	0.09	2.12	4.99
1603	65.22	15.87	2.67	1.47	0.14	2.15	4.62
1371	65.97	15.90	1.96	1.41	0.15	2.11	3.64
1435	67.88	15.64	1.01	1.48	0.04	1.90	3.64
1346	68.30	15.31	1.87	1.11	0.06	1.22	3.88
1619	76.57	12.66	1.25	0.07	0.05	0.32	0.28
1604	52.23	17.15	3.34	4.18	0.13	7.41	8.19
1453	68.24	16.21	1.14	0.38	0.09	1.40	3.55
1517	72.13	14.58	0.66	1.49	0.06	0.99	1.57
1535	72.68	12.97	1.49	0.68	0.09	1.39	1.61
1513	55.36	16.27	2.70	3.70	0.21	5.37	7.57
1445	55.52	17.20	3.23	3.24	0.03	5.01	6.65
1493	55.99	16.99	3.57	3.63	0.09	4.00	7.08
1510	56.00	15.77	2.04	4.10	0.08	6.69	6.72
1436	56.38	16.94	2.64	3.47	0.15	4.60	6.86
1403	57.26	16.64	2.69	3.38	0.08	4.74	6.16
1404	58.10	17.37	3.35	2.95	0.10	3.28	5.67
1437	58.52	15.68	1.85	3.40	0.11	6.00	6.16
1548	50.99	19.66	2.54	4.84	0.11	3.64	7.69
1569	50.40	18.72	4.38	1.73	0.32	4.46	12.53
1567	57.69	18.27	2.40	3.28	0.09	3.57	5.49
1502	55.66	17.15	3.42	3.89	0.05	5.04	7.00
1500	58.53	17.21	2.82	3.36	0.16	3.65	7.15
1578	56.18	15.67	2.64	4.12	0.17	6.58	6.72
1519	58.37	16.70	2.70	3.55	0.18	3.99	5.66
1353	58.03	17.46	2.26	3.88	0.07	3.69	6.30

Samples are loca

LE 1

from Ocna de Fier — Dognecea region

Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O^+	Total
3.29	2.59	0.79	0.25	0.57	0.05	0.19	99.81
3.71	2.64	0.67	0.24	0.49	0.00	0.67	99.79
3.82	2.67	0.66	0.31	0.00	0.05	0.66	99.78
3.72	2.75	0.60	0.45	0.00	0.00	0.55	99.88
3.75	2.70	0.67	0.26	0.30	0.06	0.71	100.17
3.60	2.85	0.62	0.22	0.28	0.00	0.89	100.23
3.60	2.80	0.63	0.21	0.66	0.00	0.84	100.15
3.74	3.11	0.63	0.32	0.00	0.07	0.44	99.63
3.46	2.09	0.61	0.23	0.00	0.54	1.25	99.90
3.91	2.27	0.67	0.27	0.00	0.00	0.72	99.60
4.00	3.00	0.58	0.23	0.00	0.00	0.57	99.59
3.65	2.80	0.62	0.27	0.45	0.00	0.75	100.39
3.35	3.03	0.60	0.20	0.38	0.60	0.77	99.79
4.03	2.66	0.63	0.55	0.00	0.00	0.62	99.62
3.80	3.09	0.59	0.22	0.00	0.09	0.60	100.21
3.45	3.05	0.62	0.20	0.42	0.00	0.57	100.39
3.37	3.27	0.54	0.26	0.00	0.07	1.00	99.84
3.74	3.01	0.54	0.24	0.00	0.04	0.66	99.59
3.89	2.83	0.47	0.25	0.00	0,00	0.92	100.24
3.60	3.04	0.54	0.19	0.36	0.00	0.59	100.46
3.75	3.24	0.51	0.15	0.50	0.00	0.40	99.69
3.72	2.33	0.43	0.21	0.00	0.28	0.85	99.65
3.74	2.93	0.44	0.12	0.00	0.00	0.68	99.66
3.00	4.70	0.17	0.07	0.39	0.00	0.22	99.75
3.47	1.54	0.91	0.28	0.00	0.00	1.39	100.22
3.88	3.50	0.45	0.15	0.31	0.02	0.79	100.12
5.21	1.51	0.20	0.07	0.32	0.03	0.95	99.79
3.10	4.90	0.27	0.09	0.50	0.00	0.30	100.07
4.24	2.27	0.96	0.25	0.69	0.07	0.63	100.35
3.90	2.05	1.06	0.51	0.52	0.00	1.53	100.45
4.29	1.30	1.06	0.34	0.00	0.11	1.13	99.68
3.15	2.60	0.71	0.20	0.71	0.03	1.18	99.97
3.55	2.25	0.89	0.25	0.48	0.04	1.42	99.91
3.70	2.30	0.86	0.27	0.87	0.05	1.10	100.08
3.47	2.80	0.93	0.27	0.40	0.12	1.34	100.11
3.65	2.26	0.73	0.39	0.00	0.03	0.87	99.65
3.80	1.75	0.90	0.47	0.00	0.96	1.75	99.94
3.55	0.52	1.08	0.43	0.70	0.00	1.51	100.33
3.81	2.08	0.82	0.31	0.00	0.51	1.47	100.23
3.72	1.92	0.90	0.48	0.00	0.05	0.82	100.10
3.56	2.12	0.80	0.24	0.00	0.05	0.22	99.91
3.30	2.05	0.87	0.25	0.82	0.00	1.07	100.47
3.59	2.46	0.85	0.29	0.27	0.05	1.14	99.84
3.72	2.25	0.93	0.34	0.00	0.06	0.90	99.89

ted in Plate I.

Annex to Tables 1 and 2

1416, Porphyry quartz microdiorite, Valea Mică (phenocrysts of Pl, Ho, Bi and groundmass);

1358, Granodiorite, Aron Valley (Pl-45.2; FK-9.9; Q-19.6; Bi-9.4; Ho-13.2; Acc-2.7%);

1401, Granodiorite, Ţiganului Ravine (Pl-54.7; FK-7; Q-17.4; Bi-10.9; Ho-7.5; Acc-2.5%);

1459, Granodiorite, Petru şi Pavel Ravine (Pl-51; FK-13.7; Q-17.3; Bi-8.2; Ho-8.2; Acc-1.6%);

1429, Granodiorite, Ogaşul Rău (Pl-55.1; FK-11.2; Q-15.7; Bi-6.7; Ho-9.7; Acc-1.5%);

1344, Granodiorite, Lacului Mic Valley (Pl-42.1; FK-20.3; Q-17.3; Bi-6.4; Ho-10.9; Acc-3.0%);

1420, Porphyry granodiorite, Dognecea Valley (Pl-48.8; FK-16.6; Q-18.7; Bi-5.3; Ho-8.5; Acc-2.1%);

1474, Tonalite, Enăşoanei Valley (Pl-56.8; Q-32.3; Bi-9.9; Acc-1%);

1494, Granodiorite, Croitorului Ravine (Pl-43.9; FK-6.1; Q-20.6; Bi-5.3; Ho-20.6; Acc-3.5%);

1351, Porphyry granodiorite, Bradului Valley (Pl-52.2; FK-15.8; Q-19.2; Bi-4.4; Ho-6,9; Acc-1.5%);

1512, Porphyry granodiorite, Izvorului Valley (Pl-44.8; FK-16.2; Q-21.4; Bi-9.0; Ho+Cpx — 6.6; Acc-2.1%);

1593, Porphyry granodiorite, Friptoria Ravine (Pl-49.7; FK-18.6; Q-15.2; Bi-5.2; Ho-10; Acc-2.3%);

1375, Granodiorite, Moim Ravine (Pl-46.4; FK-10; Q-17.7; Bi-16.4; Ho-7.3; Acc-2.3%);

1537, Porphyry granodiorite, Moraviţei Valley (Pl; FK; Q; Bi; Hb; Acc);

1444, Granodiorite, Dealovăţ Ravine (Pl-42.5; FK-18.9; Q-20.5; Bi-5.8; Ho-10.4; Acc-1.9%);

1525, Porphyry microgranodiorite, Ogaşul cu Peri (Pl-35.5; FK-29.4; Q-25.6; Bi-3.8; Ho-4 7; Acc-0.9%);

1602, Porphyry granodiorite, Friptoria Ravine (Pl-51.2; FK-19.0; Q-19.0; Bi-2.8; Ho-7.3; Acc-0.8%);

1531, Porphyry microgranodiorite, Rozalia Ravine (Pl; FK; Q; Bi; Hb; Acc);

1603, Porphyry granodiorite, Groza Mare Ravine (Pl; FK; Q; B; Hb; Acc);

1371, Porphyry granodiorite, Moim Ravine (Pl-45.5; FK-16.4; Q-24.3; Bi-6.3; Ho-6.3; Acc-1.1%);

1435, Granodiorite, Opîrnecea Ravine (Pl-58.7 ; FK-5.9 ; Q-17.2 ; Bi-8.3 ; Ho-8.3 ; Acc-1.7%) ;

1346, Porphyry microgranodiorite, Lacul Mic Valley (Pl-51.3 ; FK-19.4 ; Q-18.1 ; Bi-9.1 ; Ho-1.3 ; Acc-0.9%) ;

1619, Granite, Popii Ravine (Pl ; FK ; Q ; Bi ; Acc) ;

1604, Andesite, Groza Mare Quarry (phenocrysts : Pl ; Hb ; groundmass : Pl ; Hb ; Bi) ;

1453, Dacite (Petru și Pavel Ravine) (phenocrysts : Pl ; Q ; Hb ; groundmass) ;

1517, Dacite (Heneț Ravine) (phenocrysts : Pl-18.0 ; Q-4.2 ; Bi-1.1 ; groundmass 76.7%) ;

1535, Rhyolite (phenocrysts : Pl ; FK ; Q ; Hb ; Bi ; groundmass) ;

1513, Microdioritic enclave, Izvor Ravine (Pl-53.1 ; FK-3.1 ; Q-5.8 ; Bi-15.0 ; Ho + Cpx — 20.8 ; Acc-2.3%) ;

1445, Micromonzodioritic enclave, Dealovăț Ravine (Pl-47.6 ; FK-11.7 ; Q-5.6 ; Bi-7.8 ; Ho-23.0 ; Acc-4.3%) ;

1493, Micromonzodioritic enclave, Croitorului Ravine (Pl-54.9 ; FK-7.0 ; Q-8.5 ; Bi-4.2 ; Ho-20 ; Acc-4.9%) ;

1510, Micromonzodioritic enclave, Izvor Ravine (Pl-42.4 ; FK-10.0 ; Q-5.6 ; Bi-13.4; Ho-28.1 ; Acc-0.4%) ;

1436, Micromonzodioritic enclave, Opîrnecea Ravine (Pl-50.2 ; FK-7.6 ; Q-9.5 ; Bi-11.5 ; Ho-19.3 ; Acc-2.2%) ;

1403, Micromonzodioritic enclave, Țiganului Ravine (Pl-52.6 ; FK-6.9 ; Q-7.6 ; Bi-9.5 ; Ho-21.7 ; Acc-1.6%) ;

1404, Microdioritic enclave, Țiganului Ravine (Pl-57.9 ; FK-3.0 ; Q-3.7 ; Bi-8.1 ; Ho-22.9 ; Acc-4.4%) ;

1437, Micromonzodioritic enclave, Opîrnecea Ravine (Pl-42.7 ; FK-8.3 ; Q-11.1 ; Bi-7.5 ; Ho-29.6 ; Acc-0.8%) ;

1548, Gabbro, Ferendia Valley (Pl-69.8 ; FK-1.7 ; Q-1.7 ; Bi-5.0 ; Ho-19.3 ; Acc-2.7%);

1569, Gabbro, Moravitei Valley (Pl-65.2 ; Ho-34.0 ; Acc-0.9%) ;

1567, Porphyry, gabbro-diorite biotitized, Cariera Terezia Mare (Pl ; Ho ; Q ; Acc);

1502, Quartz-gabbro diorite, Vîrîți Ravine (Pl-55.0 ; FK-4.4 ; Q-8.4 ; Bi-9.2 ; Ho + Cpy — 19.9 ; Acc-3.2%) ;

1500, Microgabbro-porphyry quartz diorite, Vîrîți Ravine (Pl-40.0 ; Bi + Ho — 4.0 ; Cpx + Opx — 14.5 ; Acc-2.8 ; mesostasis — 38.8%) ;

1578, Porphyry quartz microdiorite, Izvorul Negru Ravine (Pl-46.0 ; FK-2.6 ; Bi-10.7 ; Ho-36.4 ; Acc-0.7%) ;

1519, Porphyry quartz monzodiorite, Ogașul cu Peri (Pl-54.4 ; FK-7.5 ; Q-11.9 ; Bi-7.5 ; Ho-16.2 ; Acc-2.4%) ;

1353, Porphyry quartz monzodiorite, Biniș Ravine (Pl-52.6 ; FK-6.6 ; Q-12.5 ; Bi-12.5 ; Ho-13.8 ; Acc-2.1%).

TABLE 2

Trace elements in banatitic rocks from Ocna de Fier-Dognecea region

Sample	Pb	Cu	Sn	Ga	Ni	Co	Cr	V	Sc	Yb	Y	La	Sr	Ba	Li
1418	13	30	4.5	17	22	16	44	160	18	1.8	20	30	630	520	26
1358	13	20	3	16	13	13	29	74	12	1	12	<30	650	550	19
1401	12	15	3	17	18	13	36	90	13	1.3	14	30	650	520	21
1459	25	26	<2	20	12	13	27	90	9.5	1.2	14	34	490	540	29
1429	13	220	2.6	18	15	12	37	70	11	1	12	<30	700	530	45
1344	13	13	<2	12	13	12	28	75	11	0.9	12	<30	570	580	32
1380	13	23	<2	15	14	12	31	78	11	0.7	9	<30	380	480	25
1420	14	36	2.2	17	14	12	31	62	10	0.9	11	<30	720	500	30
1474	8.5	240	4	27	16	20	49	110	12	1.4	13	30	360	420	33
1494	23	26	<2	20	13	15	22	140	15	1.9	18	34	490	480	19
1351	14	20	2	14	11	11	22	68	10	1	10	<30	400	520	22
1512	18	7.5	2.5	16	11	13	26	85	10	2	14	15	480	500	21
1593	17	9	2.7	17	13	13	25	90	9	1.2	13	34	700	570	7
1375	10	73	2.5	16	12	10	29	65	10	1.1	12	<30	380	520	35
1532	22	26	3.3	19	12	12	31	100	10	1.4	14	36	480	530	21
1444	22	18	<2	19	15	14	34	100	10	1.2	14	35	420	500	38
1525	13	95	2.5	16	11	11	27	100	10	1.3	14	40	400	600	20
1602	12	15	2.4	12	14	12	30	75	8	1.1	12	<30	420	530	20
1531	11	9.5	2.3	17	11	13	26	85	9	1.7	15	44	600	550	40
1603	16	25	2	18	14	14	31	95	9.5	1.6	16	34	530	570	24
1371	25	58	2.4	15	10	7	18	56	8	0.9	12	32	460	620	27
1435	13	36	<2	18	14	11	23	65	7	0.5	6	<30	570	470	30
1346	18	9.5	<2	15	7.5	6	11	40	5.5	1	9.5	30	540	680	15
1535	26	9.5	2.4	15	5.5	6	17	34	4	1.2	11	34	150	390	4
1619	21	6	<2	13	4	2	4	14	2	0.6	5	<30	85	400	25
1604	23	23	<2	15	105	28	170	120	17	1.1	14	<30	780	440	26
1453	29	14	<2	17	21	5	12	62	5.5	2	15	<30	570	470	12
1517	10	14	<2	21	12	10	6	18	2	0.8	<10	<30	220	255	28
1513	20	19	4.5	18	43	22	95	145	24	2.4	29	39	430	215	34
1445	25	8	8	22	22	17	50	200	22	1.9	18	44	270	340	30
1493	10	180	6	20	21	22	32	170	18	1.8	21	34	470	330	12
1510	17	36	3.4	20	130	23	410	145	22	1.2	15	30	360	540	18
1436	14	14	5	18	24	15	34	115	17	1.6	15	<30	340	1050	30
1403	6.5	8	4	18	32	18	95	120	20	1.2	14	<30	620	500	19
1404	11	48	4	19	17	14	45	130	12	1.7	16	38	570	530	27
1437	14	15	7	18	57	17	200	160	17	1.7	15	30	450	450	27
1548	19	135	12	22	16	38	13	190	18	2	23	<30	720	310	20
1569	34	20	2.2	17	42	22	50	220	25	1.9	23	<30	700	175	25
1567	12	22	3.1	19	11	18	13	160	13	1.8	19	34	400	360	37
1502	19	54	5	26	25	23	67	160	20	1.4	13	30	730	450	19
1500	19	33	4.5	18	31	21	50	185	19	1.9	23	<30	600	490	26
1578	11	30	3	15	77	25	200	125	15	1.2	16	<30	670	420	60
1519	20	12	5	19	19	20	19	165	18	2	24	30	620	550	28
1353	74	30	4.7	18	13	15	26	125	18	1.6	18	<30	570	570	9.5

however, form a network of aplitic veinlets when entering the marginal zones of the massif, already crystallized, or the surrounding crystalline schists. It is only a local differentiation, not subsequent veins.

Like all banatites within Bocşa 3, the Ocna de Fier-Dognecea granodiorites are light-coloured rocks with the M index varying between 10 and 25, very frequently 15-20, within which melanocrates are represented by common hornblende and biotite and leucocrates by plagioclases, quartz and potash feldspar. Plagioclase An_{42-38} with extremely rare centres An_{55-50}, displays a recurrent zoning typical of all banatites in this stage, with small variations of the anorthitic component around the value An_{40} and marginal zones An_{24-20}.

2.4. *Vein Rocks Subsequent to the Granodioritic Massif*

Although several basic bodies mentioned above occur as dyke we shall describe here only the dyke rocks (some of them proved by succession relationships, others by similarities) subsequent to the granodioritic massif. They are represented by andesites and lamprophyres, on the one hand, and dacites and rhyolites, on the other hand.

In our opinion the rock described by Codarcea (1931, Fig. 19) as odinite in the Groza Mare quarry is an andesite, occurring as a dyke in granodiorites and crossed by an acid dyke. Although the groundmass of the rock possesses a divergent structure similar to lamprophyres, the presence of numerous phenocrysts of intermediary plagioclase-andesine (a character specific to andesites not to lamprophyres) beside hornblende and uralitized pyroxene, as well as the abovementioned age relationships (andesitic dyke previous to rhyolite) make us prefer the denomination of andesite, possibly porphyric microdiorite. As a matter of fact in Banat lamprophyres have been observed only subsequent to the latest banatitic differentiates — rhyolite.

Rocks with a clear lamprophyric character were found in Ogaşul cu Imală Ravine, where they are represented by spessartites.

Dacites and rhyolites intrude both the granodioritic massif and the surrounding crystalline schists. They show phenocrysts of quartz, plagioclase$\pm$potash feldspar, biotite and hornblende within a microcrystalline groundmass, more rarely a cryptocrystalline one (Heneţ Ravine).

3. **Geochemistry of the Banatitic Magmatites**

The first chemical study of the banatites in the Ocna de Fier-Dognecea region was effectuated by Codarcea (1931). We shall present here 43 new chemical and spectral analyses of early basic bodies, enclaves, granodioritic rocks of the massif and subsequent vein rocks, belonging to the banatitic magmatism in this region (Tabs. 1, 2). For a thorough image of the northern part of the "plutonic banatitic zone" in the West Banat 23 chemical and spectral analyses were performed on banatites representative for the southern part of the "plutonic banatitic zone", between Maidan (Oraviţa) and Moldova Nouă (Tabs. 3, 4)

TABLE 3

Chemical analyses in banatitic rocks from Oravița — Moldova Nouă region

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	H_2O^+	Total
46	62.71	16.10	2.41	2.21	0.08	2.69	5.10	3.84	2.52	0.42	0.19	0.15	0.14	1.06	99.74
26 A	67.40	15.00	1.82	1.69	0.05	1.94	4.20	3.87	2.70	0.51	0.13	0.00	0.07	0.63	100.07
26 B	63.91	15.66	1.68	1.12	0.04	1.80	5.13	3.91	3.15	0.48	0.14	0.60	0.08	2.18	99.95
29	65.60	15.15	2.23	1.99	0.07	2.21	4.41	3.90	2.67	0.63	0.10	0.00	0.10	0.35	99.50
33	49.00	17.45	4.57	4.73	0.17	6.94	10.93	2.87	0.20	0.83	0.23	0.00	0.04	1.86	99.85
1	67.00	15.35	1.41	0.96	0.07	2.01	5.33	3.62	2.35	0.55	0.18	0.00	0.11	0.86	99.90
21	51.40	16.30	3.83	4.58	0.13	5.87	10.41	3.52	1.53	1.07	0.14	0.00	0.08	0.69	99.62
25	54.00	13.50	3.83	4.31	0.17	7.09	10.55	3.00	1.40	0.99	0.22	0.00	0.08	0.52	99.53
47	54.02	17.80	4.35	3.10	0.14	4.40	8.03	3.67	1.67	1.00	0.26	0.00	0.10	1.36	99.98
16	54.40	18.00	2.22	4.02	0.12	4.53	6.86	4.00	1.87	0.92	0.30	0.61	0.34	1.40	99.89
7 B	55.20	17.30	3.42	3.11	0.12	3.81	6.84	2.18	3.89	1.00	0.21	0.00	0.14	2.22	99.50
20	56.40	17.00	3.40	3.49	0.13	4.28	7.38	3.80	1.93	0.97	0.20	0.00	0.05	0.58	99.65
7 A	56.75	16.70	3.49	3.46	0.14	3.58	7.07	3.87	2.15	1.09	0.24	0.00	0.07	0.90	99.57
2	57.50	14.85	3.36	4.03	0.12	4.40	7.37	3.45	2.40	0.96	0.28	0.00	0.07	0.70	99.55
13	57.75	17.17	2.41	1.53	0.12	3.74	9.51	3.73	0.95	0.32	0.52	0.00	0.06	1.55	99.41
8	58.00	13.80	1.64	4.16	0.13	5.23	6.13	3.57	2.35	0.80	0.13	1.78	0.09	2.32	100.21
12	60.00	16.25	2.80	2.79	0.12	4.19	6.57	3.55	2.30	0.80	0.15	0.00	0.03	0.32	99.90
31	68.00	16.15	1.06	0.93	0.06	2.19	4.82	5.12	0.35	0.59	0.14	0.00	0.04	0.86	100.34
37	62.74	16.14	2.65	2.18	0.10	2.79	5.20	3.85	2.05	0.63	0.19	0.00	0.11	0.70	99.43
34	59.65	16.43	3.24	2.56	0.12	4.40	5.68	4.20	1.58	0.62	0.23	0.35	0.15	1.33	100.67
42	60.47	16.00	2.09	2.49	0.14	3.07	5.95	3.85	1.95	0.66	0.20	0.48	0.63	1.16	99.69
44	62.63	15.94	1.99	2.33	0.12	2.67	4.97	3.32	1.92	0.64	0.22	1.20	0.45	0.90	99.69
43	62.81	15.90	2.24	2.04	0.06	2.63	5.28	3.72	2.11	0.50	0.19	0.40	0.17	1.16	99.36

Samples: 46,26 A, 26 B, 29 = Maidan; 33 = Oravița (Lacu Mare); 1,21, 25, 47, 16,7 B, 20, 7 A, 2, 13,8 = Ciclova; 31 = Ilidia; 37 = Sasca; 34 = Cărbunari; 42, 44, 43 = Modova Nouă.

Annex to Tables 3 and 4

46. Tonalite, Oravița (Pl, FK, Q, Bi, Hb, Acc) ;

26A. Porphyry granodiorite, Maidan (Pl, FK, Q, Bi, Hb, Acc) ;

26B. Porphyry granodiorite, Maidan (Pl, FK, Q, Bi, Hb, Acc) ;

29. Porphyry granodiorite, Maidan (Pl, FK, Q, Bi, Hb, Acc) ;

33. Gabbro, Oravița (Pl, Hb, Cpx, Acc) ;

1. Porphyry granodiorite, north of Ciclova (Pl, FK, Q, Hb) ;

21. Diorite-gabbro, Ciclova (Pl, Q, Cpx, Hb, Bi, Acc) ;

25. Diorite-gabbro, Ciclova (Pl, R, Opx, Hb, Bi, Acc) ;

47 Diorite, Ciclova (Pl, Q, Hb, Bi, Acc) ;

16. Quartz diorite, Ciclova (Pl, Q, Hb, Bi, Acc) ;

7B. Quartz monzodiorite, Ciclova (Pl, FK, Q, Hb, Bi, Acc) ;

20. Quartz diorite, Ciclova (Pl, Q, Cpx, Hb, Bi, Acc) ;

7A. Quartz diorite, Ciclova (Pl, Q, Cpx, Hb, Bi, Acc) ;

2. Quartz diorite enclave, north of Ciclova (Pl, FK, Q, Hb, Acc) ;

13. Quartz diorite, Ciclova (Pl, Q, Cpx, Bi, Acc) ;

8. Andesite, Ciclova, Țiganilor Ravine (phenocrysts : Pl, Q, Hb ; groundmass) ;

12. Quartz monzodiorite, Ciclova (Pl, FK, Q, Cpx, Hb, Acc) ;

31. Granodiorite, Ilidia (Pl, FK, Q, Hb, Acc) ;

37. Granodiorite, Sasca (Pl, FK, Q, Hb, Bi, Acc) ;

34. Quartz diorite, Cărbunari (Pl, FK, Q, Hb, Bi, Acc) ;

42. Quartz diorite, Moldova Nouă-borehole, Băieș area (Pl, FK, Q, Hb, Bi, Acc);

44. Porphyry quartz microdiorite, Moldova Nouă-borehole, Băieș area (Pl, FK, Q, Hb, Bi, Acc) ;

43. Tonalite, Moldova Nouă-borehole, Băieș area (Pl, FK, Q, Hb, Bi, Acc).

TABLE 4

Trace elements in banatitic rocks from Oravița-Moldova Nouă region

No.	Sample	Pb	Cu	Sn	Ga	Ni	Co	Cr	V	Sc	Zr	Yb	Y	La	Sr	Ba	Li
1	46	13	93	<2	22	10	8.5	15	95	7	80	1.1	10	<30	410	550	—
2	26 A	28	13	<2	17	9.5	4.5	15	53	85	150	1.4	11	<30	780	480	18
3	26 B	13	8.5	<2	16	8	4	8	80	5	70	0.8	10	<30	330	620	—
4	29	17	35	<2	18	12	5.5	22	82	11	105	1.6	14	<30	950	500	18
5	33	6	40	4	18	48	34	47	195	25	15	1.6	15	<30	3000	180	10
6	1	15	82	3	18	9.5	5.5	20	84	10	100	2.5	22	30	750	600	5
7	21	18	17	<2	17	33	17	30	230	28	70	2.3	24	<30	1500	360	26
8	25	19	100	<2	15	90	17	230	190	28	88	1.8	21	<30	900	260	14
9	47	10	63	3	17	13	16	5.5	190	15	80	1.1	13	<30	740	430	—
10	16	10	57	<2	14	34	16	33	180	20	130	1.8	26	<30	800	560	27
11	7 B	13	18	<2	23	9.5	10	9	135	13	94	1.1	13	<30	920	600	—
12	20	28	15	2.5	18	22	13	55	200	23	140	1.9	24	<30	1350	440	35
13	7 A	30	33	<2	18	16	14	24	210	23	145	2.2	26	36	560	360	20
14	2	65	220	5	18	30	11	54	180	21	180	2.7	30	40	600	420	4.5
15	13	7.5	34	<2	12	15	8	16	110	24	70	4	38	60	1650	250	6
16	8	63	65	<2	15	44	15	170	155	23	82	2.4	21	<30	540	310	82
17	12	36	20	<2	16	39	14	115	150	16	145	2	21	<30	530	350	18
18	31	23	10	<2	18	13	4	22	56	10	135	1.6	12	<30	680	180	20
19	37	13	12	3	18	22	14	40	85	12	165	1.6	16	34	500	540	21
20	34	17	37	4	21	39	18	75	135	21	120	2.9	23	34	450	430	12
21	42	9	5.5	3	17	16	11	27	105	17	105	2.3	17	<30	640	540	4.5
22	44	13	6.5	3	18	18	14	25	120	15	98	2.6	20	46	960	570	4.5
23	43	36	12	3	22	15	10	21	73	11	98	2	17	<30	480	540	12

A comparison of the analytical data presented in the mentioned tables indicates, on the one hand, a chemical homogeneity of granodioritic banatites in these regions and, on the other hand, the similarity between early basic bodies and enclaves from granodiorites. These features are illustrated on the graphic representations drawn up on the basis of the chemical parameters.

SiO_2/Na_2O+K_2O diagram (on which the limits of the fields of differentiate rocks coming from olivine alkali basalts-I, high alumina basalts-II and tholeiitic basalts-III according to Kuno, 1968) makes possible the assigning of all the rocks of the massif, as well as of most of the early basic rocks and of enclaves, to the high alumina field, as in case of the rocks from the Bocșa 3 intrusion north of the Bîrzava Valley. As compared with the rocks of Bocșa 1, 2 and Surduc intrusions, mostly plotted in field I, products of the calc-alkaline stage (basic bodies and enclaves — phase $B_{3.1}$ and granodiorites phase $B_{3.2}$ clearly differentiate by a lower content in alkalies at similar $SiO_2\%$ (Russo-Săndulescu, Berza, 1980).

Analyses carried out on samples from the southern part of the "plutonic banatitic zone" fall also within field II, thus showing similarities with products of Bocșa 3.1 (Oravița, Ciclova) and Bocșa 3.2 (Maidan, Ilidia, Sasca, Cărbunari, Moldova Nouă) phases.

On $F(Fe_2O_3 \times 0.9+FeO)$—$A(Na_2O+K_2O)$—$M(MgO)$ diagram, in which field I corresponds to the hypersthenic differentiation (calc-alka-

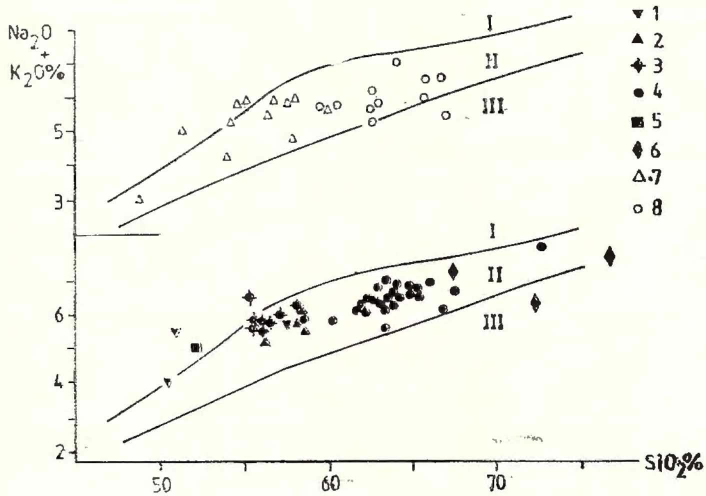

Fig. 3. — $SiO_2/Na_2O + K_2O$ diagram.

1, Early basic bodies east of the massif; 2, early basic bodies west of the massif; 3, enclaves; 4, rocks of the massif; 5, andesitic dyke; 6, rhyolitic and dacitic dykes subsequent to the Ocna de Fier-Dognecea massif; 7, bodies in the Ciclova-Oravița zone; 8, bodies in the Maidan, Ilidia, Sasca, Cărbunari, Moldova Nouă zones.

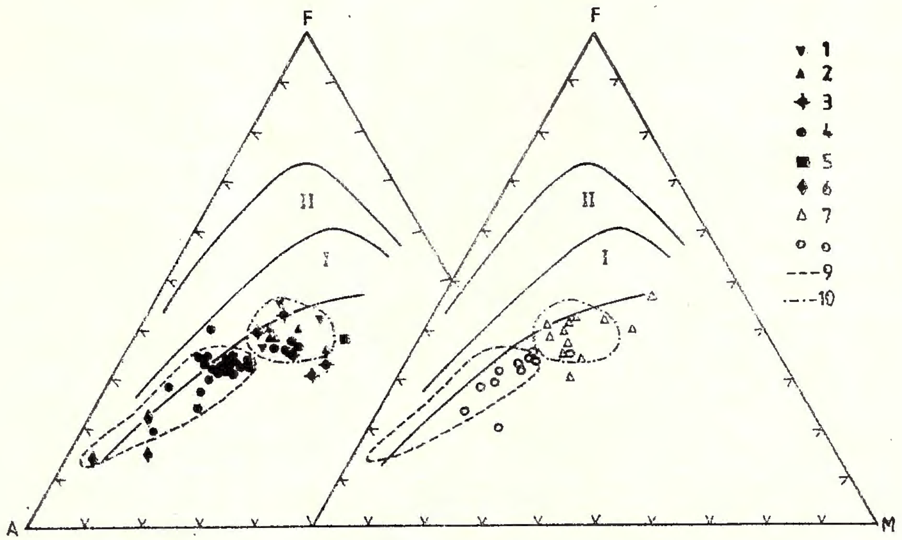

Fig. 4. — FAM diagram.

1 — 8 see Figure 3; 9, field of early basic rocks; 10, field of the rocks of the Ocna de Fier-Dognecea massif.

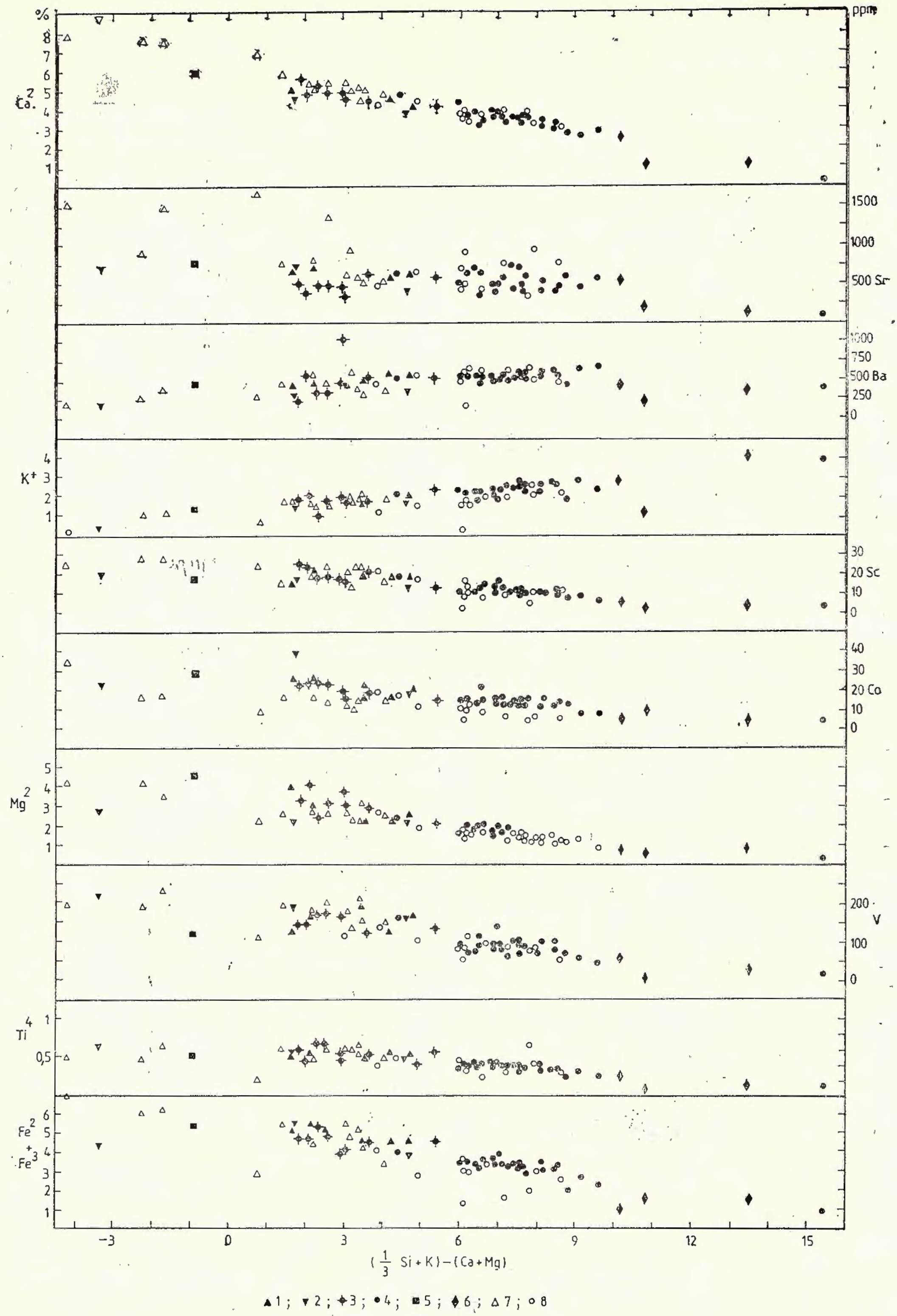

Fig. 5. — Nockolds-Allen differentiation diagram. See legend of Figure 3.

line) series and field II to the pigeonitic (tholeiitic) one, after Kuno (1968), one can observe the concentration of the analyses of enclaves and early basic rocks ($B_{3.1}$) in a unique field, whereas the granodiorites of the massif ($B_{3.2}$) indicate a tendency of enrichment in alkalies. The similarity of the Ciclova-Oravița rocks with phase $B_{3.1}$ is obvious, whereas the analyses in the southern part of the massif fall in the granodiorites field. As compared with products of the stage with a potassic tendency (Bocșa 1, 2 and Surduc), the differentiation of the calc-alkaline stage (Bocșa 3 type) takes place at small values of the parameter F (Russo-Săndulescu, Berza, 1980).

A classical representation — Nockolds-Allen differentiation diagram — points out : a) superposition of projection of enclave analyses from granodiorites, early basic bodies in the Ocna de Fier-Dognecea region and the Ciclova-Oravița intrusion ; b) a good alignment of all plutonic rocks of the west Banat, with no significant discontinuities or slope differences between granodiorites, on the one hand, and enclaves and more basic rocks, on the other hand ; c) all analysed rocks indicate differentiation tendencies with an obvious calc-alkaline character.

4. Conclusions

The present study completes, south of the Bîrzava Valley, our research on the Bocșa composite body (Russo-Săndulescu et al., 1978). There resulted that in the southern zone crops out a main granodioritic body which intrudes and cuts more basic consanguineous rocks. Their study, from isolated bodies or enclaves, made possible the detailing of the image of the banatitic magmatism evolution of the Bocșa-Dognecea region.

A first stage is characterized by a differentiation with a potassic tendency, achieved during two intrusion stages, Bocșa 1 and Bocșa 2. K/Ar radiometric datings obtained on rocks from these intrusion phases indicated values ranging between 87-80 m.y. (Russo-Săndulescu et al., 1986).

Products of the calc-alkaline stage, having a different spatial position (on a N-S trend, unlike the NE-SW trend of the intrusions B_1 and B_2) and different ages (65-56 m.y., Russo-Săndulescu et al., 1986), are represented by a phase of basic dykes (Bocșa 3.1) and the big granodioritic intrusion (Bocșa 3.2). North of Bîrzava, the latter comes into contact with the B_2 unit along a tectonic line and southwards it creeps in between crystalline schists up to Dognecea.

Petrochemical and geochemical features of the basic rocks from early dykes and enclaves showed, on the one hand, significant differences as compared with the basic products of the stage with a potassic tendency (B_1 and B_2) and, on the other hand, similarities with the $B_{3.2}$ granodiorites (presence, almost exclusively, among mafic minerals, of hornblende and biotite, recurrently zoned plagioclase, and in chemical respect low contents of K, Fe, Ti, V, Sc). This consanguinity is attributed to the differentiation of some intermediary magmas formed after subduction (see Rădulescu and Săndulescu's model, 1973). Thus, within a magmatic reservoir lying somewhere between the origin place of the magma and the present location, a certain differentiation of the initial dioritic magma was achieved by fractional crystallization and gravitational accumulation, first the basic differentiates were released (which generated early gabbroic, monzodioritic and dioritic dykes — $B_{3.1}$), followed by the emplacement of the $B_{3.2}$ granodiorites, and later on by dyke differentiates — rhyolites and dacites.

Geochemical features of rocks coming from the intrusions between the Carașului Valley and the Danube (southern part of the "plutonic banatites zone") pointed out their appurtenance to the calc-alkaline stage. The main intrusion of Ciclova and the gabbroic body of Oravița (Lacul Mare) correlate well with products of the $B_{3.1}$ phase.

The Maidan intrusions, the westernmost body at Ciclova (porphyry diorites according to Cioflica et al., 1980), the Ilidia, Sasca, Cărbunari and Moldova Nouă intrusions are similar geochemically with granodiorites of the $B_{3.2}$ phase, although most of them had previously been regarded as more basic.

Finally, west of the Reșița-Moldova Nouă synclinorium the two plutonic stages (with potassic or calc-alkaline tendencies) were followed by a stage within which occur dykes with different chemistry and structures — andesites, dacites, rhyolites, as well as lamprophyres, whose affiliation to previous banatitic products is still to be proved.

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STUDIUL PETROLOGIC AL BANATITELOR DIN REGIUNEA OCNA DE FIER-DOGNECEA (BANAT)

(Rezumat)

Cel mai mare pluton banatitic (magmatism cretacic superior), care aflorează în România, se dezvoltă atît la nord de valea Bîrzavei-masivul Bocşa, cît şi la sud de această vale, în regiunea Ocna de Fier-Dognecea. În cadrul masivului Bocşa s-a demonstrat (Russo-Săndulescu et al., 1978) existenţa a trei intruziuni distincte, denumite, în ordinea succesiunii şi de la vest spre est, Bocşa 1 (B_1), Bocşa 2 (B_2) şi Bocşa 3 (B_3). Intruziunile B_1 şi B_2, comagmatice, sînt caracterizate de un chimism cu tendinţă potasică, iar din punct de vedere petrografic şi mineralogic prin prezenţa unor roci bazice şi, respectiv, a piroxenilor. Ocupînd partea centrală şi estică a corpului compus Bocşa, intruziunea B_3 se deosebeşte prin natura sa net calcoalcalină şi predominarea granodioritelor cu hornblendă şi biotit ; acestea conţin numeroase enclave de monzodiorite porfirice, roci care se găsesc adesea la periferia corpului principal ca mici dyke-uri ce străbat şisturile cristaline şi sînt apoi intersectate de granodiorite. Datorită lipsei de asemănare cu rocile unităţilor B_1 şi B_2, pe de o parte, şi consanguinităţii clare dintre corpurile mici monzodioritice şi granodioritele plutonului, pe de altă parte, am stabilit (Russo-Săndulescu, Berza, 1977, 1980) că în stadiul de intruziuni plutonice calcoalcaline au fost puse în loc la început roci mai bazice — B_3 faza 1 ($B_{3.1}$ urmate de masa mare a granodioritelor — B_3 faza 2 ($B_{3.2}$).

La sud de valea Bîrzavei, studii mai detaliate asupra banatitelor de la vest de zona Reşiţa-Moldova Nouă au publicat Codarcea (1931), Radu-Mercus (1962), Constantinof (1972), Vlad (1974), Gheorghiţă (1975), Constantinescu (1980), Cioflică et al. (1980). Banatitele din zona Ocna de Fier au fost cartate şi descrise petrografic în mare amănunţime de către Codarcea (1931), astfel încît imaginea cartografică realizată atunci rămîne valabilă şi în prezent.

Prin studiul de faţă am realizat completarea la sud de valea Bîrzavei, în regiunea Ocna de Fier-Dognecea, a cercetărilor noastre între-

prinse asupra masivului compus Bocșa (Russo-Săndulescu et al., 1978). A reieșit astfel că în zona sudică aflorează un corp principal granodioritic, care străbate și enclavează roci consanguine mai bazice. Studiul acestora, din corpuri izolate sau enclave, a permis detalierea imaginii evoluției magmatismului banatitic din regiunea Bocșa-Dognecea.

Un prim stadiu este caracterizat printr-o diferențiere cu tendință potasică realizată pe parcursul a două etape de intruziune, Bocșa 1 și Bocșa 2. Determinări de vîrste radiometrice K/Ar obținute pe rocile din aceste faze de intruziune au arătat valori între 87-80 m.a. (Russo-Săndulescu et al., 1984).

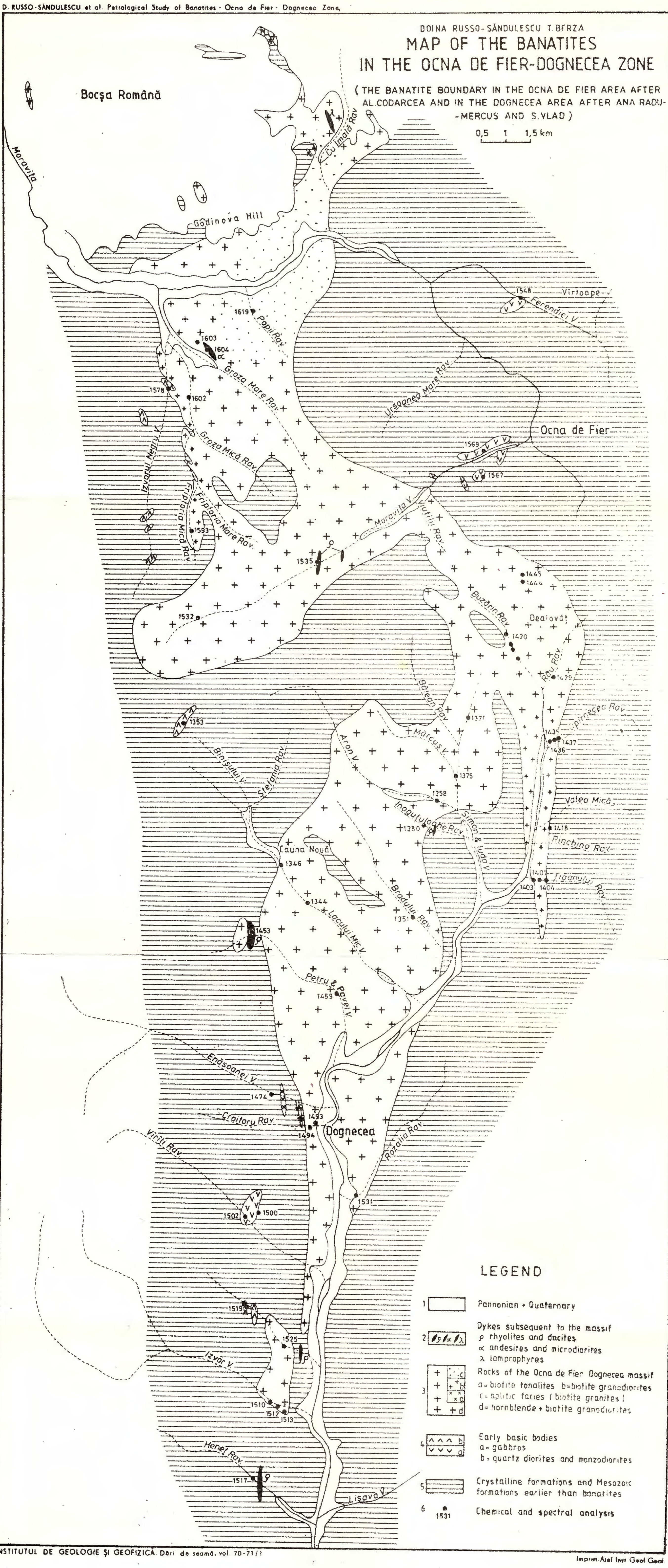
Cu poziția spațială diferită (pe o direcție N-S, spre deosebire de orientarea NE-SW a intruziunilor B_1 și B_2) și vîrste diferite (65-56 m.a. Russo-Săndulescu et al., 1986), produsele stadiului următor, calcoalcalin, sînt reprezentate printr-o fază de dyke-uri bazice (Bocșa$_{3.1}$) și marea intruziune granodioritică (Bocșa$_{3.2}$). La nord de Bîrzava aceasta din urmă ia contact în lungul unei linii tectonice cu unitatea B_2, pentru ca spre sud să se insinueze între șisturile cristaline pînă la Dognecea.

Caracterele petrografice și geochimice ale rocilor bazice din dyke-uri și enclave au arătat, pe de o parte, diferențe notabile în raport cu produsele bazice ale stadiului cu tendință potasică (B_1 și B_2) și, pe de altă parte, asemănări cu granodioritele $B_{3.2}$ (prezența aproape în exclusivitate între mafice a hornblendei și biotitului, plagioclazii, zonați recurent, iar chimic conținuturi scăzute în K, Fe, Ti, V, Sc). Atribuim această consanguinitate diferențierii unor magme intermediare generate în urma subducției (vezi modelul Rădulescu și Săndulescu, 1973). Astfel, într-un rezervor magmatic situat undeva între locul de generare al magmei și locul actual de amplasare, prin cristalizare fracționată și acumulare gravitațională s-a putut realiza o oarecare diferențiere a magmei dioritice inițiale ; mai întîi au fost expulzate diferențiatele bazice (care au dat dyke-urile gabbroice, monzodioritice și dioritice precursoare —$B_{3.1}$) iar apoi a urmat punerea în loc a granodioritelor $B_{3.2}$ și, mai tîrziu, a diferențiatelor filoniene-riolite și dacite.

Caracterele geochimice ale rocilor provenite din intruziunile dintre Valea Carașului și Dunăre (partea sudică a „zonei banatitelor plutonice") au arătat că acestea aparțin stadiului calcoalcalin. Intruziunea principală de la Ciclova ca și corpul gabbroic de la Oravița (Lacul Mare) se corelează foarte bine cu produsele fazei $B_{3.1}$.

Rocile intruziunilor Maidan, cel mai vestic corp de la Ciclova (diorite porfirice după Cioflică et al., 1980), Ilidia, Sasca, Cărbunari și Moldova Nouă prezintă o mare asemănare geochimică cu granodioritele fazei $B_{3.2}$, deși o parte dintre ele fuseseră anterior considerate mai bazice.

În sfîrșit, în zona de la vest de sinclinoriul Reșița-Moldova Nouă cele două stadii plutonice (cu tendință potasică și calcoalcalin) sînt urmate de un stadiu final în care apar dyke-uri cu chimism și structuri variate — andezite, dacite, riolite precum și diferite lamprofire — a căror afiliere la produsele banatitice anterioare este o problemă care rămîne deschisă.



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

Project 195: Ophiolites and Lithosphere of Marginal Seas

IUGS UNESCO

STRUCTURE, PETROLOGY AND GEOCHEMISTRY OF THE ALMAŞ-SĂLIŞTE ULTRAMAFIC BODY (MUREŞ ZONE)[1]

BY

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Ultramafics. Layered intrusion. Peridotite. Gabbro. Magmas differentiation. Chemical composition. Trace elements. Basaltic complex. Ophiolites. Ocean-floor basalts. Jurassic. Pre-Oxfordian. Apuseni Mountains — South Apuseni Mountains — Metaliferi Mountains.

Abstract

The Almaş-Sălişte ultramafic body represents a layered intrusion, mostly eroded. Within its structure three horizons can be distinguished: a lower peridotitic horizon, an upper gabbrodoleritic horizon and a transition horizon, chiefly made up of melagabbros. This body is the result of the differentiation *in situ* of a melagabbroic or gabbroperidotitic magma intrusion, formed in the mantle up to 100 km deep, independent of the tholeiitic basaltic magma. The peridotites of the lower horizon correspond to the ultramafic cumulates of the layered intrusions. The crystallization of the intrusive body took place in the ocean-floor basaltic complex (O_1) of the Jurassic-Pre-Oxfordian ophiolitic series in the Mureş Zone, at a depth of 3-4 km.

Résumé

Structure, pétrologie et géochimie du corps de roches ultrabasiques de Almaş-Sălişte (zone de Mureş). Le corps de roches ultrabasiques de Almaş-Sălişte est un corps stratifié dont la structure comporte un horizon péridotitique inférieur, un horizon gabbro-doléritique supérieur et un horizon de transition constitué de mélagabbros érodés en grande partie. Il est le résultat de la différenciation *in situ* d'une intrusion de magma mélagabbroïque ou gabbro-péridotitique formé à une profondeur de presque 100 km indépendamment du magma basal-

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tique-tholéiitique. Pendant la cristallisation du magma de l'horizon inférieur-péridotitique se développe la suivante série de réactions caractéristiques : olivine-clinopyroxène-hornblende-biotite. Les péridotites de l'horizon inférieur correspondent aux cumulats ultrabasiques des intrusions stratifiées. La cristallisation du corps intrusif a eu lieu dans le complexe basaltique de fond océanique O_1 de la série ophiolitique d'âge jurassique-préoxfordien de la zone de Mureș à 3-4 km de profondeur.

Introduction

The ultramafic rocks usually constitute most of the ophiolitic rocks within which they form, together with gabbros or without them, an important complex situated in their base. This peridotitic complex (O_4) does not crop out in the spreading area of the ophiolitic series of the Mureș Zone. Small bodies of such rocks occur in the axial zone of the Mureș Plate oceanic crust, which represents the median part of this zone (Savu, 1983). One of these bodies is that of Almaș-Săliște, which will be described in the present paper.

The ultramafic body, reported by Savu in 1953 and studied in detail in 1979 (unpublished report), is situated in the lower basin of the Strîmbu Valley, at the confluence with the Șovaru Brook (Pl.). It lies in the Pietriș-Almaș-Săliște-Băgara-Visca-Luncoi anticlinal zone, north of the Cerbia acid intrusive body, which crosses the Jurassic-Pre-Oxfordian ocean-floor basaltic complex (O_1) of the ophiolitic series of the Mureș Zone, including the ultramafic body (Savu et al., 1984). In this area, the basaltic complex consists of basalts, hyalobasalts, variolites and anamesites, locally in association with pyroclastic rocks. A sill made up of quartz dolerites occurs among these submarine lava flows (Savu et al., 1970). These rocks represent a tholeiitic magmatic series.

In the northern part of the region the ocean-floor basaltic complex is unconformably overlain by island-arc basalt-andesite and andesites pyroclastics, Upper Jurassic in age (Savu et al., 1984), which host a small olistolith of Jurassic limestone.

Structure of the Ultramafic Body

The NE-SW trending ultramafic body is 800 m long and about 220 m wide (Pl.). It chiefly consists of peridotites (olivine-clinopyroxene-brown or colourless hornblende-biotite-peridotites), mostly serpentinized (kämmererite-bearing serpentinites) ; fresh peridotitic rocks occur only in the lower part. Small amounts of plagioclase (An_{53}) peridotites are locally found in the lower horizon. The upper part of the body, intruded by a felsitic porphyry vein, was affected by the hydrothermal solutions of the latter, the ultramafic rocks being listvenitized. Gabbrodolerites are found in the southeasternmost part of the body

There are different opinions on the classification of ultramafic rocks (Streckeisen, 1967 ; Johannsen, 1938 ; Hatch et al., 1961). Nakamura (1971) classified the peridotitic rocks in peridotites with less that 10% plagioclase and plagioclase-bearing peridotites, when plagioclase exceeds 10% of the rock volume.

In our opinion, there are two groups of ultramafic rocks, according to their origin : 1, dunites and orthopyroxene- or clinopyroxene-bearing peridotites of Alpine type, that usually form the fourth complex (O_4) of the ophiolitic series, resulting from the crystallization of the ultramafic magma, rich in magnesium (peridotitic magma — MgO=31-41%) ; 2, ultramafic rocks (peridotites) such as hornblende-augite olivinites (Johannsen, 1938), without plagioclase or with little plagioclase (e.g. picrites according to Hatch et al., 1961) resulting from the differentiation of a melagabbroic magma (MgO=25-31%, Savu, 1962) or a picritic magma (Wager and Brown, 1968), from which olivine gabbros separated by differentiation in the upper part and ultramafic rocks consisting of olivine-clinopyroxene-hornblende-biotite-peridotites in the lower part, like at Lugar and in the Mureş Zone. The latter should be regarded as secondary peridotites formed through differentiation. They pass to rocks in which plagioclase occurs as well besides the four mentioned minerals, like in picrites (Hatch et al., 1961) or troctolites, which make the transition towards the upper horizon represented by olivine gabbros.

The rocks of the intermediary horizon have been included in the group of melagabbros (Savu, 1962). The intermediary and upper horizons of this body are mostly eroded. The Almaş-Sălişte ultramafic rocks belong to the second group of ultramafic rocks.

Considering all this, the rocks of the Almaş-Sălişte ultramafic body can be assigned to peridotites (plag.=0), plagioclase peridotites (plag.=0-10%), melagabbros (plag.=10-30%) and clinopyroxene and/or olivine gabbrodolerites (plag.=45-55%).

Geochemistry and Origin of Ultramafic Rocks

Nine samples have been analysed for the geochemical study of the ultramafic body (Tab. 1, 2 and 3). The principal oxides of these rocks vary as follows : SiO_2=38.51-40.25% ; Al_2O_3=4.40-7.50% ; Fe_2O_3=4.17-7.00% ; FeO=4.05-5.91% ; MnO=0.14-0.22% ; MgO=26.36-30.60% ; CaO=3.40-5.68% ; Na_2O=0.35-0.80% ; TiO_2=0.34-0.52% ; P_2O_5=0.05-0.14%. After their chemical composition these rocks correspond to peridotites of Lugar type or to augite-hornblende olivinites (Johannsen, 1938) ; as regards the magma type they belong to a peridotitic magma (Tab. 2).

The trace elements distribution (Tab. 3) also points out the ultramafic character of the rocks. The contents of Ni (1100 to 1500 ppm) are a bit lower than the average value (1500 to 2000 ppm) established by Turekian and Wedepohl (1961) for this type of rocks. The contents of chrome and vanadium are higher than their averages calculated by the same authors. The Cr/Ni ratio varies from 2 to 3.5.

The differentiation of the primary tholeiitic magma (the gabbroic magma or that of ocean-floor basalts of the ophiolitic series) develops into two directions, resulting in : 1, iron concentration with formation

TABLE 1

Chemical composition of ultramafic rocks

No.	1	2	3	4	5	6	7	8	9
Sample no.	100	21/1	99	104	22/2	106	21A	108	102
Rock	Peridotite	Peridotite	Peridotite	Peridotite	Peridotite	Peridotite	Peridotite	Peridotite	Peridotite
Location	Şovaru B.	Strîmbu B.	Şovaru B.	Şovaru B.	Strîmbu B.	Şovaru B.	Strîmbu B.	Şovaru B.	Şovaru B.
SiO_2	38.51	39.32	39.38	39.40	39.55	39.74	39.95	40.18	40.25
Al_2O_3	5.14	5.09	5.37	5.19	6.00	6.90	5.57	7.50	4.40
Fe_2O_3	5.41	6.15	6.81	5.10	5.53	4.23	6.48	4.17	7.00
FeO	5.11	4.21	4.09	4.92	5.64	5.91	4.87	5.87	4.05
MnO	0.14	0.14	0.14	0.17	0.15	0.18	0.16	0.22	0.14
MgO	29.87	30.19	29.02	30.31	29.13	26.85	28.58	26.36	30.60
CaO	3.81	3.77	4.05	3.81	3.40	5.68	3.47	5.11	3.36
Na_2O	0.50	0.55	0.70	0.36	0.60	0.62	0.75	0.80	0.35
K_2O	0	0	0	0	0	0	0	0	0
TiO_2	0.38	0.38	0.34	0.40	0.42	0.51	0.45	0.52	0.40
P_2O_5	0.10	0.13	0.05	0.14	0.07	0.12	0.09	0.14	0.11
CO_2	—	0.48	—	—	0.20	—	—	—	—
S	0.092	0.098	0.071	0.074	0.061	0.100	0.048	0.110	0.099
Fe(S)	0.08	0.08	0.06	0.06	0.05	0.09	0.04	0.09	0.08
H_2O^+	9.39	9.10	8.48	10.07	9.40	8.40	8.96	8.34	9.30
Cr_2O_3	0.73	0.48	0.67	0.58	0.52	0.41	0.55	0.40	0.42
NiO	0.18	0.17	0.18	0.17	0.16	0.15	0.15	0.14	0.19
Total	99.44	100.06	99.42	100.75	100.88	99.89	100.11	99.43	100.74

of ferrogabbros and ferrobasalts, and 2, concentration of SiO_2, Na_2O and volatiles with formation of spilites, granophyres and albite plagiogranites (Savu et al., 1985). As the ultramafic rocks of the two above-mentioned groups (peridotitic and melagabbroic) do not appear in this process, one can deduce that they came from magmas with different origins, as Hess (1938) established for the peridotitic magma. Consequently we should admit that the magma which rise to the ultramafic bodies in the basaltic complex of the Mureş Zone was a melagabbroic (Savu, 1962), gabbroperidotitic or picritic magma (Wager, Brown, 1968), formed as a result of the differential melting of the mantle at a depth of 100 km, under the Mureş Ocean spreading zone.

TABLE 2

Niggli parameters

No	1	2	3	4	5	6	7	8	9
Sample no.	100	21/1	99	104	22/2	106	21A	108	102
Si	63.09	64.58	65.10	64.55	65.32	67.10	66.83	68.61	72.83
al	5.43	5.20	5.66	5.39	6.23	7.15	5.87	7.84	4.97
fm	87.07	87.40	86.01	87.49	86.69	81.48	86.68	81.48	87.89
c	6.71	6.60	7.15	6.71	6.09	10.34	6.25	9.35	6.54
alk	0.79	0.80	1.08	0.41	0.99	1.03	1.20	1.33	0.60
k	0	0	0	0	0	0	0	0	0
mg	0.84	0.84	0.83	0.81	0.83	0.82	0.82	0.82	0.94
c/fm	0.08	0.07	0.08	0.07	0.07	0.12	0.07	0.11	0.07
ti	0.47	0.47	0.43	0.49	0.51	0.62	0.55	0.66	0.54
p	0.10	0.12	0.05	0.13	0.14	0.12	0.09	0.14	0.11
w	0.49	0.57	0.60	0.48	0.47	0.39	0.54	0.39	0.60
Qz	—40.07	—38.62	—39.22	—37.09	—38.64	—37.02	—37.97	—36.71	—29.57
Q	9.87	10.60	10.84	11.20	11.18	12.73	11.70	13.40	14.90
L	10.97	10.20	11.72	10.10	12.49	13.93	12.13	15.29	9.30
M	79.16	79.20	77.54	78.70	76.33	73.34	76.17	71.40	75.80
Magma type	perido-titic	perido-titic	perido-titic	perido-titic	perido-titic	perido-titic	perido-titic	perido-titic	perido-titic

The melagabbroic character of the magma results clearly from the fact that the rocks generated by it plot, on the diagram in Figure 1, in the upper part of the field of the Papua and Oman ultramafic rocks

TABLE 3

Trace elements (ppm) in ultramafic rocks

No.	Sample no.	Ni	Cr	Co	V	Sc	Cu
1	100	1450	5000	140	180	18	15
2	21/1	1300	3700	145	170	21	23
3	99	1400	4500	140	165	18	11
4	104	1350	4000	120	160	15	16
5	22/2	1250	3550	120	190	19	23
6	106	1200	2800	120	195	22	27
7	21A	1350	3300	120	160	16	8
8	108	1100	2750	120	210	24	75
9	102	1500	2900	126	160	16	50

mentioned by Malpas and Stevens (1977). Therefore, they are intermediary ultramafic rocks between primary peridotites of Alpine type and gabbroic rocks, as indicated on the diagram in Figure 2 drawn

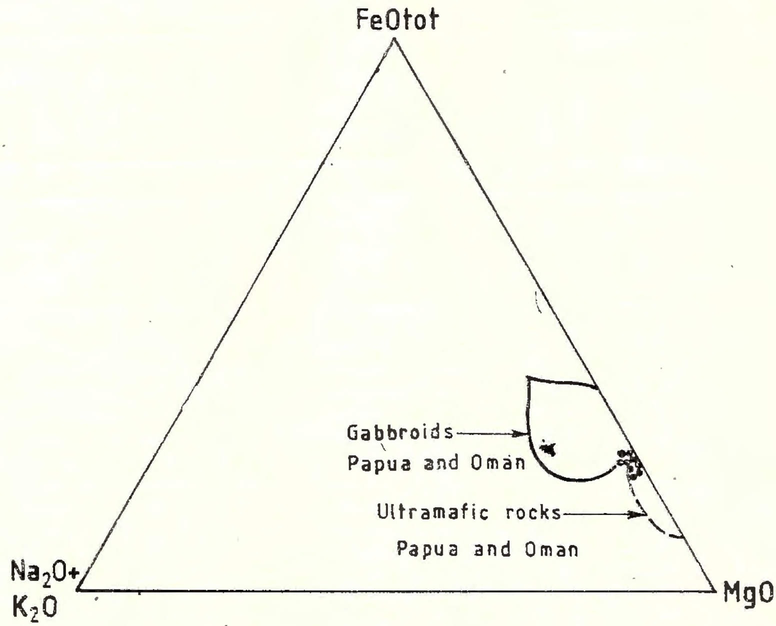

Fig. 1. — FeO tot — MgO — Na_2O + K_2O diagram (after Malpas and Stevens, 1977).

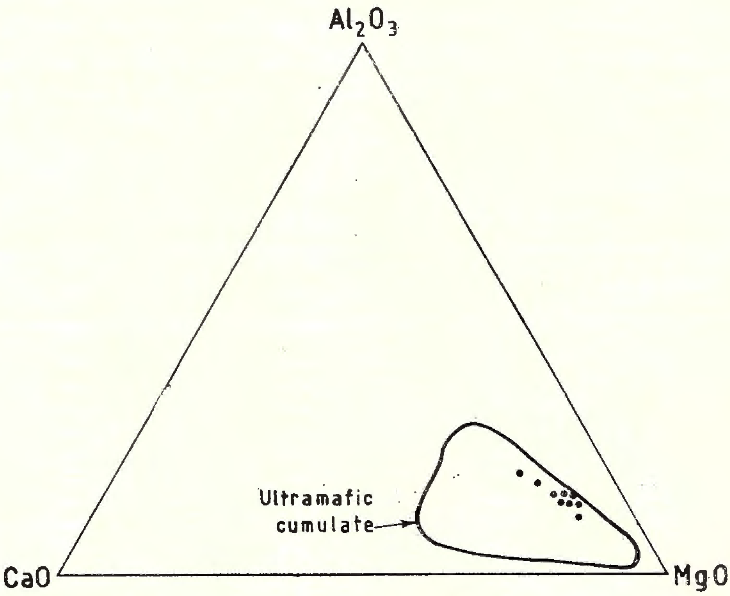

Fig. 2. — Al_2O_3 — MgO — CaO diagram (after Coleman, 1977).

up after Coleman (1977). On this diagram the rocks plot in the upper part of the field of ultramafic ophiolites with cumulate character.

The melagabbroic magma formed in the mantle migrated towards surface near the spreading zone and intruded the basaltic complex on the Mureş Ocean floor, where it differentiated *in situ*, generating a small stratified body. This body has a peridotite horizon in the base, an olivine and/or diopside gabbro horizon in the upper part and a melagabbro horizon between the two mentioned ones.

The fractional crystallization, which have taken place within the intrusion of the melagabbroic magma leading to its stratification, must have had the following evolution. The melagabbroic magma with a reduced viscosity differentiated *in situ* at shallow depth (probably 3-4 km considering the thickness of the basaltic complex) under the influence of gravity, decreasing temperature and an intermediate PH_2O pressure. The first minerals formed are magnetite, chrome spinel and olivine, sinking towards the bottom of the intrusion. They are followed by the crystallization of plagioclase which floats towards the top of the intrusion. Thus, inside the intrusive body three horizons of magma with crystals formed, which differ from the chemical point of view from both one another and from the primary melagabbroic magma from which they differentiated. Crystallization continues in the three horizons of magma with crystals and the chemical composition changes gradually so that for each horizon several typical minerals are formed (Savu, 1962).

Therefore, an homogeneous melagabbroic magma gives rise to a solid ultramafic body within which three horizons of specific rocks can be distinguished : peridotitic, melagabbroic and gabbroic. The gabbroic horizon has a very small thickness, most of the ultramafic body consisting of peridotites, plagioclase peridotites and melagabbros, as in case of the Lugar sill and the Toba complex (Nakamura, 1971).

The process of formation of the peridotites from the mentioned bodies is shown on the diagram in Figure 3, drawn up after Malpas

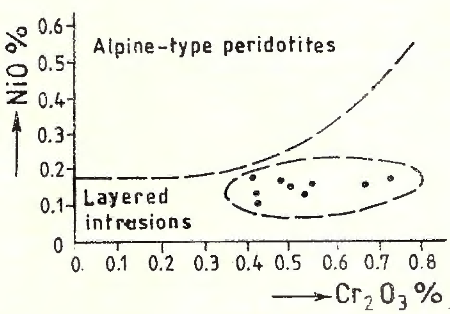

Fig. 3. — NiO — Cr_2O_3 diagram (after Malpas and Stevens, 1977).

and Stevens (1977). On this diagram the rocks forming the Almaş-Sălişte ultramafic body plot in the field of the rocks from the layered intrusions.

Postmagmatic residual solutions activity determined the serpentinization of rocks in the lower horizons and the autometamorphism of the gabbros in the upper horizon. These alterations are the result of the ocean-floor metamorphism.

As shown on the geological section (Plate), there are only 400 m from the level hosting the ultramafic body — within the ocean-floor basaltic complex — up to the stratigraphic unconformity between the latter and the Upper Jurassic island arc volcanic rocks. It indicates that a large part of the basaltic complex was eroded before the deposition of the island arc volcanic rocks and then the upper part of the ultramafic body was eroded by the Strîmbu and Șovaru valleys. The erosion took place under conditions of submergence and it was very intensive in this zone of anticlinal-submarine rise at the beginning of the closing process of the Mureș Ocean, when subduction began, that is during the Late Kimmerian movements.

Conclusions

The Almaș-Săliște ultramafic body represents a layered intrusion. Within its structure three horizons can be distinguished : a lower peridotitic horizon, an upper gabbrodoleritic horizon and a transition horizon, the last two horizons being mostly eroded.

This body is the result of the differentiation *in situ* of a melagabbroic or gabbroperidotitic magma intrusion, which was formed in the mantle up to 100 km deep, independent of the tholeiitic basaltic magma.

During the crystallization of the magma from the lower (peridotitic) horizon, the following series of characteristic reactions occurs : olivine-clinopyroxene-hornblende-biotite (phlogopite).

In petrographic respect peridotites of the lower horizon correspond to the ultramafic cumulates from the layered intrusions.

Crystallization of the ultramafic body took place in the ocean-floor basaltic complex (O_1) of the ophiolitic series in the Mureș Zone, at a depth of 3-4 km.

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STRUCTURA, PETROLOGIA ŞI GEOCHIMIA CORPULUI DE ROCI ULTRABAZICE DE LA ALMAŞ-SĂLIŞTE (ZONA MUREŞ)

(Rezumat)

Corpul de roci ultrabazice de la Almaş-Sălişte se găseşte în zona de ridicare anticlinală Pietriş — Almaş-Sălişte — Băgara — Visca — Luncoi, fiind situat în complexul bazaltic de fund oceanic al seriei ofiolitice din zona Mureş, de vîrstă jurasică-preoxfordiană. Acest complex constă din bazalte, hialobazalte, variolite, anamesite, rar piroclastite, precum şi din dolerite şi dolerite cuarţifere. El este acoperit de vulcanite de arc insular (J_3) la nord, iar la sud este străbătut de corpul intrusiv de la Cerbia.

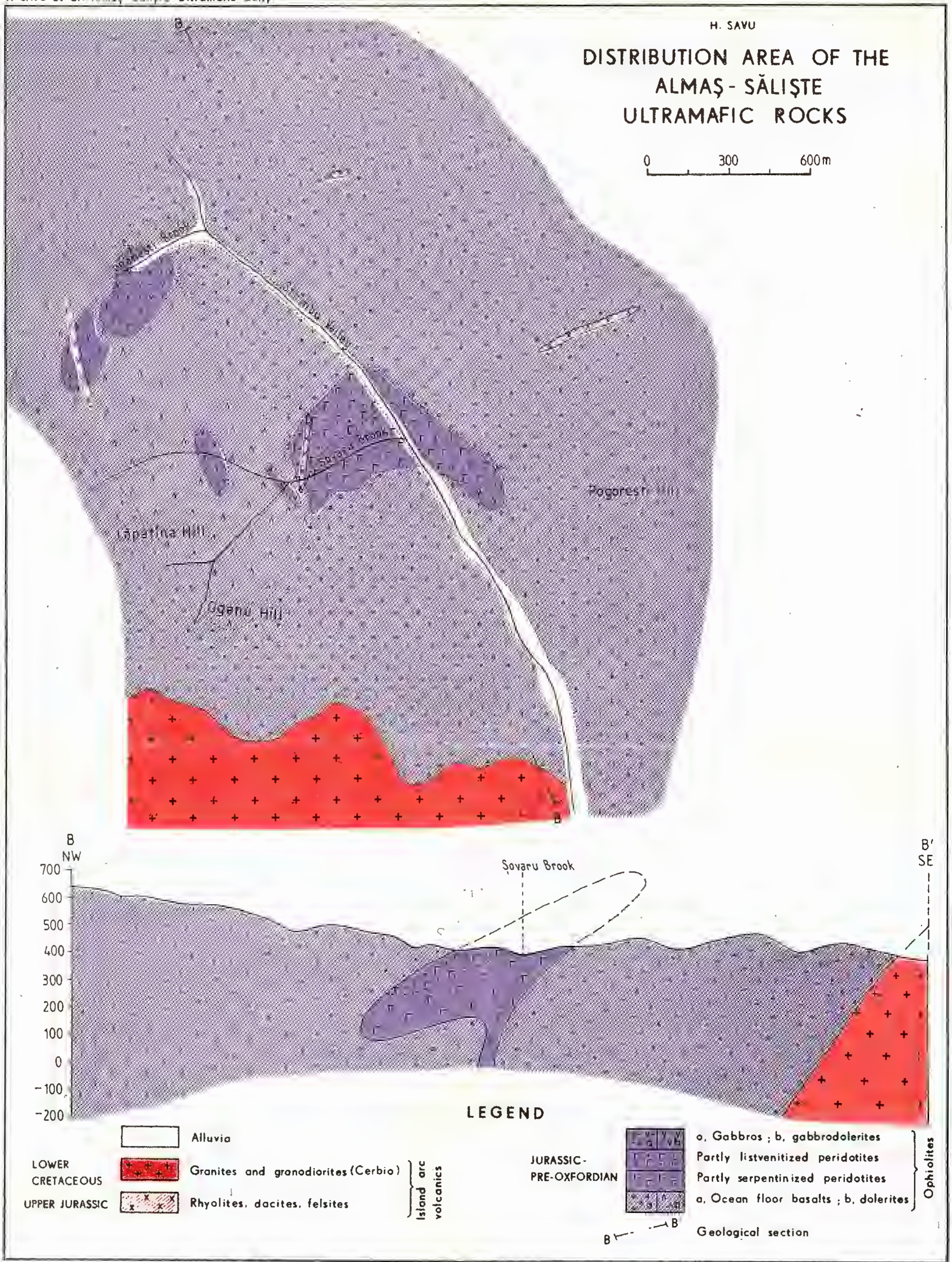
Corpul ultrabazic are o lungime de 800 m şi grosimea de aproximativ 220 m (pl.). El este un corp stratificat şi constă dintr-un orizont de peridotite situat în partea inferioară, peste care stau peridotite cu plagioclaz şi melagabbrouri ce fac parte dintr-un orizont interme-

diar, în prezent erodat în cea mai mare parte. Aceste roci sînt parțial serpentinizate și listvenitizate. Ceea ce se mai păstrează dintr-un al treilea orizont, cel superior, ar fi doar gabbro-doleritele din extremitatea de sud-est a corpului.

Se arată că în natură există două serii de roci ultrabazice, rezultate din două tipuri de magmă formate în manta independent : magma peridotitică (MgO = 31-41%) și magma melagabbroică, gabbroperidotitică sau picritică (MgO = 25-31%) .Autorii consideră că rocile ultrabazice și bazice din corpul de la Almaș-Săliște au rezultat din diferențierea *in situ* a unei magme melagabbroice. Aceste roci sînt repartizate la următoarele petrotipuri : peridotite (plagioclaz = 0%), peridotite cu plagioclaz (plag. = 0-10%), melagabbrouri (plag. = 10-30%) și gabbrodolerite cu clinopiroxen sau olivină (plag. = 45-55%).

Compoziția chimică (tab. 1) arată că peridotitele de la Almaș-Săliște se aseamănă cu olivinitele cu augit și hornblendă sau cu peridotitele de tip Lugar, avînd SiO_2 = 38,51-40,25% și MgO = 26,36-30,60%. După valoarea parametrilor magmatici (tab. 2) aceste roci corespund la o magmă peridotitică. Conținuturile de elemente minore (tab. 3) indică de asemenea roci ultrabazice, care se caracterizează prin raportul Cr/Ni = 2-3,5.

Deoarece în condițiile diferențierii magmei bazaltice-tholeiitice, care conduce la formarea ferrogabbrourilor și a ferrobazaltelor într-un sens și a plagiogranitelor cu albit în alt sens, rocile ultrabazice nu se regăsesc, rezultă că ele au provenit dintr-o magmă melagabbroică, formată independent prin topirea parțială a mantalei. Faptul că rocile de la Almaș-Săliște au provenit dintr-o astfel de magmă, rezultă din modul cum se proiectează ele la marginea cîmpului de proiecție a rocilor ultrabazice, către cîmpul gabbrourilor (fig. 1 și 2). Această magmă s-a intrus în complexul bazaltic de fund oceanic și s-a diferențiat *in situ*, rezultînd cele trei orizonturi, care sînt caracteristice și pentru celelalte corpuri ultrabazice stratificate din zona Mureș (fig. 3). Formarea acestor orizonturi a depins de procesul de cristalizare fracționată și de gravitație, datorită cărora cristalele de olivină, magnetit și spinel cromifer s-au scufundat spre partea inferioară a intruziunilor, iar cele cu plagioclaz au flotat spre partea superioară a acestora.



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

BIMODAL VOLCANISM IN THE NORTHWESTERN ISLAND ARC OF THE MUREȘ ZONE [1]

BY

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Island arc volcanism. Bimodal volcanism. Ophiolites. Tectonic unit. Ocean floor. Basaltic complex. Calc-alkali magmas. Tholeiitic magma. Spilites. Apuseni Mountains — South Apuseni Mountains — Drocea Mountains.

Abstract

The Criș tectonic unit has occurred as a result of the folding of the geological formations within the northwestern trough of the Mureș Zone. Its basement is an ophiolitic one and consists of rocks belonging to the Pre-Oxfordian ocean-floor basaltic complex (O_1). The volcanism, which developed concomitantly with the sedimentation of the Upper Jurassic flysch formations in the mentioned trough, is a bimodal island arc volcanism. It gave rise to a subalkaline volcanic series, within which two rock groups can be distinguished: melanocrate and leucocrate rocks. The bimodal volcanism in the northwestern island arc of the Mureș Zone differs from the volcanism in the southeastern island arc, which is tipically calc-alkaline. It shows that the tectonic assymetry of the Mureș Zone is mirrored in the volcanism, as well. There is a clear differentiation as regards the content of Na_2O between the ophiolitic spilites coming from the differentiation of the tholeiitic magma and the spilitized (albitized) basalts of the intra-oceanic island arc volcanism. Owing to the geochemical features the spilitic rocks of both magmatic series often have a different behaviour as compared to that of the basic rocks of the mentioned series, especially when Na_2O is taken into account in the variation diagrams.

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Résumé

Volcanisme à caractère bimodal de l'arc insulaire nord-ouest de la zone de Mureş. L'unité tectonique de Criş est formée à la suite du plissement des formations géologiques de la fosse nord-ouest de la zone de Mureş. Son soubassement est ophiolitique, étant constitué de roches du complexe basaltique de fond océanique préoxfordien (O_1) de la zone. Le volcanisme, qui se développe dans cette fosse, simultanément à la sédimentation des formations de flysch jurassiques supérieures, est un volcanisme d'arc insulaire à caractère bimodal. Il a généré une série volcanique subalcaline comprenant deux groupes de roches : mélanocrates et leucocrates. Par ces caractères pétrologiques le volcanisme d'arc insulaire nord-ouest se différencie de celui d'arc insulaire sud-est de la zone de Mureş, qui est typiquement calco-alcalin, fait qui dénote que l'asymétrie tectonique de la zone de Mureş se traduit aussi dans les aspects du volcanisme. Il y a entre les spilites ophiolitiques résultées de la séparation du magma tholéiitique et les basaltes spilitisés (albitisés) du volcanisme d'arc insulaire submarin une nette différence concernant la teneur en Na_2O. Dues aux caractéristiques géochimiques, les roches des deux séries magmatiques n'ont pas le plus souvent la façon de comportement des roches basiques de ces séries, surtout quand on prend en considération la teneur en Na_2O dans les diagrammes de variation.

Introduction

The island arc in the northwestern trough of the Mureş Zone lies between Şiştarovăţ and Şoimuş Buceava on a distance of 50 km (Pl. I). This trough is filled with Upper Jurassic-Lower Cretaceous flysch, the alignment of the island arc being marked from place to place by volcanic structures (Savu, 1983) which crop out from the sediments.

Volcanic rocks were reported from several places. In 1912 Loczy pointed out cinerites related to blocks of Portlandian limestones in Lower Cretaceous deposits. Papiu (1953) mentioned basic and acid volcanic rocks in the Sinaia Beds in the Saturani Valley, the latter being assigned to banatites. Savu (1962 a, b) described similar rocks in the J_3-Cr_1 flysch at Pîrneşti and Troaş attributing them to a Late Kimmerian calc-alkaline and alkaline volcanism, different from the older ophiolitic one. Savu (1957, 1958 and 1982, unpub. report) studied the volcanic rocks in the Saturău-Şoimuş Buceava (Savu et al., 1970, Pl. I), Lupeşti and Taleşinţ region. Lately, Savu et al. (1982) have described the volcanic rocks at Pătîrş. Although volcanic rocks were studied in different places of the island arc no synthesis paper on them has been elaborated. We hope that the present paper will fill up this goal. As the volcanic rocks in the flysch have sometimes been assimilated with the ophiolites of the basement, we shall briefly present these rocks for comparison.

Evolution of Sedimentary and Volcanic Processes

In order to understand the evolution of the Drocea Trough, within which the bimodal volcanism develops, the succession of sedimentary deposits will be described from the beginning of its formation (Callovian[4]-Oxfordian) up to its folding due to Austrian and Laramian movements, which gave rise to several tectonic units (Papiu, 1953; Lupu, 1975). For our study the Criş Unit is of importance, whose flysch deposits include the volcanic rocks.

Ophiolitic rocks in the basement are represented by basic (basalts, amygdaloidal basalts, variolites and spilites) lava flows (Pl. II, Fig. 2), sometimes sills of dolerites and quartz dolerites. These rocks, usually found in pillow lava facies, belong to the ocean-floor basaltic complex (O_l) of the Mureş Zone (Savu, 1983). They crop out within the lower part of the flysch deposits on the Vladin Brook, Pănuşeasca, Orbilor, Bucevița and Muşii valleys along the faulted anticline lying between Saturani and Baia valleys.

The sedimentation of the Upper Jurassic-Lower Cretaceous flysch (Papiu, 1953; Savu, 1958; Lupu, 1975) begins over the ophiolitic basement. It comprises two rock complexes: a lower complex and an upper complex. a) The reddish, volcano-sedimentary lower complex belongs to the Upper Jurassic and consists of jaspers (radiolarites) and red ar-

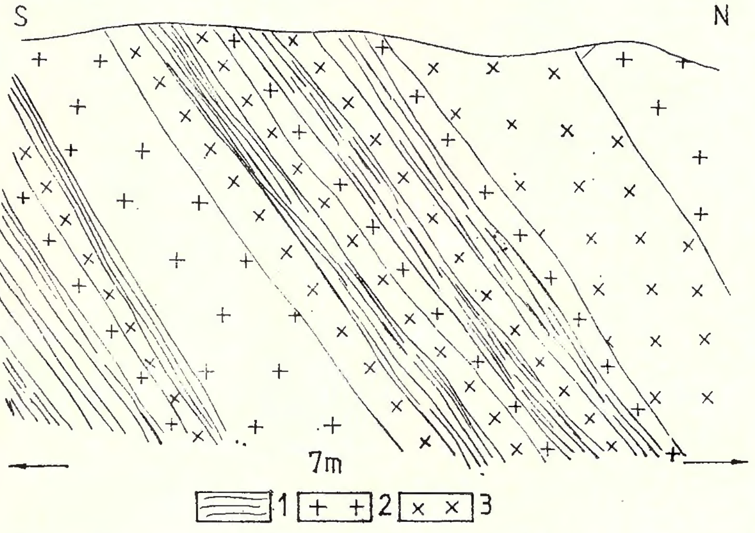

Fig. 1. — Succession of jaspers (1), rhyolitic tuffs (2) and orthophyres (3) in the Saturani Valley (Şoimuş-Buceava).

gillites (Figs. 1 and 2), interbedded with limestones with tuffaceous elements (Pl. II, Fig. 1), island arc volcanic rocks and bands of manganese oxides. b) The upper complex (Lower Cretaceous) is formed of marly deposits alternating with limestones folded during the Austrian orogenesis, like the rocks of the lower horizon.

The island arc volcanic rocks developed concomitantly with the sedimentation of the flysch lower complex. Only locally they occur in the upper complex too. It is a pre-orogen submarine volcanism and due to its particularities it has a character of bimodal volcanism (Rittmann, 1967). This volcanism develops along an arc of volcanic islands

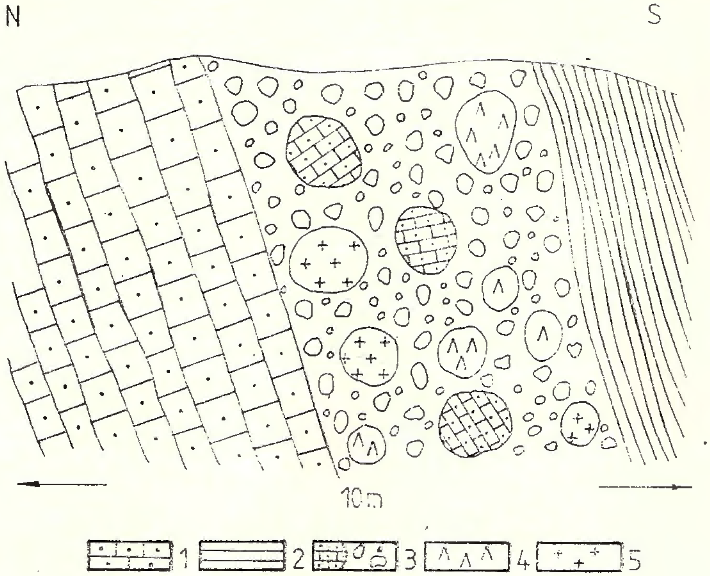

Fig. 2. — Succession of limestones bearing tuffogenous elements (1), jaspers (2), polygenous agglomerates or volcanic melange (3), bearing blocks of basic rocks (4) and acid rocks (5) in the Tisa Valley (Troaş).

(Savu, 1983), situated somewhere along the Drocea Trough (Pl. I). It generates volcanic structures of central type, burried in the flysch deposits, which mark the above-mentioned alignment by the volcanoes from Zeldiş Valley, Piatra Albă Summit, Troaş, Pîrneşti, Lupeşti (Savu, 1962 a ; 1962 b), Laleşinţ and Pătîrş (Savu et al., 1982). In the block lying between Baia and Laleşinţ, sunk due to important faults the island arc alignment is overlain by the overlapping of diabases (Papiu, 1953) or ophiolites (Savu, 1957), called the Techereu-Căpîlnaş Nappe (Lupu, 1975).

In all the mentioned regions the products of this volcanism are represented by pyroclastic rocks, and seldom by lava flows. In the zone of volcanic apparata there is a succession of basic, acid and alkaline eruptions which constitute stratovolcanoes burried in deposits of the flysch lower complex, whose products are laterally intercalated among them. Alternations of acid tuffs and radiolarites are locally found. Coral reefs fixed themselves on volcanic cones with intermittent activity during periods of calm. At the next eruption both the volcanic rocks and the reef limestones were thrown into the sea and sedimented around the volcanic apparata (Loczy, 1912) in the form of "polygenous agglomerates" (Savu, 1962), locally with more or less rounded elements (volcanic conglomerates) made up of igneous rocks with different compositions and reef limestones. This formation has characteristics of a "volcanic mélange". Stramberg limestones are found in the Tithonian-Neocomian flysch, also as olistoliths, e.g. Piatra Sfintei Marii on the Plotunu Brook (Pîrneşti).

The Upper Jurassic volcanism usually starts with basaltic rocks (Pl II, Fig. 3) representing the IAV_1 complex of the southeastern island arc — but it is not a rule for all volcanoes — which alternate with eruptions of alkaline and acid rocks ; the last products are the rhyolitic ones, equivalent of the IAV_2 complex of the same southeastern arc (Savu, 1983). The bimodal character of the volcanism results from the lack of andesitic rocks from the eruption series, so that their products can be attributed to two distinct rock groups : melanocrates and leucocrates. This particularity differentiates the sequence of volcanic rocks of this arc from that of the southeastern island arc, where there is the whole series (basalt-andesite-dacite-rhyolite) of the differentiation of a calc-alkaline basaltic magma. Another particularity is that the volcanic rocks of the southeastern island arc are more important as regards the volume — basalts and andesites predominate — whereas in the northwestern arc the volcanic rocks are less abundant, acid and alkaline rocks prevailing.

In the Mureş Zone the Tithonian-Neocomian volcanic activity represents a submarine island arc volcanism, coeval with the Alpine flysch, which presents several particularities in comparison with the island arc volcanism coeval with the Neogene molasse.

Geochemistry and Genesis of Ophiolitic Rocks

In ophiolitic rocks SiO_2 varies from 44.40 to 53.98%, Fe_2O_3 from 2.54 to 5.52% and FeO from 2.60 to 10.61%. The last two values resemble the variation of iron oxides in the rocks of the sheeted dyke complex (O_2), which shows that the rocks of this complex have equivalents in the ocean-floor basaltic complex (O_1) of the ophiolitic series. Na_2O varies from 2.32 to 5.15%, indicating that not all ophiolitic rocks are spilites provided that in spilitic rocks Na_2O ranges between 3.53 and more than 5% ; the content of K_2O is generally low demonstrating that these rocks are ocean-floor basalts according to Miyashiro (1975). The presence of spilites is shown on the diagram in Figure 3 (Irvine and Baragar, 1971) on which only basalts plot in the tholeiitic rock field. They gradually enriched in iron, according to the differentiation line of the tholeiitic series. The other tholeiitic rocks enriched in Na_2O due to the process of differentiation towards albite-granitic magmas which shift from the field of tholeiitic rocks to that of calc-alkaline rocks as in case of acid and spilitic differentiates of the sheeted dyke complex in the Drocea Mts and of ocean-floor basalts at Baia de Aramă. On the diagram in Figure 4 (Rittmann, 1967) the ophiolitic rocks

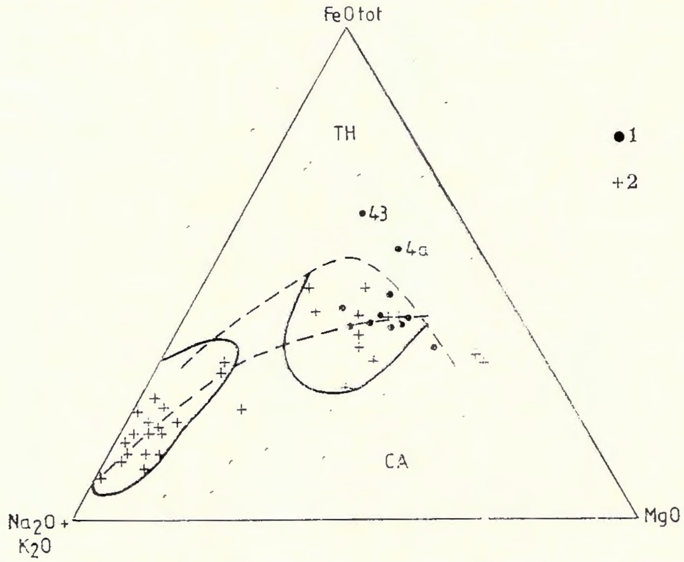

Fig. 3. — FeO tot — MgO — $Na_2O + K_2O$ diagram. 1, ophiolites ; 2, island arc volcanics (melanocrates).

mostly plot in the simatic field, which indicates their origin in the upper mantle.

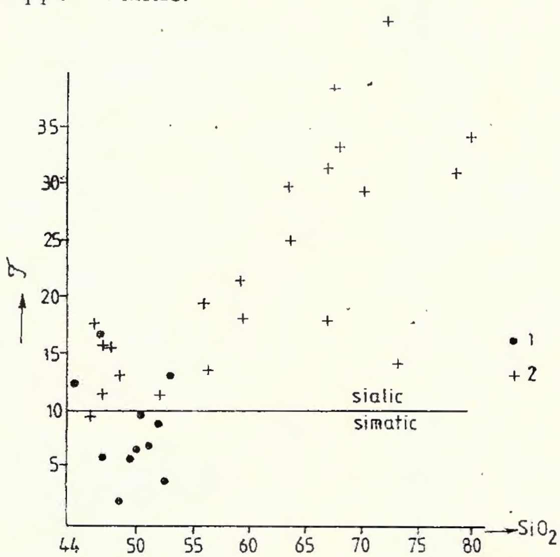

Fig. 4. — τ — SiO_2 diagram. 1, ophiolites ; 2, island arc volcanics (melanocrates).

The ophiolitic rocks are characterized by contents of minor elements (Tab. 1) similar to those of the ocean floor basic rocks in the

TABLE 1

Chemicalo composition of ophiolitic rocks

No	1	2	3	4	5	6	7	8	9	10	11
Sample no. Oxides (%)	67	30	42	43	4a	38	28	39	29	3	22
SiO_2	44.30	46.87	46.97	48.34	49.10	49.86	50.20	51.06	51.80	52.20	52.98
Al_2O_3	15.39	14.95	19.85	12.53	13.89	15.26	14.00	14.88	15.09	11.59	15.82
Fe_2O_3	4.17	2.69	2.54	5.52	3.27	3.14	2.87	4.19	2.07	4.80	4.27
FeO	3.35	4.07	2.60	10.61	8.69	4.79	4.62	3.30	5.63	6.01	3.05
MnO	0.16	0.15	0.16	0.22	0.21	0.13	0.14	0.12	0.14	0.11	0.10
MgO	6.92	5.14	6.57	5.05	6.55	6.52	7.31	4.34	7.28	8.36	5.97
CaO	14.19	11.19	11.80	5.86	9.95	9.25	10.76	9.74	7.53	5.58	6.96
Na_2O	2.67	4.31	2.32	3.83	2.83	4.19	3.60	5.15	4.45	4.63	4.30
K_2O	1.02	1.20	0.38	0.40	0.37	0.35	0.16	—	0.41	0.40	0.46
TiO_2	0.99	1.84	1.06	3.71	1.94	1.71	1.08	1.48	1.22	1.94	0.89
P_2O_5	0.10	0.23	0.24	0.35	0.16	0.21	0.20	0.22	0.24	0.28	0.17
CO_2	5.32	4.94	1.31	—	—	0.99	2.62	3.38	1.86	—	—
S	0.02	—	—	—	0.23	—	0.12	—	0.05	0.22	—
Fe(S)	0.02	—	—	—	0.20	—	0.10	—	0.04	0.19	—
H_2O^+	2.91	2.30	3.56	3.79	2.31	2.88	2.51	1.62	4.23	3.23	4.25
Total	100.53	99.87	99.35	100.21	99.70	99.29	100.28	99.48	99.86	99.54	99.22
Trace elements (ppm)											
Ni	150	82	120	31	77	30	170	90	125	310	80
Co	25	21	24	31	28	16	28	24	26	23	16
Cr	460	310	340	58	185	65	580	300	295	420	250
V	220	300	400	280	480	290	240	240	255	300	255
Sc	30	26	32	43	31	20	31	34	30	20	25
Zr	55	90	105	160	110	140	90	65	90	180	68
Nb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Y	21	25	25	58	37	50	23	23	23	48	17
Yb	2.4	2.7	2.5	6.5	3.8	5.5	2.8	2.4	2.3	5	1.6
La	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Ba	65	250	60	13	22	13	44	38	24	56	34
Sr	200	180	220	75	125	100	280	160	340	125	90
Pb	3.5	3.5	3	2.5	6	<2	21	2.5	3.5	< 2	6
Cu	26	36	32	3.5	8.5	36	48	28	34	3	28
Ga	11	15	15	24	18	16	15	12	16	14	11
Sn	<2	2	<2	3	< 2	2.5	< 2	< 2	2	< 2	< 2

1, basalt — Valea Pietroasă Brook; 2, spilite — Vladin Valley; 3, basalt — Valea Orbilor Brook; 4, spilite — Valea Orbilor Brook; 5, dolerite — Muşa Brook; 6, spilite — Valea Pănuşească Brook; 7. spilite — Vladin Valley; 8, spilite (variolite) — Valea Pănuşească Brook; 9, spilite — Vladin Valley; 10, basalt — Muşa Brook; 11, variolite — Saturani Valley.

Mureș Zone. Ni and Cr have contents varying within wide limits whereas the contents of Co, V and Sc vary within restricted limits. The contents of Zr, Y, Yb indicate tholeiitic basic rocks (Fig. 5) similar to those in the rest of the Mureș Zone. There are positive correlations between Zr, Y and Yb. La was not found in ophiolitic rocks, its limit

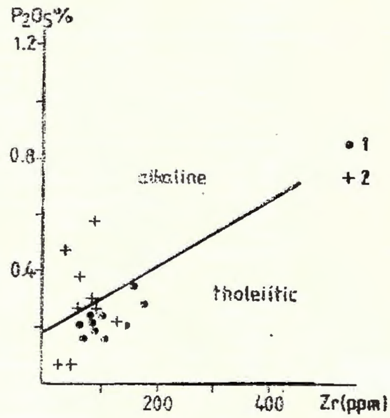

Fig. 5. — P_2O_5 — Zr diagram (Beccaluva et al., 1977). 1, ophiolites ; 2, island arc volcanics (melanocrates).

of detection being at 30 ppm. Except for sample 30 all the other ophiolites contain Ba (13-65 ppm), which situates them between abyssal tholeiitic basalts (Miyashiro, 1975). The low contents of Ba are in agreement with the small amounts of K_2O in rocks. Sr has values ranging from 75 to 340 ppm, their average being of 172 ppm. According to the diagram of Hart et al. (1970) this value indicates that the tholeiitic magma formed in the mantle at a depth of about 100-140 km.

The fact that these rocks represent ocean-floor tholeiitic rocks is shown clearly on the diagram in Figure 6 (Pearce, 1975), where they

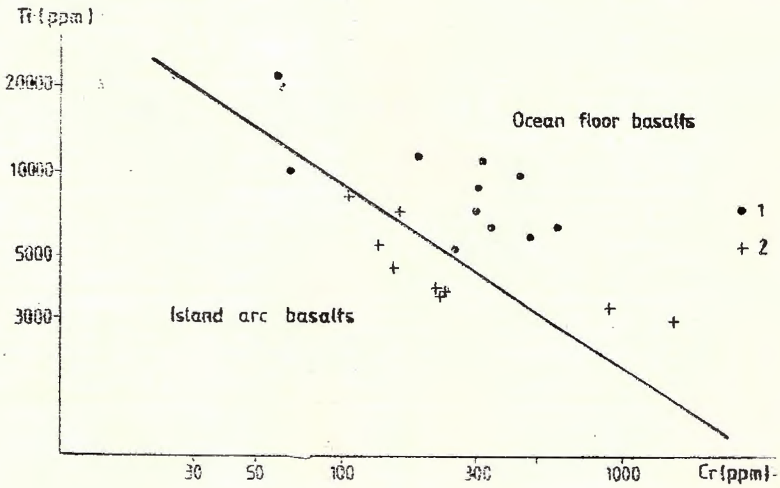

Fig. 6. — Ti — Cr diagram.
1, ophiolites ; 2, island arc volcanics (melanocrates).

plot in the field of ocean floor basalts, and the diagram in Figure 7 (Shervais, 1982), where they fall in the MORB field.

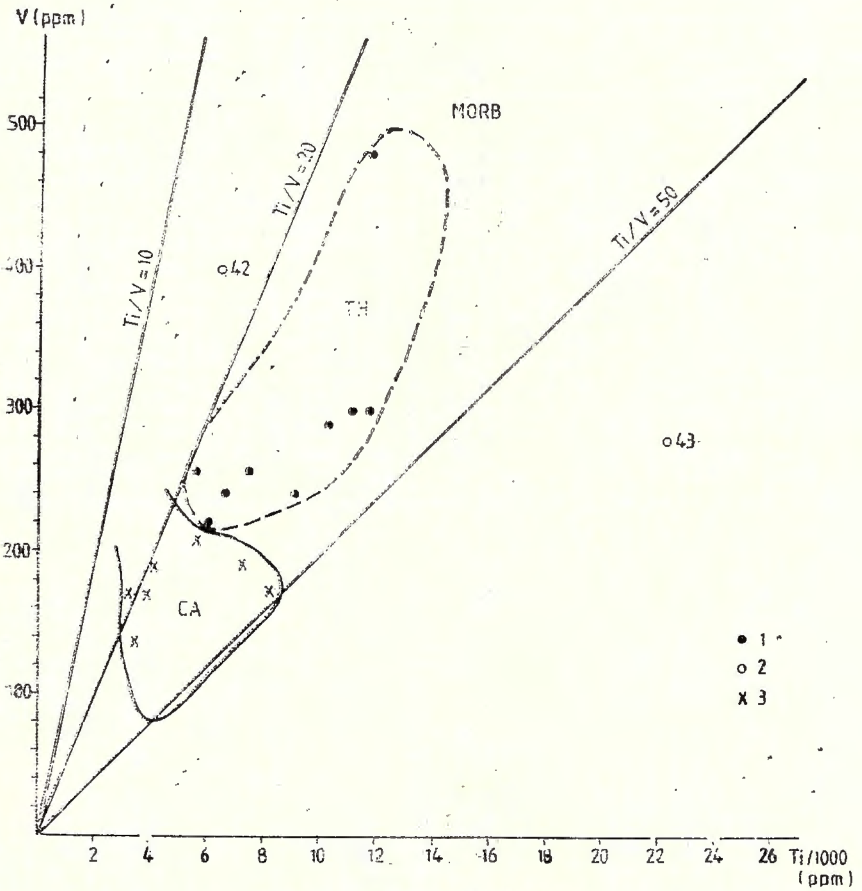

Fig. 7. — Ti — V diagram.

1, ophiolites ; 2, ocean floor spilites ; 3, island arc volcanics (melanocrates). TH, field of tholeiites from median oceanic ridges (MORB) ; CA, field of calc-alkaline basalts and of island arc tholeiites from New Hebrides.

Petrography of Island Arc Volcanic Rocks

Melanocrate rocks are represented by basalts, melabasalts and spilitized rocks. Basalts have a porphyritic structure being constituted of a hyalopilitic groundmass and phenocrysts of augite (Pl. II, Fig. 3) twinned after (100) and of plagioclase (An_{55}). Spilitized basalts (Tab. 2) contain Na_2O in smaller amounts (3.32-3.76%) than in spilites of the ophiolitic series (3.60-5.15%). Therefore they must be regarded as spilitized basalts in reaction with the sea water in which although

TA

Chemical composition

Melanocrate rocks

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sample no.	132	4	69a	26	56	5	68	53	46	32	10	45	78	76	13
Oxides (%)															
SiO_2	40.60	44.87	46.29	46.80	46.90	47.56	48.80	52.20	55.77	56.40	59.06	59.10	63.65	63.85	64.21
Al_2O_3	14.59	14.57	11.25	18.16	13.22	16.12	9.53	17.21	17.83	15.59	17.88	16.00	14.79	16.10	17.04
Fe_2O_3	2.82	4.50	2.23	6.53	5.32	4.87	2.90	5.39	2.58	6.54	1.70	1.98	1.37	2.66	3.66
FeO	1.37	3.20	5.29	1.21	1.95	4.24	5.32	2.03	2.83	1.98	3.54	3.87	0.82	0.78	0.58
MnO	0.09	0.26	0.20	0.06	0.07	0.20	0.20	0.07	0.13	0.24	0.03	0.13	0.08	0.05	0.10
MgO	4.66	4.70	14.38	3.05	7.00	8.28	13.41	5.25	4.62	4.02	3.06	5.30	0.36	1.37	1.56
CaO	16.68	11.90	8.75	8.97	10.25	6.57	9.17	7.43	7.21	5.76	1.18	5.84	2.98	0.98	2.42
Na_2O	2.44	3.32	1.68	2.50	3.48	2.96	2.68	3.76	2.82	3.46	6.34	4.62	2.25	0.56	6.00
K_2O	1.41	0.46	1.21	2.79	0.29	2.17	0.24	1.16	1.33	3.19	2.72	0.53	9.66	10.76	1.70
TiO_2	0.66	1.20	0.56	1.39	0.63	0.86	0.51	1.20	0.77	0.91	0.54	0.64	0.42	0.62	0.09
P_2O_5	0.08	0.04	0.48	0.58	0.08	0.23	0.38	0.20	0.27	0.30	1.01	0.23	0.10	0.06	0.05
CO_2	10.14	7.50	1.85	3.69	6.96	1.21	1.94	0.44	—	0.32	—	—	2.19	—	—
S	0.05	—	0.12	0.02	0.12	—	0.09	0.03	—	0.04	0.20	0.02	0.07	0.06	—
Fe(S)	0.04	—	0.10	0.02	0.10	—	0.07	0.02	—	0.03	—	0.02	0.06	0.05	—
H_2O^+	4.23	2.25	4.44	4.15	3.76	4.44	4.28	4.49	3.10	1.89	—	2.60	0.65	1.42	2.35
Total	99.86	99.51	99.46	99.92	100.13	99.71	99.52	100.88	99.26	100.77	100.45	100.88	99.45	99.51	100.53
Trace elements (ppm)															
Ni			130	30	50		230	40	35	38		50	12	15	30
Co			18	9	22		30	15	12	16		15	3.5	6.5	12.5
Cr			900	105	220		1500	160	150	135		230	7	<2	220
V			135	170	170		170	190	90	210		190	50	36	145
Sc			18	25	25		25	32	13	21		19	6,5	9	26
Zr			42	90	33		65	65	95	90		130	320	280	46
Nb			<10	<10	<10		<10	<10	<10	<10		<10	10	<10	<10
Y			15	30	13		20	20	19	24		19	33	42	17
Yb			1.3	2.8	1.2		1	2.5	1.9	2.1		2.0	3.6	4.8	1.8
La			34	32	<30		38	<30	42	56		40	30	30	<30
Ba			120	175	55		55	210	570	1050		340	1500	750	315
Sr			170	420	185		75	560	820	850		900	150	90	250
Pb			11	<2	5		12	8	7	9,5		7	3	7	4,5
Cu			48	5	13		18	4	16	15		24	10	7.5	3
Ga			9,5	12	11		12.5	13	17	19		20	5	7	12.5
Sn			2	<2	<2		<2	2	2	<2		2	2	3	<2

1, Amygdaloidal basalt — Saturani Valley; 2, spilite — Valea Pietroasă Brook; 3, melabasalt — Cîrligatu Valley; 7, melabasalt — Cîrligatu Summit; 8, spilite — Varnicu Valley (Lalcşinţ) (Laleşinţ); 9, basalt — Varnicu Varnicu Valley (Laleşinţ); 13, orthophyre — Crăciun Brook (Troaş); 14, orthophyre—Crăciun Brook (Troaş); Brook (Troaş); 18, orthophyre — Varnicu Valley (Laleşinţ); 19, dacite — Saturani Valley; 20, quartz — keratophyre— 23, rhyolite — Buceava; 24, rhyolite — Saturani Valley; 25, rhyolite — Vladin Valley; 26, rhyolite— Slatina keratophyre — Crăciun Brook (Troaş); 30 rhyolite — Slatian

Analyses no. 2 after Savu (1962 a); nos. 6, 11, 15 and 23 after Savu (1962 b);

plagioclase (An_{8-10}) is albitized, CaO and other chemical elements are not removed from the rock, but included in epidote, calcite and other secondary minerals.

BLE 2

of island arc volcanics

Leucocrate rocks

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
49	75	47	8	11	9	61	17	12	27	92g	74	33	77	92c	92d
66.80	66.85	67.60	68.20	70.38	73.00	73.10	73.27	73.85	74.00	76.35	77.60	78.00	78.40	79.60	79.78
15.80	13.09	15.85	11.23	12.99	12.57	13.70	12.12	13.19	13.45	10.95	12.02	11.42	12.12	10.60	10.44
2.82	2.14	2.57	0.92	0.69	0.09	1.34	1.42	0.04	0.74	0.89	0.82	0.06	0.31	0.91	0.45
0.21	1.57	0.43	2.83	1.37	1.24	1.13	0.56	0.88	0.72	0.29	0.64	1.22	0.76	0.05	0.28
0.07	0.10	0.08	0.08	0.02	0.03	0.01	0.07	0.02	0.03	0.09	0.03	0	0.02	0.06	0.03
0.70	1.28	0.66	5.15	0.13	0.53	0.30	0.54	0.13	0.29	0.75	0.28	0.49	0.20	0.37	0.54
1.45	3.07	2.16	3.80	3.04	2.62	1.50	0.99	0.14	0.13	0.77	0.25	0.91	0.15	0.98	0.85
4.81	3.26	4.28	2.91	7.42	5.73	6.90	4.32	1.69	3.09	2.26	5.59	4.20	6.61	3.85	2.90
5.82	3.26	5.10	2.44	0.14	0.78	0.56	4.82	8.57	6.75	4.80	1.55	1.78	0.21	1.75	2.98
0.35	0.55	0.30	0.25	0.19	0.16	0.48	—	0.18	0.25	0.15	0.13	0.17	0.18	0.20	0.14
0.20	0.36	0.16	0.20	0.08	0.08	0.14	0.06	0.10	0.08	0.04	0.12	0.08	0.08	0.06	0.04
—	2.24	—	—	2—00	1—20	0.80	0.66	—	—	—	—	—	—	—	—
0.07	0.10	0.02	0.07	0.20	0.20	0.04	—	0.10	0.03	0.06	0.03	0.11	0.02	0.08	0.08
0.06	0.08	0.02	0.06	0.17	0.17	0.03	—	0.08	0.03	0.05	0.03	0.09	0.02	0.07	0.07
1.41	1.51	1.47	2.40	0.65	1.33	0.81	0.71	0.48	0.38	2.15	0.74	0.81	0.43	1.31	1.03
100.57	99.46	100.70	100.54	99.47	99.73	100.84	100.00	99.45	99.97	99.54	99.83	99.34	99.51	99.89	99.61
4.5	8	2.5		10	6	6.5		7.5	7	9.5	5	7.5	6	10	7.5
4	4.5	3.5	7	3	3	2		<2	2	3	<2	<2	<2	5.5	5
3	11	2		10	6	6		6.5	4.5	4	4.5	8	5.5	2	4
42	34	26	57	36	20	12		20	26	16	14	22	17	23	5
3.5	8	2.5	6.5	6.5	<2	9		<2	<2	7	<2	<2	2	12	2
280	170	250	125	300	170	270		220	210	10	190	220	180	140	85
13	<10	14	13	<10	12	<10		17	14	<10	17	16	20	<10	<10
16	36	11	<10	38	10	40		11	12	<10	13	13	13	<10	<10
1.4	4.4	1	<1	6	<1	4.4		1	1	< 1	1.1	1	1.6	1	<1
75	30	46	30	32	35	32		58	42	<30	50	55	40	<30	<30
1900	400	1700	700	28	160	90		1200	950	550	250	420	32	480	480
320	185	550	34	340	280	200		135	125	120	220	400	115	150	135
9.5	8	6	3	3	3	40		4	4	21	7	4.5	6.5	22	38
8	7.5	6.5	33	3.5	13	9		9.5	4	9.5	6.5	7	9	12	7
12	15	14	8,5	9	5	7.5		8	9.5	10	10	9	12	11	11
3	2.5	2.5	<2	3	<2	3		2	2.5	2	<2	<2	2.5	3	<2

Summit; 4, amygdaloidal basalt — Vladin Valley; 5, spilite — Valea Pietroasă Brook; 6, basalt — Zeldiş Valley (Laleşinţ); 10, oligophyre — Clifa Summit; 11, oligophyre — Luncşor Brook (Pîrneşti); 12, spilite — 15, keratophyre — Tisa Valley (Troaş); 16, orthophyre — Varnicu Valley (Laleşinţ); 17, dacite — Crăciun Brook Saturani Valley; 21, quartz—keratophyre—Saturani Valley; 22, quartz-keratophyre—Valea Pietroasă Brook; Valley (Pătîrş); 27, quartz-keratophyre — Clifa Summit; 28, quartz-keratophyre—Clifa Summit; 29, quartz-Valley (Pătîrş); 31, rhyolite — Slatina Valley (Pătîrş).
nos. 26, 30 and 31 after Savu et al. (1982).

Melabasalts or augitites are rocks rich in augite (c ∧ Ng=48°). Initially they have been described as limburgites (Savu, 1962 a), another variety of melabasalt, a denomination based on the results of two former chemical analyses. A new study of the rocks under the Cîrligatu Summit as well as new chemical analyses (Tab. 2) made us consider them augitites, which are melabasalts belonging to the ankaramite family, according to Tyrrell (1960), all the more as ankaramites are to be found in the island arc volcanics in the Mureș Zone (Visca), rocks similar in chemical respect, too (Tab. 2).

Oligophyres or oligoclase porphyrites (Savu, 1962a) are included into this group being closer to the melanocrate rocks. They differ from the mugearites (Hatch et al., 1961) because are formed of oligoclase (An_{12-28}) phenocrysts and groundmass with chlorite flakes and rare crystals of augite.

The group of leucocrate rocks is represented by orthophyres (paleotrachytes), dacites, felsites, rhyolites and their albitized forms (e.g. keratophyres, quartz-keratophyres). Like spilites, the albitized rocks of the second group are found in smaller amounts as against the other leucocrate rocks of this family : orthophyres (paleotrachytes) : keratophyres = 6 : 1 ; dacites : quartz-keratophyres = 4 : 1 ; rhyolites : quartz-keratophyres = 4 : 1. The same conclusion also results from the chemical composition of the rocks (Tab. 2), in which K_2O varies between 0.14 and 10.76%, and Na_2O between 0.65 and 7.42%. Therefore the character of spilite-keratophyre series, according to Dewey and Fleet (1911), is less evident. However, the rock association shows that they belong to such a series and they represent products of a pre-orogen and bimodal island arc volcanism.

Keratophyres formed at the expense of trachytic rocks which underwent metasomatic (secondary) transformations. They display phenocrysts of plagioclase (An_5), sodaclase (Johannsen, 1937) or potash feldspar replaced by low-temperature fine-twinned albite. Quartz-keratophyres, formed at the expense of dacites and rhyolites, differ from them because their potash feldspar is a fine-twinned albite (schachbrettalbite). It is worth mentioning that the biotite lamellae were either altered or resorbed. The albitized potash feldspar (sodaclase) presents a reaction aureole on margins like the orthoclase in unalbitized rocks.

Geochemistry and Origin of Island Arc Volcanics

The values of oxides (Tab. 2) indicate a clear differentiation of volcanics in the two groups of melanocrate and leucocrate rocks. The high content of MgO in melabasalts is due to the accumulation of augite crystals, which corresponds to a considerable amount of CaO, except for the amount of calcium indicated by CO_2. In melanocrate rocks the content of K_2O generally exceeds 0.50% and according to Miyashiro (1975) this character differentiates calc-alkaline basic rocks from tholeiitic rocks. The content of SiO_2 is very high in rhyolites (70.30-79.78%) and that of K_2O in trachytes (orthophyres) varies between 5.10 and 10.76% pointing out their alkaline character.

On the diagram in Figure 3 all island arc volcanics plot in the calc-alkaline domain, where it constitutes two distinct fields. These fields are situated along a curve which reveals the direction of differentiation of calc-alkaline (Miyashiro, 1975) or subalkaline series. An exception is the two melabasalts which, due to the high content of MgO, plot in the tholeiitic rocks field and an oligophyre (no. 10) situated between the two mentioned fields [5]. All this shows that the rocks of the bimodal volcanism constitute a subalkaline volcanic series and represent a "collateral series" of differentiation with a calc-alkaline character pointed out among the Upper Jurassic-Lower Cretaceous volcanic rocks in the Drocea Mts (Savu, 1962 b).

The distribution of minor elements (Tab. 2) also shows two rock groups in the bimodal sequence (Fig. 8). In melanocrate rocks the

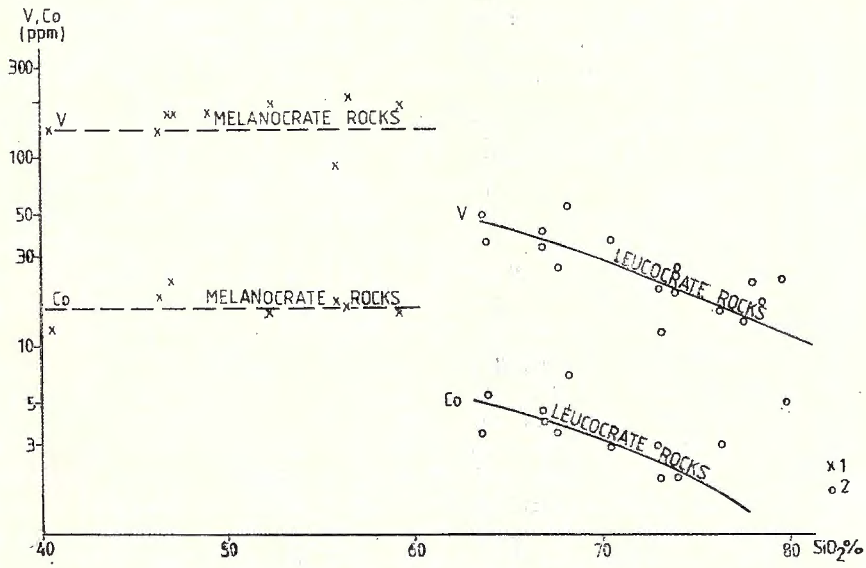

Fig. 8. — V, Co — SiO_2 diagram.
Island arc volcanics: 1, melanocrates; 2, leucocrates.

siderophile elements present lower contents than in the ophiolitic basalts. An exception is the melanocrate basalts (cumulates) which have high contents of Cr and Ni. In leucocrate rocks these elements are found in much smaller amounts which decrease simultaneously with the increase of the contents of SiO_2. Zr, Y and Yb display lower contents in island arc melanocrate rocks than in ophiolitic basalts. In leucocrate rocks the content of Zr is higher than in melanocrate rocks. The contents of Y and Yb are higher only in melanocrate rocks and in most alkaline terms, situated at the beginning of the leucocrate rock group. The values of these two elements decrease in the other terms of the leucocrate series, even below the level of the constituents in melanocrate rocks. La, which in ophiolitic rocks is situated below the detection limit (<30 ppm), shows contents up to 56 ppm in melanocrate rocks. It occurs in most of the leucocrate rocks, its contents varying between 30 and 75 ppm. In ophiolitic and island arc melanocrate rocks the content of Nb is <10 ppm; it has been determined in almost 50% of leucocrate rocks, in which its content varies between 12 and

20 ppm. Except for two samples, the melanocrate rocks contain a higher amount of Ba than the ophiolitic rocks which corresponds to the higher content of K_2O. In leucocrate rocks the contents of Ba are quite varied, depending on the content of K_2O. In albitized rocks (keratophyres) the content of Ba decreases (Tab. 2) concomitantly with the sensible decrease of the K_2O. In melanocrate rocks Sr displays values ranging from 75 to 900 ppm. The average of these contents is of 470 ppm which would indicate, according to the diagram of Hart et al. (1970), that the parental magma formed at a depth of about 400 km. This differentiates the bimodal volcanism of the northwestern island arc in the Mureș Zone from the southeastern island arc volcanism. In case of the latter it has been established that the primary magma formed at a depth of 250 km. In leucocrate rocks the content of Sr varies within wide limits.

As regards the origin of the bimodal volcanism it is obvious that it is the result of the subduction of the NW plate or microplate of the Apuseni Mountains — which included oceanic crust southwards and sialic crust northwards — under the Mureș Zone. Parental magma formed through the melting of the subducted ophiolitic oceanic crust, according to Savu's model (1983, Fig. 1). It is noteworthy that the possible similarities between the melanocrate rocks of this series and the tholeiitic rocks of the ophiolitic series might reveal this origin.

Rittmann (1967) explained the bimodal character of the volcanism through the existence of two independent magma sources : the upper mantle for basaltic magmas and the sialic crust for acid magmas. Condie and Hayslip (1975) explained the bimodal character of the volcanism at Medicine Lake, California, considering that the basic magmas resulted from a subducted eclogite slab and the acid magmas from the sialic crust. This point of view might also constitute an explanation for the bimodal volcanism in the Mureș Zone. In this case, if we consider that the melanocrate rocks are the result of the melting of the oceanic crust subducted at about 400 km deep, then we should admit that the leucocrate rocks originated in a slab of sialic crust drawn at depth on the Benioff plane, which is hard to admit.

On the diagram in Figure 4 all the melanocrate and leucocrate rocks plot in the sialic field, so that it is out of question for the former to originate in the mantle. On the diagram in Figure 5 the melanocrate rocks show an obvious tendency towards the alkaline magmas, which might explain the origin of the whole subalkaline volcanic series in a basaltic magma with an alkaline tendency. Therefore, it results that this magma formed on the Benioff plane gave rise through differentiation to oligoclase basalts and then to trachytic and acid rocks, in the same way in which the volcanic series of the southeastern island arc, constituted of basalt-andesite-dacite-rhyolite, also resulted from the differentiation of a calc-alkaline basaltic magma. All this shows clearly that the asymmetry of the Mureș Zone is indicated not only by its tectonics but also by the character of the volcanic rocks in the two marginal island arcs. The recurrence of the magmatic activity might be explained, in both cases, by successive eruptions, whose magmas erupted either from several magma chambers or from different parts of a single magma chamber from depth, in which the primary magma had separated into melanocrate and leucocrate differentiates.

The association of melanocrate volcanic rocks has typical characteristics of island arc volcanic rocks (Figs. 6, 7). On the diagram in Figure 6 only the two melabasalts occur to the right of the delimitation line of the two domains ; they also exceed the plotting field of the tholeiitic series due to a particular concentration of chrome through the accumulation of augite crystals.

Inferrences

1. The basement of the Criş Unit, which occurred as a result of the folding of the formations in the northwestern trough of the Mureş Zone, is ophiolitic ; it consists of rocks belonging to the pre-Oxfordian ocean floor basaltic complex (O_1) in this zone.

2. The volcanism synchronous to the sedimentation of the Upper Jurassic flysch formations is bimodal and displays a character of island arc volcanism.

3. It generates a subalkaline series, within which two rock groups can be distinguished : melanocrate and leucocrate rocks.

4. The petrological features of the volcanism in the northwestern arc differentiate it from that in the southeastern island arc, which is typical calc-alkaline. It indicates that the tectonic asymmetry of the Mureş Zone is reflected in the volcanism.

[4] P. Dumitrică in Bleahu et al. (1981).

[5] It seems that the oligophyres are the only feeble connection between the melanocrate and the leucocrate rocks.

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QUESTION

I. Balintoni : You have mentioned the existence of two parallel island arcs. Were they active concomitantly or successively ? Are they connected with one or two subduction planes ?

Answer : The two island arcs were active concomitantly and are connected with two subduction planes.

DISCUSSIONS

M. Lupu : We consider that the term bimodal magmatism is not used in a correct sense because, normally, it has to be connected with distensional but not with compressional movements as it has been regarded by the authors.

The ophiolitic sequence is not only pre-Callovian in age but it reaches also the Tithonian ; thus on a regional scale it is synchronous with the calc-alkaline one, of course in different tectonic settings.

The flysch deposits of the Criş Nappe succeede, on an inner scale, the limy sequence while on an outer one they partly replace it.

Answer: My colleague's statement concerning the use of the term bimodal volcanism is not exact as it has been used in connection with subduction phenomena (Condie and Hayslip, 1975), and if there is subduction there is also island arc volcanism; under special conditions of a subalkaline magma differentiation it can get a bimodal character.

As regards the fact that ocean floor basalts would continue in the Mureş Zone up to the Tithonian, I think that Dr. Lupu either mistakes the island arc basalts of the flysch with ocean-floor basalts of the basement or he is misled by the scale-structure of the flysch including also Liassic ocean floor basalts of the basement. Anyhow he excludes the possibility that the two basaltic types might be separated by petrographic and geochemical methods.

VULCANISMUL CU CARACTER BIMODAL DIN ARCUL INSULAR NORD-VESTIC AL ZONEI MUREŞ

(Rezumat)

Rocile vulcanice din arcul insular nord-vestic al zonei Mureş apar într-o serie de structuri vulcanice, îngropate în partea inferioară a flişului jurasic superior—cretacic inferior din unitatea tectonică de Criş. Ele se distribuie de-a lungul unui aliniament situat între Şiştarovăţ şi Şoimuş-Buceava, pe o distanţă de 50 km (pl. I).

Vulcanismul bimodal, care a generat aceste vulcanite, s-a manifestat în cuprinsul fosei Drocea concomitent cu sedimentarea primei părţi a flişului, peste un fundament ofiolitic jurasic-preoxfordian, reprezentat prin complexul bazaltelor de fund oceanic (O_I). Se formează astfel structuri vulcanice constituite în principal din piroclastite de roci bazice şi acide asociate adesea cu blocuri de calcare recifale (aglomerate poligene), rezultate din distrugerea conurilor vulcanice, pe care se instalaseră recifi coraligeni, de către exploziile vulcanice intermitente (fig. 1 şi 2).

Compoziţia chimică şi conţinuturile de elemente minore din rocile ofiolitice din fundament (tab. 1 şi fig. 3-7) arată că rocile corespund bazaltelor de fund oceanic sau tholeiitelor din ridge-urile oceanice mediane.

Produsele vulcanismului bimodal se separă în grupa rocilor melanocrate reprezentată prin bazalte porfirice, melabazalte (augitite), bazalte spilitizate şi oligofire şi în grupa rocilor leucocrate, formată din ortofire (paleotrahite), dacite şi riolite, precum şi prin formele albitizate ale acestora, keratofirele şi cuarţ-keratofirele, al căror feldspat potasic este înlocuit de albit fin-maclat, de temperatură scăzută.

Compoziţia chimică şi distribuţia elementelor minore (tab. 2) sînt caracteristice pentru cele două grupe de roci din suita bimodală (fig. 3,

4, 8). Poziția rocilor pe diferite diagrame arată că ele sînt produsul unui vulcanism de arc insular (fig. 7). Magma primară, din care au derivat rocile, a fost o magmă bazaltică cu tendință alcalină (fig. 5), formată pe planul Beniof, la adîncimea de cca 400 km, în condițiile subducției crustei oceanice jurasice-preoxfordiene sub zona Mureș. Din această magmă parentală s-au separat rocile bazaltice (melanocrate) pe de o parte și cele alcaline și acide (leucocrate) pe de alta. Recurența vulcanismului bimodal a fost determinată de emisii alternative de magme melanocrate și leucocrate din diferitele părți ale bazinului magmatic, în care se separaseră acestea datorită procesului de diferențiere.

Seria de vulcanite din suita bimodală are caracter subalcalin. Prin caracterele sale petrologice și geochimice această serie vulcanică se deosebește de cea din arcul insular sud-estic, care este tipic calco-alcalină. Aceasta arată că asimetria tectonică a zonei Mureș se reflectă și în caracteristica rocilor vulcanice din cele două arcuri insulare marginale.

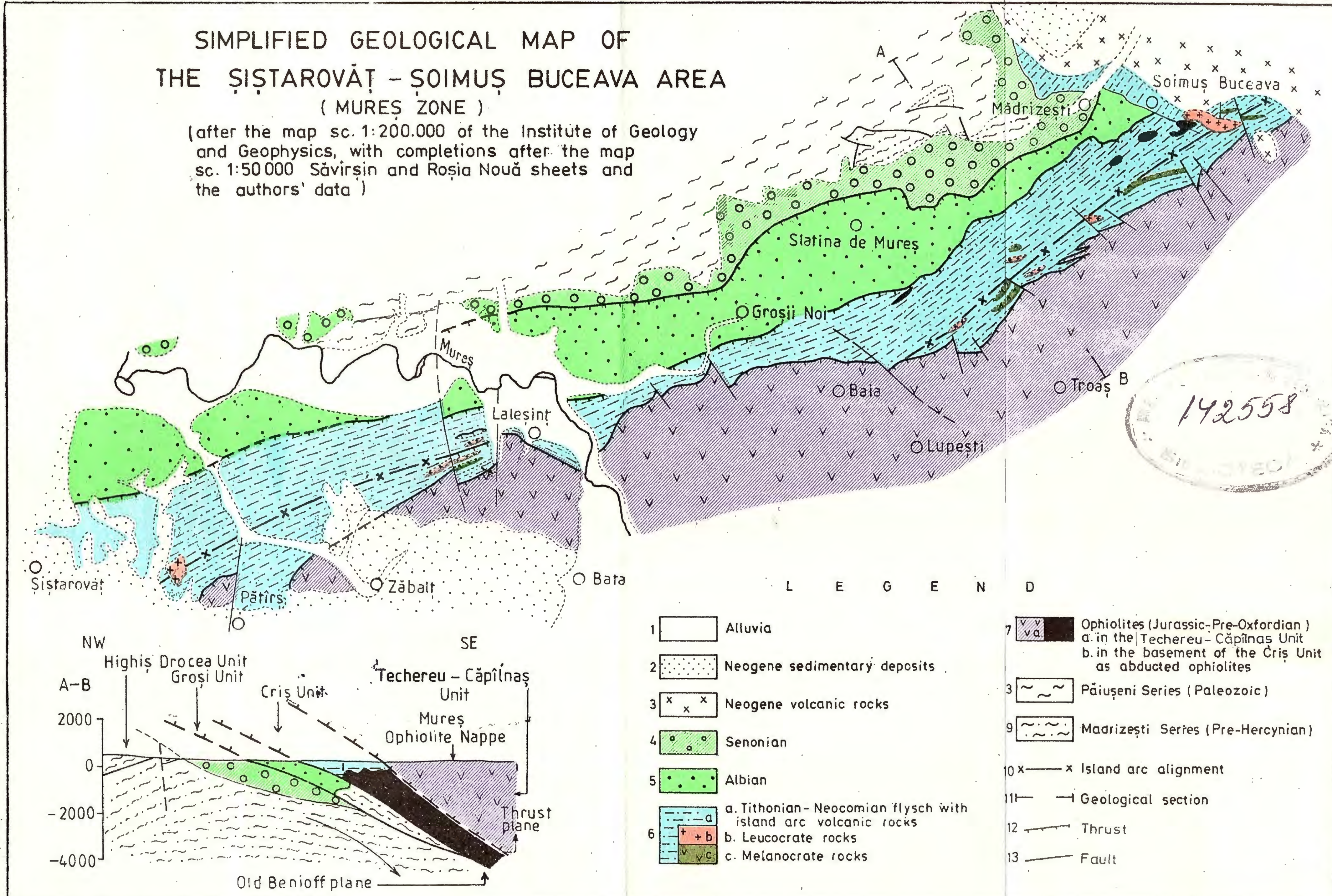
EXPLANATION OF PLATE

Plate II

Fig. 1. — Limestones with eruptive elements of island arc volcanics. Tisa Valley (Troaș).

Fig. 2. — Spilite with intersertal texture in the ophiolitic basement. Vladin Valley. Nic. +, × 50.

Fig. 3 — Island arc porphyritic basalt with augite phenocrysts. Zeldiș Valley. Nic. +, × 25.



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

IUGS UNESCO

Project 195 : Ophiolites and lithosphere of marginal seas

ULTRAMAFIC ROCKS OLISTOLITHS FROM THE JURASSIC FORMATIONS ON THE CRAIU VALLEY (MUNTELE MIC) : PETROLOGY AND GEOCHEMISTRY [1]

BY

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Keratophyres. Jurassic. Olistoliths. Olistostrome. Ultramafic rocks. Serpentinization. Withinplate volcanism. Island arc volcanism. Low grade metamorphism. Peridotite. Petrogenesis. Chemical composition. Southern Carpathians — Danubian sedimentary domain — Feneș Zone.

Abstract

Within Jurassic sedimentary deposits and keratophyric volcanics from the Craiu Valley (Muntele Mic — Southern Carpathians), there are several olistoliths of serpentinized ultramafic rocks. They have been obducted from a dismembered ophiolitic series. The presence of ultramafic rock olistoliths into an olistostrome whose matrix is both sedimentary and pyroclastic (coloured melange) shows that their embedment took place when into the Jurassic sea on the Transylvanian microplate manifested a within-plate or an island arc volcanism. Ultramafic rocks are completely serpentinized and adapted to a very low metamorphism (anchimetamorphism) conditions which affected the Jurassic formations. They are composed of peridotites of Alpine type influenced by metamorphism like the ultramafic rocks from the Severin Nappe in the Mehedinți Plateau.

Résumé

Olistolithes de roches ultrabasiques des formations jurassiques de Valea Craiu (Muntele Mic) : pétrologie et géochimie. Les dépôts sédimentaires et les

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volcanites kératophyriques jurassiques du bassin de Valea Craiu (Muntele Mic — Carpathes Meridionales) contiennent des olistolithes de roches ultrabasiques serpentinisées. Elles sont le résultat d'une obduction de la série ophiolitique disloquée. La présence des olistolithes de roches ultrabasiques dans une olistostrome à matrices sédimentaire et pyroclastique (coloured melange) relève que leur insédimentation s'est produite au moment où dans la mer jurassique de la Microplaque transylvaine a eu lieu un volcanisme sous-marin d'arc insulaire ou „d'intraplaque". Les roches ultrabasiques sont entièrement serpentinisées, en subissant les conditions d'anchimétamorphisme faible, qui ont affecté les formations jurassiques. Leur composition comporte des péridotites de type alpin, affectées par des processus de métamorphisme tout comme les ultrabasites de la nappe de Severin du plateau de Mehedinți.

Introduction

In Mesozoic sedimentary formations, a few serpentinites bodies were known on the Craiu Valley in SE of Muntele Mic, even at the end of the last century (Schafarzik, 1899). These rocks have been more recently investigated on various occasions, especially for possible asbestos concentrations, by Răileanu (1953), Răduță et al. (1957), Bîră (1958), Gherasi et al. (1970), as well as on the occasion of drawing the 1 : 50.000 map, the Muntele Mic sheet (1981), when the authors of this paper studied them too. Lately, Savu (1985) showed that the ultramafic rocks from this region represent olistoliths.

Geology of Ultramafic Rocks Olistoliths

Serpentinized rocks from this valley are not intrusive bodies, as it was before assumed, but they represent olistoliths of ultramafic-ophiolitic rocks — embedded in the Jurassic olistostrome (J_2 — J_3 — Savu, 1985). They are nine, among which a more important olistolith is situated on the Izvorul Craiului, under the overthrust of the Muntele Mic nappe, another one in the Mîloasa Valley, four on the Craiu Valley downstream of the cable-car station and three on the Izvorul Largului, the Craiu Valley left tributary (Pl.).

These olistoliths have been flattened during the tectonical processes, which determined the folding and the anchimetamorphism of the Jurassic olistostrome. Their length varies from 1.000 to 300 m and their thickness from 200 to 50 m. In some places, they are sheared and present a foliation with polished planes.

Inside one of the olistoliths on the Izvorul Largului, we found also a dolerite separation, which could represent a block tectonically included in a classical ophiolitic melange bearing a serpentinic matrix, from which the olistolith has been taken out and then embedded in the Jurassic olistostrome (Savu, 1985).

The matrix where these olistoliths are included is composed of various rocks. So, the eastern olistoliths are placed in carbonatic sandstones and arkosian rocks having a gritty or microconglomeratic aspect, in clay, grey-black shales, all of them being very low metamorphosed. The arkosian rocks contain granules of feldspars, similar to those from the Muntele Mic granite, which is situated at NW. The western olistoliths which are placed at a lower level than the above olistoliths, are gathered in a pyroclastic anchimetamorphosed matrix consisting of bostonitic, trachytic and keratophyric agglomerates and tuffs with an obvious foliation. They are crossed by veins of bostonites, trachytes, porphyritic rocks bearing a syenitic character and keratophyres (Bîră, 1958; Gherasi et al., 1970). At their turn, the eruptive rocks are crossed by veins of quartz with a rolling extinction which certify the anchimetamorfism that took place.

1. Keratophyres and trachytes are white-yellow or grey rocks which form the main part of the pyroclastics in the region. They have a porphyritic texture containing a groundmass of trachytic texture, in places divergent or microgranular in which float phenocrysts of partially or totally albitized orthoclase (Schachbrettalbite). Fresh phenocrysts of orthoclase (—2 V = 60-64°) are twinned after the Karlsbad or Baveno laws; they are sometimes broken or rolled during the lava flow. A sodium amphibole is rarely met.

At the same time, within the pyroclastic mass, there are keratophyric tuffs and agglomerates as well as tuffites intercalated in the clay-gritty deposits and in the black shales.

2. Quartz syenites form small intrusive bodies. These rocks are grey-red, have granular texture, sometimes a porphyritic one, which contains potassium feldspar and oligoclase, and melanocratic primary minerals among which a green-olive biotite, have been chloritized. Potassium feldspar is prismatic and has the Karlsbad twin. It is often replaced by very fine twinned albite (Schachbrettalbite), of low temperature. The plagioclase is an albite-oligoclase usually clear, seldom polysynthetically twinned. The rocks also contain a little quartz (0-5%) and pyrite.

3. The bostonites are vein rocks, sometimes with a porphyritic texture which contain potassium feldspar in long divergent crystals, rarely parallel. The rock also contains biotite, interstitial quartz, chlorite and carbonates.

4. The oligophyres and albitophyres form veins and sills. They consist of a microgranular groundmass where there are phenocrysts of plagioclase (An 8-12) polysynthetically twinned. Melanocratic minerals represented by hornblende and biotite, are usually chloritized.

5. Basalts also form veins. They are green and consist of a groundmass bearing phenocrysts of pyroxene and plagioclase. The groundmass contains a fine network of diverging plagioclase crystals and in their interstitials there are small pyroxene crystals. Clinopyroxene phenocrysts are prismatic and weakly pleochroic in pink having the extinction angle (c $\wedge$ Ng) of 45° to 48°, which indicates a titanaugite. In places we noticed a brown hornblende and biotite lamellae, minerals which could indicate a basalt with an alkaline tendency. Plagioclase phenocrysts are mostly substituted by calcite. From the petrographical point of view,

the volcanics associated in the Muntele Mic Jurassic deposits were considered to be similar to the Lias ones from the Codlea basin and to the vein rocks from the Șinca Nouă-Poiana Mărului-Holbov region (Savu, 1968; 1980), which belong to a submarine within-plate volcanism (Savu et al., 1984), feature which we can meet in the volcanism in the west of the South Carpathians (Savu, 1985). The absence of chemical and spectral analyses cannot permit us to clarify their tectonic setting.

In this part of the region, where the olistoliths matrix is of volcanic nature we can say that the formation gets a melange character bearing a pyroclastic matrix (Coloured melange-Gansser, 1959), without forming an ophiolitic melange (Mercier, Vergely, 1972), but a pyroclastic olistostrome containing olistoliths of ophiolitic rocks (Savu, 1985).

Taking into consideration the fact that in the south, in the Cozia Mts Zone at Cornereva, volcanics similar to those from the Craiu Valley. are situated in the Jurassic deposits from the Toarcian-Oxfordian interval (Năstăseanu, 1980), it is also possible that the formations where are embedded the olistoliths of ophiolitic rocks belong to the Middle Jurassic, passing eventually to the Upper Jurassic.

Bîră (1958) described the Jurassic formations as "infragetic" ones. Taking into account the fact that they contain olistoliths of ultramafic rocks as well as the Azuga beds from the Severin nappe (Savu, 1985), we must see in these formations an equivalent of the latest, both belonging to the Jurassic olistostrome (J_2-J_3) as Savu established in 1982. In comparison with the Azuga beds from the Severin nappe, the Jurassic formations from the Muntele Mic are terrigenous-volcanogenous and are found *"in situ"* (autochthonous) because the arkosian rocks contain as we shall see reworked elements from the Muntele Mic granitoids situated to NW of our map (Plate).

Petrographical Data Regarding Olistoliths

Ultramafic rocks olistoliths are completely serpentinized they consisting of a compact serpentinic mass of lizardit-antigoritic nature, minerals whose lamellae are disposed on two main directions. Here and there in this mass appear the outlines of bastite pseudomorphoses after an orthopyroxene, showing that the rocks resulted from some peridotites (harzburgites) serpentinization. We often see a foliation formed during the anchimetamorphism processes, which affected the Jurassic olistostrome and the ultramafic rocks olistoliths.

As a result of primary minerals serpentinization from their crystalline network was eliminated iron, which is forming fine grains or swarms of a secondary magnetite dust spread in the whole rock. Within the serpentinites, we often notice patches and seldom veins or isolated kämmererite lamellae, a chromiferous chlorite, pleochroic in violet and pink. On the Craiu Valley, within the serpentinites occurs a chlorite concentration composed of clinochlor lamellae and magnetite grains (Table 1).

TABLE 1

Chemical Composition of Craiu Valley Chlorite

SiO_2	27.10	TiO_2	4.32
Al_2O_3	19.85	P_2O_5	1.80
Fe_2O_3	2.33	CO_2	0.10
FeO	11.13	S	0.047
MnO	0.35	Fe(S)	0.041
MgO	20.25	H_2O^+	9.11
CaO	4.11		
		Total	100.53

Veins of chrysotilic asbestos often cross the serpentinites, whose fibres are perpendicularly on the vein walls. As Prichard (1979) has reported, this mineral begins to form when all the olivine in the rock is serpentinized, similar being the case with the Craiu Valley rocks.

Both in the Craiu Valley olistoliths and especially in the Izvoru Largului ones, take place metasomatic processes of talcitization and especially serpentinitic rock listwanitization.

a) Talcitization processes replace almost the whole rock. Talc mass also contains small remnants of unreplaced serpentinite and kämmererite. Numerous asbestos veins cross also the talc rocks. Often appear grains of secondary magnetite having irregular outline and a fine dust, formed of this mineral which seems to be redistributed in the rock at the same time with talcitization.

b) Listwanitization is manifesting by the substitution of serpentinitic rocks with magnesite, a mineral which appears in incipient stages of the rocks carbonatization in idiomorphic crystals, isolated or groupped in small swarms sometimes also in veins. Magnesium carbonate develops to a compact earthly mass, being mainly formed by magnesite in irregular grains, where are still kept rare small serpentinite patches. This magnesitic mass is crossed by chrysotile veins.

There are also cases when in the same serpentinitic rock take place both talcization and listwanitization processes, this aspect being met especially on the Izvoru Largului. In such situations, rocks are formed by bands or small irregular magnesite patches situated inside the talc mass.

The dolerite from the ophiolitic melange olistolith of Izvoru Largului has an ophitic texture, formed of a plagioclase crystals network in whose mass develops a clinopyroxene in which the plagioclase crystals are included. Plagioclase crystals (An 50) are twinned after the albite law and are more acid in composition toward the margin ; on the cleavages and in the center, these crystals are sericitized. Clinopyroxene is almost uralitized and in some places is chloritized. Often appear magnetite grains usually with an irregular outline.

This dolerite has an obvious feature of a tholeiitic rock and cannot belong to the volcanics in which are the olistoliths embedded. It belongs to the same ophiolitic series as the last ones.

Geochemistry of Ultramafic Rocks

In order to know the geochemistry of ultramafic rocks olistoliths, we analysed chemically six serpentinitic rocks (Tab. 2). As it results from table 2, the ultramafic rocks have a peridotite (harzburgite) composition, the main chemical components varying as follows: SiO_2 40.80-45.20%; Fe_2O_3 5.19-7.90%; FeO 2.03-2.69%; MgO 32.65-37.85%; Cr_2O_3 0.29-0.84%; NiO 0.26-0.43%. Only one rock contains 0.19% Na_2O, to which corresponds 1.08% CaO, a bigger content than in other ultramafic rocks. These two contents could indicate the presence of a peridotite bearing rare plagioclase crystals. In these rocks, sulphides appear in small quantities because Fe(S) varies from 0.03 to 0.04% (Tab. 2).

TABLE 2

Chemical composition of ultramafic rocks from Craiu Valley

No.	1	2	3	4	5	6
Sample	65	70	64	69	66	71
Type of rock	serpentinite	serpentinite	serpentinite	serpentinite	serpentinite	serpentinite
SiO_2	40.80	40.85	41.60	41.70	41.80	45.20
Al_2O_3	0.77	1.09	2.21	1.10	0.35	1.43
Fe_2O_3	7.33	5.19	5.45	5.83	5.99	7.90
FeO	2.69	2.03	2.47	2.24	2.40	2.39
MnO	0.12	0.05	0.13	0.08	0.07	0.15
MgO	37.40	37.42	36.00	36.70	37.85	32.65
CaO	0.62	0.17	1.08	0.14	0.20	0.30
Na_2O	0	0	0.19	0	0	0
TiO_2	0	0.01	0.12	0.18	0	0.01
P_2O_5	0.01	0.01	0.03	0.02	0.02	0.15
CO_2	—	—	0.35	—	—	—
S	0.043	0.036	0.036	0.043	0.47	0.43
Fe(S)	0.04	0.03	0.03	0.04	0.04	0.04
H_2O^+	9.37	12.73	10.40	10.77	10.96	9.05
Cr_2O_3	0.38	0.44	0.48	0.37	0.29	0.84
NiO	0.34	0.36	0.33	0.33	0.26	0.43
Total	99.91	100.41	100.96	99.54	100.27	100.58
Ni	2.600	2.600	2.100	2.600	2.800	3.400
Cr	3.300	2.600	2.000	2.600	2.800	5.800
Co	135	130	100	130	150	145
V	120	92	42	92	62	60
Sc	16	15	6.5	10.5	9	7
Cu	9	10.5	23	13	5	6
Ga	2	<2	<2	2.5	2	3
Ba	110	80	22	30	7	7
Sr	15	<10	<10	<10	<10	<10

These rocks have been analysed by emission spectrography, obtaining the results from table 2 in which we notice the big quantities of Cr and Ni. Because we did not see chromiferous spinels under the microscope, we suppose that the chrome could be included in the silicates network. Regarding Ni and taking into consideration that the chemical analyses point some sulphur too, we consider that besides the silicates network, this element could be present also in the pyrite or pyrrhotite grains. Cobalt varies from 100 to 150 ppm, similar values to those in other series of ultramafic rocks as well as those in the ophiolites from the Mehedinți Plateau (Savu et al., 1985).

Scandium contents vary from 6.5 to 16 ppm and are a little lower than those in ultrabasites from the Severin nappe. Copper, gallium and strontium have generally small values. We remark reduced Ba contents which characterize the ocean floor rocks.

Origin of Ultramafic Rocks Olistoliths

Previous investigations considered ultramafic rocks from the Craiu Valley as intrusive bodies. Relations of these ultramafic rocks with surrounding formations and the great number of isolated bodies but groupped on a small area, makes impossible such an interpretation. In 1985, Savu has shown that these bodies are olistoliths as those from the Mehedinți Plateau which come from a dismembered ophiolitic series. This ophiolitic series is forming in the Lower Jurassic, somewhere in an ocean zone (Carpathian Ocean) situated between the Moessian Plate and the Transylvanian one from where the olistoliths were obducted in the epicontinental Jurassic sea, which had invaded the Transylvanian submerged Plate.

The olistoliths have a similar origin as those from the Mehedinți Plateau, which we mentioned above, as it results from the rock composition, as we saw before and especially from their position on various

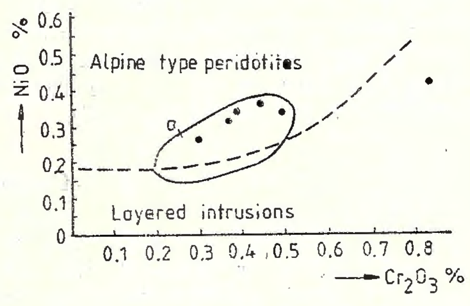

Fig. 1. — NiO-Cr_2O_3 diagram. a, distribution field of ultramafic rocks from the Mehedinți Plateau.

diagrams. So, on a NiO — Cr_2O_3 diagram (Fig. 1) after Malpas and Stevens (1977), the ultramafic rocks from both regions, are situated within alpine peridotites occuping the same field which shows that they formed under the same conditions on the Carpathian ocean floor (ocean crust).

Both serpentinitic rocks on the Craiu Valley and those from the Mehedinți Plateau came from an ultramafic complex. They are situated mainly within the metamorphosed peridotites domain, in the richest field in MgO as results from the diagrams in Figure 2, after Coleman (1977). On the diagram in Figure 2b, the rocks are situated in the field

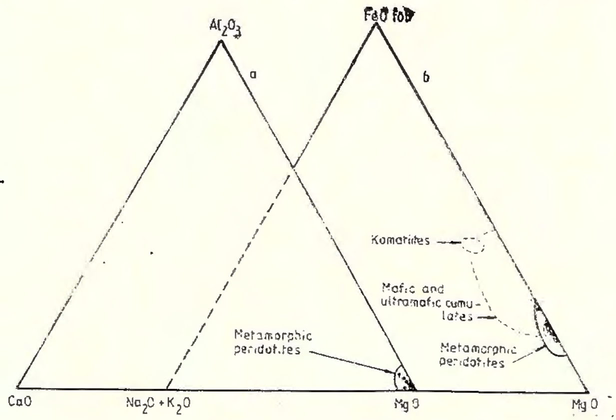

Fig. 2. — FeO tot — MgO — $Na_2O + K_2O$ and Al_2O_3 — MgO — CaO diagrams.

of ultrabasites from Papua and Oman (Malpas, Stevens, 1977). All these data confirm the same origin of the Craiu Valley olistoliths and of those from the Severin Nappe in the Mehedinți Plateau.

The Jurassic sedimentary and volcanic formations as well as the ultramafic rocks olistoliths are affected by anchimetamorphism processes under thermodynamic conditions of so-called "very low grade of metamorphism" (Winkler, 1970 ; T-300°-370° ; P H_2O ~ 3 Kb). In the case of olistoliths, the anchimetamorphism overlies ocean floor metamorphism which affected the ophiolitic (ultramafic) rocks in their origin zone. Because these rocks adapted to the anchimetamorphism conditions, they have been completely serpentinized, a process which make disappear totally the first metamorphism effects and even the elements of primary magmatic texture as in the case of ultramafic rocks olistoliths from the Severin Nappe (Savu, 1985).

Conclusions

We conclude the following from this paper :

Ultramafic rocks olistoliths on the Craiu Valley represent obducted olistoliths from a dismembered ophiolitic series.

Their presence in the olistostrome, whose matrix is both sedimentary and pyroclastic (coloured melange), shows that olistoliths insedimentation took place when in the Jurassic sea on the Transylvanian sialic microplate manifested a submarine volcanism of "within plate" character.

Ultramafic rocks are completely serpentinized in the conditions of the Late Kimmerian anchimetamorphism which affected the Jurassic formations.

The rocks composition corresponds to alpine peridotites, influenced by metamorphic processes as well as the ultrabasites from the Severin Nappe in the Mehedinți Plateau.

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QUESTIONS

M. Săndulescu : Which are the sedimentologic criteria on which account you state that the described formations belong to the olistostromes ?

Answer : The presence of ultramafic rock olistoliths, which occur as blocks embedded both in the detrital facies and in the volcano-sedimentary one or only in the volcanic facies of the Jurassic formation (J_2-J_3), stresses its olistostrome character (see Mercier and Vergely, 1972 and Hsü, 1974).

I. Solomon : Can you make a comparison between the magmatism in the study zone and that in the Metaliferi Mountains ?

Answer : Yes, it is possible to make a comparison between them. However, there are some differences between the two types of magmatism. Both the volcanism in the Muntele Mic — Cozia (Corneareva) and the island arc volcanism in the Metaliferi Mountains (Mureş Zone) develop at the upper part of the Jurassic but the volcanism in the first region develops from the Toarcian till the Oxfordian, possibly later, and the volcanism in the Mureş Zone from the end of the Callovian till the terminal part of the Portlandian, eventually passing in the first part of the Lower Cretaceous.

As regards the ophiolitic rocks in the Mureş Zone and those in the ocean lying between the Moesian Plate and the Transylvanian one they formed on the ocean floor in the first part of the Jurassic (J_1-J_2).

DISCUSSIONS

T. Berza : This paper brings new petrographic and geochemical data regarding some occurrences of ultramafic rocks which are known for a long time, but have not been minutely investigated. 1. Concerning the interpretation as olistoliths of the respective serpentinites, this option being adopted by the authors, I consider that there are no concrete arguments to plead for this. Thus, on the wide area occupied by both the Jurassic detrital formation and by volcano-sedimentary one (among these formations, there are either tectonic relations — Codarcea, 1940 — or a stratigraphic succession — Năstăseanu, 1979) occurrences of ultramafic rocks are gathered only in the Valea Craiu zone, about on a NS alignment and to east also on a NS alignment in the Olteana and Şucu Valleys. In the last case, Dr. H. Kräutner notices that the ultrabasites are situated in the continuation of the fault which bound to east occurrences of Lower Paleozoic to Rîul Rece, Rîul Lung and Rîul Alb.

2. It wonders the fact that an ultramafic body (which is said to be olistolith) is figured on the map crossing the limit between detrital Jurassic and volcano-sedimentary one. If the field situation is correctly drawn (and it is very probable that this is real) then it is more probable that these are intrusion relations.

3. Although there are some doubts concerning the ultramafic magma, the pre-

sence of such bodies on important fractures has to be investigated. I remind you of the existence within the Tismana granitic massif of a body bearing serpentinized phlogopite pyroxenites, this body being situated on an important fault which affects the Jurassic deposits as well. To conclude, I consider that N. Gherasi, H. P. Hann and E. Match initial interpretation of these serpentinites as representative ultramafic intrusions, remains the best one.

Answer : 1. The essential argument to interpret the ultramafic rock bodies as olistoliths is the fact that they occur as blocks embedded in the Jurassic formation (J_2-J_3). For these olistoliths to have come on a fault, whose existence cannot be proved, this one should have been active at the same time with the Jurassic formation sedimentation ; the western overthrust plane (Pl.) is later formed. As it is less probable that the small post-Jurassic fault, which Kräutner talks about, to have attained the upper mantle and it is much less probable that the small bodies of serpentinites on the Şucu and Olteana Valleys have passed through the Sialic crust, which is about 40 km in the Southern Carpathians to attain the actual level, we think that these bodies are olistoliths too.
This fact supports our opinion arguing that olistoliths are widely spread in the Jurassic formation.

2. It is normal that an olistolith intersects at one time the sedimentation plane between two formations or two layers, if it was embedded during their sedimentation. Because of that, on the map, the body seems to cut the respective limits. As we have mentioned above, among these bodies of ultramafic rocks and surrounding formations, we cannot notice intrusion or diapirism relations.
3. Concerning the small body of phlogopite pyroxenite from Tismana late-kinematic granite and considering its composition and the arguments from point 1, it seems that not even it did cross the Sialic crust in order to come to the upper part of the granitoid body but it was taken from the depth by the latter with whose magma it seems that it already acted. Both in this case, and on the Şucu and Olteana Valleys the association of ultramafic rocks-faults has to be at random, because in the world we know numerous major fractures with which do not associate bodies of ultramafic rocks but only volcanic rocks.

OLISTOLITELE DE ROCI ULTRABAZICE DIN FORMAŢIUNILE JURASICE DE PE VALEA CRAIU (MUNTELE MIC) : PETROLOGIE ŞI GEOCHIMIE

(Rezumat)

Corpurile de roci ultrabazice serpentinizate din bazinul văii Craiului nu sînt intrusive, ci reprezintă olistolite ofiolitice însedimentate în olistostroma jurasică (J_2-J_3) obduse dintr-o serie ofiolitică dezmembrată.

Olistolitele din partea de est a ariei lor de răspîndire sînt cantonate în gresii carbonatice, roci arcoziene şi în şisturi argiloase cenuşiu-negricioase toate slab metamorfozate. Olistolitele din partea de vest a ariei sînt cuprinse într-o matrice de natură piroclastică anchimetamorfică, constituită din tufuri şi aglomerate bostonitice, trahitice şi kerato-

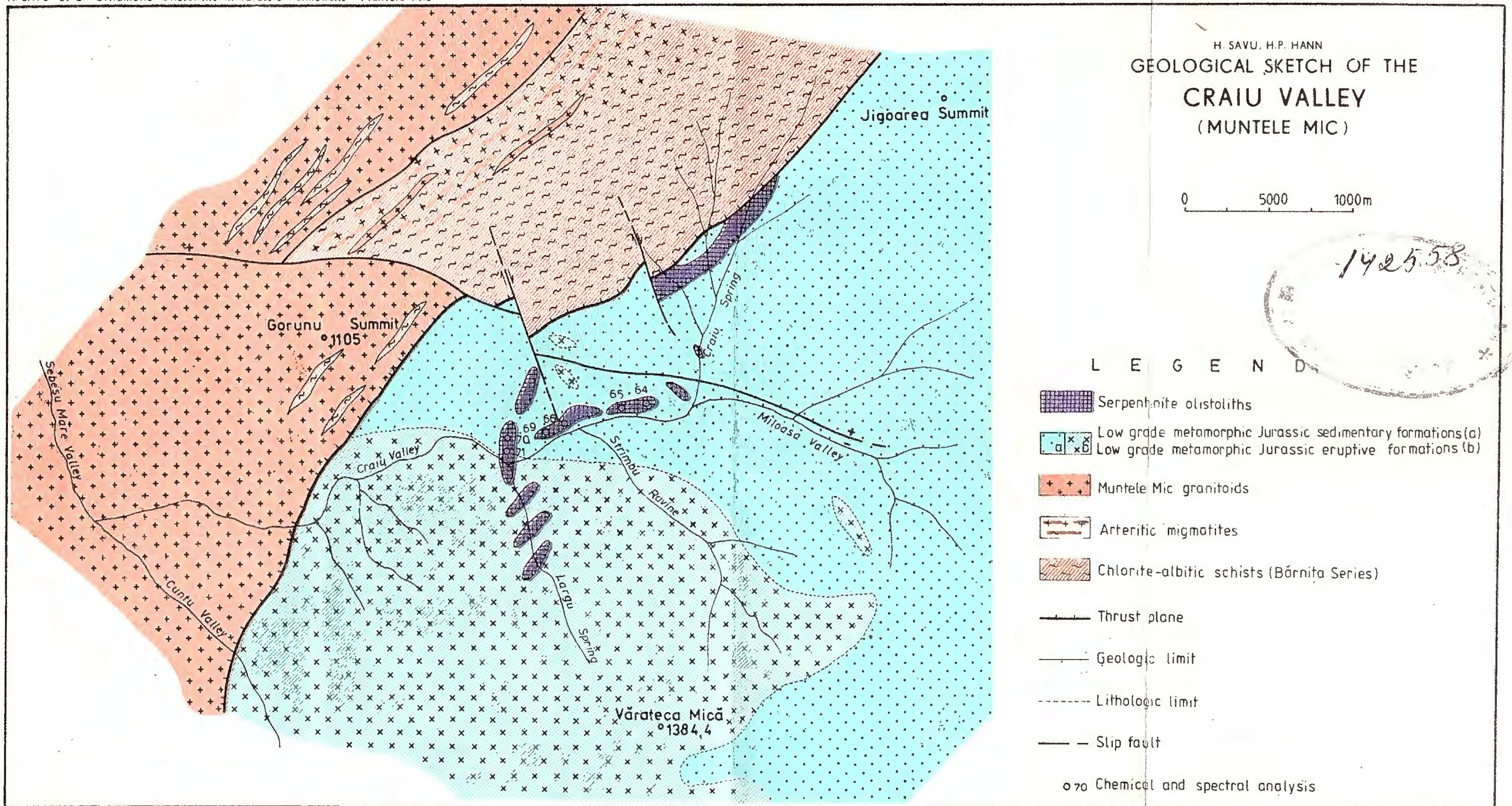
firice, care prezintă o foliație evidentă. Acestea sînt străbătute de filoane de bostonite, trahite, roci porfirice cu caracter sienitic și keratofire de asemenea afectate de anchimetamorfism.

Prezența olistolitelor de roci ultrabazice într-o olistostromă a cărei matrice este atît sedimentară cît și piroclastică (coloured melange) arată că însedimentarea lor s-a produs, cînd în marea jurasică de pe Microplaca Transilvană se manifesta un vulcanism submarin de „intraplacă", determinat de procesele de subducție.

Olistolitele de roci ultrabazice sînt complet serpentinizate, ele fiind alcătuite în întregime dintr-o masă serpentinică compactă, de natură lizardit-antigoritică. Conturele pseudomorfozelor de bastit după un ortopiroxen arată că rocile au rezultat din serpentinizarea unor peridotite harzburgitice. În masa serpentinitelor a mai fost identificat kämmererit (un clorit cromifer), un cuib de cloritit constituit din clinoclor și magnetit și filonașe de azbest chrisotilic. Rocile serpentinice au fost supuse unor fenomene metasomatice de talcizare și de listvenitizare. Cînd s-au suprapus aceste fenomene, rocile sînt formate din benzi sau zone neregulate de magnezit situate în masa de talc.

Din analizele chimice rezultă că rocile ultrabazice au o compoziție de peridotite de tip alpin. Din analizele spectrale se remarcă conținuturile ridicate de Cr și Ni. Se observă conținuturi reduse în Ba, fapt caracteristic pentru rocile de fund oceanic.

Datele chimice confirmă concluzia, că olistolitele din această regiune au aceeași origine cu cele din pînza de Severin din Platoul Mehedinți. Toate rocile din regiune sînt afectate de procese de anchimetamorfism, care, în cazul olistolitelor, se suprapun peste efectele metamorfismului de fund oceanic ce afectase ofiolitele (ultrabazice) în zona lor de origine. Astfel au fost complet serpentinizate, proces care a șters în întregime efectele primului metamorfism și chiar elementele structurii magmatice primare.



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

PETROLOGY, GEOCHEMISTRY AND ORIGIN OF MAFIC OPHIOLITIC ROCKS WITHIN THE OBÎRȘIA CLOȘANI-BAIA DE ARAMĂ REGION (MEHEDINȚI PLATEAU) [1]

BY

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Mafic rocks. Basalts. Ophiolites. Low grade metamorphism. Olistoplate. Olistostrome. Chemical composition. Tholeiitic magma. Trace elements. Severin Nappe. Transylvanian continental plate. Southern Carpathians — Sedimentary Danubian domain — Cerna-Cazane Zone ; Coșuștea — Balta — Baia de Aramă Zone.

Abstract

Basic very low metamorphic rocks compose a big slab or an olistoplate (olistonappe) incorporated in the Severin Nappe olistostrome (J_2-Cr_1) which is overthrust on the eastern margin of the Transylvanian continental plate. They consist of basaltic flows (hyalobasalts, variolites, basalts, amygdaloidal basalts and anamesites) often in pillow lava facies, associated to dolerites, agglomerates and tuffs, with intercalations of abyssal red argillites, black shales and jaspers with flattened radiolars. Rock chemical composition, minor elements and rare earths contents characterize an ophiolitic series. This ophiolitic series has been formed on the floor of the Carpathian Ocean from tholeiitic magma, which occurred in the mantle at about 125 km depth.

Résumé

Pétrologie, géochimie et origine des roches ophiolitiques basiques de la région d'Obîrșia Cloșani-Baia de Aramă (plateau de Mehedinți). Les roches basiques anchimétamorphiques forment une olistoplaque insédimentée dans l'olistostrome jurassique-néocomienne (J_2-Cr_1) de la nappe de Severin, charriée sur

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la marge orientale de la plaque continentale transylvaine. Elles sont constituées de coulées basaltiques (hyalobasaltes, variolites, basaltes, basaltes amigdaloïdes et anamésites) souvent en faciès de pillow lava, associées à dolérites, agglomérats et tufs à intercalations d'argilites rouges et noires et à jaspes à radiolaires aplatis. La composition chimique des roches, les éléments mineurs et les terres rares sont caractéristiques pour une série ophiolitique. Cette série ophiolitique s'est constituée sur le fond de l'Océan carpathique, des magmas tholéiitiques, formés dans le manteau supérieur à une profondeur de 125 km.

Introduction

Mafic rocks within the ophiolitic series in the north of the Mehedinți Plateau have been previously refered to, but have not been studied from petrological and geochemical point of view. We think this paper will do this. It takes into consideration the results of our previous investigations (Savu et al., 1983, unpublished data).

Drăghiceanu (1885), Ștefănescu (1888) and Mrazec (1896) did the first observations on the Mehedinți Plateau which contributed to the establishment of the overthrust nappe structure of the Southern Carpathians (Murgoci, 1905). In 1940, Codarcea described between the Getic Nappe and the Danubian Autochthon, a parautochthon represented by the Severin Nappe which came from somewhere in the west. Later, Trifulescu and Mureșan (1962) are interested in mafic and ultramafic rocks. In 1962, Drăghici evidenced the fractures, which affect the Bahna Outlier. In 1982, Stănoiu supposed that the olistolith formation in the Severin Nappe belongs to the Upper Cretaceous Wildflysch and not to the Upper Jurassic-Lower Cretaceous as Codarcea said in 1940. Recently, Cioflica et al. (1980) presented as ophiolites only the mafic rocks, the ultramafic ones being considered as protrusions according to Șeclăman and Mărunțiu (1981) and Mărunțiu (1983). They consider the mafic rocks to be synchronous with the sedimentary deposits of the Severin Nappe which are supposed to belong to the Sinaia beds (Cr_1).

Basic rocks have been investigated by Savu (1980) in a synthesis paper and in two recent guides (Savu et al., 1978 ; Cioflica et al., 1981). Savu (1985) drew up the geotectonic model of Alpine ophiolites formation in the Mehedinți Plateau.

Geological Structure and Tectonical Position of the Ophiolitic Rocks

Geological structure is dominated by three tectonic units (Pl. I) : (1) the Danubian Autochthon, (2) the parautochthon (the Severin Nappe) and (3) the Bahna Outlier which belongs to the Getic Nappe (Codarcea, 1940).

The Severin Nappe composed of the Azuga beds (Codarcea, 1940) where ophiolitic rocks are also included, thrusts the Upper Cretaceous Wildflysch in the Danubian Autochthon, which contains olistoliths from the Severin Nappe and the basement Jurassic limestones (Pl. I). Stănoiu (1982) denied this nappe in the northern Mehedinți Plateau. Our investigations (Savu, 1985) show that it exists and it is composed of a Jurassic-Neocomian olistostrome (J_2-Cr_1) whose anchimetamorphic matrix includes olistoliths of ultramafic rocks, ophiolitic melange, crystalline schists and an olistoplate of Liasic basalts (diabases), the components of a subduction complex. It is not clear if the Severin Nappe moved after the Wildflysch had been formed or slid and was embedded in it during its formation, so that it could be considered as an olistonappe similar to the Cerna Nappe described by Stănoiu (1982).

The Severin Nappe represents only a part of the Jurassic-Neocomian olistostrome (Savu, 1985) which differs from the Upper Cretaceous Wildflysch because it does not include olistoliths of the Upper Jurassic-Lower Cretaceous limestones as the last one. In the west of the region (Valea Verde), the Jurassic olistostrome passes up to pelitic deposits which include only olistoliths of tectonized Precambrian crystalline schists and which represent the Sinaia Lower Cretaceous beds according to Codarcea (1940).

At the base of the Severin Nappe, drillings point out a tectonic melange (tectonic breccia — Jacotă et al., 1978) which discontinuously develops and occurs more obviously at north-east of Obîrșia Cloșani and south of the Ocna Hill (Pl. I). This formed by the shearing of the Jurassic-Neocomian olistostrome content during the nappe slide over the Upper Crètaceous Wildflysch and represents an obvious proof of this phenomenon.

The formations of the Jurassic-Neocomian olistostrome and the Azuga beds have been affected by anchimetamorphism processes at the end of the Late Kimmerian movements (143.7-127.9$\pm$5 m.y., K/Ar, Lemne et al., 1983), when the ophiolitic rocks have been metamorphosed as well.

Within the Severin Nappe, the olistoplate of mafic rocks extends from the Măgura Peak under the Bahna crystalline outlier, to Ponoare (Pl. I). It continues under this outlier to NE too, because the basic rocks occur on its margin at north of Titirlești and Brebina, but becomes thinner in this direction and disappears. Within the basalt olistoplate, we can notice tectonic inclusions composed of exotic blocks of Precambrian crystalline schists, serpentinites and even Azuga beds (Pl I), which shows that while the last were forming in the Severin Trough, the olistostrome was also involved in the friction zone between the two convergent plates. From structural point of view, in the zones bearing exotic blocks, the olistoplate is similar to the so-called "coloured melange" described by Gansser (1959) in the Middle East. Because of that, it could be considered an ophiolitic melange bearing a basaltic matrix (basaltic melange) and through its way of formation, it is similar to the ophiolitic melange (serpentinitic melange).

Basalts often occur in pillow lava facies (Pl. II, Pl. III, Fig. 1) or as simple flows, alternating sometimes with tuffs and basic agglomerates. We seldom meet doleritic sills and dykes. On the Dragu Brook and at the mouth of the Șipot Brook as well as on the Brebina Valley, among basalts flows intercalate levels of basic tuffs associated to red abyssal argillites and jaspers bearing radiolars flattened during the anchimetamorphism.

On the Borloveanu, Turcu and Mărășești valleys as well as in the Mărășești-Ponoare tunnel, among the tuffs intercalate black shales which remind us of black shales of the Schela formation (Lias) on the exterior border of the Danubian Autochthon. This intercalation of black shales supports a horizon of pyroclastics and basaltic flows, in which intercalate levels of Cu and pyrite mineralizations from the region. Therefore, the black shales intercalation becomes a guiding level which divides the basic rocks into lower and upper basalts (Jacotă et al., unpublished data). Another small intercalation of black shales occurs on the Borloveanu Brook at a stratigraphic level superior to the guiding level. Over the basaltic plate there are olistoliths of serpentinites, everything being covered by the anchimetamorphic schists of the Jurassic-Neocomian olistostrome.

Levels of black shales, abyssal red argillites and jaspers and especially those of basic tuffs maintain only inside the basaltic plate and do not extend outside in the Jurassic-Neocomian olistostrome matrix. This fact shows that undoubtedly basalts are older than the olistostrome in which was embedded the olistoplate and they did not form concomitently with it as other authors supposed. The presence of some small olistoliths of basalts and gabbros in the olistostrome confirms this point of view (Savu, 1985).

Considering that the Severin Nappe olistoliths represent components of a dismembered and consumed ocean crust, we have to admit that from the Carpathian ocean floor which evoluated between the Transylvanian and the Moesian Plate (Fig. 1A) have been first obducted the olistoliths of basalts, rocks which there composed the upper complex (O_1) situated on the ultrabasites complex (O_4) and then the olistoliths from the last one. The olistoliths have been successively obducted and embedded within the Jurassic olistostrome which was forming inside and on the border of the Severin Trough (eugeosynclinal zone, see Rutland, 1973) between the two convergent plates mentioned above (Fig. 1B). Today, these plates are represented by the actual Precambrian crystalline formations of the Moesian Plate and the Southern Carpathians which are in collision of continent/continent type (Fig. 1C). In order to support this outlook, we later brought a lot of arguments (Savu, 1985). To these we add today the geophysical ones according to Airinei (1982). A consequence of subduction processes which occured also during the Upper Cretaceous, is represented by the basalt-andesitic volcanics which are found in the Wildflysch between Balta and the Șușița Valley as well as the other banatites in the Banat.

At the end of the Wildflysch sedimentation on the Transylvanian sialic plate (Danubian Autochthon), when subduction is more accentuated and when started the Laramian movements, from the Severin Trough is broken an important plate of the olistostrome (Fig. 1C) and is pushed (obducted or overthrust) to the west over or in the Wildflysch and so resulted the Severin Nappe. Almost at the same time, or immediately after this, from the west the Getic Nappe gradually thrust and will cover all the later structures. Afterwards, the region is refolded (Pl. I), then the whole structure together with the basaltic olistoplate is influenced by several fracture systems, among which the most important

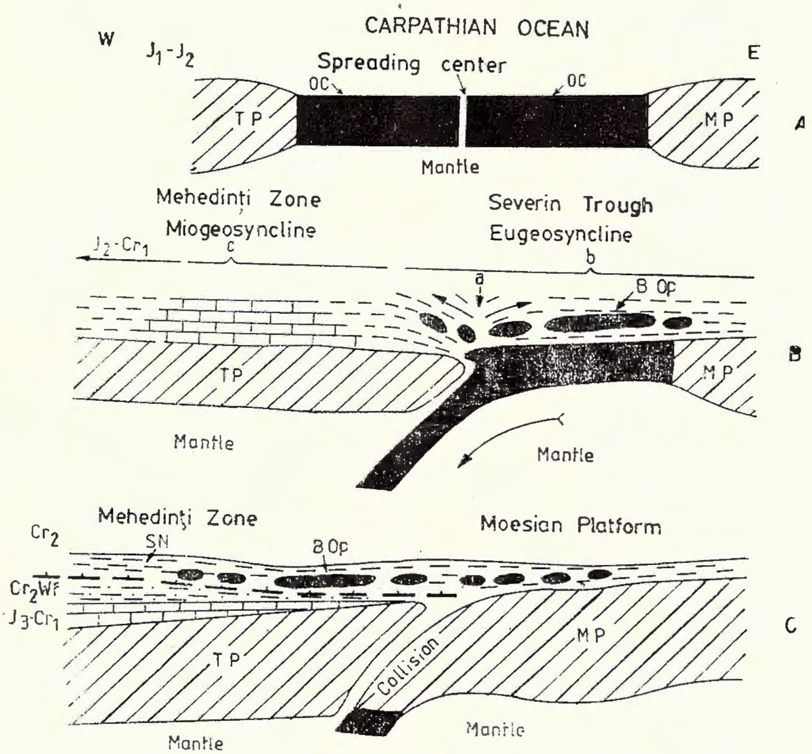

Fig. 1. — Model for the succession of geotectonical events which cause the formation and actual position of the olistoplate (olistonappe) of ophiolitic rocks from the Mehedinți Plateau. A, formation and spreading of the Carpathian Ocean between the Transylvanian Plate (TP) and the Moesian Plate (MP) during the Lias; OC, ocean crust. B, formation of the Jurassic-Neocomian olistostrome (J_2-Cr_1) under the conditions of ocean zone closure and subduction of its crust; a, subduction zone and formation zone of basic and ultramafic rocks and ophiolitic melange olistoliths which were obducted in two different directions; b, zone of the Severin Trough — olistostrome with pellitic matrix; B Op, Mărășești olistoplate (olistonappe) of basic rocks which was obducted and incorporated in the olistostrome with pellitic matrix (eugeosyncline zone); c, zone of epicontinental sea (Mehedinți Plateau and Eastern Banat) — olistostrome with terrigenous, carbonatic and volcano-sedimentary matrix (miogeosyncline zone). C, formation of the Severin Nappe (SN) which was thrust over or inside the Upper Cretaceous wildflysch (Cr_2, Wf) after the subduction up to the collision of continent/continent type of the two convergent plates; B Op, basic rocks olistoplate in the Severin Nappe.

is the Brebina fault (Pl. I). They cause vertical movements and slips of the blocks separated by them.

Regarding the above phenomena, we have to mention that there are also other opinions (Codarcea, 1940 ; Săndulescu, 1975 ; Stănoiu, 1982) according to which the Severin Nappe came from somewhere in the west, being pushed forward by the Getic Nappe.

Petrographic and Mineralogical Data

The association of rocks within the basalt olistoplate is composed of hyalobasalts, basalts, amygdaloidal basalts, anamesites, dolerites, agglomerates and tuffs. Here and there, the rocks are hydrothermally alterated, especially the lower basalts and are often crossed by veins of epidote, quartz, calcite, seldom by sulphides. Some of them are epidotizated, resulting so epidosites. They have been deformed under conditions of Late Kimmerian anchimetamorphism, having a S_1 incipient foliation and a S_2 cleavage.

1. Hyalobasalts and variolites form the crust of pillow lava separations. They are mainly composed of devitrified glass and partially replaced by chlorite. We seldom notice microlites and alterated microphenocrysts (Pl. III, Fig. 2) of plagioclase and of clinopyroxene substituted by chlorite. Within the variolites, plagioclase laths, which often are of albite, are gathered in rosettes, sheaves or garlands.

2. Basalts and amygdaloidal basalts (Pl. III, Fig. 3) have an intersertal or intergranular texture. They are composed of a network of plagioclase laths (An_{8-10}) within which there are chloritized glass and crystal of augite, magnetite maybe pyrite too. Amygdals have a zoned structure being filled with quartz on the borders and chlorite inside or on the margins with pistacite and inside with chlorite. There are also amygdals which are composed of only one of these minerals. In more intensely deformed rocks, amygdals are flattened and longer so that they may attain 5-10 mm length.

3. Anamesites contain a little chloritized glass which is placed within the interstitials of plagioclase network. It associates with augite and magnetite.

4. Dolerites have an ophitic texture and are composed of alterated plagioclase (An_{10-12}), augite and magnetite. Clinopyroxene ($c \wedge Ng = 48°$) has a poikilitic texture.

5. Agglomerates are composed of basalt blocks cemented with tuff, seldom silica and calcite and are sometimes flattened and lengthened (Măgura Valley). They are composed of devitrified glass, chlorite, magnetite dust, seldom augite and long microlites or albitic plagioclase microphenocrysts.

6. Basaltic tuffs have a crystallo-vitroclastic texture on which laid an incipient foliation. The primary minerals and glass have been replaced by chlorite associated with fine grains of secondary magnetite, as well

TABLE 1

Chemical composition of basic rocks

No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	Fe (S)	H_2O^+	Total
1	44.40	18.16	3.81	6.41	0.15	7.77	13.04	1.78	0.11	0.85	0.12	—	0.18	0.16	3.27	100.21
2	46.40	16.51	1.46	7.36	0.25	8.67	4.96	2.60	1.17	1.33	0.18	2.08	0.21	0.18	6.29	99.65
3	46.80	14.90	3.79	6.66	0.16	7.84	10.78	2.56	0.19	1.28	0.18	—	0.12	0.10	4.11	99.47
4	47.60	16.02	1.51	6.55	0.20	7.60	10.09	2.17	0.13	1.16	0.12	2.61	0.20	0.17	4.50	100.63
5	47.60	19.31	1.00	6.94	0.15	8.00	9.15	2.23	0.15	0.99	0.14	1.00	0.17	0.15	3.75	100.78
6	48.20	16.91	2.69	7.42	0.15	7.72	7.56	3.17	0.17	1.21	0.22	—	0.22	0.19	4.73	100.56
7	49.40	18.86	1.79	4.67	0.08	9.90	2.04	4.67	0.94	0.98	0.30	—	0.11	0.09	5.90	99.80
8	49.60	16.76	1.37	5.47	0.14	7.11	10.34	3.25	0.54	1.40	0.18	0.17	0.10	0.09	3.90	100.42
9	49.60	16.09	1.85	5.93	0.14	9.07	8.51	3.85	0.39	1.06	0.08	—	0.26	0.23	3.64	110.70
10	50.00	15.89	2.58	6.30	0.15	8.55	8.60	3.55	0.10	1.26	0.16	—	0.20	0.17	3.10	100.61
11	50.00	15.66	1.60	7.04	0.15	8.50	8.83	3.58	0.09	1.16	0.12	—	0.19	0.16	3.27	100.35
12	50.80	14.42	2.65	6.70	0.17	7.50	11.32	2.53	0.65	1.19	0.16	—	0.22	0.19	2.32	100.89
13	50.82	14 67	2.61	6.67	0.16	7.26	10.98	2.66	0.42	1.32	0.08	—	0.12	0.10	2.82	100.69
14	51.20	16.96	2.39	5.03	0.11	6.00	9.51	3.11	0.20	1.04	0.16	—	0.10	0.09	4.36	100.26
15	51.50	16.41	1.48	6.50	0.14	8.75	6.13	4.75	0.07	1.02	0.08	—	0.19	0.16	3.62	100.79
16	51.80	14.59	2.29	6.33	0.22	6.93	7.55	4.47	0.13	1.24	0.22	—	0.27	0.23	4.30	100.57
17	51.90	15.60	3.46	4.62	0.16	6.71	10.32	3.88	0.05	0.96	0.16	—	0.26	0.17	2.25	100.44
18	52.40	15.29	3.19	5.00	0.11	6.00	8.81	3.12	0.19	1.25	0.22	—	0.19	0.16	4.05	99.98
19	39.30	12.39	3.69	1.58	0.14	10.62	26.78	0.01	0.04	0.52	0	1.35	0.13	0.11	2.95	99.61

1, dolerite — Măgura Peak; 2, 4, basalts — Mărășești — Ponoare tunnel; 3, basalt — Băroaia Valley; 5, porphyritic basalt — Măgura Valley; 6, hyalobasalt — Turcu Valley; 7, amygdaloidal basalt (spilite) — Brebina Valley; 8, spilite — Dragu Valley; 9, 16 and 18, spilites — Turcu Valley; 10, 11 and 17, spilites — Măgura Valley; 12, basalt — Malareca Valley; 13, basalt — Ponoare Valley; 14, spilite — Ponoare Valley; 15, hyalobasalt (spilite) — Măgura Valley; 19, epidotized basalt — Turcu Valley.

as by albite and sericite which are formed on the account of plagioclase. Tuffs in whose structure enters a S_1 foliation, are crossed by veins of quartz and chlorite. We notice in all tuffs besides a S_1 foliation a S_2 cleavage too.

Geochemistry

This chapter deals with petrochemical aspects and distribution of trace elements.

1. Chemical composition of the rocks (Tab. 1) underlines their basaltic feature. Excepting two rocks, the other ones contain K_2O between 0.04 and 0.65% which indicate the existence of the ocean-floor tholeiites (Miyashiro, 1975). TiO_2 varies from 0.52 to 1.40% characterizing an ophiolitic series of "high-Ti" type, similar to the basic rocks from median ocean ridges (Serri, Saitta, 1980). The content of P_2O_5 varies from 0 to 0.30%; P_2O_5/Zr ratio (Beccaluva et al., 1977) places the rocks among tholeiites. FeOtot/MgO ratio varies in the series of analysed rocks from 0.47 to 1.34 which shows according to Miyashiro (1975) that they represent basalts of ocean-floor. In relation with our opinions (Savu et al., 1985b), they are attributed to undifferentiated tholeiites from the upper basaltic complex (O_1) of ophiolitic series with FeOtot/MgO$<$2. But we notice, as we have shown already (Savu et al., 1985a) an enrichment of Fe and Ti in some rocks and more Na_2O and SiO_2 in other ones. These features mark the two trends of the differentiation of tholeiitic magma even during this stage.

The tholeiitic character of the rocks is clearly evidentiated by the Figure 2 (Miyashiro, 1975). On the diagram SiO_2-FeOtot/MgO, some rocks shift in the CA field because of the higher content of SiO_2. On the diagram in Figure 3 (Irvine, Baragar, 1971), the rocks are placed

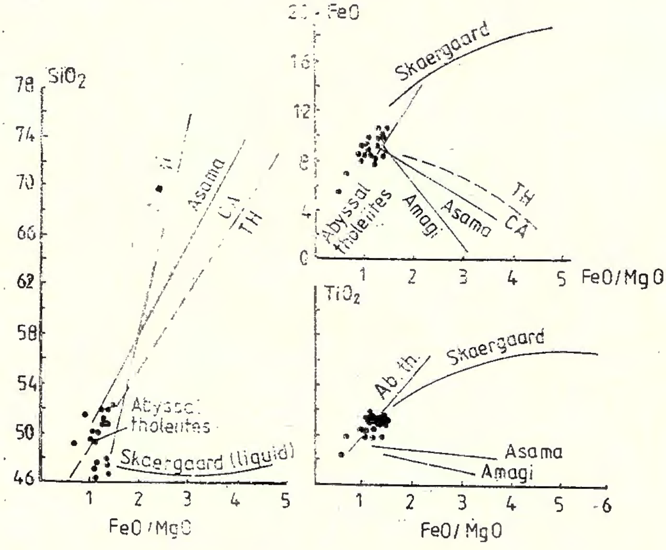

Fig. 2. — SiO_2, FeOtot, TiO_2-FeOtot/MgO diagrams.

within TH field, but spilites shift in the CA domain because Na_2O varies from 0.01 to 4.75%. If the typical tholeiitic basalts contain 2.50% Na_2O (Miyashiro, 1975) even 3%, the rest of the rocks have

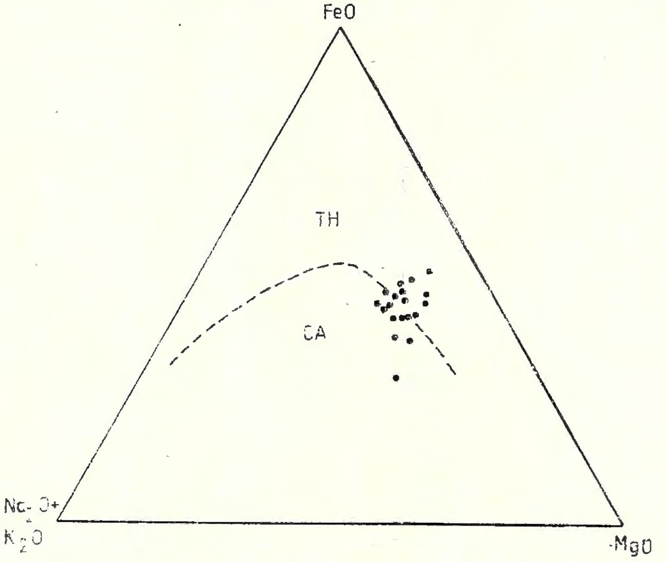

Fig. 3. — FeOtot-MgO-Na_2O+K_2O diagram.

to be assigned to spilites in which this component is more than 3%. Indeed, all rocks from CA field contain Na_2O from 3.11 to 4.75%.

If SiO_2 and Na_2O increase proportionally when spilites form by tholeiitic magma differentiation, it results that the rocks which stray of the behaviour of ocean-floor basalts on these two diagrams, are differentiated spilites (orthospilites. Savu et al., 1985). The tholeiitic magma has two trends of differentiation : one leads to the iron concentration (Fenner, 1929) and the formation of ferrobasaltic magmas and another one leads to the separation of the albite-granitic magmas which generate trondhjemitic granites bearing albite (Beccaluva et al., 1979 ; Ohnenstetter and Ohnenstetter, 1980). On this differentiation line are also situated orthospilites (Savu et al., 1985a). This conclusion is underlined by the fact that, although all rocks have been influenced by anchimetamorphism because of which their plagioclase has been decalcified-albitized, not all of them have high contents of Na_2O, only the orthospilites. In the case of "secondary spilitization" by hydrothermal alteration, reaction with marine water or by basalts metamorphism, CaO from plagioclase passes in carbonates or epidote depending on temperature and does not leave the rock anymore. As a result, although the rock is changed, its chemical composition shows its initial feature : basaltic or spilitic.

2. The contents of trace elements (Tab. 2) are characteristic for the basic rocks from ophiolitic series, excepting the epidotized basalt.

Ni and Cr have a large domain of variation, the relation between the minim and maxim value being about 1 : 10. Cobalt, vanadium and

TABLE 2

Trace elements (ppm) in basic rocks

Nr. crt.	Ni	Co	Cr	V	Sc	Nb	Zr	Y	Yb	La	Ba	Sr	Pb	Cu	Ga	Sn
1	300	30	550	95	20	<10	16	<10	<1	<30	<10	<10	<2	8.5	2	<2
2	160	52	300	180	26	<10	50	16	1.4	<30	18	150	<2	160	12	<2
3	100	19	270	170	22	<10	66	19	1.5	<30	72	26	<2	3	14	<2
4	125	45	200	200	39	<10	82	27	2.1	<30	20	46	2.5	60	16	<2
5	70	28	260	160	24	<10	72	20	1.5	<30	16	210	3	75	13	<2
6	115	38	480	260	40	<10	70	22	1.9	<30	22	200	2	45	7.5	<2
7	60	30	200	185	24	<10	58	22	1.8	<30	42	135	3	50	15	<2
8	200	27	400	215	23	<10	55	18	2.2	<30	82	135		67		
9	105	38	320	220	38	<10	80	26	2.3	<30	52	120	<2	30	9	<2
10	70	24	240	190	26	<10	56	19	1.7	<30	65	155	<2	48	11	<2
11	75	27	210	180	37	<10	70	20	1.6	<30	46	190	2.5	65	12	2.5
12	70	27	125	160	37	<10	67	18	1.8	<30	50	200	2.5	48	11	<2
13	35	24	50	165	26	<10	63	18	1.8	<30	82	260	2	65	13	<2
14	40	20	70	140	24	<10	56	15	1.5	<30	65	170	2.5	40	15	<2
15	125	28	230	170	23	<10	52	16	1.5	<30	44	149	2	45	10	2.5
16	90	26	300	140	23	<10	75	18	1.5	<30	48	230	2.5	37	8	<2
17	48	18	110	180	21	<10	60	18	1.5	<30	56	170	<2	44	10	2.5
18	78	21	190	125	29	<10	55	16	1.3	<30	46	370	2.5	60	10	<2
19	38	32	46	140	20	<10	70	18	1.2	<30	25	70	2	44	7.5	<2

The same legend as in Table 1.

scandium are characterized by contents, the variation of which is more limited; the ratio between minim and maxim value is 1 : 2, for Sc and 1 : 3 for Co. Zirconium and ytrium have reduced contents characteristic for the series of ocean-floor basic rocks. REE (Tab. 3) have also values which indicate the character of ocean-floor basalts for the basic rocks (Fig. 4).

TABLE 3

Distribution of REE (ppm) in basic rocks

Rock Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
La	7.8	8.2	4.8	4.4	3.5	5.2	1.7	4.6	5.2	3.6	6.1	3.4	1.3	—	3.2
Ce	30	29	48	17	20	15	33	44	7	12	48	29	35	18	33
Sm	1.8	1.8	1.1	1.3	1.4	1.6	0.9	1.8	1.3	2.5	3.2	2.1	2.2	1.8	1.9
Eu	0.63	0.68	0.45	0.57	0.72	0.47	0.52	0.50	0.55	0.67	0.56	0.57	0.58	0.38	0.56
Lu	—	—	—	0.39	—	0.20	0.27	0.31	—	0.21	0.39	0.40	0.48	0.31	—

1, basalt — Mărăşeşti — Ponoare tunnel; 2, 10, basalts — Brebina Valley; 3, basalt — Bradu Brook; 4, 5, basalt — Băroaia Valley; 6, basalt — Dragu Brook; 7, basalt — Măgura Valley; 8, basalt — Turcu Valley: 9, porphyritic basalt — Măgura Valley; 11, dolerite — Băroaia Valley; 12, basalt — Malareca Valley; 13, basalt — Ponoare; 14, dolerite — Măgura Peak; 15, basalt — Ghinii Valley.

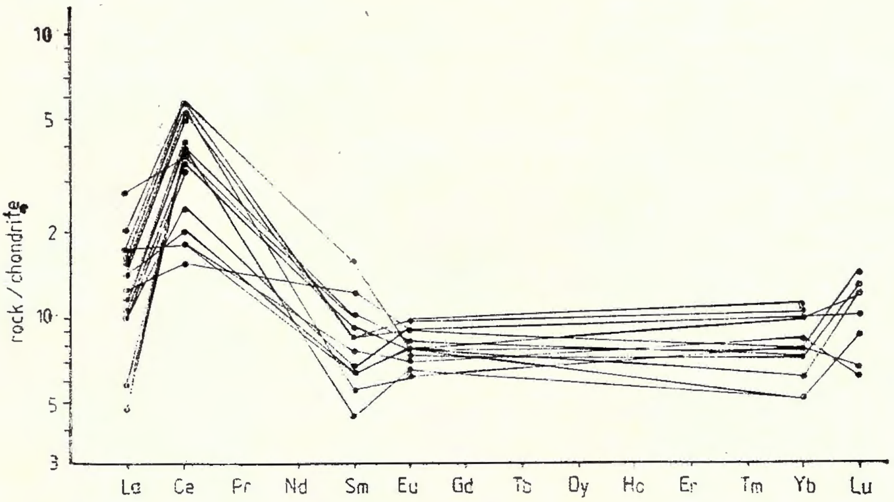

Fig. 4. — Chondrite-normalized REE patterns for the basic rocks of the Mehedinţi Plateau.

Barium varies from 16 to 82 ppm. On the diagram in Figure 5 (Miyashiro, 1975) all rocks are situated within the field of abyssal tholeiites corresponding to basalts of ocean-floor. Strontium has also

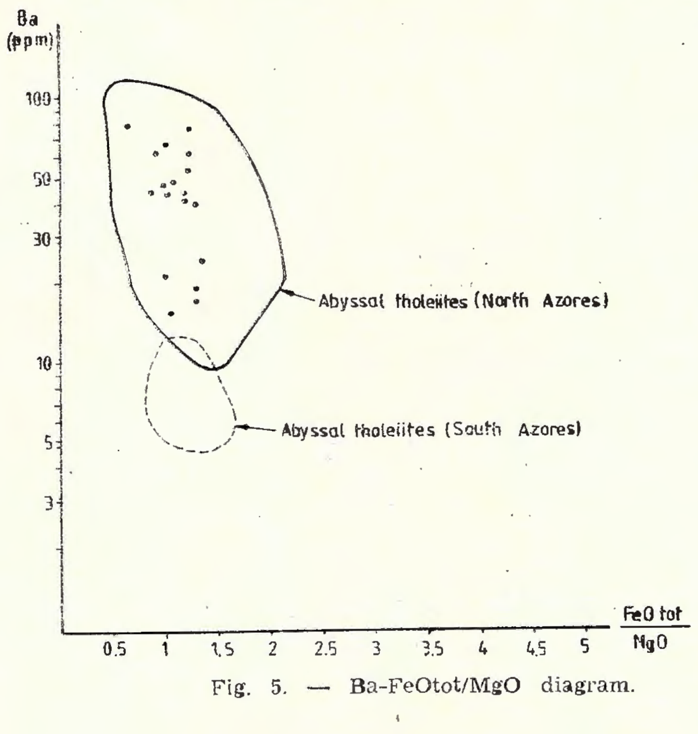

Fig. 5. — Ba-FeOtot/MgO diagram.

contents between 26 and 330 ppm ; Sr average in all series of rocks is 165 ppm. On Hart et al. (1970) diagram, this value shows that the parental tholeiitic magma formed in the mantle at about 125 km depth.

Origin of Ophiolitic Rocks

Owing to the above data, during the Lias in the mantle formed a magmatic chamber (Macdonald, 1982) from which erupted on the Carpathian ocean-floor basic magmas in the spreading zone. So resulted a basaltic complex of ocean-floor (Savu, 1980) under which there were

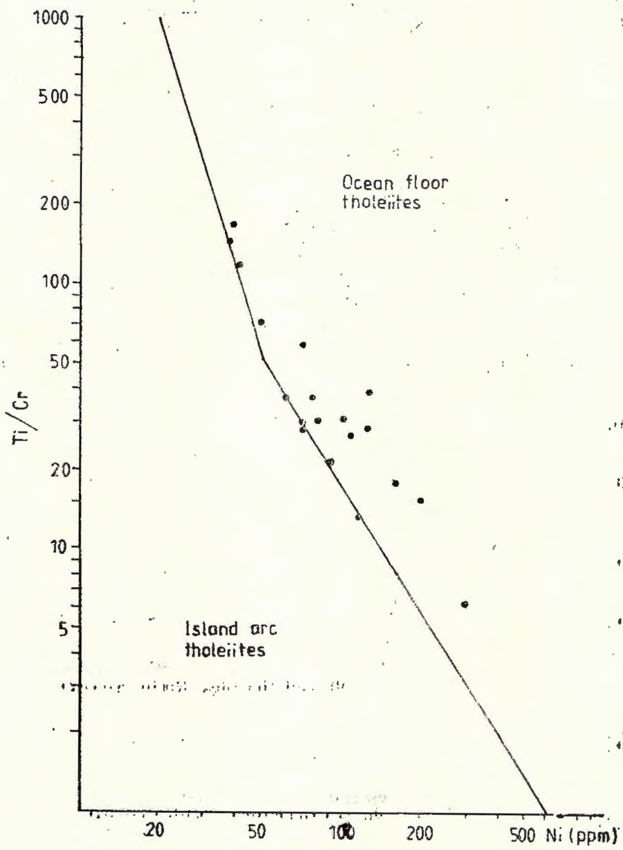

Fig. 6. — Ti/Cr-Ni diagram.

the other complexes of the ocean crust (Fig. 1). The formation of the Mehedinți Plateau ophiolitic series on the ocean-floor is clearly shown by the diagram in Figure 6 (Beccaluva et al., 1977) and Figure 7

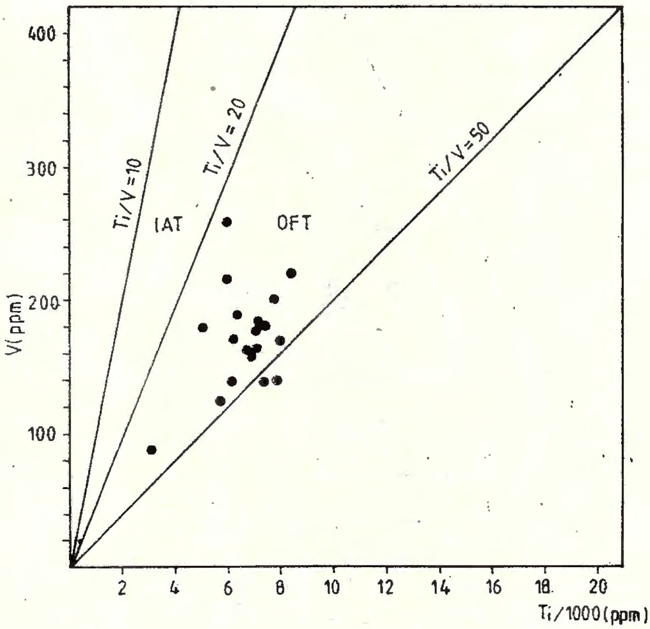

Fig. 7. — V-Ti/1000 diagram.

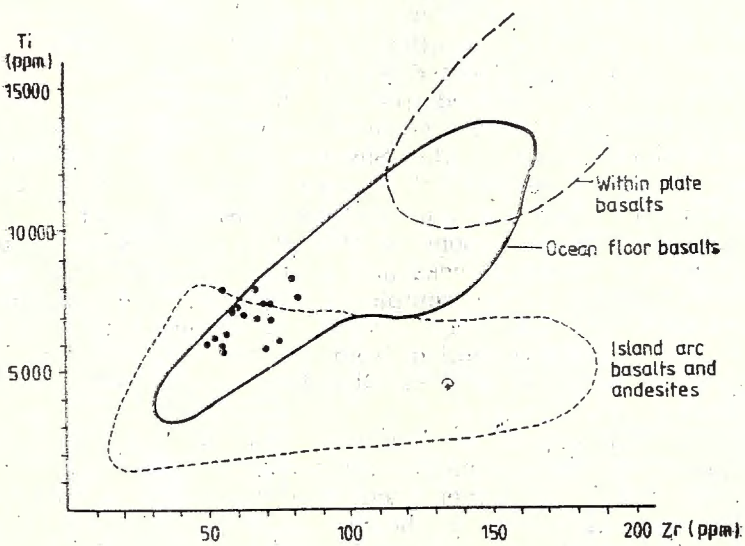

Fig. 8. — Ti-Zr diagram.

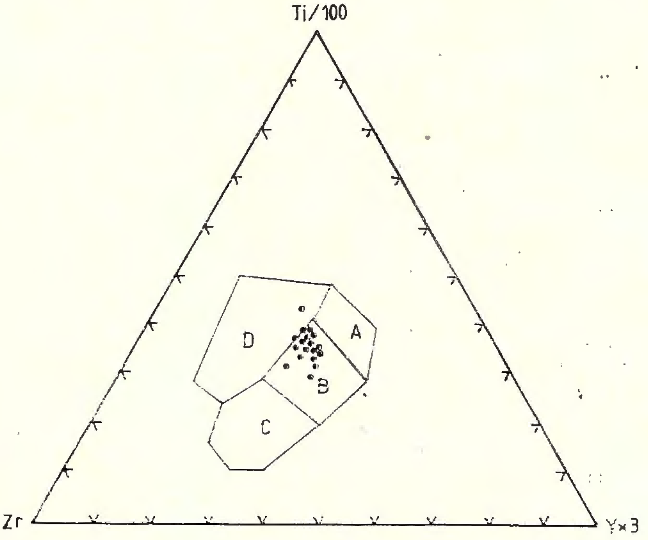

Fig. 9. — Ti/100-Y×3-Zr diagram.

(Shervais, 1982). The same results are obtained by plotting the basic rocks on diagrams in Figure 8 (Pearce, Gale, 1977) and Figure 9 (Pearce, Cann, 1973).

Conclusions

We draw the following conclusions.

The ophiolitic rocks from the Mehedinți Plateau, including the basaltic olistoplate, are alochthonous (Abbate et al., 1972; Coleman, Irwin, 1974) they being situated within the Severin Nappe (Pl. I).

These ophiolites resulted from the dismembered Liasic crust of the Carpathian ocean and occur as olistoliths within the Jurassic (J_2-J_3) — Neocomian olistostrome of the Severin Nappe which formed in the Severin Trough at the same time with the closure of the ocean zone being influenced there by anchimetamorphism (Fig. 1).

The olistoliths correspond to two groups of ophiolitic rocks: one group of basic (tholeiitic) rocks and another group of ultramafic rocks which in fact represent two complexes specific for the Carpathian ocean crust out of which have been scraped the ophiolites; they have been embedded as they were pulled from the ocean crust: first olistoliths (olistoplate) of basic rocks then olistoliths of ultramafic rocks and of ophiolitic melange.

At the beginning of the Laramian movements one part of the Jurassic-Neocomian olistostrome in the trough is broken and pushed to west over or inside the Upper Cretaceous Wildflysch on external border of the Transylvanian Plate as the Severin Nappe, then overthrust from west the Getic Nappe to which also belongs the Bahna crystalline outlier.

Then follows the refolding of the whole edifice, the basic rocks olistoplate with its matrix forming a syncline (Pl. I).

Therefore, results the alochthonous ophiolitic series from the Mehedinți Plateau represented by olistoliths of basic and ultramafic rocks, the only traces of an ocean which closed and whose crust was dismembered and almost totally consummed.

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[3] Ultramafic rocks within the region (Pl. I), which also occur as olistoliths, some of them being situated on the basaltic olistoplate (olistonappe) or tectonically included in it — among which one has bigger sizes (olistoplate or olistonappe of Obîrșia Cloșani) — have been studied in a recent work: H. Savu, C. Udrescu, V. Neacșu (1985). Petrology and geochemistry of ultramafic rocks and ophiolitic melange olistoliths in the olistostrome of the Severin Nappe between Godeanu and Baia de Aramă (Southern Carpathians). Rev. Roum. Géol., Géophys., Géogr., Géologie, 29, p. 45-53, Bucarest.

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QUESTIONS

D. Săndulescu: Could you make any differences concerning the neominerals which occur during the ocean floor metamorphism in comparison with those which occur during the low grade metamorphism?

Answer: The effects of ocean floor metamorphism have been mostly wiped out by the Late Kimmerian anchimetamorphism. However, we think that the epidotizations and epidotites are the products of the ocean floor metamorphism.

M. Ștefănescu: Are there paleontologic arguments for a Lower Jurassic age of the olistostrome?

Answer: Only the mafic and ultramafic olistoliths come from a Liasic ocean crust. The olistostrome was found in the trough starting with Middle Jurassic end and up to Lower Cretaceous, when it is affected by a very low grade metamorphism (143-127 ym K/Ar).

M. Ștefănescu: The geochemical arguments of an oceanic origin of mafic rocks attributed to the Severin Unit are welcome because they stress one's more their position in the nappe. The Severin Nappe is not an isolated structural element limited only to the South Carpathians. It is the equivalent of the Ceahlău Nappe from East Carpathians, more precisely of its internal part, which is known as the Bratocea digitation. Within the Sinaia beds of the Bratocea digitation, there are intercalated mafic rocks attributed to the Azuga beds (together with silicolites, radiolarites, red and green phyllites). On this paquet, there develops a continuous succession of flysch which begins in the Upper Tithonian up to the Aptian (Sinaia beds, Comarnic beds or their internal equivalent, Piscu cu Brazi facies). Therefore, we can deduce both that the last mafic rocks (the youngest) in normal position and not allochthonous are Berriasian and that sedimentation has not been interrupted by important tectonic events which would have generated the Jurassic-Upper Cretaceous olistostrome; taking into consideration the continuation of the Severin Nappe inside the Ceahlău Nappe (Bratocea digitation) and because Dr. Savu's paleotectonic interpretation implies the whole accumulation zone of the Sinaia flysch, we think that the above interpretation should have considered the data outside Banat as well. Concerning the moving direction of the unit with the Sinaia beds, we wish to mention that numerous microfolds of the Sinaia flysch indicate an inside to outside movement, which contrasts with the interpretation in the communication.

Answer: The relation between the sedimentary matrix of the Azuga and Sinaia beds bearing exotic blocks of mafic and ultramafic rocks and crystalline schists show that they are olistoliths and I guess that in East Carpathians such rocks have the same character. That is why in the interpretation in the East Carpathians you should consider the processes within the Mehedinţi Plateau as well. Concerning the microfolds within the Sinaia beds, it is sure they did not form during the overthrusting but a little earlier during the formations folding when the Azuga beds were affected by the very low grade metamorphism. And, if the subduction took place from east to west, it is obvious that the structures vergence should have been eastern. The latter overthrust is different in direction, at least in the case of the Severin Nappe from the Mehedinţi Plateau.

PETROLOGIA, GEOCHIMIA ŞI ORIGINEA ROCILOR OFIOLITICE BAZICE DIN REGIUNEA OBÎRŞIA CLOŞANI-BAIA DE ARAMĂ (PLATOUL MEHEDINŢI)

(Rezumat)

Rocile ofiolitice din Platoul Mehedinţi sînt alohtone (pl. I), ele fiind cantonate în olistostroma jurasică-neocomiană a pînzei de Severin. Ele sînt reprezentate prin olistolite de roci bazice şi ultrabazice, între care se remarcă o importantă olistoplacă de roci bazaltice. Aceasta este constituită din curgeri de bazalte în facies de pillow lava, printre care se disting hialobazalte, variolite, bazalte, bazalte amigdaloide, anamesite, dolerite, aglomerate şi tufuri bazaltice, cu care se asociază intercalaţii de jaspuri, argilite roşii şi şisturi negre. Rocile ofiolitice au suferit şi ele, ca şi olistostroma jurasică, un proces de anchimetamorfism. Ca urmare, în ele şi mai ales în tufuri, s-au imprimat pe alocuri o foliaţie S_1 şi un clivaj S_2.

Analizele chimice (tab. 1) şi elementele minore (tab. 2) arată că rocile bazice s-au format pe fundul Oceanului carpatic, deoarece pe diferite diagrame (fig. 2-9) ele se situează în cîmpul rocilor tholeiitice de fund oceanic. Aceste roci au rezultat dintr-o magmă tholeiitică ce a luat naştere în manta, la adîncimea de 125 km, aşa cum arată proiecţia mediei conţinuturilor de stronţiu pe diagrama construită de Hart et al. (1970). Conţinuturile de titan din aceste roci indică, de asemenea, că ele aparţin seriei ofiolitice de tip high-Ti, care după Serri şi Saitta (1980) este asemănătoare cu rocile tholeiitice din ridgeurile oceanice mediane.

Pămînturile rare din aceste roci bazaltice au de asemenea conţinuturi cu valori apropiate (tab. 3), specifice bazaltelor de fund oceanic, aşa cum reiese şi din diagrama din figura 4.

Olistoplaca de roci ofiolitice a provenit din dezmembrarea crustei Oceanului carpatic, de unde a fost obdusă și însedimentată în olistostroma jurasică (J_2-J_3)-neocomiană a pînzei de Severin, ce s-a format în fosa de Severin, odată cu închiderea zonei oceanice și subducerea crustei acestuia în condițiile mișcării convergente a plăcii moesice și a plăcii transilvane. Olistostroma a suferit un proces de anchimetamorfism care a afectat atît matricea, cît și olistolitele de roci bazice și ultrabazice.

Olistolitele corespund la două grupe de roci ofiolitice : o grupă de roci bazice tholeiitice de care ne-am ocupat în această lucrare și o grupă de roci ultrabazice descrisă de noi cu alte ocazii. Acestea reprezintă două complexe specifice ale crustei oceanice, din care au fost rupte olistolitele, fiind însedimentate apoi în olistostromă în ordinea în care au fost smulse ele : olistolite (olistoplaca) de roci bazaltice, urmate de olistolite de roci ultrabazice și de mélange ofiolitic (m. serpentinitic).

La începutul mișcărilor laramice, cînd se reactivează și procesele de subducție, o parte din olistostroma jurasică din fosă este ruptă și împinsă spre vest peste sau în Wildflischul cretacic superior — de pe marginea externă (estică) a plăcii transilvane, formînd astfel pînza de Severin. Peste aceasta șariază de la vest spre est pînza getică, ce a acoperit toate structurile anterioare. La această pînză aparține și petecul cristalin de Bahna (pl. I). Urmează recutarea întregului edificiu, astfel că olistoplaca de roci bazice mulează împreună cu matricea sa forma unui sinclinal (pl. I).

Se formează astfel seria ofiolitică alohtonă din Platoul Mehedinți, reprezentată prin olistolitele de roci bazice și ultrabazice, singurele vestigii ale unui ocean ce s-a închis și a cărei crustă a fost dezmembrată și aproape în întregime consumată.

EXPLANATION OF PLATES

Plate II

Fig. 1. — Flattened pillow lava on Turcu Valley.

Fig. 2. — Flattened pillow lava on Turcu Valley.

Plate III

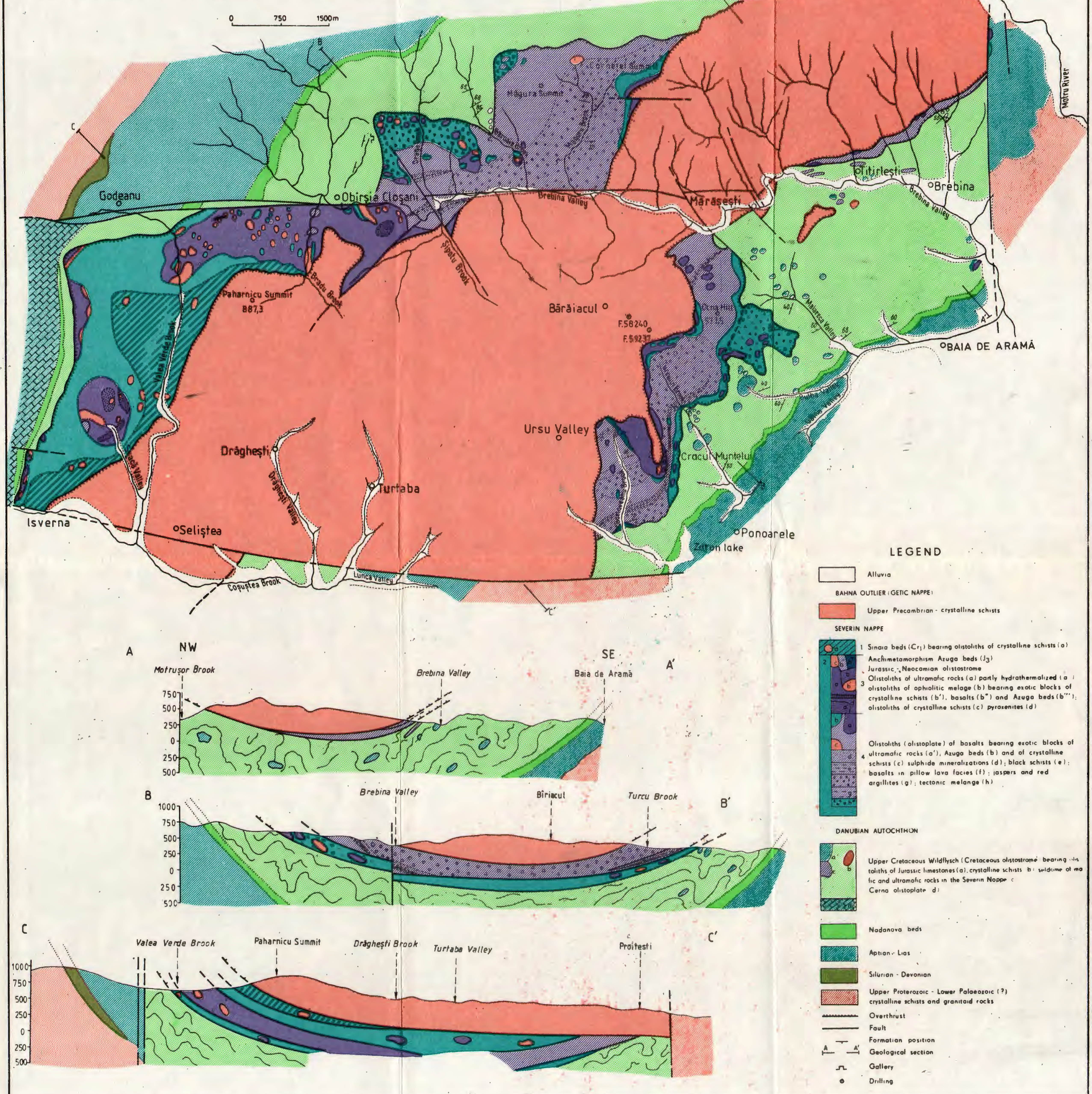
Fig. 1. — Basalts in pillow lava facies on Turcu Valley.

Fig. 2. — Hyalobasalt — Măgura Valley. Nic. ||, × 25.

Fig. 3. — Amygdaloid basalt — Mărășești-Ponoare tunnel. Nic. ||, × 25.

H. SAVU

GEOLOGICAL MAP OF ISVERNA - OBÎRŞIA CLOŞANI - BAIA DE ARAMĂ REGION



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

IUGS UNESCO

Project 5 : Corre'..ion of Pre-Variscan and Variscan Events Mr..iterranean Belt

PERMIAN IGNIMBRITIC ROCKS OF THE SOUTH BANAT (SVINIȚA-BAIA NOUĂ-TÎLVA FRASINULUI) [1]

BY

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Ignimbrites. Permian. Povalina Formation. Trescovăț Formation. Rhyolitic ignimbrites. Rhyodacitic ignimbrites. Mineralogical composition. Chemical composition. South Carpathians — Sedimentary Danubian Domain — Svinița-Svinecea Zone.

Abstract

Permian ignimbritic rocks of the South Banat belong to two formations: Povalina formation (dacitic volcanic conglomerates intercalated with rhyodacitic ignimbritic flows and terrigene epiclastic material) and the Trescovăț formation (rhyolitic ignimbritic flows). The ignimbritic character of the Permian eruptions results from their morphology, their extention and thickness, the structural and textural particularities, and the chemical and mineralogical composition of the rocks

Résumé

Roches ignimbritiques permiennes du Banat du Sud (Svinița-Baia Nouă-Tîlva Frasinului). Dans le Banat du Sud se développent des roches ignimbritiques permiennes. Elles appartiennent à deux formations : formation de Povalina (conglomérats volcaniques dacitiques intercalés dans des coulées rhyodacitiques ignim-

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britiques auxquelles s'ajoutent d'une manière subordonnée du matériel épiclastique terrigène) et formation de Trescovăț, constituée exclusivement des coulées ignimbritiques rhyolitiques. Le caractère ignimbritique des éruptions permiennes résulte des particularités structurales et texturales, de la composition chimique et minéralogique des roches composantes.

Introduction

Permian effusive rocks of the South Banat were mentioned or described as quartz porphyries by Boué, Foetterle, Tietze, Böckh, Telegd, Schafarzik (fide Răileanu, 1953) in the 19th century. Also as quartz porphyries they were described by Codarcea (1953), Răileanu (1953, 1957, 1960) and Boldur, Stănoiu and Stillă (1963, 1964).

Field and laboratory researches carried out recently have pointed out the development of an ignimbritic rhyodacitic volcanism in the study area.

Description of Permian Volcanics

Permian volcanics can be found on a surface of about 200 sq. km. They unconformably overlie either Carboniferous volcano-sedimentary formations or a Cambrian-Upper Precambrian basement, represented by crystalline schists, gabbros and serpentinites, and are overlain by the Liassic (Răileanu, 1957).

Permian volcanics consist of ignimbritic flows and epiclastics. Considering the tectonic evolution of the region, the lithology of the sedimentary deposits and the chronology of the volcanic events, Stănoiu and Stan (1986) have divided this complex into two formations : Povalina volcano-sedimentary formation, at the lower part, and Trescovăț volcanic formation, at the upper part.

Povalina Volcano-Sedimentary Formation

This formation consists chiefly of a more or less intimate mixture of red sandstones and schists ($\pm$limestones), dacitic volcanic conglomerates and microconglomerates, within which ignimbritic rhyodacites are intercalated.

The above-mentioned formation occurs in the left-side of the Danube, between Munteana and Povalina. It also crops out in the left tributaries of the Danube, on the Ionașeva Brook, Ielișeva Brook, Gropan Ravine, Povalina Brook, as well as in the Sirinia Valley spring zone and the upper basin of the Mraconia Valley.

In some zones sandstones clearly prevail over the dacitic conglomerates ; in other zones (with a considerable areal development) the Povalina formation is represented by dacitic volcanic conglomerates and microconglomerates (90-100%), locally in association with ignimbritic rhyodacitic flows (Stănoiu, Stan, 1986). Elements of gneisses, quartz, red sandstones, gabbros, serpentinites or andesite-basalts are sometimes found in conglomerates on relatively small areas.

Volcanic conglomerates and microconglomerates as well as ignimbritic flows have been studied in petrochemical respect.

a) The dacitic volcanic conglomerates and microconglomerates of the Povalina formation consist of mostly rounded, well rolled elements, with sizes up to 15-20 cm. Sometimes they have a breccious, angular character and sizes up to 5-10 cm. The colour of conglomerates and microconglomerates varies strikingly from one zone to another or even from one element to another : green-violaceous, grey, yellow. However, the brick-red colour prevails, being determined by the iron oxides. Conglomerates are generally devoid of stratifications ; in places a torrential cross stratification is observed. The matrix is psephitic-gritty, slightly ferruginous. According to Răileanu, the thickness exceeds 1 000 m.

The petrochemical study of the elements forming conglomerates points to their dacitic character, sometimes keratophyric.

Microscopically one can observe either an ununiformly devitrified vitreous mass, impregnated with iron oxides$\pm$phenocrysts, that represent 10-15% of the rock, or angular or subangular fragments of pumice or glass and a large amount of detrital or magmatic phenocrysts (50-70%). The fragments of pumice and glass are generally not welded; fiammes, that locally give rise to eutaxitic textures, have also been identified.

Phenocrysts are represented by albite-oligoclase, oligoclase or andesine, quartz, biotite (sometimes baueritized) and hornblende.

Plagioclase is polysynthetically twinned and locally zoned, replaced by calcite or sericite.

Magmatic quartz is strongly corroded ; a detrital, broken, chippy quartz, with smaller sizes, sometimes occurs beside it or independent of it. Quartz — both magmatic and detrital — can be lacking ; however, in the groundmass there is always a sufficient amount of SiO_2 which, together with K_2O, testifies the assigning of these rocks to dacites.

Biotite is often opacitized. Locally chlorite occurs. Fresh biotite flakes were observed exceptionally.

Hornblende is opacitized or chloritized and it could be recognized after its basal contours.

Iron oxide is omnipresent. The rock has yellow-reddish or grey-reddish spotted colours.

The rock texture is extremely various : vitroclastic, vitrocrystalloclastic, eutaxitic. The ratio groundmass/phenocrysts is highly variable.

b) Ignimbritic rhyodacites of the Povalina formation are found as intercalations in volcanic epiclastic rocks. In several cases they cannot be mapped. Nevertheless, in the lower and upper course of the Staricica Valley, Hurculovăț Hills and Tîlva Frasinului they are individualized.

Ignimbritic rhyodacites show a reddish-violaceous colour ; they are extremely hard. Sometimes they form vertical, ruiniform columns other times ignimbritic rocks are tabular, pseudostratified.

The microscopic analysis indicates that these rocks often consist of angular or subangular submillimetric fragments of devitrified glass, cemented with a fine, almost isotropic powder ; in other cases both the fragments and their binder are impregnated with quartz micrograins with more or less dented margins. Phenocrysts are often lacking from these rocks ; when present, they usually represent small percentages (2-5%). They are represented by corroded, magmatic quartz $\pm$ kaolinized-sericitized potash feldspar and sericitized-calcitized plagioclase. Albite usually has a chessboard structure. Granophyre-like textures resulting from the close association of quartz-feldspar are frequently found. Locally, the groundmass of ignimbritic rhyodacites displays spherulitic textures resulting from devitrification ; the keratophyric aspect is suggested in some cases.

Biotite and hornblende (opacitized, sericitized or chloritized) occur more rarely than in the dacite volcanic conglomerates of the Povalina formation.

Microscopically, the rock resembles fine- or coarse-grained tuffs impregnated with quartz grains and spotted with iron oxides. Small amounts of phenocrysts seldom occur in this devitrified tuffaceous mass in different stages. The mixed character of tuffs and lavas are specific to the ignimbritic rocks.

Trescovăț Volcanic Formation

Trescovăț volcanic formation consists only of ignimbritic rhyolitic rocks ; detrital sedimentary material does not occur. They crop out in the middle and upper course of the Staricica Valley, Streniac, Cucuiova and Trescovăț summits, spring area of the Livadița Valley and Argista Ravine. The tabular-shaped formation covers the older deposits like a plate.

The colour of the rocks varies, but the light colours are typical : white-yellowish, grey, white ; they are often spotted with iron oxides. These rocks are hard and very hard, slightly greasy due to the frequent kaolinitizations and sericitizations. Fluidal structures are often observed macroscopically.

Under the microscope the rocks display characters of tuffo-lavas. The magmatic phenocrysts — made up of quartz, potash feldspar, plagioclase, biotite (sometimes baueritized) and very rarely hornblende — participate in variable proportions, in most cases they represent 5-10% of the rock mass. Phenocrysts are not frequently found. Mesostasis consists of a devitrified fine- or coarse-grained tuff, with a cryptocrystalline-felsitic texture. It is worth mentioning that, even within the same thin section devitrification has different intensities. Locally millimetric or submillimetric particles, with angular or subangular contours, strongly devitrified and cemented with a very fine, almost isotropic or poorly cryptocrystalline tuffaceous material, are also found. Submillimetric quartz grains, round, lobate, elongated, with dented margins, with an ordered distribution or at random in the rock mass, occur very frequently. They partly replace some phenocrysts on cleavages, breakings or twinning planes. Chalcedony is more rarely observed, filling voids preexistent in the rock. The mentioned quartz grains clearly differ as regards the sizes and morphology from magmatic quartz. The latter is found as phenocrysts (∅ 1-3 mm), corroded, with xenomorphic contours or as chippy fragments more or less resorbed.

Plagioclase (albite-oligoclase) is polysynthetically twinned ; it is frequently sericitized and calcitized.

Potash feldspar occurs quite often in thin sections, and is partly or totally covered with a fine kaoline powder.

Biotite is totally or partly baueritized, chloritized or opacitized.

Hornblende entirely opacitized is rarely found.

Fiammes can be observed in a devitrified mesostasis in some cases.

Chemistry

The chemical study of the South Banat volcanic rocks is based on 15 analyses for major elements and 14 analyses for trace elements.

Major Elements

The oxide values are presented in Table 1. SiO_2 amount is high, often much higher than for rhyolites. The variation interval ranges between 73.51 and 81.0%. For this reason the Niggli parameter *si* shows chiefly high and very high values (491-686) and consequently the magma group cannot be specified in most cases (Table 2).

The SiO_2 amount increases from the older rocks to the younger ones: 74.06-77.02% for elements from volcanic conglomerates, 73.51-79.52% for ignimbritic flows of the Povalina formation, 77.16-81.0% for the ignimbritic flows of the Trescovăț formation. The significant amount of SiO_2 is testified not by the magmatic quartz phenocrysts found in relatively small amounts (sometimes the magmatic quartz is lacking) but by the glass from mesostasis.

On Streckeisen's *Q-A-P-* diagram (Fig. 1) volcanic conglomerates (3 samples) plot in the dacite field ; ignimbrites of the Povalina formation (6 samples) are found in the rhyolite and dacite areas ; ignimbrites of the Trescovăț formation (6 samples) occur in the rhyolite field.

On the *alk-al* diagram (Fig. 2) ignimbritic rhyolites, rhyodacites and dacites plot in the alkaline and intermediary-alkaline field. The salic character is obvious (Fig. 3).

Ignimbritic volcanics are poor in MgO and Fe_2O_3+FeO, but Na_2O+K_2O are found in significant amounts (Fig. 4). Volcanic conglomerates richer in femic minerals (biotite and hornblende) have MgO and Fe_2O_3+ FeO in great amounts as against the other volcanics.

TABLE 1

Permian volcanics of South Banat.

Chemical composition

No.	Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O^+	CO_2	S	Fe(S)	Total	Fe_2O_3 Total	Location	Denomination of formation and rock type	
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	60	67.22	0.37	16.33	1.63	1.27	0.13	0.77	2.51	3.10	3.15	0.28	2.18	0.50	0.05	0.04	99.53	0.10	Povalina Valley		
2	70	77.16	0.09	13.15	0.33	0.16	0.02	0.31	0.25	4.28	2.03	0.07	1.72	0.00	0.05	0.04	99.66	0.58	Left summit		
3	16	78.31	0.00	12.15	0.46	0.10	0.06	0.37	0.65	3.08	2.78	0.00	0.86	0.84	0.10	0.09	99.85	0.70	Staricica Valley	ignimbritic rhyolites	Trescovăț formation
4	12	78.32	0.08	10.15	0.32	0.00	0.02	0.14	2.14	5.68	2.36	0.00	0.81	0.00	0.07	0.06	100.15	0.40	Staricea Valley		
5	92	80.07	0.14	11.78	0.07	0.11	0.00	0.23	0.22	5.80	0.22	0.08	1.12	0.00	0.05	0.04	99.93	0.26	Staricea Valley		
6	11	81.00	0.02	10.00	0.16	0.03	0.03	0.15	2.66	5.10	0.00	0.08	0.97	0.00	0.09	0.08	100.37	0.30	Trescovăț Hill		
7	39	73.51	0.22	12.90	2.40	0.00	0.03	0.51	0.46	4.48	3.46	0.00	1.47	0.00	0.08	0.07	99.59	2.50	Dunării Valley		
8	44	73.58	0.15	13.40	0.92	0.00	0.03	0.31	0.42	6.30	3.70	0.00	0.95	0.00	0.08	0.07	99.91	1.00	Ielişeva Valley		
9	48	74.90	0.14	13.60	1.27	0.10	0.02	0.48	0.29	5.40	2.70	0.03	1.12	0.00	0.08	0.07	100.20	1.46	Ielişeva Valley	ignimbritic rhyodacites	
10	36	74.93	0.20	12.35	2.18	0.00	0.02	0.38	0.35	3.36	4.28	0.05	1.93	0.00	0.07	0.06	100.16	2.26	Dunării Valley		Volcano-sedimentary Povalina formation
11	41	79.46	0.02	12.24	0.14	0.03	0.02	0.02	0.43	0.00	6.80	0.00	0.45	0.00	0.08	0.07	99.76	0.27	Dunării Valley		
12	42	79.52	0.06	11.00	0.40	0.03	0.04	0.12	0.98	1.48	5.16	0.01	0.40	0.68	0.07	0.06	100.01	0.50	Dunării Valley		
13	57	74.06	0.33	13.62	1.63	0.35	0.03	0.92	2.20	1.84	3.85	0.07	0.91	0.00	0.06	0.05	99.92	2.09	Răspute Valley		
14	85	75.06	0.35	13.30	1.80	0.51	0.02	0.40	1.62	1.34	4.35	0.10	0.60	0.00	0.06	0.05	99.56	2.44	Dunării Valley	dacitic volcanic conglomerates	
15	87	77.02	0.19	11.84	1.49	0.79	0.00	0.31	1.18	2.00	4.17	0.07	0.50	0.00	0.05	0.04	99.65	1.65	Dunării Valley		

Analyst, Elena Colios.

Na_2O predominates quantitatively in volcanic conglomerates over K_2O. In ignimbritic rhyodacites of the Povalina formation K_2O clearly predominates quantitatively ; in case of the ignimbritic rhyolites of the Trescovăț formation K_2O increases while Na_2O decreases (Fig. 5). The

TABLE 2

Permian volcanics of South Banat

Niggli parameters

No.	Sample no.	*Si*	*al*	*fm*	*c*	*alk*	*Q*	*A*	*P*	Magma type
1	60	321	46.0	17.0	12.9	24.0	26.2	53.8	19.6	trondhjemitic
2	70	575	57.3	5.8	1.8	34.9	41.9	23.1	34.5	?
3	16	579	52.8	7.5	4.9	34.6	43.6	18.6	37.3	?
4	12	538	40.9	2.9	15.7	40.5	40.3	36.1	23.3	?
5	92	686	59.7	4.6	2.0	33.5	49.2	34.7	16.1	?
6	11	661	48.0	2.5	23.0	26.4	53.3	30.9	15.7	?
7	39	436	45.2	15.0	2.8	37.0	31.4	28.4	40.2	trondhjemitic
8	44	431	46.1	6.7	2.5	44.7	25.1	39.1	35.8	trondhjemitic
9	48	466	49.7	10.5	1.9	37.8	32.9	32.4	34.5	leucogranitic
10	36	462	44.8	14.0	2.2	38.8	33.1	45.8	21.1	leucogranitic
11	41	549	50.2	0.8	3.3	45.6	35.7	0.0	64.2	?
12	42	561	46.3	3.8	7.3	42.3	39.7	9.2	51.0	?
13	57	409	44.0	16.0	13.0	27.0	36.2	11.2	52.7	trondhjemitic
14	85	442	46.0	13.8	10.2	29.7	37.1	6.4	56.4	trondhjemitic
15	87	491	44.4	13.8	8.0	33.7	39.6	12.5	48.9	?

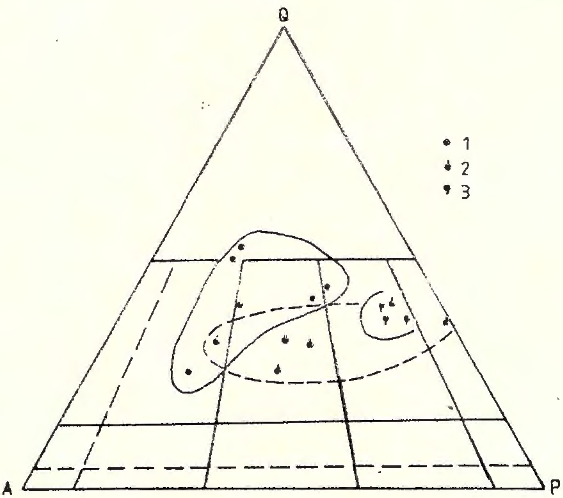

Fig. 1. — *QAP* Streckeisen diagram ; Normative composition. Trescovăț volcanic formation : ignimbritic rhyolites (1); Povalina volcano-sedimentary formation : ignimbritic rhyodacites (2) and dacitic volcanic conglomerates (3).

results of the chemical analyses correspond to the microscopic observations. Potash feldspar does not occur as phenocrysts in the conglomerates of the Povalina formation ; unlike it albite-oligoclase is omni-

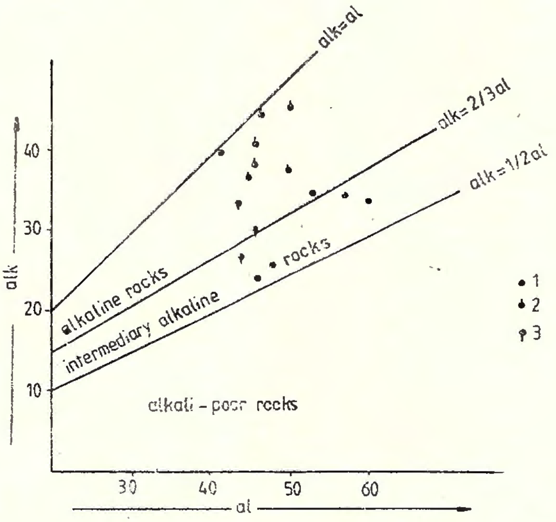

Fig. 2. — *al-alk* diagram. Legend as in Figure 1.

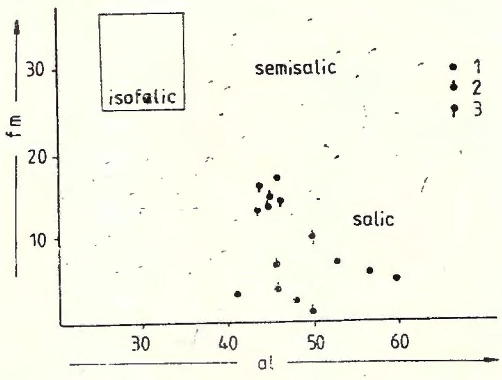

Fig. 3. — *al-fm* diagram. Legend as in Figure 1.

present here. In ignimbritic rhyodacites of the Povalina formation potash feldspar is found beside albite-oligoclase. In the Trescovăţ formation potash feldspar occurs, whereas albite can be lacking.

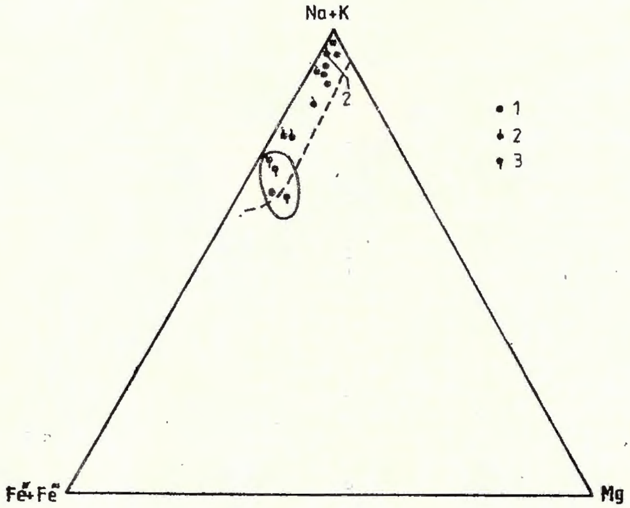

Fig. 4. — Na+K — Fe''+Fe'''-Mg diagram. Legend as in Figure 1.

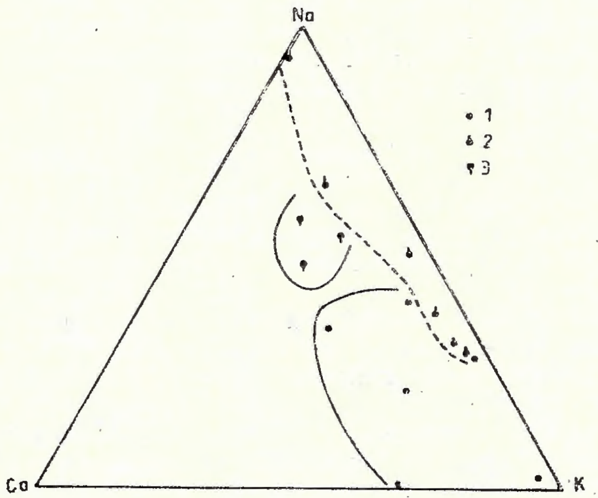

Fig. 5. — Na-Ca-K diagram. Legend as in Figure 1.

Trace Elements

Table 3 shows that the values of the trace elements (ppm) are generally lower and very close one another in one of three groups analysed. It is worth mentioning that the Ni, Cr, V values are higher

TABLE 3

Permian volcanics of South Banat

Trace elements (ppm)

No.	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Yb	Y	La	Nb	Zr	Sr	Ba
1	60	19	<2	10	<3	2.5	<2	1	2.5	1.5	1	<10	34	14	190	270	750
2	70	9	<2	11	3.5	3	<2	1.5	<2	1.5	1.8	16	<30	20	46	40	350
3	16	75	6	10	3.5	2.5	<2	<1	<2	1.5	1.3	13	<30	10	50	32	300
4	12	30	4	11	5	3	<2	<1	6.5	2.5	1.8	18	<30	14	50	30	330
5	92	8	2	12	4	5	<2	3.5	4	1.5	1.6	11	<30	17	55	15	300
6	11	19	2.5	9	4	2.5	<2	<1	3	1.5	1.7	12	<30	10	30	63	220
7	44	15	10	13	4	4.5	<2	2.5	4.5	2.5	1	11	<30	<10	75	50	730
8	48	16	4	12	3.5	2.5	<2	<1	4	3	1.2	12	<30	10	56	27	630
9	36	21	12	12	2.5	8.5	2	11	6	1.5	0.8	<10	<30	<10	110	64	640
10	41	32	3	7.5	4.0	4.5	<2	6.5	<2	2	1.3	12	<30	<10	53	55	65
11	42	12	3.5	5	4	4.5	2	8	<2	2.5	1.5	15	<30	12	44	85	390
12	57	22	3	14	2	6	2	13	15	2.5	1.6	17	30	12	220	250	800
13	85	8.5	3	13	2	7.5	2	13	12	2	1.1	11	44	17	250	340	460
14	87	21	4.5	10	2	12	<2	5	8	1.5	0.9	<10	30	13	170	220	650

Analyst, Irina Bratosin.

in the volcanic conglomerates of the Povalina formation, which has higher amounts of femic minerals as compared to other ignimbritic rocks. La, Zr and Sr values are lower in the ignimbritic flows as against the volcanic conglomerates of the Povalina formation.

Conclusions

The ignimbritic character of the Permian eruptions in the South Banat results from their morphology, spreading and thickness, their structural and textural particularities and their chemical and mineralogical composition.

In the Svinița-Baia Nouă-Tîlva Frasinului zone, the Permian volcanic rocks are represented by the Povalina formation (volcanic conglomerates intercalated with ignimbritic flows) and the Trescovăț formation (ignimbritic flows).

The chemical composition is : quartz, albite, oligoclase (andesine) $\pm$ orthoclase, biotite $\pm$ hornblende.

Permian volcanics are rich in alkalies (4.23-7.98%) and poor in Fe_2O_3 + FeO (0.11-1.68%) and MgO (0.01-0.55%). The SiO_2 amount is large and very large, usually exceeding 75% (sometimes reaching 81%). Such high values of SiO_2 are typical of the ignimbritic rocks (Zavarițki, 1955).

The petrochemical features of these rocks testify their appurtenance to rhyolites and dacites. Sometimes they possess a keratophyric aspect. Nevertheless, a slight differentiation of magmas in time is obvious : the first effusions had a dacitic character whereas the last ones — a rhyolitic one.

Permian eruptions occur on a surface of about 200 sq km in the area of study, but they have a wider spreading : to the north they are partly overlain by Mesozoic formations ; south of the Danube they are found up to Yugoslavia. "Permian quartziferous porphyry" occurrences (in fact ignimbritic rocks) are also known at Toplet and Mehadia (Dimitrescu, 1959). The thickness of the formation is of hundreds of metres. The ignimbritic rhyodacites are tabular, in places pseudostratified.

The ambiguous aspects of tuffs and lavas specific to ignimbritic rocks can be observed both macroscopically and microscopically. Rocks with porphyric textures, typical of the acid effusive rocks, contain phenocrysts of feldspar ± quartz ± femic minerals, while those with pseudostratified structures are deprived of phenocrysts. However, in most cases the phenocryst ratio does not exceed 10-15%. The colours also vary from brick-red to grey-yellow or grey-white. Macroscopically pumice fragments typical of the ignimbritic eruptions are rarely observed. Nevertheless, Răileanu (1953) mentioned them : ..."quartziferous porphyries on the Bîrgăul Surcovaciei Ravine do not contain phenocrysts. They have a volcanic scoriaceous aspect". Under the microscope, the tuffaceous aspect of the rhyodacitic ignimbrites is shown by the millimetric or submillimetric pumice or volcanic glass fragments, cemented by a fine aleuritic powder. The vitroclastic fragments often have a devitrification degree different from the matrix so that these fragments can be recognized. In other thin sections, phenocrysts of feldspar ± quartz ± biotite ± hornblende are found beside pumice or glass fragments in the more or less devitrified mesostasis. If the recrystallization of the groundmass is dominant or total the contours between fragments and mesostasis are scarcely visible or invisible so that the magmatic phenocrysts flow in a homogeneous mass ; tuff-lavas get the characters of effusive magmatic rocks with porphyric textures and massive structures. However, even in such cases, ignimbrites have a particular aspect which differentiates them from the magmatic flows proper ; they resemble silicified effusive rocks. Small oval quartz grains, ellipsoidally lobated with dented margins in places impregnate the mesostasis or partially replace feldspar. This microgranular quartz — different as regards the morphology and sizes of corroded and resorbed magmatic quartz phenocrysts — has subsequently crystallized. Quartz occurs in the pumice vacuoles or in the voids of the tuffaceous material and, at the same time, replaced partly the plagioclase phenocrysts. This subsequently crystallized quartz was probably a tridymite or a cristobalite initially, and after some time it got the more stable symmetry of quartz. Rx investigations effectuated on some samples did not indicated the presence of cristobalite or tridymite, as expected. The process of "autometamorphic silicification" points out the hard and fairly hard character of the ignimbrites occurring in this region. It also testifies why the SiO_2 amount in these rocks is often too high even for the chemical composition of the rhyolites.

The eutaxitic structures with fiammes are observed both macroscopically and microscopically especially in the ignimbritic rocks found in the Trescovăț Hill. However, in most cases they are quite vaguely outlined or are missing because of the recrystallization processes subsequently underwent by rocks. Axiolitic structures are very seldom found.

In the Svinița-Baia Nouă-Tîlva Frasinului ignimbritic rhyolites and dacites are represented by vitroclastic tuffs, unwelded vitrocrystalloclastic tuff-lavas, welded tuffs and lithoclastic tuffs.

The dacitic volcanic conglomerates, the intercalations of ignimbritic flows and the sedimentary rocks prove that the Povalina formation deposited under a molasse regime. The Povalina formation is overlain by the Trescovăț formation made up of ignimbritic rhyolitic flows.

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ROCI IGNIMBRITICE PERMIENE ÎN BANATUL DE SUD (SVINIȚA-BAIA NOUĂ-TÎLVA FRASINULUI)

(Rezumat)

Caracterul ignimbritic al erupțiilor permiene din Banatul de sud rezultă din forma de zăcămînt, extinderea și grosimea lor, din particularitățile structurale și texturale din compoziția chimică și mineralogică pe care rocile le prezintă.

Vulcanitele permiene din zona Svinita-Baia Nouă-Tîlva Frasinului sînt reprezentate prin formațiunea de Povalina (conglomerate vulcanice intercalate cu pînze ignimbritice și formațiunea de Trescovăț (pînze ignimbritice).

Compoziția mineralogică a rocilor ignimbritice este simplă : cuarț, albit-oligoclaz (andezin) $\pm$ ortoclaz, biotit $\pm$ hornblendă.

Vulcanitele permiene sînt bogate în alcalii (4,23-7,98%), sărace în Fe_2O_3 + FeO (0,11-1,68%) și MgO (0,01-0,55%). Cantitatea de SiO_2 este mare și foarte mare, depășind frecvent 75%, ajungînd chiar pînă la 81%. Asemenea creșteri importante de SiO_2 sînt specifice rocilor ignimbritice (Zavarițki, 1955).

Caracterele petrochimice ale acestor roci justifică încadrarea lor la dacite, riodacite și riolite. Se constată o ușoară diferențiere a magmelor în timp : primele efuziuni au avut un caracter dacitic în timp ce ultimele au avut un caracter riolitic (diagrama *Q-A-P*).

Erupțiile permiene apar pe o suprafață de peste 200 km^2 în perimetrul cercetat. Ele au în realitate o extindere mult mai mare ; la sud de Dunăre vulcanitele se continuă în R.S.F. Iugoslavia, iar spre nord sînt acoperite în parte de formațiunile mezozoice. Alte cîteva iviri apar spre est, la Topleț și Mehadia. Grosimea formațiunii este de sute de metri. Forma de zăcămînt a ignimbritelor este tabulară, pseudostratiformă.

Aspectele intermediare, ambigue, între tufuri și lave, specifice rocilor ignimbritice se observă atît macroscopic cît și microscopic. Unele roci conțin fenocristale, altele nu.

Fragmentele de ponce specifice rocilor ignimbritice se observă de asemenea macroscopic și microscopic.

În unele secțiuni subțiri apar alături de fragmente de ponce, sticlă și cimentul aleuritic mai mult sau mai puțin devitrificate — fenocristale de feldspat $\pm$ cuarț $\pm$ biotit $\pm$ hornblendă. Dacă recristalizarea masei de bază este foarte avansată, conturele dintre fragment și ciment sînt șterse aproape complet sau complet, astfel încît fenocristalele magmatice plutesc într-o masă omogenă ; tufo-lavele împrumută caracterele unor roci magmatice efuzive cu structuri porfirice și texturi masive. În asemenea cazuri rocile ignimbritice se deosebesc de curgerile magmatice datorită prezenței unor granule mici de cuarț cu forme diverse — ovoidale, lobate, elipsoidale, cu marginile zimțate — care impregnează mezostaza ori substituie parțial feldspatul. Acest cuarț microgranular, deosebit ca morfologie și dimensiuni de fenocristalele de cuarț magmatice (corodate și resorbite) a cristalizat din faza de vapori conținută în suspensie în momentul erupției, în vacuolele poncei sau ale materialului tufaceu. Foarte probabil o parte din acest cuarț s-a depus inițial ca tridimit sau cristobalit. Procesul acesta de „silicifiere autometamorfică" explică caracterul dur și foarte dur al ignimbritelor din regiune ; el explică în același timp de ce cantitatea de SiO_2 din ignimbrite este deseori anormal de ridicată chiar pentru compoziția chimică a unor riolite.

Structurile eutaxitice cu fiamme se observă macroscopic și microscopic în special în pînzele ignimbritice din dealul Trescovăț. În majoritatea cazurilor acestea sînt vag sugerate sau lipsesc complet datorită proceselor de recristalizare pe care rocile le-au suferit ulterior. Foarte rar au fost observate și structuri axiolitice.

Prezența conglomeratelor vulcanice dacitice, a intercalațiilor de pînze ignimbritice și în subsidiar a rocilor sedimentare arată că formațiunea de Povalina s-a depus într-un regim de molasă. Peste formațiunea de Povalina se așază formațiunea de Trescovăț alcătuită exclusiv din curgeri riolitice ignimbritice.

EXPLANATION OF PLATES

Plate I

Fig. 1. — Incipiently devitrified fiammes (F), cemented in a more devitrified aleuritic tuffaceous mass (T). Eutaxitic texture. Staricea Valley. N ||; 25 ×.

Fig. 2. — Fiammes impregnated with iron oxides, quartz and alkali feldspar in vapour phase (F); cement is cryptocrystalline (T); magmatic quartz (Q). Eutaxitic texture. Trescovăț Hill. N ||; 25 ×.

Fig. 3. — Ponce fragment (P) surrounded by glass fragments (S); glassy aleuritic cement (T). Vitrolithoclastic texture. Right tributary Staricea Valley. N +; 25 ×.

Fig. 4. — Gradual devitrification of the glassy, tuffaceous groundmass (T); quartz + chalcedony (C). Left tributary Staricea Valley. N ||; 25 ×.

Plate II

Fig. 1. — Breccious aspect of some unwelded tuffs. Poorly devitrified glass fragments, with concave outlines as a result of spraying of ponce and glass (S). Aleuritic cement is more intensely devitrified (T). Right tributary Staricea Valley. N ||; 25 ×.

Fig. 2. — Ignimbrites including three generations of quartz: quartz from mesostasis, finely crystallized, resulting from the groundmass devitrification (white), magmatic quartz with geometric outlines, partly corroded (Q), and quartz in vapour phase deposited as inlays in one of the rock voids (C). Staricea Valley. N +; 25 ×.

Fig. 3. — Amygdaloid structures: quartz and chalcedony (C), formed from the vapour phase, full the rock voids. On the top a magmatic quartz phenocryst (Q). Livadița Valley. N +; 25 ×.

Fig. 4. — Aspect of "silicified rock" of some tuffs impregnated with quartz (white) deposited in the vapour phase. On the top right side a magmatic quartz crystal (Q). Ielișeva Valley. N +; 25 ×.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

FORMATIONS PERMIENNES DE TOPLEȚ-MEHADIA-BOLVAȘNIȚA (BANAT) [1]

PAR

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Ignimbrites. Dykes. Quartz keratophyres. Sodic plagidacites. Permian. Mineralogical composition. Calc-alkali magmas. Volcano-sedimentary formation. South Carpathians — Sedimentary Danubian Domain — Feneș Zone.

Résumé

Les volcanites permiennes de la zone de Presacina (Banat) sont représentées par des coulées ignimbritiques et par des dykes de kératophyres±quartzifères (dacites sodiques). Composition minéralogique : albite-oligoclase acide±quartz±biotite±hornblende. Les coulées ignimbritiques sont intercalées dans des dépôts sédimentaires permiens constitués de conglomérats, grès et grès argileux rouges. Une grande partie des éléments de conglomérats proviennent des kératophyres±quartzifères.

La formation permienne a un caractère de molasse. La puissance des dépôts dépasse 1000 m. Ils surmontent transgressivement et d'une manière discordante les schistes cristallins d'âge précambrien-cambrien. A leur tour ils sont recouverts transgressivement et d'une manière discordante par des formations jurassiques inférieures ou plus récentes.

Les volcanites appartiennent aux magmas calco-alcalins ; elles sont pauvres en fer et magnésium mais riches en sodium et silice.

Abstract

Topleț-Mehadia-Bolvașnița Permian Formations (Banat). Permain volcanics occurring in the Presacina Zone (Banat) are represented by ignimbritic quartz — keratophyre flows and dykes (Na-dacites). The mineralogical composition is represented by albite-acid oligoclase±quartz±biotite±hornblende. The ignimbritic flows are intercalated in Permian sedimentary deposits consisting of conglomerates sandstones and red clayey sandstones. Several conglomerate elements come from quartz-keratophyres. The Permian formation has a molasse character. The thickness of the deposits exceeds 1 000 m. They transgressively and unconformably overlie Precambrian-Cambrian crystalline schists and are transgressively and un-

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conformably overlain by Lower Jurassic and more recent formations. Volcanics belong to calc-alkaline magmas ; they are poor in magnesium and rich in sodium ana silicas.

Introduction

Les formations permiennes de Toplet-Mehadia-Bolvașnița sont situées dans la partie sud-est du Banat. Elles font partie de l'unité du domaine danubien, zone de Presacina (Codarcea, 1940). La formation permienne, de direction N-S, a une longueur de plus de 20 km. La largeur maximum est de 2,5 à 3 km, mais d'habitude elle ne dépasse pas 1 ou 1,5 km.

Les formations permiennes sédimentaires et éruptives sont consignées dans cette partie du Banat dès la moitié du XIX[e] siècle dans les ouvrages de Foetterle, Stur et Tietze (fide Codarcea, 1940). Codarcea (1940) et Dimitrescu (1959) mentionnent également l'existence du Permien dans la zone de Presacina.

Des recherches portant sur les formations permiennes du secteur de Toplet-Mehadia-Bolvașnița ont été effectuées par Gheorghiu (1958), Iliescu (1963), Gheruci et Serafimovici (1963, 1964, 1966), Năstăseanu (1979), Năstăseanu et al. (1973, 1981), Voicu et Serafimovici (1982).

La plupart des prédécesseurs ont étudié ces formations au point de vue lithostratigraphique et stratigraphique. L'étude pétrochimique sera effectuée dans la présente note.

Formation permienne

La formation permienne est constituée d'un mélange caractéristique des dépôts de molasse : conglomérats à textures massives ou vaguement entrecroisées en alternance ou intimement associées aux épiclastites fines ou grossières, grès et argiles gréseuses rouges. Dans cette formation de molasse s'intercalent à niveaux différents des coulées de kératophyres $\pm$ quartzifères d'aspects ignimbritiques. Parfois, la formation est traversée par des dykes de kératophyres $\pm$ quartzifères.

Les conglomérats, polygènes, comportent des éléments angulaires ou subangulaires de kératophyres quartzifères, des schistes cristallins, des roches granitoïdes, des quartz métamorphiques, plus rarement des aplites et des lamprophyres. Le diamètre de ces éléments atteint 20 à 25 cm. Généralement, ce sont les éléments provenus des kératophyres qui prédominent sur toute l'aire de développement des formations permiennes. Les conglomérats sont associés aux épiclastites fines, aux grès, aux argiles gréseuses rouges ou aux tufo-laves.

Les épiclastites fines identiques à la matrice des conglomérats s'individualisent d'une manière prégnante tout comme à l'est de la gare d'Iablanița. Ici, dans une ancienne carrière de 250 m environ se développe un matériel détritique-terrigène, représenté par des grès parfois faiblement carbonatés et par des grès argileux rouges, mélangé à un matériel détritique volcanogène microconglomératique ou gréseux. Sporadiquement, apparaissent des éléments de conglomérats.

Les grès et les argiles gréseuses rouges s'individualisent et apparaissent soit en tant que lentilles en conglomérats à divers niveaux soit comme bandes d'épaisseurs appréciables. Ceux affleurant dans la vallée de Sfîrdinul ont une épaisseur d'approximativement 500 m et reposent sur des conglomérats (Năstăseanu, 1979). Les kératophyres±quartzifères à caractères de tufo-laves se développent également à divers niveaux dans les dépôts sédimentaires permiens. Elles ont des couleurs rouge brique, verdâtre blanchâtre et des puissances décimétriques. Les kératophyres forment souvent le liant des conglomérats avec le matériel épiclastique, les grès et les grès argileux rouges. Les dykes de kératophyres± quartzifères ont des épaisseurs d'environ 150 à 200 m et des longueurs de 4 à 6 km. Ils apparaissent à l'est de Bolvașnița et sont orientés N-S.

La formation permienne volcano-sédimentaire de la zone de Presacina dont l'épaisseur dépasse 1000 m surmonte d'une manière transgressive et discordante le soubassement cristallin-granitique d'âge précambrien-cambrien.

Les formations permiennes sont recouvertes à leur tour transgressivement et d'une manière discordante par des dépôts jurassiques inférieurs ou plus récents (Codarcea, 1940 ; Năstăseanu, 1979).

L'âge de ces dépôts est attribué par Năstăseanu et al. (1981) à l'Autunien selon la ressemblance de faciès avec les dépôts permiens de la zone de Sirinia où ont été identifiées des plantes fossiles. Une colonne stratigraphique synthétique des dépôts permiens de la zone de Presacina est présentée dans la figure 1.

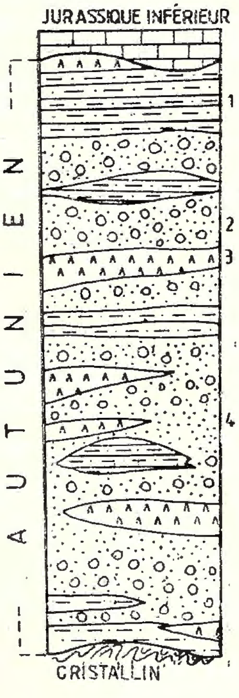

Fig. 1. — Colonne stratigraphique synthétique à travers la formation volcano-sédimentaire permienne de la zone de Presacina.
1, grès et grès argileux ; 2, conglomérats polygènes ; 3, coulées de kératophyres±quartzifères ignimbritiques ; 4, épiclastites fines.

Observations microscopiques sur les volcanites permiennes

Les volcanites permiennes sont représentées par des kératophyres quartzifères. La composition minéralogique est la suivante : albite-oligoclase acide$\pm$quartz$\pm$biotite$\pm$hornblende. Exceptionnellement on a aussi identifié l'albite à structures de tablette d'échecs. Ces minéraux apparaissent souvent à titre des phénocrystaux englobés dans une masse fondamentale qui peut avoir des structures variées. Parfois, les phénocristaux sont très rares ou manquent. La mésostase contient surtout des microlites d'albite-oligoclase acide et de verre plus ou moins dévitrifié. Apparaissent assez fréquemment des microgranules de quartz. Parmi les minéraux secondaires, la séricite est omniprésente, formée tant au profit des phénocristaux de plagioclase que de la masse de base. D'une grande fréquence sont également la limonite et la calcite. La chlorite et l'épidote se forment plus rarement au profit de la biotite ou de la hornblende. La biotite est parfois bauéritisée. Fréquemment la hornblende et la biotite sont opacitisées.

Les kératophyres$\pm$quartzifères se développent sous forme de coulées ignimbritiques et de dykes. La plupart des éléments de conglomérats proviennent des roches kératophyriques.

Les coulées de kératophyres$\pm$quartzifères ont des caractères ignimbritiques tel que nous l'avons déjà mentionné. Ces caractères sont soulignés par des structures relictes eutaxitiques, des fragments de ponce non soudés ou bien soudés, mais très rarement à contours ovoïdaux ou angulaires, cimentés d'une poussière fine d'habitude dévitrifiée. Les pores des fragments de ponce et de la masse de base sont souvent remplis de quartz hydrothermal déposé depuis la phase de vapeurs.

Le rapport entre la masse de base et les phénocristaux est variable : les phénocristaux sont parfois très rares ou même ils manquent, d'autre fois ils s'accumulent dans une quantité tellement grande qu'ils occupent 70 à 80% du volume de la roche.

Dans bien des cas, les phénocristaux à physionomie typique pour les roches magmatiques (quartz bipyramidé, corrodé, plagioclase à contours idiomorphes) se trouvent dans la même mésostase avec de cristaux à physionomie détritique (quartz et plagioclases fragmentés, plus ou moins

TA

Volcanites permiennes de

Composition

No.	No. de l'échant.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5
1	586a	73,51	0,29	14,00	1,59	0,06	0,08	0,32	1,57	1,12	5,26	0,05
2	603	73,44	0,46	14,25	2,71	0,23	0,05	1,03	0,54	0,83	4,91	0,11
3	610	71,90	0,33	14,50	2,16	0,21	0,02	0,66	1,18	2,77	4,34	0,00
4	614	70,83	0,45	15,50	1,52	1,28	0,00	1,20	0,47	2,26	3,78	0,09
5	612	70,37	0,40	14,15	1,53	1,07	0,02	1,02	2,00	1,81	3,79	0,10
6	618	68,62	0,49	15,40	3,56	0,26	0,05	0,80	0,86	3,01	4,64	0,12
7	621	68,14	0,46	15,35	2,30	0,79	0,03	2,19	1,64	2,47	3,89	0,12
8	619	67,10	0,49	14,60	1,47	0,77	0,05	3,04	1,90	3,64	2,54	0,07

Analiste : Elena Colios.

roulés, biotite courbée ou rompue). Il arrive souvent que la biotite soit fortement ondulée durant le processus de coulée.

La dévitrification différenciée de la masse de base est un autre caractère spécifique des tufo-laves de cette zone et des ignimbrites en général.

Au microscope, dans la structure de ces roches, on a observé la présence des xénolites (0,2 à 0,5 mm) des schistes cristallins, des grès des roches éruptives.

Certains caractères mentionnés tels les structures eutaxitiques, les fragments de ponce soudés ou non soudés, sont dans la plupart des cas complètement absents ou vaguement observés, du fait de la dévitrification de la masse de base et des fragments composants y englobés. Les structures relictes peuvent être aussi reconnues si le degré de dévitrification des fragments de ponce diffère de celui de la mésostase, quand la dévitrification n'est pas très avancée.

Les structures de la masse de base sont vitroclastiques, felsitiques ou pilotaxitiques, les dernières déterminées par l'arrangement subparallèle des microlites d'albite.

Les dykes de kéraotphyres$\pm$quartzifères présentent toujours des structures porphyriques à phénocristaux et pâte, des structures clairement magmatiques.

La mésostase a des structures microgranulaire, felsitique ou pilotaxitique.

Chimisme des roches éruptives

L'étude chimique des roches éruptives de Topleț-Mehadia-Bolvașnița a 8 analyses complètes des silicates et 8 analyses quantitatives des éléments mineurs.

Eléments majeurs

Les valeurs des oxydes sont illustrées dans le tableau 1. Les intervalles de variation pour les principaux oxydes sont les suivants :

SiO_2 = 67,10-73,51 MgO = 0,32-3,04
Al_2O_3 = 14,00—15,50 CaO = 0,47-2,00
Fe_2O_3 = 1,47-3,56 K_2O = 0,83-3,64
FeO = 0,66-1,28 Na_2O = 2,54-5,26

BLEAU 1

Topleț — Mehadia — Bolvașnița

chimique

H_2O^+	CO_2	S	Fe(s)	Total	Fe_2O_3 Total	Localisation et forme de gisement
0,34	1,49	0,06	0,05	99,79	1,73	V. Secărstita ; tufo-laves
0,94	0,00	0,05	0,04	99,59	3,02	Piatra Pușcată : tufo-laves
1,40	0,00	0,05	0,04	99,56	2,45	Cariera Iablanița : tufo-laves
0,77	1,56	0,07	0,06	99,84	3,04	Bolvașnița ; dyke
1,89	1,33	0,05	0,04	99,57	2,78	Bolvașnița ; dyke
1,12	0,59	0,05	0,04	99,61	3,91	V. Greatca ; dyke
2,17	0,00	0,08	0,08	99,70	3,27	V. Greatca ; dyke
2,68	1,20	0,07	0,06	99,68	2,40	V. Greatca ; dyke

La quantité SiO_2 est grande surtout pour les coulées de kératophyres± quartzifères ignimbritiques (71,90 à 73,53%, tabl. 1). Le fait est déterminé non seulement par la présence des cristaux de quartz, qui parfois peuvent manquer, mais aussi par l'existence du verre de la mésostase ou/et par l'éxistence des microgranules de quartz hydrothermal déposé dans les pores de la roche.

Sur le diagramme *Q-A-P* préconisé par Streckeisen (composition normative ; fig. 2), sept sur huit échantillons se situent dans le champ

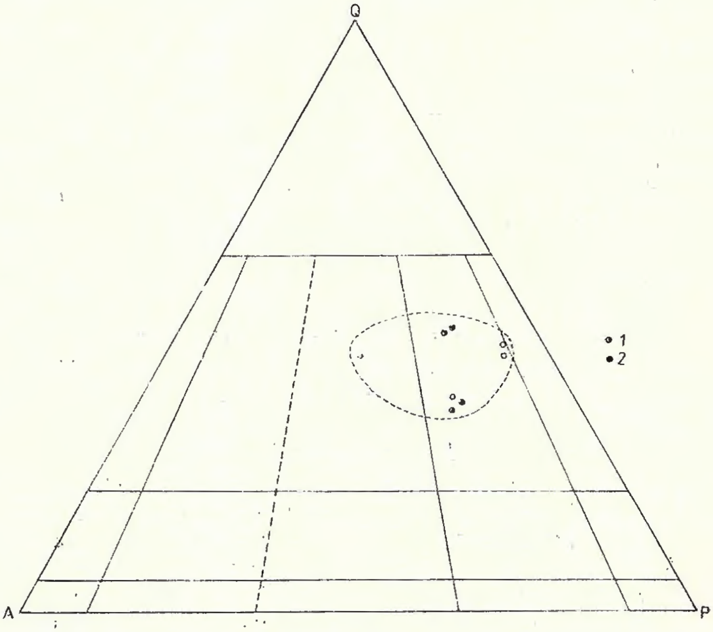

Fig. 2. — Diagramme Streckeisen *Q-A-P* (composition normative). 1, coulée de kératophyres±quartzifères ignimbritiques ; 2, dykes de kératophyres±quartzifères.

des dacites et un échantillon dans le champ des rhyodacites. Si nous envisageons cette classification selon des critères chimiques et prenant en considération la présence exclusive du plagioclase acide nous pouvons dénommer les kératophyres quartzifères aussi des dacites sodiques.

L'échantillon 619 (tabl. 1 et fig. 2) qui se situe dans l'aire des dacites contient une quantité plus grande de K_2O et de MgO en comparaison des autres roches. Cette situation est redevable, suivant que les observations le prouvent, au fait que la roche a dans sa composition beaucoup de biotite.

Les roches analysées, pour lesquelles on a calculé les paramètres Niggli, proviennent des magmas calco-alcalins comme : trondhjémitique (5), granitique (2) et leucogranitique (tabl. 2).

TABLEAU 2

Volcanites permiennes de Toplej-Mehadia-Bolvașnița

Paramètres Niggli, Q—A—P, type de magma

No. de l'échant.	*Q*	*A*	*P*	*Si*	*al*	*fm*	*c*	*alk*	Type de magma
586 a	42,7	7,4	49,9	418,0	46,9	10,5	9,6	33,1	trondhjemitique
603	45,4	5,6	49,0	405,4	46,4	21,3	3,2	29,2	trondhjemitique
610	35,8	18,0	46,2	386,3	45,9	15,2	6,8	32,1	leucogranitique
614	45,8	16,0	38,2	376,7	48,6	21,6	2,7	27,2	trondhjemitique
612	47,6	12,9	39,5	371,6	44,0	19,2	11,3	25,5	tronhdjemitique
618	33,6	20,7	45,7	333,3	44,1	20,3	4,5	31,2	trondhjemitique
621	33,2	17,3	47,6	311,0	41,3	26,3	8,0	24,4	granitique
619	42,9	27,7	29,4	307,7	39,5	29,3	9,3	21,9	granitique

Les kératophyres±quartzifères sont figurées sur le diagramme *al-alk* (fig. 3) dans le champ des roches alcalines et intermédiaires. Elles ont des caractères saliques et semisaliques (fig. 4).

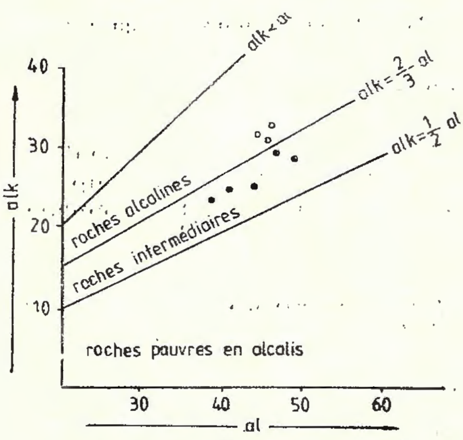

Fig. 3. — Diagramme *al-alk*. Légende tout comme la figure 1.

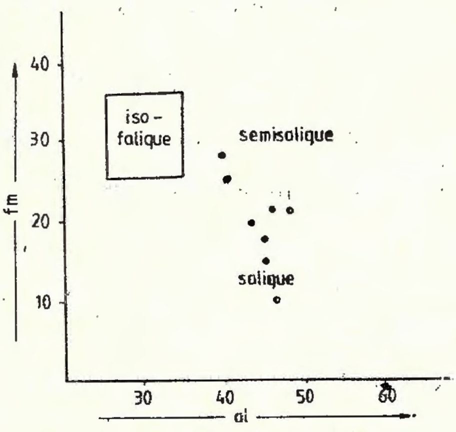

Fig. 4. — Diagramme *al-fm*. Légende tout comme la figure 1.

Les volcanites permiennes de la zone de Presacina sont pauvres en Fe_2O_3+FeO et en MgO ; par rapport à ces oxydes les quantités de Na_2O+K_2O sont notables (fig. 5) ; Na_2O prédomine quantitativement sur K_2O (excepté l'échantillon 619). Généralement K_2O > CaO (fig. 6).

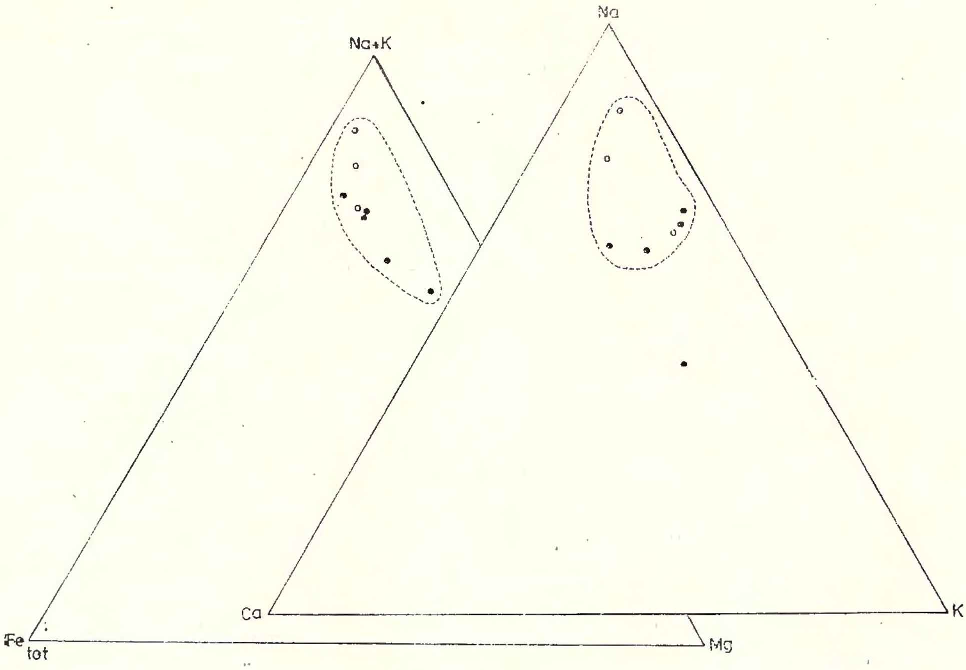

Fig. 5. — Diagramme Na+K — Fe_{tot} — Mg. Légende tout comme la figure 1.

Fig. 6. — Diagramme Na — Ca — K. Légende tout comme la figure 1.

Eléments mineurs

Les valeurs déterminées pour les éléments mineurs (ppm) sont inscrits dans le tableau 3. Celles-ci sont petites et très petites comprises entre les limites suivantes : Pb = 7-24, Cu = 4,5-12 (exceptionnelle-

TABLEAU 3

Volcanites permiennes de Toplet-Mehadia-Bolvaşniţa
Eléments mineurs (ppm)

No.	No. de l'échat.	Pb	Cu	Sn	Ga	Ni	Co	Cr	V	Sc	Zr	Yb	Y	La	Sr	Ba
1	586a	20	52	5	12	11	2,5	9	7,5	3	130	<0,5	6,5	<30	190	180
2	603	20	8,5	2,5	12	9,5	3	10	18	5,5	105	0,5	8,5	30	320	150
3	610	23	8,5	<2	14	15	3,5	22	33	4,5	125	0,5	9	30	330	930
4	614	7	11	<2	15	11	4,5	9	30	5,5	175	0,7	11	34	165	250
5	612	12	12	<2	13	11	4	8,5	22	5,5	145	0,6	10	35	110	185
6	618	24	8,5	2	14	12	4,5	9	11	6	175	0,7	15	40	145	650
7	621	16	12	2	13	22	7	24	43	7,5	130	0,8	15	35	210	530
8	619	10	4,5	3,5	12	16	6	17	29	5,5	100	0,5	8	<30	120	550

Analiste : Irina Bratosin. Pour tous les échantillons : Mo < 2 ; Ag < 1 ; Nb < 10.

ment 52), Sn = < 2-5, Ga = 12-15, Ni = 9,5-22, Co = 2,5-7, Cr = 8,5-24, V = 7,5-43, Sc 3-7,5, Zr = 100-175, Yb = < 0,5-0,8, Y = 6,5-15, La = < 30-40, Sr = 110-330, Ba = 150-930.

Observations tectoniques

Après le dépôt de la formation volcano-sédimentaire de molasse vers la fin du Permien (mouvements varisques) ou au début du Mésozoïque (mouvements alpins), dans le secteur de Topleț-Mehadia s'est produit un déplacement en bloc de l'ouest à l'est des formations permiennes vers la série de Corbu. Cela est relevé par les effets dynamométamorphiques observés grâce à une lamination intense tout près du contact, autant dans les schistes cristallins appartenant à la „série de Corbu" que dans les formations permiennes ; les inclinaisons des couches y sont presque verticales.

D'importantes dislocations disjonctives ont poursuivies cet événement. Selon l'image cartographique, les formations permiennes situées entre Topleț et Mehadia sont délimitées à l'ouest et à l'est par deux systèmes majeurs de failles de plus de 15 km et orientées N-S. Vers l'ouest, les formations permiennes viennent en contact avec les schistes cristallins de la „série de Corbu" et à l'est avec les dépôts jurassiques inférieurs ou bien les schistes cristallins du groupe de Neamțu. Ces trois compartiments ainsi délimités, de l'ouest vers l'est, sont les suivants : schistes cristallins de la „série de Corbu", formation permienne et dépôts jurassiques.

Dans les secteurs de Mehadia-Bolvașnița il y a deux failles orientées également N-S, de longueurs dépassant 10 km. Les éruptions permiennes y sont représentées par un dyke de kératophyres quartzifères d'une longueur de plus de 6 km, orienté aussi N-S. Les coulées de kératophyres $\pm$quartzifères sont moins nombreuses que dans la zone de Topleț-Mehadia.

Conclusions

Les volcanites permiennes de la zone de Presacina sont représentées par des kératophyres$\pm$quartzifères. Les coulées de kératophyres quartzifères ont des caractères relictes spécifiques aux roches ignimbritiques. Elles s'intercalent à divers niveaux dans la formation sédimentaire représentée par des conglomérats, épiclastites, grès et grès argilleux rouges. Maints éléments des conglomérats proviennent des kératophyres quartzifères.

La formation permienne d'épaisseurs supérieures à 1000 m a caractère de molasse. Elle est parfois traversée par des dykes de kératophyres quartzifères orientées N-S. Ces dykes peuvent être considérés en tant que canaux d'accès des tufo-laves vers la surface.

Les volcanites, au point de vue chimique, sont des roches calco-alcalines pauvres en fer et magnésium et riches en sodium et silice.

La formation volcano-sédimentaire de Topleț-Mehadia-Bolvașnița surmonte transgressivement et d'une manière discordante un soubassement cristallino-granitique d'âge précambrien-cambrien (groupe de Neamţu et „série de Corbu"). A leur tour les formations permiennes sont recouvertes transgressivement et d'une manière discordante par des dépôts jurassiques inférieurs ou plus récents (Codarcea, 1940 ; Năstăseanu, 1979).

La formation permienne de la zone de Presacina peut être aussi parallélisée pétrographiquement et du point de vue des conditions de sédimentation avec les formations de Povolina de la zone de Şirinia. Il est possible que l'âge de ces formations soit autunien (Năstăseanu, 1979).

Les formations permiennes du secteur de Topleţ-Mehadia sont dynamo-métamorphosées et faiblement déplacées allant de l'ouest à l'est vers la „série de Corbu". Ce mouvement s'est produit à la fin du Permien ou au début du Mésozoïque. Suivant à cet événement, les formations permiennes ont été délimitées d'une manière tranchante de l'ouest à l'est par deux failles d'envergure de direction N-S.

Dans le secteur de Mehadia-Bolvaşniţa se développent aussi deux failles orientées N-S. Les éruptions permiennes y sont représentées par un dyke de kératophyres$\pm$quartzifères dépassant 6 km et orienté également N-S. Les coulées de kératophyres quartzifères sont moins fréquentes que dans la zone de Topleţ-Mehadia.

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QUESTION

M. Săndulescu : Dans les soi-disantes épiclastites avez-vous rencontré des fragments de schistes cristallins ? Pouvez-vous les préciser en détail et de quel type sont-ils pour pouvoir affirmer avec certitude l'aire source de ce matériel détritique ?

Réponse : Les épiclastites fines et les conglomérats polygènes avec lesquels ils s'associent sont constitués par des éléments et des fragments de schistes cristallins appartenant au groupe de Neamţu.

FORMAŢIUNILE PERMIENE DE LA TOPLEŢ-MEHADIA-BOLVAŞNIŢA (BANAT)

(Rezumat)

Vulcanitele permiene din zona Presacina sînt reprezentate prin keratofire±cuarţifere. Compoziţia mineralogică : albit, albit-oligoclaz acid±cuarţ±biotit±hornblendă. Minerale secundare : frecvent se observă sericitul, limonitul şi calcitul, mai rar apar cloritul şi epidotul. Hornblenda şi biotitul sînt de regulă opacitizate.

Curgerile de keratofire cuarţifere au caractere structurale relicte specifice rocilor ignimbritice. Acestea sînt evidenţiate de structuri eutaxitice, de fragmente de ponce foarte rar sudate, de fragmente de ponce nesudate cu conture ovoidale cimentate cu un praf fin de regulă devitrificat. Frecvent devitrificarea este foarte avansată astfel că aceste caractere relicte sînt complet şterse.

Curgerile de keratofire cuarţifere se intercalează la diferite nivele în formaţiunea sedimentară reprezentată prin conglomerate, gresii şi gresii argiloase roşii. Multe din elementele de conglomerate provin din keratofire cuarţifere. Întreaga formaţiune permiană are caracter de molasă. Uneori este străbătută de dyke-uri de keratofire cuarţifere orientate N-S. Acestea pot fi interpretate ca reprezentînd canalele de acces spre suprafaţă a keratofirelor ignimbritice.

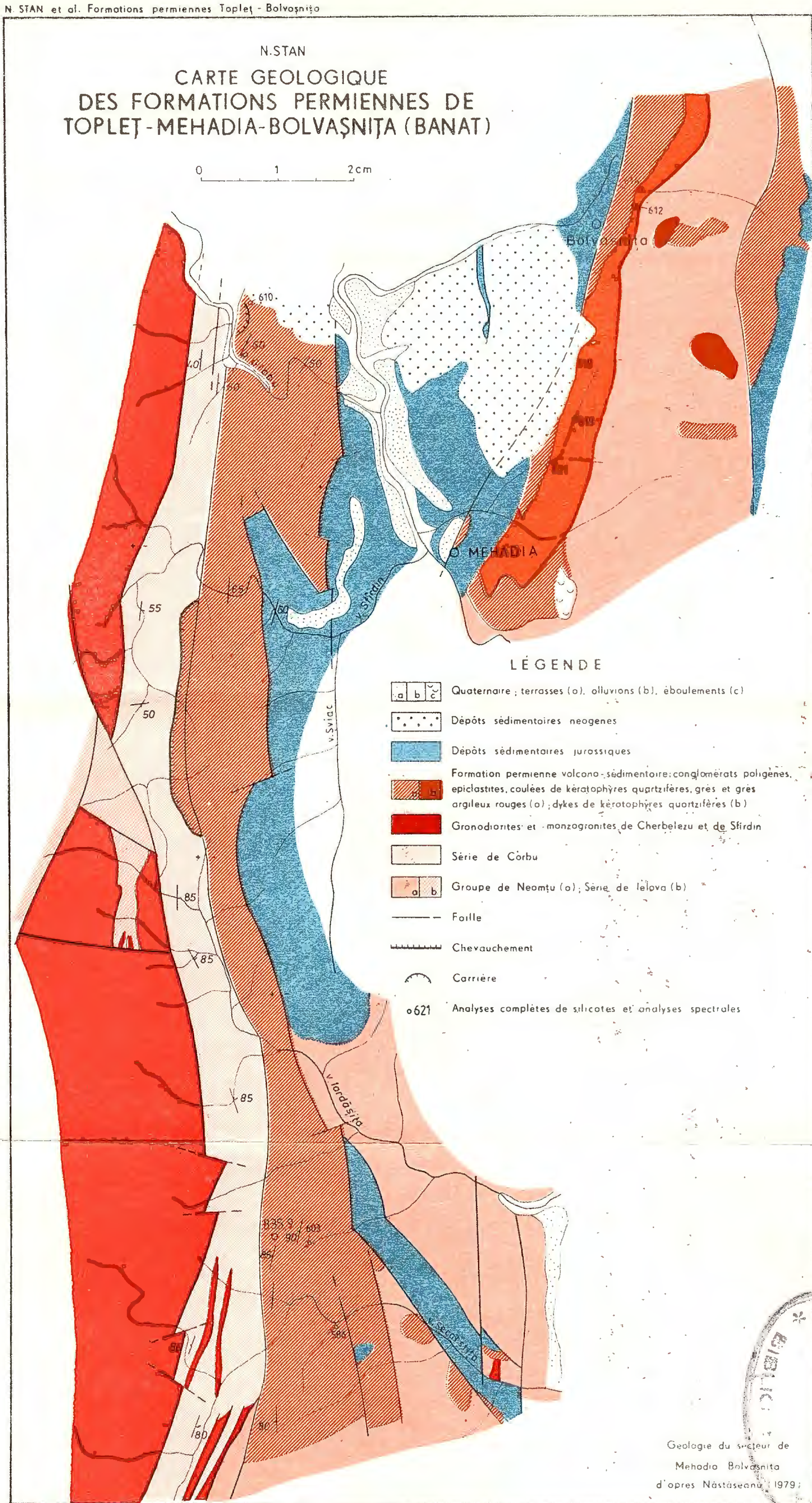
Formaţiunea vulcano-sedimentară-epiclastică de la Topleţ-Mehadia-Bolvaşniţa poate fi paralelizată din punct de vedere petrografic şi al

condițiilor de sedimentare cu formațiunea de Povalina din zona Sirinia (Stănoiu, Stan, 1986). Este foarte probabil ca vîrsta acestor formațiuni să fie autuniană (Năstăseanu, 1979).

Vulcanitele provin din magme calco-alcaline sărace în fier și magneziu, bogate în sodiu și silice.

Formațiunea vulcano-sedimentară permiană din zona Presacina se așază transgresiv și discordant peste un fundament granitic — cristalin de vîrstă Precambrian-Cambrian (grupul de Neamțu și seria de Corbu). La rîndul lor formațiunile permiene a căror grosime depășește 1000 m sînt acoperite transgresiv și discordant de depozite jurasic-inferioare sau mai noi (Codarcea, 1940 ; Năstăseanu, 1979).

În sectorul Topleț-Mehadia formațiunile permiene sînt dinamometamorfozate și ușor deplasate de la vest la est către „seria de Corbu". Această mișcare s-a produs la sfîrșitul Permianului (mișcările varisce) sau la începutul Mezozoicului (mișcările alpine). După acest eveniment formațiunile permiene au fost delimitate tranșant la vest și la est de două falii de anvergură lungi de peste 15 km orientate N-S.



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

EOCRETACEOUS GRANITOIDS FROM THE SOUTH APUSENI [1]

BY

AVRAM ȘTEFAN [2]

Granitoids. Cretaceous. Ophiolites. Banatites. Isotopic age. K-Ar method. Minerals, features, physiography. Chemical composition. Magmatic differentiation. Petrographic provinces. Apuseni Mountains — Southern Apuseni — Drocea Mountains ; Metaliferi Mountains.

Abstract

Field and laboratory data which we lately obtained make us conclude that most of granitoid eruptive rocks which compose the bodies crossing ophiolitic magmatic products north of Mureș, have to be excluded from the banatitic rock group (Lower Post-Maastrichtian-Paleogene) and included to an older Eocretaceous magmatism. This fact is partly suggested by the K/Ar isotopic dating.

Physiographical features of these rock minerals and their chemical composition are similar to those included as blocks within the Senonian and Albian sedimentary formations at south of the Bihor Mts as well as in the Feneș Layers (Barremian-Lower Aptian) and the Meteș ones (Upper Aptian-Albian) from Trascău, being obviously different from the banatitic rocks.

Résumé

Granitoïdes éocrétacés des Monts Apuseni du Sud. Les données de terrain et de laboratoire obtenues ces dernières années nous ont mené à la conclusion que la majorité des roches éruptives granitoïdes constituant les corps qui traversent les produits magmatiques ophiolitiques du nord de Mureș (Pietroasa-Căzănești, Săvîrșin, Cerbia, Dealu Mare-Podele, Ampoița) ne sont pas similaires au groupe des roches banatitiques (post-Maestrichtien inférieur-Paléocène). Elles doivent être attribuées à un magmatisme plus ancien — éocrétacé — fait relevé

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également par les données d'âges isotopiques, obtenues par la méthode K/Ar (Borcoş et al., 1980 ; Lemne et al., 1981, 1982, 1983 ; Savu et al., 1984).

Les caractères physiographiques des minéraux de ces roches et leur composition chimique sont voisins de ceux des blocs englobés dans des formations sédimentaires sénoniennes et albiennes de la partie sud des monts Bihor ainsi que dans les couches de Feneş (Barrémien-Aptien inférieur) et dans celles de Meteş (Aptien supérieur-Albien) de Trascău, étant tout à fait différentes des roches banatitiques.

Introduction

Last years investigations in the southern part of the Apuseni Mts offered data which allowed us to notice some differences of mineralogic composition and physiography of the crystals, as well as of chemical composition between the genuine banatitic rocks (which penetrate through the Maastrichtian deposits) and those which are forming the bodies from Cerbia, Pietroasa-Căzăneşti and Dealu Mare-Podele (Ştefan in Udubaşa et al., 1981, 1982, 1984 ; Ştefan in Lupu et al., 1983, 1984) which pierce only the ophiolitic magmatites.

The identification of some granitoid boulders, having the same features, within the sedimentary Senonian and Albian deposits from hydrographic basins of the Obîrşia and Znilu-Rişculiţa valleys northward of the Crişul Alb, as well as in the sedimentary Barremian-Lower Aptian deposits of the Feneş Formation and in those belonging to the Upper Aptian-Albian of the Meteş Formation in the southern part of the Trascău Mts (Lupu et al., 1982, 1983) point out an Eocretaceous magmatic activity, mainly intrusive (Lupu et al., 1984) which generated granodiorite-granite rocks, rich in Na_2O and tonalite-sodic granite ones with less basic quartz-dioritic differentiation products ; data of isotopic ages, obtained through the K/Ar method in the laboratories of the Institute of Geology and Geophysics, confirm this conclusion (Lemne et al., 1979, 1981, 1982, 1983) which was partly advanced (Borcoş, Andrei, 1980 ; Borcoş in Lemne et al., 1981 ; Savu in Lemne et al., 1983 ; Savu in Savu et al., 1984 ; Ştefan in Lemne et al., 1983).

Without studing magmatic rocks of the compound intrusive body from Săvîrşin on account of the issued data (Savu, Vasiliu, 1966 ; Savu, Mîndroiu, 1980 ; Savu et al., 1966, 1979, 1984) as well as from a few own observations, it seems to result that many of these magmatites display similar features with those from Cerbia and Pietroasa-Căzăneşti, all of them being considered as banatites up to now ; because, as we have shown before, the rocks with the same characteristics are enclosed in the Cretaceous (Senonian and Albian) deposits, it results that this massif has an Eocretaceous age too.

Isotopic ages (K/Ar method) confirm this supposition (Savu, in Lemne et al., 1983 ; Savu et al., 1984) although previous data (Rb/Sr method, Herz et al., 1974) rise the question of some newer magmatic processes (60 mil. years) of banatitic origin ; did megacrystals of potassic feldspar from the Săvîrșin granite occur subsequently after the emplacement of the massif rocks ?!

Occurrences of Eocretaceous Granitoids and their Petrographic Features

The Cerbia eruptive massif consists mainly of granodiorite-granites (Cioflica, 1964) with large structural variations depending on the rock position within the body and without more important basic differentiation products. Aplites and porphyritic micrograniteses as later differentiation products of granitic magma, form small sized bodies and pierce hypidiomorphic, granular rocks, which were previously consolidated.

The rocks are composed, in variable quantities, of oligoclase very weakly zoned (33-50%), orthoclase-sometimes microperthitic (18-37%), quartz with undulatory extinction (27-33%), to which biotite (1.5-3.8%) is added and only sporadically hornblende (0-1%). Accesory minerals as iron oxides, apatite and often titanite and zircon do not exceed 1%. As secondary minerals appear : albite, sericite, clay minerals, chlorite, calcite and very often epidote ; partially both sphene and opaque minerals do occur secondary too.

At the north-eastern extremity of the Cerbia granodiorite-granitic massif (on the Valea Mare and the Strîmbu brook) appear diorite-tonalites with highly zoned plagioclase, whose peculiar aspects and due to the quartz contents and its undulatory extinction suggest the pertinency of these rocks to Eocretaceous magmatites.

The composition of these rocks varies a lot : plagioclase (An_{27-46}) — 63-74% ; quartz — 2.3-23.5% ; pyroxene — 0-5% ; hornblende (mostly as rims of magmatic reaction around pyroxene) — 0-15% ; orthoclase — 0.1-2.5% ; apatite — 0.1-0.2% ; opaque minerals (which mostly result secondary) — 2.5-4%.

Within the dykes swarms that penetrate the ophiolitic magmatites in the surroundings of the Cerbia massif, was identified a large range of porphyritic rocks with variations of texture and composition but similar with the granodiorite-granite rocks as regards the mineralogic, geochemical and physiographic features of the crystals (Cioflica, 1964 ; Ștefan in Lupu et al., 1983). According to the mineralogic composition and textural variations, the following rocks have been separated : porphyritic quartz-microdiorites, porphyritic microgranodiorites — granodiorite porphyres — dacites, porphyritic microgranites-rhyolites, to which rocks as oligophyres, albitophyres and orthophyres are added ; due to their phenocrysts of quartz and their high content in alkalis, these last rocks could be considered as keratophyres.

The intrusive sphenolitic body (Cioflica, 1962) from Pietroasa-Căzănești consists mostly of sodic granite-tonalite. A little more basic differentiation products (quartz-diorites) are less important as volume and are situated at the extremity of the massif.

The uneven composition of the rocks which are made of quartz with a strong undulatory extinction (19-50%), plagioclase (43-79%) up to 46% An (in the quartz-diorites) or oligoclase-albite (in the majority of the granitoids), alkaline feldspar (1-7%) allow the separation of several varieties. Besides these mafic minerals such as biotite and sometimes hornblende, generally strongly chloritized and with separations of iron oxides are added. In the quartz-diorites, rhombic and monoclinic pyroxenes, often uralitized, occur. Albite oligoclasic plagioclases (often with undulatory extinctions) from tonalites and sodic granites are twinned but not zoned or present only a clear rim with a continuous extinction ; they often form myrmekitic intergrowths with the quartz. Sometimes hypidiomorphic crystals of twinned albite show oligoclase relics in the core ; in this case, it seems to be an intramagmatic process. Later albitization along the fissures or cleavage planes develop the albite crystals twinned in fine lamellae which corrode primary oligoclase-albitic plagioclases. Accessory apatite and secondary minerals as albite, calcite, sericite, epidote, chlorite and clay minerals are noticed more frequently.

Around the Pietroasa body, cogenetic rocks which form dykes, exhibit similar composition and large structural variations.

Small sized bodies, generally of quartz-dioritic composition from Dealu Mare-Podele zone probably belong to the same petrographic granitoid-Eocretaceous province. These magmatites are similar to those belonging to the extremity of the Pietroasa sphenolite, suggesting that a tonalite-sodic granite body could develop in the depth, especially westwards.

From mineralogic point of view, the rocks are constituted mostly of labrador-andesine plagioclase seldom peripherically zoned, with zones less marked than in the banatites and without reccurrences characteristic to the last ones. But, several times plagioclases show a more acid rim with continuous extinction. Albite often pseudomorphoses plagioclase, and sericite, calcite and zeolites do appear. Among the mafic minerals, the rhombic and monoclinic pyroxenes, often pseudomorphosed by fibrous amphyboles, calcite, chlorite or bastite and grains of iron oxides situated sometimes along the cleavage planes are noticed. Common hornblende is converted into chlorite. Scarce orthoclase mantling plagioclase and sometimes forming intergrowths with quartz do occur ; sometimes potassic feldspar was not identified microscopically. Xenomorphic quartz as small sized grains appear interstitially and often shows undulatory extinction.

In the same zone, base metal mineralization from the Valea Mare-Podele basin spatially associated with the granodiorite porphyry do occur. Plagioclase of oligoclase composition is sometimes weakly zoned but the zones limits are not very obvious and the variation of the composition from one zone to another is very low ; the mineral is highly pseudomorphosed by sericite. Quartz as phenocrysts has undulatory extinction. Among femic minerals appears only biotite and it is often chloritized. Newly formed calcite and epidote on account of femic mineral or of plagioclase phenocrysts together with clay minerals and sericite, which pseudomorphose the feldspars from the quartz-feldspatic microgranular groundmass are distinguished.

Maastrichtian conglomerates from the Obîrşia valley, northward of the Crişul Alb include centimetric and decimetric elements of granitoid rocks, more often hypidiomorphic equigranular ones or porphyritic and basaltic rocks often spilitized.

Among the granitoids predominate tonalites which according to the contents of minerals and plagioclase acidity, pass to trondhjemites, quartz-diorites and sodic granites. In the thin sections of the boulders (16), eleven porphyritic microtonalites and tonalites, two granodiorite porphyres-dacites, two rhyolites, and one porphyritic quartz-micro-diorite have been identified.

In all thin section of granitoid rocks (poor in potassic feldspar) the quartz appears as well, developed crystals with undulatory extinction. In the granular rocks, generally tonalitic, quartz forms often intergrowths with nonzoned albite-oligoclase, but twinned polysynthetically or after the albite-Karlsbad low. Within a thin section of a tonalite-quartz-dioritic rock andesine (37% An) with undulatory extinction, secondary albitized has been identified; meanwhile, biotite includes plagioclase being included itself by the quartz. In other thin sections the abundent apatite appears fresh within a thick pattern of chlorite, formed on the biotite account. Although femic minerals are completely chloritized giving rise also to iron oxides, it seems that the only primary mineral is the biotite. Within porphyritic rocks, besides biotite was identified also chloritized amphybole, both in granodiorite porphyries-dacites and in some porphyritic microtonalites. Almost always plagioclases in these granitoid rocks are converted into clay minerals or sericite; sericite results often on account of more basic oligoclasic cores, while clay minerals are formed on account of albite which is twinned polysynthetically and corrode all the other minerals. It is obvious that the albite is late magmatic. Calcitizations are less frequent.

In Albian and Maastrichtian conglomerates from the Znilu Valley, near Rișculița, northward of the Crișul Alb, boulders of granitoid rocks such as tonalite and rhyolite, rich in Na_2O with the same physiographic features of the minerals have been encountered. Thus in the tonalites, plagioclases are represented either by albitized andesine, or by an oligoclase rimmed by a limpid albite. Potassic feldspar, in small quantities, mantles the plagioclase and the biotite is baueritized. Both plagioclase (generally nonzoned) and especially the quartz show strong undulatory extinction.

Similar boulders of granitoid rocks included in the Cretaceous sedimentary deposits have been described by Berbeleac (1968) in the eastern part of the Metaliferi Mts near the Valea Mică place. Some base metal mineralization associated to these magmatites have been mentioned by the same author.

North-eastwards in the south part of the Trascău Mts, granitoid rocks which pierce the ophiolites, considered to belong to the banatites have been described and chemically characterized by Nicolae (1981).

The microscopic observations both on our own samples and on those kindly provided by our collegue Dr. Nicolae Ionel, lead to the conclusion that these rocks are older than the banatites being identical to those included as boulders in the deposits from the Meteș and Feneș Formations. Some data concerning the isotopic ages support this conclusion (Lemne et al., 1982) and recently have been assigned to the other granitoid rocks of the Eocretaceous magmatites family (Lupu et al., 1984). Nicolae (1981) showed that Borcoş et al. (1980) supposed an acid Mesocretaceous magmatism in the eastern part of the Metaliferi Mts, to which they include : granitoid rocks intercepted in the drillings from Copand and Aiud in the western part of the Transylvanian Depression under the Eocene deposits ; boulders of granitoids included in the Albian Wildflysch as well as dacitic rocks from the eastern zone of Vorța. To this point of view agrees only partly Nicolae (1981).

Ampoița granitoids which penetrate the ophiolitic rocks generating hornfelses as amphibolitic facies (Nicolae, 1981) are represented according to this author by monzogranites, granodiorites, tonalites and diorites, constituting "apophyses of a larger body, developed in the depth, which could have a complex evolution".

Our field and laboratory observations show that quartz-dioritic-tonalitic rocks made up of plagioclase, amphybole, quartz, a little alkaline feldspar, opaque minerals and apatite are affected frequently by cataclasis and obviously penetrate the basaltic lavas and the ophiolitic dolerites (on the left slope of the Biserica Brook, left tributary of the Ampoița Valley, near Ampoița).

Plagioclases with positive relief, twinned but practically nonzoned less clear than the alkaline feldspars, are full of sericite and clay minerals ± epidote, with a clear rim of acid-oligoclasic composition and with a continuous extinction. Plagioclase macles are sometimes curved or fissured and quartz has a strong undulatory extinction being fissured and crushed at the same time.

Within the same zone, appear granitoids of granodioritic-tonalitic composition, constituted of acid plagioclase, alkaline feldspars, quartz and biotite. In these rocks, plagioclases weakly sericitized are crossed by thin albite veins, are less turbid, but have the same physiographic features : a main internal part of the crystal with uniform extinction is surrounded by a rim of 0.05-0.1 mm in thickness, having a more and more acid composition towards the margin which continuously extincts. In the same thin section, quartz has undulatory extinction and the twinning planes of the plagioclase as well as the separation planes of mesoperthitic alkaline feldspar are a little curved or fissured.

Granodiorite-tonalite is penetrated by veins of porphyritic microgranites consisting of acid oligoclase, quartz, alkaline feldspar (in this case without exolutions) and chloritized biotite, with separation of oxides or iron hydroxides.

Tonalite-granodiorite rocks, strongly cataclased, which seem to pierce also the ophiolites on the left tributary of the Ampoița Valley, downstream the Biserica Brook, belong to the same Eocretaceous magmatism, which was confirmed by isotopic ages (Lemne et al., 1982).

The rock is made up of acid plagioclase, quartz, alkaline feldspar, biotite and opaque minerals, to which are secondary added : epidote, sphene, pennine and clay minerals. Often there are present fissures filled with albite ± quartz which crosscut the rock. At the same time, the plagioclases are nonzoned and quartz shows undulatory extinction.

Within the Gorbu brook basin, left tributary of the Ampoița, at western limit of this place, granodioritic, granular hypidiomorphic rocks composed of plagioclase, quartz, alkaline feldspar, hornblende and biotite penetrate the ophiolites and generate amphibolite facies hornfelses (Boștinescu et al., 1981). The granodiorites include xenolites of porphyritic quartz-microdiorites of similar composition, but richer in amphyboles and opaque minerals, plagioclases being more sericitized or converted into clay minerals and sometimes pseudomorphosed by epidote. A higher acid rim, with continuous extinction, frames also the plagioclase and the mesoperthitic alkaline feldspar proves its high content in sodium. Not only quartz, but also plagioclase and alkaline feldspar has undulatory extinction.

Quartz-dioritic-tonalitic rocks which outcrops under the Miocene deposits, on the road toward Ampoița, left of the Biserica Brook have some features a little different than those other granitoids and more similar to the banatites.

From macroscopic point of view, the rock is massive, grey in colour, faneritic-equigranular and similar to a gabbro.

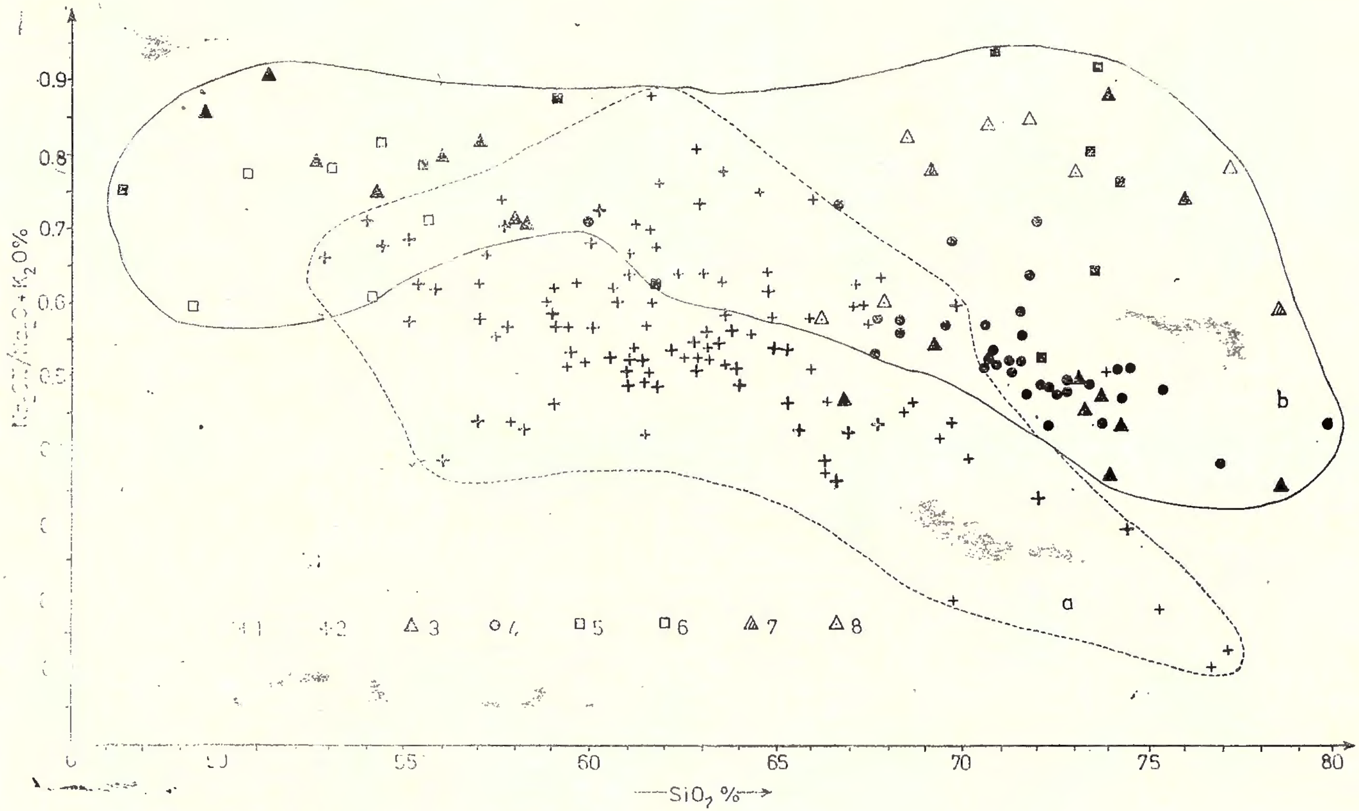
Under the microscope, one may distinguish plagioclases (ranging up to 50% An), twinned and zoned, especially toward the crystal edge in this case noticing also weak reccurrences. Quartz, often with undulatory extinction does not exceed 20% of the rock volume. Green hornblende is added to leucocratic minerals. Secondary appear : epidote, calcite and sericite. Often central part of the crystal is strongly saussuritized while the zoned crystal is limpid toward the margin.

Within the hydrographic basin of the Țelna valley are present granitoid of tonalitic-granodioritic composition up to sodic granites included by the Upper Aptian-Albian deposits of the Meteș Formation as well as in the Barremian-Lower Aptian ones of the Feneș Formation (Lupu et al., 1982).

The rocks are mainly constituted of plagioclase, generally albite-oligoclase, sometimes with andesine relics (An_{37}). Plagioclases are not zoned, with a rim with negative relief, which continuously extincts. Alkaline sodic-potassic feldspar, often mesoperthitic, microscopically distinguished and emphasized by the chemical analyses (Ștefan and Nicolae, in Lupu et al., 1982) is sometimes intergrown, alike the oligoclase-albitic plagioclase, with the quartz. Biotite is always almost chloritized, and sometimes baueritized. Seldom amphybole appears and is pseudomorphosed by chlorite and calcite. Undulatory extinction both of the plagioclase feldspar and the alkaline ones and especially of the quartz has been noticed.

Distinctive Chemical Features of Granitoids and Banatitic Rocks

A geochemical characterization of granitoid rocks that form the eruptive massifs of Pietroasa and Cerbia or are included as boulders in the Cretaceous sedimentary deposits from the South Bihor and the Trascău Mts is given in the previous works (Udubașa et al., 1981, 1982, 1984 ; Lupu et al., 1982, 1983, 1984) and we are not supposed to discuss this aspect in the present paper. But, starting from the statement that granitoid Eocretaceous rocks are much richer in Na_2O than banatitic ones, we drew a diagram in which, on the ordonate, have been projected



Distribution fields of banatitic magmatic rocks (a) and of Eocretaceous granitoids (b).
Banatites: 1, Porphyritic (subvolcanic) rocks Măgureaua Vaţei; 2, Equigranular rocks (hypoabyssal-plutonic), Măgureaua Vaţei, South Bihor. Eocretaceous magmatites; 3, Granites-granodiorites; quartz diorites and associated porphyritic rocks, Săvîrşin; 4, Granites-granodiorites and associated porphyritic rocks, Cerbia; 5, Tonalites-sodic granites; quartz diorites, Pietroasa (Căzăneşti); 6, Quartz diorites, Dealu Mare, Valea Mare (Podele); 7, Granitoid (tonalites, sodic granites, microgranitic rhyolites) blocks in Senonian and Albian deposits, South Bihor; 8, Granitoid (tonalites, quartz diorites, granodiorites, sodic granites blocks in Meteş and Feneş beds, Trascău.

relations as $Na_2O\%/Na_2O + K_2O\%$ and on the abscissa, the contents in $SiO_2\%$. On this diagram are projected all granitoid magmatites from the Drocea, Metaliferi and Trascău Mts which we and other authors have analysed and presented since 1960, as well as equigranular or porphyritic banatites from the Măgureaua Vaței-Birtin Valley, to which the granular banatites from the area between the Crișul Alb and the Arieșul Mic are added.

The diagram points out on one hand two distinct fields as regards the rocks of the two petrographic provinces and on the other hand an obvious differentiation related to a large variation of the content in SiO_2 for banatitic calcoalkaline magmas (of initial granodioritic composition) in contrast with one weakerly expressed for the magma (granitic, richer in sodium) which generated the granitoids. It is possible that the magma which early generated weakly quartzferrous diorites has been intensely contaminated with sialic crust material, eventually within an intermediary magmatic chamber, generating granitic magmas rich in Na, from which crystallized most of the granitoid rocks. While the differentiation process went on, the magma becomes richer and richer in K_2O but having at the same time a high content in Na_2O, giving rise to alkaline feldspar which crystallizes under calmer conditions and because of more stable pressure suffered an exsolution into the two components, sometimes having typical features of a mesoperthite. Within the small bodies, the cooling took place rapidly and thus the exsolution was not possible, the high content in Na_2O of the alkaline feldspar being pointed out by the chemical analyses. In the larger massifs such as Cerbia and Săvîrșin consolidated at relatively deeper levels, the K_2O content is weakly higher comparing to that of the subvolcanic bodies or lava flows associated to and emplaced earlier and also against the rocks from the less important occurrences. It results that within the area of the quartz-diorites and tonalites development, the existence of granodioritic-granitic bodies, eventually accompanied by mineralizations, could be possible towards the depth.

Conclusions

1. The physiographic features of the minerals and the mineralogic and chemical composition of some intrusive rocks, which penetrate the ophiolites in the southern part of the Apuseni Mts as well as the presence of the same petrographic rock types, as boulders included by the Barremian-Aptian and Senonian deposits from the Trascău and the South Bihor allow us to outline an Eocretaceous magmatic province.

2. Most of the rocks from the boulders included by the sedimentary deposits as these which outcrop at Pietroasa-Căzănești and Ampoița, have a tonalitic composition with tendencies towards sodic granites.

3. Although the Cerbia and Săvîrșin massifs have generally a granodiorite-granitic composition, the content in Na as well as the plagioclase composition (more acid and more sodic than in similar rocks which penetrate the Senonian deposits) give the differences from the corresponding banatites.

4. The presence of some reduced quantity of quartz-dioritic differentiates and the lack of some quartz-andesitic volcanics more or less of the same age and similar composition show the differences among these rocks and the banatites, as well.

5. Continuous range of differentiation products — typical for banatites — is much less obvious in the case of the Eocretaceous granitoids.

6. The absence of the zoning of the plagioclase from the tonalitic or granodiorite-granitic granitoids, as well as their character less marked and reccurrent (sometimes present in the case of quartz-diorites) with the presence of a more acid rim (which continuously extincts) and by undulatory extinction of quartz, separate also granitoids from banatites.

7. The high content in Na of the alkaline feldspar, sometimes shown by mesoperthitic exsolutions as by the higher ratio $Na_2O\%/ Na_2O + K_2O\%$ in comparison with the contents in $SiO_2\%$ show the differences among the magmatites from the two petrographic provinces.

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QUESTIONS

D. Săndulescu : Besides the isotopic ages, which arguments are taken into account to consider the granitoids as the products of a peculiar Eocretaceous magmatism, being known that within the Mureş Zone, there are sodic differentiated belonging to an older island arc magmatism ?

Answer: The aim of the present paper is supposed to demonstrate that the above mentioned granitoids do not belong to the banatitic rocks. The Eocretaceous age of these rocks has been assumed due to the fields relations such as:

1. The granitoid are included as boulders within the Barremian-Aptian, Albian and Senonian deposits;

2. The granitoids penetrate both the basaltic and andesitic products of a magmatism of 180-140 m.y. age.

Some data concerning the isotopic age (non-mentioned in this paper) are supporting our conclusions.

It cannot be denied that a certain relation between granitoids and products of basic magmatism could exist, although according to Herz et al. (1974) who dealt with the granitoids from Săvîrşin have noticed that the banatites "do not display an obvious relation with the ophiolitic rocks", but Rb/Sr and Sr^{87}/Sr^{86} ratios suggest their provenience from a magma highly contaminated with crustal Sialic material". Discontinuity in time and the differentiation of chemical and mineralogical features of these granitoid rocks in comparison with the great amount of basalts and andesites earlier emplaced, led us to the conclusion that the granitoids should be included within an apart petrographic province — Eocretaceous in age.

GRANITOIDELE EOCRETACICE DIN APUSENII DE SUD

(Rezumat)

Datele de teren şi laborator, pe care le-am obţinut în ultimul timp, conduc la concluzia că majoritatea rocilor granitoide, care străbat produsele magmatice ofiolitice de la nord de Mureş (Pietroasa-Căzăneşti, **Săvîrşin, Cerbia, Dealu Mare-Podele şi Ampoiţa)** trebuie excluse din rîndul banatitelor (post-maastrichtian-inferior-paleogene) şi atribuite unui magmatism mai vechi — eocretacic.

Compoziţia chimică şi mineralogică, precum şi caracterele fiziografice ale mineralelor din granitoidele eocretacice (deosebite de ale rocilor banatitice) sînt similare cu ale acelora din blocurile înglobate în formaţiunile sedimentare senoniene şi albiene din partea de sud a munţilor Bihor, sau în stratele de Feneş (Barremian-Apţian inferior) şi în cele de Meteş (Apţian superior-Albian) din munţii Trascău.

Vîrstele izotopice, obţinute prin metoda K/Ar în laboratoarele Institutului de Geologie şi Geofizică, sprijină de asemenea atribuirea granitoidelor din zonele menţionate unui magmatism anterior punerii în loc a rocilor banatitice — eocretacic (Lemne et al., 1979, 1981, 1982, 1983).

Majoritatea rocilor din blocurile înglobate în depozitele sedimentare menţionate, ca şi cele care aflorează la Pietroasa-Căzăneşti şi Ampoiţa prezintă o compoziţie tonalitică fiind constituite în principal din cuarţ şi oligoclaz acid-albit.

Cu toate că granitoidele din masivele de la Săvîrșin și Cerbia au în esență o compoziție granodiorit-granitică, caracterul mai acid al plagioclazului și respectiv conținutul mai ridicat în Na_2O al rocilor specific granitoidelor — eocretacice — le diferențiază de magmatitele banatitice.

Absența unei suite continue de diferențiate în cazul granitoidelor eocretacice, care este caracteristică pentru rocile banatitice, diferențiază de asemenea produsele magmatice ale celor două provincii petrografice.

În sfîrșit, extincțiile intens ondulatorii ale granulelor de cuarț și (în general) absența zonelor în plagioclazii din granitoidele tonalitice și granodiorit-granitice eocretacice, precum și caracterul acestor zone mai puțin tranșant și recurent în cazul (mai rar) dioritelor cuarțifere, alături de prezența unei rame late, mai acide, care stinge continuu, caracterizează de asemenea rocile eocretacice și le separă de cele banatitice.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

PETROLOGICAL STUDY OF THE ALPINE MAGMATITES IN THE LINK ZONE BETWEEN THE APUSENI MOUNTAINS AND THE OAŞ-GUTÎI-ŢIBLEŞ VOLCANIC CHAIN [1]

BY

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Alpine magmatites. Banatitic magmatism. Cretaceous. Rhyodacite. Quartzites. Chemical composition. Neogene volcanism. Subvolcanic bodies. Apuseni Mountains — Northern Apuseni Mountains — Meseş Mountains; Paleogene zone in NW Transylvania.

Abstract

The geological structure of the region lying between the Apuseni Mountains and the Oaş-Gutîi-Ţibleş volcanic chain is made up of: a. the basement, represented by crystalline schists and Triassic deposits; b. the formations of the posttectonic cover (Upper Cretaceous, Paleogene and Miocene deposits); c. the banatitic and Neogene eruptive rocks. The banatitic magmatism (less developed in the study area) evolved during two cycles, as in the north Apuseni Mts. From the first cycle (well represented by andesites, dacites and rhyolites in the Vlădeasa massif) only the rhyolites occurring within the Moigrad zone are correlatable within their equivalents of the eruptive massif. These rocks are frequently reworked in the Jibou Beds (Paleocene-Lower Lutetian) and especially in the Marly Conglomeratic Horizon (Lower Miocene). The Valea Chioarului vitroclastic rhyodacites, with a Na_2O/K_2O ratio differing from that of other banatitic calc-alkaline rocks (of similar composition), have probably been emplaced during the first cycle, too. Quartz andesites-quartz diorite porphyries, dacites-granodiorite porphyries and microgranite rhyolites intruding the crystalline formations in the Meseş Mts are correlatable with products of the second banatitic magmatic cycle in the Vlădeasa and Gilău Mts. The last magmatic manifestations in the region are represented by andesite-porphyritic microdiorites subvolcanic bodies which pierce the Chattian Zimbor Beds. These rocks belong to the Neogene volcanism and do not represent a continuity of the banatitic magmatism in time.

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Résumé

Etude pétrologique des magmatites alpines de la zone de liaison entre les Monts Apuseni et la chaîne volcanique de Oaş-Gutîi-Ţibleş. A la constitution géologique de la région comprise entre les Monts Apuseni et le massif de Preluca participent : des formations du soubassement représentées par des schistes cristallins et par des dépôts triasiques ; des formations de la couverture post-tectonique représentées par des dépôts crétacés supérieurs, paléogènes et miocènes ; des roches éruptives banatitiques et néogènes.

Le magmatisme banatitique (réduit comme ampleur dans l'aire étudiée) s'est déroulé, tout comme dans les Apuseni du Nord, dans le cadre de deux cycles.

Du premier cycle (bien représenté dans le massif Vlădeasa par des andésites, des dacites et des rhyolites) seulement les rhyolites contourées dans la zone du Moigrad sont parfaitement corrélables avec leurs correspondants du massif eruptif ; ces roches sont remaniées dans les couches de Jibou (Paléocène-Lutétien inférieur) et abondamment dans l'horizon conglomératique marneux (Miocène inférieur).

Les rhyodacites vitroclastiques de Valea Chioarului, ayant un rapport $Na_2O : K_2O$ différent envers celui des autres roches calcoalcalines banatitiques (de composition comparable) appartiennent probablement toujours au premier cycle.

Les andésites quartzifères-porphyres quartzdioritiques, les dacites-porphyres granodioritiques et rhyolites microgranitiques, qui traversent les formations cristallophylliennes des monts Meseş, sont corrélables avec les produits du deuxième cycle magmatique banatitique de Vlădeasa et de Gilău.

Les dernières manifestations magmatiques de la région sont matérialisées par des corps subvolcaniques d'andésites-microdiorites porphyriques, qui, dans la zone du Moigrad, traversent les couches de Zimbor d'âge chattien ; ces roches appartiennent au volcanisme néogène et ne représentent pas une continuité en temps du magmatisme banatitique.

Introduction

Field researches (1979, 1980) effectuated in the link zone between the northernmost part of the Vlădeasa eruptive massif (to the south) and the Valea Chioarului bentonitized rhyodacitic body (to the north) (Pl. I) took into account banatitic and Neogene eruptive rocks as well as their relationship with the surrounding formations.

The large spreading area of the Alpine magmatites did not allow the geological mapping of the whole area. Consequently, on the basis of the available information (Gherasi et al., 1967 ; Lupu et al., 1967 ; Rusu, 1967 ; Saulea et al., 1967 ; Ignat, 1973 ; Ştefan et al., 1974 ; Rusu et al., 1977 ; Marinescu et al., 1982) we confined ourselves to identify the eruptive bodies and locally to establish their morphology. The published data as well as those mentioned in the geological reports have been used in our attempt to give a unitary image of the magmatism in the study area. Among the authors who studied the eruptive rocks in the area under discussion mention should be made of Chiriac (1953, 1962), Hofmann (1879, 1891), Ignat (1973), Ignat, Ignat (1964), Ignat Nedelcu (1966), Iliescu (1965), Kalmar (1975), Kalmar, Ionescu (1969), Mîrza, Ghergariu (1963), Noveanu (1960), Rusu (1967, 1977), Soroiu (1977), Szentes (1950), Ştefan et al. (1974), Ştefan et al. (1980), Ştefan et al. (1981).

Geological Setting

The geological structure of the region consists of the basement (crystalline schists and Triassic deposits), the posttectonic cover formations (Upper Cretaceous, Paleogene and Miocene deposits), and the banatitic and Neogene eruptive rocks.

Basement

Crystalline schists in the Meseş Mts belong to two distinct metamorphic series : Someş Series (Upper Precambrian A) and Meseş Series (Upper Precambrian B). According to the latest hypothesis illustrated by Horvath on the Tusa Sheet (Marinescu et al., 1982), the Someş Series (metamorphites — almandine amphibolite facies), belonging to the Bihor Unit, is overlain by the Meseş Series (metamorphites — greenschist facies). The mentioned author, who continued Ignat's research (1973), distinguished several formations in the above-mentioned series, as follows :

— within the Someş Series : a lower terrigenous formation (quartzitic micaschists), a leptino-amphibolitic formation (micaschists and quartzites with intercalations of quartzitic paragneisses, augen gneisses, leptinites, amphibolites, etc.) and an upper terrigenous formation (micaschists with quartzitic schists) ;

— within the Meseş Series : Pria terrigenous formation (muscovitic quartz schists) at the bottom and basic tuffaceous formation (chlorite schists and muscovite schists with intercalations of quartz-feldspathic schists and actinolite schists) at the top.

In the Meseş Mts the Triassic deposits are found on reduced areas, directly overlying the crystalline schists of the Someş Series. Lithologically they are represented by conglomerates, quartzitic sandstones, clay shales, dolomites and limestones ascribed to the Werfenian-Anisian.

Posttectonic Cover

The Upper Cretaceous deposits represent the first term of the cover. In the Meseş Mts they are found locally, only south of Zalău ; they consist of conglomerates, sandstones and marly-clays with intercalations of calcareous breccias and Gosau-type fossiliferous limestones (Santonian-Campanian). In Valea Chioarului locality the Upper Cretaceous deposits occur as islands being covered by the Paleogene red clays complex. They are made up of siltic marls alternating with marly sandstones or limy sandstones with a Coniacian fauna (Chiriac, 1962 ; Mîrza, Ghergariu, 1963).

The Paleogene deposits begin with a thick pile of continental-lacustrine rocks (Lower Variegated Clay Complex = Jibou Beds) consisting of pebbles and conglomerates with a red clay-sandy matrix, variegated clays and greenish sands. The Jibou Beds represent the first formation that includes boulders of banatitic eruptive ; pebbles of Măguricea-type rhyolites and Puguiorul Hill dacites occur frequently in the Moigrad Zone. The Lower Variegated Clays Complex covers the Paleocene-Lower Lutetian time interval. A sedimentary gap might exist between the basal level of lateritic polygenous breccias in the Preluca area (Kalmar, 1975), considered of Danian age, and the remaining of the formation (within which only the Cuisian is proved paleontologically).

There follows the lower marine series (for the stratigraphic succession in the Meseş Zone, see Rusu et al., 1978) consisting of formations attributed to the Upper Lutetian-basal Priabonian. Among them mention should be made of the Mortănuşa Beds (marls and grey siltic clays interbedded with marly-limestones) of Upper Lutetian age, in which Iliescu (1965) includes rhyolites and quartz porphyries "as a 1.5-2 m thick stratiform intercalation". The study of the Racova Valley basin points out clearly that such an intercalation does not exist. The rhyolite blocks, present along the tributaries of the Racova Valley, originate in the deposits of the Marly Conglomeratic Horizon (Lower Miocene) preserved on three slopes, east of the Benesat-Cuceu-Moigrad Fault (Pl. II).

The Turbuţa Beds (green clays, dolomites and gypsums) — a Priabonian lacustrine continental formation — are intruded by the Stîna andesite dyke (Pl. II).

The upper marine series (Upper Priabonian-early Rupelian) includes the Cluj Limestone and the Brebi Marls, the latter ones being slightly affected by the Măgura Moigradului microdioritic body.

There follows Oligocene formations mostly brackish, among which the red clays of the Zimbor Beds represent the latest deposits that come into contact with the Neogene eruptive in the Moigrad Zone.

The Miocene deposits transgressively and unconformably overlie different older terms, among which the Marly Conglomeratic Horizon (Rusu, 1967) formed here (a local equivalent of the Chechiş Marls) from a packet of conglomerates and one of marls with Chechiş-type microfauna of Lower Miocene age. At the base occurs a level with blocks of eruptive rocks (cca 1 m in diameter) encountered in the whole outcropping area of the horizon, north of the Răpaos Valley.

Conglomerates deposited on a pre-existent relief cover the Măguricea banatitic eruptive rhyolites and seem to include rhyolite olistolithic blocks (Puguiorul Summit).

Middle and Upper Miocene formations belonging to the Sylvanian Basin also occur in the area of study.

Tectonic Considerations

The main tectonic accident in the study area is the "Moigrad Fault" which led to the disappearance of the Meseş crystalline — sunk several hundreds of metres in the northern compartment — and the emplacement during several stages of the eruptive rocks. This major break of the crust facilitated the appearance of the banatitic eruptions (terminal Cretaceous-early Paleogene). The intersection of the Moigrad Fault Zone with the Benesat-Cuceu-Moigrad Fault (post-Badenian — pre-Pannonian) determined the emplacement conditions of the Moigrad subvolcanic bodies.

As regards the Valea Chioarului eruptive body, it lies in a graben zone (between the Ţicău and Preluca crystalline massifs) wherein the Upper Cretaceous deposits have not been eroded.

Magmatic Rocks

In the study region the Alpine magmatites are represented by banatitic and Neogene eruptive rocks.

Banatitic and Pre-Banatitic (?) Eruptive Rocks

The reduced size of the banatitic bodies and, more often, the lack of direct relations between the petrotypes noticed in this region make difficult the correlations.

The research carried out in the eastern Vlădeasa (Ştefan, 1980) shows that the banatitic magmatism of cycle I starts with andesites, followed by dacites and rhyolites overlying (or intruding) the Lower Maastrichtian deposits.

In the area under consideration the rhyolites in the Moigrad Zone are the only rocks perfectly correlatable with volcanics outlined in the Vlădeasa. Although not found in outcrops, the presence of andesite xenoliths within rhyolites proves the existence of such products in this zone, as well.

The rocks of the subvolcanic bodies which pierce the Meseş crystalline are correlatable with similar magmatites of cycle II in the Vlădeasa and Gilău Mts (Ştefan et al., 1982).

Banatitic rhyolitic volcanics are found in the Moigrad area both as blocks or olistoliths insedimented in Miocene deposits, or as enrooted bodies exposed by erosion from under the same deposits. The rhyolitic bodies in this zone were considered by Hofmann (1879) as link elements between the Vlădeasa trachytes and the Vihorlat-Gutîi eruptive (Sarmatian).

Later, Iliescu (1965) asserted the time and space continuity of the banatitic magmatism from the southern part (Muntele Mare (?!) and Vlădeasa) towards the Neogene volcanism of the Gutîi Mts.

Dacites

Besides the two fresh dacite outcrops nearby the northern boundary of the Vlădeasa eruptive massif, already described (Ştefan, 1980), no similar rocks occur in the Meseş crystalline.

South of the Puguiorul Summit in the Moigrad Zone, the olistolith of eruptive rocks is mostly constituted of pyroclastic rhyolites, which to the east come into contact with dacites, included as xenoliths; the last ones are considered older than the banatites. The fact that on a large area blocks of dacites are included beside rhyolites within sedimentary deposits prove an eruptive manifestation of a certain importance. Unlike the fresh dacite outlined in the Vlădeasa massif, mostly emplaced under subvolcanic conditions, the dacite from the olistolith found in the Puguiorul Summit has an effusive character and is more altered. The mentioned rock resembles the dacite type included as blocks in the breccious conglomerates which overlie the Lower Maastrichtian marly-clays and are themselves overlain by andesitic lava flows from the Drăganului Valley spring zone which start the Vlădeasa banatitic magmatism.

Microscopically the rock consists of a cryptocrystalline groundmass (50%), invaded by chlorite and sericite. In places fragments with convex-concave outlines (shards) of devitrified glass within which, under crossed nicols only, fine-grained quartz can be distinguished.

The groundmass includes plagioclase phenocrysts, corroded quartz and femic minerals, generally pseudomorphosed. Plagioclase (An_{22-72}) twinned but unzoned, is intensely replaced by albite or it displays a grey clayey film, often pierced through by thin flakes of micaceous minerals; more rarely it is replaced by minerals belonging to the epidote or zeolite group. Hornblende is seldom preserved as fresh relics; most often it is recognized only after its basal outlines, filled either with quartz grains and opaque minerals or with chlorite. Biotite with apatite inclusions is usually baueritized.

Valea Chioarului Vitroclastic Rhyodacites

The vitroclastic rhyodacitic body, more or less bentonitized, forms a dyke of 450 m in length at +285 m horizon and of 330 m at +221 m horizon. The dyke with a N34W trending generally dips cca 40° SSW and has a thickness of 40-50 m, reaching 60 m in the slightly bent zone and thinning out towards NNW. The mine workings and drillings demonstrated that to the north the length of the dyke decreases towards depth, and to the south, where after Kalmar and Ionescu (1969) it would be cut by Olăriţa Valley Fault, it remains at the same parallel. The dyke shape of this body was pointed out by Mârza and Ghergariu (1963) who, at the same time, disagreed with the supergene origin of bentonites on account of tuffs (Szentes, 1950; Chiriac, 1953; Noveanu, 1960). The mentioned authors stated that bentonite originates in the "vitreous rhyolite under the influence of hypogene thermal solutions (especially on account of the glass)." Kalmar and Ionescu (1969) described in this zone a wedge-like neck with a SW trend, and Kalmar (1975) mentioned that the Valea Chioarului eruptive neck lies on a length of cca 1 km and dips 55-75 NNE (?!). Kalmar also stated that the relationships of the rhyodacite body with the surrounding rocks clearly indicate the character of an extrusion and not of an interlayered tuff bed; the emplacement took place as "an extrusion of a semivitreous viscous mass rich in volatiles at high temperatures".

We mostly agree with Kalmar's opinion and consider that in Valea Chioarului there were conditions (graben zone) favourable for the enrichment in volatiles, especially water vapours. Thus, took place the increase of the magma volume through a swelling process which led (near the surface) to the accumulation of pumice still nonsolidified and plastic. In the end the film of the gas bubbles was broken as "shards" and the pyromagma, made up of a gas suspension with small glass fragments and free crystals, consolidated rapidly under subvolcanic conditions giving rise to rocks with vitroclastic textures.

Surface and underground evidence from Valea Chioarului points to direct contacts between the bentonitized rhyodacitic dyke and the red deposits of the Jibou Beds ; nevertheless it does not clear up the relations between them. Starting from the K/Ar age determinations for the Valea Chioarului rhyodacites (64.1±1.9 m.y. — Soroiu, 1977 ; 64.94±3.98 m.y. for fresh rock and 75.76±3.15 m.y. and 94.94±3.98 m.y., respectively, for rocks with xenoliths of crystalline schists, siltites and tuffs — Lemne et al., 1982), two interpretations are possible : 1) tectonic relations between the eruptive dyke, occurring as a horst in the Paleogene sedimentary deposits (unlikely) and 2) intrusion of the subvolcanic body into the basal horizon of polygenous breccias of the Lower Variegated Clay Complex (Jibou Beds), a lateritic horizon typical of the Preluca area. This independent horizon, included into the Lower Variegated Clay Complex, is undoubtedly of pre-Montian or post-Coniacian age, being probably formed at the beginning of the Danian.

It is to be noticed that the elliptic enrooted body (10 × 30 m) that might intrude the Turbuţa Beds (Kalmar, 1975, p. 191 and Pl. III), illustrated on the map west of the Duruşa Hill, does not exist. Our detailed study points out only pebbles of banatitic microgranitic rhyolites similar to those from Stîrci and Fetindia, originating in the base of the Badenian deposits. Provided that this body (with the same origin and age as that from Valea Chioarului) existed, the post-Lower Priabonian age of the eruptive emplacement would have been proved and it would contradict the absolute age determinations.

The Valea Chioarului rhyodacites are massive rocks, of a dark-grey, sometimes whitish colour, poor in phenocrysts and containing xenoliths of crystalline schists, sedimentary deposits and eruptive rocks The red-violaceous colour of some parts of the vitroclastic rhyodacites, very frequent in outcrops, and that of bentonite nearby the contact with sedimentary deposits was considered by Mârza and Ghergariu (1963) due to descending infiltration of the iron hydroxides from Eocene clays.

Within the Valea Chioarului vitroclastic rhyodacites one can usually distinguish fragments of white tuffs, with a similar composition but frequently more intensely montmorillonitized than the rock including them ; when these tuff fragments occur as parallel lenses (resembling fiammes) the rock shows a general eutaxitic aspect.

It is worth mentioning that the Valea Chioarului rhyodacite is mostly altered into sodium montmorillonite, remaining fresh only the central zones of the body, occurring as cores surrounded by a greenish bentonite mass nearby them and of violaceous colour towards the contact with Eocene red-violaceous clays.

Under the microscope the rhyodacitic rock consists of a vitroclastic groundmass, with glass fragments, irregular, slightly devitrified, including rare phenocrysts (less than 15%) of quartz, plagioclase, potash feldspar and biotite. Feldspars and especially quartz are corroded. Often these crystals are fissured, some of them displaying a slight undulatory extinction.

Nuclei or zones with incipient bentonitization are frequently noticed in the rhyodacite groundmass. The grey-yellowish, sometimes brown clay minerals display a scale-like aspect and more rarely a lamellar one. Within these hydrothermalized zones phenocrysts usually remain fresh, biotite opacitizations or baueritizations being seldom noticed. Depositions of fibrous chalcedony occur along fissures or filling the voids.

Among phenocrysts plagioclase with a positive relief, twinned and often zoned, predominates. The content of anorthites varies from 23 to 31% An. The core of the crystals is always more basic but the external zones display recurrences.

Potash feldspar with a small -2V is quantitatively subordinated to plagioclase and often shows Karlsbad or Baveno twins.

Rhyolites in the Moigrad Zone

The vitroclastic, more rarely eutaxitic rhyolites occurring in the Măguricea and Puguiorul hills are grey-greenish porphyritic rocks, with a massive and oriented structure, resembling similar petrotypes in the East Vlădeasa (Ştefan, 1980). Such rocks do not occur in the Meseş Crystalline. Their initial spreading in the rest of the region is unknown.

As in the Vlădeasa massif one has to admit that in the magmatic chamber from which this type of rhyolites originated there were conditions favourable for the enrichment of the melt in volatiles and especially in water vapours. It is likely that this is a Laramian sinking zone taking into account that the region lies along the Moigrad Fault zone. The conditions permitted the magma rise up to a certain level where, by differentiation and contamination, the melting enriched in water, becoming almost foamy before its release at surface or its consolidation in this state as superficial subvolcanoes.

Microscopically, rhyolites with feldspar and quartz angular phenocrysts, often fissured (protoclastic textures), are almost identical to similar rocks from the Vlădeasa main body, the only difference lying in the fact that in the study region the eutaxitic facies are less abundant. Oligoclase, twinned but unzoned, is often intensely albitized. Orthoclase (locally perthitic) is found only in thin sections coming from the Măguricea Hill rhyolites where biotite occurs, too.

In the rock groundmass (70-90%) usually cryptocrystalline, in places microcrystalline or vitreous, especially under parallel nicols one can observe numerous glass fragments (mostly devitrified) with X, Y, U shapes, typical of welded tuffs or ignimbrites (Ross, Smith, 1961; Cook, 1966). Under cross nicols in these "shards" one can notice granular quartz beside limpid and polysynthetically twinned albite. Generally the rock matrix is uniform, rarely showing an orientation ten-

-dency which reminds us of the eutaxitic structures, very obvious in the Vlădeasa rhyolites. In such cases, the fragments of glass or pumice seem to mould the phenocrysts and suggest either a laminar flow (McCall, 1965) or a plastic flattening as a result of a sinking process (Smith, 1960). Like in the Vlădeasa massif, in the study region rhyolites are very rich in xenoliths (up to 5%) of crystalline schists, Vlădeasa-type andesites, dacites from the Puguiorul Hill and even rhyolites with the same composition representing the first consolidated fraction, fragmented and included (probably still in a plastic state) into the rhyolitic melt.

Banatitic eruptive bodies hosted in the crystalline schists of the Meseş Mts are represented by quartz andesites-quartzdiorite porphyries, dacite-granodiorite porphyries and microgranitic rhyolites.

Quartz Andesites—Quartzdioritic Porphyries

Quartz andesites, locally with transitions to quartzdiorite porphyries, are found only in the southernmost part of the region, in the Poicului Valley basin, northeast of Ciucea, where usually they form independent bodies, generally as dykes with a N15-20°E trending. In the body on the Ciungilor Stream, east of Ciucea, andesites-quartzdiorite porphyries constitute the border of the dacite-granodioritic porphyry body. Andesites are porphyritic massive rocks, of a grey or yellowish colour (when more intensely altered). The mineralogical composition of andesites is comparable to that of dacites, the only difference being the lower amount of phenocrysts, particularly of quartz ; the sizes of the plagioclase phenocrysts (rare enough) locally reach 1 cm.

Microscopically, twinned plagioclase (An_{35-37}) is intensely albitized and in places is entirely replaced. Hornblende and biotite are intensely substituted, being usually recognized after their crystallographic outlines and the alteration mode. Pyroxenes are more often hardly observed ; even if they existed the abundance of chlorite, which pseudomorphoses the preexistent femic minerals and invades the groundmass, makes difficult their recognition. The grey-brownish groundmass is usually microcrystalline, plagioclase acicular microlites, without a preferential arrangement, being often distinguished. Other times the granulation of the groundmass increases, the rock grading into quartzdioritic porphyries. Fissures filled with microgranular quartz often crosscut the rock.

Dacites—Granodioritic Porphyries

Granodioritic rocks with a massive structure and porphyritic textures, of a grey colour, sometimes yellowish-rusty (when altered), form the bodies from the Ciungilor Stream, east of Ciucea, and those from the basin of the Poicului and Poniţa valleys, north of Huta. The dyke of granodioritic porphyries grading into dacites includes xenoliths of porphyritic microdiorites similar to those reported from Hodiş (Ştefan, 1980). The spatial association between dacites-granodioritic porphyries and quartz andesites-quartzdioritic porphyries, as well as the xenolithic character make possible the correlation of these rocks with the Vlădeasa magmatites of cycle II.

Under the microscope, the rock consists of cryptocrystalline groundmass (50-70%), granophyric or microgranular, within which clearly outlined quartz grains are observed beside xenomorphic potash feldspar microlites.

Plagioclase phenocrysts are twinned and intensely albitized or in places argillized and consequently improper for accurate determinations. Hornblende and biotite are often pseudomorphosed by chlorite or calcite and quartz, grains of iron oxides, opaque minerals being separated.

Microgranitic Rhyolites

Alkali rhyolites, often microgranitic, nearby Stîrci and Fetindia, hosted in the crystalline schists as NE trending dykes, may represent either final products (alkali-rich) of the melting that generated vitroclastic rhyolites of cycle I (Măguricea, Puguiorul) or, as we presume, final products of the magma that generated the other rocks of the cycle II, hosted in the Meseş crystalline.

Macroscopically, they are massive rocks, locally banded and slightly porphyritic (5-10% phenocrysts). Alkali rhyolites are of white or grey or yellowish colour and occur generally fresh ; however, sometimes they are intensely sericitized.

The rock groundmass is in places granophyric, more often spherulitic or microgranular (quartz-feldspathic).

Grey cryptocrystalline bands alternate with narrower, limpid, microgranular quartz bands. The crystallization rate of the groundmass is more marked around the phenocrysts usually strongly corroded by it.

Among phenocrysts, quartz, plagioclase and orthoclase are generally fresh, whereas biotite is baueritized. Plagioclase is twinned but unzoned and shows a slightly negative relief although in a thin section the content of 33% An was determined on a twinned crystal. In the same thin section potash feldspar displays an angle of $-2V=60°$ corresponding to orthoclase.

Neogene Magmatic Rocks
(Quartz Andesites and Quartz Porphyritic Microdiorites)

Neogene eruptive rocks occur in the zone of the Moigrad, Jac and Stîna localities. They are represented by subvolcanic bodies of andesites and porphyritic microdiorites, practically of the same composition, the only difference consisting in the crystallization degree of the groundmass.

Andesites are massive rocks, with a porphyritic aspect, within which phenocrysts of plagioclase and femic minerals included in a blackish aphanitic groundmass are noticed macroscopically. The intruded sedimentary deposits are affected on a very restricted area around the andesite bodies, being injected and hardened by the high temperatures without formation of hornfelses. Metasomatic products and mineralizations are lacking.

Porphyritic microdiorites represent the main body at Măgura Moigradului as well as other small bodies at Jac, Pomăt and Citera Hill. They are massive rocks with a fine phaneritic groundmass within which plagioclase and pyroxene phenocrysts are noticed. At the periphery of the bodies the groundmass is finer, the rock grading into a diorite porphyry. In this case too the surrounding sedimentary deposits are slightly affected, being not changed into hornfelses ; the latter ones occur only at the expense of xenoliths included into microdiorite.

Under the microscope andesites show a cryptocrystalline groundmass, sometimes pilotaxitic, with microcrystalline gradings in case of diorite porphyries, when quartz grains are visible besides plagioclases and femic minerals.

Phenocrysts are mainly represented by twinned and zoned plagioclases (An_{54-55}) and pyroxenes (monocline, more rarely rhombic). Pyroxenes are often serpentinized, uralitized or chloritized. In places green biotite occurs beside chlorite. Common hornblende is found accidentally. The rock frequently contains grains of iron oxides. Sometimes alveoles filled with calcite and quartz are distinguished in the microlitic groundmass with much chlorite formed at the expense of the pre-existent femic minerals.

In thin sections microdiorites display a microgranular network of plagioclase feldspars, whose interstices are filled with pyroxenes and more rarely with quartz (intergranular textures).

Phenocrysts are represented by monoclinic pyroxene and labrador. Hornblende and biotite are found accidentally. Pyroxenes are altered (probably deuteric). Magnetite is abundant enough (3-6.5%).

Within the Măgura Moigradului porphyritic microdiorites xenoliths are converted into hornfelses with hercynite, corundum and probably margarite, in association with biotite and andalusite (?), at present intensely sericitized. Diopside hornfelses formed at the expense of andesites in the northern part of the Măgura Moigradului.

Petrochemical and Geochemical Considerations of the Alpine Magmatites

The samples of banatitic eruptive rocks analysed chemically (Tab. 1) point out normal contents for the respective petrotypes. In addition to the banatitic rocks a dacite sample from the Puguiorul Hill was analysed, the dacite emplacement being considered earlier as against banatites. Several observations are clearly pointed out in Table 1, as follows :

—the analysed rocks are generally fresh ; the andesites and dacites from dykes hosted in the Meseş crystalline are more altered automorphously ;

— the composition of the quartzdiorite porphyries resembles that of the dacites-granodiorite porphyries ;

— Na_2O/K_2O ratio, for values comparable to SiO_2, is clearly superunitary for the Valea Chioarului rhyodacites ;

— high contents of H_2O for the same rhyodacites indicate a vitreous groundmass and the bentonitization degree.

TABLE 1

Chemical composition of banatitic eruptive rocks

No.	Sample no.	Rock type and location	OXIDES %															
			SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	S	Fe(S)	H_2O	Total
1	8455	Microgranitic rhyolite, Fetindia	78.04	0.08	12.04	0.56	0.05	0.03	0.04	0.23	3.30	4.76	0.01	0.00	0.10	0.08	0.75	100.07
2	8457	Microgranitic rhyolite, Fetindia	78.03	0.00	12.25	0.46	0.05	0.03	0.08	0.19	3.76	3.62	0.00	0.00	0.06	0.05	0.01	99.59
3	8116	Vitroclastic rhyolite, Măguricea Hill	74.39	0.26	13.95	1.26	0.28	0.03	0.30	0.28	3.28	4.28	0.04	0.00	0.09	0.08	1.25	99.73
4	8805	Vitroclastic rhyodacite, Valea Chioarului mine	74.20	0.15	11.50	1.37	0.00	0.04	0.52	0.68	4.04	2.35	0.03	0.00	0.03	0.02	5.00	99.93
5	8808 c	Rhyodacitic bentonitized tuff, Untului Brook	72.89	0.18	12.54	1.33	0.00	0.05	1.53	0.60	2.90	0.85	0.05	0.00	0.04	0.03	6.62	99.81
6	8808 A	Grey vitroclastic rhyodacite with tuffs, Untului Brook	71.78	0.18	12.55	0.98	0.00	0.03	0.58	0.75	4.00	1.73	0.04	0.00	0.04	0.03	6.96	99.65
7	8808 B	Vitroclastic rhyodacite with white tuff fiammes, Untului Brook	71.54	0.17	12.80	1.21	0.00	0.02	0.55	0.78	4.14	1.60	0.03	0.00	0.03	0.02	7.01	99.90
8	8443 A	Dacite, Poicului Valley	67.42	0.42	15.14	2.01	1.19	0.08	1.43	2.00	4.28	3.12	0.14	1.31	0.08	0.07	1.55	100.27
9	8441	Granodioritic porphyry, Ciungilor Brook	67.00	0.45	15.29	1.97	1.55	0.07	1.42	1.99	4.48	3.12	0.13	1.09	0.08	0.07	1.56	100.27
10	8441 B	Quartzdioritic porphyry, Ciungilor Brook	64.64	0.69	15.59	2.05	2.24	0.09	1.63	2.00	4.94	3.48	0.28	0.98	0.08	0.07	1.50	100.26
11	8087	Dacite, Puguiorul Summit	66.33	0.56	16.40	1.48	2.50	0.07	1.46	1.05	4.54	3.24	0.14	0.00	0.10	0.09	2.12	100.08

TABLE 2

Trace elements in banatitic eruptive rocks (p.p.m.)

No.	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Se	Zr	Yb	Y	La	Sr	Ba
1	8455	26	2.5	15	5	3.5	<2	3	2	3	110	3.8	23	<30	36	520
2	8457	73	2.5	20	6	3.5	<2	1.5	2	3.5	105	3	28	<30	15	360
3	8116	20	1.5	14	3.5	2	<2	3	13	6	300	4.8	36	70	185	2050
4	8805	27	4.5	18	2.5	4	2	4.5	5	6	170	4	32	65	200	630
5	8808 C	21	3.5	30	3.5	2.5	2	3.5	12	6	160	9	56	39	290	480
6	8808 A	29	4	12	2	3.5	2	4	6	5	185	2	16	35	350	700
7	8808 B	16	3	16	2	2	2.5	3	4	4	110	1.4	14	30	370	650
8	8843 A	46	7.5	20	3.5	8	7	6	49	7	245	3.1	28	35	125	600
9	8441	60	15	22	4	7	6.5	9.5	47	8.5	235	3.4	28	33	160	770
10	8441 B	23	8,5	22	3.5	8	7	5	43	13	320	3.5	33	30	225	730
11	8087	17	7	16	3	13	9	18.	55	7.5	235	2.8	23	37	270	900

The contents of trace elements of the rocks analysed chemically have been determined by emission spectrography (Tab. 2) ; the values can be compared with those known in similar petrotypes from Vlădeasa. Ba/Sr ratio for the Valea Chioarului rhyodacites is smaller (1.7-3.2) than in banatitic rocks (11-24) with a similar composition.

The chemical (Tab. 3) and spectral (Tab. 4) analyses of six samples of Neogene andesites and microdiorites also point to normal contents for the major and trace elements.

Starting from the Niggli and QAP parameters (acc. to the CIPW standard) and relying on the Nockolds-Allen differentiation index several diagrams have been drawn up (Ştefan et al., 1980 ; Ştefan et al., 1981), but they are not suggestive for the differentiation process. It is due to a very similar composition (Neogene eruptive rocks) or to the absence of more basic terms (banatitic rocks). Furthermore the Valea Chioarului rhyodacites originate in a different magmatic reservoir. For these reasons we shall present only diagrams that differentiate the analysed rocks.

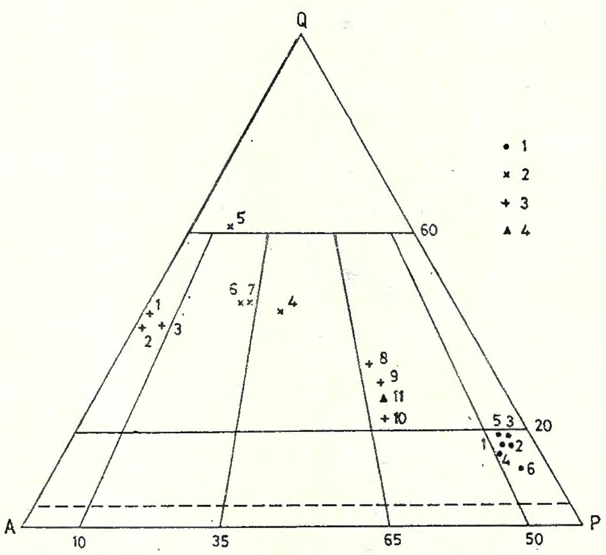

Fig. 1. — Normative *QAP* diagram (figures 1-11, 1-6, respectively, correspond to those in tables 1 and 3).

1, Neogene andesites-porphyritic microdiorites ; 2, banatitic rhyodacites ; 3, banatitic rhyolites, quartz andesites-quartz-dioritic porphyries, dacites-granodioritic porphyries, micro-granitic rhyolites ; 4, pre-banatitic dacites.

Thus, the QAP diagram shows the close association of the Neogene eruptive rocks in the andesite field, the quartz diorites respectively (Fig. 1).

Dacites and granodiorite porphyries plot in the corresponding field. The plotting of the quartzdiorite porphyries at the base of the dacite field is due to the relatively high content of CO_2.

TABLE 3

Chemical composition of Neogene eruptive rocks

No.	Sample no.	Rock type and location	OXIDES %														
			SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	S	Fe(S)	H_2O^+	Total
1	8057	Porphyry microdiorite, Măgura — Hill — Moigrad	56.49	0.77	18.05	4.35	3.79	0.13	3.43	7.72	3.28	0.78	0.32	0.00	0.14	0.12	0.91	100.28
2	8073	Pyroxene andesite, Stîna	53.74	0.90	19.05	4.38	3.80	0.13	2.70	9.02	2.76	0.70	0.35	0.59	0.15	0.13	1.28	99.68
3	8074	Pyroxene andesite, Stîna	53.33	1.00	18.65	4.88	3.80	0.16	2.40	8.85	2.72	0.68	0.35	0.60	0.10	0.09	2.10	99.71
4	8067	Pyroxene andesite, Citera Hill — Jac	52.81	0.97	18.95	6.33	2.83	0.09	3.31	8.78	2.82	0.81	0.35	0.00	0.13	0.11	1.56	98.85
5	8068	Pyroxene andesite, Pomăt Hill — Moigrad	52.18	1.01	18.50	4.67	4.79	0.19	2.55	9.00	2.72	0.73	0.37	1.57	0.12	0.10	1.24	99.75
6	8095	Porphyry microdiorite, Pomăt Hill — Moidrad	51.46	1.24	18.80	5.51	3.95	0.21	4.16	9.11	2.72	0.70	0.24	0.00	0.11	0.09	1.61	99.91

TABLE 4

Trace elements (p.p.m.) in Neogene eruptive rocks

No.	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Zr	Yb	Y	La	Sr	Ba
1	8057	3	8.5	19	<2	7.5	15	4	145	11	170	2.1	17	<30	470	170
2	8073	4.5	9	19	7	5.5	14	2	100	8.5	145	1.9	19	<30	900	240
3	8074	2	11	19	<2	6.5	17	2.5	130	11	180	2.2	25	<30	730	210
4	8067	4.5	11	21	<2	5.5	15	4.5	100	8.5	135	1.9	17	<30	550	240
5	8068	2	21	20	<2	8.5	12	5	87	7.5	105	1.2	15	<30	480	215
6	8095	2	12	13	<2	12	222	16	150	16	120	2.1	20	<30	570	240

In case of the Valea Chioarului rhyodacites only the fresh rock plots in the respective field, the other samples falling in the rhyolite field. However, for all volcanic rocks corresponding to granites the denomination of rhyolites would be more suitable (Streckeisen, 1979), that of rhyodacite being used only for rocks falling nearby the granodiorite-granite fields.

Măguricea biotite pyroclastic rhyolites migrated (artificially) in the alkali rhyolites field, which also contains the microgranitic rhyolites analysed by us.

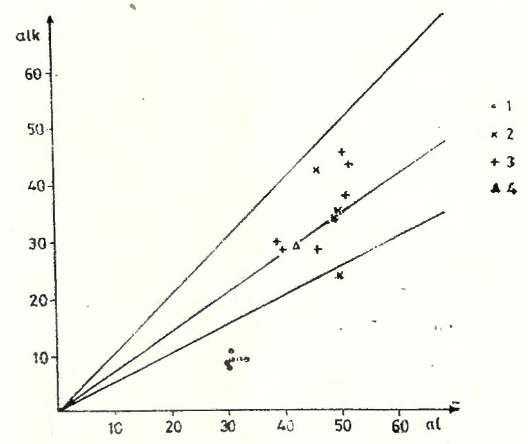

Fig. 2. — *alk : al* diagram. See legend of Figure 1.

On the *alk : al* diagram (Fig. 2) the banatitic rocks, excepting the bentonitized tuff included in the Valea Chioarului rhyodacites, plot in the alkali and intermediary fields whereas the Neogene rocks fall in the alkali-poor field.

On the *QLM* diagram (Fig. 3) all rocks plot in the suprasaturated calc-alkaline field, being grouped after their chemical composition.

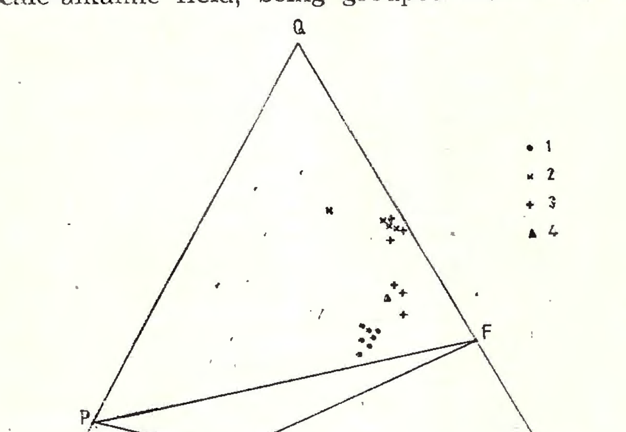

Fig. 3. — *QML* diagram. See legend of Figure 1.

The correlation diagrams (Fig. 4) of some pairs of trace elements (Ni : Co — Fig. 4 a ; V : Sc — Fig. 4 b ; V : Ni — Fig. 4 c) separate clearly the banatitic eruptive rocks from the Neogene ones.

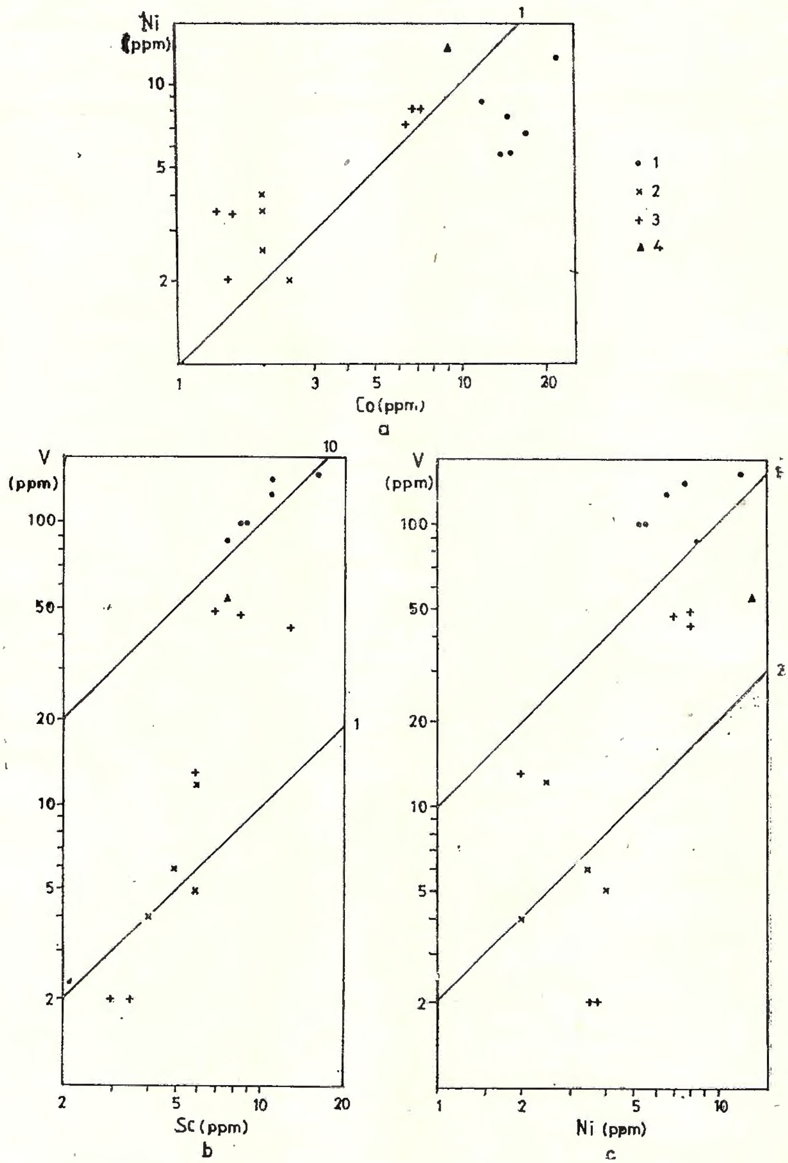

Fig. 4. — Correlation diagrams for Ni : Co (4 a) ; V : Sc (4 b) ; V : Ni (4 c). See legend of Figure 1.

In conclusion, (1) there is no continuity in time between the manifestations of the banatitic magmatism and of the Neogene ones ;

(2) except the Valea Chioarului rhyodacites, the banatitic magmatites (less developed and abundant in the study area as against the Apuseni Mountains) can be correlated (as succession of emplacement and composition) with similar ones in the Vlădeasa massif.

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QUESTIONS

M. Săndulescu : On what basis do you consider an olistolith the rhyolitic body mentioned in your paper ?

2. The comparison of the banatitic rocks in the study region with those in the Vlădeasa Massif is made by the author under different aspects. Have you any proof that they are not comagmatic ?

Answers : 1. In the Puguoiru Summit the rhyolitic body seems to float within the Miocene sedimentary rocks ; here the crystalline basement is much sunk. That is why we consider it an olistolith. Maybe the terms sedimentary klippe should be more appropriate in this case.

2. Excepting the Valea Chioarului rhyodacites there is no such an argument.

STUDIUL PETROLOGIC AL MAGMATITELOR ALPINE DIN ZONA DE LEGĂTURĂ DINTRE MUNȚII APUSENI ȘI LANȚUL VULCANIC OAȘ-GUTÎI-ȚIBLEȘ

(Rezumat)

La alcătuirea geologică a regiunii cuprinse între Munții Apuseni și masivul Preluca participă : formațiuni ale fundamentului reprezentate prin șisturi cristaline (Precambrian superior) și depozite triasice (Verfenian-Anisian) ; formațiuni ale cuverturii posttectonice reprezentate prin depozite cretacic-superioare (Senonian), paleogene (Paleocen-Oligocen) și miocene ; roci eruptive banatitice și neogene.

Accidentul tectonic principal din regiune este „Falia Moigradului", care a facilitat apariția la sfîrșitul Cretacicului și începutul Paleogenului a erupțiilor banatitice de la Ortelec. Corpul banatitic de la Valea Chioarului se situează într-o zonă de graben dintre masivele cristaline Țicău și Preluca.

Intersectarea zonei de faliere a Moigradului de către falia Benesat-Cuceu-Moigrad (mai nouă) a realizat condițiile punerii în loc în timpul Sarmațianului a corpurilor subvulcanice de la Moigrad.

Magmatismul banatitic (redus ca amploare în aria cercetată) s-a desfășurat, ca și în Apusenii de nord, în cadrul a două cicluri.

Din primul ciclu (bine reprezentat în masivul Vlădeasa prin andezite, dacite și riolite) riolitele vitroclastice sau eutaxitice din dealurile Măguricea și Puguiorul (zona Moigrad) sînt corelabile perfect corespondentelor lor din masivul eruptiv banatitic de la sud. Aceste riolite, care înglobează fragmente de andezite și dacite, sînt remaniate în stratele de Jibou (Paleocen-Lutețian inferior) și din abundență, în orizontul conglomeratic marnos (Miocen inferior).

Riodacitele vitroclastice, mai mult sau mai puțin bentonitizate, de la Valea Chioarului, cu un raport $Na_2O : K_2O$ diferit față de al celorlalte roci riolitice și riodacitice banatitice, aparțin probabil tot ciclului I.

Andezitele cuarțifere-porfirele cuarțdioritice, dacitele-porfirele granodioritice și riolitele microgranitice, care străbat formațiunile cristalofiliene din munții Meseș, se corelează ca succesiune de punere în loc și compoziție cu produsele celui de-al II-lea ciclu magmatic banatitic din Vlădeasa și Gilău.

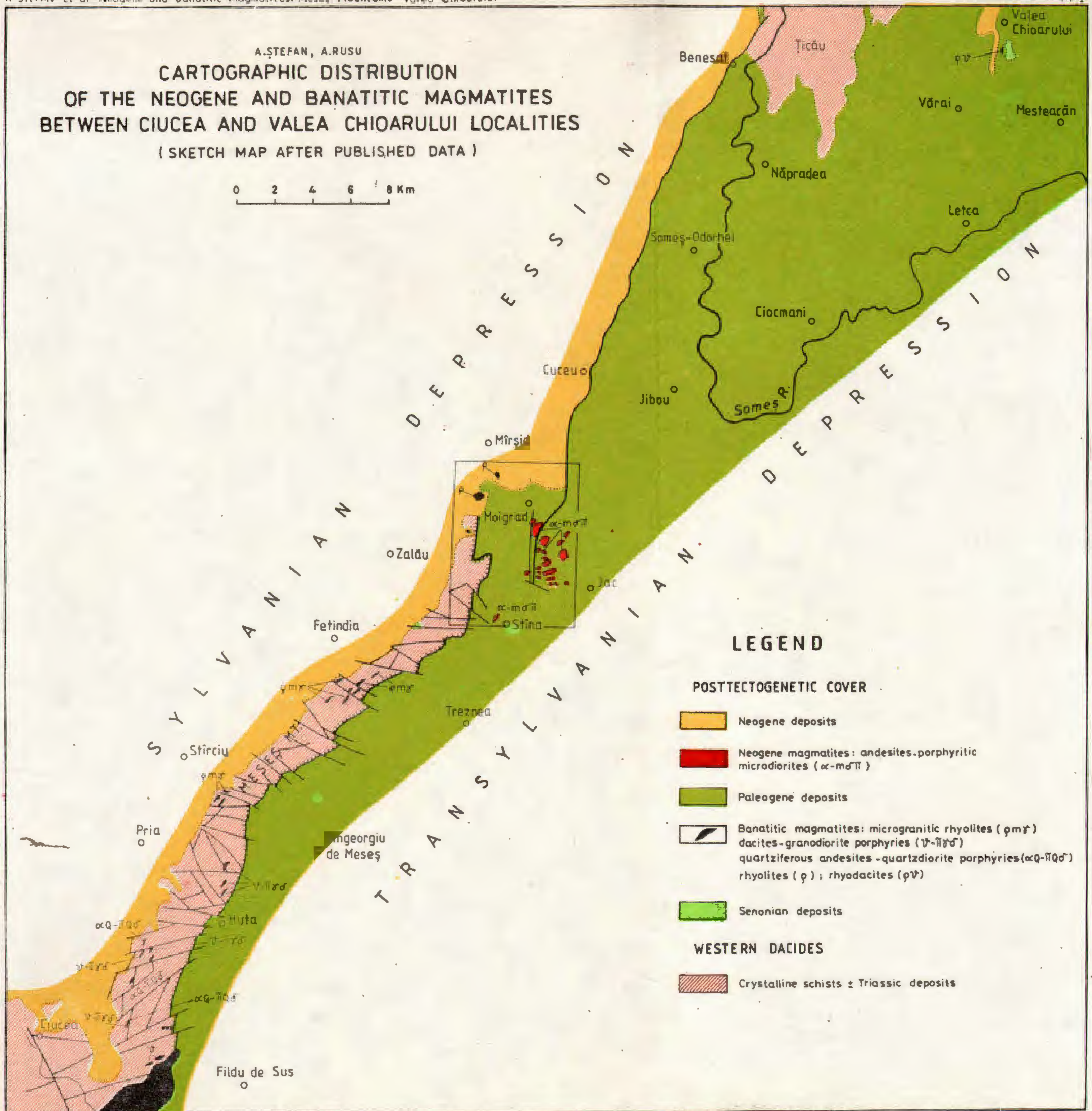
Ultimele manifestări magmatice în regiune sînt reprezentate prin corpurile subvulcanice de andezite-microdiorite porfirice, care (în zona

Moigrad) străbat stratele de Zimbor de vîrstă chattiană ; aceste roci aparţin vulcanismului neogen şi nu reprezintă o continuitate în timp a magmatismului banatitic.

EXPLANATION OF PLATE

Plate III

Fig. 1. — Neogene andesite, Pomăt Hill, Moigrad, N+ ; × 10.
Fig. 2. — Microgranitic rhyolite, East Fetindia, N+ ; × 10.
Fig. 3. — Andesite. Ciungilor Brook, N+ ; × 10.
Fig. 4. — Vitroclastic rhyodacite, Valea Chioarului, N+ ; × 10.



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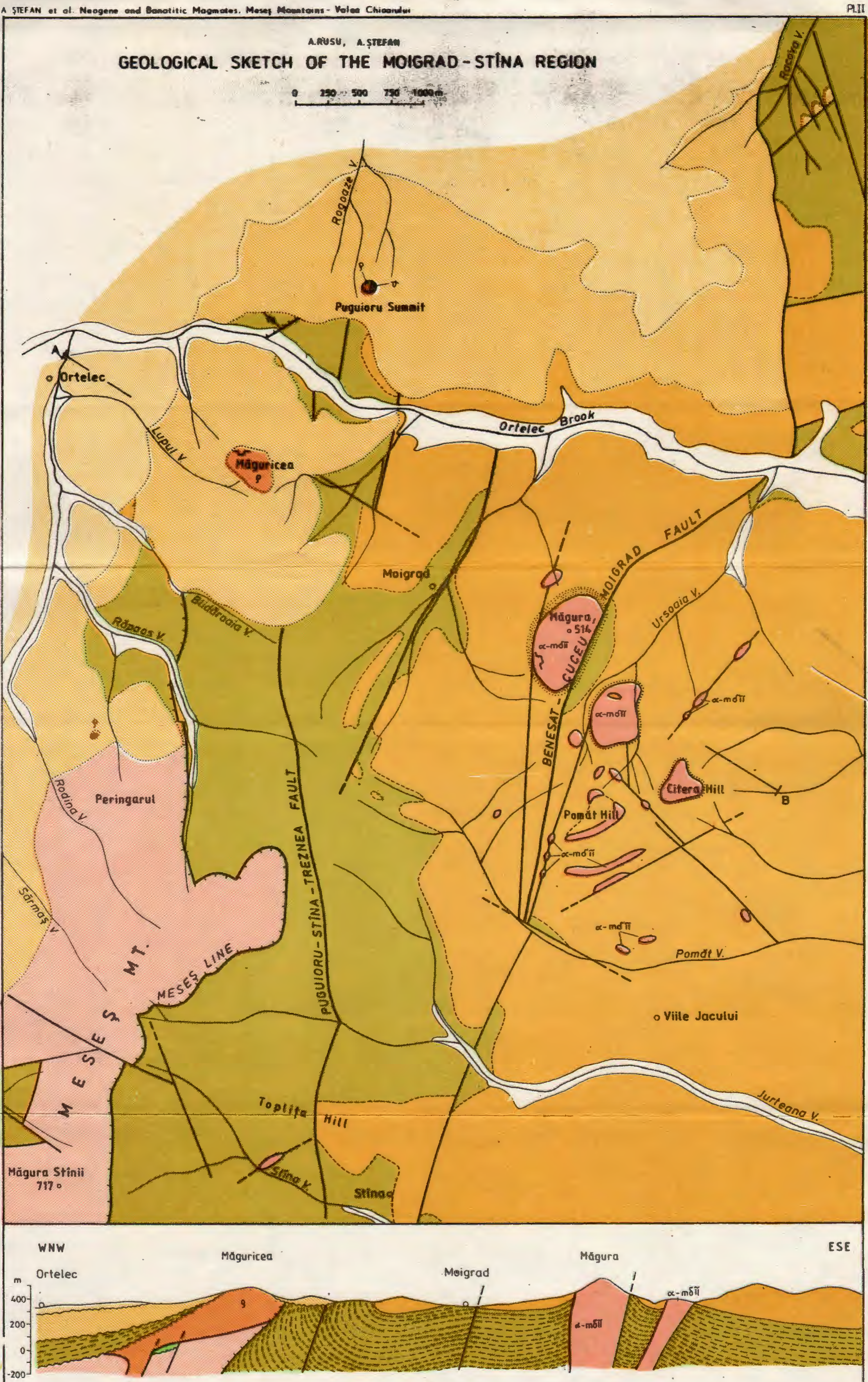

LEGEND

QUATERNARY	Alluvial deposits	Thermal contact aureole
UPPER MIOCENE	Neogene magmatites: andesites-porphyritic microdiorites (α-mδπ)	Olistolith
MIDDLE MIOCENE	Dej Tuff Complex	Conformable boundary
LOWER MIOCENE	Conglomerates, marls, sandstones	Unconformable boundary
OLIGOCENE	Hoia Beds - Zimbor Beds	Vertical and subvertical fault
EOCENE	Jibou Beds - Brebi marls	Thrust fault
SENONIAN - PALEOGENE	Banatites: rhyolites (ρ)	Strike-slip fault
SENONIAN	Deposits in Gosau facies a. dacites (δ)	Quarry
UPPER PRECAMBRIAN LOWER PALEOZOIC + MESOZOIC	Crystalline schists and Triassic deposits	A — B Position of the geological section

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR METAMORFICE

NOTĂ PRELIMINARĂ ASUPRA PREZENȚEI ECLOGITELOR ÎN MUNȚII FĂGĂRAȘ DE EST[1]

DE

ANETA BALABAN[2]

Eclogite. Cumpăna Series. Mineralogical composition. Clinopyroxene. Garnet. South Carpathians — Getic and crystalline Supragetic domains — Făgăraș Mountains.

Abstract

Preliminary Note on the Presence of Eclogites in the Eastern Făgăraș Mountains. Eclogites mainly constituted of clinopyroxenes and garnets have been found within the Cumpăna Series in the eastern Făgăraș Mts. They occur as fragments on the Crucișoara Brook (Vulcănița Valley).

Résumé

Note préliminaire sur la présence des éclogites dans la partie est des monts Făgăraș. Dans la série de Cumpăna des monts Făgăraș (sa partie est) se développent des éclogites constituées principalement des clinopyroxènes et des grenats Elles apparaissent sous forme de fragments le long du ruisseau de Crucișoara (vallée de Vulcănița).

Cu răspîndire restrînsă, formînd intercalații, mici lentile sau noduli în masa altor roci, eclogitele (termen introdus de Haüy în 1822) ridică probleme de mineralogie și petrogeneză foarte dificile.

Dintre cercetătorii care au abordat problematica eclogitelor menționăm pe Eskola (1920), Yoder (1962), Withe (1964), Coleman et al. (1965), Banno, Matsui (1965), Church (1968) și Smulikowski (1980).

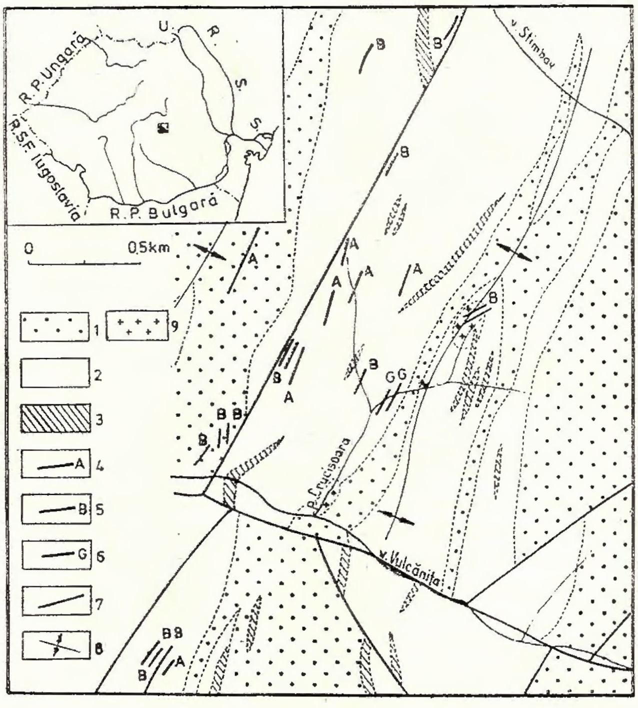
[1] Depusă la 8 mai 1984, acceptată pentru comunicare și publicare la 16 mai 1984, comunicată în ședința din 18 mai 1984.

[2] Institutul de Geologie și Geofizică. Str. Caransebeș nr. 1, R 79678, București, 32.

O serie de ocurenţe de eclogite din Carpaţii Meridionali au fost prezentate în diverse lucrări de Mrazec (1897 — prima menţiune a acestor roci în România), Streckeisen (1930), Codarcea (1937), Gherasi (1956), Gherasi et al. (1971), Kasper, Focşa (1972), Gheuca, Dinică (1981, 1983), Hann (1983) şi Dimitrescu (1984).

Pe pîrîul Crucişoara, în bazinul văii Vulcăniţa, afluent pe stînga al văii Holbavului, au fost identificate fragmente şi mici blocuri de eclogite. Este prima semnalare a acestor roci în munţii Făgăraş de est.

Ambianţa geologică în care apar fragmentele este dominată de prezenţa gnaiselor cu nivele de şisturi amfibolice (seria de Cumpăna), cărora li se adaugă mici iviri de microgabbrouri şi dyke-uri de roci bazice (fig.).



Schiţa geologică a zonei văii Crucişoara (munţii Făgăraş de est) şi amplasarea pe teritoriul R.S.R.

1, migmatite ; 2, micaşisturi şi paragnaise ; 3, şisturi amfibolice ; 4, roci filoniene acide ; 5, roci filoniene bazice ; 6, microgabbrouri ; 7, falie ; 8, ax anticlinal ; 9, blocuri de eclogite.

Geological sketch of the Crucişoara Valley zone (East Făgăraş Mountains) and its location in the Romanian territory.

1, migmatites ; 2, micaschists and paragneisses ; 3, amphibolic schists ; 4, acid vein rocks ; 5, basic vein rocks ; 6, microgabbros ; 7, fault ; 8, anticlinal axis ; 9, eclogyte blocks.

Obiectul prezentei note îl constituie o rocă „pestriță“ cu un fond în tonuri de verde, formînd benzi ondulate larg, în care se disting granați roșii.

Analiza microscopică a pus în evidență prezența clinopiroxenilor (olivinei) și granaților ca minerale principale. Subordonat mai apar zoizit, clinozoizit, actinot, rutil, ilmenit, pirită, calcopirită și cuarț.

O parte din minerale sînt greu de determinat optic din cauza dimensiunilor reduse sau din cauza unor anomalii optice apărute ca urmare a deformărilor suferite de rocă.

Analiza raporturilor dintre minerale a permis separarea mai multor generații. Cea mai veche parageneză este reprezentată de granat și piroxen.

Granații cu dimensiuni mari (4-8 mm), contururi euhedrale sau subhedrale, prezintă numeroase spărturi invadate de o masă de minerale fin granulare. Cele mai multe porfiroblaste prezintă coroane de reacție formate dintr-un agregat fibros, foarte fin, de piroxeni și amfiboli. Mărimea acestor coroane de reacție depășește uneori 1 mm și în acest caz pot fi observate macroscopic sub forma unei dungi de culoare mai închisă care înconjoară granatul.

Analiza Rx[3] a granatului a pus în evidență prezența termenilor piralspitici pirop-almandin. Parametrul celulei elementare $a_0 = 11{,}547 \pm 0{,}003$ Å a fost calculat din difractogramă.

Clinopiroxenii aparțin la două generații distincte, diferențiate prin dimensiuni, grad de idiomorfism și tendințe de orientare spațială deosebite.

Clinopiroxenii din prima generație formează granule subhedrale atingînd 1 mm, fără un pleocroism evident și cu clivaj bun după o singură direcție.

Determinarea unor constante optice indică prezența termenilor diopsid-jadeit (pleocroism inexistent, extincție în jurul valorii de 38°, alungire pozitivă, 2V=65°-70°, semn optic pozitiv — granule grupate în jurul granaților) și egirin (pleocroism foarte slab în tente de verde pal, extincție între 5°-7°, alungire negativă, 2V=65°-70°).

Analiza Rx[3] a unui material de culoare verde, omogenă, separat la lupa binoculară, a indicat prezența termenilor egirin și jadeit.

Clinopiroxenii din a doua generație formează împreună cu amfibolul coroanele de reacție din jurul granaților.

Cea de a treia generație de minerale este reprezentată prin pirită, calcopirită (granule rare) și cuarț.

Menționăm că într-o singură secțiune a fost întîlnită olivină, incipient serpentinizată, alături de granați cu coroane de reacție bine dezvoltate, fără a mai putea fi decelate și alte minerale.

Analiza chimică (tab. 1) și valorile parametrilor Niggli calculate din aceasta (*si*=87 ; *al*=27 ; *alk*=4,62 ; *c*=27 ; *k*=0,06 ; *mg*=0,8) indică o rocă bazică, săracă în silice, bogată în MgO, CaO și Al_2O_3.

Analiza spectrală (probă globală) (tab. 2) atrage atenția numai prin valoarea mai ridicată a cromului (3.400 ppm).

TABELUL 1

Rezultatele analizei chimice a eclogitului de pe valea Crucișoara

	%		%
SiO_2	43,62	CaO	12.70
TiO_2	0,69	K_2O	0.22
Al_2O_3	23,27	Na_2O	2.23
Fe_2O_3	1,10	P_2O_5	0.11
FeO	2,82	CO_2	1.32
MnO	0,09		
MgO	11,44		

Analist : Grigorescu E., Întreprinderea de Prospecțiuni Geologice și Geofizice.

TABELUL 2

Rezultatele analizei spectrale a eclogitului de pe valea Crucișoara

	(ppm)		(ppm)
Pb	36	Y	165
Cu	55	Sc	32
Zn	<30	Nb	10
Sn	2	Zr	14
Ca	7.5	Yb	1.2
Ni	280	Sr	180
Co	34	Ba	150
Cr	3400		

Analist : Bratosin I., Institutul de Geologie și Geofizică.

Prin caracteristicile lor, eclogitele de pe pîrîul Crucișoara se apropie cel mai mult de grupul „B" în sensul clasificării lui Coleman et al. (1965).

Nefiind precizat locul în care eclogite sînt *„in situ"* și avînd destul de puține date mineralogice nu ne putem exprima deocamdată asupra genezei acestor roci.

Deformările tectonice vizibile pe eșantioanele analizate sugerează posibilitatea unui transport tectonic.

Nu este exclus ca o parte din șisturile amfibolice cu granați care apar pe interfluviul dintre pîraiele Răchițelei (Venelu)-Stimbav să fie retromorfite ale unor roci de tip eclogitic.

[3] Analist : F. Popescu, Institutul de Geologie și Geofizică.

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PRELIMINARY NOTE ON THE PRESENCE OF ECLOGITES IN THE EAST FĂGĂRAŞ MOUNTAINS

(Summary)

Fragments and small blocks of eclogites, mainly consisting of clinopyroxene and garnet, were found in the Crucişoara Brook (Vulcăniţa Valley basin) in the East Făgăraş Mountains. These rocks were assigned to the Cumpăna Series.

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PETROLOGIA ROCILOR METAMORFICE

LE DANUBIEN DES MONTS DE PETREANU ET DE RETEZAT DANS LA RÉGION DE RÎU MARE [1]

PAR

RADU DIMITRESCU [2]

Microtectonics. Foliation. Schistosity. Granite. Lower Cadomian. Folding. Fracturing. Fault system. Tectonic unit. Alpine Nappe. South Carpathians — Crystalline Danubian Domain — Retezat-Petreanu-Pietrii Mountains.

Résumé

Dans le Danubien inférieur des monts de Petreanu-Retezat, la succession des événements tectoniques est probablement la suivante : 1. naissance de la foliation S_1 dans les formations de Rof, de Nisipoasa et de Bodu ; 1a. intrusion des massifs de granitoïdes de Furcătura et de Petreanu ; 2. plissement F_2 NNE-SSO à développement de la foliation de transposition S_2 (première foliation dans les métagranitoïdes) ; 3. plissement F_3 ENE-OSO, replissant les foliations antérieures et produisant la foliation S_3 (probablement varisque) ; 4, fracturation de la région avec la formation du système de failles de Rîu Mare, parallèle avec la schistosité S_4 ; 5. formation des nappes (probablement alpines), les unités danubiennes supérieures chevauchant le Danubien inférieur.

Abstract

Danubian of the Petreanu-Retezat Mountains in the Rîu Mare Region. In the Lower Danubian of the Petreanu-Retezat Mountains, the succession of the tectonic events is probably the following : 1, development of the S_1 foliation in the Rof, Nisipoasa and Bodu formations ; 1a, intrusion of the Furcătura and Petreanu granitoid massifs (probably Lower Cadomian) ; 2, NNE-SSW trending F_2 folding with the development of the S_2 transpositon foliation (the first one in metagranitoids) ; ENE-WSW trending F_3 folding, refolding the earlier foliations

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[2] Universitatea Al. I. Cuza, Facultatea de Biologie-Geografie-Geologie. Str. 23 August nr. 20A, Iași.

and producing the S_3 foliation (probably Variscan) ; 4, fracturing of the region with the formation of the Rîu Mare fault system parallel to the S_4 schistosity ; 5, nappe formation (probably Alpine), the Upper Danubian units overridding the Lower Danubian.

Les dernières années ont vu paraître de nouvelles manières d'envisager les problèmes de la structure du domaine danubien des Carpathes Méridionales. La région étudiée, située au nord des monts de Petreanu et de Retezat, qui a été l'objet de nos recherches antérieures (Gherasi, Dimitrescu, 1968, 1970 ; Soroiu et al., 1972), a également représenté un point de départ pour de récentes opinions. Dans le but d'une révision aussi solide que possible, nous avons consacré une partie de nos campagnes de 1980, 1981 et 1982 à la réambulation du territoire compris entre les vallées de Nucșoara et de Zeicani.

Les faits sur lesquels devaient se fonder nos nouvelles observations étaient aussi représentés par d'autres travaux publiés (Gherasi et al., 1968 ; Gherasi, Medeșan, 1968) ou par des manuscrits (Gherasi et al., 1974). La présente note n'aurait pas pu être conçue de même sans les idées d'ordre général exprimées par Kräutner et Berza (Kräutner, 1980 ; Kräutner et al., 1981 ; Berza et al., 1983), à qui nous exprimons notre reconnaissance. Nous avons eu également de fructueux échanges d'opinions avec Maçaleț qui étudie la région de l'est de la vallée de Nucșoara. Notre maître à tous à été le géologue Gherasi.

La structure en nappes du domaine danubien est à présent, selon notre avis, un fait accepté. Dans la région que nous allons présenter apparaissent des unités appartenant aussi bien au Danubien inférieur qu'au Danubien supérieur. La trace du charriage qui les sépare est représentée par la ligne tectonique de la base des formations de Barnița et de Măgura, le long de laquelle celles-ci viennent en contact avec divers termes du Danubien inférieur : les formations de Nucșoara, de Rîușorul, de Nisipoasa, de Bodu, les gneiss granitoïdes de Furcătura et de Petreanu. Nous avons déjà montré (Gherasi, Dimitrescu, 1968, 1970) „la position discordante de la série de Zeicani en rapport avec les autres séries cristallines". Vers l'est, cette ligne tectonique se raccordait au chevauchement au sud de la „série de Drăgșan" sur la „série de Tulișa" d'après Micu et Paraschivescu (1970), mais nous considérons que ces auteurs l'ont tracée un peu plus au nord qu'en réalité. Vers l'ouest, la même ligne tectonique se continue avec le chevauchement des schistes cristallins plus anciens (préhercyniens) sur la formation de Vidra du groupe de Tulișa (Paléozoïque) entre Bistra Bucovei et Poiana Mărului, chevauchement figuré tant sur la feuille 1 : 200.000 de Deva (Gherasi et al., 1967) que dans d'autres notes (Gherasi et al., 1968 ; Gherasi et al., 1974 ; Savu et al., 1978).

Le Danubien inférieur et le Danubien supérieur sont constitués à leur tour par plusieurs unités : celles du Danubien supérieur ont probablement le rang de nappes, celles du Danubien inférieur de notre région probablement pas. Le cadre général des unités tectoniques étant

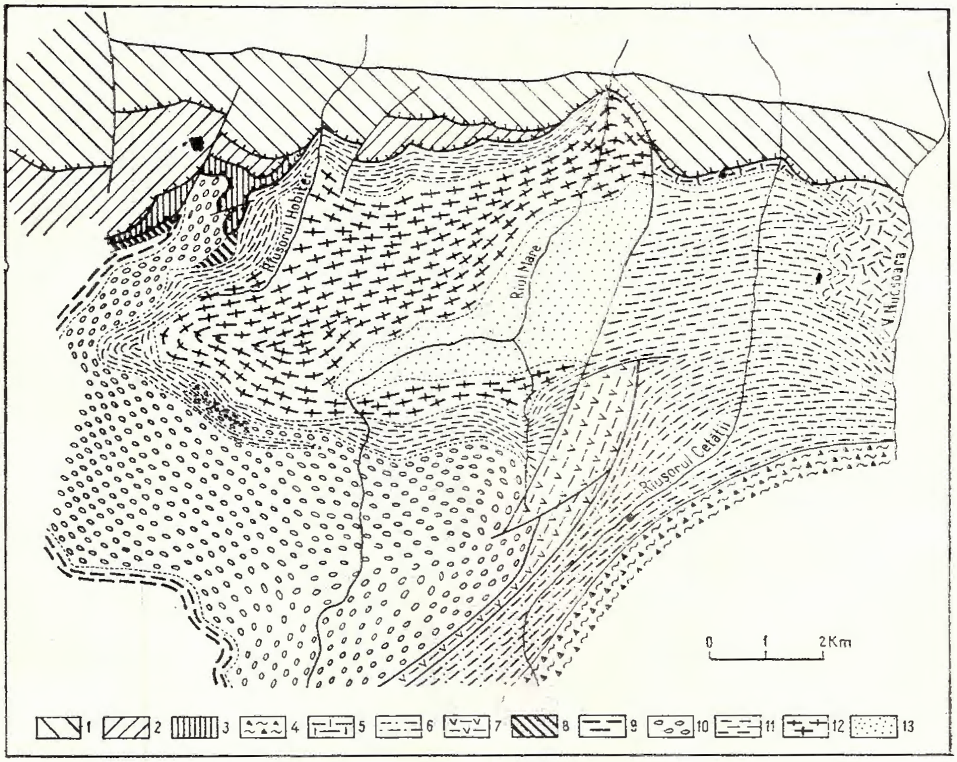

Fig. 1. — Esquisse tectonique de la partie nord des monts de Petreanu et de Retezat (région de Rîu Mare).

Danubien supérieur : Unité de Măru. 1, Formation de Zeicani. Unité de Muntele Mic ; 2, Formation de Măgura. Unité de Poiana Mărului ; 3, Formation de Barniţa.

Danubien inférieur : 4, Groupe de Drăgşanu. Compartiment de Nucşoara ; 5, Formation de Nucşoara ; 6, Formation de Rîuşorul ; 7, Formation de Picui. Compartiment de Petreanu-Rof ; 8, Phyllades et calcaires de Poleatcu (Coposu) ; 9, Formation de Bodu ; 10, Gneiss granitoïde de Petreanu ; 11, Formation de Nisipoasa ; 12, Gneiss granitoïde de Furcătura ; 13, Formation de Rof.

fixé dans ses grandes lignes (Kräutner et al., 1981 ; Berza et al., 1983), nous allons l'adopter tel quel pour notre note sans le discuter, excepté les cas où nous lui apportons des modifications.

I. Danubien inférieur

1. *Compartiment de Petreanu-Rof*

En considérant leur position actuelle dans le cadre de l'unité de Petreanu-Rof, les unités lithostratigraphiques sont en relation de superposition (à partir de l'axe de l'antiforme de Rof vers le haut) : formation leptyno-amphibolitique de Rof, gneiss granitoïde de Furcătura, for-

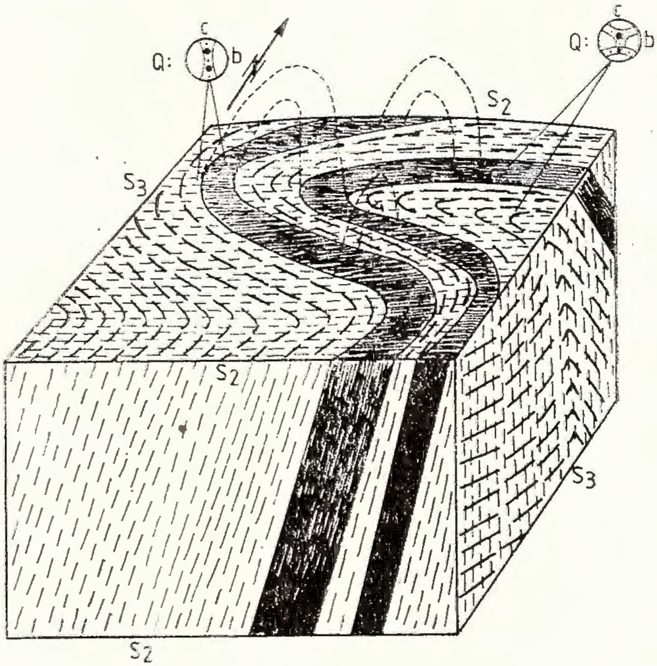

Fig. 2. — Bloc-diagramme schématique avec la structure du compartiment de Petreanu-Rof.

mation des schistes quartzeux à biotite de Nisipoasa, gneiss granitoïde de Petreanu, formation de Bodu, phyllades et calcaires de Poleatcu. Si nous envisageons les deux gneiss en tant qu'anciennes intrusions de granitoïdes, nous allons décrire d'abord en ordre ascendant les formations sédimentogènes et ensuite les gneiss.

a) La formation leptyno-amphibolitique de Rof (Gherasi, Dimitrescu, 1968, 1970 ; Gherasi et al., 1974 ; Kräutner, 1980 ; Kräutner et al., 1981) n'affleure que le long de la vallée de Rîu Mare et de ses affluents entre la vallée de Șipote et la vallée de Barnița, à l'est du gneiss de Furcătura. Elle est formée de micaschistes à grenats, de leptynites, d'amphibolites (fréquemment à structure de Garbenschiefer, à hornblendes de taille centimétrique), de schistes quartzeux à biotite, avec un niveau local de quartzites graphiteux. La chlorite, très répandue, est un produit de la diaphthorèse. La foliation S_1, marquée par les alternances lithologiques, est transposée par la foliation dominante S_2 qui décrit une large voûte antiforme (Gherasi, Dimitrescu, 1970 ; Morariu, 1982). Le miroir des plis mésoscopiques de la première foliation S_2 est très incliné. On observe en plus une foliation S_3 moins pénétrative (EO), matérialisée par le développement des micas. La position de S_2 est fréquemment EO, à pendages nord au sud qui marquent la voûte de l'antiforme de Rof.

Au microscope sont à relever : la transformation partielle de la hornblende en biotite et en épidote, la biotite de la seconde génération, en cristaux à forte largeur, caractéristiques plutôt du métamorphisme de contact, ne présente pas d'orientation préférentielle et tend à imprimer à la roche (de foliation prononcée d'ailleurs) une structure décussée (la biotite de la première génération est parfois microplissée), la chloritisation partielle de la biotite de la première schistosité S_1 et la formation d'une chlorite tout le long de la troisième schistosité S_3, la présence de fines plages séériciteuses à aspect pinitique, formées parfois aux dépens du plagioclase (le dernier étant en général un oligoclase dépourvu de relief).

Deux analyses chimiques de roches de la formation de Rof de la vallée de Rîu Mare (une amphibolite (30) et une leptynite (59), exécutées par Cristea) ainsi que les paramètres Niggli ont les valeurs suivantes :

	30	59
SiO_2	58,67	66,42
TiO_2	0,67	0,50
Al_2O_3	18,87	14,34
Fe_2O_3	1,83	3,08
FeO	3,43	1,75
MnO	0,08	0,08
MgO	2,85	1,35
CaO	5,25	4,90
Na_2O	4,31	4,36
K_2O	2,14	1,39
P_2O_5	0,13	0,08
CO_2	—	1,20
H_2O^+	1,28	0,17
H_2O^-	0,20	0,17
	99,71%	99,79%

	30	59
si	191	271
al	36	34
c	18	21
fm	28	23
alk	18	21
mg	0,50	0,35
k	0,25	0,17
c/fm	0,7	0,9

L'amphibolite se place dans le tétraèdre de Niggli à la limite entre le champ des roches éruptives et le champ des sédiments argileux ; les paramètres Niggli s'inscrivent bien dans le type de magma normal-quartz dioritique.

La leptynite se situe dans le tétraèdre du champ des roches éruptives, les valeurs Niggli se plaçant dans le groupe des magmas granodioritiques. Si l'on emploie de plus la méthode de Davoine (1968) pour une teneur en $CaO > 2,5\%$ et en $Na_2O + K_2O < 7\%$ il résulte en fait un caractère d'ortholeptynite métadacitique.

Il ne serait pas exclu que la formation de Rof soit constituée par un complexe sédimentaire-volcanogène (andésitique-dacitique).

b) La formation des schistes quartzeux à biotite de Nisipoasa (Kräutner, 1980 ; Kräutner et al., 1981) peut être poursuivie comme une bande étroite entre les gneiss de Furcătura et de Petreanu à partir de la vallée de Căldarea, intersectant deux fois la vallée de Rîușorul Hobiței, jusqu'au versant septentrional du mont de Furcătura Clopotivei. Cette formation a été incluse aux formations de Rîușoru (Gherasi, Dimitrescu, 1968, 1970) ou de Măgura (Gherasi et al., 1974). Les schistes fins quartzo-biotitiques, souvent d'aspect moiré, contenant de petits grenats, admettent une intercalation discontinue d'amphibolites (Făgețel, Roșia, Furcătura). C'est toujours dans cette formation que la lentille de quartz de Pietriceaua Albă est englobée.

L'examen microscopique met en évidence comme caractéristique la texture schisteuse parfaitement plane de ces roches, imprégnées souvent par une petite quantité de pigment graphiteux. Les grenats, toujours idiomorphes, ne présentent pas d'inclusions et ne sont pas fissurés.

Comme nous l'avons déjà constaté la diaphthorèse n'est pas présente dans cette formation.

b_1) Les schistes quartzeux à biotite de Nisipoasa sont recouverts dans le sommet de Coposu par des phyllades séririciteuses satinées grises de clivage axial et montrant une linéation de crénulation prononcée. Les phyllonites dérivées de la précédente formation, ou formation indépendante, peuvent être parallélisées aux phyllades de Poleatcu qui recouvrent la formation de Bodu ?

c) La formation de Bodu (Gherasi, 1937 ; Kräutner, 1980 ; Kräutner et al., 1981) comporte des micaschistes et des paragneiss à deux micas, parfois grenatifères, des quartzites ($\pm$ biotitiques), des schistes quartzo-amphiboliques à grenats, des amphibolites (parfois à hornblendes centimétriques) et des serpentinites antigoritiques. Elle se développe à l'ouest du gneiss de Petreanu.

La foliation dominante S_2 de la formation de Bodu transpose des plis très aplatis de S_1.

c_1) A la partie terminale de la formation de Bodu, à partir du bassin de la Zlotina vers l'ouest se développe un niveau mince de phyllades séririciteuses gris noirâtres, satinées (semblables aux phyllades de Coposu), recouvertes par des calcaires cristallins : les phyllades et les calcaires de Poleatcu (Gherasi et al., 1974). Font-ils partie (en tant que niveau phyllonitique) ou non de la formation de Bodu ? Celle-ci comporte des calcaires beaucoup plus au sud, dans la zone de Zeicu (Gherasi, 1937).

d) Le gneiss granitique de Furcătura constitue un corps stratoïde ayant la forme d'un croissant ou bien d'un fer à cheval, intercalé entre les formations de Rof et de Nisipoasa et qui peut être poursuivi de la vallée de Lăcurele (Lespezi) à la vallée de Bălan. Il traverse deux fois la vallée de Rîu Mare et présente le développement maximum dans le mont de Furcătura Clopotivei. Les réambulations des dernières années nous ont convaincu que ce corps représente une intrusion granitique affectée par deux phases de métamorphisme ; on peut donc le désigner comme „métagranite" ou comme „orthogneiss" au sens classique.

Les gneiss à biotite ou à muscovite peuvent avoir des textures massives ou rubanées et ne présentent que dans quelques secteurs la

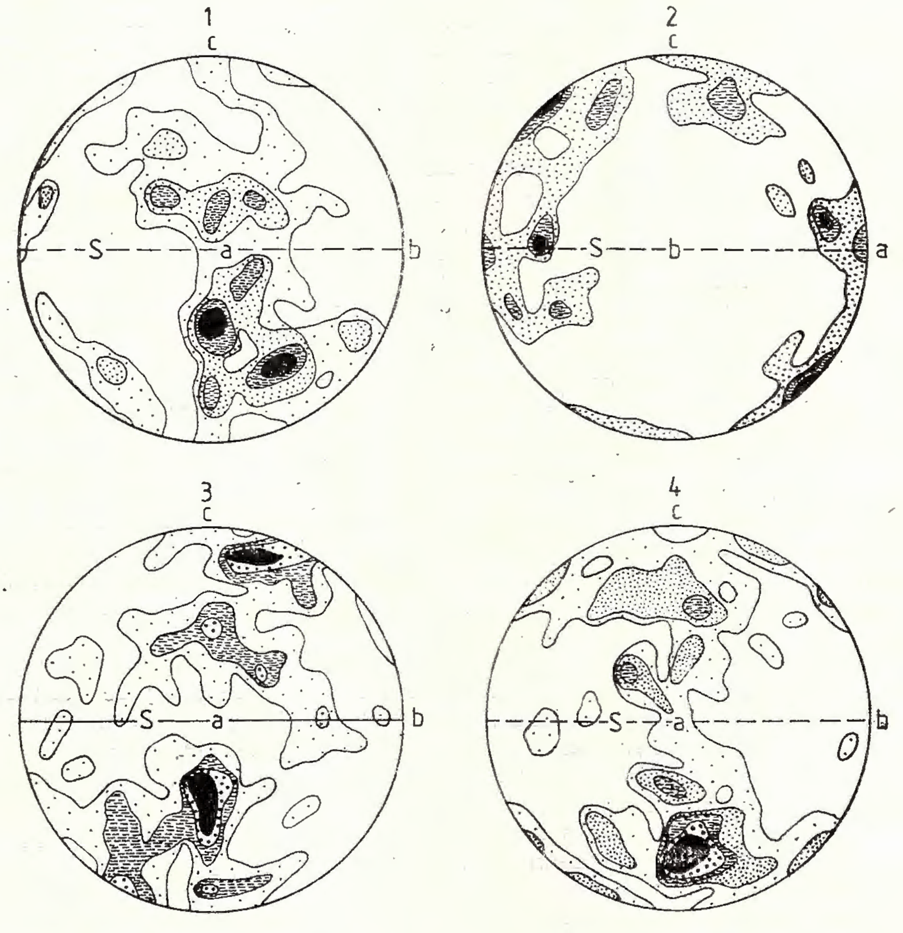

Fig. 3. — 1, 200 a.o. quartz, gneiss de Furcătura, Rîu Mare ; ⊥ a (1-2-3-4%) ; 2, 100 a.o. quartz, gneiss de Furcătura, Rîu Mare ; ⊥ b (2-4-6%) ; 3, 200 a.o. quartz, schiste quartzeux, Formation de Nisipoasa, monts de Furcătura ; ⊥ a (1-2-3-4%) ; 4, 200 a.o. quartz, gneiss de Furcătura, Făgețel ; ⊥ a (1-2-3-4-5%).

structure porphyroïde à mégablastes de feldspath potassique. Ils sont traversés par des filons d'aplites ou par des pegmatoïdes. Des aspects migmatiques métatectiques (diadysites, nébulites) apparaissent souvent.

Le principal élément structural mésoscopique planaire dans les gneiss granitiques de Furcătura est une foliation gneissique pénétrative, résultant de l'alternance (à l'échelle millimétrique) de bandes leucocrates avec d'autres à prédominance biotitique. Cette foliation S_2 (rubanement) est parallèle et contemporaine à la schistosité S_2 de la formation de Rof et elle a une direction entre EO et ENE-OSO, à pendage nord sur le flanc septentrional de l'antiforme de Rof ; sur le flanc méridional de celle-ci elle a la direction EO à pendage sud ; dans l'axe de l'antiforme, elle subit une inflexion, le raccord entre les positions des flancs ayant des directions entre N-S et N30°E et des pendages d'environ 70° vers le SE ou vers le NO.

Un second élément structural mésoscopique des gneiss de Furcătura est la schistosité S_3 consistant en plans de lamination à blasthèse de muscovite. Elle a l'orientation constante EO-N80°E, à pendages de 40° à 70° vers le S ou vers le N. Elle ne se différencie de S_2 que dans l'axe de l'antiforme, où elle la recoupe orthogonalement ; sur les flancs, les deux foliations se confondent presque totalement. La schistosité S_3 du gneiss coïncide avec S_3 de la formation de Rof.

L'élément linéaire prédominant des gneiss de Furcătura est constitué par des bandes de biotite orientées N20°-45°E, qui représentent en fait les intersections entre S_2 et S_3.

Nous avons déjà montré (Gherasi, Dimitrescu, 1970) que dans la vallée de Vaia et sur la crête de Jura (affleurement à présent bien visible le long d'une chaussée) apparaissent des filons d'aplites à quelques mètres du contact intrusif subvertical gneiss de Furcătura/formation de Rof, filons qui traversent cette dernière formation. Dans les amphibolites de celle-ci se développent des mégacristaux gris de feldspath.

Dans la vallée de Bălan affleure sur plus de dix mètres le contact entre le gneiss de Furcătura et la formation de Rof ; ce contact, parfaitement tranchant, qui n'est pas accompagné par des laminages parallèles, a une orientation N80°O/35°NE et il est intersecté par une foliation commune des deux formations géologiques à position N80°E/35°NO ; la linéation est orientée N60°E/13°NE.

En lames minces, dans les gneiss granitiques de Furcătura apparaissent les restes d'une ancienne structure hypidiomorphe-granulaire de roche intrusive, affectée par une intense blastomylonitisation avec la formation de plages et de rubans de quartz „lamellaire discordant et imbriqué" (Bellière, 1971). Localement la structure passe à des aspects „paragneissiques" ; parfois apparaissent aussi des plages équigranoblastiques avec tous les minéraux uniformément développés (plagioclase, microcline, quartz, muscovite) et rarement se produit une ségrégation de bandes feldspathiques et de bandes quartzeuses. Le plagioclase de la mésostase et le microcline des porphyroblastes sont altérés, avec formation de séricite et d'épidote, le microcline de la mésostase étant relativement frais. Il existe aussi bien de la biotite magmatique, en larges cristaux tabulaires, relictes de l'intrusion, que de la biotite lamellaire plus tardive à tendance de se disposer en files. On remarque dans quelques lames la présence de deux schistosités S_2 et S_3 perpendiculaires ou obliques, matérialisées par des micas (biotite et muscovite). Des grenats de dimensions très réduites sont aussi présents.

e) Le gneiss granitique de Petreanu constitue un corps stratoïde ayant la forme de la lettre S, situé entre les formations de Nisipoasa et de Bodu, pouvant être poursuivi à partir de la vallée de Zlotina, à travers le mont de Petreanu et la vallée de Rîu Mare, jusqu'au mont de Tomeasa. Il a l'aspect d'un gneiss granitique à biotite et à mégablastes lenticulaires de microcline de 1 à 3 cm de longueur. Le gneiss renferme des intercalations de schistes biotitiques, de quartzites et d'amphibolites ; vers celles-ci tout comme vers la formation de Bodu on observe parfois des transitions graduelles, par l'intermédiaire de gneiss lenticulaires (perlés), manifestations d'une migmatisation métablastique, ainsi que l'apparition des mégablastes de microcline. Bien que l'aspect prédominant soit celui d'un gneiss oeillé, on rencontre aussi des roches à grain plus fin presque massives. Nous considérons que les processus migmatiques se produisent à la périphérie de l'intrusion d'un autre corps granitoïde, celui de Petreanu, affecté d'endoblasthèse et à présent polymétamorphique.

Vers la formation de Nisipoasa, le gneiss de Petreanu se ramifie en plusieurs corps filoniens concordants qui la traversent.

L'âge précambrien du gneiss de Petreanu est attesté par la valeur de 656 ($\pm$ 19) m.a. obtenue par la méthode K/Ar sur une enclave biotitique (Soroiu et al., 1970, 1972), à laquelle s'ajoute une valeur de 527 m.a., toujours pour la biotite (Soroiu et al., 1970).

Le gneiss de Petreanu comporte aussi les deux éléments structuraux mésoscopiques planaires S_2 et S_3, ayant les mêmes caractères que ceux du gneiss de Furcătura. La foliation S_2 (le rubanement) est, aussi parallèle au contour général du corps gneissique, sa trajectoire décrivant une forme en S qui moule l'antiforme de Rof ; la foliation S_3 est en général orientée EO/35°-80° S ; les deux foliations se confondent sur le flanc sud de l'antiforme, mais elles s'entrecroisent orthogonalement sur la vallée de Rîu Mare à partir de Gura Zlatei vers l'amont. La linéation minérale de la biotite a une direction comprise entre le NNE et le NNO.

En lames minces on peut observer une structure partiellement semblable à celle des gneiss de Furcătura : des relictes d'aspect de roche plutonique, contenant du quartz granulé en traînées blastomylonitiques, cette granulation affectant assez fréquemment même les feldspaths ; en contraste avec le plagioclase intensément séricitisé et épidotisé, le feldspath potassique — autant celui développé en porphyroblastes que celui finement granulaire — est frais. On remarque aussi dans quelques lames des porphyroclastes de quartz et de plagioclase, moulés par des rubans finement granoblastiques à quartz et à biotite. On observe également deux schistosités à angle aigu S_2 et S_3, matérialisées non seulement par la disposition des micas, mais aussi par des bandes de quartz et d'épidote. Dans le gneiss de Petreanu apparaissent localement des poches de chlorite monominérales, probablement contemporaines de la diaphtorèse alpine.

2. *Compartiment de Nucşoara*

f) La formation de Rîuşorul (Pavelescu, 1953 ; Gherasi, Dimitrescu, 1968, 1970 ; Gherasi et al., 1974) constitue une bande de terrains orientée NE-SO, entre la vallée de Nucşoara et celle de Rîu Mare, délimitée par d'importantes lignes de dislocation. Elle est formée par des schistes quartzeux à biotite, des schistes micacés à grenats et à graphite, à intercalations de schistes quartzeux muscovitiques gris et, plus rarement, d'amphibolites à zoïzite ou de phyllades à aiguilles d'actinote. Localement, la formation de Rîuşorul est affectée par une intense rétromorphose, la chloritisation générale de la biotite imprimant une couleur vert clair aux roches, qui ont été confondues antérieurement avec celles de la „série de Drăgşanu". Vers le SO, par une phyllonitisation accentuée, cette formation passe à la „série des phyllades de Rîu Mare", constituée par des „phyllades" noirâtres ou grises, graphiteuses, quartzo-sériciteuses ou calcaires, parfois à fines lamelles de biotite relicte.

Dans le sommet d'Ascuţitu s'intercale dans la formation de Rîuşorul un gneiss oeillé. Micu et Paraschivescu (1970) le considèrent comme un microconglomérat.

Les amphibolites de la vallée de Rîuşoru Cetăţii qui affleurent dans Lunca Negrii (au confluent de la vallée de Cerna), décrites par Gherasi et Medeşan (1968) en tant que partie de la „série de Barniţa-Zeicani" (une analyse chimique est présentée dans l'ouvrage cité), appartiennent en fait à la formation de Rîuşorul.

L'élément structural mésoscopique planaire prédominant de la formation de Rîuşorul est une foliation S_4 axiale en rapport avec les microplis centimétriques serrés d'une foliation S_3 ; la position de S_4 est NE-SO à pendage SE, au sud de l'axe de l'antiforme de Rof, qui affecte aussi le compartiment de Nucşoara ; sur le flanc septentrional de l'antiforme, les positions de S_3 sont EO/20°-70°N. Les linéations ont l'orientation ENE.

Dans l'axe de l'antiforme de Rof, sur la vallée de Rîuşoru Cetăţii, dans le soubassement de la formation de Rîuşorul apparaissent quelques blocs de schistes à grenats de taille centimétrique et d'amphibolites de type Garbenschiefer, à hornblendes de quelques centimètres, intensément diaphtorisées. Les roches ressemblent à celles de la formation de Rof et pourraient constituer une boutonnière du soubassement de la formation de Rîuşorul.

g) La formation de Nucşoara (Macaleţ, 1983) recouvre la formation de Rîuşorul à partir de Măgura Zimbrului, par la vallée de Rîuşoru Cetăţii jusqu'à la vallée de Nucşoara. Elle est constituée de schistes quartzeux graphiteux à aspect phylliteux et de schistes blancs quartzeux à séricite. Elle admet des intercalations de calcaires cristallins gris, de calcschistes, ainsi que des serpentines à antigorite (± talc), décrites par Micu et Paraschivescu (1970). Sa couleur grise a donné lieu à des confusions. Pavelescu (1953), Micu et Paraschivescu (1970) l'ont considerée être l'une des formations du groupe de Tulişa.

La schistosité axiale S_3 de la formation de Nucşoara est dominante, accompagnée d'une prononcée linéation de crénulation orientée ENE. Le phénomène de transposition est particulièrement clair, surtout dans le cas des intercalations calcaires (Rîuşoru Cetăţii, affluents de la vallée de Nucşoara).

h) La formation des amphibolites de Picui (Gherasi et al., 1974) occupe une bande de terrains mince délimitée entre deux failles orientées NE-SO, entre les vallées de Bulz (affluent méridional de la vallée de Lăcurele) et de Radeş. Comme intercalations on y observe de minces passées de roches blanches quartzeuses ($\pm$feldspath, biotite). Les foliations S_4 ont des directions NE à pendages SE.

II. **Danubien supérieur**

1. *Unité de Poiana Mărului*

i) La formation de Barniţa (Gherasi et al., 1968 ; Gherasi, Savu, 1969) n'apparaît que dans le bassin de la Zlotina et sur la crête à l'est de celle-ci. Elle est représentée par des roches d'aspect de schistes verts tufogènes à chlorite, épidote, parfois séricite et albite, très satinés. Vers le SO, au-delà des limites de notre région, à Poiana Mărului la formation de Barniţa passe à ce que Gherasi et Medeşan (1968) ont appelé „série de Baicu" et Kräutner (1980) formation de Rîu Şes. Il y a des arguments en faveur de l'âge cambrien de cette formation (Gherasi et al., 1973).

2. *Unité de Muntele Mic*

j) La formation de Măgura (Gherasi et al., 1968, 1974) occupe une bande de terrains orientée E-O, qui s'étrécit à partir de la crête de Vîrful Pietrii-Vîrful Otului vers l'est jusqu'au versant nord de Furcătura Clopotivei. Elle est formée par des schistes quartzo-albitiques à biotite et muscovite, en plaquettes et par des paragneiss blancs à muscovite, à intercalations d'amphibolites (ayant l'aspect de métadiorites). Parfois, une feldspathisation métablastique (lentilles de microcline très frais) indique l'existence de processus migmatiques incipients (probablement comme échos lointains de l'intrusion du massif granitoïde de Muntele Mic). Elle engendre des gneiss oeillés. Les roches de la formation sont souvent rétromorphosées, avec formation de chlorite. Ce n'est que rarement qu'on peut observer dans les lames minces de ces roches probablement métaarkosiennes à déformation postcristalline intense (micas courbés, lamelles de macle cassées), la présence de deux schistosités à angle d'environ 45°. Les deux schistosités sont accompagnées par la blasthèse de la biotite.

La foliation de transposition S_2 est l'élément structural planaire prédominant de la formation de Măgura.

L'examen attentif ne montre aucune ressemblance avec la formation de Rîuşorul, contrairement aux affirmations antérieures.

3. *Unité de Măru*

k) La formation de Zeicani (Gherasi, Dimitrescu, 1968, 1970 ; Gherasi et al., 1968) apparaît au nord de la région étudiée, formant une bande de terrains orientée E-O entre les vallées de Zeicani et de Nucșoara (et se prolongeant au-delà de celles-ci vers l'est et vers l'ouest).

Le membre inférieur de la formation est constituée par des schistes verts albitiques chloriteux à épidote, calcite, muscovite ou quartz, par des schistes actinolitiques à chlorite et par des amphibolites. Une analyse chimique d'une de ces dernières roches se trouve dans la note de Gherasi et Medeșan (1968). Ce membre a été détaché par Gherasi et al. (1974) de la formation de Zeicani et attribué à la formation de Măgura.

Le membre supérieur de la formation de Zeicani est formé de gneiss à muscovite, parfois à lentilles de feldspath plagioclase, ayant plutôt une origine détritique (dans ce cas les roches représentent des métagraywackes à larges „porphyroblastes de muscovite"), à minces intercalations de schistes blancs quartzo-albitiques. Vers la partie supérieure de ce membre réapparaissent des roches vertes, Gherasi et al. (1974) les considérant en tant que „complexe supérieur". La structure de métagraywacke, à fragments lenticulaires de roches renfermées dans des zones séricitеuses quartzo-feldspathiques (± grenats, biotite), à feuillets de muscovite largement développée, nous paraît évidente au microscope, bien qu'elle soit susceptible d'autres interprétations (Berza, communication verbale).

Des phénomènes de migmatisation métablastique se développent dans ces roches, sous la forme de lentilles millimétriques de microcline, phénomènes erronément liés auparavant par nous à des gneiss granitiques de Petreanu.

Toute la formation de Zeicani montre les traces d'une forte rétromorphose. Des indications sur son âge pourraient être données par les formes récoltées par Micu et Paraschivescu (1970) des vallées de Nucșoara, de Sălășelul et de Rîul Alb et du mont Colțul Mare, où des schistes „séricito-chloriteux" ont été faussement attribués par eux à la „série" de Tulișa. Ces schistes contiendraient une association sporo-protistologique d'âge protérozoïque (cambrien ?).

L'élément structural planaire mésoscopique prédominant dans la formation de Zeicani est une foliation axiale S_2, ayant l'orientation EO/30°-70°N (S_1 décrivant des plis mésoscopiques très aigus, de l'ordre des centimètres). Cette foliation passe très souvent à une foliation de transposition.

Les éléments linéaires (crénulations et linéations minérales de la chlorite) sont orientés E-O.

En lames minces on observe souvent la présence de deux schistosités dans les roches de la formation de Zeicani.

III. Structure

Nous n'argumenterons pas dans cette note la division en Danubien inférieur et supérieur et, dans le cadre de ce dernier, en unités (probablement à rang de nappes) de Poiana Mărului, de Muntele Mic et de Măru, de bas en haut (voir Kräutner et al., 1981). Nous n'allons discuter que le Danubien inférieur dans lequel une faille importante orientée NE-SO, faisant partie d'un faisceau de failles (système de Rîu Mare), délimite le compartiment de Nucșoara au SE et un compartiment complexe au NO que nous appelons Petreanu-Rof.

Vers le SE, les formations du compartiment de Nucșoara prennent contact au long d'une autre faille majeure avec les formations du groupe de Drăgșanu, qui ne seront pas analysées dans la présente note.

En ce qui concerne la structure du compartiment de Petreanu-Rof, bien des commentaires peuvent être faits. En 1945 Codarcea a émis l'hypothèse d'un charriage du gneiss de Furcătura sur la formation de Rof. Ce point de vue a été combattu par nous (Gherasi, Dimitrescu, 1968, 1970) et nous avons conclu que, si l'on admettait ce charriage, il faudrait — pour rester conséquents — admettre aussi le charriage des gneiss de Petreanu sur la formation de Nisipoasa. Effectivement, dix ans plus tard, Kräutner et al. (1981) et Berza et al. (1983) en jetant les bases incontestables de la conception nappiste du Danubien, ont admis la possibilité de l'existence de deux unités superposées sur une unité de Rof, notamment d'une unité de Furcătura et d'une unité de Petreanu.

Nous allons, dans les pages suivantes, développer notre point de vue actuel, selon lequel il existe une seule unité tectonique de Petreanu-Rof. Suivant nous, les relations primaires entre les deux gneiss granitiques et leur couverture schisteuse sont des relations d'intrusion magmatique, compliquée par des processus périphériques de migmatisation, spécialement dans le cas du gneiss de Petreanu. La position géométrique actuelle des trois formations métasédimentaires et des deux formations métaéruptives résulterait de la superposition de deux phases de plissement, chacune accompagnée de la naissance d'une schistosité de plan axial ; la première (S_1) ayant la direction NNE-SSO et la seconde (S_3) la direction ENE-OSO.

La première schistosité, à l'orientation initiale mentionnée plus haut, a été déformée par le second plissement, en subissant les inflexions décrites antérieurement, parallèles aux contours des deux corps gneissiques. La seconde schistosité n'a plus été replissée, sa direction restant constante.

D'après Berza (communication verbale) les deux surfaces de charriage supposées (antérieurement, par lui-même) ne présentent aucune trace de diaphthorèse dynamique chloriteuse, le minéral-index qui croît le long des plans de schistosité respectifs étant la biotite, ce qui serait incompatible avec tout ce que nous connaissons aussi bien à propos des charriages alpins des Carpathes que des charriages hercyniens. Un charriage prévarisque ne saurait être exclu en principe, mais il ne bénéficierait plus de l'argument de la structure générale en nappes du Danubien, qui a un autre âge, plus récent.

Revenant au moment de l'intrusion des deux corps de granitoïdes, il n'est pas exclu qu'ils aient initialement constitué une seule nappe intrusive ultérieurement plissée. Là-dessus nous préférons comme solution une structure anticlinale plutôt que synclinale, pour des raisons évidentes eu égard à l'enracinement de l'intrusion.

La zonalité du „pétrofabric" mise en évidence par nous (Gherasi, Dimitrescu, 1968, 1970) est le produit de la troisième phase de plissement F_3. Dans ce cadre, le quartz de la formation de Rof et celui du gneiss de Furcătura présentent une orientation de type „Pseudozweigürteltektonit" (petits cercles autour de l'axe *c*, unis par un bras sur *a* et un maximum entre *a* et *c)*, tandis que dans la formation de Nisipoasa et dans le gneiss de Petreanu nous nous trouvons devant des ceintures *ac*. L'étude microstructurale de quatre nouvelles lames orientées du gneiss de Furcătura et des schistes quartzeux à biotite de Nisipoasa ont confirmé ce point de vue.

Ci-dessous nous essayons de faire une reconstitution de la succession des événements tectoniques (phases de déformation) qui ont affecté la région :

1. Développement d'une schistosité S_1 (de stratification ?) dans les formations de Rof, de Nisipoasa et de Bodu, avec leur métamorphisme en faciès amphibolite, probablement en connexion avec un processus de plissement F_1.

Cette schistosité S_1 est évidente dans les formations de Rof et de Bodu, mais nous ne pouvons pas dans le stade actuel de nos connaissances discerner un plan d'ensemble du plissement F_1, les unités lithologiques ne pouvant être que difficilement poursuivies à cause de la transposition ultérieure.

1a. En même temps avec ce développement se produit, semble-t-il, l'intrusion cadomienne ancienne (656 m.a. K/Ar) de deux corps de granitoïdes (éventuellement d'un seul) : Furcătura et Petreanu, intrusion(s) concordante(s) accompagnée(s) d'une large auréole de contact dans la formation de Rof (une blasthèse de la biotite en cristaux tabulaires de forte largeur, de deuxième génération ; une possible recristallisation non orientée de la hornblende en „Garbenschiefer", analogue selon nous à la structure Widmanstätten des métallurgistes ; peut-être une cristallisation des grenats dans la formation de Nisipoasa ; une métablasthèse feldspathique dans la formation de Bodu).

2. Plissement F_2 à direction NNE-SSO des trois formations ainsi que des granitoïdes, à développement d'une forte schistosité S_2 qui provoque la transposition de S_1, étant toutefois la première foliation qui affecte le(s) granitoïde(s) devenu(s) gneiss. Métamorphisme en faciès amphibolite à épidote. La schistosité S_2 est très visible, étant commune pour toutes les formations du compartiment de Petreanu-Rof, les gneiss granitoïdes inclus dominant dans l'image mésoscopique ; elle moule les limites actuelles des gneiss de Petreanu et de Furcătura. Ces limites tout comme la trajectoire générale de S_2 ont l'allure de la lettre S.

3. Plissement F_3 à direction ENE-OSO de toutes les formations mentionnées : replissement de la foliation S_2 à développement d'une schistosité S_3 ; métamorphisme en faciès des schistes verts, zone à biotite ; définitivation de la microstructure du quartz, peut-être amorcement de l'antiforme de Rof, à mettre en corrélation avec le rajeunissement hercynien des âges K/Ar (270, 288 m.a. pour les gneiss de Petreanu, 226 m.a. pour les gneiss de Furcătura, 296 m.a. pour la formation de Rof) (Soroiu et al., 1972). La schistosité S_3 se manifeste assez clairement dans la formation de Rof et dans les gneiss granitoïdes, se re-

trouvant dans les formations de Rîușorul et de Nucșoara dans la partie nord du compartiment de Nucșoara. Elle a une direction constante ENE et ce ne sont que ses pendages qui diffèrent comme sens et comme valeur sur les deux flancs de l'antiforme de Rof. A l'est de notre région, cette schistosité semble être celle qui affecte les formations du groupe de Tulișa à partir de la crête de Știrbina vers la vallée de Rîu Bărbat ainsi que vers l'ouest dans la formation de Vidra.

4. Fracturation de la région avec la formation du système de failles de Rîu Mare, phyllonitisation de la formation de Rîușorul avec transposition de la foliation S_3 par une nouvelle schistosité S_4 orientée NE-SO ; rétromorphisme en zone à chlorite, présent dans quelques secteurs des formations géologiques décrites ci-dessus. La schistosité S_4 prédomine dans les formations de Rîușorul et de Picui, dans la partie sud du compartiment de Nucșoara.

La corrélation des phases de plissement du Danubien inférieur avec celles du Danubien supérieur est, naturellement, difficile à réaliser ; toutefois la notation conventionnelle des dernières phases par F_1 et F_2, correspondant aux schistosités S_1 et S_2 observées dans les formations de Măgura et de Zeicani, n'est pas tout à fait erronée.

5. Charriage, probablement alpin (synchrone au charriage gétique?) des unités danubiennes supérieures sur le Danubien inférieur, à rajeunissement des âges K/Ar (89 m.a. pour la formation de Zeicani, 154 m.a. pour la formation de Rof) (Soroiu et al., 1972).

6. Bombement général du cristallin avec l'apparition de la fenêtre d'érosion du Danubien inférieur, définitivation de l'antiforme de Rof, formation de la faille — évidente dans le relief — qui sépare le cristallin du bassin de Hațeg, sont des événements alpins plus tardifs.

En revenant sur la structure du compartiment de Petreanu-Rof, qui a retenu spécialement notre attention, nous soulignons que l'allure en S des limites géologiques (partiellement recoupées par le système des failles de Rîu Mare) résulte de la superposition des plissements F_3 et F_2. Pour le domaine supragétique des Carpathes Méridionales, de telles superpositions ont été déjà constatées dans le massif de Făgăraș (Dimitrescu, 1978) et dans le Banat (Iancu, in Kräutner et al., 1981). Pour le domaine gétique des observations analogues existent (Maier et al., 1975 ; Iancu, Hârtopanu, 1979 ; Gurău, 1982). L'auteur dispose des données inédites qui attestent la présence des déformations plicatives répétées dans le massif de Ezer ainsi que dans le groupe de Someș des monts Apuseni (Someșul Rece, carrière de Rîșca Mică).

Dans la présente note nous soutenons donc la présence des mêmes processus de replissement dans le domaine danubien des Carpathes Méridionales.

Problèmes de corrélation

Nous avons essayé d'éviter toute affirmation concernant la corrélation entre diverses formations géologiques appartenant à des unités tectoniques différentes. Nous n'avons inclus dans une formation que ce que peut être poursuivi de près en près. Les questions concernant ces corrélations sont toutefois légitimes et nous ne les éviterons pas, mais nous ne nous prononçons pas dans la phase actuelle en faveur de l'une des solutions possibles, pour ne pas retomber dans les erreurs du passé.

a) La formation de Zeicani du Danubien supérieur est-elle un équivalent d'une partie du groupe de Drăgşanu (Kräutner, 1980 ; Kräutner et al., 1981) du Danubien inférieur ?

b) Dans le cadre du Danubien supérieur, la formation de Zeicani représente-t-elle un équivalent de la formation de Barniţa (Gherasi et al., 1968 ; Gherasi, Savu, 1969) = de Baicu (Gherasi, Medeşan, 1968) = Rîu Şes (Kräutner, 1980) ?

c) Dans le cadre du Danubien inférieur, peut-on faire la corrélation entre la formation de Nisipoasa du compartiment de Petreanu-Rof et la formation de Rîuşorul du compartiment de Nucşoara ?

d) Les phyllades de Coposu et les phyllades ainsi que les calcaires de Poleatcu (compartiment de Petreanu-Rof) trouvent-ils un équivalent dans la formation de Nucşoara (compartiment de Nucşoara) ?

e) Le soubassement de la formation de Rîuşorul est-il constitué par la formation de Rof ?

f) Existe-t-il une affinité entre les amphibolites de Picui et celles de la formation de Rof ou bien celles du groupe de Drăgşanu ou celles intercalées dans la formation de Rîuşorul ?

g) Selon notre opinion sur la structure du compartiment de Petreanu-Rof, la formation de Bodu devient un équivalent géométrique (pas nécessairement stratigraphique) de la formation de Rof ; y a-t-il une affinité entre les deux formations ? Il paraît que non, étant donné que les intrusions de Furcătura et de Petreanu auraient pu les surprendre dans de diverses relations réciproques, dues à des événements antérieurs.

h) Le Cambrien est-il représenté dans la formation de Zeicani ?

i) Que représentent les métaconglomérats à galets de quartz et de diorites (non mentionnés jusqu'ici dans cette note) pincés (?) dans la formation de Rîuşorul à environ 1,5 km au NO du sommet de Strugari ?

j) Que représentent les roches blanches quartz-porphyriques (non mentionnées jusqu'ici dans cette note), peu ou non laminées (toutefois transposées par un plissement plus récent), à phénocristaux de quartz corrodé et de feldspaths totalement altérés qui traversent les formations de Picui et de Rîuşorul ?

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QUESTIONS

I. Balintoni : Quelles sont les reliques structurales et paragénétiques antérieures à S_2 ?
2. Combien de générations de biotite peuvent être séparées dans la séquence des métamorphites du Danubien inférieur et quelle est leur relation avec les foliations?
3. Quelles sont les preuves d'antériorité de la biotite plus grosse que longue par rapport à celle plus longue que grosse ?

Réponse : 1. Antérieure à S_2 est la foliation S_1 — de stratification ? ($= S_0$?) et une génération de biotite microplissée.
2. Je n'ai pas insisté sur les détails des relations de la biotite avec les autres foliations ; j'ai établi seulement qu'il y a deux générations de biotite au moins.
3. La biotite plus gros-tabulaire, dépourvue d'orientation préférentielle, est ultérieure à celle microplisée

DISCUSSIONS

V. Iancu : La note présente des données fort intéressantes sur l'histoire métamorphique et sur les structures préalpines des formations polymétamorphes précambriennes et des granitoïdes associés de la partie ouest du Danubien inférieur.

Une série d'observations effectuées dans des affleurements spectaculaires de Rîul Mare révèlent l'évolution préalpine compliquée des métamorphites de la formation de Rof. Celle-ci présente des paragenèses minérales superposées attestant une évolution polycyclique. Une génération de minéraux reliques (par exemple almandin, biotite, hornblende) sont réorganisés dans une matrice mésométamorphique disposée sur le plan de la foliation S_2. Une paragenèse subséquente de minéraux stables dans le faciès des schistes verts est corrélable aux plans S_3. Les mêmes affleurements mettent en évidence l'association de ces deux plans avec deux systèmes de plis métriques et décimétriques à directions axiales presque perpendiculaires et à plans axiaux sous-horizontaux. La position sous-horizontale des plans axiaux ainsi que les charnières plissées prouvent leur implication dans des déformations régionales de compression et/ou de cisaillement auxquelles ont participé également les granitoïdes associés.

DANUBIANUL MUNȚILOR PETREANU ȘI RETEZAT ÎN REGIUNEA RÎUL MARE

(Rezumat)

Regiunea studiată în timpul campaniilor din 1980, 1981 și 1982 cuprinde unitățile aparținînd atît Danubianului inferior cît și Danubianului superior, ultimele avînd probabil rangul de pînze.

I. Danubianul inferior

1. *Compartimentul Petreanu-Rof*

a) Formațiunea leptino-amfibolitică de Rof este constituită din micașisturi cu granați, șisturi cuarțoase cu biotit, leptinite și amfibolite. O foliație S_1 definită prin alternanțe litologice este transpusă de către șistozitatea dominantă S_2 ; o a treia șistozitate S_3, mai puțin penetrativă, este marcată de o dezvoltarte de mice.

b) Formațiunea de șisturi cuarțoase cu biotit de Nisipoasa admite o intercalație discontinuă de amfibolite. Ea este acoperită de filite satinate gri de Coposu.

c) Formațiunea de Bodu se compune din micașisturi, paragnaise, cuarțite cu biotit, amfibolite și serpentinite. La partea sa superioară ea este acoperită de filite sericitoase și de calcare cristaline.

g) Gnaisul granitoid de Furcătura reprezintă o intruziune stratiformă pusă în loc între formațiunile de Rof și Nisipoasa și afectată de două faze de metamorfism. O foliație metamorfică S_2, paralelă cu șistozitatea S_2 a șisturilor care le găzduiesc, se curbează după limitele masivului gnaisic : o a doua șistozitate S_3 o traversează în șarnierele de cute și se confundă aproape cu ea pe flancuri.

e) Gnaisul granitoid de Petreanu constituie de asemenea o intruziune stratoidă pusă în loc între formațiunile Nisipoasa și Bodu (vîrstă K-Ar : 656 $\pm$ 19 m.a.) și afectată de aceleași foliații S_2 și S_3.

2. *Compartimentul Nucșoara*

f) Formațiunea de Rîușorul este formată din șisturi cuarțoase gri cu biotit, cîteodată cu grafit sau granați, admițînd intercalații de amfibolite și de șisturi cuarțoase cu muscovit.

g) Formațiunea de Nucșoara acoperă formațiunea de Rîușorul și se compune din șisturi cuarțo-grafitoase, șisturi cuarțo-sericitoase, calcșisturi și calcare cristaline, admițînd intercalații de serpentinite cu talc. Structura sa mezoscopică este dominată de șistozitatea S_3.

h) Formațiunea amfibolitelor de Picui admite intercalații de roci albe cuarțoase ($\pm$feldspat, biotit).

II. Danubianul superior

1. *Unitatea de Poiana Mărului*

i) Formațiunea de Barnița se compune din șisturi verzi tufogene cu clorit, epidot, albit, cîteodată sericit.

2. *Unitatea de Muntele Mic*

j) Formațiunea de Măgura este constituită din șisturi cuarțoase (± albit) cu biotit și muscovit și din paragnaise albe cu muscovit, cu intercalații de amfibolite (metadiorite); pe alocuri ea este feldspatizată cu formarea de gnaise oculare.

3. *Unitatea de Măru*

k) Formațiunea de Zeicani cuprinde doi membri : membrul inferior este format din șisturi verzi cu clorit, albit, epidot, calcit, muscovit și amfibolite, în timp ce membrul superior se constituie din gnaise cu muscovit, cîteodată cu lentile de feldspat, și a fost considerat ca provenind din greywacke. Întreaga formațiune de Zeicani este intens retromorfozată, structura sa mezoscopică fiind dominată de două șistozități.

Structură

Contrar opiniilor anterioare (inclusiv opiniilor noastre), noi considerăm că relațiile primordiale ale celor două masive de gnaise cu învelișul lor șistos sînt relații intrusive magmatice, complicate de către fenomene periferice de migmatizare, mai ales pentru gnaisul de Petreanu. Poziția actuală a celor trei formațiuni metamorfice și a celor două masive metaeruptive din compartimentul Petreanu-Rof ar rezulta din superpoziția a două faze de cutare F_2 și F_3, fiecare însoțită de dezvoltarea unei șistozități de plan axial, S_2 și S_3; axa de cutare F_2 este orientată NNE-SSV, a doua F_3 avînd direcția ENE-VSV. Rezultă de aici o alură în formă de S a limitelor geologice și superpoziția următoare de jos în sus : formațiunea de Rof, gnaisul de Furcătura, formațiunea de Nisipoasa, gnaisul de Petreanu, formațiunea de Bodu.

O reconstituire a succesiunii de evenimente tectonice care ar fi afectat Danubianul inferior este următoarea :

1. Dezvoltarea unei șistozități S_1 (de stratificație ?) legată de o fază de cutare F_1 în formațiunile de Rof, Nisipoasa și Bodu, sincronă cu metamorfoza lor în facies amfibolitic.

1a. Intruziunea, probabil cadomiană veche, a celor două masive de granitoide, Furcătura și Petreanu, constituind poate un singur corp stratiform (?).

2. Cutarea F_2 pe direcția NNE-SSV a celor trei formațiuni precum și a celor două masive, cu dezvoltarea unei șistozități S_2 care transpune foliația S_1, fiind în același timp prima foliație care afectează granitoidul (ele) devenit(e) gnaise. Metamorfism repetat în facies de amfibolite cu epidot.

3. Cutarea F_3 cu orientare ENE-VSV a tuturor formațiunilor menționate ; recutarea foliației S_2 cu dezvoltarea unei șistozități S_3 ; metamorfism în zonă cu biotit, probabil în raport cu întinerirea hercinică a vîrstelor K-Ar (270, 288 m.a. pentru gnaisele de Petreanu, 226 m.a. pentru gnaisele de Furcătura, 296 m.a. pentru formațiunea de Rof). Poate formarea antiformei Rof.

4. Formarea sistemului de falii Rîul Mare, filonitizarea formațiunii de Rîușorul cu transpunerea unei șistozități mai vechi (S_3) de către una mai recentă (S_4).

5. Șariajul, probabil alpin, al unităților danubiene superioare peste Danubianul inferior, cu întinerirea vîrstelor K-Ar (89 m.a. pentru formațiunea de Zeicani, 154 m.a. pentru formațiunea de Rof).

6. Evenimentele alpine mai tardive : bombare generală a Danubianului cu apariția ferestrei de eroziune a Danubianului inferior, prin accentuarea antiformei Rof, precum și formarea faliei care separă formațiunile cristaline de bazinul Hațeg.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR METAMORFICE

INTERSECTING ISOGRADES — A POSSIBLE WAY TO FIND OUT THE POLYMETAMORPHISM. AN EXAMPLE : THE SOMEŞ SERIES [1]

BY

ION HÂRTOPANU [2], PAULINA HÂRTOPANU [2]

Isogrades metamorphism. Metamorphism cycle. Someş Series. Metamorphism phase. Mineralogic method. Mineral paragenesis. Biotite-chlorite. Kyanite+staurolite. Almandine-staurolite. Apuseni Mountains — Northern Apuseni — Gilău Massif.

Abstract

On account of mineral crystallization succession and of the deformations which are identified under microscope and mesoscopic scale are traced metamorphism isogrades in the Someş Series from the Gilău crystalline. Using the notion of intersecting isograde with a new meaning, it is shown that biotite-chlorite isograde belonging to new metamorphic cycle intersects isogrades kyanite+staurolite-staurolite and almandine-staurolite belonging to an old metamorphic cycle. We conclude that the way we use intersecting isogrades notion is a method added to that of discovering mineral generations in order to establish the position of an individual metamorphic event used to distinguish phase from cycle respectively.

Résumé

Isogrades intersectants — une possibilité potentielle de décèlement du polymétamorphisme. Un exemple : série de Someş. Compte tenu de la succession de cristallisation minérale et des déformations identifiées au microscope et à l'échelle mésoscopique on a tracé les isogrades de métamorphisme dans la série de Someş du cristallin de Gilău. En employant la notion d'isograde intersectant en un sens inédit, on établit que l'isograde biotite-chlorite appartenant à un cycle métamorphique nouveau entrecroise les isogrades disthène+staurotide-staurotide et almandin-staurotide appartenant à un cycle métamorphique ancien. On conclut qu'en plus de la découverte de nouvelles générations de minéraux, l'emploi „des

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isogrades intersectants" est une modalité complémentaire, en vue d'établir le rang d'un événement métamorphique individuel, respectivement la différence entre phase et cycle.

Introduction

In the last decade, the study of polycyclic character of metamorphic formations became compulsory for each deep analysis of crystalline rocks. In spite of this fact, there are a lot of investigators who avoid to discuss or tackle this subject. There are several reasons, but we remark a few :

— lack of stratigraphical discordances tracking down among formations belonging to various orogenic cycles ;
— difficulty to discover various generations of minerals and deformations ;
— non-identification of basic conglomerates associated to discordances ;
— overlapping of various types of folds ;
— rejuvenations because of new metamorphic events modifying initial isotopic composition.

Otherwise, we must show that numerous papers describe the polymetamorphism from a region without discussing its consequences either from structural point of view or from the presentation and the distribution of metamorphic zones (in space), as when the rocks which are implied, would belong to an unique metamorphic event.

This paper tries to discuss this last point namely it shows that there is a correspondent in space for each metamorphic event, which is represented in the field by individualized metamorphic zones. Two or several metamorphic events are characterized by specific zones and metamorphism intensity, which normally have not to coincide. Therefore, these zones will overlap only partially and the planes appointing isoconditions (metamorphism isogrades) will intersect.

The notion of intersecting isograde is already known from Carmichael works (1970) ; we shall show its significance later on. In the Whetstone Lake-Ontario region, four isograde curves have been drawn on account of the following reactions :

1. chlorite + muscovite + garnet $\rightleftharpoons$ staurolite + biotite + quartz + H_2O
2. chlorite + muscovite + staurolite + quartz $\rightleftharpoons$ kyanite + biotite + H_2O
3. kyanite $\rightleftharpoons$ sillimanite
4. staurolite + muscovite + quartz $\rightleftharpoons$ sillimanite + garnet + biotite + H_2O.

From this enumeration, we can see the following :

— these isogrades order is ascending from the point of view of metamorphism intensity ;
— three of these isogrades imply a fluid phase : H_2O ; all are dehydration reactions ;
— the rocks, which contain the above isogrades (in keeping with the implied mineral associations) are metapellites.

The fifth isograde, drawn by Carmichael, intersects the others and involves another fluid phase : CO_2. The characteristic reaction of this isograde is the following :
— biotite + calcite + quartz ⇌ calcium amphybole + K-feldspar + Co_2 + H_2O.

The rocks of this reaction are carbonatic ones and the fluids are water and CO_2.

Numerous investigations are interested in Carmichael's intersecting isogrades, especially because the intersection of the reaction curves in $T-X_{H_2O}$ and $T-X_{CO_2}$ space respectively, shows with anticipation an intersection in the field of corresponding isogrades. This fact is already proved.

Isogrades intersection is possible — as it was shown — because the reactions are not isochemical and the fifth reaction is obviously different, through its chemistry (and by implied fluid phases) from the other four reactions. This affirmation, from our point of view, becomes a major weak point of the theory of intersecting isogrades. Therefore, being necessary to consider only one lithological element from the whole metamorphic area, we are talking about — to say metapellites — in most of the cases, the isogrades will circumscribe or succeed after quasi-parallel planes. Thus, no notion of intersecting isograde will have a content. But, on our opinion, there is a situation when isogrades can intersect and mineral associations we are talking about, are born on an identical lithological basement. This situation represents the subject of this paper.

Intersecting Isogrades from the Someş Series

The Gilău crystalline contains as its main component, a mesometamorphic series : the Someş Series. It is placed at west and east of the Muntele Mare granitic body and the zone, we are going to investigate, is situated at east of the above granitic body. The most recent lithostratigraphy of this series was drawn within the Valea Ierii and Muntele Mare maps (Hârtopanu et al., 1982 a, b) and appears as follows (Fig. 1) :
— Lower terrigenous formation (of micaschists and graphite quartzites) composed of an environment with micaschists and garnets, plagiogneisses with intercalations of amphibolites, crystalline limestones, graphite quartzites and graphite schists, plagiogneisses with oligoclase porphyroblasts, etc.
— Formation of quartz-feldspar gneisses (median) composed of quartz-feldspar gneisses with intercalations of quartzites, amphibolites and micaschists.
— Upper terrigenous formation composed of micaschists and feldspar quartzites is met only at west of the Muntele Mare granite, so it is not in the area, we are discussing here.

Polymetamorphic character of the Someş Series was studied many years ago and variable significances were found. So, Dimitrescu (1958, 1966) shows it through partial chloritization of garnet porphyroblasts, Trif (1961) through the overlapping of several metamorphism types (contact,

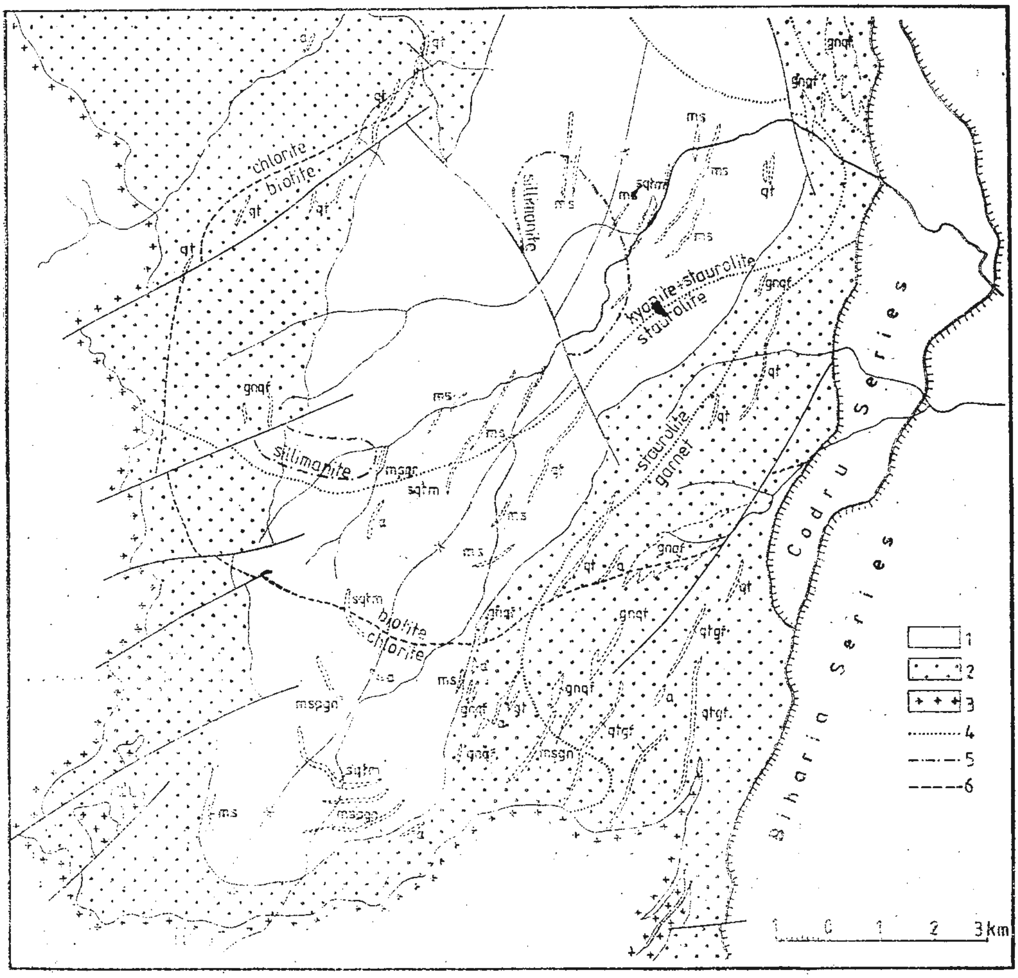

Fig. 1. — Lithostratigraphic sketch and of metamorphism in the Someş Series. Lithologic entities. 1, Median formation of quartz-feldspathic gneisses ; 2, Lower terrigene formation ; 3, Muntele Mare granite. a-amphibolites, amphibolic gneisses ; ms-micaschists ; mspgn-micaschists-plagiogneisses ; qt-quartzites ; qtgf-graphitic quartzites ; sqtm-quartzito-micaceous schists ; gnqf-quartz-feldspathic gneisses. Isogrades of metamorphism successive cycles : 4, I cycle ; 5, II cycle ; 6, III cycle.

progressive regional and retrograde). Giuşcă et al. (1967), Mârza (1969) and Mureşan (1980) also refer to the diaphthoresis when argue the polymetamorphism of the Someş Series.

More recently, Hârtopanu et al. (1983) analysed the polycyclic character of metapellitic formations of the Someş Series on account of the study of deformations, of textural relations and punctiform chemical analyses on the zoned minerals. It is also important to show that textural study of other formations (plagiogneisses with oligoclase porphyroblasts, amphibolites etc.), partially argue the polycyclic character of this series.

The Someş Series metapellites are widely spread, either composing the most part of the basic formation or as intercalations in the median formation. They are mostly composed of plagiogneisses, micaschists and quartz-micaceous schists $\pm$ graphite, garnet, staurolite, kyanite, sillimanite. At east of the Someş Series, metapellitic complex has characteristic intercalations of graphite rocks — from quartzites to micaceous schists with graphite.

The study of textural relations in the Someş Series metapellites points three cycles of mineral neoformation. The first cycle consists of blastesis of garnet, kyanite and staurolite of the first generation in small deformed, broken crystals, which are chaotically gathered in polycrystal and polymineral lenses. In the center of the garnet crystals, there are fine, undetermined inclusions which also characterize the crystals of kyanite and staurolite. After this blastesis stage, takes place a strong deformation as a S plane with a very powerful penetrative character. At the level of this plane takes place the neoformation of micaceous minerals, of lentiliform quartz segregates, individualization of polycrystal lenses of kyanite, garnet and staurolite as well as garnet synkinematic rise. At the same time, were born bandings from amphibolic and quartz-feldspathic rocks. Static component is represented by neoformation of the second generation kyanite and staurolite porphyroblasts.

After D_2 deformational stage, developed on island areas, the sillimanite, which rises in very different orientated needles, sometimes focussed on the first generation kyanite.

Next deformation cycle D_3 is represented by a S_3 plane (crenulation foliation) with a variable penetrative character and accompanied by a micaceous and / or chloritous mineral neoformation. Static component is represented by the neoformation of biotite and chlorite with random orientations.

S_2 and S_3 planes from D_2 and D_3 deformation cycles are well individualized. S_2 plane is so penetrative that can efface old $S_{0,1}$ plane. In comparison with S_2 plane big falls, S_3 plane is quasihorizontal.

Microscopic observations pointed out crystals zonings, among which the garnet's are the most obvious ones. To this optical zoning corresponds a kryptical chemical zoning which was pointed out through punctiform analysis by means of electronic microsonde. It was noticed that the profile through a garnet shows a severe CaO zoning, a profile like a bell at manganese. FeO, CaO and MgO have symmetrical complex profiles because of discontinuous rise which characterizes the polyphase metamorphism. Within transversal chemical profile, there is a low content in manganese in the same way as Fe content rises ; this is equivalent to the rise of almandinic component to spessartinic detriment which generally indicate intense physical conditions of metamorphism and synchronous with static ones of sillimanite. The diminuation of CaO content, according to Råheim and Green (1974) is equivalent to a high temperature and stationary pressure which can be also corroborated with sillimanite blastesis. In a similar way, Hollister (1969) showed that MgO/FeO relation is rising with the metamorphism degree. B direction (Fig. 2) represents garnet's rise under higher temperature conditions.

The map of metamorphism isogrades from the Someş Series at east of the Muntele Mare granite points to our field considerations mentioned above (Fig. 1). So, the first metamorphism cycle is repre-

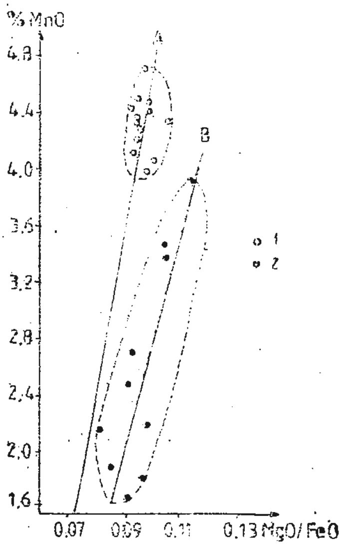

Fig. 2. — MnO-MgO/FeO plot for a garnet from the Someş Series. 1, Values for the center of a garnet crystal; 2, Values for the margin of a garnet crystal (acc. to Hârtopanu et al., 1981).

sented by isogrades of staurolite + kyanite — staurolite and almandine — staurolite which circumscribe themselves.

Static sillimanite rise is also represented by two small islands outlined by this mineral isograde. Subsequent character of the second cycle metamorphism, represented by sillimanite zone, is obvious especially by the hiatus caused by the lack of kyanite zone in the first cycle of metamorphism.

At last, biotite-chlorite isograde means the third metamorphic cycle with a similar subsequent position shown either by S_3 planes subsequency (when form chlorite and / or biotite) to S_2 planes (with which synchronically form garnet, micas but also with staurolite and kyanite formed before or after S_2) either through the intersection of biotite-chlorite isograde plane with almandine-staurolite and staurolite + kyanite-staurolite planes.

Next table presents evolution of main metamorphic minerals crystallization in relation with deformation stages (Fig. 3).

What problems appear from intersecting isograde planes?

a) First, certain personality of M_3 metamorphism with chlorite and biotite which has not to be considered as an usual retromorphism but is a prograde metamorphism from chlorite zone to biotite one. The area of this metamorphism crosses previous metamorphism, characteristic index minerals for the last one, therefore getting a relic character

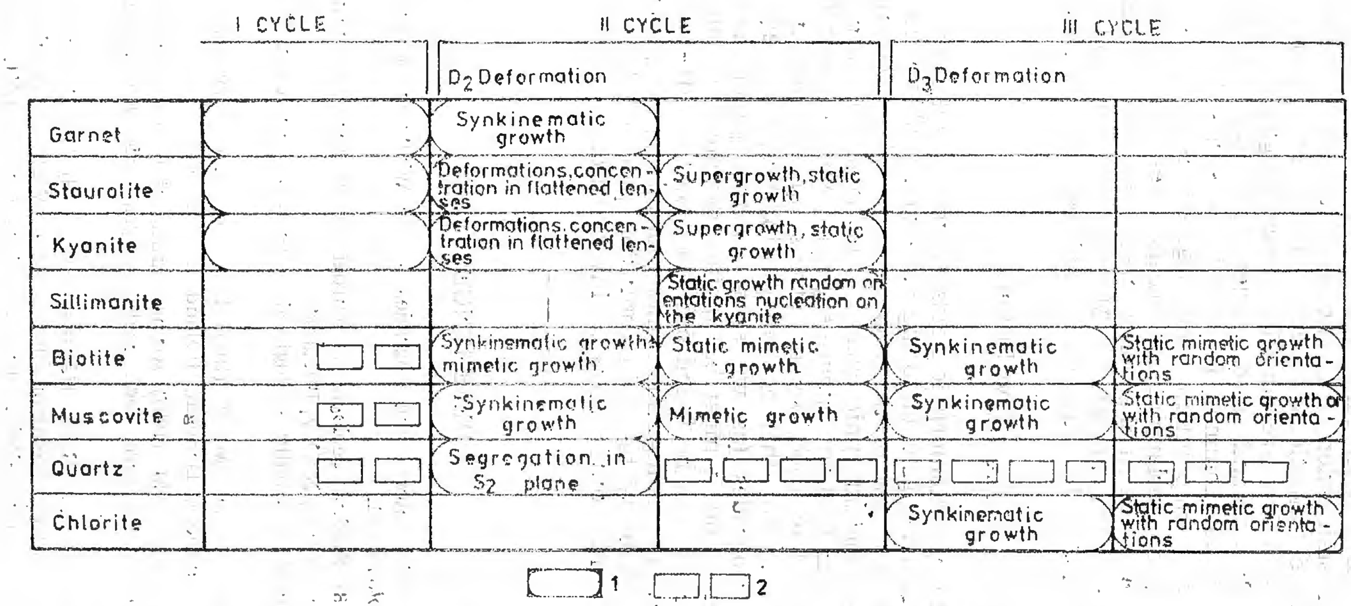

Fig. 3. — Evolution of metamorphic crystallization and of the deformation in the metamorphic Someş Series. 1, Mineral blastesis; 2, Supposed mineral blastesis.

b) D_3 deformations primed mineral neoformation with chlorite or biotite but they have been surpassed by mineral neoformation (subsequent static crystallization, mimetic or with random orientations); at their turn, D_3 deformations exceeded the Someş Series area, crenulation foliations which are identical morphologically, are also met in the adjacent Biharia and Arada series. It shows that this last deformation moment was common for the three series.

c) Possibility to map intersecting isogrades is as we saw, circumstantial, supposing an overlapping of a weaker metamorphism on another one, more powerful — as in the Someş Series case, where deformations and neoformations which characterize M_3 metamorphism, did not succeed to destroy the whole old paragenesis and especially index minerals.

Conclusions

The problem of metamorphic fields recycle is not new, but to find out polycyclic character goes on being an actual problem. In the introduction, we remind a few of the ways how to solve this problem but, the repetition of a metamorphic cycle has to be proved through several ways. One way is to find out minerals generations and its deformations. Although, it is widely used, some authors appreciating it a lot, we consider that having no other control possibilities, the method to find out intersecting isogrades (as we show in this paper) is a helping means, very useful and it must be applied as much as mineral relics and their relative age can be found out. We also think that this method represents a way to distinguish a metamorphic cycle personality, so increasing the probability to avoid confusion phase-cycle which means very much if we miss other ways of investigation.

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IZOGRADELE INTERSECTANTE — O POSIBILITATE POTENŢIALĂ DE DEPISTARE A POLIMETAMORFISMULUI. UN EXEMPLU : SERIA DE SOMEŞ

(Rezumat)

Pe baza succesiunii de cristalizare minerală şi a deformărilor, identificate la microscop şi la scară mezoscopică sînt trasate izogradele de metamorfism în seria de Someş, din cristalinul Gilăului. Folosindu-se noţiunea de izograd intersectant într-un sens inedit se arată că izogradul biotit-clorit aparţinînd unui ciclu metamorfic nou intersectează izogradele disten+staurolit-staurolit şi almandin-staurolit aparţinînd unui ciclu metamorfic vechi. Se conchide că metodica folosirii izogradelor intersectante este o modalitate complimentară aceleia a depistării generaţiilor de minerale, pentru stabilirea rangului unui eveniment metamorfic individual, respectiv în discernerea dintre fază şi ciclu.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR METAMORFICE

PETROLOGICAL DATA ON THE METAMORPHITES IN THE NORTHERN SIDE OF THE LOCVA MASSIF[1]

BY

VIORICA IANCU[2]

Metamorphic formation. Precambrian. Paleozoic. Lithofacies. Multiphase metamorphism. Metavolcanics Greenschists facies. Stilpnomelane zone. South Carpathians — Getic and crystalline Supragetic domains — Locva Mountains.

Abstract

The metamorphites in the northern side of the Locva massif can be referred to three groups of formations : Precambrian, Lower Paleozoic and Middle Paleozoic. The Bocşiţa-Drimoxa Formation (Upper Precambrian) is a mostly terrigene, polymetamorphic sequence, reactivated during the Caledonian orogenesis. The Naidaş Formation (Cambrian-Silurian ?) consists of basic and acid metavolcanics interlayered with metasediments of a continental origin, related to pre- or primorogene basic intrusions. It is a polydeformed formation, with a polystadial initial metamorphism (Caledonian) under conditions of the greenschists facies. The Zlatiţa Formation (Devonian-Lower Carboniferous) is represented by clastic rocks related to basic and acid volcanics, affected by Variscan low-grade metamorphism (stilpnomelane zone).

Résumé

Données pétrologiques concernant les métamorphites du versant septentrional du massif de Locva. Les métamorphites de cette zone peuvent être réparties à trois groupes de formations : précambrienne (protérozoïque), paléozoïque inférieure et paléozoïque moyenne. La formation de Bocşiţa-Drimoxa (Précambrien supérieur) est une séquence particulièrement terrigène, polymétamorphe, réactivée

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pendant l'orogenèse calédonienne. La formation de Naidaş (Cambrien-Silurien ?) est constituée des métavolcanites basiques et acides interstratifiées par des métasédiments de provenance continentale, associées aux intrusions basiques préorogènes ou primorogènes. Elle est une formation polydéformée, à métamorphisme initial polyphasique (calédonien) dans les conditions du faciès des schistes verts.

La formation de Zlatiţa (Dévonien-Carbonifère inférieur) est représentée par des roches clastiques associées aux volcanites basiques et acides, affectées d'un métamorphisme varisque de faible intensité (zone à stilpnomélane).

1. Introduction

This paper presents preliminary data on the metamorphites in the northern side of the Locva massif. These data have been obtained by detailed researches carried out on several reconaissance profiles. The geological map scale 1 : 50 000, drawn up by Maier (1974), represents the starting point of the researches.

According to Maier (1974) the metamorphic formations of the Locva massif represent a Paleozoic succession within which two series can be individualized : the Locva Series (Ordovician-Silurian) and the Lescoviţa Series (Devonian-Lower Carboniferous). Palynological data have been published later on (Maier, Visarion, 1976).

Several petrographical data, the relationships between minerals belonging to superimposed parageneses and the relationships between the lithostratigraphic units with a different metamorphic and deformational evolution are partly in disagreement with Maier's opinion (1974) on the individuality and appurtenance of the metamorphic series (Fig. a, b).

Three sequences have been individualized on the basis of the above-mentioned criteria, as follows : the Bocşiţa-Drimoxa Formation (Upper Precambrian), the Naidaş Formation (Lower Paleozoic) and the Zlatiţa Formation (Middle Paleozoic).

The eastern part of the Locva Series (Ordovician-Silurian ; Maier, 1974) represents polymetamorphic Precambrian metamorphites. Both lithologically and as regards the metamorphic evolution this series can be compared with the Bocşiţa-Drimoxa Formation (Precambrian) in the Bocşa-Caraşului Valley zone (Codarcea, 1931 ; Constantinof, 1980 ; Iancu, 1981). Consequently we shall refer to it as the "Bocşiţa-Drimoxa Formation". Maier (1974) considered this sequence as Ordovician-Silurian in age with Caledonian metamorphism in greenschist facies.

Kräutner, Iancu (in Kräutner et al., 1981) and Iancu (in Năstăseanu et al., 1981) have separated a part of the "Complex E_I" as a Precambrian sequence on the basis of the mineralogical and petrographical description made by Maier (1974).

The majority of the pre-Devonian (Lower Paleozoic) metamorphites, which will be individualized as the "Naidaş Formation" and assigned to the "Locva Group", have been separated by Maier (1974) within the Complex E_3 of the Lescoviţa Series (Devonian-Carboniferous), with Variscan metamorphism. Chitinozoans specific to the Silurian have

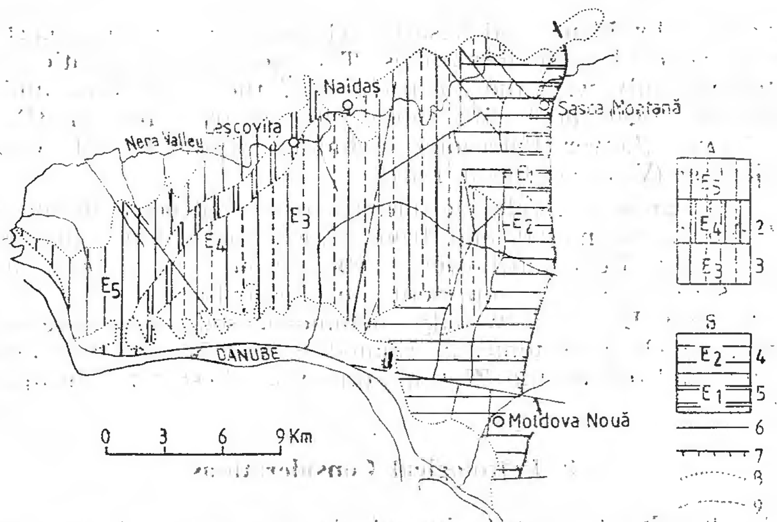

Fig. a. — Stratigraphical-tectonic sketch (Maier, 1974).
A) Lescoviţa Series (Devonian-Lower Carboniferous) : 1, Stilpnomelane schists complex ; 2, terrigene schists complex ; 3, basic tuffogene-magmatogene schists complex. B) Locva Series (Ordovician-Silurian) : 4, albite porphyroblasts-bearing schists complex (Bocşiţa-Drimoxa zone) ; 5, gneissic complex (Buchin zone) ; 6, fault ; 7, Alpine thrust plane ; 8, unconformity boundary ; 9, boundary between complexes.

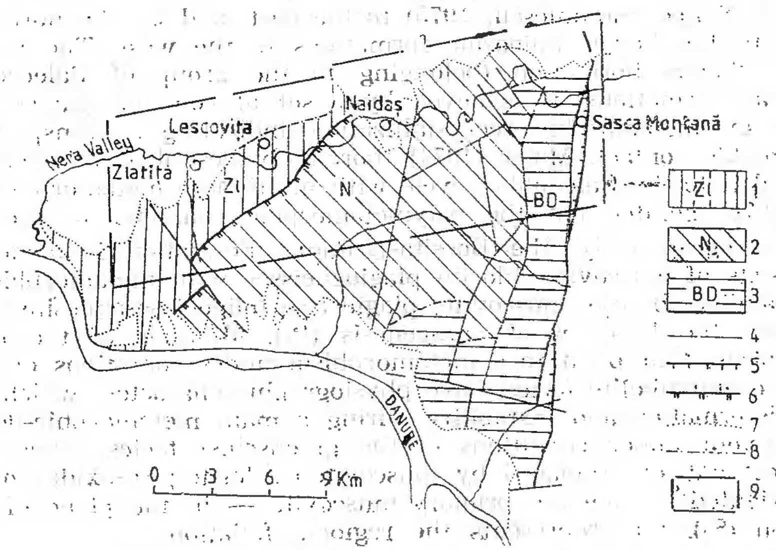

Fig. b. — Structural and lithostratigraphical sketch, reinterpreted.
1, Zlatiţa Formation (Devonian-Lower Carboniferous) ; 2, Naidaş Formation (Cambrian-Ordovician) ; 3, Bocşiţa-Drimoxa Formation (Upper Precambrian) ; 4, fault ; 5, Alpine thrust fault (plane of the Sasca-Gornjak Nappe) ; 5, Variscan thrust fault ; 7, unconformity boundary ; 8, premetamorphic unconformity boundary ; 9, study area.

been reported by Maier and Visarion (1976) in the eastern part of the occurrence zone of these formations. The mentioned formations can be correlated partially with the greenschists of the Valea Carașului Series (Constantinof, 1980) and with those referred by Iancu (1981) to the Vodnic Group (Lower Paleozoic) including acritarchs of Cambrian-Ordovician age (Visarion, Iancu, 1984).

The terrigene and volcanic formations — that occur in the western part of the Locva massif and from which the palynological samples pointing to the Devonian-Lower Carboniferous have been analysed (Maier, Visarion, 1976) — represent the "Lescovița Series *s. str.*" (Complexes E_4 and E_5). The weakly metamorphosed volcano-sedimentary formation, which is tectonically related to the Naidaș Formation, has been individualized as the Zlatița Formation (Lescovița Group, Middle Paleozoic).

2. Petrological Considerations

Structurally, the crystalline of the Locva massif represents the southern prolongation of the Bocșa-Nappe — a major unit of the group of the Lower Supragetic Nappes (Iancu, 1982), considered as pre-Laramian on the basis of regional correlation.

2.1. *Bocșița-Drimoxa Formation.* This Precambrian formation lies in the eastern part of the Locva massif (Fig.). It is delimited by the tectonic contact with the Permo-Mesozoic formations of the Sasca-Gornjak Nappe (Săndulescu, 1975) to the east, and by the normal contact with the Lower Paleozoic formations to the west. The transition to the Naidaș Formation (belonging to the group of Paleozoic-pre-Devonian formations) is achieved by a set of common planes accompanied by metamorphic recrystallization indicating a transposed unconformable contact. Maier (1974) thoroughly described this series and assigned it to the Caledonian cycle with multiphase metamorphism. Andrei (1976) pointed out the polymetamorphic character of the series.

Petrographically, the Bocșița-Drimoxa Formation is monotonous. It consists of muscovite-chlorite plagiogneisses with metamorphic relics of almandine, biotite, muscovite, plagioclase (oligoclase-andesine), which represent the first set of paragenesis (P_1). Minerals of the primary paragenesis, that point to a metamorphism under conditions of the almandine amphibolite facies, have physiographic characters which testify their deformation and instability during a main metamorphic-deformational event under conditions of the greenschist facies. Thus, biotite is almost entirely replaced by muscovite+chlorite+Fe-oxides minerals or reoriented — like the primary muscovite — in the plane of a new foliation (S_2), that represents the regional foliation.

Relict garnet is included either in interkinematic albite (albite 1) or in that synchronous with S_2 (albite 2). Locally it is strongly chloritized and included in the neoformation matrix (Pl. I, Fig. 1).

Relict plagioclase is partly distroyed, being found as metamorphic pyroclasts, lentilized or penetrated by the foliation S_2 (Pl. I, Figs. 3, 4).

In better adapted metamorphically "bands", it is entirely replaced by oriented quartz-albitic polycrystalline clusters (Pl. I, Fig. 3). The interkinematic phase, well represented by acid albite-oligoclase, quartz and epidote, is also affected by the deformations which led to the formation of the foliation S_2.

Interkinematic feldspar contains inclusions with different trendings as against the rock matrix (Se), as mentioned by Maier (1974) (Pl. I, Fig. 2).

The minerals formed during the second metamorphic event, which constitute the second superimposed synkinematic paragenesis (P_2), are : muscovite 2, chlorite, epidote, albite 2, Fe-oxides.

In the Bocşiţa-Drimoxa Formation one can also observe a band of lenticular granitic gneisses with microcline and muscovite with an approximate N-S trending, which seems to represent metamorphosed allochthonous granitoids. The allochthonous character is suggested by the absence of high-grade metamorphism in the surrounding rocks (which have not reached the isograde of anatexis). The effects of the thermodynamic metamorphism are represented by the feldspar deformation, quartz recrystallization and muscovite formation in the marginal areas.

Several observations can be made in microstructural respect. The premetamorphic sedimentary structures cannot be recognized any longer. The regional foliation is a secondary metamorphic foliation marked by reoriented relict micaceous minerals or by newly-formed minerals, stable in the greenschist facies (Pl. I, Fig. 4). The same paragenesis is typical of the first metamorphism of the suprajacent Lower Paleozoic Formations. Foliation S_1 is a relict metamorphic foliation as compared to S_2 and is preserved in the axes of the relict intrafolial microfolds. Microscopically S_1 foliation can be recognized inside the metamorphic porphyroclasts of interkinematic albite as an internal S marked by inclusions of garnet, muscovite, quartz or opaque powder (Pl. I, Figs. 1, 2). Both foliations — S_1 and S_2 — are affected by kink-type microfolds and by shearing foliations.

All this determines us to regard the "Locva" Formation (Maier, 1974) as a Precambrian sequence reactivated during the Caledonian orogenesis. It is found in the axis of a Paleozoic anticlinal structure.

2.2. *Naidaş Formation.* This formation belongs to the pre-Devonian Paleozoic formations (Locva Group) ascribed to the Caledonian cycle.

The Naidaş Formation is characterized by the abundance of basic and acid volcanics related to terrigene formations and to gabbro-dioritic and granitic intrusions.

The terrigene rocks are chiefly represented by quartz schists with muscovite, chlorite, epidote and porphyroblastic albite (late kinematic). The schistosity foliation (S_1) is conspicuous and is accompanied by metamorphic differentiation, with subsequent deformations (Pl. III, Fig. 4). Generally, these rocks do not preserve premetamorphic relics and display a multiphase crystallization and a slight superimposed metamorphic reorganization.

Basic tuffaceous schists are well-foliated greenschists, made up of chlorite, epidote-clinozoisite, actinote, albite and quartz, in variable amounts. They are rocks with stable parageneses in the greenschist facies conditions, trending in the plane of S_1 foliation or statically grown, post-S_1 (especially albite). Although they do not preserve pre-metamorphic structures, they display clastic minerals (amphiboles, sphene, epidote, and rarely pyroxene), coming from pre-metamorphic magmatic rocks.

Most of the greenschists are homogeneous, well crystallized ; they seem to represent flows of basic rocks. Maier (1974) reported pillow-lava structures ; their composition is similar to that of the basalts (Întorsureanu et al., 1983).

Acid volcanic rocks are represented by metarhyolites and metarhyodacites, which form tabular bodies intercalated in the basic rocks and metamorphosed together with them. Unlike basic volcanics they preserve pre-metamorphic volcanic structures (aphanitic structures, porphyritic structures and marginal-chilled structures) and magmatic minerals ; different degrees of metamorphic adaptation, according to the thickness of the initial bodies, can be observed. These structures and the phenocrysts of bipyramidal quartz, plagioclase and potash feldspar are well preserved in the central zones of the bodies with a porphyritic structure (Pl. I, Fig. 1). The effect of the metamorphism is illustrated by the slight subgranulations and lentilizations of the phenocrysts, by the oriented crystallization of the matrix minerals as well as the occurrence of "pressure shadows" in the extention of the plagioclase phenocrysts. In marginal zones deformations are more plastic ; one can observe bendings of the twin planes, marked lentilizations of the phenocrysts having marginal reactions and marked crystallization of oriented metamorphic minerals : quartz, muscovite, albite, chlorite, locally biotite, comparable with those from the host rocks. Thus, marginal zones may resemble muscovite quartz-feldspathic schists pointing to the penetrative character of the metamorphic foliation as well as to the modification of the initial composition by metamorphic differentiation (Pl. II, Fig. 2). In these rocks the measurable foliation is S_1, frequently parallel to the premetamorphic contact as the acid rocks behaved competently, having concentric-type folds.

The acid rocks, especially the aphanitic ones, are in places well recrystallized. They possess rare phenocrysts and microcrystalline structures, which make them resemble aplites or micrograanites.

The adaptation of the potash feldspar phenocrysts to metamorphism is shown by exsolutions and poor muscovitizations in the central zones. Plagioclases display albite aureoles.

Basic intrusive rocks are represented by metagabbros-metadiorites. Unlike greenschists, basic intrusive rocks preserve both magmatic structures and relics of pre-metamorphic magmatic minerals. The great majority of these rocks is found as lenticular or lenticular-tabular bodies with superimposed metamorphic structures, showing mixed mineral assemblages : magmatic relics and metamorphic minerals.

Magmatic relics (uralitized pyroxenes, amphiboles, sphene, epidote-zoisite, ilmenite) are included into a well-crystallized, oriented metamorphic matrix. An intermediary paragenesis, that represents a prekinematic, static phase, consists of green-bluish hornblende, chlorite, muscovite, found as nests between the primary magmatic minerals. They represent either a final magmatic stage, or an initial, static metamorphism prior to the regional metamorphism.

The metamorphic paragenesis is represented by actinote, chlorite, epidote-clinozoisite, albite, calcite. The metamorphic foliation is conspicuous in the marginal zones ; it is the only one visible in these rocks.

Acid intrusive rocks are gneissic granitoids that possess a lenticular-augen structure, resulting from subgranulation and oriented recrystallization (Pl. II, Fig. 4). One can recognize relict porphyroclasts of microcline, plagioclase, quartz, biotite and a well-crystallized, oriented, metamorphic matrix made up of muscovite, quartz, chlorite, and albite.

The relationships between the mentioned rocks are relatively clear as regards the volcanic and terrigene rocks. Thus, it is noted that the green-coloured rocks form stratiform depositions alternating either with flows of acid rocks (rhyodacites), later on folded together and metamorphosed.

The adaptation to the metamorphism conditions was differentiate : the basic rocks underwent strong transformations and complete reorganization after metamorphic foliation of plan-axial type (S_1), whereas the acid rocks behaved more competently, recording better the initial relations.

Structural observations refer especially to micro- and mesostructures, which allowed the differentiation of three moments of deformation.

Folding B_1, synchronous with the main metamorphism, shows a general NE-SW trending and is marked by metric folds in competent rocks, whose axial planes are parallel to foliation S_1 in incompetent rocks. These folds display microfolds B_1 with a penetrative foliation S_1 (Pl. III, Figs. 1, 2) marked by a metamorphic differentiation but locally obliterated by the late-kinematic crystallization of albite. Folding B_2 was accompanied by a reorientation of the micaceous minerals and by a recrystallization after a set of planes (S_2), partly penetrative, correlated with a reactivation under lower conditions of metamorphism (Pl. III, Figs. 3, 4). The appearance of multiphase stilpnomelane in acid rocks that sometimes initially reached the conditions of the "biotite" isograde indicate physical conditions similar to those in which the Variscan metamorphism of the Zlatiţa Formation developed (Pl. II, Fig. 3).

Folding B_3 is pointed out by the SSW shifting of the previous folds (that show subhorizontal axial planes), the decametric "drag-folds" in reverse flank and by the appearance of kink-type microfolds and the post-S_2 crenulation microfolds in incompetent rocks.

The relations between the terrigene-tuffaceous and volcanic rocks with the intrusive rocks are less distinct. The basic intrusive rocks (gabbros-monzogabbros-diorites) display spatial relationships apparently concordant with the volcanic and terrigene rocks due to the metamorphic and structural modifications underwent during the main metamorphism, which make possible their characterization as pre-metamorphic rocks. The moment of intrusions would be situated between the deposition of the volcano-sedimentary complex and the regional metamorphism, either pre-orogen or in an early folding phase (primorogenic intrusions sensu Lundqvist, 1979).

The position of the granitoid rocks and their relation with the other types of rocks is difficult to specify and it is still under study. Some of the rocks described by Maier (1974) as aplites and microgranites possess porphyritic textures, being metarhyolites. Granites occurring in the eastern part of the formation possess metamorphic textures; they may represent either primorogenic or synorogenic granites.

In conclusion, the mode of association, the petrographic constitution and the chemistry of the volcanic rocks (Întorsureanu et al., 1983) point to the existence of a basic-acid bimodal volcanism, within the deposition of continental-type detrital formations with reduced thicknesses. The spatial association with gabbro-dioritic rocks may be due to pre- or primorogenic intrusions. The orogenic intrusion of the granitic rocks is at most synchronous with the principal metamorphism developed under conditions of the greenschist facies.

2.3. Zlatița Formation. This formation broadly represents complexes E_4 and E_5 (Maier, 1974), ascribed by us to an independent lithostratigraphic entity, as they possess a metamorphic-deformational lithology and evolution differing from that of the Naidaș Formation. Maier (1974) noted the existence of a transgression unconformity of complex E_5 (of the stilpnomelane schists).

The low-grade regional metamorphism did not changed essentially the pre-metamorphic lithology and allowed the reconstitution of a more simple evolution of the whole sequence comprised into the complexes E_4 and E_5.

The palynological ages obtained on samples from the two complexes (Maier, Visarion, 1976) indicate the Middle Paleozoic age (Devonian-Lower Carboniferous); it is in conformity with the unitary character of the mentioned complexes as regards the deformational and metamorphism elements, as well as the relationships with the pre-Devonian formations.

The contact between the two sequences — the Naidaș Formation (pre-Devonian) and the Zlatița Formation — is marked by a set of superimposed lamination planes intersecting the metamorphic foliations of the two sequences along a contact which seems to represent a Variscan overthrusting.

From petrographic point of view, the Zlatița Formation consists of terrigene rocks grading (by rhythmical alternations) into basic metatuffs with much clastic material (terrigene or magmatogene). Bodies of dioritic intrusive rocks occur as well. At the top of the sequence, developed around the locality of Zlatița, the terrigene rocks are more quartzitic; they include metamorphic stilpnomelane and display flows concordant with the metamorphosed dacitic bedding.

Terrigene schists are represented by metasandstones, metagrauwacke, feldspathic metaquartzites, sericite or graphite quartz schists, acid or basic tuffitogene schists.

The coarse rocks (of metasandstones or metagrauwacke type) preserve clastic elements : quartz, plagioclase, garnet (Pl. V, Figs. 1, 2, 4), with rolled or subangular contours, clastic micas (deferrized biotite, muscovite) occurring in the plane of the bedding foliation. In places the detrital micas are deformed, reoriented in S_1 plane or underwent a retrograde alteration.

The metamorphic paragenesis is represented by sericite, chlorite, stilpnomelane, quartz, albite, oriented in the plane of the S_1 foliation (Pl. V, Figs. 3, 4).

Basic metatuffs are green-coloured rocks, with a well-preserved bedding, especially when the clastic content is significant. The clastic elements are : amphiboles, epidote-zoisite, feldspar, sphene, opaque minerals, which show angular or subangular contours. In rocks with terrigene content detrital muscovite is widely developed in the bedding plane. Metamorphic minerals, oriented in S_1 plane, are represented by actinote, chlorite, sericite, epidote-clinozoisite, stilpnomelane, quartz, albite.

In metasedimentary rocks (terrigene and tuffaceous), the bedding (S_0) is well preserved and can be noticed either in the hinge of the microfolds B_1 (synchronous with S_1) in fine, incompetent sequences (Pl. V, Fig. 1) or in the metric folds affecting more competent rocks. Metamorphic foliation (S_1) is penetrative and marked by metamorphic minerals in all incompetent rocks rich in micas and actinote (Pl. V, Figs. 2, 4) and nonpenetrative in competent rocks (Pl. V, Fig. 1).

Metadacites are found as tabular bodies (flows) approximately concordant with the bedding and show well-preserved porphyritic structures (Pl. IV, Fig. 1).

Plagioclase phenocrysts are slightly lentilized and possess pressure shadows in which polygonal quartz crystallizes. In marginal zones they are penetrated by micas (stilpnomelane) (Pl. IV, Fig. 2).

The microcrystalline mass is metamorphically recrystallized. It consists of quartz, albite, stilpnomelane, chlorite, epidote-clinozoisite and marks a metamorphic foliation S_1 (Pl. IV, Figs. 2, 3).

In places these rocks are very rich in stilpnomelane oriented in S_1 planes, which also crystallized statically, post-S_1, or on shear planes (Pl. IV, Fig. 3).

Metadiorites form lenticular bodies with metamorphic foliations conspicuous in marginal zones. They preserve structures and relict magmatic minerals.

Premetamorphic relics are especially amphiboles (brown hornblende and green hornblende, deformed, fasciculate and actinolitized), plagioclase, sphene, epidote, opaque minerals (Pl. IV, Fig. 4).

The oriented metamorphic groundmass (S_1) consists of actinote, epidote-clinozoisite, chlorite, albite (also found as a marginal zone of the relict plagioclase), quartz, muscovite.

In conclusion, Zlatiţa Formation represents a continental volcano-sedimentary lithostratigraphic entity with a coarse detrital supply, and a relatively low graded bedding and roundness. Both the terrigene and the tuffaceous rocks preserve the initial bedding (S_0), the metamorphic foliation is partly penetrative and marked by metamorphic minerals specific to the stilpnomelane zone of the greenschist facies.

The folding synchronous with the regional metamorphism (S_1) generated crenulation microfolds, whose axial planes (S_1) are penetrative and dense in incompetent fine rocks, and metric concentric or chevron folds in competent rocks. The folding B_2 is represented by open folds, metric up to decametric, associated with kink microfolds and microcrenulations post-S_1. The deformations related to phase B_2 are similar with those of phase B_3 in the Naidaş Formation and seem to be generated by common deformations that preceeded or accompanied the mentioned overthrusting.

3. Conclusions

1. Several lithostratigraphic entities have been redefined and separated : Bocşiţa-Drimoxa Formation (Upper Precambrian), Naidaş Formation (Lower Paleozoic) and Zlatiţa Formation (Middle Paleozoic).

2. Petrographically, the Bocşiţa-Drimoxa Formation is represented by polymetamorphic plagiogneisses with superposed parageneses. The Naidaş Formation is constituted of terrigene formations related to basic and acid volcanics and to gabbro-dioritic intrusions affected by Caledonian metamorphism in the greenschist facies. The Zlatiţa Formation is represented by terrigene and basic volcanic deposits associated with flows of acid volcanics and basic intrusive bodies affected by a low-grade metamorphism (stilpnomelane zone) during the Variscan orogenesis.

3. From the deformational point of view, the Bocşiţa-Drimoxa Formation represents a polycycle sequence, with advanced adaptation synchronous with the prograde metamorphism of the Naidaş Formation. The initial unconformable contact is marked by a set of common planes, with stable parageneses under conditions of the greenschist facies.

The Naidaş Formation is a polydeformed sequence. It displays a polystadial crystallization as against the B_1 folding phase and partial recrystallization synchronous with phase B_2/S_2. Its adaptation to deformation and metamorphism was complete in the terrigene and tuffaceous basic rocks whereas the acid volcanics and intrusions preserve inherited (premetamorphic) relict structures and minerals.

The Zlatiţa Formation displays one folding phase with related metamorphism. It possesses composite foliations (S_0+S_1). Metamorphic planes (S_1) are partly penetrative and the premetamorphic structures are well preserved in all rocks. The contact with the Naidaş Formation is marked by a set of shear planes, associated probably with a Variscan overthrust.

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QUESTIONS

D. Russo-Săndulescu: 1. Are there similarities or differences between the magmatites of the Naidaş Formation and those of the Zlatiţa Formation?

2. If they are similar, how do you explain the continuity of the same type of magmatism from the Lower Paleozoic till the Devonian and meanwhile some of them underwent a previous metamorphism.

Answers: 1. Petrographically there are small differences between the acid volcanics of the Naidaş Formation (metarhyolites, metarhyodacites with muscovite and metamorphic biotite in the oriented mass) and those of the Zlatiţa Formation (metadacites with stilpnomelane). Basic intrusive rocks of the Naidaş Formation are diorite-gabbros-monzogabbros, whereas diorites are mostly to be found in the Zlatiţa Formation. No metagranites have been found in the Zlatiţa Formation. The small number of chemical analyses carried out (30 analyses, in Întorsureanu et al., 1983) made impossible a clear differentiation in geochemical respect.

2. I have not mentioned the existence of a continuous and unitary magmatic activity from the Lower Paleozoic till the Lower Carboniferous. The different age of the metasediments from the two formations (Naidaş and Zlatiţa), the

stratigraphic gap between the two formations, the deformational evolution and the different metamorphism made us associate them with two sedimentary cycles included into the Caledonian and Variscan orogeneses, respectively. The metamorphism gave rise to rocks different from the mineralogical and structural points of view. The similar premetamorphic features can be explained only by the existence of relatively similar geotectonic conditions in different areas and time intervals. Later on both formations came into direct relationships by overthrust.

N. Stan: You mentioned a garnet of a sedimentary origin identified in one of the metamorphic series under discussion. Why is this garnet not metamorphic?

Answer: I mentioned the presence of a clastic garnet in the Zlatița Formation with a low-grade metamorphism — stilpnomelane zone. The Zlatița Formation is characterized by the preservation of premetamorphic sedimentary and magmatic structures and by the presence of mixed mineral assemblages: premetamorphic relics and metamorphic neoformation minerals (sericite, chlorite, epidote, albite, stilpnomelane). Garnet fragments (broken, cemented, etc) are found beside an important fraction of other clastic minerals: quartz, muscovite, biotite, feldspar in poorly metamorphosed terrigene rocks.

DATE PETROLOGICE PRIVIND METAMORFITELE DIN VERSANTUL NORDIC AL MASIVULUI LOCVA

(Rezumat)

Cercetările întreprinse în partea nordică a masivului Locva au permis individualizarea a trei entități litostratigrafice cu constituție petrografică și evoluție metamorfică-deformațională diferită.

Formațiunea de Bocșița-Drimoxa este constituită predominant din plagiognaise muscovito-cloritoase cu relicte metamorfice de almandin, biotit, plagioclaz, asociate cu gnaise granitice cu muscovit. Ea reprezintă o secvență precambriană reactivată în cursul orogenezei caledoniene. Contactul cu formațiunea suprajacentă este un contact transpus, obliterat de deformare și recristalizare metamorfică.

Formațiunea de Naidaș reprezintă o secvență din grupul paleozoic inferior (grupul Locva). Ea este constituită predominant din roci vulcanogene bazice și acide și roci sedimentare de proveniență continentală, asociate spațial cu intruziuni bazice. Întreaga secvență a fost metamorfozată în condițiile faciesului de șisturi verzi (zonele cu clorit și biotit), în cursul orogenezei caledoniene. Deformările și cristalizările polifazice au fost urmate de deformări suprapuse în cursul orogenezei varistice.

Formațiunea de Zlatița, ce face parte din grupul Paleozoic mediu, este constituită din formațiuni terigene asociate cu tufuri bazice și curgeri acide, metamorfozate la nivelul zonei cu stilpnomelan (faciesul șisturilor verzi). Datele palinologice (Maier, Visarion, 1976) au eviden-

țiat vîrsta Devonian-Carbonifer inferior a acestei secvențe, metamorfozată în orogeneza varistică.

Datele petrologice permit caracterizarea celor două secvențe de vîrstă diferită ca reprezentînd asociații constituite din roci terigene și vulcanogene bazice și acide generate în faze pre-orogene, în condiții continentale. Corpurile de roci bazice faneroblastice pot reprezenta intruziuni fie pre-orogene fie primorogene. Complexele astfel rezultate au fost ulterior implicate în orogenezele caledoniană și respectiv varistică, marcate de metamorfism regional dinamotermic. Contactul dintre cele două formațiuni paleozoice este marcat de o linie de încălecare final-varistică.

EXPLANATION OF PLATES

Plate I

Bocșița-Drimoxa Formation (Precambrian)

Fig. 1. — Muscovite-chlorite plagiogneiss with relict garnet (G) included in interkinematic plagioclase (Plg) with Si different from Se (= S_2). N ||, × 18.

Fig. 2. — Porphyroclast of lentilized interkinematic plagioclase (Plg) with oriented relict inclusions (Si). N+, × 36.

Fig. 3. — Interkinematic plagioclase with intracrystalline reorganization in the foliation plane S_2. N+, ×36.

Fig. 4. — Plagiogneiss with pre-S_2 relics of plagioclase (Plg) and partial transposition after S_2 — Pa_2 (axial plane of microfold B_2). N+, × 18.

Plate II

Naidaș Formation (Lower Paleozoic)

Fig. 1. — Metarhyolite with plagioclase (Plg) and quartz phenocrysts (Q). Metamorphically recrystallized matrix (S_1). N+, × 18.

Fig. 2. — Metarhyolite with pre-metamorphic relics of plagioclase (Plg) and quartz (Q) with metamorphic muscovite (Mu) in the oriented matrix (S_1). N+, × 18.

Fig. 3. — Metarhyodacite with multiphase crystallized stilpnomelane. N ||, × 18.

Fig. 4. — Metagranite with lentilized pre-metamorphic plagioclase (Plg). Recrystallized subgranulation matrix. N+, × 18.

Plate III

Naidaş Formation

Fig. 1. — Flattened microfold B_1 in muscovite-chlorite quartz schists with axial plane foliation (S_1) marked by epimetamorphic minerals. N ||, × 18.
Fig 2. — Microfold B_1 synchronous with S_1 in tuffaceous greenschists. N ||, × 18.
Fig. 3. — Late kinematic albite porphyroblasts (Ab) partly penetrated by foliation S_2 and by neoformation "inclusions". N ||, × 36.
Fig. 4. — Muscovite-chlorite quartz schists with foliation S_1 marked by metamorphic differentiation and affected by crenulation microfolds B_2, with partly penetrative S_2. N ||, × 36.

Plate IV

Zlatiţa Formation (Middle Paleozoic)

Fig. 1. — Metadacite with magmatic relict phenocrysts of plagioclase and quartz. N+, × 18.
Fig. 2. — Metadacite with relict phenocryst of plagioclase (Plg) and metamorphic stilpnomelane (Sp). N+, × 36.
Fig. 3. — Post-S_1 stilpnomelane (Sp) on shear planes. N+, × 18.
Fig. 4. — Metadiorite with magmatic relict phenoclast of hornblende (Hb) in oriented epimetamorphic matrix (S_1). N ||, × 18.

Plate V

Zlatiţa Formation

Fig. 1. — Metatuffite with well-preserved stratification S_0 and S_1 partly penetrative. N ||, × 18.
Fig. 2. — Basic metatuff with relict epiclastic structure. Incomplete reorganization after S_1. N ||, × 36.
Fig. 3. — Metasiltite with post-S_1 crenulation microfolds, with non-penetrative plan axial B_2 (Pa_2). N+, × 18.
Fig. 4. — Micaceous quartz schist with S_1 marked by metamorphic minerals (chlorite, sericite, stilpnomelane, quartz) with sedimentary relict garnet (G). N ||, × 18.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR METAMORFICE

ON THE PRESENCE OF GARNET IN THE METAMORPHICS OF THE ȚIBĂU SERIES IN THE CÎRLIBABA AREA, EAST CARPATHIANS[1]

BY

LIVIU NEDELCU[2]

Țibău Series. Garnet biotitic paragneisses. Polymetamorphism. Retrograde metamorphism. Alpine metamorphism. Foliations. Deformations. Mineral parageneses. Eastern Carpathians — Crystalline-Mesozoic Zone — Bistriței Mountains.

Abstract

Within the Țibău Series in the Cîrlibaba region, first time was noticed a level of biotitic paragneisses bearing garnet, which allowed the reconstitution of metamorphic history of respective formations and pointing out of their polymetamorphic character. Foliation-deformation-paragenesis relations sugest that these formations resulted in three metamorphic events (M_1, M_2, M_3) which are each defined by a set of S planes and by a mineral own neoformation. Their corroboration with the metamorphism of the other series in East Carpathians makes us conclude that the first metamorphism (M_1) where develops garnet paragenesis could be Caledonian or even older, the second metamorphism (M_2) which is retrograde in relation to the first one, could be Variscan and the third metamorphism essentially dynamic, could be Alpine. On this account we can equate, at least partially, the Țibău Series to the Rebra Series.

Résumé

Présence du grenat dans les métamorphites de la série de Țibău de la région de Cîrlibaba (Carpathes Orientales). La découverte pour la première fois d'un niveau de paragneiss biotitiques à grenat, dans la série de Țibău de la région de Cîrlibaba, a permis de reconstituer l'histoire métamorphe des formations respectives et la mise en évidence de leur caractère polymétamorphe. Les relations foliation-déformation-paragenèse suggèrent que ces formations se sont

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constituées au cours de trois événements métamorphes (M_1, M_2, M_3), définis chacun par un groupe de plans S et par une néoformation minérale propre. Leur corroboration avec le métamorphisme des autres séries des Carpathes Orientales mène à la conclusion que le premier métamorphisme (M_1) où se développe la paragenèse à grenat, pourrait être calédonien ou plus ancien, le deuxième métamorphisme (M_2), rétrograde par rapport au premier, pourrait être varisque et le troisième métamorphisme, essentiellement dynamique, pourrait être alpin. Là-dessus, on devrait faire une équivalence, au moins partielle, de la série de Ţibău avec la série de Rebra.

Introduction

So far there are a lot of data and various opinions about the metamorphic formations which Bercia et al. (1971) named the Ţibău Series.

So, Iliescu and Kräutner (1975) consider them to be of Lower Carboniferous age on account of palinological arguments. Pitulea and Visarion (1972) attributed to the Bistra Series formations (Pitulea, 1972) which partially see in parallel with the Ţibău Series an Upper Devonian-Lower Carboniferous age. Within the Rahov massif, similar formations (the Kusinsk Series) have been said to belong either to the Upper Paleozoic (Boiko, 1970), or to the Triassic (Slavin, 1966). In the Maramureş Mts, Zincenco et al. (1982) consider that the "Ţibău group" which includes also the Ţibău Series, is constituted of Triassic rocks, because the carbonatic formation of the Ţibău Series is similar to the carbonatic rocks of the sub-Bucovinian Triassic.

Regarding this series metamorphism, opinions are divided too: 1) Hercynian metamorphism (Sudetian phase) in the green schist facies (Bercia et al., 1971, 1976); 2) Late Kimmerian metamorphism (148 ± 2 m.y.), on account of the K/Ar determinations (Zincenco et al., 1982); 3) pre-Caledonian metamorphism, in the almandine-amphybolite facies for the Ţibău Series formations within the Şaru Dornei and Suhărzel regions, which are said to belong now to the Rebra Series (Balintoni et al., 1982; Balintoni, 1984). This series formations develop on important areals in the north of the Bistriţa Mts, on the Ţibău and Cîrlibaba Valleys. At south of Cîrlibaba up to Ciocăneşti, they form four parallel alignments, then up to the south they appear discontinuously up to Şaru Dornei. Equivalent formations to this series, but having a more reduced development, are known within the Vaser-Vişeu region, in the Bistra basin and the Rahov massif (Bercia et al., 1971). On the Delniţa-Putna Valley alignment, metamorphites of the Ţibău Series interpose between the Putna pre-alpine base nappe in the Bucovinian Nappe socle and the sub-Bucovinian Triassic, this situation being seen either as a tectonic slice (Bercia et al., 1971) or as an overthrusting nappe ("Delniţa Nappe" = Rodna Nappe in the Bucovinian Nappe socle — Nedelcu et al., 1982).

Garnet Parageneses

In 1982, the author investigated the Cîrlibaba region and for the first time he noticed garnet in the formations which belong to the lower complex (Tb_i) of the Ţibău Series (Bercia et al., 1971). Garnet occurrence was remarked only in one point situated in the way escarpment which goes up the left slope of the Bistriţa Aurie, from the Liţu quarry to the Dadu mountain manganese mine. Here the forest way exhibits successive crystalline formations belonging to the Tulgheş Series (Tg_1 and Tg_2 complexes) from the sub-Bucovinian Nappe which support tectonically carbonatic formations of the Ţibău Series (Tb_i complex) (Nedelcu et al., 1983). Because we already presented these formations in details (Nedelcu, 1978, 1980), for our purpose, we shall resort only to the sequence of the Ţibău Series where we noticed the garnet. The respective sequence is opened by the Liţu-Dadu way around the km. 1.5 and followed up to north-east on about 500 m (Fig. 1). Upside, its succession is the following : massive grey-whitty

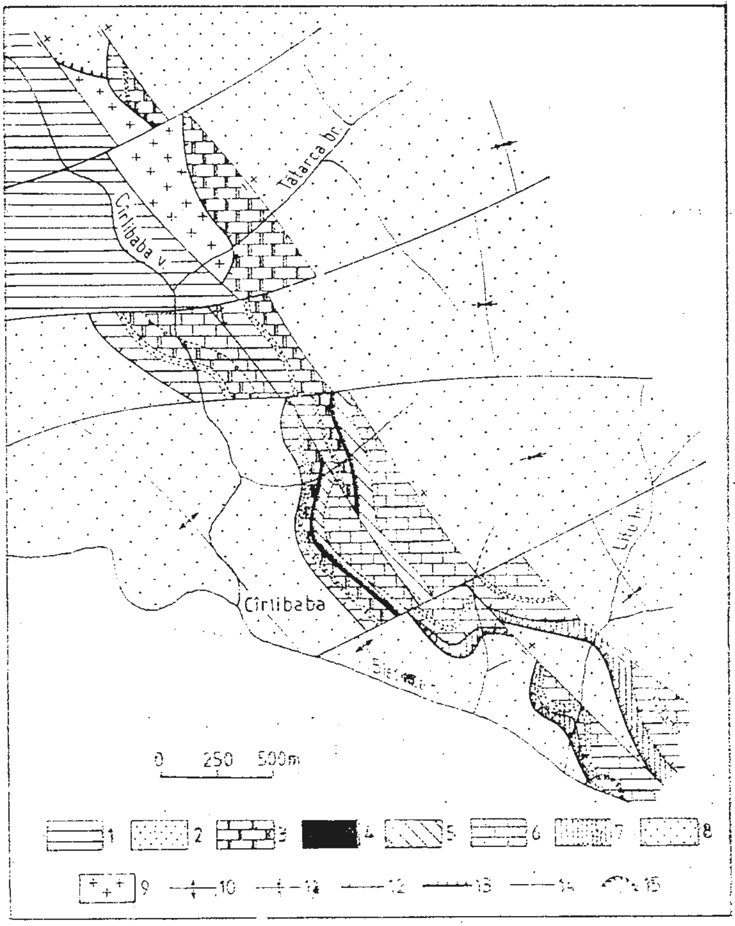


Fig. 1. — Geological sketch of the Cîrlibaba zone bearing occurrences of garnet-biotitic paragneisses. Ţibău Series (Bucovinian Nappe ; 1-6). 1, biotitic-graphitic schists ; 2, black quartzites ; 3, dolomites ; 4, garnet biotitic paragneisses ; 5, saccharoid white limestones ; 6, quartzitic limestones ; 7, Bretila Series (sub-Bucovinian Nappe) ; ocular, retromorphic mylonitized gneisses ; 8, Tulgheş Series (sub-Bucovinian Nappe) ; 9, Pietrosu Bistriţei porphyroids ; 10, anticlinal axis ; 11, synclinal axis ; 12, Alpine overthrust plane ; 12, pre-Alpine overthrust plane ; 14, fault ; 15, quarry.

dolomites, sometimes banded, then an intercalation of 1-2 m thickness of biotitic paragneisses, which are followed by a thin level (2-5 m) of white saccharoidal limestones. These paragneisses which we considered "biotitic schists" (Nedelcu, 1980) are composed of a mineral association in which the garnet is also present. From the macroscopical point of view, the respective biotitic paragneisses are grey-greenish rocks with a compact aspect but with a more marked fissility along two visible foliations (S_2 and S_3).

On one of the foliations, we can notice the garnet, often cataclased and laminated. Microscopic observations on these rocks point out some mineral parageneses which belong to the following mineralogical association : quartz + muscovite + biotite + plagioclase + garnet + tourmaline + apatite + ilmenite (→ sphene). This association was probably created during several metamorphic events, this fact being suggested both by the relations among the foliations and by mutual relations noticed among these foliations and mineral parageneses associated to them (Table).

TABLE

Relations between foliation and mineral parageneses in garnet-biotitic paragneisses from the Ţibău Series (Cîrlibaba)

Foliation	Metamorphism		Mineral paragenesis
	Event	Deformation stage	
S_1	M_1	syn-tectonical	quartz + muscovite + biotite + garnet + ilmenite + apatite
		post-tectonical	
S_2 (lamination)	M_2	syn-tectonical	transpositions of mineral parageneses from the foliation S_1 in S_2
		post-tectonical	quartz + phengitic muscovite + chlorite + tourmaline + sphene (ilmenite) : recrystallizations in the pressure shadows and on the S_2 planes
S_3 (crenulation)	M_3	syn-tectonical	shearings and transpositions of mineral parageneses from S_1 and S_2

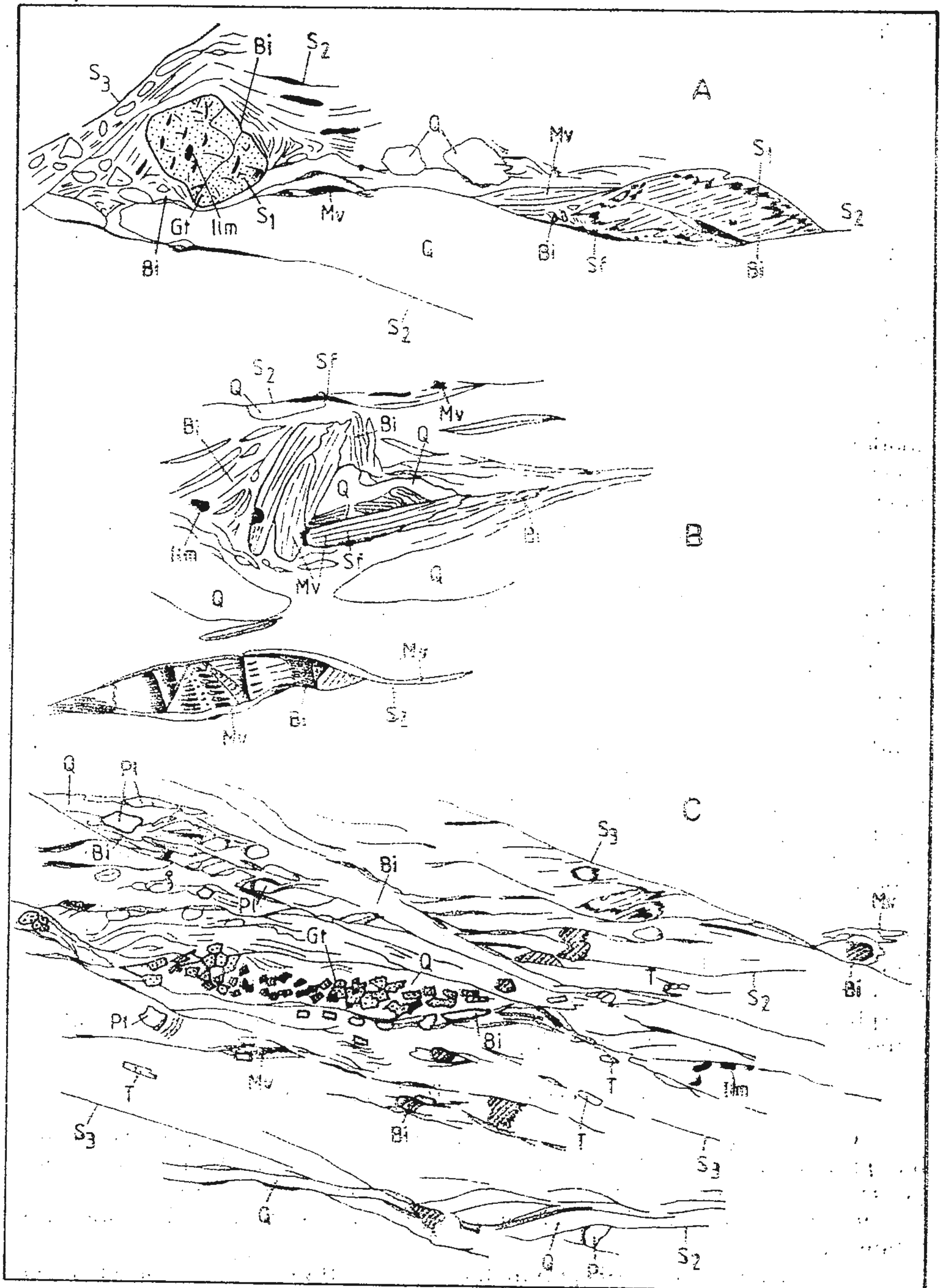
In order to reconstitute the rock metamorphic history, we shall resort just to these relations. Because of the overlapping of several metamorphic events, the S_0 foliation (bedding) was completely obliterated. The first metamorphic foliation S_1, which is not so visible, is betrayed by the orientation of mica fine flakes. Mutual relations between minerals suggest that this foliation was probably followed by a mineral neoformation which took place in two stages in relation with the syn- and respectively post-tectonical deformation. During the first stage, crystallized quartz, small muscovite and biotite flakes, plagioclase and ilmenite. During the second stage post-tectonical relaxation facilitated the circulation of metamorphic fluids, the nucleation and the recrystallization. So, developed faneroblastically quartz, muscovite, biotite, apatite and crystallized garnet. Ilmenite oriented inclusions prove the garnet post-tectonical formation and represent S_i (Spry, 1976) equivalent to S_1 in the rock. The S_2 foliation of lamination, intensely penetrative caused an almost total transposition of mineral paragenesis from S_1. So, quartz was either ground and laminated, or turned round on the plane of the S_2 foliation. Sometimes, when it is associated to mica, forms agglomerates or nonharmonious folds, which can indicate by their image the direction where relative movement between two neighbouring planes of S_2 took place. Succession of deformation-recrystallization processes during the formation of the S_2 foliation is suggested by mica behaviour. From transversal positions, they are turned round and transposed in the S_2 planes (Fig. 2 B). During the transposition, micas pass some deformations, shown by undulatory extinctions, kinks, dismemberments. Although the transposition is almost total, we often notice fusiform aspects or "horse tails". In other cases, mica flakes are wrapped by S_2 planes, which affect them mechanically too. Within their pressure shadows, the neoformation phengitic muscovite of small dimensions recrystallizes. Garnet usually small (1-2 mm), has square outlines and a little round edges (Fig. 2 A). It is often wrapped and turned round on the S_2 planes and in its pressure shadows recrystallize the quartz and phengitic muscovite. In other cases, garnet crystals have been completely smashed and laid within some small quartz lenses partially recrystallized along the S_2 foliation, because of advanced lamination (Fig. 2 C). On the planes of the same foliation, ilmenite is pseudomorphosed by sphene, which point out together with mica and quartz recrystallizations, a post-tectonical static stage. Taking into consideration that sphene represents stable metamorphic phase under the conditions of green schist facies, but which reduces its field during the upper-grade metamorphism in favour of ilmenite (Force, 1976), we consider that ilmenite→sphene transformation would suggest a metamorphic retrograde stage. Because this kind of transformation takes place only on the S_2 planes, it results that the metamorphism which generated the respective foliation is retrograde.

The S_3 foliation of crenulation is the most penetrative. It remarks by shearing and transpositions of mineral parageneses from the S_1 and S_2 foliations, without being followed by a corresponding mineralogenesis. As a consequence, this foliation can be caused by a dynamic metamorphism in a phase subsequent to the metamorphisms which generated the foliations S_1 and S_2.

Considerations on Metamorphism

Considering the metamorphic history of biotitic paragneisses bearing garnet and also of the formations which include them (the Țibău Series), on account of the succession of metamorphic events and of the foliation-deformation-paragenesis relations, we can conclude the following :

1. Garnet rocks are polymetamorphic ; they pass at least three metamorphic events (M_1, M_2, M_3) among which the last is essentially dynamic ;


A
B
C
S3
Bi
S2
S1
Gt
Ilm
Mv
Q
Sf
Pl
T

2. Each metamorphic event is defined by a set of own planes S and by an own mineral neoformation ;

3. In relation with the first foliations S_0 and S_1, which are mostly oblitered, the foliations S_2 and S_3 are strongly penetrative and constitute planes with a marked fissility ;

4. For the first metamorphism (M_1), the mineral paragenesis contains garnet that would suggest that its isograde was reached ; the second (M_2) would be retrograde in relation with the first, on account both of the transformation ilmenite→sphene, and on account of the observation that in the region general chloritization of biotite is settled on the foliation S_2 ;

5. Corroborating these observations regarding the metamorphism of the Țibău Series with those concerning the metamorphism of the other crystalline series in the East Carpathians, we can suppose that the first metamorphism (M_1) would be Caledonian or even older, the second metamorphism (M_2) with retrograde character, would be Variscan and the third (M_3) essentially dynamic, would be caused by alpine overthrusts.

As concerns these conclusions, one could object that garnet is a pre-metamorphic relic. This objection cannot be taken into consideration because of two reasons :

a) garnet is associated with biotite, which show a metamorphism under the conditions of almandine-amphybolite facies ;

b) similar parageneses with garnet have not been met in any Paleozoic Series in the East Carpathians, even in those transgressive on a bretilian substratum, which could provide such mineral relics (the Rusaia Series).

Regarding the possibilities to equate the formations of the Țibău Series in the region with the formations of higher metamorphic grade, lately it is said that these could belong to the Rebra Series. So, Balintoni et al. (1982) consider the formations of the Țibău Series in the Suhărzel and Șaru Dornei regions to belong to the Rebra Series. Their affiliation to the Rebra Series is proved as follows :

a) On account of the rocks metamorphic history, which prove a first metamorphism in the almandine-amphybolite facies followed by a retromorphism at the chlorite level ;

Fig. 2. — Relations between foliations and mineral parageneses within garnet-biotitic paragneisses from the Țibău Series (Cîrlibaba). A, garnet bearing ilmenite inclusions, turned round S_2 foliation planes, within pressure shadows recrystallized phenogitic muscovite and quartz ; biotite and muscovite are partially or totally transposed in S_2 ; B, mica flakes (muscovite, biotite) transversally placed and turned round on S_2 planes to total transposition ; quartz is uneven deformed and micas have kinks ; C, crushed garnet on S_3 lamination planes within some recrystallized quartz lenses ; subordinated transpositions of micas, plagioclase, tourmaline and garnet on S_3 crenulation cleavages.

Abbreviations : Bi = biotite ; Gt = garnet ; Ilm = ilmenite ; Mv = muscovite ; Pl = plagioclase ; Q = quartz ; Sf = sphene ; T = tourmaline ; S_1, S_2, S_3 = foliations.

b) On account of the lower structural position of the series within the Bucovinian Nappe, a similar position with that of the Rebra Series in the south of the mentioned regions.

With the same arguments, we can continue the idea that the formations of the Ţibău Series in the Cîrlibaba region, where we noticed garnet, could, at least partially, belong to the Rebra Series.

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QUESTIONS

V. Iancu : 1. In which was included in the Ţibău Series (on the area you investigated), there can be separated a sequence bearing lithofacial features and different evolution from what you consider to represent the almandine retromorphics ?
2. If you compare the presented retromorphics with the Rebra Series rocks (Proterozoic with initial metamorphism — Pre-Caledonian), why do you assign the oldest paragenesis (association of S_1 plane) to a Caledonian event and not to a Pre-Caledonian one ?

Answer : 1. The almandine retromorphics represent something new in the Ţibău Series and if there were met even in the carbonate sequence which characterizes this series, plead for an own metamorphic evolution of the whole pile which was formerly said to be attributed to the Ţibău Series. But we do not exclude the possibility to develop a lithostratigraphic sequence with different evolution which could not be separated by lithofacial context of the Ţibău Series. Its confirmation would involve a redefinition of the Ţibău Series.
2. Certainly from the point of view of metamorphic history, garnet retromorphics could be at least partly compared with the Rebra Series (initial Pre-Caledonian metamorphism). Lack of direct evidences which could help the comparison between the two series makes us impossible for the moment, to state for sure that respective retromorphics belong to the Caledonian or Pre-Caledonian metamorphism.

DISCUSSIONS

H. Kräutner : Through the new mineralogic and petrographic data concerning all the rocks of the Ţibău Series, the author talks again about the doubt also expressed by Balintoni in 1981 regarding the petrographic features and the age of this crystalline series. Mineralogic and petrographic data and textural and structural aspects which are presented here cannot be taken as final arguments to admit an initial metamorphism in the almandine amphibolite facies, followed by a general retromorphism in the green schist facies. There are also possibilities to interpret these data either admiting some relic minerals of sedimentary rocks, or accepting local reach of biotite and garnet isogrades during the Variscan metamorphism. Similar situations have been described during the Paleozoic in the Southern and Eastern Carpathians, and polystage character of blastesis and Variscan deformation is very well-known.

This kind of interpretation agree with high thermal gradient resulted from the study of the Ţibău Series micas and with Carboniferous palinologic associations which have been identified in the Ţibău Series in numerous sectors of the Bistriţa Mts. On the other side, it is obvious the fact that it is no possibility to see a lithostratigraphic correlation with one of the Pre-Cambrian formations which are known in the Carpathians. The Ţibău carbonate formation has better affinities with carbonate formations of the Lower Carboniferous in the Rodnei and Poiana Ruscă Mts, than with that of the Rebra group.

As a consequence, now we see no reasons to renounce the meaning we gave to define the Ţibău Series (Bercia et al., 1971).

PREZENŢA GRANATULUI ÎN METAMORFITELE SERIEI DE ŢIBĂU DIN REGIUNEA CÎRLIBABA (CARPAŢII ORIENTALI))

(Rezumat)

În complexul inferior carbonatic al seriei de Ţibău (Tb_1) a fost semnalat recent, în regiunea Cîrlibaba, un nivel de paragnaise biotitice cu granat. Pe baza relaţiilor foliaţie-deformare-parageneză observate, a putut fi reconstituită succesiunea evenimentelor metamorfe, rezultînd caracterul polimetamorf al rocilor cu granat. Istoria formării lor este marcată de cel puţin trei evenimente metamorfe decelabile : M_1, M_2, M_3, fiecare eveniment fiind definit de un set de plane S corespondente — S_1, S_2, S_3 — şi de o neoformaţie minerală proprie. Primul metamorfism (M_1) este corelat cu dezvoltarea paragenezei cu granat ; al doilea metamorfism (M_2), retrograd în raport cu primul, relevă condiţii de stabilitate în zona cloritului : transformarea ilmenit → sfen, cloritizarea la scară regională a biotitului pe planele S_2 ; al treilea metamorfism (M_3), esenţial dinamic, a fost generat de şariaje. Pe baza coroborării acestora cu metamorfismul celorlalte serii cristaline din Carpaţii Orientali, se presupune că primul metamorfism ar putea fi caledonian sau mai vechi, al doilea varistic, iar al treilea alpin. În acest caz, există posibilitatea echivalării, cel puţin parţială, a seriei de Ţibău cu seria de Rebra, datorită corespondenţei de metamorfism şi a poziţiei structurale asemănătoare cu aceasta (Balintoni, 1984 ; Balintoni et al., 1982).

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR METAMORFICE

NEW DATA REGARDING THE LEAOTA MTS ECLOGITES [1]

BY

GAVRIL SĂBĂU [2], MIHAI TATU [2], DRAGOȘ GĂBUDEANU [3]

Lithostratigraphy. Amphibole and zoisite eclogites. Kyanite gneisses and amphibolites. Mineral assemblages. Chemical composition. Temperature intervals. Petrogenesis. Deep fractures. Granitic intrusions. South Carpatians — Getic nappe — Leaota Mountains.

Abstract

In the south-eastern part of the Leaota crystalline at various lithostratigraphical levels, there have been identified eight eclogite occurrences bearing amphybole and zoisite. These occurrences are placed in an exotic position towards the host schists. The moderate content in pyrope of garnet and the presence of primary carinthine indicate a lower temperature formation than that of B group eclogites (Coleman, 1965). The conditions of generation correspond to an interval of T=650-850° at pressures up to 15-17 kb (facies of gneisses with kyanite and amphibolites — Dobrețov et al., 1970). The magmatic origin of eclogites is chemically and mineralogically argued. Their emplacement was done on deep fracture zones in orogenic conditions.

Résumé

Nouvelles données sur les éclogites des monts de Leaota. Dans la partie sud-est du cristallin de Leaota, à divers niveaux lithostratigraphiques, on a identifié 8 occurences d'éclogites à amphibole et zoïzite en position exotique par rapport aux schistes envoisinants. La teneur modérée en pyrope du grenat et la présence du carinthine primaire indiquent des températures de formation plus basses

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que celles des éclogites du groupe B (Coleman, 1965). Les conditions de formation correspondent à l'intervalle T = 650°-850° à des pressions jusqu'à 15 à 17 kb („faciès des gneiss et des amphibolites à disthène" — Dobrețov et al., 1970).

La filiation magmatique des éclogites est argumentée chimiquement et minéralogiquement. La mise en place s'est réalisée sur des zones de fracture profonde dans les conditions d'orogène.

Introduction

In 1882, Haüy introduced the name of eclogite in the geological terminology. At the beginning of the 20th century, it was widespread in the description of the rocks compound of omphacite and garnet (almandine-pyrope-grossular solid solution). However, some petrologists refer to several clinopyroxene-pyral garnet rocks as eclogites. Eskola (1920) suggested the name of eclogitic facies starting from the rock with the same name.

In order to define correctly both this term and the related facies, we consider the solid solution character of main component minerals, very important being the jadeitic component in clinopyroxene, miscibility of pyralspitic and granditic terms as well as high pyrope content in the garnet.

Relevant literature often described eclogites which contain other main minerals besides the critical association omphacite-garnet. In keeping with this aspect, Coleman et al. (1965) distinguished kyanite-, amphybole-, orthopyroxene-, plagioclase- bearing eclogites.

In 1897, Mrazec described the South Carpathians eclogites, for the first time in our country. They constituted also an object for study for Streckeisen (1930), Vendl (1932), Paliuc (1937), Codarcea (1937), Pavelescu (1957), Trifulescu et al. (1962), Gherasi et al. (1971), Bercia and Bercia (1972), Kasper, Focșa (1972), Andrei et al. (1975, 1976), Mânecan (1976), Vasilescu (1976), Iancu, Hârtopanu (1980), Gheuca, Dinică (1981, 1983), Chirică et al. (1982), Hann (1983).

The Leaota Mts eclogites were first noticed by Gherasi (1956), being afterwards studied from mineralogic and petrographic point of view by Gherasi et al. (1971). The authors cite two occurrences (Valea lui Dăniș and Bughița Albeștilor) within the base amphibolite (the level of the Bughea amphibolites — Gheuca and Dinică, 1983) which are considered to be hornfelses at the contact of the Albești granite with the amphibolites.

In 1984, on account of the last lithostratigraphic detailed works, Dimitrescu reconsiders the eclogites character as results of regional metamorphism having an autochthonous position among amphibolites. This opinion corresponds on the whole to that of Gheuca and Dinică (1983).

L. Rădulescu noticed an occurrence of eclogites on the Țîbra Mică-Țîbra Mare interriver (oral communication).

În 1984, Gheuca and Dinică (in Udubașa et al., 1984) cite four new occurrences.

From lithostratigraphic point of view, Gheuca and Dinică separate crystallophyllian rocks in the Leaota Mts in : the Voinești formation (paragneisses with interspersed Valea Hotarului gneisses and ocular gneisses ; the Albești granite ; the Bughea amphibolites level) ; the Lerești formation (the Românescu schists level ; the Valea Dobriașu mica gneisses level ; the Lalu granite ; the Clăbucet gneisses level ; the Valea Frasinului schists level) and the Călușu formation, all belonging to Upper Precambrian and being structurally concordant and differentiatedly retromorphosed.

This paper relies on data concerning eight eclogite occurrences situated as follows : in the Voinești formation paragneisses (Podul Runcului, Păiș-Tîncava, Runcu Valley, right slope), in the Bughea amphibolites level (Muntele Țîbra, Muntele Făgețel) and in the Românescu schists level (Dealul Mălăiești and Dealul Călugărul-Bordei) (Pl. I). Excepting the Podul Runcului occurrence cited by Chirică (1982), the other ones are noticed for the first time. These occurrences of small dimensions have lentiliform or spheroidal shape and contact with adjacent formations by means of a mylonitic facies of amphibolitic composition.

Mineralogic and Petrologic Features

From macroscopic point of view, eclogites from the above-mentioned occurrences have various aspects. In the case of nontransformed varieties (Podul Runcului, Muntele Făgețel, Valea lui Dăniș), the texture is massive, compact ; the rock is composed of a grey, pale greenish mass where one may distinguish millimetric crystals of red garnet and grass green pyroxene. In accordance with the intensity of retrograde transformations, the rock gets a schistous facies, the groundmass becomes greyish, garnets form a dark green reaction rim of secondary amphyboles (Muntele Țîbra, Dealul Mălăești, Călugărul-Bordei, Păiș-Tîncava). These transformations intensify to the bodies margins and differ in keeping with the occurrence, generally being various in ascent from the Voinești to the Lerești formation.

From microscopic point of view, in nontransformed varieties, the texture is granoblastic, in mosaic, inequigranular, massive and weakly oriented (the primary amphybole gives the orientation) ; retromorphic varieties are completely oriented. Sometimes, the minerals are deformed and fissured even in fresh varieties. On account of textular relations, was identified the following primary paragenesis : garnet, clinopyroxene (omphacite), amphybole I, zoisite I, rutile (Pl. II, Fig. 1) $\pm$ pyrrhotine and pentlandite (Pl. II, Fig. 3). A secondary association overlies these and contains : zoisite II, clinozoisite, amphybole II, muscovite, microcline, albite, quartz, magnetite, sphene.

Garnet appears as euhedral porphyroblasts (in nontransformed eclogites) and subhedral to anhedral ones (in retromorphosed eclogites) occupying about 35% from the rock's volume. Dimensions vary from tenths of mm up to 5-6 mm seldom varying more. Garnet crystals are often broken and have rutile inclusions. Within the retromorphosed varieties garnet is corroded on fissures of albite, chlorite, amphybole II and quartz. In the studied occurrences, amphybole II is focussed around garnet without forming kelyphitic textures. Garnet often appears included in amphybole I.

Refraction index determined in liquids is 1,774. This correlated to the value of parameter $a_0 = 11,559 \pm 0,001$ Å, calculated after diffractograme [4] and specific weight [5] $G = 3,888\ g/cm^3$ permit us to evaluate the chemical composition : $Alm_{48}\ Pyr_{25}\ Gro_{26}\ And_1$ (Fig. 1).

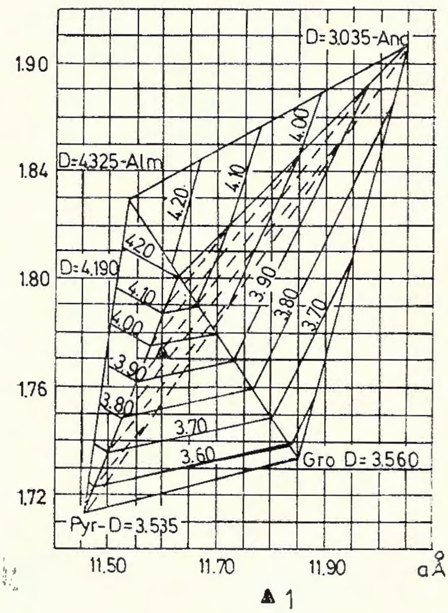

Fig. 1. — Plot of the values for "a" reticular parameter, "n" refraction index and "G" specific weight of garnet in Podu Runcului eclogite, on Winchell diagram. 1. garnet from Podu Runcului eclogite.

Clinopyroxene appears anhedral in crystals of about 0,50-3 mm and occupies about 20% of the fresh rock volume, in retromorphosed varieties being quantitatively reduced. Around clinopyroxene crystals forms a symplectic corona of finely intergrown diopside and plagioclase.

Within nontransformed varieties, the symplektic corona is very thin at the interface clinopyroxene-amphybole I, this process being amplified in retromorphosed varieties and leading to a diablastic texture where amphybole I completely disappears and clinopyroxene appears as isolated relics.

Optical constants determined by means of universal stage indicate an omphacitic composition with limited variations of the participation of jadeite, acmite and Tschermak molecule ($+2V=56°-72°$, $c \wedge Ng=30-45°$).

Refraction indexes determined in liquids are : $Ng = 1,680$; $Nm = 1,675$; $Np = 1,669$. Value $d_{221} = 2,968$ Å calculated through the diffractograme [4] for omphacite in the Podu Runcului eclogites, correlated to Nm value permit to estimate the composition from Essene-Fyfe (1967) diagram (Fig. 2).

Amphyboles. Within fresh eclogites appears in high quantity a colourless amphybole or exhibiting a weak pleochroism (grey-green-pale yellow-reddish to pale green) in anhedral grains which are more

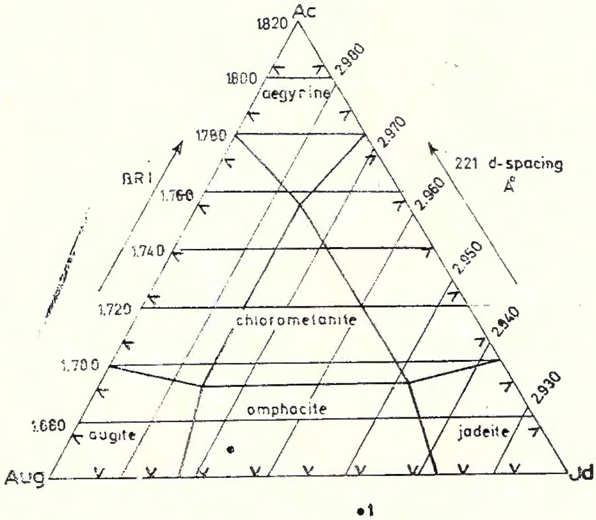

Fig. 2. — Plot of the values for "d" parameter and "n" refraction index for clinopyroxene on Essene and Fyfe diagram. 1, omphacite from Podu Runcului eclogite.

developed than pyroxene. Optical constants determined at the universal stage are : $-2V=72-76°$, $c \wedge Ng=16°$. Refraction index Nm determined in liquids is 1,628. Determined values are similar to optical constants of the Alps carinthine (Heritsch and Kahler, 1960).

Optical features and the occurrence may frame the amphybole I within the carinthines group, term claimed to be abandoned by Leake (1978). We consider this suggestion not to be justified, because although carinthine chemism is similar to the pargasite's, its optical features and undoubtedly the structural ones are rather different.

During retromorphic processes, carinthine passes two types of progressive intensity changes up to its disappearance in the association. So, within incipient stages (Dăniș), it has a thin symplektic corona similar to the pyroxene's (Pl. II, Fig. 2). Its composition often modifies selectively (marginally, on cleavages and fissures) more intensely at the interface with garnet resulting a secondary amphybole.

Zoisite I occurs as submillimetrical rods isolated or divergently associated always euhedral. Terminal faces are often present. It frequently appears intergranularly or as inclusions in amphybole I and seldom in omphacite.

Rutile occurs as subhedral inclusions from hundreds up to tenths of mm within the minerals of primary association, tending to focus in garnet.

Pyrrhotine bearing flame pentlandite exolutions (Pl. II, Fig. 3) of premetamorphic relict nature was identified in the Păiș-Tîncava and Făgețel occurrences.

During retrograde transformations appear mineralogical and textular modifications. So, around the amphyboles and especially pyroxenes, a symplektic corona forms. During initial stages of transformations, component minerals, represented probably by diopside and albite cannot be precisely identified under the microscope, because of their small sizes. At the same time, with the increase of retromorphism intensity, symplektite quantitatively increases and at last passes to a largely crystallized intergrowth of amphybole II with albite. Concomitently amphybole II (with $-2V=80\text{-}92°$; $c \wedge Ng$ sometimes anormally high, up to 28-34° ; intense yellow brown-light green-bluish green pleochroism) forms on account of amphybole I, replacing it marginally, on cleavages and on mechanical discontinuities in optical continuity. This process is more intensely at interface with garnet covering it with amphybole II.

Gradual transformations of amphyboles and apparition of intermediary terms disagree the opinion according to which eclogites amphyboles would form an homogeneous community both among them and with those from host amphybolic formations (Machatschki and Walitzi, 1962).

Zoisite II and clinozoisite form widely developed aggregates constituted of subhedral types which corrode older minerals. A sphene corona surrounds rutile and magnetite individualizes as a mineral phase.

Muscovite which was quoted as primary mineral in some eclogites (polytype 2M — Coleman et al., 1965) occurs in the Leaota Mts eclogites, only as a retromorphism result which sometimes has metasomatic aspects (polytype 3T, with $-2V = 5\text{-}7°$; $d_{003} = 9{,}925$; $d_{006} = 4{,}94$; $d_{112} = 2.459$; $d_{202} = 2.49$)[7].

Locally (the Runcu Valley) we notice a secondary contribution of alkalis and silica materialized by apparition of some veins of quartz, albite, muscovite and sometimes microcline.

Petrochemical Features

In order to characterize eclogites from general chemical point of view, we used some samples from quoted occurrences. The results of chemical analyses are given in table. They are used to calculate Niggli parameters which indicate magmatic filiation of our studied

TABLE

Total chemical analyses of eclogites from Leaota

No. of sample / Oxydes	1	2	3	4	5	6	7	8
SiO_2	45.90	49.51	56.59	49.59	49.79	49.20	47.35	49.91
Al_2O_3	25.25	7.76	14.53	14.55	13.62	11.94	13.07	16.56
Fe_2O_3	3.55	10.30	4.72	2.80	8.04	6.20	9.02	4.84
FeO	6.26	7.21	7.27	7.56	7.42	5.85	8.52	5.54
MnO	0.16	1.40	0.12	0.21	0.25	0.17	1.60	0.32
MgO	5.16	7.90	4.50	9.40	6.30	6.90	6.20	6.20
CaO	10.15	10.63	6.65	9.94	8.09	9.95	9.44	9.45
Na_2O	1.83	0.95	3.01	2.65	2.62	3.12	1.45	3.78
K_2O	0.28	0.40	0.68	0.68	0.58	1.10	0.56	0.97
TiO_2	0.20	0.57	0.90	0.85	2.02	0.60	1.48	0.92
P_2O_5	0.00	0.36	0.08	0.07	0.07	0.26	0.25	0.07
CO_2	0.00	0.99	0.48	0.48	0.50	1.45	1.05	0.22
Stotal	0.22	0.00	0.00	0.00	0.10	0.00	0.07	0.00
SO_3^{-2}	0.19	0.00	0.00	0.00	0.09	0.00	0.00	0.00
H_2O^+	0.36	0.22	0.16	0.77	0.22	1.10	0.49	0.85
H_2O^-	0.10	0.33	0.07	0.08	0.00	0.40	0.33	0.07
PC	0.46	1.44				1.95		
Total	99.98	99.97	99.76	99.63	99.70	100.19	100.88	99.70

1, Podu Runcului ; 2, Valea Runcului ; 3, Dealul Călugărul-Bordei ; 4, Dealul Mălăeşti ; 5, Valea lui Dăniş ; 6, Muntele Făgeţel ; 7, Muntele Ţibra ; 8, Valea Păiş (Tîncava).

Analysts : F. Papia (1) ; Z. Pintilie (2,7) ; E. Apostol (6) ; C. Agrigoroaei (3, 4, 5, 8).

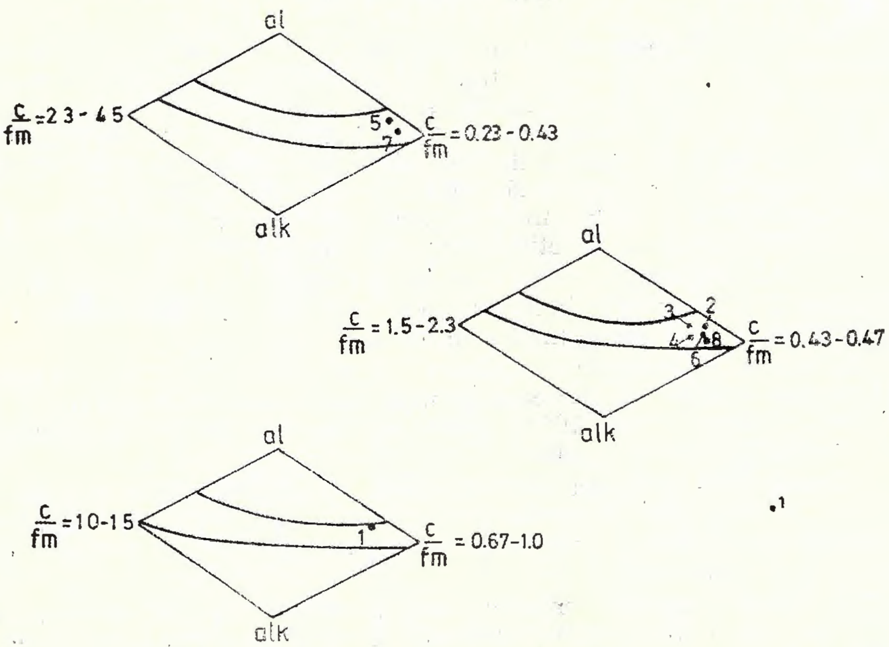

Fig. 3. — *al-alk-c/fm* diagram ; 1, eclogite.

material (Fig. 3). Excepting only the sample 3 — Călugărul-Bordei, samples are situated in subsaturated domain in silica (*QLM* diagram, Fig. 4). This situation was noticed also by Dimitrescu (oral commu-

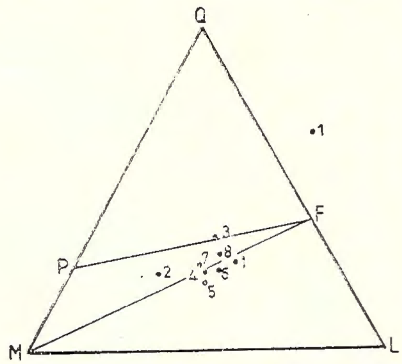

Fig. 4. — *QML* diagram; **1, eclogite.**

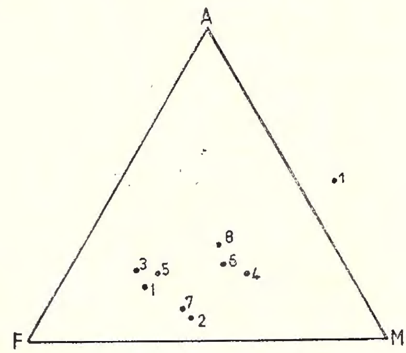

Fig. 5. — *AFM* diagram; 1, eclogite.

nication, 1984). Ferromagnesian, weakly alkaline character with marked dispersion is obvious on *AFM* diagram (Fig. 5). These aspects place the eclogites within alkaline olivinic basalts up to tholeiites.

Genetic Considerations

Up to now, there are two opinions on eclogites genesis in the Leaota Mts. The first says that they would be the results of pyrometamorphism at contact of the Albești granite and base amphibolite (Gherasi et al., 1971); the second points their formation *in situ* as an ultrametamorphism result within the amphibolites context (Bughea amphibolites level — Gheuca, Dinică, 1983; Dimitrescu, 1984).

The occurrences cited in this paper are situated both in the Bughea amphibolites and at other stratigraphical levels.

All of them outline exotic features given by the contrast of metamorphism and chemistry between them and adjacent formations, this situation excluding their formation *in situ*.

Eclogites metamorphism proves to be of higher grade because they contain omphacite, pyroxene where is present Tschermak molecule a thermal index (White, 1964), while in the adjacent rocks, pyroxene is met neither as relict diopside.

Higher pressures are demonstrated by jadeitic molecule participation (White, 1964) in omphacite and by apparition of mixed terms of grandites-piralspites, this being concomitantly with plagioclase disappearance (Wyllie, 1971).

Primary carinthine presence and moderate pyrope content of garnet indicate lower temperatures than those characteristic to eclogitic facies *s. str.*, the pressure being comparable. According to Dobrețov et al. (1970), the association is characteristic to thermal-baric domain having 650-850°C respectively more than 10 Kb, maybe 15-17 Kb, this domain being called "facies of kyanite bearing gneisses and amphibolites".

Chemical contrast with host formations, which is obvious when they are muscovite-chloritous albitic schists and biotitic paragneisses, appears as well within amphibolitic environments through more magnesian and alkaline character of eclogites.

On account of chemical differences between eclogites and amphibolites (Dimitrescu, 1984) assesses selective eclogitization *in situ* in water absence of more alkaline parts of amphibolites.

But, carinthine existence proves a high water activity, which as well as the metamorphism contrast disagrees this opinion.

Eclogites magmatic filiation mentioned above is indicated by the chemistry and presence of pentlandite exolutions in pyrrhotine.

Experimental petrology data correlated to seismics and gravimetry data indicate presence in the upper side of the mantle, under Moho discontinuity, of a domain of basic composition where gabbro-eclogite or peridotite-eclogite phase changes take place.

According to Yoder and Tilley (1962), eclogites would intrude in solid stage in the crust on structural discontinuity zones. At the same time, Smulikowski (1980) points that in the crustal domain a mechanical mixture between material from upper mantle and sialic one takes place on fractures.

Another point of view shows that during subduction, under certain temperature and pressure conditions, partial fusion and metamorphosation of ocean crust take place forming eclogite and peridotite (Ringwood, 1977).

For the Leaota eclogites, it is difficult to find which model is real from these two. Anyhow, solid state migration of eclogitic material from deep zones on the planes of mechanical discontinuity is obvious. Actual geological situation does not permit to point out these planes, later obliterated by several metamorphic events, so that eclogites cores appear as tectonical inclusions within the metamorphic fields associated to leucocratic and mafic gneisses and common micaschists with garnet and kyanite (Church, 1968), this situation being similar to that described by Hann (1983) in the Căpățîna Mts. These bodies emplacement moment antedates a process of potassic metasomatosis (the Runcu Valley) which is the most probable linked to similar events in the Albești granite and adjacent rocks accomplished in the final stage of granite consolidation.

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[4] Diffractometer TUR-M-61, goniometer HZG-3, CuKα radiation x=1,537395 KX, paper speed 600 mm/s, goniometer speed 1°/min. Analyst: T. Urcan, I.P.G.G.

[5] Analyst: Al. Achim, I.P.G.G., Bucharest.

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QUESTIONS

I. Balintoni : 1. Which are the formation conditions of carinthine ?

2. Which is, in your opinion, the significance of the lack of foliation within the eclogites ?

3. Which are the metamorphic parageneses and do you think they are generated by only one metamorphic event or by several ones ?

Answer : 1. Previously unreported in our country, carinthine belongs on account of textural relationships, to the primary paragenesis. It is a mineral which indicates pressures corresponding to the eclogitic facies (up to 15-17 kb) and a little lower temperatures (650°-850°C) under conditions of high water activity.

2. The lack of foliation in nontransformed varieties is a structural argument for their allochthonous character ; subsequent massive structure preservation is due to the high tectonic competence of eclogites.

3. Metamorphic parageneses which we found in the eclogites, excepting the primary one, are as follows : diopside-plagioclase, amphibole II-albite, muscovite-

albite-quartz$\pm$microcline. They probably belong to several metamorphic events, although it is difficult to establish their number under conditions when mineral neoformation cannot be related to some deformational moments.

DISCUSSIONS

I. Dinică : This paper is important for its mineralogic and chemical data confirming the existence of some high pressure minerals in these rocks. But, we have to remark that most of the eclogite blocks occur at the level of Bughea amphibolites. The authors can confirm this fact. I am convinced that those two or three points which seem to except this rule are actually connected to this level as well, their genesis being probably determined by an adequate chemistry. Otherwise, at Podul Runcului, the authors show that the eclogite which is placed in the paragneisses, has an amphibolitic cover. But Bughea amphibolitic level contains paragneisses too. For the Păiș valley, our mapping data show that there are several closely-spaced antithetic faults, which can repeat the same amphibolitic level. In this paper, the authors mention that the eclogite retromorphism leads to a rock in which secondary amphibole is associated to albite, this kind of association also characterizing the Bughea amphibolites. Our hypothesis (Gheuca, Dinică, 1981, 1983) regarding ultrametamorphism of the rocks in the Leaota Crystalline completely integrates two observation facts namely lithostratigraphic control of the Albești granite as well as of the eclogites which are obviously related to the Bughea amphibolites.

I. Gheuca : This paper brings valuable contributions concerning PT conditions of eclogite formation and their petrographic evolution, but the conclusion regarding their emplacement on a tectonic way in metamorphics pile, ends a little abruptly, this paper being not enough demonstrated. A simple tectonic structure given by clear lithostratigraphic markers as this one from this region, excludes the existence of old profound fractures which are obliterated later on, as the authors supposed. At the same time, a mechanism to emplace these matrix lenses which are more than host rocks through tectonic transport on the fractures, along tens of kilometers, in the Continental Crust, it is difficult to imagine. On the other side, eclogite relation with mafic rocks having obvious lithostratigraphic control within the pile is difficult to contest about. Besides those mentioned above, the hypothesis of the eclogite formation within regional metamorphism of the pile under ultrametamorphism conditions (Gherasi, 1952 ; Gherasi, Arghir, 1963 — I.G.G. reports ; Gheuca, Dinică, 1981), is much better argued.

NOI DATE ASUPRA ECLOGITELOR DIN MUNȚII LEAOTA

(Rezumat)

În sectorul sud-estic al cristalinului Leaotei au fost identificate opt iviri de eclogite la diferite nivele litostratigrafice. Aceste iviri sînt lentiliforme sau nodulare și au dimensiuni reduse, contrastînd din punct de vedere chimic și mineralogic cu formațiunile adiacente.

Asociaţia primară granat-omfacit-carinthin-zoizit-rutitl este afectată de procese retromorfe de intensitate variabilă.

Participarea termenilor extremi în mineralele soluţie solidă a fost determinată pe baza datelor optice şi röntgenostructurale. Conţinutul în pirop al granatului, participarea termenului jadeitic în omfacit şi prezenţa carinthinului primar indică presiuni ridicate de formare (pînă la 15-17 Kbari) şi temperaturi mai scăzute (650-850°C) decît cele corespunzătoare eclogitelor din terenurile cu migmatite şi gnaise retromorfozate (grupul B — Coleman, 1965), condiţii care după Dobreţov et al. (1970) corespund „faciesului gnaiselor şi amfibolitelor cu disten".

Structurile de dezamestec pirotină-pentlandit cît şi chimismul indică pentru aceste roci o filiaţie magmatică.

În acord cu datele geofizice şi de petrologie experimentală din literatură, eclogitele provin din zone profunde. Punerea lor în loc în formaţiunile cristalofiliene din munţii Leaota s-a produs pe discontinuităţi rupturale profunde, obliterate de evenimentele metamorfice şi tectonice ulterioare.

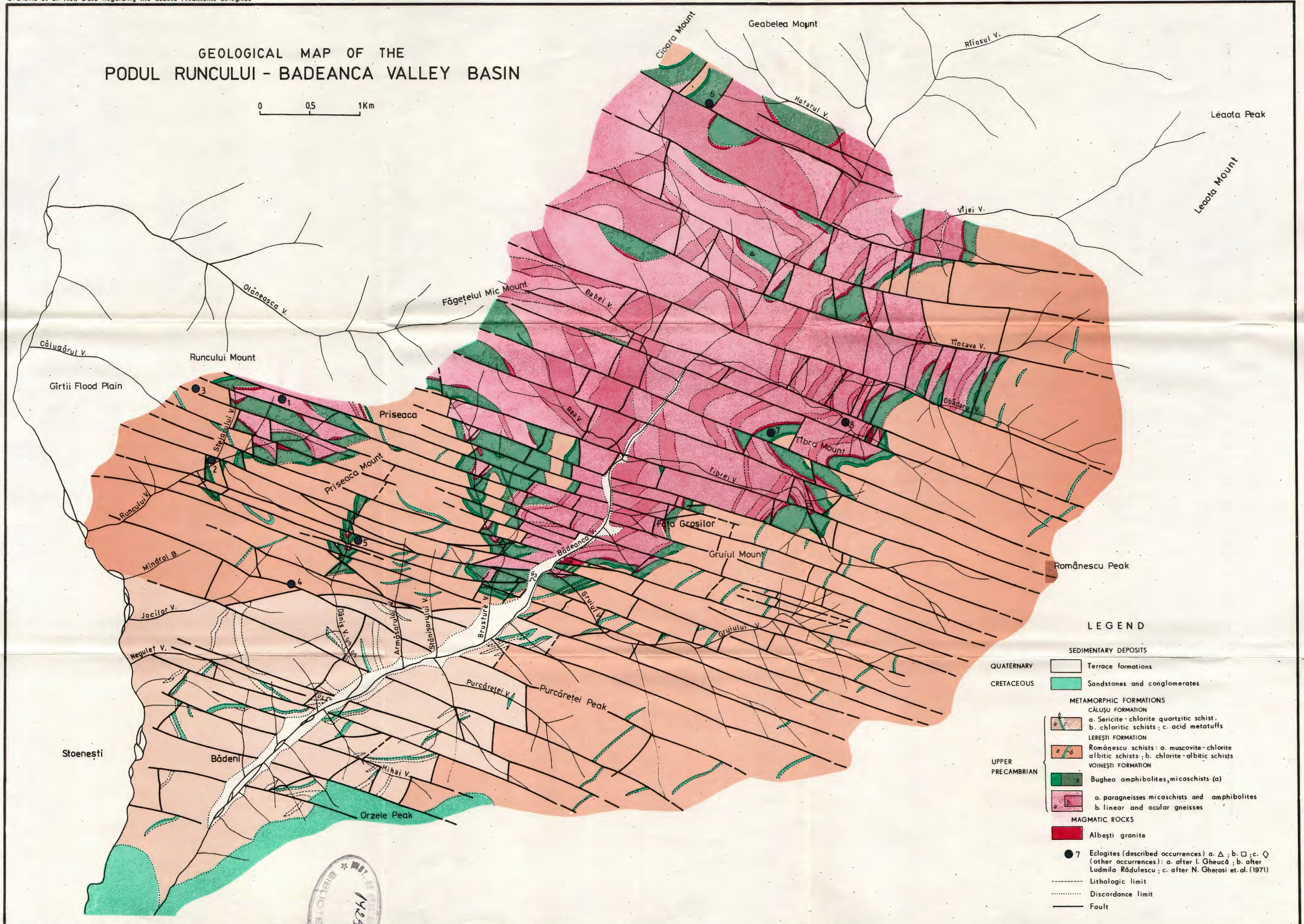
EXPLANATION OF PLATE

Plate II

Fig. 1. — Eclogite from Podu Runcului. (1, garnet ; 2, omphacite ; 3, carinthine ; 4, zoisite). N ||, × 25.

Fig. 2. — Eclogite from Valea lui Dăniş. Carinthine (1) and omphacite (2) with simplectitic borders (3), amphibole II (4) occurred at the interface carinthine-garnet (5). N ||, × 25.

Fig. 3. — Eclogite from Păiş (Tîncava).
Pyrrhotine (1) with pentlandite exsolution (2). N ||, × 50, air.



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

PETROLOGIA ROCILOR METAMORFICE

KYANITE PARAGNEISSES IN THE DRĂGȘANU GROUP (PARÎNG MOUNTAINS — SOUTH CARPATHIANS)[1]

BY

IOAN SOLOMON[2]

Amphibolites. Almandine amphibolite facies. Staurolite subfacies. Kyanite. Index mineral. Almandine. Parîng Series. Mineral association. Prograde metamorphism. South Carpathians — Crystalline Danubian Domain — Parîng Mountains.

Abstract

Kyanite has been identified within the metamorphites in the lower part of the Drăgșanu Group (Parîng Series, amphibolite complex) in the Polatiștea Valley (western part of the Parîng Mts). The occurrence of this index mineral in association with andesine+hornblende+almandine points to conditions of the prograde metamorphism of the Parîng Series at the level of the almandine-amphibolite facies, staurolite-almandine subfacies.

Résumé

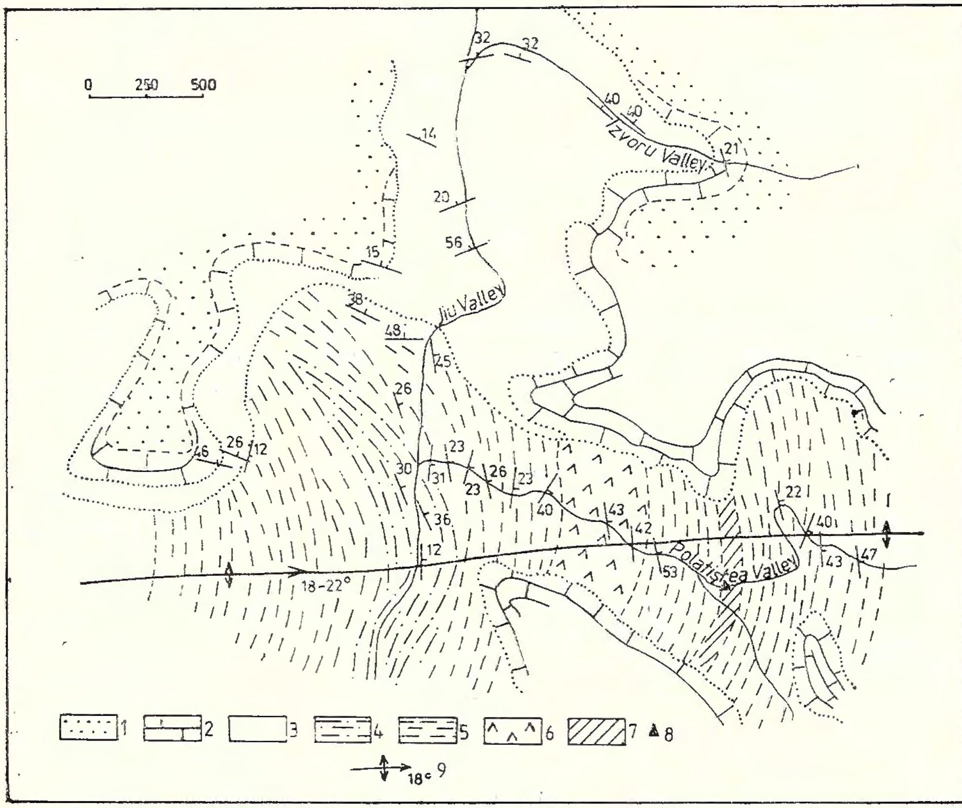
Paragneiss à disthène du groupe de Drăgșanu (monts Parîng — Carpathes Méridionales). On a identifié dans les métamorphites de la partie inférieure du groupe de Drăgșanu (série de Parîng, complexe des amphibolites) la présence du disthène sur la vallée de Polatiștea (à l'ouest des monts Parîng).

La présence de ce mineral index à côté de l'association andésine+hornblende+almandin indique les conditions du métamorphisme prograde de la série de Parîng au niveau du faciès des amphibolites à almandin, sous-faciès staurotide-almandin.

[1] Received December 20, 1982, accepted for communication and publication February 22, 1983, communicated in the meeting April 8, 1983.

[2] Întreprinderea de Prospecțiuni Geologice și Geofizice. Str. Caransebeș nr. 1, R 79678, București, 32.

The index minerals of the Al_2SiO_5 suite, specific to the Barrovian low-pressure and medium-temperature metamorphism, are rarely found within the Danubian crystalline schists — the Drăgșanu Group. Their scarcity determined us to point out a new site of the kyanite appearance in the lower course of the Polatiștea Valley, left tributary of the Jiu Valley, in the defile area (Fig.).



Geological sketch of the Jiu Valley area.
1, Phyllites of the Gîrbovu Formation ; 2, Oslea Limestone ; 3, Vîlcan Series ; Parîng Series ; 4, almandine-bearing amphibolic gneisses ; 5, banded amphibolic gneisses ; 6, metaperidotites ; 7, kyanite-bearing gneisses ; 8, outcropping site of the kyanite-bearing gneisses ; 9, anticlinal axis.

The Polatiștea Valley opens longitudinally, amphibolites occurring in the area of the Jiu anticline, after having fragmented the plate of the Oslea limestones and the phyllites in the base of the Gîrbovu Formation (Stănoiu, 1976).

In our opinion the Drăgșanu Group is represented by formations subsequently referred to the Parîng amphibolitic series [3] (regarded as a complex by Paliuc, 1937 ; Manolescu, 1937 ; Pavelescu, 1953) of terminal Precambrian age (Solomon et al., 1976) and to the Vîlcan Series

(Savu et al., 1973), equivalent of the clastic series (Manolescu, 1937) or of the sericite chlorite complex of the Drăgșanu Series (Pavelescu, 1953), of Cambrian age (Solomon et al., 1976).

Metamorphites belonging to the Drăgșanu Group are transgressively and unconformably overlain by low-grade metamorphites of the Gîrbovu Formation, probably of Lower Carboniferous age.

The Parîng Series consists of a strong pile of banded amphibolic gneisses (basic metatuffs), in association with orthoamphibolites (metaquartzdiorites, metadiorites, metagabbros and metaperidotites, partly serpentinized), hornblende-almandine-biotite gneisses, muscovite-biotite gneisses and biotite-almandine-kyanite gneisses.

The Vîlcan Series — the second term of the Drăgșanu Group — consists of a pile of terrigene and basic volcanic metarocks, represented by green gneisses with acicular amphibole, biotite-muscovite gneisses, amphibole-epidote-chlorite-sericite gneisses, epidote sericite-chlorite quartz schists, sericite-graphite quartz schists, sericite-chlorite schists, etc.

An 8-10 m thick level of metaconglomerates with pebbles made up of paragneisses, quartz gneisses and quartzites occurs in several places in the base of the Vîlcan Series (West Jiu-Cîmpu Mielului, Jiu Defile, Cîndetu Summit, etc.). An angular and metamorphic unconformity can be recognized in the western and northern flanks of the Sigleu Mt (Vîlcan Mts), also situated in the base of the series.

The presence of two "series" within the Drăgșanu Group has been contested by Berza (1975), who considers the metamorphites of the Vîlcan Series to be the result of the Paleozoic retromorphism over the amphibolic gneisses.

Taking into account this hypothesis, it is expected that all the Paleozoic low-grade metamorphic formations should overlie a horizon consisting of sericite-chlorite-epidote schists, sericite-chlorite schists, etc. In the study region the mentioned succession is found only in the Jiu Defile, north of the confluence with the Izvorului Valley, whereas in the Polatiștea Valley almandine amphibolite gneisses, relatively fresh, crop out under Paleozoic formations. A similar situation is encountered in the northern flank of the Oslea Mt as well as in other zones. In the south-east of the Retezat Mts, the Vîlcan Series consists of a pile of about 1200-1400 m thick, partly overlain by Paleozoic formations. All these relationships which can be generalized almost in the whole outcropping area of the Danubian formations, do not testify Berza's hypothesis (1975).

In the Polatiștea Valley kyanite has been identified in a level (30-40 m) of biotite-almandine paragneisses, with a nodular structure given by the local agglomeration of plagioclase and quartz.

The paragneiss level is intercalated between thick packets of banded amphibolite gneisses, the whole succession being referred to the amphibolite complex (sensu Berza, 1978) of the Parîng Series.

Detailed petrographic descriptions of the amphibolic rocks and of other petrographic constituents of the amphibolite complex can be found in several papers : Paliuc (1937) ; Manolescu (1937) ; Pavelescu and Pavelescu (1964) ; Anton (1973).

Kyanite, which occurs in paragneisses as 2-4 mm long crystals, is pinitized. Due to pinitization, kyanite crystals have skeleton-like structures. The cleavage is perfect after (100) and good after (010). Ng : c=30-32°, —2V=80-82°.

The paragenesis is represented by quartz + plagioclase An_{38} + biotite + muscovite + almandine + kyanite + apatite.

The mineral association pointed out in the Jiu Defile zone andesine + hornblende + almandine, beside other determinations — An_{40-45}+ hornblende (Paliuc, 1937) ; An_{38} + hornblende (Anton, 1973) and the kyanite paragenesis in the Polatiștea Valley — testify the conditions of the medium pressure and temperature metamorphism (prograde), estimated by Berza at about 6-9 kb and 600°C, specific to the almandine amphibolite facies, staurolite-almandine subfacies, for the metamorphites of the Parîng Series.

The identification of the kyanite rocks in the Polatiștea Valley enlarges the occurrence area of kyanite, up to now reported only from some zones of the Danubian Domain, between Latorița and Olteț (Ghika-Budești, 1937) ; Motru Valley Basin (Berza and Seghedi, 1975) ; Mraconia Zone (Bercia, 1968) ; Rudăria Valley (Mărunțiu, 1976).

The Parîng Series metamorphites have subsequently been affected by regional metamorphic processes, known in the whole outcropping area of the Danubian metamorphites.

The effects of the retromorphism, produced during the Caledonian, Hercynian and Alpine orogeneses, are represented by plagioclase saussuritization, biotite and almandine chloritization, kyanite pinitization and a new generation of quartz, albite and sericite.

[3] The amphibolite series has a wide outcropping area in the north of the Parîng Mts, and for this reason we called it the Parîng Series.

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PARAGNAISE CU DISTEN ÎN GRUPUL DE DRĂGȘANU (MUNȚII PARÎNG — CARPAȚII MERIDIONALI)

(Rezumat)

Grupul de Drăgșanu cuprinde, în accepția noastră, două unități litostratigrafice : 1) seria de Parîng, amfibolitică, corespunzătoatre complexului amfibolitelor după Manolescu (1937) ; Pavelescu (1953) ; seriei de Drăgșan după Savu (1973) și parțial formațiunii de Drăgșan după Berza (1978) și 2) seria de Vîlcan, alcătuită din metaroci terigene și metaroci vulcanogene bazice.

Seria de Parîng este constituită dintr-un complex inferior, al amfibolitelor și un complex al gnaiselor micacee (Berza, 1978).

În complexul inferior, deschis pe valea Polatiștea, sînt cuprinse gnaise amfibolice rubanate, gnaise amfibolice cu almandin, metaperidotite parțial serpentinizate și paragnaise cu biotit, almandin și disten.

În paragnaise a fost întîlnită următoarea parageneză : cuarț + plagioclaz An_{38} + biotit + muscovit + almandin + disten + apatit.

Prezența distenului în rocile terigene, gnaisice, precum și a asociației andezin + hornblendă + almandin sînt argumente care permit încadrarea seriei de Parîng în faciesul amfibolitelor cu almandin, subfaciesul staurolit-almandin.

Seria de Parîng a fost ulterior afectată de un poliretromorfism manifestat în Paleozoic și în Mezozoic (orogenezele caledoniană, hercinică și alpină).

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

PETROCHEMICAL CONSIDERATIONS ON THE CAPRA VALLEY METAMORPHICS (THE FĂGĂRAȘ MTS) [1]

BY

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Metamorphic formations. Lithofacies. Chemical composition. Măgura Cîinenilor Formation. Suru Formation. Migmatite. Distribution. Geochemistry. Southern Carpathians — Crystalline Getic and Supragetic domains — Făgăraș Mountains.

Abstract

This paper deals with the comparative petrochemical study of Măgura Cîinenilor formation (Cumpăna subgroup) and Suru formation (Făgăraș subgroup) considering common types of rocks (micaschists, paragneisses, amphibolites) on account of 48 chemical and spectral analyses on the same samples. We point out differentiations between these two formations, regarding both major chemistry (situation of SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, Na_2O, MnO) and minor chemistry (at micaschists and paragneisses Pb, Sc, Ba, Sr have contents in ppm higher in Măgura Cîinenilor formation in comparison with Suru formation, while Ni, Cr, V, Co situation is reverse). At amphibolites Cu and Zn contents are higher in Suru formation than in Măgura Cîinenilor formation and Sc and Sr situation is reverse. Migmatites from Măgura Cîinenilor formation are geochemically individualized because of the increase of Pb and Nb contents and obvious decrease of Ni, Cr, Co, V, Sc, Ba, Sr, Cu, Zn. Suru formation retromorphism is pointed out by hydration and oxidation phenomena which determine H_2O^+ and Fe_2O_3 substantial increase and oxidation degree as well. Anomal contents out of samples near the tectonic contact between the two formations, reflect a more intense supergene circulation favoured by this contact.

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Résumé

Considérations pétrochimiques sur les métamorphites du bassin de la vallée de Capra (monts Făgăraș). La présente note porte sur une étude pétrochimique comparatif entre la formation de Măgura Cîinenilor (sous-groupe de Cumpăna) et la formation de Suru (sous-groupe de Făgăraș), compte tenu des types communs de roches (micaschistes, paragneiss, amphibolites) sur base de 48 analyses chimiques et spectrales (exécutées sur les mêmes échantillons). On a mis en évidence des différences entre les deux formations autant du point de vue du chimisme majeur (situation SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, Na_2O, MnO) que du chimisme mineur (les teneurs en Pb, Sc, Ba, Sr des micaschistes et des paragneiss sont plus élevées dans la formation de Măgura Cîinenilor que dans celle de Suru, alors que les teneurs en Ni, Cr, V, Co est inverse. Ce en Cu et Zn des amphibolites sont plus élevées dans la formation de Suru que dans celle de Măgura Cîinenilor et la situation est inverse pour les teneurs en Sc et Sr).

Les migmatites de la formation de Măgura Cîinenilor s'individualisent géochimiquement par augmentation des teneurs en Pb et Nb et par diminuation marquante de Ni, Cr, Co, V, Sc, Ba, Sr, Cu, Zn. Le rétromorphisme de la formation de Suru est révélé par des phénomènes de hydratation et d'oxydation qui déterminent la hausse substantielle de H_2O^+ et de Fe_2O_3 et implicitement du degré d'oxydation.

Les teneurs anomales des échantillons recueillis du voisinage du contact tectonique de ces deux formations dénotent une circulation plus intense supergène favorisée par ce contact.

From lithostratigraphic point of view (according to Balintoni et al., 1984), the Capra Valley basin (which represents the spring area of the Argeș river) includes the Măgura Cîinenilor and the Suru formations.

The Măgura Cîinenilor formation which belongs to the Cumpăna subgroup, especially includes paragneisses and micaschists, whose alternations often include amphibolitic bands and seldom intercalations of ocular migmatites or bearing an equigranular aspect. The upper side of this formation comes tectonically into contact with the upper side of the Suru formation from the Făgăraș subgroup within the Capra Valley areal.

The Suru formation is situated in the southern slope of the Făgăraș peak (upstream of the Capra Valley confluence with the Lespezi brook) as well as in the peak zone. It includes an alternation of carbonatic and amphibolic rocks within a quartzitic-micaceous background with a variable occurrence of feldspars. Sometimes occur graphitic rocks too.

If starting with the half of the last century, the Făgăraș Mts have drawn the attention from other points of view, petrochemical problems began to be studied at the same time with the prospecting laborious work after 1955. So, Arion and Ignat (1970) gave seven chemical analyses on migmatites belonging to the Cumpăna subgroup. Anton and Constantinescu (1982) issued an article on some amphibolites in the Făgăraș Mts in which there are also given 19 chemical analyses; Dimitrescu and Cocîrță (1983) did petrochemically six chemical and spectral analyses on the Suru formation amphibolites.

Recent and numerous investigations which are done in order to understand geological conditions which control syngenetic mineralizations in the Capra Valley, facilitated a big number of chemical and spectral analyses (Balintoni et al., 1984) on several types of rocks.

Chemical and Spectral Analyses

Chemical analyses which are done in the IPGG Bucharest labs (Emilia Cîrciumaru analyst) on our samples had in view oxides dose (SiO_2, Al_2O_3, FeO, Fe_2O_3, MnO, MgO, CaO, TiO_2, Na_2O, K_2O, P_2O_5, H_2O^+, H_2O^-, CO_2) and total S in weight percentages (Tab. 1, 2) on the samples from the Capra Valley, the zone of the Bîlea tunnel (Pl. III) and upstream of the Buda Valley (two samples). The samples come from micaschists, paragneisses, amphibolites, migmatites, quartzitic graphitic schists and carbonatic schists. First three types of rocks are common both to the Măgura Cîinenilor formation and to the Suru, the migmatites only to the first and the last two types only to the Suru.

Spectral analyses (Tab. 5, 6) did Ana Șerbănescu on the material from the samples chemically analysed.

On account of chemical analyses, we calculated the Niggli and Semenenko parameters (Tab. 3, 4).

Discussions on the Chemistry and Distribution of Major Elements

Comparing oxides contents on types of rocks from the two formations, according to silica (Pl. I), we notice the following:

— similarities regarding TiO_2, Na_2O, CaO, MgO, FeO and Al_2O_3 participation for the rocks they have in common;

— a bigger K_2O quantity in micaschists and paragneisses of the Măgura Cîinenilor formation;

— a richment of Fe_2O_3 in the rocks of the Suru formation. From the point of silica view, amphibolites of the Suru formation include smaller contents and paragneisses of the Măgura Cîinenilor formation in bigger contents.

The Suru formation differs from the Măgura Cîinenilor one through the migmatites presence in the last one. From geochemical point of view, these rocks differ clearly from the other quartz-feldspathic rocks. So, while silica rise, we notice, in comparison with paragneisses a K_2O and Na_2O increase, on one hand, and a decrease of all the other analysed oxides.

TABLE 1

Chemical composition of the rocks in the Măgura Cîinenilor formation

No.	No. of sample	Oxides														Total %
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O^-	H_2O^+	S	
1	23	46.97	3.45	14.80	2.48	9.80	0.16	6.70	9.94	0.85	2.62	0.47	0.23	0.02	0.09	99.21
2	9	48.29	1.95	13.70	1.13	11.20	0.25	6.60	11.62	0.51	2.32	0.17	0.31	0.40	0.15	98.78
3	27	49.42	1.90	15.34	1.07	10.09	0.25	7.60	8.54	0.42	2.62	0.17	0.21	0.22	0.14	98.46
4	16	50.70	1.65	16.30	0.68	9.42	0.23	6.30	7.98	1.27	2.35	0.17	0.18	0.66	—	98.85
5	1	51.46	1.05	17.36	2.51	7.57	0.21	6.30	7.98	0.85	3.63	0.15	0.23	0.02	0.05	100.26
6	20	53.14	1.55	15.20	0.95	9.05	0.21	6.10	8.68	1.19	2.02	0.18	0.15	0.60	1.03	99.09
7	13	54.73	1.15	19.89	1.19	6.97	0.12	3.80	2.21	3.74	2.99	0.10	0.25	2.05	—	99.12
8	11	56.08	1.05	23.01	1.24	5.64	0.18	1.90	1.54	4.67	1.38	0.10	0.34	2.47	0.06	99.73
9	21	56.72	1.05	22.79	0.52	6.60	0.18	2.40	1.12	3.65	1.50	0.07	0.31	2.03	0.04	99.02
10	6938 A	56.78	0.80	15.89	1.09	5.19	0.14	5.60	4.62	5.22	1.81	0.11	0.14	1.03	0.02	99.06
11	28	58.76	1.30	19.18	0.36	6.23	0.09	3.60	1.96	2.80	1.95	0.19	0.17	2.30	0.76	99.61
12	12	59.27	1.00	21.18	0.61	5.56	0.21	2.60	1.12	3.91	1.38	0.12	0.62	2.04	0.04	99.70
13	6938 B	59.52	0.75	17.28	1.02	5.19	0.07	1.30	6.16	1.80	1.76	0.11	0.14	1.00	0.01	99.11
14	10	61.35	1.05	17.63	0.38	5.19	0.14	3.40	4.76	1.96	2.85	0.18	0.21	0.65	0.06	99.87
15	14	61.44	1.05	17.05	0.24	6.08	0.14	3.20	3.50	2.55	2.85	0.11	0.21	0.93	0.14	99.66
16	22	61.88	0.90	18.85	0.60	4.67	0.09	3.20	1.26	3.74	2.40	0.22	0.24	1.65	0.05	99.80
17	17	64.20	0.90	17.73	0.38	5.19	0.12	2.30	1.96	3.31	1.98	0.10	0.23	1.36	0.03	99.83
18	4	65.20	1.05	15.95	0.29	5.26	0.14	2.50	1.26	4.25	1.47	0.12	0.18	2.04	0.06	99.84
19	26	65.21	—	16.85	0.67	4.67	0.11	2.70	2.10	2.55	3.15	0.23	0.19	0.79	0.12	99.74
20	15	65.41	0.90	16.30	0.42	4.89	0.14	1.80	2.66	2.55	3.09	0.10	0.22	0.73	0.04	99.29
21	18	66.40	0.40	17.10	0.26	2.08	0.11	2.30	4.06	2.21	3.90	0.07	0.16	0.37	—	99.42
22	5	67.20	0.80	15.58	0.20	3.93	0.10	1.80	2.38	3.91	2.88	0.20	0.21	0.57	0.07	99.91
23	2	69.49	0.90	14.21	0.41	4.45	0.10	1.80	1.40	2.72	2.13	0.13	0.17	1.24	0.03	99.22
24	8	70.63	0.30	14.57	0.35	2.45	0.11	1.50	2.24	4.25	3.00	0.10	0.23	0.16	0.05	100.00
25	24	71.29	0.30	14.40	0.21	1.85	0.12	1.90	1.82	3.74	2.89	0.21	0.23	0.41	0.05	99.90
26	19	72.30	0.30	14.18	0.06	1.63	0.07	1.00	2.10	4.08	3.75	0.08	0.14	0.14	0.04	99.91
27	6	74.02	0.30	11.90	0.42	2.15	0.07	1.20	1.96	4.25	3.15	0.07	0.16	0.40	0.05	100.16
28	7	74.77	—	12.84	0.16	1.33	0.05	0.40	1.68	4.59	3.75	0.02	0.26	0.30	0.03	100.22

29	25	75.76	—	12.22	0.31	1.19	0.03	1.00	1.26	4.76	3.00	0.02	—	0.20	0.06	100.09
30	3	75.79	—	12.17	0.20	1.33	0.03	0.80	1.40	4.25	3.84	0.02	0.17	0.35	0.04	100.43
Arithmetic mean	Micaschists	59.45	1.07	19.76	0.66	5.87	0.15	2.66	1.70	3.64	1.96	0.11	0.30	1.95	0.22	
	Paragneisses	66.53	0.69	16.14	0.40	3.80	0.11	2.28	2.51	3.18	2.86	0.16	0.20	0.76	0.06	
	Amphibolites	50.00	1.93	15.45	1.54	9.52	0.22	6.60	9.12	1.02	2.59	0.22	0.22	0.32	0.09	
	Migmatites	75.01	—	12.28	0.30	1.50	0.04	0.85	1.56	4.46	3.43	0.03	0.22	0.31	0.04	

23, Amphibolite. Capra valley, upstream the confluence with Modrugaz valley; 9, Amphibolite. Capra valley, upstream the confluence with Mîndra valley; 27, Amphibolite. Capra valley, upstream the confluence with Lespezi valley; 16, Amphibolite. Capra valley; 1, Amphibolite. End of Vidraru lake; 20, Amphibolic gneiss. Capra valley; 13, Micaschist bearing garnets and sillimanite. Capra valley, the confluence with Modrugaz valley; 11, Micaschist bearing garnets and sillimanite. Capra valley, downstream the confluence with Modrugaz valley; 21, Micaschist bearing staurolite and disthen. Capra valley; 6938 A. Paragneiss. Buda Valley, upper course; 28, Micaschist. Capra valley, downstream the confluence with Lespezi valley; 12, Micaschist bearing garnets, disthen and sillimanite. Capra valley; 6938 B. Paragneiss. Buda valley, upper course; 10, Paragneiss. Capra valley; 14, Paragneiss. Capra valley, confluence with Modrugaz valley;

22, Paragneiss. Capra valley; 17, Paragneiss. Capra valley; 4, Micaschist. Capra valley; 5, Paragneiss. Capra valley. 2, Paragneiss. Capra valley. 8, Paragneiss Capra valley; 26, Paragneiss. Capra valley; 15, Micaschist. Capra valley; 18, Paragneiss bearing disthen. Capra valley; 24, Paragneiss. Capra valley; 19, Paragneiss. Capra valley; 6, Ocular migmatite. Capra valley; 7, Migmatite. Capra valley, confluence with Mîndra valley; 25, Migmatite, Capra valley; 3, Migmatite. Capra valley.

TABLE 2

Chemical composition of the rocks in the Suru formation

No.	No. of sample	Oxides															Total %
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	H_2O^-	H_2O^+	S total	
1	29	35.54	2.25	12.86	0.96	8.02	0.18	4.70	17.78	2.20	0.68	0.49	2.76	0.48	0.13	0.23	89.26
2	35	41.61	1.55	14.77	5.16	7.13	0.36	5.50	9.94	3.27	0.27	0.14	5.85	0.15	3.14	0.02	99.86
3	36	46.02	2.55	16.92	4.74	8.02	0.25	5.90	6.44	3.21	1.44	0.28	1.58	0.09	1.18	—	99.62
4	30	46.73	2.25	15.32	1.96	9.94	0.21	7.80	10.78	2.32	0.25	0.21	—	0.13	0.70	0.05	98.65
5	34	46.96	2.25	15.29	4.68	8.46	0.32	7.00	9.24	2.52	0.72	0.21	—	0.14	1.56	0.02	99.37
6	45	55.85	1.05	17.93	1.33	6.45	0.18	6.20	2.38	1.39	2.07	0.14	1.32	0.15	2.57	0.02	99.03
7	47	57.75	1.05	20.83	1.15	5.78	—	4.00	1.54	0.75	3.06	0.09	—	0.13	3.61	0.02	99.76
8	52	58.03	1.00	20.23	1.14	5.78	0.18	3.10	1.12	0.89	3.33	0.12	—	0.18	4.57	—	99.67
9	31	59.31	1.15	18.71	3.74	3.71	0.32	2.90	1.40	2.40	4.14	0.26	0.66	0.11	0.63	0.01	99.45
10	40	60.06	0.80	16.26	0.37	5.71	0.11	3.90	4.62	2.16	2.70	0.11	1.98	0.05	0.33	0.24	99.10
11	41	60.65	0.80	18.81	1.60	4.67	0.25	3.40	1.40	1.84	3.15	0.15	—	0.14	3.01	0.02	99.89
12	50	63.23	0.90	17.03	0.37	5.71	0.18	2.70	2.10	2.46	2.25	0.17	—	0.16	2.11	0.03	99.41
13	42	64.14	0.90	16.42	0.46	6.08	0.14	2.70	2.52	1.95	2.34	0.17	—	0.08	1.48	0.01	99.36
14	33	64.94	0.90	16.75	1.22	4.75	0.14	2.30	1.54	2.14	2.70	0.21	—	0.18	1.36	0.01	99.64
15	46	65.40	1.10	12.62	0.49	4.89	0.11	3.60	4.34	1.51	1.62	0.19	2.40	0.10	1.36	0.01	99.76
16	51	66.28	0.90	16.00	0.56	4.89	0.18	2.70	1.54	2.34	2.52	0.16	—	0.11	1.57	0.08	99.83
17	49	66.59	1.00	22.44	0.25	0.44	0.07	—	1.12	1.47	3.06	—	—	0.16	2.97	0.36	99.93
18	43	76.53	1.00	9.65	0.95	3.78	0.14	2.90	1.12	0.84	1.35	0.11	—	0.10	1.55	—	100.02
Arithmetic mean	Retro. micaschist	60.66	1.02	17.52	0.93	5.66	0.16	3.92	2.18	1.37	2.52	0.14	1.86	0.13	2.73	0.04	
	retro paragneiss	62.05	0.91	17.33	1.29	5.10	0.23	2.98	2.26	2.16	2.87	0.18	1.09	0.12	1.52	0.05	
	amphybolite	46.57	2.35	15.34	3.79	8.81	0.26	6.90	8.82	2.68	0.80	0.22	1.58	0.12	1.45	0.03	
	limy schist	38.57	1.90	13.81	3.06	7.57	0.27	5.10	13.86	2.73	0.47	0.32	4.30	0.32	1.63	0.12	
	quartz schist	76.59	1.00	9.65	0.95	3.78	0.14	2.90	1.12	0.84	1.35	0.11	0.10	0.10	1.55	—	
	graphitic schist	66.59	1.00	22.44	0.25	0.44	0.07	—	1.12	1.47	3.06	—	—	0.16	2.97	0.36	

29. Limy schist. Capra valley, confluence with Lespezi brook; 35, Limy schist. Capra valley; 36, Amphibolite. Capra valley; 30, Amphibolite. Capra valley, upstream the confluence with Lespezi brook; 34, Amphibolite. Capra valley; 45, Retromorphic micaschist. Capra valley; 47, Repromorphic micaschist. Transfăgărăşan, upstream the confluence between Capra valley and Căprioara valley; 52, Retromorphic micaschist. Northern end of the Bilea tunnel; 31, Retromorphic paragneiss. Capra Valley, 40. Retromorphic paragneiss. Capra valley. Confluence with Căprioara valley; 41, Retromorphic biotitic paragneiss. Capra valley, upstream the confluence with Căprioara valley; 50, Retromorphic biotitic paragneiss. About 500 m from southern end of the Bilea tunnel; 42, Cataclased paragneiss. Capra valley; 33, Retromorphic paragneiss. Capra valley; 46, Retromorphic micaschist. Transfăgărăşan; 51, Retromorphic micaschist. Southern end of the Bilea tunnel; 49, Graphitic schist. TCM tunnel chalet; 43, Quartz schist. Capra valley.

TABLE 3

Niggli and Semenenko parameters for the rocks of the Măgura Cîinenilor formation

No.	No. of sample	si	al	fm	c	alk	k	mg	ti	qz	c : fm	A	M	C	F	T
1	23	110.0	20.4	47.4	24.9	7.2	0.18	0.49	6.07	—19	0.52	22.08	25.28	26.96	25.67	—57.45
2	9	111.0	18.6	46.9	28.6	5.9	0.13	0.48	3.37	—13	0.61	19.83	24.16	30.58	25.42	—86.10
3	27	118.3	21.6	49.7	21.9	6.7	0.10	0.55	3.42	— 9	0.48	23.32	29.23	23.61	23.84	—32.28
4	16	129.3	24.5	45.8	21.8	7.9	0.26	0.52	3.16	— 2	0.47	26.73	26.13	23.79	23.34	—21.16
5	1	126.5	25.2	43.8	21.0	10.0	0.13	0.53	1.98	—13	0.48	28.08	25.78	23.47	22.68	—23.27
6	20	137.8	23.2	45.6	24.1	7.0	0.28	0.52	3.02	10	0.52	25.12	25.50	26.08	23.31	—34.66
7	13	172.1	36.9	39.3	7.4	16.4	0.46	0.45	2.72	7	0.18	44.27	21.39	8.94	25.39	—35.30
8	11	198.8	48.1	30.8	5.8	15.3	0.69	0.53	2.80	38	0.18	57.11	11.93	6.95	24.01	56.00
9	21	202.0	47.8	34.4	4.3	13.5	0.62	0.37	2.81	48	0.12	55.62	14.81	4.97	24.60	62.90
10	6938 A	171.9	28.4	41.3	15.0	15.4	0.65	0.61	1.82	10	0.36	33.66	30.00	17.79	18.55	— 7.16
11	28	209.8	40.4	30.0	7.5	13.1	0.49	0.49	3.49	57	0.19	46.61	22.13	8.66	22.60	48.89
12	12	221.9	46.7	34.4	4.5	14.3	0.65	0.42	2.82	65	0.13	55.00	17.08	5.29	22.64	59.69
13	6938 B	190.7	32.6	37.1	21.1	9.1	0.40	0.55	1.81	54	0.57	35.98	22.65	23.32	18.05	7.16
14	10	209.0	35.4	33.6	17.4	13.6	0.31	0.51	2.69	54	0.51	41.17	20.08	20.21	18.54	12.35
15	14	215.8	35.3	36.1	13.2	15.4	0.37	0.46	2.77	54	0.36	41.93	19.91	15.65	22.51	18.99
16	22	234.2	42.0	35.0	5.1	17.8	0.51	0.52	2.56	63	0.14	51.36	22.05	6.24	20.35	45.43
17	17	259.2	42.2	33.1	8.5	16.3	0.52	0.42	2.73	94	0.25	50.64	16.62	10.18	22.57	41.32
18	4	278.6	40.2	36.4	5.8	17.7	0.66	0.44	3.37	108	0.16	49.10	19.46	7.05	24.39	41.64
19	26	258.4	39.1	33.6	8.9	18.4	0.35	0.47	0.00	85	0.26	48.17	19.52	10.92	21.39	30.21
20	15	269.0	39.5	29.8	11.7	19.0	0.35	0.37	2.78	93	0.39	49.07	13.71	14.56	22.66	22.21
21	18	264.8	40.2	21.8	17.3	20.7	0.27	0.63	1.20	82	0.79	50.92	17.32	21.98	9.78	5.32
22	5	288.6	39.4	26.9	11.0	22.7	0.47	0.43	2.58	98	0.40	51.26	14.98	14.24	19.52	14.65
23	2	339.0	40.8	33.3	7.3	18.5	0.46	0.39	3.30	165	0.22	50.40	16.15	9.03	24.43	36.71
24	8	331.7	40.3	22.0	11.3	26.4	0.48	0.48	1.06	126	0.51	55.11	14.35	15.41	15.13	6.60
25	24	351.1	41.8	23.1	9.6	25.5	0.46	0.60	1.11	149	0.41	56.51	18.86	12.98	11.65	15.89
26	19	364.6	42.1	15.1	11.3	31.5	0.42	0.50	1.14	139	0.75	61.74	11.01	16.62	10.63	— 1.57
27	6	392.0	37.1	2.2	11.1	30.5	0.47	0.45	1.19	170	0.51	53.70	13.70	16.08	16.53	—12.15
28	7	419.3	42.4	10.7	10.1	36.8	0.45	0.31	—	172	0.94	67.41	5.31	16.04	11.25	—10.53
29	25	439.5	41.8	15.9	7.8	34.5	0.51	0.54	—	202	0.43	63.90	13.23	11.98	10.90	— 1.29
30	3	430.2	40.7	14.3	8.5	36.5	0.42	0.47	—	184	0.59	64.28	10.69	13.44	11.50	—10.62

TABLE 4

Niggli and Semenenko parameters for the rocks of the Suru formation

No.	No. of sample	si	al	c	alk	k	mg	ti	qz	c : fm	fm	A	M	C	F
1	29	81.2	17.3	43.5	5.9	0.17	0.48	3.86	—42	1.30	33.3	18.46	17.06	46.39	18.09
2	35	101.4	21.2	26.0	8.1	0.05	0.45	2.84	—31	0.58	44.7	23.28	21.92	28.48	26.31
3	36	114.5	24.8	17.2	10.0	0.23	0.46	4.77	—26	0.35	48.0	27.75	24.47	19.20	28.58
4	30	104.8	20.3	25.9	5.4	0.07	0.54	3.80	—17	0.53	48.4	21.50	27.69	27.51	23.30
5	34	108.9	20.9	23.0	6.7	0.16	0.49	3.93	—18	0.46	49.4	22.54	26.13	24.79	26.52
6	45	176.9	33.5	8.1	8.5	0.49	0.59	2.50	43	0.16	50.0	36.75	32.14	8.47	22.24
7	47	204,3	43.4	5.8	9.5	0.73	0.51	2.79	66	0.14	41.3	47.98	23.30	6.45	22.27
8	52	218.4	44.9	4.5	11.2	0.71	0.44	2.83	73	0.11	39.4	50.88	19.72	5.12	24.28
9	31	211.8	39.4	5.4	17.7	0.53	0.41	3.09	41	0.14	32.5	48.44	18.99	6.59	25.98
10	40	204.9	32.7	16.9	13.0	0.45	0.53	2.05	53	0.45	37.4	37.73	22.89	19.49	19.80
11	41	226.6	41.4	5.6	14.2	0.53	0.49	2.25	70	0.14	38.8	48.70	22.27	6.59	22.44
12	50	249.5	39.6	8.9	15.1	0.37	0.44	2.67	89	0.24	36.4	46.98	18.84	10.53	23.65
13	42	253.4	38.2	10.7	13.3	0.44	0.42	2.67	100	0.26	37.8	44.32	18.43	12.37	24.87
14	33	273.4	41.6	6.9	16.0	0.45	0.41	2.85	109	0.19	35.5	49.76	17.28	8.32	24.64
15	46	266.9	30.4	19.0	10.2	0.41	0.54	3.38	126	0.41	40.5	33.94	24.49	21.22	20.34
16	51	280.4	39.9	7.0	16.4	0.41	0.46	2.86	115	0.19	36.7	48.07	20.52	8.41	23.00
17	49	361.6	71.8	6.5	18.5	0.48	0.00	4.08	188	1.91	3.3	88.28	0.00	8.01	3.71
18	43	453.4	33.7	7.1	9.9	0.51	0.52	4.46	314	0.14	49.3	37.70	28.66	7.96	25.69

TABLE 5

Minor elements (ppm) within the rocks of the Măgura Cîinenilor formation (Cumpăna subgroup)

No.	No. of sample	Pb	Cu	Zn	Sn	Ga	Ni	Co	Cr	V	Sc	Y	Yb	Zr	Nb	La	Be	B	Ba	Sr
1	23	3	31	53	2.5	18	175	58	180	360	40	58	2.5	400	16	<30	2.0	<30	235	590
2	9	5.5	50	45	<2	15	85	70	125	640	68	60	5.4	180	<10	<30	1.4	<30	50	275
3	27	2.5	110	32	<2	11	115	70	165	530	70	38	3.7	185	<10	<30	1.4	<30	110	600
4	16	7.5	8	60	<2	16	38	42	150	460	60	48	4.4	180	<10	<30	1.7	315	245	230
5	1	3	25	<30	<2	15	42	42	100	480	51	32	3.0	105	<10	<30	1.2	<30	220	430
6	20	5	3	50	4	21	40	50	150	390	59	52	38	185	<10	<30	3.8	<30	140	140
7	13	17	38	50	3.5	21	55	22	120	190	22	40	2.6	230	11	68	4.4	40	1500	460
8	11	11	13	115	6.5	34	44	19	110	130	20	36	2.4	220	18	68	5	100	900	60
9	21	16	10	130	5.5	26	42	19	110	120	21	40	3.1	220	18	58	3.8	70	800	150
10	6938 A	29	5	<30	4	12	19	13	135	180	25	17	2.1	130	17	<30	1.3	<30	2400	290
11	28	16	50	175	5.5	20	55	17	110	140	17	28	2.0	190	<10	30	3.5	37	900	170
12	12	13	22	115	4	27	47	18	110	120	17	28	2.2	190	16	78	4.4	55	700	100
13	6938 B	14	10	75	4	17	19	19	145	170	28	20	1.8	135	<10	36	2.6	<30	500	230
14	10	7	45	34	2.5	19	44	22	110	180	22	36	2.9	300	18	40	2.2	<30	575	170
15	14	60	30	65	3.5	20	27	16	85	165	23	36	3	190	<10	30	2.1	<30	1000	320
16	22	16	27	115	4	17	46	15	90	120	16	32	2.3	250	13	40	3	30	1300	230
17	17	18	21	<30	3.5	18	36	15	65	100	17	36	3	250	<10	58	1.7	120	750	150
18	4	16	65	34	5	20	44	16	93	90	14	30	2.3	250	11	58	2.2	<30	1000	115
19	26	11	34	73	4	19	32	12.5	60	85	12.5	27	2.1	250	<10	42	2.6	<30	750	90
20	15	11	35	34	2	16	23	13	53	110	24	36	2.9	255	13	30	2.2	<30	650	210
21	18	8.5	14	55	3	17	15	8	22	65	11	33	2.5	165	10	32	1.3	<30	550	95
22	5	12	27	<30	5	20	18	9	40	60	15	42	2.6	245	11	30	2	<30	800	160
23	2	20	8	<30	2.5	17	40	14	80	80	13	36	2.8	375	16	58	3.4	<30	685	175
24	8	15	8	48	3.5	21	3	3	3.5	26	4	36	2.8	200	20	55	4.4	<30	670	180
25	24	18	10	48	9	18	8.5	3.5	11	28	4	16	1.5	110	13	30	3.2	<30	720	115
26	19	17	7.5	<30	4.5	17	6.5	3	5	23	3	25	2.8	120	<10	<30	2.2	<30	700	52
27	6	28	16	35	6	17	8.5	3	8	25	5	40	3.2	200	12	34	2.4	<30	470	52
28	7	28	11	34	6	18	3.5	2	3	13	3	55	9	190	24	32	3.2	<30	360	95
29	25	20	6	<30	5	19	3	2	4	12	2.5	35	3.4	120	17	45	3.2	<30	90	17
30	3	30	11	60	2	16	4.5	2	2.5	7	6	26	2.5	75	10	<30	2.0	<30	620	84

TABLE 6

Minor elements (ppm) within the rocks of the Suru formation

(Făgăraş subgroup)

No.	No. of sample	Pb	Cu	Zn	Sn	Ga	Ni	Co	Cr	V	Sc	Y	Yb	Zr	Nb	La	Be	B	Ba	Sr
1	29	6	130	87	3.5	16	175	28	250	150	13	22	1.3	115	14	31	<1	<30	320	565
2	35	2	70	300	2.5	12	52	42	65	220	32	27	1.2	95	<10	30	<1	<30	52	120
3	36	2	75	135	5.0	17	50	55	70	420	33	50	2.8	250	18	30	1.9	<30	260	140
4	30	<2	28	30	<2.0	15	105	58	250	500	55	38	3.0	200	10	<30	1.4	<30	95	190
5	34	7	80	230	4.0	15	70	57	100	470	43	42	2.0	250	18	<30	1.5	<30	110	320
6	45	4	30	85	4.0	17	200	32	240	110	15	27	1.9	250	<10	30	2.4	<30	580	110
7	47	3	3.5	100	3.5	17	52	19	75	110	17	34	2.8	225	<10	40	3.4	70	500	65
8	52	2	10	30	3.5	16	46	16	100	100	16	32	3.0	250	<10	30	3.2	65	850	90
9	31	16.5	10	53	3.5	21	60	28	80	110	21	47	2.6	170	<10	60	2.3	<30	720	110
10	40	20	75	<30	4.0	15	40	17	80	90	14	28	2.0	170	<10	58	3.6	65	2100	340
11	41	11	35	115	4.0	16	55	16	95	110	14	21	1.8	150	11	30	2.5	165	675	85
12	50	6.5	45	44	5.0	29	60	21	95	130	15	38	3.1	270	16	33	2.8	105	570	200
13	42	3	22	85	3.5	14	55	19	85	100	15	42	3.4	340	11	58	3.5	180	700	150
14	33	9	46	90	4.5	20	42	16	87	110	17	29	2.0	170	<10	36	1.6	100	1150	95
15	46	8	28	<30	2.5	12	52	16	115	70	14	24	1.9	300	<10	30	1.9	175	600	270
16	51	4	12	68	6.0	20	40	14	73	100	14	32	3.1	215	15	39	1.7	115	785	240
17	49	125	30	36	6.0	28	9.5	3	140	160	10	10	2.4	185	11	<30	1.5	270	1500	<1000
18	43	3	5	40	2.5	10	26	75	48	48	16	36	3.5	<1000	16	40	2.4	225	350	75

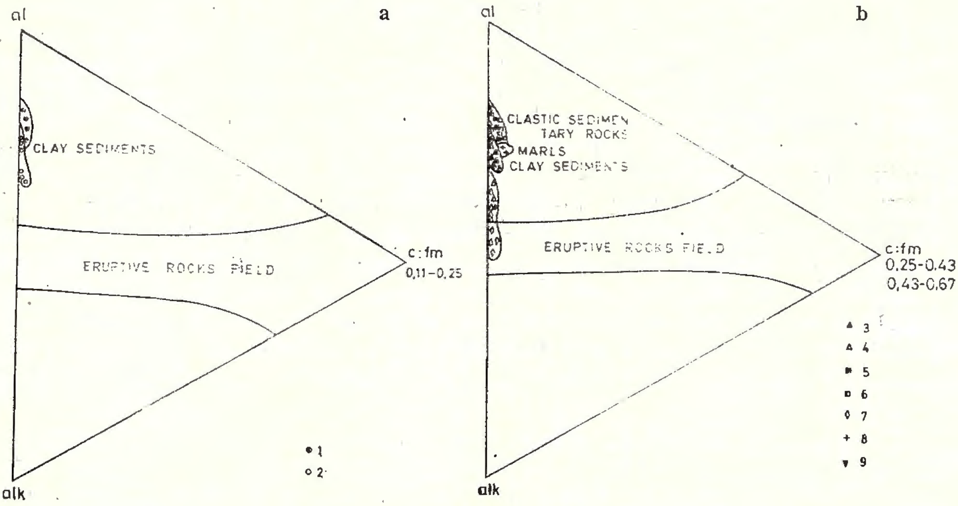
In the Niggli diagram (Fig. a) we notice that micaschists are in the second section (*c : fm*=0.11-0.25) within the field of sedimentary rocks, in distinct domains for the Măgura Cîinenilor and Suru formations. Both domains of the two types of micaschists are along the neighbourhood of the *al-alk* line, showing poor femic minerals and a lot of alumosilicating minerals. Pellitic character of premetamorphic sediments is more obvious for the Suru micaschists which are placed near the *al* corner. This micaschists differentiation on domains, would suggest various conditions of sedimentation, so the two formations could have overlaid in various environments. In Figure b, gathering II and III Niggli sections, we designed all types of rocks in the Central Făgăraș and so we notice separation of some domains along the neighbourhood of the *al-alk* line but bearing a various length and special situation on types of rocks both in the case of paragneisses and on formations.

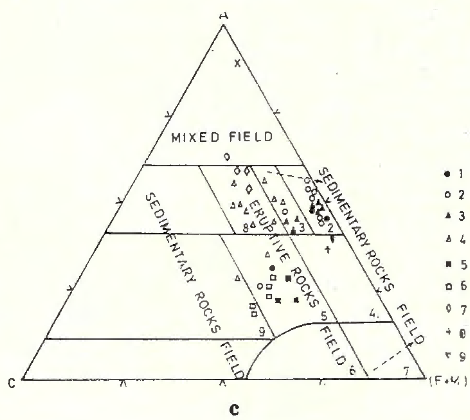
In the Semenenko diagram (Fig. c), we notice a larger distribution of all types of rocks within different classes and fields. So, micaschists of the Măgura Cîinenilor formation are framed in section 2 and 3 from the field of sedimentary rocks, while the Suru micaschists are gathered in section 2 near A-(F+M) side being placed in isochemical aluminosilicating series. Măgura Cîinenilor paragneisses overlie the field of sedimentary rocks (section 2 and 3) which is placed to the right of the diagram, on the field of eruptive rocks (section 5 and 8) and on the field of sedimentary rocks which is placed to the left of the diagram (section 9), while Suru paragneisses are framed only in section 2 and 3. This comprehensive distribution of paragneisses, as well as of amphibolites must be seen cautiously, it being not verified by Niggli diagram.

In order to verify nonconcordances between the rocks within Niggly tetrahedron and Semenenko diagram, we did a ternary diagram of CaO-K_2O-NaO variation (Fig. d) and a binary one of K_2O/Na_2O correlation (Fig. e).

In Figure d, we clearly notice both a position differentiation and a variation of oxides for the two formations. So, for the Suru formation, we point relatively constant content of Na_2O in relation with variations on CaO-K_2O line, while for the Măgura Cîinenilor formation, this content has a larger variation. Average line of contents for the Măgura Cîinenilor formation occupies an almost central position in the diagram, with flexurings to the left, while at the Suru formation, it is close to the right line and starts from CaO corner up to K_2O-Na_2O line. Values dispersion round the average line of the contents at the Măgura Cîinenilor formation is bigger than that at the Suru formation. Amphibolites behaviour also indicates some differences between the two formations.

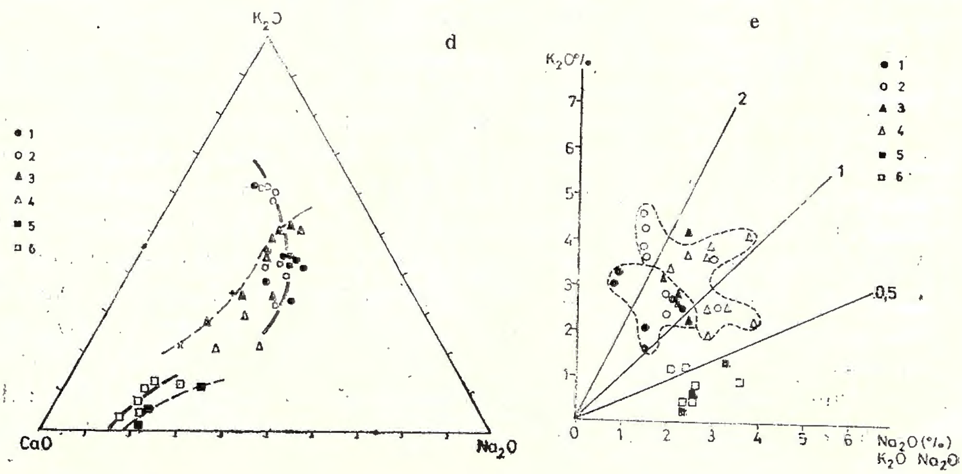
The projection of percentage values for the K_2O and Na_2O oxides on binary diagram in Figure e points the situation of the two for-





Graphical representations of metamorphics major chemistry from the Capra Valley : a) Niggli tetrahedron (section 2) ; b) Niggli tetrahedron (sections 2 and 3) ; c) Semenenko A — C — (F + K) ; diagram ; d) CaO-K_2O-Na_2O diagram ; e) K_2O : Na_2O diagram.

1, Suru micaschists ; 2, Măgura Cîinenilor micaschists ; 3, Suru paragneisses ; 4, Măgura Cîinenilor paragneisses ; 5, Suru amphibolites; 6, Măgura Cîinenilor amphibolites ; 7, migmatites ; 8, limy schists ; 9, graphitic schists.



mations micaschists and paragneisses in different fields. Amphibolites have an ambiguous behaviour and cannot be differentiated. At Suru formation, micaschists and paragneisses contain less alkalis, have a more potassic differentiated character on types of rocks, while at the Măgura Cîinenilor formation, alkalis content is higher, variation gamma of the two oxides is bigger and K_2O: Na_2O relation is closer to the unit.

We consider that d and e diagrams confirm ideas resulted from parameters projection within the Niggli tetrahedron.

Discussions about the Contents and Distribution of Minor Elements

From the list of analysed elements, some (Ba, Sr, Ni, Cr, V, Co, Pb, Ga) have to be geochemically discussed owing to their special significances, other (Zr, Sn, Cu, Zn, Be) are not so important, Mo and B have no geochemical significance for metamorphic rocks, while Nb could be interesting especially for the migmatites.

Comparing the contents of minor elements (Pl. II) on types of rocks from the two formations, we conclude the following :

— geochemical individualization of migmatites through the increase of Pb and Nb contents and obvious decrease of Ni, Cr, Co, V, Sc, Ba, Sr, Cu, Zn. Ga is constant at the level of micaschists and paragneisses ;

— contents decreases of minor elements at migmatites (rocks which take part a lot to the composition of the Măgura Cîinenilor formation and generally in the Cumpăna subgroup) make them increase in the Suru formation, which has no migmatites ;

— at micaschists and paragneisses, the Măgura Cîinenilor formation has higher contents of Pb in comparison with the Suru, while Ni, Cr, V, Co situation is reverse. Sc, Sr and Ba quantity is higher in the Măgura Cîinenilor formation than in the Suru ;

— at amphibolites, Cu and Zn quantities are bigger in the Suru formation than in the Măgura Cîinenilor,. Sc and Sr situation being reverse.

Discussions about Migmatites Chemistry. As we mentioned before, from geochemical point of view, migmatites differ from other types of rocks in the Măgura Cîinenilor formation, especially because they take part a little here, near the detection limit of Ni, Co, Cr, V, Sr and through obvious decreases of contents of Cu, Zn, Ba and Sc in comparison with metamorphics where they are housed. This fact stresses the intervention in their generation of some fluids from partial geochemical mobilization of the most mobile substances from geochemical point of view within anatexic processes which took place in various places from those where are situated today migmatites and in restites remain minor elements which contain a few migmatites.

Ga, La, Y, Yb, Nb, Zr, Be, B have contents almost similar to clarks as we expected to, in migmatites they being more related to feldspar network. But, Pb, Sn and Nb increase up to the other minor elements (Pb being even double) showing as alkalis, a coming from zones where took place anatexic processes. Regarding the penetration of big quantities of geochemically mobile substance of various composition in comparison with the host rock's, in some petrographic structures we have to accept that migmatization was favoured by shearings because only an intense deformation could create access ways for migmatizing fluids.

Retromorphism Implications in the Suru Formation Chemistry. Field and microscopic observations indicate a powerful regional retromorphism but a non-homogeneous one which took place in the Suru formation. Certainly this process supposes that prior to the Hercynian the Suru formation was found near the relief or was covered by sediments because only this fact explains the possibility of H_2O or O infiltration which facilitated hydration and oxidation reactions.

In comparison with the Măgura Cîinenilor formation, in the Suru one, we notice a H_2O^+ increase on types of common rocks. So, at micaschists and paragneisses, H_2O^+ content is double and at amphibolites is five times bigger in the Suru formation.

At the same time, an important index of retromorphism is oxidation, oxidation grade increasing a lot at the Suru formation in comparison with the Măgura Cîinenilor one. So, at micaschists, oxidation grade increases from 0.18 to 0.25 (Fe_2O_3 and FeO values represent arithmetic averages for the types of rocks which we took into consideration in the two formations).

$$\omega \text{ Măgura Cîinenilor micaschists} = \frac{2Fe_2O_3}{2Fe_2O_3 + FeO} = \frac{1.32}{7.19} = 0.18$$

$$\omega \text{ Suru micaschists} = \frac{2Fe_2O_3}{2Fe_2O_3 + FeO} = \frac{1.86}{7.42} = 0.25$$

At paragneisses as well as micaschists, curve for Fe_2O_3 (Fig.) has a descending way and a smaller content in the Măgura Cîinenilor formation, while in the Suru formation the way is ascending and Fe_2O_3 content increases and so oxidation grade increases from 0.17 to 0.33.

$$\omega \text{ Măgura Cîinenilor paragneisses} = \frac{2Fe_2O_3}{2Fe_2O_3 + FeO} = \frac{0.80}{4.60} = 0.17$$

$$\omega \text{ Suru paragneisses} = \frac{2Fe_2O_3}{2Fe_2O_3 + FeO} = \frac{2.58}{7.68} = 0.33$$

At the same time, in the Suru formation amphibolites, Fe_2O_3 increases while FeO is quasiconstant, causing the increase of oxidation grade from 0.24 to 0.47.

$$\omega \text{ Măgura Cîinenilor amphibolites} = \frac{2Fe_2O_3}{2Fe_2O_3 + FeO} = \frac{3.08}{12.60} = 0.24$$

$$\omega \text{ Suru amphibolites} = \frac{2Fe_2O_3}{2Fe_2O_3 + FeO} = \frac{7.58}{16.39} = 0.47$$

Fe_2O_3 situation indicates an obvious increase (becoming double) of oxidation grade from the Măgura Cîinenilor formation to that of Suru.

Minor elements are less implied in the retromorphism as we see in Plate II. We notice a certain richness at the Suru Formation only for boron which we can explain only because watery descending solutions stimulated boron from sediments, after the retromorphism.

Conclusions

Starting from the fact that regional metamorphism is generally isochemical, excepting migmatizations and granitizations, using chemical and spectral analyses and their graphics, we wished to discuss the following petrochemical aspects :

a) if there are or are not chemical differences between the Măgura Cîinenilor formation, which belongs to the Cumpăna subgroup and the Suru formation which belongs to the Făgăraș subgroup ;

b) chemistry variation on types of common rocks in the two formations;

c) part of major and minor chemistry in petrogenesis ;

d) geochemical significances of migmatites chemistry ;

e) retromorphism influence on chemistry.

a) Regarding the first problem, data from oxides contents related to silica indicate differentiations between the two formations, as concerns SiO_2, CaO, alkalis, Fe_2O_3, MgO and MnO. Differentiated behaviour of MgO and relation B : Ga suggest the fact that premetamorphic sediments of the two formations have been overlied in various salinity environments and therefore, in various basins.

b) Concerning the chemistry of common rocks (micaschists, paragneisses, amphibolites) of the two formations, we notice differences in SiO_2, Al_2O_3, FeO and CaO contents on types of rocks, while for TiO_2, MnO, P_2O_5 (partly at alkalis), contents are similar. The situation is different for the samples from the zone of tectonic contact of the two formations (Pl. III). Lithology of premetamorphic sediments explains enough the chemistry variations, certainly among certain limits, at the same type of metamorphics.

c) Concerning the chemistry part in metamorphics petrogenesis in the Capra basin, we shall say only that the rocks of the two formations come from distinct premetamorphic marine basins.

d) Low amounts of most of minor elements in migmatites indicate the fact that in this type of rocks are implied some fluids from partial geochemical mobilization of the most mobile substances within anatexic processes and remain in restites minor elements which have small contents in migmatites.

e) Retromorphism which affected the Suru formation is chemically recognized by hydration processes (obvious increase of H_2O^+) and oxidation ones (increase of Fe_2O_3 up to double and also of oxidation grade).

Anomalic contents in the samples near tectonic contact between the two formations, reflect a more intense supergene circulation favored by this contact.

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CONSIDERAŢII PETROCHIMICE ASUPRA METAMORFITELOR DIN BAZINUL VĂII CAPRA (MUNŢII FĂGĂRAŞ)

(Rezumat)

Bazinul văii Capra se suprapune peste două formaţiuni geologice : de Măgura Cîinenilor şi de Suru.

Un număr de 48 de probe recoltate din rocile celor două formaţiuni (micaşisturi, paragnaise, amfibolite, migmatite, şisturi cuarţitice grafitoase şi şisturi carbonatice), analizate atît chimic cît şi spectral, ne-au permis o discuţie cu caracter petrochimic, pe formaţiuni, precum şi o comparare a principalelor aspecte petrochimice ale celor două formaţiuni.

Astfel, din compararea conţinuturilor oxizilor pe tipuri de roci din cele două formaţiuni, în funcţie de silice, se constată : asemănări în ceea ce priveşte participarea TiO_2, Na_2O, CaO, MgO, FeO şi Al_2O_3 pentru rocile pe care le posedă în comun (micaşisturi, paragnaise, amfibolite) ; o pondere mai mare a K_2O în micaşisturile şi paragnaisele formaţiunii de Măgura Cîinenilor ; o îmbogăţire în Fe_2O_3 în rocile formaţiunii de Suru. Pe scara silicei amfibolitele formaţiunii de Suru se situează la conţinuturile cele mai scăzute, iar paragnaisele formaţiunii de Măgura Cîinenilor la conţinuturile cele mai ridicate. Ceea ce deosebeşte însă fundamental formaţiunea de Măgura Cîinenilor de formaţiunea de Suru este prezenţa migmatitelor în prima, roci ce se

detașează net din punct de vedere geochimic de celelalte roci cuarțo-feldspatice, căci pe un fond de creștere a silicei, comparativ cu paragnaisele, are loc o creștere a alcaliilor și o scădere evidentă a tuturor celorlalți oxizi.

În ceea ce privește conținuturile elementelor minore din compararea lor pe tipuri de roci aparținînd la cele două formațiuni rezultă :

— individualizarea geochimică a migmatitelor prin creșterea conținuturilor de Pb și Nb și scăderea evidentă a Ni, Cr, Co, V, Sc, Ba, Sr, Cu, Zn ;

— la micașisturi și paragnaise Pb, Sc, Sr și Ba au conținuturi mai ridicate în formațiunea de Măgura Cîinenilor comparativ cu cea de Suru, pe cînd situația Ni, Cr, V, Co este inversă. Ga este constant în ambele formațiuni ;

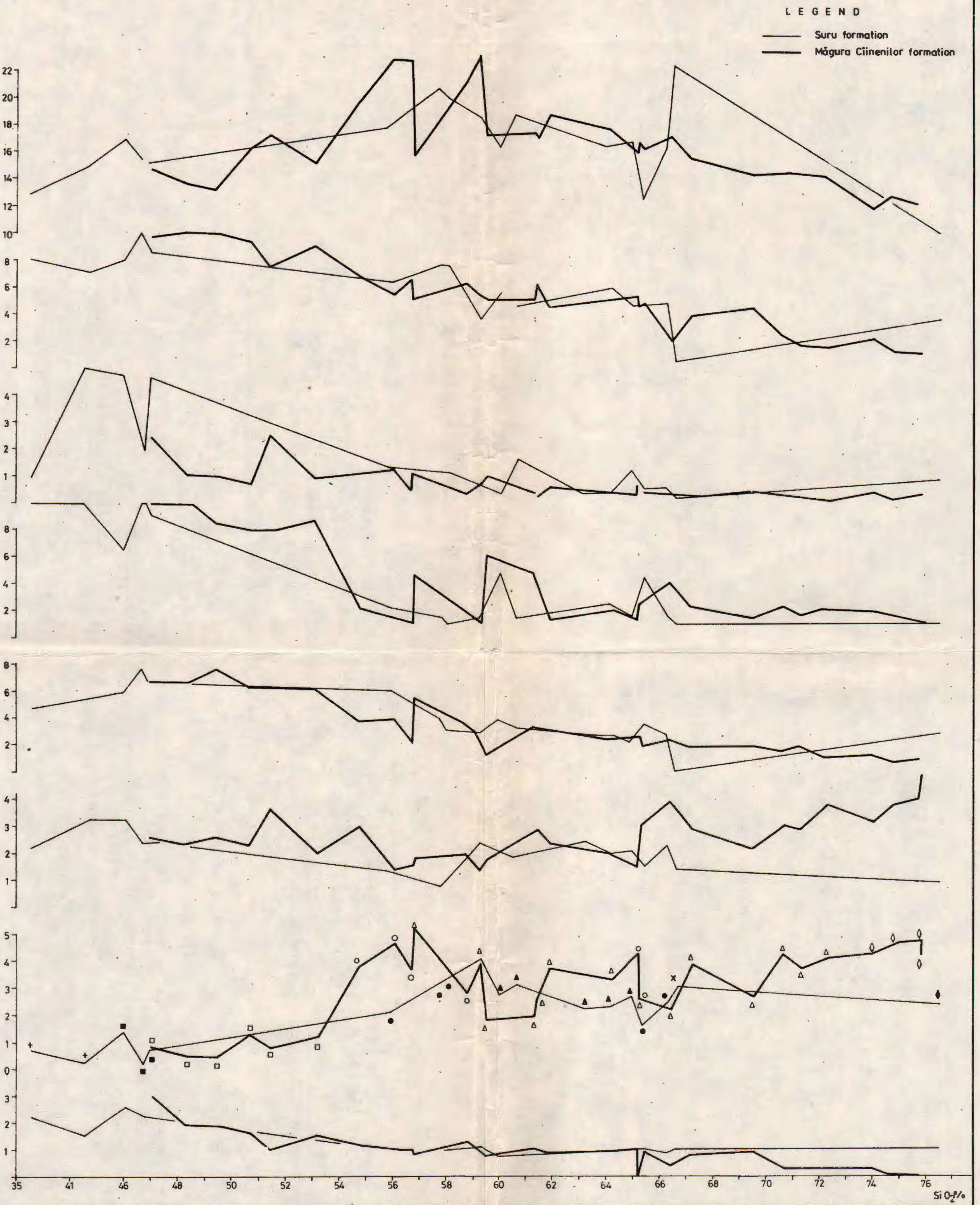
— la amfibolite Cu și Zn sînt mai mari în formațiunea de Suru decît în cea de Măgura Cîinenilor, pe cînd situația Sc și Sr este inversă.

Participarea extrem de redusă a majorității elementelor minore în migmatite indică intervenția în generarea acestui tip de roci a unor fluide provenite prin mobilizarea geochimică parțială a celor mai mobile substanțe în procese de tip anatectic și rămînerea în restite a elementelor minore care au conținuturi scăzute în migmatite.

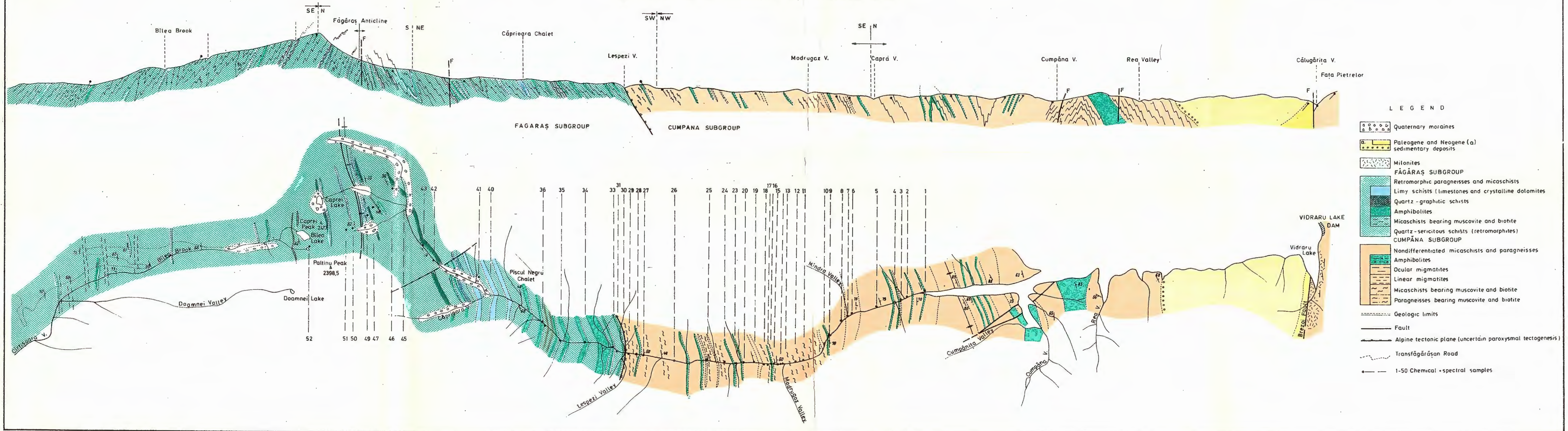
Retromorfismul, care a afectat numai formațiunea de Suru la scară regională, se recunoaște chimic prin procesele de hidratare (creșterea netă a H_2O) și oxidare (creșterea pînă la dublare a Fe_2O_3 și, implicit, a gradului de oxidare).

Conținuturile anomale din probele provenite din apropierea contactului tectonic dintre formațiunea de Măgura Cîinenilor și cea de Suru reflectă o circulație mai intensă supergenă favorizată de acest contact.

DISTRIBUTION OF MAIN OXIDES IN RELATION WITH SiO_2 WITHIN THE CAPRA VALLEY METAMORPHICS (FĂGĂRAŞ M.TS)



GEOLOGICAL PROFILES THROUGH THE CENTRAL FĂGĂRAȘ BETWEEN BÎLEA CASCADĂ and VIDRARU DAM



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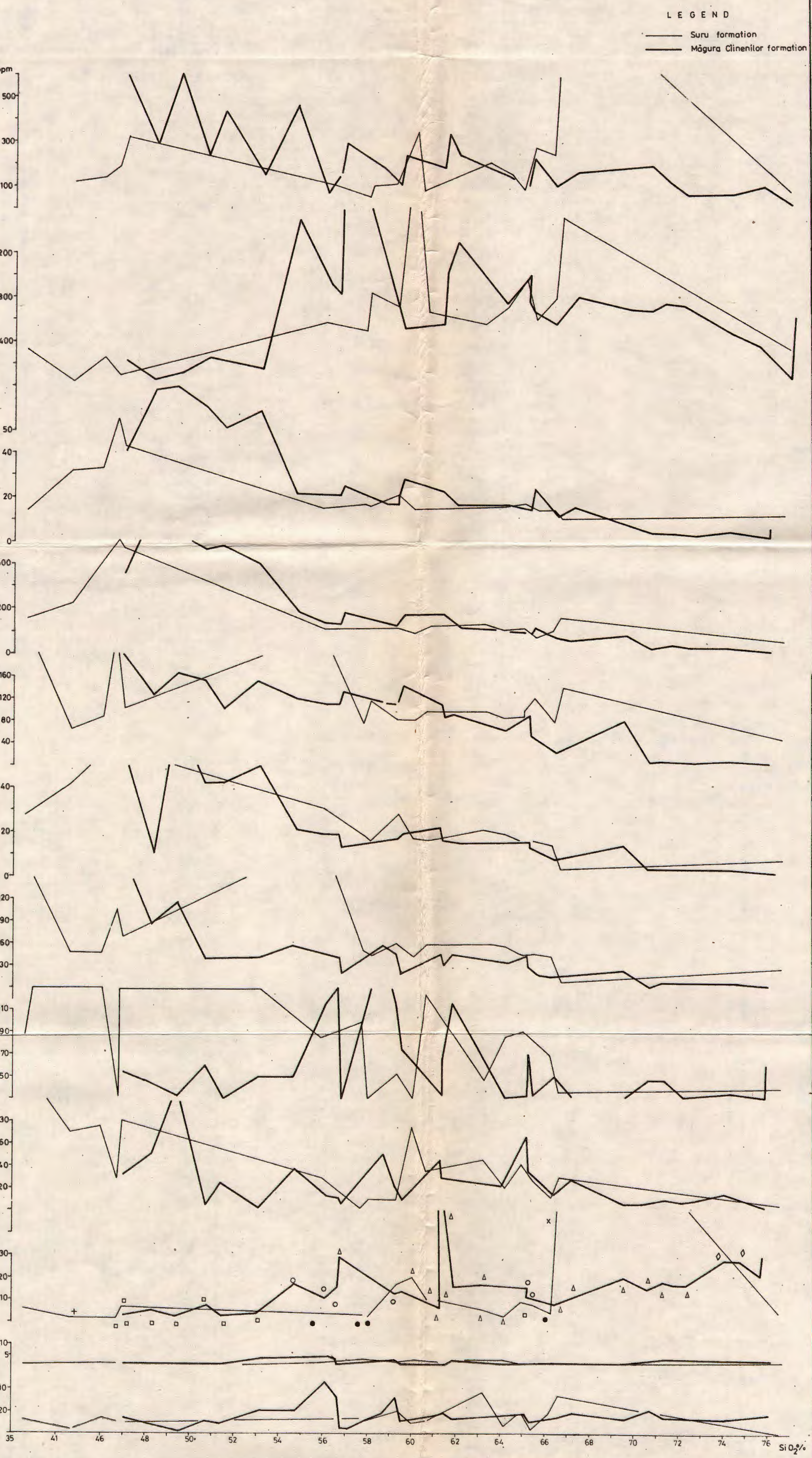
DISTRIBUTION OF MINOR ELEMENTS IN RELATION WITH SiO_2 WITHIN THE CAPRA VALLEY METAMORPHICS (FĂGĂRAȘ M.TS)



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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

GEOCHEMICAL DATA ON THE DIFFERENT ORIGIN OF TWO PHASES OF SYENITIC INTRUSION IN THE DITRĂU ALKALINE MASSIF [1]

BY

GYULA JAKAB [2]

Kyenite. Intrusion. Alkali magma. Petrochemistry. Absolute age. K/Ar method. Rare earths. Intrusive phases. Fluorine. Chlorine. East Carpathians — Crystalline-Mesozoic Zone — Giurgeu Mountains.

Abstract

Recent researches on the Ditrău alkaline massif proved, on the basis of petrochemical, geochemical and mineralogical criteria, the existence of two main phases of syenitic intrusion with a different origin: the 1st phase has a sialic character and the 2nd phase a simatic one.

Résumé

Données sur l'origine différente des deux phase d'intrusion siénitique du massif alcalin de Ditrău. Les recherches effectuées ces dernières années sur le massif de Ditrău ont montré, sur base des critères pétrochimiques, géochimiques, minéralogiques d'âge, l'existence de deux phases majeures d'intrusion siénitique et leur origine différente.

Contributions to the petrographic and petrogenetic knowledge of the Ditrău alkaline massif were brought by several authors among whom mention should be made by Streckeisen (1938, 1952-1954, 1960), Ianovici (1938), Codarcea et al. (1957), Anastasiu, Constantinescu (1979), Zincenco, Vlad (1978), Jakab (1982). In the course of time several petro-

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genetic models were presented, sometimes very different from one another. Streckeisen (1960) was the first researcher who pointed out two phases of intrusion. He admitted the existence of an external ring of red syenites and of a central stock of white nepheline syenites. That hypothesis was subsequently taken over by Zincenco and Jakab, respectively, with differences as regards the genetic interpretation.

Anastasiu and Constantinescu (1979) considered that the Ditrău alkaline massif is the result of the emplacement in adjacent zones of two magmas of different origins : a basic parental magma from a deep-seated centre, representing the northern part of the massif, and a lithomagma resulting from the partial fusion of silica-poor lithological associations in a crustal centre, representing the southern part of the massif.

It is considered that a thorough mineralogical, petrochemical and geochemical study of the two mentioned complexes — the external ring and the central stock (acc. to Streckeisen and Zincenco) — and the first and second main phase of syenitic intrusion (acc. to the present author) represent enough arguments for the mentioned concept.

A first aspect is given by the index $\tau = Al_2O_3 - Na_2O/TiO_2$ (Gottini, 1969) that, plotted on a rectangular diagram according to SiO_2 (Fig. 1 a, b), shows proof of both origin of the two phases and of the clear difference between them.

In our opinion the first phase of syenitic intrusion consists of several vein subphases, as follows : red alkali-feldspar syenites, white porphyry microsyenites, aplites and bostonites ; the second phase includes only the tinguaitic subphase.

The two diagrams point out their different origin. Syenites of the first phase and its vein subphases — granitoid-like rocks in the marginal zones — have a sialic character, whereas syenites of the second phase and tinguaites mostly display a simatic character with slight sialic tendencies. The sialic tendency is probably due to the hybridization phenomena with magmas of the first phase of syenitic intrusion. In fact the intrusion of foid syenites (2nd phase) was accompanied by a series of volatiles and alkalic solutions determining the assimilation of rocks intruded by the magma. In these circumstances the contacts between them disappeared in most of the cases so that it is difficult to establish where a complex begins and where it ends. For this reason several researchers still consider it a single intrusion.

Arguments in favour of the existence of two major phases of syenitic intrusion are also given by the K/Ar datings that emphasize obvious differences of age. For the first phase the average value determined on biotite is of about 148 m.y. and for the second one of 134 m.y. (Mînzatu et al., 1982 ; Jakab et al., 1982).

Mineralogically there are also clear differences between the rocks of the two phases of syenitic intrusion. The appearance of alkali amphiboles and of egyrine in contact zones is characteristic of the rocks of the first phase and the titaniferous amphiboles and egyrinaugite are typical of the second phase of intrusion. In case of the rocks of the first phase the alteration of nepheline into liebnerite has a general character which may be due to autometamorphism phenomena ; in case

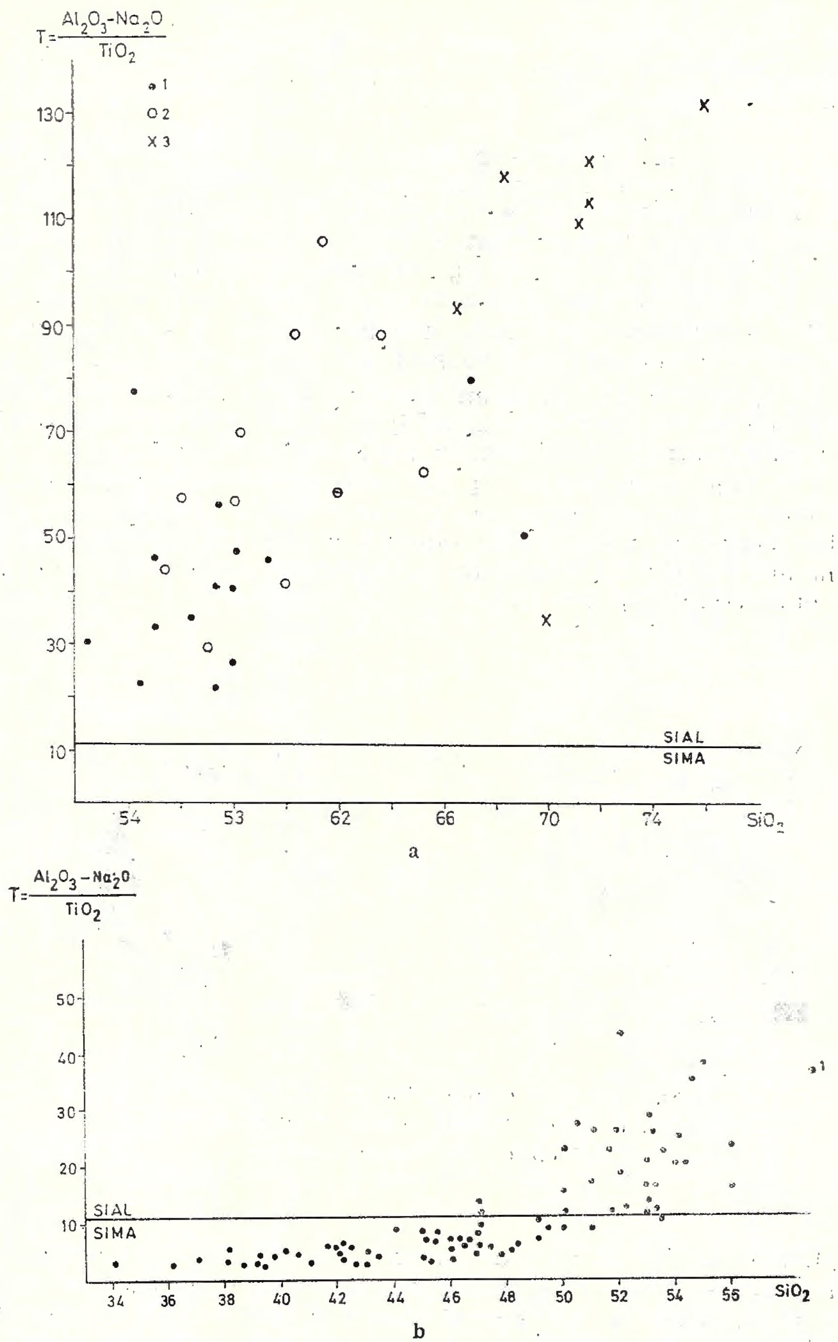


Fig. 1. — a) τ index (Gottini) for the 1st syenitic phase. 1, red syenites ; 2, porphyric microsyenites ; 3, granitoids.
b) τ index (Gottini) for the 2nd syenitic phase. 1, white syenites + tinguaites.

of the rocks of the second phase nepheline grades into analcime and sericite. These latter transformations occur on circulation zones of the pneumatolitic solutions and do not have a general character (Jakab, 1982 a).

Therefore, in the rocks belonging to the first phase of syenitic intrusion the transformations are due to autometamorphism phenomena, whereas in case of the rocks of the second phase they are due to pneumatolitic processes. That is why in foidic rocks of the second phase specific minerals occur, e.g. sodalite, cancrinite, analcime, pyrochlore, etc., which are not found in the rocks of the first phase.

The geochemical features of the two phases of syenitic intrusion bring further arguments in favour of their different origin.

Thus, thorium and uranium concentrate preferentially in different zones of the massif (Gohn et al., 1973). Uranium concentrates especially in the central zone and thorium in the marginal zone of contact.

The local superposition of the thorium anomalies over the uranium ones in marginal zones are probably due to the existence of the satellite bodies of white foidic syenites within the red syenites from the margin. We shall illustrate the arrangement of these anomalies after Gohn et al. (1973) (Fig. 2 a, b).

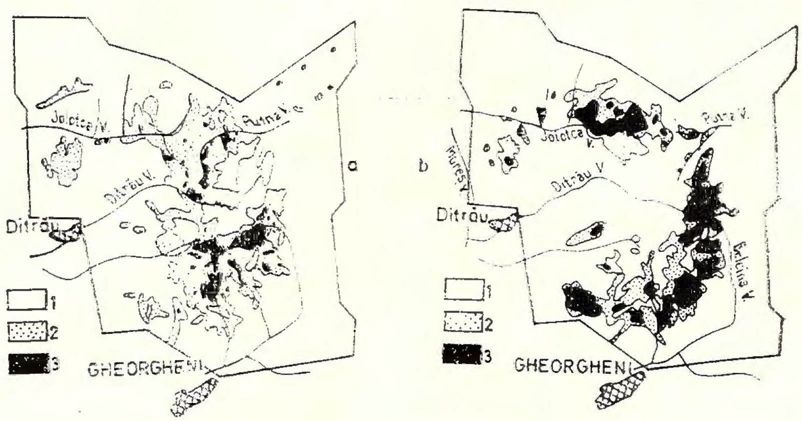


Fig. 2. — a) Map of the uranic component.
1, 3-6 imp/s ; 2, 6-15 imp/s ; 3, 15-24 imp/s.
b) Map of the thoric component.
1, 3-21 imp/s ; 2, 21-27 imp/s ; 3, 27-60 imp/s.

Likewise, the chlor and fluorine concentrate preferentially on the two zones. Fluorine is characteristic of the first phase of syenitic intrusion and chlor for the second one, as it results from the data from the relevant literature — fluor concentration mainly in more acid rocks and chlor concentration in more basic rocks. Even if the two phases are not similar in petrographic respect, their different origins can explain the different concentration of the two halogens.

Fluorine concentration in the petrographic association of the first phase is indicated by the fluorine-bearing minerals : amphiboles, micas (muscovite, biotite, lepidolite) and especially calcic fluoride (Jakab, 1981) and fluorapatite. In contrast with these mineralogical varieties the petrographic association of the second phase is characterized by chlor-bearing minerals : scapolites and sodalite. However, the lack of fluoride in this phase is the most important aspect. Rankama and Sahama (1970) emphasized the relatively intense fluor concentration in nepheline syenites and consequently its deficiency in the second phase of intrusion is an abnormal phenomenon proving its simatic origin.

The nepheline transformation into two different products within the two phases (liebnerite in the first phase and analcime in the second phase) might be also due to the fluor and chlor character, respectively, of the two complexes.

As regards barium and strontium, the ratio is small in rocks of the second phase and much higher in rocks of the first phase. Likewise, the Rb/Sr ratio is relatively small in rocks of the second phase and in the basic and ultramafic rocks at Jolotca (0.04-0.12 and 0.01-0.07, respectively) and is higher (0.52-1.38) in rocks of the first phase. Obviously these differences show proof of their different provenance. The Sr contents are clearly higher according to the deep-seated origin of the foidic syenites in the centre. The high content of strontium (acc. to Sorensen, 1974) points out that the rocks are

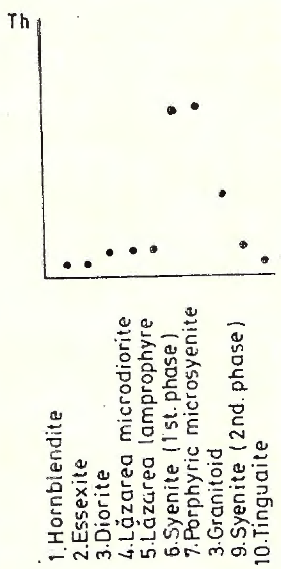
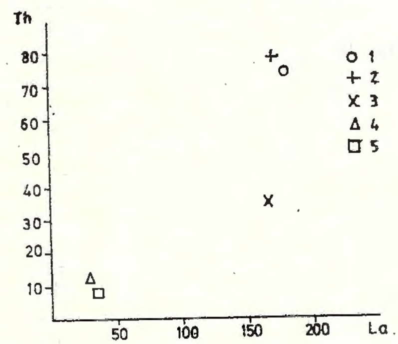


Fig. 3. — Variation of Th content in the Ditrău massif rocks

Fig. 4. — Th/La diagram. 1, syenites of the 1st phase ; 2, porphyric microsyenite ; 3, granitoid ; 4, syenite of the 2nd phase ; 5, tinguaite.



crystallization products resulting from residual meltings, and the low content indicates palingenesis products.

Thorium contents (Fig. 3) and Th-La (Fig. 4) show the same differentiations between the two phases of intrusion.

All the differentiated geochemical features of the two complexes are supported by the mutual relationships between lantanides. For the first phase the mutual relationship of the lantanides is Ce > La > Nd > > Yb > Sm > Dy[3]. This relationship is also maintained in case of granitoidic rocks and of the veins of aplites and microsyenite porphyry. After Balaşov (1976) this relationship is specific to acid, alkaline and intermediary rocks.

Central foidic syenites (second phase) have the mutual relationship Nd>Ce>La>Sm>Yb>Dy identical to that of the basic and ultramafic rocks of the Ditrău massif and to that given for meteorites and particularly for some basic and ultramafic rocks (Balaşov, 1976). All this demonstrates the similarity of syenites of the second phase with basic and ultramafic rocks, a hypothesis already presented by Jakab (1982).

The amount of REE differs also for the two complexes. For rocks of the first phase rare earths show values varying from 442.2 to 485.8 ppm and for rocks of the second phase these contents vary from 145.8 to 190.9 ppm.

As the major magmatic phases of the Ditrău massif are represented by the basic and ultramafic complex, the marginal red syenites and the central white foidic syenites represent well individualized, independent intrusions as indicated by the study of the Nb/Ta ratio, as well. Ta is found preponderently in the first crystals, the Nb/Ta ratio increasing from the first crystals to the postmagmatic minerals (Vlasov, 1968). The three main magmatic phases and the values of the Nb/Ta ratio for some minerals specific to each phase are given below:

— basic-ultramafic complex

sphene 1.4; apatite 2.7; hornblende 5.2; ilmenite 7.6; epidote ≫.

— marginal red syenites complex (1st phase)

microcline 12; liebnerite 24; garnet 30; magnesioriebeckite 34.9; vermiculite 40.7

— central white syenites complex (2nd phase)

zirconium 1.2; egyrin 6.4; cancrinite 8.2; nepheline 30; biotite 38; sodalite 41.7; albite 43; natrolite 0.

— minerals from mineralization veins

monazite ≫; orthite ≫; fluoride ≫; xenotime ≫; carbonate ≫; lepidolite ≫; molybdenite ≫.

All the mentioned values emphasize an independent geochemical evolution within each phase of intrusion of Ta decrease and Nb increase in the order of the minerals crystallization.

Another feature which differentiates the two syenitic intrusions is given by zirconium. Thus zirconium crystals in the two complexes differ in all respects. If only one syenitic magmatic phase existed (as several researchers consider), Zr crystals should be broadly identical. But there are differences both as regards the size of the crystals, the environment and abundance, and their chemistry. The table below shows the contents of REE, Th, Sc, Ta, Fe and U for a Zr from the southwesternmost part of the massif (1st phase) and a Zr from the central zone (2nd phase).

	La	Ce	Nd	Sm	Eu	Dy	Tb	Yb	Lu	Th	Sc	Ta	Fe	U
Zirconium 1st phase	27	—	100	55	16	475	24	971	97	8559	24	—	0.06	1245
Zirconium 2nd phase	258	27	50	181	1	240	15	638	62	1510	0.7	197	0.8	3000

The above-mentioned values and the lack of mineralizations in the rocks of the second phase (mineralizations being deposited prior to the emplacement of the central white syenites) (Jakab, 1982) prove the existence of two phases of syenitic intrusion with a different origin : the 1st phase has a sialic character and the 2nd phase a simatic one.

[3] Analyses effectuated by neutron activation. I.F.I.N.

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QUESTIONS

H. G. Kräutner : 1. Can the spatial distribution of the pegmatoid facies in the central part of the massif constitute a further element in favour of the difference between the features of the exterior level and those of the central stock ?

2. Do you think that the geochemical differences between the two associations of syenitic rocks can be explained by means of a model based on transformations subsequent to their emplacement ?

Answer : 1. To a lesser extent the spatial distribution of the pegmatoid facies in the two intrusion phases can constitute an argument in favour of the differences between the two intrusions. An example is the fact that the pegmatoid facies are much more frequent in the second phase.

2. If we admit the existence of one intrusion and the postmagmatic transformation of its exterior level we cannot explain several chemical differences, such as :

— Ti concentration mostly in the second phase as compared with the first syenitic phase ;

— chloritic and fluoric character, respectively, of the two intrusions ;

— Sr concentration in the second phase of intrusion ;

— different behaviour of the rare earth in the two complexes, a.s.o.

D. Russo-Săndulescu : How do you explain the appearance in the same area of two magmas with an entirely different origin, although both gave rise to nepheline-bearing syenites ?

Answer : The basic and ultramafic rocks represent the first manifestation of magmatism in the "Ditrău area" and, as a moment, it is superposed over the period of crust spreading, corresponding to a rift zone.

After the consolidation of the dioritic-hornblenditic meltings intruding the crust in adjacent zones, probably as a result of decompression phenomena, thermal and baric disturbances took place, which produced the fusion of some parts of the crust at great depths. The lithologic associations probably had a granitic composition. Taking into account that the rocks generated by the mentioned magmas were alkaline, at least within the outcropping area of the Ditrău Massif, we presume the existence of a flux of alkaline solutions from deeper zones, they being supplied by the mantle as a result of special processes concomitantly with a thermal flux. The mixing of these solutions with deep-seated crustal material, already mobilized due to decompression processes, gave rise to syenites and granitoids as well as to vein rocks.

The sialic character of this association could thus be explained.

The intrusion of the foidic syenites (2nd syenitic phase) took place in the central zone of the massif, occurring also as satellite bodies in marginal zones penetrating the rocks of the 1st phase.

All the geochemical and petrochemical interpretations point out that this phase is of simatic origin with some contamination phenomena, which led to changes in their chemistry.

These magmas might represent the felsic differentiates of the basic magmas with which they have clear geochemical affinities. However, in this case one should also admit the existence of deep-seated alkali solutions.

In this way the appearance of two magmas with a different origin could be explained.

DISCUSSION

D. Russo-Săndulescu : Although it is very possible that the Ditrău Massif might consist of successive intrusions, it is hardly admitted that the two intrusions — nepheline syenites — are of such different origins (sialic and simatic). One should easily admit that the two intrusions are the result of differentiations within a deeper-seated magmatic basin, therefore not at the actual level of emplacement and thus, types of rocks different in geochemical respect occurred by successive pulsations. It is not unique as such basic rocks, alternating with alkaline acid rocks, also occur in the Holbav Mesozoic volcanism (Russo-Săndulescu and Săndulescu, 1981).

The rare earths analyses, which are not changed after the metamorphic processes, represent the elements which will indicate the magma origin.

DATE ASUPRA ORIGINII DIFERITE A CELOR DOUĂ FAZE DE INTRUZIUNE SIENITICĂ ÎN MASIVUL ALCALIN DE LA DITRĂU

(Rezumat)

Existența unor faze succesive de intruziune în cadrul masivului alcalin de la Ditrău a început să aibă din ce în ce mai mulți adepți. Recunoașterea acestor faze este greoaie datorită existenței reacțiilor asimilative provocate de magmele alcaline. Din acest motiv s-au căutat elemente de petrochimie, geochimie, mineralogie etc., care să aducă dovezi în favoarea existenței a două faze majore de intruziune sienitică cu subfazele lor respective și de asemenea asupra originii acestora.

O dovadă în acest sens este adusă de indicele T (Gottini) care arată originea sialică a primei faze și simatică a celei de a doua. De asemenea determinările de vîrstă K/Ar arată diferențe clare între rocile celor două faze.

Ca elemente de geochimie care argumentează existența celor două faze aducem : caracterul toric al primei faze și uranic al celei de a doua.

De asemenea, din punct de vedere al halogenilor, prima fază este fluoriferă pe cînd cea de a doua cloriferă. Aceleași dovezi sînt aduse și de elementele Sr, Ba și Rb, între cele două faze existînd valori net deosebite.

Cel mai important aspect de geochimie este dat de relațiile mutuale între lantanide. Pentru prima fază aceste relații sînt : Ce La Nd Yb Sm Dy, pe cînd pentru faza a doua : Nd Ce La Sm Yb Dy, identică cu cea a rocilor bazice și ultrabazice din masivul Ditrău.

Asupra evoluției geochimice independente a fazelor de intruziune, date importante sînt furnizate de raportul Nb/Ta.

Dovezi mineralogice pentru existența celor două faze majore de intruziune sienitică sînt date de tipurile de amfiboli și piroxeni, transformările suferite de nefelin în cele două complexe, și existența anumitor minerale într-un complex și lipsa acestora în celălalt. Zirconul, de asemenea, oferă caracteristici mineralogice și chimice deosebite în rocile celor două faze.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

K-Ar DATING OF THE BANATITIC MAGMATITES FROM THE SOUTHERN POIANA RUSCĂ MOUNTAINS (RUSCA MONTANĂ SEDIMENTARY BASIN)[1]

BY

HANS GEORG KRÄUTNER[2], ELEONORA VÂJDEA[2], OLIVIA ROMANESCU[2]

Radiometric age. K-Ar Method. Banatitic magmatites. Cretaceous. Laramian, tectogenesis. Volcano-sedimentary formation. Southern Carpathians — Neo-cretaceous-Paleogene magmatites — Poiana Ruscă.

Abstract

K-Ar ages in accordance with geological relationships and paleontological data suggest the following timing of the banatitic magmatites from the area of the Rusca Montană sedimentary basin : volcano-sedimentary formations of the extrusive cycle, 65 ± 1 Ma (Danian) ; granodiorites of the following intrusive cycle, 64 ± 2 Ma (Danian) and younger andesites, 54 ± 2 Ma (Thanetian) ; latest lamprophyres, 43 ± 2 Ma (Lutetian).

Résumé

Des âges K-Ar pour les magmatites banatitiques de la partie méridionale des monts Poiana Ruscă (bassin sédimentaire Rusca Montană). Les données radiométriques K-Ar indiquent les âges suivants pour les produits des phases principales du magmatisme banatitique : la formation volcano-sédimentaire andésitique inférieure du bassin Rusca Montană, 65 ± 1 m.a. (Danien) ; les granitoïdes de la phase intrusive principale qui percent les produits volcano-sédimentaires, 64 ± 2 m.a. (Danien) ; les andésites de la phase filonienne ultérieure aux granitoïdes, 54 ± 2 m.a. (Thanétien) ; la phase lamprophyrique tardive, 43 ± 2 m.a.

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(Lutétien). Les âges radiométriques obtenus sont en concordance avec les relations géologiques visibles sur le terrain entre les produits des différentes phases magmatiques et les dépôts sédimentaires du bassin Rusca Montană, attribués au Crétacé supérieur et au Paléocène par des données macropaléontologiques, micropaléontologiques et palynologiques.

Geological Setting

The South Carpathian segment of the banatitic province extends over the western Poiana Ruscă Mts. In the Rusca Montană sedimentary basin, a complete sequence of the magmatic products is conserved. The relationships among volcano-sedimentary formations, intrusive bodies and sedimentary deposits are exposed. Therefore, the area is particularly proper for providing progress in the timing of the banatitic magmatic evolution.

According to the relationships between different products of the magmatic activity, an evolution with at least three cycles including the following sequence of magmatic events, was recognized (Kräutner and Kräutner, 1972, 1973, 1985) (Figs. 1, 2).

Extrusive Cycle (E)

Volcano-sedimentary deposits interlayered with continental sediments are assigned to this cycle. The whole sequence of volcanics and detrital deposits reach a maximal thickness of about 3.000-3.500 m. It overlies unconformably the Upper Cretaceous flysch formation of the Rusca Montană basin and the Precambrian and Paleozoic metamorphic basement (Fig. 2), belonging both to the Getic Nappe (Sebeș-Lotru group) and to the supragetic units (Tincova group, Poiana Ruscă crystalline). From the uppermost part of the mentioned flysch formation, J. Ion (in Kräutner et al., 1983, 1984) reported micropaleontological data indicating the Upper Maastrichtian with a possible transition to the Lower Danian. The volcano-sedimentary deposits have been assigned to the Maastrichtian by Dincă, Tocorjescu (1972), Dincă (1977) relying mainly on plant remnants. According to the paleontological data from coal bearing deposits intercalated in the mentioned volcano-sedimentary sequence, a Maastrichtian (Danian) — Paleocene age was inferred by Baltreș (1966). More recently, Antonescu et al. (1983), Antonescu (in Kräutner et al., 1983) reported from the same coal deposits seven levels with an Upper Maastrichtian microflore. Therefore, the paleontological data suggest that the volcanic activity started a short time after the flysch deposition, near the Maastrichtian-Danian boundary.

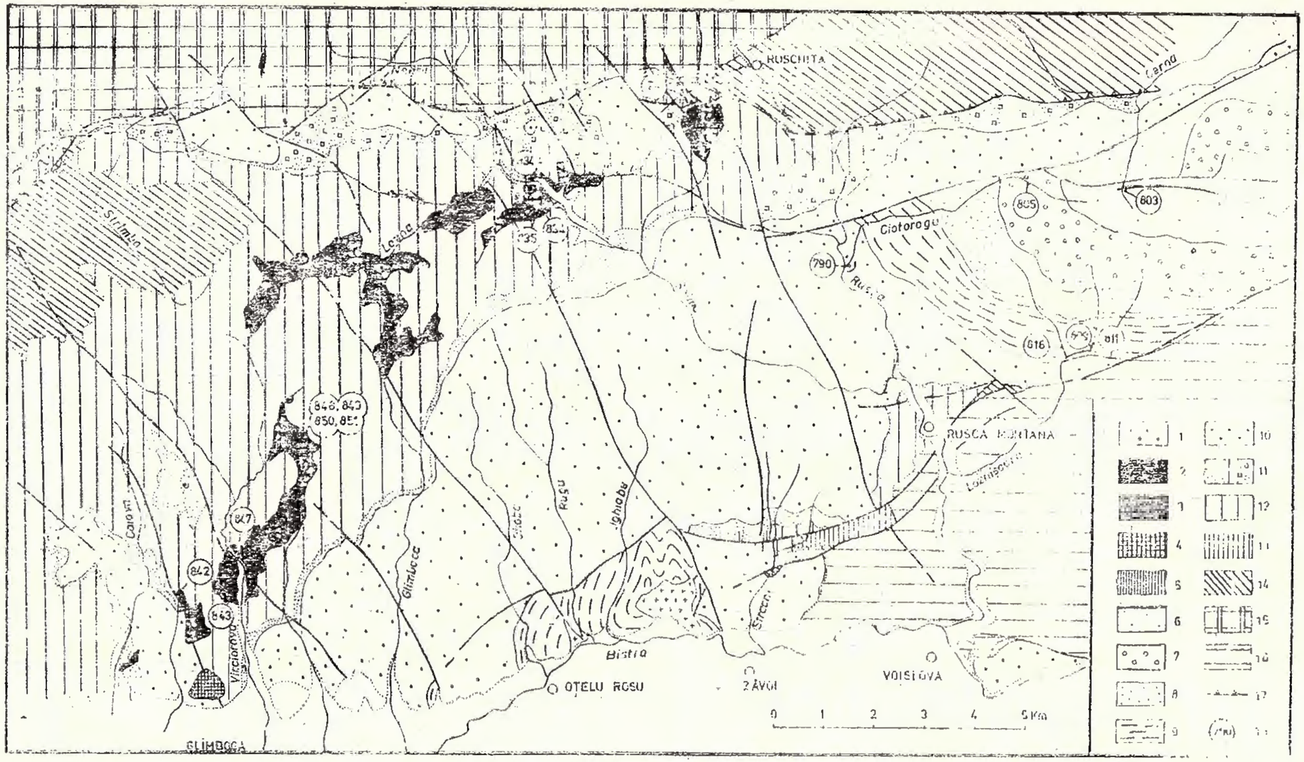

Fig. 1. — Geological map of the Rusca Montană sedimentary basin with the indication of the analysed samples (geological data according to Dincă, 1968; Kräutner, Kräutner, 1972; Kräutner, Szàsz, 1982, 1983).

Intrusive products of the Banatitic magmatism: 1, hornblende andesites and porphyric microdiorites; 2, granodiorites of the Glimboca-Ruschița pluton; 3, Andesites with hornblende and biotite; 4, hydrothermal quartzites; 5, lamprophyres (camptonites with katophorite); 6-12, Deposits of the Rusca Montană sedimentary basin: 6, Eocen (?) (Conglomerates and sandstones); 7, upper andesitic volcano-sedimentary formation; 8, sandstone formation with coals; 9, ignimbritic formation; 10, lower andesitic volcano-sedimentary formation; 11, basal conglomerates and sedimentary breccias, a) with megablocks (olistolites); 12, Cenomanian — Maastrichtian (conglomerate — sandstone formation, marly-silty formation, flysch formation). 13-16, Metamorphic basement: 13-15, Supragetic crystalline; 13, Maciova crystalline, hydrothermal quartzites, metagabbros, partly listvenites; 14, Tincova group (Proterozoic); 15, Poiana Ruscă crystalline (Silurian — Lower Carboniferous); 16, Getic crystalline — Sebeș Lotru group (Proterozoic); 17, Post-Paleocen overthrust; 18, Samples.

Three distinct phases of magmatic activity may be recognized according to a sequence of three different volcano-sedimentary formations (Fig. 2):

E. 1. *Lower andesitic volcano-sedimentary formation (Phase 1).* Rocks of mainly pyroxene andesitic and hornblende-pyroxene andesitic constitution are represented by pyroclastic deposits (agglomerates, lapilli tuffs, coarse lithic and crystal tuffs) interlayered with mixed pyroclastic-epiclastic rocks (tuffaceous conglomerates, tuffaceous sandstones, tuffaceous siltstones), epiclastic and non-volcanic detrital deposits (conglomerates, sandstones). A large extended lava flow is known as the Rusca pyroxene andesite with olivine.

E. 2. *Ignimbritic formation (Phase 2).* A sequence of 4–5 horizons of rhyodacitic, dacitic and latite-andesitic welded tuffs and breccias are intercalated in epiclastic and non-volcanic siltstones, sandstones and conglomerates. The ignimbritic formation is overlaid by a coal bearing sandstone formation. From this deposit, the mentioned palynomorphs and plant remnants have been reported.

E. 3. *Upper andesitic volcano-sedimentary formation (Phase 3).* A thick flow of breccias and hornblende-pyroxene andesites form the lower part. These rocks are overlaid by andesitic pyroclastic rocks (agglomerates and lapilli tuffs) that grade into mixed pyroclastic-epiclastic rocks and andesitic epiclastic deposits.

Intrusive Cycle (I)

Large intrusive bodies and dykes cutting the mentioned volcano-sedimentary formations are assigned to this cycle. The geological relationships between different intrusive products suggest an evolution of at least three phases.

I.1. *Microdiorites, porphyric microdiorites and andesites (Phase 1)* forming enclaves in the granodiorites of Phase 2 could be considered as the oldest intrusive rocks of the area. Similar rocks appear as independent bodies (mainly dykes) crossing either the volcano-sedimentary formations, or only the metamorphic basement without direct relationships with sedimentary or volcano-sedimentary deposits, as for example in the north of the Rusca Montană basin. Therefore, some of the dioritic-andesitic intrusions are surely younger than the volcano-sedimenary deposits, but other rocks crossing only the crystalline basement, as for example the pyroxene-diorite from Hăuzești, or the porphyric diorite from Drinova, could be synchronous or even older as the extrusive cycle.

I.2. *Large intrusive bodies consisting mainly of granodiorites with transitions to granitic and monzodioritic varieties (Phase 2)* cut the whole Upper Cretaceous sedimentary sequence and the lower volcano-sedimentary formation, generating aureolas of contact metamorphism

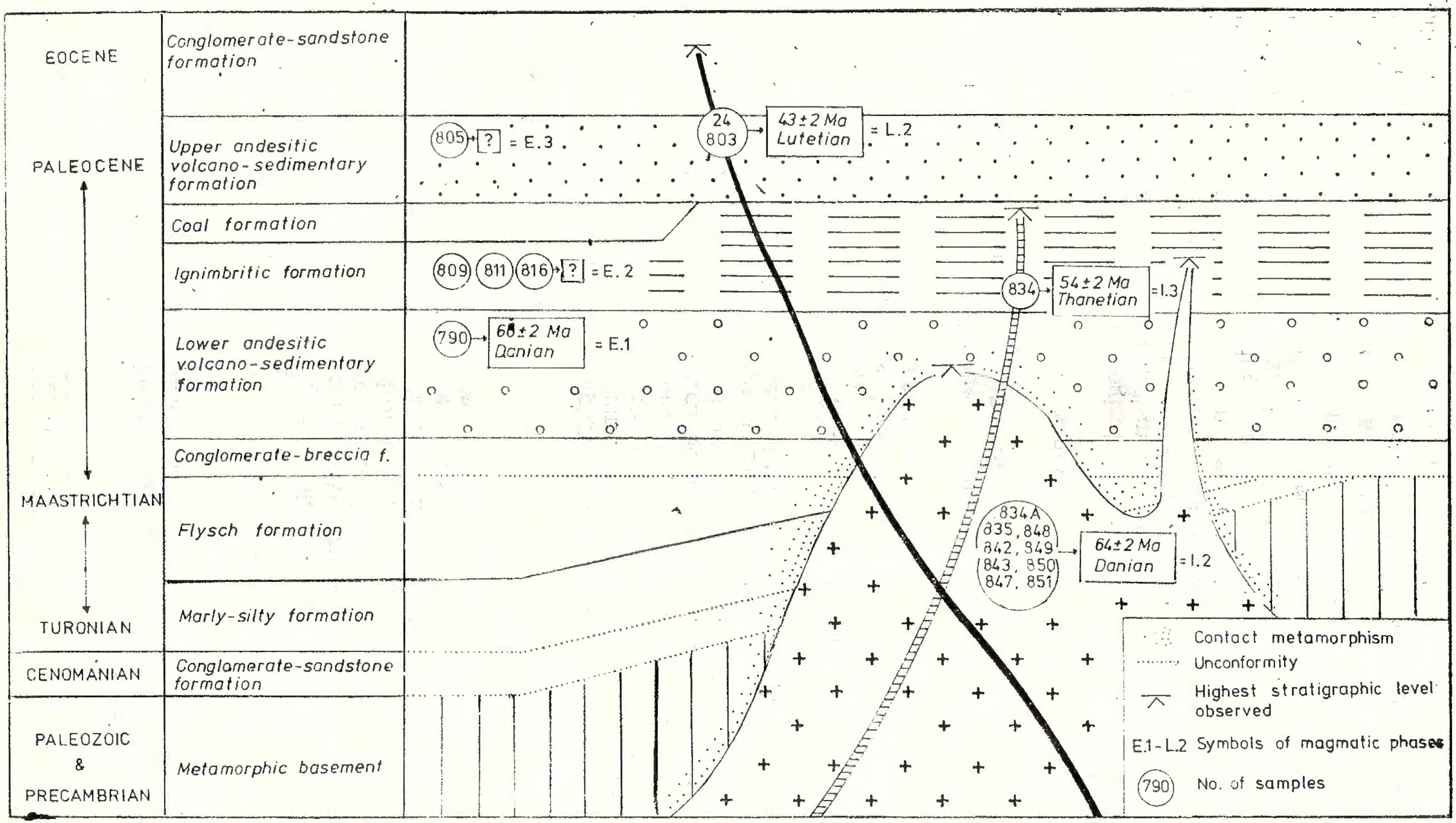

Fig. 2. — Geological relationships between different banatitic rocks and the sedimentary deposits of the Rusca Montană basin. (Stratigraphic data according to I. Ion and L. Szàsz in Kräutner et al., 1983, 1984; time scale, Odin, 1982).

with skarns and hornfelses. Apophyses of porphyric granodiorites penetrated up to the top of the ignimbritic formation. The granodiorites are cut by aplite veins, considered as the latest differentiated of this phase.

I.3. *Dykes and veins of hornblende andesites, hornblende-biotite andesites, quartz-andesites with hornblende and biotite, dacites and rhyolites (Phase 3)* cut the lower volcano-sedimentary formation, the ignimbritic formation and the intrusive granodioritic bodies. Their emplacement was successive, because dacites and rhyolites cut the andesitic dykes. An intensive hydrothermal activity was linked to the andesitic-dacitic episodes of this magmatic phase, manifested both by hydrothermal alteration of the dykes and by the formation of polymetallic sulphide ores (Ruschița, Ascuțita, Varnița, Tincova).

Lamprophyre Cycle (L)

Various types of lamprophyres, considered as the latest products related to the banatitic magmatism, are assigned to this cycle. They cut the porphyric microdiorites of Phase I.1., the granodiorites of Phase I.2., the dacites of Phase I.3 and the upper part of the sedimentary sequence of the Rusca Montană basin. This sedimentary deposits overlaid the volcano-sedimentary products of the extrusive cycle and are assigned to the Eocene. Relying on the petrographic constitution and on hydrothermal alterations, two phases are suggested :

L.1. *Calc-alkaline rocks (Phase 1)*, represented by odinites with pyroxene, pyroxene and olivine, pyroxene and hornblende ; microdiorites (malchites) ; spessartites, kersantites. All these rocks are generally affected by hydrothermal alterations.

L.2. *Rocks with alkaline tendencies (Phase 2)*, represented by camptonites with katophorite, not affected by hydrothermal alterations.

Sampling

As the mentioned geological relationships between different products of the banatitic magmatism are exposed especially in the Rusca Montană sedimentary basin, the sampling was focused on this area. Only the rocks for which relevant relationships may be directly examined, have been taken into consideration. Representative samples for the products of the following phases have been analysed (Figs. 1, 2) : extrusive phases E. 1, E. 2., E. 3. ; intrusive phases I. 2., I. 3. and lamprophyre phase L. 2. From granodiorites and camptonites, monomineral samples of biotite and katophorite respectively have been prepared by means of magnetic and microscopic separation. For the Phase I. 3., the sampling is only partly representative because not all varieties of andesites, dacites and rhyolites are suitable for K-Ar dating, owing to the fact that most of them are affected by hydrothermal alterations. Due to the same reason, calc-alkaline lamprophyres of the Phase L. 1. are missing in our sampling.

Experimental Method

Isotopic ages were determined by the K-Ar method, using isotopic dilution.

The potassium content has been measured by flame-photometry. The Argon isotopes were measured by mass spectrometry of the gas evolved from the fused samples, to which a tracer of purified $Argon^{38}$ has been added for reference. The radiogenic $Argon^{40}$ is the total $Argon^{40}$ minus the computed amount of atmospheric $Argon^{40}$, which is a function of the $Argon^{36}$ found in the sample. The isotopic composition of the Argon was measured by the statically operated AEI MS-20.

Apparent ages were calculated according to the "closed-system hypothesis" using the following constants (Steiger, Jäger, 1977) ; $\lambda\beta = 4.962 \times 10^{-10} yr^{-1}$; $\lambda\varepsilon = 0.581 \times 10^{-10} yr^{-1}$; $K^{40}/k = 1.167 \times 10^{-4}$ atom/atom ; Ar^{40}/Ar^{36} atmospheric = 295.5.

The error of the radiometric ages was calculated with the equation given by Cox and Dalrymple (1967). The error, reported as standard deviation for each age determination, is based only on laboratory data and has no geological significance.

Results

Analytical data and apparent K-Ar ages inserted in the Table 1 are ranged according to the magmatic phases and to the decrease of radiogenic Ar^{40} % (increasing contamination with atmospheric Ar).

Extrusive Cycle

E.1. A fine grained andesitic tuff from the upper part of the lower volcano-sedimentary formation (E.1) was analysed (790). The rock consists of fresh pyroxene, hornblende and plagioclase crystals and submillimetric to millimetric fragments of andesites. Only subordinately some sericitized plagioclase, opacitized hornblende and small substitution by chlorite can be noticed. The apparent age of 66.1 ± 2.5 Ma agrees, within the analytical error, with the Lower Paleocene time span ($<$ 65 Ma), suggested by the mentioned micropaleontological data.

E.2. The welded tuffs (809, 811, 816) of the ignimbritic formation provided very non-homogeneous ages. The high values (70.7 ; 82 Ma) obviously disagree with the stratigraphic position of the ignimbritic formation ; they do not plot on an isochron. This can be done to the non-homogeneous constitution of the rocks in which exotic fragments of andesites, sericitized plagioclase and metamorphic rocks from the crys-

TABLE1

Apparent K-Ar ages of banatitic rocks from the Rusca Montană basin

No.	Sample number	Location	Rock type	Analysed fraction	K %	Ar^{40} rad moles/g ($\times 10^{-11}$)	Ar^{40} rad %	Apparent age Ma
1	2	3	4	5	6	7	8	9
		Lamprophyre cycle						
1	803	South Valea Cerna	Camptonite with katophorite	WR	2.24	1.9069	52.08	44.5±2.1
2	24	Pîrîul Calea (Ruschiţa)	Camptonite with katophorite	WR	1.95	1.3342	48.53	38.8±1.9
3	24	Pîrîul Calea (Ruschiţa)	Camptonite with katophorite	Ka	1.79	1.4582	47.59	46.4±2.3
4	24	Pîrîul Calea (Ruschiţa)	Camptonite with katophorite	Ka	1.79	1.6919	39.21	53.4±3.1
		Intrusive cycle						
5	834	Valea Glăvan	Quartz andesite (microdiorite)	WR	1.41	1.3509	59.80	54.4±2.3
6	848	Galeria Ascuţita	Porphyric granodiorite	WR	2.23	2.7056	82.60	68.7±2.6
7	834A	Valea Glăvan	Grandiorite		2.33	2.8323	81.41	68.8±2.6
8	842	Valea Vîrciorova	Granodiorite	WR	2.13	2.3299	78.04	63.0±2.5
9	851	Galeria Ascuţita	Granodiorite	WR	2.04	2.2788	67.34	63.3±2.6
10	843	Valea Vîrciorova	Porphyric granodiorite	WR	1.83	1.9032	60.58	60.0±2.6
11	835	Valea Glăvan	Granodiorite	WR	2.22	2.1160	58.40	54.1±2.4
12	850	Galeria Ascuţita	Granodiorite	WR	2.47	2.6386	58.02	60.6±2.7
13	847	Valea Vîrciorova	Granodiorite	WR	1.87	2.5383	52.69	76.2±3.5
14	849	Galeria Ascuţita	Porphyric granodiorite	WR	2.67	3.4273	17.57	72.5±9.8
15	834A	Valea Glăvan	Granodiorite	Bt	7.41	8.5667	90.76	65.5±2.5
16	849	Galeria Ascuţita	Porphyric granodiorite	Bt	7.52	9.4131	90.54	70.8±1.9
17	835	Valea Glăvan	Granodiorite	Bt	6.99	8.3420	89.11	67.5±2.6
18	843	Valea Vîrciorova	Porphyric granodiorite	Bt	7.09	7.0359	82.74	56.3±2.1
19	847	Valea Vîrciorova	Granodiorite	Bt	6.60	6.9720	72.61	59.9±2.4
		Extrusive cycle						
20	805	Valea Ciolorogu	Andesite (fragment of agglomerates)	WR	2.11	2.9654	69.53	79.3±3.2
21	809	Valea Ştirbu (Lozniţoara)	Welded tuff	WR	3.32	4.1533	89.56	70.7±2.7
22	811	Valea Ştirbu Lozniţoara)	Welded tuff	WR	3.25	4.7286	82.48	82.0±3.1
23	816	Valea Nocea (Lozniţoara)	Welded tuff	WR	3.08	2.9539	77.14	54.5±2.1
24	790	Valea Ciolorogu	Pyroxene andesitic tuff	WR	2.74	3.2002	82.05	66.1±2.5

Abbreviations: WR — whole rock; Bt — biotite; Ka — katophorite.
Potassium measurements: N. Iosipenco I.P.G.G.
Argon extractions: Olivia Romanescu I.G.G.

talline basement may be recognized. Thus, an excess of Ar^{40} is to be expected in some of these rocks. The age of 45.5 Ma recorded in one of the samples (no. 23) confirms this presumption.

E.3. From the upper andesitic volcano-sedimentary formation, only a hornblende-biotite andesite with pyroxene was analysed (805). It represents a fragment from pyroclastic rocks. The high age obtained (79.3 Ma) suggests products of older magmatic phases as source for the mentioned fragment and has no geological significance for the timing of the volcano-sedimentary formation E.3.

Intrusive Cycle

I.2. All whole rock and biotite ages (no. 6-19 in table 1) refer to samples collected from different parts of the Ruschița-Glimboca granodiorite body. According to aeromagnetic and geological data, there is no doubt that the seven areas of granodiorite outcrops represented in Figs. 1, 3, belong to the same intrusive body, of about 4.5 $\times$ 20 km in horizontal section. The recorded apparent ages are not homogeneous. The values range between 54.1 — 76.2 Ma (average analytical age = 65.3 Ma) for whole rock samples and 56.3 — 70.8 Ma (average analytical age = 64.0 Ma) for biotites (Line I in table 2). This scattering of data referring to the same homogeneous intrusive body is too large to accept only cooling effects. Geological data suggest that the samples have been taken from a depth that does not exceed some hundred of meters below the top cupola of the intrusive body (Fig. 3). Therefore, only late influences or analytical errors can be taken into consideration. Having in mind this assumption, the following possible interpretations have been tested :

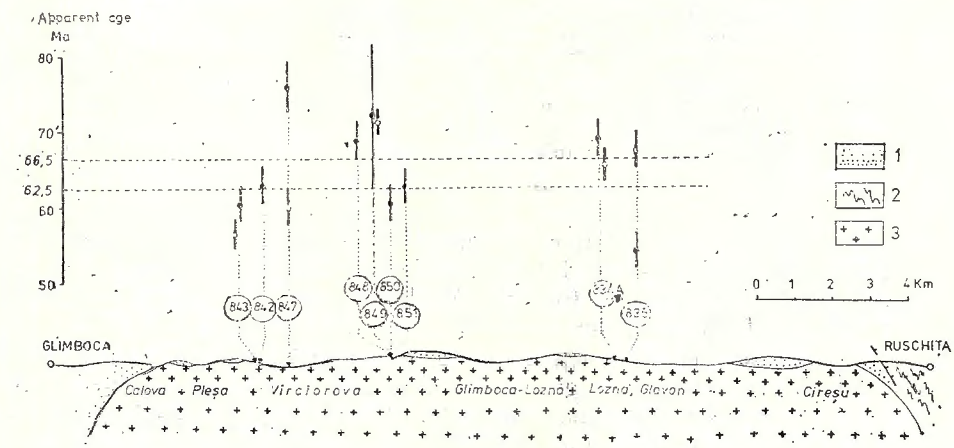

Fig. 3. — Geological cross section through the Ruschița-Glimboca granodiorite pluton ; graphical representation of the common time interval accepted by the reliable K-Ar apparent ages.

1, sedimentary deposits affected by contact metamorphism ; 2, Paleozoic and Precambrian metamorphic rocks ; 3, granodiorite.

a) Excluding isolated high and low values (847 WR, 849 WR, 835 WR, 843 B), the scattering may be reduced between 60-70 Ma with average values of 64.1 for whole rock, 65.9 Ma for biotites and 64.8 for all samples (n=10) (Line II in table 2).

b) Excluding only the high contaminated samples (849 WR, 847 WR) with $Ar^{40}_{rad} < 55\%$ the average analytical age decreases to 62.6 Ma for whole rocks, 64.0 Ma for biotites and 63.2 for all samples (n=12) (Line III in table 2).

TABLE 2

K-Ar. Average apparent ages and isochron ages for the Ruschiţa-Glimboca granodiorite intrusive body

	Used samples	Whole rock (average)	Biotite (average)	Whole rock + biotite: average	Whole rock + biotite: Ar^{40}/Ar^{36} — K^{40}/Ar^{36} isochron	Whole rock + biotite: Ar^{40}—K^{40}_{rad} isochron
I	All samples	65.3 (n = 9)	64.0 (n = 5)	64.8 (n=14)	—	—
II	Singular values excluded: (849 WR, 847 WR, 835 WR, 834 Bt)	64.1 (n = 6)	65.9 (n = 4)	64.8 (n = 10)	—	—
III	High contaminated samples excluded (Ar^{40}_{rad} % < 55): (849 WR, 847 WR)	62.6 (n = 7)	64.0 (n = 5)	63.2 (n = 12)	—	—
IV	Only highest contaminated sample (849 WR, Bt) excluded	64.4 (n = 8)	62.3 (n = 4)	63.7 (n = 12)	66.7±2.1 (n = 12)	62.5±2.7 (n = 12)
V	Samples suspected for Ar^{40}rad excess excluded: (849 WR, 849 Bt, 835 Bt, 834 A WR, 848 WR)	63.0 (n = 6)	60.6 (n = 3)	62.1 (n = 9)	64.6±2.0 (n = 9)	60.6±2.7 (n = 9)

c) A graphic solution considering the amount of analytical errors (Fig. 3) indicates the time interval 62.5-66.5 Ma as compatible for most of the analysed samples (n=10). Excluded are the aberant high and low values of the samples 843 WR, 847 WR, 849 Bt, 835 WR.

As it also results from Table 2, no significant differences can be noticed between the averages of selected and non-selected data. Therefore, it seems that the time span of 62-66 Ma may be taken into consideration for the intrusive phase I.2.

We have tried to evaluate our data by the Ar^{40}/Ar^{36} — K^{40}/Ar^{36} and Ar^{40} — K^{40} isochron methods as well (Fig. 4). Slopes and interceptions of the isochrons were computed by the method elaborated by York (1966).

As the whole rock and biotite samples plot practically on the same straight line, combinated whole rock — biotite isochron age seems to be preferable due to the greater number of samples and to the more confident correlation coefficient. The best fitted line was obtained for all data (n=12), excluding the high contaminated sample 849 (WR + Bt). The isochron age is of 66.7 ± 2.1 Ma by the Ar^{40}/Ar^{36} —

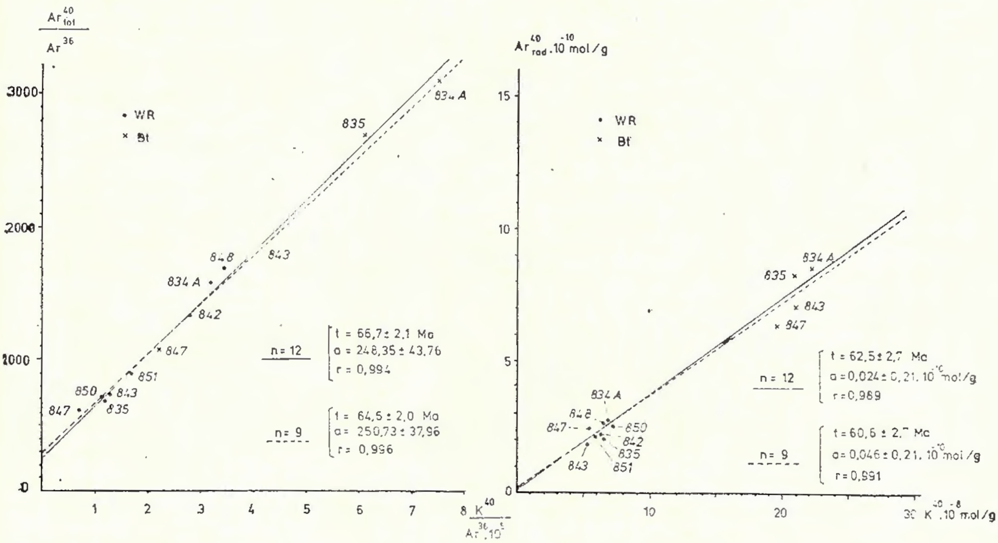

Fig. 4. — Ar^{40}_{rad}/Ar^{36} — K^{40}/Ar^{36} and Ar^{40}_{rad} — K^{40} isochrons for granodiorites of the Ruschița-Glimboca pluton.

K^{40}/Ar^{36} diagram and of 62.5 ± 2.7 Ma by the corresponding Ar^{40} — K^{40} graph. The interception with the Ar^{40}/Ar^{36} axis (248.35 ± 43.76) is definitely lower than the atmospheric ratio. An initial argon ratio below the atmospheric value is not impossible, but it is far less likely than the presence of an excess radiogenic argon in some of the samples (835 Bt, 834 WR, 848 WR). The great error of the average interception (± 43.76) indicates this. Taking into account only the positive value of error, we have obtained a more realistic interception (292.11). The slope computed with this value corresponds to an isochron age of 64.6 ± 2 Ma. The same isochron age (n=9, fig. 4) we have obtained by omitting the samples (849 WR, 849 Bt, 835 Bt, 834A WR and 848 WR), which we suspected before an excess radiogenic argon. In this case, the former isochron age (66.7 ± 2.1 Ma) is not reliable, the sample points fitting a "mixing line" in the Ar^{40}/Ar^{36} — K^{40}/Ar^{36} diagram with a defined "age" older than the age of the intrusive phase I.2.

The presence of different amounts of excess radiogenic argon is shown also on the Ar^{40}_{rad} — K^{40} diagram by the great error of the positive interception with the Ar^{40}_{rad} axis (0.034 ± 0.21. 10^{-10} mol/g).

Another attempt to compute an Ar^{40}_{rad} — K^{40} isochron, by excluding (like in the Ar^{40}/Ar^{36} — K^{40}/Ar^{36} system) the samples 849 WR, 849 Bt, 835 Bt, 834 WR, 848 WR, has maintained the same error of the interception with the Ar^{40}_{rad} axis ($0.046 \pm 0.21 . 10^{-10}$ mol/g). Therefore, the conditions of an Ar^{40}_{rad} — K^{40} isochron are not fulfilled. This explains the different age values in respect to the Ar^{40}/Ar^{36} — K^{40}/Ar^{36} isochron method (62.5 ± 2.7 Ma and 66.7 ± 2.1 Ma for n=12 ; 60.6 ± 2.7 Ma and 64.6 ± 2 Ma for n=9). The corresponding values of average analytical ages are 63.7 Ma for n=12 and 62.1 Ma for n=9 (Lines IV and V in table 2).

In conclusion we may consider 64 ± 2 Ma, as the age of the intrusion time. Therefore, the emplacement of the Ruschița-Glimboca granodiorite pluton can be assigned to the Lower Paleocene (Danian).

I.3. A single sample of quartz andesites with hornblende (834) cutting the Ruschița-Glimboca granodiorite body is available. The apparent age of 54.4 Ma is in accordance with the geological relationships and with the K-Ar ages recorded for the other magmatic phases. It suggests that the swarm of dykes and veins of the Phase I.3. intruded, at least partly, 10 Ma later than the granodiorite body, during the Late Paleocene (Thanetian).

Lamprophyre Cycle

L.2. Whole rock and katophorite samples from two camptonite veins were analysed (803, 24) (Fig. 1). The scattering of values obtained for samples of the same rock (24) could be caused by the different amount of contamination with atmospheric argon (Ar^{40}_{rad} = 48.5 — 39.2%) (Tab. 1). The average age for the four samples is 45.7 Ma. Excluding the highest contaminated katophorite sample, the average value decreasesto 43.2 Ma. The common time interval accepted by the analytical error of these three samples is 40.7 — 44.1 Ma. Therefore, the emplacement of the late lamprophyres (L.2.) is suggested between 41-45 Ma, in the Middle Eocene (Lutetian). These radiometric data are in accordance with the fact that the analysed camptonite vein (308) cuts the detrital deposits assigned to the Eocene.

Discussions and Conclusions

The K-Ar ages recorded from products of different banatitic magmatic phases are in accordance with micropaleontological data (Ion, in Kräutner et al., 1983, 1984) and the geological relationships exposed in the Rusca Montană sedimentary basin (Kräutner and Kräutner, 1972, 1985 ; Dincă, 1977 ; Szàsz in Kräutner et al., 1983). The following timing of the banatitic magmatites from the mentioned area is suggested (For the stratigraphic units, the time scale proposed by the IGPC project 133/89, Odin 1982, was used).

Extrusive Cycle :

65 ± 1 Ma (Danian) — Volcano-sedimentary formations (Phases E.1., E.2., E.3.)

Intrusive Cycle :

— (Danian) — andesites, microdiorites (Phase I.1.)

64 ± 2 Ma (Danian) — granodiorites (Ruschița-Glimboca) (Phase I.2.)

54 ± 2 Ma (Thanetian) — andesite veins (Phase I.3.)

Lamprophyre Cycle :

— ? — calcalkaline lamprophyres (Phase L.1.)
43 ± 2 Ma (Lutetian) — camptonites (Phase L.2.)

It seems that the first andesitic volcanism (E.1.) and the ignimbritic volcanism (E.2.) expelled a great quantity of pyroclastics during a short life, that probably did not surpass 1 Ma. A period of continental sedimentation with coal deposition was intercalated between them and the late andesite volcanism (E.3.). The main intrusive phase started probably a short time after or at the end of the volcanic activity. It lasts at least 10 Ma because the latest rhyolite and dacite veins are younger than the analysed quartz andesites. The probable youngest lamprophyres (L.2.) follow after another period of about 10 Ma. Conventionally, the lamprophyres have been considered as the latest products of the banatitic magmatism due to their close spatial relation with the banatitic rocks from the whole Banat. But we cannot exclude the possibility that they belong to another, younger, magmatic province.

K-Ar ages reported for other intrusive bodies of the Banat (Russo-Săndulescu et al., 1983 ; Lemne et al., 1984) suggest a larger time range for the banatitic magmatism, considering also earlier intrusions as for example Bocșa I (87.9 Ma), Bocșa II (80-81 Ma) and Surduc I (67-72 Ma). These intrusions are assigned to the Senonian, but there are no conclusive relationships with sedimentary deposits. According to their K-Ar ages, the intrusive phase I.2. from the Rusca Montană basin corresponds to the younger mainly granodioritic intrusions of the Banat (Russo-Săndulescu et al., 1983) as for example Bocșa III (65-56 Ma) and Surduc II (62-55 Ma). Lower K-Ar ages, similar with those of the Phase I.3. have been reported for banatites from Ocna de Fier-Dognecea (57-48 Ma), Ciclova-Oravița (58-48 Ma) (Russo-Săndulescu et al., 1983 ; Lemne et al., 1984 ; Mînzatu et al., 1977).

Most of the K-Ar ages reported from banatitic rocks of the Poiana Ruscă Mts by Strutinski et al., 1983, range between 70-81 Ma. According to this data, the mentioned authors suppose another evolution model for the magmatic activity in the Ruschița-Rusca Montană area, accepting that the intrusive phase I.2. (Ruschița-Glimboca granodiorites) is older than the pyroclastic deposits E1-3. The K-Ar ages recorded by Strutinski et al. (1983) are systematically older than those obtained on our samples for the same magmatic bodies. They do not agree with the mentioned geological relationships and micropaleontological data, and cannot be reliable (e.g. 70.8-75.5 Ma for the Ruschiţa-Glimboca granodiorite ; 75.8 Ma for the Rusca andesite flow intercalated in the lower volcano-sedimentary formation, E.1. ; 81.8 Ma for the camptonite with katophorite from Ruschiţa).

Of some interest could be the ages of 72-81 Ma reported by Strutinski et al., 1983 for porphyric diorites and porphyric granodiorites from the western Poiana Ruscă Mts (Tincova area). These values are comparatively higher than the over-estimated ages reported by the same authors for the rocks of the Ruschiţa-Ascuţita area (Rusca Montană). Therefore, it could be suggested that in the western part of the Poiana Ruscă, products of older magmatic phases occur within the metamorphic basement. This presumption cannot be taken into consideration for the Tincova porphyric granodiorites because those rocks seem to be younger than the post-Danian tectonic contact between the Tincova and the Poiana Ruscă crystalline (Kräutner et al., 1972) (Fig. 1).

According to the proposed time table for the area of the Rusca Montană sedimentary basin, only the extrusive cycle and the intrusive phases I.1., I.2., basically may be considered subsequently to the Laramian tectogenesis. But it must be noticed that after their deposition, during or after the Eocene, the volcano-sedimentary formations of the extrusive cycle have been overthrusted by Paleozoic and Precambrian metamorphic complexes.

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DATAREA MAGMATITELOR BANATITICE DIN POIANA RUSCĂ DE SUD PRIN METODA K-Ar (BAZINUL SEDIMENTAR RUSCA MONTANĂ)

(Rezumat)

Vîrstele K-Ar obținute pentru produse ale principalelor faze de activitate magmatică banatitică sînt în concordanță cu relațiile geologice observate, atît între diferitele tipuri de roci magmatice intrusive și extrusive (Kräutner, Kräutner, 1972), cît și față de depozitele sedimentare datate pe baze paleontologice (Baltreș, 1966 ; Dincă, Tocorjescu, 1972 ; Dincă, 1977 ; Antonescu, Ion și Szàsz în Kräutner et al., 1983). Se propune următoarea încadrare în timp a evoluției magnetismului banatitic din aria bazinului Rusca Montană (scara geocronologică după Odin, 1982).

Ciclul extrusiv : 65 $\pm$ 1 Ma (Danian). Acest ciclu include formațiunea vulcano-sedimentară andezitică inferioară, formațiunea ignimbritică și formațiunea vulcano-sedimentară andezitică superioară (fig. 2), generate în trei etape succesive de activitate vulcanică predominant extrusivă (E_1, E_2, E_3).

Ciclul intrusiv : 64-54 Ma (Danian-Thanetian) cuprinde produse a cel puțin trei faze magmatice :

Faza I.1. : (Danian). Preponderent andezite și microdiorite porfirice.

Faza I.2. : 64 $\pm$ 2 Ma (Danian). Granodiorite (plutonul Ruschița-Glimboca).

Faza I.3. : 54 $\pm$ 2 Ma (Thanetian). Filoane de andezite, subordonat dacite și riolite. Vîrsta radiometrică se referă la andezitele cuarțifere cu hornblendă care străbat plutonul granodioritic Ruschița-Glimboca. După relațiile observavabile pe teren riolitele sînt ulterioare, cel puțin, față de unele din filoanele andezitice.

Ciclul lamprofirelor : (?)-Lutețian). În mod convențional lamprofirele au fost considerate ca produse finale ale magmatismului banatitic, luînd în considerare distribuirea lor spațială în aria de aflorare a banatitelor. Nu este exclus însă ca ele să aparțină de fapt unei alte provincii magmatice, post banatitice. Pe baza caracterelor petrografice şi a transformărilor hidrotermale lamprofirele au fost atribuite la următoarele două faze :

Faza L.1. : (?), caracterizată preponderent prin spessartite (odinite) afectate de transformări hidrotermale.

Faza L.2. : 43 $\pm$ 2 Ma (Lutețian), reprezentată prin camptonite cu katoforit

Pe baza vîrstelor K-Ar de care se dispune la ora actuală (Russo-Săndulescu et al., 1983, Lemne et al., 1984, Mînzatu et al., 1977) faza intrusivă din bazinul Rusca Montană și suita filoniană care-i urmează pot fi echivalate cu intruziunile Bocșa I (65-56 Ma) și Surduc II (62-55 Ma).

Vîrstele K-Ar publicate de Strutinski et al. (1983) pentru rocile banatitice din bazinul Rusca Montană sînt sistematic mai mari față de cele obținute de noi, și nu concordă cu relațiile geologice și datele paleontologice menționate. Privite în mod relativ, vîrstele obținute de autorii menționați pentru rocile din bazinul Rusca Montană sînt mai mici în comparație cu cele înregistrate de aceiași autori pentru banatitele din regiunea Tincova-Nădrag. Acest lucru sugerează posibilitatea existenței în partea de vest a munților Poiana Ruscă a unor faze intrusive anterioare plutonului granodioritic Ruschița-Glimboca.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

NEW DATA ON THE GEOCHEMISTRY OF THE QUATERNARY BASALTS IN THE PERŞANI MOUNTAINS [1]

BY

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Basalts. Quaternary. Chemical composition. Major elements. Trace elements. Differentiation diagrams. Within-plate tectonics. Tholeiitic fractional crystallization. Petrographic nomenclature. East Carpathians — Neogene-Quaternary eruptive — Perşani.

Abstract

The petrological study of the Quaternary basalts in the Perşani Mts is interesting due to their position at the southern end of the volcanic arc of the East Carpathians and to their eruption in the Quaternary, in an within-plate tectonic setting, after the Neogene subduction. A significant and representative bulk of data on the major and trace elements (Tab. 1, 3, 4) was used for a) the chemical classification and b) the clearing out of petrogenetic matters. According to their position on the TAS diagram (Granada variant, 1983), Quaternary basalts in the Perşani Mts denominate the potassic trachybasalts ; on the F'-ANOR diagram they plot in the trachybasaltic field. The alkalinity is also indicated by the high values of Sr and Ba (Tab. 3, 4). The appurtenance to a volcanism generated in an within-plate regime and no by the subduction are proved by a) position of basalts on Zr/Y-Zr, Zr/Y-Ti/Y, Ti/100-Zr-Y. 3 diagrams ; Zr/Y $>$ C_3 ; c) plotting in the tholeiitic field and the tholeiitic-type fractional crystallization trend. Parental magma could show characteristics of a liquid coming from a lherzolitic peridotite (peridotitic nodules at Racoş Ni=1700 ppm, Co=110 ppm).

Résumé

Données nouvelles sur la géochimie des basaltes quaternaires des monts Perşani. L'étude pétrologique des basaltes quaternaires des monts Perşani suscite un intérêt particulier dû à : a) la position dans la terminaison méridionale de

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l'arc volcanique des Carpathes Orientales et b) l'éruption dans un cadre tectonique d'intraplaque pendant le Quaternaire, après la fin de la subduction néogène. Un riche et représentatif ensemble de données analytiques concernant les éléments majeurs et mineurs (tabl. 1, 3, 4) a été employé pour : a) classification chimique ; b) clarification des problèmes pétrogénétiques. Conformément à la position du diagramme TAS (variante Granada, 1983), les basaltes quaternaires de Perşani sont dénommés trachybasaltes potassiques ; sur le diagramme F'-ANOR occupent le champ des trachybasaltes. L'alcalinité est aussi indiquée par les valeurs élevées de Sr et de Ba (tabl. 3, 4). L'appartenance à un volcanisme généré en régime d'intraplaque est prouvée par : a) position des basaltes sur les diagrammes Zr/Y-Zr, Zr/Y-Ti/Y, Ti/100-Zr-Y.3 ; b) Zr/Y $> C_3$; c) projection sur le champ tholéiitique et la cristallisation fractionnée de type tholéiitique. Le magma parental a eu, peut-être, les caractères d'un liquide provenant d'une péridotite lherzolitique (dans les nodules péridotitiques de Racoş, Ni = 1700 ppm, Co = 110 ppm).

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1. Introduction

Mostly andesitic volcanic manifestations which took place in the East Carpathians during the Neogene ended in the Pleistocene with basaltic eruptions in the Perşani Mts. The knowledge of the products of this volcanic activity has recently been improved, special attention being given to the petrologic problems in the light of the modern petrogenetic and geotectonic concepts. The interest was raised by the exclusively basaltic character of the volcanic products and by their recent age as against the other volcanics of the East Carpathians, predominantly Neogene andesites. The explanation of the basalts position in an area representing the southwestern part of the East Carpathian volcanic chain aroused the interest of the researchers.

Contributions to the knowledge of the geological setting of the basaltic volcanism development in the Perşani Mts, to the pointing out of the petrographic features, of the eruptions succession and of their age, as well as to the identification of the volcanic structures were brought by Laţiu (1929), Preda (1940), Mihăilă et al. (1972), Mihăilă, Peltz (1977), Ghenea et al. (1981), Măldărescu et al. (1983). In the last decade problems concerning the petrology of the basalts were also tackled. Thus, evidence on the petrochemistry, geochemistry and petrogenesis of the Perşani basalts was presented in several synthesis papers by Peltz, Bratosin (1971), Peltz et al. (1972), Peltz, Stoian and Peltz et al. (1985), Peltz, Peltz (1983). Recently Măldărescu et al. (1983) have described a new genetic model for the magma of the Perşani basalts in connection with the conclusions of the petrographic and petrochemical study of the peridotitic nodules of the Racoş basalt.

Lately we have succeedeed to enrich the bulk of analytical data referring to the Quaternary basalts in the Perşani Mts, both for major elements and for trace elements. At the same time all the areas with basaltic volcanics have been studied. On the basis of the geological data known so far the present paper represents a thorough study of our previous considerations on the chemical classification and nomenclature, on the definition of the tectonic setting within which the volcanism was generated, and on the characterization of the parental magma.

2. Geological Setting

Within the Quaternary basaltic eruptions in Romania, the most important and diverse volcanic manifestations took place in the Perşani Mts. The products, represented by lava flows, pyroclastics, bombs, scoria, lapilli, cover the area between the localities of Rupea-Racoşul de Jos-Hoghiz-Comana (Fig. 1). The volcanism was of the mixed type;

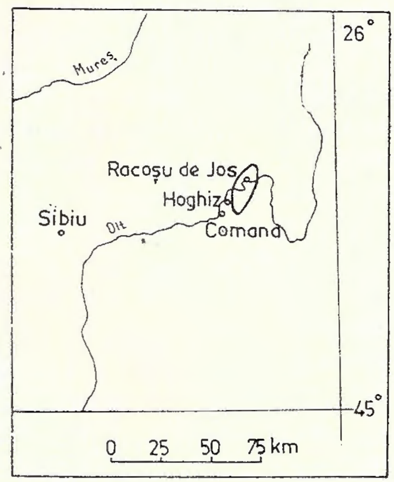


Fig. 1. — Location of the young basaltic volcanic area in the Perşani Mountains.

the most important volcanic apparata are found at Racoş, Mateiaş, Bogata. According to Rădulescu, Săndulescu (1980), Rădulescu (in Rădulescu et al., 1981) the basaltic volcanism in the Perşani Mts belongs to an within-plate magmatic activity centre subsequent to the Alpine consolidation. Rădulescu (1969) considers that this activity was favoured by a N-S trending crustal fracture extending in the area of the basalts south of the Danube. The modal mineralogical composition of basalts is dominated by phenocrysts of olivine (9-13%) and augite (6-8%). The groundmass with a hyalopilitic, intergranular, subophitic texture represents about 80% of the rock and consists of glass, plagioclase, olivine, augite and magnetite. The Racoşul de Jos basalts contain quartz exogene inclusions (Laţiu, 1929) and peridotite nodules (Măldărescu et al., 1983). The terminal Pliocene-Middle Pleistocene age of the basaltic volcanism in the study region was determined on the basis of paleontological, paleomagnetic and radiometric data (Mihăilă et al., 1972; Mihăilă, Peltz, 1977; Ghenea et al., 1981).

3. Major Elements, Chemical Classification and Nomenclature

Table 1 presents the results of 11 chemical analyses. They represent lavas (most of them), bombs and basaltic scoria. All the chemical analyses indicate fresh rocks with $H_2O < 1.5\%$, rare contents of $S=0.05\%$; only one sample has $CO_2=0.38\%$. The oxide values vary within the characteristic limits of the basalts (Peltz et al., 1972). In most of the analysed samples K_2O % contents exceed 1.5, and $K_2O+Na_2O > 4.5\%$ (Tab. 1). All this points out the alkaline character of the Perșani basalts. As a matter of fact Peltz et al. (1972) pointed out this character (relying only on two samples) as compared to other basaltic areas in Romania and in the world.

The main contribution which might be brought by the available petrochemical data refers to the classification and nomenclature of the basalts. The first attempt of classifying the young basalts in Romania in chemical respect (Peltz et al., 1972) was to include the Racoș and Mateiaș basalts into the alkaline basalts group and to define them as "olivine basalts with virtual nepheline". The principles of chemical classification as a result of the activity carried out by the IUGS Subcommission on the Systematics of Igneous Rocks have been improved.

Lately (Granada, Spain, 1983) the Subcommission has recommended the use of the TAS ($Na_2O + K_2O — SiO_2$) diagram for the classification of the volcanic rocks. On this diagram, most of the basalts of the Perșani Mts plot in the field of the potash trachybasalt; three samples with alkalis less than 4.5% fall in the field of the basalts with normative nepheline (Fig. 2 a). The mentioned diagram renders evident the potassic character of the majority of the study basalts.

The same character is illustrated by the position of basalts on the K_2O-SiO_2 diagram, Ewart's variant, 1982 (Fig. 2 b). Seven samples plot at the bottom of the absarokite field; three samples from Hegheș and Racoș fall in the potassium-rich basalts field and the sample from Bogata falls at the top of the normal basalts field. Although most of the samples plot in the absarokite field, the average value inclusive, we consider that on the whole the rocks under discussion cannot be regarded as shoshonites. In our opinion the denomination "high potassium basalt with a shoshonitic tendency" would be proper. At the same time this denomination is in agreement with the position of most of the basalts on the TAS diagram, Granada variant (1983).

Figure 2c illustrates the position of basalts on the diagram of chemical classification proposed by La Roche et al. (1980). As the synthetic parameters R_1=4Si-11 (Na+K)-2(Fe+Ti) and R_2=6Ca+2Mg+Al include most of the cations constituting the analysed rocks, specifications on their denomination are also brought. It is of note that six of the samples plot in the field of alkali basalts (Racoș, Hegheș, Rupea, Bogata) and other 3 samples from Racoș in the olivine basalts field. Two sam-

TABLE 1

Chemical composition and average values

No.	Location	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O	CO_2	S	Total
1	Mateiaş	45.61	1.70	15.60	2.82	7.00	0.17	9.89	9.86	2.03	4.11	0.61	0.30	—	—	99.70
2	Racoş	46.37	1.66	16.47	7.62	2.18	0.19	9.44	9.35	1.77	3.32	0.57	1.42	—	—	100.36
3	Hegheş	47.08	1.62	16.98	3.86	5.38	0.19	9.26	9.01	1.58	3.12	0.53	1.46	—	—	100.07
4	Racoş	47.47	1.61	15.36	2.72	6.87	0.18	9.38	9.58	1.93	3.90	0.58	0.32	—	0.05	99.99
5	Hegheş	47.48	1.41	16.42	8.26	0.67	0.17	10.03	9.35	1.44	3.72	0.41	0.59	—	—	99.95
6	Racoş	47.57	1.59	16.99	2.61	5.65	0.16	8.92	9.49	1.88	3.34	0.57	1.20	0.38	—	100.35
7	Racoş	47.61	1.62	16.26	2.14	6.48	0.15	10.53	10.16	1.38	3.19	0.35	0.24	—	—	100.11
8	Rupea	47.85	1.59	16.21	4.56	5.10	0.19	8.50	9.17	1.81	4.02	0.52	0.29	—	0.04	99.88
9	Bogata	48.39	1.55	16.04	3.12	5.72	0.17	8.95	9.70	1.11	3.55	0.51	0.96	—	0.05	99.86
10	Racoş	48.41	1.44	15.90	2.89	5.93	0.17	9.74	9.65	1.39	3.36	0.39	0.30	—	0.05	99.66
11	Comana	48.83	1.51	16.28	2.89	5.96	0.18	7.96	9.34	1.86	3.81	0.47	0.62	—	0.05	99.70
12	AVERAGE	47.51	1.59	16.21	3.95	5.17	0.17	9.32	9.51	1.65	3.58	0.50	0.70			

Analyst: No. 1.7 — Cecilia Vasiliu, published 1972; no. 2, 3, 5, 6 — Cecilia Vasiliu unpublished data; no. 4 and 7—11 Erna Călinescu unpublished data. Rock — type; no. 1, 2, 4, 6—11 lava flow; 3 bombs; 5 scoria.

ples from Racoş and Rupea fall in the basanites field due to the smaller values of R_1 as against higher values of R_2.

F′-ANOR diagram (Streckeisen, Le Maitre, 1979) (Fig. 2 b) was also used for classification. These parameters, calculated on the basis of the CIPW norm, proved their usefulness as a nomenclature closer

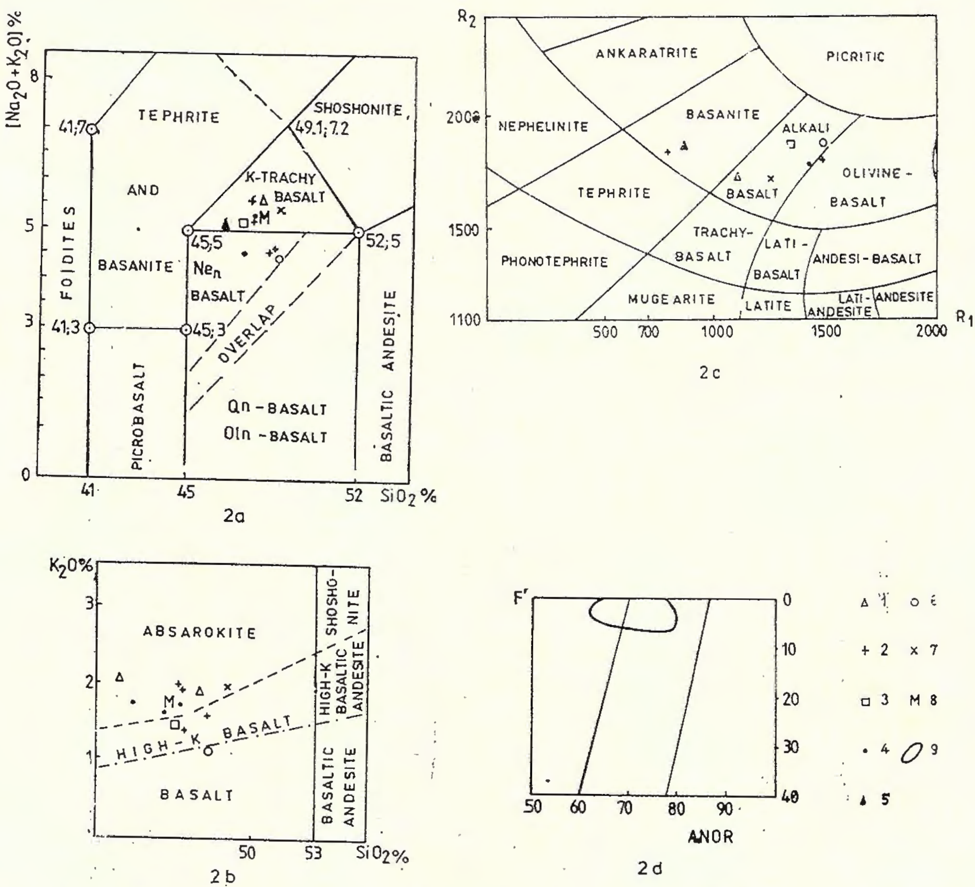


Fig. 2. — Diagrams of chemical classification: a, $Na_2O+K_2O-SiO_2$ (IUGS Subcommission, 1983); b, K_2O-SiO_2 (Ewart, 1983); c, R_1-R_2 (La Roche et al., 1980); d, F′-ANOR (Streckeisen, Le Maitre, 1979).
1, Rupea; 2, Racoş; 3, Hegheş-lava; 4, Hegheş-scoria; 5, Mateiaş; 6, Bogata; 7, Comana; 8, average value; 9, trachybasalts field.

to the chemism and mineralogy of the volcanic rocks was thus achieved. It is noticed that all the basalt samples included in Table 1 plot in the fields 10 a′ and 9′, corresponding to trachybasalt. The nomenclature indications on the F′-ANOR diagram coincide with those on the TAS diagram.

Table 2 shows the nomenclature of the samples from Table 1 according to the patterns of chemical classification used.

TABLE 2

Nomenclature of Quaternary basalts from Perşani Mts.

No	TAS	$K_2O - SiO_2$	$R_1 - R_2$	F' — ANOR
1	K—Trachybasalt	Absarokite	Basanite	Trachybasalt
2	,,	,,	Alkali basalt	,,
3	Ne_n-Basalt	High-K-Basalt	,,	,,
4	,,	Absarokite	,,	,,
5	,,	,,	Olivine basalt	,,
6	K-Trachybasalt	High-K-Basalt	,,	,,
7	,,	Absarokite	,,	,,
8	,,	,,	Alkali basalt	,,
9	,,	Basalt	,,	,,
10	Ne_n-Basalt	High-K-Basalt	Basanite	,,
11	K-Trachybasalt	Absarokite	Alkali basalt	,,

4. Trace Elements

Trace elements have been determined by emission spectrography. The samples represent all the areas with basaltic rocks in the region. The variation domains and the average values of some of the trace elements as well as the ratios between them are presented in Table 3 — basaltic lava exposures in the Perşani area — and in Table 4 — massive and clastic, consolidated and mobile products of the Heghes volcano. These analyses complete the data on the Racoş, Mateiaş and Bogata basalts published in 1971. Table 3 points out that: a) Co, V, Sc, Zr display close values in all the areas except Comana where the

TABLE 3

Trace element average data.
Quaternary basalts. Perşani Mts.

Location		Co	V	Sc	Zr	Y	Yb	Sr	Ba	Ba/Sr	Zr/Y	Ti/Y
Rupea (n = 1)		46	210	24	260	22	2.3	800	950	1.19	11.8	432
Hoghiz (n = 1)		38	185	22	180	20	2	1100	1600	1.45	9	455
Bogata (n = 2)	Δ	42	210	24	180	18	2	710	800	1.13	9.7	484
		43	240	21	185	19	2.1	1600	2800	1.75	10	522
	$\overline{X}$	42.5	225	22.5	183	18.5	2			1.44	9.85	503
Racoş lower lava flow (n=6)	Δ	36	185	22	135	16	1.7	600	580	0.84	8	424
		44	280	28	185	21	2.1	950	1100	1.54	9.4	581
	$\overline{X}$	40	215	24	160	19	2	713	756	1.06	8.5	478
Racoş upper lava flow (n = 4)	Δ	38	185	22	125	18	1.7	420	700	1.00	6.9	437
		47	250	26	170	19	2.3	700	750	1.66	9.4	539
	$\overline{X}$	42	214	24	156	18	2	610	725	1.2	8.5	493
Comana (n = 2)	Δ	27	140	18	140	17	1.7	750	700	0.92	8	500
		42	145	19	145	18	1.7	830	770	0.93	8.2	588
	$\overline{X}$	34.5	143	18.5	143	17.5	1.7	790	735	0.925	8.1	544

n = number of analyses; Δ = range of variation; $\overline{X}$ = arithmetical mean.

values are lower; b) Y, Yb, Sr, Ba display similar values in all the areas. In case of Sr and Ba the differences are more obvious even within the same structure (e.g. Bogata).

The high content of Ba in the Perșani basalts was mentioned in a previous paper (Peltz, Bratosin, 1971) and was explained by the high percentage of normative nepheline. The high values of Sr and Ba can be due to primary carbonates occurring around plagioclase at Racoș (Măldărescu et al., 1983). On the whole, the high contents of Sr and Ba point to the alkalinity of the Perșani basalts.

The explosive products of the Hegheș volcano (Racoșul de Jos) (Tab. 4) are poorer in Co, V, Sc as compared to the Perșani basaltic

TABLE 4

Trace element average data.
Quaternary basaltic rocks, Hegheș Volcano

Rock-type		Ni	Co	Cr	V	Sc	Zr	Y	Yb	Sr	Ba	Ba/Sr	Zr/Y	Ti/Y
lava-flow (n = 3)	Δ	160	26	260	80	18	147	23	1.6	720	650	0.86	6.4	374
		175	27	290	100	19	200	25	1.8	880	1000	1.14	8.00	409
	$\bar{X}$	170	26	276	90	18	172	24	1.7	783	790	1.00	7.2	393
bomb (n = 4)	Δ	115	21	185	63	15	137	20	1.5	750	680	0.91	5.9	318
		140	23	260	80	18	181	29	2	800	850	1.13	6.8	365
	$\bar{X}$	131	22	234	70	16.5	150	24	1.8	765	765	1.00	6.3	342
scoria (n = 2)	Δ	95	20	190	65	15	139	22	1.6	760	720	0.95	6.2	316
		130	23	260	85	18	156	25	1,9	1000	1000	1,00	6,3	381
	$\bar{X}$	112	21.5	225	75	16.5	148	23.5	1.8	880	860	0.97	6.25	348
tuff (n = 4)	Δ	60	12	150	46	12	157	21	1.4	490	600	1.08	7.1	329
		95	18	200	125	15	178	24	2	800	1000	1.25	8.4	382
	$\bar{X}$	80	15.5	178	90	14	171	22	1.7	703	835	1.19	7.8	351

lavas (Tab. 3). Similar contents are observed at Zr, Yb, Sr, Ba and higher contents at Y. Considering that the explosive products of the Hegheș volcano erupted later (Middle Pleistocene) than most of the basalts in the study area (Lower Pleistocene) a decrease of the concentration of compatible elements, characterizing the parental magma, concomitantly with its evolution in time, is observed.

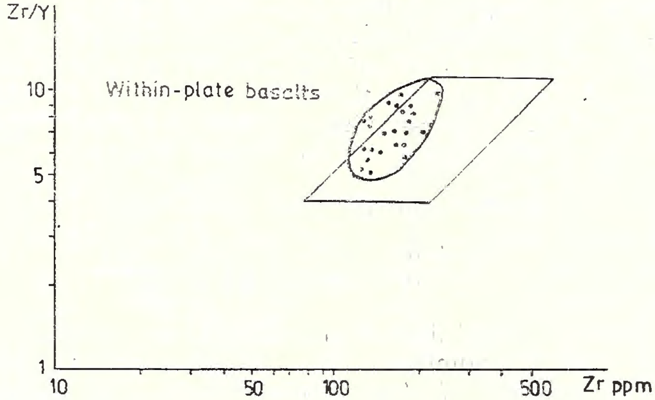
5. Ti, Zr, Y Distribution and Tectonic Setting

According to their geotectonic position, the basalts of the Perșani Mts have been regarded as within-plate (Rădulescu in Rădulescu et al., 1981), but no geochemical arguments have been brought in this respect.

As at present there is enough evidence on the distribution of the trace elements in these volcanics, Ti, Zr and Y — elements with a quite reduced mobility — have been used in testing the character of the magma type generated in the within-plate tectonic regime.

Several papers on petrology published recently showed that binary or ternary diagrams drawn up on the basis of the relationships among Ti, Zr, Y point out the magma type according to the tectonic setting. As shown further the results obtained by us testify the applicability of these diagrams to the youngest basalts of the Carpathian arc.

Pearce and Norry (1979) demonstrated that the Zr/Y-Zr diagram gives evidence on the tectonic setting within which basalts eruption took place. Due to the values Zr/Y > 6 and Zr > 135 ppm (Tables 3, 4) all basalts in the Perşani Mts plot in the within-plate basalts field (Fig. 3 a). At the same time the character of within-plate basaltic magma is also illustrated by the position of the basaltic field in the Zr/Y-Zr



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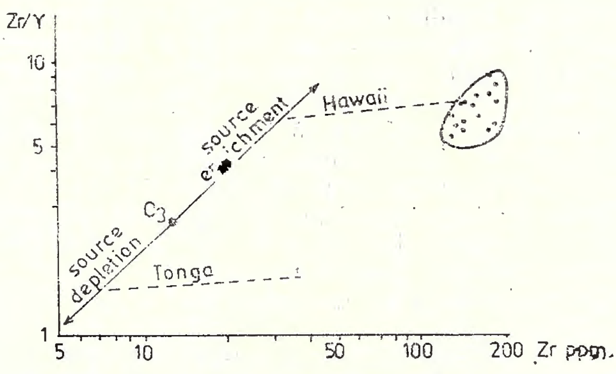

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Fig. 3. — Zr/Y diagram (Pearce, Norry, 1979). a, distribution of basalts field in Perşani ; b, distribution of basalts fields in Perşani as compared with some volcanic suites and standard C_3.

(Fig. 3 b) at higher values than that of the C_3 chondritic standard. According to the above-mentioned authors the within-plate basalts are related to Zr/Y > C_3 sources (standard chondrite) and the island arc basalts and MORB-type ones are in association with Zr/Y < C_3 sources. The mineralogical composition of the young basalts in the Perşani Mts dominated by the olivine-clinopyroxene-plagioclase association, points out a fractional crystallization trend of tholeiitic type. The same trend was considered by Pearce and Norry (1979) as characteristic of the intraplate basaltic magmas. It is of note that the tholeiitic affinity of the analysed rocks is indicated by: plotting in the tholeiite field (Miyashiro, 1974) due to low values of SiO_2 correlated with FeO/MgO (0.79-1.08); small increase of SiO_2 accompanied by the decrease of FeO and TiO_2 (Table 1).

The appurtenance to basaltic magmas generated in the within-plate regime is also illustrated by the plotting of the analysed samples in specific fields on the representative diagrams: Zr/Y-Ti/Y (Pearce, Gale, 1977) (Fig. 4) and Ti/100-Zr-Y.3 (Pearce, Cann, 1973) (Fig. 5 a, b). Due to the slightly different values of Ti, Zr and Y distributed in three of the samples, they plot outside the field of within-plate basalts, in its close vicinity (Fig. 3). These samples represent the products of the explosive moments (bombs, scoria) of the Hegheş volcano.

6. Petrogenetic Considerations

Recent petrological studies referring also to the young basalts in the Perşani Mts include considerations on the genesis and characters of the parental magma.

In the paper on the Pliocene and Quaternary basalts in Romania, Peltz et al. (1972) admitted the provenance of the Perşani basalts in the magma of the olivine-bearing alkali basalt. The values of Ni = 140-225 ppm correlated with those of Co = 25-53 ppm (Peltz, Bratosin, 1971) are comparable with those considered by Taylor (1969) significant for basalts originating in the upper mantle.

REE, Rb, Sr and K distribution led to a petrogenetic model according to which basaltic magma represents a melting of the garnet peridotite type, enriched in light REE. The values of K/Rb=317 correlated with Rb/Sr=0.0486, K/Sr=15 indicate that the magma coming from the mantle has not been altered by the supply of the litospheric material (Peltz, Stoian, 1985; Peltz et al., 1985).

On the basis of mineralogical and geochemical observations Măldărescu et al. (1983) accepted the origin in the mantle of the Racoşul de Jos lherzolitic nodules. The peridotites with the composition of these nodules have been regarded as the generator of the alkali basalts in this region.

In the Perşani basalts K/Rb ratio ranges from 200 to 472 (average value = 317) and Ba/Sr $\simeq$ or > 1. Taking into account these values and the presence of the lherzolitic peridotite in the Racoşul de Jos basalts, as well as Robin's points of view (1982), several observations can be made on the parental magma which complete our petrogenetic evidence (Peltz et al., 1972; Peltz, Peltz, 1983; Peltz et al., 1985). The parental magma generating the high-K basalts in the Perşani Mts could

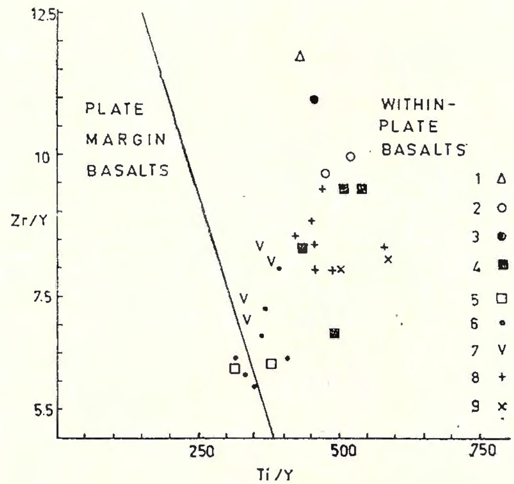

Fig. 4. — Zr/Y-Ti/Y (Pearce, Gale, 1977).
1, Rupea, lava ; 2, Bogata, lava ; 3, Hoghiz, lava ; 4, Racoş, upper lava ; 5, Hegheş, scoria ; 6, Hegheş, bomb ; 7, Hegheş, tuff ; 8, Racoş, lower lava ; 9, Comana, lava.

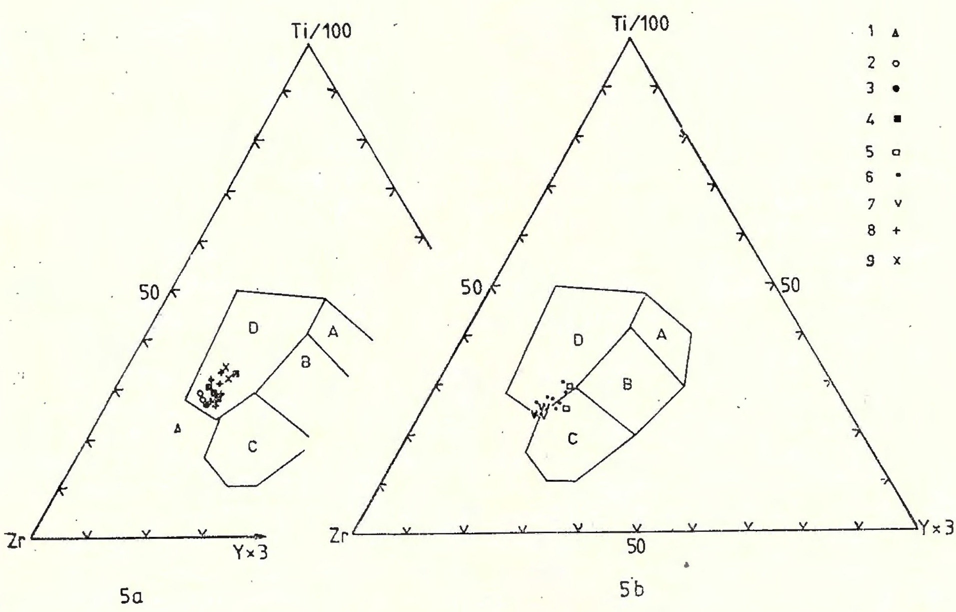

Fig. 5. — Ti/100-Zr-Y.3 diagram (Pearce, Cann, 1973) for the separation of basalt assemblages. Field D, within-plate basalts (WPB). Field B, oceanic basalts (OFB). Fields A, B potassium-poor tholeiites (LKT). Fields C, B calc-alkali basalts (CAB). Explanation of legend as in Figure 4.

have the characters of a liquid coming from a lherzolitic peridotite (Măldărescu et al., 1983). The content of Ni = 1000-2000 ppm, Co = 100-200 ppm (Taylor, 1969) is admitted for peridotites. In the Racoș peridotitic nodules we determined Ni = 1700 ppm and Co = 110 ppm.

The values Rb, Ba, Sr were controlled by the amphibole melting, which determined the enrichment in Ba as against Sr, the decrease of the average value of the K/Rb ratio from 1000-1500 to K/Rb ≃ 200-300. As the stability zone of the amphibole is situated at a depth smaller than 70 km, the above mentioned condition can be achieved if one accepts (acc. to Măldărescu et al., 1983) that the deep mantle was raised by convection currents up to cca 60 km.

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DATE NOI PRIVIND GEOCHIMIA BAZALTELOR CUATERNARE DIN MUNŢII PERŞANI

(Rezumat)

În cadrul eruptivismului bazaltic cuaternar din România, cele mai importante şi mai diversificate manifestări vulcanice au avut loc în Munţii Perşani. Produsele reprezentate prin curgeri de lavă, piro-

clastite, bombe, scorii, lapilli, ocupă aria dintre localitățile Rupea-Racoșul de Jos-Hoghiz-Comana (fig. 1). Vulcanismul a avut un caracter mixt ; cele mai importante aparate se localizează la Racoș, Mateiaș, Bogata. În acord cu Rădulescu, Săndulescu (1980), Rădulescu (în Rădulescu et al., 1981) vulcanismul bazaltic din Perșani aparține unui centru de activitate magmatică intra-placă ce a apărut după consolidarea alpină. Rădulescu (1969) consideră că această activitate a fost favorizată de o fractură crustală orientată nord-sud care se prelungește în aria bazaltelor de la sud de Dunăre.

Studiul petrologic al bazaltelor cuaternare din Munții Perșani suscită un interes particular datorită : a) poziției lor la terminația sudică a arcului vulcanic tînăr din Carpații Orientali ; b) erupției lor într-un cadru tectonic de intra-placă, după finalizarea subducției neogene. Un bogat și reprezentativ fond de date analitice privind elementele majore și minore (tab. 1, 3, 4) a fost folosit pentru a) clasificarea chimică ; b) clarificarea unor probleme petrogenetice. Conform poziției în diagrama TAS (varianta Granada, 1983) bazaltele cuaternare din Perșani se denumesc trahibazalte potasice ; în diagrama F'-ANOR ocupă cîmpul trahibazaltelor. Caracterul alcalin, pronunțat potasic, este evidențiat și de poziția în diagramele R_1-R_2, K_2O-SiO_2 (tab. 2). Alcalinitatea este indicată și de valorile ridicate ale Sr și Ba. Apartenența la un vulcanism generat în regim de intra-placă și nu de subducție este dovedită de : a) poziția bazaltelor analizate în diagramele Zr/Y-Zr, Zr/Y-Ti/Y, Ti/100-Zr-Y.3 ; b) Zr/Y $>$ C_3 (chondrit etalon) ; c) proiecția în cîmpul tholeiitic și trendul de cristalizare fracționată de tip tholeiitic.

Studiile petrologice din ultimii ani care s-au referit și la bazaltele tinere din Munții Perșani conțin unele considerații privitoare la geneza și la caracterele magmei parentale. În lucrarea asupra bazaltelor pliocene și cuaternare din România (Peltz et al., 1972), se admite proveniența bazaltelor din Perșani din magma bazaltului alcalin cu olivină. Valorile Ni=140-225 ppm în corelație cu ale Co=25-53 ppm (Peltz, Bratosin, 1971) sînt comparabile cu cele care au fost considerate de Taylor (1969) semnificative pentru bazaltele provenite din mantaua superioară.

Distribuția T.R., Rb, Sr, K, a condus la considerarea unui model petrogenetic conform căruia magma bazaltică reprezintă o topitură de tipul peridotitului granatifer îmbogățită în T.R. ușoare. Valorile K/Rb=317 corelate cu Rb/Sr=0,0486, K/Sr=15, arată că magma provenită din manta nu a fost modificată de aportul materialului litosferic (Peltz, Stoian, 1985 ; Peltz et al., 1985).

Pe baza observațiilor mineralogice și geochimice, Măldărescu et al., 1983 acceptă originea din manta a nodulilor lherzolitici de la Racoșul de Jos. Peridotitele avînd compoziția acestor noduli au fost considerate materialul generator al bazaltelor alcaline din regiune.

În bazaltele din Munții Perșani K/Rb este cuprins între 200-472, cu valoarea medie=317, iar Ba/Sr $\simeq$ sau $>$ 1. Considerînd aceste valori, precum și evidența prezenței în bazaltele de la Racoșul de Jos a nodulilor de peridotit lherzolitic, în acord și cu punctele de vedere argumentate de Robin (1982), se pot face următoarele observații cu privire la magma parentală. Acestea vizează completarea considerațiilor petrogenetice susţinute de noi anterior (Peltz et al., 1972 ; Peltz, Peltz, 1983 ; Peltz et al., 1985). Magma parentală din care provin bazaltele bogate în potasiu din Munţii Perşani a putut avea caracterele unui lichid rezultat dintr-un peridotit lherzolitic (Mădărescu et al., 1983). Se admite că în peridotite conţinutul de Ni=1000-2000 ppm, cel de Co=100-200 ppm (Taylor, 1969). În nodulii peridotitici de la Racoş noi am determinat, Ni=1700 ppm şi Co=110 ppm.

Valorile Rb, Ba, Sr au fost controlate de topirea amfibolului. Această topire a produs îmbogăţirea Ba faţă de Sr, reducerea valorii medii a K/Rb de la 1000-1500 la K/Rb 200-300. Zona de stabilitate a amfibolilor situîndu-se la o adîncime mai mică de 70 km, condiţia de mai sus poate fi îndeplinită dacă se acceptă în acord cu Mădărescu et al., 1983 că mantaua profundă a fost ridicată de curenţii de convecţie pînă la circa 60 km.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

SIGNIFICANCE OF K-Ar RADIOMETRIC AGES OBTAINED IN THE BANATITIC PLUTONIC AREA OF BANAT [1]

BY

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Banatites. Plutons. Radiometric age. K/Ar method. Magmas differentiation. Cretaceous. Paleocene. South Carpathians — Neocretaceous-Paleocene magmatites — Bocşa — Ocna de Fier — Surduc.

Abstract

The present paper presents 12 K/Ar radiometric ages obtained on banatitic plutonic magmatites. The Surduc and Bocşa plutons are made up of successive intrusions. The first magma pulsations, showing weak alkaline up to shoshonitic affinities, are emplaced subsequent to the Getic Nappe overthrust which in the South Carpathians took place in the Upper Senonian or the end of the Senonian ; the apparent ages obtained are of 87-81 m.y. at Bocşa and of 75-78 m.y. at Surduc. Later intrusions, mostly granodioritic, were emplaced during the Paleocene (the apparent ages vary between 65 and 55 m.y.), therefore they are post-Laramian.

Résumé

Signification des âges radiométriques (K-Ar) obtenus dans la zone des plutons banatitiques du Banat. On discute dans la note 12 âges radiométriques K/Ar obtenus sur des plutons banatitiques de Surduc et de Bocşa qui sont constitués des intrusions successives. Les premières, ayant des affinités légèrement alcalines à shoshonitiques, sont mises en place avant le charriage principal de la nappe gétique qui, dans les Carpathes Méridionales, s'est produit pendant le Sénonien supérieur ou vers la fin du Sénonien ; les âges apparents obtenus sont de 87 à 81 m.a. à Bocşa et de 75 à 78 m.a. à Surduc. Les intrusions principalement granodioritiques sont mises en place ultérieurement durant le Paléocène (les âges apparents vont de 65 à 55 m.a.), c'est-à-dire postlaramiens.

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Introduction

Banatitic intrusive magmatites are known in Banat both in the Supragetic Units and in the Getic Nappe, being considered as emplaced after the Laramian tectonic phase (Giușcă et al., 1966) that in the South Carpathians concluded the Getic and Supragetic overthrusts.

Considering the spatial distribution of the banatitic intrusions and the geophysical data, Russo-Săndulescu and Berza (1977) distinguished a "zone of plutonic banatites" mostly developed west of the frontal part of the Supragetic Nappe (apophyses of the Moldova Nouă-Oravița pluton, outcropping also in the Getic Nappe) and a zone of "hypabyssal banatites" represented by small bodies and veins, found especially east of the Reșița-Moldova Nouă synclinorium, within the Getic Nappe.

Geochronological analyses (K-Ar method) presented in this paper were obtained from two major intrusions (Surduc and Bocșa massifs), known as the westernmost exposures in the zone of plutonic banatites. Both massifs intrude the crystalline schists of the Supragetic Nappe and are overlain by the Neogene deposits of the "Pannonian Depression". As there are no relationships with older sediments, these plutons were considered of Paleocene age, like the whole banatitic intrusive magmatism.

Location of Samples

a) The Surduc banatitic massif (Fig. 1), although with a small outcropping area, can be regarded after the geophysical anomalies as one of the big plutons in Banat extending westwards under the deposits

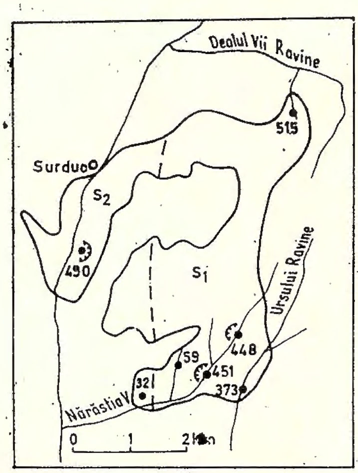


Fig. 1. — Sample location in the Surduc massif.

of the Pannonian Depression. Taking into account the structural and petrographical relationships Russo-Săndulescu (1969, 1977) distinguished within the outcropping zone two units — Surduc 1 (S_1) and Surduc 2 (S_2) — regarded as successive intrusions.

The eastern unit (S_1) is characterized by: 1) the presence of a differentiation in "schlieren" of extremely variable sizes (from hundreds of metres to microscopic ones), made up of gabbroic, monzodioritic and quartz monzonitic rocks, with syenitic segregations; 2) the existence, within the gabbroic rocks, of metric to centimetric inclusions of olivine + pyroxene gabbronorites and of anorthosites with cumulate structures; 3) the presence of a former generation of cumulus-type minerals (plagioclase and clinopyroxenes with exsolutions) in monzodioritic and monzonitic differentiates; 4) basic chemism and with alkaline tendencies of shoshonitic type [3].

The western unit (S_2) represents a subsequent intrusion, relatively homogeneous structurally and petrographically. Only porphyric facies were recognized at the contact with S_1 unit, the rocks being generally represented by monzogranites and granodiorites with clearly recurrent zoned plagioclase, hornblende and biotite; pyroxene and more rarely plagioclase with bitownite nuclei occur in equigranular facies.

b) The Bocşa massif (Fig. 2) displays a more complex structure (Russo-Săndulescu et al., 1978), both because three successive intrusions

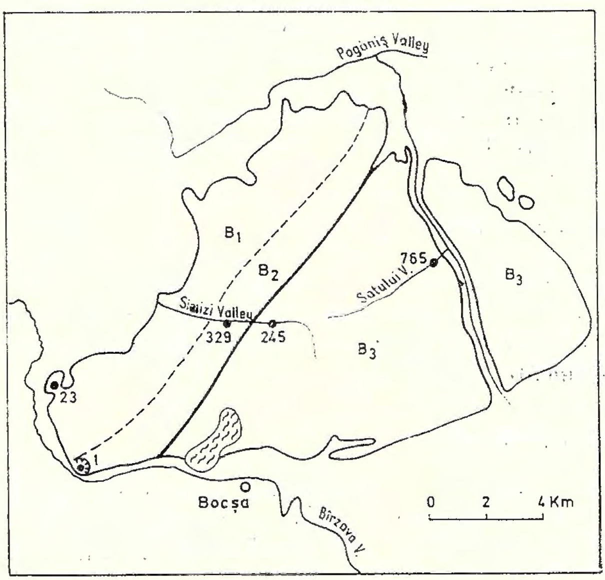


Fig. 2. — Sample location in the Bocşa massif.

can be separated and because of the existence, within an apparently unitary massif, of a tectonic contact along which rocks originating from magmas with a different chemical composition and evolution come into contact. In the western part of the massif, where the Bocşa 1 (B_1) and Bocşa 2 (B_2) units occur, rocks similar in petrographic and chemical respect with those from the Surduc 1 massif are exposed as adjoining megadykes, whereas to the east of the mentioned contact, in Bocşa 3 (B_3) unit, typical calc-alkaline granodiorites are to be found.

The characteristic features of the first pulsation B_1 are, as follows : 1) the extremely complicated "schlieren" structure displaying a wide variety of petrographic types (diorite-gabbros, quartz monzodiorites and monzonites, granites) ; 2) the existence of rare centimetric nodules of anorthosites with cumulate structures ; 3) the occurrence of "cumulus"-type plagioclases, or only of bitownite nuclei in plagioclases of the monzodioritic differentiates, as well as of a clinopyroxene with exsolutions of ferromagnesian phase ; 4) basic and subalkaline chemistry within which rocks with a high content of alkalies are accompanied by high amounts of calcium and siderophile elements (Fe, Ti, V, Sc).

B_2 unit appears as a subsequent pulsation, with a character of differentiate more acid as against B_1, showing a moderate petrographic variety, the majority of rocks being attributed to monzogranite and granodiorite group, quartz monzodiorite being subordinate. The presence of basic plagioclase nuclei and of pyroxene relics in hornblende is similar with the B_1 unit.

B_3 unit occupies two thirds of the visible surface of the Bocşa massif. It is characterized by a notable petrographic homogeneity, the rocks belonging to the hornblende-biotite granodiorites group. Another feature is given by the plagioclase with a constant global composition An_{44-40}, but very zoned, usually of recurrent type. Finally, the chemistry of this unit is typically calc-alkaline with relatively low contents of alkalies and moderate contents of calcium.

The main microscopic characteristics of the analysed rocks, both in the Surduc and in the Bocşa massifs are rendered in Table 1 and the locations in Figures 1 and 2.

Analytical Results

The samples were mostly analysed chemically and spectrally (the results are given in the mentioned papers on the two massifs), and for some of them there are chemical analyses for the same rock type with very close location.

Analytical Methods

Radiometric ages were determined by means of the K-Ar method. The samples were analysed as mineral fraction or as whole rock. The method of argon extraction and purification is the classical one used by Dalrymple and Lamphere (1968) with synthetic zeolite trap, copper oxide furnance and two titanium furnaces. Argon dosage was carried out by the isotopic dilution method using ^{38}Ar as tracer, with the following purity : $^{38}Ar=98.34\%$, $^{36}Ar=0.72\%$, $^{40}Ar=0.94\%$.

Argon isotopes were measured by statistically operated mass spectrometer AEI-20. 3-4 inputs of the gas in the spectrometer were effectuated. $^{40}Ar/^{38}Ar$ and $^{38}Ar/^{36}Ar$ ratios were determined by analysis of regression for the "zero" moment of gas input.

Apparent ages were calculated by "the closed system hypothesis". Radiogenic argon-40 represents total argon-40 corrected for the tracer argon-40 minus atmospheric argon-40. $^{40}Ar/^{36}Ar$ atmospheric ratio$=295.5$.

TABLE 1

Microscopic characters of the analysed rocks

Sample	Structure	Quartz	Potash feldspar	Plagioclase	Pyroxenes	Hornblende	Biotite
1	2	3	4	5	6	7	8
S_1 448, 373 quartz monzodiorites	heterogranular up to equigranular	very little xenomorphous	microperthitic, poikilitic mass	two generations : a) idiomorphic, unzoned or one or two marginal zones ; b) weakly zoned with labradorite corroded centres	idiomorphous orthopyroxene and allotriomorphic heterogranular clinopyroxene	seldom uralite on clinopyroxene	poikilitic crystals including pyroxene, seldom chloritized
59, 451 quartz gabbros	equigranular, with oriented plagioclase	very little xenomorphous or not visible microscopically	—	two generations : a) idiomorphic, unzoned, oriented ; b) weakly zoned with corroded basic nuclei	orthopyroxene locallly mantled by clinopyroxene and allotriomorph. clinopyroxene	very little uralite on clinopyroxene	coarse- up to medium-grained poikilitic biotite
515 quartz monzonite	megaporphyric, „monzonitic"	granular, xenomorphic and myrmekitic	microperthitic, widespread masses	centimetric, automorphous phenocrysts with large corroded basic nuclei	allotriomorph. weakly uralitized or chloritized clinopyroxene	very little uralite	phenocrysts locally chloritized or epidotized on margins
S_2 490 monzogranite	equigranular	granular, xenomorph.	granular xenomorph. locally as poikilitic mass	idiomorphous marginally zoned	clinopyroxene idiomorphic crystals, weakly uralitized	xenomorph. green hornblende and uralite on clinopyroxene	idiomorphic

TABLE 1 (continuation)

1	2	3	4	5	6	7	8
32 monzogranite	porphyric	fine-grained in mesostasis	fine-grained in mesostasis	idiomorphic phenocrysts, zoned	—	idiomorphic green hornblende, partly chloritized	idiomorphic, parly chloritized
B_{1+2} 23 monzonite	„equigranular, monzonitic"	scarce, fine-grained, xenomorphic	widespread masses, poikilitic, microperthitic	two generations : a) idiomorphic unzoned ; b) weakly zoned with corroded basic nuclei	idiomorphic orthopyroxene, allotriomorphic clinopyroxene corroded by hornblende	green-olive hornblende, corroded clinopyroxene	poikilitic masses
329, 1 monzogranite	equigranular	granular, xenomorphic	poikilitic, widespread masses	two generations : a) idiomorphic unzoned ; b) weakly zoned with corroded basic nuclei	scarce remnants of clinopyroxene in hornblende	heteromorphic green hornblende	idiomorphic, locally glomeroporphyric
B_3 765, 245 granodiorite	equigranular	granular, xenomorphic	coarse-grained, locally poikilitic	idiomorphic, strongly zoned (recurrent type)	—	idiomorphic, green hornblende	idiomorphic, weakly chloritized

The following constants were used (Steiger, Jager, 1977):

$\lambda\beta = 4.963 \times 10^{-10}$ yr^{-1}

$\lambda c = 0.581 \times 10^{-10}$ yr^{-1}

$^{40}K/K = 1.167 \times 10^{-4}$ mol/mol

Potassium content was determined by the flamme-photometry.

Apparent ages (Tab. 2) are reported with standard deviation to the probability level of 68%.

TABLE 2

No.	Sample	K %	Ar^{40}_{rad} ($\times 10^{-12}$mol/g)	Ar^{40}_{rad} %	Ar^{36} ($\times 10^{-12}$mol/g)	Apparent age my $\pm 1\sigma$
1	448 Rw (S_1)	2.84	379.997	91.96	0.112	75.56±2.73
2	59 b (S_1)	6.25	754.625	86.85	0.391	68.32±2.48
3	451 Rw (S_1)	1.15	138.374	46.02	0.549	68.09±2.80
4	515 b (S_1)	6.15	743.700	89.58	0.292	68.40±2.47
5	373 Rw (S_1)	2.81	369.338	50.29	0.934	74.25±3.05
6	490 b (S_2)	5.28	579.690	66.10	1.005	62.23±2.30
7	32 b (S_2)	5.46	556.291	34.80	3.526	55.42±2.68
8	23 b (B_1)	7.62	1190.861	88.97	0.499	87.94±3.27
9	329 b (B_2)	5.33	756.202	83.64	0.500	80.01±2.90
10	1 Rw (B_2)	3.91	562.933	82.27	0.410	81.17±3.10
11	765 b (B_3)	6.42	743.415	75.50	0.816	65.57±2.47
12	245 b (B_3)	5.75	575.387	58.16	1.400	56.79±2.32

Rw = Whole rock

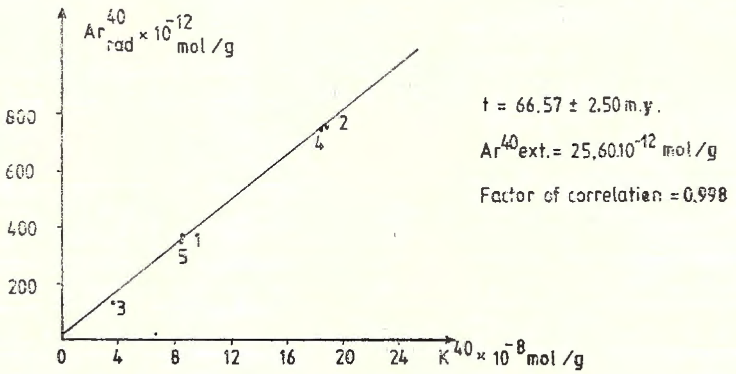
b = Biotite

The error reported represents the analytical error of age determination calculated after Cox and Dalrymple's formula (1967), which includes the error of potassium dosage, atmospheric pollution, error of ^{38}Ar tracer dosage, error of determination of $^{40}Ar/^{38}Ar$ and $^{38}Ar/^{36}Ar$ isotopic ratios.

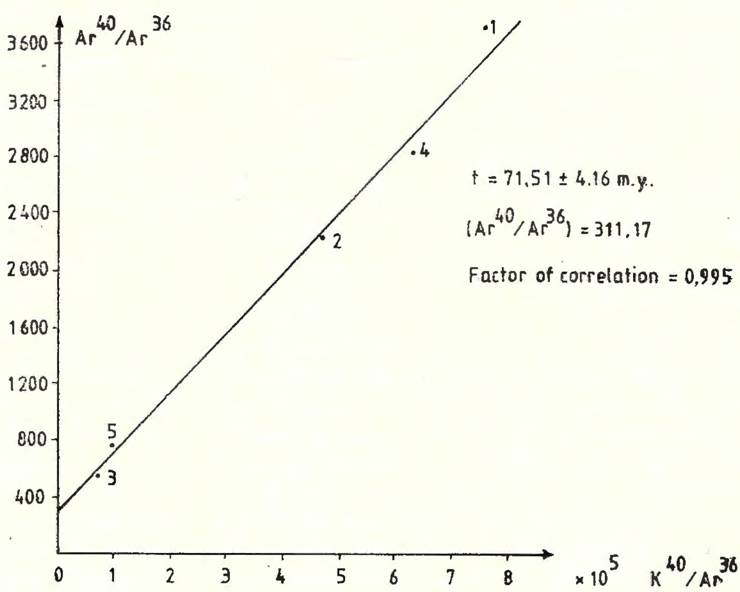
Samples 1-5 (Tab. 2) from the Surduc 1 body show a good correlation ($r=0.998$ on ^{40}Ar rad vs. ^{40}K diagram and $r=0.995$ on the $^{40}Ar/^{36}Ar$ vs. $^{40}K/^{36}Ar$ diagram) that accounts for the calculation of an isochrone in the two systems of representation.

Relevant literature points out that the best interpretations of isochrone ages are those confirmed by two methods of representation, the only way of proving the geological validity of the calculated isochrone (Shafiqullah, Damon, 1974).

On the diagram y = ^{40}Ar rad, x = ^{40}K (Fig. 3 a) the analytical data are situated on an isochrone of 66.57 ± 2.50 m.y. with an excess ^{40}Ar given by the interception of the isochrone with y axis of 25.60×10^{-12} mol/g.



a



b

Fig. 3. — Isochrons drawn up on the basis of analyses on whole rock and biotite of Surduc 1 intrusion.

The radiogenic argon was calculated relying on the assumption that all nonradiogenic argon has the isotopic composition of the atmospheric argon.

Isochrone represents the time of closure of the system. The samples from Surduc 1 lend the following isotopic model :

^{40}Ar m = ^{40}Ar rad + ^{40}Ar at + ^{40}Ar ex(ct), in which

^{40}Ar m = argon 40 measured

^{40}Ar rad = argon 40 radiogenic

^{40}Ar at = argon 40 atmospheric

^{40}Ar ex = argon 40 excess.

The constant amount of argon 40 excess for the five samples is of 25.60×10^{-12} mol/g, about 6% as against the average content of the calculated radiogenic argon.

The isochrone age is significant and is smaller than the individual apparent ages. The individual apparent ages which indicate the moment of the system closing are those of the samples with the highest content of K (59 b and 515 b).

^{40}Ar/^{36}Ar vs. ^{40}K/^{36}Ar diagram presumes the following isotopic model given by the general equation :
^{40}Ar m/^{36}Ar m = ^{40}Ar rad/^{36}Ar m + ^{40}Ar at/^{36} Ar m + ^{40}Ar ex/^{36}Ar m — ^{40}Ar dif/^{36}Ar m, in which the indices have the above-mentioned significance and ^{40}Ar dif represents ^{40}Ar lost by diffusion.

The geological validity of the isochrone is given by the condition :
^{40}Ar at/^{36}Ar m + ^{40}Ar ex/^{36}Ar m — ^{40}Ar dif/^{36}Ar m = ct

Therefore a suite of cogenetic samples with different apparent ages show a nonradiogenic component with constant ^{40}Ar/^{36} Ar ratio, a component already incorporated at the beginning of the radioactive decay.

According to this model the age calculated from the isochrone (Fig. 3 b) is of 71.51±4.16 m.y., with an ^{40}Ar/^{36}Ar=311.17 ratio of the initial nonradiogenic component (a ratio about 6% higher than that of the atmospheric argon, ^{40}Ar at/^{36}Ar at = 295.5).

The external component is evident on this diagram too with about the same percentage. The ages calculated from isochrones, using both methods of representation are similar within the limit of the analytical errors : 66.57±2.5 m.y. and 71.51±4.16 m.y., a fact indicating the geologic validity of the obtained values. Thus, one may consider that the closure of the system ranges between 67 and 72 m.y. It represents the cooling ages of the magma crystallization, which in case of plutonic rocks may be younger than the ages of emplacement on condition that these rocks have not been disturbed due to subsequent thermal or tectonic events which rejuvenated them.

Considerations on the Age of the Banatitic Plutons

Considering all the mentioned facts as well as the geological observations one might presume that the first intrusion within the Surduc massif (S_1) had a complex magmatic evolution. The occurrence of gabbronorite and anorthosite inclusions as well as of cumulus-type crystals (plagioclase and pyroxenes), previously formed, shows proof of the existence of at least of an already-consolidated part within the magma generating the Surduc differentiates, thus the nonradiogenic external (initial) component of ^{40}Ar being explained.

Livingston et al. (1967) proved that the excess of initial ^{40}Ar is found in the plagioclases of monzonitic plutons, being incorporated during the parental magma crystallization.

Therefore it is possible that the Surduc pluton might contain either elements of an intermediary magmatic chamber, with an evolution of the layered igneous type (anorthosite nodules, "cumulus" inherited plagioclase crystals, etc.), later taken over by the new magma impuls that has not succeeded to melt them entirely, or within the same magmatic chamber the crystallization which had started under conditions of absence of tectonic stress was interrupted and the already consolidated elements were disturbed and only partly remelted.

Taking into account the contrasting chemical features of some of gabbroic and anorthositic nodules as against the general differentiation trend within the S_1 intrusion the former hypothesis is more probable, which presumes the existence of already crystallized rocks that give apparent ages of 74-75 m.y. (the nodules might be even older) as compared with the closure of the system therefore of the consolidation of the massif inferred from the isochrone, which ranges between 67-72 m.y.

In comparison with the first intrusion at Surduc, the second one displays younger apparent ages (Tab. 2). The difference between the two samples might be explained by weak phenomena of hydrothermal autometamorphism noticed at sample 32.

For the Bocșa massif one could not drawn up an isochrone which could be verified by two methods because of the small number of samples.

However, the apparent ages (Tab. 2) pointed out a succession of values for B_1, B_2 and B_3 from 87.9 m.y. B_1, 80-81 m.y. B_2, to 65-56 m.y. B_3.

As compared with the first Surduc intrusion (S_1) the megadykes in the western part of the Bocșa massif (B_1, B_2) indicated older K/Ar apparent ages although the petrological features and the chemism are similar (the presence of relict elements with basic magma characteristics both at Surduc and at Bocșa 1-2).

B_3 and S_2 intrusions indicate similar ages as they seem to have been emplaced almost at the same time, but they show relatively different petrological characteristics; granodiorites from B_3 are typically calc-alkaline, the magmatic differentiation being independent of the western units B_1 and B_2 whereas monzogranites from S_2 still preserve some mineralogical and chemical features resembling S_1 unit emplaced previously.

K/Ar radiometric data within the Surduc and Bocșa plutonic massifs led to significant conclusions regarding the intrusive magmatic activity in Banat.

1. Geological evidence on the presence of successive intrusions within big banatitic plutonic massifs was established. At Bocșa mega-dykes in the western part of the massif were already consolidated, therefore ended their evolution, between 87 m.y. (B_1) and 80-81 m.y. (B_2). Later on, B_3 intrusion, emplaced subsequently, points to ages of 65-56 m.y.

At Surduc, S_1 unit indicates apparent ages of 75-68 m.y. quite similar, within the limit of analytical errors, with the ages calculated from isochrones — 67-72 m.y. — as compared with S_2 unit which shows ages of 62-55 m.y.

One may infer that the emplacement of the banatitic plutons in the Carpathians during the Upper Cretaceous-Paleogene time represents a magmatic "epoch" with an episodic character with two culminations.

2. The existence of basic magmatites with alkali differentiates of monzonite or potassic syenites-shoshonites type, about 87-74 m.y. at Surduc and West Bocșa, located within the Lower Senonian like some intrusions in Bulgaria (Boyadjiev, 1981), differing from the typical calc-alkaline banatitic magmatites of Bocșa 3-Ocna de Fier-Dognecea-Oravița type located in the Paleogene (65-55 m.y.), that is post-Laramian.

As regards the basic magmatites, it is worth mentioning that they had been considered by previous researchers as products of a differentiation specific to banatites, from generally granodioritic magmas to poor alkaline (monzonitic) or basic terms (Giușcă et al., 1966).

Our researches which pointed out the existence of a different previous magma, at least within the above-mentioned massifs, are now confirmed both by the different ages of the intrusions and by the pointing out (on diagram) of an external component of argon within S_1 intrusion where olivine gabbronorites and anorthosites are to be found. It is very likely that the emplacement of these first intrusions might be older considering that the ages of the calculated isochrones represent the cooling ages of the bodies.

3. As compared with the time interval within which, according to the geological evidence, the first crust shortening — the crust consumption inclusively — took place in connection with the overthrust of the Getic Nappe (underthrust of the Danubian Unit), that is the Upper Senonian or the end of the Senonian, the studied magmatites occur in two different situations.

The Lower Senonian magmatites (S_1 and B_{1-2}) would be older than the overthrust processes, and the Paleogene ones subsequent to them. This classification is also underlined by the petrochemical features of the magmas generating the two groups of plutons.

This conclusion is also significant as regards the explanation of the origin of the two magmas which might be more or less different. In this respect one might presume that the basic magmas with alkaline tendencies are geotectonically related to a period of distension prior to the overthrusting whereas the second group of plutons, younger, subsequent to the overthrusting, possesses the characteristics of magmas linked with subduction processes. Nevertheless suppositions can be made either on the source area of the magmas, which may be different, or on the composition of the melted material generating different magmas. All this will be presented in a paper on the Surduc massif (Russo-Săndulescu, Bratosin, Vlad, Ianc, 1986).

[3] The petrochemical characters of the Surduc massif are presented in another paper included also in the present volume.

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SEMNIFICAȚIA VÎRSTELOR RADIOMETRICE (K-Ar) OBȚINUTE ÎN ZONA PLUTONILOR BANATITICI DIN BANAT

(Rezumat)

Magmatitele intrusive banatitice au fost considerate pînă acum că s-au pus în loc după faza tectonică laramică; acestea sînt distribuite spațial într-o „zonă a banatitelor plutonice“ cu dezvoltare preponde-

rentă în cadrul pînzei supragetice și o „zonă a banatitelor hipabisice" care apar mai ales la est de sinclinoriul Reșița-Moldova Nouă, în cadrul pînzei getice (Russo-Săndulescu și Berza, 1977).

Analizele geocronologice (metoda K/Ar) sînt obținute pe roci și minerale aparținînd plutonilor Bocșa și Surduc din zona plutonilor banatitici. Aceste corpuri sînt alcătuite din intruziuni succesive, dintre care primele au afinități alcaline, cu diferențiate de natură shoshonitică, fiind urmate de punerea în loc a magmelor calcoalcaline, granodioritice.

La Surduc, intruziunea S_1, anterioară, prezintă vîrste aparente între 75 și 68 m.a., destul de asemănătoare în limita erorilor analitice cu vîrstele calculate din izocrone, adică 67 și 72 m.a. (vîrstele izocrone sînt obținute prin două metode de reprezentare, punîndu-se în evidență și prezența unei componente externe de Ar 40) La Bocșa, primele intruziuni s-au consolidat aproximativ între 87 și 81 m.a.

Plutonitele granodioritice, atît la Surduc cît și la Bocșa, prezintă vîrste aparente între 65 și 55 m.a.

Din corelarea datelor geologice cu vîrstele radiometrice se poate conchide că masivele plutonice de la Surduc și Bocșa au avut o istorie magmatică mai complexă. Primele veniri de magmă în care s-au recunoscut incluziuni de gabbronorite și anortozite cu structuri de cumulate s-au pus în loc anterior față de principala scurtare de scoarță — deci consum de scoarță — legată de șariajul pînzei getice (subșariajul unității danubiene) adică în Senonianul superior sau sfîrșitul Senonianului. Corpurile preponderent granodioritice de natură tipic calcoalcalină sînt amplasate în Paleocen, ulterior proceselor de șariaj.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

THE RADIOMETRIC AGE (K/Ar) AND THE ORIGIN OF THE SĂVÎRȘIN GRANITOID MASSIF AND OF OTHER LATE KIMMERIAN INTRUSIONS FROM THE MUREȘ ZONE.[1]

BY

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Laramian granitoid. Radiometric age. K/Ar Method. Granitoid. Isochrones. Island arc. Late Kimmerian magmatic province. Calc-alkaline differentiation. Apuseni Mountains — Southern Apuseni — Drocea Mountains — Metaliferi Mountains.

Abstract

For the Săvîrșin alpine granitoid massif (Mureș Zone) which was considered to belong to banatitic (Laramian) magmatic province, we obtained radiometric ages which correspond to an isochron Ar^{40}rad-K^{40} of 121.34 ± 4 m.y. and to an isochron Ar^{40}/Ar^{36}-K^{40}/Ar^{36} of 128.6 ± 1.0 m.y. Because we also obtained close radiometric ages for Cerbia intrusive body and for other acid and alkaline intrusions from Drocea Mts, whose rocks are similar to those from Săvîrșin massif, we consider that all mentioned intrusions have been emplaced during the same stage of the evolution of the two Late Kimmerian island arcs from the Mureș Zone. Săvîrșin and Cerbia granitoid massifs belong to the southern island arc and the veins and bodies of acid and alkaline rocks from Vărădia-Troaș, Roșia Nouă and Obîrșia belong to the northern one. On account of the mentioned data, these intrusions cannot belong to banatitic province, as they were before considered. Together with the volcanics of the two island arcs from the Mureș Zone, they belong to a Late Kimmerian calc-alkaline magmatic province.

Résumé

Age radiométrique (K/Ar) et origine du massif granitoïde de Săvîrșin et des autres intrusions néokimmériennes de la zone de Mureș. Pour le massif granitoïde alpin de Săvîrșin (zone de Mureș) qui était antérieurement considéré comme appartenant au magmatisme banatitique (laramien) on a obtenu des âges radiométriques correspondant à un isochrone Ar^{40}rad.-K^{40} de 121,34 ± 4 m.a. et à une isochrone Ar^{40}/Ar^{36}-K^{40}/Ar^{36} de 128,6 ± 1,0 m.a. Du fait que des âges radiométriques semblables ont été obtenus pour le corps intrusif de Cerbia et pour d'autres intrusions acides et alcalines des monts Drocea, dont les roches

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sont similaires au celles de Săvîrșin, on envisage que toutes les intrusions mentionnées ont été mises en place pendant la même étape de l'évolution de ces deux arcs insulaires néokimmériens de la zone de Mureș. Les massifs granitoïdes de Săvîrșin et de Cerbia appartiennent à l'arc insulaire méridional alors que les filons et les corps de roches acides et alcalines de Vărădia-Troaș, de Roșia Nouă et d'Obîrșia, à celui septentrional. A partir des données susmentionnées, ces intrusions ne peuvent pas être réparties à la province banatitique, tel qu'elles ont été antérieurement considérées, mais à une province magmatique calco-alcaline néokimmérienne (y compris les volcanites de ces deux arcs insulaires de la zone de Mureș).

Introduction

The Săvîrșin granitoid massif is situated in the south of the Drocea Mts within the series of the Alpine ophiolites from the Mureș Zone. Our investigations (Lemne et al., 1979 ; Savu et al., 1984) on radiometric age of this granitoid massif gave us data regarding the exact period when it was emplaced and its origin. These two elements constitute the subject of this paper.

The Massif Structure

As Savu (1953) and the more recent investigations (Savu et al., 1966 ; Savu, Mîndroiu, 1980) showed the Săvîrșin intrusive massif is formed of two main bodies which were emplaced successively. The first body, the northern one, resulted from successive intrusions of diorites and quartz diorites, rocks which are found on its margin. Then follows the Temeșești granodiorite, which forms the main part of the body which is crossed by dykes of aplites and lamprophyres (kersantites) and veins of quartz with molybdenite. The second body, the southern one, is composed of the Săvîrșin white-pink granite bearing biotite and hornblende, which is widely porphyritic (Savu, Vasiliu, 1966) and has a marginal facies composed of fine granular granite. This intrusion was crossed at its turn, by aplites and pegmatoid rocks, sometimes bearing granophyric tendency. We have to underline that in the outcrop, the Săvîrșin granite changes quickly enough passing into a characteristic grus.

Because, from the petrographic and petrochemical point of view, the rocks of the massif have a lot of similarities with the banatitic rocks (Laramian) in the Northern Apuseni and Banat, this composite granitoid massif was considered — as the other acid intrusions in the Mureș Zone — as a banatitic body (Codarcea, 1931 ; Savu et al., 1966 ; Giușcă et al., 1966), therefore a Laramian massif.

Radiometric Age of the Massif

In order to establish the age of the granitoid massif, we analysed by the K/Ar method (isotopic dilution) seven biotite samples and various representative rocks of acid composition (Tab.). Values of aparent

TABLE

Data of radiogeneous age obtained on the biotites and rocks within the Săvîrşin granitoid body

No.	No. of sample	Type of rock and place	Analysed fraction	K %	100 Ar^{40} rad. / Ar^{40} tot	Ar^{40} rad. / 10^{-10} mol/g	t ± 1 σ
1	114	Granodiorite, Ciumani Valley	whole rock	2.65	94.60	5.9374	124.8 ± 4.8
2	115	Aplite, Bălan Brook	whole rock	4.18	91.28	9.7203	129.3 ± 4.9
3	116	Granite in marginal facies, Mladin Brook	whole rock	4.04	97.87	9.3618	128.9 ± 4.8
4	2 B	Granodiorite, Roşelii Valley	biotite	4.80	83.19	11.0868	128.5 ± 4.7
5	3 B	Granodiorite, Valea Mare, Temeşeşti	biotite	2.72	76.48	6.9851	142.3 ± 5.4
6	5 B	Granite, Valea Mare, in the south of the Mureş	biotite	5.94	92.18	13.8572	129.8 ± 3.9
7	6 B	Granodiorite, Ciumani Valley	biotite	7.11	84.65	15.8469	124.2 ± 5.2

radiometric age vary between 124.2 ± 5.2 and 142.3 ± 5.4 m.y. Besides these samples, we also analysed other two Săvîrşin granites, one in Hălăliş (no. 11/64) another one in the Troaş valley mouth (no. 1) which probably because of an incipient alteration of biotite, the mineral which we analysed, they gave younger ages of 77.2 ± 3.3 m.y. and 85.8 ± 4.3 m.y. respectively.

Data of aparent age from table 1 have been used to calculate the isochronic age in two systems of coordinates. In the system Ar^{40}/Ar^{36} — K^{40}/Ar^{36} (Fig. 1) we obtained the value of 128.6 ± 1 m.y. and a value of initial argon ratio (Ar^{40}/Ar^{36}) of 290.48 which is very close to the value of atmospheric argon. In the system rad. Ar^{40}-K^{40} (Fig. 2), we obtained 121.34 ± 4 m.y. The ages calculated through the two systems are comparable in the limit of determination errors and so the isochronic ages have a geological valability (Shafiqullah, Damon, 1974). Because in the system Ar^{40}/Ar^{36} — K^{40}/Ar^{36} the samples have the best correlation ($r = 1$) we consider the value of 128.6 ± 1 m.y. as the closed age of the system.

The obtained values show that the granitoid massif of Săvîrşin with its two parts was emplaced in the Neocomian, before the Barremian which is transgressive in the region and its intrusion was caused by the Late Kimmerian movement. According to Savu et al. (1983; 1984a) at the same time were emplaced numerous veins and small bodies of granitic and syenogranitic porphyres which are crossing the ophiolites between Vărădia and Troaş, for which have been determined isochronic ages of 116 and 120 m.y. (Lemne et al., 1983). Savu (1962a) showed that these rocks belong to the Late Kimmerian magmatic province.

During the same period, it seems that is also emplaced the Cerbia granitoid massif (Savu et al., 1984 b) for which a more recent radiometric age determination gave 108.3 ± 4 m.y. These conclusions are

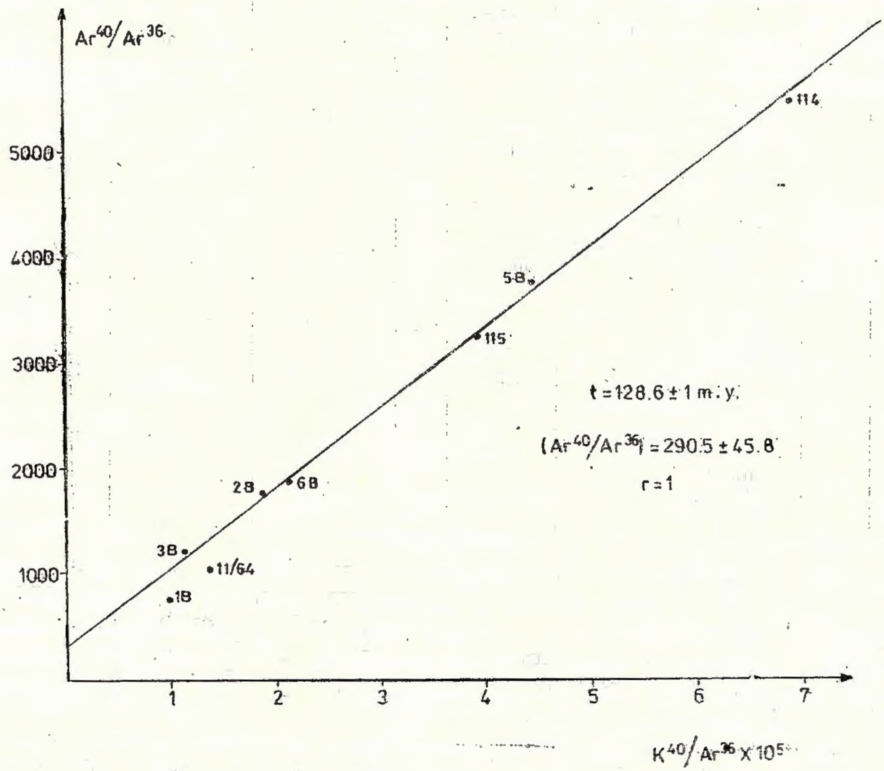

Fig. 1. —Ar^{40}rad. versus K^{40} plot of data from the Săvîrșin massif.

also stressed by the following geological observations (Savu et al., 1984 b).

1. The petrographic and metallogenetic similarity of granitoid bodies from Săvîrșin and Cerbia.

2. The granitoid body from Cerbia which is enrooted in the south, on Valea Mare (Almaș-Săliște) is crossed by veins of basaltic rocks very similar to those from the southern Late Kimmerian island arc in the Mureș Zone.

3. Some rocks as granitic, granodioritic and granosyenitic porphyries which are associated to the two granitoid massifs or which occur among the veins and bodies from Vărădia-Troaș region or isolated in the rest of the Mureș Zone are very similar among them and at the same time with the leucocratic volcanics from IAV_2 complex of the two island arcs in the Mureș Zone, which is situated under the Upper-Jurassic limestones and is intercalated between the jasper formation at the basis of the J_3-Cr_1 flysch. Therefore, some geologists said that all

of them belong to the Laramian banatitic eruptions (Teodoru et al., 1963). It is obvious that the two massifs (Săvîrșin and Cerbia) were emplaced on the southern margin of the Mureș Plate (Fig. 3) and not

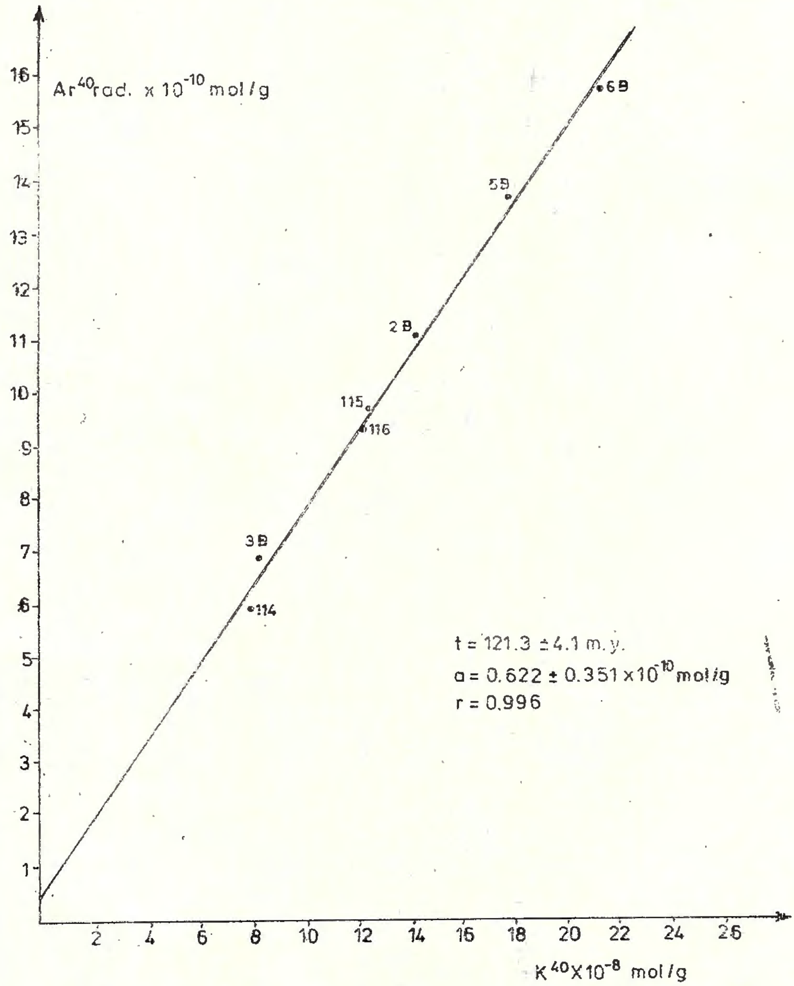

Fig. 2. — Ar^{40}/Ar^{36} versus K^{40}/Ar^{36} plot of data from the Săvîrșin massif.

— as it was previously believed — on a NE-SW alignments, and the Vărădia-Troaș dykes and bodies on its northern margin, the last rocks belonging to the northern island arc.

All these data make us conclude that a lot of leucocratic intrusive bodies in the Mureș Zone and especially in its south part, which are previously considered as banatitic bodies, are not Laramian. They belong to the Upper Jurassic-Lower Cretaceous magmatites from the two island arcs of the Mureș Zone, intruded on the margins of the Mureș ophiolitic plate under which were subducted the plates from north and

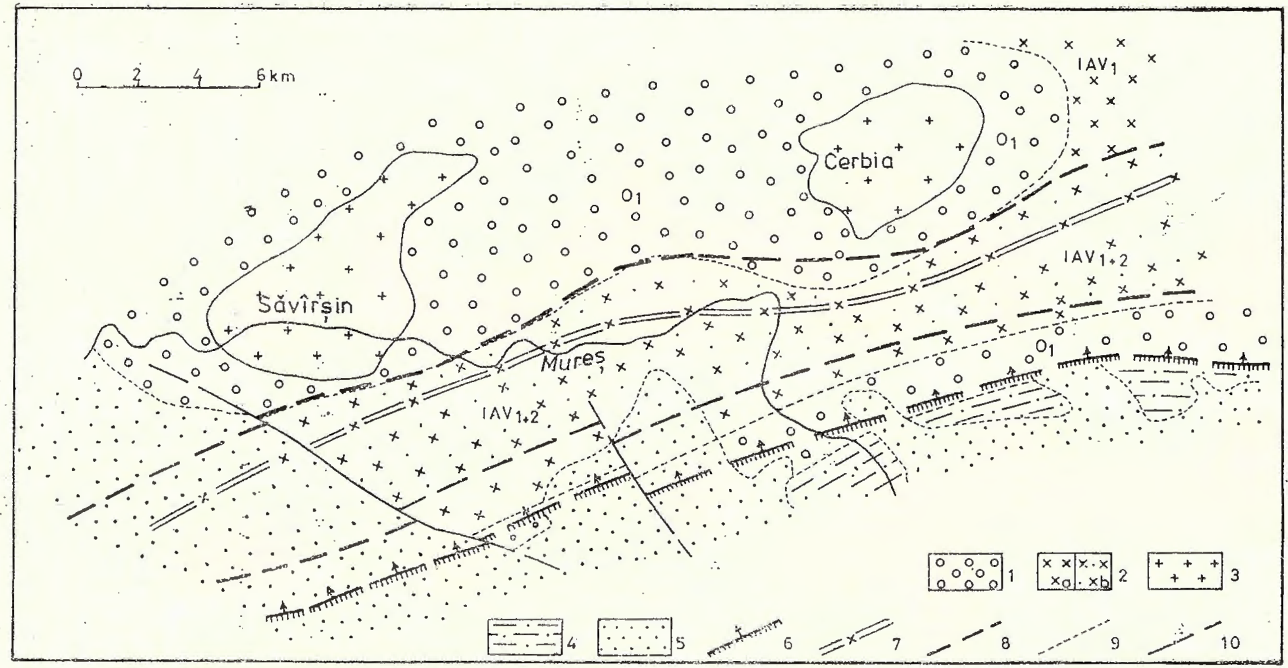

Fig. 3. — Position of granitoid bodies of Săvîrșin and Cerbia in relation with southern island arc of Mureș Zone. 1, ophiolitic-ocean plate (complex of ocean floor basalts (O_1) (J_1-J_2); 2, the formations of southern island arc (IAV_1-a and IAV_1+IAV_2-b) with crystalline schists, recrystallized limestones and ophiolitic rocks olistoliths (J_2-Cr_1); 3, granitoid intrusions of Săvîrșin and Cerbia; 4, transgressive Barremian-Aptian formations; 5, sedimentary deposits and laramian and postlaramian volcanics; 6, limit of underthrust of the Sialic part of the Transylvanian plate; 7, volcanic alignment of island arc (J_2-Cr_1); 8, gravimetric negative anomaly; 9, geological limit; 10, fault.

south (Savu, 1983). The intrusive bodies from Săvîrşin and Cerbia belong to the southern island arc of the Mureş Zone (Fig. 3) and the acid and alkaline dykes and bodies from Vărădia-Troaş, Roşia Nouă and Obîrşia to the northern one.

Origin of the Granitoid Massif

Regarding the origin of the Săvîrşin granitoid massif, we showed that it was previously considered a banatitic body, therefore formed — as the other Laramian intrusions — from a lithogeneous magma (Codarcea, 1931 ; Giuşcă et al., 1966). For the other banatitic intrusions outside the Mureş Zone such an origin is not a problem, because they are placed inside the crystalline schists of the two tectonic plates in the south and north of the Mureş Zone. In order to explain the origin from a lithogeneous magma of the Săvîrşin granitoid massif as well as of the other intrusive bodies considered banatitic in the Drocea and Metaliferi Mts, situated in the ophiolites, rocks of ocean-floor, it was necessary a sialic basement under the ophiolite mass in the Mureş Zone. Indeed, the geotectonic models for the Mureş Zone structure from that period, contained — because of this idea and because of the presence of some olistoliths of crystalline schists considered as rooted scales (Ghiţulescu, Socolescu, 1941) — a sialic basement (Savu, 1962b ; Savu, 1967) which did not agree with the meaning of the ocean floor where the Mureş Zone ophiolites had formed.

No sooner than 1981, a new conception about a new model of geotectonic evolution of the Mureş Zone was created (Savu, 1983). Now, it can explain the origin of acid intrusions which are crossing the ophiolites in this zone. On this occasion it was shown that at the beginning (J_1-J_2) the Mureş Zone developed as an ocean-floor, but at the end of the Callovian began its closure, which is accompanied by bilateral subduction processes, resulting the two island arcs mentioned above. On the southern margin of the Mureş Zone, as well as on the

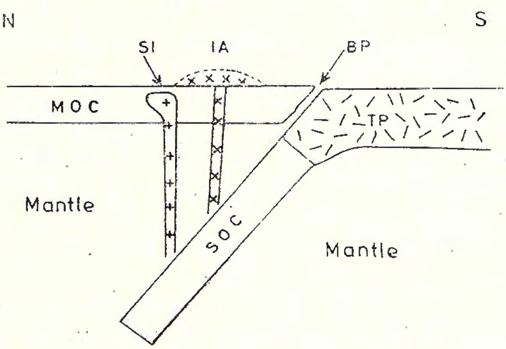

Fig. 4. — Geotectonic model for the formation of the intrusive body of Săvîrşin. MOC, ocean crust of the Mureş plate ; SOC, subducted ocean crust ; TP, Sialic part of the Transylvanian plate ; BP, Benioff plane ; IA, southern island arc in the Mureş Zone ; SI, Săvîrşin intrusion.

northern one, the ocean crust was broken and the part welded to the Transylvanian Plate was subducted to north under the Mureş ocean plate (Fig. 3), the last being obducted on the continental (sialic) part of the Transylvanian Plate (MOC in Fig. 4).

Therefore, from the magmas formed by melting of ocean crust subducted on the Benioff plane, results the volcanism of southern island arc (Savu, 1983) which manifested from the Upper Jurassic to the Lower Cretaceous, extending on the whole zone, its magmatic rocks being visible on the Căpîlnaș-Vălișoara-Almașu Mare alignment nowadays.

As we can see in Figures 3 and 4, the volcanic alignment of southern island arc is formed during the first stage of subduction process which lasts between the end of the Callovian and the beginning of the Neocomian. Now took place the intraocean calc-alkaline and weakly alkaline volcanic eruptions which generated two volcanic complexes, the second (IAV_2) being composed of leucocratic rocks (Savu, 1983 ; Savu et al., 1981).

During a later stage in the Neocomian, the island arc magmatic activity has an intrusive character and magmas formed from the ocean crust melting, strongly differentiated are emplaced as intrusive bodies similar to those from Săvîrșin and Cerbia which are placed along the island arc (Fig. 4) within the Lias ophiolitic rocks, which are metamorphosed at the contact. According to Mitchell and Bell (1973) classification this stage with acid intrusive rocks belongs to the 7th stage of the island arc evolution. We have to remark that on this island arc took place between Cărmăzinești-Vălișoara at north of Vorța — where the reef barrier is missing — acid volcanic eruptions (Savu et al., 1984b) for which have been found ages of 120-110 m.y. (Lemne et al., 1979 ; Savu et al., 1984b).

Regarding the banatitic province, Cotta (1865) understood by this nomination all the rocks in the Banat and surrounding regions which have been emplaced after the Jurassic,maybe after the Cretaceous almost at the same time. The exact period of banatitic rocks emplacement at the end of the Upper Cretaceous and the beginning of the Paleogene was indicated by Codarcea (1931) and Giușcă et al. (1966). They assigned them to the Laramian orogenesis, including here also the acid and intermediary intrusive rocks in the Mureș Zone, which we talk about here.

In the light of the above data, the magmatic rocks which we discussed here, as granitoid intrusions from Săvîrșin, Cerbia, dykes and small bodies of acid and alkaline rocks from Vărădia-Troaș and others which belong to the magmatic activity of the two island arcs cannot be assigned to the banatitic (Laramian) province. Generally, they could be considered as island arc magmatites from a Late Kimmerian province.

Conclusions

We draw the following conclusions here :

Data of radiometric age which we obtained for the Săvîrșin eruptive massif correspond to an isochron Ar^{40}rad. — K^{40} of 121.3 $\pm$ 4.1 m.y. and to a isochron Ar^{40}/Ar^{36} — K^{40}/Ar^{36} of 128.6 $\pm$ 1.0 m.y. ;

Because close radiometric ages have been obtained also for the Cerbia intrusive body and other acid and alkaline eruptions from the

Drocea Mts whose rocks are similar to those from Săvîrşin, we consider that all the intrusions mentioned have been emplaced during the same stage in the evolution of the two Late Kimmerian island arcs from the Mureş Zone ;

The Săvîrşin and Cerbia granitoid bodies belong to the southern island arc, while the dykes and bodies of acid and alkaline rocks from Vărădia-Troaş, Roşia Nouă and Obîrşia, to the northern one ;

On account of these data, these intrusions cannot be assigned to the banatitic magmatites as they were previously considered but they belong to a magmatic calc-alkaline Late Kimmerian province, together with the volcanics of the two island arcs in the Mureş Zone.

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QUESTIONS

D. Russo-Săndulescu: How do you explain the younger radiometric age, "banatitic" according to you, determined by another method also in the area of the Săvîrșin massif (Hertz et al., 1974).

Answer: First of all because the rocks analysed by Hertz et al. (1974) are situated at great distances from the Săvîrșin massif and secondarily as the Măgureaua Vaței banatitic body exists, small bodies (veins) of banatitic rocks can exist in the Mureș Zone, too.

VÎRSTA RADIOMETRICĂ (K/Ar) ȘI ORIGINEA MASIVULUI GRANITOID DE LA SĂVÎRȘIN ȘI A ALTOR INTRUZIUNI NEOKIMMERICE DIN ZONA MUREȘ

(Rezumat)

Masivul granitoid de la Săvîrșin este format din două părți principale: partea nordică constituită din diorite, cuarțdiorite, granodiorite, aplite, lamprofire și filoane de cuarț și partea sudică alcătuită din granitul de Săvîrșin, cu un facies marginal, străbătut de filoane de aplite.

Vîrstele radiometrice aparente determinate pe biotite și roci variază între 124,2 $\pm$ 5,2 și 142,3 $\pm$ 3,4 ma (tab.); două probe au dat vîrste mai mici. Vîrstele izocrone calculate pe două sisteme de coordonate (fig. 1, 2) corespund la 128,6 $\pm$ 1 ma și respectiv 121,34 $\pm$ 4 ma, dintre care prima valoare considerăm că reprezintă vîrsta de închidere

a sistemului. Valorile obţinute arată că corpul granitoid a fost pus în loc la sfîrşitul Neocomianului şi înaintea Barremianului, intruziunea lui fiind în legătură cu mişcările neokimmerice. În acelaşi timp au fost puse în loc corpul granitoid de la Cerbia şi filoanele şi micile corpuri de porfire granitice şi sienogranitice din regiunea Vărădia-Troaş şi altele.

Datele de vîrstă radiometrică arată că intruziunile de mai sus nu sînt banatitice (laramice) cum s-a crezut anterior. Poziţia lor ca intruziuni pe marginile plăcii oceanice a Mureşului, unde se distribuie paralel cu aliniamentele celor două arcuri insulare din regiune (fig. 3), conduce la concluzia că aceste corpuri eruptive sînt legate de magmatismul de arc insular neokimmeric.

În partea sudică a zonei Mureş subducerea sub ea a crustei oceanice liasice care era sudată la placa transilvană are loc într-o perioadă ce începe în Calovianul superior şi se încheie la sfîrşitul Neocomianului, timp în care crusta oceanică se topeşte şi din ea rezultă magme calco-alcaline. Aceste magme vor genera într-un prim stadiu vulcanismul arcului insular, iar într-un stadiu mai tîrziu, intruziunile de la Săvîrşin, Cerbia şi altele (fig. 4).

Deoarece corpurile de roci banatitice, între care erau cuprinse anterior şi cele prezentate mai sus, au fost puse în loc la sfîrşitul Cretacicului şi începutul Paleogenului, intruziunile de roci granitoide discutate în lucrare nu pot fi încadrate în această categorie. Ele pot fi considerate, împreună cu vulcanitele din cele două arcuri insulare, drept produsele magmatice ale provinciei eruptive neokimmerice.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

DISTRIBUTION OF U, Th, K, REE AND OTHER TRACE ELEMENTS IN ISLAND ARC VOLCANICS AND SOME OPHIOLITES FROM VAȚA-VORȚA-VĂLIȘOARA REGION (MUREȘ ZONE) [1]

BY

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Magmatic rocks. Mesozoic. Ophiolites. Island arc volcanics. U, Th, K, REE. Ti, Y, Zr. Chemical composition. Trace elements. Apuseni Mountains — Southern Apuseni — Metaliferi Mountains.

Abstract

Within Vața-Vorța-Vălișoara region in the Mureș Zone, we distinguish two series of Alpine-Prelaramian magmatic rocks : (a) an ophiolitic series (J_1-J_2) in the basement and (b) a series of island arc volcanics (J_3-Cr_1). U, Th, K contents are generally higher in the series of island arc volcanics than in the ophiolitic series. Lanthanides determined in the series of island arc volcanics are specific for calc-alkaline series and are generally higher than the average we know for this kind of rocks. Ti, Y and Zr contents also underline the fact that these rocks belong to the series of island arc volcanics.

Résumé

Distribution de U, Th, K, terres rares et d'autres éléments mineurs dans les volcanites d'arc insulaire et dans quelques ophiolites de la région de Vața-Vorța-Vălișoara (zone de Mureș). La région de Vața-Vorța-Vălișoara de la zone de Mureș se caractérise par des roches magmatiques alpines-prélaramiennes : a) une série ophiolitique (J_1-J_2) dans le soubassement et b) une série de volcanites d'arc insulaire (J_3-C_1). Les teneurs en U, Th et K sont en général plus grandes dans la série des volcanites d'arc insulaire que dans la série ophioli-

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tique. Les contenus des lantanides déterminés dans la sérié des volcanites d'arc insulaire sont spécifiques aux séries calco-alcalines et leur moyenne étant plus élevée que la moyenne connue en littérature pour des roches similaires. Les teneurs en Ti, Y et Zr soulignent aussi l'appartenance des roches analysées aux séries de volcanites d'arc insulaire.

Introduction

Trace elements distribution is specific for each magmatic rock series which is forming during one ocean zone evolution. In order to know radioactive elements, REE and other minor elements behavior, in the two Mesozoic magmatic series from the Mureș Zone, in 1979, 1980 and 1981, Lemne and co-workers (unpublished data) have geochemically investigated the region from Vața, Vorța and Vălișoara, the elements being determined by natural gamma spectrometry, neutrons activation and X fluorescence.

Ghițulescu and Socolescu (1941), Iacob (1953), Cioflica (1961), Trifulescu (1963), Savu and Nicolae (1975 a) have investigated this region from the geological, petrographical and metallogenetical point of view. Savu and Nicolae (1975 b), Udubașa and co-workers (unpublished data) have also studied the sulphides mineralizations from Vorța and Valea Lungă respectively, around which the eruptive rocks are strongly alterated.

Savu et al. (1981), Savu et al. (1982), Savu et al. (1984) and Savu et al. (1985) have recently studied in the south part of this region the eruptive rocks petrology and the trace elements contents determined by means of emission spectrography.

Considerations Regarding the Geological Structure of the Region

In 1978, Savu and co-workers have noticed that in the Mureș Zone, there are two important series of Alpine-Prelaramian magmatic rocks, namely an ophiolitic rock series which was forming on this zone ocean floor, under spreading conditions and another series of island arc volcanics. It was later shown that the calc-alkaline and alkaline volcanics were formed along two marginal island arcs (Savu, 1983).

Next investigations in the Vața-Vorța-Vălișoara region have shown that the two series of magmatic rocks mentioned above were also present here, namely (1) the ophiolitic rock series of Jurassic-preoxfordian age and (2) the series of island arc volcanics of Upper Jurassic-Lower Cretaceous age. As Herz et al. (1974) stated, the first rock series was formed 180 mil. years ago and the second between 140 and 120 mil. years ago. Lemne et al. (unpublished data) obtained close values for some rocks of the second series.

(1) The basement ophiolitic rock series is largely developed in the western part of the Mureș Zone till a sinuous limit placed westwards between Basarabeasa, Vața de Sus, Almaș Săliște and Zam, approximately along the western margin of the enclosed map (Fig. 1),

which is the boundary of the series of island arc volcanics, developing in the east area. East of this limit, within the region, the ophiolitic rock series also appears under island arc volcanics but only within the inliers of Visca, Luncoi and in the tectonic rise from Glodghilești-Săliștioara area (Savu, 1983).

The ophiolitic rock series is represented by the upper complex of ocean floor tholeiitic basalts (O_1) namely intersertal basalts, spilites, anamesites and variolites usually in the pillow lava facies, where tachylites and basaltic pyroclastics very seldom interbedded. To the south of Vorța, there are lenses of limestones recrystallized under the conditions of the ocean floor metamorphism. Within the inliers of Visca and Luncoi in this complex of submarine effusive rocks, there are also some small bodies of gabbros, melagabbros and even rocks with a close peridotitic character.

(2) The series of island arc volcanics covers almost the whole region and is represented especially by pyroclastics of calc-alkaline rocks from the volcanoes of the SE island arc of Mureș Zone, the axle of which passes by Zam-Dealu Mare-Vălișoara localities. These volcanics can be assigned to two characteristic complexes (Savu, 1983) : a) the lower complex (IAV_1) and b) the upper complex (IAV_2).

a) The lower complex (IAV_1) of andesitic basalts is very widely spread occupying the whole region except the above mentioned inliers, where it was eroded. This complex is mainly composed of agglomerates, rarely flows of porphyritic and glomero-porphyritic basalts, bearing phenocrysts of augite often twinned after the plane (100) such as those of Vața de Sus, porphyritic basalts bearing plagioclase (An 45-50) phenocrysts sometimes pyroxenes as well, usually amygdaloidal, ankaramites (Visca) and andesites bearing pyroxenes and green-brown hornblende, rocks among which often interbedded basaltic tuffs, here and there pyroclastics of amphibole andesites and radiolarites. Within the pyroclastics, we seldom meet great blocks of limestones, crystalline schists and tholeiitic rocks, which represent olistoliths scraped from the southern microplate and respectively from the tectonically raised zones of the ophiolitic basement (Savu, 1983 ; Savu et al., unpublished data). It is worth to be mentioned "the polygenous agglomerates" as well, which we often meet in Vălișoara-Săliștioara-Vorța region.

b) The upper complex (IAV_2) of island arc volcanics is usually limited to the axial zone of the island arc. It is generally composed of more acid rocks — although there appear basaltic rocks recurrences as well — which are represented by pyroclastics, rarely flows of quartz andesites bearing green hornblende, dacites and rhyolites. These alternate with radiolarites and also contain great blocks of synchronous Upper-Jurassic reefs limestones, and gabbros (Savu, 1983). At Dealu Mare, they bear Jurassic limestones which extend west of Cărmăzinești up to Căpîlnaș, along the island arc as a reef barrier which developed within the Upper Jurassic-Lower Cretaceous sea.

The eruptive rocks from the upper complex are intruded by igneous veins, dikes and small bodies orientated parallel to the island arc direction. Lemne et al. (unpublished data) pointed out a newer radiogenic age (120 mil. years) for some of them. As Savu et al. (unpublished data) have shown, to them can be associated the acid intrusive body of Cerbia, which could represent together with other similar bodies, the acid intrusive phase of island arc volcanism or the seventh

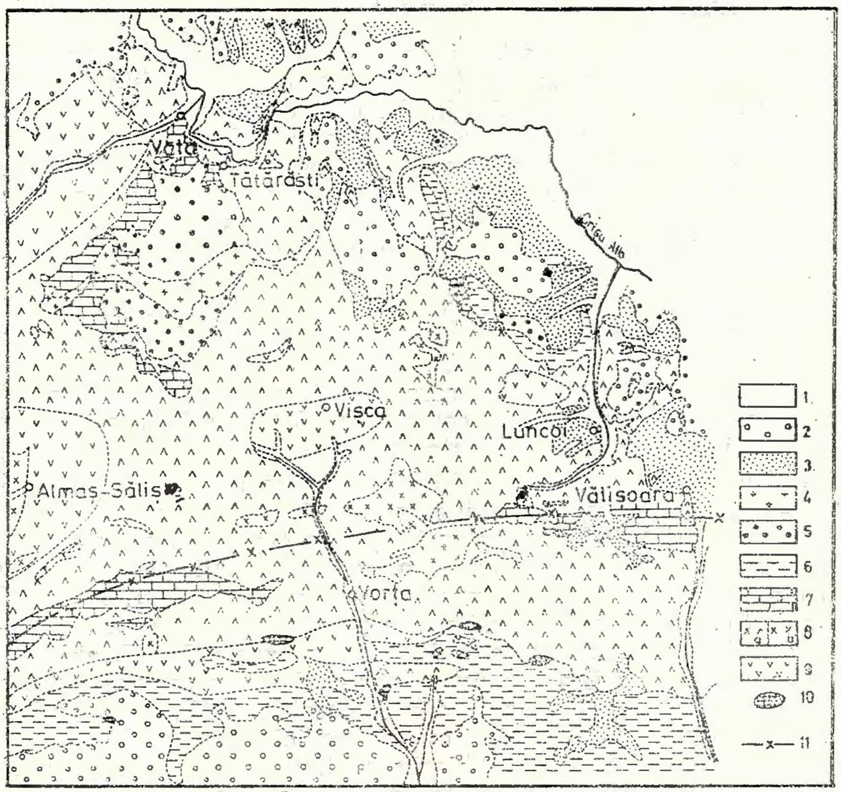

Fig. 1. — Geological map of the Vața-Vorța-Vălișoara region (acc. to the Geological map of Romania, sc. 1 : 200,000).
1, alluvia ; 2, Neogene volcanics ; 3, Neogene sedimentary deposits ; 4, Late Kimmerian or Laramian plutonic rocks ; 5, Upper Cretaceous ; 6, Lower Cretaceous ; 7, Upper Jurassic ; 8, Late Kimmerian volcanics of island arc : a, basic ; b, intermediary and acid ; 9, ophiolites ; 10, crystalline schist olistoliths ; 11, island arc alignment.

magmatic stage as Mitchell and Bell (1973) stated. We mention that oligophyres and orthophyres have been met as pyroclastics at the Upper Jurassic level, possibly at the Neocomian base.

Lower Cretaceous formations and then those of the Upper Cretaceous mostly eroded, overlie all eruptive rocks. The last ones and the older eruptive rocks are crossed by banatitic intrusions which metamorphose them at the contact in Măgureaua Vaței region. Then follows the sedimentation of Tertiary deposits and neogen volcanism the products of which lie at NE of investigated region (Fig. 1).

Distribution of U, Th and K

Natural radioactive elements have been determined in 246 samples of island arc volcanics (Tab. 1) and in 33 ophiolitic rocks (Tab. 2). The calc-alkaline basaltic rocks of island arc contain U from 0.1 to 4.5 ppm having several higher frequency domains as it results from the Table 3 and Figure 2 : one domain with a little higher contents (0.8–2.0 ppm U) is in the basalts from Vața-Tătărești Zone, the other basaltic rocks bearing smaller or constant contents of U. The exception is made by the basalts with augite phenocrysts and glomeroporphyritic texture

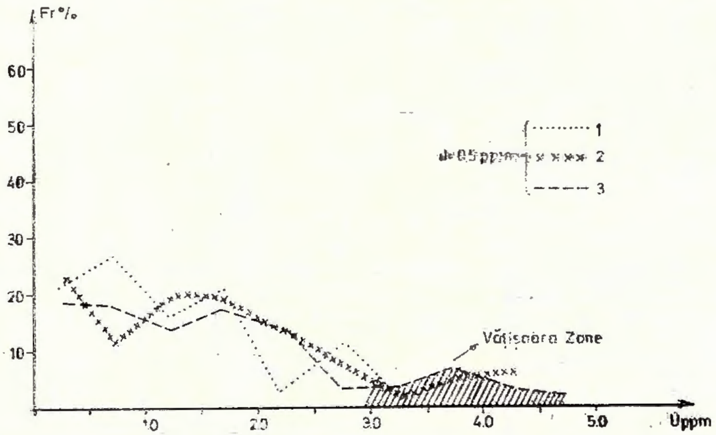

Fig. 2. — U frequency in island arc basalts.
1, Vorța-Dealu Mare basalts ; 2, Țebea-Visca-Luncoi basalts ; 3, basalts bearing augite phenocrysts from Vățișoara-Tătărăști Zone.

from the Vățișoara Valley, whose U contents vary from 3 to 4.5 ppm. We can also mention some here basalts from Luncoiul de Jos Zone which contain 3 to 5 ppm U, much higher values than 0.5 ppm U average given by Lambert and Heier (1967) for basic rocks.

U contents in andesites (Tab. 1 and 4) are higher than those in basaltic rocks of island arc. They vary from 0.6 to 3.1 ppm, most values being at the upper part of the variation domain. The highest values of U have been determined in amphibole and pyroxene andesites from Gliganu Hill. Basement ophiolitic rocks contain U in smaller quantities than island arc basalts varying from 0 to 0.6 ppm.

Concerning Th distribution in island arc volcanics, we distinguish three zones with specific contents. So, the smallest contents (3 to 14 ppm Th) situated over the average of Lambert and Heier (1967) for basic rocks, have been determined in basalts from Visca-Vorța-Dealu Mare-Vălișoara Zone. The second zone, where Th contents have a higher frequency between the values of 10 to 27 ppm, is represented by the Tătărăști-Țebea-Valea Lungă (Luncoi) area which is situated in the north of the previous zone. The highest values have been determined in basalts bearing pyroxene phenocrysts in Vățișoara Zone, where we obtained a little higher U contents. In these rocks, Th varies from 36

TABLE 1

Distribution of U, Th, K, REE and other trace elements in island arc volcanics

No.	Sample	Rock type	Place	U ppm	Th ppm	K %	La ppm	Ce ppm	Sm ppm	Eu ppm	Tb ppm	Lu ppm	Sc ppm	Co ppm	Hf ppm	Ta ppm	Yb ppm	Y ppm	Zr ppm	Nb ppm	Rb ppm	Sr ppm	TiO_2 %
1	1	Porphyritic basalt (pyr)	Vața de Sus	1.0	38.0	2.7	119	238	11.1	2.9	1.5		20.6	29.3	1.9	sld							
2	2	Porphyritic basalt (pyr)	Vața de Sus				101	196	7.4	2.8	1.5		21.0	29.6	1.6	1.6							
3	3	Porphyritic basalt (pyr)	Vața de Sus	12.0	56.0	2.0	110	284	10.9	2.7	2.7	0.29	22.6	27.7	2.0			30.8	110	10.7	30.0	1717	0.79
4	4	Porphyritic basalt (pyr)	Vața de Sus	1.7	14.2	2.9	121	288	11.3	3.1	2.5	0.18	22.5	26.4	4.5			24.5	114	15.7	45.8	1611	0.85
5	5	Porphyritic basalt (pyr)	Vața de Sus	3.6	41.3	2.3	121	266	10.1	2.7	2.3	0.18	26.0	31.9	4.4			32.3	124	16.3	30.8	1454	0.79
6	6	Porphyritic basalt (pyr)	Vața de Sus	14.8	45.4	2.4	120	302	11.1	3.4	2.8	0.16	21.8	28.6	6.5			36.4	108	11.1	24.0	1753	0.66
7	7	Porphyritic basalt (glassy)	Vața de Sus	4.0	37.0	2.4	118	244	9.9	2.9	1.3	0.12	25.0	30.2	2.3			28.0	96	13.3	38.3	2030	0.34
8	8	Porpyritic basalt (pyr)	Vața de Sus	2.9	40.0	2.3	108	255	10.9	2.8	2.1	—	23.5	25.4	4.3			21.9	70	9.6	23.2	2994	0.49
9	9	Porphyritic basalt (pyr)	Vața de Sus	2.1	36.0	1.6	93	235	10.4	2.8	1.9	—	24.5	28.6	5.0			37.5	99	12.7	8.0	1894	0.39
10	10	Porphyritic basalt (pyr)	Vața de Sus	3.5	44.0	1.0	86	291	11.1	3.3	2.1	0.30	21.0	23.0	6.4			28.3	109	14.9	6.4	2276	0.71
11	12	Porphyritic basalt (pyr)	Vața de Sus	4.2	42.0	3.0	104	270	11.3	3.1	2.5	0.15	20.5	29.3	2.0			27.5	143	12.5	28.5	1138	0.65
12	13	Porphyritic basalt (pyr)	Vața de Sus	3.7	42.0	2.3	115	237	10.6	3.3	2.3	0.25	23.9	28.0	6.7			43.6	148	7.0	40.5	1683	0.93
13	14	Porphyritic basalt (pyr)	Vața de Sus	3.4	45.5	2.9	118	302	12.4	3.4	2.6	0.29	18.5	31.0	4.9			31.8	149	8.8	34.0	1452	0.69
14	15	Porphyritic basalt (pyr)	Vața de Sus	4.5	41.5	2.6	107	236	10.4	2.7	2.2	0.22	25.4	34.0	2.8			32.5	148	11.6	19.6	1107	0.82
15	16	Porphyritic basalt (pyr)	Vața de Sus	3.5	45.0	3.7	131	299	3.1	3.1	2.5	0.16	20.5	28.3	3.2			28.8	152	14.0	47.2	1366	0.80
16	29	Porphyritic basalt amygd. (spilite)	Vața de Sus	2.0	6.0	2.2																	
17	33	Amygdaloidal basalt	Vața de Sus	0.9	7.0	1.6																	
18	34	Porphyritic basalt (pyr)	Vața de Sus	1.7	13.0	2.0																	
19	35	Porphyritic basalt (pyr)	Vața de Sus	2.4	37.0	1.1	110	254	10.0	2.5	2.2		26.1	39.8	3.9	1.1		33.5	138	5.2	2.3	961	0.57
20	36	Porphyritic basalt (pyr)	Vața de Sus	1.2	13.0	1.5																	
21	37	Porphyritic basalt (pl)	Vața de Sus	1.3	14.0	0.9																	
22	38	Porphyritic basalt (pyr)	Vața de Sus	2.4	14.0	2.2																	
23	39	Porphyritic basalt (pyr)	Vața de Sus	1.9	19.0	0.4																	
24	40	Porphyritic basalt (pyr)	Vața de Sus	1.8	15.0	1.3																	
25	41	Porphyritic basalt (pyr)	Vața de Sus	2.1	14.0	1.7																	
26	43	Porphyritic basalt (pyr)	Vața de Sus	2.6	41.0	2.4	138	305	9.8	3.9	2.1		23.5	32.8	2.5	1.8		39.4	150	7.1	9.3	836	1.10
27	44	Porphyritic basalt(pyr+ho)	Vața de Sus	0.4	15.0	1.1																	
28	45	Porphyritic basalt (pyr)	Vața de Sus	1.5	8.0	1.4																	
29	46	Amygd. spilite basalt	Vața de Sus	0.9	8.0	1.2																	
30	48	Porphyritic basalt (pyr)	Vața de Sus	1.5	41.0	0.4																	
31	49	Porphyritic basalt (pl)	Vața de Sus	0.4	8.0	1.9																	
32	50	Altcrated basalt	Vața de Sus	0.8	4.0	0.3																	
33	146	Porphyritic basalt (pyr)	Vața de Sus	1.3	18.0	2.3	50	125	5.7	2.5	1.8		25.0	30.6	4.2	1.1							
34	147	Porphyritic basalt (pyr)	Vața de Sus	1.3	13.0	1.6																	
35	148	Porphyritic basalt (pyr)	Vața de Sus	0.9	14.0	1.4																	
36	149	Porphyritic basalt (pyr)	Vața de Ssus	0.9	5.0	0.3																	
37	151	Porphyritic basalt (pl) almygd. alterated	Vața de Sus	0.2	5.0	3.0																	
38	152	Porphyritic basalt (pyr)	Vața de Sus	4.7	8.0	3.3																	
39	153	Porphyritic basalt (pyr)	Vața de Sus	2.3	8.0	0.8																	
40	154	Amygd. porphyritic basalt (pyr + pl)	Vața de Sus	0.1	8.0	1.2																	
41	158	Porphyritic basalt (pyr)	Vața de Sus	0.3	5.0	0.2																	

42	162	Alter. porphyritic basalt (pl)	Vața de Sus	0.2	6.0	1.2																	
43	31	Alter. basaltic tuff	Vața de Sus	2.4	10.0	0.6																	
44	150	Tuff of porph. basalt(pyr)	Vața de Sus	0.9	4.0	0.2																	
45	32	Basaltic tuff (pyr)	Vața de Sus	1.6	14.0	0.2																	
46	30	Andesite bearing hornblende	Vața de Sus	0.7	22.0	0.3	31	117	2.4	1.8	1.9		9.5	11.4	3.2								
47	42	And. with hornbl. + biotite	Vața de Sus	1.6	10.0	0.5																	
48	189	Porphyritic basalt (pyr)	Tătărăștii de Criș	1.6	12.0	1.8																	
49	191	Porphyritic basalt (pl)	Tătărăștii de Criș	1.7	10.0	1.6																	
50	192	Porphyritic basalt (pl)	Tătărăștii de Criș	1.8	11.0	1.4																	
51	193	Porphyritic basalt (pl)																					
52	200	Hydroth. porph. ba-	Tătărăștii de Criș	0.6	5.0	0.8																	
		salt (pl)	Tătărăștii de Criș	0.5	13.0	0.3																	
53	202	Porphyritic basalt (pyr)	Tătărăștii de Criș	2.0	22.0	0.6	34	143	3.8	2.3	1.6		15.5	11.0	5.7	0.8							
54	203	Porphyritic basalt (pl)	Tătărăștii de Criș	1.2	9.0	0.6																	
55	205	Porpyritic basalt (pyr)	Tătărăștii de Criș	0.9	5.0	1.3																	
56	207	Porphyritic basalt (pyr)	Tătărăștii de Criș	1.6	17.0	0.1																	
57	208	Porphyritic basalt (pyr + pl)	Tătărăștii de Criș	1.7	22.0	3.0	46	124	5.2	2.1	1.5		12.3	17.5	4.2	1.3							
58	209	Porphyritic basalt (pl)	Tătărăștii de Criș	1.3	13.0	4.0																	
59	210	Hydroth. basaltic tuff	Tătărăștii de Criș	2.0	20.0	5.2	44	99	3.1	1.9	1.3		8.3	12.0	3.9	0.9		29.4	141	13.2	37.4	841	0.54
60	190	Andesitic basalt (pl)	Tătărăștii de Criș	2.4	12.0	0.9																	
61	188	Andesite (pyr + ho)	Tătărăștii de Criș	1.8	13.0	1.8																	
62	194	Andesite (ho)	Tătărăștii de Criș	0.7	21.0	0.1	43	99	7.5	1.4	2.5		17.4	20.2	5.5	1.7							
63	195	Andesite (ho)	Tătărăștii de Criș	4.0	38.0	0.2	114	238	104	2.9	1.5		20.6	29.3	1.9	1.4		34.6	182	16.2	6.8	327	0.73
64	201	Andesite (ho)	Tătărăștii de Criș	0.0	13.0	0.1																	
65	204	Hydroth. orthophyre	Tătărăștii de Criș	1.6	12.0	0.9																	
66	206	Hydroth. orthophyre. (biotite)	Tătărăștii de Criș	1.0	11.0	0.7																	
67	68	Porphyritic basalt (pl)	Țebea Valley	0.9	8.1	0.9																	
68	69	Amygd. porph. basalt (pl)	Țebea Valley	0.9	8.0	1.0																	
69	64	Hydroth. basaltic tuff (pl)	Țebea Valley	0.5	23.5	1.0	55.6	63.6		2.1	0.85		16.3	22.9	2.5	1.1							
70	67	Porph. basaltic tuff (pl)	Țebea Valley	0.9	8.7	1.1																	
71	70	Basaltic tuff (pl)	Țebea Valley	2.0	14.8	1.5	63.8	105.5		2.45	0.94		28.3	30.0	2.45								
72	63	Pyr. andesite	Țebea Valley	2.7	14.7	1.6																	
73	62	Quartz andesite	Țebea Valley	2.7	14.8	1.5																	
74	65	Hornblende andesite	Țebea Valley	1.0	9.1	2.0																	
75	66	Calcitized felsite		0.6	10.0	2.0																	
76	144	Brecc. porphyritic basalt	Visca-Almășel Valley	1.6	12.1	2.0																	
77	146	Brecc. porph. basalt	Visca-Almășel Valley	1.6	9.0	1.1																	
78	147	Amygd. basalt	Visca-Almășel Valley	0.0	6.4	2.4																	
79	150	Brecc. basalt	Visca-Scoarța Valley	0.0	1.1	0.7																	
80	151	Brecc. basalt	Visca-Scoarța Valley	0.0	2.2	1.2																	

TABLE 1 — Continuation

No.	Sample	Rock type	Place	U	Th	K	La	Ce	Sm	Eu	Tb	Lu	Sc	Co	Hf	Ta	Yb
81	153	Porphyritic basalt	Visca-Scoarța Valley	1.4	7.3	1.1											
82	156	Porphyritic basalt	Visca-Scoarța Valley	1.5	8.0	1.1											
83	157	Porphyritic basalt	Visca-Scoarța Valley	2.2	8.6	1.0											
84	158	Porphyritic basalt	Visca-Scoarța Valley	2.4	9.7	1.0											
85	159	Porphyritic basalt	Visca-Scoarța Valley	1.5	9.4	1.2											
86	162	Porphyritic basalt	Visca-Scoarța Valley	2.0	8.8	1.4											
87	163	Amygdaloidal basalt	Visca-Scoarța Valley	1.7	10.0	0.6											
88	145	Andes. bas. pyroclastics	Visca-Almășel Valley	2.3	12.3	1.2											
89	148	Andes. bas. pyroclastics	Visca-Almășel Valley	2.6	22.8	3.6	37.6	103	5.6	1.2	1.9		5.8	4.5	6.2	0.84	2.8
90	154	Andes. bas. pyroclastics	Visca-Scoarța Valley	2.2	9.3	2.0											
91	155	Andes. bas. pyroclastics	Visca-Scoarța Valley	3.8	19.2	1.4											
92	142	Rhyolite	Visca-Almășel Valley	3.7	19.1	2.7											
93	143	Rhyolite (basalt enclaves)	Visca-Almășel Valley	3.3	13.9	1.2											
94	145	Rhyolite (brecciated)	Visca-Almășel Valley	2.3	12.3	1.2											
95	119	Porphyritic basalt	Luncoiul de Jos	5.3	27.5	1.7	39.5	98.5	8.3	1.7	2.0		10.4	4.9	6.3	0.55	4.9
96	120	Porphyritic basalt	Luncoiul de Jos	3.8	22.0	1.6	43.7	90.6	9.0	1.8	2.4		11.2	5.9	6.7	0.68	3.6
97	122	Hydroth. basalt	Luncoiul de Jos	3.8	20.4	1.0											
98	123	Hydroth. basalt	Luncoiul de Jos	2.7	26.0	2.0	36.5	95.6	7.2	1.15	2.2		8.68	6.2	5.0	0.83	4.0
99	124	Porphyritic basalt	Luncoiul de Jos	1.0	4.4	1.2											
100	106	Amygd. basalt	Valea Lungă Brook	3.5	25.0	2.6	70.0	182.0	10.1	3.3	1.4		26.2	30.1	5.0	0.65	0.8
101	107	Hyaline basalt	Valea Lungă Brook	2.5	19.3	3.6	61.5	129.2	9.4	1.95	1.6		22.8	24.1	3.7	0.7	
102	108	Porphyritic basalt	Valea Lungă Brook	1.6	17.5	2.4	58.2	129.0	9.1	2.4	1.97		22.4	26.4	1.1	0.84	1.9
103	109	Porphyritic basalt	Valea Lungă Brook	2.6	17.0	1.3	46.4	90.4	6.2	1.9	1.5		17.1	20.3	3.7	1.2	2.3
104	110	Porphyritic basalt	Valea Lungă Brook	2.0	14.1	1.0											
105	111	Porphyritic basalt	Valea Lungă Brook	2.7	11.7	1.6											
106	112	Porphyritic basalt	Valea Lungă Brook	1.2	11.2	1.6											
107	105	Basaltic agglomerate	Valea Lungă Brook	2.4	17.2	2.6	46.3	121.8	7.8	1.9	1.03		17.8	18.9	3.7	0.59	1.6
108	113	Basaltic agglomerate	Valea Lungă Brook	2.3	12.6	1.8											
109	114	Basaltic agglomerate	Valea Lungă Brook	2.4	14.8	1.7											
110	115	Basaltic agglomerate	Luncoiul de Jos	0.7	11.2	2.1											
111	168	Porphyritic basalt	Piticarea brook	0.0	1.0	0.1											
112	175	Porphyritic basalt	Piticarea brook	1.0	6.0	0.8											
113	180	Amygd. basalt	Piticarea brook	3.7	12.0	0.9											
114	176	Basalt	Piticarea brook	0.9	5.0	0.8											
115	178	Basalt (alter.)	Piticarea brook	3.2	18.0	2.0											
116	179	Basalt (alter.)	Piticarea brook	1.0	22.0	0.1	7	82	1.8	1.2	1.9		4.2	2.3	6.8	0.9	
117	169	Basalt	Piticarea brook	0.0	1.5	0.6											
118	171	Basalt	Piticarea brook	0.0	5.0	0.9											

TABLE 1 — Continuation

No.	Sample	Rock type	Place	U	Th	K	La	Ce	Sm	Eu	Tb	Lu	Sc	Co	Hf	Ta	Yb	Y	Zr	Nb	Rb	Sr	TiO_2
119	172	Basalt	Piticarea brook	0.3	6.0	1.4																	
120	174	Basalt	Piticarea brook	2.6	11.0	1.9																	
121	72	Porphyritic basalt	Vorța	1.9	7.4	0.5												21.8	111	6.60	35.3	649	0.703
122	73	Basalt (hydroth)	Vorța	1.9	5.7	1.0												18.2	109	5.23	65.7	68.4	0.551
123	79	Basalt	Vorța	1.5	5.7	1.2																	
124	82	Basalt	Vorța-Mori brook	0.9	2.9	1.1												19.3	90.8	6.52	60.7	291	0.852
125	60	Basalt	Homorod Valley	2.9	4.8	1.4												24.2	114	5.01	76.9	104	0.522
126	61	Hydroth. basalt	Homorod Valley	0.7	7.5	2.0												39.4	103	5.84	95.9	54.8	0.625
127	80	Porph. basalt (pl) hydroth.	Vorța	0.3	3.3	0.7																	
128	81	Andesitic basalt	Vorța-Mori brook	0.8	4.5	0.3												19.5	96.6	6.92	29.1	438	0.495
129	85	Hydroth. andesitic basalt	Vorța-Mori brook	1.3	3.9	1.3																	
130	86	Hydroth. and. basalt	Vorța-Mori brook	1.9	3.8	0.4																	
131	87	Andesitic basalt	Vorța-Mori brook	1.0	7.3	1.0																	
132	64	Andesite with hornbl.	Homorod Valley	0.6	11.1	1.7												22.1	138	681	535	215	0.416
133	65	Andesite with ho + pyr	Homorod Valley	2.0	8.2	2.1												20.4	148	7.83	63.1	232	0.722
134	66	Andesite with ho + pyr	Homorod Valley	2.2	6.9	1.5												22.9	137	6.09	69.8	287	0.527
135	67	Quartz andesite	Homorod Valley	0.9	9.9	4.2	31.5	39.3	3.45	0.73	0.69	0.27	5.6	7.95	4.4	2.1							
136	68	Quartz andesite	Homorod Valley	2.4	11.6	5.3		53	3.64	0.99	0.88	0.39	6.86	3.5	5.5	0.53							
137	69	Quartz andesite	Homorod Valley	2.2	10.1	4.4	32.5	46.5	3.5	1.05	0.65	0.38	6.6	5.2	4.5	0.33							
138	70	Quartz andesite (ho)	Homorod Valley	2.4	8.6	3.5	32.1	43.8	2.8	0.78	0.5	0.51	5.6	4.4	3.7	0.52							
139	71	Hydrothermal andesite	Homorod Valley	1.4	4.5	5.9												25.3	151	8.78	134	319	0.543
140	75	Andesite (ho)	Vorța	1.9	9.4	2.4	26.2	38.1	3.4	0.75	0.65	0.13	8.2	6.8	4.6	0.48							
141	78	Andesite (ho)	Vorța	2.1	8.2	1.9																	
142	83	Andesite (ho)	Vorța-Mori Brook	1.8	7.0	2.7												16	167	6.4	78.6	193	0.579
143	84	Andesite	Vorța-Mori Brook	1.9	9.0	4.4	33.5	52.4	4.6	1.12	0.89	0.39	5.8	4.9	4.3								
144	89	Andesite (ho)	Vorța-Mori Brook	1.5	8.8	1.8																	
145	92	Rhyodacite	Vorța Valley	2.1	5.9	2.9																	
146	93	Rhyodacite	Vorța Valley	2.4	9.2	1.7																	
147	94	Rhyodacite	Vorța Valley	2.4	6.7	3.6																	
148	198	Rhyolite	Vorța Valley	1.6	9.4	1.9																	
149	199	Rhyolite	Vorța Valley	1.8	8.0	4.7																	
150	200	Rhyolite	Vorța Valley	2.2	9.5	1.5																	
151	144	Amygd. basalt	Bărăști Valley	0.8	2.1	0.6																	
152	145	Amygd. basalt (agglom)	Bărăști Valley	0.6	2.3	0.4																	
153	131	Andesite (ho)	Bărăști Valley	1.5	8.3	1.9																	
154	132	Andesite	Bărăști Valley	1.3	7.8	2.4																	
155	133	Andesite	Bărăști Valley	0.8	10.4	1.9																	
156	134	Andesite Q, ho + bi	Bărăști Valley	1.1	8.4	2.7																	
157	141	Andesite Q, ho + bi	Bărăști Valley	0.9	8.6	3.1																	
158	142	Andesite Q, ho + bi	Bărăști Valley	1.4	7.3	3.2																	
159	135	Dacite	Bărăști Valley	0.6	10.8	3.2																	
160	138	Dacite	Bărăști Valley	0.6	10.3	3.6																	

TABLE 1 — Continuation

No.	Sample	Rock type	Place	U	Th	K	La	Co	Sm	Eu	Tb	Lu	Sc	Co	Hf	Ta	Yb	Y	Z_2	Nb	Rb	Sr	TiO_2
161	139	Dacite	Bărăşti Valley	0.5	11.9	3.3																	
162	140	Dacite	Bărăşti Balley	1.3	10.2	3.8																	
163	182	Brecciated basalt	Dumeşti Valley	1.1	6.6	2.9																	
164	185	Porphyritic basalt	Dumeşti Valley	0.4	3.5	0.0																	
165	188	Amygd. basalt	Dumeşti Valley	1.7	9.5	2.2																	
166	180	Anamesite	Dumeşti Valley	1.5	5.5	1.2																	
167	164	Agglomerate porph. (bas. pyr)	Dumeşti Valley	0.0	1.9	0.9																	
168	165	Agglom. porph. (bas. pl)	Dumeşti Valley	0.6	3.1	0.3																	
169	177	Agglomerate	Dumeşti Valley	1.0	5.6	1.6																	
170	178	Agglom. (amygd. bas.)	Dumeşti Valley	1.1	4.2	1.4																	
171	166	Pyroclastite bas. + andes.	Dumeşti Valley	0.7	4.0	1.0																	
172	167	Pyrocl. basalt + andesite	Dumeşti Valley	0.7	4.1	1.0																	
173	168	Pyrocl. basalt + andesite	Dumeşti Valley	0.4	5.6	0.4																	
174	181	Pyrocl. basalt + andesite	Dumeşti Valley	0.9	4.9	1.3																	
175	170	Andesite basalt	Dumeşti Valley	0.0	5.6	0.8																	
176	172	Andesite basalt	Dumeşti Valley	0.4	5.7	1.6																	
177	173	Andesite basalt	Dumeşti Valley	1.3	7.3	1.7																	
178	174	Andesite basalt	Dumeşti Valley	1.2	6.0	1.7																	
179	175	Andesite basalt	Dumeşti Valley	1.0	7.4	0.9																	
180	176	Andesite basalt	Dumeşti Velley	2.0	6.7	1.9																	
181	169	Rhyodacite	Dumeşti Valley	1.5	9.1	2.1																	
182	171	Rhyodacite	Dumeşti Valley	0.0	5.6	0.8																	
183	183	Rhyodacite	Dumeşti Valley	0.9	7.2	2.5																	
184	184	Rhyolite (with basaltic eclaves)	Dumeşti Valley	1.0	7.2	2.4																	
185	186	Rhyolite	Dumeşti Valley	1.4	8.1	1.9																	
186	96	Porph. basalt (pl)	Gliganul Hill	0.6	2.6	1.1																	
187	98	Porph. basalt (pl)	Gliganul Hill	1.0	4.2	1.0												13.7	53.6	4.56	57.1	3521	0.711
188	113	Porph. basalt (pl)	Gliganul Hill	0.6	3.2	0.7												24.2	80.5	6.42	36.2	69.1	0.605
189	115	Hydroth. porph. basalt (pl)	Gliganul Hill	1.6	3.4	0.9												18.5	109.0	5.64	4.91	95.0	1.05
190	116	Porph. basalt (pyr + pl)	Gliganul Hill	0.4	2.6	0.5																	

No.	Sample	Rock type	Place	U	Th	K	LA	Co	Sm	Eu	Tb	Lu	Sc	Co	Hf	Ta	Yb	Y	Zr	Nb	Rb	Sr	TiO_2	Fe_2O_3
191	97	Pyroclastite bas + andesite	Gliganul Hill	1.6	8.3	0.8																		
192	108	Andesitic basalt	Gliganul Hill	0.9	6.4	2.0												17.4	92.3	4.08	57.2	464	0.917	
193	110	Andesite	Gliganul Hill	2.5	8.6	5.0												14.6	166	4.47	77.2	155	0.480	
194	99	Andesite (ho)	Gliganul Hill	2.6	10.4	4.8												20.4	175	7.67	99.3	101	0.512	
195	100	Andesite (ho)	Gliganul Hill	1.2	11.7	4.5	20.4																	
196	101	Andesite (ho)	Gliganul Hill	2.3	10.9	4.2																		
197	102	Andesite (ho)	Gliganul Hill	1.7	11.2	4.4																		
198	103	Andesite (Q)	Gliganul Hill	2.3	9.9	4.4																		
199	104	Andesite (Q)	Gliganul Hill	2.9	10.3	4.4																		
200	105	Andesite (Q + bi)	Gliganul Hill	1.9	11.3	4.2																		
201	106	Andesite (Q + bi)	Gliganul Hill	3.1	9.1	4.4												22.6	171	7.25	100	132	0.499	
202	107	Andesite (ho)	Gliganul Hill	2.9	10.2	6.1												21.8	177	6.34	118	137	0.382	
203	112	Andesite (ho)	Gliganul Hill	2.0	4.4	2.1												15.3	199	5.29	75.2	47.5	0.673	
204	114	Andesite (ho)	Gliganul Hill	2.2	7.9	2.7												18.2	170	6.74	80.4	114	0.434	
205	147	Porph. basalt (pyr)	Gialacuta	0.0	6.4	2.4																		
206	148	Amygd. basalt	Gialacuta	1.6	5.9	0.9																		
207	150	Amygd. basalt	Gialacuta	0.9	4.4	1.1																		
208	153	Porph. basalt (pl + pyr)	Gialacuta	1.3	7.8	2.2																		
209	154	Hydroth. basalt	Gialacuta	0.9	9.7	2.1																		
210	146	Bas. agglom. (bas. porph. pl)	Gialacuta	2.1	5.1	0.5																		
211	149	Bas. agglom. (amygd. bas.)	Gialacuta	1.6	4.1	1.6																		
212	151	Bas. agglom. (bas. porph. pl)	Gialacuta	1.3	4.2	0.5																		
213	155	Bas. agglom. (bas. porph. pl)	Gialacuta	1.1	3.0	0.7																		
214	156	Bas.agglom.(bas.porph. pl)	Gialacuta	2.2	5.6	1.1																		
215	120	Hydroth. basalt	Dealu Mare	0.6	2.8	0.9																		
216	121	Porph. basalt (pl) hydroth.	Dealu Mare	2.8	8.9	1.7	2.02	39.7	5.08	0.92	0.77	0.27	11.4	12.2	5.02		3.0	15.5	160			320	100	5.03
217	122	Hydroth. basalt	Dealu Mare	1.3	3.1	0.2																		
218	125	Porph. basalt (pl)	Dealu Mare	1.8	6.9	0.4																		
219	127	Hydroth. porph. bas. (pl)	Dealu Mare	0.7	3.8	1.1																		
220	129	Porph. basalt (pl)	Dealu Mare	1.9	3.9	1.2																		

TABLE 1— Continuation

No.	Sample	Rock type	Place	U	Th	K	La	Co	Sm	Eu	Tb	Lu	Sc	Co	Hf	Ta	Yb	Y	Zr	Nb	Rb	Sr	TiO_2
221	130	Amygd. basalt	Dealu Mare	—	—																140	170	
222	128	Porph. basalt (pl)	Dealu Mare	3.3	6.8	2.2	28.1	35.8	4.7	1.72	1.1	0.71	16.5	11.9	3.86		3.8	2.2	175		110		
223	124	Basaltic tuff (hydroth)	Dealu Mare	2.3	10.3	1.7	35.6	96.6	6.84	2.49	1.84	0.82	15.7	6.55	5.8		3.8	46	250				
224	117	Andesite (ho + bi)	Dealu Mare	1.5	11.0	3.5																	
225	4	Porphyritic basalt (pyr)	Orezi Valley	0.9	2.8	0.8																	
226	5	Porphyritic basalt (pyr + pl)	Orezi Valley	1.3	5.0	1.7																	
227	7	Amygdaloidal basalt	Orezi Valley	1.2	2.5	1.3																	
228	8	Porph. basalt (pyr + pl)	Orezi Valley	2.5	6.5	2.7	20.4	36.7	4.1	1.1	0.73	0.52	7.7	8.2	4.5		3.1	16	160				250
229	9	Porph. basalt (pl) hydroth.	Orezi Valley	0.8	3.7	0.7																	
230	10	Porph. basalt (pyr)	Orezi Valley	1.6	3.3	2.1																	
231	1	Bas.agglom. (bas.porph. pyr+pl)	Orezi Valley	0.1	5.5	2.1																	
232	3	Bas. agglom. (bas. porphy. pyr + pl)	Orezi Valley	1.3	2.9	1.0	11.3	28.8	3.4	0.76	0.69	0.48	25.9	21	2.84								
233	11	Agglomerate (bas. porph. pl)	Orezi Valley	0.5	3.5	0.8																	
234	12	Agglomerate (bas. pyr)	Orezi Valley	1.8	3.8	0.8																	
235	168	Amygd. bas. (pl)	Oana Valley	1.2	2.8	1.8																	
236	157	Bas. agglom. (amygd. bas)	Oana Valley	1.8	7.7	0.5																	
237	158	Quartz andesite	Oana Valley	3.0	12.4	3.2																	
238	159	Felsite	Oana Valley	0.4	3.2	0.6																	
240	160	Felsite	Oana Valley	1.2	12.5	1.2																	
241	161	Rhyodacite	Oana Valley	1.6	8.5	2.3																	
242	162	Rhyodacite	Oana Valley	2.1	7.5	1.9																	
243	163	Rhyodacite	Oana Valley	1.3	8.1	0.7																	
244	164	Rhyodacite	Oana Valley	1.6	7.7	2.2																	
245	165	Rhyodacite	Oana Valley	1.4	7.7	3.6																	
246	166	Rhyodacite	Oana Valley	2.0	6.6	1.6																	

TABLE 2

Distribution of U, Th and K in ophiolitic rocks

No.	Sample	Rock type	Place	U ppm	Th ppm	K %
1	183	Variolite	Piticarea Brook	0.0	1.5	0.8
2	184	Variolite	Piticarea Brook	0.0	2.0	0.5
3	185	Variolite	Piticarea Brook	0.0	2.0	0.5
4	186	Basalt	Piticarea Brook	0.0	2.0	0.8
5	187	Basalt	Piticarea Brook	0.0	2.0	0.7
6	132	Variolite	Visca — Almăşel Valley	0.2	0.6	0.1
7	133	Gabbro-dolerite	Visca-Almăşel Valley	0.1	1.0	0.1
8	136	Basalt	Visca-Almăşel Valley	0.0	0.9	0.1
9	138	Brecciated basalt	Visca-Almăşel Valley	0.1	1.4	0.3
10	139	Brecciated basalt	Visca-Almăşel Valley	0.1	2.3	0.6
11	140	Brecciated basalt	Visca-Almăşel Valley	0.1	0.8	0.8
12	149	Variolite	Visca-Scoarţei Valley	0.1	1.3	0.2
13	116	Porphyritic basalt	Luncoiul de Jos	0.1	1.6	0.5
14	117	Calcitizated basalt	Luncoiul de Jos	0.2	1.7	0.8
15	118	Calcitizated basalt	Luncoiul de Jos	0.6	1.0	0.2
16	121	Amygdaloidal basalt	Luncoiul de Jos	0.7	1.3	0.5
17	125	Basaltic agglomerate	Luncoi Valley	0.6	3.4	0.5
18	126	Basaltic agglomerate	Luncoi Valley	0.9	4.0	0.5
19	118	Basalt	South Dealu Mare	0.5	2.4	—
20	119	Basalt	South Dealu Mare	0.0	2.7	0.5
21	120	Basalt	South Dealu Mare	0.6	2.8	0.8
22	37	Dolerite	Valea Lungă Brook	0.0	0.8	0.2
23	38	Dolerite	Valea Lungă Brook	0.0	0.6	0.8
24	44	Anamesite	Valea Lungă Brook	0.1	0.1	0.6
25	54	Basalt	Valea Lungă Brook	0.2	6.6	0.8
26	56	Alterated basalt	Valea Lungă Brook	0.1	1.7	2.2
27	22	Alterated basalt	Săliştioara	—	3.6	0.2
28	134	Anamesite	Visca-Almaş Valley	0.4	0.1	0.1
29	137	Anamesite	Visca-Almaş Valley	0	1.3	0.1
30	160	Dolerite	Visca-Scoarţa Valley	1.3	8.9	1.0
31	161	Dolerite	Visca-Scoarţa Valley	0.5	4.4	0.5
32	177	Anamesite	Piticarea Brook	1.5	12.0	1.7
33	173	Dolerite	Piticarea Brook	1.0	3.0	0.8

TABLE 3

Frequent limits of the U, Th, K contents in the basic rocks

No.	Total number of samples	Place	U ppm	Th ppm	K %
1	24	Ocean floor (ophiolitic) rocks	0—0.6	0.1—2.3	0.1—0.8
		Island arc basalts			
2	17	Văţişoara Valley	3.0—4.5	36—56	2—3
3	26	Vaţa de Sus	0.8—2.0	5—14	0.4—2.2
4	12	Tătărăştii de Criş	1.2—2.0	10—22	0.3—2.0
5	10	Piticarea Brook	0—1.0	1—6	
			1—3	13—22	0.1—2.0
6	3	Ţebea Valley	0.5—2.0	8—23	1.0—1.5
7	12	Visca-Scoarţa Valley	0.0—2.4	6—10	1.0—1.4
8	17	Dumeşti Valley	0.4—1.7	3—7	0.8—1.7
9	10	Gialacuta	0.9—2.2	3—7	0.5—1.6
10	8	Dealu Mare	1.3—2.3	4—7	0.2—1.2
11	8	Luncoiul de Jos	3—5	20—27	1.6—2.0
12	10	Valea Lungă Brook	2.3—2.4	11—17	1.7—2.6
13	9	Vorţa	0.8—1.9	3—7	0.5—1.4
14	2	Homorod Valley	0.7—2.9	4.3—7.5	1.4—2.0
15	2	Bărăşti Valley	0.6—0.8	2.1—2.3	0.4—0.6
16	7	Gliganul Hill	0.6—1.6	2.6—8.0	0.7—1.1
17	10	Orezi Valley	0.8—1.3	2.5—5.5	0.8—1.3
18	2	Oana Valley	1.2—1.8	3—7.0	0.5—1.8

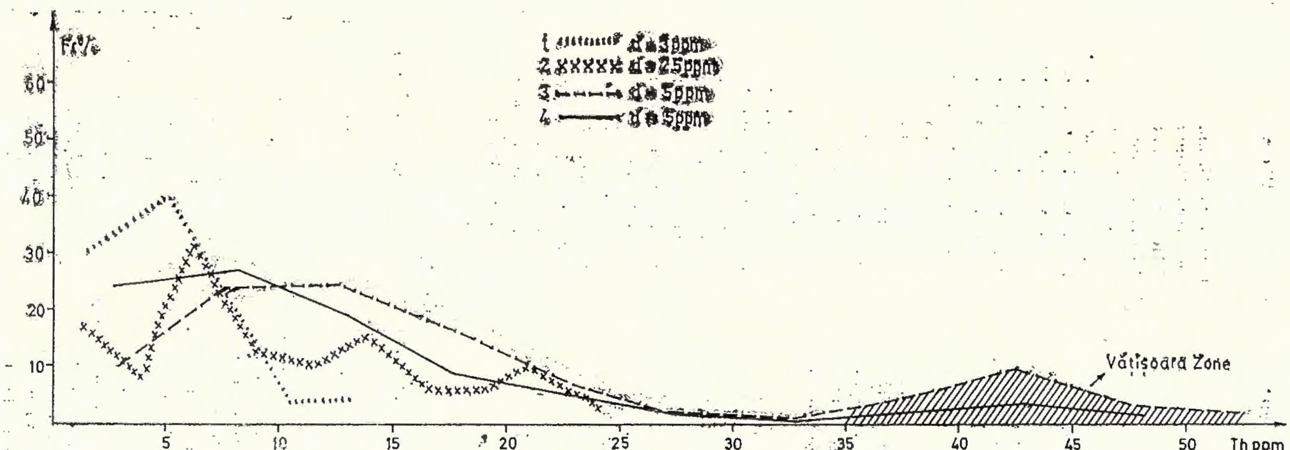

Fig. 3. — Th frequency in island arc basalts.
1, 2, 3, same zones as în fig. 2 ; 4, curve of cumulated frequency.

TABLE 4

Frequent limits of the U, Th, K contents in the andesites

No.	Total number of samples	Place	U ppm	Th ppm	K %
1	4	Tătărăştii de Criş	0.7—4	12—38	0.1—1.8
2	2	Ţebea Valley	0.6—2.7	9—15	1.5—2.0
3	8	Homorod Valley	0.6—2.4	7—12	2.0—6.0
4	5	Vorţa	1.5—2.1	7—9	1.8—4.4
5	6	Bărăşti Valley	0.8—1.5	7—10	1.9—3.2
6	11	Gliganul Hill	1.7—3.1	9—11	4.2—4.5
7	1	Oana Valley	1.2	12.4	3.2
8	1	Dealu Mare	1.5	11.0	3.5

to 56 ppm (Tab. 1 and 3 ; Fig. 3 and 5). These values are much higher than 1.6 ppm Th average established by Lambert and Heier (1967) for basic rocks.

The contents of Th are more constant in andesites, they varying from 7 to 15 ppm, values which are over the 7.0 ppm average of Lambert and Heier (1967) for dioritic rocks. The highest values have been obtained for Th in andesites from Tătărăşti area where they vary from 12 to 38 ppm (Tab. 1 and 4, Fig. 6).

In ophiolitic rocks, Th and U contents are very low, from 0.1 to 2.3 ppm (Tab. 2 and 3) as in other tholeiitic basalts (Jacques, Chappell, 1980).

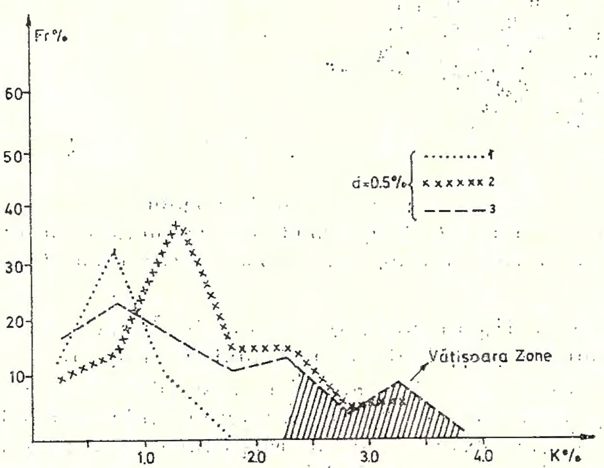

Fig. 4. — K frequency in island arc basalts.
1, 2, 3, same zones as in fig. 2.

In island arc volcanics, K varies from 0.2 to 2.6% except the basalts bearing augite phenocrysts from the Vătişoara Valley, where it varies from 2 to 3% (Tab. 1 and 3 and Fig. 4). Because these values exceed a lot the K average for basic rocks, it is possible that the above basalts should be weakly alkaline as basalts from the NW island arc of Mureș Zone, which Savu and co-workers described in 1983. K con-

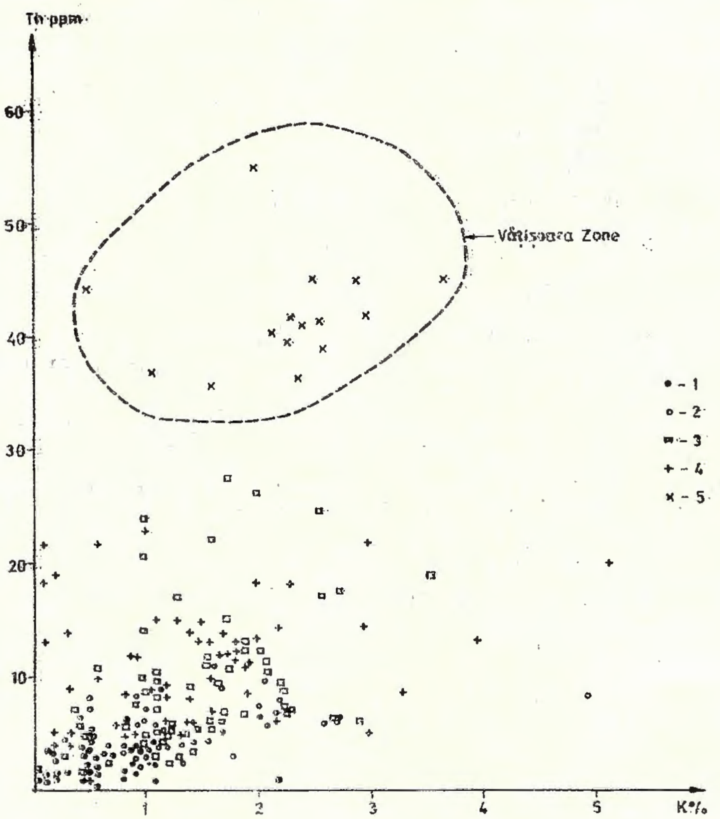

Fig. 5. — Th-K diagram.
1, ophiolitic rocks ; 2, 3, 4, island arc volcanics from the zones in fig. 2. ; 5, basalts bearing augite phenocrysts from Vățișoara Zone.

tents come up to 6% in andesitic rocks, the highest values bearing the andesites from Gliganu Hill (Tab. 1 and 4 ; Fig. 6).

In ophiolitic rocks, K content is low (Tab. 2 and 3) ; it does not exceed 0.8%, most part of the rocks having under 0.5% K, value which correspond to the observation of Miyashiro (1975), who also noticed that K_2O contents in abyssal tholeiitic or ocean floor rocks are very low.

Distribution of REE and other Trace Elements

Th, U and K high content in basaltic rocks bearing augite phenocrysts from the Vățișoara Valley makes us select them for the lanthanides and Ti, Zr, Rb and Y analyses (Tab. 1). In these rocks, we have obtained high values of La (130-140 ppm) and of Ce (200-270 ppm), which are obviously much higher than those we know about basaltic rocks from other island arc volcanic series. We must underline that the contents in light lanthanites from all analysed basaltic rocks of

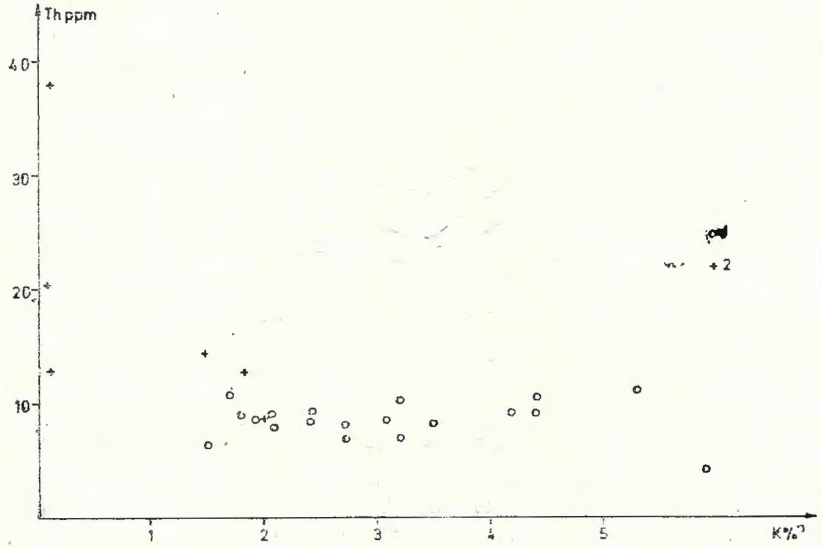

Fig. 6. — Th-K diagram for andesites.

1, andesites from Țebea-Visca-Luncoi Zone; 2, andesites from Tătărăști Zone.

island arc in Vața-Vorța-Vălișoara region, are higher than those we know from relevant literature, they varying from 30 to 40 ppm for La and being of approximately 100 ppm for Ce.

The other analysed elements (Sm, Eu, Tb, Co, Rb, Sr, Sc) confirm the fact that the basalts bearing augite phenocrysts from Vățișoara area have a special position among volcanics of island arc in the region, because their contents in these rocks are two or three times higher than the contents in other basaltic rocks of the island arc (Tab. 1). REE values from the volcanic series of island arc are close to those obtained by Arth and Hanson (1972) from calc-alkaline rocks. On the diagram in Figure 7, where are presented the chondrite-normalized REE patterns for basalts and andesites from various zones of the investigated region, we can notice that the curves look like those of calc-alkaline rocks in island arcs. At the same time, we see the Eu negative anomaly which appears within the strongly differrentiated volcanic rock series (Philpotts, Schnetzler, 1968).

Curves appearance which shows an accentuated descending in the whole pattern of REE from La to Lu, differs clearly from the shapes of REE curves of the ocean floor basalts, placed in MORB field (Fig. 7).

Regarding Ti, Y and Zr values, they are somehow constant in all basaltic rocks of island arc (Tab. 1), they being similar to those of calc-alkaline basalts indicated by Pearce and Cann (1973). They show that

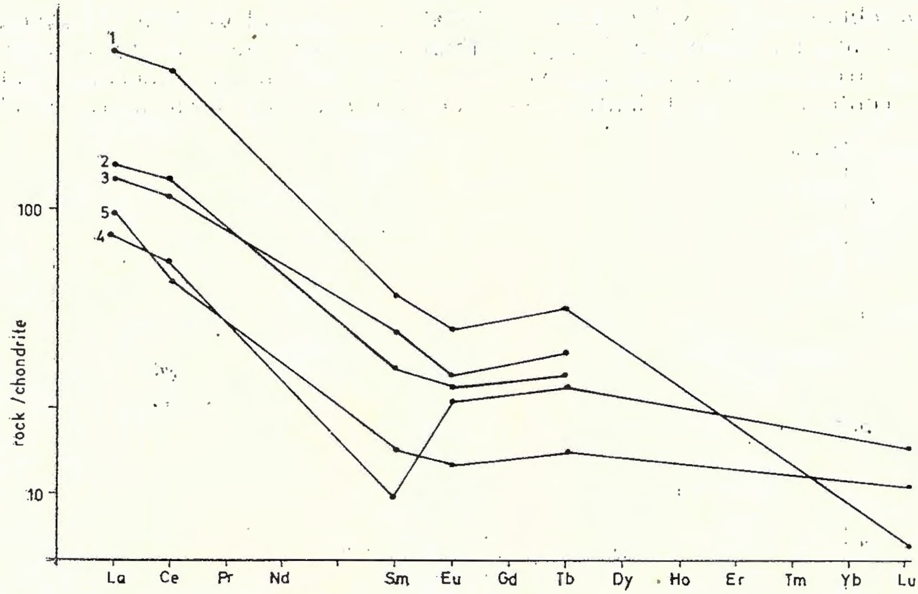

Fig. 7. — Chondrite-normalized REE patterns for the island arc volcanics. 1, basalts bearing augite phenocrysts from Vățișoara Zone; 2, basalts from Tătărăști Zone; 3, basalts from Țebea-Visca-Luncoi Zone; 4, basalts from Vorța-Dealu Mare Zone; 5, andesites.

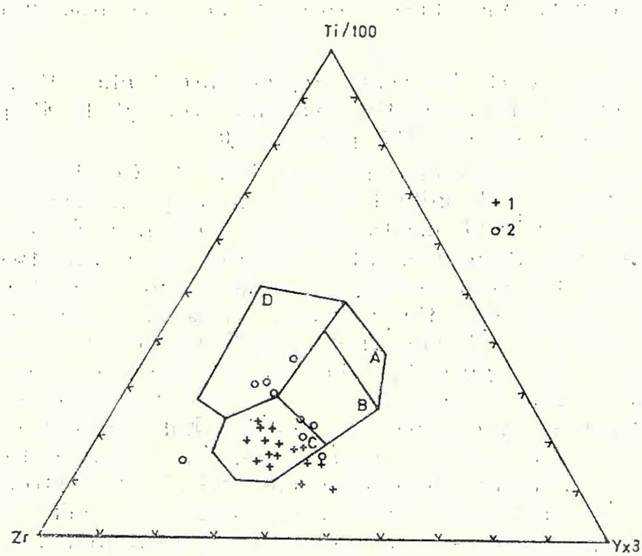

Fig. 8. — Ti-Y-Zr diagram (according to Pearce and Cann, 1973).
1, basalts from Vața-Vățișoara-Tătărăști Zone; 2, basalts from Vorța-Dealu Mare Zone.

even the basalts from the Vățișoara Valley, which although have the above characteristics, belong to the series of Upper Jurassic island arc volcanics. This conclusion is stressed by the way in which are plotted

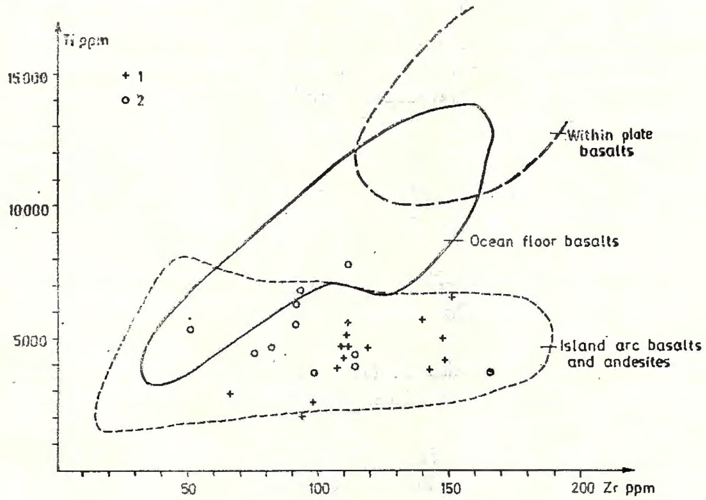

Fig. 9. — Ti-Zr diagram (according to Pearce and Gale, 1977).
1, basalts from Vața-Vățișoara-Tătărăști Zone ; 2, basalts from Vorța-Dealu Mare zone.

the basaltic rocks of island arc on the diagram of Figures 8 and 9, where they are all focussed in the field of island arc basalts and andesites.

Conclusions

The present paper makes us conclude the following :

1. In the region, we can distinguish two series of Mesozoic magmatic rocks : (a) a basement ophiolitic series and (b) a series of island arc volcanics.

2. U, Th and K contents are generally higher in the series of island arc volcanics than in ophiolitic series.

3. The content values in REE group, which are determined in island arc volcanics are specific for calc-alkaline series and are generally higher than their average known from relevant literature.

4. Ti, Y and Zr contents and their relationships underline the fact that the analysed rocks belong to the series of island arc volcanics.

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DISTRIBUȚIA U, Th, K, PĂMÎNTURILOR RARE ȘI A ALTOR ELEMENTE MINORE ÎN VULCANITELE DE ARC INSULAR ȘI UNELE OFIOLITE DIN REGIUNEA VAȚA-VORȚA-VĂLIȘOARA (ZONA MUREȘ)

(Rezumat)

Regiunea cercetată se găsește în partea centrală a zonei Mureș, ea fiind situată imediat la est de limita sinuoasă, care separă domeniul în care se dezvoltă larg seria ofiolitică (J_1-J_2) spre vest și seria vulcanitelor de arc insular (J_3-Cr_1) spre est. În cuprinsul regiunii rocile ofiolitice apar în două ferestre de eroziune, la sud de Vorța și pe marginea de vest, restul regiunii fiind acoperit de vulcanite de arc insular (fig. 1).

Elementele radioactive naturale U, Th și K au fost determinate atît în rocile ofiolitice din fundament, cît și în vulcanitele de arc insular (tab. 1, 2). Valorile lor în rocile ofiolitice sînt foarte reduse (fig. 2-6) și mult mai mici față de vulcanitele de arc insular. În acestea din urmă s-au determinat conținuturi mai ridicate de elemente radioactive în bazaltele cu fenocristale de augit de la Vățișoara. În andezite aceste elemente prezintă conținuturi mai ridicate decît în bazalte.

Lantanidele și alte elemente minore au fost determinate numai în vulcanitele de arc insular (tab. 1).

În rocile bazaltice lantanidele au valori normale pentru vulcanitele bazice de arc insular, La atingînd 30-40 ppm, iar Ce-100 ppm. Fac excepție bazaltele cu fenocristale de augit de la Vățișoara, în care La variază între 130 și 140 ppm, iar Ce între 200 și 270 ppm (tab. 1). Se remarcă și în cazul distribuției lantanidelor bazaltele piroxenice de la Vățișoara, în care valorile acestor elemente sînt de 2-3 ori mai mari

decît cele din celelalte roci vulcanice. Diagrama din figura 6 arată că spectrul total al lantanidelor din vulcanitele de arc insular este specific seriilor calco-alcaline, el fiind diferit de cel al bazaltelor din ridge-urile oceanice mediane (MORB).

Elementele Ti, Y și Zr sînt oarecum constante în bazaltele de arc insular (tab. 1), valorile lor fiind asemănătoare cu cele din bazaltele calco-alcaline. Aceste valori demonstrează că bazaltele cu fenocristale de augit de la Vățișoara, deși prezintă o serie de particularități, aparțin totuși seriei de vulcanite de arc insular, așa cum rezultă și din diagramele din figurile 8 și 9, pe care toate rocile bazaltice și andezitice din această serie vulcanică se situează în cîmpul bazaltelor de arc insular.

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GEOCHIMIE

Rb, Sr, Zr, Th, U, K DISTRIBUTION IN THE NEOGENE VOLCANICS OF THE SOUTH HARGHITA MOUNTAINS [1]

BY

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Geochemical distribution. Rb, Sr, Zr, Th, U, K. Magmas differentiation. Calc-alkali magmatism. Shoshonitic magma. East Carpathians — Neogene-Quaternary eruptive — Harghita.

Abstract

The abundance of Rb, Sr, Zr, Th, U, K in the main volcanic apparata of the South Harghita Mts has been determined. Chemically, the volcanic rocks show from N to S a continuous variation from calc-alkaline basaltic andesites to andesites, high-K andesites and high-K dacites. Two intrusive domes — shoshonitic and banakitic, respectively — are found in the southernmost part of the area. The geochemical features of the "incompatible" elements analysed point out the existence of two magma types in the South Harghita Mts : a calc-alkaline magma, which develops by a gradual increase of SiO_2, K_2O, Na_2O, Sr, Th, U from north to south, within six volcanic apparata, and a shoshonitic magma, which occurs within two intrusive domes and shows a low content of SiO_2, high content of K_2O, Na_2O and Th and very high contents of Sr (2170 ppm). The similarity of the gheochemical data from the South Harghita Mts with geochemical features of island arc and with continental margin andesites seems to suggest (in this case) magma formation independent of the geotectonic conditions. Nevertheless, it increases the significance of the following factors : 1) southward increase in depth of the source region, generating an ever reduced rate of partial melting ; 2) differentiation processes by fractional crystallization (processes that took place during the magma rise in intermediary magmatic chambers more or less related to assimilation processes).

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Résumé

Considérations sur la distribution de Rb, Sr, Zr, Th, U, K des volcanites néogènes des monts Harghita du Sud. On a déterminé l'abondance en Rb, Sr, Zr, Th, U, K des principaux appareils volcaniques des monts Harghita du Sud. Chimiquement, les roches volcaniques présentent une variation continue des andésites calco-alcalines pauvres en silicium aux andésites, aux andésites riches en K et aux dacites riches en K, allant du nord au sud. Dans l'extrémité méridionale il y a deux dômes intrusifs, l'un de shoshonites et l'autre de banakites. Les caractéristiques géochimiques des éléments „incompatibles" analysés relèvent pour les monts Harghita du Sud l'existence de deux types de magmas ;

— l'un calcoalcalin, qui évolue par augmentation progressive de SiO_2, K_2O, Na_2O, Sr, Th, U, le long de l'arc du nord au sud, dans le cadre de six appareils volcaniques ;

— l'autre shoshonitique, qui semble peu développé spatialement dans les deux dômes intrusifs et qui présente une teneur réduite en SiO_2, une teneur élevée en K_2O, Na_2O et Th et une teneur très élevée en Sr (2170 ppm).

Le ressemblance des données géochimiques des andésites de Harghita du Sud autant avec les caractères géochimiques des andésites des arcs insulaires qu'avec ceux des andésites des marges continentales suggère, semble-t-il, qu'il s'agit pour notre région de l'indépendance de la formation des magmas à la suite des conditions géotectoniques. Elle met en évidence également la grande importance des suivants facteurs : (1) profondeur de la région-source (du nord au sud le degré de fusion partielle décroît progressivement) et (2) processus de différenciation par cristallisation fractionnée, processus produits au cours de la migration du magma dans des chambres magmatiques intermédiaires, associés plus ou moins aux processus d'assimilation.

1. Introduction

The South Harghita Mts have attracted the geologists' attention since earlier times because they display the latest volcanic activity in the Călimani-Gurghiu-Harghita area, represent a well-preserved apparata (Rădulescu, 1973 a, c) and possess a great petrographic, mineralogical and chemical variety. The hypo- and hyperthermal springs and the gas emissions, indicating the possible existence of a deep-seated body of magmatic rocks still hot (Rădulescu et al., 1981), are also noteworthy.

The present paper describes the results of the geochemical study carried out on the main volcanic apparata in the South Harghita Mts with a view to a better knowledge of the petrogenetic relations of the calc-alkaline and shoshonitic association, of the geochemical features of the volcanic arc, according to the gradual rejuvenation of the volcanic activity (Rădulescu, 1973 a), as well as of the geochemical features of the volcanic apparata, of the volcanic products and of the petrographic types.

Geochemical studies have been effectuated by Peltz et al. (1973 a, b), Treiber (1974), Peccerillo and Taylor (1976 a), Bencini, Peccerillo (1977), Peltz et al. (1985 a, b). Except Treiber (1974) who presents analyses of major elements belonging to volcanic structures of the South Harghita

Mts, the other papers refer to the whole Călimani-Gurghiu-Harghita chain dealing with the genesis of the magmatism, either on the basis of major elements or of trace elements.

2. Geological and Volcanic Setting

The South Harghita Mts represent the southernmost part of the Călimani-Gurghiu-Harghita eruptive chain. They are bounded to the north by the Miercurea Ciuc-Odorhei road and to the south by the Malnaș-Băi, their length being of cca 40 km. Unlike the remaining of the Călimani-Gurghiu-North Harghita volcanic range, situated at the boundary between the East Transylvanian Depression to the east and formations belonging to the Crystalline-Mesozoic zone to the west, the basement of the South Harghita Mts consists of folded formations of the East Carpathians internal units which form the internal flysch and the Crystalline-Mesozoic zone. These formations bound to the east and west the volcanic zone, their existence being proved by the basement of the younger basins of the Lower Ciuc (to the east) and Baraolt (to the southwest).

The magmatic activity took place during two main phases, to which two structural compartments correspond : the volcano-sedimentary lower compartment and the stratovolcanic upper compartment developed in the Upper Malvensian-Upper Pliocene time-span (Rădulescu et al., 1964, 1973, 1981).

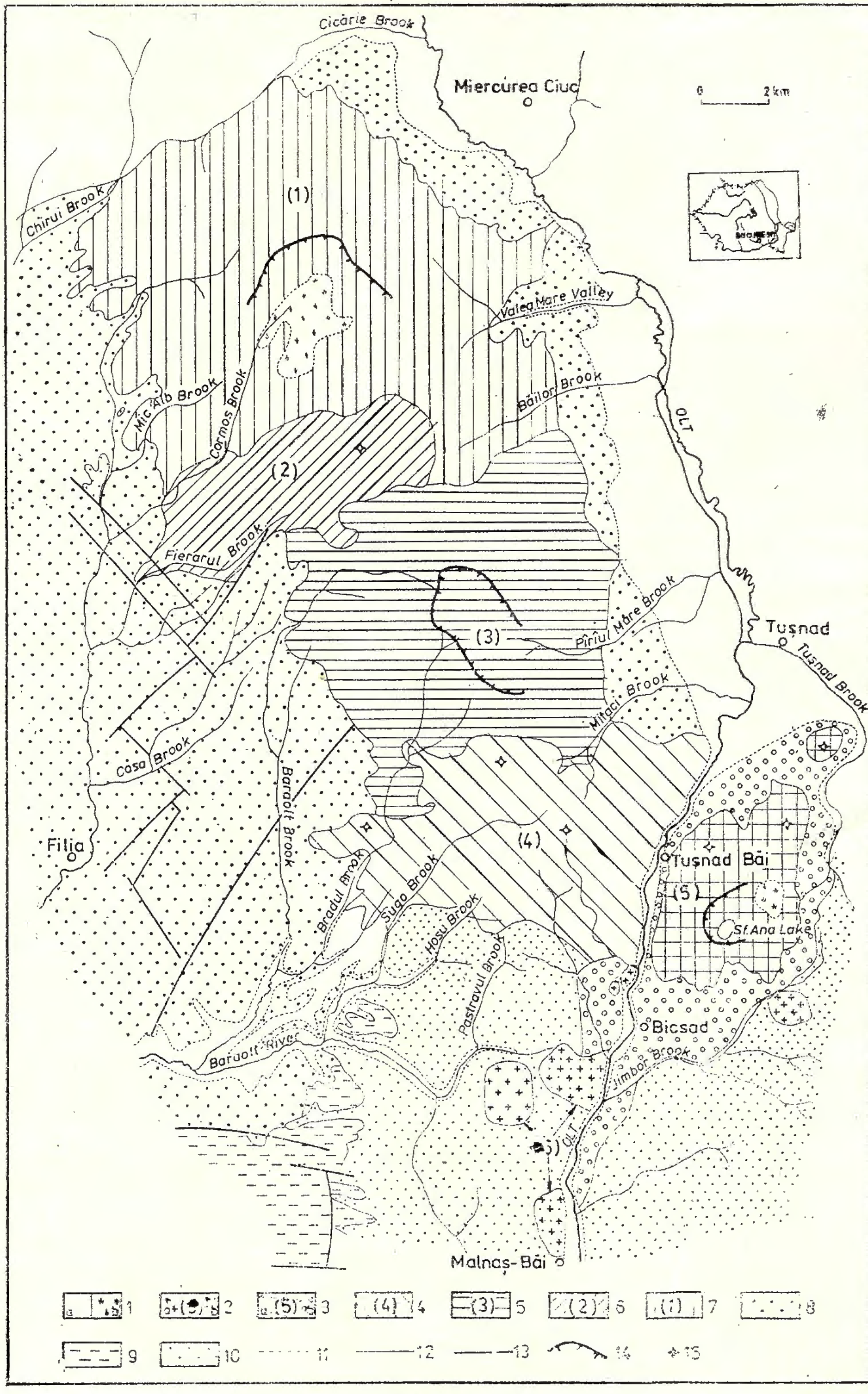
Evidence on the spatial position and petrographic features of the volcanic products (lavas, pyroclastics), within the upper structural compartment made possible the delimitation of the known volcanic apparata, as shown on the map scale 1 : 200 000, sheet Odorhei, and also presented by Motoi et al. (1976), as follows : Luci (1), Fagul (2), Cucu (3), Pilișca (4), Sf. Ana-Mohoș (5) extrusive and intrusive volcanic domes in the Bixad-Malnaș-Băi region (6) (Fig. 1).

3. Chemical Evidence Compared with Other Orogenic Zones

98 chemical analyses have been carried out in order to determine the contents of SiO_2, K_2O and Na_2O (Tab.). For the same samples the contents of Rb, Sr and Zr have been determined by nondispersive XRF spectrometry, and U, Th and K by means of gamma spectrometry for 82 samples (Tab.). Samples marked with O of the lower compartment and samples marked with 1, 2, 3, 4, 5, 6 of the upper compartment, corresponding to the mentioned volcanic apparata, have been grouped separatedly.

SiO_2 and K_2O values allow the classification of the rocks on the SiO_2/K_2O diagram (Peccerillo, Taylor, 1976 b) for which the rock distribution to the island arc tholeiitic (I), calc-alkaline (II), K-rich calc-alkaline (III) and shoshonitic (IV) series has been taken into account (Fig. 2).

It has been observed that the rock groups 0, 1, 2, 3, 4 belong to the calc-alkaline series (II), 3, 4, 5 and four samples from 6 to the K-rich calc-alkaline series (III), and six samples from 6 correspond to the shoshonitic series (IV).



Cicărie Brook
Miercurea Ciuc
0
2 km
Chirui Brook
(1)
Valea Mare Valley
Mic Alb Brook
Cormoş Brook
Băilor Brook
OLT
(2)
Fierarul Brook
(3)
Pîrîul Mare Brook
Tuşnad
Tuşnad Brook
Mitaci Brook
Coşa Brook
Baraolt Brook
Filia
(4)
Tuşnad Băi
(5)
Sf. Ana Lake
Bradul Brook
Şugo Brook
Hoşu Brook
Păstrăvul Brook
Bicsad
Baraolt River
Jimbor Brook
OLT
Malnaş-Băi
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Fig. 1.

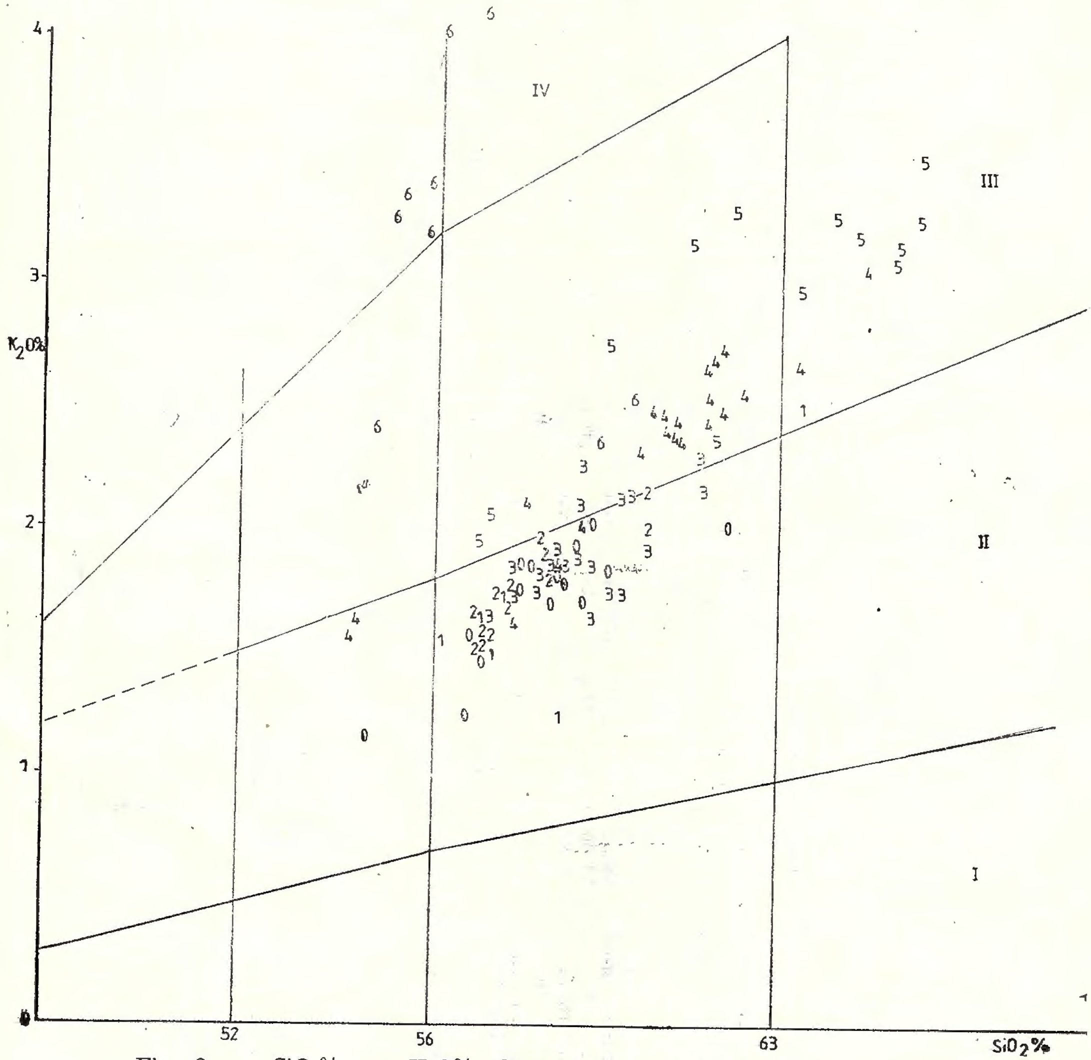


Fig. 2. — $SiO_2\%$ vs. $K_2O\%$ diagram (Peccerillo and Taylor, 1976). Symbols as in Table 1.

Fig. 1. — Geological sketch of the South Harghita Mountains (after geological maps sc. 1 : 50 000 — Chirui, Baraolt, Sînmartin and from Moţoi et al., 1976). 1, Quaternary : a, alluvia and terraces ; b, marshes ; 2, a, calc-alkaline extrusive domes in the Bixad-Malnaş-Băi Zone (6) ; b, shoshonitic intrusive domes in the Bixad-Malnaş-Băi Zone (6) ; 3, Sf. Ana-Mohoş volcanic apparata : a, massive volcanics ; b, pyroclastics ; 4, Pilişca volcanic apparata (4) ; 5, Cucu volcanic apparata (3) ; 6, Fagul volcanic apparata (2) ; 7, Luci volcanic apparata (1) ; 8, volcano-sedimentary lower compartment ; 9, Pliocene sedimentary of the Baraolt basin ; 10, Mesozoic sedimentary of the flysch zone ; geological boundary with the Quaternary ; 12, geological boundary ; 13, fault ; 14, crater ; 15, vent.

TABLE

Partial analyses of major and trace elements from the studied area. In the table are included the Rb/Sr, K/Rb, Th/U ratios

I. (0) *Lower Compartment*

Sample no.	Phenocryst **	Location	SiO_2	K_2O	Na_2O	Rb	Sr	Zr	Rb/Sr	K	K/Rb	U	Th	Th/U
H—323	Pl, Cpx, Opx	Biborțeni	54.65	1.16	2.90	36	340	120	0.107	0.96	266	1.4	5.9	4.21 (l)*
55	Pl, Cpx, Opx, Hb	Covacius Brook	56.62	1.25	2.95	45	310	120	0.146	1.04	231	—	—	— (v)
H—267	Pl, Opx, Cpx	Cormoș Brook	56.72	1.56	3.31	48	480	140	0.101	1.30	271	1.5	7.3	4.87 (v)
H—323A	Pl, Opx, Cpx	Biborțeni	56.88	1.49	3.04	53	400	130	0.131	1.24	234	—	—	— (l)
H—27	Pl, Opx, Hb, Bi	Herculian Brook	57.54	1.86	3.56	55	570	130	0.095	1.54	280	1.6	5.8	3.62 (v)
H—27 A	Pl, Opx, Hb, Cp	,, ,,	57.60	1.69	3.60	64	500	140	0.128	1.40	219	—	—	— (v)
H—201	Pl, Opx, Cp , Hb, Bi	,, ,,	57.97	1.85	3.62	58	400	130	0.147	1.54	265	2.1	9.1	4.33 (v)
14	Pl, Opx, Cpx, Hb	Cormoș Brook	58.34	1.70	3.30	63	380	130	0.164	1.41	224	—	—	— (v)
H—214	Pl, Opx, Hb, Cpx	Herculian Brook	58.57	1.82	3.34	65	400	150	0.164	1.51	232	2.5	9.3	3.72 (e)
H—296L	Pl, Opx, Cpx, Hb, Ol	,, ,,	58.60	1.78	3.24	56	350	120	0.160	1.48	264	2.4	9.4	3.92 (l)
57	Pl, Cpx, Opx, Hb	Muhor Brook	58.82	1.92	3.49	61	320	160	0.190	1.59	261	2.1	9.5	4.52 (l)
49	Pl. Cpx, Opx, Hb	Covacius Brook	59.12	1.70	3.35	54	360	120	0.149	1.41	261	—	—	— (l)
H—237	Pl, Opx, Hb	Păstrăvilor Brook	59.30	2.06	3.40	76	420	140	0.182	1.71	225	2.4	10.2	4.25 (v)
H—296	Pl, Opx, Cpx, Hb, Ol	Herculian Brook	59.53	1.83	3.56	53	360	130	0.149	1.52	287	2.1	9.8	4.66 (v)
H—289	Pl, Hb, Opx, Cpx, Bi	Durca Brook	61.92	2.02	3.94	54	490	140	0.109	1.68	311	2.7	10.6	3.93 (v)
II. *Upper compartment*														
1. Luci Volcano														
H—242	Pl, Opx, Cpx	Cormoș Brook	56.15	1.54	3.13	69	400	130	0.174	1.28	186	1.9	8.0	4.21 (l)
1	Pl, Opx, Cpx	Bătătura Cailor Brook	57.03	1.65	3.30	109	330	160	0.332	1.37	126	—	—	— (l)
11	Pl, Opx, Cpx	Holoșag Brook	57.24	1.50	3.20	59	530	110	0.112	1.25	212	—	—	— (l)
26	Pl, Opx, Cpx	Cormoș Brook	57.38	1.55	3.25	97	300	150	0.320	1.29	133	—	—	— (l)
T—151	Pl, Opx, Cpx, Ol	Valea Mare Brook	57.49	1.72	3.30	69	340	150	0.181	1.43	207	1.5	9.0	6.0 (l)
19	Pl, Opx, Cpx,	Alb Brook	58.60	1.75	3.25	110	210	190	0.516	1.45	132	—	—	— (l)
T—150	Pl, Hb, Opx, Cpx	Valea Mare Brook	63.49	2.50	2.90	109	230	130	0.478	2.08	191	1.4	12.4	8.86 (b)

Continuation TABLE

2. *Fagul Volcano*														
38	Pl, Opx, Cpx, Hb	Fierarul Brook	56.90	1.50	3.24	59	600	130	0.090	1.25	212	1.9	7.9	4.16 (l)
H–327	Pl, Opx, Cpx, Hb	Lugojul Brook	56.96	1 67	3.02	53	570	120	0.092	1.39	262	2.4	8.7	3.62 (l)
H–221	Pl, Opx, Cpx, Hb	Lugojul Brook	56.98	1.54	3.32	61	590	130	0.104	1.28	210	1.9	7.7	4.05 (l)
H–220	Pl, Opx, Cpx, Hb	,, ,,	57.05	1.60	3.27	51	570	120	0.090	1.33	261	1.7	8.1	4.76 (l)
H–222	Pl, Opx, Cpx, Hb	,, ,,	57.10	1.58	3.32	61	570	120	0.167	1.31	215	1.5	7.2	4.80 (l)
H–359	Pl, Opx, Hb, Cpx, Ol	,, ,,	57.30	1.75	3.13	72	360	140	0.197	1.45	201	2.5	8.6	3.44 (l)
H–215	Pl, Opx, Hb, Bi	Fierarul Brook	57.47	1.73	3.21	62	390	130	0.159	1.44	235	2.5	8.8	3.52 (l)
H–329	Pl, Opx, Cpx, Hb	Covacius Brook	57.60	1.79	3.23	71	430	130	0.163	1.49	210	2.1	9.1	4.33 (l)
H–219	Pl, Opx, Cpx, Hb	Lugojul Brook	58.16	1.97	2.97	72	270	140	0.271	1.64	228	1.8	10.7	5.94 (l)
H–216	Pl, Opx, Cpx, Hb, Bi	Fierarul Brook	58.31	1.82	3.23	69	410	130	0.169	1.51	219	2.1	9.3	4.43 (l)
H–341	Pl, Opx, Cpx	Lugojul Brook	58.31	1.91	3.25	79	370	130	0.212	1.59	201	2.1	10.1	4.81 (l)
37	Pl, Opx, Cpx, Hb	Fierarul Brook	59.00	1.95	3.40	73	480	110	0.152	1.62	222	—	—	— (l)
H–335	Pl, Opx, Cpx, Hb	Lugojul Brook	60.28	2.16	3.31	89	370	140	0.243	1.79	201	2.4	12.1	5.04 (l)
H–334	Pl, Opx, Cpx, Hb	,, ,,	60.31	2.01	3.15	82	320	140	0.250	1.67	204	—	—	— (l)
3. *Cucu Volcano*														
75 A	Pl, Hb, Cpx, Ol	Herculian Brook	57.00	1.65	3.80	56	390	140	0.144	1.37	245	—	—	— (l)
H–272	Pl, Opx, Hb, Cpx, Ol	Durca Brook	57.62	1.75	3.78	61	550	130	0.111	1.45	238	—	—	— (l)
H–278	Pl, Hb, Opx, Cpx, Bi	,, ,,	57.64	1.86	3.92	66	530	130	0.124	1.54	233	2.6	8.2	3.15 (l)
H–270	Pl, Hb, Opx, Cpx	Cucu Hill	58.09	1.74	3.50	64	530	140	0.120	1.44	225	—	—	— (l)
H–281	Pl, Hb, Opx, Cpx	Durca Brook	58.25	1.84	3.94	53	560	140	0.094	1.53	289	1.8	9.8	5.44 (l)
H–260	Pl, Hb, Opx	Cormoş Brook	58.43	1.85	2.35	74	300	140	0.246	1.54	208	—	—	— (e)
H–275	Pl, Hb, Opx, Cpx, Ol, Bi	Durca Brook	58.57	1.86	3.64	64	610	130	0.104	1.54	241	—	—	— (l)
T–90	Pl, Hb, Opx, Cpx	Mitaci Brook	58.64	1.87	3.96	66	470	140	0.138	1.55	235	2.3	11.0	4.78 (l)
H–333	Pl, Opx, Hb, Cpx	Lugojul Brook	58.66	1.92	2.80	73	350	140	0.210	1.59	218	3.0	9.0	3.00 (e)
H–223	Pl, Hb, Opx, Bi	Fierarul Brook	58.86	1.91	3.47	75	430	140	0.174	1.59	212	2.6	9.6	3.69 (v)
H–268	Pl, Hb, Opx, Bi	Durca Brook	58.95	2.11	3.53	61	440	130	0.141	1.75	287	2.7	10.0	3.70 (l)
H–247	Pl, Opx, Hb	Cormoş Brook	59.10	2.28	3.24	91	330	130	0.277	1.89	208	2.8	11.8	4.21 (v)
H–271	Pl, Hb, Opx, Cpx, Bi	Cucu Hill	59.20	1.85	3.75	48	530	140	0.090	1.54	321	—	—	— (l)
75	Pl, Hb, Opx, Cpx	Herculian Brook	59.57	1.77	4.14	40	630	130	0.063	1.47	367	2.3	8.0	3.48 (l)
H–276	Pl, Hb, Opx, Cpx, Bi	Durca Brook	59.76	2.16	3.63	80	400	140	0.203	1.79	224	2.8	12.7	4.53 (l)
H–318	Pl, Hb, Opx, Cpx	Herculian Brook	59.77	1.76	3.48	55	430	120	0.127	1.46	265	2.3	8.6	3.74 (l)
H–273	Pl, Bb, Opx, Cpx	Durca Brook	60.00	2.14	3.66	78	440	130	0.175	1.78	228	2.7	12.0	4.44 (l)
H–234	Pl, Hb, Opx, Cpx, Bi	Păstrăvilor Brook	60.34	1.94	3.20	76	430	130	0.175	1.61	212	2.9	10.7	3.69 (e)
H–226	Pl, Opx, Cpx. Bi	Fierarul Brook	61.36	2.31	3.63	76	500	150	0.153	1.92	253	2.7	12.0	4.44 (v)
H–274	Pl, Hb, Opx, Bi	Durca Brook	61.53	2.14	3.64	67	390	150	0.170	1.78	266	3.1	11.0	3.55 (v)

Continuation TABLE

Sample no.	Phenocryst	Location	SiO_2	K_2O	Na_2O	Rb	Sr	Zr	Rb/Sr	K	K/Rb	U	Th	Th/U
4. *Pilişca Volcano*														
T—96	Pl, Cpx, Opx, Ol	Mitaci Brook	54.22	1.56	3.37	35	910	140	0.038	1.28	366	1.7	5.4	3.18(v)
T—95	Pl, Cpx, Opx, Ol	,, ,,	54.47	1.63	3.58	47	790	130	0.059	1.38	287	2.1	5.8	2.76 (v)
T—61	Pl, Cpx, Opx, Ol	Olt River	57.56	1.63	3.68	43	720	130	0.060	1.35	314	1.7	6.6	3.89 (v)
T—3A	Pl, Opx, Cpx, Hb, Ol	Hollo Brook	57.87	2.12	3.67	65	1040	160	0.062	1.76	271	3.5	8.5	2.43 (l)
T—77	Pl, Hb, Opx, Cpx	Olt River	58.95	2.02	4.05	68	970	160	0.070	1.68	247	2.2	9.2	4.18 (l)
T—15	Pl, Hb, Bi	Pilişca Hill	60.31	2.32	4.21	76	830	140	0.091	1.93	254	3.6	11.9	3.30 (l)
T—12	Pl, Hb, Bi	,, ,,	60.48	2.48	4.09	89	930	150	0.096	2.06	231	3.3	11.6	3.51 (v)
T—80	Pl, Opx, Cpx, Bi	Olt River	60.72	2.41	4.02	70	1320	170	0.052	2.00	286	3.0	9.0	3.00 (b)
T—117	Pl, Hb, Bi	Baniasz Brook	60.73	2.47	4.10	88	860	180	0.102	2.05	233	3.4	11.4	3.36 (l)
T—84	Pl, Opx, Cpx, Hb	Sărac Brook	60.92	2.36	3.92	76	1310	170	0.057	1.96	258	3.3	7.6	2.30 (b)
T—5A	Pl, Opx, Cpx, Hb	Hollo Brool	61.04	2.36	3.77	74	1420	180	0.051	1.96	265	3.4	8.8	2.59 (b)
T—9	Pl, Hb, Bi	,, ,,	61.48	2.66	3.87	70	680	130	0.102	2.21	316	2.8	11.2	4.00 (l)
T—100	Pl, Hb, Bi	Pilişca Hill	61.61	2.44	4.45	63	970	160	0.064	2.03	322	3.0	12.5	4.17 (v)
T—59	Pl, Hb, Bi	Olt River	61.61	2.54	4.22	78	820	140	0.094	2.11	270	3.3	13.3	4.03 (v)
T—103	Pl, Hb, Bi	Pilişca Hill	61.68	2.69	3.94	81	1050	170	0.077	2.23	275	3.2	13.4	4.19 (l)
T—101	Pl, Hb, Bi	,, ,,	61.73	2.72	4.26	81	1250	160	0.064	2.26	279	2.9	9.8	3.38 (l)
T—106	Pl, Bi, Hb	,, ,,	61.76	2.49	3.69	88	860	180	0.102	2.07	235	2.3	13.1	5.70 (l)
T—16	Pl, Hb, Bi	,, ,,	62.28	3.57	3.77	94	900	150	0.104	2.13	226	3.5	11.0	3.14 (l)
T—22	Pl, Bi, Hb	Hollo Broo	63.48	2.78	4.10	106	860	160	0.123	2.31	218	3.7	11.5	3.11 (l)
T—17	Pl, Hb, Bi	Pilişca Hill	64.74	3.16	4.05	112	870	190	0.129	2.62	234	3.7	15.4	4.16 (l)
5. *Sf. Ana-Mohoş Volcano*														
T—72	Pl, Hb	Apor Hill	56.92	1.95	4.11	63	890	150	0.070	1.62	257	2.3	9.3	4.05 (l)
T—70	Pl, Hb, Cpx	,, ,,	57.20	2.06	3.65	62	840	150	0.073	1.71	276	2.3	9.4	4.09 (l)
T—125	Pl, Hb, Cpx, Bi	Mohoş Hill	59.55	2.76	4.27	54	1340	170	0.040	2.29	424	4.4	12.0	2.73 (v)
T—124	Pl, Hb, Bi, Cpx	Ciomad Hill	61.32	3.16	4.24	78	1390	170	0.055	2.62	336	3.1	11.6	3.75 (v)
T—33	Pl, Opx, Cpx	Olt River	61.63	2.37	3.90	57	1350	160	0.042	1.97	346	3.0	9.0	3.00 (l)
T—45	Pl, Hb, Bi	Bicsad Brook	62.18	3.30	4.51	95	1290	170	0.073	2.74	288	4.1	15.0	3.66 (l)

T—28p	Pl, Hb, Bi	Olt River	63.43	2.98	4.43	76	1600	170	0.047	2.47	325	3.3	9.5	2.88 (e)
T—28	Pl, Hb, Bi	,, ,,	64.09	3.27	4.46	83	1420	170	0.058	2.71	327	4.1	14.6	3.56 (e)
T—25	Pl, Hb, Bi	,, ,,	64.52	3.21	4.14	90	1350	170	0.066	2.66	296	4.0	14.5	3.62 (e)
T—68	Pl, Bi, Hb	Apor Hill	65.30	3.10	4.62	108	1330	190	0.081	2.57	238	3.7	14.8	4.00 (l)
T—36	Pl, Hb, Bi	Ciomad Hill	65.42	3.16	4.50	100	1220	180	0.082	2.62	262	4.4	14.2	3.23 (l)
T—67	Pl, Bi, Hb	Apor Hill	65.80	3.26	4.44	101	1400	190	0.072	2.71	268	3.8	14.8	3.90 (v)
T—44	Pl, Bi, Hb	Bicsad Brook	65.82	3.53	4.53	104	1310	180	0.079	2.93	282	4.5	15.2	3.38 (v)
6. *Extrusive and intrusive volcanic domes from Bicsad-Malnaş region*														
T—86	Pl, Opx, Cpx, Ol	Piatra Şoimilor Quarry	54.71	2.41	3.11	96	520	200	0.186	2.00	208	4.6	11.0	2.39 (b)
T—134B	Pl, Cpx, Opx, Ol, Q, Bi, Hb	Malnaş 1 Quarry	55.10	3.26	3.61	58	1620	240	0.035	2.71	467	2.6	9.5	3.66 (b)
T—134A	Pl, Cpx, Opx, Ol, Q, Bi, Hb	,, ,,		3.36	3.86	46	1440	210	0.031	2.79	606	2.2	10.1	4.59 (b)
T—134	Pl, Cpx, Opx, Ol, Q, Bi, Hb	,, ,,	55.88	3.40	3.75	55	1600	230	0.034	2.82	513	2.6	9.9	3.81 (b)
T—135	Pl, Cpx, Opx, Ol, Q, Bi, Hb	Malnaş 2 Quarry	55.88	3.20	3.71	49	1490	210	0.033	2.66	543	2.4	9.7	4.05(b)
T—144	Pl, Cpx, Ol, Opx, Bi, Q	Bicsad Quarry	56.10	4.06	3.69	60	2150	290	0.028	3.37	562	3.8	14.1	3.71 (b)
T—146	Pl, Cpx, Ol, Opx, Bi, Q	,, ,,	56.90	4.12	3.61	58	2170	300	0.026	3.42	590	3.4	15.5	4.56 (b)
T—141	Pl, Bi, Hb, Cpx, Opx	Murgul Mare Hill	59.30	2.34	3.87	75	540	150	0.140	1.94	259	2.6	11.4	4.39 (l)
T—140	Pl, Bi, Hb, Cpx, Opx	,, ,,	59.96	2.53	4.12	80	590	140	0.136	2.10	263	2.8	11.8	4.22 (l)

* Sample from : (l) — lava flow ; (v) — volcanoclastic rocks ; (e) — epiclastic rocks ; (b) — intrusive bodies.

** Pl — plagioclase ; Opx — orthopyroxene ; Cpx — clinopyroxene ; Ol — olivine ; Hb — hornblende ; Bi — biotite ; Q — quartz.

A linear increase of the rock alkalinity both within each structure concurrently with the SiO_2 increase, as well as a gradual increase from N to S in the other volcanic apparata is also noticed.

According to the chemical classification most of the rocks of groups 0, 1, 2, 3 plot in the upper part of the andesite field and groups 4 and 5 and a part of group 3 in the K-rich andesite field. The majority of the samples ascribed to group 5 are referred to the K-rich dacite field, two samples from group 4 and one sample from group 1 inclusively. For these rocks the denomination after chemical criteria does not correspond to the former petrographic determination (Szöke, 1963 ; Lazăr, Arghir, 1964 ; Peltz et al., 1973).

It is assumed that the high content of K_2O is due to the biotite abundance and the high values of SiO_2 to the chemical features of the rock groundmass.

Samples belonging to the Murgul Mic and Luget (6) intrusive domes indicate a different position as compared to the other analysed samples. Four samples are ascribed to shoshonites and two to banakites (also mentioned in the same classification by Bencini and Peccerillo, 1977 ; Peltz et al., 1985). From petrographic-mineralogic point of view these rocks have been regarded as basaltic andesites by Szadeczky (1930), Szöke (1963), Lazăr, Arghir (1964), Peltz et al. (1973), Treiber (1974) or as andesites by Moțoi et al. (1976). Consequently, the correlation of the mineralogical evidence with the chemical one is necessary for a correct denomination of the mentioned rocks.

Murgul Mare, Dealul Mare extrusive domes (6) possess K-rich calc-alkaline-type petrographical and geochemical features as against the above-mentioned intrusive domes. Piatra Șoimilor body (6) has a special position ; it falls in the field of andesites poor in Si and rich in K.

The abundance of trace elements — Rb, Sr, Zr, Th, U — considered as "incompatible" elements has been compared to the evidence given in the relevant literature which generally corresponds to magmas generated under conditions of plate collision (Taylor, 1969 ; Jakeš, Gill, 1970 ; Jakeš, White, 1972 ; Jakeš, 1973 ; Dupuy, Lefevre, 1974 ; Gill, 1981).

It has been noted that the abundance in these "incompatible" elements occurs only in case of some of the andesites of groups 0 and 1, typical of the island-arc calc-alkaline rocks. Groups 2, 3, 4, 5 point out a successive increase of the Sr, Zr, Th, U values from N to S concomitantly with the petrographic changes (gradual enrichment in hornblende and biotite of the andesites) indicating similarities with continental and "intracontinental andesites" (Jakeš, 1973).

The samples from Murgul Mic and Luget intrusive domes are referred to the shoshonitic associations due to their fairly high values of Sr, comparable only with those from Fiji (Gill, 1970). The highest values are those from the Bixad Olt quarry with Sr=2150-2170 ppm. The other samples from group 6 are similar with continental margin calc-alkaline associations.

Rb variations limits range between 33 ppm and 112 ppm.

The positive correlation of K with Rb (Fig. 3) indicates conspicuous similarities for groups 0, 1, 2 with island arc andesites from New Guinea, and for groups 3, 4, 5 with continental andesites from Peru and Chile. The value of the K/Rb ratio for shoshonites is of

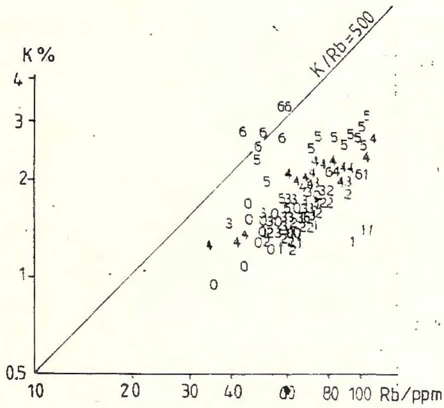


Fig. 3. — K% vs. Rp ppm diagram. Symbols as in Table

500 being similar to shoshonites from Peru and Fiji (Dupuy and Lefévre, 1974), whereas the calc-alkaline groups display an average value (about 250) for the mentioned ratio.

A special position occupy the rocks of group 1 with high values of Rb (97-110 ppm) which do not belong to the general correlation tendency of the other groups.

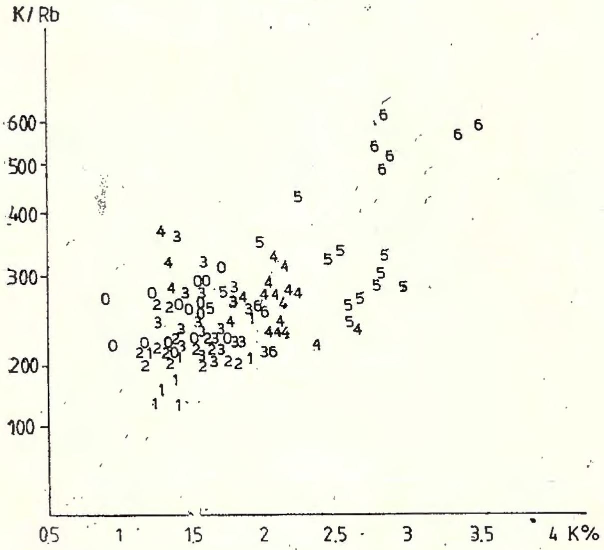


Fig. 4. — K/Rb vs. K% diagram. Symbols as in Table.

K/Rb ratio (Fig. 4) shows a slight tendency of increase concomitantly with the content of K, unusual for calc-alkaline andesites which show generally a decrease of this ratio (Gill, 1981).

Sr diagram depending on Rb (Fig. 5) points out cluster domains of Sr for the same variation interval of the Rb concentrations. Interruptions occur between domains. The following domains of the Sr

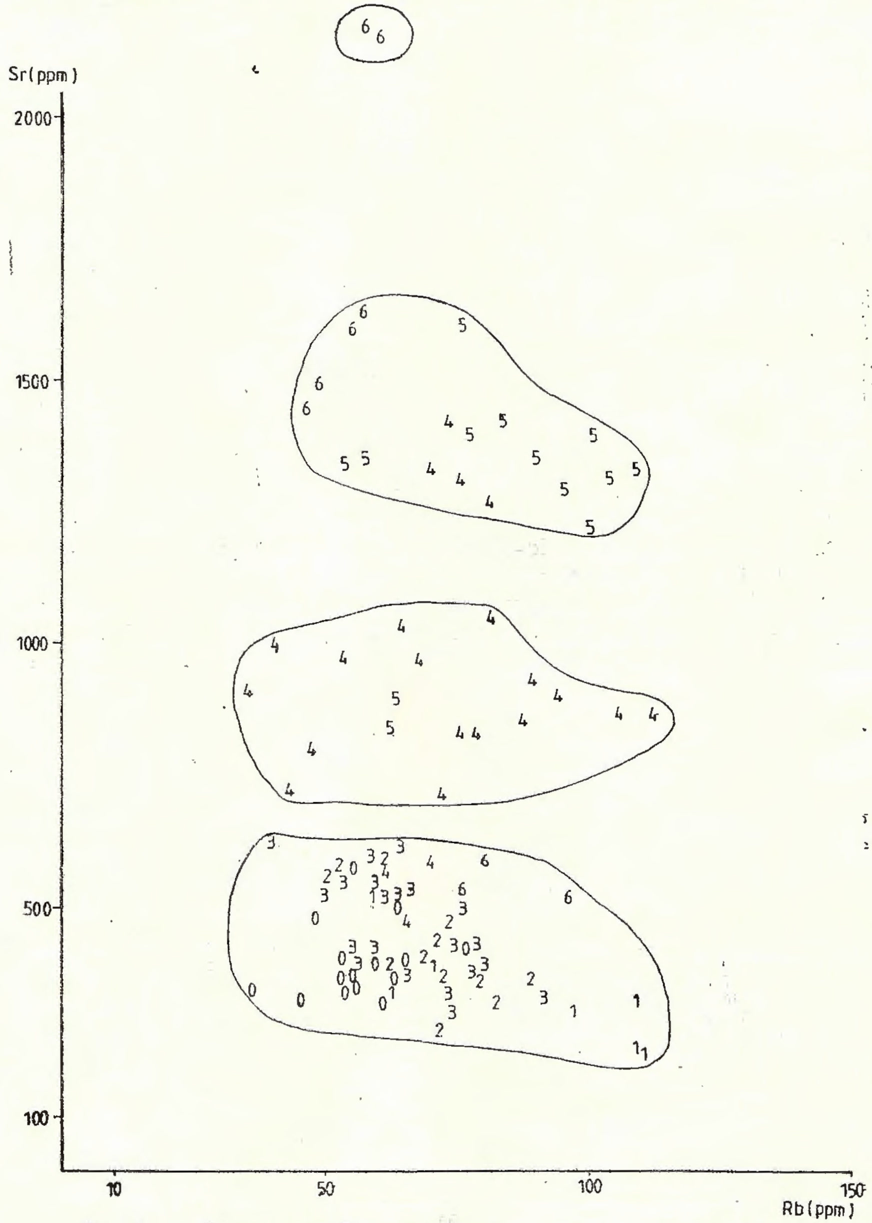


Fig. 5. — Sr ppm vs. Rb ppm diagram. Symbols as in Table.

concentration are to be mentioned : 200-600 ppm for groups 0, 1, 2, 3 and two samples from group 6 ; 700-1000 ppm Sr for group 4 and two samples, the oldest ones within the volcanic apparata no. 5; 1200-1500 ppm Sr for group 5 and three samples, the most recent ones within the volcanic apparata no. 4. Shoshonites belong to the third field (1440-1620 ppm) and banakites reach maximum values of 2170 ppm Sr and form a distinct domain.

A comparison of this diagram with the evidence given by Gill (1981) for orogenic andesites in different geotectonic situations renders evident the same characteristics of classification on domains of Sr variation depending on Rb. Thus, andesites from the first domain (200-600 ppm Sr) show similarities with andesites from the Aleutine and Sumatra, those from the second domain (700-1000 ppm Sr) with andesites from the Eolian arc, and those from the domain 1100-1500 ppm Sr with andesites from the Cascade Mts. An increase of the Sr values is observed from one interval to another indicating gradual geochemical modifications from an island arc geotectonic regime to a continental margin geotectonic regime.

Thorium varies from 5.4 to 15.4 ppm and uranium from 1.4 to 4.6 ppm. The lower values correspond to the island arc and the high values to the continental margins.

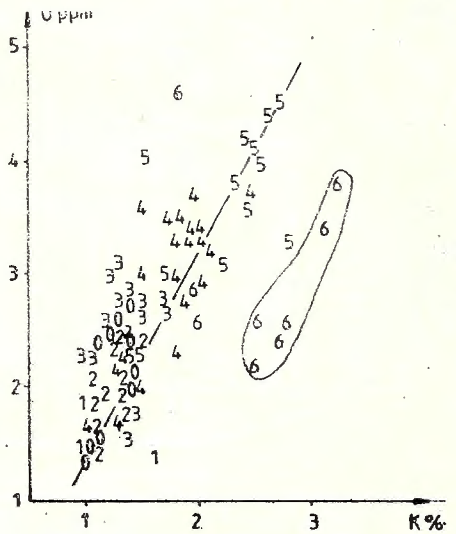


Fig. 6. — U ppm vs. K% diagram. Symbols as in Table.

Thorium shows a good direct correlation with potassium. Uranium also displays a gradual increase in all groups concurrently with the increase of the content in K. It may be observed that the shoshonitic rocks also have a different position; generally they possess smaller U values for higher contents of K (Fig. 6) as against the successive linear increase of the values within the calc-alkaline groups. The same tendency is observed in case of Th and U, the Th/U ratio being constant.

The plotting of the Rb/Sr values according to K_2O (Fig. 7) points to a statistical decrease of the Rb/Sr ratio from group 1 to group 5. The sixth group shows a special variation.

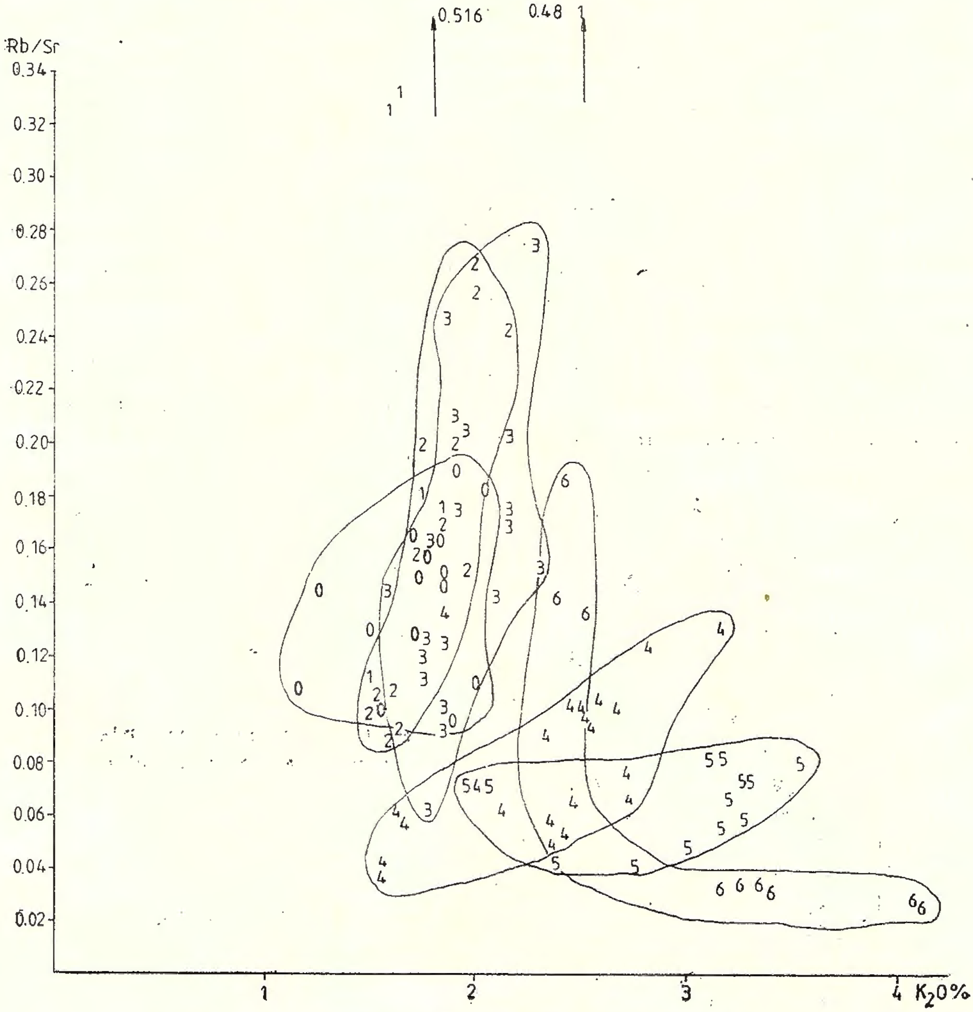


Fig. 7. — Rb/Sr vs. $K_2O\%$ diagram. Symbols as in Table.

Within the petrotypes (Tab.) Rb, Sr, Zr, Th, U indicate an increase of the values from pyroxene types to pyroxene hornblende types, hornblende pyroxene types, hornblende pyroxene biotite types, hornblende biotite types and biotite hornblende types.

The same petrotype belonging to different volcanic apparata clearly differentiate on the basis of the content of "incompatible" elements studied (Tab.).

All these observations point out, on the one hand, the existence of a geochemical consanguinity on apparata not on petrographic types and, on the other hand, the fact that the mineralogy of the phenocrysts does not affect the abundance of trace elements in rocks indicating that the Sr, Th, Ba distribution and possibly that of Rb depends on the groundmass.

4. Discussion

The correlation of paleovolcanic, petrographic and geochemical aspects of the Călimani-Gurghiu-Harghita eruptive chain with the bulk of geological data made possible the outlining of models which indicate their provenance through the plate collision and subduction (Rădulescu, Săndulescu, 1973 ; Bleahu et al., 1973). Although situated on continental basement, volcanics are compared in geochemical respect with island arc calc-alkaline associations (Boccaletti et al., 1973 ; Bencini, Peccerillo, 1977).

The present paper points out in the study zone (South Harghita) similarities with both the island-arc calc-alkaline volcanics (samples from groups 0, 1, 2) and with the continental marginal ones (groups 3, 4, 5 and a part of group 6). Within group 6 shoshonitic-like rocks have been distinguished.

It is of note that there is a gradual transition from north to south from calc-alkaline types specific to island arc magmatites to calc-alkaline types typical of the continental margin type, the last products possessing a shoshonitic character. Therefore, there is a systematic modification of the geochemical features from N to S along the volcanic chain which took place concurrently with the migration in time in the same direction of the volcanic products (as proved by Rădulescu, 1973 a). In the calc-alkaline domain there is a gradual increase of SiO_2, K_2O, Na_2O, Sr, Th, U. The shoshonitic products with which the volcanic activity ended display low values of SiO_2, Rb and U and high values of K_2O, Sr and Th.

This model of volcanic arc geochemical evolution is similar to the geochemical models from Lesser Antilles and Papua-New Guinea, where the shoshonitic associations which close the time and space evolution of the arc do not migrate perpendicular to the trench-arc system, but along it, being concentrated towards the end of its spatial development (Arculus, Johnson, 1978).

The geochemical particularities of the calc-alkaline volcanics allow us to presume their provenance in primary magmas which developed under similar conditions but differentiated gradually from the beginning due to different degrees of partial melting and then they reached intermediary magmatic chambers which gave the geochemical features of the magmas responsible for the generation of volcanic apparata in the study region. Within these chambers the magma is supposed to have undergone complex differentiation processes by fractional crystallization or other complex processes such as assimilation (Rădulescu, 1973 b; Rădulescu, Dimitriu, 1973 ; Bencini, Peccerillo, 1977 ; Peltz et al., 1982).

Rb/Sr diagram for K_2O (Fig. 6) indicates a decrease of the Rb/Sr ratio along the arc, close to the value characteristic of the upper mantle. It permits us to surmise an even greater depth of the primary magma formation from north to south, which correlated with a gradual decrease of the degree of partial melting of the primary magma. This decrease determines the gradual enrichment in SiO_2, K_2O, Sr, Th, U and Zr. The same conclusion is suggested by the increase of the Sr concentration from north to south (Fig. 4), also indicating an ever greater depth of the magma formation (considering that Sr remains constant during the differentiation processes — Hart et al., 1970).

As known, in the sequence of differentiated magmatic rocks the Rb/Sr ratio tends to increase proportionally to the increase of the differentiation rate. In our case, the correlation is clearly shown by group 1 (Luci volcanic apparatus) whose high values of the Rb/Sr ratio and of Rb point to a marked differentiation process (as compared with other groups) by fractional crystallization implying probably plagioclase and hornblende.

Shoshonitic rocks of the South Harghita imply the existence of an independent primary magma, as shown locally by Bencini and Peccerillo (1977) and extended by Peltz et al. (1985) to the whole Tușnad-Malnaș area. Our geochemical evidence indicates values similar to the shoshonites from Peru, Fiji and New Guinea (Gill, 1970 ; Dupuy et al., 1976). The fact that the magma generating shoshonites in the South Harghita is distinct is proved also by the distribution of the REE (Peccerillo, Taylor, 1976 a), which indicates a continuous fractionation of both the light rare earths elements and of the heavy ones. The magma distinctive character may be explained by the low rate of partial melting either of the assemblage of garnet-bearing lherzolites (Dupuy et al., 1977) or of one of the garnet-bearing pyroxenites (Peccerillo, Taylor, 1976 a) ; both assemblages can release a garnet-rich residuum at the level of the bottom of the upper mantle. Garnet, as a residual phase, is the main mineral which would fraction both the light rare earths elements and the heavy ones under high-pressure conditions.

5. Conclusions

In conclusion, products of two magma types are to be found in the Harghita Mts : a calc-alkaline magma, which develops by an increase of SiO_2, K_2O, Na_2O and the incompatible elements to the north and south, within six groups of specific evolution, and a distinct shoshonitic magma occurring locally within two intrusive domes situated in the southernmost part of the eruptive chain, which display low values of SiO_2 and high values of K_2O, Na_2O, Th and especially Sr.

The similarity of the geochemical data obtained for the South Harghita Mts with the geochemical features of the island arc andesites and with the continental margin andesites seems to suggest (in this case) the formation of the magma independent of the geotectonic conditions (constants of continental basement type).

The discrepancy between our geochemical evidence, indicating an apparently evolutive regime, and the proved geotectonic regime (Rădulescu, Săndulescu, 1973), constantly stationary, leads inevitably to the control of the geochemical evolution way by other factors than the geotectonic ones : (1) depth of the source-region (which increases from N to S), generating an ever reduced rate of partial melting ; (2) products of differentiation by fractional crystallization (processes that took place during the magma rise in intermediary magmatic chambers more or less related to assimilation processes).

Therefore our model is new as against the magmatic arcs whose geochemical way of development imitates the usual evolution related to the modification of the geotectonic setting.

Acknowledgements

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DISCUSSION

D. Russo-Săndulescu: The genetic model with the basic changing of the geotectonic conditions over about 40 km, which is stressed out by the authors, is difficult to be accepted taking into account that in the Harghita Mountains, and generally within the whole volcanic zone, the tectonic background is similar and homogeneous. For this reason and also because the petrographic studies are insufficiently developed in respect of the large number of analytical data the conclusions have a high degree of incertitude.

CONSIDERAȚII ASUPRA DISTRIBUȚIEI Rb, Sr, Zr, Th, U, K ÎN VULCANITELE NEOGENE DIN MUNȚII HARGHITA DE SUD

(Rezumat)

I. *Introducere*

Lucrarea este o investigație geochimică efectuată în cadrul lanțului vulcanic Harghita de sud cu scopul unei mai bune cunoașteri a relațiilor petrogenetice a rocilor vulcanice calco-alcaline și shoshonitice.

2. *Cadrul geologic și vulcanologic*

Munții Harghita de sud constituie extremitatea sudică a lanțului eruptiv Călimani-Gurghiu-Harghita; prezintă un fundament alcătuit din formațiuni cutate ale unităților interne ale Carpaților Orientali ce alcătuiesc flișul intern și zona cristalino-mezozoică.

Activitatea vulcanică a avut loc ca în întreg lanțul în cadrul a două compartimente structurale : compartimentul inferior vulcano-sedimentar și compartimentul superior-stratovulcanic în intervalul malvensian superior-pliocen superior (Rădulescu et al., 1964, 1973, 1981).

În cadrul compartimentului superior activitatea vulcanică de natură andezitică se desfășoară în cadrul următoarelor aparate vulcanice de la nord la sud : Luci, Fagul, Cucu, Pilișca, Sf. Ana-Mohoș. La sud de aparatele vulcanice apar o serie de domuri extruzive (Murgul Mare, Dealul Mare, Piatra Șoimilor) și intrusive (Murgul Mic, Luget), care încheie activitatea vulcanică a lanțului eruptiv (Rădulescu, 1973 a).

3. *Prezentarea datelor chimice comparativ cu alte zone orogenice*

Studiul geochimic cuprinde un număr de 98 analize, care au determinat SiO_2, K_2O, Na_2O, Rb, Sr, și Zr, dintre care pentru 82 au fost determinate U, Th, K.

Au fost colectate 15 probe din compartimentul inferior (0) și 83 de probe din compartimentul superior, care reprezintă corespunzător distribuția în jurul principalelor aparate : (1) Luci — 7 probe ; (2) Fagul — 14 probe ; (3) Cucu — 20 probe ; (4) Pilișca — 19 probe ; (5) Sf. Ana-Mohoș — 13 probe, iar pentru domurile extrusive și intrusive din zona Bicsad-Malnaș (6) — 10 probe.

Diagrama SiO_2/K_2O (Peccerillo, Taylor, 1976) indică repartiția rocilor la seriile calco-alcaline (0, 1, 2, 3, 4), calco-alcaline bogate în K (5, 4, 3, 6) și shoshonitice (6).

De remarcat creșterea liniară a alcalinității rocilor funcție de SiO_2 atît în cadrul fiecărui aparat cît și de la un aparat la altul. Probele din domul intrusiv Luget se grupează la shoshonite, iar cele din corpul Murgul Mic la banakite.

Se mai separă următoarele tipuri de roci : andezite sărace în siliciu (din 4, 0), andezite sărace în siliciu, bogate în K (din 6), andezite (din 0, 1, 2, 3), andezite puternic potasice (din 3, 4, 5, 6), dacite puternic potasice (din 5, 4, 1). Consemnăm că denumirea de dacite nu corespunde cu determinările petrografice (tab.).

Abundența în elementele Rb, Sr, Zr, Th, U a fost comparată cu datele analitice din literatură, care corespund în general magmelor generate în condiții de coliziune a plăcilor (Taylor, 1969 ; Jakeš, Gill, 1970 ; Jakeš, White, 1972 ; Jakeš, 1973 ; Gill, 1981). Elementele „incompatibile" analizate prezintă pentru o parte a andezitelor grupărilor 0 și 1 — asemănări cu rocile calco-alcaline din arcuri insulare. Se produce succesiv spre aparatele 2, 3, 4, 5 deci de la N spre S o creștere a valorilor Rb, Sr, Th, U, concomitent cu schimbări de natură petrografică (creșterea conținutului în hornblendă și biotit), ce indică asemănări geochimice cu andezite din margini continentale. Probele colectate din corpurile Luget și Murgul Mic (shoshonite și banakite) indică clare similitudini cu asociații shoshonitice din Peru sau insulele Fiji (Gill, 1970).

Rb prezintă valori între 35-112 ppm ; se observă o corelație directă bună a Rb cu K (fig. 3) pentru grupările 0, 2, 4, 5. Pentru grupările 0, 1, 2 se observă asemănări cu andezite de arc insular iar pentru 3, 4, 5, cu andezite din margini continentale. Raportul K/Rb separă din nou shoshonitele, cu valori în jur de 500, față de vulcanitele calco-alcaline, ce au un raport în jur de 250.

Diagrama Sr la Rb (fig. 5) evidențiază domenii de puncte cu concentrații similare ale Sr pentru același interval de variație a concentrațiilor în Rb : între 200-600 ppm asemănătoare andezitelor din arcuri insulare ; între 700-1000 ppm — asemănătoare cu andezite din peninsule continentale și între 1200-1500 ppm asemănătoare cu andezite din margini continentale

Th variază între 5,4-15,4 ; iar U între 1,4-4,6. Valorile mai mici au corespondență cu arcuri insulare, iar valorile mari cu cele din margini continentale. Atît Th cît și U indică corelații directe bune cu K.

4. *Discuția datelor*

Distribuția elementelor „incompatibile" sugerează o modificare sistematică a caracterelor geochimice de la N spre S de-a lungul arcului vulcanic, modificare produsă simultan cu migrarea în timp în aceeași direcție a produselor vulcanice (Rădulescu, 1973 a). Această situație este subliniată de trecerea gradată a caracterelor geochimice ale Harghitei de sud, de la afinități cu andezite calco-alcaline de arcuri insulare spre afinități cu andezite calco-alcaline din margini continentale, ultimele produse avînd un caracter shoshonitic. Acest model de arc vulcanic este similar cu modelele Antilele Mici și Papua — Noua Guinee, unde migrarea geochimică spațială și temporală se face de-a lungul arcului și nu perpendicular pe acesta (Arculus, Johnson, 1978).

Diagrama Rb/Sr funcție de K_2O scoate în evidență o diminuare a raportului Rb/Sr de-a lungul arcului, fapt care permite să presupunem o adîncime din ce în ce mai mare pentru formarea magmelor primare, de la nord la sud, ceea ce se corelează cu o scădere progresivă a gradului de topire parțială a magmei primare.

Pentru magma calco-alcalină se presupun procese de diferențiere și asimilare în camere magmatice intermediare, caracteristice fiecărui aparat vulcanic.

Rocile shoshonitice din regiunea studiată presupun existența unei magme primare independente (Bencini, Peccerillo, 1977 ; Peltz et al., 1982) formată probabil prin topire parțială la nivelul mantalei superioare a unui ansamblu de lerzolite granatifere (Dupuy et al., 1977) sau piroxenice granatifere (Peccerillo, Taylor, 1976 a).

Discrepanța marcantă între datele noastre geochimice, care sugerează un regim geotectonic aparent evolutiv și regimul geotectonic demonstrat (Rădulescu, Săndulescu, 1973), ca staționar constant în realitate (tip soclu continental), conduce la concluzia finală a controlării manierei evoluției geochimice de către alți factori decît cei geotectonici ; este vorba de adîncimea regiunii sursă a magmei și diferențierea prin cristalizare fracționată a acesteia (± asimilare) în camere magmatice intermediare.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

U, Th AND K DISTRIBUTION IN THE BISTRICIOR-STRUNIOR AND CĂLIMANI CALDERA ERUPTIVE UNITS — NORTH CĂLIMANI MOUNTAINS [1]

BY

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U, Th, K. Stratovolcano. Caldera. Volcanic structure. Andesites. Multistage evolution. Magmas differentiation. Geochemical distribution. East Carpathians — Neogene-Quaternary eruptive — Călimani.

Abstract

The comparative geochemical study performed on 105 U, Th, K analyses within the upper compartment volcanic units of Bistricior-Strunior (BSU) and the Călimani Caldera (CCU) points to the following characteristics : BSU, less evolved in volcanological respect (stratovolcanoes with late intrusions), displays lower values for U (0.5-2.8) and Th (1.4-7.2), indicating similarities with island arc andesites. The analysed eruptive products, although coming from different time moments, account for a magma which evolved under similar conditions pointing to nonsignificant differentiation processes. CCU is an evolved structure in volcanological respect (caldera with resurgent dome) ; the values of U vary from 0.6 to 4.8 and of Th from 2.3 to 18.9 indicating for the pre-caldera stage a bimodal distribution. The volcanological observations on the multistage evolution of the caldera are confirmed (Seghedi, 1982 a). The volcanic products with small values of U, Th, K show similarities with the island arc volcanic rocks but they are subordinated, as regards the volume, to those with values similar to the continental margin andesites. A source of common magma is estimated, which developed by complex processes of differentiation and assimilation within several magmatic chambers. The solphatarian postvolcanic activity leads to the decrease of the contents of U, Th, K, whereas the hydrometasomatic activity affecting the intrusive stock contributes to the significant increase of the radioactivity of the transformation products.

Résumé

Distribution de U, Th, K dans les unités éruptives de Bistricior-Strunior et la caldeira de Călimani — monts de Călimani du Nord. L'étude géochimique

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comparative effectuée sur 105 analyses concernant la distribution de U, Th, K des unités volcaniques du compartiment supérieur de Bistricior-Strunior (UBS) et de la caldeira de Călimani (UCC) relève que :

— UBS est moins évoluée du point de vue volcanologique (stratovolcans à intrusions tardives), tient des valeurs plus petites pour U (0,5 à 2,8) et pour Th (1,4 à 7,2) et présente des similitudes avec les andésites des arcs insulaires. Les produits éruptifs analysés, bien qu'engendrés au cours de divers intervalles de temps, attestent la présence d'un magma qui a évolué en des conditions similaires désignant des processus de différenciation non significatifs.

— UCC est une structure évoluée que la première (caldeira à dôme résurgent) ; elle présente des valeurs pour l'U entre 0,6 et 4,8 et pour le Th entre 2,3 et 18,9 ayant pour le stade précaldeira une distribution bimodale.

On vérifie les observations volcanologiques concernant l'évolution polystadiale de la caldeira (Seghedi, 1982 a). Les produits volcaniques à valeurs petites de U, Th, K dénotent des similitudes avec les roches volcaniques des arcs insulaires, étant toutefois subordonnés comme volume aux produits à valeurs similaires aux andésites des marges continentales. On a estimé une source de magma commune dont l'évolution est marquée par des processus de différenciation et d'assimilation dans le cadre de plusieurs chambres magmatiques.

L'activité postmagmatique solphatarienne mène à la diminuation des teneurs de U, Th, K, alors que l'activité hydrométasomatique affecte le stock intrusif en contribuant à l'accroissement de la radioactivité des produits de transformation.

1. Introduction

In the North Călimani Mts the geological and volcanological research aiming at the clearing out of the geological structure and of the succession of the eruptive products were carried out concomitantly with detailed petrographic and geochemical studies (Seghedi, 1982 a ; Seghedi in Stoica et al., 1981).

The present paper points up the characterization of the U, Th and K distribution within two main volcanic units in the North Călimani Mts and the petrogenetic implications resulting from the study of these elements.

The first studies on the distribution of U, Th, K radioactive elements in the Călimani Mts area have been elaborated by Peltz et al. (1973, 1982). These papers mainly present the characteristics of the U, Th, K distribution within different petrotypes.

2. Geological Data

The North Călimani Mts represent a complex volcanic region dominated by the Călimani Caldera well preserved morphologically.

The performed geological studies are in agreement with the previous papers (Rădulescu et al., 1964, 1973, 1981) which point out the existence of two structural compartments for the whole Călimani-Gurghiu-Harghita volcanic area : lower compartment (volcano-sedimentary) and upper compartment (stratovolcanic).

Geological researches led to the separation of volcanic structures on the basis of the evidence on the origin and way of distribution of the volcanic products within the upper compartment as well as on the basis of the detailed petrological studies (Seghedi in Stoica et al., 1981 ; Seghedi, 1982 a). The term of volcanic units has been recently adopted (Peltz, Seghedi, 1982 ; Seghedi, 1982 b). The volcanic products of the lower compartment (in the NE Călimani area) show a complex lithology and their paleovolcanic appurtenance is difficult to determine as they are mostly covered by lavas and pyroclastics of the upper compartment ; they belong to the Buciniș-Neagra, Dorna volcanic unit (Peltz, Seghedi, 1982).

Bistricior-Strunior Unit

This unit is delimited by the Colbu Brook to the west and by the Dorna Brook and its tributary (Tihu Brook) to the east. It is dominated by the Bistricior, Strunior and Străcior summits, which probably functioned as eruption centres.

The basement of the region is well exposed and consists of Oligocene sedimentary deposits characterized by an alternation of clays, marls and sandstones. The general trending of the sediments is NW-SE with SW dips.

The sediments are pierced by sills, dykes and subvolcanic bodies belonging to the Bîrgău subvolcanic zone (Rădulescu et al., 1973). Subvolcanic magmatic rocks display a great textural (microdiorites, andesites) and mineralogical variety (hornblende ; pyroxene ; pyroxene and hornblende). Eastwards these bodies extend up to the Dorna Valley.

The sedimentary basement, intruded by Bîrgău-type subvolcanics, is overlain by the first products of the lower compartment. They are restricted as regards the volume and the surface and are represented by a volcanoclastic complex, epiclastics and thin lava intercalations. The petrographic types are diverse, basaltic andesites, pyroxene andesites and pyroxene-hornblende andesites predominating. In the western part of the structure the basement is directly overlain by a level of nondifferentiated coarse pyroclastics with elements of pyroxene andesites.

The sedimentary basement and the products of the lower compartment are overlain by those of the upper compartment, the most numerous ones and with the widest distribution.

The main products are the lavas with discontinuous intercalations of pyroclastic breccias or autoclastic volcanic breccias (sensu Parsons, 1969), usually affected by postvolcanic solutions which deposit quartz, calcite, chlorite, etc. Basaltic andesites, pyroxene andesites, hornblende andesites and pyroxene-hornblende andesites have been distinguished.

The main eruption centres were probably situated in front of the Bistricior Summit, Strunior Summit and Străcior Summit. The thickness of the volcanic pile belonging to the upper compartment varies from 300 to 500 m.

The eruptive activity continued with an intrusive moment. Microdioritic and dioritic bodies pierced the volcanic structure and gave rise to an aureole of hornfelses at the contact with the formations penetrating them (sedimentary deposits, volcanics). The biggest and best known body is situated on the Aurari Brook. Eastwards another body occurs on the first tributary of the Strunior Brook. Small apophyses are found on the Viișoara Hill and the Tihu Brook. The bodies are disposed on an E-W alignment.

Călimani Caldera Unit

This structure is delimited by the spring area of the Dorna Valley to the west and by the Neagra Broștenilor Brook to the east. It consists of a caldera-type edifice with a resurgent dome which developed during several stages (Seghedi, 1982 a, b). The Călimani Caldera Unit lies east of the Bistricior-Strunior structure.

The first products of the lower compartment rest on Paleogene-Oligocene sedimentary formations to the west and on metamorphic rocks of the Bretila and Rebra series to the east.

The succession commences with a volcanoclastic complex (pyroclastics and epiclastics) with lava intercalations (hornblende andesites) exposed on the Tomnatecul, Deliganul and Buciniș brooks. This complex is overlain by lava flows represented by basaltic andesites, separated under the name of Coverca-type basaltic andesites and aphyric andesites.

At the upper part of the lower compartment one can observe a sequence of nondifferentiated pyroclastic breccias, with elements of basaltic andesites, pyroxene andesites and pyroxene-hornblende andesites with metric intercalations of lavas (pyroxene andesites, hornblende andesites).

The upper compartment (stratovolcanic) shows a less complicated structure in the central and eastern part of the caldera, where a structure with volcanic centres in front of the Rețitiș, Voevodeasa, Călimani Izvor-Călimani Cerbuc summits can be distinguished. Lavas with rare pyroclastic intercalations pertaining to pyroxene ± hornblende andesites occur almost exclusively. The lava flows are located at the top of the volcanic structure of the caldera (2,000 m) and their thickness ranges from 300 to 600.

In the eastern part of the caldera another structure can be noticed in front of the Negoiul Unguresc and Pietrosul summits. The pile of lavas and of pyroclastics (subordinate) of the same pyroxene ± hornblende andesites is of 150-200 m. At the lower part there is a stratovolcanic complex (pyroclastic breccias and lavas) made up, in petrographic respect, of basaltic andesites, pyroxene-hornblende andesites and hornblende-pyroxene andesites.

The present-day form of the caldera edifice is generated by collaps. The volcanic activity continues with effusive, explosive and intrusive products within the caldera. The main petrographic petrotypes are represented by basaltic andesites, pyroxene andesites, hornblende-pyroxene andesites.

In the next stage the volcanic products within the caldera were intruded by a monzodioritic intrusive stock which metamorphosed them thermally at the contact (hornblende hornfels facies).

In the Călimani Caldera the magmatic activity ended with biotite-hornblende-quartz andesites which form an extrusive dome in front of the Pietricelul Summit.

In this paper the Bistricior-Strunior and Călimani Caldera units will be marked BSU and CCU, respectively.

3. Observations on the U, Th, K Distribution

U, Th and K were determined by gamma spectrometry. The measurements were effectuated with a scintillation detector well-type with NaI crystal activated with Tl, photomultiplier and an analyser with 400 SA-40 B-type channels — "Intertechnique". The samples (0.5 kg) have been measured on hour. Cs^{137} (0.661 MeV) radioactive isotope was used for the standardization of the widening of the analyser channel. The calculated error for U and Th was of $\pm 2.5\%$ and for K 3.6%.

41 analyses on U, Th, K were carried out for BSU (Tab. 1). The classification of the analyses was made according to their position within the eruptive succession : 8 samples represent dykes and sills of the Bîrgău-type andesites, 3 samples — elements of andesites from a nondifferentiated pyroclastic sequence (lower compartment), 24 samples — lavas from the stratovolcanic formation (upper compartment) ; 6 samples — dioritic intrusive bodies (upper compartment).

Table 2 shows 64 analyses on U, Th, K for CCU, marked in the order of the emplacement of the eruptive products (Seghedi, 1982). All samples belong to the upper compartment : 17 samples from andesites belonging to the effusive explosive stage from the Pietrosul-Negoiul Unguresc structure ; 19 samples from the mainly effusive pre-caldera stage ; 4 samples from the explosive effusive pre-caldera stage ; 7 samples from the monzodioritic-dioritic intrusive post-caldera stage and 4 samples from the final effusive stage. 10 analyses were carried out on hydrometasomatically altered monzodiorites and 2 on andesites affected by the postvolcanic activity in the sulphur accumulation zone.

Tables 1 and 2 render the Th/U values and the numbers used in diagrams as conventional signs.

Having a comparable number of analyses — 50 in CCU (without the 12 analyses from hydrothermalized rocks) and 41 in BSU — the population mean M was calculated after the formula : $M = \bar{X} \pm \frac{Sx}{n} Z$ ($\bar{X}$ = arithmetical mean, Sx = standard deviation, n = sample number, Z = statistic coefficient linked with the number of samples and the degree of certainty).

TABLE 1

U, Th, K analyses in the Bistricior-Strunior Unit

No.	Sample no.	Location	Rock type	Symbol on diagram	U ppm	Th ppm	K %	Th/U
1	I—24	Aurari Brook	μδ	4	1.8	6.2	0.5	3.44
2	Z—36A	Strunior Brook	μδ py am	4	1.2	5.3	1.0	4.41
3	Z—23	Bistricior Crest	μδ	4	1.5	4.6	0.9	3.07
4	B.I.G.	Colbu Gallery	μδ py	4	0.9	4.3	1.1	4.77
5	Z—36	Strunior Brook	μδ py	4	1.2	3.0	0.5	2.50
6	Z—5	Strunior Brook	μδ py	4	1.2	3.0	0.7	2.50
7	Z—26	Curmătura Crest	αpy am	3	1.2	7.2	1.0	6.00
8	Z—11	Strunior Brook	αpy	3	1.8	7.0	1.4	3.89
9	C—39	Strunior Summit	αpy am	3	0.9	6.4	0.6	7.11
10	V—4	Viişoara Hill	αpy am	3	2.8	4.9	1.0	1.75
11	Z—103	Zgîrciu Brook	αpy	3	0.9	4.7	0.7	5.22
12	C—33	Viişoara Hill	αpy	3	1.4	4.2	0.7	3.00
13	1119	Tuţurgău Summit	αpy am	3	1.0	4.3	1.3	4.30
14	1107	Viişoara Hill	αam py	3	1.8	3.8	0.8	2.11
15	1118	Tuţurgău Summit	αpy	3	1.3	3.8	0.8	2.92
16	1112	Strunior Summit	αpy am	3	1.1	3.7	0.7	3.36
17	1114	Bistricior Summit	αpy	3	1.2	3.6	0.6	3.00
18	1109	Viişoara Hill	αpy	3	1.4	3.5	0.8	2.50
19	1111	Strunior Summit	αpy am	3	1.0	3.5	0.6	3.50
20	Z—51	Tihu Crest	αpy	3	1.3	3.5	0.8	2.69
21	Z—10	Strunior Brook	αpy	3	0.7	3.4	0.5	4.86
22	V—7	Viişoara Hill	αpy	3	1.0	3.2	1.0	3.20
23	Z—79A	Zgîrciu Brook	αpy	3	1.6	3.2	0.8	2.00
24	Z—22	E Bistricior Crest	αpy	3	1.3	3.1	0.6	2.38
25	Z—42	E Strunior Crest	αpy	3	1.5	3.0	1.1	2.00
26	1110	Viişoara Hill	αpy	3	1.4	3.0	0.4	2.14
27	Z—19	Strunior Brook	αpy am	3	1.0	2,2,7	0.8	2.70
28	1113	Bistricior Summit	αpy	3	1.0	2.7	0.8	2.70
29	Z—17A	Strunior Brook	αpy	3	1.4	2.6	0.6	1.86
30	Z—17	Strunior Brook	αpy	3	0.5	1.9	0.5	3.80
31	B.I.—1	Bistriţa Brook Dam	αam py	2	1.0	4.0	0.9	4.00
32	1115	Irimie Brook	αpy	2	1.3	3.8	0.8	2.92
33	1117	Irimie Brook	αpy	2	1.7	3.8	1.3	2.23
34	C—14	Cocoşul Brook	αam	1	2.2	6.6	1.7	3.00
35	A—1	Aurari Brook	μδπpy	1	2.4	5.8	1.3	2.41
36	1105	Cocoşul Brook	αpy	1	1.3	4.6	0.6	3.53
37	A—3	Aurari Brook	αpy	1	1.0	4.5	0.9	4.50
38	C—11	Cocoşul Brook	αpy am	1	1.3	3.7	0.7	2.84
39	C—1	Colbu Brook	αpy	1	1.3	3.4	0.7	2.61
40	I—5	Irimie Brook	αam	1	0.7	2.8	0.6	4.00
41	V—9	Viişoara Hill	μδpy am	1	1.0	1.4	0.7	1.40

TABLE 2

U, Th, K analyses in the Călimani Caldera Unit

No.	Sample no.	Location	Rock type	Symbol on diagram	U ppm	Th ppm	K %	Th/U
1	2	3	4	5	6	7	8	9
1	1155/1	Pietricelul structural drilling gallery XX	αpropil.		1.6	6.0	1.6	3.75
2	CF—9	Pietricelul	αcu sulf		0.3	0.7	0.0	2.33
33	8	Iancului Crest	μmzδ biot.		10.0	33.8	3.4	3.38
4	19	Pinului Brook	μmzδ alb.		3.1	29.6	3.2	9.55
5	17	Pinului Brook	μmzδ biot.		3.6	26.5	0.4	7.36
6	15	Iancului Crest	μmzδ act.		4.2	20.2	2.2	4.81
7	13	Iancului Crest	μmzδ biot.		4.7	19.2	3.5	4.08
8	11a	Iancului Crest	μmzδ biot.		5.7	19.0	3.0	3.33
9	20	Pinului Brook	μmzδ act.		2.6	18.8	3.4	7.23
10	5	Iancului Crest	μmzδ biot.		4.3	15.1	1.3	3.51
11	4	Iancului Crest	μmzδ act.		3.3	14.4	2.4	4.36
12	3	Iancului Crest	μmzδ act.		3.9	14.3	2.6	3.87
13	18	Pinului Brook	μmzδ act.		2.6	8.8	4.9	3.38
14	CF—2	Pietricelul Summit	αbi am q	5	2.1	13.0	1.6	6.19
15	CF—3	Pietricelul Summit	αbi am q	5	2.1	12.6	1.6	6.00
16	ST—4	Pietricelul Summit	αbi am q	5	3.5	12.4	2.2	3.54
17	CF—1	Pietricelul Summit	αbi am q	5	3.0	11.2	1.9	3.73
18	347	Smidei Crest	μmzδ	4	4.6	14.8	2.3	3.22
19	GR—2	Dumitrelu Brook	μmzδ	4	3.1	14.8	2.0	4.77
20	GR—2	Neagra Brook	μmzδ	4	3.6	12.8	2.2	3.55
21	517	Dumitrelu Brook	mzδ	4	4.8	8.7	2.6	1.81
22	28	Dumitrelu Brook	μδ	4	2.7	6.7	2.6	1.81
23	CC—26	Dumitrelu Mic Brook	μδ	4	1.7	4.3	1.3	2.53
24	537	Haita Brook	mzδ	4	2.3	3.8	2.4	1.65
25	CC—23	Pietros Brook	αpy	3	1.2	5.5	1.1	4.58
26	CF—8	Negoiu Rom. Summit	αpy	3	1.7	5.2	0.7	3.05
27	CC—24A	Pietros Brook	αpy am	3	1.5	5.0	0.9	3.33
28	27	Dumitrelu Brook	αpy β	3	1.5	3.7	0.8	2.46
29	CC—29	Negoiul Ung. Crest	αpy am	2	3.6	18.9	2.6	5.25
30	CC—4	Negoiul Ung. Crest	αpy am	2	3.0	17.9	1.8	5.97
31	CC—7	Negoiul Ung. Crest	αpy am	2	3.0	17.4	2.0	5.80
32	CC—1	Nicovala	αpy am	2	3.4	17.0	2.0	5.60
33	CC—5	Negoi Crest	αpy	2	2.6	17.0	1.9	6.53
34	CC—8	Negoiul Ung. Crest	αpy am	2	3.1	16.6	2.7	5.35
35	35390/1	Borehole 35390 Iezer	αpy	2	4.6	16.4	1.8	3.56
36	CC—6	Negoiul Ung. Crest	αpy am	2	3.2	16.4	1.9	5.12
37	35391/1	Borehole 35391 Iezer	αpy am	2	2.4	15.8	1.6	6.58
38	CC—9	Negoiul Ung. Crest	αpy am	2	3.6	15.5	2.3	4.30
39	CF—7	Reţiţiş Crest	αpy am	2	2.4	15.0	2.1	6.25
40	CC—24	Pietros Summit	αpy am	2	4.2	14.6	2.3	3.47
41	447/2	Borehole 447 Bradul Ciont	αpy am	2	2.5	14.4	1.6	5.76
42	447/1	Borehole 447 Br.Ciont	αpy am	2	3.0	14.2	2.0	4.73
43	CF—6	Reţiţiş Crest	αpy	2	3.6	14.1	1.8	3.91
44	CC—16	Reţiţiş Summit	αpy	2	2.8	13.5	2.0	4.82
45	CC—17	Negoiul Ung. Summit	αpy am	2	2.9	13.2	1.5	4.55

Continuation TABLE 2

1	2	3	4	5	6	7	8	9
46	CF–4	Reţitiş Crest	αpy am	2	2.8	12.7	2.0	4.53
47	CF–5	Reţitiş Crest	αpy	2	2.8	12.7	2.0	4.53
48	CC–15	Negoi Brook	αpy am	1	1.5	9.8	1.7	6.53
49	CC–2	Negoi Brook	αpy	1	1.2	7.7	1.7	6.41
50	CC–14	Negoi Brook	αam py	1	0.9	7.5	1.5	8.33
51	CC–13	Negoi Brook	αam py	1	1.2	6.5	1.6	5.41
52	CC–5	Negoiul Ung. Crest	αam py	1	2.1	4.9	1.3	2.33
53	CC–22	Pietros Brook	αβ	1	1.2	4.8	1.0	4.00
54	CC–11	Negoi Brook	αβ	1	1.0	4.6	1.0	4.00
55	CC–19	Pietros Brook	αβ	1	0.6	4.2	0.8	7.00
56	CC–25	Maria Tereza Road	αβ	1	0.8	3.7	1.0	4.62
57	CC–27	Maria Tereza Road	αβ	1	0.8	3.7	0.8	4.62
58	CC–10	Negoi Brook	αβ	1	0.6	3.5	0.7	5.83
59	CC–30	Negoi Brook	αβ	1	0.6	3.4	0.7	5.66
60	CC–20	Pietros Brook	αβ	1	1.1	3.0	0.9	2.72
61	CC–12	Negoi Brook	αβ	1	0.6	2.8	0.9	4.66
62	CC–28	Road Maria Tereza	αβ	1	0.6	2.8	1.0	4.66
63	1400/2	Pietricelul structural drilling	αβ	1	0.9	2.4	0.6	2.66
64	CC–18	Pietros Brook	αβ	1	1.0	2.3	0.8	2.30

Symbols used in tables : μδ = microdiorite ; μδπ = porphyry microdiorite ; μmzδ = micromonzodiorite ; μmzδπ = porphyry micromonzodiorite ; mzδ = monzodiorite ; α = andesite ; αβ = basaltic andesite ; py = pyroxene ; am = hornblende ; bi = biotite ; q = quartz. propil. = propylitized ; biotit. = biotitized ; alb. = albitized ; act. = actinolitized.

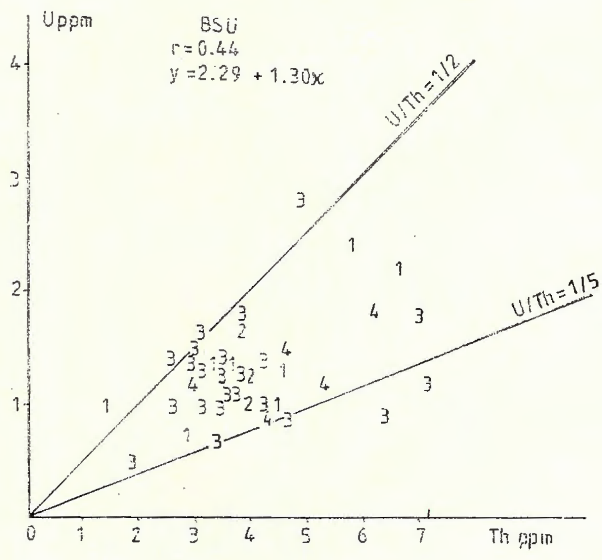
For a degree of certainty of 95% the following values were obtained :

	BSU	CCU
Th–K	$r = 0.5$	$r = 0.84$
U–K	$r = 0.48$	$r = 0.84$

	BSU	CCU
U	$\overline{X} = 1.30$ $1.16 < \mu < 1.44$	$\overline{X} = 2.1$ $1.91 < \mu < 2,58$
Th	$\overline{X} = 3.99$ $3.58 < \mu < 4.39$	$\overline{X} = 9.76$ $8.25 < \mu < 11.27$
K	$\overline{X} = 0.82$ $0.73 < \mu < 0.91$	$\overline{X} = 1.55$ $1.39 < \mu < 1.71$

The variation limits of U and Th in the studied rocks correspond to the data from literature for the orogenic andesites. According to Mason and McDonald (1978) and to Gill (1981) U values for calc-alkaline magmatites from island arcs are of about 2.5 ppm and from continental margins of 4.6 ppm. Th increases from 6 ppm at magmatites from island arcs up to 16 ppm at those from continental margins. One can observe that the Th values from BSU are similar with island arc andesites. The same affiliations with andesites from island arcs have the andesites from the base of the Pietrosul-Negoiul Unguresc structure (pre-caldera), the post-caldera ones belonging to the same structure and some of the samples from the intrusive monzodioritic-dioritic rocks (CCU). Andesites at the top of the caldera (pre-caldera), some of the monzodioritic intrusive rocks and biotite-hornblende-quartz andesites — of Pietricelul type — show geochemical affinities with calc-alkaline rocks from the continental margins.

Fig. 1. — U ppm vs. Th ppm diagram within BSU. Symbols as in Table 1.



Analyses carried out on hydrothermalized rocks from CCU evidence the following features : the two samples from the area of the sulphur accumulations indicate low values of U, Th and K, in keeping with the data given by Peltz et al. (1973). Hydrothermal alterations on monzodioritic rocks determine an increase of the content of Th (up to 33.8 ppm) and of K (up to 4.9%) due especially to processes of biotitization, albitization and actinolitization. U generally shows values similar to fresh monzodiorites, excepting sample no 8 (U = 10 ppm).

On diagrams U-Th, Th-K, U-K one followed in parallel the distribution and the BSU and CCU characteristic features. The analyses on hydrothermalized rocks were not included on diagrams.

On the diagram U-Th (Fig. 1) from BSU the values range within an interval of 1/2-1/5 U-Th. The correlation coefficient r = 0.44.

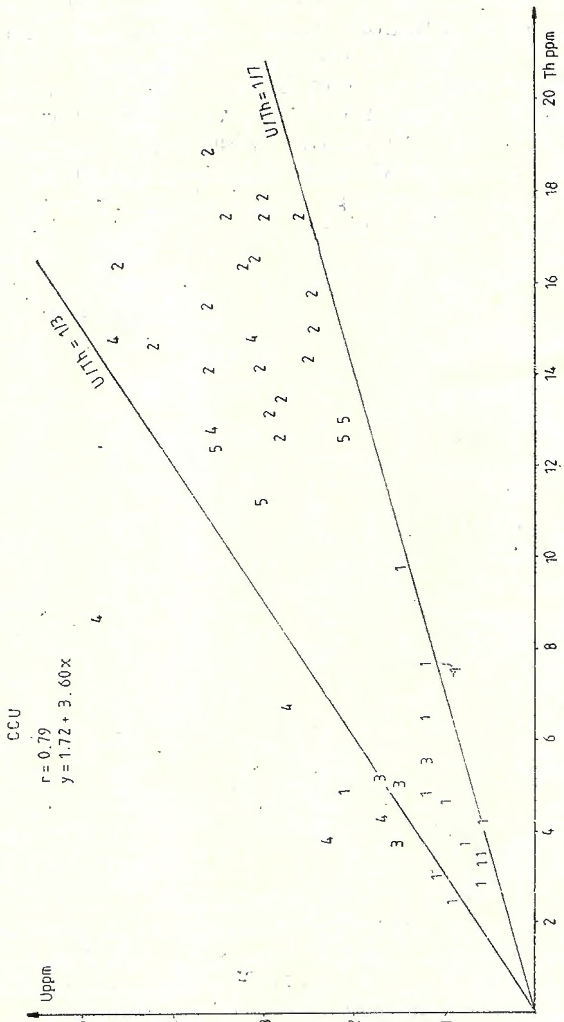


Fig. 2. — U ppm vs. Th ppm diagram within CCU. Symbols as in Table 2

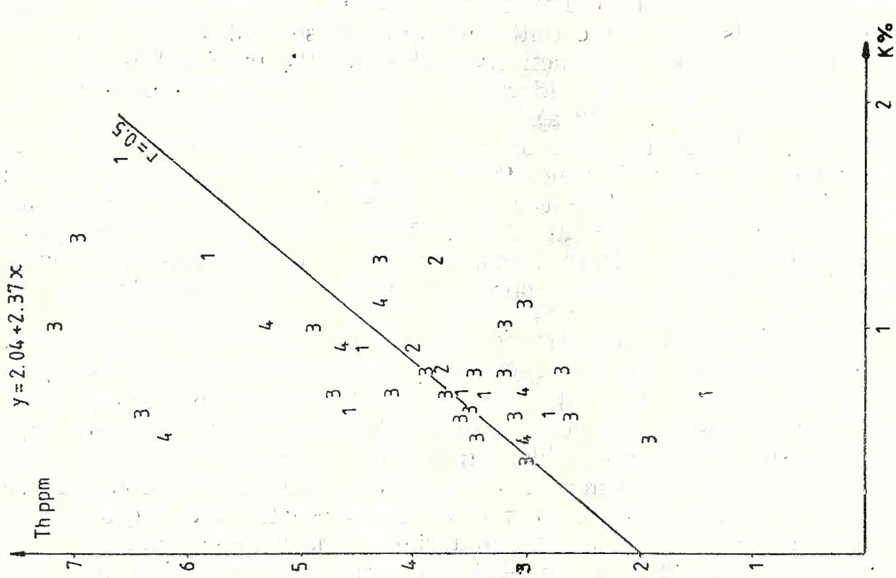


Fig. 3. — Th ppm vs K% diagram within BSU. Symbols as in Table 1.

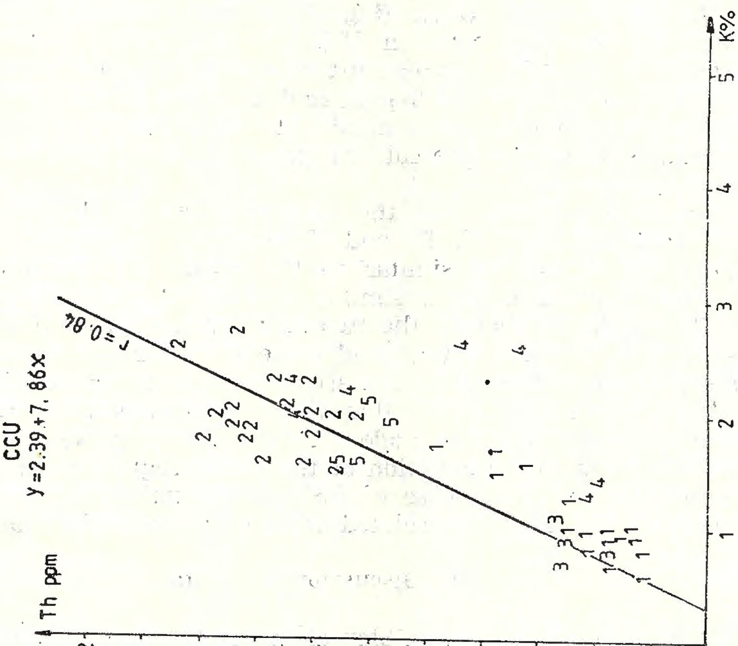


Fig. 4. — Th ppm vs. K% diagram within CCU. Symbols as in Table 2.

On the diagram U-Th (Fig. 2) within the CCU structures the samples are grouped between U-Th = 1/3 and 1/7, the correlation coefficient r = 0.79. Two cluster areas are observed: a) U = 0.5-1.5 ppm and Th = 2.5-8 ppm and b) U = 2.5-4.5 ppm and Th = 13-19 ppm — pointing to a bimodality of geochemical distribution of the products from the pre-caldera phase in the Pietrosul-Negoiul Unguresc structure.

One can observe that the last products of the main evolution stages are enriched in U, Th and K. Analyses on intrusive rocks point to the same disposition similar to the effusive formations; however, they contain more U at a similar amount of Th.

Studied in parallel on the two structures, Th-K and U-K diagrams (Figs. 3, 4, 5, 6) point out a good correlation for the succession of the eruption processes from BSU and CCU, with better correlations for CCU.

It is worth mentioning that the most conspicuous differentiation between BSU and CCU is made after K. The high values of CCU indicate, according to the equation of the linear regression, a surplus of K as against Th and U. In case of BSU the situation is reverse, showing a surplus of U and Th correlated with very low values of K.

4. Discussion of Data

The analysed "incompatible" elements (U, Th, K) made it possible to evidence some features of the magmatic evolution within the two volcanic units

It has been noted that CCU is more radioactive than BSU, thus pointing to a more complex magmatic evolution either by differentiation processes or by assimilation This fact is also emphasized by volcanologic evidence : BSU is a volcanic unit consisting of several volcanic centres with effusive and explosive activity, subsequently intruded by dioritic intrusive bodies. CCU is a caldera-type volcanic unit with a resurgent intrusive dome (Seghedi, 1982 a).

Within BSU on the same areal, corresponding to moments of volcanic activity different in time, the U, Th, K values occur within the same variation interval, like the distribution of major and trace elements (Seghedi in Stoica et al., 1981). One can state that the eruptive products belonging to different moments in time originate in magmas that evolved under the same conditions with unsignificant differentiation processes.

U, Th, K values with CCU account for the volcanological and geochemical evidence on the polystage evolution of the caldera (Seghedi, 1982 a). Products of the pre-caldera stratovolcanic stage point to a gradual increase of the content of U, Th, K so that the last effusive products at the top of the caldera (pre-collaps) are richer (U = 2.4-4.6 ppm, Th = 12.7-18.9 ppm; K = 1.5-2.7%). For these products we presume the existence of complex processes of partial melting differentiation and assimilation of crustal material of the primary magma.

The products of the post-caldera stratovolcanic stage are less represented. On the whole they might evidence the recurrent character of the moment.

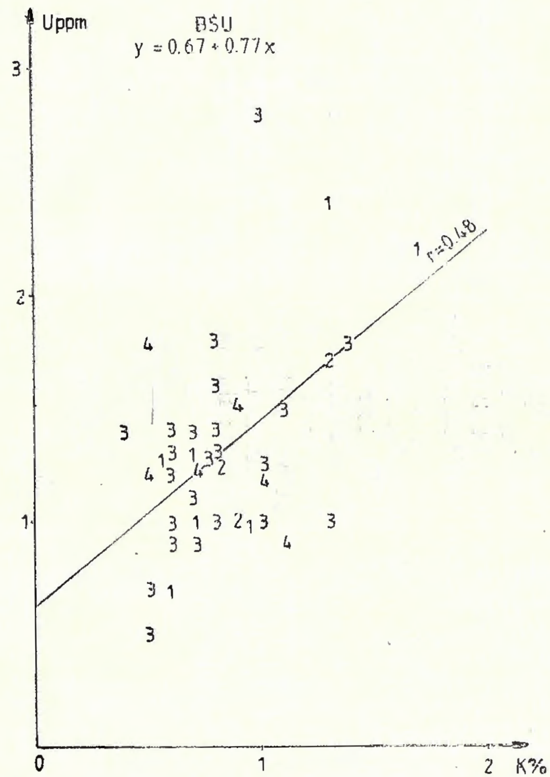


Fig. 5. — U ppm vs. K% diagram within BSU. BSU. Symbols as in Table 1.

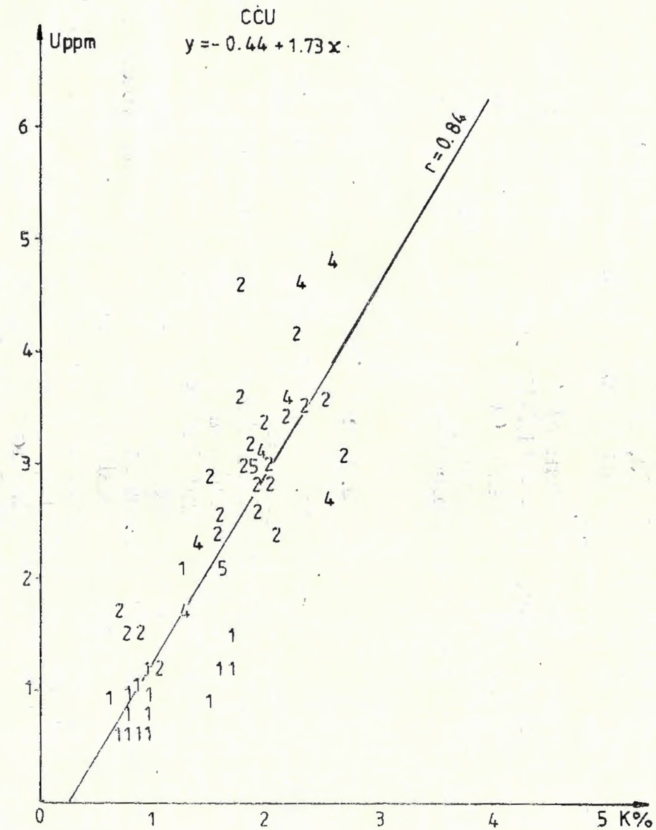


Fig. 6. — U ppm vs. K% diagram within CCU. Symbols as in Table 2.

The products of the monzodioritic-dioritic intrusive stage indicate a wide variation of the U, Th, K values (U = 1.7-4.8 ppm, Th = 3.8-14.8 ppm, K = 1.1-2.9%) as a result of processes of differentiation *in situ* of the intrusive stock.

The final effusive moment of CCU values shows high values of U = 2.1-3.5 ppm and Th = 11.2-13 ppm.

It is estimated that within CCU there is common magma source which probably evolved differently in time by partial melting processes, further by differentiation processes and assimilation within distinct magmatic chambers.

5. Conclusions

Based on 105 analyses of U, Th, K, the present paper brings first more detailed data on the distribution of the mentioned elements in major volcanic structures of the upper compartment of the North Călimani Mts (Bistricior-Strunior and Călimani Caldera structures).

The contents of U and Th within BSU and within the first volcanic manifestations in the pre- and post-caldera stages of CCU indicate geochemical similarities in the island arc andesitic volcanic rocks. Pyroxene ± hornblende andesites, with which the pre-caldera effusive stage ends, a part of the monzodioritic intrusions and the last effusive products of the succession (biotite-hornblende-quartz andesites) present U and Th values similar to the andesitic volcanic rocks of continental margins (Mason, McDonald, 1978). These observations are in agreement with the evidence provided by the study of the trace elements (Seghedi, 1982 a).

Geochemical comparisons with data from relevant literature concerning calc-alkaline magmatites of island arcs and continental margins indicate particularities of the magma generating the volcanic units of the Călimani Mts which do not take into account the geotectonic setting, in this case of continental type.

Solphatarian post-volcanic activity determines the decrease of the rock radioactivity whereas the hydrometasomatic activity affecting the monzodioritic intrusive stock contributes to an increase of the radioactivity of the altered rocks especially Th and K.

U, Th, K distribution depending on the succession of the eruptive products points out that CCU is more radioactive than BSU because, on the one hand, CCU is more evolved in volcanologic respect than BSU and, on the other hand, magmas generating the products of the two structures show more obvious differentiation features for CCU.

The characteristic features of the U, Th, K distribution within CCU confirms to a large extent the volcanological and geochemical data on its multistage evolution (Seghedi, 1982).

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DISTRIBUŢIA U, Th, K ÎN UNITĂŢILE ERUPTIVE BISTRICIOR-STRUNIOR ŞI CALDERA CĂLIMANI — MUNŢII CĂLIMANI DE NORD

(Rezumat)

1. *Introducere*

Lucrarea urmăreşte să evidenţieze caracteristicile distribuţiei elementelor radioactive U, Th, K, din cadrul a două unităţi vulcanice importante din aria munţilor Călimani de nord : unitatea Bistricior-Strunior (UBS) şi unitatea Caldera Călimani (UCC). Se are în vedere evidenţierea implicaţiilor petrogenetice care reies din studiul acestor elemente.

2. *Observații geologice*

Studiile geologice au condus la separarea unor unități vulcanice, pe baza observațiilor privind natura și modul de distribuție a produselor vulcanice din cadrul compartimentului superior vulcanic.

Urmează o succintă caracterizare geologică a unităților vulcanice :

— UBS — este unitatea centrală a compartimentului superior din cadrul munților Călimani (Peltz, Seghedi, 1982). Fundamentul sedimentar oligocen este străbătut de sill-uri, dyke-uri și corpuri subvulcanice de andezite și diorite aparținînd zonei subvulcanice Bîrgău (Rădulescu et al., 1973). Acestea sînt notate în diagrame cu cifra 1. Urmează produse dintr-un complex vulcanoclastic aparținînd compartimentului inferior (notate cu 2). Edificiul compartimentului superior (300-500 m) este alcătuit din lave și brecii vulcanice autoclastice andezitice (notate cu 3). Activitatea eruptivă se încheie cu intruziuni dioritice aliniate pe direcția est-vest (notate cu 4).

— UCC — este unitatea estică a compartimentului superior din masivul Călimani. Compartimentul inferior este mai bine deschis, mai complex alcătuit. În bază apare un complex vulcanoclastic andezitic, peste care stă un nivel de brecii piroclastice. Activitatea compartimentului inferior este încheiată de o serie de vulcani de lave, reprezentați prin andezite bazaltice.

Compartimentul superior are în bază o succesiune de curgeri de lave și brecii piroclastice constituită din andezite bazaltice și andezite (în dreptul structurii Pietrosul-Negoiul Unguresc) — notate în diagrame cu cifra 1. La partea superioară a calderei se află un volum foarte mare de lave andezitice (notate cu 2), care încheie stadiul precalderă. După collapsul care a generat caldera, în interiorul ei se edifică o serie de aparate vulcanice minore (cu lave piroclastite și corpuri) — notate în diagrame cu cifra 3. În interiorul calderei străbate ulterior un stock monzodioritic, dioritic (notat cu 4) căruia i se asociază o serie de intruziuni minore andezitice și micromonzodioritice. Activitatea UCC se încheie cu un moment efuziv final reprezentat prin domul extruziv andezitic — Pietricelul (notat cu 5).

3. *Observații privind distribuția U, Th, K*

În cadrul UBS au fost executate 41 analize U, Th, K pe roci proaspete (tab. 1), iar în cadrul UCC — 64 analize (tab. 2), din care 12 pe roci hidrotermalizate și restul pe roci proaspete. S-au calculat mediile populațiilor μ care indică valori mai mari ale radioactivității în UCC.

Conform comparațiilor cu datele din literatură (Mason, McDonald, 1978) — valorile pentru U, Th din cadrul UBS indică similitudini cu andezite din arcuri insulare. În cadrul UCC produsele vulcanice cu valori mai mici ale U, Th relevă aceleași similitudini cu roci vulcanice din arcuri insulare. Volumul mare de produse precalderă de la partea superioară a acesteia precum și o bună parte din produsele momentelor postcalderă indică similitudini cu andezite din margini continentale.

Rocile hidrotermalizate din aria acumulărilor de sulf indică valori scăzute de U, Th, K. Transformările hidrotermale pe roci monzodioritice produc o creștere importantă în Th (pînă la 33,8 ppm) și K (pînă la 4,9%) datorită mai ales proceselor de biotitizare, albitizare, actinolitizare.

Diagrama U la Th (fig. 1) din UBS prezintă un coeficient de corelare $r = 0{,}44$, iar în cadrul UCC o corelație și mai bună $r = 0{,}79$. Produsele precalderă din cadrul UCC relevă o distribuție geochimică bimodală. De asemenea remarcăm că ultimele produse ale principalelor stadii de evoluție sînt îmbogățite în U, Th, K.

Diagramele Th la K și U la K privite în paralel pe cele două unități evidențiază o corelare bună conform succesiunii produselor de erupție (fig. 3, 4, 5, 6).

4. *Discuția datelor*

Distribuția U, Th, K funcție de succesiunea produselor eruptive relevă un fond radioactiv mai ridicat al UCC față de UBS. Acest lucru se explică printr-o complexitate mai mare vulcanologică (calderă cu dom intrusiv resurgent față de stratovulcani cu intruziuni ulterioare.

În cadrul UBS deși produsele eruptive provin din stadii diferite în timp, ele au ca fond comun o magmă similară, ce indică în general procese nesemnificative de diferențiere în cadrul camerelor magmatice în care au evoluat.

Valorile U, Th, K din UCC confirmă observațiile vulcanologice și geochimice efectuate anterior (Seghedi, 1982 a), privind evoluția polistadială a calderei. Se poate aprecia pentru UCC o sursă de magmă comună ce a evoluat prin complexe procese de diferențiere și asimilare în cadrul mai multor camere magmatice.

Comparațiile geochimice cu datele din literatură pentru rocile magmatice calco-alcaline din arcuri insulare și margini continentale, ne indică particularități deosebite ale magmelor ce generează unitățile vulcanice, ce nu țin cont de situarea geotectonică, în cazul nostru de tip continental.

D. S. Inst. Geol. Geofiz. vol. 70-71/1 (1983 ; 1984), 1986, pag. 493-503

1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

GEOCHIMIE

PRELIMINARY DATA ON THE K-Ar AGES OF THE ALPINE MAGMATITES BETWEEN TINCOVA AND RUSCHIȚA (SOUTH-WESTERN POIANA RUSCĂ) [1]

BY

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Absolute age. K-Ar method. Banatites. Alpine magmatites. Middle Campanian. Lower Maastrichtian. Granodiorites. South Carpathians — Getic and Supragetic domains — Crystalline — Poiana Ruscă Mountains.

Abstract

The paper presents the results of 20 radioisotopic age determinations carried out by means of the K-Ar method on Alpine magmatites from the southwestern part of the Poiana Ruscă massif (South Carpathians). The interpretation of these results allowed the identification of at least one pre-banatitic eruptive phase whose age cannot be specified precisely. The second significant moment of magmatic activity is emphasized by ages of 81-80 Ma (Middle Campanian) and corresponds to the beginning of the banatitic manifestations. The emplacement of the Alunul and Cireșul (Ruschița) granodioritic bodies marks another moment of the banatitic activity, which manifested at the upper part of the Campanian and in the Lower Maastrichtian (75-70 Ma). The last phase (Paleocene) seems to be unsignificant for the evolution of the banatitic magmatism in the study region.

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Résumé

Données préliminaires concernant les âges K-Ar des magmatites alpines entre Tincova et Ruschiţa (Poiana Ruscă du sud-ouest). Dans cette note sont présents les résultats de 20 déterminations d'âge radioisotopique obtenus par la méthode K-Ar sur des magmatites alpines provenant du versant SO du massif de Poiana Ruscă (Carpathes Méridionales). L'interprétation de ces résultats a permis d'identifier au moins une phase éruptive prébanatitique dont l'âge ne peut pas être rigoureusement précisé. Le deuxième moment important d'activité magmatique est mis en évidence par les âges de 81-80 m.a. (Campanien moyen) et correspond au début d'activité banatitique. La mise en place des corps granodioritiques d'Alunul et de Cireşul (Ruschiţa) marque un autre moment de l'activité banatitique, qui occupe la partie supérieure du Campanien et le Maestrichtien inférieur (âges de 75 à 70 m.a.). Une dernière phase, paléocène, semble avoir un rôle insignifiant dans l'évolution du magmatisme banatitique de la région.

Between July 1981 and May 1982 the Institute of Physics and Nuclear Engineering Bucharest-Măgurele carried out 20 isotopic age determinations on eruptive rocks affiliated to the Alpine magmatism in the Poiana Ruscă Mts. Samples were collected from an area lying in the southwestern part of the massif, between the localities of Tincova and Ruschiţa (Fig.). They comprise a wide variety of rocks, both in composition and texture and in their mode of emplacement, ranging from the most basic rocks (e.g. Ruschiţa camptonite, Rusca pyroxene- and olivine-bearing basaltoid andesite) to the most acid ones (aplites) coming from interstratified flows, dykes or subvolcanic bodies. Through that a thorough representation of the Alpine magmatites in the region under discussion has been endeavoured. The obtained ages are rendered in the table.

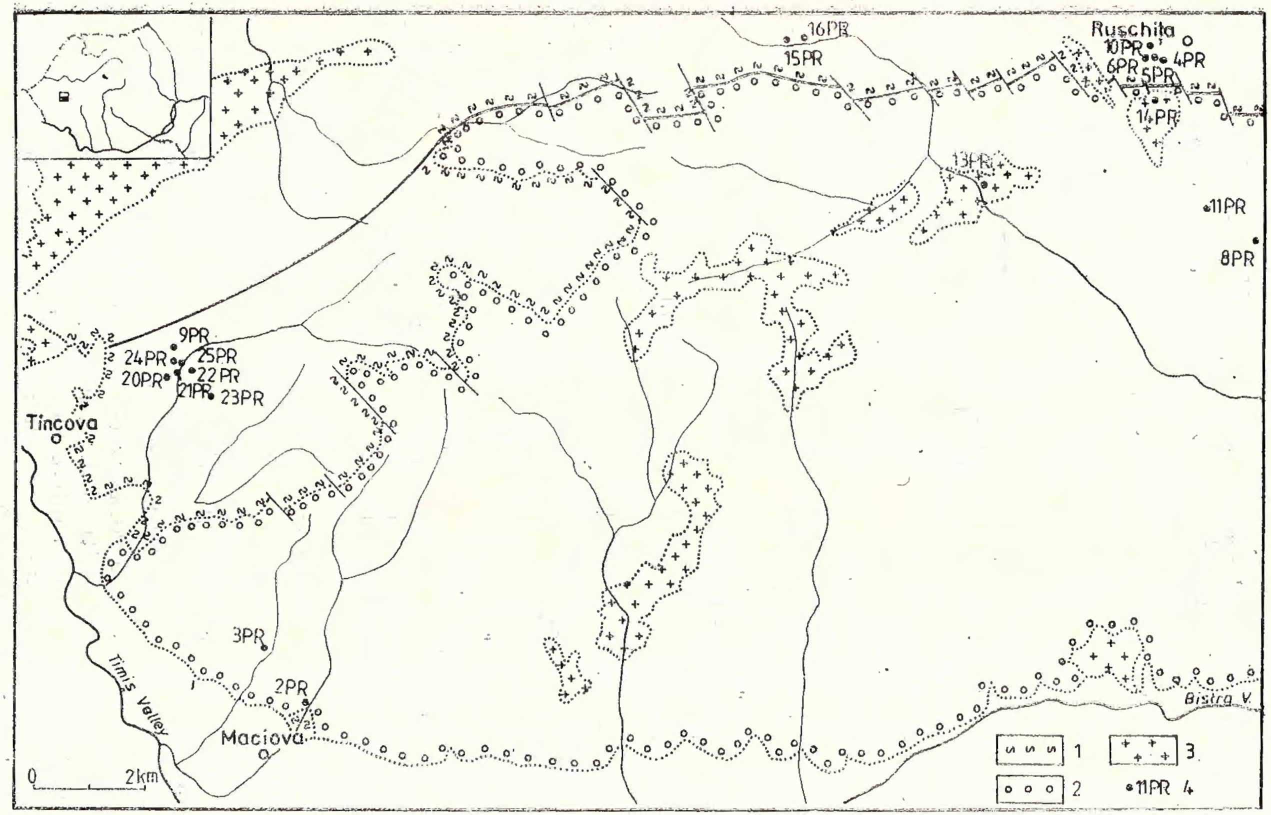
The datings were worked out on concentrates of biotite (6) or femic minerals (9), as well as on whole rocks (5) using the K-Ar method. For K determination the method of fast neutron activation was used and for radiogenic Ar determination the analysis of thermal neutron activation. For the age calculation the following constants were considered :

$$\lambda\beta = 4.962 \cdot 10^{-10}\ a^{-1}$$

$$\lambda e + \lambda' e = 0.581 \cdot 10^{-10}\ a^{-1}$$

$$40\ K/K = 1.1926 \cdot 10^{-4}\ g/g$$

The precision of the methods employed was checked by K and radiogenic Ar determinations on standard samples dated by K-Ar method in the Laboratory of Geochronology of the Federal Polytechnic Institute in Zürich (Soroiu, 1982).



Sketch with the distribution of radiometrically dated samples.
1, Crystalline formations ; 2, sedimentary formations of the Rusca Montană basin ; 3, banatitic bodies ; 4, sampling place.

Discussion of the Results

On the whole, the determined ages (Tab.) range between 81.8 and 64.4 Ma, approximately corresponding to the Middle Campanian-basal Paleocene. The results will be discussed in groups, taking into account the appurtenance of the samples to the two banatitic metallogenetic zones in the southwestern part of the Poiana Ruscă massif : Tincova-Nădrag and Ruschița-Ascuțita districts (Kräutner and Kräutner, 1973).

TABLE

K—Ar ages of some Alpine magmatites in the SW Poiana Ruscă

Sample	Rock type	Analyzed material *	K (%)	^{40}Ar rad. 10^{-9} g/g	Age (Ma)
2 PR	Diorite porphyry	FM	0.615	3.16	72.7±3.6
3 PR	Basic tuffite	FM	2.270	10.87	67.8±2.0
4 PR	Quartz diorite porphyry	FM	1.200	6.29	74.1±2.2
5 PR	Granodiorite porphyry	B	6.610	37.61	80.3±2.4
6 PR	Quartz diorite porphyry	B	4.690	26.63	80.1±2.4
8 PR	Basaltoid andesite	WR	3.380	18.14	75.8±2.3
9 PR	Granodiorite porphyry	FM	6.090	35.10	81.3±2.4
10 PR	Camptonite	FM	1.370	7.95	81.8±2.4
11 PR	Dacite	WR	1.170	5.73	69.3±2.1
13 PR	Granodiorite	B	5.760	30.77	75.5±2.3
14 PR	Granodiorite	B	6.970	34.88	70.8±2.1
15 PR	Latite	WR	2.720	14.68	76.2±2.3
16 PR	Quartz porphyry	WR	2.260	12.38	77.4±2.3
20 PR	Diorite porphyry	FM	1.500	6.82	64.4±1.9
21 PR	Diorite porphyry	FM	2.780	15.94	80.9±2.4
22 PR—nM	Diorite porphyry	FM	1.530	8.46	78.1±2.3
22 PR—M	Diorite porphyry	FM	1.670	8.50	72.0±3.0
23 PR	Diorite porphyry	FM	3.190	16.41	72.7±2.2
24 PR	Aplite	WR	2.930	15.05	72.6±2.2
25 PR	Granodiorite porphyry	B	5.680	32.92	81.7±2.5

* FM = femic minerals (hornblende, biotite) ; B = biotite ; WR = whole rock.

1. In the Tincova-Nădrag district the radioisotopic ages obtained, correlated with the petro-structural features of the sampled rocks, indicate their affiliation to at least three moments of magmatic activity.

1.1. The oldest eruptive rocks were rendered evident not properly by datings but by their petro-structural features which clearly distinguished them from all the eruptive rocks analysed. The rocks — dioritic porphyries — were found as metric dykes intercalated within gneisses in the prospect pits of the Vălișor area. They show a porphyritic texture with a hypidiomorphic-granular groundmass. They differ from all the other eruptive rocks in this zone by the incipient metamorphism they underwent (Pl. I, Figs. 1, 2) which approaches them to the crystalline schists they intrude, however, unconformably. Another similitude with the latter consists in their thermal alteration, visible on a very large area, including not only the crystalline schists but also the sedimentary rocks from the western margin of the Rusca basin. The dioritic porphyries are formed of phenocrysts of plagioclase feldspar (14-15%), common hornblende, often with brownish hues (15-21%), and rarely biotite (less than 1%) floating in a groundmass (65-70%) made up of plagioclase laths, amphiboles, quartz and quartzo-feldspathic aggregates as well as titanite, apatite and opaque minerals. The thermal alteration manifested by the appearance of a new generation of biotite preferentially spread on and around hornblende phenocrysts, but also found in the groundmass.

The isotopic ages of these rocks are of 80.9 Ma and were obtained by four determinations (samples 21 PR, 22 PR-M, 22 PR-nM, and 23 PR) out of which two on different fractions (magnetic and nonmagnetic, respectively) of the same rock. As the rocks were thermally altered by subsequent eruptions they should be older than 80.9% Ma which, however, represents only a hybrid age not relevant for the real age of the rocks under discussion. As known, in the Rusca basin the first volcanic manifestations occurred in the Middle Turonian (88-86 Ma) when a level of basic tuffites, with reworked hornblende, pyroxene, zoned plagioclase and fragments of volcanic rocks deposited in this basin (Strutinski, Bucur, in press). The dating of those products (sample 3 PR) gave an unreliable age, as we subsequently found out that these rocks, although far off from any more important exposure of an eruptive body, include minerals from the epidote group which can be but the result of contact phenomena.

The described vein rocks might represent subvolcanic equivalents of the reworked eruptions found in Turonian deposits or they might as well be older considering the incipient metamorphism underwent by them.

1.2. The next moment of magmatic activity is represented by granodioritic porphyries in the left side of the Tincovița Valley, also intercepted by mine workings. Granodioritic porphyries form dykes, some of them tens of metres thick and hundreds of metres long. Generally, they have an obvious porphyritic texture (Pl. I, Fig. 3) consisting of phenocrysts of plagioclase feldspar (28-41%), quartz (1-4%), hornblende (6-18%), and biotite (2-5%) spread in a fine-grained groundmass (43-51%) formed of quartz, plagioclase feldspar, potash feldspar, biotite and opaque minerals. Micrographic (Pl. II, Fig. 1) or spherulitic structures occur locally in the groundmass. The rocks are unmetamorphosed, except the frequent and varied autometasomatism phenomena. Two determinations were performed on biotitic concentrates (samples 9 PR and 25 PR), the ages obtained being practically identical (81.3 and 81.7 Ma, respectively). The granodioritic porphyries probably represent apophyses of an extensive, deep-seated batholith, which would explain the very large contact aureole in the overlying rocks, whose extent was noticed by Strutinski and Paica (unpublished data) as far as the Maciova

Valley. This igneous body constitutes the most probable source of the Cu-Mo mineralizations known in the study area.

On the basis of the determined age (72.6 Ma), an aplitic rock (sample 24 PR) originating in the same area as the above-mentioned granodioritic porphyries should be assigned to a more recent magmatic phase which, as will be shown further on, was well outlined in the Ruschiţa-Ascuţita district. There are, however, genetic-structural considerations that make this supposition improbable. The considered rock occurs as a 3-4 m thick dyke in the thermally altered biotite gneisses. Compositionally it resembles the aplitic veins frequently cross-cutting the granodioritic porphyries or forming selvages with a variable thickness (5-50 cm) at the contact of these dykes with the surrounding gneisses. It consists of corroded quartz, oligoclase and biotite phenocrysts (about 10%) in a fine-grained simplectitic matrix formed mainly of quartz and alkaline feldspar with subordinate sericite (90%). Both the corroded aspect of the phenocrysts and the presence of dark "spots" against the whitish background of the rock which under the microscope represent almost circular zones, within which a sericite enrichment is observed, sustain the hypothesis that we are in the presence of a replacement structure formed probably at the expense of a rock whose initial composition and structure was that of a granodioritic porphyry. The part played by metasomatism in the formation of aplites at the expense of granitic rocks was described conclusively by Drescher-Kaden (1969). In our case the particularity consists in the whole substitution of the granodioritic dyke by aplite. Consequently the obtained age would only notify the end of the replacement process.

1.3. The last moment of the magmatic activity in the Tincova area is represented by a dyke of diorite porphyries. The rock consists of phenocrysts of plagioclase feldspar (30%), hornblende (14%), biotite (less than 1%) and quartz (less than 1%) in a groundmass (55%) made up of plagioclase, hornblende, recrystallized glass and opaque minerals. The isotopic age of this rock (sample 20 PR) is of 64.4 Ma indicating the Cretaceous-Paleogene boundary. The products of this moment seem to be entirely subordinated to the previous ones.

2. In the Ruschiţa-Ascuţita metallogenetic district there is a much larger range of the analysed products although no rocks, equivalents to those representing the first phase in the Tincova area, are to be found here. Thus, the ten samples dated represent almost all different petrographic types. Among them the olivine-bearing basaltoid andesite of Rusca (Kräutner, Kräutner, 1972) occupies a special place as it represents a lava flow interstratified with Maastrichtian continental-lagoonal deposits and its isotopic age can therefore be confronted with its stratigraphic position. If we consider as basis of our discussions the geochronological scale recommended by Odin and Hunziker (1978) the stratigraphic position of the basaltoid andesite within the Maastrichtian sedimentary pile should correspond to an absolute age of 69-70 Ma. The isotopic age determined by us is of 75.8 $\pm$ 2.3 Ma (sample 8 PR), but it must not surprise too much considering that the submarine basaltic flows almost always contain excess Ar probably due to an incomplete

degasification of ^{40}Ar preexisting in the magma, determined mostly by the sudden cooling of the lavas (Kaneoka, 1975).

2.1. Corresponding somehow to the second magmatic phase from the Tincova area at Ruschița there are both granodioritic porphyries (sample 5 PR) and quartziferous dioritic porhpyries (sample 6 PR), as well as varieties of rocks generally not specific to the banatitic province — more alkaline products such as latites (sample 15 PR) and quartz porphyries (sample 16 PR) the latter being exposed in the area between Pîrîul Negrii Brook and Afinarul Mic Brook. Under the microscope latite (Pl. II, Fig. 2) shows a porphyritic texture consisting of phenocrysts of oligoclase (3-5%) and chlorite pseudomorphs after pyroxene (2-3%) within a pilotaxitic groundmass mostly formed of albite microlites beside quartz and chlorite.

The quartz porphyry (Pl. II, Fig. 3) is characterized by phenocrysts of oligoclase and orthoclase (2-3%), bipyramidal quartz (1-2%), in places intensely corroded, and biotite (less than 1%) within a microgranular groundmass, within which spherulitic and micrographic structures are frequently noticed.

The katophorite camptonite of Ruschița (sample 10 PR) is also assigned to this phase according to its isotopic age. On this rock even the oldest age (81.8 Ma) was obtained from the 20 determinations effectuated. This is very surprising, the more so as the lamprophyres in the area of study are regarded as the last differentiates of the banatitic magmatism. Moreover, similar rocks as regards the composition were reported by Kräutner and Kräutner (1972) in the eastern part of the Rusca Montană basin, where they intrude the upper horizons of the Maastrichtian deposits. For this reason our datings should be regarded cautiously, a recheck being necessary.

2.2. The last moment of magmatic activity quite well outlined in the Ruschița area is that which generated the Cireșul and Alunul granodioritic bodies, both with a remarkable petrographic uniformity. The rock texture is holocrystalline-equigranular except the marginal zones where porphyritic facies are observed. The rocks consist of plagioclase feldspar (39-45%), potash feldspar (21-22%), quartz (19-21%), amphibole (6-8%) and biotite (3-12%) beside subunitary amounts of accessory minerals (apatite, zircon, magnetite). The isotopic age determinations on these rocks indicate 70.8 Ma for the Cireșul body (sample 14 PR) and 75.5 Ma for the Alunul body (sample 13 PR). Within the admitted errors, these bodies are to be attributed stratigraphically to the Campanian-Maastrichtian boundary and to the Lower Maastrichtian. A similar age (69.3 Ma) was obtained on a dacite (sample 11 PR) which constitutes two small bodies in the upper course of the Porcului Brook (Strutinski, 1986). The rock displays a porphyritic texture; the feldspar and femic phenocrysts float in a quartz-feldspar-biotite groundmass. As similar rocks occur in the Cucea Valley basin, in association with granodioritic porphyries, along a line joining the Cireșul and Alunul bodies, they probably represent the near-surface facies of these bodies in a sunken sector (Strutinski, 1986). As the dacite bodies occur in gritty-clayey formations of Santonian-Campanian age it is unlikely that in the moment of their emplacement the overlying Maastrichtian sediments had been very thick as on the contrary the igneous rocks should have shown hypabyssal facies. This statement pleads for the isotopic age determined by us the more so as we know that in case that the intrusions took place in the Paleogene, as it is customarily admitted today, they would have had on their top a pile of Maastrichtian sediments of some thousands of metres thick and in this case the dacitic bodies at the level of the Santonian-Campanian deposits could not be credibly explained.

Conclusions

The interpretation of the radioisotopic ages determined up to now on the eruptive rocks of the southwestern Poiana Ruscă massif leads to several conclusions :

1. One or several phases of magmatic activity manifested undoubtedly before the Middle Campanian. The rocks corresponding to these phases preserved their primary textures in spite of being overprinted by a low-grade regional metamorphism. These rocks might be of Turonian age considering that the first tuffitic rocks within the Rusca Montană basin are found at the level of the Middle Turonian (Strutinski, Bucur, in press). In this case the regional metamorphism should be attributed to the Mediterranean folding phase. The rocks subsequently underwent a thermal event and consequently they were poorly altered thermally together with the surrounding crystalline schists. This event determined the expulsion, probably entirely, of the argon previously accumulated. It is very likely that the process took place 81 Ma ago.

2. The latter event follows chronologically in the development of magmatism in the region under discussion. It is represented both in the Tincova and in the Ruschița zones. It is considered to correspond to the beginning of the banatitic magmatic activity that continued uninterruptedly up to the Paleogene.

3. The Alunul and Cireșul granodioritic bodies were emplaced at the end of the Campanian — the beginning of the Maastrichtian. Consequently, they turn out to be older than most of the pyroclastics of the Maastrichtian volcano-sedimentary formation. The presence of the dacite bodies intruding the Santonian-Campanian sediments is in favour of this statement.

4. "Laramian" (Paleogene) magmatites seem to be subordinate quantitatively in respect of the products of the previous phases.

5. According to Stille, banatites represent products of a subsequent magmatism. As they are likely to be anti-Paleogene, they cannot be considered as subsequent to the Laramian phase but to the Mediterranean one, recently proved in the Poiana Ruscă massif (Strutinski et al., 1983 ; Strutinski, 1986). Thus is also solved the problem of the Maastrichtian volcanic activity, several concepts connected with it — such as "sub-Hercynian volcanism" or "precocious subsequent volcanism" — becoming worthless at least within the Poiana Ruscă massif.

6. Isotopic ages of the banatitic rocks in the Poiana Ruscă massif can be broadly correlated with those obtained by Boyadjiev and Lilov (1981) for similar products found on an alignment which obviously represents the extension of the banatitic province in the Sredna Gora massif (Bulgaria).

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DISCUSSIONS

M. Bleahu : The absolute age data presented lately seem to indicate banatites older than the Lower Paleogene ones called "subsequent". Thus, the existence of an older magmatism, called "pre-Laramian" or "pre-banatitic" is confirmed. As a matter of fact this problem is not of great importance from the point of view of the general tectonics as, according to global tectonics, one can hardly specify what is "subsequent" considering that the magmatism is concomitent with a continuous subduction. In the light of the new evidence it is obvious that such a subduction took place from the beginning of the Senonian till the Lower Paleogene.

I. Balintoni : The existence of a late regional metamorphism which should have oriented the hornblende crystals and should have generated a biotite is not proved enough, the age attributed to this metamorphism being Turonian. It is worth mentioning that in Poiana Ruscă Mountains there are both K-Ar ages and palynological ones indicating an Upper Paleozoic age for the last metamorphism which has not generated minerals established above the chlorite zone. Biotite — in transversal position — is generally pre-Hercynian. A thermal event does not always mean a metamorphism, at least in the ethymological sense of the word and it is not compulsory that a thermal event should be correlated with a paragenesis.

Answer : It has been admitted that the poorly metamorphosed eruptive rocks might be of Turonian age without excluding the possibility that they are older. The metamorphism taken into account is first of all a transposition one. Considering that in the study region the Mediterranean movements had been very active, it is possible that an incipient regional metamorphism might have manifested in connection with them.

DATE PRELIMINARE PRIVIND VÎRSTELE K-Ar ALE MAGMATITELOR ALPINE DINTRE TINCOVA ŞI RUSCHIŢA (POIANA RUSCĂ DE SUD-VEST)

(Rezumat)

În vederea unei diferenţieri pe criterii radiocronologice şi petrografic-structurale a produselor magmatismului banatitic din masivul Poiana Ruscă (Carpaţii Meridionali), în 1981-1982 s-au efectuat 20 determinări de vîrstă izotopică prin metoda K-Ar pe roci eruptive provenind din districtele metalogenetice Tincova-Nădrag şi Ruschiţa-Ascuţita. Pe baza interpretării rezultatelor obţinute, în districtul Tincova-Nădrag s-au putut contura cel puţin trei momente de activitate magmatică :

1. Unul sau chiar mai multe momente au avut loc cu siguranţă înainte de Campanianul mediu. Rocile corespunzînd acestei etape sînt reprezentate prin porfirite dioritice afectate de un incipient metamorfism regional şi cornificate împreună cu formaţiunile cristalofiliene înconjurătoare. Vîrstele obţinute (80,9-72,0 m.a.) nu pot fi considerate reale, ele marcînd doar acest ultim eveniment termic din evoluţia lor.

2. Următorul moment important al activității magmatice a dat naștere unei succesiuni de dyke-uri de porfire granodioritice, pentru care s-au obținut vîrste de 81 m.a. (Campanian mediu). Aceste roci prezintă deseori evidente transformări autometasomatice-hidrotermale și alcătuiesc apofizele unui corp batolitic profund, care stă probabil la originea mineralizațiilor de Cu-Mo cunoscute în regiune. Cu produsele acestui moment începe activitatea magmatică banatitică *stricto sensu*.

3. Un ultim moment de activitate magmatică este reprezentat printr-un dyke de porfirite dioritice pentru care s-a obținut o vîrstă de 64,4 m.a. (Paleocen bazal). Judecînd după ponderea mică pe care o au produsele sale, acest moment pare să aibă o însemnătate cu totul subordonată, încheind activitatea banatitică din regiune.

În districtul Ruschița-Ascuțita rocile eruptive banatitice se pot încadra la două momente de activitate magmatică :

1. Cea dintîi fază este echivalentă celei cu care începe activitatea banatitică în regiunea Tincova, fiind reprezentată printr-o varietate mai mare de roci : porfire granodioritice, porfirite dioritice cuarțifere, latite și porfire cuarțifere. Vîrstele obținute se încadrează în intervalul 81,8-76,2 m.a. (Campanian mediu-superior).

2. A doua fază este răspunzătoare pentru punerea în loc a importantelor masive granodioritice Alunul și Cireșul precum și a unor corespondente subvulcanice ale acestora. Vîrstele obținute (75,5-69,3 m.a.) se încadrează în Campanianul superior-Maastrichtianul inferior.

Vîrstele obținute de noi pe rocile banatitice din masivul Poiana Ruscă sînt mai mari decît se admite în general pentru aceste roci, însă se corelează foarte bine cu cele obținute de Boyadjiev și Lilov (1981) pentru produse similare aflate pe un aliniament ce reprezintă în mod evident continuarea provinciei banatitice în masivul Sredna Gora din Bulgaria.

EXPLANATION OF PLATES

Plate I

Fig. 1. — Diorite porphyry. Trending of the hornblende phenocrysts due to an incipient regional metamorphism and their replacement by small-sized biotitic aggregates is observed. 1 N ; × 30.

Fig. 2. — Diorite porphyry. Prism of hornblende mechanically deformed during metamorphism. 1 N ; × 30.

Fig. 3. — Granodiorite porphyry. Phenocrysts of zoned plagioclase feldspar, quartz, hornblende and biotite within a microgranular groundmass. + N ; × 30.

Plate II

Fig. 1. — Micrographic texture in the groundmass of a granodiorite porphyry. + N ; × 30.

Fig. 2. — Pilotaxitic texture in a latite. + N ; × 85.

Fig. 3. — Quartz porphyry. Oligoclase phenocryst (right, bottom) within a groundmass with an aplitic, partly spherolitic texture (left, top). + N ; × 120.

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1. **MINERALOGIE — PETROLOGIE — GEOCHIMIE**

SEDIMENTOLOGIE

CARACTÈRES MINÉRALOGIQUES DU GRÈS DE FUSARU DU BASSIN DE LA VALLÉE DE MOLDOVA (CARPATHES ORIENTALES)[1]

PAR

GRIGORE ALEXANDRESCU[2], VENERA CODARCEA[2]

Fusaru Sandstone. Heavy minerals. Minerals association: Opaque minerals. Garnet. Chlorite. Staurolite. Zircon. Rutile. East Carpathians — External flysch zone — Obcina Mare.

Résumé

On présente dans cette note les minéraux lourds du grès de Fusaru (Oligocène) du flysch des Carpathes Orientales, d'entre les vallées de Moldova et de Moldovița. On a identifié les suivantes associations : a) minéraux opaques+grenats+chlorite (partie inférieure du grès de Fusaru) et b) minéraux opaques+staurotide+zircon+rutile (parties moyenne et supérieure du grès de Fusaru).

Abstract

Mineralogical Characteristics of the Fusaru Sandstone in the Moldova Valley Basin (East Carpathians). The present paper deals with heavy minerals within the Fusaru Sandstone (Oligocene) in the external flysch zone of the northern part of the East Carpathians (Moldova and Moldovița valleys). The following association was found : a) opaque minerals+garnets+chlorite (lower part of the Fusaru Sandstone) and b) opaque minerals+garnets+staurolite+zircon+rutile (middle and upper parts of the Fusaru Sandstone).

A) Données stratigraphiques générales

Dans la partie septentrionale des Carpathes Orientales (bassins des vallées de Moldova et de Moldovița) le Paléogène de l'unité de

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Tarcău présente certaines particularités faciales observées tant dans la série éocène que dans la série oligocène-miocène inférieure.

Les principaux aspects lithofaciaux de la série oligocène-miocène inférieure sont donnés par le développement, dans la zone interne de l'unité de Tarcău, d'une pile arénitique connue sous le nom de grès de Fusaru, alors que dans les zones médiane et externe le grès de Fusaru est substitué progressivement par le grès de Kliwa. Ces deux entités lithostratigraphiques se différencient nettement du point de vue pétrographique, entre elles se développant des zones d'interpénétration. Le grès de Fusaru aussi bien que le grès de Kliwa reposent sur un substratum commun (marnes bitumineuses, ménilites inférieures et schistes dysodiliques inférieurs), tous les deux supportant les couches de Vinețișu.

a) *Grès de Fusaru (Popescu-Voitești, 1910 ; Oligocène).* Le grès de Fusaru d'entre les vallées de Suceava et de Moldova a un développement plus grand dans la zone interne de l'unité de Tarcău (Ionesi, 1963, 1971) zone qui correspond à ce que les géologues polonais et soviétiques ont désigné sous le nom de „dépression centrale carpathique" et qui occupe la même position stratigraphique que le grès de Fusaru, entre les vallées de Teleajen et de Buzău ou bien entre les vallées de Trotuș et de Bistrița, étant située entre les schistes dysodiliques inférieurs et les couches de Vinețișu (Preda, 1925 ; Popescu, 1952 ; Pătruț, 1955 ; Grigoraș, 1955 ; Băncilă, 1955, 1958).

Notons que le grès de Fusaru d'entre les vallées de Suceava et de Moldova est représenté par une succession des roches arénitiques en alternance avec des roches lutitiques d'une épaisseur de 40 à 700 m. Les arénites se disposent en couches épaisses de 0,3 à 3 m, localement même plus épaisses, de granulation fine, moyenne ou grossière, présentant souvent des particularités des microconglomérats voire même des conglomérats.

En plus de ces deux types de roches (arénitiques et lutitiques) qui impriment la note caractéristique du grès de Fusaru, en étroite connexion avec celui-ci, se développent aussi des roches carbonatées soit sous forme de concrétions (ellipsoïdales ou sphéroïdales), soit sous forme de couches continues (1 à 10 cm) de lamination fine (calcaires laminés) ou bien des calcaires en couches minces (1 à 8 cm) sans lamination (calcaires non laminés). Ces calcaires sont connus sous le nom de calcaires de Jaslo, disposés sur un intervalle d'environ 1 à 3 m d'épaisseur, situés à presque 280-350 m d'épaisseur stratigraphique par rapport à la limite avec les schistes dysodiliques inférieurs. Les calcaires de Jaslo ont été également rencontrés dans le grès de Kliwa dans la zone médiane de l'unité de Tarcău du bassin de la vallée de Moldova (Alexandrescu et Brustur, 1982), étant situés au même niveau stratigraphique tout comme ceux contenus dans le grès de Fusaru.

b) *Caractères minéralogiques.* Par suite de l'examen optique du grès de Fusaru, on a mis en évidence la structure psammopséphitique dont le rapport fragments litiques/fragments de cristaux est en faveur des derniers. La texture des arénites est compacte et le degré de triage est moyen (ψ = 0,30 à 0,85). Le liant à structure basale, plus rarement de contact, est de nature carbonatée, ayant un degré réduit de participation, se présente soit sous forme de petites plages criptocristallines épousant étroitement les roches clastiques, soit sous forme de zones bien cristallisées, clivées parfaitement et provenues des dépôts ultérieurs.

Le matériel lithique provient tant des roches sédimentaires préexistantes (calcaires, marno-calcaires, silicolithes) que des roches métamorphiques (métaquartzites, schistes chlorito-muscovito-quartzeux) ou bien des roches éruptives (porphyres, etc.). Parmi les fragments de calcaires préexistants se remarquent les calcaires micritiques à Calpionellidae ex gr. *Crassicolaria parvula* Rem, d'âge tithonique supérieur-berriasien (pl. II, fig. 4). Les fragments de silicolithes ont un degré élevé de roulement et une texture rubanée. Les fragments de schistes chlorito-muscovito-quartzeux présentent des contours irréguliers et des structures parallèles contenant de grandes quantités de chlorite et de muscovite (pl. II, fig. 9).

Les roches éruptives comportent aussi des fragments de porphyres, des tufs porphyriques à contours arrondis et à pâte fondamentale partiellement dévitrifiée ou argilisée. Les porphyres présentent des agglomérations de microlites feldspathiques, tandis que les tufs sont constitués d'une masse cinéritique isotropisée à rares microlites de pyroxènes.

Les constituants allogènes (clastiques) sont représentés par des granules de quartz provenues des orto- et métaquartzites, des arénites préexistantes, des feldspaths potassiques (à structures pertitiques et restes de macles de Karlsbad) et des plagioclases (maclés ou non polysynthétiquement). D'habitude les plagioclases sont séricitisés et argilisés partiellement, du fait du degré de roulement et d'arrondissage (Ro = 0,7 à 0,9) et se présentent sous deux aspects : des granules petites, parfaitement roulées provenant certainement de plusieurs cycles de sédimentation et des granules moins angulaires ou semiangulaires provenant des roches éruptives, fait relevé aussi par les macles de Karlsbad.

Du groupe des phyllosilicates, rien que la biotite et la muscovite sont mieux développées sous forme de lamelles (contorsionnées, ondulées et fusiformes) tandis que la chlorite est présente en lames minces, groupées en plages ou bien moulant les contours des autres clastites pareillement à un ciment de surcroissance. Parmi les granules à caractère accessoire il y a lieu de mentionner le rutile (cristaux idiomorphes), les grenats (arrondis ou angulaires), l'épidote (agglomérations microgranulaires) ou la tourmaline (inclusions aciculaires).

Le matériel allogène représente le produit des cycles de sédimentation répétés et les fragments litiques suggèrent un apport aussi bien de la zone du noyau cristallin des Carpathes Orientales que des roches sédimentaires préexistantes de la zone du flysch crétacé.

Parmi les minéraux autigènes rappelons la présence des minéraux opaques représentés par la pyrite et la marcassite en glomérules framboïdales et oxydes comme magnétite, ilménite, hématite et limonite.

B) Provenance des échantillons

On a recueilli du grès de Fusaru des bassins des vallées de Moldovița et de Moldova (fig. 1) 39 échantillons provenant de 9 coupes ; à partir du NO au SE ces coupes sont :

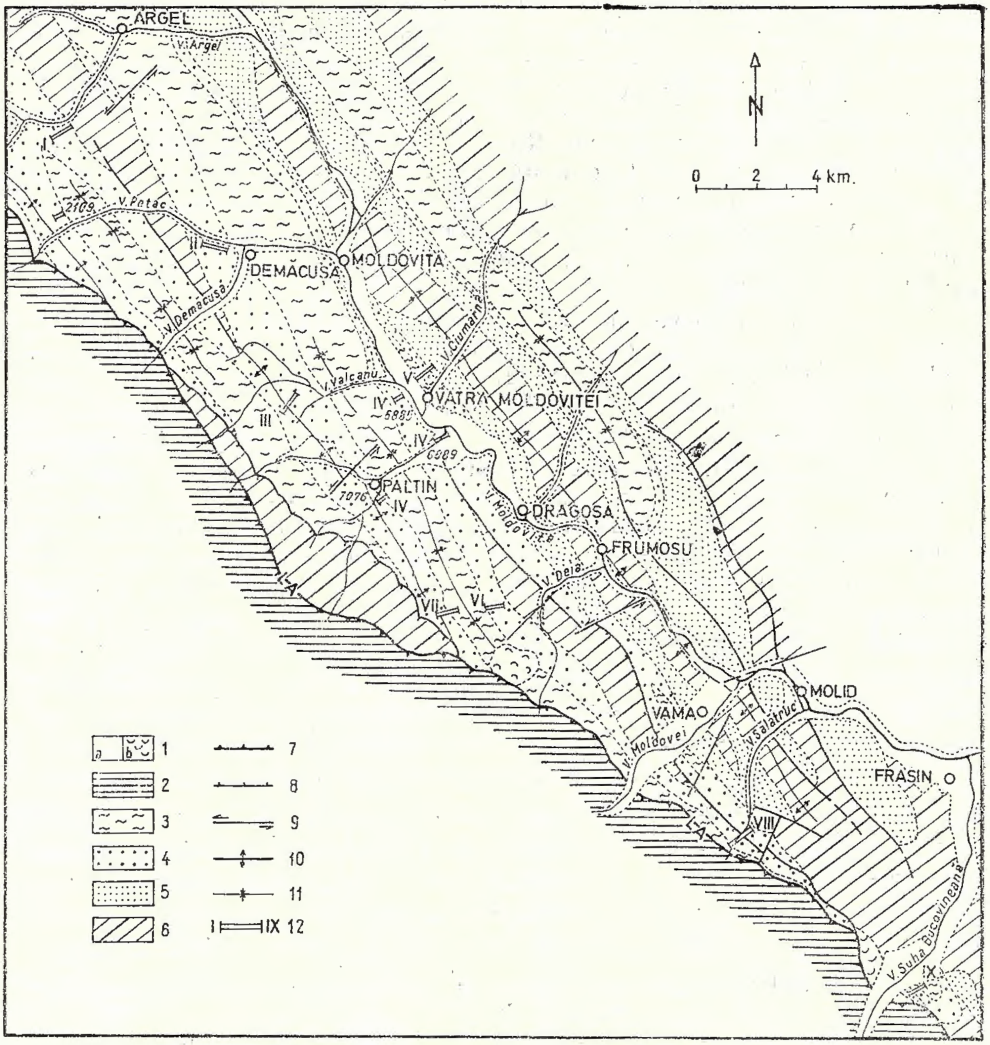

Fig. 1. — Esquisse géologique de la zone d'Argel-Vama par Gr. Alexandrescu, avec l'emplacement des échantillons recueillis et analysés du grès de Fusaru. 1, Quaternaire : (a), terrasses et alluvions, (b), éboulements ; 2, unité d'Audia, unité de Tarcău ; 3, couches de Vinețișu ; 4, grès de Fusaru ; 5, grès de Kliwa ; 6, formations oligocènes inférieures, éocènes et crétacées non divisées ; 7, ligne de charriage d'Audia (LA) ; 8, faille inverse ; 9, faille transversale ; 10, axe anticlinal ; 11, axe synclinal ; 12, coupes analysées.

I. *Coupe de la vallée d'Argel* (fig. 2) située sur le flanc ouest de l'anticlinal faillé de Ştuba, à presque 150 ou 180 m en aval du confluent du ruisseau de Turculova et de la vallée d'Argel, approximativement allant de la partie médiane à la partie basale du grès de Fusaru.

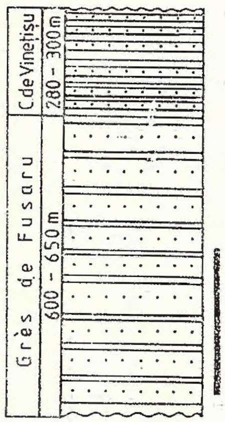

Fig. 2. — Colonne stratigraphique de détail dans la vallée d'Argel (coupe I). La ligne externe des figures 2, 3, 4, 5, 6, 7, et 8 montre l'intervalle d'où on a prélevé les échantillons.

II. *Coupe de la vallée de Demăcuşa-Petac* (fig. 3) localisée sur le flanc est de l'anticlinal faillé de Ştuba (échantillons 1867, 1869, 1870) ; l'échantillon 2109 a été récolté de la partie moyenne du grès de Fusaru du versant est de l'anticlinal de Petac, en amont du confluent du ruisseau du Turculova-Petac et de la vallée de Petac-Demăcuşa.

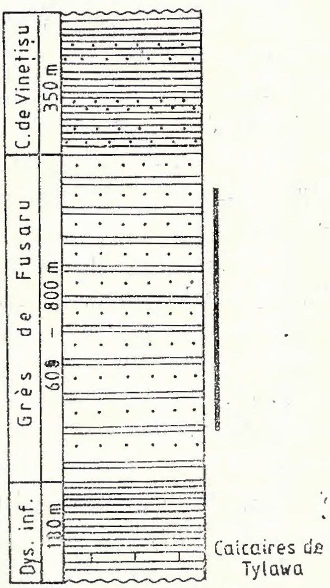

Fig. 3. — Colonne stratigraphique de détail dans la vallée de Demăcuşa-Petac (coupe II).

III. *Coupe de la vallée de Valcanu* (fig. 4) du flanc est de l'anticlinal de Ştuba (échantillons 7053, 7054, 7057, 7058, 7059) au-dessous du niveau des calcaires de Jaslo (400 m environ au-dessous de la limite du grès de Fusaru avec les couches de Vineţişu) ; l'échantillon 7060 a

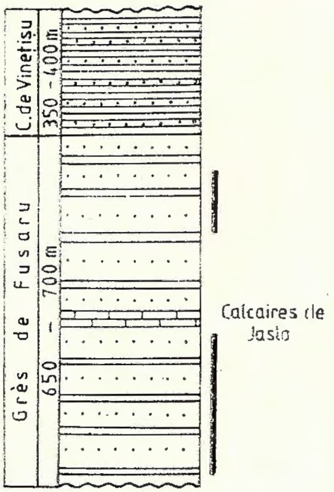

Fig. 4. — Colonne stratigraphique de détail sur le ruisseau de Valcanu (coupe III).

été recueilli du flanc ouest du même anticlinal, à presque 500 m au-dessous du grès de Fusaru avec les couches de Vineţişu, donc, vers la partie moyenne de cette pile d'arénites.

IV. *Coupe de la vallée de Moldoviţa*, en aval du confluent de la vallée du ruisseau de Valcanu et de la vallée de Moldoviţa (flanc ouest de l'anticlinal d'Argel-Vama), au-dessous des calcaires de Jaslo (l'échantillon 6885) ; l'échantillon 6889 de la vallée de Moldoviţa, en amont du confluent du ruisseau Vasile et de la vallée de Moldoviţa au-dessus des calcaires de Jaslo, alors que 7076 de la vallée de Paltinul du flanc ouest de l'anticlinal de Ştuba au-dessous des calcaires de Jaslo.

V. *Coupe du ruisseau* Troci, à Vatra Moldoviţei au-dessus de la limite avec les couches de Vineţişu, flanc ouest de l'anticlinal d'Argel Vama (ici, l'épaisseur du grès de Fusaru est seulement de 40 à 50 m).

VI. *Coupe de la vallée de Deia* (fig. 5), localité Frumosu, en aval du confluent du ruisseau de Ţabrea et de la vallée de Deia, à presque 50 m au-dessous de la limite avec les couches de Vineţişu jusqu'au-dessous des calcaires de Jaslo (échantillons 2542/1-11). Le grès de Fusaru occupe le flanc ouest de l'anticlinal faillé de Miclăuşa.

VII. *Coupe du ruisseau Poieni* (fig. 6), localité Deia-Frumosu, se développant sur le versant est de l'anticlinal de Ştuba (dans la zone d'effondrement de la structure). Les échantillons 6639 et 6640 proviennent de la partie supérieure du grès de Fusaru, aux environs de la limite avec les couches de Vineţişu.

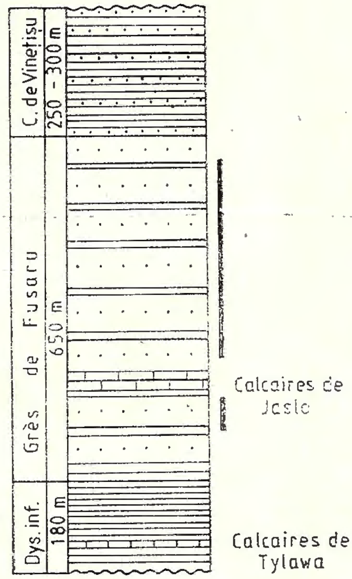

Fig. 5. — Colonne stratigraphique de détail sur le ruisseau de Deia (coupe VI).

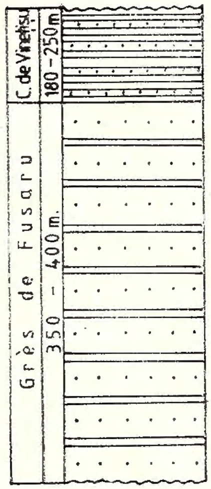

Fig. 6. — Colonne stratigraphique de détail sur le ruisseau de Poieni-Deia (coupe VII).

VIII. *Coupe de la vallée de Sălătruc* (fig. 7, échantillons 2543/1-2543/2), du flanc est de l'anticlinal faillé de Miclăușa, au-dessus des calcaires de Jaslo, parties moyenne et supérieure du grès de Fusaru.

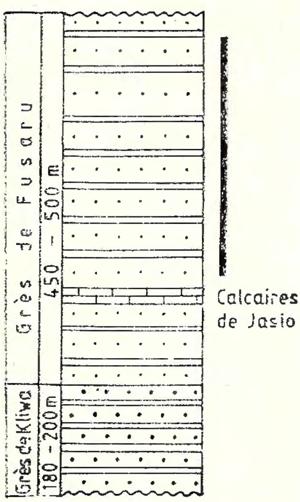

Fig. 7. — Colonne stratigraphique de détail dans le vallée de Sălătruc (coupe VIII).

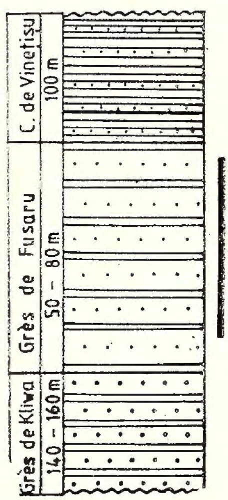

Fig. 8. — Colonne stratigraphique de détail dans la vallée de Suha Bucovineană (coupe IX).

TA

Analyse minéralogique de la fraction lourde

No.	No. des échant.	Provenance	Poids des échant. après traitement à HCl	Poids de la fraction leurde	Minéraux opaques	Grenats	Hornblende	Epidote + zoïzite	Staurotide
1	1834	Vallée d'Argel	23	0,0131	42,13	24,88	—	0,83	3,41
2	2109	Vallée de Demăcuşa-Petac (Vallée de Moldoviţa)	2	0,0136	29,58	55,95	—	—	1,25
3	1867		8	0,2075	30,96	36,77	—	—	1,64
4	1869		15	0,0236	17,73	61,16	2,49	—	1,93
5	1870		10	0,0509	43,83	46,68	1,64	—	1,42
6	6885 B	Vallée de Moldoviţa	3	0,3041	10,00	55,41	—	—	5,09
7	7076		7	0,2038	47,35	36,27	3,08	—	—
8	6889		15	0,2145	13,52	60,65	—	—	6,89
9	7053	Vallée de Valcanu (Vatra Moldoviţei)	29	0,2834	23,13	36,62	1,89	—	6,63
10	7054		19	0,0636	17,87	50,53	0,83	—	6,80
11	7057		21	0,2574	23,41	55,60	—	—	4,47
12	7058		7	0,7801	21,86	49,56	—	—	15,95
13	7059		3	0,8205	27,50	51,65	—	—	—
14	7060		10	0,3149	49,86	33,24	—	—	3,47
15	2542/1	Vallée de Moldoviţa	17,33	0,1712	46,67	32,28	4,23	1,19	5,40
16	2542/2		19,33	0,5705	55,18	32,49	3,58	1,26	1,90
17	2542/3		16	0,2239	33,12	43,74	—	—	4,36
18	2542/4		17,66	0,1467	53,05	32,14	0,60	0,52	5,19
19	2542/5		16,33	0,2002	43,62	35,82	1,55	—	11,22
20	2542/6		15,00	0,4783	49,28	25,54	—	—	3,42
21	2542/7		18,33	0,4672	50,94	17,34	0,58	—	6,72
22	2542/8		13,33	0,9360	44,95	27,13	0,51	—	11,77
23	2542/9		19,66	0,2208	22,83	34,72	—	—	3,83
24	2542/10		15,66	0,3217	24,00	30,38	0,36	—	1,92
25	2542/11		13,66	0,3681	24,74	40,21	6,32	—	8,47
26	6939	Ruisseau Poieni (Vallée de Deia)	15,00	0,3072	25,60	52,35	—	0,73	7,00
27	6940		33	0,2804	29,20	56,23	—	—	2,93
28	1757	Ruisseau Troci (Vatra Moldoviţei)	10	0,0127	31,16	45,93	0,42	1,75	4,38
29	2543/1	Vallée de Sălătruc (Vallée de Moldova)	22,33	0,3669	32,63	45,14	—	0,26	8,15
30	2543/2		24,33	0,0784	39,99	35,40	1,16	0,45	5,93
31	2543/3		25,33	0,4796	33,99	38,62	—	0,53	7,75
32	2543/4		22,66	0,5182	35,94	24,01	1,11	—	9,21
33	2543/5		24,33	0,1375	48,68	26,85	2,59	0,80	11,19
34	2543/6		22	0,0143	36,90	13,42	0,64	—	5,32
35	2543/7		11	0,0724	52,60	29,53	0,45	0,23	7,29
36	2543/8		7	0,0273	49,45	38,25	—	—	7,75
37	1856/1	Vallèe de Suha Bucovineană (Stulpicani)	3	0,1830	23,86	53,38	—	—	3,03
38	1856/2		5	0,2175	22,85	66,35	—	—	5,82
39	1857		4	0,0217	15,01	65,03	—	—	—

BLEAU 1

du grès de Fusaru (Vallée de Moldova)

Rutile	Zircon	Tourmaline	Chlorite	Biotite	Monazite	Sphène	Glaucophane	Sillimanite	Pyroxènes	Disthène	Brookite	Anatase	Chloritoïde	Corindon	Actinote
2,14	0,84	0,77	23,81	0,94	—	—	—	—	—	—	—	—	—	0,25	—
4,31	3,08	2,11	—	—	—	—	—	—	1,18	1,23	1,36	—	—	—	—
—	—	—	—	9,85	—	—	—	10,95	—	—	—	—	—	—	—
6,64	5,27	0,81	2,29	0,76	—	1,05	—	—	—	—	—	—	—	—	—
4,06	1,15	0,99	—	—	—	—	—	—	—	0,23	—	—	—	—	—
—	9,37	—	18,12	2,01	—	—	—	—	—	—	—	—	—	—	—
4,11	—	3,02	2,84	—	—	—	—	—	0,52	—	—	—	—	—	0,42
1,97	4,22	4,35	5,44	—	—	—	—	—	3,19	—	—	—	—	—	—
17,71	—	1,86	12,22	—	—	—	—	—	—	—	—	—	—	—	—
10,15	4,78	0,82	3,00	—	2,65	—	—	—	0,90	—	—	—	1,67	—	—
5,12	5,48	1,88	—	—	—	—	—	—	4,17	—	—	—	—	—	—
—	—	—	12,63	—	—	—	—	—	—	—	—	—	—	—	—
4,66	9,70	—	—	2,81	—	3,68	—	—	—	—	—	—	—	—	—
2,65	4,25	—	4,57	0,91	—	—	—	—	1,08	—	—	—	—	—	—
2,88	2,19	1,49	2,34	0,29	—	—	0,51	0,53	—	—	—	—	—	—	—
0,84	3,31	0,41	—	0,72	0,34	—	—	—	—	—	—	—	—	—	—
—	—	—	9,67	3,87	—	2,58	—	—	—	—	2,66	—	—	—	—
0,22	3,09	1,85	2,50	0,15	—	—	—	—	0,50	0,19	—	—	—	—	—
—	0,41	0,90	6,13	—	—	—	—	0,35	—	—	—	—	—	—	—
2,11	4,31	0,52	14	0,12	0,21	—	—	—	—	—	0,33	0,16	—	—	—
1,91	2,63	1,57	16	0,91	—	—	—	1,19	—	—	—	—	0,21	—	—
2,08	1,67	1,62	9,39	—	0,33	—	—	—	0,55	—	—	—	—	—	—
1,94	4,71	0,71	24,73	2,11	—	—	—	—	3,42	—	—	—	—	—	—
0,47	4,71	1,61	28,88	3,86	—	—	—	—	2,57	—	—	0,44	—	—	—
5,76	1,30	1,40	10,77	—	—	—	—	—	0,99	—	—	—	—	—	—
5,60	7,00	1,37	0,64	0,64	1,79	—	—	—	—	0,80	—	—	—	—	—
5,55	3,57	1,63	—	—	—	—	—	—	0,89	—	—	—	—	—	—
6,12	3,58	2,46	1,92	0,38	—	—	—	—	0,52	—	—	—	—	—	0,42
1,00	1,25	1,72	6,18	1,26	1,49	—	0,43	—	—	0,49	—	—	—	—	—
0,58	0,62	0,71	14,04	0,45	—	—	—	—	—	0,73	—	—	—	—	—
0,22	1,91	0,82	12,76	—	—	—	—	1,06	—	2,34	—	—	—	—	—
0,52	2,23	1,05	17,24	8,03	—	—	—	—	—	0,64	—	—	—	—	—
2,07	1,82	0,5	4,69	—	0,81	—	—	—	—	—	—	—	—	—	—
—	0,92	0,63	39,51	1,23	—	—	—	—	0,69	0,74	—	—	—	—	—
2,89	2,16	2,06	—	0,20	—	0,26	—	—	1,33	—	—	—	—	—	—
—	—	1,80	—	2,75	—	—	—	—	—	—	—	—	—	—	—
3,47	16,52	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	5,73	—	—	—	—	—
13,22	3,54	3,30	—	—	—	—	—	—	—	—	—	—	—	—	—

IX. *Coupe de la vallée de Suha Bucovineană* (fig. 8), à Stulpicani, vers la partie nord du mont Girilău (910 m). C'est ici que le grès de Fusaru a une épaisseur de presque 50 à 80 m et se développe sur le flanc ouest du synclinal de Plotonița (l'échantillon 1856/1 provient de la partie inférieure, l'échantillon 1856/2 de la partie moyenne et l'échantillon 1857 de la partie supérieure du grès de Fusaru).

C) Teneur en minéraux lourds

Par suite des opérations de traitements chimiques et de tamissage on a résulté trois classes granulométriques : classe de 0,50 à 0,25 mm, classe de 0,25 à 0,16 mm et classe de 0,16 à 0,06 mm. Après la séparation avec bromophorme on a obtenu des minéraux de la fraction lourde examinés ensuite microscopiquement et finalement on a fait l'analyse globale sur chaque échantillon (tab. 1 ; fig. 9).

Les moyennes sur coupe de la fraction lourde supérieures à 0,06 mm sont illustrées dans le tableau 2.

On a constaté de l'analyse des valeurs quantitatives que la plupart des espèces minérales reviennent à la classe de 0,16 à 0,06 mm et les plus élevées valeurs quantitatives se trouvent généralement dans la coupe du ruisseau Valcanu (anticlinal de Ștuba, fig. 9).

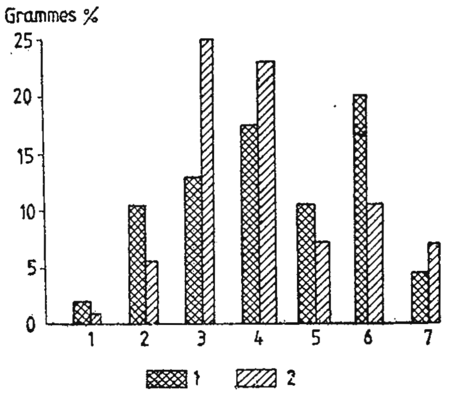

Fig. 9. — Graphique du rapport entre le poids de l'échantillon et le poids de la fraction lourde.
1, vallée d'Argel ; 2, vallée de Demăcușa ; 3, vallée de Valcanu ; 4, vallée de Deia ; 5, vallée de Troci ; 6, vallée de Sălătruc ; 7, vallée de Suha Bucovineană. 1. reste des grammes d'échantillon à la suite du traitement à HCl ; 2, grammes de fraction lourde.

a) *Analyse minéralogique de la fraction lourde.* Les échantillons analysés ont mises en évidence les suivantes espèces minérales, dont la participation de pourcentage est figurée dans les tableaux (1 et 2) : minéraux opaques, grenats, hornblende, épidote-zoïzite, staurotide, rutile, zircon, tourmaline, chlorite, biotite, monazite, sphène, glaucophane, sillimanite, pyroxènes, disthène, brookite, anatase, chloritoïde, corindon et actinote. Les résultats obtenus révèlent que les plus grandes accumulations quantitatives sont celles des grenats à pourcentage variant entre 24,28 et 61,39, les maximums étant enregistrés dans les coupes des vallées de Demăcușa (II), de Moldovița (IV), de Deia (VI), de ruisseau Poieni (VII) et de Suha Bucovineană (IX).

Le grenat incolore appartient aux variétés grossulaire-almandin et représente le minéral avec la fréquence la plus élevée de la frac-

TABLEAU 2

Moyennes de la fraction lourde du grès de Fusaru (Vallée de Moldova)

No.	Provenance	Minéraux opaques	Grenats	Hornblende	Epidote + Zoïzite	Staurotide	Rutile	Zircon	Tourmaline	Chlorite	Biotite	Monazite	Sphène	Glaucophane	Sillimanite	Pyroxènes	Disthène	Brookite	Anatase	Chloritoïde	Corindon	Actinote
1	Vallée d'Argel	42,13	24,88	—	0,83	3,41	2,14	0,84	0,77	—	0,94	—	—	—	—	—	—	—	—	0,25	—	—
2	Vallée de Demăcușa	30,52	50,14	1,03	—	4,06	3,75	2,37	0,98	0,57	2,65	—	0,26	—	2,74	0,29	0,36	0,34	—	—	—	—
3	Vallée de Moldovița	23,62	50,77	1,02	—	3,99	2,03	4,53	2,46	8,80	0,67	—	—	—	—	1,24	—	—	—	—	—	0,14
4	Vallée de Valcanu	27,39	46,51	0,45	—	6,25	6,74	4,05	0,76	5,43	—	0,44	0,61	—	—	1,03	—	—	—	0,27	—	—
5	Vallée de Deia	40,85	31,98	1,62	0,27	5,84	1,66	2,57	1,09	11,31	1,09	0,08	0,23	0,05	0,24	0,73	0,01	0,27	0,05	0,02	—	—
6	Ruisseau Poieni (Vallée de Moldovița)	27,40	54,29	—	0,27	4,97	5,58	5,29	1,50	0,32	0,32	0,89	—	—	—	0,45	0,40	—	—	—	—	—
7	Ruisseau Troci (Vatra Moldoviței)	31,16	45,93	0,42	1,75	4,38	6,12	3,58	2,46	1,92	0,38	—	—	—	—	0,52	—	—	—	—	—	—
8	Vallée de Sălătruc	41,27	31,40	0,74	0,28	7,82	1,03	1,36	1,16	11,81	1,74	0,29	0,03	0,05	0,13	0,26	0,62	—	—	—	—	—
9	Vallée Suha Bucovineană (Stulpicani)	20,50	61,39	—	—	2,94	5,54	6,84	1,09	—	—	—	—	—	—	—	1,90	—	—	—	—	—

tion lourde et il est présent dans toutes les échantillons. On remarque leur prédominance dans les classes granulométriques fines et la faible participation ou même leur absence dans les classes plus grossières.

Vu la distribution sur coupes des grenats on peut affirmer qu'ils s'accumulent surtout dans les parties moyenne et supérieure du grès de Fusaru (vallées de Demăcuşa, Deia, Sălătruc), tandis que dans la vallée de Suha Bucovineană ils se sont massivement accumulés (61,39%). En totalisant la moyenne de participation des grenats on observe une nette supériorité de la valeur pour la vallée de Moldova (fig. 10).

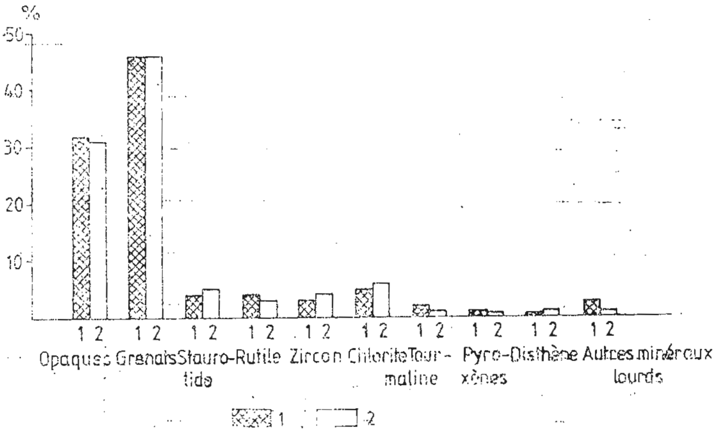

Fig. 10. — Répartition des minéraux lourds dans les bassins des vallées de Moldova et de Moldoviţa.
1, bassin de la vallée de Moldoviţa ; 2, bassin de la vallée de Moldova.

Les minéraux opaques par rapport aux grenats présentent les accumulations les plus grandes là où les grenats enregistrent les valeurs les plus basses. Cependant, quelques coupes se caractérisent par des valeurs plus élevées, telles les vallées d'Argel, de Deia et de Sălătruc, alors que d'autres coupes ont des valeurs plus réduites comme la vallée de Suha Bucovineană, à Stulpicani (20,5%).

Les oxydes sont représentés par magnétite, ilménite, hématite et limonite et les sulfures par pyrite et marcassite. Parmi les oxydes, seulement la magnétite et l'ilménite apparaissent sous forme de granules bien individualisées, ayant des degrés de roulement différents, des fragments de cristaux ou des formes cristallographiques (octoèdres et respectivement des cristaux tabulaires munis d'arêtes arrondies), par rapport à la hématite et au limonite d'habitude aux formes de poussière ou bien de croûtes concrétionnées souvent altérées partiellement en limonite. La coexistence des oxydes et des sulfures dans le grès de Fusaru peut suggérer autant leur origine des milieux de sédimentation initiaux que leur formation épigénétique.

Selon la valeur des pourcentages c'est la chlorite qui vient après les minéraux opaques, ayant une extension bien plus grande dans les vallées de Deia, de Moldoviţa et de Sălătruc. Outre la chlorite d'origine détritique, ont été aussi identifiées des lames minces de chlorite qui ont résulté probablement de l'altération des biotites (relevée seulement par les rares lamelles de sagénite) tout comme de l'altération partielle des grenats et de la hornblende (pl. I, fig. 10). Des minéraux dont la source primaire doit être cherchée dans l'aréal des roches cristallophylliennes mésométamorphiques, il faut rappeler hornblende, épidote-zoïzite (tous les deux à participations insignifiantes), staurotide, disthène, biotite, glaucophane, sillimanite et actinote, les derniers à participations subunitaires ou même accessoires (pl. I, figs. 8, 11, 12 ; pl. II, figs. 1, 5).

La hornblende verte apparaît en quantités très petites, d'une grande fréquence dans les coupes de Deia (VI) et de Sălătruc (VIII), plus abondante dans la classe 0,16 à 0,06 mm. Elle se présente sous forme de prismes courts avec les marges à franges, étant partiellement chloritisée (pl. I, figs. 3, 6 ; pl. II, fig. 5). Sa faible participation de pourcentage dans la composition de la fraction lourde suggère autant l'intense altération prédépositionnelle que l'absence initiale du détritus dans ce minéral.

La staurotide est présente dans toutes les classes (avec quelques exceptions) bien que les valeurs de pourcentage sur coupes soient

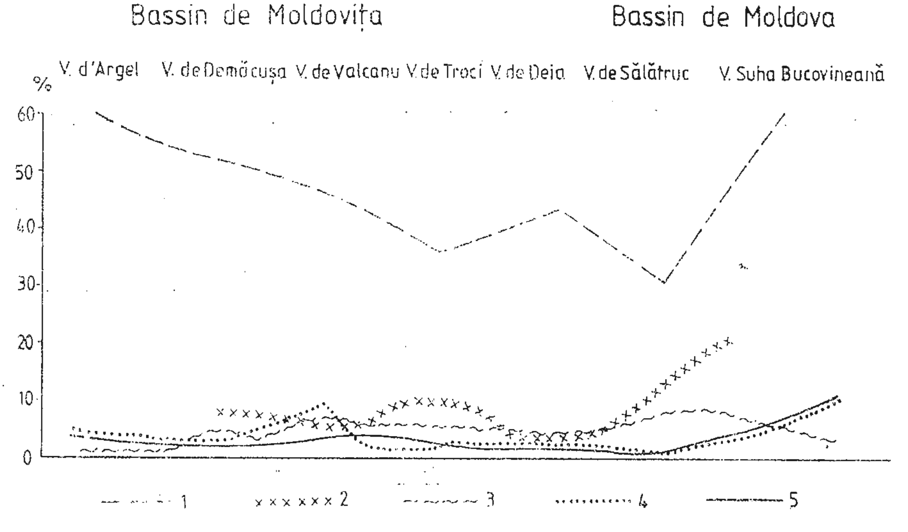

Fig. 11. — Teneur en principaux minéraux lourds des bassins des vallées de Moldova et de Moldovița.
1, grenats ; 2, chlorite ; 3, staurotide ; 4, rutile ; 5, zircon.

variables, les moyennes pour les deux zones (bassins de Moldovița et de Moldova) sont presque égales, fait qui dénote des sources d'apport communes (fig. 11).

Le rutile et le zircon ont la fréquence la plus élevée du groupe des minéraux très résistents au transport et à l'altération, et la tourmaline, le sphène et la monazite sont sporadiques pareillement aux autres composants de la fraction lourde (tabl. 1 et 2).

b) *Caractères morphoscopiques.* La forme, les dimensions, le degré de roulement et d'aplatisation des minéraux détritiques (Ro = 0,7 à 0,9) sont des sources d'information ainsi que des indices qui relèvent non seulement la distance et la durée du transport mais aussi les conditions paléoclimatiques. La coexistence des formes arrondies, anguleuses et aplaties de la même espèce minérale ou des espèces différentes dénote qu'il s'agit d'un mélange de granules transportées sur des distances appréciables et de granules transportées sur des distances petites (tabl. 3).

Les formes arrondies suggèrent non pas un transport de longue durée mais aussi des remaniements répétés, à la différence des granules anguleuses qui suggèrent autrement un transport rapide sur des distances courtes sans qu'un processus de polissage et d'arrondissement plus prolongé ait eu lieu. Le rapport entre les minéraux très résistents et ceux à résistence moyenne est de 1/0,47.

On remarque la participation en proportion de 60% des minéraux à formes arrondies, en comparaison de 25-30% de ceux à formes anguleuses et de presque 10% de ceux idiomorphes. Du reste, dans le groupe des minéraux idiomorphes, le zircon a la primauté par ordre décroissant sur tourmaline, rutile, minéraux opaques, chlorite et staurotide. Les formes arrondies abondent dans les trois classes granulométriques séparées, les plus nombreux étant les minéraux opaques suivis des minéraux transparents (grenats, chlorite, zircon, tourmaline, rutile et staurotide).

Les formes anguleuses sont subordonnées à celles arrondies, les grenats et la staurotide étant les plus affectés dans leur chemin jusqu'au milieu de dépôt ; les cas où une partie des minéraux opaques tels chlorite, tourmaline et zircon ont subi des heurts suivis des ruptures prédépositionnelles sont rares.

Du groupe des minéraux opaques les formes arrondies sont d'une grande fréquence tant pour les oxydes de fer que surtout pour les sulfures mais, par rapport aux oxydes qui sont remaniés, les sulfures sont pénécontemporaines (tabl. 4). Elles sont représentées par pyrite, chalcopyrite (autigène), la fréquence maximum étant dans la coupe de Deia (VI) et manquent dans les coupes d'Argel (I) et de Demăcuşa (II). Sporadiquement ont été identifiées quelques granules idiomorphes d'ilménite et de magnétite dans les échantillons de la vallée de Moldoviţa.

Les grenats, composants de base de la fraction lourde, apparaissent dans une égale mesure dans les granules anguleuses et arrondies, le rapport étant 1 : 1, fait qui n'exclut pas la possibilité que leur distribution soit inégale sur les coupes. Les formes arrondies sont concentrées surtout dans la coupe de Demăcuşa-Petac (II), la partie supérieure de la coupe de Valcanu (III) et les parties moyenne et inférieure des coupes de Deia (VI) et de Sălătruc (VIII). Ont été aussi identifiées des granules d'aspect mamélonné et des cristaux idiomorphes (pl. II, fig. 2).

Les cristaux (pl. II, fig. 3) à marges bien conservées traduisent un transport court et rapide tout comme dans le cas des cristaux idiomorphes de zircon (pl. I, fig. 2) d'aspect prismatique bipyramidal ; les formes euédriques de rutile (pl. II, fig. 8) présentent souvent des concrescences sur les faces latérales du prisme ou bien des bourgeonne-

TABLEAU 3

Aspect morphoscopique des principaux minéraux opaques du grès de Fusaru

No.	No. de l'échantillon	PROVENANCE	Minéraux opaques				
			Magné-tite	Héma-tite	Ilméni-te	Limoni-te	Sulfu-res ⊛
1	1834	Vallée d'Argel	•	•	•	•••	—
2	2109	Vallée de Demăcuşa	•	•••	•	•••	•
3	1867		—	• •	—	—	—
4	1869		•	•••	—	• •	—
5	1870		• •	•••	• •	• •	—
6	6885 B	Vallée de Moldoviţa	• •	•••	—	• •	—
7	7076		•••	•	—	• •	—
8	6889		• •	•	• •	• •	•
9	7053	Vallée de Valcanu (Vatra Moldoviţei)	• •	•	•	• •	• •
10	7054		•	• •	—	•••	• •
11	7057		•	• •	•	• •	• •
12	7058		•	• •	•	• •	• •
13	7059		—	•••	—	•	—
14	7060		•	• •	•	•	•••
15	2542 / 1	Vallée de Deia (vallée de Moldoviţa)	•	•	•	•	•••
16	2542 / 2		—	• •	•	• •	• •
17	2542 / 3		—	• •	•	• •	• •
18	2542 / 4		•	—	• •	•	•••
19	2542 / 5		•	•	•	• •	•••
20	2542 / 6		•	•	•	•	•••
21	2542 / 7		•	• •	• •	• •	•••
22	2542 / 8		•	•	• •	•	•••
23	2542 / 9		—	•	•	•	•••
24	2542 / 10		• •	•	•	•	• •
25	2542 / 11		•	•	•	•	•••
26	6939	Ruisseau de Poieni (vallée de Deia)	—	—	•	• •	•••
27	6940		—	—	—	• •	•••
28	1757	Ruisseau de Troci (Vatra Moldoviţei)	•	•••	•	•	—
29	2543 / 1	Vallée de Sălătruc (vallée de Moldova)	—	•	• •	•	•••
30	2543 / 2		• •	• •	• •	• •	•
31	2543 / 3		—	•		•	—
32	2543 / 4		• •	•••	•	•••	•
33	2543 / 5		•	•	•	•	•••
34	2543 / 6		•••	•	•	•	•
35	2543 / 7		—	•	—	—	—
36	2543 / 8		—	•	•	—	—
37	1356 / 1	Vallée Suha Bucovineană (Stulpicani)	—	• •	•	•	—
38	1356 / 2		•	•	—	•	• •
39	1357		—	• •	—	• •	•

Légende :

— absent

• – rare

• • – frequent

••• – très fréquent

⊛ – sulfures de Cu + Fe (glomérules) framboïdes

TABLEAU 4

Fréquences des minéraux opaques du grès de Fusaru

No.	No. de l'échantillon	PROVENANCE	Formes idiomorphes							Formes arrondies							Formes rugueuses						
			Minéraux opaques	Grenats	Chlorite	Staurotide	Rutile	Tourmaline	Zircon	Minéraux opaques	Grenats	Chlorite	Staurotide	Rutile	Tourmaline	Zircon	Minéraux opaques	Grenats	Chlorite	Staurotide	Rutile	Tourmaline	Zircon
1	1834	Vallée d'Argel	+	-	-	-	+	+++	+++	+++	+++	+++	-	+++	+	-	++	++	+	+++	+	-	-
2	2109	Vallée de Demăcuşa-Petac (vallée de Moldoviţa)	-	-	-	-	-	+	++	+++	++	+	-	+	+++	++	+	+++	-	+++	++	-	-
3	1867		-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	++	-	+	-	-	-
4	1869		+	+	-	-	-	+	++	+++	++	+	-	+++	-	+	++	+++	-	+++	-	-	-
5	1870		+	+	-	-	-	+	+	+++	++	-	-	++	-	++	-	+++	-	++	+	-	-
6	6885 B	Vallée de Moldoviţa	-	+	-	-	-	-	+++	++	++	+++	-	-	-	+	+	++	-	++	-	-	-
7	7076		-	+	-	-	-	+	-	++	++	+	-	+	-	-	-	++	-	-	-	-	-
8	6889		-	+	-	-	+	++	++	++	++	++	-	+	+	+	+	++	+	++	-	-	-
9	7053	Vallée de Valcanu (↖ Vatra Moldoviţei)	+	+	-	-	-	+	-	+++	++	+++	+	++	-	-	+	++	+	++	+	-	-
10	7054		+	+	-	-	+	+++	+++	+++	+++	+	+	+	+	+	+	++	-	++	++	-	+
11	7057		-	-	-	-	-	-	++	+++	+++	-	-	+	+	+	-	++	-	+++	-	-	-
12	7058		-	-	-	-	-	-	-	+	-	+	-	-	-	-	+	+	-	+	-	-	-
13	7059		-	+	-	-	-	-	+	+++	++	-	-	+	-	+	-	++	-	-	-	-	-
14	7060		+	+	+	-	+	-	+++	+++	+	+++	+++	+	-	+	+	+++	-	+	-	-	-
15	2542/1	Vallée de Deia (vallée de Moldoviţa)	-	-	-	-	+	+	+++	+++	++	-	-	+	+	++	+	+++	-	+	+	+	+
16	2542/2		-	-	-	-	+	+	+	+++	++	+	-	+	+	+	+++	+++	-	+++	+	+	+
17	2542/3		+	-	-	-	-	-	-	+	++	+	-	-	-	-	-	-	-	+	-	-	-
18	2542/4		+	++	-	-	+	+	+++	+++	+++	-	+	+	-	+	-	+	-	+	-	-	-
19	2542/5		+	+++	-	-	+	+	+	++	++	+	+	-	-	-	+	+	-	+	-	-	-
20	2542/6		-	+	-	-	+	+	+++	+++	+++	+	-	+	-	+	-	++	+	+++	-	-	-
21	2542/7		-	+	-	-	-	++	+	+++	+++	-	-	+++	-	+	+	+	++	-	++	-	-
22	2542/8		-	+	-	-	-	+	-	+++	++	++	-	+	+	+	+	++	-	++	++	-	-
23	2542/9		-	-	-	-	++	+	+++	+++	+++	-	-	-	-	-	-	++	-	++	-	-	-
24	2542/10		-	-	-	-	-	+	-	+++	+++	+	-	+	-	++	+	++	-	++	-	-	-
25	2542/11		+		+		+	-	+	++	++	-	+	+	-	+	-	++	-	+	-	-	-
26	6939	Ruisseau de Poieni (vallée de Deia)	-	+	-	-	+	+++	+	+++	+	+	-	++	+	+++	-	+++	-	+++	-	-	-
27	6940		-	+	-	-	+	+	+	+++	+	-	-	++	+	+	-	++	-	+	-	-	+
28	1757	Ruisseau de Troci (vallée de Moldov.)	-	-	-	-	+++	+++	+++	+++	+	+++	-	-	+	+	+	+++	-	+	+	-	-
29	2543/1	Vallée de Sălătruc (vallée de Moldova)	+	+	-	-	+	+	++	+++	++	+	-	+	-	+	-	+	-	+	-	-	-
30	2543/2		-	++	-	-	-	+	+	-	+	+	-	+	+	+	-	+++	-	+	-	-	-
31	2543/3		-	-	-	-	-	-	-	++	+++	++	-	+	-	+	-	-	-	++	-	-	-
32	2543/4		-	-	-	-	-	-	-	++	++	+	-	+	+	+	-	+	-	++	-	-	-
33	2543/5		+	+	-	-	-	-	++	-	++	+	-	+	+	+		+++	-	+	-	-	-
34	2543/6		+	-	-	+	-	-	-	+++	+	++	-	+	+	+	-	++	-	-	-	-	-
35	2543/7		-	-	-	-	-	-	-	+++	++	+	-	+	+++	++	-	+	-	+	-	-	+
36	2543/3		-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	++	-	+	-	-	-
37	1856/1	Vallée Suha Bucovineană (Stulpicani)	-	-	-	-	-	-	-	++	++	-	++	+	-	+	+	+	-	-	-	-	-
38	1856/2		-	-	-	-	-	-	-	++	++	-	-	-	-	+	-	+++	-	+	-	-	-
39	1857		-	+	-	-	-	-	+	+++	+	-	-	+	+	+	-	+++	-	-	-	-	-

LÉGENDE

- \- absent
- \+ rare
- ++ fréquent
- +++ tres fréquent

ments ; les modifications polymorphes du rutile (carrée et rhombique) sont tout à fait sporadiques (pl. I, figs. 4, 7).

La chlorite est d'habitude d'aspect lamellaire et rarement anguleux.

Du groupe des minéraux très résistents à l'altération et au transport (rutile, tourmaline et zircon), seul le rutile a été rencontré sous tous les aspects morphoscopiques, tandis que le zircon anguleux est très rare et la tourmaline anguleuse manque.

Les cristaux idiomorphes de tourmaline plus fréquents en prismes allongés, parallèles à l'axe vertical, ont été identifiés dans les coupes d'Argel (I), des vallées de Moldovița (IV), de Valcanu (III) et de Poieni (VII).

La staurotide anguleuse, plus rarement arrondie, est le minéral qui à la suite des processus mécaniques se fragmente mais ne s'altère pas ; ce ne sont que les grenats qui dépassent comme fréquence, le rapport grenats/staurotide dans le cadre du groupe des formes anguleuses étant de 3 : 1. Il s'ensuit de la statistique de la répartition des minéraux de divers aspects morphoscopiques que les formes euédriques abondent dans la vallée de Moldovița, tandis que dans la vallée de Moldova sont dominantes les formes arrondies et anguleuses.

Les aspects morphoscopiques des minéraux lourds des échantillons analysés montrent que le matériel minéral a été recueilli des aréals différents et que le matériel détritique est le résultat des dénudations rapides et progressives des zones à roches éruptives, métamorphiques et sédimentaires.

e) *Zones terrigéno-minéralogiques*. Les résultats des analyses morphoscopiques nous mènent à supposer que la plupart des formes arrondies (grenats, rutile et zircon) ont leur origine dans les arénites préexistantes. Les roches métamorphiques ont engendré les grenats, la staurotide, le disthène et la tourmaline (à contours arrondis ou prismatiques) ; des roches éruptives proviennent aussi bien le zircon et la tourmaline (à contours euédriques) que le sphène, la monazite, la brookite et l'anatase (à contours irréguliers) et des pegmatites une partie des grenats, de la tourmaline et de la monazite. Tous ces minéraux ont été repris, rédéposés et rédistribués dans le bassin où s'est formé le grès de Fusaru.

Une faible participation caractérise le détritus minéral des formations cristallophylliennes des Carpathes Orientales ainsi que quelques minéraux tels épidote-zoïzite, hornblende, disthène et sillimanite.

On a constaté, par suite de l'étude optique des minéraux lourds de la fraction grossière, qu'à la constitution du grès de Fusaru participent deux associations, à savoir : une association spécifique surtout à la partie inférieure (au-dessous des calcaires de Jaslo) de type opaques (30%) + grenats (44%) + chlorite (9,74%) ; une association spécifique aux parties moyenne et supérieure (au-dessus des calcaires de Jaslo) ayant communs les premiers 3 minéraux de l'association précédente (minéraux opaques — 34% + grenats — 41,90% + chlorite — 6,40%) auxquels s'ajoutent staurotide (6,76%) + zircon (6,86%) + rutile (4,90%).

Tant la partie inférieure du grès de Fusaru que les parties moyenne et supérieure se caractérisent par la participation en quantités réduites de la tourmaline et des pyroxènes.

D) Conclusions

L'analyse des minéraux opaques de la fraction grossière > 0,06 mm a mis en évidence la présence de 21 espèces minérales.

On peut affirmer que tous les éléments composants de la fraction lourde du grès de Fusaru des bassins des vallées de Moldova et de Moldoviţa présentent un degré avansé d'hétérogénéité en sens horizontal et vertical.

Les résultats des analyses minéralogiques ne dénotent pas des différences d'ordre qualitatif, mais au contraire d'ordre quantitatif, les accumulations des minéraux lourds offrent la possibilité de délimiter les suivantes associations : minéraux opaques + grenats + chlorite d'une part et minéraux opaques + grenats + staurotide + chlorite + zircon + rutile.

Toutes les deux associations contiennent de la tourmaline et des pyroxènes.

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CARACTERELE MINERALOGICE ALE GRESIEI DE FUSARU DIN BAZINUL VĂII MOLDOVA (CARPAȚII ORIENTALI)

(Rezumat)

Seria oligocen-miocen-inferioară din partea internă a unității de Tarcău este caracterizată mai ales prin dezvoltarea unei stive de arenite, cunoscută sub numele de gresia de Fusaru, iar în zonele mediană și externă aceasta este substituită treptat de gresia de Kliwa.

Atît gresia de Fusaru, cît și gresia de Kliwa repauzează pe un substrat comun (marne bituminoase cu menilite inferioare și șisturi disodilice inferioare) și ambele suportă stratele de Vinețișu.

Spre partea externă a unității de Tarcău, gresia de Kliwa suportă șisturile disodilice și menilitele superioare, în care se găsesc intercalate bentonite și tufite („tuful" de Falcău, Alexandrescu et al., 1984). Relațiile dintre stratele de Vinețișu și șisturile disodilice și menilitele superioare din această parte a Carpaților nu s-au elucidat încă.

Gresia de Fusaru (40-700 m) este alcătuită dintr-o succesiune alternantă de roci arenitice (0,2-3 m) și roci lutitice, care pe alocuri capătă aspect de pseudodisodile. Din intercalațiile de arenite (văile Moldovița și Moldova) s-au recoltat un număr de 39 probe, care provin de pe 9 profile, localizate în schița anexată (fig. 1). În urma operațiilor de tratare chimică și sitare, s-au obținut cele trei clase granulometrice : 0,50 — 0,25 mm ; 0,25 — 0,16 mm și 0,16 — 0,06 mm. Fracția grea obținută a fost examinată la microscop și însumată pe fiecare probă (tabel 1). Mediile pe profile ale fracției grele, mai mare de 0,06 mm sînt întabulate în tabelul 2.

Examenul optic a pus în evidență următoarele specii minerale : minerale opace (oxizi și sulfuri), granați, hornblendă, epidot — zoizit, staurolit, rutil, zircon, turmalină, clorit, biotit, monazit, sfen, glaucofan, sillimanit, piroxeni, disten și actinot. Granații au acumulările cele mai ridicate, ale căror procente variază între 24,28-61,39 și predomină în clasa fină.

De asemenea, s-a constatat că mineralele opace au acumulările cele mai mari, acolo unde granații înregistrează valorile cele mai scăzute.

Oxizii sînt reprezentați prin magnetit, ilmenit, hematit și limonit, iar sulfurile prin pirită și marcasită (granule sau framboizi), ultima alterată de obicei în limonit.

S-au conturat două asociații : o asociație specifică mai ales părții inferioare a gresiei de Fusaru de tip opace (30%) + granați (44%) + clorit (9,74%) și o asociație specifică părții mijlocii și superioare avînd comune primele 3 minerale din asociația precedentă (opace 34% + granați 41,90% + clorit 6,40%) la care se adaugă staurolitul (6,76%) + zirconul (6,86%) + rutilul (4,90%).

Aspectele morfoscopice ale mineralelor grele constituie dovada provenienței materialului mineral din surse și areale diferite, acest material fiind rezultatul denudărilor rapide și progresive, din zone cu roci eruptive, metamorfice și sedimentare. Elementele componente ale fracției grele din gresia de Fusaru prezintă un mare grad de eterogenitate atît în sens orizontal cît și vertical.

EXPLICATIONS DES PLANCHES

Planche I

Fig. 1. — Zircon ; échantillon 1834 — vallée d'Argel-Moldovița ; N ‖ ; × 70 ; classe de 0,25 à 0,16 mm.

Fig. 2. — Zircon ; échantillon 7060 — vallée de Valcanu-Vatra Moldoviței ; N ‖ ; × 70 ; classe de 0,25 à 0,16 mm.

Fig. 3. — Hornblende (a) et augite (b) — vallée de Sălătruc-Vama ; N ‖ ; × 70 ; classe de 0,50 à 0,25 mm.

Fig. 4. — Brookite ; échantillon 2542/3 — vallée de Deia-Frumosu ; N ‖ ; × 70 ; classe de 0,16 à 0,06 mm.

Fig. 5. — Staurotide ; échantillon 2542/4 — vallée de Deia-Frumosu ; N ‖ ; × 70 ; classe de 0,16 à 0,06 mm.

Fig. 6. — Ensemble de minéraux lourds : a, hornblende ; b, hyperstène ; c, tourmaline ; échantillon 2542/10 — vallée de Deia-Frumosu ; N ‖ ; × 70 ; classe de 0,16 à 0,06 mm.

Fig. 7. — Anatase ; échantillon 2542/10 — vallée de Deia-Frumosu ; N ‖ ; × 70 ; classe de 0,16 à 0,06 mm.

Fig. 8. — Biotite ; échantillon 2542/10 — vallée de Deia-Frumosu ; N ‖ ; × 70 ; classe de 0,16 à 0,06 mm.

Fig. 9. — Grenat cassé en gradins ; échantillon 2543/1 — vallée de Sălătruc-Vama ; N ‖ ; × 70 ; classe de 0,16 à 0,06 mm.

Fig. 10. — Chlorite à surface irrégulière et striée ; échantillon 1834 — vallée d'Argel-vallée de Moldovița ; N ‖ ; × 25 ; classe de 0,50 à 0,25 mm.

Fig. 11. — Biotite à aiguilles de sagénite ; échantillon 2543/2 — vallée de Sălătruc-Vama ; N ‖ ; × 25 ; classe de 0,50 à 0,25 mm.

Fig. 12. — Agglomérations de prismes de zoïzite ; échantillon 2543/1 — vallée de Sălătruc-Vama ; N ‖ ; × 25 ; classe de 0,50 à 0.25 mm.

Planche II

Fig. 1. — Staurotide (a) et disthène (b) ; échantillon 1870 — vallée de Demăcușa-Petac ; N ‖ ; × 75 ; classe de 0,50 à 0,25 mm.

Fig. 2. — Grenat idiomorphe ; échantillon 2542/5 — vallée de Deia ; N ‖ ; × 75 ; classe de 0,25 à 0,16 mm.

Fig. 3. — Tourmaline idiomorphe ; échantillon 1856/2 — vallée de Suha Bucovineană-Stulpicani ; N ‖ ; × 25 ; classe de 0,16 à 0,06 mm.

Fig. 4. — Section à travers le grès de Fusaru comportant un fragment de micrite criptocristallin à Crassiocolaria ex gr. cf parvula Remane ; échantillon 1867 — vallée de Demăcușa-Petac ; N ‖ ; × 75.

Fig. 5. — Ensemble de minéraux lourds: a, hornblende; b, disthène; c, rutile; échantillon 7053 — vallée de Valcanu-Vatra Moldoviței; clase de 0,16 à 0,06 mm.

Fig 6. — Rutile corrodé d'une ancienne macle „en forme d'âme" ; échantillon 1757 ruisseau de Troci-Vatra Moldoviței ; N ‖ ; × 330 ; classe de 0,16 à 0,06 mm.

Fig. 7. — Grenat subangulaire à concavités — échantillon 7076 ; vallée de Moldovița ; N ‖ ; × 25 ; classe de 0,16 à 0,06 mm.

Fig. 8. — Rutile en bourgeons ; échantillon 1834 — vallée d'Argel-Moldovița ; N ‖ ; × 360 ; classe de 0,16 à 0,06 mm.

Fig. 9. — Section à travers le grès de Fusaru ; échantillon 1856/2 — vallée Suha Bucovineană-Stulpicani ; N ‖ ; × 75.

Les nombres de provenance des échantillons représentent les nombres des points d'observation en terrain.

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1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

SEDIMENTOLOGIE

TEXTURAL STUDY OF A CORE FROM THE TARANTO SUBMARINE VALLEY (IONIC SEA) [1]

BY

GLICHERIE CARAIVAN [2]

Sedimentary processes. Submarine valley. Pelagic sedimentation. Turbiditic facies. Lithofacies. Submarine cores. Study drillings. Ionic Sea.

Abstract

The detailed textural study effectuated by the author of this paper pointed up that the sediments in the Taranto submarine valley deposited by means of three sedimentation processes: pelagic sedimentation, sedimentation by weak density currents and turbiditic sedimentation. The pelagic sedimentation represents the general background for the turbiditic levels. The frequency and the thickness of the sandy sequences indicate the existence of two turbiditic facies: proximal and distal. The deposits of the proximal facies contain thicker and more numerous sandy levels. The deposits of the distal facies, remote from the main terrigene material, are more uniform, the sandy levels being thinner and more rare. The location of the turbiditic levels, usually at the upper part of the cores, may be regarded as the result of modifications of the hydrodynamic equilibrium generated by the Holocene transgression.

Résumé

Etude texturale d'une carotte de la vallée Taranto (mer Ionienne). L'étude texturale détaillée effectuée par l'auteur a relevé que les sédiments de la vallée sous-marine Taranto sont déposés au cours de trois processus de sédimentation : sédimentation par courants de densité lents, sédimentation turbiditique et sédimentation pélagique.

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La sédimentation pélagique offre le cadre général où se sont formés d'une manière sporadique les niveaux turbiditiques. La fréquence de l'apparition et la puissance des séquences sableuses suggèrent l'existence de deux faciès turbiditiques proximal et distal.

Les dépôts du faciès proximal contiennent des niveaux sableux plus épais et plus nombreux.

Les dépôts du faciès distal, plus loin de la source principale de matériel terrigène sont plus uniformes, les niveaux sableux étant minces et plus rares.

La localisation des niveaux turbiditiques d'habitude à la partie supérieure des carottes, peut être envisagée en tant que le résultat des modifications d'équilibre hydrodynamique produites par la transgression holocène.

Introduction

In the summer of 1974 the National Research Council (NRC) of Italy, by the Laboratory of Marine Geology of Bologna, organized an expedition on board the "R. V. Bannok" in the Ionic Sea during which,

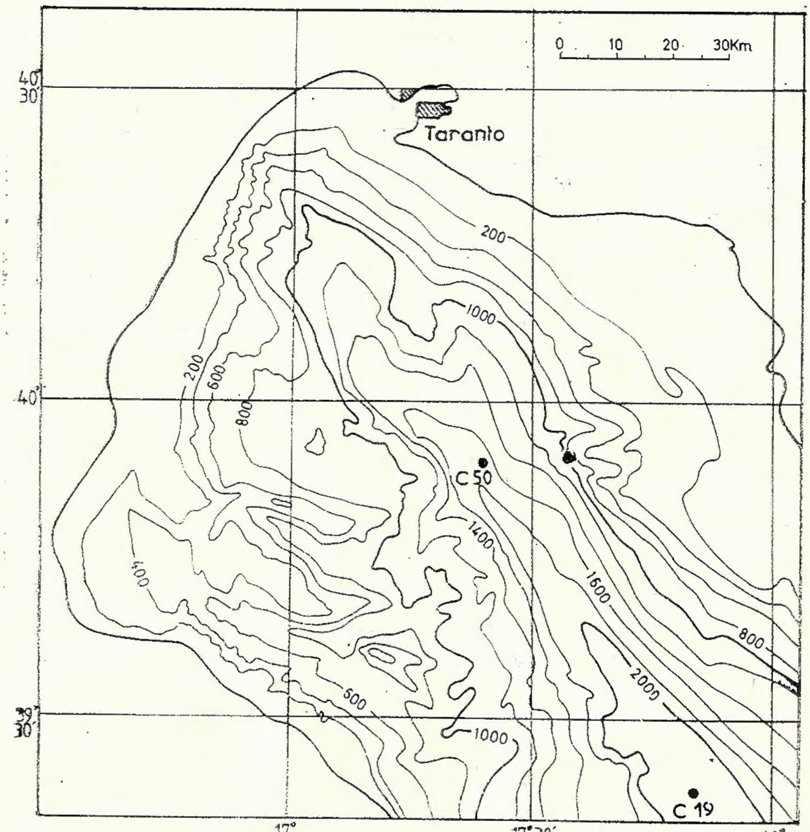

Fig. 1. — Geographic location of the described cores.

among others, several corings were carried out by means of piston gravitational corer. The present paper deals with one of the cores — I-74-19 — sampled on that occasion. This core was taken off from the bottom of the Taranto Valley, at a depth of 2291 m, the coordinates of the station being 39°23.4′ lat. N and 17°53′ long. E (Fig. 1). The core testing was carried out in the Laboratory of Marine Geology in Bologna. Samples have been collected both from mudy levels and from sandy ones. The reduced thickness and frequence of the latter (0.5-4 cm) imposed the "peel" sampling subsequently studied under the microscope.

With a view to giving information on the levels well placed on the lithological column small samples (11-30 g) have been collected. We tried to avoid contamination with material from the disturbed, peripheral zones of the core.

Textural data have been obtained combining the sieving with sedimentometry according to the method used within the Laboratory of Marine Geology of Bologna. The sieving was effectuated with a set of sieves, disposed at an interval of 1/2 phi. For the material finer than 4 phi the photoextinction sedimentometer was used, the granulometric distribution for the interval 4-10 phi was recorded.

Textural parameters have been obtained using Folk and Ward's formulas (1957). As the cumulative curves usually remain open on the log paper, their continuity towards the value of 14 phi has been estimated. The coarse fractions, which contain exclusively organogenous material without transport traces, have not been taken into account.

Textural parameters determined on peel, by counting and direct measurement under the microscope, have been changed into parameters comparable with those resulting from sieving, using the correlation diagrams given by Friedman (1962).

Lithology

Core I-74-19 is of 488 cm long (Figs. 2, 3, 4). The intercepted sediments are mostly clays of a grey colour, with rare sandy levels and a lot of light-coloured, clayey laminas displaying a more siltic character.

The thicknesses of the sandy levels vary between 2-3 mm and 4 cm. Due to their thinness their structure is not so obvious. On a peel from the visible level of 152-154 cm a graded bedding can be noticed (Fig. 5). Dark-coloured skeletic organogenous particles are found at the lower and upper part of the level and in the second third of the interval the material is finer, dark-coloured displaying mineral features. The structure points to two superimposed incomplete sedimentary units with a graded bedding. In case of the more consistent sandy levels (more than 1 cm thick) both the basal and the upper contacts have an erosive character. The sandy sequence from the level 176-184 cm (Fig. 4) was disturbed during the coring and gave rise to the appearance of the opposite dips of the neighbouring clayey laminas.

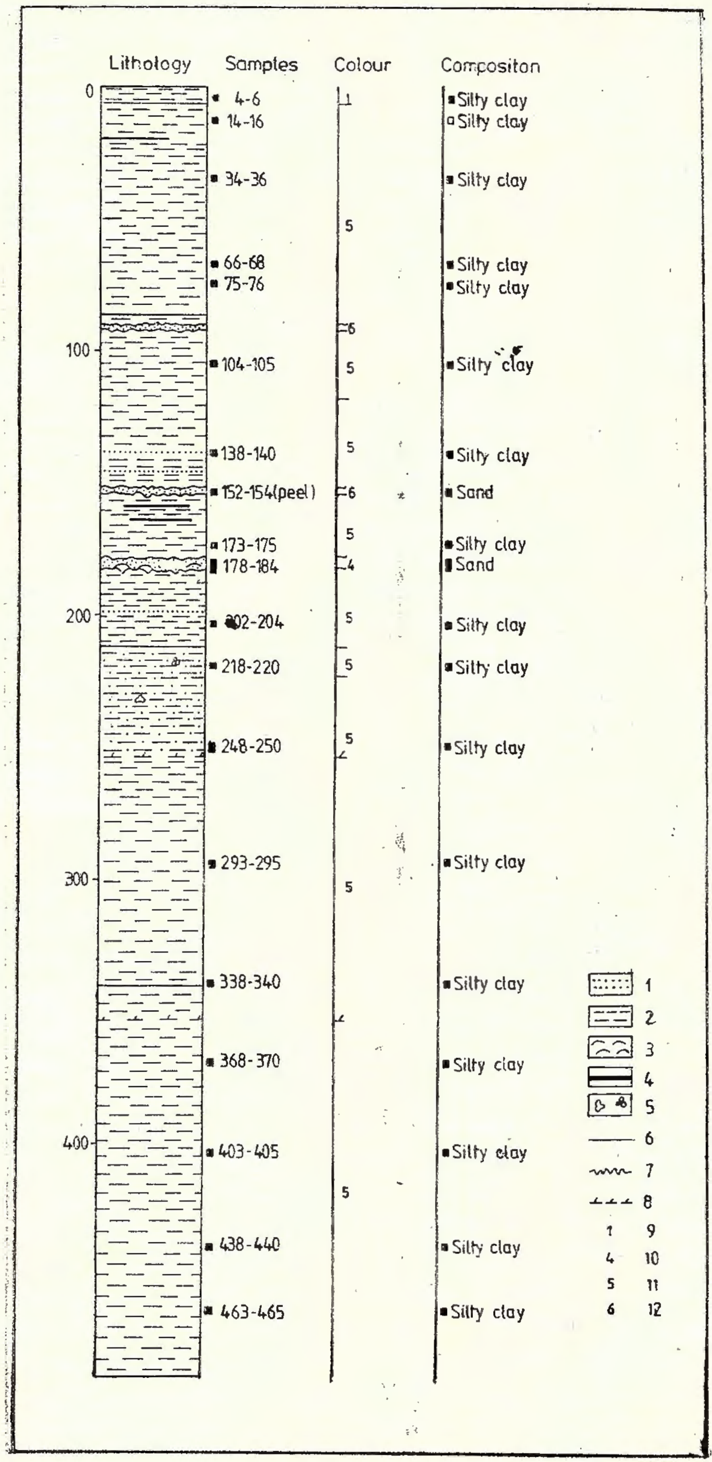

Fig. 2. — Lithologic column of core I-74-19. Sediment types: 1, sandy; 2, clayey; 3, shell hash; 4, laminae; 5, nodules. Contacts: 6, obvious; 7, irregular; 8, obscure. Colour index: 9, yellow; 10, yellow gray; 11, gray; 12, dark gray.

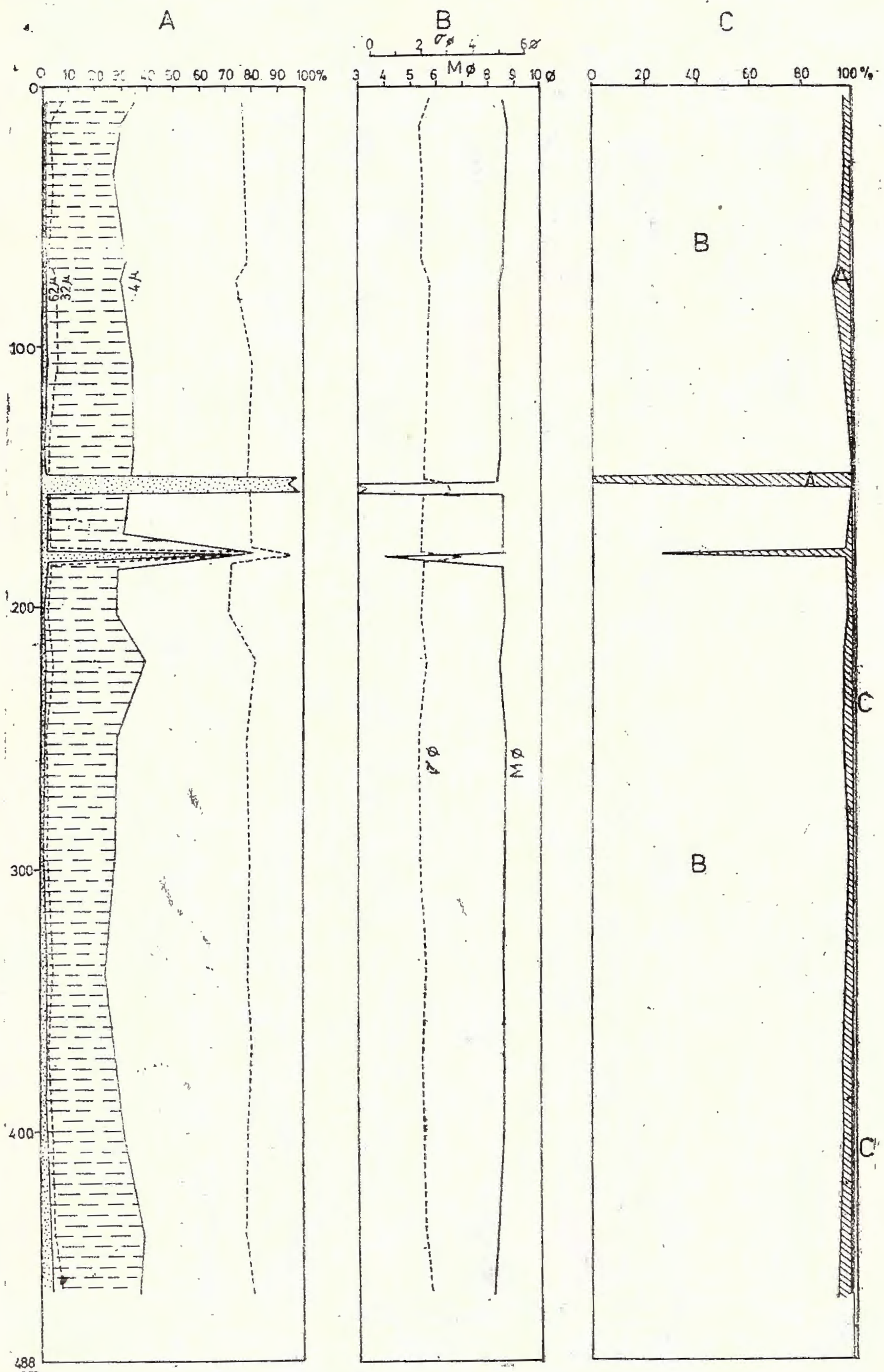

Fig. 3. — Vertical variation of the following parameters: frequency distribution of granulometric fractions (A), mean, MØ and standard deviation, σØ (B), frequency of granulometric populations (C).

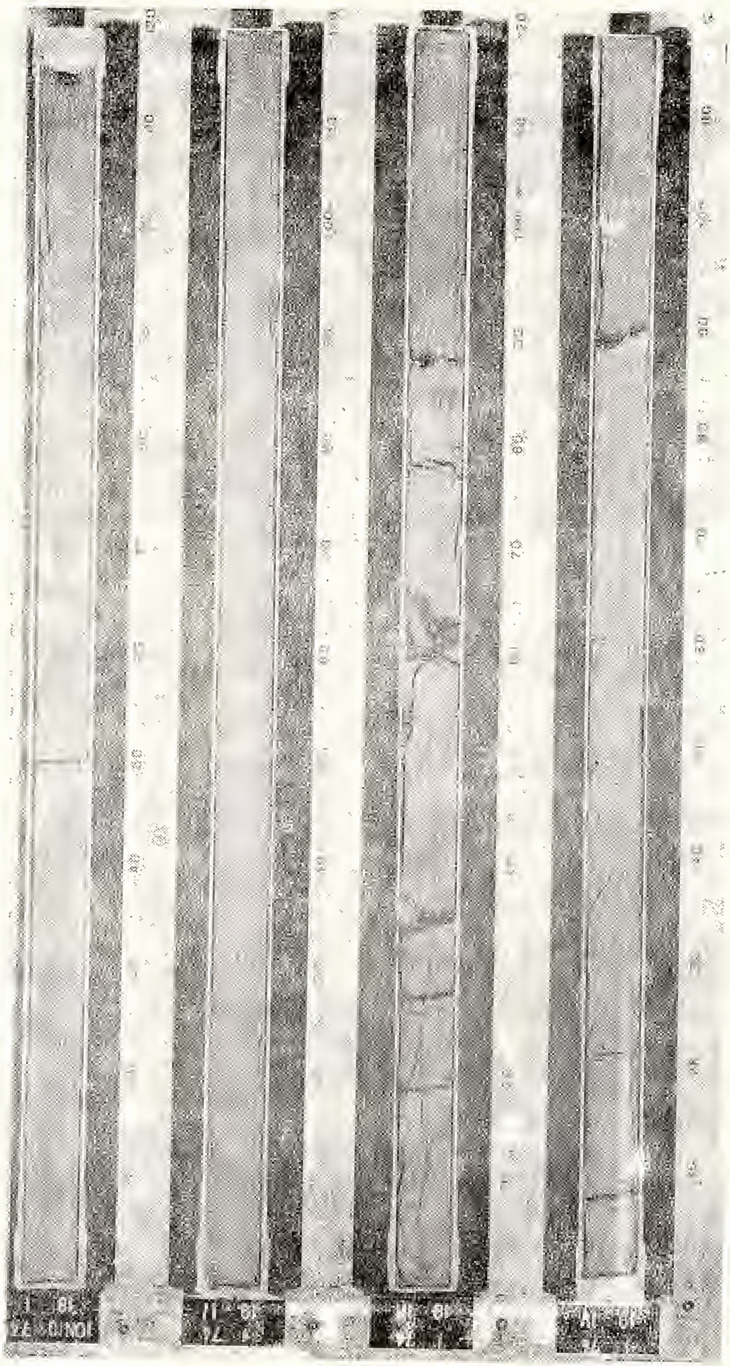

Fig. 4. — General view of core I-74-19.

Clayey sequences consist of a dense alternation of dark- and light-coloured silty laminas.

The main types of sediments, indicated on Shepard's diagram (1954), are represented by silty clay and sand (Figs. 2, 6).

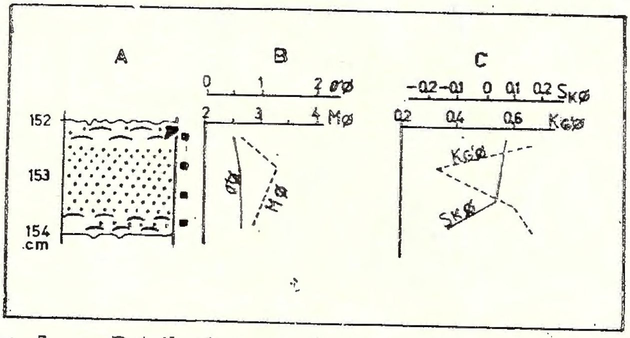

Fig. 5. — Detail view on the interval 152-154 cm from core I-74-19. See explanation for Figure 2.

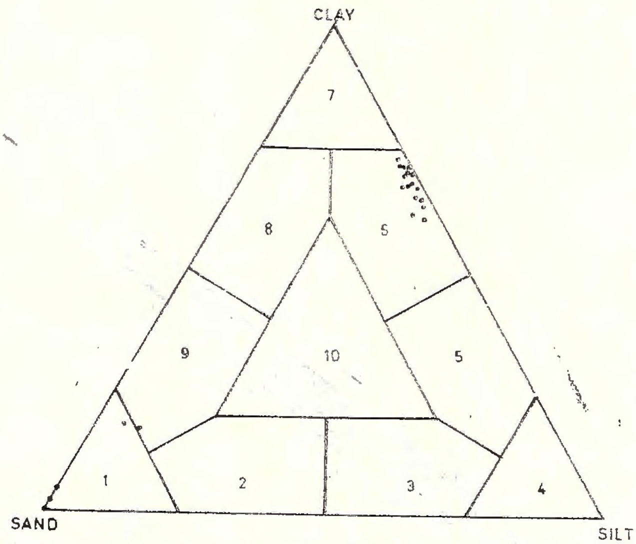

Fig. 6. — Shepard's diagram with sediment types from core I-74-19.

1, sand ; 2, silty sand ; 3, sandy silt ; 4, silt ; 5, clay silt ; 6, silty clay ; 7, clay ; 8, sandy clay ; 9, clay sand ; 10, loam.

Vertical Distribution of the Grain Populations

The studied marine sediments mainly consist of 2-3 primary populations of grains, transported by rolling, saltation and suspension, called by Visher (1959) C, A and B populations (Fig. 7). Population B represents 93-99.2 per cent of the clayey-silty sediments, whereas populations A and C 1.5-7 per cent and 0.2-0.6 per cent, respectively.

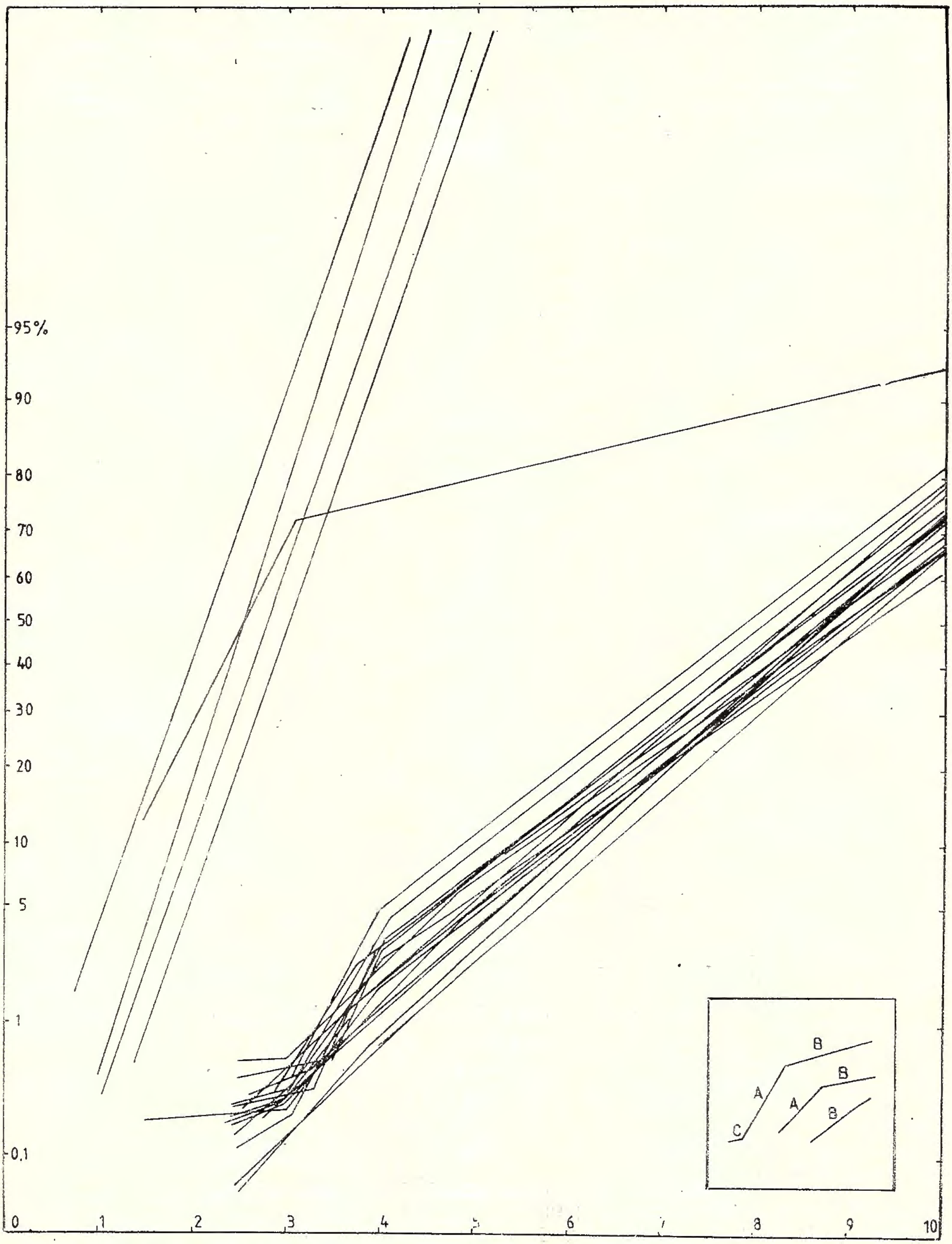

Fig. 7. — Line segments resulting from the interpretation of granulometric curves. In the bottom right corner: variation tendency of granulometric populations A, B, C.

The sandy levels contain one or two populations : B and/or A — 0-28% and 100-73%, respectively — indicating the significance of transport by saltation and of deposition by graded suspensions within the mechanisms of turbiditic sedimentation.

Textural Parameters

Textural parameters vary in two different ways, according to the type of sedimentation.

The "mean" values vary between 8.30 and 8.80 phi (Fig. 3) for the fine, pelagic sediments and between 4.11 and 4.23 phi for the sandy, turbiditic levels.

The mean values, determined by direct measurement under the microscope on the peel from the turbiditic level 152-154 cm, show variations from 2.58 phi in the base to 3.12 phi in the second third of the interval and then there is a sudden increase to 2.90 phi in the upper part (Figs. 5-8).

The standard deviation (Folk and Ward, 1957) displays values of 1.37-1.92 phi for the silty clays and of 2.92-2.97 phi for turbidites. In the sandy level 152-154 cm, the grading of the material is improved (Fig. 5 B) as the material becomes finer.

Skewness (Folk and Ward, 1957) has also two variation domains : negative (between -0.17 and -0.60 phi) for the fine-grained, pelagic sediments and positive (between 0.71 and 0.77 phi) for the sandy sediments, transported by turbidity currents.

Within the turbiditic sequence at the level 152-154 cm (Fig. 5 C), skewness (S_K) varies from slightly negative values (-0.02 phi) in the base to slightly positive values towards the upper part.

Kurtosis values (K_G — Folk and Ward, 1957) point to mesokurtic distributions (0.45-0.54 phi) for pelagic sediments to leptokurtic distributions (0.59-0.63 phi) for turbidites.

Within the turbiditic level 152-154 cm (Fig. 5 C), K_G varies from high leptokurtic values (0.67 phi) to highly platikurtic ones (0.33 phi) in the second third and then again leptokurtic values in the upper part.

The "mean" values were plotted versus the values of the standard deviation, skewness versus kurtosis values (Figs. 8-10)[3]. These diagrams illustrate the existence of three fields within which the points are concentrated.

C/M diagram (Passega, 1964) allows a more general definition of the deposition way of the particles. C/M diagram points up two phenomena (Fig. 11) :

a) material transport as graded suspensions from sandy levels by means of turbidity currents ; the points plot in a zone approximately parallel to line C=M (QR segment) ;

b) deposition of fine sediments (silty clays) from uniform and pelagic suspensions (field T).

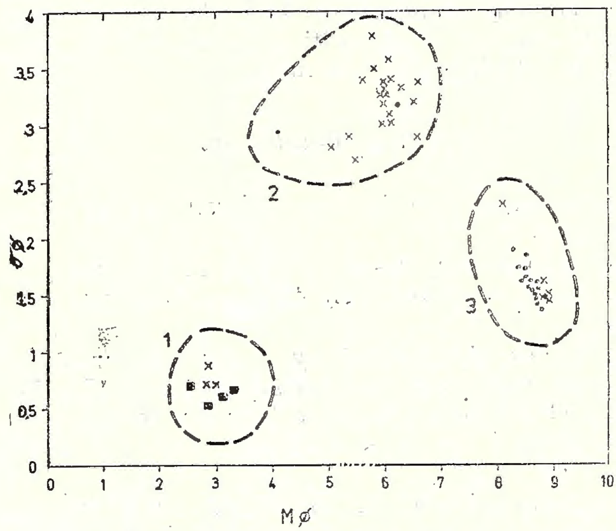

Fig. 8. — $M_{\varnothing}/\sigma_{\varnothing}$ diagram. The three fields (1, 2, 3) are explained in the text.

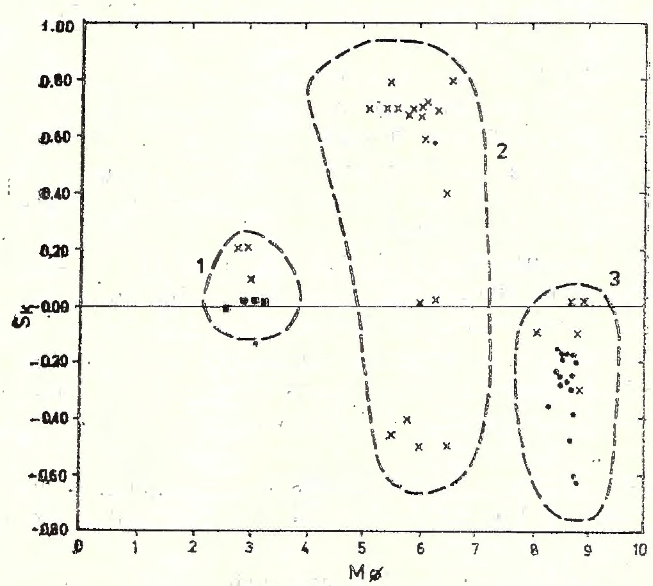

Fig. 9. — $M_{\varnothing}/S_k$ diagram. The three fields (1, 2, 3) are explained in the text.

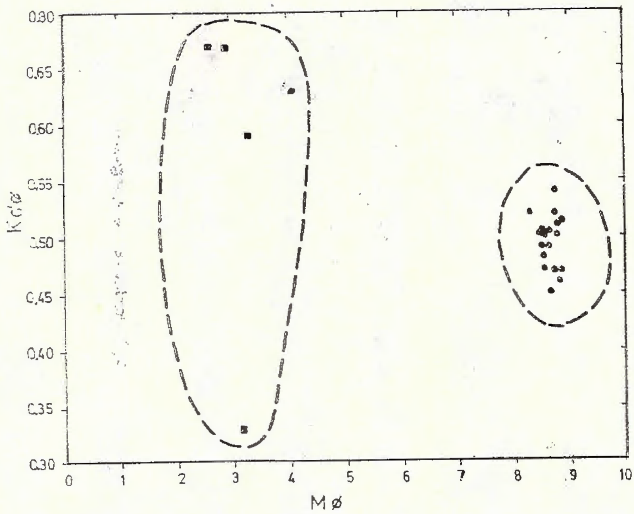

Fig. 10. — $M_{\emptyset}/K_{G'}$ diagram.

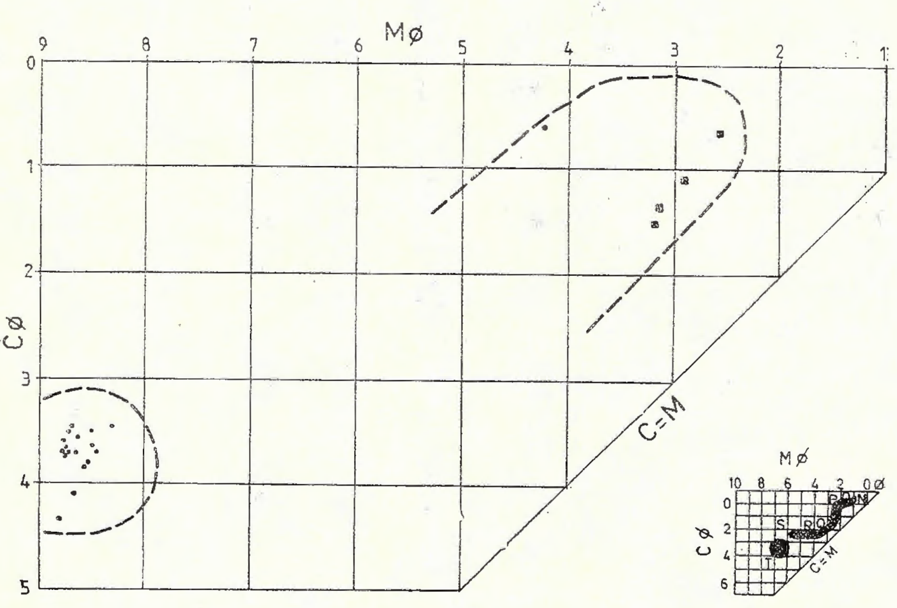

Fig. 11. — C/M diagram for sediments from core I-74-19. In the bottom right corner : Passega's diagram (1964) in black.

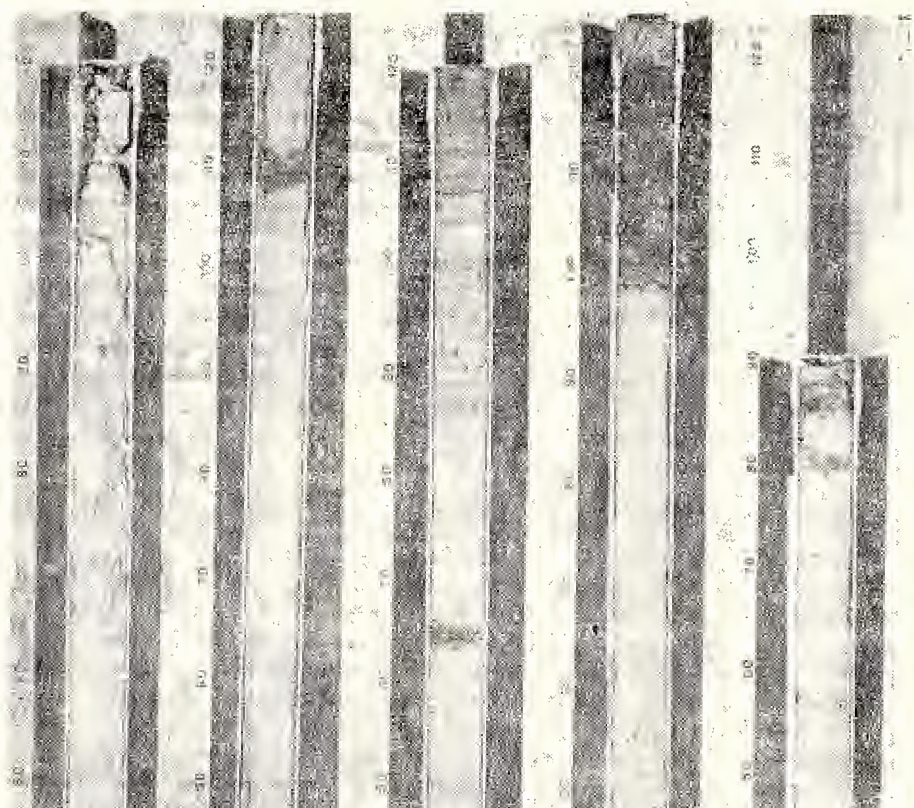

Fig. 12. — General view of core 1-73-50.

Mechanisms of Transport and Deposition

Textural characteristics of the sediments intercepted by cores I-74-19 and I-74-50 [3] indicate the action of three mechanisms of sedimentation.

a) Pelagic sedimentation prevails. Pelagic depositions accumulated when the bottom currents were very weak. They are partly biogenic, partly clayey. Pelagic sediments indicate a sorting from moderate to weak (Fig. 8) and a negative asymmetry (Fig. 9). The kurtosis values are mainly mesokurtic (Fig. 10).

b) Weak density currents along the Taranto Valley can transport silty and sandy material. Thus, light-coloured clay and sandy silts deposited on the clayey background of the sedimentary column.

It is noteworthy the scarcity or even the absence of the silty laminas in the lower part of the cores (Figs. 4, 12) and their abundance in the upper part of the sedimentary column. It may be correlated with regional climate modifications which generated intense changes between water bodies from the surface and from depth.

On the $M/\sigma_{\varnothing}$ and M/S_k diagrams (Figs. 8, 9), the clayey silts and the silty clays, carried by currents, occupy field 2 ; the sorting is very poor and the asymmetry is highly variable.

c) Turbidity currents, generated by the metastable accumulations of sediments at the edge of the Taranto gulf shelf, cross the Taranto submarine valley and its tributaries.

Turbidity currents are spasmodic, the turbiditic levels being interlayered with pelagic sediments. The sandy turbiditic levels of the core I-74-19 are thin and rare (Fig. 4) and those of core I-73-50 (Fig. 12) are thicker and more numerous. It is due to the distal and proximal position, respectively, of the mentioned cores as against the main supply core of the Taranto submarine valley (Fig. 1).

Each of the turbiditic sequences of the cores I-74-19 and I-73-50 (Figs. 5, 12) consist of two superimposed units with graded bedding.

As pointed out by Jipa (1974) for the Black Sea turbidites, in our case too the multiple graded bedding represents the result of two main pulsations within the turbidity current or perhaps of two superimposed turbidites.

Conclusions

Sediments from the Taranto Valley deposited by means of three sedimentation processes : pelagic sedimentation ; sedimentation by weak density turbidity currents ; turbiditic sedimentation.

Pelagic sedimentation offers the general background of the episodic turbiditic levels. The frequency and thickness of the sandy sequences indicate the existence of two turbiditic facies : proximal and distal. The deposits of the proximal facies, intercepted by core I-74-50, contain thicker and more numerous sandy levels.

The deposits of the distal facies, remote from the main source of terrigene material, are more uniform, the sandy levels being thinner and more rare.

The disposition of the turbiditic levels, usually in the upper part of the cores, may indicate hydrodynamic alterations due to the Holocene transgression.

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[3] On the diagrams in Figures 8 and 9 occur values of Inman's parameters (1952), determined by Giovanni Gabbianelli for his graduate paper at the Institute of Geology of Bologna. The values refer to the core I-73-50.

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STUDIUL TEXTURAL AL UNEI CAROTE DE PE VALEA TARANTO (MAREA IONICĂ)

(Rezumat)

Studiul textural, detaliat de autor, a evidenţiat faptul că sedimentele de pe valea submarină Taranto sînt depuse prin intermediul a trei procese de sedimentare : sedimentarea prin curenţi de densitate lenţi, sedimentarea turbiditică şi sedimentarea pelagică.

Sedimentarea pelagică oferă cadrul general, pe care se grefează, episodic, nivelele turbiditice. Frecvenţa apariţiei şi grosimea secvenţelor nisipoase sugerează existenţa a două faciesuri turbiditice : proximale şi distale.

Depozitele faciesului proximal conţin nivele nisipoase mai groase şi mai numeroase.

Depozitele faciesului distal, îndepărtate de sursa principală de material terigen, sînt mai uniforme, nivelele nisipoase fiind mai subţiri şi mai rare.

Localizarea nivelelor turbiditice, de obicei la partea superioară a carotelor, poate fi interpretată ca rezultat al unor modificări de echilibru hidrodinamic, generate de transgresiunea holocenă.

D. S. Inst. Geol. Geofiz. vol. 70-71/1 (1983 ; 1984), 1986, pag. 541—551

1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

SEDIMENTOLOGIE

PRÉSENCE DU ZIRCON ET DU BADDELEYITE DANS DES ROCHES TUFFITIQUES ET DES DIATOMITES DE LA ZONE EXTERNE DES CARPATHES ORIENTALES [1]

PAR

VENERA CODARCEA [2], GRIGORE ALEXANDRESCU [2]

Zircon. Baddeleyite. Tuffitic rocks. Diatomite. Falcău Tuff. Upper dysodilic shales. Oligocene — Lower Miocene. East Carpathians — External Flysch Zone.

Résumé

La note traite le problème de la coexistence du zircon et du baddeleyite dans le tuf de Falcău et dans les diatomites de Sibiciu-Buzău. Le tuf de Falcău est situé dans les schistes dysodiliques supérieurs, à environ 4 ou 5 m de profondeur, au-dessous de la limite ménilites supérieures/dysodiles supérieures d'âge oligocène-miocène inférieur. Les deux minéraux du zircon proviennent des cycles de remaniement répétés et antérieurs à la formation du „tuf" de Falcău et des diatomites.

Abstract

On the Presence of Zirconium and Baddeleyite in Some Tuffitic Rocks and Diatoms in the External Zones of the East Carpathians. This paper deals with the coexistence of zirconium and baddeleyite in the Falcău "Tuff" and Sibiciu-Buzău diatoms. The Falcău "Tuff" is situated in the upper dysodilic shales, at about 4-5 m below the upper menilite / upper dysodile limit, Oligocene-Lower Miocene in age. The two minerals of zirconium come from prior materials reworked in repeated cycles previous to the formation of the Falcău "Tuff" and of the diatoms.

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Introduction. La zone externe des Carpathes Orientales roumaines appartenant à deux unités structurales majeures (unité de Tarcău et unité des plis marginaux) comprend l'intervalle Oligocène-Miocène inférieur développé dans un faciès particulier, à roches bitumineuses, roches siliceuses (ménilites) et arénites quartzeuses de type Kliwa. Dans les Carpathes Orientales (parties centrale et septentrionale) se développent, en connexion avec les roches susmentionnées, des roches tuffitiques à divers degrés d'altération (Alexandrescu et al., 1984).

D'un tel niveau tufacé (le „tuf" de Falcău entre les vallées de Suceviţa et de Oituz) tout comme des diatomites de Sibiciu-Buzău ont été prélevés des échantillons afin de faire l'analyse de la composition minéralogique de la fraction lourde. Mais ce qui nous a attiré l'attention a été la fréquence et la coexistence des minéraux de zircon.

Quoique dans les lames minces des roches tuffitiques („tuf" de Falcău) on ait constaté des pourcentages très élevés de verre volcanique, dans la fraction lourde analysée, seulement dans quelques échantillons (vallée de Slănic-Moldova) le verre volcanique est non altéré et présente des pourcentages élevés (pl., fig. 10). D'autres fois, le verre s'altère et se transforme en glauconite (pl., fig. 16) ou bien il manque soit à la suite de son altération antérieure, soit à la suite de son altération au cours des traitements chimiques précurseurs à la séparation de la fraction lourde à l'aide du bromoforme. Si des oxydes de fer additionnent le long des fissures ou sur ses surfaces, il apparaît aussi dans la fraction lourde.

L'étude optique de la fraction > 0,06 mm a relevé la présence, dans la fraction légère, du quartz (arrondi ou anguleux), des feldspaths (maclés polysynthétiquement) et de la muscovite. On a identifié dans la fraction lourde 18 espèces minérales (tableau). Parmi les minéraux à grande accumulation notons les minéraux opaques, ensuite les minéraux de zircon, grenats, rutile, glauconite, pyroxènes, verre volcanique, monazite, disthène, staurotide, épidote, zoïzite, chlorite et tourmaline,

TABL

Analyse minéralogique globale des tuffites et des

No.	Lieu de provenance	Type de roche	Minéraux opaques	Verre volcanique	Pyroxènes	Hornblende	Biotite
1	Ruisseau Ţiganca-vallée Humorului	„Tuf" de Falcău	40,24	—	—	—	2,37
2	Ruisseau Dulcea-vallée Humorului		7,17	—	—	—	—
3	Ruisseau Falcău-vallée Calu		58,31	—	—	—	0,57
4	Vallée Slănic-Moldova		13,13	68,45	1,18	—	—
5	Vallée Sibiciu-Buzău	Diatomite	11,68	0,03	0,04	0,07	—

les autres minéraux tels biotite, hornblende, sphène et corindon sont accessoires (pl., figs. 7, 15 g, h).

Les minéraux opaques sont représentés par la pyrite autigène d'aspect framboïdal et ayant des formes idiomorphes de dodécaèdres pentagonaux. Les apports terrigènes ont enrichi la fraction lourde par des granules arrondies de magnétite et d'ilménite présentant de fréquentes macles polysynthétiques.

Parmi les minéraux lourds transparents qui entrent dans la constitution de la diatomite et du „tuf" de Falcău, la prémière place revient aux minéraux de zircon qui se présentent sous deux formes distinctes : silicate (a) et oxyde (b).

a) Le zircon est la forme la plus répandue de la fraction lourde des sédiments allant des plus anciens aux plus récents. Le zircon des échantillons analysés apparaît soit à titre de prismes allongés selon l'axe principal (pl., fig. 7 a), soit en tant que prismes à terminaisons pyramidales selon la face (111) (pl., figs. 4 b, 11, 12) et plus rarement sous formes de granules arrondies (pl., fig. 15 f), très rarement allongées.

Saxena (1966) décrit bon nombre des formes du zircon qui vont des granules euédriques, anédriques, ellipsoïdales aux prismes allongés à pyramides obtuses.

Dans quelques échantillons du „tuf" de Falcău ont été identifiés des cristaux de zircon à surcroissances ou bourgeonnements sur l'une des faces latérales du prisme (100) ou bien (110), (pl., figs. 6, 8, 13). On distingue chez quelques cristaux (pl., fig. 8) des zones marginales opacitisées tant au cristal mère qu'au bourgeon, parallèles à celles intérieures de la partie transparente. En concrescence avec le zircon apparaissent aussi bien des baguettes de titanite (pl., fig. 8) que du baddeleyite (pl., fig. 6).

Saxena (1966) décrit le processus de surcroissance du zircon, en mentionnant plusieurs étapes de passage des formes prismatiques aux

EAU

diatomites de l'Oligocène-Miocène inférieur %

Baddeleyite	Zircon	Glauconite	Rutile	Grenats	Monazite	Disthène	Staurotide	Epidote-Zoïzite	Chlorite	Tourmaline	Titanite	Chloritoïde
—	17,99	4,74	1,68	12,26	8,37	2,19	1,52	—	—	—	1,60	—
62,53	13,44	—	3,14	8,66	—	2,70	—	3,61	0,58	2,31	—	—
24,67	8,82	—	1,65	1,86	—	0,71	1,44	0,97	0,49	0,61	0,39	—
—	9,05	5,25	—	2,96	—	—	—	—	—	—	—	—
83,28	1,28	—	0,28	1,63	0,06	0,57	0,50	—	—	0,53	—	0,04

formes arrondies munies de surfaces claires ou à inclusions, en supposant qu'il s'agirait de deux périodes de formation du zircon : par autigenèse dans les roches sédimentaires et par syngenèse dans les roches métamorphiques.

b) L'oxyde de zircon est rarement rencontré et il est connu sous le nom de baddeleyite ou brasilite. Le minéral porte le nom de son découvreur, Baddeley, étant le premier qui l'a identifié en Sri-Lanka (Ceylon) au XIX^{e} siècle. Son grande extension au Brésil (Husak, 1899) a mené certains auteurs de le dénommer brasilite. Il est vrai qu'en 1930 à Pocos de Caldas (Brésil) ce minéral a été exploité pour ses contenus petits de hafnium, uranium, thorium, niobium, fer et cuivre.

Occurence. En Roumanie, le baddeleyite a été mentionné dans le cristallin des monts Preluca, dans la zone de contact des calcaires avec les pegmatites (Stanciu, 1955). Ultérieurement, le baddeleyite a été rencontré dans les alluvions provenues du massif siénitique de Ditrău sous forme de granules de teinte brune, en association avec zircon, grenats, monazite, rutile, titanite, ilménite et d'autres (Codarcea et al., 1958).

En plus du baddeleyite primaire accessoire, il a été obtenu, dans notre pays, des masses fondues de silicates en mélange avec Al_2O_3 et SiO_2 nécessaires à l'industrie des matériaux de construction (Mercus, 1981).

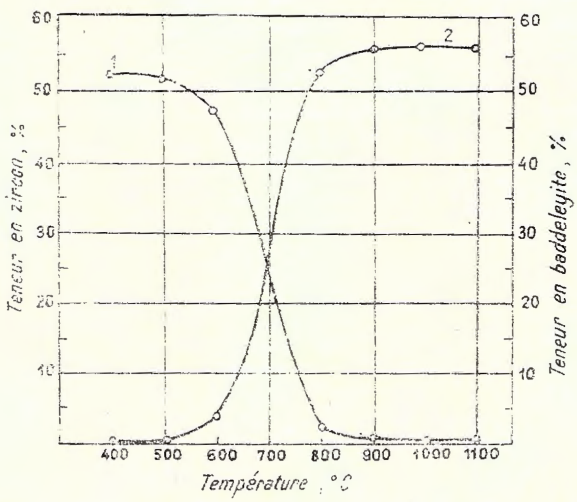

Fig. 1. — Température de formation du zircon et du baddeleyite (selon Abdel Rahim, 1976).

D'autres chercheurs (Abdel Rahim, 1976) montrent que le processus de séparation du zircon et du baddeleyite des masses fondues de zircon en mélange avec Al_2O_3 et SiO_2 soumis à des élévations progressives de température, détermine la séparation de ces deux minéraux à des intervalles précis (fig. 1).

Le baddeleyite a été cité à titre de minéral primaire contenu en divers types de roches comme âge et origine (magmatiques, métamorphiques et sédimentaires), non seulement dans l'espace terrestre que celui extraterrestre (la lune).

Siivola (1977), Keil et Fricker (1974), Frantsensson (1970), Fieremans et Ottenburg (1979), Raber et Haggerty (1977), Peres et Gomez (1968), Konev (1978) et Heinrich (1970) mentionnent le baddeleyite dans les roches diabasiques et gabbroïques, kimberlites, carbonatites, skarns, intrusions pegmatoïdes et alluvions.

Ramdohr (1974) analysant les échantillons recueillis de la lune par les vaisseaux spatiaux Apollo 11 et Apollo 12 mentionne, en association avec le zircon et le baddeleyite, une série de minéraux comme ulvospinelle, rutile et d'autres. L'auteur décrit le baddeleyite sous la forme de microagrégats de teinte brun-jaunâtre, voisins de ceux rencontrés par nous.

Caractères optiques et mode de présentation. Dans nos échantillons le baddeleyite apparaît d'habitude sous forme de granules isolées (pl., fig. 5) ou groupées jusqu'à de véritables concroissances s'ils ont des dimensions plus grandes (pl., fig. 2) ou d'agglomérations en plage s'ils ont des dimensions petites (pl., figs. 1, 3, 9).

Les différences optiques entre le zircon et le baddeleyite sont évidentes, puisque le baddeleyite est brun-jaunâtre, et le zircon est le plus souvent incolore ; le baddeleyite cristallise dans le système monoclinique, est négatif et a une extinction de 10° à 13°, alors que le zircon cristallise en système tétragonal, est positif (très rarement biaxe) et a une extinction droite. Le pléocroïsme du baddeleyite va des nuances rouge-brunes sur z, vert foncé sur y et rouge-brunes sur x ; la dispersion du baddeleyite est forte tout comme la biréfringence ; 2E est très grande (70°) et l'indice de réfraction est fort élevé : ng = 2,20 ; np = 2,13 ; le zircon ne présente pas de clivage, le baddeleyite a un bon clivage basal. Le poids spécifique du zircon est de 4,6 à 4,7, celui du baddeleyite est de 5,6. La température de formation de ces minéraux est différente ainsi que leurs points de fusion.

Pour identifier le cation Zr^{+4}, l'étude optique a été complétée des résultats des analyses spectrales, thermodifférentielles et röntgénographiques [3].

Les analyses A.T.D. ont relevé deux effets endotermes pour le zircon à 680°C et à 1115°C et pour le baddeleyite un effet exoterme à 580°C et deux effets endotermes, l'un à 850°C et l'autre au-dessus de la température de fusion du zircon.

Les diffractogrammes ont été obtenus avec l'appareil TUR M. 61 à radiations de K α, à anticathode de Cu. Les analyses ont donné les valeurs suivantes pour les distances intraréticulaires : 3,29–3,30 ; 2,51–2,52;

2,06-2,07 pour le zircon et 3,67-3,71 ; 3,16-3,18 ; 2,53-2,55 pour le baddeleyite (fig. 2).

Le rapport entre le nombre moyen de granules de zircon et de baddeleyite des roches tuffitiques étudiées ainsi que des diatomites de Sibiciu-Buzău est visiblement en faveur du baddeleyite qui repré-

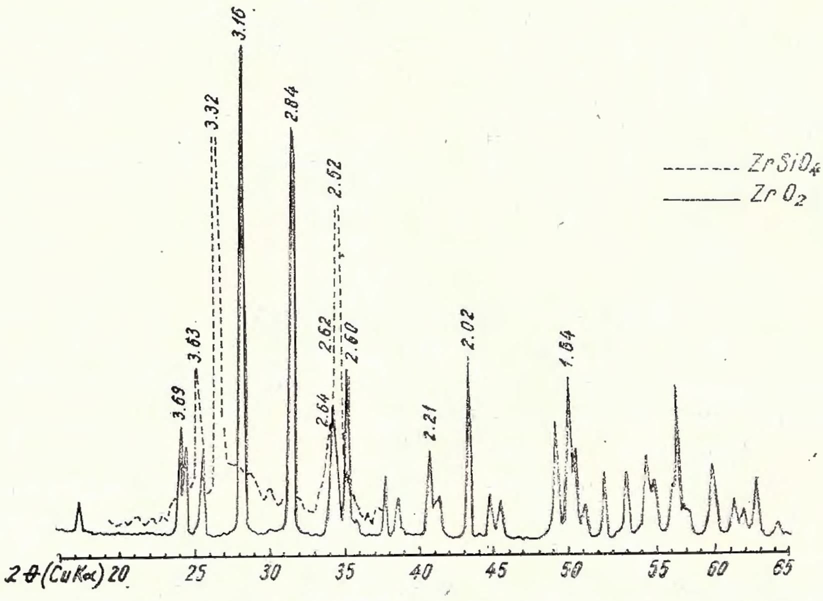

Fig. 2. — Diffractogramme du zircon et du baddeleyite.

sente 62,53% et respectivement 83,28% en comparaison du zircon représentant 13,44%, respectivement 1,28%. Si nous considérons que ces pourcentages sont rapportés à la fraction lourde des roches tuffitiques et de la diatomite qui pèse environ un gramme de 100 grammes d'échantillon analysé, les pourcentages revenant à ces deux minéraux lourds sont notamment symboliques, nous aidant seulement en vue de préciser les caractères optiques et d'établir les associations paragénétiques.

Conclusions. La présence des minéraux de zircon des roches tuffitiques („tuf" de Falcău) et des diatomites de Sibiciu-Buzău constitue la caractéristique minéralogique de ces dépôts, en suggérant l'existence de deux provinces terrigéno-minéralogiques, à paragenèses à part :

— zircon+baddeleyite±verre volcanique+glauconite±pyroxènes pour le „tuf" de Falcău ;

— baddeleyite+minéraux opaques pour la diatomite.

Les associations paragénétiques mentionnées et la coexistence des multiples aspects morphoscopiques des minéraux relèvent que les matériaux de la source principale de ces deux minéraux de zircon ont été repris par les cycles répétés de remaniement ; les surcroissances et les bourgeonnements par autigenèse des cristaux de zircon sont antérieurs à la formation des roches tuffitiques et des diatomites.

[3] Déterminations effectuées par C. Udrescu, V. Iosof et I. Vanghelie à qui nous adressons nos remerciements.

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QUESTION

Al. Szakacs : Quelle est la composition volcanique de la tuffite en question?

Réponse : La composition éruptive-volcanique de la „tuffite" de Falcău, tuffite qui a généré les cristaux de zircon et de baddeleyite, est représentée surtout par verre, à valeurs de 80 à 85% dans la masse de la tuffite, pyroxènes à pourcentages réduits, hornblende et biotite.

DISCUSSION

M. Micu : Si le baddeleyite est un minéral relativement rare dans les associations de minéraux lourds (peu connu chez nous du fait du nombre réduit des études) il est à noter que les échantillons de Moldova proviennent d'un niveau stratigraphique différent par rapport aux niveaux de la vallée du Buzău.

PREZENŢA ZIRCONULUI ŞI A BADDELEYITULUI ÎN UNELE ROCI TUFITICE ŞI DIATOMITE DIN ZONA EXTERNĂ A CARPAŢILOR ORIENTALI

(Rezumat)

Zona externă a Carpaţilor Orientali din ţara noastră aparţinînd la două unităţi structurale majore (unitatea de Tarcău şi unitatea cutelor marginale) are intervalul Oligocen-Miocen inferior dezvoltat într-un facies particular, cu roci bituminoase, roci silicioase (menilite) şi arenite cuarţoase de tip Kliwa.

În conexiune cu rocile menţionate în părţile centrală şi nordică a Carpaţilor Orientali, se găsesc roci tufitice cu diferite grade de alterare cantonate în şisturile disodilice superioare şi în menilitele superioare (Alexandrescu et al., 1984).

Analiza mineralogică a fracţiei grele din probele recoltate din nivelul tufaceu, „tuful" de Falcău între văile Suceviţa-Oituz şi din diatomitele de la Sibiciu-Buzău, a evidenţiat prezenţa mineralelor de zirconiu.

Studiul optic al fracţiei > 0,06 mm a pus în evidenţă în cadrul fracţiei grele 18 specii minerale (tabel), care în ordine descrescătoare sînt : minerale opace, minerale de zirconiu, granaţi, rutil, glauconit, piroxeni, sticlă vulcanică, monazit, disten, staurolit, epidot, zoizit, clorit şi turmalină, iar biotitul, hornblenda, sfenul şi corindonul sînt accesorii. Dintre acestea specifice erupţiilor care au dat naştere rocilor tufitice respective în afara sticlei vulcanice sînt piroxenii, biotitul şi hornblenda (pl., fig. 7 b, fig. 15 h).

Mineralele de zirconiu sînt reprezentate prin : ortosilicatul de zirconiu și oxidul de zirconiu, cunoscut sub numele de baddeleyit sau brazilit.

În preparatele noastre baddeleyitul apare sub formă de granule izolate (pl., fig. 5) sau grupate pînă la veritabile concreșteri cînd ating dimensiuni mai mari (pl., fig. 2) ; iar atunci cînd sînt de dimensiuni mici formează aglomerări în plajă (pl., fig. 1, 3, 9) asemănătoare celor descrise în probele aduse de pe Selena de navele spațiale Apollo 11 și 12.

Raportul dintre numărul mediu de granule de zircon și de baddeleyit este net în favoarea baddeleyitului comparativ cu zirconul.

Sursa principală a zirconului și a baddeleyitului au fost materialele reluate în repetatele cicluri de remaniere, iar supracreșterile și înmuguririle prin autigeneza cristalelor de zircon sînt anterioare formării rocilor tufitice și diatomitelor.

EXPLICATION DE LA PLANCHE

Fig. 1. — Baddeleyite (a) et chlorite (b) ; échantillon 69, ruisseau Dracului-Geamăna ; N || ; × 25.

Fig. 2. — Baddeleyite ; échantillon 2, vallée de Sibiciu-Buzău ; N || ; × 125.

Fig. 3. — Baddeleyite ; échantillon 1, ruisseau de Falcău-vallée Calu ; N || ; × 25.

Fig. 4. — Sphène (a) et zircon (b) ; échantillon 2961 ; ruisseau Țiganca-vallée Humorului ; N || ; × 120.

Fig. 5. — Baddeleyite ; échantillon 3, vallée de Sibiciu-Buzău ; N || ; × 125.

Fig. 6. — Zircon à surcroissance ; échantillon 4, ruisseau Dulcea-vallée Humorului ; N || ; × 125.

Fig. 7. — Zircon (a) et biotite (b) ; échantillon 1, ruisseau de Falcău-vallée Calu ; N || ; × 120.

Fig. 8. — Zircon en bourgeons ; échantillon 2, ruisseau Dulcea-vallée Humorului ; N || ; × 125.

Fig. 9. — Baddeleyite ; échantillon 2, ruisseau Brusturatu-vallée du Tazlău ; N || ; × 25.

Fig. 10. — Verre ; échantillon 3, vallée du Slănic-Moldova ; N || ; × 125.

Fig. 11. — Zircon ; échantillon 3, vallée du Slănic-Moldova ; N || ; × 25.

Fig. 12. — Zircon ; échantillon 5, ruisseau de Falcău-vallée Calu ; N || ; × 25.

Fig. 13. — Zircon à surcroissance latérale ; échantillon 3, ruisseau de Falcău-vallée Calu ; N || ; × 125.

Fig. 14. — Spicule de spongiaire ; échantillon 3, vallée du Slănic-Moldova ; N || ; × 125.

Fig. 15. — Ensemble de minéraux lourds ; échantillon 4, ruisseau Dulcea-vallée Humorului : a, disthène ; b, grenats ; c, rutile ; d, tourmaline ; e, chlorite ; f, zircon, g, grenats, h, augite ; N || ; × 25.

Fig. 16. — Granules de glauconite ; échantillon 2961, ruisseau Țiganca-vallée Humorului ; N || ; × 25 (125).

Les nombres de provenance des échantillons représentent les nombres des points d'observation en terrain.

D. S. Inst. Geol. Geofiz. vol. 70-71/1 (1983 ; 1984), 1986, pag. 551

1. MINERALOGIE — PETROLOGIE — GEOCHIMIE

BOOK REVIEW

E. A. ROMANKEVICH : *Geochemistry of Organic Matter in the Ocean.* Springer Verlag, 1984, 334 p., 68 Figures, 77 Tables.

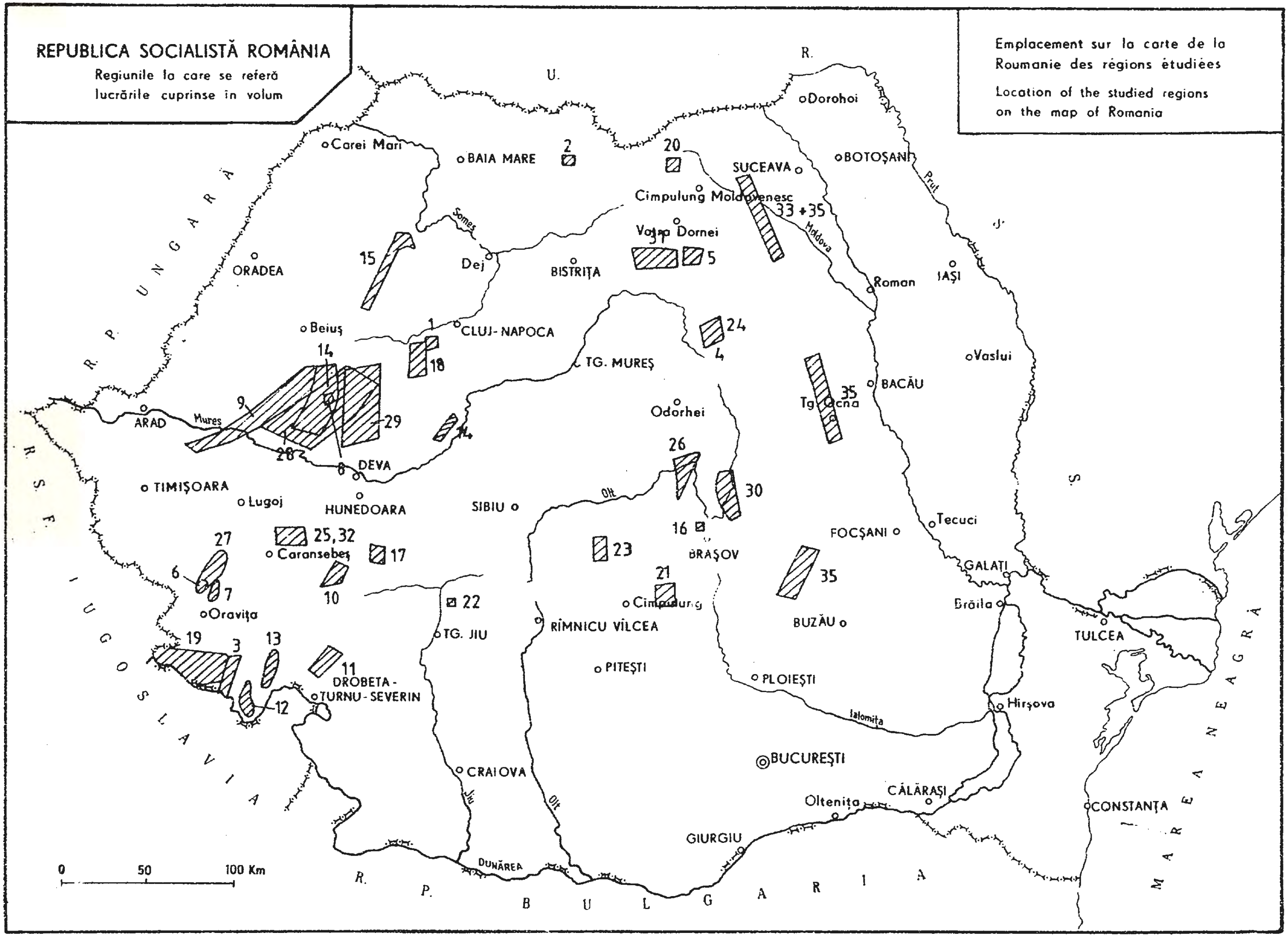
A landmark in the development of the ocean biochemistry, Romankevich's book gives a complete overview on the fate of organic matter in the Ocean ; the source of organic matter (coming not only from rivers but also through eolian transfer as well as by cosmogenic input and technogenous pollution), its distribution and transformation during sedimentation and diagenesis are minutely presented ; on such a basis the evaluation of the oil and gas forming potentialities in the oceans is further discussed. It is thus worth noticing that practically all the organic matter (up to 90%) accumulates in the sediments of continental slopes suggesting thus the major ocean areas favourable for hunting submarine oil fields.

The book is subdivided into 9 chapters ; the first one deals with the "Sources of organic matter in the ocean", including both autochthonous and allochthonous sources (26 p.) ; the second chapter (27 p.) gives data on "Carbon of dissolved organic matter in the ocean" (total quantity, time of residence, distribution patterns) ; chapter 3, "Carbon of particulate organic matter" (59 p.) and 4, "Organic carbon in late Quaternary sediments of seas and oceans" (56 p.) are the most extensive and full of information. "Nitrogen and phosphorus in the process of sedimentogenesis" form the matter of the chapter 5 (26 p.). Chemical form of the organic matter is presented in the chapters 6, "Proteinaceous compounds and aminoacids", (12 p.), and 7 "Carbohydrates" (30 p.). "Chemical transformation of lipids during sedimentogenesis" is treated in chapter 8. The last chapter (9) of the book is that dealing with "Specific organic compounds" (20 p.) (such as humic substances). The book ends with "Conclusions" (10 p.) and a very extensive and useful lot of "References" (30 p.).

Unfortunately, the book lacks a subject index which would have facilitate the "discovery" of items in such an information-rich volume. However, the structure of each chapter may partly substitute for the index.

This useful book will surely find a large number of readers among which also many geoscientists interested in an up-to-date overview on one of the most important compounds of marine sediments, i.e. the organic matter and its manifold aspects and its bearing on oil formation.

G. Udubașa



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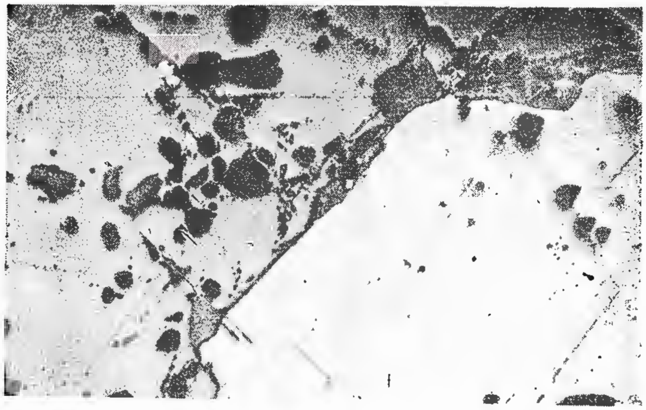

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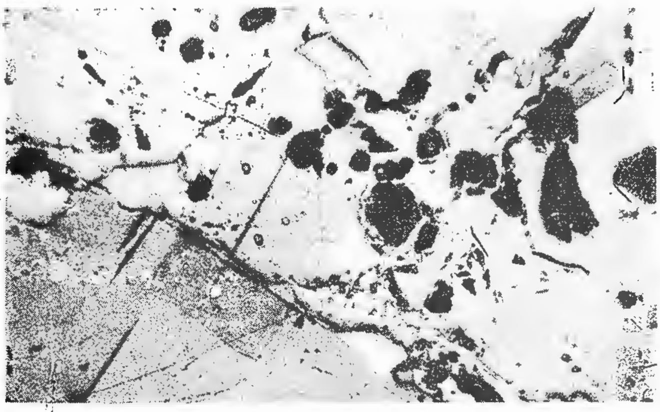

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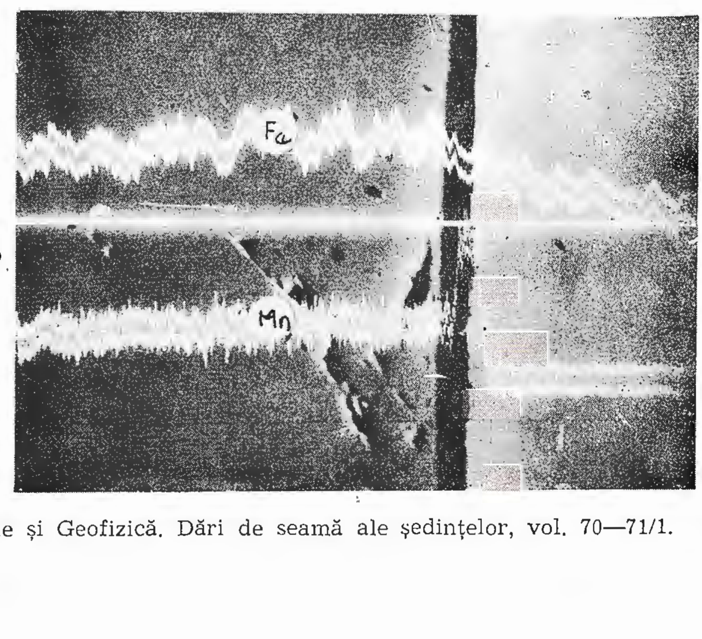

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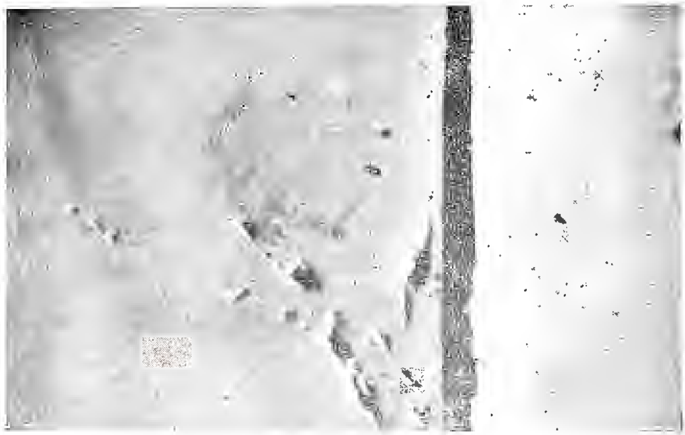

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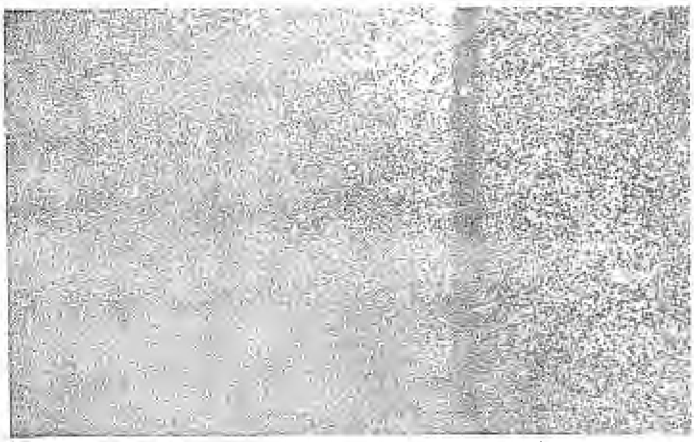

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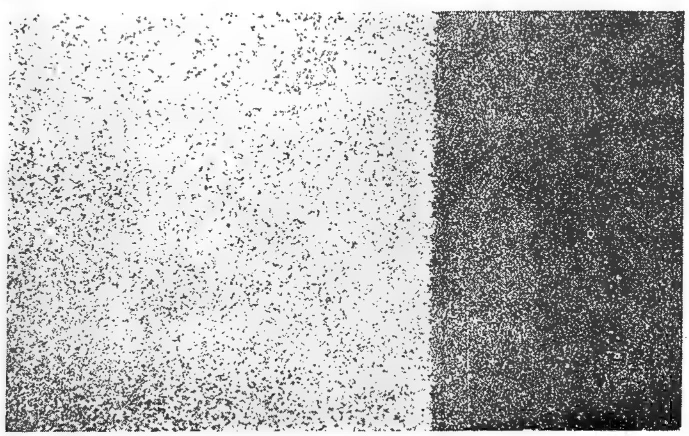

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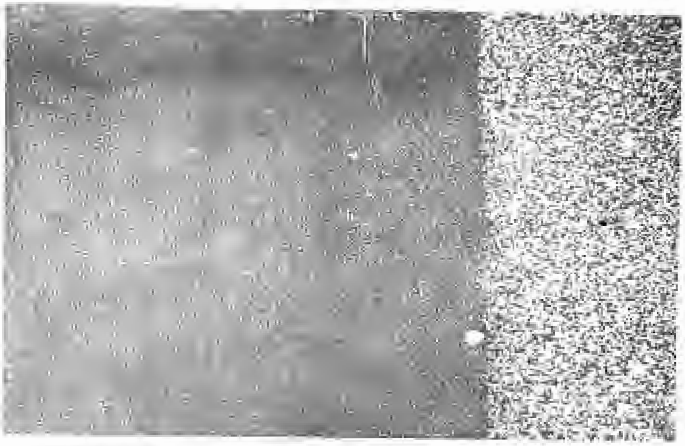

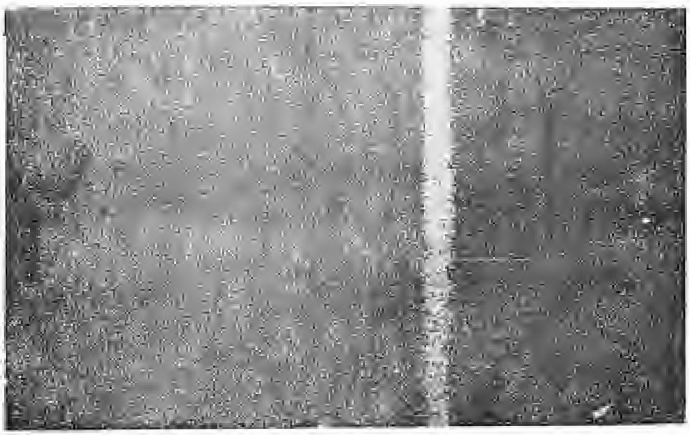

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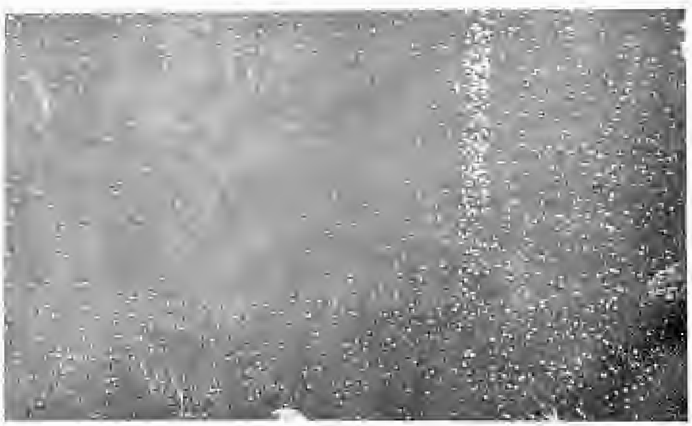

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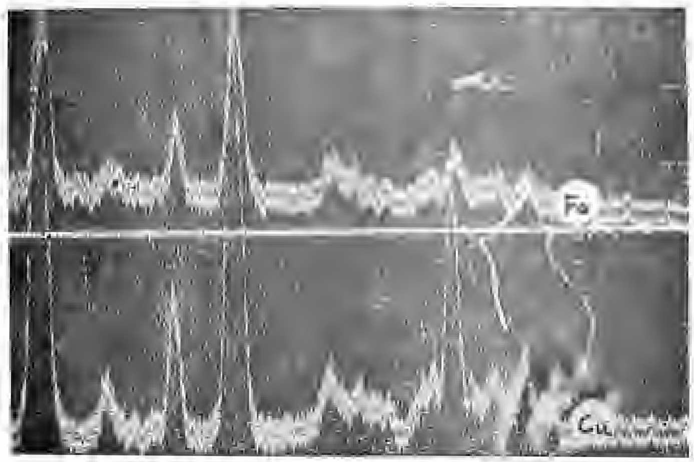

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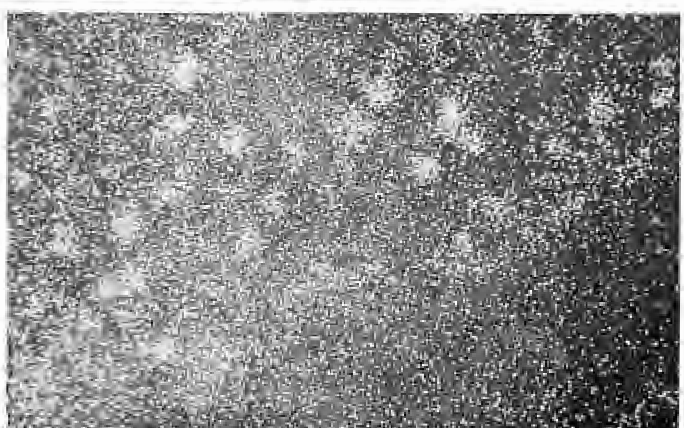

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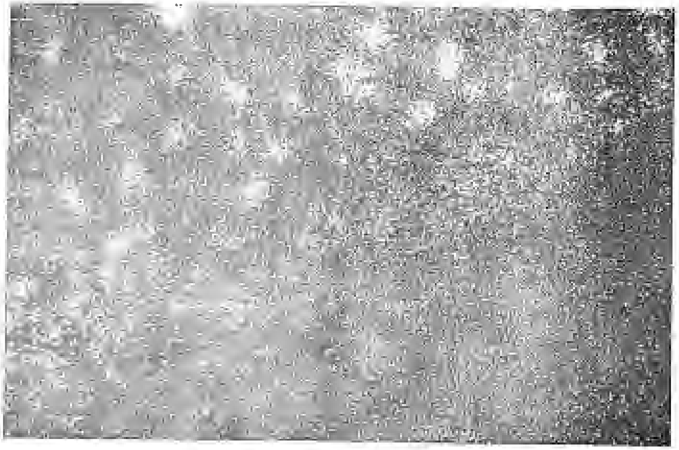

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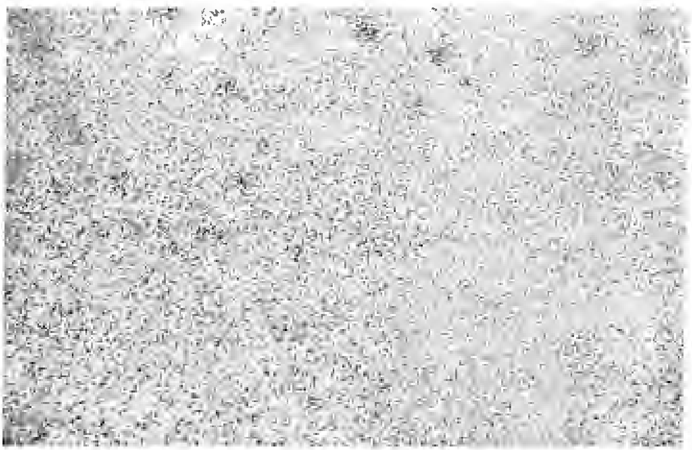

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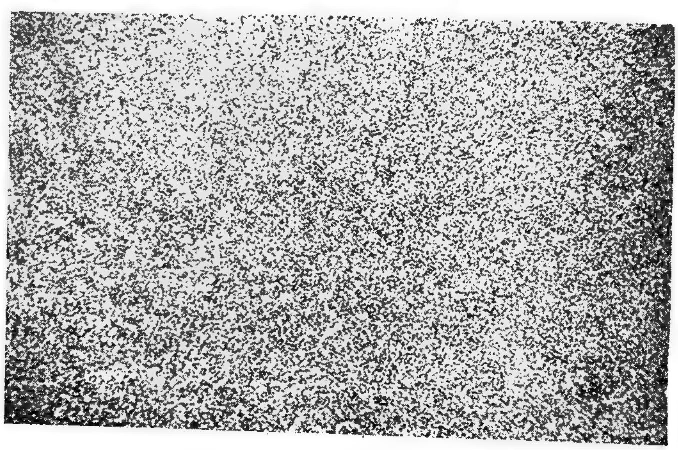

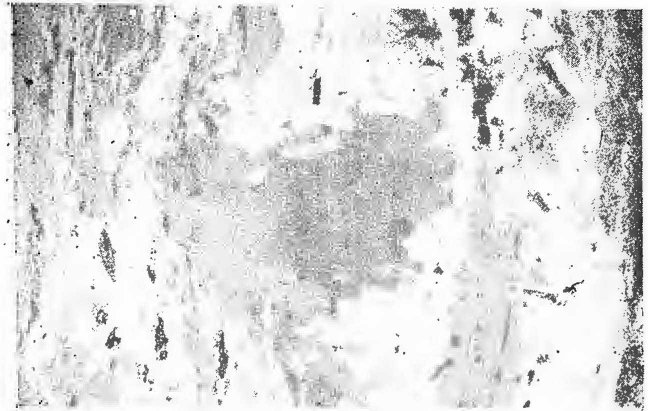

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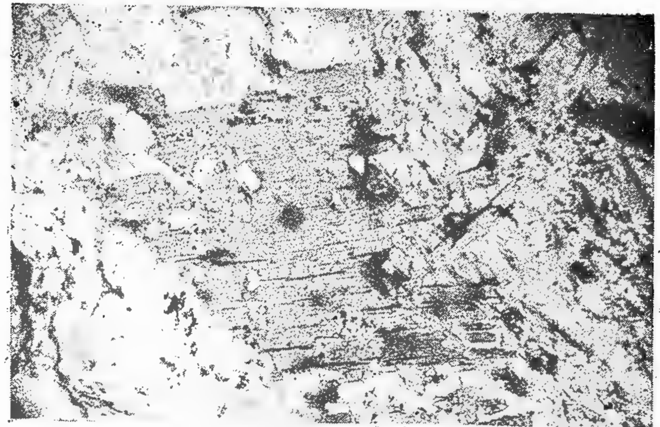

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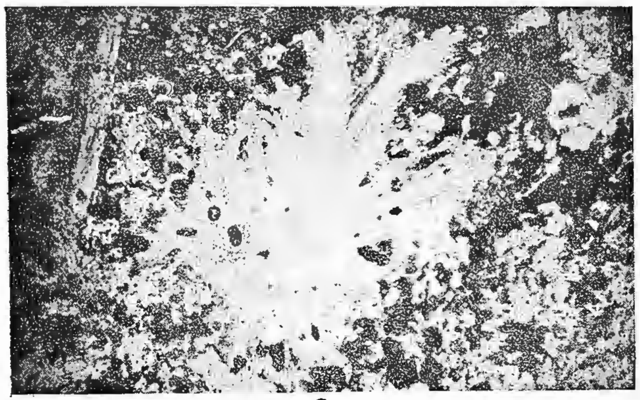

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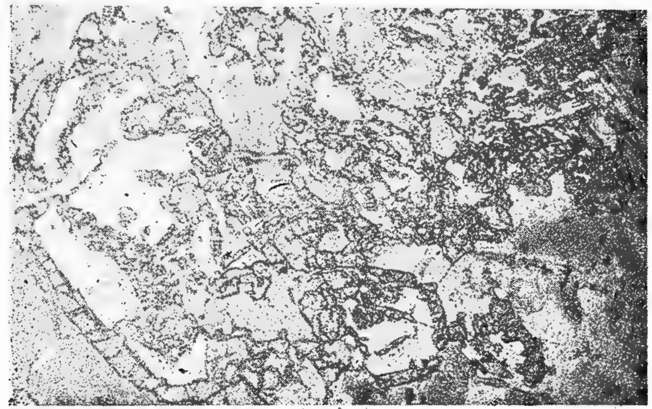

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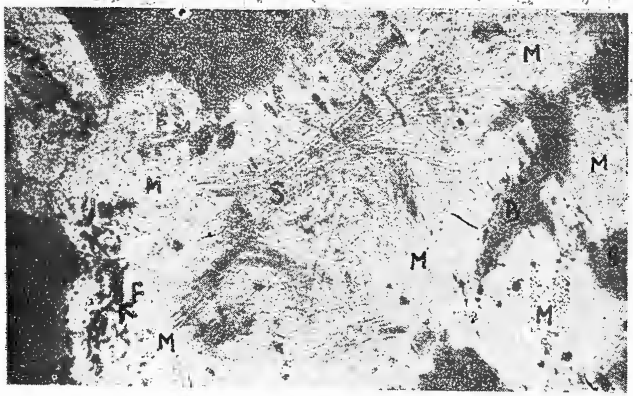
S. MÎNZATU, G. JAKAB. Auréole de contact du massif Ditrău (Lăzarea). Pl. II



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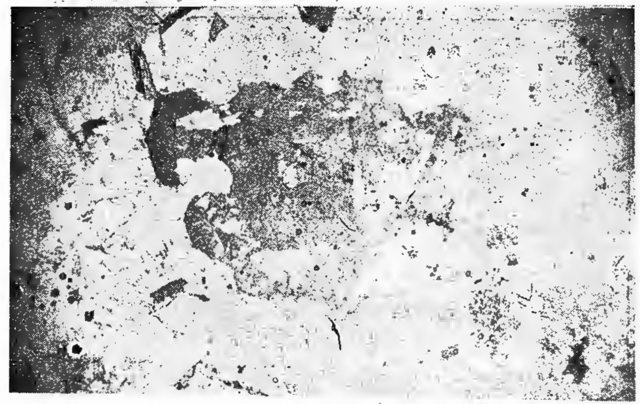

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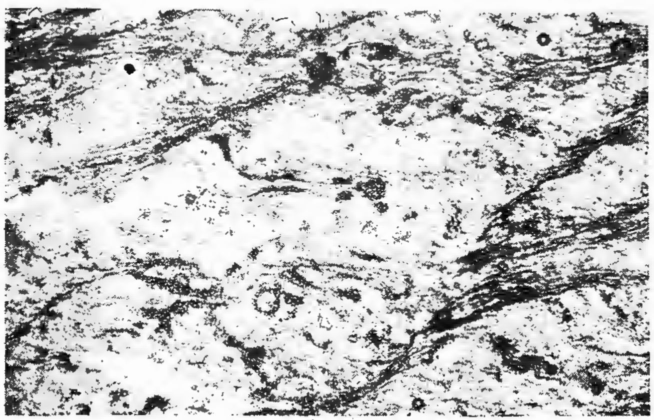

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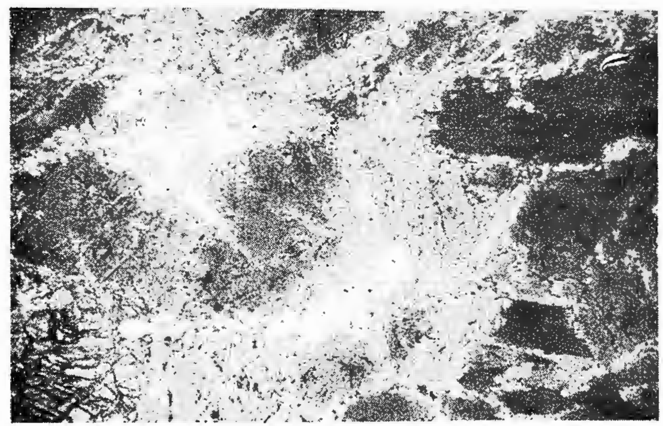

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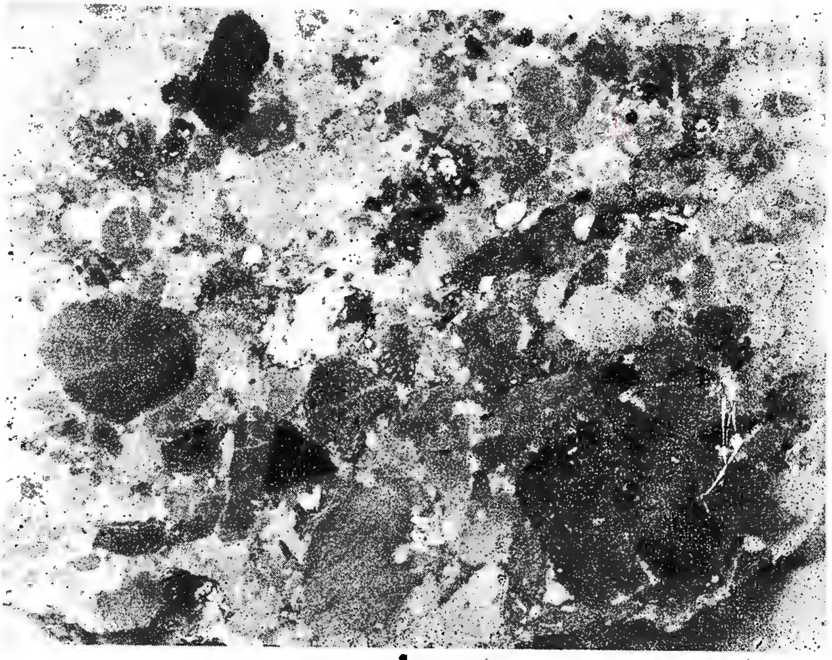

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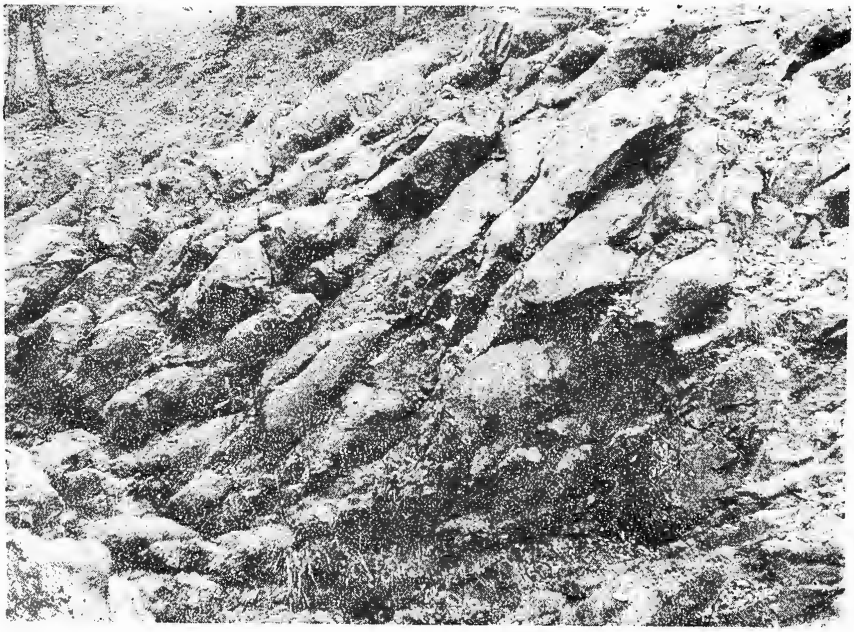

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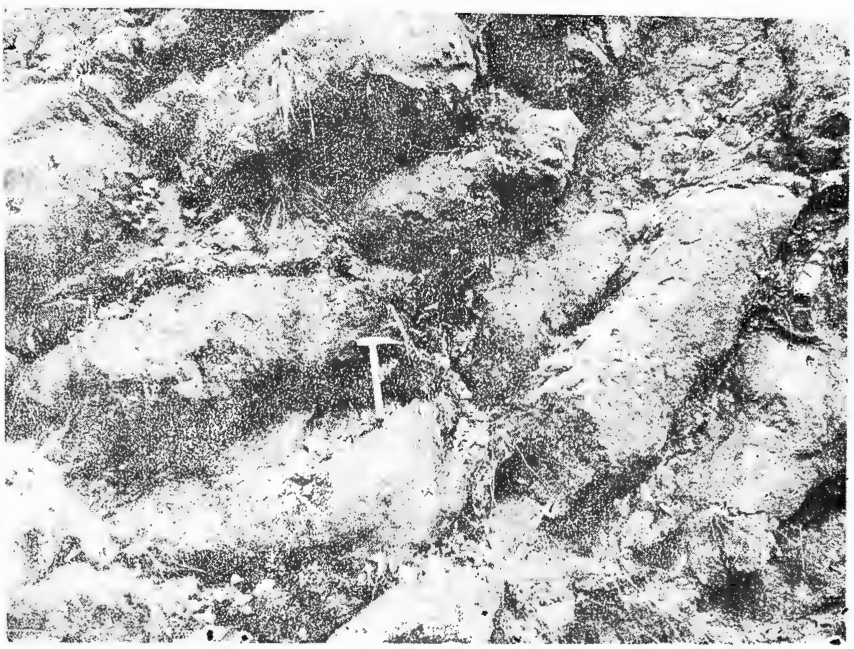

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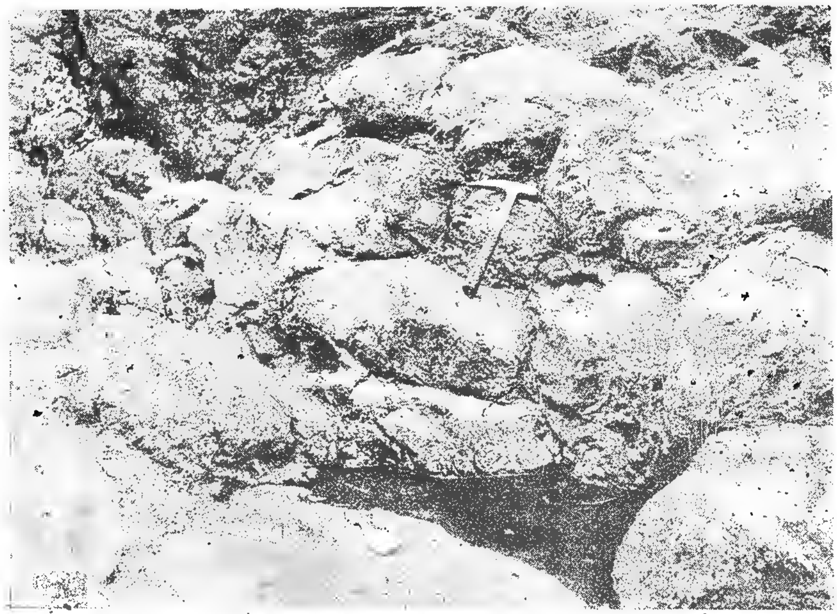

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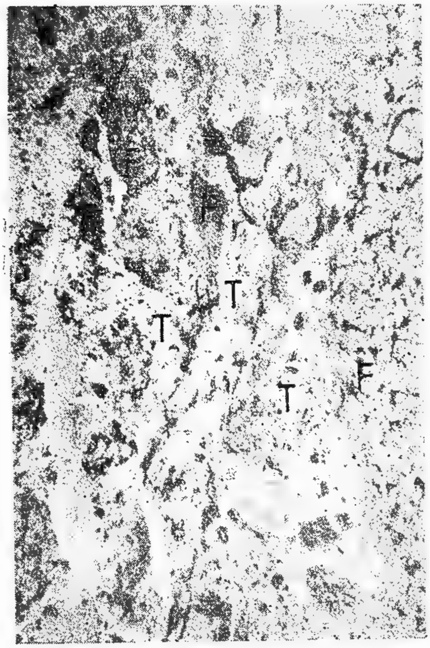

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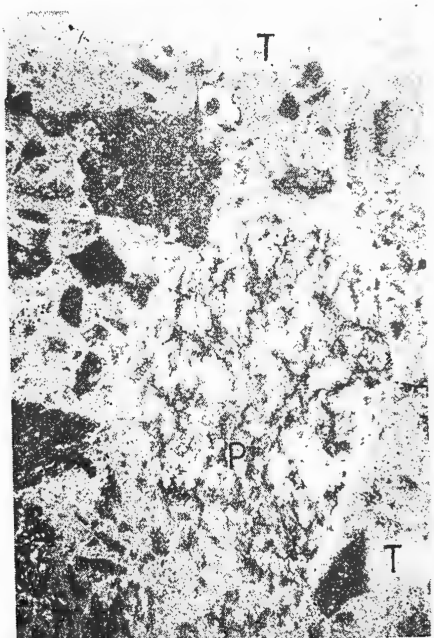

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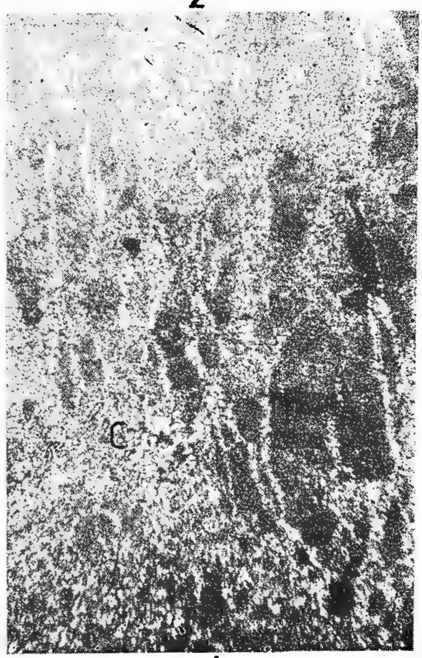

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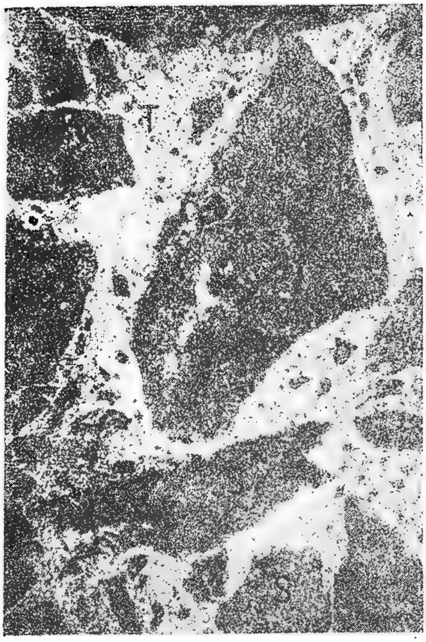

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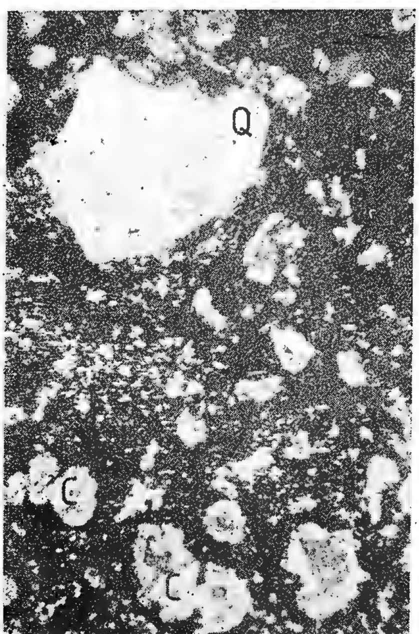

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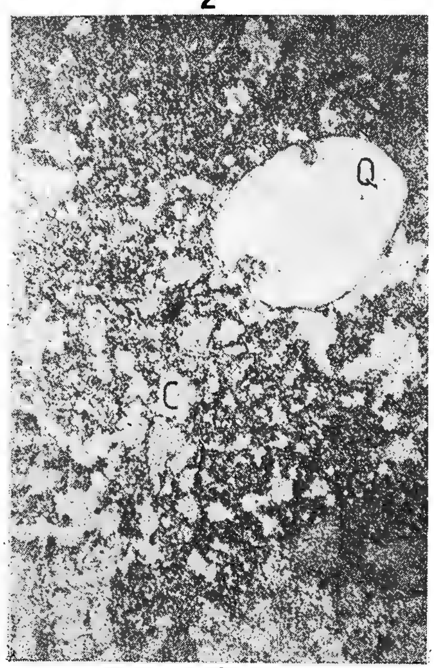

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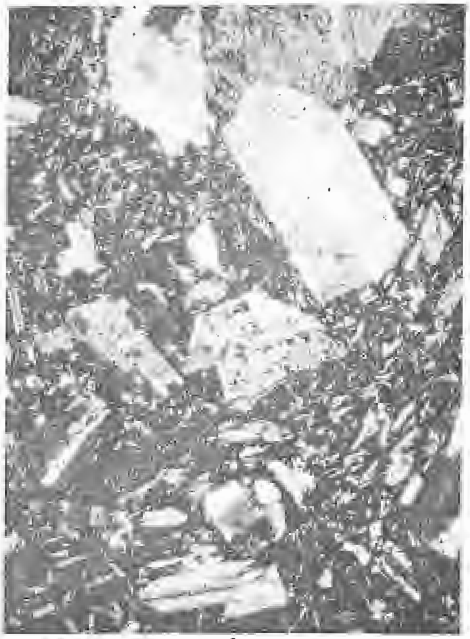

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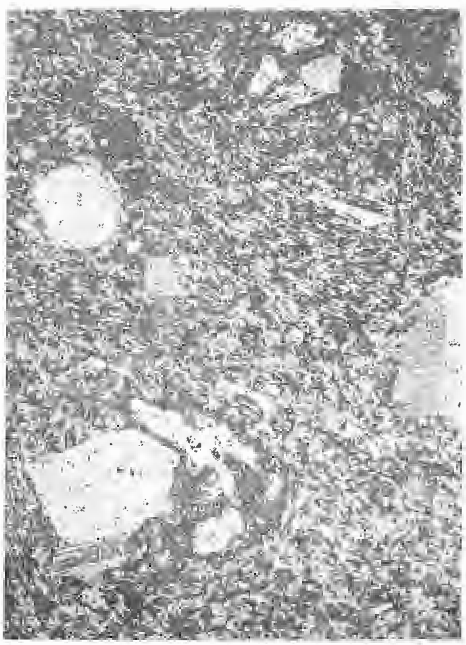

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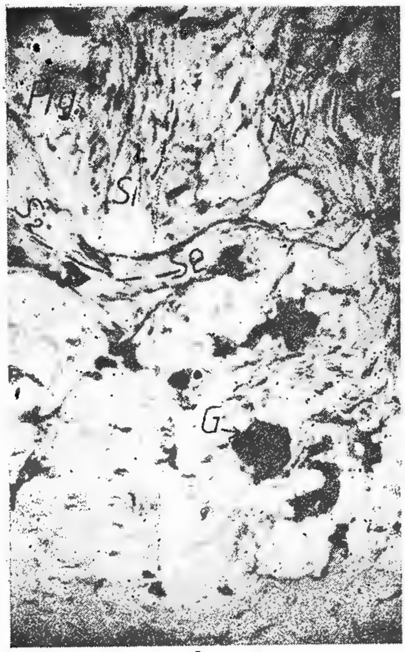

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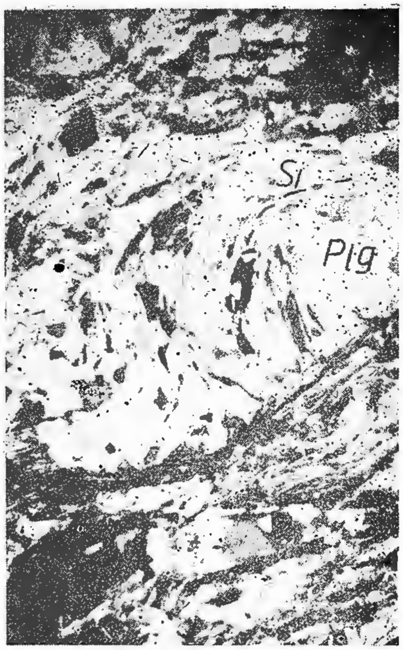

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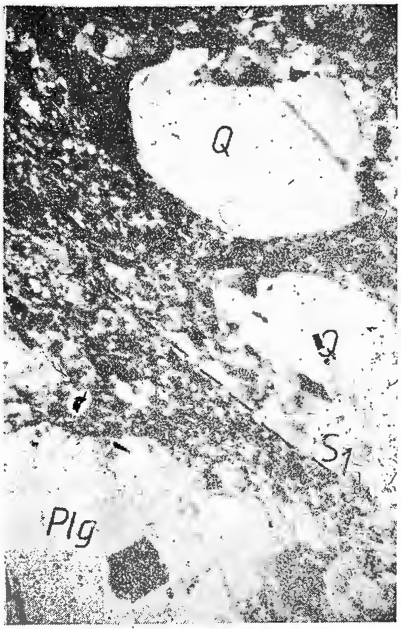

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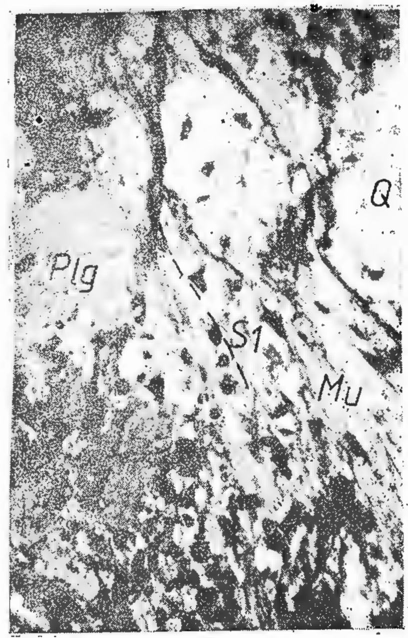

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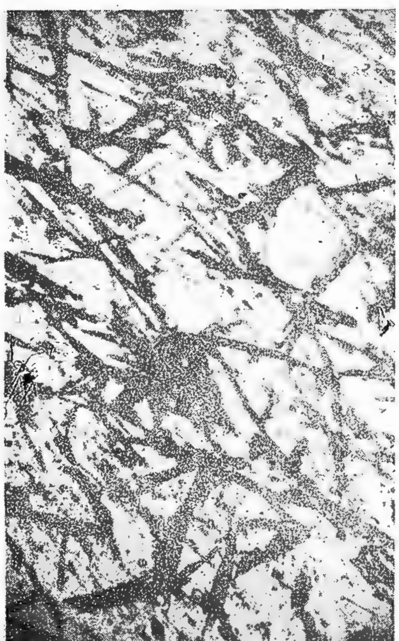

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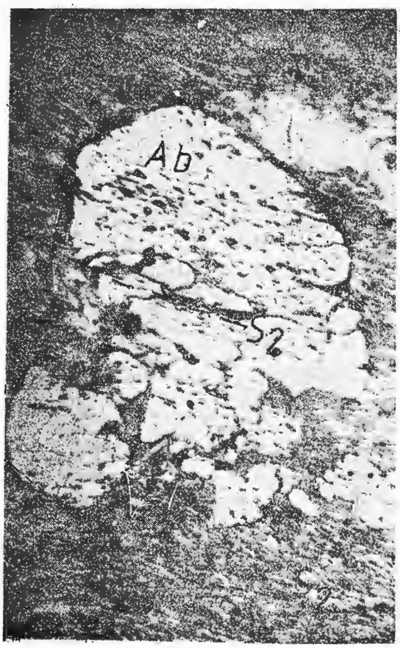

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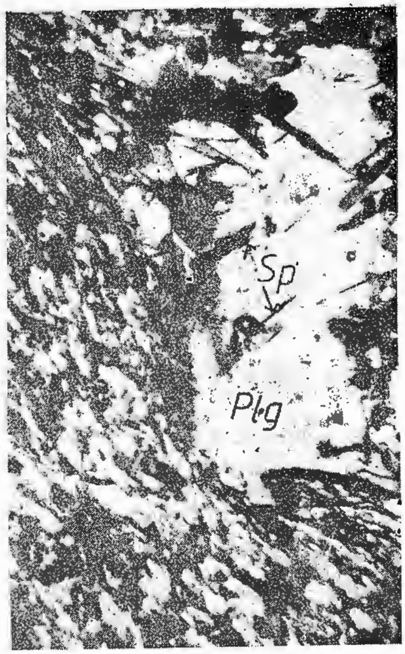

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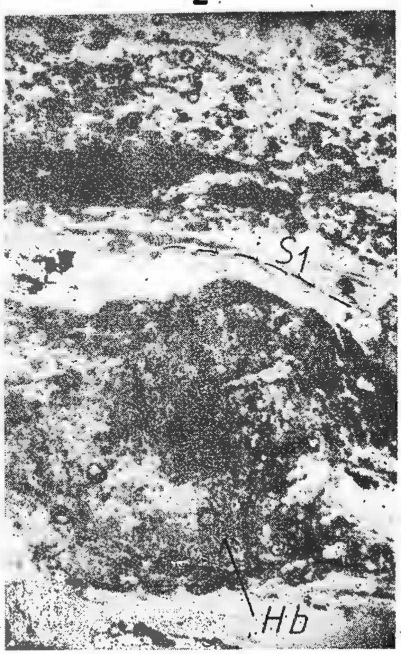

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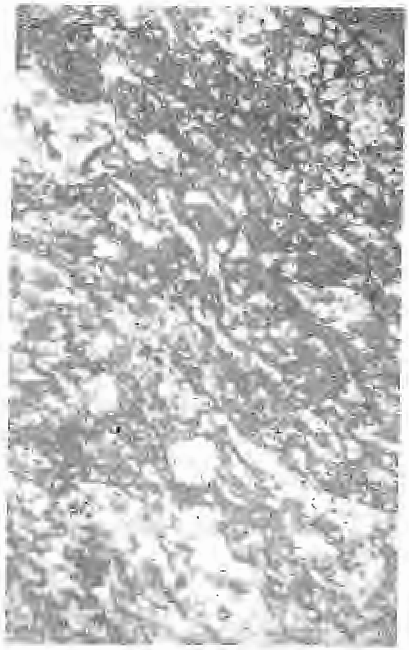

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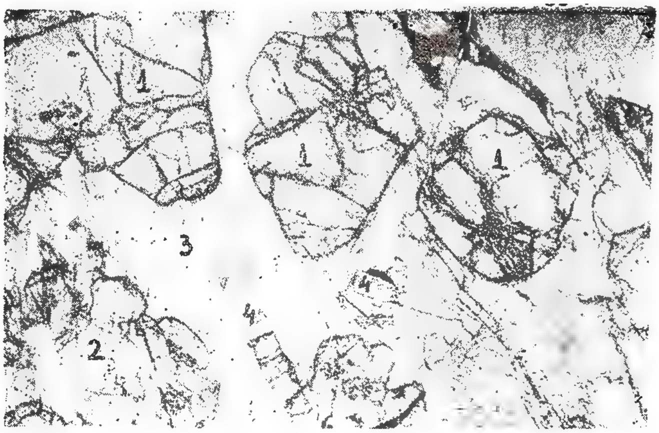

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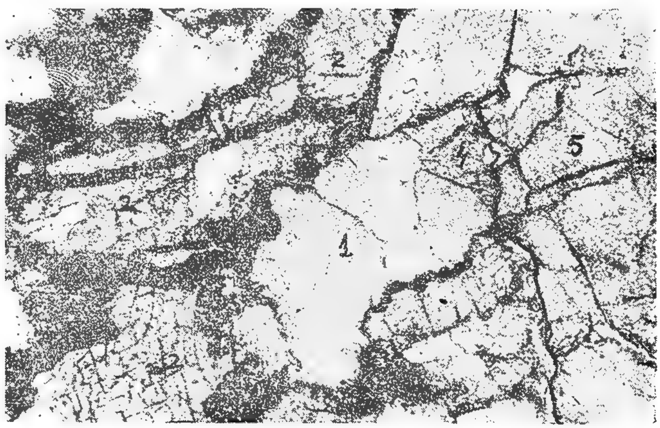

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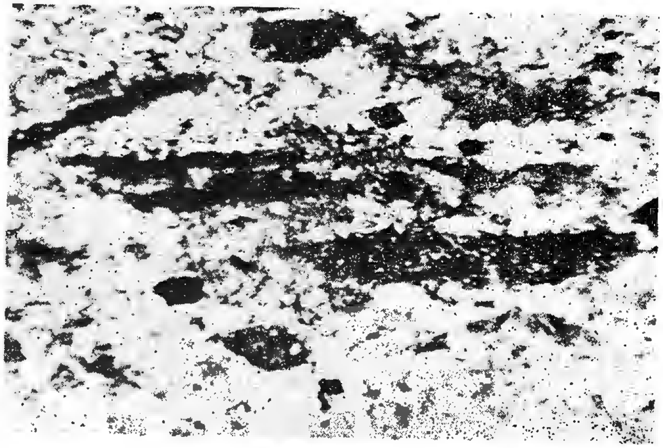

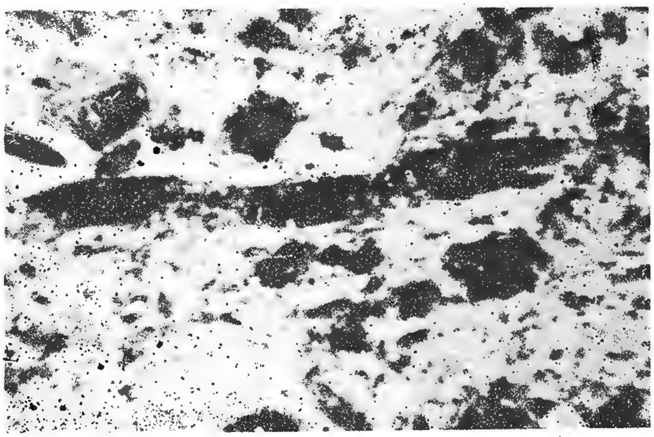
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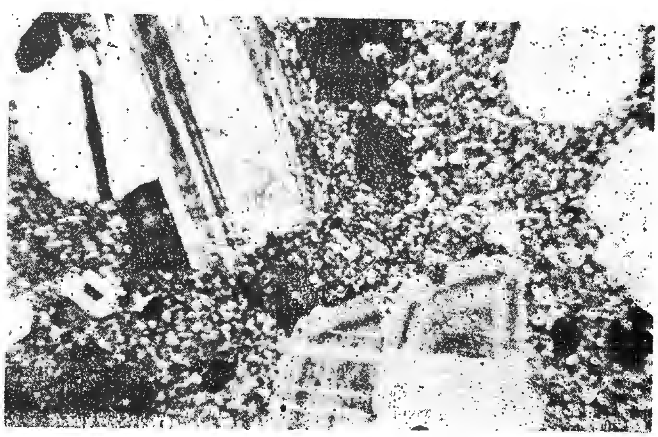

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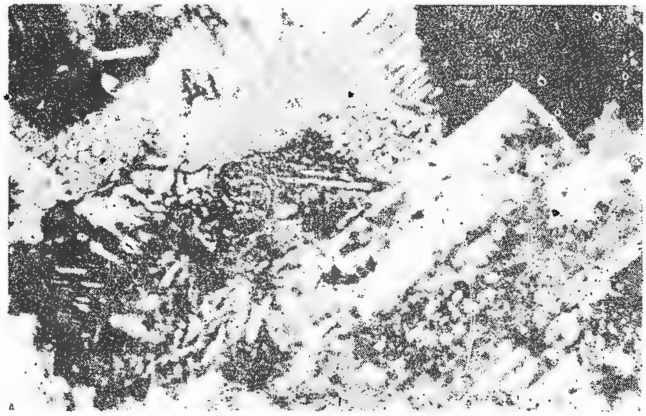

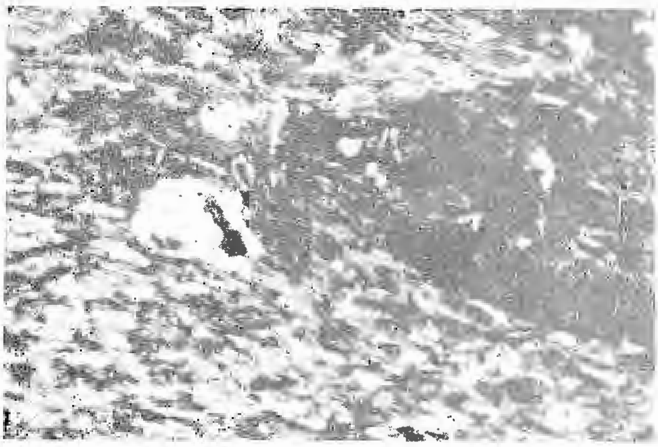
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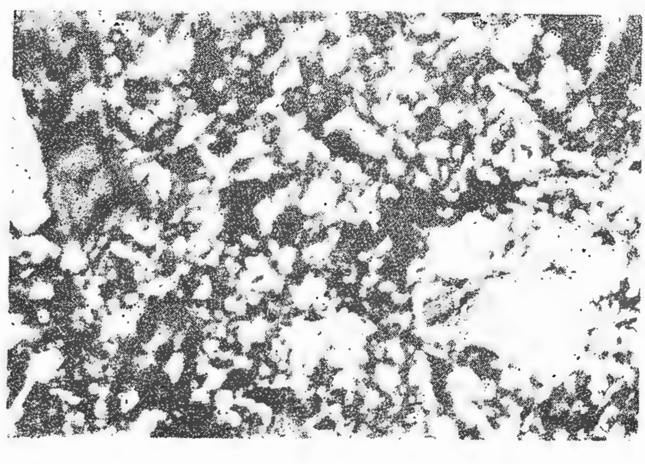

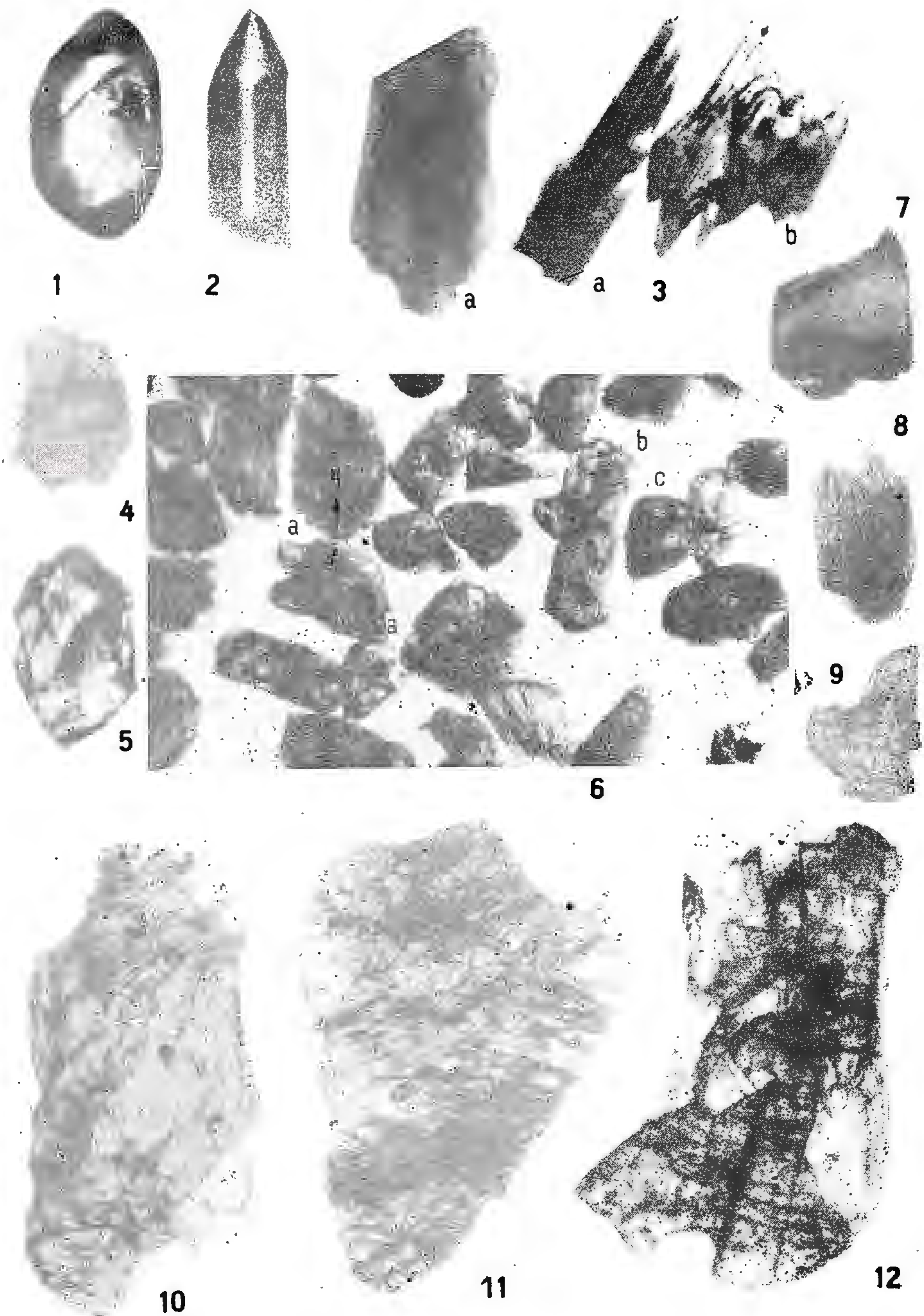
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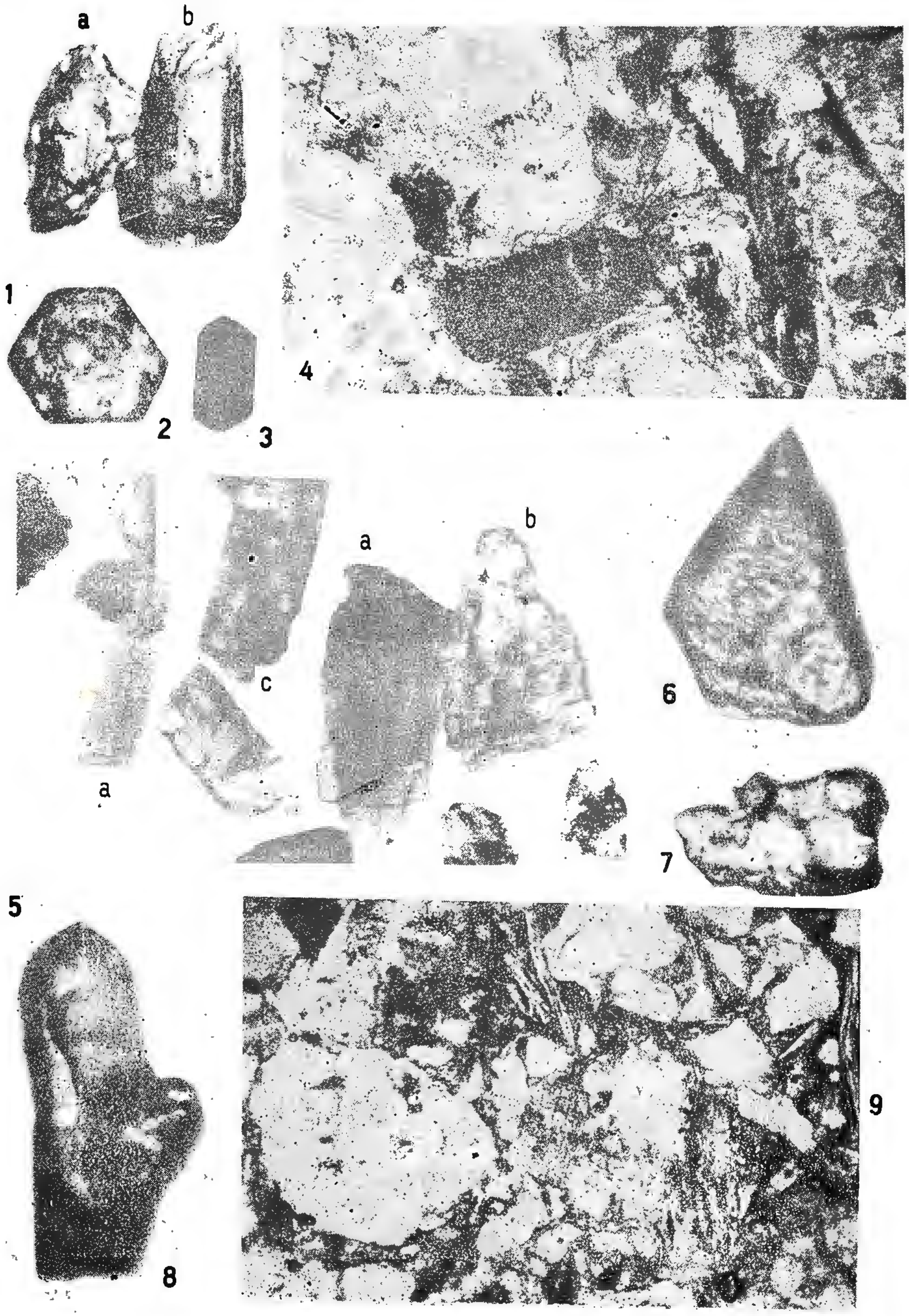
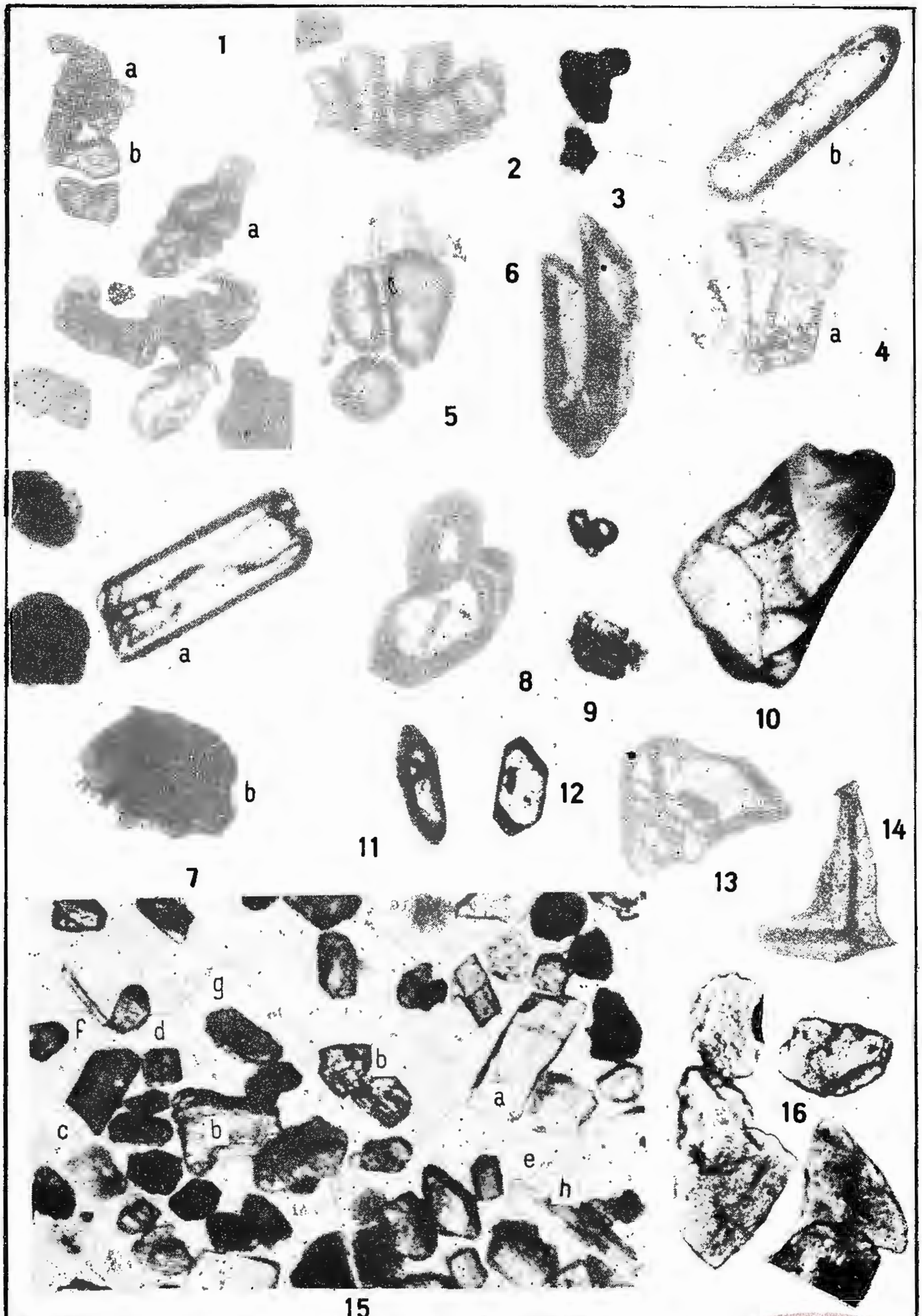
GR. ALEXANDRESCU, V. CODARCEA. Caractères minéralogiques du grès de Fusaru. Pl. II



V. CODARCEA, GR. ALEXANDRESCU. Zircon et baddeleyite dans les Carpathes Orientales.



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