

Romanian Journal of MINERAL DEPOSITS

continuation of

DĂRI DE SEAMĂ ALE ȘEDINTELOR INSTITUTULUI DE GEOLOGIE ȘI GEOTECNICĂ
COMPTES RENDUS DES SÉANCES DE L'INSTITUT DE GEOLOGIE ET GÉOPHYSIQUE
(2. Zăcămintele)

Founded 1906 by the Geological Institute of Romania

ISSN 1220-5648

Vol. 76

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Institutul Geologic al României
București - 1995

GEOLOGICAL INSTITUTE OF ROMANIA

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ROMANIAN JOURNAL OF MINERAL DEPOSITS supersedes "Dări de Seamă ale Ședințelor", Series 2/Zăcămintele - the last volume with this title being No. 74.

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The manuscripts should be sent to the scientific editor and/or executive secretary. Correspondence concerning advertisements, announcements and subscriptions should be sent to the Managing Editor.

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ISSN 1220-5648

Classification index for libraries 55(058)

*Printed by the Geological Institute of Romania
Bucharest*

JIDOȘTIȚA "BLASTOMYLONITIC" ZONE – PALEOTECTONIC AND METALLOGENETIC SIGNIFICANCE

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Key words: Mineralization. Sulphides. Blastomylonite. Shear zone. Structural controls. South Carpathians.

Abstract: The structural discontinuity marked by the blastomylonites from the Porțile de Fier Outlier (belonging to the Getic Nappe) outlines a crustal, low angle deep-seated shear zone. This ante-Paleozoic shear plane is obliterated by transposition and blastesis under mesometamorphic conditions; it delimits lithological entities which are part of a regional lithotectonic (nappe) complex with a polymetamorphic evolution. In the zone of the tectonic plane, and especially in the upper lithotectonic units, metalliferous occurrences of "deep-seated related shear zones" type are present. They are represented by: arsenopyrite (with gold content), pyrite, pyrrhotite, galena, sphalerite, hosted in metamorphic segregation quartz, forming bands and folded lenses, with a structural control imposed by D₂ structures (S₂ foliations, B₂ folds). The deep, dynamic metamorphism, correlable with the M₂ regional event, took place under conditions specific for the amphibolite-cordierite facies and contributed to the concentration of the metalliferous elements, which were successively pre-concentrated from protors originating in various crustal and infracrustal levels.

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1. Introduction

The "Luchita Zone" from the Porțile de Fier outlier, belonging to the Getic Nappe, pointed out due to its structural peculiarities by Codarcea (1940), was considered by Conovici, Conovici (unpublished data) to mark an overthrust plane of uncertain (Alpine or pre-Alpine) age. We described in detail the "blastomylonitic Jidoștița Zone" (Iancu et al., 1980), carrying out also several structural studies based on differentiated measurements (Iancu, Hărtopan, 1982).

The conclusions concerning the tectonic significance of the microblastic rocks of Jidoștița type were confirmed both in the crystalline rocks of the Porțile de Fier outlier and in the Căpățâna Mts. where they appear as structural "apexes" on the one hand, and in other zones of the South Carpathians (e.g. Lotru, Sebeș, Semenik Mountains), on the other. In some cases the microblastic rocks accompany the transitions to phaneroblastic rocks from different metamorphic assemblages or complexes, marking major structural discontinuities (Iancu et al., 1989).

The "Jidoștița type" microblastic facies resulted through structural and mineralogical reorganisation, having an obvious paleo-tectonic significance, and being in connection with ante-Paleozoic deep crustal shear zones. The "mylonitic" zone accompanied by polyphase blastesis at the level of the amphibolite facies delimits lithostructural entities on a regional scale, coming from various "terrains", and suggesting different geotectonic conditions.

The petrographic and structural features of blastomylonites may be quite varied, depending on the petrographic type on which the effects of the dynamic metamorphism act; at the same time, sequences of rocks from various successions may have a similar structural petrographic aspect, if they do not show a marked lithological contrast.

A major obstacle in discerning and mapping the "contacts" or "discontinuities" of this type is represented by the convergence of the characteristics of the dynamic metamorphism products and those of the regional metamorphism. Blastomylonites are metamor-

phics resulted through dynamic metamorphism, and the main problem arising is to discern and dissociate the products of the dynamic metamorphism from those of the regional metamorphism. But these discontinuities are not always accompanied by microblastic rocks or blastomylonites; in fact the Phanerozoic overthrust superficial nappes are not always marked by mylonites.

Practically the tracing of the structural discontinuity planes in the Precambrian complexes requires regional mappings and comparative petrological studies, as it has already been attempted in recent years (Iancu et al., 1989, 1990; Iancu, Mărunțiu, 1994).

An important observation, mentioned in the report of 1980 (Iancu et al., 1980), regarded the concentration of the arsenopyrite mineralizations (with gold content) in bands and lenses of metamorphic segregation quartz located in the vicinity of the "blastomylonitic" zone, in rocks of the Sebeș-Lotru Series. The structural and metamorphic control indicates a metamorphic genesis, connected with the deep dynamic metamorphism, materialized also by blastomylonites.

Although we have initially compared these mineralizations to those at Valea lui Stan from the Lotru Mountains (Udubașă et al., 1976), we consider them to be "hosted" by different sequences, the genetic processes involved in the concentration of the metalliferous elements being variously explained for the two zones. But the genetic association with shear zones can be maintained (Udubașă, Hann, 1987).

The mineralized quartz occurrences at Jidoștița were considered to have resulted from the effects of the dynamic metamorphism that accompanied crustal deep-seated shear zones under mesometamorphic conditions in the course of some Precambrian dynamo-metamorphic events (Iancu et al., 1989).

This interpretation differs essentially from the one belonging to the authors that correlated the mineralizations at Jidoștița with recent post-nappe faults, circulated by hydrothermal solutions (Andrei et al., 1974-1976; Conovici, Conovici, 1975).

The spatial association between some products of the dynamic metamorphism (blastomylonites) with metalliferous concentrations observed in the Căpățanii, Sebeș-Cibin, and Semenici Mountains (Iancu et al., 1989) confirms the genetic correlation I made with the Jidoștița Zone.

2. Jidoștița "Blastomylonitic" Zone - Lithotectonic Discontinuity

Unlike the Alpine or Paleozoic tectonic contacts at a small angle from the Carpathian area, that could be more easily pointed out, the ante-Paleozoic tectonic contacts are more difficult to distinguish and draw due to:

- the structural convergences of the deep dynamic metamorphism products (mesometamorphic blastomylonites) with metamorphics generated in isofacial regional dynamo-thermal processes or, in the case of the strongly subgrained rocks, with low-grade metamorphics and mylonites;

- the petrographic convergences resulting from the dynamic structural reorganisation under mesometamorphic conditions of some rocks belonging to various successions;

- the obliteration of the mechanical discontinuities, (of the shear zones) through structural reorganisation and blastesis, giving rise to some zones of apparent metamorphic transition by means of a set of common, blastomylonitic foliations and bandings (the case of the synmetamorphic nappes);

- the superposition of some folding, metamorphism, shearing processes in the areas of polyphase evolution.

Due to the difficulty in the direct following on the field and to the cartographic representation of the tectonic contact "plane" between sequences belonging to the (Precambrian) "Sebeș-Lotru" crystalline and the Jidoștița "formation", a complex argumentation is necessary, based on a comparative study involving structural and lithostratigraphic criteria as well as an analysis of the metamorphic deformational evolution of the lithotectonic entities coming into contact.

The structural aspects analysed on various scales and in successive stages have been synthesized in the structural sketches from Figure 1 and Plates I, II.

They illustrate:

- the internal structures of the contacting lithotectonic units, underlining the structural contrast, favoured also by the lithological contrast between them;

- the morphological aspect of the discontinuity or of the "tectonic plane", extrapolated from the local (Fig. 1) or regional (Pl. I, II) outcrop data, which suggests a plane at a small angle.

a) Bălvănești Lithotectonic Unit

The crystalline complex from the Bălvănești lithotectonic upper unit includes:

- the plagiogneiss, Topolnița Formation, a sequence of supracrustal, polydeformed, polymetamorphosed rocks;

- products of metamorphic and migmatitic segregation (quartz, sometimes mineralized, pegmatites, migmatitic neosoma), with non-tectonic initial structures, but with an obvious structural control;

- in situ anatectic magmatites (granitoids), showing isotropic or mimetic structures (in the case of the products of the partial anatexis);

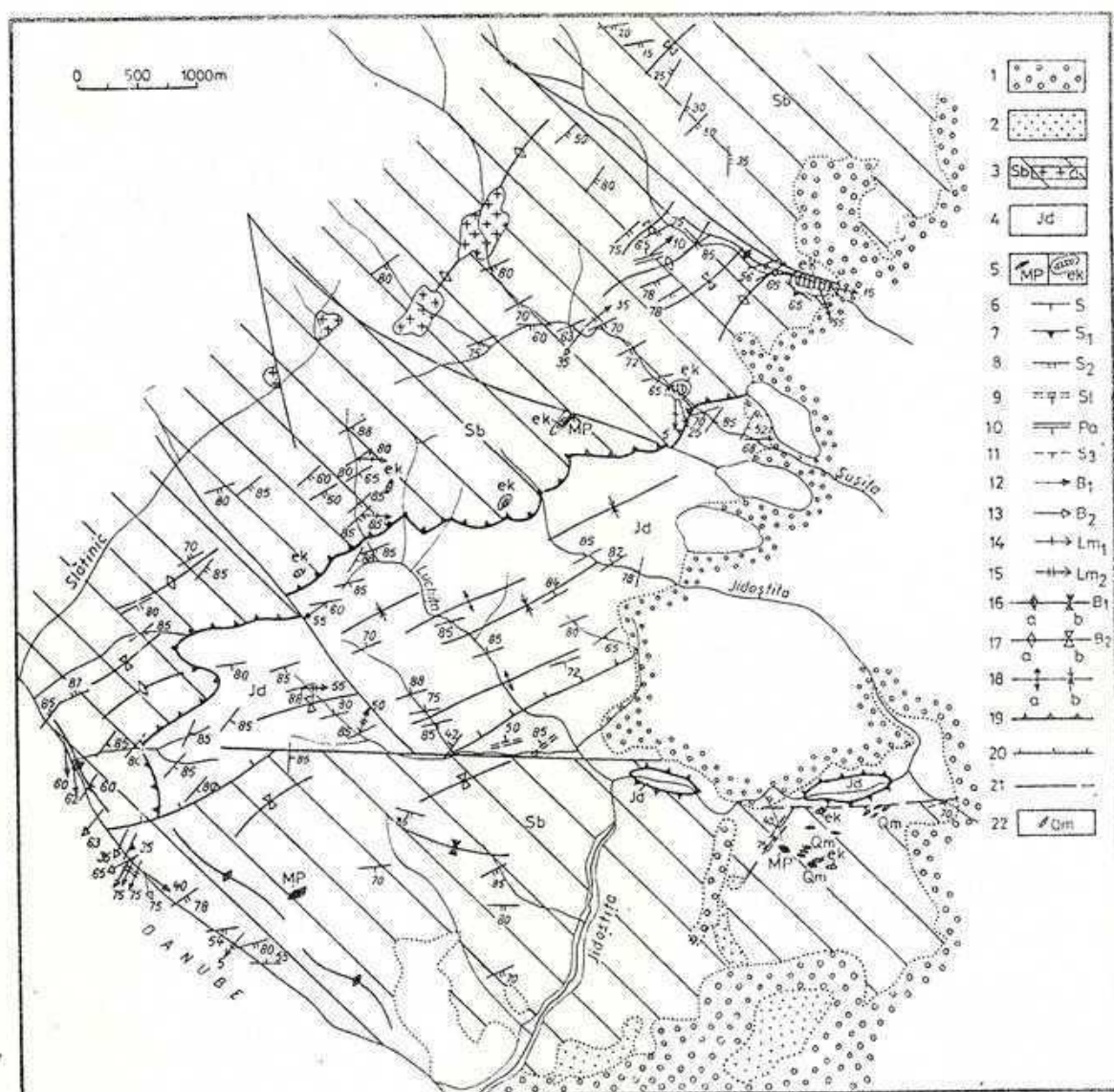


Fig. 1 - Structural map - Jidoștița Zone. 1, Neogene deposits of the post-Laramian cover. Getic Nappe Portile de Fier outlier; 2, Mesozoic formations; 3, Metamorphic formations of the Sebeș Group (Sebeș-Lotru Series divided) (Sb); a) in situ anatexitic granitoids; 4, Jidoștița Formation; 5, Exotic rocks: metaultramafics, MP; amphibolitized eclogites, ek; 6, undifferentiated metamorphic foliation; 7, S₁ foliation; 8, S₂ foliation; 9, Lamination (shear plane); 10, Axial plane of mesoscopic fold; 11, Fault plane; 12, B₁ fold hinge; 13, B₂ fold hinge; 14, Relict lineation (M₁); 15, Mineral lineation (M₂); 16, Axes of F₁ folds: a, antiform; b, synform; 17, Axes of F₂ folds: a, antiform; b, synform; 18, Axes of folds in the Jidoștița Formation; 19, Pre-Alpine tectonic plane (structural discontinuity); 20, Reverse fault; 21, Fault; 22, Metamorphic, mineralized quartz lens.

- exotic, anisofacial rock bodies (eclogites, granulites, metaultramafics) that preserve relict structures prior to M₁ (granulitic, coronitic, symplectitic) and mark on regional scale a Proterozoic cryptic paleosuture (Iancu et al., 1987).

The Topolnita Formation is a prevalently plagiogneissic sequence which is part of a succession of supracrustal rocks of "Sebeș type", containing intercalations of quartzitic plagiogneisses and quartzites, amphibolites, quartz-feldspathic gneisses and subordi-

nately marbles. Both on the outcrop scale and on regional scale, two generations of folds are preserved (represented in a different manner on the sketches from Figure 1 and Plates I, II) with essentially different orientations: approximately NW-SE in the case of the F₁ folds and approximately NE-SW in the case of the F₂ folds.

In the more competent sequences the two generations of folds coexist, the lithological markers indicating dome and basin-like elongated structures, consid-

ered to be the result of the coexistence of the variously oriented structures, generated in the D_1 and D_2 structogenetic stages, and of the partial transpositions after the D_2 structural directions.

On the other hand, in the incompetent sequences, the strongly elongated F_2 folds are accompanied by strong transpositions after S_2 , rarely permitting the preservation of the old structures (Pl. II).

The existence of the planar and linear structural elements of several generations in the Mehedinți crystalline was demonstrated by Iancu, Hărtopan (1982), and illustrated in tectonograms based on numerous differentiated microstructural measurements.

The analysis of the parageneses and index minerals correlable with the D_1 - M_1 and D_2 - M_2 dynamothermal events shows that the successive deformations took place under conditions specific for the amphibolite facies, being differentiated through the baric regime. Thus, the first D_1 - M_1 metamorphic event is characterized by the existence of the index minerals specific for the Barrovian facies series (kyanite, almandine, staurolite) similar to the situation in the Bahna outlier (Hărtopan, 1986), while the D_2 - M_2 event is characterized by paragenetic associations specific for the low pressure facies series (sillimanite + cordierite + potassium feldspar; sillimanite + muscovite; andalusite) (Iancu et al., 1987).

The superposed zonality, specific for the M_2 event (although it could not be cartographically represented), is accompanied at the level of the sillimanite + potassium feldspar zone by metatectic-anatectic migmatization.

The complex of exotic, infracrustal rocks is represented by allochthonous bodies occurring at various lithological levels, but above the contact with the Jidoștița Formation. These are represented by: eclogites, granulites, or bimodal granulitic gneisses (with compositional banding), metaultramafics. The high-grade polymetamorphism of the eclogites and ultramafics (the eclogitic facies followed by the granulitic one) as well as the presence of the banded granulitic rocks determined us (Iancu et al., 1988) to consider their emplacement connected with deep crustal shearings at the level of the lower crust and of the subcontinental upper mantle, initially in the conditions of the eclogitic and granulitic facies (high grade mylonites), and at the level of the amphibolite facies.

The retrograde adaptations at the level of the amphibolite facies of the exotic rocks took place in successive stages, simultaneously with the M_1 and M_2 regional events.

b) Jidoștița Lithotectonic Unit

Initially separated under the name of the Jidoștița "Series", the lithological sequence cropping out in

the lower tectonic unit is lithologically monotonous, consisting of biotitic plagiogneisses, quartzitic plagiogneisses, quartzites and very rarely amphibolites.

The sequence exposed in the "windows" from the Poștile de Fier outlier is characterized by the ubiquity of the microblastic structures and the existence of the metric alternations of microblastic and phaneroblastic metamorphics.

The microblastic rocks are considered to mark the apical zones of the lower unit and, therefore, the proximity to the tectonic plane between the two lithotectonic units.

The amplitude of the effects of the subgranulation shearing and dynamothermal transposition processes exceed the outcrop scale, reaching 1-200 m, and the outcrop area covers entirely the areas exposed by the tectonic windows. At the same time the preservation of the inherited phaneroblastic facies gives the impression of lithological alternations, being correlated with the density of the shearing planes and the transposition grade of the lithons in the zone of the tectonic plane.

The internal structures of the Jidoștița Unit are marked by a strong mechanical transposition, accompanied by mineralogical reorganisation according to the S_2 foliation and bandings, associated with a tight F_2 folding (Fig. 1). The generally straightened positions of the S_2 foliations contrast with the low angle morphology of the tectonic contact.

On the other hand, the transition from one unit to another is seemingly gradual on profiles and at the outcrop scale, through the S_2 foliations (Fig. 1).

Owing to the intense shearing and transposition processes, in the Jidoștița Unit, the relict structures prior to the F_2/S_2 generation are rarely preserved.

c) Tectonic Contact - Structural Peculiarities

As it is shown by the description of the lithotectonic (or lithostructural) units, the tectonic contact between them presents several peculiarities as follows:

- in the Jidoștița zone it is marked by microblastic rocks "intercalated" in the phaneroblastic rocks showing an areal distribution and being 1-200 m in thickness;

- the transition from one unit to another takes place gradually (over hundreds of metres) through the very dense and penetrative S_2 foliations;

- the paragenetic associations corresponding to the D_2 (F_2 , S_2) deformational event are those specific for the M_2 thermal event, common to both units; in the Poștile de Fier outlier the latter is characterized by the succession of zones as follows: sillimanite + cordierite + potassium feldspar; sillimanite + muscovite; andalusite (the succession of zones specific for the low pressure facies series (cf. Hietanen, 1967; Miyashiro, 1975);

– the relict structures and minerals (porphyroclasts) of the first M_1 dynamo-thermal event are well preserved in the upper tectonic unit even in the plane zone; the lower tectonic unit is marked by the predominance of the microblastic rocks resulted through mineralogical and structural reorganization under dynamic conditions, reflecting a maximal intensity of the shearing processes; the neoformation minerals are as follows: biotite, muscovite, plagioclase, garnet $\pm$ sillimanite $\pm$ andalusite;

– the morphology of the plane obviously suggests a mechanical discontinuity at small angle (Fig. 1, Pl. II), that was initially subhorizontal.

Macroscopically and microscopically the relict porphyroclasts from M_1 are visible; they are flat, rotated (garnet, plagioclase) or sheared and "stretched" as "spots" (plagioclase, biotite); micas appear as fascicles and reoriented or often replaced by micas of the second generation (biotite, muscovite).

The recrystallized (quartz, plagioclase, biotite) or neoformed (zoisite?, sillimanite, muscovite) phases are also oriented, generating either bandings and mineral lineations or "duplex" type foliations or "foliation fishes" (the case of the very micaceous rocks).

Some minerals, especially quartz, show intracrystalline deformations (undulatory extinctions, deformational bands in the pre-existing grains), effects of boundary migration, pressure solution and oriented recrystallization under stress (elongated grains in the S_2 plane).

The postkinematic recrystallization (post- S_2) of quartz, present as grains with clear extinction and mosaic-like aspect, was connected with a more recent thermal event (M_3) correlated with the in situ anatectic granitoids (Iancu et al., 1987).

The structurally controlled quartz bodies are very important in following the mineralizations, representing depositions from synmetamorphic siliceous solutions enriched in metalliferous elements. Under the microscope the zones within rocks strongly affected by the "pressure solution" round the porphyroclasts become poor in quartz, which is redeposited and recrystallized within the dilatation spaces or within the spaces with "pressure shadow". Both the mentioned microscopic and mesoscopic evidences are considered to illustrate the effects of the dynamic metamorphism during the solubilization reactions under pressure (of quartz and of the metalliferous elements within rocks) as well as the mobile character of the thermal siliceous solutions that migrated mostly in an ascendent direction – with respect to the maximal shear zone – towards the open spaces (model described by Thomkinson, 1988).

The lineations marked by minerals or mineral aggregates in the S_2 plane are very characteristic of the

plagiogneiss "packets".

On the other hand, in the "packets" or lithons of more fissile, micaceous rocks, intersection lineations marked by micas (see Iancu, Hărtopanu, 1982), similar to those from the "S-C type mylonites" (Berthé et al., 1979) can be noticed in the S_2 plane.

3. Metalliferous Occurrences – Their Structural Control

The arsenopyrite mineralizations at Jidoștița were investigated by prospection and exploration works. They were described by Andrei et al. (1974–1976) – as hydrothermal mineralizations, located on recent faults consisting of mispickel (arsenopyrite), pyrite, blende (sphalerite), galena (in quartz gangue).

The report elaborated by Iancu et al. (1980) provided several new data that led to a different interpretation from the one accepted until then for the Jidoștița Zone.

Several aspects were pointed out as follows:

– the presence of the metalliferous quartz concentrations within the metamorphic segregation quartz, occurring as folded bands and lenses (Fig. 2) but also as veins;

– the structural control of the mineralized quartz concentrations illustrated by the presence of the bands and lenses in the S_2 foliations and in the (F_2) folds;

– location of the mineralized quartz lenses in micaschists and plagiogneisses belonging to the Topolnița (Sebeș Group) in the Bălvănești upper lithotectonic unit, in the vicinity of the structural discontinuity marked by microblastic rocks. Similar concentrations dominated by pyrite occur also in the plagiogneisses of the Jidoștița Formation (e.g. Luchita Valley).

These observations led to the idea of a metamorphic genesis connected with ante-Paleozoic deep seated dynamic metamorphic processes in amphibolite facies conditions.

The mineral association specific for the Jidoștița mineralized zone contains: pyrite-chalcopryrite-arsenopyrite-sphalerite-galena-pyrite II, presented in the order of their formation (P. Hărtopanu, in Iancu et al., 1980).

Compared to arsenopyrite, chalcopryrite and pyrite appear as relict phases, and sphalerite (with pyrite ex-solutions) and galena are younger phases; this paragenesis is genetically correlable with the deep dynamic metamorphism, its protor being the above described crystalline complex (Jidoștița Formation, situated under the tectonic plane, the exotic anizofacial rocks and the Topolnița Formation).

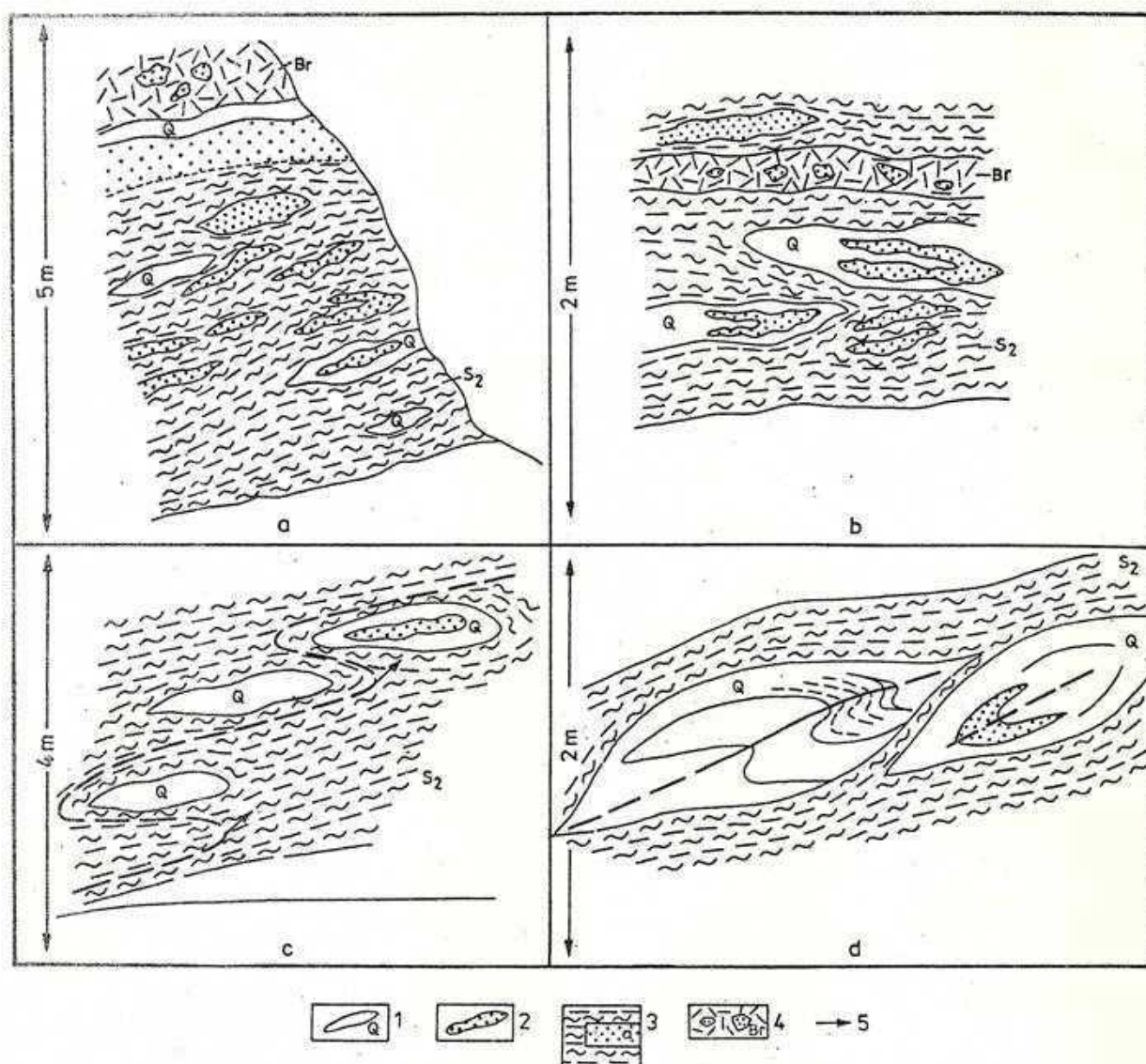


Fig. 2 - Outcrop sketches in the Jidoștița mineralized Zone (Jidoștița Valley - Valea Roșie). a) Metamorphic quartz and ore lenses (arsenopyrite, pyrite, galena±sphalerite) in an alternation of paragneisses, micaschists, quartzites with general S_2 foliation; Br - breccified ore level. b) Intrafolial lenses and folds marked by metamorphic quartz and ore, transposed in the S_2 foliation plane. c) Recumbent and sheared drag-folds and lens-like metamorphic quartz (± ore). d) Shear folds in "tectonic inclusions" containing metamorphic quartz and ore. 1, Quartz lens; 2, ore lens; 3, micaschists and plagiogneisses with quartzite bands (a); 4, breccified ore level; 5, hinge of mesoscopic fold.

The existence of the occurrences with regenerated sulfides (pyrite, chalcopyrite, arsenopyrite) in the form of veinlets and depositions on younger, postmetamorphic faults both in the Jidoștița and Gradsca zones (Porțile de Fier outlier) as well as in the Căpățanii Mountains (Costești Valley) was noticed.

As indicated by the above-mentioned data, the structural control of the mineralized quartz segregations is accompanied by a certain lithologic-petrographic control, the host rocks being micaschists and plagiogneisses. This suggests that the final protor

of the thermal solutions rich in silica is represented by the quartzous, aluminous rocks, with silica excess, from both tectonic units which, through metamorphic and dynamic reactivation, permitted the release of silica readjustment metamorphic reactions during the M_2 event.

The physical conditions suggested by the specific parageneses of the host rocks indicate relatively higher temperatures (the zones: muscovite+sillimanite, sillimanite+cordierite+potassium feldspar) and relatively low pressures compared with the M_1 event (character-

ized by the kyanite bearing parageneses).

It can be estimated, however, that in the case of the crystalline complexes from the Getic Nappe (the Porțile de Fier outlier inclusively) the gold concentration within sulfides (arsenopyrite, pyrite) can be explained through a polymetamorphic evolution, through successive concentrations, as a consequence of the spatial superposition of the dynamic or dynamothermal events.

The "Jidoștița type" mineralizations at the outcrop scale reveal banded fabrics imprinted by the recurring of the (centimetric or decimetric) ore and quartz bands disposed according to the metamorphic foliations. One can also notice a repetition at various levels, obviously resulted through folding and transposition processes, as is shown by the outcrops on the Valea Roșie and Gradsca Valley (Fig. 2). The presence of the mineralized quartz bands in the foliation plane and in the hinges of the B_2 folds seems to have been facilitated by the existence of the dilatation spaces, while the interruptions and lenticulations are spatially associated with the limbs of these folds. These aspects as well as the effects of the subsequent deformations (B_3 folds, new shearings etc.) explain the lenticular aspect of the mineralization, the lack of continuity on a constant direction as well as the disintegration of the initial lenses, so that the ore (also stretched, lenticized) may occur both included within quartz and in direct contact with the host rock.

Microscopically arsenopyrite quantitatively prevails; it shows effects of brittle deformation, being cemented with quartz or more recent sulfides (sphalerite, galena).

The secondary minerals are represented by skorodite and hydrogoethite.

4. Genetic and Paleotectonic Considerations

The genetic and paleotectonic significance of the metalliferous occurrences at Jidoștița can be understood based on the specific, local data on the one hand, and on the regional structural context, on the other.

The compared lithological and structural study of the Precambrian metamorphic formations of the Getic crystalline made possible an original approach that led to the division of this crystalline into lithotectonic or lithostructural units within which the Lotru, Sebeș, Cumpăna, Făgăraș and Luchița "groups" were separated.

The lithostructural entities were delimited by major structural discontinuities (Iancu, Mărunțiu, 1994) which, in most cases mark deep-seated crustal shear zones. In some cases (model b, Fig. 3) the latter suggest mechanical discontinuity planes at a low angle, similar overthrust planes (ex. Mehedinți, Căpățâna

Mountains). This type of paleoplane is marked by microblastic rocks or tectonic melanges with eclogite, granulite, metaultramafite blocks originating from the level of the lower crust and the upper mantle (the exotic intracontinental rock complex from the Getic Nappe). A subsequent dynamothermal (M_2) reactivation could obliterate and transpose this discontinuity.

In some other cases (model a, Fig. 3) the apparent transitions achieved by blastomylonitic rocks through some common foliations (S_2) obliterate these discontinuities by a synchronous dynamothermal event (M_2). This is the case of metamorphic nappes, an example being the "contact" between the Lotru and Sebeș groups (Lotru basin Valley).

In model c (Fig. 3) we suppose the existence of different age and mechanism of emplacement for the ante-Paleozoic discontinuities implying also Proterozoic granulitic terrains from the Getic crystalline (e.g. relations between the Ursu and Sebeș, and respectively Lotru group). All these cases are difficult to notice in the course of some usual mappings.

In this context, the paleotectonic significance of the Jidoștița "blastomylonitic" Zone and of the gold arsenopyrite mineralizations occurrences, spatially and genetically associated, is closely related to the regional problems of the lithotectonic entities contacting one another, a situation analysed in this paper.

As results from the presentation of the structural-metamorphic data, the Jidoștița "blastomylonitic" Zone marks a tectonic paleoplane characterized by a structural low angle discontinuity, formed by deep crustal shearing.

We can retain the paleotectonic significance of the microblastic and blastomylonitic rocks and their close association with some metalliferous occurrences.

Lithostratigraphically, the Jidoștița formation is difficult to correlate but there are three possibilities: an independent group (Luchița" cf. Iancu et al., 1989); a "Lotru" type sequence (Iancu, Mărunțiu, 1994), or a part from a granulitic complex, situated between the Sebeș and Lotru megasequences.

In the case of the Jidoștița "blastomylonites" the dynamic factor involved in the concentration of the metalliferous elements (arsenopyrite and pyrite with gold content, sphalerite, galena and chalcopryrite) was represented by repeated crustal shearing prior to the M_2 event and subsequently, in the M_2 metamorphic event which took place in the conditions of the amphibolite-cordierite facies. The location of the mineralization in the metamorphic quartz (bands and lenses) and the gold contents of the quartz determined through neutron activation (0.062–0.086 ppm) close to the gold contents of sulfides (pyrite 0.130–0.368 ppm) point to an obvious genetic correlation and common sources. In this case the described crystalline complex contains

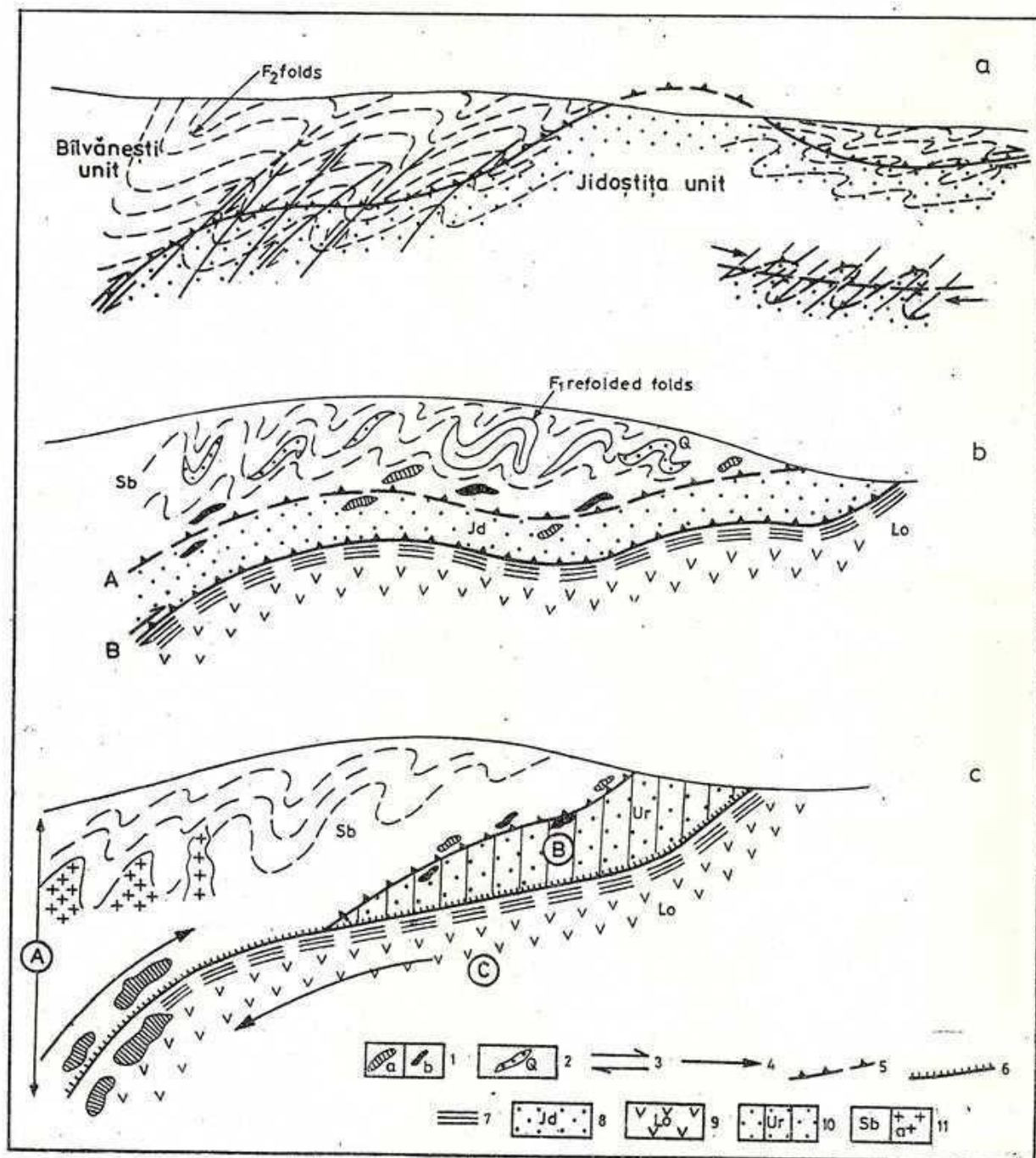


Fig. 3 - Possible models for structural discontinuities from the Getic Crystalline. a) Structural discontinuity generated by deep shearing synchronous with a dynamo-thermal reactivation (M_2). b) Deep structural unconformity (A) (marked by eclogites, granulites, metaultramafics), reactivated at an upper structural level; simple shear at a lower geometric level (B), in mesometamorphic conditions. c) Structural discontinuities of various ages, between continental crustal complexes with anatectic granitoids (A), granulitic terrains (B) and oceanic crust terrains (metamorphic complexes originating from magmatic-sedimentary associations of oceanic crust type). 1, Eclogite, granulite (a) and metaultramafic (b) bodies; 2, metamorphic quartz lenses; 3, shear sense; 4, tectonic transport directions; 5, reactivated (relict) structural discontinuity; 6, ante-Paleozoic overthrust or metamorphic nappe; 7, shear zone marked by blastomylonites; 8, Jidoștița Formation (Jd); 9, Lotru Group (Lo); 10, Ursu Group (Ur); 11, Sebeș Group (Sb); a, anatectic granitoids.

both the rocks that likely constituted the final sources of the mineralized siliceous solutions (micaschists and plagiogneisses) and rocks originating in the Jidoștița Unit or in deeper zones (eclogites, granulites, metaultramafics, which might have furnished metalliferous elements, gold inclusively, in stages previous to M_2 .

Thus, through successive concentrations, the polymetamorphic rocks from the present crystalline complex could take over and concentrate gold and other metalliferous elements from protors which are difficult to specify now.

Regional observations carried out on the Getic crystalline allowed the pointing out of a clear structural correlation between some metalliferous occurrences (sulfides with gold content on the one hand, and several pronounced tectonic discontinuities and blastomylonites on the other hand). Acknowledging the important role of the deep dynamic metamorphism in the generation of some concentrations of metalliferous minerals, these occurrences will be designated as "deep seated shear zones related". Due to the dynamic factor of metamorphism, they may be considered to belong to the great category of "tectogenetic" mineralizations (Udubaș, 1987) or "shear zones related" (Udubaș, Hann, 1987). By the convergence of their characters and the similarity of their physical conditions, the products of the dynamic metamorphism are difficult to differentiate from the products of the regional metamorphism, which justifies the necessity of the specialized structural study in the case of the structurally controlled metalliferous occurrences, correlated with "deep seated shear zones".

In this sense two types of structurally-tectonically conditioned occurrences are distinguished as follows:

a) occurrences correlated with dynamic metamorphism processes marked also by blastomylonite zones; theoretically they may accompany deep seated shear zones (thrust faults) or "transpression" type zones (high angle).

b) regenerated occurrences - formed by remobilization of some pre-existing mineralizations as a result of shallow level shearings.

As regards the spatial relationships with the maximal shear zones one could notice:

- metalliferous occurrences situated "above" the tectonic discontinuities in quartz or quartz-feldspathic segregations.

Such examples are to be found on the Jidoștița, Roșia, Gradsca (Mehedinți) valleys; on the Costești Valley in the Căpățâna Mountains. These occurrences consist of gold bearing arsenopyrite, pyrite, pyrrhotite, chalcopyrite, sphalerite, galena.

- occurrences hosted in the maximal shear zones, namely in blastomylonites; metalliferous minerals

(pyrite, pyrrhotite) are disposed in the plane of the blastomylonitic foliation.

Example: Nergănița Valley (Semenic Mts), Râmăști Valley (Căpățâna Mts).

In some cases the mentioned mineralizations, generated in the course of some Precambrian tectogenetic events show evidence of more recent tectonic reactivation.

Metalliferous minerals occur as mobilizations on fissures and in newer, Phanerozoic shear planes. Such regenerated, superposed mineralizations are to be found in the Mehedinți and in the Căpățâna Mountains.

In some zones, the mentioned blastomylonitic rocks contain also metalliferous minerals (especially oxides) dispersed in the mass of the restructured rocks. Examples: the Cărpiniș-Căpâlna blastomylonitic zone, the blastomylonites from the Făgăraș Mountains in the contact zone of the Măgura Căinenilor Formation and the Suru Formation etc.

All these situations prove the existence of a common factor of processing and concentration: the dynamic metamorphism that accompanies the crustal (deep-seated) shear zones. On the other hand, the varied compositions as well as the quite varied host rocks lead to the idea of an important influence due to the nature of the protors and the successive processings (in the case of the polymetamorphic rocks) as well as to the local or specific physical conditions (movement rate, chemical gradients, fluid pressure, etc.).

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Received: April 22, 1991.

Accepted: May 17, 1991.

Presented at the scientific session of the Institute of Geology and Geophysics: May 21, 1991.

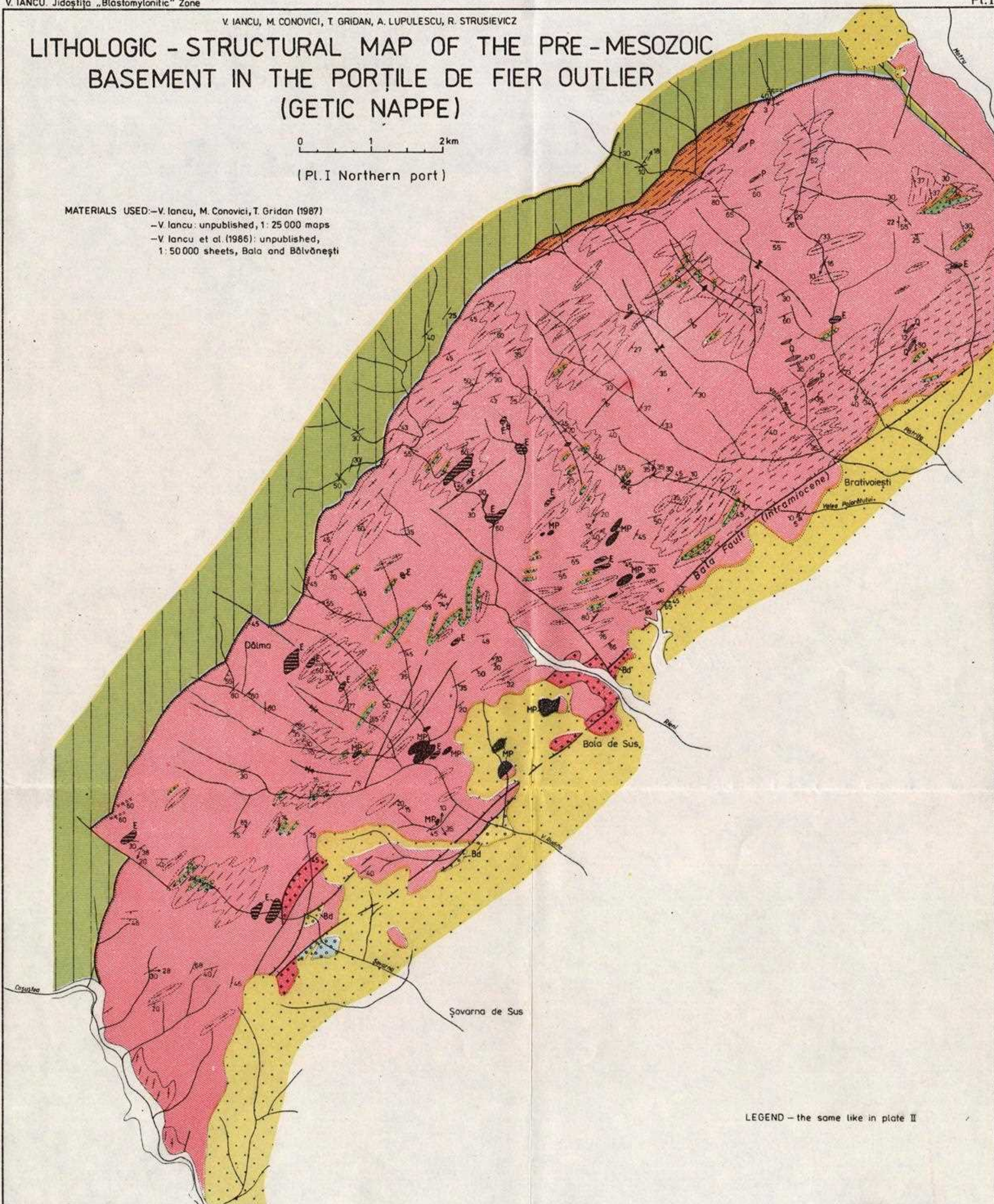
V. IANCU, M. CONOVICI, T. GRIDAN, A. LUPULESCU, R. STRUSIEVICZ

LITHOLOGIC - STRUCTURAL MAP OF THE PRE-MESOZOIC BASEMENT IN THE PORȚILE DE FIER OUTLIER (GETIC NAPPE)

0 1 2 km

(Pl. I Northern part)

MATERIALS USED:—V. Iancu, M. Conovici, T. Gridan (1987)
—V. Iancu: unpublished, 1: 25 000 maps
—V. Iancu et al. (1986): unpublished,
1: 50 000 sheets, Bala and Bălvănești

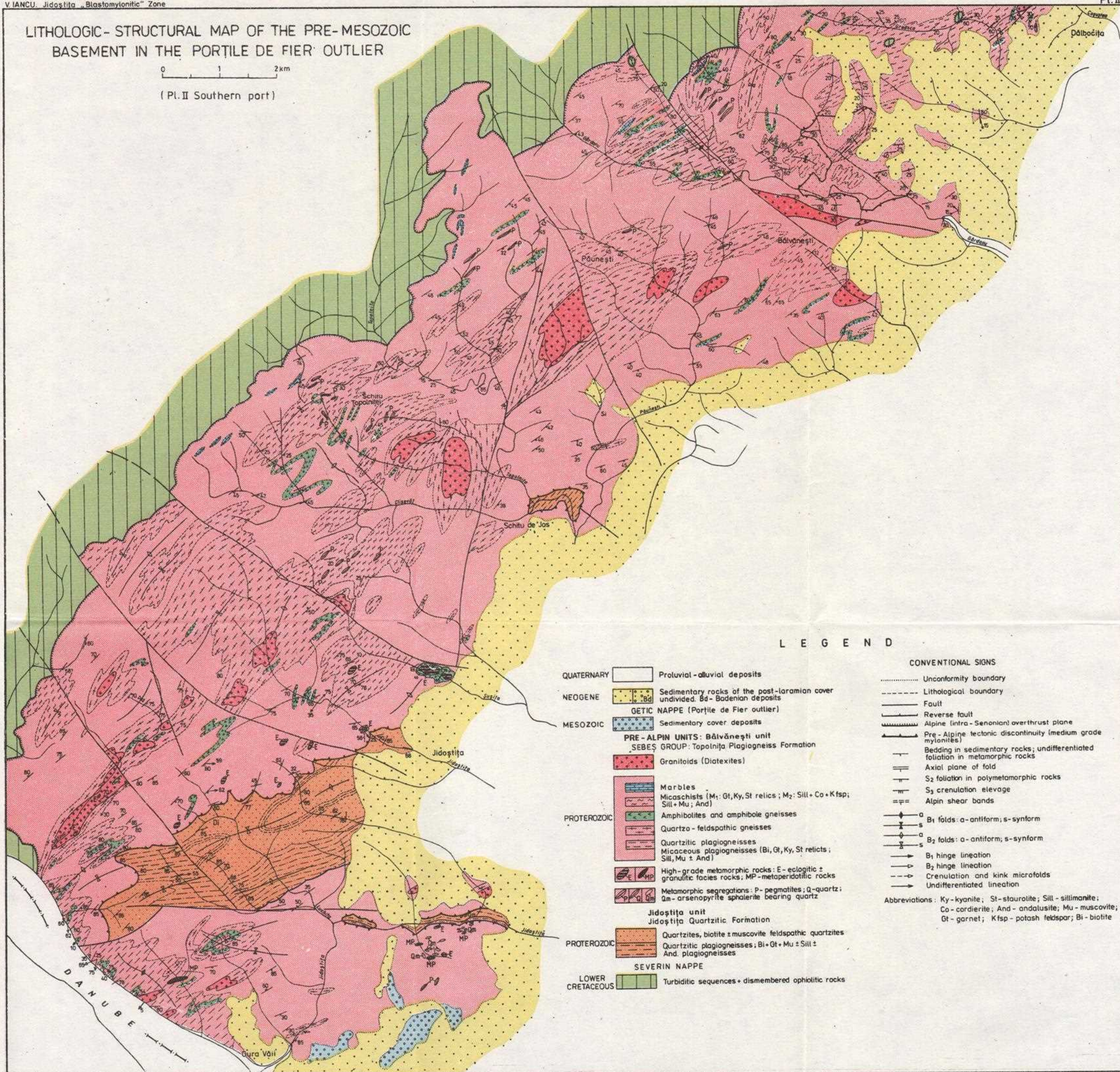


LEGEND — the same like in plate II

LITHOLOGIC-STRUCTURAL MAP OF THE PRE-MESOZOIC
BASEMENT IN THE PORTILE DE FIER OUTLIER

0 1 2 km

(Pl. II Southern part)



EPIGENETIC MINERALIZATIONS ON THE EASTERN FLANK OF THE RARĂU MARGINAL SYNCLINE (EAST CARPATHIANS)

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Key words: Mineralization. Sulphides. Hydrothermal processes. Major elements. Minor elements. Structural controls. Lithologic controls. Fluid inclusions. Decrepitation. Absolute age. Pb/Pb. East Carpathians.

Abstract: The region between Slătioara to the north and Ostra to the south is situated on the eastern flank of the Rarău marginal syncline (East Carpathians) and corresponds to the Bucovinian Nappe, which consists of a crystalline basement, in its turn made up of several pre-Alpine nappes – Putna Nappe, Chiril Nappe and Rarău Nappe on the one hand, and of a Mesozoic sedimentary cover, on the other; eastwards the Bucovinian Nappe overthrusts the inner flysch of the Ceahlău Unit. The crystalline formations host several epigenetic hydrothermal mineralizations, the primary parageneses - formed in at least three stages - comprising pyrite, chalcopyrite, galena, sphalerite, tetrahedrite, bournonite, oligist, marcasite, arsenopyrite, quartz, siderite, barite, witherite, and chlorite. The zones showing indications of epigenetic mineralizations lie on an alignment trending approximately north-south, corresponding to a major fracture that constituted an access way for the mineralizing solutions. The deposit form of the mineralizations is represented by veins, impregnation and stockwork, showing a greater development in the intersection zones of the main fracture with the competent rock levels - quartzites, metasandstones, acid metavolcanics and gneisses.

The presence of some sulfide mineralizations in the Stulpicani commune (at Gemenea) is mentioned by Solescu in 1948. Approximately ten years later Ianovici et al. (1957) study the polymetallic sulfide mineralizations with barite gangue at Gemenea; Tănăsescu and Pitulea (1958-1965) point out and study the barite mineralization at Ostra, and Idriceanu (1960) points out a sulfide mineralization with quartz and barite gangue on the Botoșan Brook.

All these studies reveal the epigenetic character of the barite and polymetallic sulfide mineralizations between Slătioara and Ostra, suggesting their possible correlation.

The more recent synthesis studies made by Ignat et al. (1985), Vodă and Vodă (1985), Vodă et al. (1987) on the basis of the prospection, exploration and exploitation works led to the consideration of a wider metallogenetic context. Thus the barite and sulfide epigenetic mineralizations formed in the distention period at the beginning of the continental rift stage, at the end of the Jurassic, in the same phase that led to

the emplacement of the Ditrău alkaline massif.

I. Tectonics and Geology of the Region

The region dealt with in the present paper consists of the formations of the Bucovinian Alpine Nappe which thrusts eastwards over the flysch of the Ceahlău Unit. Within the Bucovinian Nappe metamorphic formations disposed in several pre-Alpine Nappes (Putna, Chiril and Rarău) and a sedimentary cover represented by Mesozoic deposits (Fig. 1) can be distinguished.

The Putna Nappe, consisting of the crystalline formations of the Tulgheș Group, is represented between Slătioara and Ostra by the upper part of the volcano-sedimentary formation (Tg₃) - the Moroșan and the Fundul Moldovei members, and by the lower part of the blastodetrital formation (Tg₄)-Bașca member (Podășcă et al., 1986).

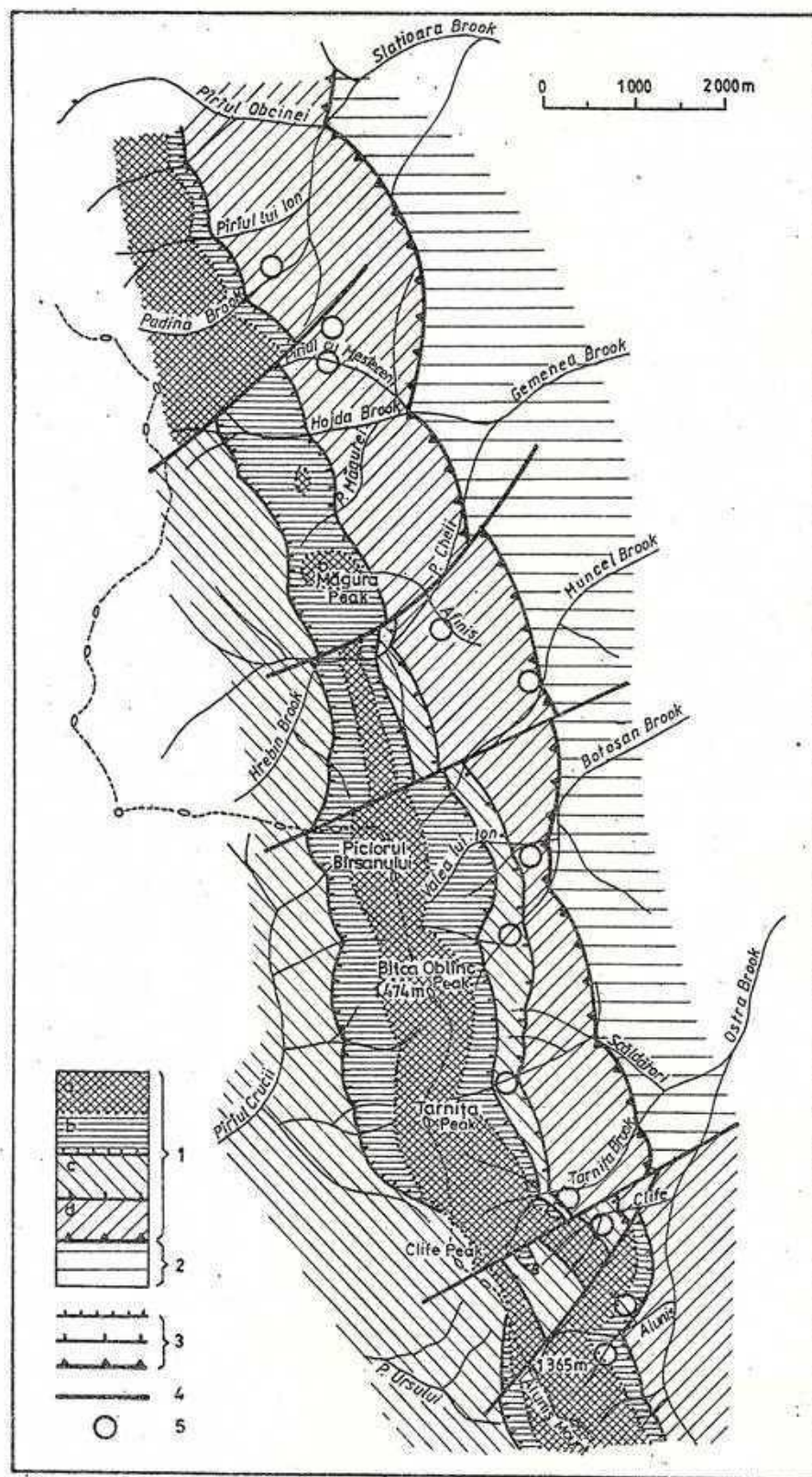


Fig. 1 - Structural sketch of the eastern flank of the Rarău marginal syncline, between Slătioara and Ostra. 1, Bucovinian Nappe: a, Mesozoic sedimentary; b, Rarău Nappe; c, Chiril Nappe; d, Putna Nappe; 2, Ceahlău Nappe; 3, Overthrusts; 4, Faults; 5, Epigenetic mineralized zones.

On the whole the formations of the Tulgheș Group consist of several varieties of quartz-sericite-chlorite schists making up the petrographic background, which contains, especially in the Fundul Moldovei Member, several dominantly quartz-feldspathic $\pm$ muscovite levels which genetically represent metapsammites and acid metavolcanics.

The Chiril Nappe represented by the Chiril Formation, thrusts over the Putna Nappe, being in its turn overthrust by the Rarău Nappe.

The Chiril Formation is characterised by the pronounced mylonitization, represented at present by the typically crystalloclastic structures; phenoclasts being represented by plagioclase and, subordinately, muscovite, biotite, garnet and hornblende; also concomitantly with mylonitization intense retromorphism processes took place, the corresponding minerals being chlorite, albite, epidote, calcite and actinolite.

For these rocks an initial progressive metamorphism may be admitted at the level of the zones with biotite and almandine, the resulted products corresponding to the plagiogneisses and micaschists with muscovite and biotite $\pm$ garnet, with which feldspathic quartzites, amphibolic schists and amphibolites are associated.

The Rarău Nappe, consisting of the Rarău Formation, overthrusts the Chiril Nappe or overlies directly the Putna Nappe. Petrographically the Rarău Formation consists of microcline gneisses $\pm$ biotite, often showing a reddish shade due to a fine hematite dispersion in the mass of microcline phenoblasts - Rarău gneisses with which micaschists and garnet muscovite-biotitic plagiogneisses and amphibolitic rocks associate.

In the Bucovinian Nappe the general structural directions are approximately NNW-SSE; this nappe is divided by numerous directional faults, probably older, and transverse faults in several compartments.

In order to create a detailed structural image, we measured in outcrops or in the mining works the position of the planar structural elements (schistosity, cleavages and fissures) and of the linear ones (microfold axes). Starting from the tautozonality of the schistosity and longitudinal fissures we represented graphically the β axis ($\approx B$) and the deformation ellipsoid; it follows that the AC plane overlaps the maximum of the measured ac fissure systems; also, the poles of the axes of the longitudinal microfolds plot in the maximum zone of the ac fissure systems ($\approx B$ axes). It is worth mentioning that the measurements were made especially in the levels of quartz-feldspathic rocks belonging to the Tulgheș Group. Microtectonic studies have pointed out that locally the structural directions (B axis) may appear different from the general structural image, becoming approximately east-west. The rotation of these structural directions, sometimes

up to 90° , cannot be interpreted only through the fault systems, but also through some local overthrusts. The most obvious local overthrust (the "Afiniș overthrust") in the Putna Nappe formations appears between the Cheilor Brook and the Muncel Brook (Fig. 2).

II. Mineralized Zones

Between Slătioara to the north and Oștra to the south, several zones with epigenetic hydrothermal mineralizations are known.

On the Padina Brook, left branch of the Slătioara Valley, at about 500 m upstream the confluence (altitude of 860 m), the mineralization investigated by three galleries, consists in different proportions of chalcopryrite and galena, with which tetrahedrite, bournonite and sphalerite are associated; the gangue minerals are mainly represented by quartz, barite and siderite.

On the Pârâul cu Mesteceni Brook, on the right bank, at about 625 m upstream the confluence with the Diacul Brook (altitude of 860 m) a few metres thick hydrothermal quartz vein is exposed, containing a pyrite mineralization; the vein sends numerous apophyses in the host rocks, while vugs are often encountered. Also, on the interfluvium between the Padina Brook and Pârâul cu Mesteceni Brook (altitude of 980 m) several blocks and fragments of strongly silicified tectonic breccia are encountered; under the microscope only the hydrothermal quartz was pointed out as epigenetic mineral.

On the Afiniș Brook (right tributary of the Cheilor Brook) a mineralization of polymetallic sulfides $\pm$ barite was investigated by galleries and boreholes.

At the level of galleries I, II and III a vein was pointed out reaching 53-120 m in length and 0.1-2.5 m in thickness, while at the level of gallery IV three vein zones were intercepted.

The vein mineralization generally has a massive structure, consisting mainly of chalcopryrite and galena in various proportions, and subordinately sphalerite, tetrahedrite, bournonite, pyrite and arsenopyrite; gangue consists especially of quartz and sometimes siderite and barite. Both in the hangingwall and the footwall of the veins there occur prevalently pyrite impregnation zones.

As regards the petrogenetic context, it is to note the constant presence of the above-mentioned mineralizations in the mass of the same rock type - muscovite quartz-feldspathic rocks (mostly metapsammites) - usually in the immediate vicinity of or just at the contact with quartz-sericite $\pm$ graphite schists.

On the Valea lui Ion Brook (left branch of the Botoșan Brook), on a small waste dump from the right bank, at about 325 m from the confluence, fragments

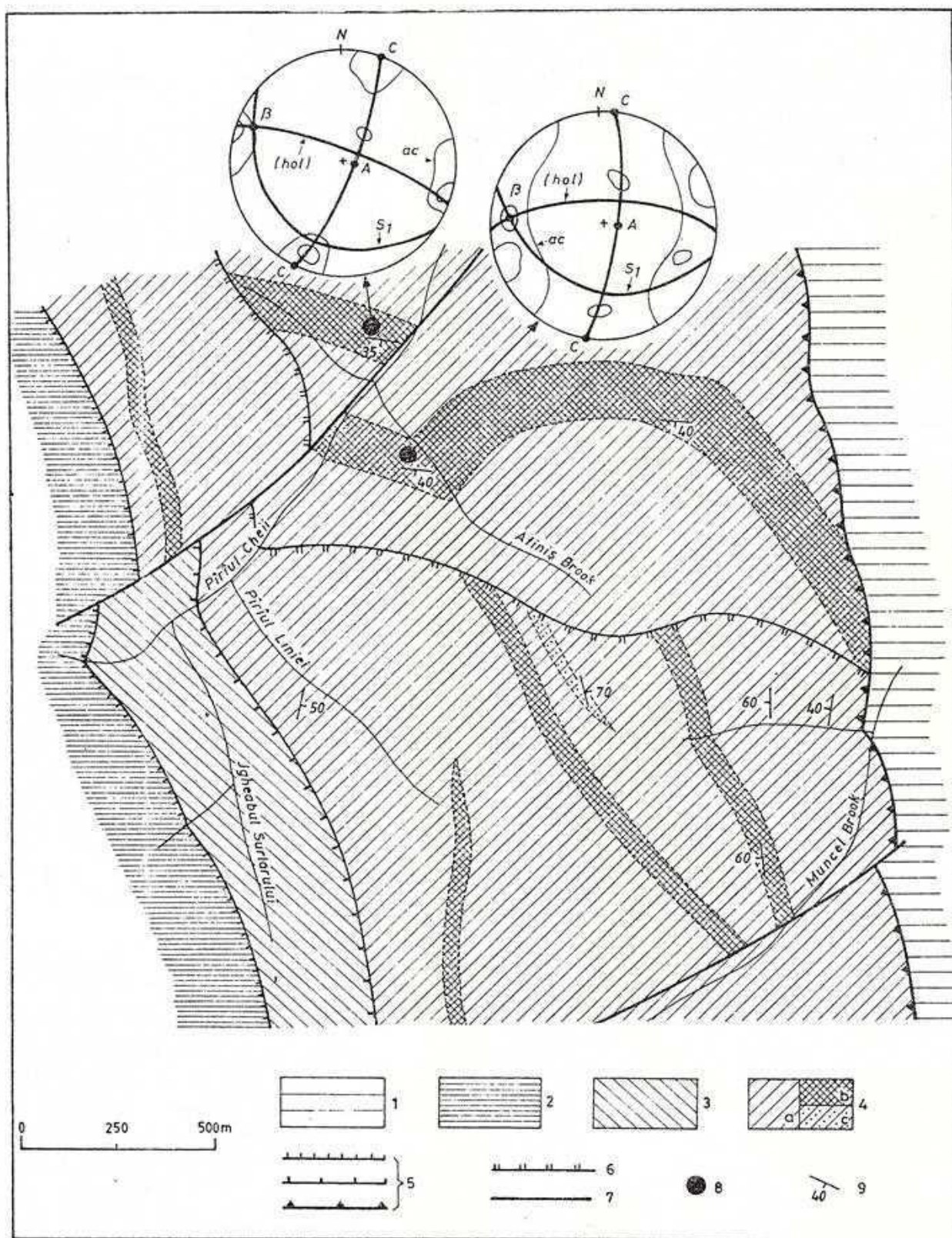


Fig. 2 – Geologic sketch of the zone between the Cheilor Brook and the Muncel Brook. 1, Ceahlău Nappe (Sinaia Beds); 2, Rarău Formation: gneisses, micaschists, amphibolites; 3, Chiril Formation: biotite-muscovite micaschists, paragneisses, amphibolic schists; 4, Tulgheș Group: a, quartz-sericite±chlorite±graphite schists; b, quartz-feldspathic rocks (metasandstones, acid metavolcanics); c, chlorite-albite schists; 5, Overthrusts; 6, Afiniș overthrust; 7, Faults; 8, Tectonograms (plotting in the lower hemisphere); 9, Schistosity position.

consisting of quartz and pyrite containing siderite clusters and veinlets, accompanied or not by chalcopyrite, are to be found.

On the left bank of the Muncel Brook, in the immediate vicinity of the contact with the flysch, in a strongly brecciated quartz-feldspathic level, a siderite impregnation is present; some barite fragments were also encountered.

On the Botoșan Brook, about 1000 m upstream the confluence with the Valea lui Ion Brook a mineralization consisting mainly of sphalerite and galena occurs in strongly brecciated quartz-muscovitic mylonites (hydrothermal quartz may exceed 50 % in some samples), probably belonging to the Chiril Formation; pyrite is also found associated with hydrothermal quartz.

On the Scăldători Brook, in the zone of one confluence (altitude of about 1010 m), the quartz-albitic ultramylonites (cataclased paragneisses) are crossed in every direction by carbonate veinlets (calcite and sub-ordinately siderite) with which a lamellar hematite mineralization (oligist) is associated; pyrite is also present in small amounts.

On the Târnița Brook, on the right bank (at approximately 300 m downstream the confluence of the two branches - altitude of 920 m) a metric level consisting of an alternation of quartz-feldspathic and prevailingly quartz-muscovite bands develops. Tectonically the situation is similar to that in the Afiniș zone, at least with respect to the approximately east-west strike of this level. On the whole the rocks show an advanced brecciation degree, in places the brecciation being accompanied by a pronounced hydrothermalization.

The hydrothermal mineralization consists of siderite, quartz, subordinately barite and witherite, and as opaque minerals, of galena, sphalerite, chalcopyrite and tetrahedrite.

On the Clife Brook, between its two branches at about 100 m upstream the confluence in the vicinity of the contact with the sedimentary, a 12-15 m thick level of muscovite quartz-feldspathic rocks (feldspathic quartzites to plagiogneisses), crossed in every direction by hydrothermal quartz veinlets, is exposed. The quartz-feldspathic rocks are intensely cataclased throughout their thickness and contain a barite mineralization in the form of veinlets (the greatest of them being about 30 cm thick), clusters and impregnation; siderite is poorly developed. Downstream the mineralization, quartz-feldspathic rocks contact a thin level of graphite quartz schists. In some zones mylonitization is pronounced, the graphite rocks generally favouring the shift of the quartz-feldspathic blocks after the system of fissures, thus the general aspect is that of a breccia with white, quartzitic or quartz-feldspathic elements of various sizes and black graphite cement.

Also on the Clife Brook, approximately 100 m downstream the confluence of its two branches (910 m), a strong siderite impregnation develops in a quartz-feldspathic level.

The investigation carried out between the Clife and Alunișul Mare Brooks (galleries XXIV, XXIII, III and XXXV and in the lower part of the Ostra quarry) pointed out also the presence of hydrothermal quartz in various cataclasion stages, especially in the formations under the Rarău Nappe.

In this zone, where the barite mineralizations are to be found in at least two pre-Alpine tectonic units - the Putina Nappe and the Rarău Nappe - it should be noted that barite usually occurs as centimetric discordant (ascendant) veins in the formations underlying the Rarău Nappe, and as impregnation, lenses or bodies of considerable size in the Rarău gneiss mass.

III. Mineralogy and Chemism of Mineralizations

1. Mineralogy

Pyrite is the earliest metallic mineral, forming idiomorphic crystals, sometimes up to 0.5 mm, both associated with hydrothermal quartz, which cements the fragments of the host rocks, and included and corroded by chalcopyrite.

Chalcopyrite is usually strongly cataclased; it includes idiomorphic pyrite crystals, being in its turn included and crossed by numerous galena, tetrahedrite, bournonite veinlets.

Galena appears as patches and veinlets in which no individual crystals can be distinguished or, in some cases, microcrystalline aggregates of mosaic-like structure; it often penetrates the chalcopyrite mass, corroding it.

Tetrahedrite may be the dominant mineral in some samples, while in others it appears entirely subordinated. If the tetrahedrite-galena contact clearly appears as a distinct line, the tetrahedrite-chalcopyrite or galena-chalcopyrite contact appears diffuse, indicating in both cases the chalcopyrite corrosion; this aspect points to the fact that tetrahedrite and galena belong to the same generation, being younger than chalcopyrite.

Bournonite appears in most cases intergrown with tetrahedrite, especially with rounded forms containing chalcopyrite remains. The maximal and minimal values of the reflection capacity of bournonite (sample 53 - Afiniș Brook) are as follows (the standard values are in brackets): red 35-30 (33.5-31); yellow: 36.5-31.8 (35.5-33); green: 37.5-32.5 (36.5-34); blue: 39.5-34.5 (37.5-34). A slight deviation towards greater of the maximal reflectivity values with respect to the theoretical values can be noticed. The veinlets consisting

of galena, tetrahedrite and bournonite disperse sometimes in impregnation zones in the chalcopryite mass.

Sphalerite is usually present in small amounts, sometimes as large crystals. It may belong to two generations – one, prior to chalcopryite, usually containing chalcopryite exsolutions, and the other, subsequent to chalcopryite, associated with galena, devoid of chalcopryite exsolutions.

Marcasite occurs only isolated as individual lamellae or lamellar aggregates, more often south of the Clife Brook.

Arsenopyrite, like *marcasite*, appears quite rarely, as long prismatic or acicular crystals in the quartz and chalcopryite mass or as tiny grains grown on *marcasite* lamellae.

Hematite is found in greater amounts only on the Scăldători Brook and in the zone of the Ostra quarry as lamellae varying in size.

Insignificant amounts of *covellite* and *chalcosine* are sometimes associated with the chalcopryite mineralization.

Quartz is the dominant gangue mineral, especially in paragenesis with pyrite and chalcopryite, forming veins and clusters of largely crystallized structure. In places the quartz crystals show a zoned aspect, the successive growth stages being marked by the reduced or abundant presence of the opaque minerals. It may occur isolated or associated with *siderite*; when it is in contact with *barite*, quartz is corroded by the latter. Some of the hydrothermal quartz may appear strongly brecciated and some may appear unfractured; in these cases, the unfractured crystals probably represent a younger quartz formed in a different mineralization phase.

Siderite is a principal gangue mineral associated both with the chalcopryite and especially the galena, tetrahedrite and bournonite mineralization; it may be associated with the quartz of the later generations as well as with *barite*, as veinlets, often ramified and clusters, both in veins and within the rock around them, sometimes even as isolated rhombohedral crystals.

Siderite is very abundant (up to 20 %) in the hydrothermalized levels on the Muncel Brook, Tarnița Brook and on the Clife Brook, downstream the confluence of the two branches (Fig. 3), forming both transverse and conformable veinlets showing mosaic texture. The transverse veinlets, usually of more reduced thicknesses; ramify in front of the prevailing micaceous bands, partly or even totally replacing *muscovite*; the *muscovite* rests from the *siderite* mass have low birefringence, being light-grey – yellowish in colour of the first order; also, *siderite* may partially replace *feldspar*.

Barite is the main hydrothermal mineral between the Alunișul Mare and the Clife Brook. It appears as

veins or impregnations, especially in the Rarău gneiss mass, but also in the quartz-sericite±graphite schists of the Tulgheș Group, exposed both on the lowest bench of the Ostra quarry (approximately at the level of the Alunișul Mare Brook) and in some galleries (for example gallery XXIV). To the north of the Clife Brook, up to Slătioara, *barite* appears sporadically, especially in the zones of the Afiniș and Padina Brooks, paragenetically associated with sulfides.

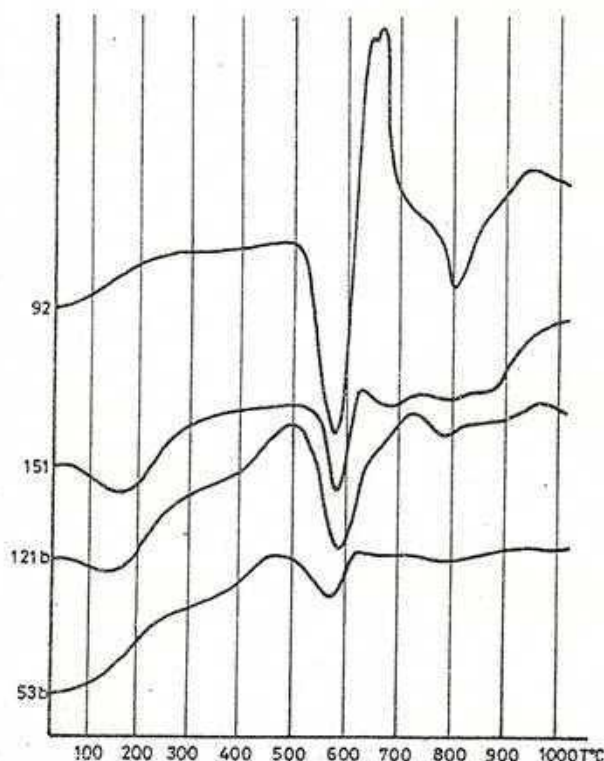


Fig. 3 – Differential thermic curves: 92 – *siderite*, Valea lui Ion; 151 – *sideritized muscovite paragneiss*, Clife Brook; 121b – *sideritized muscovite metasandstone*, Tarnița Brook; 53b – *muscovite arkosian metasandstone impregnated with siderite*, Afiniș Brook.

Analysing the relationship with the other gangue minerals, it is evident that *barite* penetrates on the fissures of the hydrothermal quartz, corroding it; the fact that *barite* is younger than hydrothermal quartz is also illustrated by the presence of some quartz veinlets which contain *barite* in their central part. In respect of *siderite*, *barite* may be concomitant with it or younger, *barite* veinlets intersecting the *siderite* zones or *siderite* rests occurring in the *barite* mass.

Both *siderite* and *barite* are characterized by a high capacity of corroding, impregnating and even replacing hydrothermal quartz as well as the minerals of the host rocks – *microcline*, *plagioclase* and *muscovite*, resulting in, for instance, the *baritized gneisses* of the Rarău Formation.

Except for the great *barite* accumulations south of

the Clife Brook, witherite rarely occurs, being associated with calcite, chalcedony and chlorite.

Goethite, *azurite* and *malachite* are the most frequent secondary, supergene minerals.

2. Chemism

In order to point out the possible correlations among the metallic elements, 12 chemical (for Cu, Pb, Zn) and spectral analyses were carried out on informative samples collected from the zone of the galleries on the Padina and Afiniș Brooks, where there are the richest mineralogical associations, comprising almost all the hydrothermal minerals encountered between Slătioara and Ostra (tab. 1, 2).

IV. Considerations on the Genesis and Age of Mineralizations

1. Structural and Lithological Control

All the mineralized zones described between Slătioara to the north and Ostra to the south lie on an alignment generally trending approximately north-south, corresponding to a major fracture. Due to its regional extent this fracture crosses formations with various physico-chemical and mechanical properties. That is why in some portions the fracture remained closed throughout its evolution, while in some other parts, especially where crossing competent (brittle)

Table 1
Results of the Chemical Analyses for Cu, Pb, Zn and Location of Samples

	46b	47b	50c	53a	53b	53c	53f	54a	55	57	58a	59a
Cu	1.07	7.20	11.47	13.87	1.47	4.27	5.07	9.87	11.73	1.53	2.87	2.89
Pb	11.71	6.43	8.29	0.69	0.20	0.11	0.09	0.20	2.14	3.37	5.03	2.11
Zn	0.20	0.19	0.35	0.08	0.02	0.05	0.04	0.14	0.13	0.05	0.10	0.04

Padina Brook: 46b - massive mineralization from the waste dump of the gallery on the left bank;
47b - massive mineralization on the waste dump of the gallery on the left bank.

Afiniș Brook: 50c - massive mineralization, directional gallery 2 NE, l.m. 15 from gallery IV;
53 - directional gallery 3 NE, l.m. 25 from gallery IV; a - massive mineralization; b - mineralized rock from the footwall of the vein at the immediate contact; c - disseminated mineralization above the massive zone, also within the vein; f - disseminated mineralization at about 0.5 m in the footwall;
54a - massive mineralization, directional gallery 3 NE, l.m. 27;
55 - massive mineralization, directional gallery 3 NE, l.m. 30;
57 - massive mineralization at the entrance of gallery III, from the upper part of the vein;
59a - massive mineralization at the entrance of gallery III from the lower part of the vein.

Table 2
Results of Spectral Analyses (ppm)

Sample	As	Sb	Mn	Ni	Bi	Cd	Ti	Ag	Co
46b		900	175	25	900	40	500	>300	3
47b	300	>3000	>3000	80	1500	50	100	>300	11
50c	2600	>3000	60	30	1300	50	100	>300	4
53a		450	50	50	125	15	100	140	6
53b		100	>3000	10	1200	15	200	125	
53c			80	60	22	30	250	40	7
53f			90	10	25	10	250	18	3
54a	300	1300	50	35	225	25	100	>300	4
55		600	50	60	175	15	100	200	5
57		200	350	20	120	10	500	70	
58a		1100	900	28	50	10	100	270	
59a		100	1800	38	45	18	1500	50	5

It is worth noting first of all the high copper, lead, silver and stibium content within most samples. The only significant correlations are the positive ones between lead and silver, and stibium and silver on the one hand, and the negative correlation between copper and silver, on the other (Figs 4, 5, 6). A gravimetric analysis carried out on sample 47b (Padina Brook) indicated 1204g/t Ag.

rocks, it could be open during some periods, thus serving as access way for the mineralizing solutions. These competent rocks are represented by quartz or quartz-feldspathic rocks in the Tulgheș Group and in the Chiril Formation, and by gneisses, especially microcline gneisses, in the Rarău Formation.

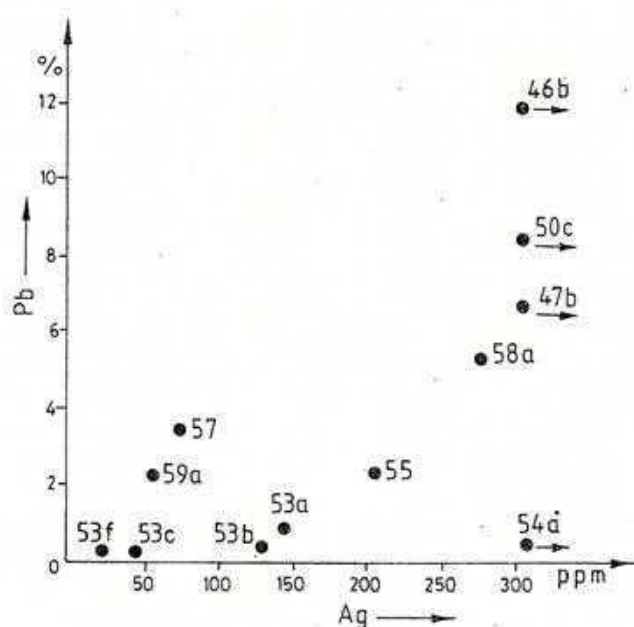


Fig. 4 - Lead-silver correlation.

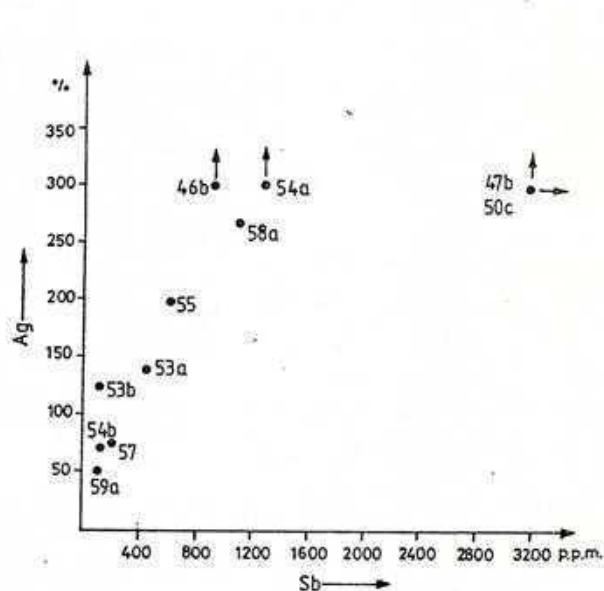


Fig. 5 - Silver-stibium correlation.

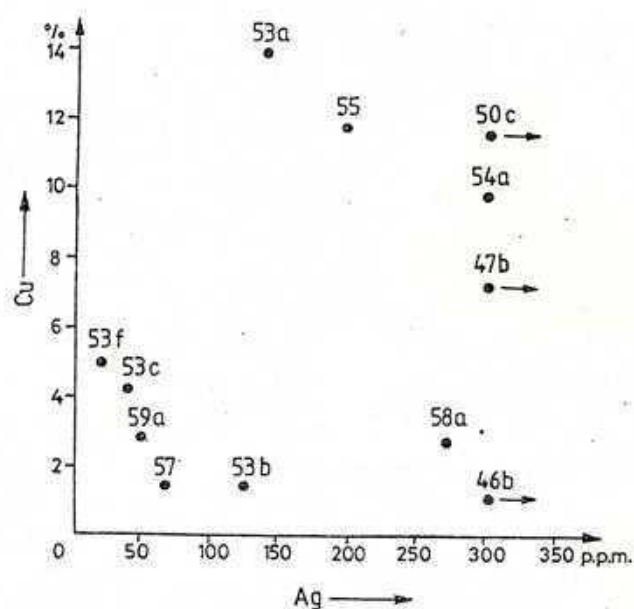


Fig. 6 - Copper-silver correlation.

Between Slătioara and Clife the fracture zone constituting the access way is characterized now by an advanced brecciation, in most cases accompanied by a pronounced silicification $\pm$ pyritization.

In this zone, where the encountered hydrothermal mineralizations are hosted especially in the formations of the Tulgheș Group (subordinately maybe also in the Chiril Formation), the mineralizations develop mostly on transversal alignments with respect to the main fractures. There are possible two hypotheses concerning this situation as follows: a) the mineralizations

deposited on auxiliary transverse fractures or b) the main fracture is transversal with respect to the detail geologic structure, the mineralizing solutions laterally migrating along certain distances, in the mass of the brecciated rocks levels or on the contact zone between the competent and incompetent rocks.

The detailed observations made at the surface and in the mining works support the latter hypothesis, a reason why prospects for the development of the polymetallic mineralizations $\pm$ barite $\pm$ siderite are to be found in the vicinity of the intersection zones of the

fractures with the competent rocks.

The presence of the large barite bodies in the Rarău gneiss mass south of the Clife Brook is due to the fact that, given the reduced thickness of the Rarău Nappe, the competent microcline gneisses were strongly mylonitized over large areas; moreover, one can take into consideration also the "screen" towards the surface consisting of sedimentary rocks.

Thus the deposit form of the barite mineralization from the Oștra quarry may be considered to be a stock-work.

2. Succession of the Deposition of the Mineralizations

The study of the spatial and temporal relationships among the minerals making up the hydrothermal mineralizations indicates that there are at least three stages (pulsations) in the deposition succession.

a) In the first stage hydrothermal quartz±pyrite deposited, cementing the cataclased rock fragments along fractures.

b) The subsequent reactivation of the fractures caused a new brecciation, this time mainly of the hydrothermal quartz resulted in the first stage. Concomitantly with brecciation or later a second mineralization stage takes place, in which the principal metallic mineral was chalcopryite, accompanied or not by galena, tetrahedrite or sphalerite; the corresponding gangue minerals are mainly represented by quartz (the second zone in the case of the zoned crystals)±siderite.

c) In the third stage, probably subsequent to a new tectonization, especially galena, sphalerite, tetrahedrite and bournonite deposited, accompanied or not by chalcopryite; anyway, where sphalerite is in greater amount, the presence of chalcopryite is insignificant. The gangue minerals are quartz (corresponding to the third zone in the case of the zoned crystals), siderite and barite.

A fourth paragenesis, the most recent one, can be well observed only in the zone of the Oștra quarry, in the vicinity of the contact with the sedimentary, represented by the generally collomorphic pyrite, hematite, calcite, witherite, chalcedony and chlorite.

The lack of some significant correlations among most metallic elements also indicates that the mineralizations are superposed, polyascendant; taking into consideration the iron from the quartz gangue pyrite mineralization as well as barium from the zones in which barite is the principal hydrothermal mineral, it can be concluded that the metallic elements underwent a pronounced geochemical differentiation process during their migration from the source to the host rock.

The low porosity as well as the chemical inertia of the quartz feldspathic rocks generally allowed the circulation of the mineralizing solutions only along the

fracture zones. The immediate effect was in most cases the vein-like deposit form, the impregnation zones being of reduced extent. Also within the formations of the Tulgheș Group, the sericite-chlorite and graphite schists constituted a "screen" in the dispersion of the solutions, these being determined to migrate along the contact zones.

3. Geothermometric Data

In order to estimate the formation temperatures of the epigenetic hydrothermal minerals, we analysed the differential dilatation of some polycrystalline cylindrical samples, heated by a gradient to 10° C/minute; the obtained curves are shown in Figure 7.

Samples 53a, 54 and 55 of dominantly cupriferous mineralization, at the level of gallery IV Afiniș, with quartz gangue (pointed out through the accentuation of the curves round the temperature of 575° C - the quartz inversion point) begin to decrepitate at about 310° C due to the pressure exerted by the fluid inclusions within the crystal mass at the homogenization temperature (of formation of the respective minerals).

Sample 115 consisting exclusively of hydrothermal quartz on the interfluvium between the Padiua Brook and the Pârâul cu Mesteceni Brook starts decrepitating also round the temperature of 310° C.

In the case of samples 58, at the entrance of gallery III Afiniș, the dilatometric curves appear somewhat different; thus sample 58a₁, consisting only of barite, decrepitated at the temperature of about 260° C, while the curve given by sample 58a₂, consisting mainly of galena bearing barite and quartz gangue, shows a decrepitation at 260° C and another one, on a large scale, at 320° C; in the latter case barite probably decrepitated first and then quartz (of a generation prior to galena and barite).

Sample 62, consisting of compact barite at the level of the ninth bench in the Oștra quarry decrepitated at about 280° C.

The above observations lead to the conclusion that barite and implicitly the mineralization with barite gangue formed round the temperature of 260-280° C (values close to those obtained by Manilici and Dumitrescu, 1980), and at least part of the quartz - which accompanies the pyrite and chalcopryite mineralization - formed at about 300-320° C.

The relatively high temperatures indicated by these determinations are supported also by other arguments, such as the presence of siderite, of the chalcopryite exsolutions within sphalerite as well as the deposition of silica as crystals from the electrolytic solutions and not as metagels from colloidal solutions.

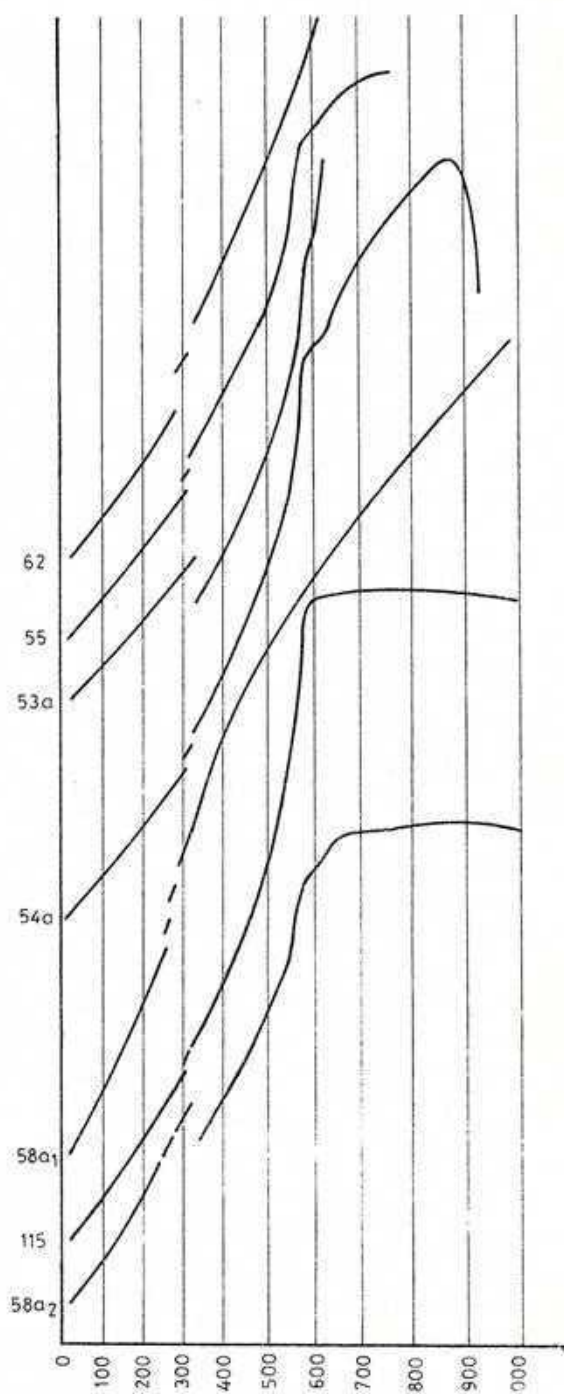


Fig. 7 - Differential dilatometric curves.

4. Geochronological Data

The analysis of the lead isotopes (L. Timofte), carried out on two galena samples (46b - Padina Brook and 58a - Afiniș Brook) through the common lead method provided the following results (Tab. 3).

On the Holmes-Houtermans diagram (Văjdea, 1968) the $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ ratios plot approx-

imately on the isochron of 300 Ma and on the growth curve of V ($V = ^{235}\text{U}/^{204}\text{Pb}$), their value being of about 0.065 (Fig. 8).

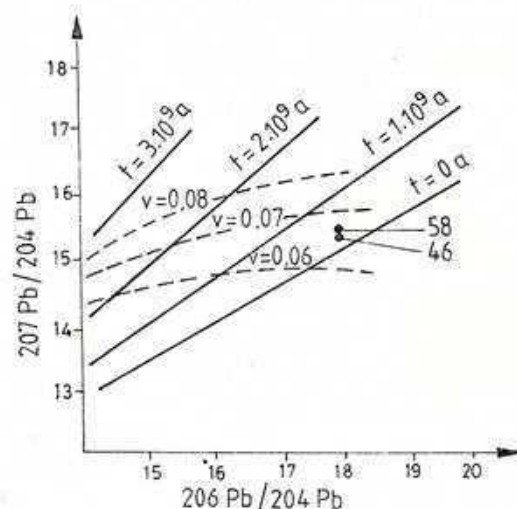


Fig. 8 - Holmes-Houtermans diagram.

The first indication (isochron of 300 Ma) points to a Hercynian lead and the value of V, approximately equal in both samples, indicates the same source for the lead.

The results of the geochronological analyses through the common lead method that indicate a Hercynian age, do not agree with the observation data in the Ostra quarry zone, where the barite mineralization extends also in the basal part of the Mesozoic sedimentary formation.

V. Conclusions

In the metamorphic formations from the basement and partly in the Ostra zone and in the base of the sedimentary formations, several epigenetic hydrothermal mineralizations are hosted.

The epigenetic parageneses comprise pyrite, chalcopyrite, galena, sphalerite, tetrahedrite, bournonite, oligist, marcasite, arsenopyrite, quartz, siderite, barite, witherite and chlorite.

All the zones between Slătioara and Ostra presenting indications of epigenetic mineralization are situated along an alignment trending approximately north-south, corresponding to a major fracture which affects the whole crystalline basement.

Between Slătioara and Clife, where the hydrothermal mineralizations are hosted especially in the formations of the Tulgheș Group and subordinately in the Chiril Formation, the mineralizations develop in most

Table 3
Results of Geochronological Analyses through the Cammon Lead Method

Sample	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{208}\text{Pb}/^{204}\text{Pb}$	$^{206}\text{Pb}/^{207}\text{Pb}$
46 b	17.91033	15.38192	37.74240	1.16449
58 a	17.87665	15.32661	37.62412	1.16539

Analyst Timofte Laurențiu, I.F.A. București.

References

- cases on transversal alignments with respect to the direction of the main fracture; this can be explained by the fact that the hydrothermal solutions laterally migrated, over certain distances, in the mass of brecciated rocks, resulting in veins and impregnations.
- The presence of the large barite bodies in the Rarău gneiss mass south of the Clife Brook is due to the fact that, given the reduced thickness of the nappe, the competent microcline gneisses were strongly mylonitized over large zones, the prevailing deposit form being the stockwork.
- At least three stages can be distinguished in the mineral deposition succession as follows:
- 1) In the first stage hydrothermal quartz±pyrite deposited, cementing the cataclased rocks along fractures.
 - 2) The subsequent reactivation of fractures brought about another brecciation, this time mainly of the quartz resulted in the first stage; concomitantly with the brecciation or possibly later a second mineralization stage takes place, in which the principal metallic mineral is chalcopryrite, the gangue minerals being represented by quartz±siderite.
 - 3) In the third stage, probably subsequent to a new tectonization, especially galena, sphalerite, tetrahedrite and bournonite formed, accompanied or not by chalcopryrite; the gangue minerals are quartz, siderite and barite.
- Geothermometric determinations indicated a formation temperature of 260–280° C for barite and implicitly for the barite parageneses, and of 300–320° C for at least part of the quartz – that accompanying the pyrite and chalcopryrite mineralization from the first two stages. We also consider that the colloidal iron sulfide and the collomorphic silica encountered especially in the Ostra quarry zone belong to another possibly both temporally and genetically independent stage of the discussed mineralizations.
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Presented at the scientific session of the
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Plate I

Fig. 1 - Quartz veinlet in muscovite quartz-feldspathic metapsammite; N +, x 40.

Fig. 2 - Quartz zoned crystals in the massive metallic mineralization; N +, x 100.

Fig. 3 - Fissured hydrothermal quartz; N +, x 40.

Fig. 4 - Siderite from a cluster showing a massive structure; N +, x 40.

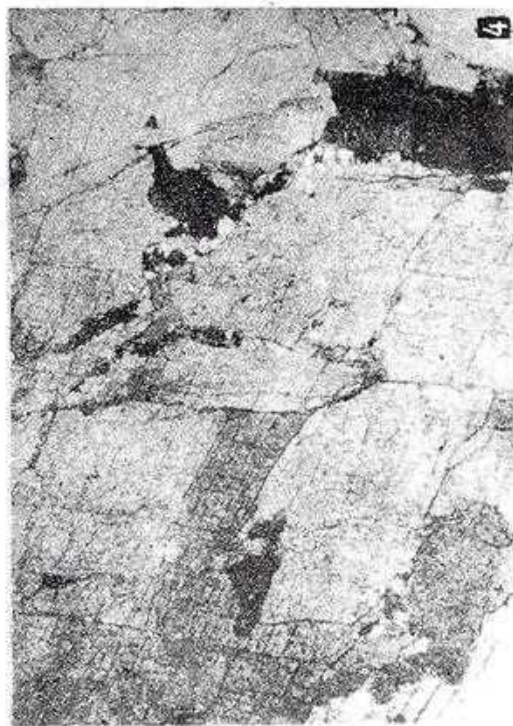
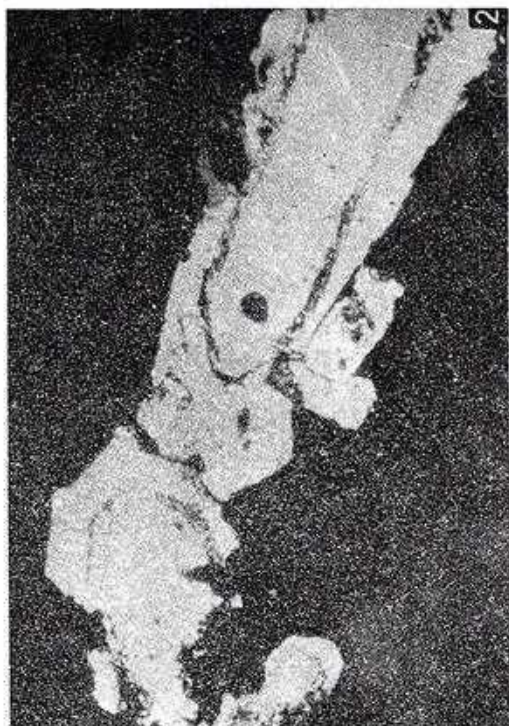
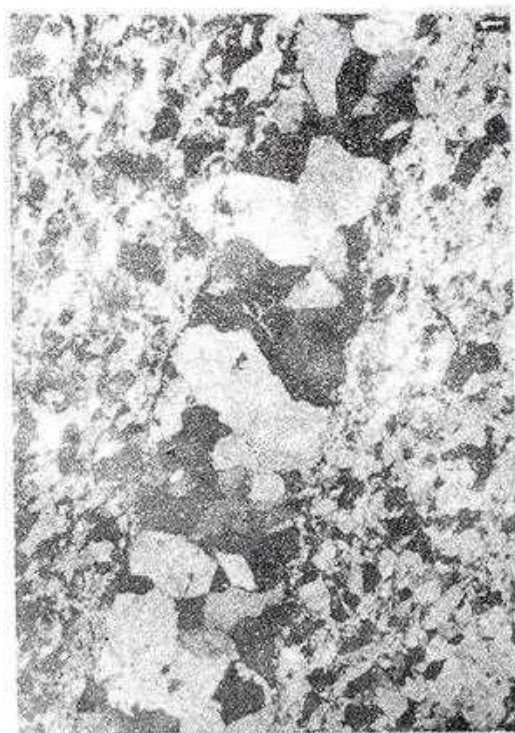


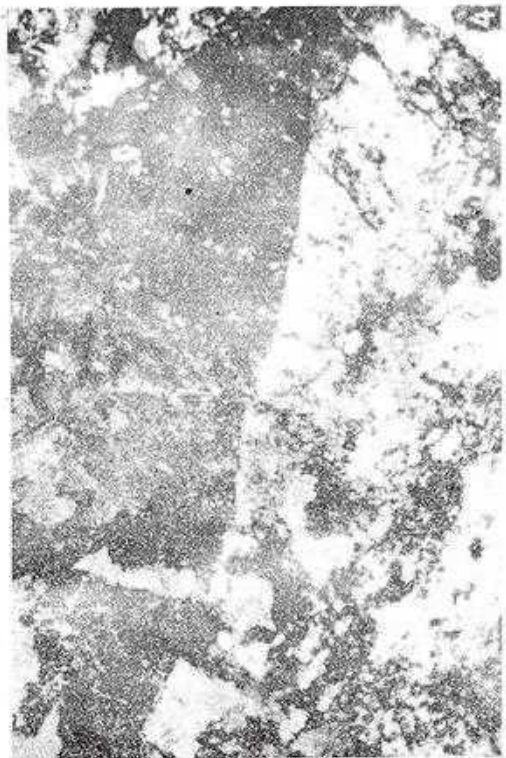
Plate II

Fig. 1 – Discordant siderite veinlet containing barite in the central part; N +, x 100.

Fig. 2 – Barite including and corroding hydrothermal quartz crystals; N +, x 100.

Fig. 3 – Hydrothermal quartz idiomorphic crystal containing barite impregnation, included in the barite mass; N +, x 40.

Fig. 4 – Microcline phenoblast from the Rarău gneisses partly replaced by siderite and barite (siderite occurs especially as isolated crystals, and barite forms variously oriented veinlets); N +, x 40.



THE IRON AND BARITE MINERALIZATIONS FROM THE DELNIȚA-BOTOȘEL ZONE (EAST CARPATHIANS)

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Key words: Mineralization. Iron ores. Barite deposits. Sedimentary rocks. Triassic. Fluid inclusions. Decrepitation. East Carpathians.

Abstract: The discussed mineralizations are hosted in the formations of the Sub-Bucovinian Unit, consisting mainly of siderite, ferrodolomite, dolomite, barite, hematite and pyrite, beside which there are small amounts of chalcopryrite, sphalerite, galena, tetrahedrite, witherite, chalcedony and chlorite that have an important genetic significance. The studies carried out revealed a similarity to almost identity between these mineralizations and those corresponding to the upper stages of the epigenetic (hydrothermal) mineralizations from the Slătioara-Gemenea-Ostra zone (the third and fourth mineralization stages) both as regards the mineralogical parageneses and the formation temperature, structure and forms of deposit. With respect to age and origin, we think that the epigenetic mineralizations from the two zones (Slătioara-Gemenea-Ostra and Delnița-Botoșel, respectively) formed at the beginning of the continental rift stage at the end of the Jurassic, a stage with which the vein-like basic magmatites and the Ditrău alkaline massif are connected.

The object of this paper consists in the study of the iron and barite mineralizations from the Delnița-Botoșel Zone in view of their possible correlation with the epigenetic mineralizations from the Ostra-Gemenea-Slătioara Zone that constituted the subject of a previous study (Macalet et al., in this volume).

The Delnița-Botoșel Zone is situated on the eastern slope of the Obcina-Mestecăniș region, the brooks crossing it being tributaries of the Moldova River upstream the Fundul Moldovei locality.

The main structural peculiarity of the geological formations hosting the mineralizations which are to be discussed consists in the fact that, unlike those from the Slătioara-Ostra zone, they belong to the Sub-Bucovinian Unit (Kräutner et al., 1975, 1984; Vodă et al., 1986; Zincenco, 1988).

The Sub-Bucovinian Unit from the Delnița-Botoșel zone consists of a crystalline basement and a discontinuous Triassic sedimentary cover, which, in their turn,

underlie the crystalline formations of the Țibău Formation.

The crystalline basement consists mainly of quartz-sericite-chlorite schists, muscovite quartzites and quartz-feldspathic rocks assigned to the Tulgheș Group (Kräutner et al., 1975, 1984).

The Triassic sedimentary cover comprises a basal detrital horizon and a carbonatic complex (Cărunțu, 1972; Săndulescu, 1976; Iacobescu and Potec, 1978; Zincenco, 1988); in places the detrital horizon may lack, the carbonatic rocks overlying directly the crystalline basement.

The Țibău Formation consists of carbonatic crystalline, prevailing dolomitic rocks, quartzites and muscovite-chlorite schists in various mylonitization stages.

Structurally the Țibău Formation appears thrust over the Triassic sedimentary cover of the Sub-Bucovinian Unit, being in its turn overlain by the main

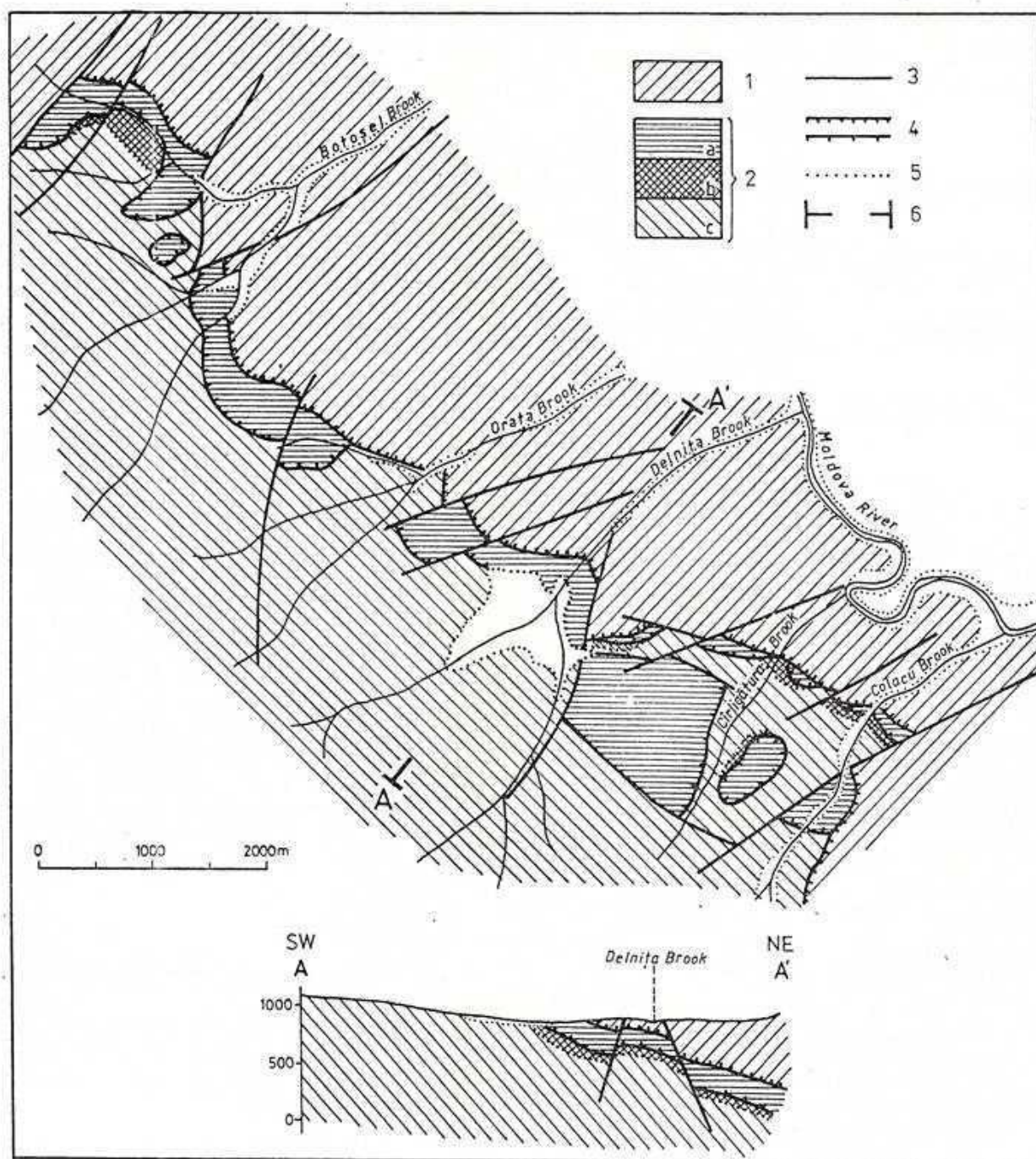


Fig. 1 - Structural sketch of the Delnița-Botoșel Zone (according to Kräutner *et al.*, 1975). 1, Bucovinian Unit (Tulghes Group (Tg₃, Tg₄ formations); 2, Sub-Bucovinian Unit: a) Tîbău Formation; b) Triassic sedimentary; c) Tulghes Group; 3, faults; 4, overthrust lines; 5, transgression boundary; 6, geologic section.

body of the Bucovinian Unit (Fig. 1). Due to this position, Bercia *et al.* (1976) considered the Tîbău Formation to show the characteristics of a rabotage slice - the "Delnița rabotage slice". Subsequently Zinenco (1988) considered the Triassic sedimentary to be also thrust over the crystalline basement; that is why

the author thinks the name of the "Delnița rabotage slices" is more correct, thus including also the Triassic deposits.

Our observations in the mining works at Delnița show that in most cases the contact between the sedimentary cover and the crystalline basement appears

shifted, but we consider that the shifts are not great, the shift of the two lithostratigraphic units being the effect of the different behaviour of the respective formations under the impact of the movements subsequent to the Triassic sedimentation.

I. General Consideration on the Triassic Sedimentary Formations and Their Mineralizations

Most of the mineralizations from the Delnița zone are hosted in Triassic sedimentary formations.

The detrital basal horizon consists of sandstones and conglomerates directly overlying the crystalline basement. The elements of these rocks are represented especially by quartz and muscovite or, more rarely, quartzitic rock fragments; sandstones bearing siliceous-sericitic cement and carbonatic cement can be distinguished; in addition to the mentioned minerals, chloritized biotite, zircon, tourmaline etc are also to be found.

The Carbonatic Complex is the most developed, constituting in fact the main formation bearing mineralizations. Although all the intermediate terms between limestones and dolomites are encountered, dolomites prevail; also, a certain amount of detrital material may be present, especially quartz and muscovite and in some cases gritty dolomites.

The rocks of the carbonatic complex are cryptogranular to microgranular (of micritic aspect), generally compact, ranging in colour from light-grey to dark-grey, sometimes showing a brown tint.

The previous investigations of the iron mineralizations from the Delnița zone show that these mineralizations correspond to two different facies - a carbonatic one, developed towards ESE (between Delnița and Cărligătura) and an oxydic one, towards WNW (between Delnița and Orata) (Nichita et al., 1967; Iacobescu and Potec, 1978; Zencenco, 1988). Taking into consideration the stratigraphic position, the carbonatic facies would be towards the lower part and the oxydic one towards the upper part.

In the carbonatic facies, iron is hosted mainly by siderite, possibly manganosiderite and ferrodolomite, while in the oxydic facies it is hosted almost exclusively by hematite.

As regards the genesis of the mineralizations in the Delnița zone, the investigations carried out so far reveal three genetic models:

a) metasomatic-hydrothermal genesis (Iacobescu and Potec, 1978; Vodă et al., 1986);

b) syngenetic-diagenetic sedimentary genesis (Zencenco, 1988);

c) mixed genesis-sedimentary for the mineralizations from the oxydic facies and hydrothermal for those from

the carbonatic one (Nichita et al., 1967; Băgu and Rădulescu, 1968).

In this context it is worth noting that the researchers who accept at least partly the hydrothermal genesis, mention the presence of the mineralizations also in the crystalline formations of the basement.

II. Description of the Mineralizations

The mining works at Delnița intercepted several mineralizations formed of carbonates (siderite, ferrodolomite, dolomite, calcite, witherite), barite, hematite, pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, calcedony and chlorite.

Siderite is the main iron mineral of the "carbonatic facies" which is largely developed in the south-eastern part of the zone. Although the highest siderite concentrations are situated towards the lower part of the sedimentary formation, siderite is found both in the crystalline formations from the basement and in the upper part of the carbonatic complex.

The deposit appears as veins, which are usually conformable and more rarely show a random disposition, clusters and impregnations.

The sideritic ore generally has a phaneritic (0.5-3.0 mm), idiomorphic, hypidiomorphic and more rarely xenomorphic granular structure, often forming parallel (Pl., Fig. 1) or radial aggregates.

In some samples the largely developed crystals show a zonal structure, alternating light-coloured zones with darker ones; also, in places an opaque, microcrystalline powder is to be found on the surface of the crystals, on cleavages and on fissures, as a result of the oxidation processes.

Through the heating of the unaltered samples, the dissociation takes place in two stages - first a weak dissociation between 500-540° C takes place, then, on a large scale, at over 560° C (Fig. 2, samples 272a and 215), which leads to the conclusion that the siderite network also contains a certain manganese amount.

The prevailingly sideritic aggregates preserve remnants either from the detrital rocks of the basal horizon or from the dolomites of the carbonatic complex. The detrital material is represented both by quartz-micaceous psammite fragments, sometimes bearing hematitic cement, and by isolated quartz grains and muscovite lamellae, both minerals being strongly corroded by siderite (Pl., Fig. 2).

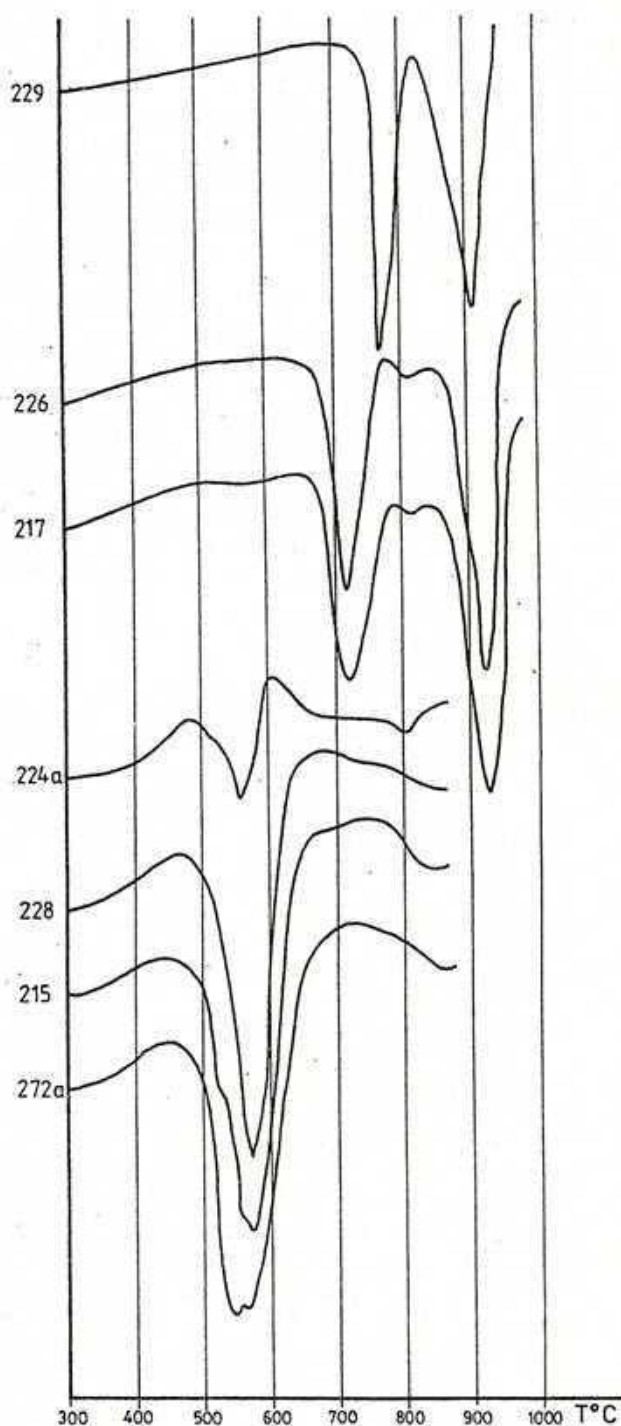


Fig. 2 - Differentiated thermal curves: 272a, 215, 228 - siderite; 224a - siderite+barite; 217, 226 - ferrodolomite; 229 - dolomite.

In most cases siderite is associated with barite, which is younger; the siderite±barite aggregates are in their turn crossed by calcite and calcedony veinlets with which pyrite associates in some samples.

Ferrodolomite and dolomite (Figs. 2 and 3 - samples 217, 226a, 229) form a continuous series. Both the

deposit form and the structure are similar to those of the sideritic ore, from which they differ only in colour, which is usually light-grey, sometimes showing a slightly yellowish tint.

In many cases the aggregates consisting of these minerals show numerous voids and spongy texture; also, they preserve remnants from the cryptocrystalline sedimentary dolomitic rock. Like siderite, ferrodolomite and dolomite appear associated with barite.

Calcite is sporadically encountered in a small amount, either as diaclasses in the carbonatic complex or associated with pyrite together with the cryptocrystalline silica; in some cases calcite, associated or not with pyrite, replaces barite.

Barite has been cited by several researchers (Nichita et al., 1964; Băgu and Rădulescu, 1968; Iacobescu and Potec, 1978).

As in the case of the iron carbonates, the deposit forms of the barite mineralization consist of veins, impregnations and clusters hosted both in the quartz-muscovite schists from the basement and especially in the Triassic sedimentary formations.

In the crystalline schists from the immediate vicinity of the sedimentary formations (both formations appearing strongly laminated) conformable veins of barite and impregnations, usually associated with siderite, are to be found.

In the Triassic sedimentary formations barite may form monomineral accumulations or associate with siderite (Pl., Fig. 3).

The barite monomineral aggregates present a large crystallized structure with clear, prismatic or tabular, variously oriented crystals. Barite in its turn may appear replaced by calcite, associated or not with pyrite or partly transformed into witherite; also the larger crystals are usually fractured and recemented with calcite, pyrite or hematite (Pl., Fig. 4).

In the vicinity of the siderite and barite veins hosted in the sedimentary dolomites, a partial recrystallization of the cryptocrystalline dolomite, sometimes as rhombohedrons of zonary structure have been noticed. This remark leads to the conclusion that the recrystallization of the sedimentary dolomite took place due to the hydrothermal solutions, from which siderite and barite deposited. The recrystallization had a prevalently allochemical character, mainly with iron contribution.

Hematite, the main iron mineral of the "oxidic facies", is widely distributed both in the deposits of the detrital horizon and especially in those of the carbonatic complex, generally appearing as micronic lamellae which have a relatively non-uniform distribution.

The carbonatic rocks include bands devoid of hematite that alternate with some in which the hematite amount is high or even prevalent. The low

crystallization grade and the stratiform aspect are arguments in favour of the sedimentary genesis of the hematite showing these features.

Beside the hematite exhibiting the above-described features, within the sedimentary dolomites veins of reduced thickness (0.1–0.2 m) consisting mainly of hematite±barite have been intercepted; in this case hematite forms an almost compact mass with largely developed lamellae. Compared with barite, hematite is younger, impregnating or including the barite crystals (Pl., Fig. 4); hematite is partly transformed into goethite.

Pyrite is a mineral frequently found in the mineralizations at Delnița, especially in the strongly tectonized zones, but it is not characteristic of a certain stratigraphic level.

The pyrite amount varies from one sample to another, occurring mostly as impregnation, in the form of veinlets, small clusters or individual crystals, generally of reduced dimensions (0.01–0.05 mm).

The fact that in most cases the veinlets are connected with the massive clusters indicates that this pyrite belongs to a single generation; pyrite is associated with calcite and cryptocrystalline silica.

Unlike the iron carbonates (siderite, ferrodolomite), barite, and probably hematite, the pyrite exhibiting the above-described features is younger.

Chalcopyrite, sphalerite, galena and tetrahedrite usually occur together as small-sized clusters in the siderite and barite aggregates. The association of these minerals ± older pyrite is similar to the parageneses encountered in the Slătioara-Gemenea zone and farther towards the south up to the Târnița Brook.

Chalcopyrite may occur also as micronic crystals in the calcite diachases from the sedimentary dolomites or as isolated crystals or veinlets in the siderite aggregates, following the intergranular limits or penetrating on the fissures of the large siderite crystals.

Of the supergene secondary minerals, goethite is the most frequent, being formed in the oxidation zones at the expense of siderite and pyrite; psilomelane, gypsum, melanterite, malachite and azurite are also found in smaller amounts.

The siderite and barite mineralizations were encountered also in the mining works from the upper basin of the Botoșel Brook within the same structural and lithostratigraphic frame as that of Delnița.

Thus, in the quartz-feldspathic formations of the Tulgheș Group under the Triassic sedimentary, a siderite vein was intercepted, which exhibits a coarse, uniformly grained structure, containing small barite and sulphide amounts; the vein intersecting almost at a right angle the massive syngenetic pyrite levels is about 1 m thick.

Also, in the Triassic dolomites, an almost 0.5 m thick

barite vein was found.

III. Geothermometric Data

The differential dilatometric analyses carried out on barite and siderite samples pointed out in some cases the presence of the fluid inclusions which, at the homogenization temperature, produced the decrepitation of the sample (Fig. 3, samples 215, 224b, 226b and 272a).

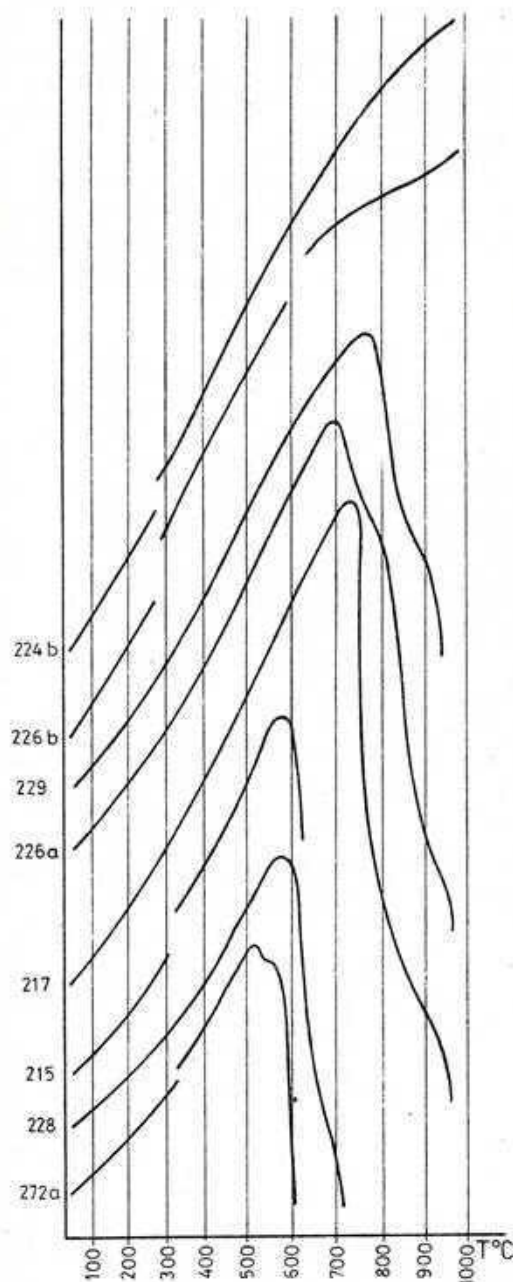


Fig.3 - Differential dilatometric curves: 228, 272a- siderite; 215-siderite+barite; 217, 226 a-ferrodolomite; 229-dolomite; 226b-barite+ferrodolomite; 224b-barite

The samples 215 and 272a, consisting prevalingly of siderite and, subordinately, barite, decrepitated round the temperature of 310°C , while sample 226b, in which the prevailing mineral was barite, associated with a small ferrodolomite amount (a correlation also with the curve given by sample 226a should be made), decrepitated at about 280°C ; finally, sample 224b, formed only of barite, decrepitated at 260°C .

Although the decrepitation phenomenon was pointed out in a small number of samples, the obtained results totally agree with the microscopic observations that led to the conclusion that, in most cases, siderite belongs to a mineralization stage prior to that in which the main mineral was barite.

Taking into consideration these results, it can be stated that the barite and siderite mineralizations (and also ferrodolomite and dolomite) formed within a temperature interval ranging between $260\text{--}310^{\circ}\text{C}$.

IV. Microtectonic Data

Having in view the scarcity of outcrops in the zone of mineralizations at Delnița, we measured in the mining works the planar mesoscopic elements from the Triassic dolomitic rocks - stratification and fissures - and the position of some veins. Based on these measurements, we have drawn two tectonograms (Fig. 4), which show that at the level of horizon -50 m, the B tec-

tonic axis strikes WNW-ESE, dipping slightly eastwards ($116^{\circ}/10^{\circ}$), while at the level of horizon -150 m the B axis strikes approximately W-E, also with eastern dipping ($78^{\circ}/16^{\circ}$).

In both cases the poles of most carbonate and barite veins plot in the maximum zone of (S_0) stratification poles, thereby indicating that the veins are generally conformable with the stratification.

V. Conclusions

From the genetic point of view, the studied mineralizations are similar to those in the Slătioara-Gemenea-Ostra Zone - hydrothermal epigenetic, respectively (Macalet *et al.*, in this volume). But in the Delnița-Botoșel Zone the fractures crossing the formations of the Tulgheș Group favoured the ascension of the solutions up to the prevalingly carbonatic sedimentary formations in various cataclasisation stages; the latter constituted a medium favourable to the dispersion of the solutions, generally parallel to the contact and to the depositions of the mineralizations (Fig. 5). Also, the filling of the open spaces, formed as a result of the tectonization, was accompanied in some cases by several metasomatic phenomena, favoured both by the greater permeability of the carbonatic rocks - due to the diagenetic dolomitization processes - and by the high solubility of these rocks.

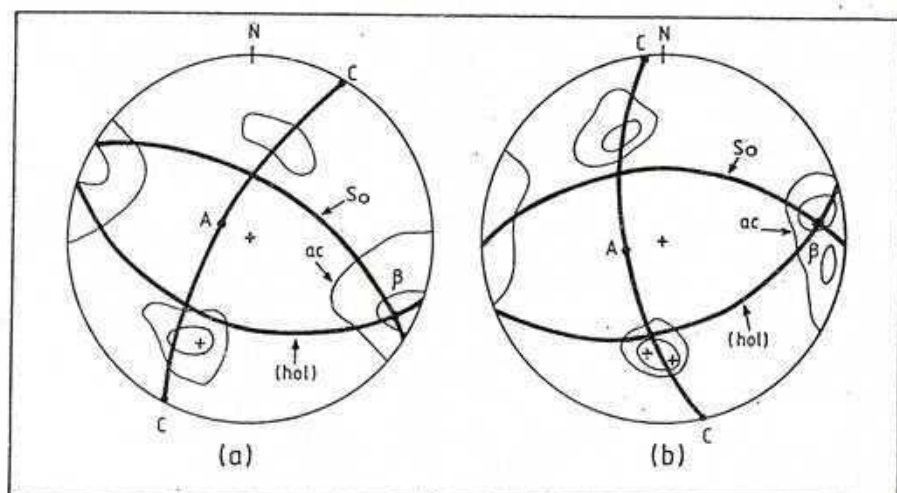


Fig. 4 - Tectonograms for the Triassic dolomites from the mining works at Delnița: a) horizon -50 m; b) horizon -150 m; S_0 - stratifications; (hol) and ac - fissures; + - poles of the veins (Plotting in the lower hemisphere).

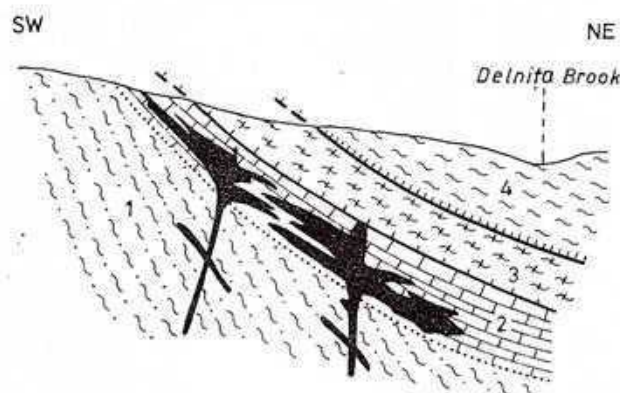


Fig. 5 - Simplified model suggesting the genesis and form of deposit of the mineralizations at Delnița. 1, Tulghes Group from the Sub-Bucovinian Unit; 2, Triassic sedimentary; 3, Țibău Formation; 4, Tulghes Group from Bucovinian Unit.

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Received: April 29, 1991.

Accepted: May 30, 1991.

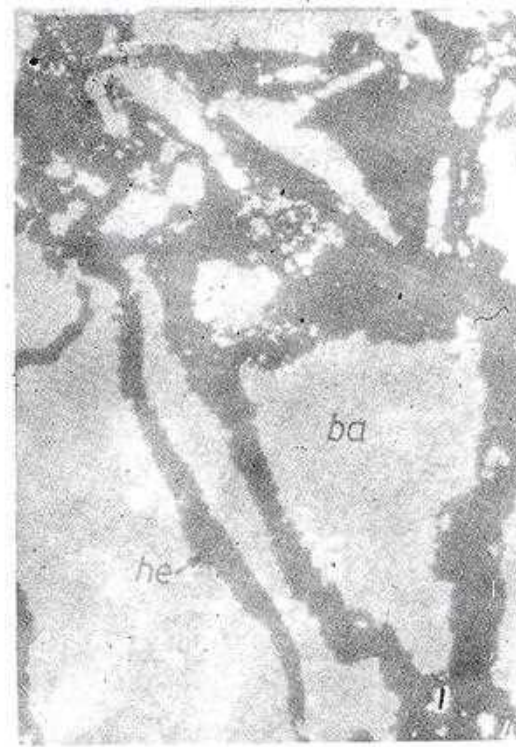
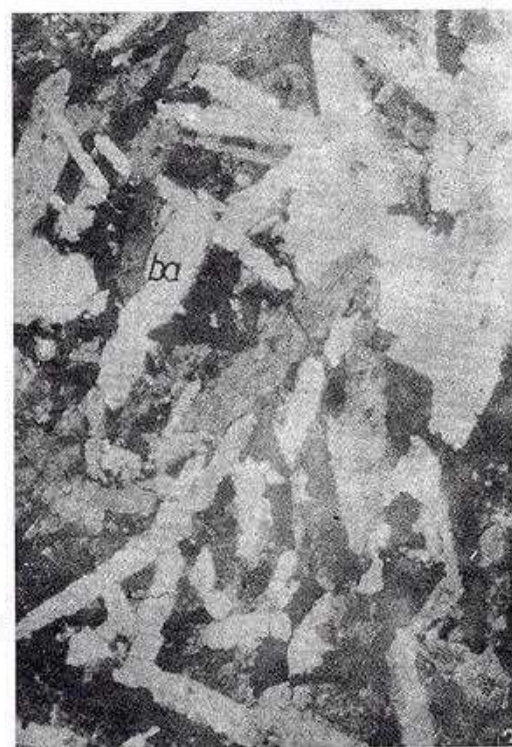
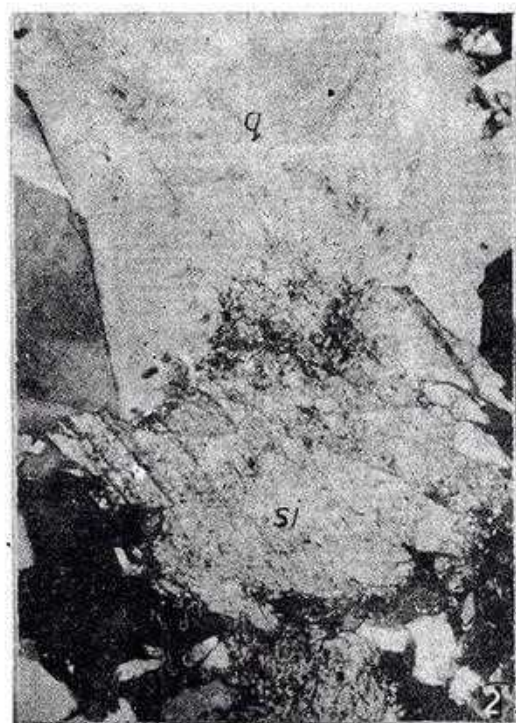
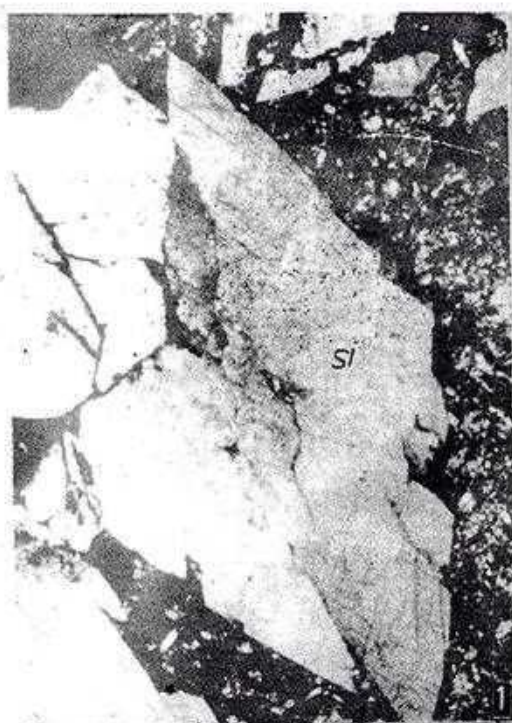
Presented at the scientific session of the Institute of Geology and Geophysics: June 11, 1991.

Fig. 1 - Largely developed siderite crystals (si) on the background of a sedimentary - fine arenitic rock; N +, x 100.

Fig. 2 - Siderite (si) corroding a quartz crystal (q); N +, x 100.

Fig. 3 - Barite idiomorphic crystals (ba) developed on the sideritic background; N +, x 40.

Fig. 4 - Cataclased barite (ba) recemented with hematite (he); N ||, x 40.



RELATIONSHIPS BETWEEN ALTERATIONS, PORPHYRY COPPER-GOLD AND BASE METAL-GOLD HYDROTHERMAL VEIN MINERALIZATIONS IN TERTIARY INTRUSIONS, TALAGIU AREA, ZARAND MOUNTAINS

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Key words: Mineralization. Hydrothermal processes. Base metals. Porphyry copper. Gold. Sulphides. Andesites. Tertiary. Zoning. Zarand Mts - Apuseni Mts.

Abstract: In the Talagiu area a porphyry copper-gold and vein mineralization occurs in a Tertiary subvolcanic andesitic-microdioritic body. The main mineralized veins form a well-defined paragenetic sequence, showing a simplified mineralogy progressing through: 1. pyrite-chalcopyrite $\pm$ Au + anhydrite + other base metal sulphides; 2. pyrite $\pm$ gold + quartz + clay minerals; 3. base metal sulphides + quartz + clay minerals $\pm$ gold, and 4. silver sulphosalts + native silver + base metal sulphides + quartz + barite. The latter paragenetic sequence occurs especially outside the Talagiu caldera.

Introduction

The Talagiu area is located in the eastern part of the Zarand Mountains and is considered as a metallogenic district (Fig. 1).

1. Regional Geology and Structure

In the Talagiu area the following units are recognized (Berbeleac et al., 1981, 1989; Berbeleac, Andrei, 1989): 1. the lower unit represents the base on which the volcanic intrusive complex has developed, consisting of Upper Paleozoic metamorphic rocks, Mesozoic ocean floor basalts, Jurassic-Lower Cretaceous volcanic island arc rocks (basalts-rhyolites-andesites) and sedimentary rocks; 2. a Badenian-Sarmatian volcano-sedimentary formation made up of interbedded hornblende and hypersthene-augite $\pm$ hornblende andesitic agglomerates and lava flows, and 3. Sarmatian-Pannonian? volcanics. The volcanics have been generated in a complex volcanic structure - probably an advanced caldera (Berbeleac et al., 1981; Berbeleac,

Andrei, 1989). This caldera (Fig. 2) is built up, in the order of the volcanic

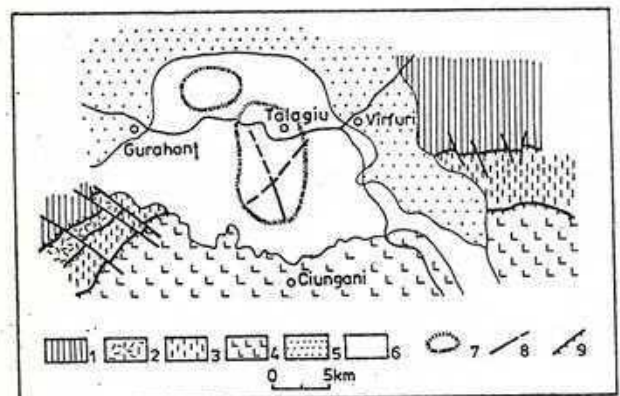


Fig. 1 - Geological sketch of the East Zarand Mountains (according to Săndulescu, 1984, modified). 1, Biharia Nappe System (metamorphic schists); 2, Groși Nappe (Albian Wildflysch); 3, Criș Nappe (Tithonian-Neocomian Flysch, Aptian-Albian Wildflysch); 4, Techereu-Drocea Nappe (Jurassic-Lower Cretaceous volcanic and sedimentary rocks); 5, Neogene molasse; 6, Tertiary volcanic rocks; 7, caldera; 8, fault; 9, nappe.

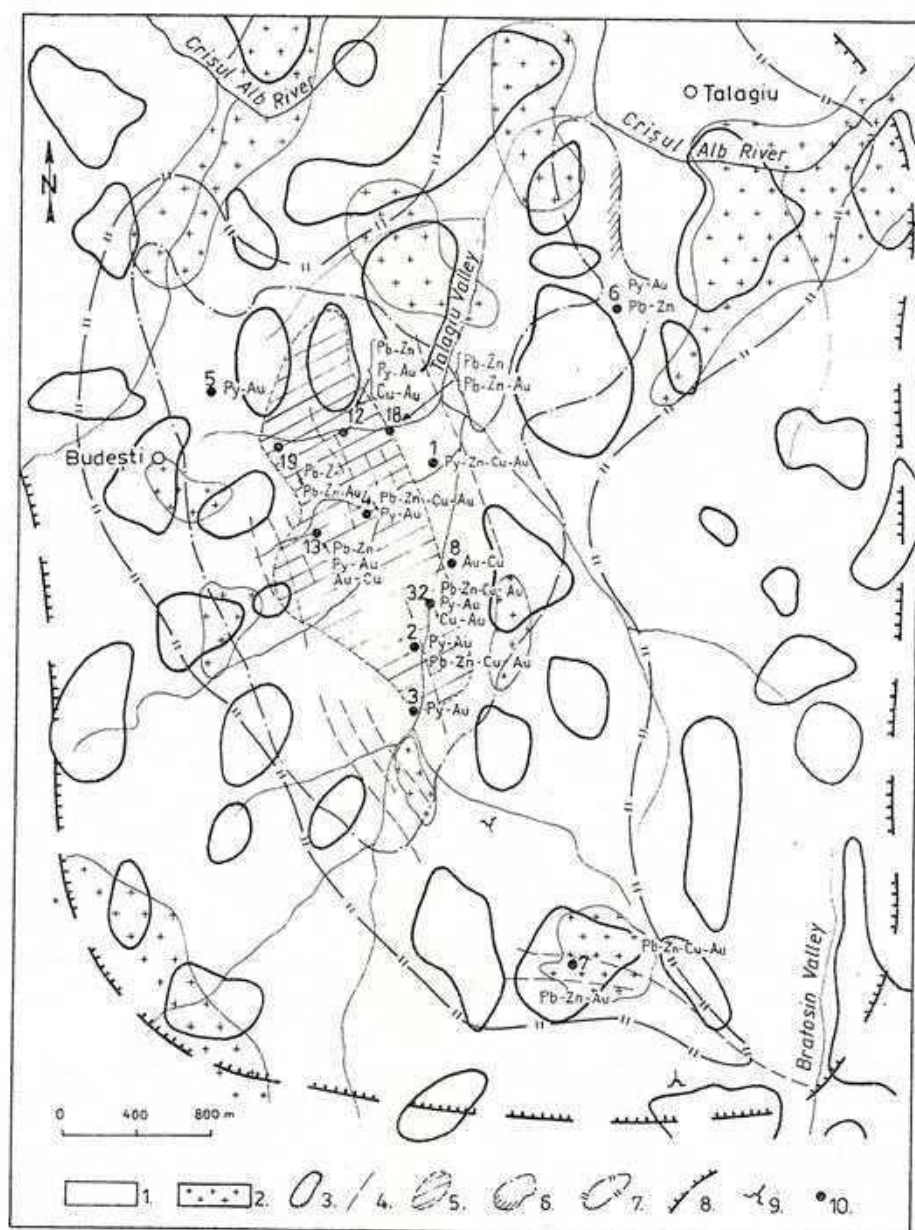


Fig. 2 - Geological sketch of the Talagiu area: 1, Sarmatian-Pannonian hornblende-hypersthene andesitic volcanoclastics and volcanics; 2, andesitic bodies according to geological data; 3, intrusive bodies according to geophysical data; 4, fracture and ore veins; 5, subvolcanic andesitic-microdioritic body and porphyry copper ore body; 6, intense argillic alteration; 7, outer limit of propylitic alteration; 8, caldera boundary; 9, gallery; 10, drillhole. Py-Au, Pb-Zn-Cu-Au, Pb-Zn etc. types of mineralizations.

evolution sequence, of the following rock types: 1) hornblende and hypersthene andesites - effusive and explosive products (Upper Badenian) formed in the pre-caldera stage; 2) various types of pyroxene andesites - the most representative volcanic rocks in the Zarand Mountains - with augite±hypersthene or

with hypersthene±augite, hornblende etc. (Upper Badenian-Sarmatian), probably formed in the caldera stage and 3) hornblende-hypersthene+augite andesites and microdiorites (Sarmatian-Pannonian?), probably corresponding to the post-caldera stage. These rocks appear as lava, pyroclastics and intrusions (dyke, necks

etc.) within or round the caldera boundary. Intrusive hornblende-hypersthene±augite andesites and porphyry microdiorite occur along the inner rim and the outer rim of the caldera (Fig. 2). The inner ring is ellipsoidal in shape (3.2 x 1.6 km) and comprises, according to gravity data, more than 13 andesite-microdiorite bodies. The outer ring of the caldera is located at a distance of 400–1200 m from the inner ring and consists also of a number of andesite-microdiorite intrusions. Some of these bodies represent volcanic necks (Varatec Hill).

The central part of the caldera comprises a subvolcanic andesite-microdiorite body. This body (2 x 0.6 km) cuts the lower units and is cut by hornblende-hypersthene±augite andesitic dykes as the youngest magmatic rocks.

The evolution of the Talagiu volcanic structure has been controlled by the intersection of the alpine regional northeast trending nappe systems (Groși Nappe, Criș Nappe, Techereu-Drocea Nappe – Săndulescu, 1984) with northwest-southeast and east-west trending normal faults (Fig. 1). The Tertiary northwest-southeast and east-west trending normal faults are numerous in the Talagiu caldera and some of them represent ore veins and ore breccia zones. Many intrusion bodies, mineralizations, geophysical anomalies (Borcoș et al., unpubl. data, 1983) are recognized along the supposed concentric faults. The numerous faults lie subparallel to the contact of the volcanic body and are especially approximately centered round it.

2. Alteration Zoning and Mineralogy

Geological and geophysical (gravity, magnetic, electrical and radioactivity) data suggest that intensive hydrothermal alteration covers an area more than 6 km long, 3.2 km wide and 0.5 to 1.3 km deep (Borcoș et al., 1983, unpubl. data). Strong clay alteration can be seen in the Talagiu Valley (Berbeleac, Andrei, 1989).

In the caldera area the degree of hydrothermal alteration increases from the outer boundary of the inner ring to the central part of the subvolcanic body (Fig. 2), while to the outer ring the rocks are generally fresh or show hydrothermal alterations only along fractures.

The horizontal zonality stands out especially by the propylitic and intermediate argillic alteration in the area of the inner ring, and intermediate and advanced argillic rocks to and within the subvolcanic body. On the vertical scale the hydrothermal alteration in the area of the subvolcanic body shows the following zonality downwards (Berbeleac, Andrei, 1989) (Fig. 3): intermediate or advanced argillic → propylitic → phyllic → feldspathic. This kind of alteration is characteristic of the porphyry copper deposit.

The intermediate and advanced argillic rocks form the envelope of the subvolcanic ore body (Fig. 4) or appear along the fractures situated in propylitic rocks. They reach more than 300–500 m in depth. The main clay minerals within argillic rocks are (Neacsu, 1986, unpubl. data): smectite, dickite, kaolinite, nacrite, halloysite, chlorite, pyrophyllite, interlayered minerals (tosudite, hectorite, illite-smectite, illite-chlorite, pyrophyllite-illite, pyrophyllite-smectite), allopheane etc. These minerals are associated in different proportions with quartz, feldspars, alunite, carbonates, gypsum, anhydrite, pyrite, rutile etc.

The kaolinite alteration indicates a type of hydrothermal fluid distinct from that responsible for the alteration through the rest of the system: this fluid formed at the near-surface (from condensation of steaming ground waters) and had acid-sulphate composition (due to the oxidation of H₂S) as opposed to the near-neutral pH, NaCl fluid responsible for the formation of smectite, illite and chlorite.

The propylitic alteration is observed outside the argillic and phyllic zones (Fig. 5). In the propylitic zones mafic minerals are altered to chlorite, actinolite and/or epidote±clay minerals, pyrite and feldspars are slightly altered to albite, sericite, calcite, clay minerals and/or epidote.

The phyllic alteration is widely developed at depth (Fig. 4). It appears between the argillic zone in the upper part and the feldspathic zone in the lower part. The sericite hydromicas-illite-quartz-anhydrite + pyrite-chalcopryrite-rutile is the most common assemblage for this alteration zone. In porphyry-copper the abundance of smoky quartz-pyrite + chalcopryrite-anhydrite is very common (Fig. 5).

The feldspathic zone is distributed mainly within the andesite-diorite subvolcanic body. Within this zone, in which most of the drillholes remained, two assemblages are characteristic: quartz-biotite-albite-K feldspar-anhydrite-pyrite-chalcopryrite and quartz-biotite-chlorite-sericite-K feldspar-magnetite-anhydrite-pyrite-chalcopryrite. Also very common are the fissures with quartz-pyrite-chalcopryrite + biotite-feldspar, and chlorite-actinolite-magnetite ± biotite, anhydrite, pyrite, chalcopryrite (Fig. 5a,b).

The above described type of hydrothermal alteration are very common in the Cu-Au porphyry deposits of Romania (Musariu, Valea Morii, Voia etc.) (Berbeleac, 1985) and in the south-west of the Pacific (Papua, New Guinea - Eastoe, 1978), Mineral Park, Arizona (Lang, Eastoe, 1988), the Philippines (Luodon, 1976) etc.

3. Mineralizations

Seven main types of mineralizations are known in the Talagiu-Răstoci area: 1) porphyry copper-gold;

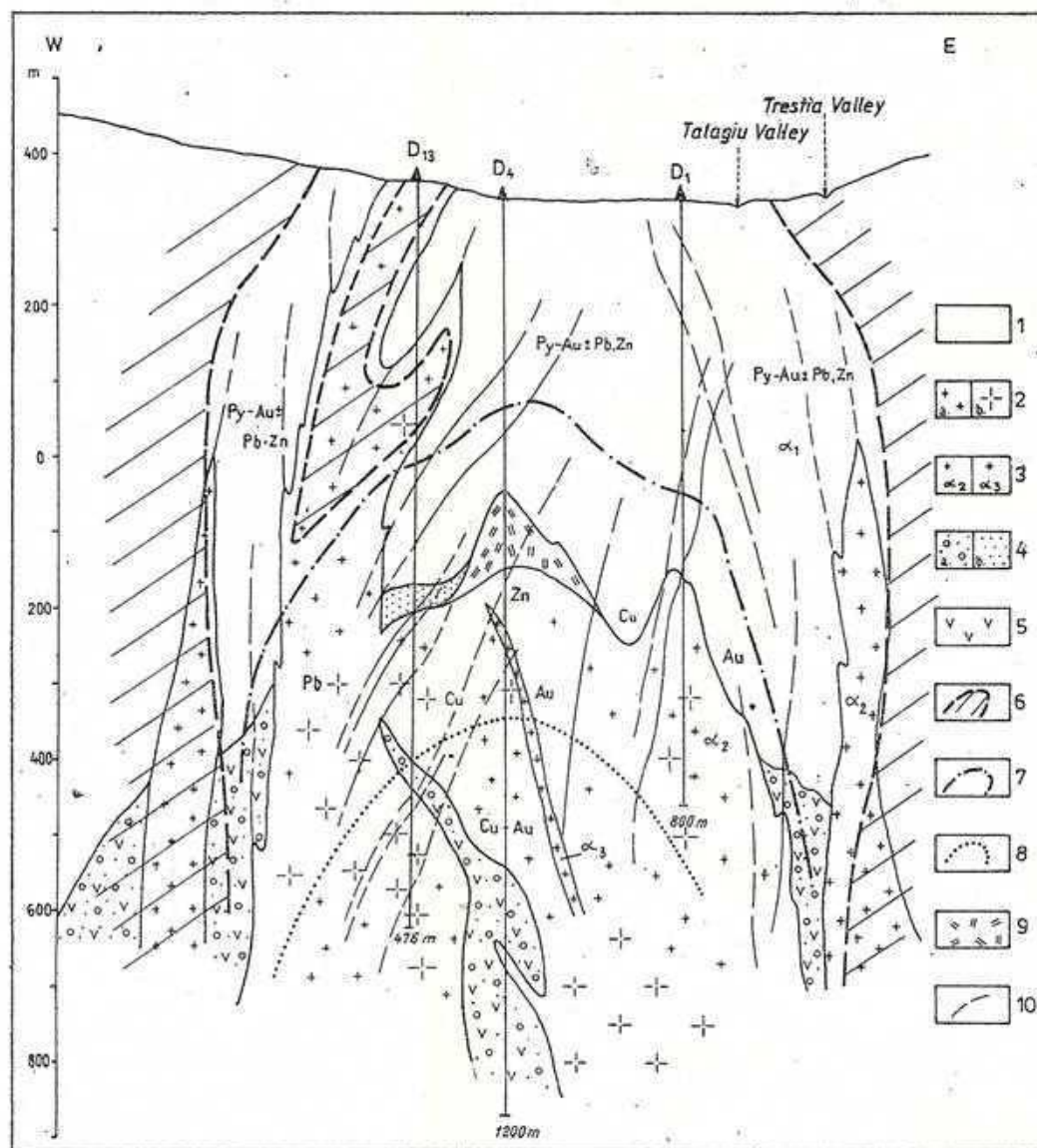


Fig. 3 - Geological cross-section within the subvolcanic body in the Talagiu area. 1, lavas and pyroclastic andesitic rocks (Upper Badenian-Sarmatian); 2, hornblende-hypersthene-andesite (a), microdiorite porphyry (b); 3, pyroxene andesite (a) and hornblende-hypersthene andesite (b) (Sarmatian-Pannonian); 4, conglomerate (a) and sandstone (b); 5, hornfels; 6, propylitic alteration; 7, boundary between argillic and phyllic alteration; 8, boundary between phyllic and feldspathic alteration; 9, quartz-pyrite±gold stockwork; 10, mineralized fracture. Py-Au±Pb, Zn, Pb-Zn-Cu-Au, Cu-Au vertical zonality of mineralization.

2) copper ± gold veins; 3) quartz-pyrite ± gold veins and stockworks; 4) lead-zinc-gold-silver veins; 5) silver sulphosalts dominated veins; 6) lead-zinc veins and impregnated zones, and 7) copper-gold veins. Silver sulphosalts dominated veins are present especially in the Răstoci area. All the veins, breccias and stockworks stages occur within the porphyry deposit proper but lead-zinc and gold sulphosalt veins occur round or

outside the porphyry copper-gold deposit.

3.1. Porphyry Copper-Gold Deposit

The porphyry copper-gold mineralization is noticed everywhere within and round the hornblende-hypersthene-andesite-microdioritic subvolcanic body in the Talagiu caldera (Fig. 2).

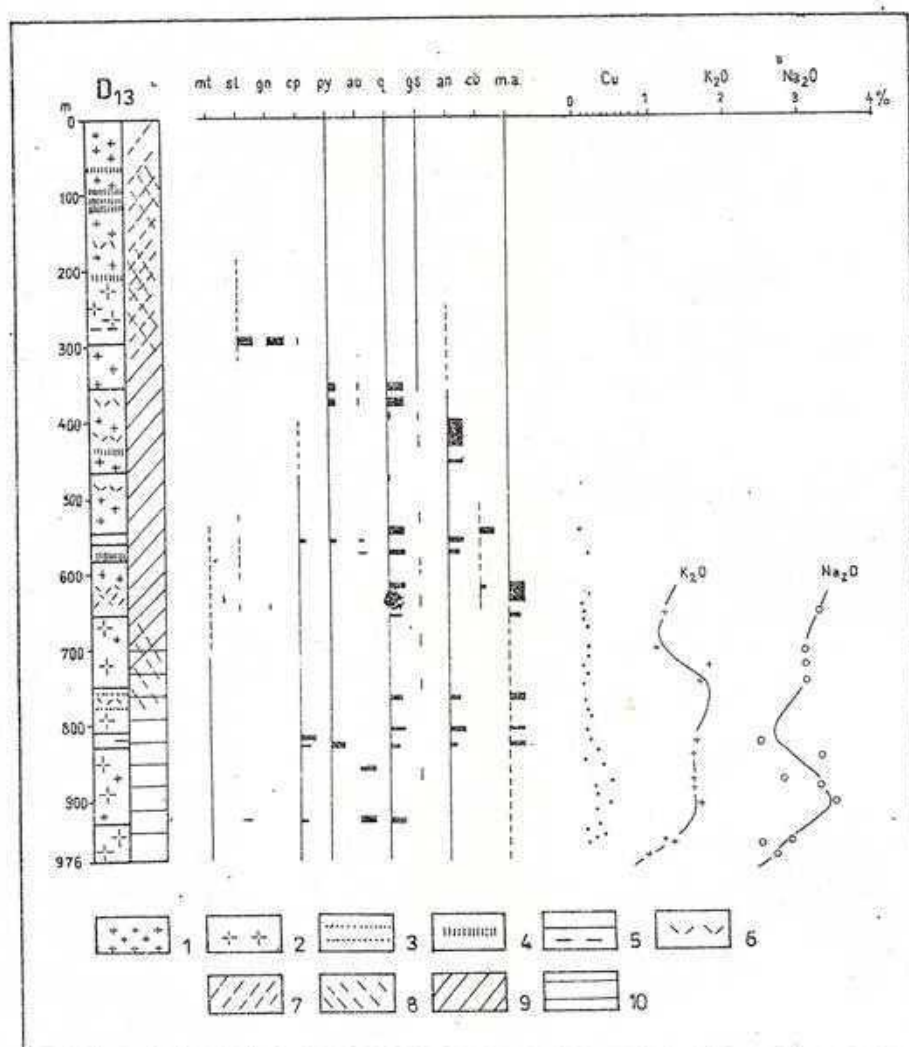


Fig. 4 - Lithological column of variation of hydrothermal alteration, mineral assemblages and Cu, K₂O, Na₂O variation (%) in drillhole N0. 13. 1, hornblende-hypersthene andesite lava (a) and intrusions (b); 2, microdiorite porphyry; 3, sandstones (Badenian); 4, fractures filling with clay minerals and fragments of rocks ("glam"); 5, mineralized fracture; 6, breccia body (stockwork) and fracture zone. Type of hydrothermal alteration: 7, propylitic; 8, argillic; 9, phyllic; 10, feldspathic. Symbols: mt - magnetite; sl - sphalerite; gn - galena; cp - chalcopyrite; py - pyrite; au - gold; q - quartz; gs - gypsum; an - anhydrite; cb - carbonates; m.a. - clay minerals.

This mineralization is genetically related to the sub-volcanic body. It forms a stockwork of porphyry disseminated copper-gold, oval in shape and 2 x 0.6 km in areal extent. The size of the ore body, insufficiently known, seems to correspond to the subvolcanic body. The porphyry ore appears within the deeper portions of the propylitic, phyllic and feldspathic zones of an andesite-microdioritic body and in the altered Badenian sediments situated round it.

The porphyry system has been reported by a number of drillings (Fig. 1) at 150-900 m below surface and reaches the depth of more than 1300 m. Grade of copper is 0.1-0.4 % Cu.

The mineral assemblage in the porphyry copper-Au deposit is simple. Pyrite, chalcopyrite and rutile are common minerals, bornite and chalcocite, covellite are rare, and molybdenite is noticed. In the feldspathic zone magnetite is often frequent. It appears

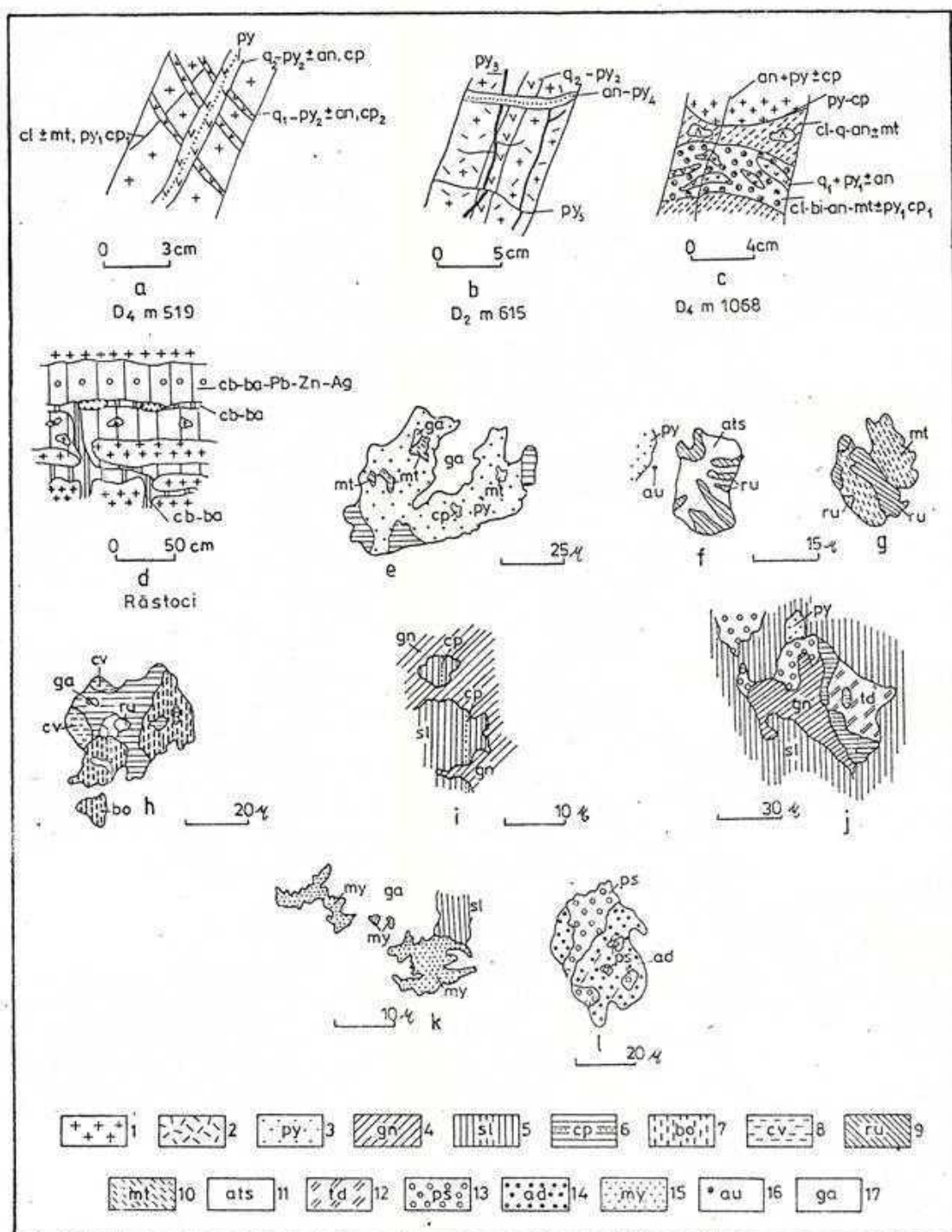


Fig. 5 - Macroscopic and microscopic details on the ore from the Talagiu area. 1, andesites; 2, brecciations; 3, pyrite (py); 4, galena (gn); 5, sphalerite (sl); 6, chalcopryite (cp); 7, bornite (bo); 8, covellite (cv); 9, rutile (ru); 10, magnetite (mt); 11, anatase (ats); 12, tetrahedrite (td); 13, proustite (ps) - stephanite; 14, andorite (ad)?; 15, niargyrite (my); 16, gold (au); 17, gangue minerals. D₄, D₂ - drillholes; e-f - drillhole No. 12; h - drillhole No. 2; j-k-l - Răstoci.

associated with pyrite and chalcopryite in chlorite-anhydrite±biotite (Fig. 5a, c, e) or within quartz-pyrite veinlets. In places it appears as small inclusions in pyrite (Fig. 5e) or is replaced by hematite and rutile

(Fig. 5g). As regards pyrite and chalcopyrite, at least 4-5 and 1-3 generations of quartz $\pm$ anhydrite (Fig. 5a, b) and anhydrite-pyrite-chalcopyrite veinlets (Fig. 5c) respectively are noticed. In general, pyrite is older than chalcopyrite but in some cases pyrite shows small inclusions of chalcopyrite partially replaced by bornite. In breccia zones or round some fractures which are located within the porphyry copper mineralization, chalcopyrite is replaced by bornite, chalcocite, covellite, limonite, goethite etc. (Fig. 5h). In places it contains also small inclusions of rutile, hematite, magnetite and gangue minerals. As a rule, chalcopyrite replaces the pyrite grains and includes a great variety of minerals.

The highest concentrations of copper and gold seem to be in those parts of the ore body located in the phyllic and feldspathic zones where the networks and disseminations of chalcopyrite and pyrite are frequent. Cu-Au and Na₂O-K₂O (Fig. 4) vary sympathetically and the highest grades are usually coincident. Gold is present, at least partly, as micron particles (Fig. 5f) of native metal. The introduction and precipitation of a large gold amount within the porphyry system would imply an abnormally high fO₂/fS₂ ratio.

The porphyry copper-gold mineralization is cut by ore veinlets, veins and stockworks which have been subsequently formed.

3.2. Vein Mineralizations

The veins consist of several stages of quartz, anhydrite, carbonate, sulphide minerals. Clay minerals and pyrite predominate in wall rocks adjacent to some near-surface segments of veins. The direct observations show that the distribution of ore veins, breccias and stockworks confirms a spatial and genetical association with the subvolcanic body. The parent magma for the Talagiu subvolcanic body and other satellite intrusions, those corresponding in age to vein deposits, most likely provided heat for the hydrothermal circulation and vein deposition in the Talagiu district.

Copper $\pm$ Gold Veins

The assemblage of these veins is anhydrite (gypsum)-pyrite-chalcopyrite-rutile $\pm$ sphalerite, galena, tetrahedrite, biotite, magnetite, chlorite, clay minerals, calcite. Intergrowth textures and solid inclusions distributions suggest that all the above-mentioned minerals, except gypsum and calcite, are contemporaneous. These veins do not appear at the surface and they have been noticed at depth, especially in argillic and phyllic zones. We note that at the surface or near it the white, white-grey, pinkish anhydrite from the veins is totally replaced by gypsum. There is no zonation from edge to centre in these

veins. It is important to note that the anhydrite veins are 0.1-1 m in width, exceptionally 2-3 m, and their existence is marked by abundant and large (5-10 m) anhydrite-pyrite-chalcopyrite-clay minerals fissures or breccia zones within the surrounding rocks.

Pyrite $\pm$ Gold Veins and Stockworks

These veins may be an important source for gold. They are numerous and contain especially pyrite and rutile. Small amounts of chalcopyrite, sphalerite, galena, gold, anhydrite, gypsum, clay minerals etc. appear. The most representative veins with breccia textures have been noticed in drillhole No. 13.

The quartz-pyrite stockworks have been intercepted by drillholes Nos. 3 and 4. They represent abundant millimetric, rarely centimetric, smoky quartz-pyrite fissures which serve as a cement for silicified and argillized andesite fragments and blocks (0.01-0.02 m). The genesis of these stockworks is not clear.

Lead-Zinc-Gold-Silver Veins

Polymetallic-gold quartz veins consist of mineralized fractures striking WNW-ESE and probably NNW-SSE. The host rock (andesite) is argillized and sericitized in the veins selvage. The ore veins are known within hypersthene-augite andesites of the Bratosin Hill and the Gura Lupului Brook, and within or round the subvolcanic andesitic-microdioritic body of the Talagiu Valley-Galiței Brook (Fig. 2).

The morphological aspects of the lead-zinc-gold-silver quartz veins differ from one place to another. Thus at Bratosin Hill-Gura Lupului Brook the mineralized fracture (N 70-80° W/75-90° SW and NE) forms a single and composite lenticular body. The fracture mined at Bratosin (484 m) and Talagiu (380 m) levels is more than 600 m long and 0.1-7 m thick. The host rock is fresh or propylitized. It consists of hypersthene-augite andesites and is distinguished by angular, usually intensely silicified andesite blocks in an argillaceous matrix. At the present surface level supergene alunite, quartz, calcadony, kaolinite and interstratified smectite-illite clay alterations are often adjacent to the breccia-bearing polymetallic-gold quartz veins. The blocks in the vein are disseminated with pyrite and marcasite and round them there are usually millimetric depositions of sphalerite, galena, tetrahedrite and small amounts of chalcopyrite, sylvanite and gold. Geodes are very rare and comprise tabular and transparent crystals of barite and white clay minerals (kaolinite). Sphalerites are substituted by galena, tetrahedrite (Fig. 5j) and chalcopyrite. Usually, sphalerite exhibits

no chalcopryrite exsolutions (Fig. 5i). The paragenetic sequence in the lead-zinc-gold-silver veins is: quartz-pyrite-rutile-sphalerite-galena-tetrahedrite-chalcopryrite-sylvanite-gold-marcasite-barite-clay minerals.

Numerous fissures, some of them 0.05–0.20 m thick, crosscut, as in the case of drillhole No. 2 (m 573–577), the previous quartz-pyrite $\pm$ chalcopryrite, anhydrite veinlets of the porphyry copper-gold stage of mineralization. The polymetallic-gold quartz veins usually comprise: pyrite, cleiophanic sphalerite, galena, tetrahedrite, chalcopryrite and gold. The gangue minerals are: quartz, calcite, barite and clay minerals. Gold has been noticed in small grains within quartz (10–50 μ m).

Lead-Zinc Veins

In the Galiței Brook, near the joint with Valea cea Bună (Fig. 2) and in some drillholes (Nos. 12, 13, 19, 9), lead-zinc veins and impregnated zones have been identified. The veins appear in intensely fissured and argillized andesites, and comprise sphalerite, galena, tetrahedrite and small amounts of pyrite and chalcopryrite (Fig. 5i). The gangue consists of clay minerals (kaolinite) and subordinately carbonates and barite.

Silver Sulphosalts-Dominated Veins

This type of mineralization has been identified especially in the Răstoci area, about 7 km West of Talagiu (Fig. 1). Here several veins and impregnation zones with N-S and WNW-ESE strikes are known. The veins are located within propylitic pyroclastic rocks, hypersthene-hornblende $\pm$ augite andesite in composition (Badenian-Sarmatian, volcano-sedimentary formation). At the present surface, except the veins on the Crișul Alb River, all the others have undergone strong supergene alteration processes. The primary mineralization in the Crișul Alb veins consists of pyrite, sphalerite, galena, tetrahedrite, chalcopryrite, bournonite, stephanite, proustite, polybasite, pyrrhotite, miargyrite, andorite (?), native silver, quartz, carbonates (rhodochrosite, dolomite), clay minerals and barite. The vein (0.10–0.20 m thick) shows a breccia texture (Fig. 5d). The silver sulphosalt minerals usually form very fine-grained aggregates, sometimes with skeletal aspects, and replace pyrite, galena, sphalerite and tetrahedrite (Fig. 5j, k). Commonly intergrown among them, also silver sulphosalts have been noticed, which may contain inclusions of gangue minerals (quartz, carbonates), tetrahedrite and base metal sulphides (Fig. 5j, k, l). We underline the fact that, at surface or near it, the veins include Mn and Fe oxides representing the result of weathering.

Copper-Gold Veins

These veins are probably one of the most important sources for gold. They are known at depth and have been remarked in some drillholes (Nos. 8, 13). Except the vein from drillhole No. 8 (m 616.00–616.9), in which the dolomite is the main gangue mineral, in all the others quartz is the dominant gangue mineral.

The veins dip by more than 70°. The strikes are generally the N 10–30° W conforming with structural trend of the district (Fig. 2). The traceable strike lengths of individual veins are not yet known, but some of them are likely to be more than 0.5–1 km long. The individual veins range from 3 cm to 3 m in width.

The copper-gold veins characteristically consist of coherent quartz-sulphide material, sometimes alternating with fault gangue, in which quartz, sulphide and wall rock fragments are found. Crustifications and open-space-filling textures are as a rule very rare.

The paragenetic ore mineral sequence is based on typical mineral relationships, noted for all above-mentioned veins, though minor differences sometimes occur between individual veins. It seems to be as follows: pyrrhotite-pyrite₁-chalcopryrite₁-rutile-pyrite₂-sphalerite-tetrahedrite-silver sulphosalts-chalcopryrite₂-galena₁-chalcopryrite₃-galena₂-gold-bornite-chalcocite-covellite-goethite-native silver-native gold (Fig. 5). The vein formation is separated into three distinct stages on the basis of consistent replacement textures and brecciation events recognized in polished sections.

In stage 1 the mineralization is characterized by minor pyrite and chalcopryrite. Trace amounts of sericite, pyrrhotite and rutile occur. Pyrite was the first ore mineral.

In stage 2 quartz and pyrite are the main minerals, sericite and hydromica are abundant; sphalerite, galena, tetrahedrite, silver sulphosalts, chalcopryrite and hypogene clay minerals are present in minor amounts. There is a brecciation event between stage 2 and stage 1.

Quartz, carbonates (dolomite, calcite), sericite, pyrite, chalcopryrite, galena, native gold occur in various amounts in stage 3. Chalcopryrite is the main ore mineral veining and replacing all the other hypogene minerals except the vein from drillhole No. 8 (m 615–619.9) where chalcopryrite and pyrite are the dominant ore minerals.

4. Conclusions

1. In the Talagiu area the Tertiary volcanics have been generated in a complex structure - probably an advanced caldera (7 x 3.5 km), which is built up especially by pyroclastics, lavas and intrusive bodies of pyroxene $\pm$ hornblende andesite rocks,

Sarmatian-Pannonian in age. The inner rim of caldera (3.2 x 1.6 km) comprises a subvolcanic andesitic-microdioritic body (2x0.6 km) and many small andesitic dykes. The small veins and dykes of the hornblende-hypersthene+augite andesites seem to be the youngest magmatic rocks.

2. In the inner ring and near its border, large and intense hydrothermal alteration and mineralization processes took place.

3. The hydrothermal alteration and mineralization products show a vertical and horizontal zonality: advanced and intermediate argillic alterations (pyrite $\pm$ Au; Pb-Zn-Au-Ag $\pm$ Cu) in the upper part of the subvolcanic body and in the inner ring of caldera and propylitic (Cu-Au; Pb-Zn-Au-Ag $\pm$ Cu) $\rightarrow$ phyllic (Cu-Au; Pb-Zn-Cu-Au-Ag) $\rightarrow$ feldspathic (Cu-Au) to the depth of the subvolcanic body and propylitic in the outer ring of the caldera.

4. The porphyry Cu-Au body occurs in the inner ring, within the depth of the subvolcanic body (150-900 m below the surface) and the sulphide veins and stockworks in the upper parts of the subvolcanic structure and to the marginal ring of caldera. The vein mineralizations are subsequent in comparison with the porphyry mineralizations and show especially a vertical distribution of the paragenetic minerals.

5. The alteration and mineralization products are probably the result of a mixing process in which the contribution of meteoric water was very important. The hydrothermal system probably represents successive influxes of hypersaline fluids ($> 350^{\circ}$ C) from the following assemblages: anhydrite-pyrite $\pm$ chalcocopyrite of low salinity, lower temperature fluids ($> 100^{\circ}$ C) of lead-zinc-gold-silver veins, copper-gold veins etc.

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Received: February 22, 1993.

Accepted: September 13, 1993.

Presented at the scientific session of the

Institute of Geology and Geophysics: October 30, 1989.

LIASSIC GABBROS FROM THE BANIEȘ VALLEY (MUREȘ ZONE): PETROLOGY AND GEOCHEMISTRY

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Key words: Gabbros. Lower Jurassic. Layered intrusions. Magma. Tholeiitic composition. Magmatic differentiation. Major elements. Minor elements. Rare earths. Apuseni Mountains.

Abstract: The gabbroic body on the Banieș Valley lies north of Săvârșin, in the southern part of the Mureș Zone. It represents a rest from the lower part of a much more important gabbro body that has been destroyed by the Late-Kimmerian intrusions in the region and eroded. It differs from the other gabbroic bodies from the Mureș Zone by the peculiarities of its layered structure with two horizons, of which the lower one has a planar structure. The rocks of the lower horizon show poikilitic hornblende megacrystals. Although it has these peculiarities, it belongs to the Liassic ophiolitic rocks (180 Ma) from the Mureș Zone. The parental magma was a tholeiitic one, formed in the mantle, along a mid-ocean ridge of normal type. This magma underwent a process of gravitational differentiation that led to the formation of the layered structure of the body and of the planar structure of the lower horizon, in which poikilitic hornblende megacrystals formed.

Introduction

On the Banieș Valley, north of Săvârșin, the Liassic ophiolites from the ocean crust fragment, obducted in the axial zone of the ophiolitic suture or the Mureș Zone, host a gabbroic body which was pointed out by Savu (1953). This body shows some structural-petrographic peculiarities in comparison with the other gabbroic bodies associated with the Liassic ophiolites from the Mureș Zone. That is why it was not certain whether it was of the same age as the ophiolites or it represented a Late-Kimmerian intrusion, the body being in contact with such a type of intrusions. In order to elucidate this uncertainty, it has been petrologically and geochemically investigated. The results of these researches will be further presented.

Structure of the Gabbroic Body and Petrographic Aspects

The gabbroic body on the Banieș Valley is of about 9 sq. km, covering most of the upper basin of this valley. Its structure consists of two horizons as follows:

a lower horizon formed of gabbros exhibiting a planar structure and hornblende megacrystals, and an upper horizon made up of normal gabbros showing a massive structure (Fig. 1).

The structure of this body and its position with respect to the surrounding eruptive rocks show that it represents only a part from the base of a larger, NE-SW trending basic intrusive body that was dismembered by erosion and by the two successive intrusions of the Late-Kimmerian granitoid massif of Săvârșin; these are represented by the granodiorite-diorite intrusion of Temeșești and by that of the Săvârșin granite (Savu, 1953; Savu 1995). The presence in this zone of a few small gabbro intrusions (Sârbu Valley; Contrava Valley) indicates that the former gabbroic body probably extended from the south-west of the present-day body to the northeastern extremity of the granodiorite-diorite intrusion of Temeșești. It is noteworthy that the gabbroic bodies of Cuiăș, Almaș-Săliște and Ciungani-Căzănești were dismembered in the same way.

The northern part of the gabbroic body was affected by an E-W trending, almost vertical fault, along which it contacts the rocks of the ophiolite basalt complex (O_1) from the Mureș Zone.

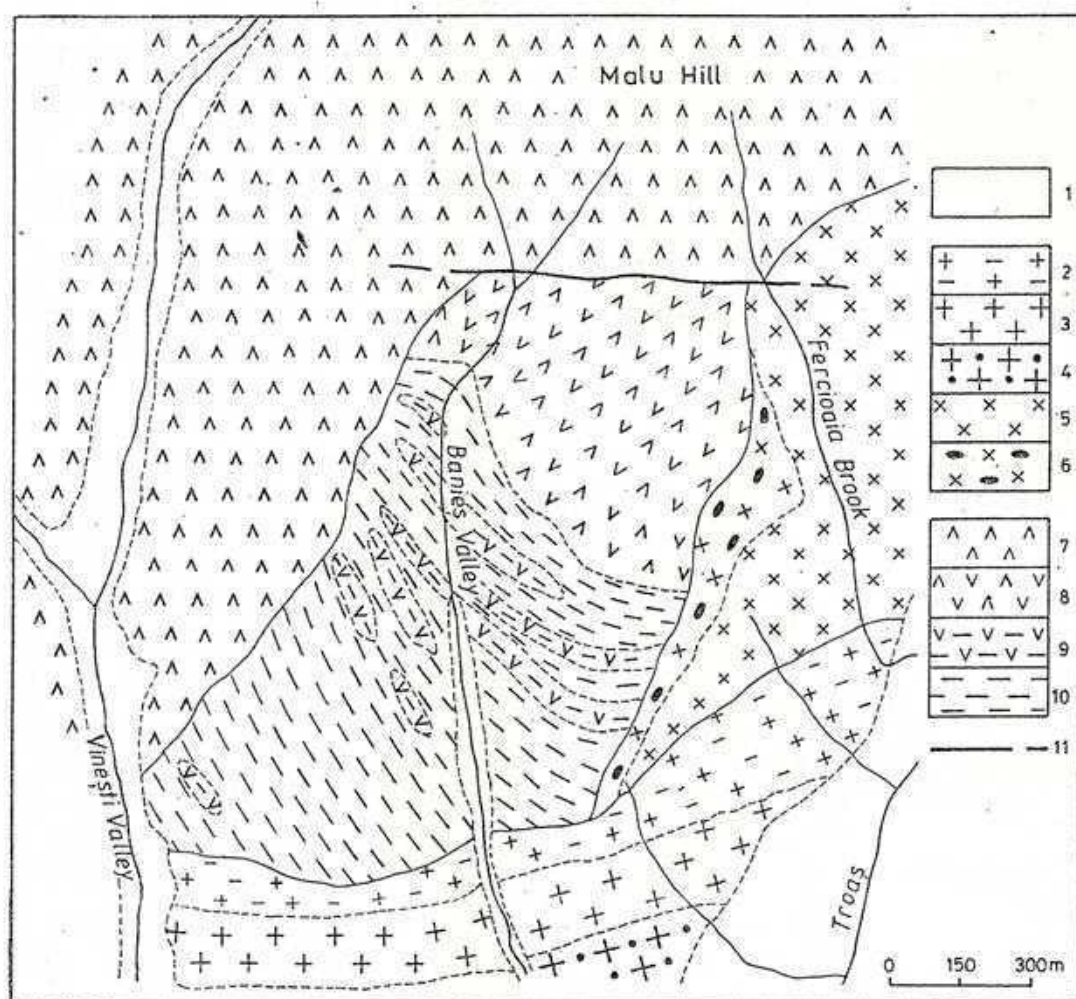


Fig. 1 – Geologic map of the gabbroic body on the Baniș Valley and of the surrounding geological formations. 1, alluvia; Late-Kimmerian intrusions of the Săvârșin granitoid massif: 2, granite in marginal facies; 3, normal granites; 4, coarse porphyritic granite; 5, granodiorites; 6, diorites with melanocrate schlieren; Liassic ophiolites comprising also the gabbroic body: 7, basalts and dolerites; 8, normal gabbros (upper horizon); 9, ferrogabbros; 10, gabbros and microgabbros with planar structure; 11, fault.

The gabbroic body consists of several rock types. Thus the lower horizon of planar structure comprises microgabbros, gabbros and ferrogabbros, all of them with hornblende megacrysts. Ferrogabbros form thin (0.5-1 m) levels or laminae (Irvine, 1982) that indicate the beginning of the rhythmic layering (Wager, Brown, 1968) of the body. The rhythmic layering is parallel to the planar structure of this horizon. Both structural elements slightly dip northwards (Fig. 1). The upper horizon comprises normal gabbro and melagabbro. These latter was noticed only as blocks on the Baniș and Fercioaia Brooks. These blocks might originate in a lenticular separation within the normal gabbros on the northern margin of the body, situated on the ridge between the two mentioned Brooks, which is now covered by soil. It is noteworthy that such mela-

gabbro lenses also occur in the gabbroic body of Cuias (Savu et al., 1994).

Microgabbros represent the most widespread rocks within the lower horizon of the basic body. They have an oriented (planar) structure (Balk, 1937) and often porphyritic texture determined by the presence within them of some hornblende poikilitic megacrysts. Their groundmass shows a very fine (0.02-0.8 mm) granulation which consists of tiny plagioclase, clinopyroxene and magnetite crystals. Plagioclase (An 70-50) is present in crystals with albite and pericline twins, often having the internal part weakly saussuritized. The elongation direction of the crystals is situated in the planar structure plane of the rock. Clinopyroxene, a diopside ($c\angle Ng=40^\circ$), is xenomorphic and is locally replaced by a brown-greenish amphibole. Mag-

netite is also xenomorphic, occurring as very small grains.

After the crystallization of these minerals 3 to 5 cm long brown-greenish hornblende megacrystals with poikilitic texture formed within the rock. They usually develop in flat crystals, oriented in the planar structure plane. They show the following pleochroism: Ng=brownish-green; Nm=brown-greenish; Np=slightly greenish-yellowish. During growth these megacrystals included the other minerals from the rock which they corroded so that only rests of them remained, pyroxene and magnetite locally disappearing almost completely (Fig. 2).

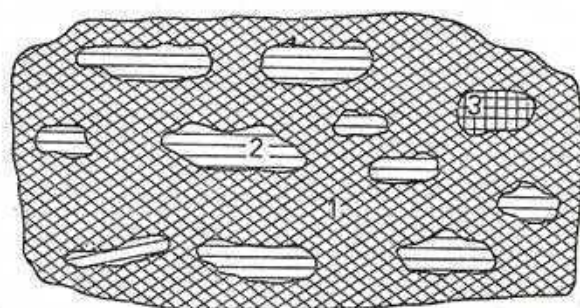


Fig. 2 - Poikilitic structure of a brown-greenish hornblende megacrystal (1), in which plagioclase (2) and clinopyroxene (3) crystals rests are included.

The crystal rests included in hornblende are parallel to the rock structure. This relationship shows the late formation of megacrystals, probably as deuteric mineral formations resulted from the intercumulus magmatic residues. Referring to other minerals in the gabbros, Wager and Brown (1968) showed that the intercumulus liquid, which crystallized slowly and quietly, allows the formation of rare crystallization centres that will generate large poikilitic crystals. It should be mentioned that other gabbros with such amphibole megacrystals are not known in the Mureş Zone or in the numerous gabbroic bodies described by Wager and Brown (1968). In the gabbroic body of Almaş-Sălişte small crystals of deuteric amphibole occurs only on fissures (Savu et al., 1984).

The diopside gabbros with planar structure are similar to microgabbros with respect to texture and mineralogical composition, and differ from them by the coarser granulation (3-5 mm). Plagioclase develops in tabular crystals, oriented parallel to the planar structure. It is polysynthetically twinned and shows a variable composition, being more basic inside (An 70) and more acid towards the margins (An 50). Clinopyroxene is usually a diallage which shows iron oxide exsolutions on the cleavage planes. Sometimes it is partly uraltized, and on fissures it is replaced by a brown-greenish

hornblende, locally also by chlorite. Magnetite usually occurs as xenomorphic grains. Small apatite crystals are rarely found. Flat megacrystals of brown-greenish hornblende also occur within these rocks, being situated in the planar structure plane, and including and corroding the other minerals.

Ferrogabbros are rarely found. They have a mineralogical composition and structure similar to those of the above-described gabbros, from which they differ by the higher vanadiferous Ti-magnetite amount (3-6 %).

The normal gabbros from the upper horizon of the gabbroic body consist also of plagioclase, diopside and magnetite that crystallize in the order of their presentation, which is a characteristic of the tholeiitic rocks. The plagioclase crystals (An 70-50) are hypidiomorphic, like in the other gabbroic rocks. They are polysynthetically twinned and show a composition varying from the centre towards the margins. They are weakly saussuritized in the central part. The diopside crystals are usually xenomorphic and partly uraltized or replaced by chlorite. Magnetite is also xenomorphic. Pistacite veinlets formed on fissures.

Melagabbros are black rocks formed mainly of clinopyroxene, olivine, hornblende and a little plagioclase. Clinopyroxene occurs in xenomorphic crystals, partly or totally replaced by uraltite and green-actinolitic hornblende, leading to the separation of secondary iron oxides. Olivine was totally replaced by serpentine and locally by talc. These rocks also contain green and brown hornblende, which is also poikilitic.

Geochemistry and Tectonic Setting

The study of the gabbroic body is based on the analysis of 11 samples of the most representative rocks (Tab. 1). Taking into consideration the chemical composition, the gabbroic rocks fall into three characteristic groups, which were also distinguished by the petrographic study as follows: gabbros, gabbros and microgabbros with hornblende (nos. 5 and 7) megacrystals, and ferrogabbros (nos. 1 and 2). All these rocks plot in the tholeiitic rocks field on the diagram from Figure 3 (Irvine, Baragar, 1971), which shows that they do not belong to the Late-Kimmerian island arc rocks.

The common gabbros, which comprise most of the rocks, have a normal chemical composition, in which SiO₂ varies between 41.80 and 45 %, the other chemical components ranging within the limits known for such rocks. The gabbros with poikilitic hornblende megacrystals plot closer to the MgO corner on the diagram from Figure 3, this component reaching more than 13.50 % of the rock composition. Although normal, the SiO₂ values are closer to the lower range of the variation domain of this component.

Table 1
Chemical composition of the Banieş gabbroic rocks

No	1	2	3	4	5	6	7	8	9	10	11
SiO ₂	38.45	38.78	41.80	41.86	43.50	43.54	44.50	45.11	46.12	47.16	48.45
TiO ₂	2.04	2.24	1.44	1.64	0.05	1.12	1.20	1.88	1.72	1.16	0.84
Al ₂ O ₃	15.50	15.30	15.90	16.04	15.85	19.34	16.94	15.10	16.24	16.04	19.64
Fe ₂ O ₃	11.11	10.07	7.41	7.45	3.40	5.41	6.45	6.83	6.19	6.25	4.63
FeO	8.31	8.40	6.91	7.24	7.80	5.67	2.30	6.02	5.90	4.38	4.12
MnO	0.19	0.20	0.17	0.24	1.30	0.18	0.90	0.20	0.22	0.20	0.14
MgO	7.74	7.91	7.98	6.75	13.50	7.07	13.82	6.73	8.01	6.37	5.87
CaO	13.68	13.96	16.23	14.06	9.90	13.52	10.40	13.10	11.05	14.10	9.97
K ₂ O	0.18	0.34	0.21	0.25	0.26	0.49	0.40	0.31	0.31	0.40	0.27
Na ₂ O	1.07	1.04	1.13	1.67	1.35	1.59	2.50	2.37	2.01	2.70	3.18
P ₂ O ₅	0.25	0.31	0.22	0.19	0.05	0.19	0.08	0.18	0.14	0.10	0.31
H ₂ O ⁺	1.54	1.56	0.82	3.06	1.68	2.14	0.50	1.85	2.26	1.48	2.31
S	0.44	0.25	0.38	0.33	0.14	0.25	-	0.33	0.31	0.31	0.25
Total	100.50	100.36	100.40	100.78	98.78	100.51	99.99	100.01	100.48	100.65	99.98
Ni ppm	100	72	65	13	-	32	-	72	140	100	46
Co	80	53	60	45	-	34	-	37	38	29	20
Cr	32	25	85	21	-	70	-	175	300	280	125
V	1100	800	720	700	-	410	-	400	470	270	310
Sc	80	65	76	48	-	50	-	55	60	48	35
Zr	36	33	34	34	-	30	-	42	42	46	28
Y	21	25	21	15	-	22	-	33	34	24	23
Yb	2.6	2.2	2.2	2.2	-	2.1	-	2.7	4.6	3.8	1.9
Ba	<10	<10	23	25	-	36	-	22	22	<10	30
Sr	340	300	380	420	-	520	-	240	230	220	520
Cu	200	230	120	135	-	34	-	36	8	20	10
Zn	100	100	90	70	-	75	-	70	75	78	40
Ga	20	23	20	22	-	17	-	17	23	20	22
U	-	0.2	0.5	0.3	-	0.2	-	-	-	0.3	-
Th	-	0.3	0.7	0.4	-	0.2	-	-	-	0.2	-

The rocks analysed in the table are: 1 and 2, ferrogabbros; 3, 4 and 6, microgabbros; 5 and 7, gabbros with hornblende megacrysts; 8, 9 and 10, gabbros with planar structure; 11, gabbro with normal structure. Pb < 2 ppm; Sn < 2 ppm.

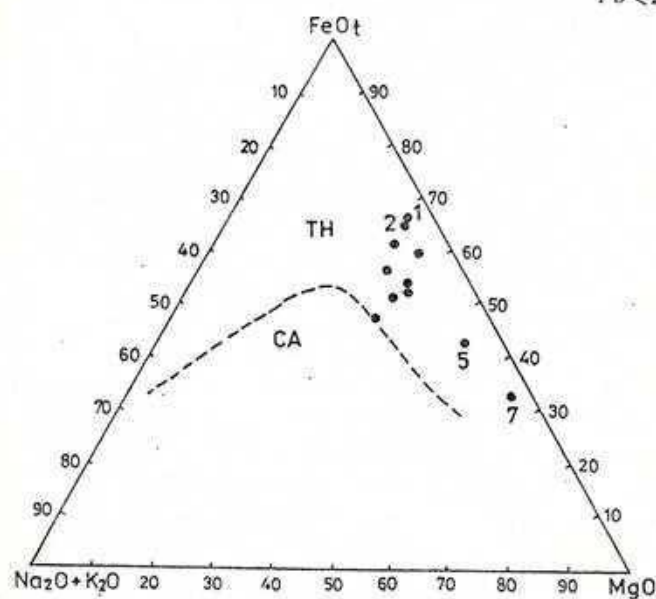


Fig. 3 - Plot of the gabbroic rocks on the FeOt-MgO-Na₂O+K₂O diagram. TH, tholeiitic; CA, calc-alkaline.

It results that the MgO excess is due to a supply determined by the formation of the deuteric hornblende megacrysts which are more numerous in the two samples. Ferrogabbros contain less than 39 % SiO₂ and are rich in iron and titanium. Thus in the two samples FeO(total) ranges between 17.45 % and 18.30 %, while TiO₂ represents 2.04 % and 2.24 % respectively. On the diagram from Figure 3 they plot closer to the FeOt corner. The 4 % TiO₂ in magnetite indicates a crystallization temperature of 780° C.

The high iron and titanium contents in ferrogabbros clearly mark one of the tendencies of the tholeiitic magma differentiation (Savu et al., 1984). The residual tholeiitic magmas concentrate iron - giving rise to ferrogabbroic magmas - and, as shown in Table 1, the elements that are geochemically related to it - Ti and V. The V contents amount to 800 and 1000 ppm respectively, exceeding more than two times the contents of this element in most of the normal gabbros.

According to Shervais (1982), the Ti and V ratio places the rocks in the basaltic series of the mid-ocean ridges (MORB). The tholeiitic magma differentiation determined great variations of the Fe, Ti and V contents in these rocks.

The other trace elements were influenced to a less extent by the differentiation process, a reason why they show normal contents of the ocean floor tholeiites. However, ferrogabbros are richer in Co and Sc and have lower Cr contents than in the other rocks. Nickel also shows contents varying greatly within the gabbroic rock series. It is noteworthy that the Ni contents of 72 and 100 ppm within ferrogabbros range among the highest values of all the analysed rocks. The ratio between Ti/Cr and Ni plots most of the gabbroic rocks in the ocean floor tholeiite field (OFT) on the diagram from Figure 4 (Beccaluva et al., 1979).

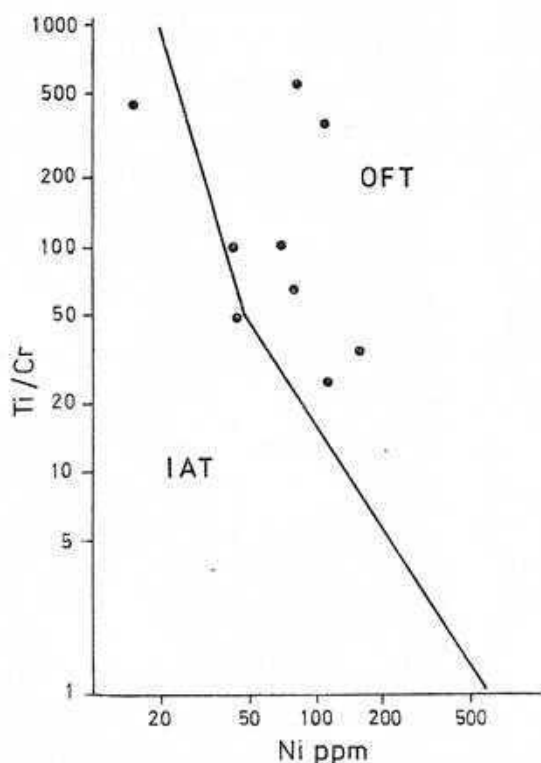


Fig. 4 - Plot of the gabbroic rocks on the Ti/Cr-Ni diagram.

Barium shows low contents throughout the gabbro series, ranging from <10 to 25 ppm, values mostly situated in the abyssal or ocean floor tholeiite field (Miyashiro, 1975). The Sr contents are also characteristic of the ocean floor basic rocks.

Of the other trace elements in Table 1, Cu and Zn are worth mentioning, being present in all the rocks; in both ferrogabbros, rocks formed of the residual tholeiitic magma, these elements show the highest contents, capable of forming minerals of their own (Savu, 1973).

The U and Th contents in the gabbroic rocks are extremely low, the average value being usually below 0.50 ppm. The Th/U ratio is also very small. These values are characteristic of the ocean floor basic rocks (Savu et al., 1986).

REE, Hf and Ta Distribution in the Gabbroic Rocks

The rare earth contents in the gabbroic rocks on the Banieș Valley are presented in Table 2.

All the analysed rocks belong to the group of normal gabbros. That is why REE show contents characteristic of the ocean floor basic rocks. They are equivalent to the REE contents in other ophiolitic rocks from the Mureș Zone, such as the normal tholeiitic basalts and dolerites from the sheeted dyke complex (O₂) (Savu, Stoian, 1988), the basalts with SiO₂ > 49.5 % from the Mureș Zone (Savu et al., 1994 a) and those from the gabbroic body of Cuiăș (Savu et al., 1994 b).

The gabbroic rocks are sometimes richer in LREE than in HREE but these two groups of elements do not differ much from each other, a fact resulting also from the small value of the ratio between them (Tab. 2) which is of 5.25, being very close to the value of this ratio in the rocks of the sheeted dyke complex from the west of the Mureș Zone (Savu, Stoian, 1988). This relation between the two groups of elements results also from the diagram in Figure 5, in which the patterns of five chondritic normalized (Nakamura, 1974) gabbroic rocks are represented. The diagram reveals a slight negative anomaly of Eu, which confirms the fractional crystallization process undergone by the tholeiitic magma from the gabbroic body (Philpotts, Schnetzler, 1968), that gave rise to the layered structure of the body.

Among the values of the other ratios from Table 2, the average value of the Ce/Yb ratio of 4.50, which is below 10, should be noted. According to Saunders (1984), it shows that the parental magma formed in the mantle, in the conditions of the normal oceanic ridge (N-type) evolution, in which the Liassic ophiolites (180 Ma - Herz et al., 1974) from the Mureș Zone formed, rocks in which the gabbroic body is hosted (Savu, Stoian, 1988). It is also noticed that the value of the (Ce/Yb)_N ratio is very close to 1 (Tab. 2). According to Schilling (1975) and Marriner & Millward (1984), this value shows that the basic rocks constituting the gabbroic body on the Banieș Valley resulted from a normal type tholeiitic magma.

The Hf as well as the Ta contents (Tab. 2) are lower than those from other basaltic rock series.

Table 2
Distribution of REE, Hf and Ta in the gabbroic rocks

No.	Sample	La	Ce	Sm	Eu	Tb	Yb ⁺⁺	Hf	Ta
1	(4)	8	13	2.4	0.74	0.70	1.9	1.8	-
2	(6)	8	15	2.9	0.84	0.53	2.1	4.5	0.8
3	(8)	6	14	2.8	0.84	0.60	2.7	5.2	1.0
4	(9)	6	13	2.5	0.67	0.50	4.6	2.1	1.0
5	(10)	6	17	2.8	0.71	0.61	3.8	1.2	0.7
Average		6.8	14.40	2.62	0.75	0.59	3.2	2.96	0.70
REE=28.36; LREE/HREE=5.25; La/Yb=2.13; (La/Sm)N=1.59; (Ce/Yb)N=1.22; Ba/La=3.38; (La/Ce)N=1.23; (Ce/Sm)N=1.30; La/Th=14.17									

+ The number in brackets indicate the sample numbers in table 1.

++ Yb was determined by emission spectrography; the other elements were determined by neutron activation analysis.

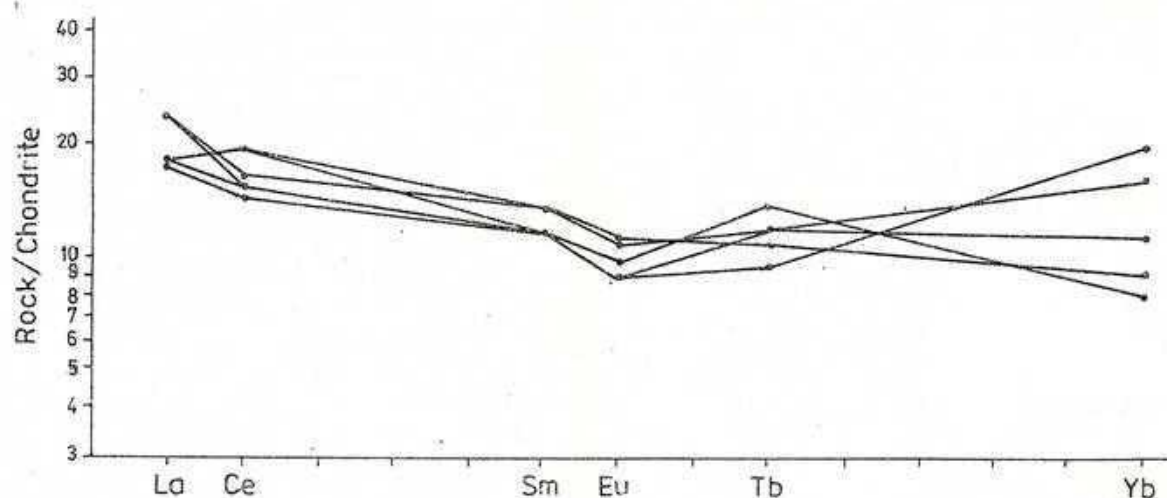


Fig. 5 - Patterns of the chondrite normalized REE from the gabbroic rocks.

Conclusions

The gabbroic body on the Baniş Valley represents a rest from the lower part of a much more important gabbroic body which was destroyed by the Late Kimmerian intrusions of Săvârşin and eroded.

Although it shows some structural and mineralogical-petrographic peculiarities, it belongs to the Liassic ophiolitic rocks from the Mureş Zone.

Geochemical data clearly show that the gabbroic body originated in a parental tholeiitic magma, formed in the mantle in the conditions of a mid-ocean ridge of normal type.

The tholeiitic magma was subjected to a gravitational (*in situ*) differentiation process that gave rise to the layered structure of the body and the planar structure of the lower horizon, in which the poikilitic hornblende megacrysts formed from the intercumulus residual magmatic liquid.

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Received: May 13, 1991

Accepted: May 15, 1991

Presented at the scientific session of the
Institute of Geology and Geophysics: June 4, 1991

THE BRUZNIC GABBROS (BANAT) – MUREŞ ZONE: THEIR STRUCTURE AND ORIGIN

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Key words: Gabbros. Layered intrusions. Magmatic differentiation. Major elements. Minor elements. Banat. Mureş Zone.

Abstract: The Bruznic gabbroic rocks from Banat are situated in the south-western extremity of the Alpine ophiolitic suture of the Mureş Zone. These rocks occur in the Coruba Brook. They are covered by Neogene (Pannonian) deposits. The rocks belong to a Liassic layered gabbroic body, which is located in the sheeted dyke complex (O_2) of the Mureş Zone ophiolites. This complex, which is larger developed in the Drocea Mountains, extends also in the pre-Neogene basement of the Bruznic area. In the gabbroic body cumulates rich in plagioclase (An 64) – olivine gabbros and diopside gabbros – form a horizon belonging to a rhythmic layered structure. This horizon is the result of an "in situ" differentiation of the parental tholeiitic magma and the sedimentation of plagioclase crystals in the magmatic chamber of the gabbroic body. The geochemical data indicate that the gabbroic rocks are ocean floor tholeiites.

1. Introduction

South of Bruznic, in Banat, gabbroic rocks have been pointed out as early as 1962 by Rădulescu et al. These rocks were not systematically studied. As they represent the south-westernmost occurrence of the Liassic ophiolites of the Mureş Zone (Mureş Suture) we considered it necessary to present their petrological and geochemical peculiarities as well as considerations on their origin.

2. Structural and petrographic aspects

The Bruznic gabbros crop out in the Coruba Brook, in its spring area, where they form the basement of the Neogene (Pannonian) deposits, on a length of around 400 m. As it was indicated by the boreholes executed by ISEM (FORADEX S.A. - Bucharest) in 1963-1965 on some magnetic anomalies, determined by the ophiolitic rocks from the basement, between Bruznic and Bata, the thickness of the Neogene cover varies between 50 and 120 m (Popescu, Munthiu, 1965).

The gabbroic body to which the gabbros cropping out in the Coruba Brook belong, is probably situated in the sheeted dyke complex (O_2) of the Mureş Zone, as it is shown in the adjoining map (Fig. 1). This conclusion resulted from the petrographic characteristics of the rock samples extracted from the mentioned boreholes (dolerites and intergranular basalts) as well as from the almost vertical position of the contact between the dolerite dykes and their hyalobasaltic chill margin (Fig. 2). The first authors (Popescu, Munthiu, 1965) who investigated the samples obtained from the boreholes of the Bata-Bruznic area, considered the mentioned ophiolitic rocks as a pile of alternating horizontal flows of basalts and dolerites.

The sheeted dyke complex (O_2) crops out north and north-west of Bata (Savu, Manea, 1982) where - in the Bata quarry - the dyke position is EW/80°S (Fig. 1). This complex extends from the Drocea Mts (Savu, 1984) towards WSW beneath the Neogene deposits of Bata and Bruznic, up to south-west of Lipova, where several NW-SE trending faults cut the ophiolitic megaslab (Andrei et al., 1975). Thus, the ophiolites

from the south-western blocks have been uplifted and more removed by erosion. Further away towards south-west of Inova fault, only the suture line between the two Alpine convergent plates (Apuseni Mts and Transylvanian plates) is preserved.

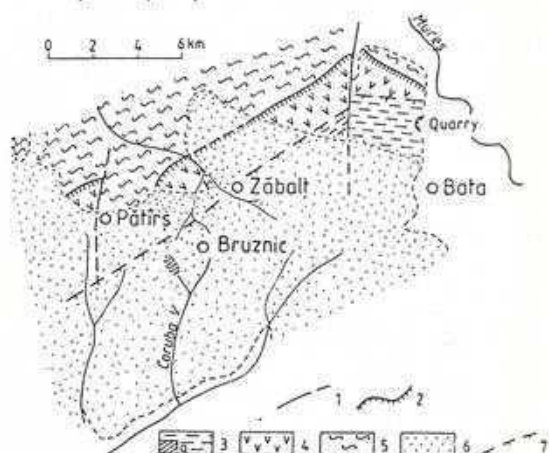


Fig. 1 - Geological map of the Bruznic - Bata region (according to the 1:200000 map published by the G.I.R., with addition). 1, fault; 2, thrust plane; 3, sheeted dyke complex (O_2); 3a, Bruznic gabbros; 4, basalt complex (O_1); 5, Tithonian-Neocomian flysch of the Criş unit; 6, Neogene sedimentary deposits; 7, thrust of the sheeted dyke complex (O_2) of the Căpâlnaş-Techeru unit over the basalt complex (O_1) of the Baia scale.

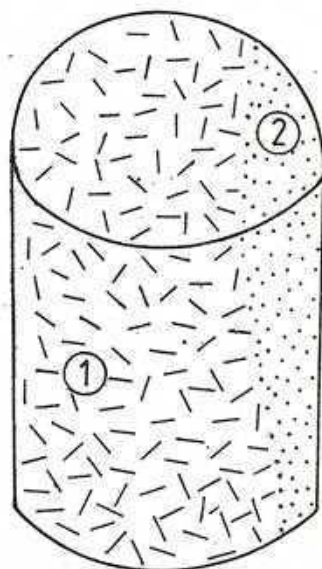


Fig. 2 - The almost vertical position of the boundary between a dolerite dyke (1) and its hyalobasaltic chill margin (2) in a sample from a Bruznic-Bata borehole (Museum of the G.I.R., Bucharest).

The mentioned sheeted dyke complex thrusts over the Baia scale consisting of the basalt complex (O_1)

and both were together thrust over the Tithonian-Neocomian flysch of Criş unit (Fig. 1).

The extension of the Bruznic gabbroic body below the Neogene sedimentary cover cannot be established because there are no boreholes in the Coruba Brook area, but its size may be estimated as similar or close to that of the Juliţa gabbroic body (Savu et al., 1982). The Bruznic gabbroic body probably trends NE-SW like the sheeted dykes, so that the Coruba Brook cuts its structures almost perpendicular to their position.

The outcrops of the Coruba Brook represent a cumulate zone of the gabbroic body constituted of olivine gabbros and diopside gabbros rich in plagioclase. These two gabbro types form alternating bands belonging to a wide structure of a layered gabbroic body. Such structures and cumulates were also observed in other gabbroic bodies from the Mureş Zone, as in those of Juliţa, Cuiaş and Almaş Sălişte (Cioflica, Savu, 1962; Savu et al., 1982; 1984). In this respect we also mention the Skaergaard gabbroic body in which the classical rhythmic layered structure was described by Wager and Brown (1968) and recently was revised by Conrad and Naslund (1989).

The olivine gabbros, which are the prevalent rocks in the gabbroic bands in the Coruba Brook, consist mainly of plagioclase (An 62-65) represented by tabular subhedral crystals with albite and pericline polysynthetic twins. The spaces between these crystals - which were the first to crystallize - are occupied by anhedral olivine and diopside crystals. Olivine presents cracks filled with iron oxides. Sometimes olivine is opacitized or transformed into secondary minerals, a process in which also fine grains of secondary iron oxides formed. The diopside ($c\angle Ng=40^\circ$) is sometimes twinned on 100 face and is uralitized; it rarely contains clusters of calcite.

In the diopside gabbros the clinopyroxene sometimes includes small-sized plagioclase crystals with albite twins. Pegmatoid gabbros rarely occur. South of the outcrops in the Coruba Brook, faser gabbros occur, too, very similar to those of Cuiaş. These rocks are diopside gabbros which were strongly deformed along some parallel crushing planes. The plagioclase crystals are broken, bent and in places altered. The clinopyroxene is completely uralitized and mostly replaced by actinolite and chlorite.

3. Geochemistry and tectonic setting

In the Bruznic gabbros the SiO_2 contents are lower than 52 per cent (Tab. 1) showing the basic composition of these rocks. The cumulates rich in plagioclase are characterized in their chemical composition by the high contents of CaO (mean 13.83 per cent) and Al_2O_3 (mean 18.36 per cent). Although these two components are present in higher amounts than in nor-

mal gabbros, their $\text{CaO}/\text{Al}_2\text{O}_3$ ratio maintains at low values, with an average of 0.75. This value stands between 0.7 and 0.8, the ranges established by Werner (1984) for its variation in ophiolitic rocks.

diagram (Fig. 4), all the rocks are situated in the lower part of "High - Ti" field which, according to Serri and Saitta (1980), represents the ocean floor ophiolite domain. This position of the rocks is explained by

Table 1
Chemical composition of the gabbroic rocks⁺

No	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	K ₂ O	Na ₂ O	P ₂ O ₅	H ₂ O ⁺	S	Total
1	47.69	0.32	17.85	0.59	4.42	0.16	8.68	15.52	0.14	2.18	0.30	1.38	0.20	99.43
2	48.56	0.16	21.23	1.79	2.79	0.10	7.70	12.72	0.18	2.35	0.24	2.74	0.13	100.69
3	48.60	0.32	19.97	1.45	3.62	0.14	7.52	13.60	0.17	2.38	0.38	1.12	0.19	99.46
4	49.08	0.48	16.00	2.06	5.67	0.15	8.51	12.70	0.14	2.43	0.39	1.79	0.02	99.42
5	49.56	0.36	17.40	3.23	2.11	0.12	8.08	14.87	0.15	2.44	0.36	1.92	0.03	100.63
6	49.97	0.40	17.75	1.22	4.28	0.13	7.62	13.62	0.18	2.55	0.30	1.33	0.16	99.51

⁺CO₂ is absent in all the analysed rocks.

Samples: 1, 3, 4, 5, olivine gabbros; 2, flasergabbro; 6, diopside gabbro.

The average normative composition of gabbros is, as follows: or - 1.43; ab - 19.70; an - 35.55; di - 26.60; hy - 3.03; ol - 10.50; ap - 0.33; il - 0.55; mt - 1.11; py - 1.16. This composition shows that the plagioclase (An 64) participates in gabbros in a proportion of 55 per cent, varying between 51 and 61 per cent. The olivine, which is present in many gabbros, is a variety rich in forsterite (76 per cent). It is noteworthy that hypersthene, as well as orthoclase, appears only in the rock norm.

As a result of the high content in Ca and Al, the Bruznic gabbros are more depleted in iron and, consequently, in trace elements geochemically correlated with the latter. Therefore, these rocks do not behave like normal gabbros on some diagrams relevant for the tectonic setting, in which elements as Fe, Ni, Ti, V and Cr were used. Thus, on the FeO - MgO - Na₂O+K₂O diagram (acc. to Irvine and Baragar, 1971) three of the six analysed gabbros normally plot in the tholeiite rock field, but the other three rocks fall in the calc-alkaline field (Fig. 3). But on the TiO₂ - FeO/FeO+MgO

their characteristic content of Ti, which varies between 900 and 2800 ppm (mean 2000 ppm). However these values are a little lower than those indicated by Pearce and Cann (1973) for the ocean floor basalts.

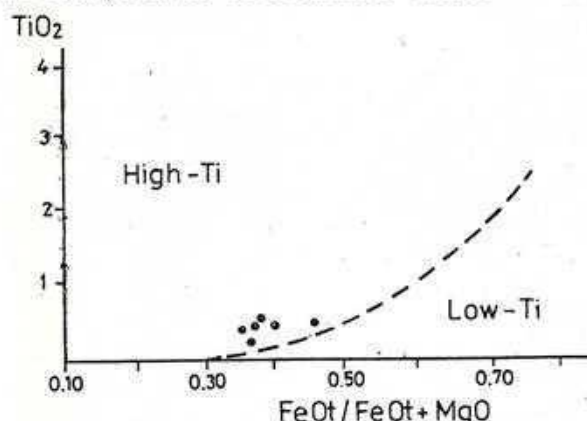


Fig. 4 - Plot of the gabbroic rocks on the TiO₂ - FeO/FeO+MgO diagram (High-Ti and Low-Ti fields acc. to Serri and Saitta, 1980).

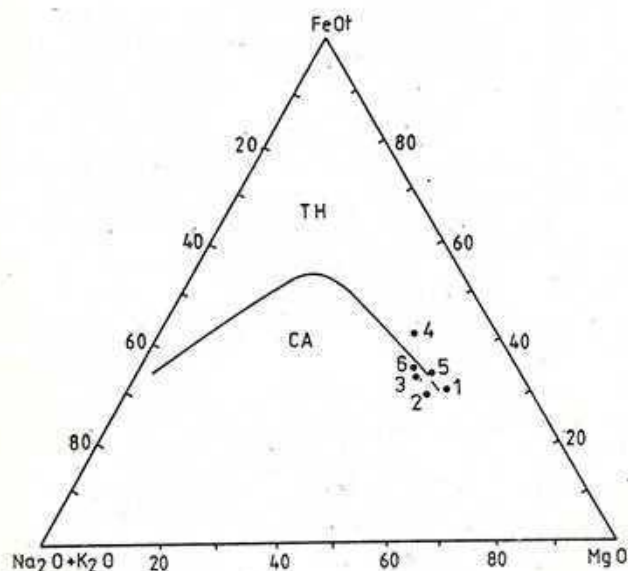


Fig. 3 - Plot of the gabbroic rocks on the FeO - MgO - Na₂O+K₂O diagram (TH and CA fields acc. to Irvine and Baragar, 1971).

The FeO/MgO ratio is lower than 2, with an average of 0.66, showing that the gabbroic rocks belong to the tholeiitic series. On the Ba - FeO/MgO diagram (acc. to Miyashiro, 1975) most of gabbroic rocks, excepting one sample which was affected by alteration processes, plot between the fields of the abyssal tholeiitic rocks from the Atlantic median ridge, north and south of Azores and from the Indian and Pacific oceans, which are ocean floor rocks, too (Fig. 5).

The Sr contents (Tab. 2), with a mean value of 157 ppm, are close to the Sr contents of different ocean floor rocks, according to Pearce and Cann (1973), with an average value of 139 ppm. The Bruznic gabbros, with a high Ca content, have higher contents of Sr. The mean value of 157 ppm Sr, plotted on Hart et al. (1970) diagram, suggests that the parental tholeiitic magma, from which the Bruznic gabbros derived,

formed in the mantle at a depth of around 100 km.

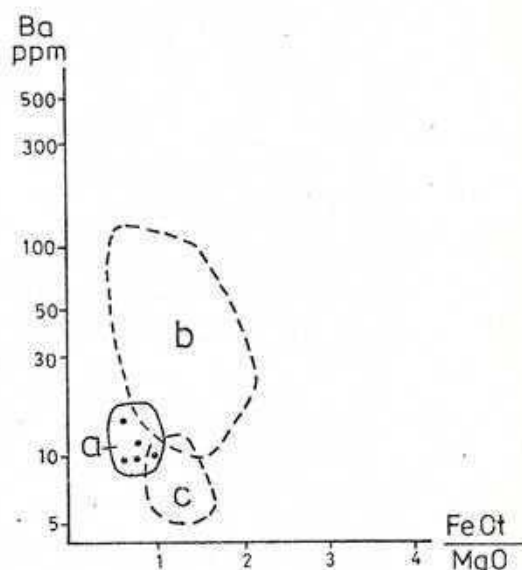


Fig. 5 - Plot of the gabbroic rocks on the Ba - FeO/MgO diagram. a, Bruznic gabbro field; b, field of the abyssal tholeiites from the Atlantic median ridge north of the Azores and from the Indian and Pacific oceans; c, field of the abyssal tholeiites from the Atlantic median ridge south of the Azores (b and c fields acc. to Miyashiro, 1975).

the latter. Therefore, on some diagrams the gabbroic rocks plot somehow different than the normal gabbros. There are also diagrams which show that the gabbroic rocks belong to the tholeiitic series and are ocean floor rocks. These characteristics are also indicated by the mean contents of some major and trace elements, as well as by the values of some ratios of these elements.

The geochemical characteristics of these gabbros correspond to that of the sheeted dyke complex (O₂) of the Mureș Zone.

The layered structure of the gabbroic body resulted by the differentiation of the parental tholeiitic magma and by the sedimentation of the plagioclase crystals. In the interstices between the plagioclase crystals olivine and diopside formed from the intercumulus liquid.

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Table 2
Trace element contents in the gabbroic rocks

No ⁺	Ni	Co	Cr	V	Sc	Zr	Y	Ba	Sr	Pb	Cu	Zn	Ga
1	90	21	520	210	33	16	12	13	130	3.5	43	<30	7
2	240	62	570	165	31	32	<10	145	170	<2	60	<30	14
3	170	27	860	165	34	17	15	10	170	<2	75	<30	8
4	135	30	470	220	36	19	17	10	110	15	105	70	7.5
5	145	30	520	250	48	13	18	10	150	11	80	<30	7.5
6	75	17	220	230	33	13	16	15	210	<2	42	<30	7

* The same samples as in Table 1. In these gabbros there are some elements with very low contents: Nb<10 ppm; Yb<1 ppm; La<30 ppm; Sn<2 ppm.

As the Bruznic gabbros contain melanocrate minerals in small amounts, they also present contents of Zr, Y and Nb (Tab. 2) lower than the normal gabbros.

4. Conclusions

The Bruznic gabbros belong to a layered gabbroic body located in the sheeted dyke complex (O₂) of the Mureș Zone. It is covered by Neogene sedimentary deposits. The gabbroic rocks of the Coruba Brook represent a horizon of cumulates rich in plagioclase, which consists of alternating bands of olivine gabbros and diopside gabbros, belonging to a rhythmic layered structure.

As the gabbroic rocks are rich in Ca and Al, evidently they are depleted in ferro-magnesian elements and in trace elements geochemically correlated with

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Received: December 19, 1991.

Accepted: May 11, 1992.

Presented at the scientific session of the
Institute of Geology and Geophysics: December 4, 1992.

EFECTE ALE TECTONICII DE PÂNZĂ METAMORFICĂ ÎN PARTEA SUPERIOARĂ A SERIEI DE LOTRU

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Key words: Tectonic units. Precambrian. Tectogenesis. P-T conditions. Chemical reactions. Geochemical controls. Mineralization. Manganese ores. South Carpathians.

Abstract: *Effects of Metamorphic Nappe Tectonics in the Upper Part of the Lotru Series:* The tectonic boundary between the uppermost Precambrian nappes of the Lotru Series (viz. the Voineasa and Semenik Nappes) has not as yet been traced with accuracy. However, the lithologic and metamorphic contrasts between them are fully reliable features in identifying and tracing the limit. During the thrust, rotational tectonics (disrupted folds, boudins, mullions) developed due to simple shear; subsequent folding resulted in open low-amplitude antiforms and tight high-amplitude synforms. The thrust surface concentrates rock types contrasting with the background, such as quartzites, tourmaline-rich rocks, manganese silicate rocks, pegmatites, and displays an obvious enrichment in light elements as Li, Be, B, as well as in Mn. Mn-rich rocks always have in footwall K-feldspar bearing gneisses and in hanging wall almandine-micaschists. These facts strongly support the idea of a petrogenetic and metallogenetic role of the thrust. The mechanism invoked are segregation processes and metamorphic reactions. The driving force of segregation could be pressure, viscosity and chemical activity gradients, while metamorphic reactions were triggered by tectonic joining of chemically contrasting rocks. They produced Mn enrichment through garnet breakdown with K-feldspar to biotite and muscovite ($2Ksp + Gar + 2H_2O = Bio + Mus + 3SiO_2$). The appearance of (minor) silica undersaturated minerals as tefroite is explained by silica consuming breakdown of staurolite with K-feldspar ($2Ksp + 6Sta + 9SiO_2 = 2Mus + 4Gar + 21Als + H_2O$).

Introducere

Definirea și mai ales separarea entităților litostratigrafice ale seriei de Lotru (Ghica-Budești, 1932) din cristalinul Getic al Carpaților Meridionali constituie încă un subiect asupra căruia nu există un acord unanim. Modelele elaborate până în prezent în diverse arii aflorare (ex: Savu, Schuster, 1977; Bercia, 1975) conțin diferențe care merg de la mici nepotriviri până la contradicții de fond, iar corelările regionale (Savu, 1975; Kräutner, 1980) sunt tributare studiilor utilizate.

Folosirea conjugată a unor criterii litostratigrafice și de istorie metamorfică (Săbău, 1944) a permis separarea și evidențierea succesiunii unor entități definite în cadrul seriei de Lotru ca unități într-o stivă de pânze metamorfice precambriene. Succesiunea debutează prin unitatea de Armeniș (în bază) care suportă pânzele de Voineasa, respectiv de Semenik.

Gradul incomplet și neuniform de acoperire a făcut însă imposibilă cartografierea exactă a limitelor în toată aria de aflorare. Pentru aceasta se impune cartarea sau reambularea unor suprafețe întinse, proces care necesită un timp îndelungat. Ca etapă a acestui proces, prezenta comunicare analizează limita dintre pânza de Semenik și cea de Voineasa în partea superioară a văii Sadului, oferind un exemplu asupra modului în care amplasarea pânzelor metamorfice poate determina acumularea unor substanțe minerale utile.

1. Construcția petrografică, criterii de separare și natura limitelor

Rocile din perimetrul investigat (Pl. I) aparțin unităților tectonice superioare, precambriene ale seriei de Lotru, respectiv pânzei de Voineasa și pânzei de Semenik (Săbău, 1994).

Pânza de Voineasa conține roci ale complexului de Vaideeni. În cadrul acestuia se disting trei tipuri de asociații litologice, ale căror relații mutuale sunt încă insuficient cunoscute, dar fiecare dintre ele suportă tectonic pânza de Semenice, constând din rocile de compoziție pelitică ale formațiunii de Negovanu Mare.

Una dintre asociații are o compoziție gnaică - amfibolică și a fost descrisă de Arion, Stoian (1986) sub numele de gnaise de Frumoasa. Acestea sunt formate din gnaise cu microclin roz sau albe, asociate cu amfibolite și gnaise microclinice cu amfiboli. Subordonat se întâlnesc intercalații de gnaise micacee predominant biotitice. Cele trei tipuri de roci alternează și prezintă tranziții mai mult sau mai puțin gradate, precum și arii largi de aflorare a rocilor amfibolice, respectiv gnaise. În cadrul lor se întâlnesc frecvent segregatii pegmatoidale care pot conține, alături de microclin, biotit sau amfiboli larg dezvoltati. Gnaisele de Frumoasa apar în perimetrul cercetat la izvoarele văii cu același nume, extinzându-se spre N până în creasta munților Cibin spre E câțiva km din cursul superior al Sadului, iar spre S foarte puțin în versantul nordic al munților Lotrului. Ele capătă o dezvoltare foarte largă, în afara perimetrului, spre V, în aval pe valea Frumoasei.

A doua asociație litologică separabilă în cadrul complexului de Vaideeni a fost definită de Arion (1988) în valea Lotrului sub denumirea de gnaise de Steaja și constă predominant din gnaise biotitice rubanate care se desfac în lespezi, conținând preponderent biotit, oligoclaz și cuarț. Frecvent biotitul este alungit, rezultând o textură liniară dată de paietele brun-negricioase de 0.5-2 x 1.5-3 mm. Oligoclazul este izometric de cca 2 mm și are o culoare gălbuie. Aceste gnaise pot conține uneori și amfiboli iar ceva mai rar prezintă noduli milimetricei aplatizați de sillimanit fibrolitic. Secvența conține subordonat amfibolite și gnaise amfibolice ± piroxeni, iar și mai rar apar micașisturi cu sillimanit, cel mai adesea nodular. Rocile ultramafice apar subordonat fiind reprezentate mai ales prin lentile de actinolite. Pegmatitele sunt foarte frecvente, ele conțin ca minerale principale feldspati, inclusiv microclin, alături de muscovit, biotit și cuarț, în proporții modale foarte variabile. Gnaisele de Steaja au o mare dezvoltare în bazinele afluenților Lotrului (Steaja, Balindru, Hoteagu) și se extind spre N pe creasta munților Lotrului, în special în zona Șteflești, apărând însă și în vârful Rozdești.

În afară de acestea se poate distinge o asociație care poartă numeroase incluziuni de roci exotice. Litologic ea este alcătuită din șisturi și gnaise predominant muscovitice cu intercalații de gnaise microclinice, și cu totul subordonat amfibolite. Rocile exotice sunt reprezentate prin lentile de eclogite și ultramafite. Eclogitele sunt frecvent retromorfozate, cel mai adesea aproape complet amfibolitizate. Pegmatitele cu mi-

croclin roz sunt foarte frecvente, sub formă de corpuri în general de mici dimensiuni în mod obișnuit discordante și plasate la limita dintre litoni cu competență diferită. Această asociație apare ca o bandă la nord de valea Sadului, mărginită de falii alpine.

Metamorfismul complexului de Vaideeni este policiclic, distingându-se două evenimente de grad mediu M_1 și M_2 . M_1 este reprezentat prin relicte destul de rar conservate de disten, rutil, staurolit și mai ales granat, iar în timpul lui M_2 a cristalizat asociația almandin-muscovit-sillimanit-ilmenit (Pl. II, fig. 1).

Pânza de Semenice este reprezentată prin roci ale formațiunii de Negovanu Mare. Constituția litologică a acestuia este de o suprinzătoare omogenitate, fiind reprezentată practic numai din roci micacee. Predomină micașisturile, care trec uneori în gnaise micacee prin creșterea conținutului de plagio-claz. Muscovitul și biotitul participă în cantități egale la constituția rocii, iar foarte frecvent apar porfiroblaste centimetrice de granat, staurolit și disten. Sunt caracteristice segregatiile, în general centimetrice, de cuarț fumuriu și porfiroblastele izometrice, rotunjite, de oligoclaz care ajung în mod excepțional la 5 cm lungime. Mai rar, rocile micacee conțin și porfiroblaste de rutil. În interiorul formațiunii nu apar pegmatite.

Pânza de Semenice aflurează în general în zonele de creastă, sub forma unor petice de grosime redusă, care coboară frecvent pe versanți. Contururile de aflorare sunt neregulate, fiind determinate de intersecția dintre o limită cu oscilații frecvente și nesistematice în jurul poziției orizontale și un relief montan. Sunt de remarcat numeroasele petice de mici dimensiuni suspendate în versanți. În ceea ce privește metamorfismul, formațiunea de Negovanu Mare conține relicte abundente ale asociației caracteristice M_1 (disten, almandin, staurolit, rutil) față de care neoformările din M_2 sunt greu de separat din cauza condițiilor metamorfice asemănătoare lui M_1 , care dau o paragenză puțin diferită (disten, almandin, staurolit, ilmenit ± sillimanit). Mineralele M_1 pot fi substituite sau pot coexista cu mineralele M_2 , caz în care același mineral apare frecvent în două generații care pot fi distinse după criterii texturale (Hărtopanu, 1978).

Caracteristicile expuse mai sus conțin suficiente criterii discriminante pentru a trasa limita între unitatea de Semenice (formațiunea de Negovanu Mare) și rocile complexului de Vaideeni, care compun unitatea de Voineasa. Până în prezent însă, această limită nu a fost trasată decât cu o mare aproximație din cauza morfologiei sale complicate, care a făcut pe majoritatea autorilor să descrie intercalații acolo unde apar de fapt repetiții prin intersecția dintre cute și relief. Acest lucru a fost posibil cu atât mai mult cu cât stilul structural al stivei este neuniform pe verticală. Astfel, în interiorul unității de Semenice elementul structural

predominant este foliația S_2 , în general constantă la scară regională, eventual cutată larg. În baza unității structura se schimbă, apărând cute cilindrice de diverse amplitudini, de la centimetrice la hectometrice, dintre care unele sunt retezate și dezrădăcinate. Apar astfel structuri cilindrice și liniare reprezentate prin budine și liti de formă columnară. Acest stil structural este expus pe șoseaua forestieră din valea Sadului, de exemplu între cabana Gâtul Berbecului și uzina electrică Sadu V, sau la coada lacului de acumulare, în aval de valea Dușa. La acest nivel structurile planare sunt extrem de inconstante, în timp ce liniatiile date de șarniere de cute și microcute, alungiri de budine și coloane au o direcție constantă (NV-SE).

În interiorul unității de Voineasa se evidențiază cute de diverse amplitudini, cu un aspect complicat care face dificilă urmărirea litiilor.

Geneza unui astfel de stil structural este perfect compatibilă cu modelul tectonic în pânză metamorfică (Săbău, 1994). În timpul încălzirii, întreaga stivă este supusă unui cuplu de forțe, care determină o curgere planară de-a lungul suprafețelor S_2 în rocile incompetente ale formațiunii de Negovanu Mare. Rezultă un tectonit de tip S. La limita dintre cele două unități apar cute de antrenare din cauza existenței unor roci de competențe diferite, care reacționează diferențiat la efort. Aceste cute se pot aplatiza sau rupe, fiind apoi "rulate" între suprafețele de alunecare plană. Astfel se realizează elemente structurale în regim tectonic rotațional (R).

În unitatea de Voineasa coexistă un regim de forfecare simplă și comprimare verticală care determină în rocile cu competențe diferite ale unității o tectonică de cutare complicată (Fig. 1).

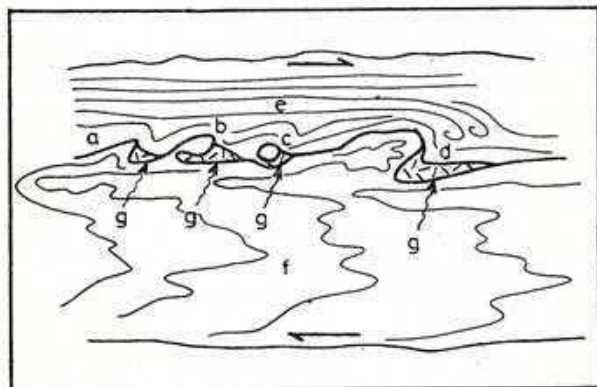


Fig. 1 - Elemente și procese structurale caracteristice la nivelul pânzei metamorfice (scara arbitrar aleasă). a) cute de antrenare; b) cute dezrădăcinate; c) budine și coloane; d) formarea de pegmatite în umbrele de presiune; e) formarea și stozitității S_2 în regim de alunecare plană în interiorul pânzei de Semenici; f) cutare în regim mixt de forfecare simplă și aplatizare verticală (forfecare pură) în unitatea de Voineasa; g) concentrarea materiilor mobile spre umbrele de presiune.

Peste elementele structurale sinmetamorfice s-au im-

primat două episoade de cutare tardive cu o morfologie aparte. Cutele constau dintr-o alternanță de sinforme cu amplitudine mare și deschidere mică și antiforme largi, dar de amplitudine mică. Rezistența diferențială la eroziune a rocilor din cele două unități a favorizat formarea creștelor în zone de antiformă, iar interacțiunea dintre morfologia terenului și forma cutelor a dus la apariția ferestrelor de eroziune în versanți și coborârea umpluturii sinformelor până în văi (Fig. 2) (Pl. I).

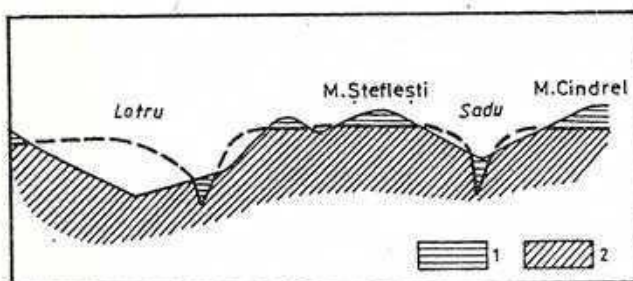


Fig. 2 - Secțiune schematică ilustrând tectonica post-pânză.

Din cartare rezultă două asemenea sisteme de cute, unele mai vechi orientate N-S, cu o amplitudine de cca 1 km și altele orientate E-V cu o amplitudine de 3-5 km, pe care s-au suprapus zonele de creastă.

Acest stil tectonic apare atunci când o secvență de roci cu vâscozitate mai mare suportând roci mai incompetente este supusă compresiunii tangențiale și a fost descris de Ramsay (1963) în Alpii Occidentali.

2. Rolul petrogenetic și metalogenetic al tectonicii de pânză

Limita dintre formațiunea de Negovanu Mare și complexul de Vaideeni nu este evidențiată doar prin trecerea de la un tip de asociație litologică la altul. Frecvent apar roci caracteristice limitei, cu o largă dezvoltare numai în dreptul acesteia. Astfel pe culmea Haneșul-Piatra Albă apar cuarțite situate strict în baza micașisturilor, stând peste gnaisele complexului de Vaideeni. Uneori micașisturile suprajacente sunt erodate. Relații similare apar la izvoarele pâraului Dăneasa.

Foarte adesea, limita este jalonată de pegmatite concordante, în general de mici dimensiuni și extrem de abundente. În multe cazuri limita se poate trasa urmărind ivirile de pegmatite. Situații extrem de caracteristice apar în culmea care coboară de la piciorul telescaunului din Păltiniș și în versantul stâng al pâraului Dăneasa. Aici eroziunea a permis păstrarea în versanți a unor petice de micașisturi care au în bază lentile concordante de pegmatite. Relații asemănătoare apar foarte clar în versantul stâng al

pârâului Grosu. Ele sunt probabil mult mai răspândite dar au trecut neobservate.

Un alt indiciu extrem de frecvent este constituit de rocile bogate în turmalină. Mineralul este acicular sau columnar și variază de la câțiva milimetri lungime până la dimensiuni decimetrice. Între numeroasele ocurențe sunt de menționat cele din zona vârfului Șteflești și izvoarele Haneșului din bazinul Lotrului.

Limita este marcată foarte frecvent de roci manganifere, constând predominant din silicați (mai ales spessartin) și subordonat carbonați. Până în prezent, aceste roci nu au fost puse în legătură cu limita dintre micașturi și gnaisele subjacente. Cu toate acestea, în numeroase deschideri foarte bune (pe valea Sadului în jurul vărsării pârâului Dușa, la sud de cantonul Muncelu, în versantul drept al pârâului Groși, la 100 m sud de stâna Bătrâna Mică) se observă succesiunea gnaise-roci manganifere-micașturi. În toate cazurile gnaisele conțin și feldspat potasic, iar micașturile sunt bogate în porfiroblaste de granat.

Situarea acestor litologii aproape exclusiv la limita menționată și absența lor în alte contexte (cu excepția cuarțitelor și a pegmatitelor, care totuși apar și în altă poziție) oferă indicații referitoare la momentul formării și mecanismele genetice.

Apariția acestor roci trebuie să fie legată de realizarea limitei la nivelul căreia se concentrează, adică de momentul încălecării, corespunzând cu evenimentul metamorfic M_2 . Mecanismele genetice cele mai probabile sunt de două tipuri, și anume: concentrarea prin segregare și neoformare prin reacții metamorfice. Procesul de segregare poate fi realizat pe mai multe căi. Un prim aspect este reprezentat de segregarea mecanică, prin care mineralele plastice se concentrează în zonele de forfecare spre care pot migra datorită gradientilor de presiune și unde pot prelua mișcarea datorită comportamentului ductil. În virtutea acestui mecanism apar cuarțitele chiar pe planul de forfecare precambrian. Stadii intermediare ale segregării au fost identificate de Arion et al. (1987), care descriu "paragneise cuarțoase cu granat" ca având o poziție de tranziție între zona cu sillimanit și cea cu staurolit și disten.

Un alt tip de segregare este realizat prin migrarea de substanță sub influența unor gradienti de presiune sau de activitate chimică și concentrarea prin ecranare în baza pânzei de Semenici. Gradientii de presiune se realizează prin apariția zonelor de distensie asociate deformărilor în regim rotațional la acest nivel. Cavitățile virtuale apărute în timpul deformării, precum și umbrele de presiune atrag fluide cu compoziții pegmatitice din rocile adiacente, determinând concentrarea pegmatitelor la acest nivel. Demn de menționat este faptul că gradientii de presiune neomogeni se formează în orice tip de curgere în regim turbulent,

de aceea și în masa unității de Voineasa apar numeroase corpuri pegmatitice. În acest context planul de pânză reprezintă nivelul superior (dar și de maximă concentrație) al apariției pegmatitelor.

În acest regim de mobilizări importante, volatilele sunt primii compuși chimici mobilizați și antrenati în mișcări ascensionale. Pânza de Semenici, aflată în mișcare plan-laminară deasupra unității de Voineasa, strivită și antrenată în curgere turbulentă, se comportă ca un ecran, ducând la precipitarea substanțelor volatile. Zona în care acestea se concentrează este suprafața de încălecare, prezentând însă aureole de dispersie extinse la nivelele adiacente. Acest comportament poate fi lesne sesizat în cazul elementelor ușoare Li, Be și B.

Concentrațiile de litiu au fost identificate în două câmpuri pegmatitice apropiate (Conțu inferior și Conțu superior) și au fost descrise de Maieru et al. (1968) și Săbău et al. (1989). Litiul este conținut în special în spodumen, dar apare și în minerale fosfatice (trifilin-litofilit, ambligonit-montebrasit, tavorit). Alături de mineralele litifere apar subordonat minerale de Sn, Nb și U asociate cu cleavelandit. Este interesant de semnalat că în pegmatitele litifere apar concentrații de beril în granule cel mai adesea de dimensiuni microscopice (Pl. II, fig. 2), iar borul apare (destul de rar) în turmalină și dumortierit (Pl. II, fig. 3). Acest ultim mineral, neidentificat până în prezent în această zonă, se prezintă sub formă de cristale aciculare, milimetrice, de culoare albastru intens, formând mici aglomerări în cuarț fumuriu. Evoluția pegmatitelor litifere descrisă în Săbău et al. (1989) oferă argumente texturale și chimice în favoarea modelului pe care-l adoptăm. Existența agregatelor grafice de muscovit și cleavelandit cu structuri helicitice demonstrează începutul cristalizării pegmatitelor în regim rotațional. Fraționarea intensă a elementelor între mineralele constituente ale pegmatitului indică pe de altă parte o evoluție în sistem închis a fluidului pegmatitic odată segregat în "capcane" aflate pe planul de încălecare.

Beriliul se concentrează într-un mod analog apărând în pegmatite cu beril. În afară de ocurența de la Conțu, în perimetru mai apare beril în imediata apropiere a vârfului Piatra Albă, sub formă unor cristale subhedrale de câțiva centimetri (Pl. II, fig. 4). Pegmatitele cu beril au stat în atenția echipelor de prospecțiuni ale TPME și IPGG, care au semnalat numeroase iviri în apropierea perimetrului: versanții pârâului Urleșu (Arion, Stoian; 1986) și văile Goța Mare (Apostoiu et al., 1982), Tancu, Despina, Mănăileasa (Maieru et al., 1968). Ivirile de beril din pegmatite se concentrează în apropierea încălecării, unde apar și cristale de talie mare, dar se mențin și la nivele inferioare, arătând o mobilitate ceva mai scăzută

decât în cazul litiului.

Borul este elementul volatil cu mobilitatea cea mai mare, suferind o concentrare foarte puternică pe planul de încălecare și menținându-se într-un interval mai larg pe verticală. Dintre mineralele cu conținut de bor se remarcă turmalina, un constituent frecvent al pegmatitelor din zonă, dar prezent și ca porfiroblaste în roci micacee. Cea mai caracteristică și frecventă apariție a turmalinei este însă chiar pe planul de încălecare, formând dese acumulări monominerale sau în asociație cu cuarțul. Îmbogățirea în turmalină persistă încă în baza pânzei de Semenice unde apar relații interesante cu distenul porfiroblastic din micașisturile formațiunii de Negovanu Mare (Pl. II, fig. 5,6).

Neoformarea prin reacții metamorfice este prin excelență mecanismul care realizează concentrări de mangan, dând naștere la roci predominant spessartinice. Aceste roci au fost descrise pe întreaga arie de aflorare a seriei de Lotru din munții Semenice (Savu, 1962) până în munții Lotrului (Bălan, David, 1978). Datele referitoare la ocurențele din Carpații Meridionali au fost sintetizate de Hărtopanu (1986).

Există mai multe interpretări privind poziția rocilor manganifere în stivă. Savu (1970) susține în munții Semenice prezența unui complex al ortoamfibolitelor și al formațiunii manganifere, diferențiate lateral din complexul micașisturilor, iar Hărtopanu, Udrescu (1981) disting în nordul masivului Sebeș un aliniament de roci manganifere care se fasciculează spre sud în trei ramuri, la vest de Valea Cugirului.

Cartarea perimetrului cercetat, precum și observațiile asupra aflorimentelor de roci manganifere din celelalte zone ale Carpaților Meridionali au relevat însă faptul că acestea ocupă o poziție unică în stivă, având rol de nivel reper (nivelul de Delinești-Săbău, 1994) la limita inferioară a pânzei de Semenice. Aliniamentele fasciculate distinse de Hărtopanu, Udrescu (1981) reprezintă intersecția acestui nivel cu suprafața topografică având întotdeauna în acoperiș micașisturile formațiunii de Negovanu Mare, iar în culcuș roci ale complexului de Vaideeni.

Compoziția mineralogică a rocilor manganifere este dominată de spessartin, dar frecvent se întâlnesc tefroit, rodonit, piroxmangit, dannemorit, rodocrozit, cuarț și subordonat jacobsit, vredenburgit, magnetit, pirofanit, hausmanit, braunit, pirotină, calcopirită, apatit, titanit, rutil, orthit (Hărtopanu, 1986). Au mai fost citate piemontit, muscovit manganifer, manganofilit, leuchtenbergit, granați calderitici, bixbyit, hematit (Bălan, David, 1978).

Geneza acumulărilor este concepută de Savu (1970) ca fiind rezultatul unui mecanism unitar. Părerii alternative susțin existența a două tipuri de roci manganifere formate în timp diferit, în condiții fizice deosebite și din surse diferite de mangan, pe baza asociațiilor

minerale, a texturilor și a conținutului de elemente minore (Hărtopanu, Udrescu, 1981).

Pentru elucidarea mecanismului genetic considerăm utilă trecerea în revistă a principalelor date de observație și de analiză acumulate până în prezent. Astfel:

a) se pot distinge două grupuri, grupul rocilor tefroite care constituie minereu de mangan și conțin tefroit substituit de alți silicați, dintre care o generație de spessartin numit spessartin II, respectiv grupul rocilor spessartinice I, care nu reprezintă un minereu și al căror spessartin este format pe seama almandinului (Hărtopanu, Udrescu, 1981);

b) în cazul primului grup succesiunea de cristalizare este tefroit-piroxmangit-rodonit-spessartin II-dannemorit, spessartinul fiind orientat după foliația S_2 , iar mineralele anterioare formând relicte precinematice (Hărtopanu, Hărtopanu, 1981);

c) Tefroitul prezintă conținuturi mai mari de Co și mai ales Ni precum și un raport superior Ni/Co față de celelalte minerale; această tendință este evidentă, dar mai puțin intensă și la mineralele secundare, inclusiv la spessartinul II, spre deosebire de spessartinul I, care nu provine din tefroit ci din almandin (Hărtopanu, Udrescu, 1981);

d) toate analizele corespund grupei depozitelor de mangan nevulcanice (Roy, 1977, fide Hărtopanu, Udrescu, 1981);

e) cele două grupuri se disting doar geochemic și nu spațial, întrucât în aceleași câmpuri citate de Hărtopanu, Udrescu (1981) (Pravăț-Lencuș, Valea Strâmbu-Bretan, Valea Untu-Bătrâna, Râșcoala) apar atât tefroit cu produsul său de transformare spessartin II, cât și spessartin I;

f) acumulările de silicați de mangan apar strict în baza formațiunii de Negovanu Mare, ca nivel reper cartabil;

g) la acest nivel există un plan de pânză metamorfică, întrucât aici apar contraste litologice, discordanțe structurale, contraste în ceea ce privește istoria metamorfică și gradul de readaptare la condițiile metamorfice M_2 (Săbău, 1994) cât și o zonă de forfecare cu structuri specifice (vezi mai sus);

h) apariția tefroitului în roci este posibilă numai într-un mediu subsaturat în silice, asociația olivină-cuarț fiind nestabilă în tot câmpul termobaric al metamorfismului; în medii lipsite de cuarț însă există ocurențe de tefroit în metamorfite de grad de la scăzut (seria de Tulgheș) până la ridicat (Nagpur);

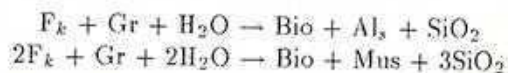
i) molecula olivinelor permite substituții izomorfe cu cantități însemnate de Pb, Zn, Co, Ni;

j) rocile manganifere au în acoperiș micașisturi cu granat, iar în culcuș gnaise conținând feldspat potasic.

Observațiile a, b, c, comparate cu observațiile d și e indică faptul că dacă operăm separații pe criterii

geochimice, mineralogice și texturale, nu înseamnă neapărat că aceste separații au relevanță în aprecierea procesului genetic. Distribuția spațială a ivirilor de silicați de mangan, conform observațiilor *e* și *f*, pledează pentru un mecanism genetic mai degrabă unitar. Observația *g* indică următoarele ipoteze alternative: fie că stiva a fost retezată în momentul încălecrii riguros la nivelul la care manganul se acumulase anterior, fie că silicații de mangan au apărut la nivelul și din cauza acestei încălecrii. Prima situație este greu de imaginat, iar cea de-a doua este în aparentă contradicție cu observația *b*. În virtutea acestei observații, Hărtopan, Hărtopan (1981) susțin existența unui tefroit moștenit dintr-un metamorfism mai vechi, caracterizat prin condiții termobarice corespunzătoare, lucru contrazis de observația *h*, conform căreia în această situație nu condițiile fizice determină apariția tefroitului ci un mediu geochimic nesaturat în silice. Pentru a înlătura această dilemă este suficient să identificăm mecanismul care poate duce la consumarea silicei și deci la crearea unui mediu geochimic favorabil formării tefroitului în decursul metamorfismului M_2 . Pe de altă parte, faptul că tefroitul este anterior episodului sincinemat M_2 nu implică neapărat formarea sa într-un eveniment anterior ci doar într-o fază precoce, fiind posibilă reacția ulterioară dintre tefroit și cuarț, venite în contact în urma deformărilor de-a lungul planului S_2 , cu formarea de spessartin orientat.

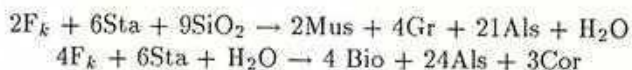
Din observațiile *g* și *j* apare evident că în decursul gariajului, micașturile cu granat, eventual disten și staurolit ale pânzei de Semenice au ajuns în contact cu gnaise conținând feldspat potasic ale pânzei de Voineasa. În condițiile metamorfismului M_2 (cca 650° C, 6 kb) feldspatul potasic, foarte mobil, se află mult în afara câmpului său de stabilitate atât cu granatul cât și cu silicații de aluminiu. Perechea almandin-feldspat potasic este stabilă la peste 3,2 kb și 760° C, curba de reacție având o pantă pozitivă, astfel încât la 6 kb temperatura este de circa 850° C (Holdaway, Lee, 1977). În aceste condiții au loc reacții de dezechilibru între feldspatul potasic și componenta feromagneziană a granatului, care în funcție de activitatea feldspatului potasic, sunt:



Întrucât componenta spessartinică a granatului este cea mai stabilă în condiții subgranulitice, în urma acestei reacții se va înregistra o puternică diluare în Fe și Mg a granatului, acesta recrystalizând sub formă de spessartin. Formarea spessartinului pe seama almandinului a fost, de altfel, susținută de Hărtopan și Hărtopan (1981) cu argumente texturale.

Dacă în micașturi există staurolit suficient de abundent, acesta reacționează, tot în condiții de

dezechilibru, cu feldspatul potasic. În funcție de activitatea feldspatului potasic reacțiile posibile sunt următoarele:



Aceste reacții sunt de mare importanță deoarece duc la apariția unor medii geochimice locale nesaturate în silice, în care excesul de mangan poate cristaliza sub formă de tefroit sau rodocrozit. Corindonul din reacția a doua poate avea caracter normativ, semnificând tot nesaturare în silice, sau chiar modal, cristalizând ca atare. Această ultimă situație a fost identificată în vârful Dobroia (Hărtopan, 1985, comunicare orală).

Cristalizarea tefroitului duce la concentrarea Co și Ni în rețeaua acestuia, realizând un proces de fracționare foarte eficient. Oricât de eficient ar fi acest proces, conținuturile rezultate se dovedesc cu două ordine de mărime mai mici decât în cazul nodurilor manganiferi.

În condițiile încălecrii se pot realiza amestecuri tectonice între zonele nesaturate în silice (cu tefroit) rezultate anterior și zone mai bogate în silice și alumina. Tefroitul va reacționa formându-se silicați de mangan secundari, între care și spessartinul II. Aceste produse vor cristaliza în medii bogate în Co și Ni, manifestând însă preferință pentru Co. Spessartinul II, crescut într-un mediu cu activitate mult mai mare a Ni decât spessartinul I, va îngloba în rețea o cantitate mai mare din acest element, ajungându-se la relația redată în observația *c*. De altfel, comparația geochimică dintre cele două tipuri de spessartin ar putea avea relevanță genetică sau termodinamică numai interpretând perechi de minerale și nu specii individuale aflate în asociații diferite, mai ales dacă acestea se află în volume restrânse de rocă, în care condițiile metamorfice este exclus să fi variat semnificativ.

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EFFECTS OF METAMORPHIC NAPPE TECTONICS IN THE UPPER PART OF THE LOTRU SERIES

Summary

The internal structure of the Lotru Series has been so far poorly understood and correlated among different areas, as incomplete knowledge of both lithological contents and structural style prevented accurate tracing of marker levels and boundaries. Mapping in the South Carpathians revealed excellent discriminating criteria for an important boundary (the M_2 -synmetamorphic thrust of Semenici Nappe over the Voineasa Nappe). A few rock varieties appear to be typical of the boundary itself, making also evident some metallogenetic effects of the thrust.

The Voineasa Nappe is built up by the Vaideeni Complex Rocks. Three contrasting petrographic assemblages that apparently grade laterally into each other can be distinguished in this complex. Polymetamorphism is documented in all three assemblages by

ill-preserved relics of a kyanite-, staurolite-, rutile-, almandine-bearing paragenesis ($M-1$ event) and pervasive neoformation of a sillimanite-muscovite zone assemblage during a M_2 event.

The top unit is constantly made up of the micaschists of the Negovanu Mare Formation (NMF), which tectonically overlies each of the three rock assemblages of Vaideeni complex. The NMF contains abundant relics of the M_1 paragenesis which is partly altered to a kyanite $\pm$ sillimanite + staurolite + almandine + ilmenite bearing assemblage during the M_2 .

The lithologic metamorphic contrasts between the two units is a fully reliable feature in identifying and tracing the boundary. Problems arise, however, from the structural style. The geometry of this boundary bears the imprint of some peculiar folding events.

Disrupted folds, boudins and mullions strongly concentrate around the thrust, indicating rotational tectonics, while at higher levels a constant S_2 foliation prevails. Within the Voineasa Nappe an intricate flow-folding is obvious at all scales. It appears that all this pattern resulted as, during the thrust, the boundary was an interface between piles with different tectonic competence. Simple shear induced planar features in the NMF, rotational tectonics along the thrust, while combined action of simple shear and vertical squeezing produced plastic flow within the Voineasa Nappe. The products of thrust tectonics were overprinted by younger folding events in a compressional regime, leading to alternating open low-amplitude antiforms and tight high-amplitude synforms, as the pile acted as a stratified mass with a sharp downward viscosity increase at the boundary. Subsequent erosion acted preferentially on micaschists rather than on gneisses, resulting a strong lithological control of the relief, as well as unusual and misleading cartographic limits.

Contrasting and characteristic rocks are concentrated along the thrust, providing further constraints in tracing the boundary: quartz may segregate until it even forms quartzites. More frequently, abundant small concordant pegmatite or quartz bodies are emplaced on the very limit, as well as tourmaline-rich rocks (up to monomineralic ones). In case garnet micaschists of the NMF overlie K-feldspar gneisses of the Voineasa Nappe a thin and constant level of manganese-silicate rocks appear, making up the most

valuable marker level of the pile. Its importance has not been recognised so far; different spatial and geometrical setting have so far been assumed. The mechanism that made possible such petrogenetic effects of the thrust are obviously chemical and mechanical segregation under the inconstant chemical potential and pressure gradients which acted during the nappe emplacement; as well as metamorphic reactions between contrasting lithologies, viz. mica-forming breakdown of the almandine and pyrope components of garnet with K-feldspar. Silica undersaturation may occur when staurolite is involved in the breakdown reactions making thus possible the appearance of Mn-Fe olivines.

These petrogenetic effects are accompanied by metallogenetic ones: a sensible enrichment in volatile elements takes place at or near the thrust, chiefly in lithium, beryllium and boron. The thrust surface is very effective as a screen which entraps Li and Be. The former seems to be only localised at the thrust, while Be gradually decreases downwards. Although B spectacularly concentrates at the boundary, tourmalinizations are also important at lower levels and persist upwards, replacing kyanite.

Primită: 22 mai 1992.

Acceptată: 21 iunie 1993.

G. SĂBĂU, I. GHEUCA

HARTA GEOLOGICĂ A BAZINULUI SUPERIOR AL RÂULUI SADU

0 1 2 km

LEGENDA

CUATERNAR

qh Depozite glaciare și aluviale

DOMENIUL GETIC

Pinza de Semenic

Formațiunea de Negovanu Mare

ms Micașturi, gnaise micacee cu granat, disten și staurolit
a Nivelul de Delinești: roci manganifere (a)

Pânza de Voineasa

Complexul de Vaideeni

Amfibolite ± granat (a); pegmatite meta-

morfice (e); segregatii de cuarț (q); cuarțite (qt)

Gnaissul de Frumosa: gnaise cu microclin

Amfibolite, gnaise amfibolice (α)

Eclogite (ek)

Metautrabazite (MP)

Gnaise micacee ± granat

Li

Turmalinizări

Be

Concentrații de spodumen

Be

Iviri de beril

Limită geologică în general

Limită litologică

Limita formațiunilor cuaternare

Pânză metamorfică precambriană

Falie

Încălecare alpină

Galerie

Haldă

PRECAMBRIAN
SUPERIOR

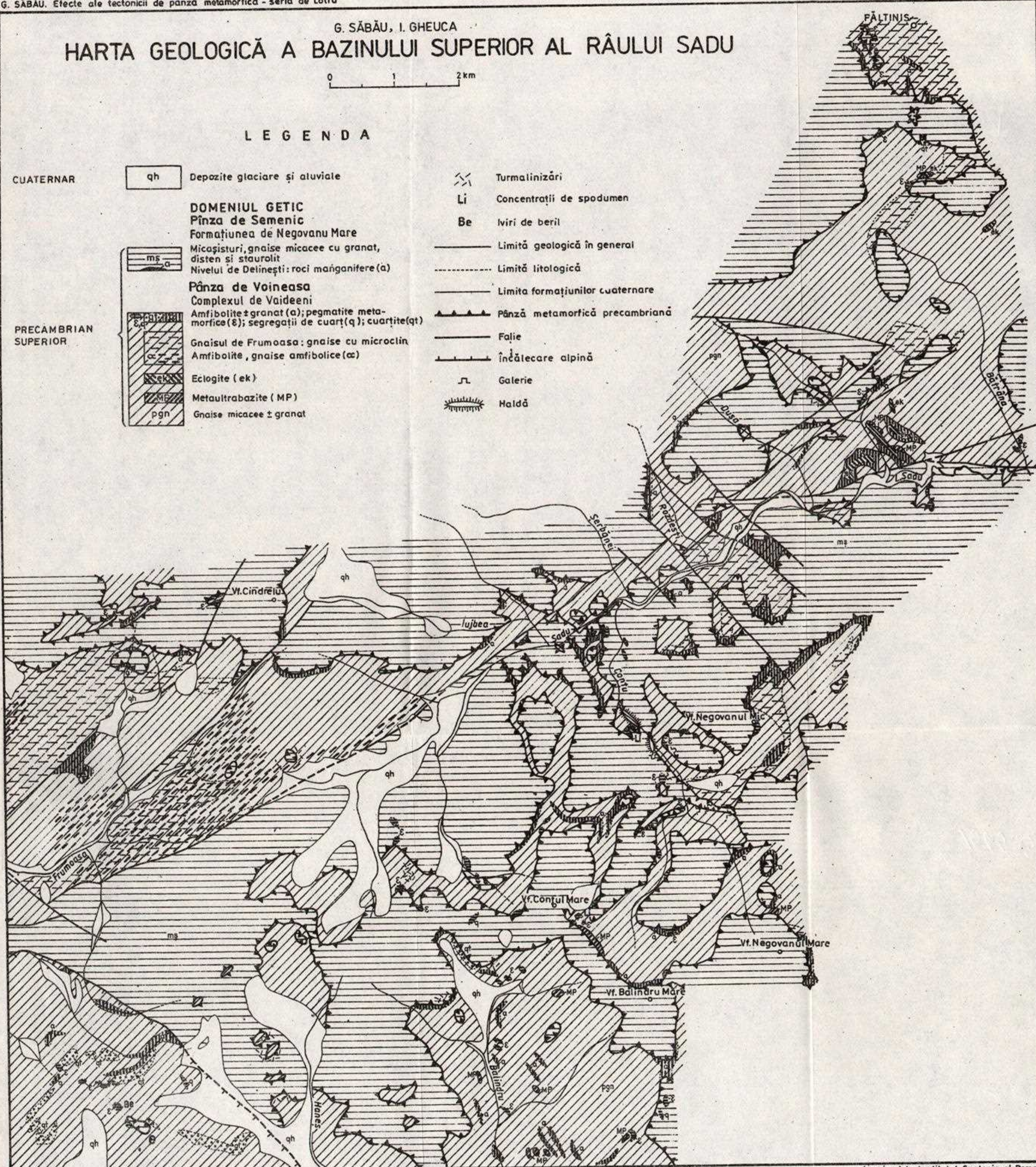
ms

a

ek

MP

pgn



Planşa II

Fig. 1 – Relicte de almandin şi staurolit (M_1) în asociaţie cu sillimanit şi biotit de neoformaţie (M_2) în unitatea de Voineasa, pârâul Dăneasa, N ||, x 10.

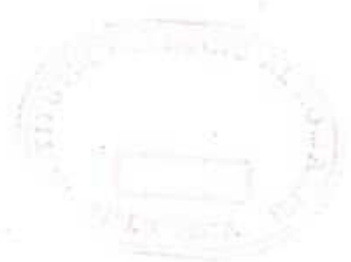
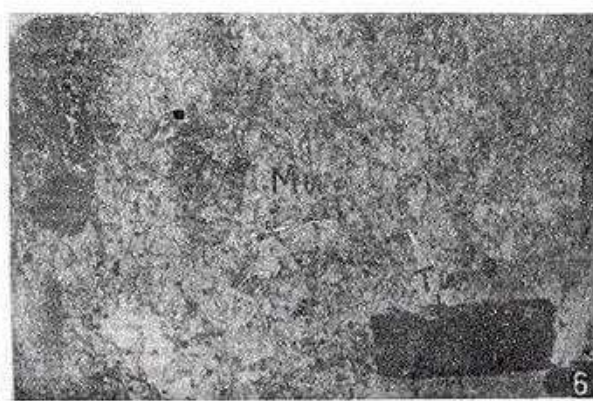
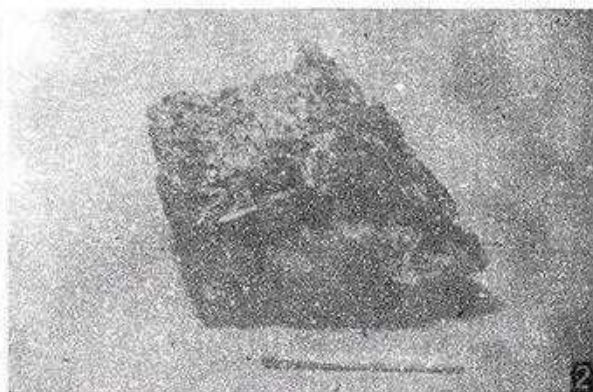
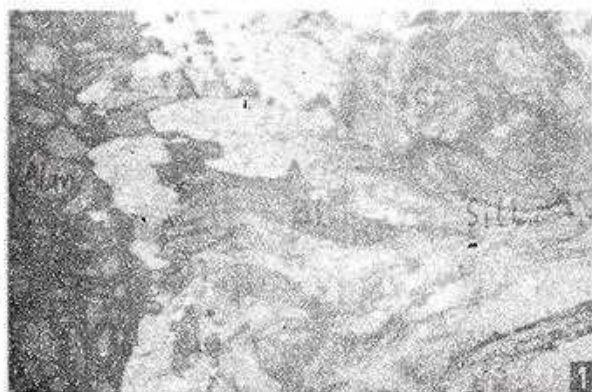
Fig. 2 – Segregaţie cuarţ-turmalină, muntele Haneş.

Fig. 3 – Asociaţie beril-cleavelandit în pegmatite litifere, pârâul Conţu, N+, x 10.

Fig. 4 – Dumortierit în cuarţ, pârâul Conţu, N ||, x 25.

Fig. 5 – Asociaţia muscovit-turmalină pe conturul unor vechi cristale de disten, muntele Cindrelu, N ||, x 10.

Fig. 6 – Fantomă de disten substituit de muscovit şi turmalină, vârful Conţu Mare, N+, x 10.



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Vor fi acceptate numai lucrările care prezintă concis și clar informații noi. Manuscrisul va fi supus lecturii critice a unuia sau mai multor specialiști; după a doua revizie nesatisfăcătoare din partea autorilor va fi respins definitiv și nu va fi înapoiat.

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Se va adăuga o filă separată cu un colontitlu de maximum 60 semne și un sumar, în care se va indica ierarhia titlurilor din text în clasificarea zecimală (1; 1.1; 1.1.1), care nu trebuie să depășească patru categorii.

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Abstractul, maximum 20 rânduri (pe filă separată), trebuie să fie în limba engleză și să prezinte pe scurt principalele rezultate și concluzii (nu o simplă listă cu subiecte abordate).

Cuvintele cheie (maximum 10) trebuie să fie în limba engleză sau franceză, corespunzător limbii în care este lucrarea (sau abstractul, dacă textul este în română), prezentate în succesiune de la general la specific și dactilografiate pe pagina cu abstractul.

Bibliografia se va dactilografia la două rânduri, în ordine alfabetică și cronologică pentru autorii cu mai mult de o lucrare. Abrevierile titlului jurnalului sau ale editurii trebuie să fie conforme cu recomandările respectivelor publicații sau cu standardele internaționale.

Exemple:

a) jurnale:

Giușcă, D. (1952) Contributions à l'étude cristallographique des niobates. *An. Com. Geol.*, XXIII, p. 259-268, București.

—, Pavelescu, L. (1954) Contribuții la studiul mineralogic al zăcămintului de la Mușca. *Comm. Acad. Rom.*, IV, 11-12, p. 658-991, București.

b) publicații speciale:

Strand, T. (1972) The Norwegian Caledonides. p. 1-20. In: Kulling, O., Strand, T. (eds.) *Scandinavian Caledonides*, 560 p., Interscience Publishers.

c) cărți:

Bălan, M. (1976) Zăcămintele manganifere de la Iacobi. Ed. Acad. Rom., 132 p., București.

d) hărți:

Ionescu, I., Popescu, P., Georgescu, G. (1990) Geological Map of Romania, scale 1:50,000, sheet Cîmpulung. Inst. Geol. Geofiz., București.

e) lucrări nepublicate sau rapoarte:

Dumitrescu, D., Ionescu, I., Moldoveanu, M. (1987) Report. Arch. Inst. Geol. Geofiz., București.

Lucrările sau cărțile publicate în rusă, bulgară, sârbă etc. trebuie menționate în bibliografie transliterind numele și titlurile. Exemplu:

Krashennikov, V. A., Basov, I. A. (1968) Stratigrafiya kainozoi. Trudy GIN, 410, 208 p., Nauka, Moscow.

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—, Pavelescu, L. (1954) Contribuții la studiul mineralogic al zăcămintului de la Mușca. *Comm. Acad. Rom.*, IV, 11-12, p. 658-991, București.

b) special issues:

Strand, T. (1972) The Norwegian Caledonides. p. 1-20. In: Kulling, O., Strand, T. (eds.) *Scandinavian Caledonides*, 560 p., Interscience Publishers.

c) books:

Bălan, M. (1976) Zăcămintele manganifere de la Iacobi. Ed. Acad. Rom., 132 p., București.

d) maps:

Ionescu, I., Popescu, P., Georgescu, G. (1990) Geological Map of Romania, scale 1:50,000, sheet Cîmpulung. *Inst. Geol. Geofiz.*, București.

e) unpublished papers or reports:

Dumitrescu, D., Ionescu, I., Moldoveanu, M. (1987) Report. *Arch. Inst. Geol. Geofiz.*, București.

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