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1. MINERALOGIE - PETROLOGIE - GEOCHIMIE

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

MINERALOGIE

CONTRIBUȚII LA CUNOAȘTEREA ASOCIAȚIILOR MINERALOGICE DIN ZONA DE CONTACT A CORPULUI ERUPTIV DE PE IZVORUL MESTEACĂN-ȚIBLEȘ [1]

DE

MARINEL KOVACS [2], PETRE RADU [2], ȘTEFAN TALPOȘ [2]

Mineral assemblage. Fluorapatite. Fluorphlogopite. Rutile. Fe and Ti oxides. Paragenesis. Diffractometry. Monzodiorite. Metasomatism. Thermic metamorphism. Autometamorphism. East Carpathians — Neogene — Quaternary eruptive — Țibleș.

Abstract

Contributions to the Study of the Mineralogical Assemblages in the Contact Area of the Igneous Body Located on the Izvorul Mesteacăn River — Țibleș Mountains. Some post-magmatic mineralogical assemblages very rich in mineral species are reported from the contact area of the monzodiorite body located on the Izvorul Mesteacăn river. Its peculiar features due to the outstanding development (both size and quantity) of some minerals — apatite and titanium minerals (especially rutile) — make it a novelty in the field of Neogene eruptive in Romania. In those areas in which apatite (diffractometric fluorapatite) is best developed — crystals of 3 cm occur on the fissures of brecciated igneous rocks — it forms intergrowths with phlogopite (fluorphlogopite) — crystals of 1 cm at the most. The titanium mineral assemblage (which occurs as centimetric clusters and veins) is characterized by rutile-ilmenite intergrowths and mineral phases of intermediate nature — hemo-ilmenite, titanium-hematite, ferri-rutile. The complex parageneses of these associations are due to their genesis within wide temperature limits (low temperature pneumatolytic-hydrothermal interval) and to the occurrence of the same mineral during several stages. The mineral phases of intermediate nature and the frequent mineral substitution point to the repeated lack of balance of fluids during the post-magmatic stage.

[1] Depusă la 10 mai 1982, acceptată pentru comunicare și publicare la 10 mai 1982, comunicată în ședința din 21 mai 1982.

[2] Întreprinderea de prospecțiuni și explorări geologice „Maramureș" Baia Mare, str. Victoriei 146.

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Introducere

Zona studiată este localizată în bazinul văii Izvorul Mesteacăn, din partea de N-E a masivului Ţibleş.

Masivul Ţibleş reprezintă un complex eruptiv neogen inclus de Peltz et al. (1972) în aria subvulcanică Toroiaga-Ţibleş-Bîrgău, alcătuit în cea mai mare parte din roci eruptive bine cristalizate, consolidate în facies subvulcanic.

Evoluţia magmatică în ansamblu, exprimată în relaţiile foarte complexe dintre diferite tipuri petrografice, în procesele foarte variate din zonele de contact cu formaţiunile sedimentare, în fenomenele postmagmatice deosebit de interesante, precum şi diferitele aspecte metalogenetice neîntîlnite în restul ariei subvulcanice, a făcut ca masivului Ţibleş să-i fie dedicate numeroase lucrări şi studii, începînd încă cu a doua jumătate a secolului trecut.

Primul studiu sistematic şi complet asupra masivului Ţibleş a fost efectuat de Pavelescu (1953).

Abordarea complexă din ultimii ani, privind aspectele structural-geologice, geofizice, petrologice şi metalogenetice a dus la o nouă imagine a acestui complex eruptiv neogen.

Udubaşa et al. (1979) semnalează pentru prima dată prezenţa skarnelor în complexul eruptiv Ţibleş, reprezentînd prima ocurenţă de skarne magneziene asociate magmatitelor neogene din România.

Edelstein et al. (1981) arată că rocile eruptive din masivul Ţibleş aparţin celor două faze distincte : o primă fază, mai acidă, în care sînt incluse microgranodioritele de Hudin şi dacitul de Tomnatec, ce se dezvoltă în partea de vest şi nord a masivului şi o a doua fază, cu caracter intermediar spre bazic, în care sînt incluse monzodioritele cuarţifere (intră în alcătuirea corpului principal Ţibleş-Bran-Măgura Neagră şi a corpului de pe Izvorul Mesteacăn), dioritele şi microdioritele cuarţifere de Arsuri (împreună cu andezitul piroxenic de Arcer mărginesc corpul principal monzodioritic), dioritele cuarţifere din zona Hudieş-Stegioara şi din zona Izvorul Negru — Izvorul Roşu, andezitele cu hornblendă de Groapa (dinspre Hudin) şi microgranodioritele de Izvorul Netedului din partea sud-estică a masivului.

Pop et al. (1981), în studiul petrologic al rocilor eruptive fac consideraţii asupra mineralogiei şi petrografiei corpului din bazinul Izvorul Mesteacănului.

Udubaşa et al. (1981a), în studiul metalogenetic al masivului Ţibleş, recunosc următoarele tipuri de mineralizaţii : 1, filoane — cele din partea centrală a masivului de temperatură înaltă şi conturarea, în zona externă a masivului, a unei centuri de temperatură joasă ; 2, mineralizaţii sub formă de impregnaţii şi diseminaţii. Primele au dezvoltare în partea sudică a masivului, constînd în vinişoare şi impregnaţii de magnetit, local asociat cu calcopirită — autorii susţinînd ideea prezenţei mineralizaţiilor de tip „porphyry copper", iar diseminaţiile sînt descrise în corpul eruptiv de pe Izvorul Mesteacăn — unde parageneza sfalerit + rutil + molibdenit + turmalină este pentru prima dată semnalată în Ţibleş.

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Udubașa et al. (1981b), în lucrarea prezentată în cadrul Congresului Carpato-Balcanic de la București — septembrie 1981, fac o sinteză a datelor de ordin geologic-structural, petrologic și metalogenetic.

În lucrarea de față autorii își propun să prezinte cîteva aspecte și particularități ale asociațiilor mineralogice din zona de contact a corpului eruptiv de pe Izvorul Mesteacăn. Trebuie făcută precizarea, că în esență, obiectul lucrării îl constituie asociațiile mineralogice corespunzătoare stadiului postmagmatic (de aport), asociații ce prezintă unele particularități — ca prezență și dezvoltare a unor minerale — nesemnalate pînă în prezent în Țibleș, ca de altfel în întreg eruptivul neogen.

Observațiile noastre se referă la o zonă strict delimitată din cadrul corpului eruptiv, de pe unul din afluenții de dreapta ai Izvorului Mesteacănului (fig. 1), din imediata vecinătate a contactului cu petecul de sedimentar de vîrstă paleogenă (după Edelstein et al., 1981) conținut ca enclavă sau ridicat în spinarea corpului. În această zonă, executarea recent, a unor lucrări de suprafață (derocările 374 și 375) a facilitat punerea în evidență a unor asociații mineralogice complexe, rezultat al suprapunerii unor procese postmagmatice cu caracter metasomatic (pneumatolitic și hidrotermal) peste cele termometamorfice.

Date mineralogice

Studiul mineralogic al formațiunilor din cadrul celor două derocări a condus la separarea (cu limite nu foarte stricte) a unor zone ; aceste zone nu trebuie privite ca reprezentînd o zonalitate a transformărilor la contact, ci ca tronsoane din profilul studiat, cu o anumită alcătuire petrografică și anumite particularități compoziționale imprimate de procesele postmagmatice cu caracter metasomatic.

Zona A, reprezintă tronsonul în care eruptivul cu caracter dioritic (cuarțifer) este puternic fisurat și brecifiat, pe zonele de brecifiere avînd loc un aport metasomatic, cu o asociație mineralogică deosebit de interesantă (fig. 2). Așa cum se poate urmări și în figura 3, dimensiunile fisurilor depășesc adesea 3 cm, cu o zonalitate destul de evidentă de dispunere a mineralelor de aport în cadrul lor (fig. 3, B, C). De remarcat proporția și dimensiunile cristalelor de flogopit și apatit, în asociație cu care, în cantități apreciabile mai apar cuarțul, cloritul, actinotul și mineralele metalice (pirotină predominant). Unele fisuri sînt căptușite cu cuarț piramidat și au galenă și blendă în cantități mici. Au fost observați și carbonații pe cîteva fisuri în care sînt asociați cu apatitul și cuarțul.

Zona B, reprezintă tronsonul în care eruptivul are un caracter mai microcristalin (microdiorit cuarțifer) și este compact. Au fost observate zone în care roca are o culoare mai deschisă și structura ușor ștearsă de transformările autometamorfice, dar asociația mineralogică de neoformație este mult mai slab reprezentată (fig. 2).

În zona C, roca are un aspect deosebit de cel din zonele A și B, în general de culoare cenușie-albicioasă, ușor verzui, cu structură ștearsă (în cîteva zone se recunoaște și cu ochiul liber eruptivul mai mărunt cristalizat). În toată masa rocii apar zone de substituție sub

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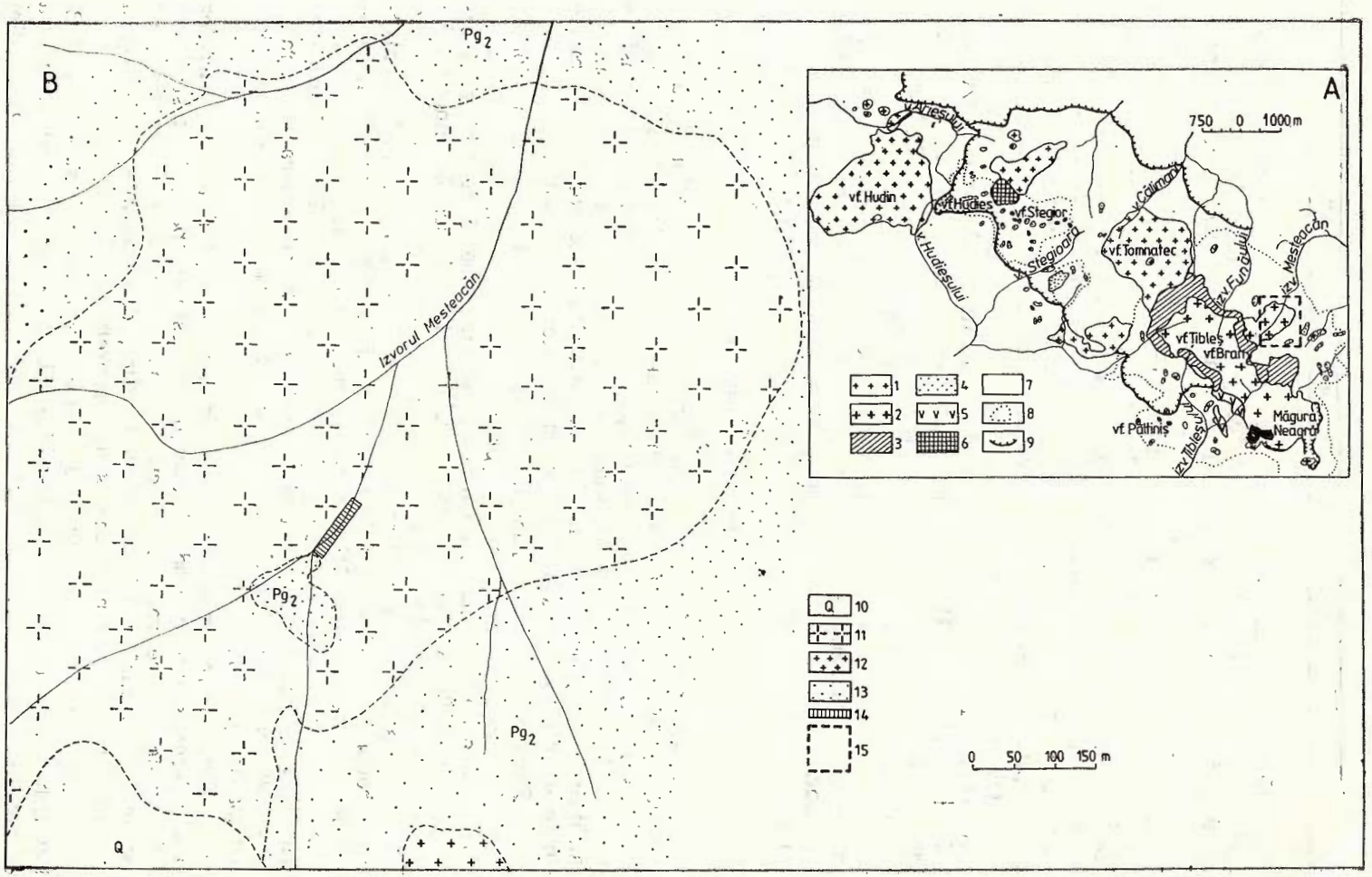


Fig. 1

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formă de filonașe și cuiburi cu epidot, actinot, tremolit, cuarț și minerale opace.

Particularitatea zonei o reprezintă prezența fisurilor ce uneori se întretaie, cu grosimi de la 0,1-1 cm și a cuiburilor ce ajung la dimensiuni de peste 5 cm, cu rutil, ilmenit, hematit și sfen.

Studiul microscopic al acestei zone a pus în evidență prezența predominantă a materialului sedimentar corneificat, în faciesul cu albit și epidot, alături de eruptivul dioritic. Manifestarea unor intense procese metasomatice pe acest tronson a dat naștere unei bogate asociații mineralogice (fig. 2), cu predominarea netă a amfibolilor (tremolit și actinot), epidotului și a mineralelor de titan.

Zona D este predominant alcătuită din eruptiv, avînd un ușor caracter monzodioritic. Pe prima porțiune prezintă zone de substituție, cel mai adesea ca filonașe cu actinot + epidot + sfen, în continuare roca devenind tot mai compactă, cu mai puține transformări. Demarcația între zona D și E este stabilită în mod convențional la m 65, unde apare o fisură de 4 cm cu galenă și blendă în cuarț.

Zona E și F prezintă unele similitudini mai ales în ceea ce privește alcătuirea petrografică. Excepție face prima porțiune din zona E, în care roca este în exclusivitate eruptiv, cu un pronunțat caracter monzo, imprimat de prezența numeroaselor concreșteri grafice dintre feldspatul potasic și cuarț. În zona fisurii de la m 65, eruptivul prezintă transformări hidrometasomatice evidente, silicifiere + sericitizare + carbonatare.

În restul zonei E (pînă în capătul din amonte al derocării 374) roca este un amestec de eruptiv și sedimentar corneificat, cu predominarea eruptivului. Corneenele aparțin zonei cu biotit și cordierit, în ele fiind prezente și minerale din zona cu albit și epidot : — actinot, tremolit, epidot. Procesele metasomatice au dat naștere unei asociații complexe (fig. 2) cu predominarea actinotului, epidotului și pirotinei.

Zona F, reprezintă derocarea 375, situată la cca 10 m amont (în versant) de derocarea 374, în prelungirea ei. La cca 35 m de capătul ei, aflorează corneene aparținînd petecului de sedimentar paleogen. În această zonă, se continuă roca cu aspect de „melanj" din zona F dar ca o particularitate, se găsesc aspectele (la o scară mult mai redusă) din

Fig. 1. — Esquisse géologique du massif éruptif de Țibleș (A) et esquisse de détail de la zone de Izvorul Mesteacăn (B).

1, microgranodiorites de Hudin et dacites de Grohot-Tomnatec ; 2, monzodiorites-monzogabbros quartzifères de Țibleș ; 3, diorites, microdiorites quartzifères de Arsuri et andésites pyroxéniques de Arcer ; 4, diorites quartzifères de la zone de Hudieș-Stegioara et de Izvorul Roșu-Izvorul Negru ; 5, granodiorites et microgranodiorites de Izvorul Netedului ; 6, andésites à hornblende de Groapa et Piatra Hudin ; 7, formations sédimentaires éocènes-oligo-miocènes ; 8, auréole de contact thermique ; 9, charriage ; 10, formations quaternaires (alluvions, éboulis) ; 11, monzodiorites, diorites et microdiorites quartzifères porphyriques ; 12, microgranodiorites porphyriques ; 13, formations paléogènes (marnes, argiles, grès) cornifiées ; 14, coupe étudiée ; 15, situation de la zone de Izvorul Mesteacăn dans le massif de Țibleș.

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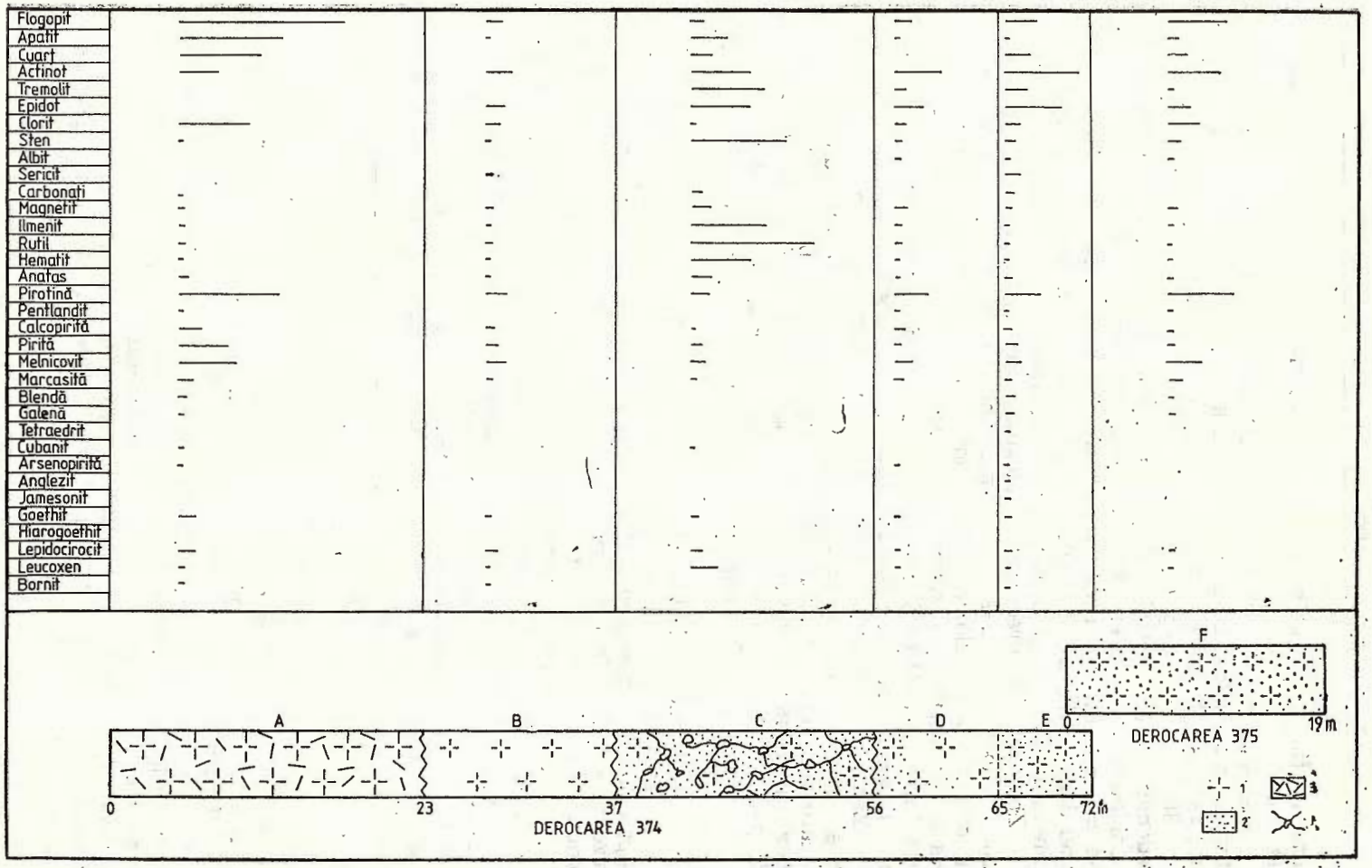


Fig. 2. — Distribution et fréquence des minéraux dans la zone de contact.
1, roches éruptives ; 2, roches sédimentaires cornifiées ; 3, brèches ; 4, nids à minerais de titane.

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zona A, sub microscop evidențiindu-se numeroase filonașe cu flogopit, apatit, cuarț și minerale opace. Acest lucru este de altfel ilustrat de asociația mineralogică de aport corespunzătoare zonei F din tabel.

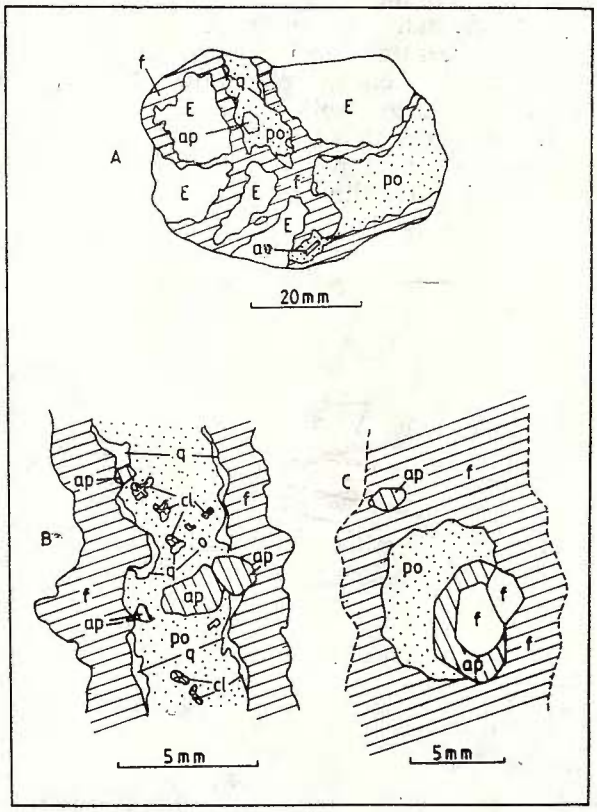


Fig. 3. — Aspects morphostructuraux de la zone à bréchifications (zone A).
A, échantillon d'éruptif bréchifié, en grandeur naturelle. B et C. Manière de disposition des minéraux et leurs relations le long des fissures (observées au binoculaire) ; ap = apatite, cl = chlorite, ph = phlogopite, q = quartz, po = pyrrhotine, E = roches éruptives.

În stadiul actual de cunoaștere al asociațiilor mineralogice de aport metasomatic, au fost obținute numeroase date asupra principalelor minerale.

Flogopitul. Cantitativ și în bună parte și dimensional, este mineralul cel mai reprezentativ. Apare în toate tronsoanele din profilul studiat, caracteristic prin cantitatea și dimensiunile cristalelor fiind pentru zona A, zona cu brecifieri. Aici el apare sub forma unor agregate lamelare pseudohexagonale, cu mărimi ale cristalelor de peste 1 cm. Este intim asociat cu apatitul, cuarțul, cloritul $\pm$ actinotul și minerale metalice.

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Observaţiile microscopice în zona fisurilor, au pus în evidenţă dispunerea oarecum zonară a flogopitului : în zona externă a fisurii la contactul cu roca eruptivă, este fin granular, cu dimensiuni milimetrice şi submilimetrice urmînd apoi o zonă, spre interiorul fisurii, cu cristale larg dezvoltate, de mai mulţi milimetri.

În nicoli paraleli prezintă culori în nuanţe de brun-galben-portocaliu şi uneori este incolor, cu un pleocroism în tente de la galben bruniu la incolor. Are caracter optic negativ, cu 2V = 8-12°, rar în unele secţiuni ⊥ (010) a putut fi măsurat un unghi maxim de extincţie de 3°. În cele mai multe cazuri pe el apar clorit şi hidroxizi de fier. Relaţiile cu celelalte minerale din asociaţia caracteristică acestei zone sînt redate în fig. 4, A, B, C şi D.

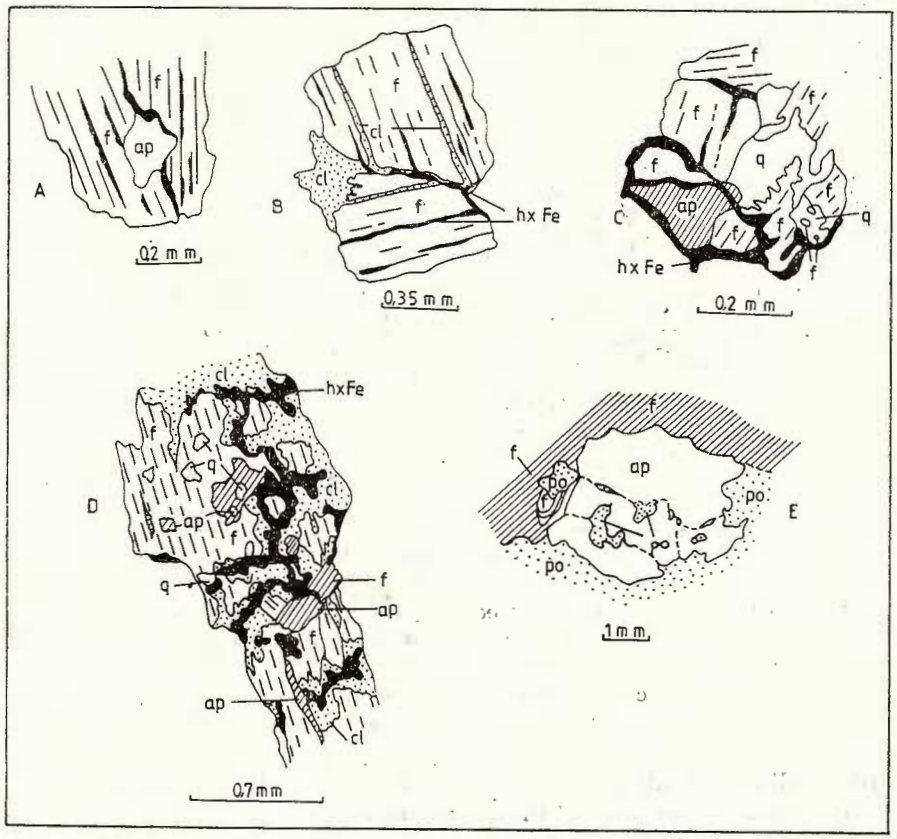


Fig. 4. — Relations entre les minéraux de l'association caractéristique à la zone de bréchifications (zone A). Apatite (ap) enrobé en phlogopite (f) — A et D, chlorite (cl) substituant le phlogopite — B et D, phlogopite de quartz (q) — C, pyrrhotine (po) pénétrant en apatite le long des fissures — E.

Difractograma unei probe monominerale de flogopit arată prezenţa unui fluorflogopit, aşa cum se poate urmări în tabel.

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Apatitul. Este mineralul cel mai reprezentativ prin particularitățile dimensionale ale cristalelor. În zona brecifierilor, au fost întîlnite cristale columnare, cu forme cristalografice perfecte de 3 cm. Este intim asociat cu flogopitul, cuarțul și mineralele metalice.

TABEL

Liniile de difracție ale fluorapatitului și fluorflogopitului

Nr.	1		2		3		4	
	d(A)	I	d(A)	I	d(A)	I	d(A)	I
1	3,44	20	3,347	p	9,958	100	9,949	fp
2	3,07	30	3,076	s	4,992	18	4,984	m
3	2,81	100	2,808	fp	3,328	100	3,326	fp
4	2,78	40	2,777	p	3,131	9	3,133	s
5	2,71	60	2,707	fp	2,900	8	2,906	s
6	2,63	30	2,627	p	2,695	5	2,699	fs
7	2,53	5	2,521	s	2,611	2	2,609	fs
8	2,30	5	2,290	fs	2,495	21	2,499	p
9	2,26	20	2,252	m	2,424	2	2,432	fs
10	2,14	10	2,139	fs	2,166	2	2,166	fs
11	2,06	10	2,060	m	1,996	75	1,995	fp
12	1,94	40	1,937	m	1,664	9	1,666	m
13	1,89	10	1,885	s	1,53	6	1,532	s
14	1,84	60	1,836	p				
15	1,80	30	1,800	s				
16	1,75	30	1,748	m				
17	1,72	30	1,720	s				
18	1,64	10	1,637	fs				
19	1,50	10	1,503	fs				
20	1,45	10	1,452	m				

1. Fluorapatit (ASTM-3-0736); 2. Fluorapatit- Izvorul Mesteacănului;; 3. Fluorflogopit-1M (ASTM-10-494); 4. Fluorflogopit — Izvorul Mesteacănului.

Trebuie subliniată prezența lui în alte 2 aspecte — în zona C, unde sub forma unor granule anhedrale, apare în masa corneenelor în cantități apreciabile, în zone în care cristalele de apatit sînt în cantități mai mari și mai bine dezvoltate ; în filonașele cu cuarț de neoformație ± sericit ± carbonați din pereții fisurii cu galenă și blendă de la m 65 (fig. 5).

Este incolor, adesea cu un aspect șagrinat caracteristic, optic negativ (uniax). Relațiile cu mineralele din asociații cu flogopit + + cuarț + clorit ± actinot + minerale metalice sînt redate în figurile 4, A, C, D și E și respectiv 5 A.

Studiul, prin difracția razelor X, al unei probe monominerale din apatitul de pe fisuri arată prezența fluorapatitului (tabel).

Actinotul și tremolitul. Alături de flogopit și apatit participă în cantități însemnate în cadrul asociațiilor metasomatice.

Actinotul, pe ansamblul profilului studiat, din punct de vedere cantitativ este imediat după flogopit. În zona cu brecifieri (zona A), în asociație cu clorit și flogopit au fost observate cristale foioase, verzi

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pînă la 5—6 mm. Prezența lui în această asociație a fost confirmată pe difractograma unei probe recoltate de pe o fisură în care cele trei minerale erau bine reprezentate (fig. 6).

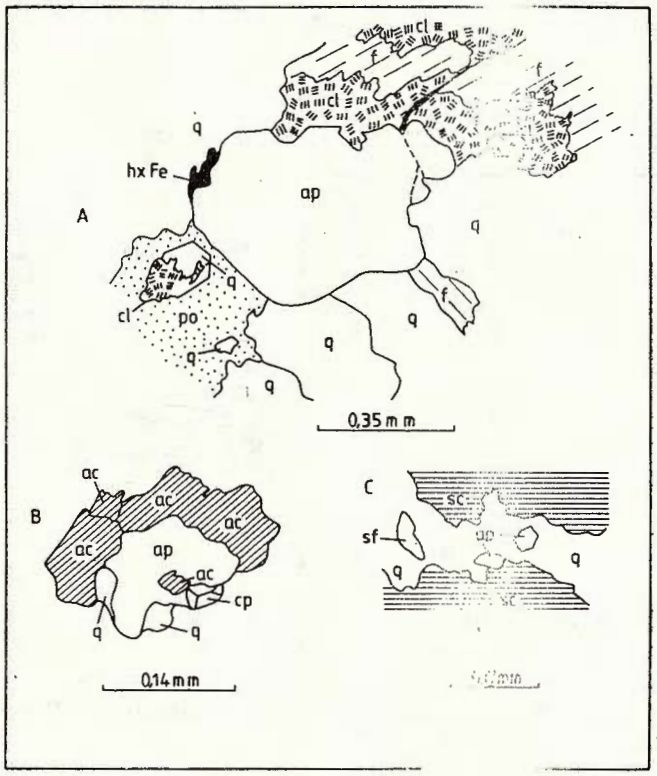


Fig. 5. — Aspects et relations entre les principaux minéraux de néoformation des zones de fort apport A — relations entre les minéraux caractéristiques de la zone à bréchifications (zone A), B — apatite (ap) en relation avec actinote (ac), épidote (ep) et quartz (q) de la zone C (versant à minerais de titane), C — apatite et sphène (sf) en filonets à quartz de néoformation de la roche fortement hydrothermalisée des parois de la fissure minéralisée du m 65.

O prezență remarcabilă a actinotului a fost observată în zona E, unde formează filonașe și cuiburi. În eruptivul monzodioritic, într-o zonă de aport cu aspectul unui cuib de cca 3 cm, actinotul apare în două ipostaze : formînd un filonaș cu cristale prismatice, aciculare, de mici dimensiuni (0,1—0,2 mm) fără a fi asociate cu alte minerale și în asociație cu epidot, sfen și apatit, larg dezvoltat (0,7 mm), uneori în agregate radiare.

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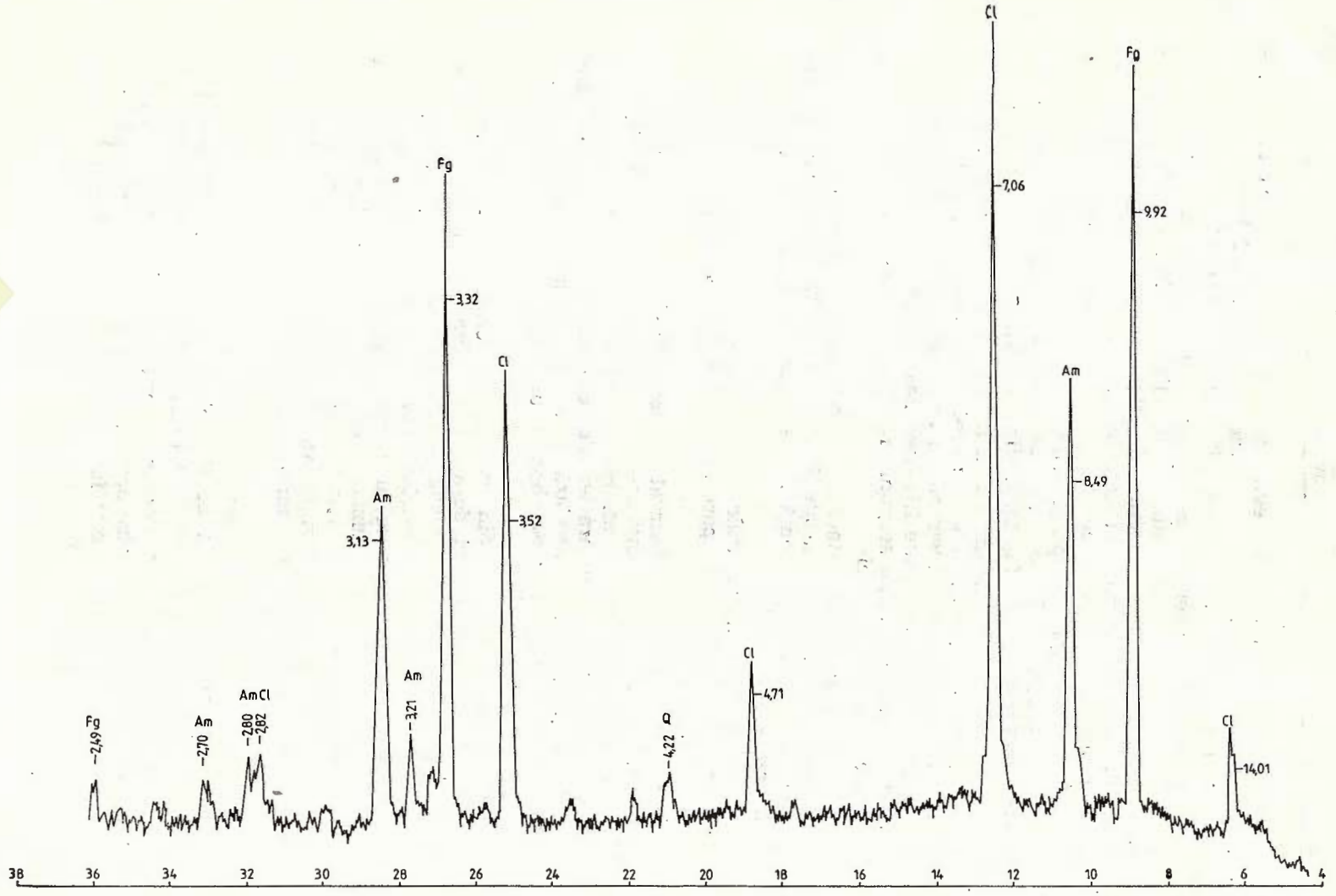


Fig. 6. — Diffractogramme de l'échantillon 4817 K recueilli d'une fissure de la zone à bréchifications (zone A), où l'amphibole de néoformation (Am) est bien représenté à côté du phlogopite (Ph) et du chlorite (Cl).

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Prezintă un pleocroism evident în tente de verde : verde închis-albăstrui-verde pal-verde gălbui, caracter negativ, cu 2 V mare Ng ∧ C maxim, măsurat pe fața 100 = 16°. Adesea este cloritizat.

Tremolitul în general este asociat cu actinotul, excepție făcînd zona cu brecifieri. O dezvoltare cantitativă și dimensională remarcabilă o are tronsonul cu minerale de titan, unde formează cuiburi, în asociație cu actinot, epidot și sfen. În această zonă atît pe tremolit cît și pe actinot se formează carbonați.

Epidotul. După flogopit și actinot este al treilea mineral ca proporții de participare din asociația de aport. O participare remarcabilă o are în zonele C și E (fig. 2), nefiind semnalat în zona cu brecifieri.

În aceste zone, alături de actinot și tremolit formează cuiburi în care cristalele de epidot au dimensiuni de peste 1 mm. În zona F, în mai multe probe, reprezentînd un amestec de eruptiv și sedimentar corneificat, au fost observate filonașe (max. 0,3 mm) de epidot, ce continuau pe toată suprafața secțiunii, rar dispersîndu-se în cuiburi. Pe el se formează actinot ± clorit.

A fost identificat pistacitul — optic negativ și culori de polarizație caracteristice (vii și variate de ordinul I și II), clinozoizitul — optic pozitiv și avînd refringență mai scăzută (în cuiburile în care apar amîndouă) și zoizitul (?).

Sfenul apare în asociațiile tuturor zonelor descrise, dar caracteristic prin proporția de participare este în zona C (tronsonul cu cuiburile cu minerale de titan).

Sub microscop s-a observat asocierea lui frecventă cu actinotul, tremolitul și epidotul. Prezintă adesea un pleocroism invers net, în tente de la brun pal la brun roșcat. Pentru majoritatea cristalelor de sfen, mai ales din zona C, este caracteristică culoarea brun roșcată, în tonuri puternice. Sfenului i se asociază în cele mai multe cazuri minerale opace, cel mai adesea rutil (s-a observat uneori macla în genunchi caracteristică acestui mineral).

Este aproape nelipsit din zonele de puternic aport și trebuie remarcată prezența sa alături de apatit, în filonașele cu cuarț de neoformație, din zona fisurii cu galenă și blendă de la m 65 (fig. 5, C).

Alături de mineralele descrise, în cantități apreciabile a fost observat cloritul, în special în zona cu brecifieri, unde este intim asociat cu flogopitul și actinotul. De remarcat prezența cloritului fibros, în agregate radiare, liber sau pe cristalele de cuarț din masa pirotinei, în zona centrală a fisurilor (fig. 5, A). În zona F (derocarea 375) apar filonașe foarte fine (sub 0,2 mm grosime) de clorit căruia i se asociază minerale opace și flogopit.

Subordonat cantitativ acestor minerale mai apare cuarțul, mai ales în zona brecifierilor, alături de flogopit și apatit, sericitul și carbonații, ultimele două bine reprezentate în zona fisurii de la m 65.

Așa cum rezultă din descrierea principalelor minerale, precum și din relațiile observate între acestea (în diversele tronsoane ale profilului studiat), ele s-au format într-un interval foarte larg de temperatură, dînd naștere unor parageneze complexe.

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Mineralele opace

Ca și mineralele prezentate anterior, mineralele opace se formează în stadii succesive, în domenii de temperatură deosebit de variate. Fiind generate în mai multe faze, care se suprapun evident, este dificil de precizat apartenența strictă la una sau alta dintre acestea. Pe baza observării relațiilor dintre minerale considerăm formarea mineralelor în următoarea succesiune :

a) magnetit, ilmenit, spinel-ulvospinel ± pirotină (hematit și rutil ca produse secundare pe seama ilmenitului) ;

b) rutil, ilmenit, hematit, magnetit, pirotină, pentlandit, cubanit, nichelină (?), linneit (?), anatas, sfen ;

c) pirotină, pirită, calcopirită, melnicovit, marcasită, arsenopirită, sfalerit, galenă, cubanit, tetraedrit, rutil, lepidocrocit.

d) calcopirită, anglezit, jamesonit, goethit + calcit.

Prima asociație (a) o considerăm ca aparținînd domeniului magmatic și are următoarele caracteristici :

— mineralele se prezintă sub formă de diseminații, atingînd 7,5% din masa rocii, cu o medie de 2-3% ;

— dimensiunile sînt de la micronice (pulbere oxidică) la microfenocristale submilimetrice (max. 0,8 mm) ;

— se remarcă concreșteri magnetit-ilmenit, neregulate sau sub formă de lamele și (rar) dezamestecuri de spinel — ulvospinel în lamelele de titanomagnetit. Uneori magnetitul este transformat într-un agregat pîslos care conservă lamelele de ilmenit, iar alteori este substituit marginal de hematit lamelar.

Următoarele asociații (b, c, d) aparțin stadiului postmagmatic, temperaturile lor de formare fiind variate.

Prin suprapunerea fazelor minerale formate în domenii de temperatură diferită se ivesc relații complexe. Ne propunem să scoatem în evidență două asociații mai deosebite :

1. Rutil, ilmenit, hematit, sfen ± magnetit ± pirotină ± tremolit, actinot, epidot, apatit ± flogopit ± clorit ;

2. Pirotină ± pentlandit + calcopirită + pirită + melnicovit ± ± marcasită + oxizi de Ti + flogopit + apatit + cuarț ± clorit ± ± actinot.

1. Prima asociație se dezvoltă foarte reprezentativ în tronsonul C (fig. 2) și prin cantitatea mare de oxizi de Ti, dispuși în cuiburi și pe fisuri, reprezintă o noutate pentru lanțul eruptiv Oaș-Gutîi-Țibleș. În stadiul actual de cunoaștere datele permit atribuirea acestei asociații stadiului pneumatolitic-hidrotermal de temperatură ridicată. Mineralele sînt larg dezvoltate și intim concrescute. Concreșterile rutil-ilmenit, sînt, fie neregulate, fie sub formă de lamele de ilmenit dispuse în rutil după una sau mai multe (max. 3) direcții (fig. 7 E).

Tipice pentru această asociație sînt fazele minerale cu compoziție intermediară de tipul hemo-ilmenit, titan-hematit și o fază de tipul (probabil) ferirutilului. Rutilul și ilmenitul sînt frecvent substituite de sfen ± hematit + leucoxen. Uneori ilmenitul trece în leucoxen + rutil. Magnetitul apare subordonat cantitativ. Cu totul excepțional se remarcă cîteva agregate, pînă la centimetrice, de magnetit foios-lamelar, cu relicte de hematit (mușchetovitizare). Au fost observate și granule

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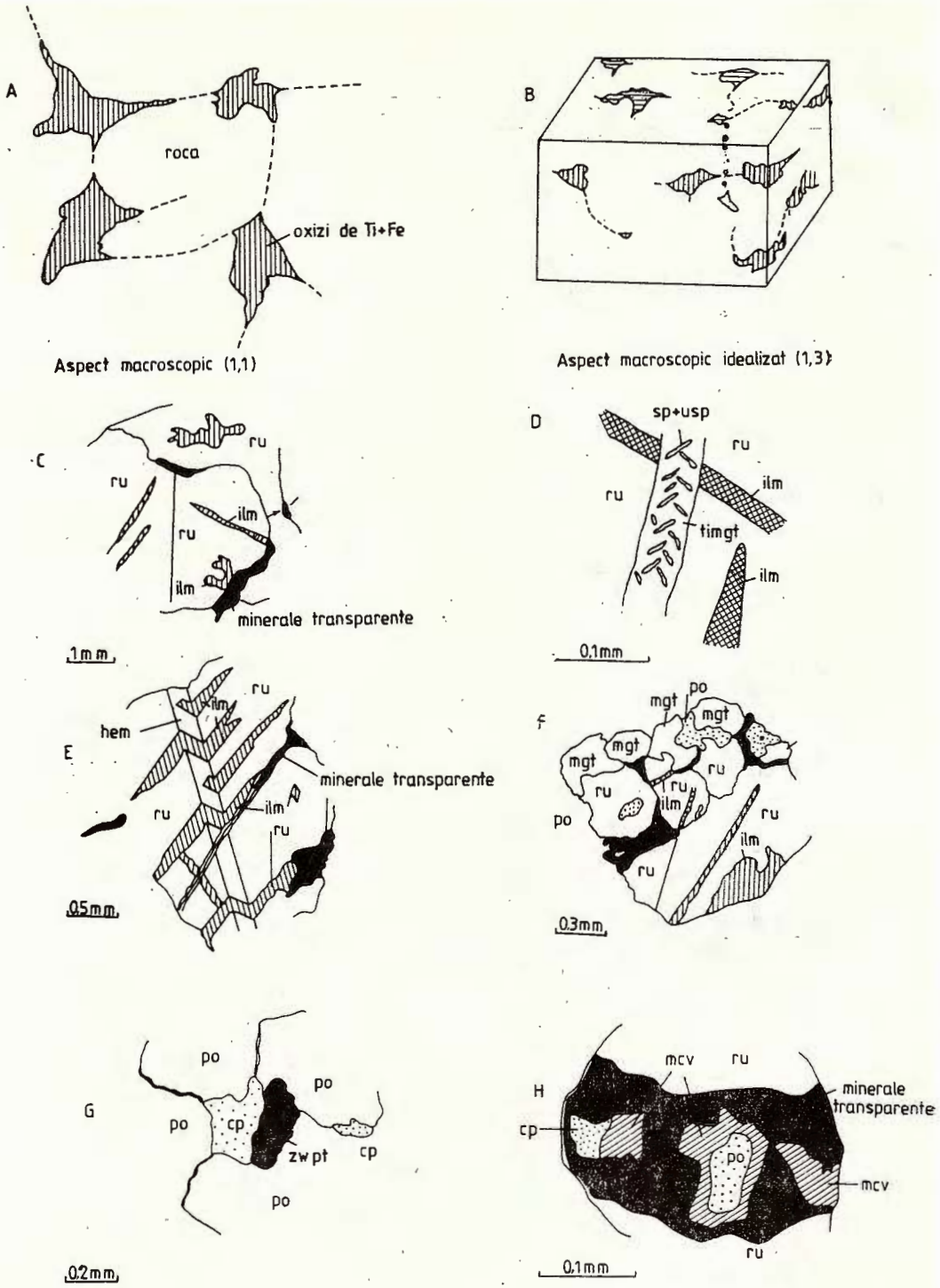


Fig. 7. — Manière de présentation des minéraux métallifères ; A, B — aspects macroscopiques ; C-H, aspects microscopiques. Abréviations : ru — rutile ; ilm — ilménite ; hem — hématite ; sp — spinelle ; usp — ulvospinelle ; tmgt — titanomagnétite ; po — pyrrhotine ; cp — chalcopyrite ; mcv — melnicovite ; zwpt — produit intermédiaire.

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de magnetit corodate de hematit (martitizare). De subliniat că în zona cu acumulări de oxizi de Ti, pirotina este mult subordonată cantitativ.

2. A doua asociație apare în tot profilul studiat, caracteristică fiind pentru zona cu brecifieri (A) și într-o mai mică măsură pentru zonele E și F. Aici pirotina, flogopitul și apatitul domină net asupra celorlalte minerale. Caracteristice sînt concrețiunile de pirotină cu calcopirită, flogopit, apatit de pe zonele de brecifiere. În masa rocii pirotina substituie frecvent melanocratele, îndeosebi flogopitul. La rîndul ei este substituită de pirită, marcasită, melnicovit (fig. 7 H). Pe lîngă modul de dispunere pe fisuri, se observă și diseminații uneori abundente (impregnație). După cum se poate observa în figurile 1 și 3, pe fisurile bine dezvoltate, pirotina ocupă întotdeauna zona centrală a fisurilor, incluzînd cristale, uneori de 3-4 mm de apatit, cuarț, flogopit, clorit.

Ulterioare acestor două asociații și dispuse pe filonașe cu grosimi de pînă la centimetrice, se observă depuneri de galenă, blendă, pirită și calcopirită ± tetraedrit ± arsenopirită ± melnicovit ± marcasită, asociate cu cuarț și uneori cu cuarț ± sericit (c).

Într-un singur caz această asociație este traversată de filonașe milimetrice de calcit, asociat cu calcopirită, jamesonit și goethit (d), care sugerează o temperatură scăzută. Atunci cînd aceste filonașe vin în contact cu galenă s-a remarcat corodarea marginală a acesteia de către anglezit.

Asociațiile mai sus prezentate conțin întotdeauna hidroxizi de fier (goethit, hidrogoethit, rar lepidocrocit) care constituie sulfurile și oxizii de Fe, uneori fiind de natură supergenă.

Concluzii

Observațiile de teren, coroborate cu studiul asociațiilor de minerale ce apar în profilul studiat, permit într-o primă instanță interpretarea desfășurării proceselor în zonă conform următorului model :

— într-o primă etapă, corespunzătoare fazei magmatice, odată cu intruderea corpului cu caracter monzodioritic are loc termometamorfozarea formațiunilor sedimentare din petecul de vîrstă paleogenă. Contactul este neregulat, eruptivul în zona din imediata vecinătate a lui, încorporînd o parte din materialul sedimentar și corneificîndu-l (vezi zonele C, E și F din figura 2) — în faciesul cu albit, epidot și în unele porțiuni înspre contact în zona cu biotit și cordierit.

Caracterul monzodioritic al corpului de pe Izvorul Mesteacăn, precum și observarea, local, într-una din rocile corneificate de la limita cu eruptivul, a unor structuri de fuziune, sugerează temperatura la contact în jur de 700—800°C.

Odată cu răcirea și consolidarea corpului eruptiv, are loc faza postmagmatică, dominată de procese metasomatice, în care temperatura și compoziția fluidelor au avut rolul determinant în formarea asociațiilor descrise. Alți factori, ca natura litologică a rocilor cît și prezența căilor de circulație specifice anumitor zone (în special zona A), au avut un rol însemnat în modul de desfășurare a proceselor postmagmatice și în final, în formarea unor roci și asociații mineralogice cu anumite particularități.

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Complexitatea paragenezelor este rezultatul atît al suprapunerii proceselor postmagmatice peste cele termometamorfice, cît şi al intervalului larg de temperatură în care ele s-au desfăşurat.

Prezenţa în cantităţi însemnate a unor mineralizatori, cum ar fi F, atestată de larga dezvoltare a fluorapatitului şi a fluorflogopitului, sugerează prezenţa fazei pneumatolitice.

Desfăşurarea proceselor hidrometasomatice, aşa după cum o arată asociaţiile şi paragenezele descrise, a avut loc într-un interval de temperatură mare. Prezenţa paragenezei rutil-ilmenit-hematit-sfen ± pirotină ± magnetit sugerează temperaturi ridicate, pe cînd parageneza calcopirită-jamesonit-calcit sugerează temperaturi scăzute.

Unele minerale aparţin mai multor parageneze, rezultat al reluării lor în mai multe faze. Complexitatea paragenezelor şi existenţa fazelor minerale cu compoziţii intermediare trădează un regim de dezechilibru al fluidelor, care s-a repetat de mai multe ori, fapt sugerat şi de frecventele substituţii reciproce dintre minerale.

Semnalarea pentru prima dată în eruptivul neogen în zona Izvorul Mesteacăn din masivul Ţibleş a unor asociaţii de aport postmagmatic deosebite prin cîteva particularităţi, între care şi larga dezvoltare a unora dintre minerale (cu importante semnificaţii sînt mineralele de Ti), îndreptăţesc speranţele autorilor în continuarea investigării acestei zone, în vederea ridicării potenţialului ei metalogenetic.

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CONTRIBUTIONS À LA CONNAISSANCE DES ASSOCIATIONS MINÉRALOGIQUES DE LA ZONE DE CONTACT DU CORP ÉRUPTIF D'IZVORUL MESTEACĂN-ȚIBLEȘ

(Résumé)

La zone étudiée est située dans le bassin de la vallée d'Izvorul Mesteacăn de la partie NE du massif de Țibleș. On a mis en évidence, dans la zone de contact du corp à caractère monzodioritique d'Izvorul Mesteacăn avec le lambeau sédimentaire d'âge paléogène, une série d'associations minéralogiques complexes, résultat de la superposition de quelques processus postmagmatiques (pneumatolitiques et hydrothermaux) sur des processus thermométamorphiques.

A la suite de l'étude minéralogique des formations, on a séparé dans la coupe étudiée (pl. I), quelques zones à constitution pétrographique et particularités compositionnelles dues aux processus postmagmatiques. Les associations minéralogiques postmagmatiques caractéristiques à chaque zone sont illustrées sur le tableau 1. Quelques minerais ont un développement quantitatif et dimensionnel remarquables.

Le phlogopite, bien que présent dans toutes les zones, est caractéristique pour la zone à bréchifications (zone A) dont ses cristaux jusqu'à 1 cm se disposent à l'intérieur des fissures en association avec apatite, quartz, chlorite±actinote et minéraux métalliques. Les relations avec ces minéraux sont représentées dans les figures 2a, b, c et d. C'est un phlogopite à pléocroïsme fort, ayant des teintes jaune-brun à incolore, de $2\ V_X = 8\text{-}12°$ et $X \wedge C$ maximum $= 3°$. Diffractométriquement, on a mis en évidence le fluorphlogopite (tableau).

L'apatite est le minéraux le plus représentatif grâce à ses particularités dimensionnelles (aussi que quantitatives dans la zone A). Les cristaux columnaires jusqu'à 3 cm se disposent le long des fissures de l'éruptif bréchifié, intimement associé au phlogopite, quartz et minéraux métalliques. Vu les relations avec les autres minéraux de l'association caractéristique de la zone A (fig. 2a, b, c, d, et 3a) l'apatite apparaît en tant que le premier minéraux formé. L'étude par diffraction des rayons X a relevé le fluorapatite (tableau).

L'actinote, de tous les minéraux de la coupe en question, est quantitativement après le phlogopite. Dans la zone A il apparaît le long des fissures en association avec le chlorite et le phlogopite (cristaux feuilletés jusqu'à 5 à 6 mm, tandis que dans la zone E il forme des filonets et des nids en association avec épidote, sphène et apatite).

Le trémolite est en général associé à l'actinote, ayant un grand développement dans la zone C, où il forme des nids à côté de l'épidote et du sphène.

L'épidote manque de la zone à bréchifications, ayant une participation remarquable dans les zones C et E, où il forme des nids et des filonets. On a aussi identifié le pistacite, le clinozoïzite et le zoïzite (?).

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Le sphène apparaît dans les associations de toutes les zones décrites (tableau 1), mais il est caractéristique à la zone C par sa grande participation. Il y a une fréquence remarquable, accompagnant les minéraux opaques, le plus souvent le rutile.

Les minéraux opaques appartennant au stade postmagmatique présentent une série de particularités dues à la superposition des phases minérales engendrées dans les domaines de température différente. On remarque deux associations minéralogiques à part :

1. Rutile, ilménite, hématite, sphène±magnétite±pyrrhotine±trémolite, actinote, épidote, apatite±phlogopite±chlorite.

2. Pyrrhotine±pentlandite+chalcopyrite+pyrite+melnicovite±marcassite+ +oxydes de Ti+phlogopite+apatite+quartz±chlorite±actinote.

La première association se développe dans la zone C (tableau 1), où elle forme des nids de plus de 5 cm et des filonets à épaisseurs de 0,1 à 1 cm ; les minerai de titane sont légèrement développés et à concroissance intime (d'évidentes concroissances sont celles de rutile/ilménite, pl. II). Tipiques pour cette association sont les phases minérales à composition intermédiaire de type hémo-ilménite, titane-hématite et une phase de type ferri-rutile. La pyrrhotine et le magnétite sont subordonnés quantitativement.

La deuxième association apparaît dans toute la coupe étudiée, étant caractéristique seulement pour la zone A et dans une petite mesure pour les zones E et F. Dans les zones de bréchification, la pyrrhotine occupe toujours la zone centrale des fissures, renferment des cristaux d'apatite, phlogopite, quartz, chlorite (fig. 1).

Ultérieurement à ces deux associations (disposées sur des filonets dont l'épaisseur atteint parfois quelques centimètres) il y a des dépôts de galène, blende, pyrite et chalcopyrite±tétraédrite±arsénopyrite±melnicovite±marcassite, associés au quartz et rarement au quartz±séricite±carbonates. Ce n'est que dans un seul endroit où cette association est traversée par des filonets millimétriques à calcite associé à chalcopyrite, jammesonite et goethite.

Les associations minéralogiques postmagmatiques se sont formées dans des conditions de température variable, relevées d'une part par la présence de la paragenèse rutile-ilménite-hématite-sphène±pyrrhotine±magnétite (pneumatolitique-hydrothermal de température élevée) et de la paragenèse chalcopyrite-jamesonite-calcite d'autre part(hydrothermal de température réduite). Un rôle important revient aux conditions physico-chimiques du système propices à l'évolution des processus postmagmatiques ; ce système a été conditionné par certains facteurs à savoir : nature lithologique des roches, présence en quantités remarquables de quelques minéralisateurs (F), existence des voies de circulation. La complexité des paragenèses et l'existence des phases minérales à compositions intermédiaires trahit un régime de déséquilibre des fluides qui s'est répété plusieurs fois, fait relevé également par de fréquentes substitutions réciproques des minéraux.

Les associations minéralogiques postmagmatiques de la zone de contact du corp éruptif d'Izvorul Mesteacăn dues à ses particularités (développement quantitatif et dimensionnel de quelques minéraux, par exemple Ti et fluorapatite) représentent une nouveauté pour l'éruptif néogène de notre pays.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

MINERALOGIE

ASUPRA PREZENȚEI RUTILULUI ȘI ANDALUZITULUI ÎN PEGMATITELE METAMORFICE ALE SERIEI DE SOMEȘ DIN MUNȚII PLOPIȘ (MUNȚII APUSENI) [1]

DE

ROBERT STRUSIEVICZ, ELISABETA STRUSIEVICZ [2]

Rutile. Andalusite. Pegmatite. Habitus. Paragenesis. Major elements. Minor elements. Mineralogical association. Ultrametamorphism. Someș Series. Apuseni Mountains-North Apuseni Mountains-Rez Mountains.

Abstract

On the Presence of Rutile and Andalusite in the Metamorphic Pegmatites of the Someș Series of the Plopiș Mountains (Apuseni Mountains). Within the Someș metamorphic series of the Plopiș Mts the emplacement of certain pegmatite bodies was accomplished by processes of ultrametamorphism and metamorphic differentiation. In the present paper it is for the first time pointed out, wihin them, the presence of rutile megacrysts as well as of andalusite crystals, in paragenesis with quartz, feldspar, muscovite, garnet, tourmaline and ilmenite. Rutile is represented by idiomorphous, large-sized crystals and is frequently twinned after (101) — "geniculated twins". The chemical composition is similar to that of the rutiles from the Semenic Mts and from the Graves Mts — Georgia (USA). The occurrence of andalusite and rutile in the same paragenesis indicates that pegmatites formed at a temperature of about 600°C and a pressure lower than 6500 bars.

Introducere

Rutilul (TiO_2) este un mineral destul de răspîndit, fiind prezent în cantități mici în multe tipuri de roci. El apare fie cu caracter accesoriu în roci magmatice și metamorfice, fie cu caracter rezidual-detritic

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[2] Întreprinderea de Prospecțiuni Geologice și Geofizice, str. Caransebeș nr. 1, București.

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în roci sedimentare. Una din ocurențele sale cele mai comune este aceea din șisturi cristaline și pegmatite, în care se dezvoltă adeseori sub formă de megablaste (exemple: Snarum și Kragerö-Norvegia, Graves Mountains-Georgia, S.U.A.).

În cadrul șisturilor cristaline de la noi din țară, rutilul este cunoscut mai ales sub forma de mineral accesoriu de dimensiuni microscopice (fie de sine stătător, fie ca rețele sagenitice incluse în biotit sau clorit). Pînă în prezent, singura zonă în care au fost găsite și descrise megablaste de rutil este provincia metamorfică a munților Semenic. Aici, Savu (1970) descrie megablaste de rutil și rutil ferifer (nigrin) de pînă la 15 cm lungime, conținute în micașisturile și migmatitele seriei de Sebeș-Lotru.

În ceea ce privește andaluzitul (Al_2SiO_5), acesta este un mineral care indică un metamorfism de temperatură ridicată, fie că este vorba de un metamorfism de contact termic (static), fie că este vorba de un metamorfism de contact sincinematic. În ambele ipoteze andaluzitul ia naștere ca urmare a temperaturilor ridicate și a presiunilor medii pînă la joase din domul termic creat de masivele intrusive. În aceste condiții paragenezele caracteristice metamorfismului barrovian devin instabile, pe seama lor luînd naștere parageneze noi în care se remarcă prezența andaluzitului, sillimanitului sau cordieritului, și care denotă condiții de metamorfism intermediar de tip Buchan sau de presiune joasă tip Abukuma sau Pirinean (Savu, 1975). În acest sens este privită prezența andaluzitului atît în seria de Sebeș-Lotru din Carpații Meridionali (Bercia, Hârtopanu, 1980), cît și în seria de Someș din munții Plopiș (Savu, 1975).

Subiectul comunicării de față îl constituie semnalarea prezenței unor megablaste de rutil și a unor cristale idiomorfe de andaluzit în pegmatitele metamorfice din munții Plopiș.

Date geologice

Rocile cristaline din munții Plopiș (numiți și munții Rez sau Șes) aparțin seriei mezometamorfice de Someș. Ele au fost metamorfozate în cadrul ciclului tectono-magmatic preassyntic (prebaicalian). În partea de est a masivului, acestea au fost încadrate la două zone metamorfice : zona cu biotit și almandin și zona cu almandin și staurolit (Cîmpeanu, Cîmpeanu, 1966). Pentru partea de vest a masivului există o hartă mai puțin detaliată (Ciornei, 1953), necorelabilă cu harta zonei estice. Foarte caracteristică pentru șisturile cristaline din munții Plopiș este prezența migmatitelor metablastice, roci descrise pentru prima dată de Kräutner (1938) sub numele de gnaise nodulare. Asociat procesului de anatexie care a dus la formarea acestor migmatite a avut loc și un proces de diferențiere metamorfică. În urma acestei diferențieri au luat naștere numeroase pegmatite metamorfice de dimensiuni reduse, intruse concordant în rocile migmatizate.

Materialul prezentat provine parțial din astfel de lentile de pegmatite din bazinul văii Bistra, precum și din aluviunile văilor Bistra, Marghita, Șinteu și Bucoveana (fig. 1).

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Pegmatitele se prezintă sub formă de lentile de dimensiuni reduse (maximum 1 m lăţime) şi cu frecvente efilări care fac dificilă urmărirea continuităţii lor. Ele au o compoziţie simplă, caracteristică pegma-

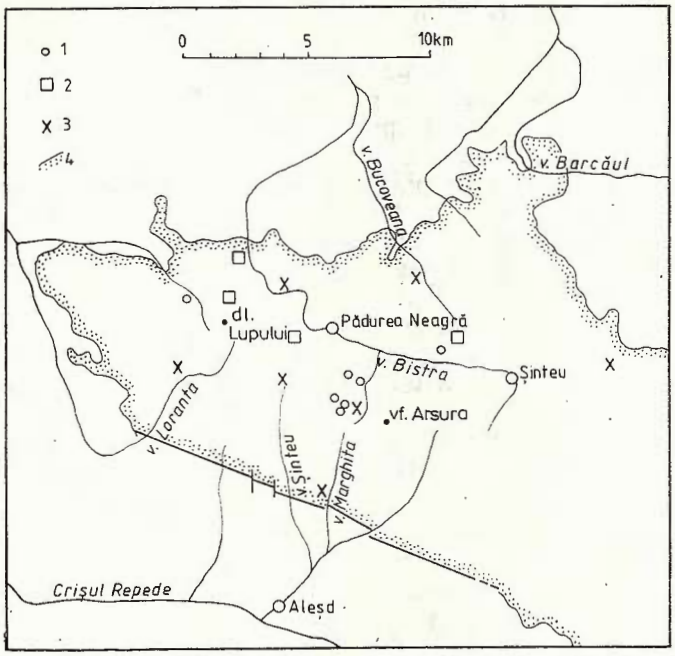


Fig. 1. — Schiţă cu localizarea ocurenţelor de rutil şi andaluzit din munţii Plopiş : 1, ocurenţe de rutil în pegmatite ; 2, ocurenţe de andaluzit în pegmatite ; 3, ocurenţe de rutil în aluviuni ; 4, limita masivului cristalin al munţilor Plopiş.
Esquisse à localisation des occurences de rutile et d'andalousite des monts Plopiş : 1, occurences de rutile en pegmatites ; 2, occurences d'andalousite en pegmatites ; 3, occurences de rutile en alluvions ; 4, limite du massif cristallin des monts Plopiş.

titelor metamorfice. Cuarţul este componentul principal şi uneori exclusiv al acestor roci. Caracterul de pegmatit este evident doar atunci cînd în cadrul lor se observă cristale larg dezvoltate de feldspat şi muscovit, în absenţa acestora pegmatitele putînd fi uşor considerate ca simple lentile de cuarţ. Feldspatul apare relativ rar şi în cantităţi mici în pegmatite, ajungînd pînă la maximum 10% din volumul rocii. El este reprezentat prin cristale mari de pînă la 5 cm lungime şi 1 cm grosime, idiomorfe, de albit-oligoclaz. În unele pegmatite este parţial afectat de fenomene de caolinizare. Muscovitul apare şi el destul de rar, fiind reprezentat prin pachete de cristale de dimensiuni centimetrice. Ca minerale accesorii mai apar sporadic granaţi (uneori intens cloritizaţi), turmalină larg cristalizată (varietatea schörlit) şi cristale lamelare de ilmenit.

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O caracteristică interesantă a acestor pegmatite o constituie prezența în cadrul lor a unor megacristale de rutil precum și a unor cristale idiomorfe de andaluzit.

Date mineralogice și chimice

Rutilul apare sub forma unor cristale prismatice, larg dezvoltate, de pînă la 10 cm lungime și 4 cm grosime. Cristalele sînt lipsite de fețe terminale, iar pe fețele de prismă au striațiuni longitudinale paralele cu axul „c" (pl., fig. 1, 2). Uneori apare și sub formă de cristale mici, aciculare, asociate în snopi. Frecvent se găsesc macle „în genunchi" cu planul de concreștere (101) (pl., fig. 3), și chiar macle polisintetice, rezultate prin repetarea acestei maclări (pl., fig. 4).

Culoarea cristalelor variază de la brun-roșcat închis și pînă la negru. Luciul este diamantin pînă la semimetalic, iar clivajul este bun după fețele de prismă, unele cristale fiind casante.

Tabelul 1 redă compoziția chimică a unui exemplar de rutil de culoare brun-roșcată (1) și a unui rutil de culoare neagră (2) în comparație cu analizele chimice a două rutile din literatură.

Analizele 1 și 2 sînt efectuate de Zamfira Pintilie (I.P.G.G.), analiza 3 este redată după Savu (1970), iar analiza 4 după Ianovici et al. (1979).

TABELUL 1

compoziția chimică a două varietăți de rutil din munții Plopiș (1 și 2) în comparație cu un rutil din Semenic (3) și un rutil din Georgia (S.U.A.) (4)

Proba / Oxizi	1 %	2 %	3 %	4 %
TiO_2	92,68	86,84	94,60	97,46
Fe_2O_3	1,69	2,65	2,80	2,62
FeO	0,28	0,86	1,44	—
Al_2O_3	—	—	1,25	—
Total	94,65	90,35	100,09	100,08

TABELUL 2

Analiza spectrografică a două varietăți de rutil din munții Plopiș (analiza a fost executată la laboratorul de spectrografie al I.P.G.G.)

Proba / Oxizi	1 ppm	2 ppm
Zr	300	300
W	700	500
Cu	1700	2000
Pb	15	15
Sn	35	35
Nb	250	250
Mn	10	30
Zn	200	200

Compoziția chimică a celor două rutile din Plopiș este apropiată de cea a rutilelor din literatură. Totalul mai mic de 100 al celor două analize se datorează prezenței unor incluziuni de cuarț dispuse pe suprafețele de clivaj ale rutilului, SiO_2-ul nefiind analizat. Din analize rezultă un conținut mai ridicat în Fe în detrimentul Ti pentru rutilul de culoare neagră. Conținutul în Fe al acestuia este însă prea mic pentru a putea fi considerat nigrin.

Analiza spectrografică a acelorași două probe a pus în evidență prezența Zr, W, Cu, Pb, Sn și Nb în cantitățile redate în tabelul 2.

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Dintre aceste elemente, Nb intră sub formă de oxid în molecula rutilului.

În cadrul pegmatitelor rutilul a fost găsit în parageneză cu cuarţ şi feldspat, cu care a cristalizat simultan.

Andaluzitul se prezintă sub formă de cristale idiomorfe, scurt prismatice, cu dimensiuni de pînă la 4 cm lungime şi 1 cm lăţime. Cristalele sînt asociate în benzi care se disting din masa de cuarţ prin culoarea lor roz. În secţiune transversală ele au un contur patratic pînă la dreptunghiular datorită dezvoltării feţelor *m* (110) dispuse la 89° (pl., fig. 5). Clivajul este bun după (110). Luciul cristalelor este sticlos iar la suprafaţă sînt acoperite de o pătură subţire de muscovit-sericit. Dintre proprietăţile sale optice se remarcă pleocroismul său evident în tonuri de roz-roz pal, extincţia dreaptă, alungirea negativă şi caracterul biax negativ.

În cadrul pegmatitelor, andaluzitul a fost găsit în parageneză doar cu cuarţ şi muscovit-sericit. Relaţiile sale cu cuarţul sînt mascate de muscovit şi sericit, care s-au dezvoltat pe seama sa şi care îl învelesc la suprafaţă. În unele cazuri se observă chiar substituţii avansate, mergînd chiar pînă la pseudomorfoze de muscovit şi sericit după andaluzit.

Consideraţii genetice

Privind în ansamblu toţi componenţii minerali ai pegmatitelor metamorfice din zonă, se poate observa existenţa a două generaţii minerale : o primă generaţie, în care au cristalizat concomitent cuarţul, feldspatul, muscovitul, granatul, turmalina, andaluzitul, rutilul şi ilmenitul, şi o a doua generaţie, de minerale secundare, cu un uşor caracter retromorf, în care au luat naştere muscovitul şi sericitul pe seama andaluzitului, cloritul pe seama granatului şi caolinitul pe seama feldspatului (fig. 2).

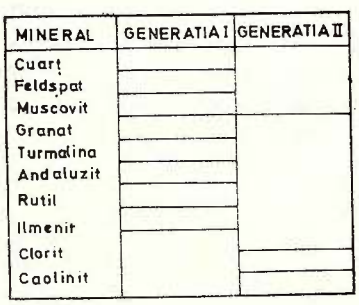


Fig. 2. — Distribuţia în timp a asociaţiei mineralogice în pegmatitele metamorfice din munţii Plopiş.
La distribution en temps de l'association minéralogique des pegmatites métamorphiques des monts Plopiş.

În ceea ce priveşte geneza celor două minerale descrise este clar că amîndouă au cristalizat din soluţiile pegmatitice ce au luat naştere prin procesul de ultrametamorfism şi diferenţiere metamorfică a rocilor metamorfice preexistente. Deci, în afară de cuarţ şi feldspat, prin acest proces a fost mobilizat şi TiO_2-ul existent în roci sub formă de rutil primar sau sub formă de substituent izomorf în molecula biotitului. Ca urmare au rezultat soluţii cuarţo-feldspatice cu conţinut de TiO_2 care

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au pătruns pe zonele de minimă rezistenţă din rocile înconjurătoare, şi care prin cristalizare au dat naştere pegmatitelor metamorfice cu rutil.

Prin analogie cu cele stabilite de Savu (1970) cu privire la condiţiile termodinamice în care a luat naştere rutilul din munţii Semenic (t=545-600°C şi p=7.000 bari), apreciem că şi în munţii Plopiş acest proces a avut loc la temperaturi ridicate şi presiuni mari. Remarcăm însă că în provincia metamorfică din munţii Semenic rutilul a fost găsit doar în micaşisturi şi în roci migmatice şi deloc în pegmatite (în acestea din urmă fiind prezent ilmenitul), în timp ce în munţii Plopiş am găsit rutil exclusiv în pegmatite. Prezenţa andaluzitului în aceeaşi paragenează cu rutilul pledează pentru o presiune mai scăzută şi o temperatură mai ridicată de formare a acestor pegmatite, în conformitate cu domeniul de stabilitate determinat de Althaus pentru acest mineral (după Savu, 1975). Luînd în considerare acest indiciu, apreciem că pegmatitele din munţii Plopiş s-au format la temperaturi în jur de 600°C şi o presiune în orice caz mai mică de 6.500 bari.

Prezenţa pegmatitelor cu rutil şi andaluzit şi mai ales apariţia acestuia din urmă vine în sprijinul ideii enunţate de Savu (1975) că în cristalinul munţilor Plopiş metamorfismul barrovian este influenţat de prezenţa în profunzime a unui masiv granitoidic (migmatic).

Concluzii

În cadrul seriei mezometamorfice de Someş din munţii Plopiş s-a ajuns, prin procese de metamorfism şi diferenţiere metamorfică, la punerea în loc a unor corpuri de pegmatite.

În această lucrare semnalăm pentru prima dată prezenţa în cadrul lor a unor megacristale de rutil şi a andaluzitului, reprezentat prin cristale idiomorfe, de dimensiuni centimetrice.

Deşi macroscopic se pot deosebi două varietăţi de rutil, una de culoare brun-roşcată şi una de culoare neagră, analizele chimice au arătat că este prezent doar rutilul, nu şi varietatea sa feriferă (nigrinul).

Prin semnalarea acestor minerale se aduce o contribuţie la mai buna cunoaştere a mineralogiei pegmatitelor din munţii Plopiş, evidenţiindu-se ca o caracteristică a lor prezenţa megacristalelor de rutil şi a andaluzitului.

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SUR LA PRÉSENCE DU RUTILE ET DE L'ANDALOUSITE DANS LES PEGMATITES MÉTAMORPHIQUES DE LA SÉRIE DE SOMEŞ DES MONTS PLOPIŞ (MONTS APUSENI)

(Résumé)

Le présent ouvrage fait connaître pour la première fois la présence du rutile et de l'andalousite dans les pegmatites métamorphiques des monts Plopiş (fig. 1).

Le rutile apparaît sous forme de cristaux prismatiques, largement développés, jusqu'à 10 cm de longueur et 4 cm de largeur (pl., fig. 1, 2). Il est fréquemment maclé d'après (101), en réalisant la macle „en genou" (pl., fig. 3), parfois étant maclé polysynthétique (pl., fig. 4).

La composition chimique de deux exemplaires de rutile, l'un de couleur brun-rougeâtre (1) et l'autre de couleur noire (2), est illustrée dans le tableau 1. Elle est voisine de celle des rutiles de Semenic et de Graves Mountains — Georgie, USA. On a établi par voie spectrographique que leur composition renferme également du Zr, Cu, Pb, Sn, Nb, Mn et Zn en quantités variables (tab. 2).

L'andalousite se présente sous forme de cristaux idiomorphes-prismatiques, à dimensions d'environ 4 cm de longueur et 1 cm de largeur. Les cristaux ont un contour carré jusqu'à rectangulaire, grâce au développement des faces m (101), disposées à 89°. Leur couleur est rose et ils sont enrobés en des fines paillettes de muscovite. Quelquefois, on trouve même des pseudomorphoses de muscovite après l'andalousite.

Vue en ensemble, l'association minéralogique des pegmatites des monts Plopiş comporte deux générations minérales : une génération où ont cristallisé le quartz, le feldspath, le muscovite, le grenat, la tourmaline, l'andalousite, le rutile, et l'ilménite et une deuxième génération où se sont formés le muscovite au dépens de l'andalousite, le chlorite au dépens du grenat et la kaolinite au dépens du feldspath (fig. 2).

La présence de l'andalousite dans la même paragenèse à côté du rutile est un indice que les pegmatites se sont formées à une température de presque 600°C et à une pression inférieure à 6.500 bars.

En signalant les deux minéraux on contribue à une meilleure connaissance de la minéralogie des pegmatites des monts Plopiş, par la présence des mégablastes de rutile et de l'andalousite à titre d'une caractéristique.

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EXPLICAȚIA PLANȘEI

Fig. 1. — Megacristale prismatice de rutil în pegmatit, valea Bistrei.
Mégacristaux prismatiques de rutile en pegmatite, vallée de Bistra.

Fig. 2. — Megacristal prismatic de rutil.
Mégacristal prismatique de rutile.

Fig. 3. — Megacristal de rutil cu macla „în genunchi" (101).
Mégacristal de rutile à macle „en genou" (101).

Fig. 4. — Megacristal de rutil maclat polisintetic.
Mégacristal de rutile maclé polysynthétique.

Fig. 5. — Cristale idiomorfe de andaluzit extrase dintr-un pegmatit, valea Bistrei (× 1).
Cristaux idiomorphes d'andalousite extraits d'un pegmatite, vallée de Bistra (× 1).

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THE DĂNEȘTI APHANITIC DACITE (HARGHITA MOUNTAINS) [1]

BY

SERGIU PELTZ [2], ROSETTE IANC [3]

Dacite. Pliocene. Major element analysis. Modal composition. Chemical classification. Petrological nomenclature. Petrochemistry. Magmatic differentiation. Dome. Paleovolcanology. East Carpathians-Neogene-Quaternary eruptive-Harghita.

Sommaire

Dacite aphanitique de Dănești (monts Harghita). La dacite aphanitique de Dănești (monts Harghita, Carpathes Orientales) est une roche de couleur grise à structure aphanitique prégnante et à texture fluidale. La composition modale : 1—6 % phénocristaux de plagioclase et hornblende verte opacitisée ; 92-93 % pâte hyalopilitique à microlites de plagioclase. SiO_2 % = 66,23; QAP(CIPW) = 26.5 ; 16,2 ; 67,3. QAP(Rittmann) = 24,88 ; 19,20 ; 55,92. CI = 4,67. Classification chimique et nomenclature (Sous-commission IUGS) = dacite. C'est pour la première fois qu'une telle roche volcanique a été identifiée dans des affleurements de l'aire Călimani-Gurghiu-Harghita. Sur base des relations avec les formations volcaniques environnantes il résulte que l'éruption a eu lieu au début des manifestations volcaniques qui en Pliocène a mené à la constitution du compartiment supérieur des monts Harghita.

1. Introduction

The Harghita volcanic area is known to be a region in which andesites show typical development. In fact, in the Călimani-Gurghiu-Harghita chain the andesites are the most frequent volcanic rocks. This was pointed out by most researchers of this volcanic area, based on the results of numerous petrographic and mineralogical investigations.

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344, București.

[3] Întreprinderea de Prospecțiuni Geologice și Geofizice, București, str. Caransebeș 1, 78344, București.

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The studies of the last decade, which regard the chemical composition of the Călimani-Harghita volcanics, have shown that many andesitic rocks with well developed groundmass have a more acid composition as compared to the modal mineralogical composition. Thus, according to chemical classifications numerous andesites are generally dacites. This implies a revaluation of the concepts regarding the occurrence of the main types — basaltic, andesitic, dacitic — of volcanic rocks in this region. One should also take into account the proper denomination of those volcanic rocks with well developed vitreous and microcrystalline groundmass, which are not satisfactorily defined by simple megascopic or microscopic studies.

Thus, of peculiar interest are those volcanic rocks with few phenocrysts or lacking in phenocrysts the mineralogical diagnosis of which does not contribute to their characterization. We are going to describe this rock type reported from the north-east of the Harghita Mts. The aphanitic texture was easily recognized and also confirmed by the microscopic investigation. In view of an accurate denomination the chemical analysis was used ; the rock was proved to be a dacite.

Rock fragments with aphanitic texture and mineralogical composition characterized by scarce plagioclase, hornblende or pyroxene phenocrysts do also occur in other parts of the Călimani-Harghita area. However, it is for the first time that the outcropping area is delimited and the deposition type is recognized ; this contributes to locating these rocks within the sequence of Pliocene eruptions to the north of the Harghita Mts (Tab. 3).

2. Location

The area covered by the aphanitic dacite is situated on the north-eastern slope of the Harghita volcanic massif, in the neighbourhood

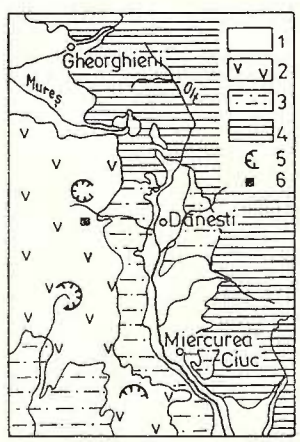


Fig. 1. — Location of the Dănești aphanitic dacite in the Harghita volcanic area (scale 1 : 1,000,000).

1, Quaternary rocks occurring in the Gheorghieni and Ciuc depressions ; 2, upper compartment (Pliocene) ; 3, lower compartment (Malvensian-Pontian) ; 4, formations of the Crystalline-Mesozoic Zone ; 5, crater ; 6, occurrence area of the aphanitic dacite.

of its boundary with the Upper Ciuc Depression, within the Dănești village (Fig. 1). The rocks crop out on the slopes of the Raczkebel brook, a right-side tributary of the Urașag river (Fig. 2) which flows

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into the Olt river on the territory of the Dăneşti village. It is an extracraterial volcanic region, situated to the south of the Ostoroş volcanic edifice with crater — the main stratovolcanic structure in the northern part of the Harghita Mts (Fig. 1).

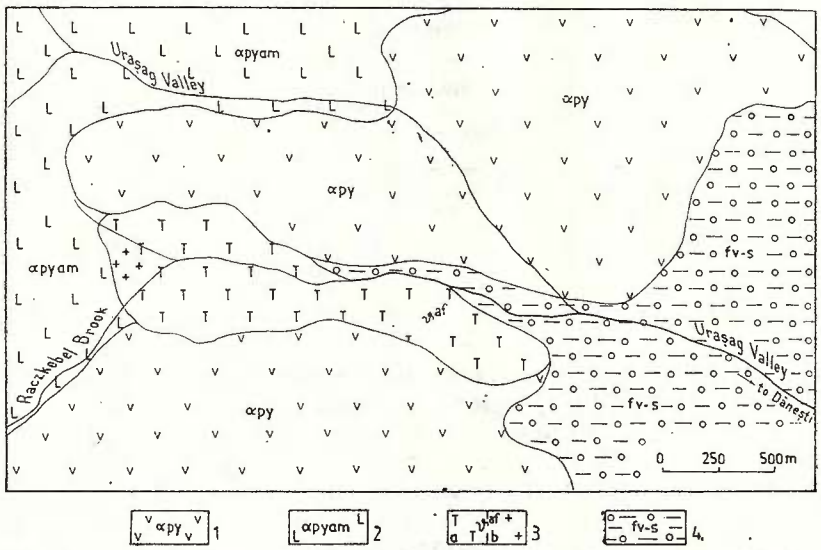


Fig. 2. — Geological sketch of the Raczkebel-Uraşag area. Northeastern Harghita Mts (scale 1 : 25,000).
1, pyroxene andesites, lavas ; 2, pyroxene and hornblende andesites, lavas ; 3, aphanitic dacites : a, lava ; b, body ; 4, volcano-sedimentary formation : pyroclastic rocks, epiclastic rocks and andesitic lavas.

3. Petrographic features

Just from the first megascopic investigation, one notices the peculiar structural and textural features of these rocks. They are fine-grained, almost completely lacking in crystals noticeable with the naked eye, of greyish or grey-brick-reddish colour. One may often recognize the microbanded structure due to the alternating millimetric bands of black, grey and white colour. They divide into plates, 2-5 cm thick.

The microscopic study points better to the aphanitic, microcrystalline texture of the rock. The rock is not a holohyaline one, as the groundmass contains, besides glass, plagioclase microlites (Pl. I, II, III).

The phenocrysts represent between 1-8% of the modal composition (Tab. 1). They are exclusively plagioclase (Pl. I) and hornblende (Pl. II, Fig. 1, 2 ; Pl. III, Fig. 1).

The plagioclase (An_{28-35}) occurs as prismatic crystals (1.8-0.35 mm) twinned according to albite and Karlsbad laws (Pl. I, Fig. 1). The hornblende is exclusively represented by the green variety (0.9-0.5 mm) entirely (Pl. II, Fig. 1) or marginally opacitized (Pl. II, Fig. 2 ; Pl. III,

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Fig. 1) as well as in prismatic-acicular sections, completely opacitized (Pl. I, Fig. 2). The phenocryst ratio of the two minerals varies between 1-4% (Tab. 1).

TABLE 1

Modal Mineralogical Composition

Minerals	Raczkebel brook Sample 38	Raczkebel brook Sample 28	Raczkebel hill Sample 41	Raczkebel brook Sample 54	Raczkebel quarry Sample 56	Raczkebel quarry Sample 57
Plagioclase	1	3.9	2.6	—	5.7	—
Hornblende	3	4.1	1.6	1	2.1	2
Phenocrysts total	4	8	4.2	1	5.8	2
Groundmass	96	92	96.8	99	94.2	98

The groundmass consists of devitrified glass on certain sections (Pl. III, Fig. 2) and of plagioclase microlites (Pl. I, Fig. 1 ; Pl. III, Fig. 1). They form parallel bands which lend to the rock its flow structure. The flow structure is pointed out in places by the hornblende microlites (Pl. I, Fig. 2). It is also to note the concentration of plagioclase microlites round the hornblende crystals (Pl. II, Fig. 1 ; Pl. III, Fig. 1). Under the microscope, one notices the more felsitic texture of the groundmass in the root area (Pl. II, Fig. 2) ; the flow structure is rather frequent in flaring and flow areas. The microbanded structure is also present as alternating bands consisting of plagioclase clusters and opacitized hornblende (Pl. I, Fig. 2) and of glass.

The above mentioned data are enough to demonstrate the necessity of adding the adjective form "aphanitic" to the denomination of the rock. According to D'Aubuisson and Haüy the term "aphanite" was used for rocks the constituents of which "are too small to be distinguished by the unaided eye", with microcrystalline or cryptocrystalline texture (Johannsen, 1962).

Although the rock we refer to contains more than 90% groundmass, it is not a glassy rock, the microlites and the cryptolites representing more than 50% of its composition. According to the classification of volcanic rocks, based on the glass content (P. Müller, in Streckeisen, 1967, p. 192), the Dănești aphanitic dacite corresponds to glass-rich rocks (25-50%).

4. Chemical composition and nomenclature data

It is natural that the mineralogical composition of aphanitic rocks does not reflect accurately their petrographic features. Therefore, the data of chemical analyses have been used. We dispose of an illustrative chemical analysis of a fresh rock (Tab. 2). A former examination of the data mentioned in Table 2 reveals that according to the SiO_2 value=66.23%, the rock is a dacite.

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Taking into account the SiO_2, K_2O and Na_2O values and the petrochemical parameters calculated according to CIPW and Rittmann norms (Tab. 2), the chemical classification of the rock has been elaborated. In keeping with most principles of chemical classification used until now and recommended by the IUGS Subcommission on the Sys-

TABLE 2

Chemical Analysis and Classification of the Aphanitic Dacite

Chemical Composition		*CIPW Norm*		*Rittmann Norm*	
SiO_2	= 66·23	Quartz	24.78	Quartz	29.72
TiO_2	= 0.47	Orthose	15.07	Sanidine	18.30
Al_2O_3	= 16.35	Albite	35.28	Andesine	53.31
Fe_2O_3	= 3.82	Anorthite	18.21	Augite	0.01
FeO	= 0.28	Corundum	0.25	Hypersthene	2.73
MnO	= 0.04	Enstatite	0.48	Magnetite	0.90
MgO	= 0.19	Ilmenite	0.68	Apatite	0.53
CaO	= 4.12	Sphene	0.28	Ilmenite	0.50
K_2O	= 2.52	Hematite	3.87	Q	24.88
Na_2O	= 4.12	Apatite	0.69	A	19.20
P_2O_5	= 0.27	Q	26.5	P	55.92
H_2O^+	= 1.18	A	16.2	CI	4.67
H_2O^-	= absent	P	57.3		
CO_2	= absent				
SO_3	= absent				
S	= absent				
Total	= 99.59				
Analyst : Rosette Ianc, 1981					

Chemical classification and nomenclature : a) Peccerillo and Taylor, 1976 (SiO_2-K_2O) : dacite ; b) Andreeva et al., 1981 ($SiO_2-Na_2O+K_2O$) : dacite ; c) IUGS Subcommission on the Systematics of Igneous Rocks, 1981 : dacite ; d) Streckeisen, 1967 (QAP) : dacite ; e) Streckeisen and Le Maitre, 1979 (Q'-ANOR) : dacite ; f) La Roche et al., 1980 ($R_1 - R_2 = 2250-769$) : rhyodacite.

tematics of Igneous Rocks, the studied rock is a dacite. It is worth mentioning that the value SiO_2=66.23, characteristic of the upper limit of the dacite variation domain, assigns this rock to the hyalodacites as proposed by La Roche et al. (1980) in his classification.

While using the data offered by the chemical analysis in order to denominate the volcanic rock under discussion, there is the problem of taking into account the term "pheno" as used by Niggli (1931), Rittmann (1952) and Streckeisen (1967). Since it is an aphanitic rock for which an accurate determination of modal mineral composition is not possible in the absence of the chemical analysis, but according to the recognizable phenocrysts, this should be called "phenoandesite". However, we dispose of a chemical analysis and the rock may be classified according to the normative composition as it was recommended by Streckeisen as early as 1967. In this case, the prefix "pheno" is no longer useful.

The authors consider that until now the igneous rocks have not been sufficiently defined according to their structural and/or textural features. The case discussed by the present note pleads for the necessity

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that in certain instances, the denomination of a volcanic rock corresponds to its chemical composition and texture. It is already known that glassy rocks are better denominated when taking into account both their structure and texture. Similar problems appear in the case of grainy rocks as well.

We consider that this problem is of great interest and should be envisaged by specialists. We would welcome the initiation of a study regarding the systematics of igneous rocks under the auspices of the IUGS Subcommission.

5. Paleovolcanologic remarks and conclusions

The Dăneşti aphanitic dacite constitutes a volcanic formation which differs from all the other ones reported until now in the north of the Harghita Mts. The relations with the surrounding volcanics, the morphological and megastructural features show that this formation consists of a slightly flaring dome, which can be seen to the north and south, associated with lava in the east. The root area was mapped at the confluence of the Raczkebel brook with a small left-side tributary, upstream the place where the former flows into the Uraşag river (Fig. 2). The aphanitic dacite lava lies over the andesite pyroclastics and lavas (pyroxene andesite) of the upper sequence of the volcano-sedimentary formation. On the slopes of the Raczkebel brook the pyroxene-hornblende andesite and pyroxene andesite lavas overlie the aphanitic dacite formation. These direct relations show that the eruption of the Dăneşti aphanitic dacite occurred during the second stage of volcanic activity in the Harghita Mts (Tab. 3).

TABLE 3

Sequence of Eruptions in the North of the Harghita Mountains (acc. to Peltz and Peltz in Mureşan et al., 1982 : Geological Map, scale : *1 : 50,000 — Voşlăbeni)*

Upper compartment (Pliocene)	Hornblende-pyroxene andesite and/or Pyroxene-hornblende andesite Pyroxene andesite Pyroxene-hornblende andesite Hornblende-pyroxene andesite Dăneşti aphanitic dacite and Răchitiş aphanitic andesite Hornblende andesite
Lower compartment (Malvensian-Pontian)	Volcano-sedimentary formation : alternating pyroclastics containing andesitic epiclastics ± andesitic lavas

Recently, Stanciu et al. (1984) have identified and described similar rocks of rhyodacite composition (SiO_2=67.70-69.10%) from borehole 19, situated in the Cocoizaş craterial area at 3.5 km west of the Raczkebel area. The Cocoizaş rhyodacite crossed by the borehole occurred as some bodies, 20-150 m thick, at different depths of 188-520 m. It is worth mentioning that the rhyodacite eruptions preceded the pyroxene andesite ones (Tab. 3).

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According to the above statements, we agree on the fact that in the north of the Harghita Mts, at the beginning of the volcanic activity which generated the upper compartment, the andesite eruptions were also accompanied by the emission of more acid products. They have been probably generated by the same parental magma which underwent differentiation processes in independent, small magmatic chambers. These magmatic chambers were also active outside the Ostoroș and Ivo-Cocoizaș volcanic edifices, being situated on an eastern branch of the Northern Harghita major tectono-magmatic alignment.

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EXPLANATION OF PLATES

Plate I

Fig. 1. — Aphanitic dacite. Raczkebel brook. Twinned plagioclase phenocryst (1) and hyalopilitic microtexture N ||, × 10.

Fig. 2. — Aphanitic dacite, Raczkebel brook. Detail of microtexture. Opacitized hornblende and plagioclase microlites ; flow structure. N ||, × 10.

Plate II

Fig. 1. — Aphanitic dacite, Raczkebel quarry. 1, Opacitized hornblende phenocryst, base section ; 2, plagioclase microlites moulding the hornblende ; partly devitrified glassy groundmass. N +, × 10.

Fig. 2. — Aphanitic dacite, Raczkebel brook. Detail of the microcrystalline microtexture in the rooting area of the dome : 1, marginally opacitized hornblende crystal. N +, × 10.

Plate III

Fig. 1. — Aphanitic dacite, Raczkebel hill. 1, marginally opacitized hornblende crystal ; cleavage characteristic of the base section ; 2, advanced crystallization in the neighbourhood of hornblende ; hyalopilitic microtexture. N ||, × 10.

Fig. 2. — Aphanitic dacite, Raczkebel brook. General view of the hyalopilitic microtexture with devitrified glass pieces. N ||, × 10.

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CHEMICAL CLASSIFICATION AND NOMENCLATURE OF VOLCANICS FROM THE SOUTH-WEST OF THE HARGHITA MOUNTAINS [1]

BY

SERGIU PELTZ [2], MARGARETA PELTZ [2], ROSETTE IANC [3]

Andesites. Basaltic andesites. Dacites. Modal composition. Chemical classification. Petrological nomenclature. Petrochemistry. Magmatic differentiation. East Carpathians-Neogene-Quaternary eruptive-Harghita.

Sommaire

Classification chimique et nomenclature des volcanites du sud-ouest des monts Harghita. A partir de l'analyse de 7 systèmes actuels de classification chimique a été examinée la nomenclature d'un nombre de 68 cas représentant des roches volcaniques massives et clastiques du sud-ouest des monts Harghita (Carpathes Orientales). La classification chimique et la nomenclature des volcanites de la région tiennent compte des recommandations des dernières années de la Sous-commission IUGS pour la systématique des roches éruptives. Vu leur composition modale les roches analysées ont été dénommées andésites à : pyroxènes, pyroxènes+hornblende, hornblende+pyroxènes, hornblende, hornblende+biotite. Conformément à la classification chimique il résulte que les andésites prédominent (75%) et le reste des volcanites sont des andésites basaltiques et des dacites. On accepte ainsi, pour la première fois, la présence dans cette région de l'association andésite basaltique-andésite-dacite. En raison de la manière dont on a dénommé les roches analysées, il s'ensuit que les méthodes Streckeisen, Le Maître (Q'-ANOR) et De la Roche et al. (R_1, R_2) réalisent une dénomination correspondante : andésites = 74-78% ; andésites basaltiques = 16% ; dacites = = 10-22%. La classification sur base de la composition normative révèle le caractère des volcanites acides à tendance alcaline. La suite andésite basaltique-andésite-dacite est le résultat de plusieurs moments d'évolution du chimisme du magma andésitique parentale vers des termes plus basiques et plus acides.

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[2] Institutul de Geologie şi Geofizică, str. Caransebeş 1, 78344 Bucureşti.

[3] Întreprinderea de Prospecţiuni Geologice şi Geofizice, str. Caransebeş 1, 78344 Bucureşti.

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1. Introduction

The volcanic area situated in the south-west of the Harghita Mts between the localities of Comăneşti-Băile Homorod-Vlăhiţa-Chirui-Lueta has been the object of our study these last years. Although the iron ores constituted the main aim of our investigations, special attention was also paid to lithologic and petrological features, to the accurate defining of types of volcanic rocks, to the study of their genesis in view of describing the volcanic formations associated with the mineralizations. Thus, the authors were concerned with the accurate denomination of volcanic rocks, as in the south-west of the Harghita Mts as well as in other parts of the Călimani-Harghita area there is an unconformity between the nomenclatures based on the mineralogical classification on the one hand and the chemical classification on the other (Peltz, 1981 ; Peltz, Peltz, 1983).

An important amount of analytical data, characteristic of all outcropping types of volcanic rocks, has been accumulated from the Lueta deposit and from boreholes. According to petrographic-mineralogical and chemical data one should define accurately the types of volcanic rocks, having in mind the opinion that in the case of volcanic rocks with developed microcrystalline or vitreous groundmass, the reduced amount of phenocrysts does not stand for the real composition of the rock and cannot be considered when defining it.

The authors of the present note aim at demonstrating that in a volcanic region of typical andesitic nature, the prevailing andesites associate with basaltic andesites and dacites, as shown by a close examination of actual chemical classification systems (according to which the volcanics are more differentiated). The chemical classification and nomenclature of volcanics from this area take into account the recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks.

Besides the accurate defining of igneous formations from the south-west of the Harghita Mts, the investigations carried out by the authors contribute to the checking up of the possibility of applying the classification and nomenclature principles based on chemical analyses from different volcanic areas of the Earth, to the study of the calc-alkaline volcanics from an East Carpathian area.

2. Geo-petrographic background

More than 90% of the area is covered by the volcanics of the lower structural compartment (volcano-sedimentary) of the Harghita Mts. The Miocene and Pannonian molasse deposits from the eastern border of the Transylvania Depression lie in the southern extremity of the area (Fig. 1). In the northern extremity, the volcano-sedimentary deposits are overlain by pyroxene andesite or pyroxene-hornblende andesite lavas. They belong to the second stage eruptions (Pliocene) which led to the building of the upper compartment of the Harghita massif.

The volcanic area is mostly (more than 70%) covered by a Quaternary formation built up of deluvial and swamp deposits.

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The volcanics from this region are the products of the first stage of subduction volcanism which took place during the Pannonian and the Pontian in the Călimani-Harghita area.

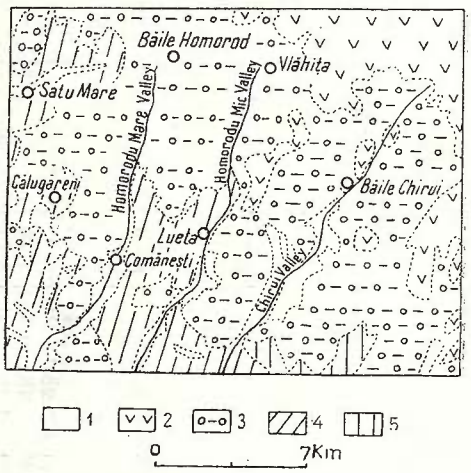


Fig. 1. — Geological sketch map of the southwestern area of the Harghita Mts (acc. to Rădulescu, Peltz, 1981).

1, Quaternary rocks ; 2, pyroxene andesites ; 3, rocks of the volcano-sedimentary formation ; 4, Neogene rocks in the Transylvanian Depression ; 5, rocks of the Crystalline-Mesozoic Zone and of the Cretaceous Flysch Zone.

The structural and lithological uniformity of the lower compartment is represented, on the whole, by the volcano-sedimentary formation. It consists of andesite volcanoclastics, terrigenous rocks and andesite lava flows.

According to their frequency the petrotypes are : pyroxene andesites, pyroxene-hornblende andesites, hornblende-pyroxene andesites, green or brown hornblende andesites. The modal mineralogical composition points to 43-84% groundmass and to the following phenocryst ratio : plagioclase (An_{29-42})=20-38% ; augite=3-18% ; hypersthene= =0.5-8% ; hornblende=0.5-5% to 10-15% It is to note the prevalence of groundmass made up of glass, plagioclase microlites±pyroxene microlites, hornblende, magnetite. On the whole (but for the tuffs), the volcanics from this region are fresh rocks.

3. Remarks on the chemical analyses

The present study concerning the chemical classification of the volcanics from the south-west of the Harghita Mts is based on 68 chemical analyses made by Rosette Ianc and Cecilia Vasiliu between 1975-1980. Table 1 includes these analyses, while Table 2 informs on their location.

The samples to be analysed have been carefully chosen from fresh rocks. This is pointed out by the low H_2O^+ values, the absence of CO_2 and S or their low values (Tab. 1). The andesitic tuffs which have altered their composition due to diagenetic processes are an exception ; H_2O values are particularly high (samples 710/142, 710/122, 704/235, Tab. 1).

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TABLE 1

Chemical Analyses of Volcanics from the South-West of the Harghita Mountains

No.	Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O^+	CO_2	S	Fe(S)	TOTAL
1	710/290	54.47	0.84	17.55	2.35	5.50	0.16	4.56	8.50	1.19	3.15	0.17	1.36	0.56			100.36
2	190	54.49	0.82	19.40	3.41	3.68	0.15	3.96	8.67	1.62	3.15	0.33	0.20		0.03	0.03	00.94
3	504/142	54.55	0.89	17.92	2.19	5.18	0.17	4.53	8.95	1.04	3.07	0.09	0.29	0.70			00.57
4	710/142	55.40	0.90	24.39	2.54	0.82	0.03	2.07	2.65	0.65	1.83	abs.	7.53	0.72			99.53
5	210	56.28	0.74	19.36	2.91	3.46	0.11	3.98	7.11	1.19	3.16	0.16	1.36				99.82
6	0.11	56.31	0.73	18.90	1.92	4.56	0.14	3.61	7.79	1.67	3.22	0.18	0.71				99.75
7	186	56.40	0.74	19.89	3.38	2.76	0.1	2.83	7.66	1.21	3.36	0.16	0.53				100.03
8	F7/122	56.42	0.73	19.13	2.83	3.92	0.14	3.85	7.65	1.45	3.31	0.19	0.41				100.03
9	0.16	56.50	0.72	18.72	3.09	3.92	0.14	3.81	7.58	1.44	3.38	0.18	0.30				100.06
10	210	56.57	0.64	17.77	2.08	3.93	0.11	5.37	8.55	1.09	2.91	0.17	0.55				99.74
11	90J	56.61	0.57	18.44	1.78	3.99	0.08	5.09	8.34	1.11	2.96	0.19	0.45		0.03		99.67
12	121J	56.62	0.72	19.20	1.62	4.39	0.12	3.67	7.25	1.69	3.10	0.18	1.28				99.84
13	7/113	56.64	0.72	19.08	4.59	1.54	0.12	4.02	7.38	1.91	3.29	0.18	0.51				100.04
14	189	56.74	0.76	18.64	3.84	2.71	0.10	3.83	7.04	1.11	2.40	0.13	2.65		traces		99.99
15	F.N.1	56.80	0.60	19.64	2.48	4.24	0.02	2.92	7.49	1.23	3.42	0.06	0.33		0.05		99.49
16	704/268	56.82	0.65	17.02	2.67	6.22	0.21	2.63	6.20	1.70	3.36	0.11	0.34	2.42	abs.		100.35
17	0.21	56.83	0.74	19.56	2.71	4.00	0.12	3.68	8.00	1.16	3.05	0.14	0.23	traces	traces		100.22
18	175	56.91	0.84	20.46	3.21	2.65	0.09	2.41	7.72	1.47	3.85	0.19	0.32	traces	traces		100.12
19	7/40	56.98	0.71	19.48	1.94	4.42	0.17	3.44	7.65	1.68	3.10	0.19	0.63				100.39
20	83J	57.08	0.69	18.98	1.71	4.22	0.12	3.37	7.45	1.68	3.05	0.20	1.27		traces		99.82
21	311	57.12	0.87	19.51	3.10	2.81	0.09	3.67	7.40	1.30	3.32		0.44				99.63
22	1/35	57.24	0.72	19.29	2.82	3.40	0.14	3.75	7.10	1.35	3.36	0.18	1.04				100.39
23	0.18	57.25	0.72	19.05	1.70	4.31	0.13	3.56	7.58	1.66	3.10	0.17	0.68				99.91
24	7/179.3	57.32	0.80	19.70	2.59	4.05	0.11	2.81	7.17	1.62	3.51	0.19	1.10				100.08
25	1.60	57.39	0.67	18.70	2.06	3.62	0.12	3.32	7.79	1.51	3.10	0.16	0.86	0.31			100.20
26	FN2	57.60	0.55	19.70	2.01	4.84	0.06	2.11	7.00	1.02	3.55	0.10	0.20	0.58	0.06		99.76
27	L222	57.87	0.78	21.02	1.30	2.34	0.08	2.21	7.65	1.28	3.49	0.23	1.66		traces		99.92
28	408	58.00	0.76	18.32	3.89	2.45	0.11	3.10	6.50	1.76	3.83	0.16	0.79				99.67
29	227	58.04	0.67	18.85	1.78	3.61	0.10	3.32	7.24	1.59	3.76	0.15	1.08		traces		100.19
30	704/240	58.08	0.56	17.42	3.05	5.12	0.19	2.83	6.43	2.03	3.71	0.10	0.31	0.58			100.41
31	465	58.28	0.91	17.97	2.86	3.19	0.12	3.32	7.15	1.53	3.37	0.10	0.89		0.02		99.71
32	602/11	58.50	0.78	21.03	3.90	1.26	0.07	1.58	6.40	1.30	1.30	0.10	0.95		0.23		99.76
33	7/431	58.51	0.61	18.72	1.02	3.46	0.12	2.44	6.61	1.65	3.42	0.20	1.37	0.70			99.87
34	605/11	58.59	0.72	18.47	2.50	3.07	0.12	3.10	7.61	1.42	3.16	0.10	0.51		0.22		99.76

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35	L52	58.64	0.57	18.41	1.02	2.95	0.09	4.39	7.51	1.72	2.93	0.14	1.17	0.18			99.72
36	L50	58.64	0.57	18.41	1.02	2.95	0.09	4.39	7.51	1.72	2.93	0.14	1.17	0.18			99.72
37	1225	58.75	0.76	22.51	2.28	0.32	0.02	1.17	2.44	0.97	1.56	0.22	7.55	1.91	0.06		100.51
38	404 B	59.00	0.80	18.22	2.82	3.08	0.12	3.28	6.70	2.08	3.78	0.17	0.27				100.32
39	713/319	59.07	0.68	17.60	1.50	3.98	0.13	2.76	7.04	2.09	3.38	0.23	0.56	1.37			100.39
40	115 J	59.10	0.66	18.84	1.73	2.59	0.08	3.64	7.73	1.71	2.99	0.18	0.17	0.35	0.33		99.83
41	7/452	59.20	0.56	17.99	4.12	0.24	0.09	4.34	7.51	1.78	3.09	0.13	1.36				100.41
42	204	59.20	0.67	18.31	2.67	3.22	0.12	3.23	6.56	1.90	3.18	0.18	0.53				99.77
43	228	59.26	0.69	18.93	1.43	3.62	0.10	3.24	6.90	1.61	3.18	0.16	0.73		0.02		99.87
44	205	59.59	0.70	18.17	2.64	3.07	0.11	3.14	6.70	1.96	3.36	0.18	0.34				99.96
45	207	59.78	0.67	17.82	2.93	2.79	0.11	3.19	6.77	1.95	3.25	0.16	0.42	0.35	0.02		100.21
46	713/307	60.11	0.54	16.00	1.60	4.25	0.14	3.76	6.52	2.02	3.33	0.22	0.48	1.25			100.22
47	502/20	60.28	0.58	18.32	2.56	2.37	0.10	2.68	7.04	1.80	3.56	0.09	0.75		0.03		100.43
48	298	60.53	0.67	17.70	2.88	2.53	0.09	3.04	6.38	1.78	3.50		0.44				99.63
49	L200	60.63	0.77	21.05	0.92	1.57	0.06	1.68	7.04	1.72	3.94	0.20	0.46		0.06	0.05	100.15
50	710/386	60.68	0.72	18.45	1.80	2.39	0.10	2.99	6.92	2.05	3.48	0.22	0.46				100.26
51	504/203	60.82	0.78	17.17	1.66	2.66	0.13	3.37	7.34	1.78	3.24		0.47		0.19		99.61
52	441	61.00	0.61	16.82	1.50	3.06	0.09	4.24	6.01	1.66	3.07	abs.	1.66				99.72
53	602/187	61.35	0.87	17.02	1.24	2.24	0.09	4.17	6.20	2.64	3.75	0.18	0.43				100.18
54	7/379	61.57	0.66	16.60	4.33	2.31	0.06	2.70	5.95	1.91	3.75	0.15	0.37				100.36
55	404 A	61.83	0.97	16.97	2.49	2.93	0.09	2.72	5.59	1.90	3.49	abs.	×.57				99.55
56	602/181	62.00	0.64	16.47	1.80	1.37	0.09	4.37	6.59	2.40	3.32	0.12	0.20		0.32		99.59
57	704/212	62.01	0.72	17.22	1.57	2.55	0.12	2.34	5.97	2.14	3.71	0.11	1.61		0.02		100.09
58	L 1	62.05	0.65	19.11	1.03	1.86	0.06	2.32	5.84	1.82	3.41	0.14	1.63				99.92
59	704/229 a	22.20	0.59	17.63	2.74	1.29	0.11	2.34	6.59	2.02	3.52	0.11	0.72		0.02		99.88
60	704/235	62.28	0.86	18.23	1.56	1.97	0.09	1.59	5.52	1.52	3.29	0.10	2.51		0.06		99.58
61	710/450	62.69	0.59	18.35	1.63	1.76	0.08	1.77	6.12	2.03	3.70	0.25	1.15				100.12
62	601/257	62.75	0.57	17.52	0.99	2.76	0.10	2.40	6.36	2.00	3.60	0.12	0.38		0.02		99.57
63	712/306	62.83	0.54	16.46	1.07	3.00	0.10	2.57	5.90	2.40	3.25	0.08	1.52				99.72
64	291	62.85	0.66	17.90	1.47	2.53	0.09	2.66	5.52	1.90	3.68	abs.	0.17		0.16		99.59
65	412	63.25	0.72	17.47	2.60	2.29	0.08	2.30	5.29	2.29	3.58	abs.	0.55				100.41
66	7/333	63.27	0.52	17.70	1.07	2.37	0.08	2.26	5.29	2.37	3.29	0.16	1.46				99.84
67	601/265	63.42	0.51	17.60	2.61	0.37	0.10	2.56	6.68	2.29	3.99	0.10	0.23		0.02		100.48
68	503/161	64.60	0.63	17.32	0.88	2.90	0.09	2.05	5.40	2.47	3.58	0.08	0.28		0.21		100.49

Analysts: Rosette Ianc, Cecilia Vasiliu

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As regards the accurate utilization of the chemical analyses in view of classification, two different opinions exist at present. Thus, at its meeting at Cambridge (1981) the IUGS Subcommission on the Systematics of Igneous Rocks has decided to adopt the method of the 100% recalculated chemical analysis, with the exclusion of H_2O. On the other hand, the Nomenclature Commission of the Petrographic Committee of Soviet Union asks the IUGS Subcommission (1979) to adopt the petrochemical classification of igneous rocks which is not based on 100% recalculated analyses, without limiting the ratio of components, including volatiles and ferric iron. It is very important to pay attention to the sorting of samples from fresh rocks, as well as to the quality of the analysis.

We join the standpoint of the Soviet Petrographic Committee and as we consider that the analyses we dispose of are qualitatively adequate, excepting the tuffs, no recalculation by excluding the water has been performed.

The chemical analyses stand for the different types of volcanic rocks according to their areal extent. Thus, 35 analyses (50% of the total) represent the pyroxene andesites, the most frequent volcanic rocks from this region. Then follow the pyroxene-hornblende andesites=18 ; hornblende-pyroxene andesites=5 ; hornblende andesites=6; hornblende-biotite andesites=1 ; tuffs=3 analyses.

4. Chemical classification and nomenclature

The authors have used the most frequent methods of chemical classification, also recommended by the IUGS Subcommission. One distinguishes : a) classification methods which take into account the graphic representations based on the SiO_2, K_2O, Na_2O relationships that account for the groups and series of igneous rocks ; b) classification methods based on the graphic representations drawn according to the normative composition.

4.1. *SiO_2-K_2O diagram (Taylor, 1969 ; Peccerillo and Taylor, 1976)*

Figure 2 shows the distribution of volcanics on the SiO_2-K_2O diagram. Most samples are plotted on the andesite field ; at the same time, three samples enter the low-Si andesite field and other four samples enter the dacite field ; eight samples are plotted on the high-K andesite field. The majority of andesites exhibit a low-K tendency and enter the upper area of field 9. As regards the nomenclature used, we note : low-Si andesite, low-Si — low-K andesite, low-Si — high-K andesite (Fig. 2) which represent a combination of denominations proposed by Taylor (1969), Peccerillo and Taylor (1976). The denomination of low-Si andesite, as compared to basaltic andesite, was considered to be better correlated with the mineralogical composition (intermediate even acid plagioclase, hornblende, pyroxenes, lack of olivine).

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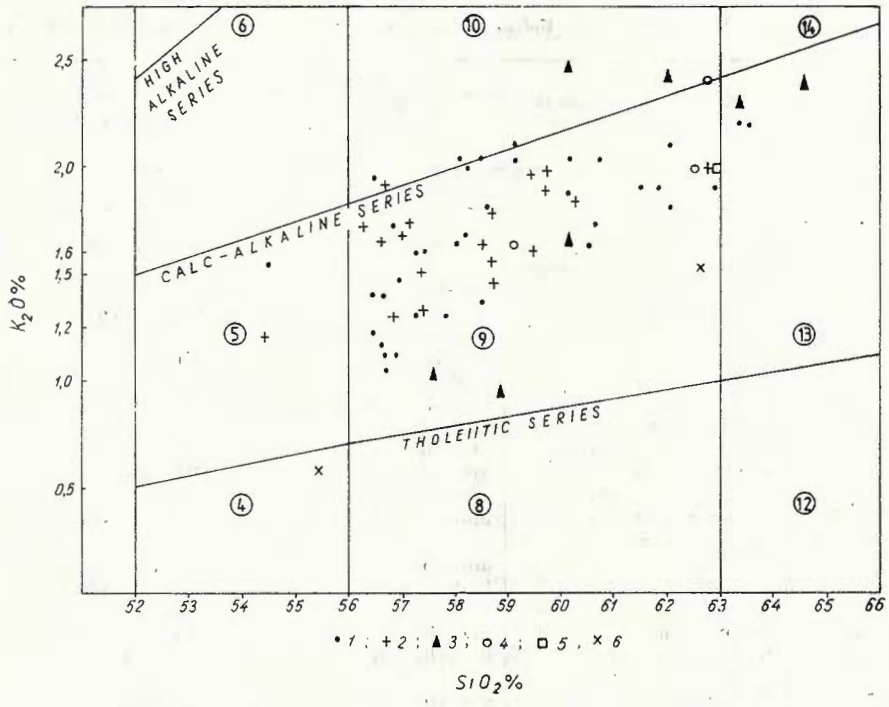


Fig. 2. — SiO_2-K_2O diagram (Taylor, 1969, Peccerillo, Taylor, 1976). 1, pyroxene andesite ; 2, pyroxene+hornblende andesite ; 3, hornblende+pyroxene andesite ; 4, hornblende andesite ; 5, hornblende+biotite andesite ; 6, andesite tuff. Denomination of fields : 4, low-K, low-Si andesite ; 5, low-Si andesite ; 6, high-K, low-Si andesite ; 8, low-K andesite ; 9, andesite ; 10, high-K andesite ; 12, low-K dacite ; 13, dacite ; 14, hig-K dacite.

4.2. *SiO_2-Na_2O+K_2O diagram (Petrographic Committee of Soviet Union, Andreeva et al., 1979, 1981)*

The distribution of volcanics on the silica-alkali diagram (Harker) points to the following : a) all rocks analysed are plotted on the upper half of the area covered by the calc-alkaline series and exhibit a low-alkaline tendency (also shown by the diagram of Fig. 2) ; b) as a result of determining SiO_2=57% as boundary between basaltic andesites and andesites and of SiO_2=64% as boundary between andesites and dacites, the number of basaltic andesites is 16 and of dacites is 1 as compared to the SiO_2-K_2O diagram (Fig. 3). Thus, the different principles had in view by the two classifications alter considerably the nomenclature of igneous rocks (Tab. 2).

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TABLE 2

Classification and Nomenclature of Volcanics from the South-West of the Harghita Mountains

No.	Sample	Modal mineralogical classification	Petrotype chemical classification	
			Taylor, 1969; Peccerillo, Taylor, 1976	SU Petrographic Committee, 1981
1	2	3	4	5
1	710/290	pyroxene andesite	low-Si andesite (5)	basaltic andesite
2	190	pyroxene-hornblende andesite	low-Si andesite (5)	basaltic andesite
3	504/142	pyroxene andesite	low-Si andesite (5)	basaltic andesite
4	710/142	andesite tuff	low-Si-low-K andesite (4)	basaltic andesite
5	210	pyroxene andesite	high-K andesite (10)	basaltic andesite
6	011	pyroxene andesite	andesite (9)	basaltic andesite
7	186	pyroxene andesite	andesite (9)	basaltic andesite
8	F 7/122	pyroxene andesite	andesite (9)	basaltic andesite
9	016	pyroxene andesite	andesite (9)	basaltic andesite
10	216	pyroxene andesite	andesite (9)	basaltic andesite
11	90 J	pyroxene andesite	andesite (9)	basaltic andesite
12	121 J	pyroxene-hornblende andesite	andesite (9)	basaltic andesite
13	7/113	pyroxene-hornblende andesite	high-K andesite (10)	basaltic andesite
14	189	pyroxene andesite	andesite (9)	basaltic andesite
15	FN 1	pyroxene-hornblende andesite	andesite (9)	basaltic andesite
16	704/268	hornblende andesite	andesite (9)	basaltic andesite
17	021	hornblende andesite	andesite (9)	basaltic andesite
18	175	hornblende andesite	andesite (9)	basaltic andesite
19	7/40	pyroxene-hornblende andesite	andesite (9)	basaltic andesite
20	883 J	pyroxene-hornblende andesite	andesite (9)	andesite (3)
21	311	pyroxene andesite	andesite (9)	andesite (3)
22	1/35	pyroxene-hornblende andesite	andesite (9)	andesite (3)
23	018	pyroxene andesite	andesite (9)	andesite (3)
24	7/179	pyroxene andesite	andesite (9)	andesite (3)
25	1/60	pyroxene-hornblende andesite	andesite (9)	andesite (3)
26	FN 2	hornblende-pyroxene andesite	andesite (9)	andesite (3)
27	222	pyroxene andesite	andesite (9)	andesite (3)
28	408	pyroxene andesite	andesite (9)	andesite (3)
29	227	pyroxene andesite	andesite (9)	andesite (3)
30	704/240	pyroxene andesite	high-K andesite (10)	andesite (3)
31	465	pyroxene-hornblende andesite	andesite (9)	andesite (3)
32	602/11	pyroxene andesite	andesite (9)	andesite (3)
33	7/431	pyroxene-hornblende andesite	andesite (9)	andesite (3)
34	605/11	pyroxene-hornblende andesite	andesite (9)	andesite (3)
35	L 52	pyroxene andesite	andesite (9)	andesite (3)
36	L 50	pyroxene andesite	andesite (9)	andesite (3)
37	710/1225	tuff	andesite (9)	andesite (3)

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1	2	3	4	5
38	404 B	pyroxene andesite	andesite (9)	andesite (3)
39	713/319	pyroxene andesite	andesite (9)	andesite (3)
40	115/7	pyroxene andesite	andesite (9)	andesite (3)
41	7/452	hornblende andesite	andesite (9)	andesite (3)
42	204	pyroxene-hornblende andesite	andesite (9)	andesite (3)
43	228	pyroxene-hornblende andesite	andesite (9)	andesite (3)
44	205	pyroxene-hornblende andesite	andesite (9)	andesite (3)
45	207	pyroxene-hornblende andesite	andesite (9)	andesite (3)
46	713/307	pyroxene andesite	andesite (9)	andesite (3)
47	502/20	pyroxene-hornblende andesite	andesite (9)	andesite (3)
48	298	pyroxene andesite	andesite (9)	andesite (3)
49	L 200	pyroxene andesite	andesite (9)	andesite (3)
50	710/386	pyroxene andesite	andesite (9)	andesite (3)
51	604/203	pyroxene andesite	andesite (9)	andesite (3)
52	441	hornblende-pyroxene andesite	andesite (9)	andesite (3)
53	602/187	pyroxene-hornblende andesite	high-K andesite (10)	andesite (3)
54	7/369	pyroxene andesite	andesite (9)	andesite (3)
55	404 A	pyroxene andesite	andesite (9)	andesite (3)
56	602/181	pyroxene-hornblende andesite	high-K andesite (10)	andesite (3)
57	704/212	hornblende-pyroxene andesite	andesite (9)	andesite (3)
58	21	pyroxene andesite	andesite (9)	andesite (3)
59	704/229	hornblende andesite	andesite (9)	andesite (3)
60	704/235	pyroxene-hornblende andesite	andesite (9)	andesite (3)
61	710/450	hornblende andesite	andesite (9)	andesite (3)
62	601/257	hornblende-biotite-quartz andesite	andesite (9)	andesite (3)
63	712/306	hornblende andesite	high-K andesite (10)	andesite (3)
64	291	pyroxene andesite	andesite (9)	andesite (3)
65	412	pyroxene andesite	dacite (13)	andesite (3)
66	7/333	hornblende-pyroxene andesite	dacite (13)	andesite (3)
67	601/265	hornblende andesite	dacite (13)	andesite (3)
68	503/161	hornblende-pyroxene andesite	dacite (13)	dacite (4)

Remarks on location : 1) samples from nos. 1, 3, 4, 8, 13, 16, 19, 22, 24, 25, 30, 32, 33, 34, 37, 39, 40, 46, 47, 50, 51, 53, 54, 56, 57, 59, 60, 61, 62, 63, 66, 67, 68 were collected from boreholes in the Vlăhița region ; the first figure represents the borehole number and the second points to the depth ; 2) samples from nos. 27, 35, 36, 49, 58 were collected from the Lueta mine ; 3) the other samples were collected from outcrops on the Homorodul Mare, Homorodul Mic, Virghiș, Chirui, Tolvajos and Ilosa Valleys.

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4.3. SiO_2-Na_2O+K_2O diagram (Cox et al., 1979)

Based on the silica/alkali ratio, the graphic representation of Cox et al. leads to a better classification of volcanics as the basaltic andesite, andesite and dacite fields are delimited according to SiO_2=55% and 63% respectively (Fig. 4). In keeping with this classification only 4.5% of analyses stand for basaltic andesites and 9% are dacites.

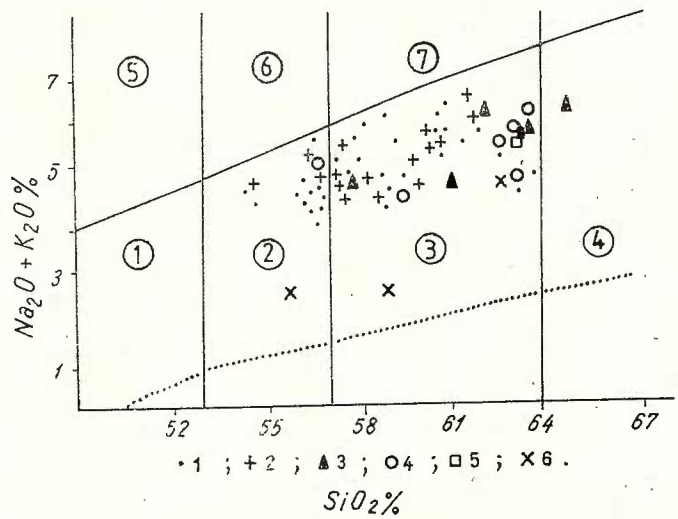


Fig. 3. — SiO_2-Na_2O+K_2O diagram (acc. to Andreeva et al., 1981). The same legend as for Figure 2. Denomination of fields : 1, basalt ; 2, basaltic andesite ; 3, andesite ; 4, dacite ; 5, subalkaline basalt ; 6, basaltic trachyandesite ; 7, trachyandesite.

4.4. QAP diagram (Streckeisen, 1967, 1972, 1976)

The values of synthetic *QAP* parameters calculated according to the CIPW and Rittmann normative composition were plotted on the upper triangle of *QAPF* diagram. The projection of chemical analyses on the *QAP* modal diagram shows some nomenclature contradictions which are due to the ways of association of normative Ab and An and/or Or.

Figure 5 shows the projection of CIPW normative values of analysed rocks. It is to note the projection of most samples (75%) on field 9*=quartz latiandesite ; 20% are plotted on field 4=dacites, 6% on field 10*=quartz andesite.

Figure 6 shows the projection of the analysed rocks within the same system, according to Rittmann norm. There are notable differences as regards the nomenclature, compared to CIPW norm, as follows : 49%=quartz andesite ; 35%=quartz latiandesite ; 12%=dacite ; 4%=plagidacite.

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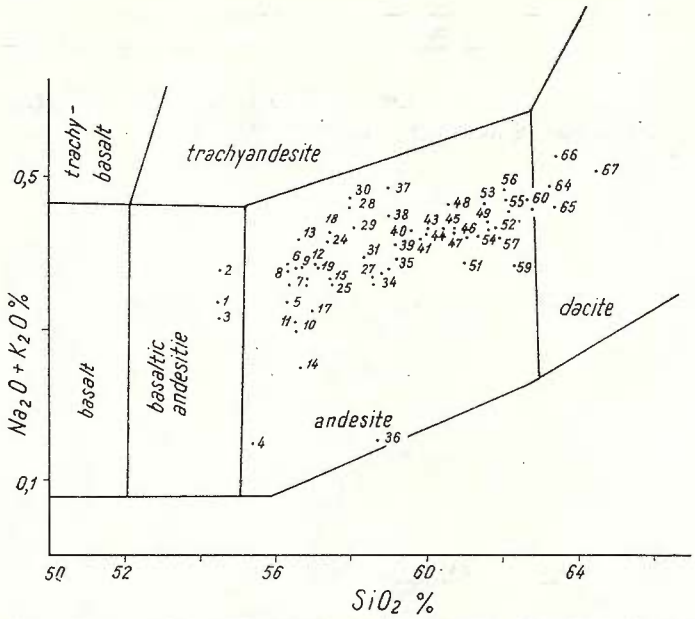


Fig. 4. — SiO_2-Na_2O+K_2O diagram (acc. to Cox et al., 1979). The same legend as for Figure 2.

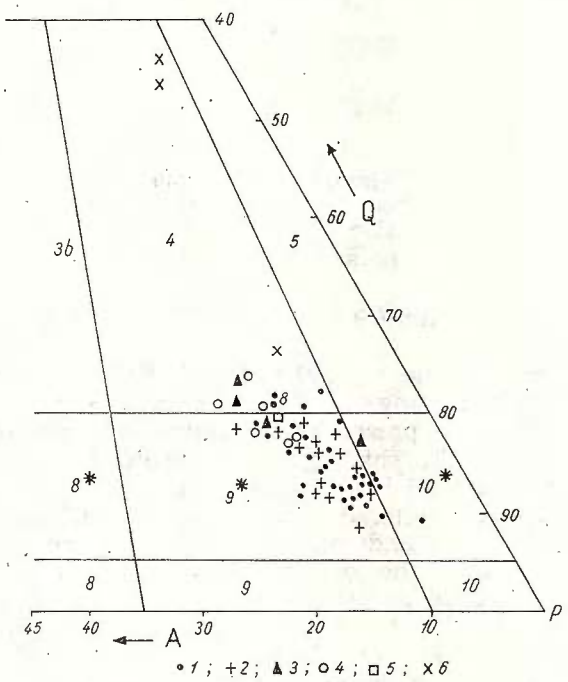


Fig. 5. — QAP diagram for CIPW norm (acc. to Streckeisen, 1967, mod. 1972, 1975).

The same legend as for Figure 2. Denomination of fields : 3b, rhyodacite ; 4, dacite ; 5, plagiodacite ; 8*, quartz latite ; 9*, quartz latiandesite ; 10*, quartz andesite ; 8, latite ; 9, latiandesite ; 10, andesite.

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In accordance with the nomenclature of *QAP* diagram, most andesites in the investigated area exhibit the features of an "alkaline quartz volcanic rock".

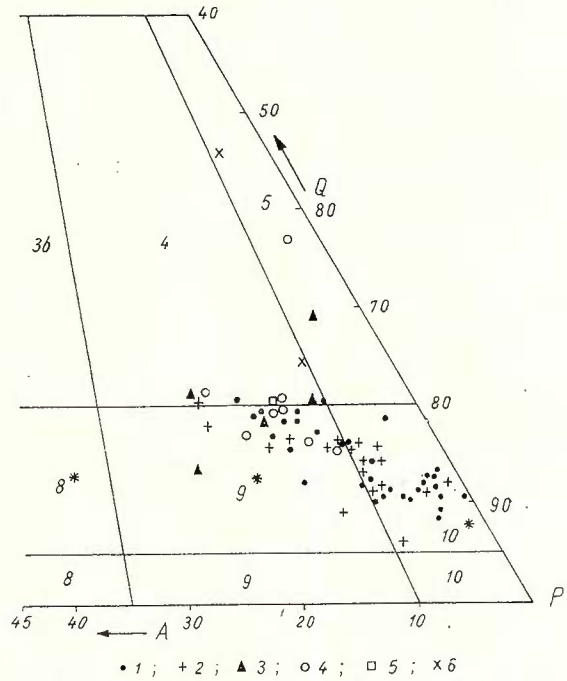


Fig. 6. — QAP diagram for Rittmann norm (acc. to Streckeisen, 1967, mod. 1972, 1975).
The same legend as for Figure 2 ; the denomination of fields the same as for Figure 5.

4.5. *Q'-ANOR diagram (Streckeisen and Le Maitre, 1979)*

The frequency of the volcanics distribution in the south-west of the Harghita Mts according to the normative synthetic parameters (CIPW), Q' and ANOR is presented in Figure 7b. As compared to *QAP* diagram, it is to note the shifting of the projection of most analysed samples from the modal field 9^+=quartz latiandesite to the normative field (10* a)=quartz andesite. An improved nomenclature of volcanics, nearer to their chemistry and mineralogy, is thus achieved.

Diagram 7a shows the density of distribution of andesites by taking into account 2196 analyses (Streckeisen, Le Maitre, 1979). The limits of isolines are 12, 10, 8, 6, 4%. It is to mention the great similarity between the position of the field of most volcanics analysed by us (Fig. 7b) and the maximum density isoline area.

4.6. *Normative plagioclase — normative colour index diagram (Irvine, Baragar, 1971)*

Figure 8 shows the classification of volcanics according to the relationship between the main normative components. The values have

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been inferred from the Rittmann normative composition. It follows that 55% of samples enter the andesite field and 45% of samples belong to the basalt field. It is the only classification diagram used by us which does not exhibit the affiliation to dacites of some of the analysed volcanics. However, it is also the sole diagram according to which the majority of samples are basalts.

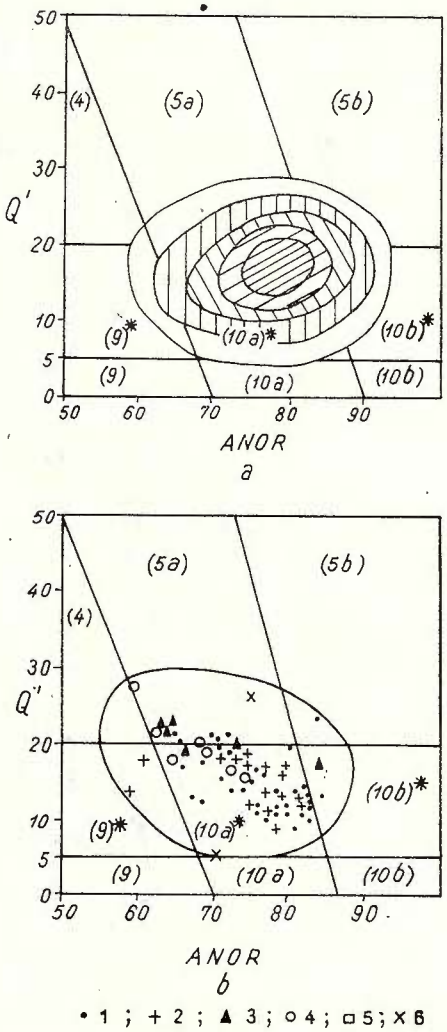


Fig. 7. — Q'-ANOR diagram (acc. to Streckeisen, Le Maitre, 1979). a, density of andesite distribution by considering 2196 analyses. Limits stated at 12, 10, 8, 6 and 4%; b, location of the andesite field in the southwestern area of the Harghita Mts.
The same legend as for Figure 2; the denomination of fields the same as for Figure 5.

4.7. *R_1-R_2 diagram (De la Roche et al., 1980)*

It is to note that both the classifications which take into account the silica-alkali relationships and those based on the projection of normative minerals on QAPF, Q'(F')-ANOR diagrams are not satisfactory, as long as the mafic components of the rocks are ignored. The drawbacks were amended by De la Roche et al. by means of R_1 and R_2

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synthetic parameters, which include the most cations of an igneous rock (Fig. 9). On diagram R_1-R_2 most of the analysed rocks (71%) are plotted

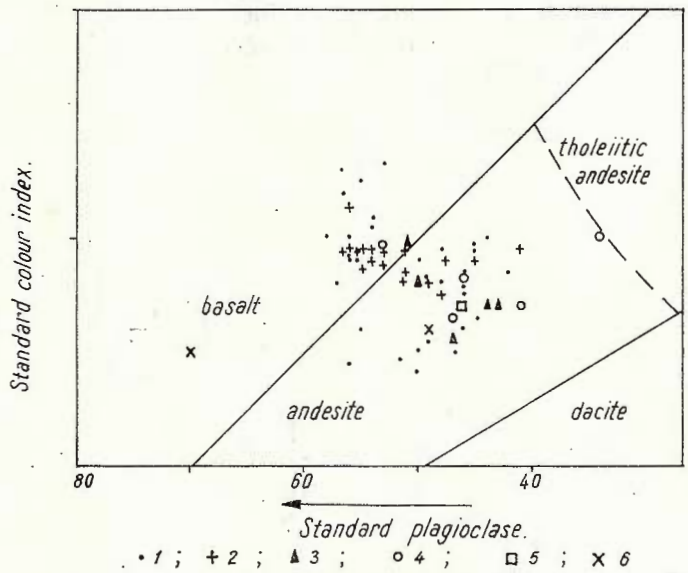


Fig. 8. — Normative plagioclase-normative colour index diagram (acc. to Irvine, Baragar, 1971). The same legend as for Figure 2.

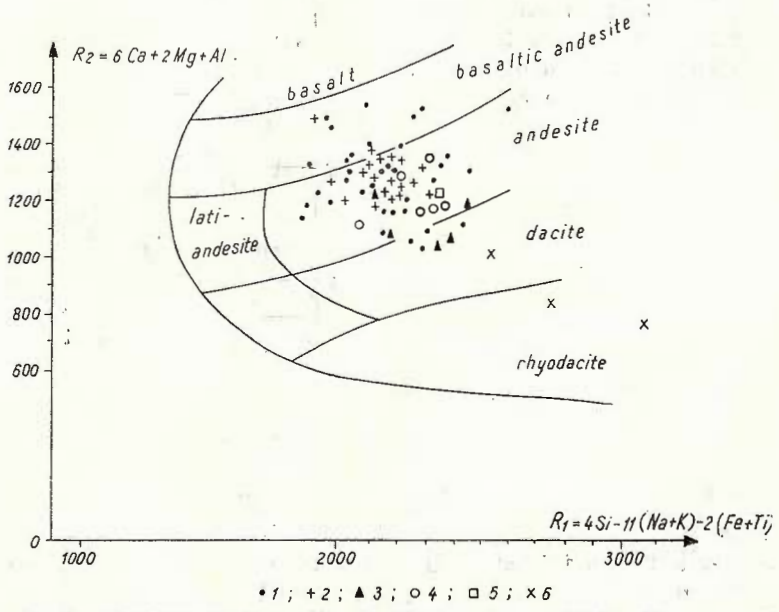


Fig. 9. — R_1-R_2 diagram (acc. to De la Roche et al., 1980). The same legend as for Figure 2.

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on the andesite field ; 16% are plotted on basaltic andesite field and 10% on the dacite field. It is worth mentioning the occurrence of two tuff samples in the rhyodacite field. On this diagram, as well as on other above mentioned ones (Figs. 2, 3, 5, 8) one notes the anomalous position of tuffs as compared to their initial chemical composition which had been altered by secondary processes.

5. Conclusions

Sixty-eight samples of volcanic rocks from the south-west of the Harghita Mts have been analysed in order to denominate them according to the chemical classification.

It was thus inferred that the rocks analysed and assigned to andesites according to their modal mineralogical composition, should be called andesites, basaltic andesites and dacites in accordance with the chemical classification. Among the methods of chemical classification recommended by the IUGS Subcommission on the Systematics of Igneous Rocks and used by us, those proposed by Streckeisen and Le Maitre (Q'-ANOR) and De la Roche et al. (R_1-R_2) supply an adequate denomination of volcanic rocks. Thus, according to the Q'-ANOR classification, the rocks analysed are : andesites=78% ; dacites=22% ; the R_1-R_2 classification points to : andesites=74% ; basaltic andesites=16% ; dacites=10%. As regards the other methods of chemical classification, it is to note that the extension of the basaltic andesite domain to 56-57% SiO_2 (Taylor, Peccerillo ; Andreeva et al.) allows the assignment of normal andesites to basaltic volcanics.

The chemical classification based on the normative composition points out the prevalence of andesites and their features of acid rocks (of quartz andesite type) with slight alkaline tendency. It is obvious that according to the *QAP* classification, most volcanics are called quartz latiandesites, while in accordance with the Q'-ANOR classification they are called quartz andesites.

The large majority of chemical classifications points out that in the structural unit of the lower compartment of the south-western Harghita Mts andesites are prevalent, being associated with basaltic andesites and dacites. Since the basaltic andesites and the dacites occur at different levels of the lower compartment lithological column (volcano-sedimentary formation), one may infer that the volcanic activity included several evolution stages of parental andesite magma chemistry to more basic or acid members.

We are grateful to Cecilia Vasiliu for providing us with chemical analyses (made between 1975-1976) and to Petre Andăr for automatic processing of CIPW and Rittmann norms.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

Project 195 : Ophiolites and Lithosphere of Marginal Seas

THE STUDY OF OPHIOLITES AND ISLAND ARC MAGMATITES IN THE BĂGARA-VISCA-LUNCOI REGION (MUREŞ ZONE — APUSENI MOUNTAINS) [1]

BY

HARALAMBIE SAVU [2], ION BERBELEAC [2], CONSTANŢA UDRESCU [2], VASILICA NEACŞU [3]

Ophiolites. Tholeiites. Initialites. Submarine island arc volcanics. Upper Jurassic. Banatites. Andesites. Neogene. Magmatic differentiation. Apuseni Mts-Southern Apuseni-Metaliferi Mts.

Sommaire

Etude des ophiolites et des magmatites d'arc insulaire de la région de Băgara-Visca-Luncoi (zone de Mureş — monts Apuseni). Dans la région de Băgara-Visca-Luncoi apparaissent des roches tholeiitiques (ophiolitiques), volcanites jurassiques supérieures d'arc insulaire, sous-marin ou „préorogène", roches néo-chimmériennes — toutes les deux séries de roches faisant partie du groupe des initialites — banatites et volcanites néogènes. Les roches ophiolitiques forment une série basaltique de fond océanique, située dans le soubassement de la région. Les volcanites jurassiques supérieures d'arc insulaire constituent une série calco-alcaline, différente de la série ophiolitique. Les roches banatitiques (laramiennes) sont représentées par de petites intrusions à caractère généralement acide, auxquelles sont liées les principales minéralisations de sulfures de la région. Les volcanites néogènes (andésites) ont une distribution fort réduite.

Introduction

In order to complete the study of the Mesozoic igneous rocks in the Metaliferi Mts, between 1980 and 1981 our investigations concerned the area situated at the top of the Vorţa Valley and in the surroundings of the localities of Luncşoara and Luncoi.

Prior to 1978, all the pre-orogenic magmatites (initialites) from the Mureş Zone or "Mureş Geosyncline" were assigned to ophiolites

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[2] Institutul de Geologie şi Geofizică, str. Caransebeş 1, 78344, Bucureşti.

[3] Întreprinderea de Prospecţiuni Geologice şi Geofizice, str. Caransebeş 1, 78344 Bucureşti.

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and divided into three stages of evolution of Alpine initial magmatism (Giuşcă et al., 1963). According to Savu et al. (1978) the ophiolitic rocks or the ocean floor ones were formed only during the first Jurassic stage, namely during the first stage of geotectonic evolution of the Mureş Zone, of pre-orogenic (initial) magmatism respectively ; during the second stage of evolution of the Mureş Zone, Upper Jurassic in age, and probably as late as the Lower Cretaceous, thus including the other two stages of the former division, calc-alkaline rocks were generated under the conditions of an island arc volcanism. This idea was later enlarged upon by Savu (1980 a, b, 1983). In the area under investigation between 1980-1981 (Savu et al., 1984) it is to note the occurrence of both initialite series, together with less important Neokimmerian and banatitic intrusions (Savu et al., 1982 b) and Neogene volcanics.

Evolution of ideas

This region was less studied before the World War I and several years after it. In 1941, Ghiţulescu and Socolescu investigated the Metaliferi Mts and noted on their map on the scale of 1 : 75,000 a homogeneous mass of basic rocks which underwent hydrothermal alteration and which seemed to belong to the melaphyre complex, probably Triassic in age. South of Luncşoara Tortonian volcanics are mentioned and to the east Jurassic limestones and Lower Cretaceous rocks do occur. Later on, Iacob (1953, 1957) reported in the west of the Metaliferi Mts Mesozoic acid rocks, such as quartz porphyries considered prior to the diabases or the melaphyres previously mentioned.

The Mesozoic igneous rocks occurring in the Vorţa Valley basin have been studied by several researchers. Thus, Cioflica (1961) describes Jurassic basalts, gabbroic rocks, different types of andesitic rocks, oligophyres, orthophyres, Barremian basalts and Laramian magmatites. In 1963, Trifulescu investigates the eastern area of the region. All the acid rock bodies which cross the diabases are considered to be banatitic intrusions. Teodoru et al. (1963) report in the east and southeast of the region basalts and their pyroclastics, crossed by banatitic intrusive rocks and Neogene andesites to which belong the acid rocks that occur between Luncşoara and Furcşoara. The data of these studies are used as such by Bordea and Borcoş (1972) in order to draw up the geological map on the scale of 1 : 50,000 sheet Brad. In 1973, Jude et al. study the Neogene volcanics at Caraci and the northern areas of the Visca-Luncoi region and delimit different types of basic and andesitic rocks which constitute lava flows and pyroclastics assigned to the Mesozoic ophiolitic series. Banatitic rocks and Neogene volcanics are also mentioned.

In the area south of the Visca locality, Savu and Nicolae (1975) report andesite pyroclastics, dacites and rhyolites and the Vorţa Formation, made up of fine tuffs associated with red argillites and jaspers. In 1978 we studied the Vălişoara-Dumeşti region (Savu et al., 1982 b) situated southeast of the appended map and in the southern area Jurassic-pre-Oxfordian ophiolites are reported , while in the north, island arc volcanics are present ; this petrological concept is still valid.

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Thus, in 1979 the area situated to the west and southwest between Almaş Sălişte, Godineşti and Zam was investigated. The igneous rocks are assigned to ophiolites and to pre-orogenic or submarine island arc volcanics (Savu et al., 1984).

In 1979 Borcoş et al. draw up the map of the basement of the Neozoic volcanics from the Metaliferi Mts, by taking into account the geological and geophysical data.

Geological structure

The geological structure of the Băgara-Visca-Luncoi region takes part in the general structure of the Mureş Zone ; it is situated in the west of the Metaliferi Mts. From tectonic point of view one should note some important structural features (Pl. I).

The region lies on a rise of the ophiolitic basement and of the island arc volcanics which acts like a major anticline, elongated WSW-ENE and dipping in the same direction. As it was previously mentioned (Savu et al., 1984), this anticline, the axis of which includes the Cerbia granitoid body, lies from the west of the Mureş Zone eastwards, along the Pietriş-Cerbia-Almaş Sălişte-Visca-Luncoi line, and is covered by the sedimentary formations and Neogene volcanic products from the embryonic rift or the Deva-Hălmagiu $\left\langle \begin{matrix} \text{Pîncota} \\ \text{Beiuş} \end{matrix} \right.$ graben. This structure was affected by several important fractures.

South of this anticline, outside our map, it is to note the synclinorium which contains the Vorţa Formation (Savu, Nicolae, 1975).

In the east of the region, the Pietriş-Luncoi anticlinal structure is concealed and the volcanic and Mesozoic sedimentary rocks are affected by a system of fractures trending NNW-SSE (Pl. I). These numerous fractures represent the fractures which occur on the western border of the above mentioned embryonic rift, along which the blocks situated to ENE sank gradually leading to the fragmentation and shifting of several layers of Mesozoic volcanic rocks. They favoured also the Neogene vulcanism which manifested along this fracture system.

The following geological formations are present in this region : ophiolites, Upper Jurassic island arc volcanics and scarce Upper Jurassic sedimentary formations, Neokimmerian and banatitic rocks, Neogene volcanics and sedimentary rocks.

1. The ophiolitic rocks constitute the basement of island arc volcanics which lie all over the region. The ophiolites crop out from under the island arc volcanics within three inliers, situated in the axial zone of the Pietriş-Luncoi anticline, such as the Visca, Valea Lungă (Luncoi) and the Stejărel inliers.

a) The Visca inlier is the most important one and occurs in the surroundings of the locality bearing the same name. It is very well correlated with an anomaly of gravimmetric maximum, reported by Andrei et al. (1971). The ophiolites which crop out on the Vorţa Valley and on its many tributaries, consist mainly of basalt flows, hyalobasalts, variolites and anamesites in pillow lava facies, with which associate tachylytes on the Vorţa Valley and Piticul Brook. These

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basaltic lava flows contain three small gabbro bodies, two of them on the Almaş Valley and one on the Scoarţa Valley. Dolerites and gabbro-dolerites associate with the gabbroic rocks. The basic rocks are affected by some transversal faults along which they are mylonitized.

If on the other borders the relationships between the overlying island arc volcanics and the basement ophiolitic rocks are of stratigraphic disconformity type, on the southern border of the inlier the contact between the two formations is marked by a longitudinal fault. This fault is pointed out by the thinning out of the island arc volcanics pile as compared to those occurring on the northern limb of the anticline, as shown by the geological section A-A' of Plate I as well as by the denser isolines of gravimmetric values along the fault area as shown by the map drawn up by V. Manu and his coworkers in 1981 (oral communication).

b) The second inlier which contains the ophiolitic rocks of the basement lies on the middle course of the Valea Lungă River, in the east of the region (Pl. I). It represents the continuation of the axial zone of the Pietriş-Luncoi anticlinal structure. In this case, just like in the case of the previous inlier, from under the pyroclastics and lava flows of island arc volcanics crop out ophiolitic rocks consisting of basalts, anamesites and dolerites, which include a small melagabbro body with peridotitic character in places.

c) The third inlier lies on the Stejărel Valley (Pl. I) and consists of ocean floor tholeiitic basalts, rocks with anamesite-doleritic features in places, which contain a small peridotite body situated in the west of the inlier.

All the rocks from the three inliers belong in fact to the upper complex of the ophiolitic rock series (Savu, 1983) previously reported by us at Roşia Nouă (Savu et al., 1970), Pătîrş (Savu et al., 1982c) and Laleşinţ (Savu, Manea, 1982). They represent a typical ocean floor basalt complex made up of basalt flows in pillow lava facies with scarce tachylyte intercalations (Pl. II, III).

2. The island arc volcanics constitute the largest part of the geological formations in this region. They consist mainly of pyroclastics with which associate scarce porphyritic basalt flows, amygdaloidal porphyritic basalts and basalt andesites. Agglomerates are prevalent and with them associate in places tuffs with scarce radiolarite and red argillite intercalations. There are also pyroclastic intercalations of amphibole andesites and dacites with perlitic structure. On the Almaş and Scoarţa brooks these pyroclastics occur at the base of the island arc volcanic pile, being overlain by the pyroclastics of porphyritic and amygdaloidal basalts which point to the recurrent nature of the island arc volcanism on one hand and to the unconformity between the Jurassic-pre-Oxfordian ophiolites of the basement and the overlying Upper Jurassic island arc volcanics, on the other hand. In the median area of the island arc, situated in the south of the region, the basalt-andesite complex (IAV_1) (Savu, 1962b) is overlain by the IAV_2 complex consisting of amphibole andesite pyroclastics, dacites and rhyolites, some of them with perlitic structure (Savu, 1983). These formations occur from

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one end to the other of the map and represent in fact the volcanics which mark the final stage of the Upper Jurassic island arc volcanism in this area. They are overlain by the Stramberg limestones of Portlandian age (Savu et al., 1984). It is to note that in the northwest of the region, the Stramberg limestones overlie directly the agglomerates of the andesite-basalt complex situated at the base of the island arc volcanic series. This position and the sequence of the island arc volcanics prove that they were formed during the Upper Jurassic. On the Luncșoara Valley there are oligophyre agglomerates and in the rest of the region there are a few oligophyre and orthophyre veins.

3. Neokimmerian and banatitic (Laramian) rocks. These rocks form several dikes and small bodies of dioritic rocks (pyroxene diorites, quartz diorites, trondhjemites, dioritic porphyrites, kersantites) which occur in the north of the region as well as in the east, near Luncoi (Trifulescu, 1963 ; Caraveteanu, Nica, 1976) and south-east (Savu et al., 1982b). They resemble the rocks which form a swarm of veins, dikes and small apophyses round the Măgureaua Vatei banatitic body lying to the northwest of this region, recently studied by Ștefan et al. (1982). The banatitic bodies cross the pyroclastics of Upper Jurassic island arc volcanics which undergo hydrothermal alteration and sulphide impregnation (Pl. I).

4. Neogene volcanics. The products of Neogene volcanism occur on the ridges situated on the northeastern border of the region. Within these areas, as well as between Luncoi and Dealul Mare, the eruptive and the Mesozoic sedimentary formations are overlain by Neogene sedimentary ones, mainly represented by gravels.

Petrology and geochemistry of ocean floor rocks

The ophiolitic rocks are represented by tachylytes, hyalobasalts, variolites, basalts, anamesites, spilites, dolerites, gabbrodolerites, gabbros, melagabbros and peridotites, previously described by Savu et al. (1984) in the western region.

Chemistry. From Table 1, which includes the results of seven analyses, one may infer the following variations of the chemical components of the rocks : SiO_2 = 44.15-50.44% ; Al_2O_3 = 8.19-16.19% ; Fe_2O_3 = 2.74-2.90% ; FeO = 3.44-6.33% ; MgO = 6.37-7.70% ; CaO = 8.60-13.84% ; Na_2O = 0.76-4.75% ; K_2O = 0.09-0.79% ; TiO_2 = 1.05-2.60%. It is to note the low K_2O content, generally less than 0.40%, which makes the rocks resemble the basalts of median oceanic ridges (Miyashiro, 1975). The great MgO amount and the small Al_2O_3 one of melagabbros show that this rock is a cumulate with modified parental geochemical features. In one of the basalts, which exhibits calcite amygdales, the CO_2 content is of 2.44% pointing to the occurrence of calcium carbonate within amygdales and on fissures.

The above mentioned data show that these rocks belong to a basic series as also proved by Table 2 which includes the values of Niggli magmatic parameters, calculated according to Burri (1959). By taking into account these values, the ophiolitic rocks generally represented

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by basalts and some gabbros, correspond to the following magma types: amphibole-peridotitic, eukritic, gabbroid and spilitic (?), which associate with a basic rock series too.

TABLE 1

Chemical composition of ophiolitic rocks

No.	1	2	3	4	5	6	7
Sample no.	46	2391	10	90	80	49	45
Rock type	gabbro-dolerite spilite	melagabbro	tachylyte	basalt	variolite	anamesite	dolerite
Location	Almăşel Valley	Valea Mare	Vorţa Valley	Tisa Valley	Piticu Valley	Almăşel Valley	Almăşel Valley
SiO_2	44.15	44.48	45.11	36.62	48.85	50.39	50.44
Al_2O_3	16.11	8.19	12.24	14.34	13.39	15.44	16.19
Fe_2O_3	5.79	5.20	7.91	5.18	4.74	5.44	2.74
FeO	6.18	5.35	6.33	3.17	6.00	3.44	5.23
MnO	0.18	0.19	0.22	0.16	0.18	0.16	0.17
MgO	6.53	21.15	6.59	7.70	7.23	7.61	6.37
CaO	8.60	7.12	8.62	3.84	11.74	9.79	8.75
Na_2O	4.75	0.61	0.76	1.83	2.09	2.31	4.24
K_2O	0.28	0.28	0.59	0.10	0.09	0.19	0.79
TiO_2	2.11	0.46	2.60	1.05	1.64	1.38	1.05
P_2O_5	0.16	0.20	0.41	0.14	0.26	0.28	0.30
CO_2	—	—	—	2.44	0.25	—	—
S	0.12	0.08	0.10	0.08	0.10	0.17	0.12
Fe(S)	0.10	0.07	0.09	0.07	0.09	0.15	0.10
H_2O	4.42	5.78	7.84	2.85	3.03	2.85	3.34
Cr_2O_3	—	0.18	—	—	—	—	—
NiO	—	0.08	—	—	—	—	—
TOTAL	99.48	99.42	99.41	99.57	99.67	99.60	99.83

The entire series of ophiolitic rocks corresponds to abyssal tholeiitic magmas, as shown by the FeO tot/MgO ratio that varies between 0.48 and 2.05 (Miyashiro, 1975). The same conclusion is supported by the diagrams of Figure 1, on which the rocks are plotted according to the values of SiO_2, FeO tot, TiO_2 as well as of the FeO tot/MgO ratio, as it was stated by Miyashiro (1975). On these diagrams, the ophiolites enter the field of tholeiitic rocks and their plots are distributed between the curve of the Skaergaard rock sequence and that one of abyssal or ocean floor tholeiites. The tholeiitic nature of the ophiolitic rocks is striking on the FeO-MgO-Na_2+K_2O diagram (Fig. 2), drawn up according to Irvine and Baragar (1971), on which the ophiolites are mostly plotted above the boundary between tholeiitic and calc-alkaline rocks. Albitized rocks are an exception (no. 45 and 46); albitization has probably altered the geochemical features of rocks, too.

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TABLE 2

Niggli parameters

No.	Sample no.	si	al	fm	c	alk	k	mg	c/fm	ti	p	w	Q_z	Q	L	M	Magma type
1	46	101.14	21.82	44.73	21.11	12.34	0.03	0.50	0.47	3.62	0.15	0.46	−47.92	20.38	42.78	36.84	spilitic
2	2391	83.40	8.99	75.22	14.34	1.45	0.21	0.78	0.19	0.63	0.16	0.46	−22.40	20.39	16.08	63.53	amphibole-peridotitic
3	10	116.40	18.65	54.76	23.79	2.80	0.32	0.46	0.43	5.11	0.45	0.52	+ 5.20	32.86	26.39	40.75	eukritic
4	90	107.68	19.47	42.07	34.22	4.24	0.03	0.62	0.81	1.87	0.14	0.59	− 9.18	29.49	30.46	40.05	gabbroic
5	80	116.14	18.69	46.46	29.89	4.96	0.03	0.55	0.64	2.91	0.25	0.41	− 3.70	30.95	29.17	39.88	gabbroic
6	49	124.81	22.52	45.65	26.02	5.81	0.05	0.61	0.56	2.62	0.29	0.59	+ 1.57	33.62	33.15	33.23	gabbroic
7	45	127.39	24.13	40.64	23.66	11.57	0.10	0.59	0.58	2.05	0.32	0.32	−18.90	29.67	40.29	30.04	gabbroic ;alk > −

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Trace element distribution. The chemically analysed rocks contain the trace elements of Table 3, which point to several geochemical features of the ophiolitic rocks. They show trace element contents

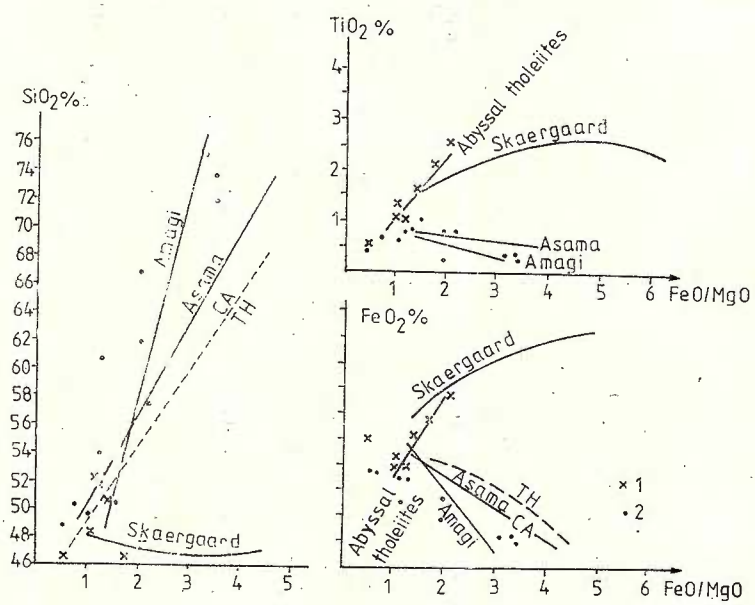


Fig. 1. — SiO_2, FeO(tot), TiO_2-FeO(tot)/MgO diagram.
1, ophiolites ; 2, island arc volcanics.

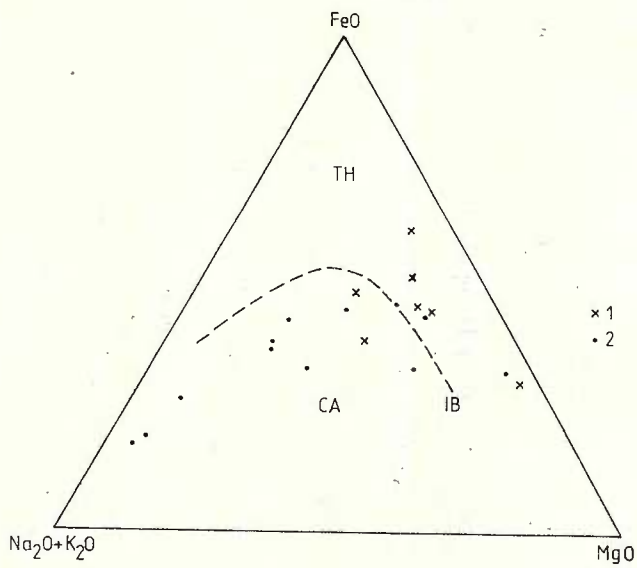


Fig. 2. — FeO(tot)-MgO-Na_2O+K_2O diagram.
1, ophiolites ; 2, island arc volcanics.

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characteristic of basic rock series (Savu, Udrescu, 1975). The melagabbro is an exception and it represents a cumulate of the tholeiitic magma with higher Ni, Cr and Co contents as compared to the other rocks, due to the prevalence of melanocrate minerals — olivine and pyroxene.

TABLE 3

Trace element distribution (ppm) in ophiolitic rocks

No.	Sample no.	Ni	Co	Cr	V	Sc	Y	Y_b	Zr	Ba	Sr	Pb	Cu	Ga
1	46	48	36	16	600	38	30	4	100	22	115	<2	25	17
2	2391	700	105	1300	170	34	13	1.5	50	60	85	4.5	32	8
3	10	92	35	190	300	35	55	6.2	210	60	400	<2	40	11.5
4	90	230	42	400	185	33	23	3	77	<10	150	<2	50	12
5	80	170	42	340	280	37	45	7	190	15	130	<2	35	17
6	49	110	33	200	260	32	33	4.5	100	32	115	3.5	48	15
7	45	60	31	160	220	37	25	3.5	80	100	450	4.5	48	16

The Co, V and Sc contents of normal tholeiitic rocks show small variations and their values are similar to the average values of these contents in the basic rocks mentioned in literature : Co=40 ppm ; Sc=27-33 ppm ; V=247 ppm (Prinz, 1967). Only the V content of the gabbro-dolerite numbered 46 is higher (600 ppm) than the one of the other basic rocks, and is correlated with the high TiO_2 content (2.11%) of the same rock. These values show that the rock has resulted from a residual magma rich in Fe, Ti and V in which vanadiferous titanomagnetite was formed during a late crystallization stage and at high depth. Similar characteristics as regards Fe and Ti are also exhibited by the tachylyte (no. 90), resulted from a residual magma rich in Fe and Ti which occurred as lava on the sea floor and consolidated as volcanic glass.

Except for sample 46, which shows a low Cr content (16 ppm), the other ophiolitic rocks exhibit Cr values which vary between 160 and 400 ppm. The variation of Ni content is more marked, between 48-230 ppm.

The Y and Yb contents increase at the same time with the Zr ones, as proved by the linear correlations Y-Zr and Yb-Zr (Fig. 3). It is to note that the melagabbro occurs, in both cases, on the same lines of positive correlation, but its plots correspond to the lowest Y, Yb and Zr values. This close correlation was also pointed out in the Julița gabbro body, situated within the Jurassic-pre-Oxfordian ophiolitic rocks (Savu et al., 1982c).

The Ba contents are generally reduced, which is characteristic of ocean floor basalts (Hart et al., 1972 ; Savu, Udrescu, 1981). On the diagram of Figure 4, drawn up according to Miyashiro (1975), Ba is plotted depending on the FeO tot/MgO ratio and the ophiolitic rocks enter the field of the Azores abyssal tholeiites. The Sr content varies

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between 85 and 450 ppm. The Sr average value of basic rocks, reported by literature, is of 544 ppm (Prinz, 1967).

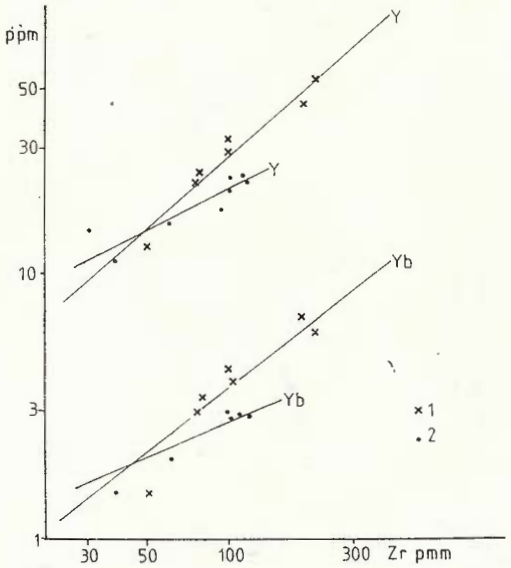


Fig. 3. — Y, Yb-Zr diagram.
1, ophiolites ; 2, island arc volcanics.

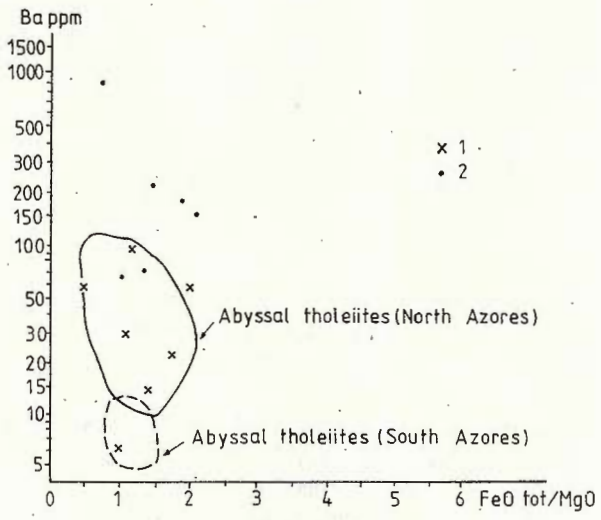


Fig. 4. — Ba-FeO(tot)/MgO diagram.
1, ophiolites ; 2, island arc volcanics.

Origin of magmas and the condition under which ophiolites were generated

The basement ophiolitic rocks were generated by simatic tholeiitic magmas, as shown by the diagram of Figure 5, drawn up according to Gottini (1969). These magmas were formed in the upper mantle,

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where differentiation processes characteristic of tholeiitic magmas took place, namely the constitution of cumulates such as the MgO-rich melagabbro and peridotite and of other ones such as the vanadiferous

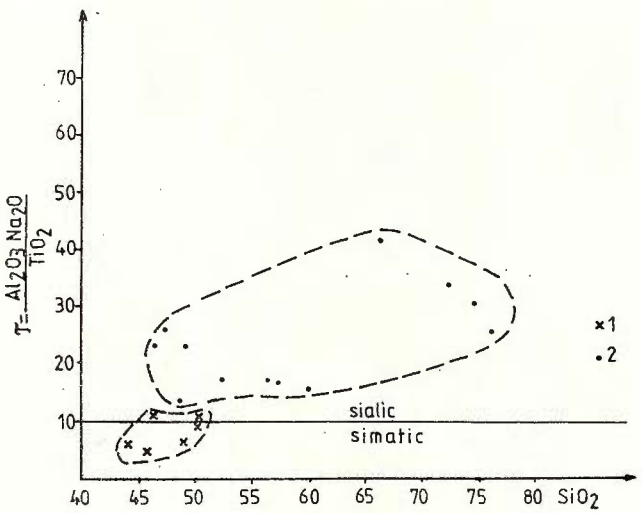


Fig. 5. — T-SiO_2 diagram.,
1, ophiolites ; 2, island arc volcanics.

titanomagnetite gabbrodolerite and of the magma which generated the iron and titanium-rich tachylyte (2.60%). As regards the gabbrodolerite the residual magma intruded the pile of ocean floor ophiolitic basalts and consolidated as a depth rock, while as regards the tachylyte, the residual magma erupted in the spreading area and came into direct contact with the marine water and cooled rapidly as volcanic glass.

The ophiolitic rocks were emplaced in the spreading area on the floor of the Mureș Ocean (Savu, Manea, 1982 ; Savu, 1983), as shown by the diagram of Figure 6, drawn up according to Pearce (1975), on which the rocks enter the field of ocean floor basalts (Savu et al., 1978 ; Savu, 1980a, b). This diagram confirms the conclusion according to which the ophiolitic rocks have been formed on the floor of the Mureș Ocean, during the Jurassic, prior to the Oxfordian, their radiogenic age being of 180 m.y. (Herz et al., 1974). The same conclusion may be inferred from another diagram drawn up according to Pearce et al. (1975) on which, excepting the melagabbro and the albitized basalt, the other rocks are plotted on the field of oceanic basalts (Fig. 7).

The genesis of ophiolitic rocks on the floor of the Mureș Ocean is related to the geotectonic evolution of the latter, its spreading being assigned to the Lower Jurassic-Oxfordian interval (Savu, 1983), when the bilateral subduction processes started and the new kimmerian movements took place (Savu, 1962 a, b). The petrological and geochemical features of the Jurassic-pre-Oxfordian basic rocks and the geotectonic conditions under which they were generated plead for their

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assignment to the ophiolitic rock series, as shown by Savu (1962 a) and confirmed subsequently on different occasions. This conclusion is also supported by the position of tholeiitic rocks on the *QLM* diagram (Savu, 1980 a). The tholeiitic rocks in the Mureș Zone are mostly

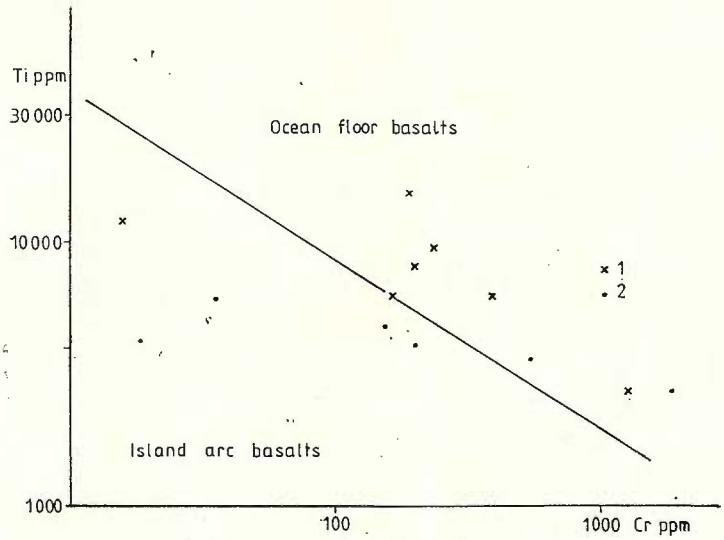


Fig. 6. — Ti-Cr diagram.
1, ophiolites ; 2, island arc volcanics.

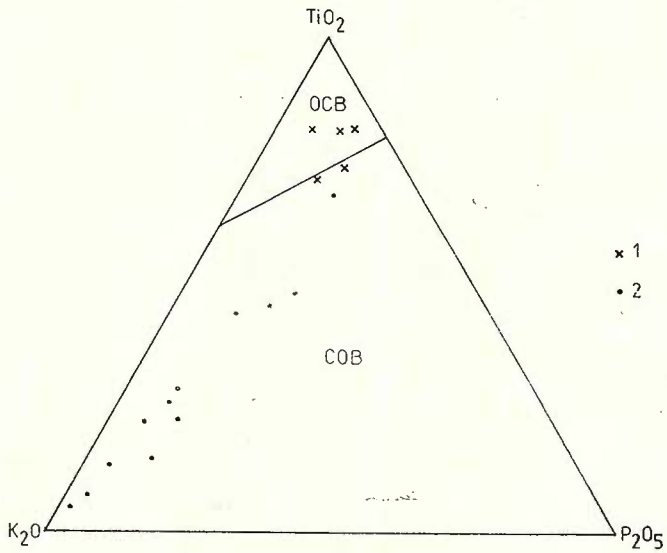


Fig. 7. — TiO_2-P_2O_5-K_2O diagram.
1, ophiolites ; 2, island arc volcanics.

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plotted on the field of basic ophiolites from typical areas, such as the Alps, Apennines and Dinarides, to which the notion of ophiolite is related (Brongniart, 1913).

Finally, the basic rocks from the basement of the study area may be assigned to the ophiolitic series in the Mureş Zone ; they represent the upper, effusive complex of the ocean floor basaltic rock series, generated under spreading conditions during the Jurassic.

Petrology and geochemistry of island arc volcanics

The island arc volcanics are much more varied as regards their petrographic and chemical features than the ophiolites. Unlike the effusive basic ophiolitic rocks characterized by intersertal-intergranular-ophitic textures, typical of submarine lava flows from spreading areas, all island arc rocks are marked by a porphyritic texture, typically volcanic due to the prevalence of pyroclastics (agglomerates and tuffs) over lavas. At Luncoi, on the slope south of Valea Lungă, there are also agglomerates, which besides basaltic or andesite-basaltic pebbles, include dolerites and gabbros.

The island arc volcanics are represented by the following characteristic petrotypes : ankaramites, basalts and basaltic andesites, amygdaloidal basalts, pyroxene and hornblende andesites, hornblende andesites, dacites, rhyolites, oligophyres and orthophyres, previously described in detail (Savu et al., 1984).

Chemistry of island arc volcanics. In order to define the petrochemical features of the island arc volcanics, 12 chemical analyses were performed on all the petrotypes occurring in this region (Tab. 4, 5). It is worth mentioning that this rock sequence is usually more acid and more varied as regards the chemical composition than the ophiolites.

From petrochemical point of view, it is to note the basaltic and andesite-basaltic rocks of the lower complex, characterized by 46.30 to 56.84% SiO_2, the andesites marked by 60 to 66% SiO_2 and acid and peracid rocks with 72 to 76% SiO_2. They form a typical island arc calc-alkaline volcanic series. As regards the first category, of basalts and andesite basalts, Al_2O_3 varies between 15.50 and 19.69% ; Fe_2O_3 = = 2.34-4.41% ; FeO = 2.07-4.81% ; MgO = 2.59-8.99% ; CaO = = 5.34-13.18% ; Na_2O = 1.98-4.27% ; K_2O = 0.18-1.76%. It is also to note that the K_2O contents are usually higher than those reported for the ophiolitic series.

The ankaramite, the structure and composition of which point to a cumulate of augite phenocrysts, reported from the magmatic basin, where it had been released during the volcanic explosion, is characterized by the decrease of Al_2O_3 and of alkalis as compared to the normal basaltic series, as well as by the obvious increase of MgO (14.31%) and CaO (13.30%). As it will be shown further on, there are changes of the ratio of different minor elements. The andesitic rocks of intermediate composition, are characterized by oxide contents which are normal for these rocks : Al_2O_3 = 13.70-15.37% ; MgO = 1.96-4.24%; CaO = 4.23-6.11% ; Na_2O = 3.29-3.45% and K_2O = 1.25-2.55%. The

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TABLE 4

Chemical composition of island arc volcanics

No	1	2	3	4	5	6	7	8	9	10	11	12
Sample no.	39	94	36	91	28	101	117	88	102	100	134	135
Rock type	ankara-mite	basalt	melaba-salt	porphy-ritic basalt	basalt	andesite	amygda-loidal basalt	pyroxene +hornblen de andesite	horn - blende andesite	rhyolyte	amphi-bole + biotite rhyolite	amphibole rhyolite
Location	Naida Valley	Visca	Scoarţa Valley	Tisa Valley	Valea Mare	Luncşoara Valley	Vorţa Valley	Tisa Valley	Luncşoara Valley	Luncşoara Valley	Ridge south of Băgara	Vorţa Valley
SiO_2	46.46	47.30	48.46	48.65	52.51	56.48	56.84	60.00	66.69	72.50	74.71	76.20
Al_2O_3	11.19	19.69	16.20	17.80	15.50	17.12	15.86	15.37	13.70	14.20	12.19	12.04
Fe_2O_3	3.97	3.56	4.00	4.41	2.34	4.11	3.18	3.12	2.81	1.74	1.67	1.11
FeO	3.80	3.58	3.21	4.81	4.81	2.57	2.07	2.18	1.22	0.31	0.31	1.24
MnO	0.18	0.14	0.17	0.16	0.10	0.19	0.22	0.10	0.09	0.04	0.04	0.05
MgO	14.31	6.57	8.99	5.70	5.40	2.94	2.59	4.24	1.96	0.56	0.55	0.71
CaO	13.30	13.18	9.62	7.72	8.20	5.34	7.20	6.11	4.23	1.06	1.48	2.74
Na_2O	0.66	1.98	2.34	4.27	2.12	4.15	3.92	3.45	3.29	3.28	3.44	3.38
K_2O	0.39	0.18	1.66	1.04	0.56	1.59	1.76	2.55	1.25	5.42	3.69	2.17
TiO_2	0.47	0.68	0.60	1.03	0.81	0.75	0.70	0.78	0.25	0.32	0.29	0.34
P_2O_5	0.17	0.14	0.29	0.26	0.31	0.21	0.24	0.24	0.19	0.11	0.13	0.13
CO_2	0.10	—	0.10	—	2.20	—	2.02	—	—	—	—	—
S	0.06	0.09	0.09	0.08	0.23	0.08	0.04	0.07	0.05	0.06	0.04	0.05
F(S)	0.05	0.08	0.07	0.07	0.20	0.07	0.03	0.06	0.04	0.05	0.03	0.04
H_2O+	4.30	2.34	3.84	3.76	4.18	3.92	3.02	2.20	3.69	1.02	0.89	0.50
Cr_2O_3	0.26	—	—	—	—	—	—	—	—	—	—	—
NiO	0.05	—	—	—	—	—	—	—	—	—	—	—
TOTAL	99.72	99.51	99.63	99.75	99.47	99.52	99.69	100.47	99.46	100.66	99.46	100.70

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TABLE 5

Niggli parameters

No.	Sample no.	Si	al	fm	c	alk	K	mg	c/fm	ti	p	w	Qr	Q	L	M	Magma type
1	39	94.14	13.37	56.03	28.84	1.76	0.26	0.77	0.51	0.69	0.14	0.48	−12.90	25.78	21.59	52.63	pyroxenitic
2	94	109.25	26.74	36.05	32.55	4.66	0.05	0.62	0.90	1.22	0.12	0.47	− 9.39	31.74	38.91	29.35	gabbroic
3	36	114.30	22.54	45.35	24.27	7.84	0.31	0.69	0.53	1.13	0.28	0.52	−17.06	29.06	36.99	33.95	gabbroic
4	91	122.87	26.56	40.44	20.84	12.16	0.14	0.53	0.51	2.01	0.27	0.45	−27.77	28.59	43.98	27.43	dioritic
5	28	153.68	26.75	40.59	25.67	6.99	0.16	0.58	0.63	1.77	0.38	0.30	+25.72	40.35	34.92	24.73	dioritic
6	101	180.50	32.27	33.29	18.32	16.12	0.20	0.42	0.55	1.82	0.26	0.59	+16.02	39.52	43.83	16.65	quartz-dioritic
7	117	188.90	31.05	27.03	25.56	16.36	0.22	0.47	0.94	1.79	0.34	0.57	+22.46	40.60	42.03	17.37	quartz-dioritic
8	88	192.80	29.08	33.83	21.07	16.02	0.33	0.60	0.62	1.89	0.33	0.55	+28.72	41.22	39.74	19.04	quartz-dioritic
9	102	292.69	35.31	27.27	19.93	17.49	0.04	0.47	0.73	0.92	0.24	0.68	+122.73	54.46	35.45	10.09	granodioritic
10	100	389.86	44.89	13.37	6.26	35.54	0.20	0.33	0.46	1.36	0.26	0.84	+154.70	54.89	40.11	5.00	trondhjemitic
11	134	441.16	42.54	14.59	9.43	33.46	0.41	0.33	0.64	1.38	0.35	0.84	+207.32	59.32	36.82	3.86	leucogranitic
12	135	432.73	40.34	16.70	16.63	26.33	0.29	0.35	0.99	1.50	0.34	0.45	+227.41	61.66	33.25	5.09	leucogranitic-granitic

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acidic rocks are marked by a high concentration of SiO_2 and alkalis and by the pronounced decrease of mafites.

The different groups of island arc volcanics have been mainly delimited by the differentiation of basalt-andesitic magmas which are calc-alkaline magmas as shown by the diagrams of Figure 1, drawn up according to Miyashiro (1975). This feature is clearly pointed out by the SiO_2-FeO tot/MgO diagram, on which the rocks are plotted on the calc-alkaline field, being parallel to the differentiation trends of the Amagi and Asama island arc volcanics, that is diverging as compared to the differentiation trends of the ophiolitic rocks from the region basement. This conclusion is accounted for by the other two diagrams on which the rocks enter the calc-alkaline field and occur along the curves of Amagi and Asama volcanoes, as well. The calc-alkaline nature of the magmas which generated the island arc volcanics is also disclosed by the diagram of Figure 2, drawn up according to Irvine and Baragar (1971), on which the rocks are plotted below the curve that delimits the fields of tholeiitic rocks from that one of calc-alkaline rocks, as it has been already mentioned in the study of Upper Jurassic island arc volcanics in the Almaș Sălișteni-Godinești-Zam region (Savu et al., 1984).

These data prove that the island arc volcanics have been generated by a calc-alkaline magma formed within a plate margin area (Savu, 1980 b). This magma differentiated into basalts and basaltic andesites to rhyolites, following the curves nos. 3 and 4 reported by Miyashiro (1975, Fig. 4) which are almost perpendicular to the side FeO tot-MgO of the diagram and represent the differentiation curves of Izu-Hakone and Amagi calc-alkaline volcanics in Japan. The oligophyres and orthophyres in this region, which have not been analysed chemically nor spectrally, represent differentiates with alkaline bearing of the collateral trend, usually accompanying the calc-alkaline evolution trend of island arc volcanics in the Mureș Zone (Savu, 1962 a, b).

Most of the island arc volcanics resemble the rocks belonging to the Al_2O_3-rich volcanics series called "high alumina basalts" (Kuno, 1960, 1966, 1968). Some diagrams have shown that one or two rocks exhibit certain chemical features close to those of the rocks of the tholeiitic series, which could account for Miyashiro's (1974) opinion that under certain conditions, the first stage of island arc volcanism might be related to the occurrence of some tholeiitic basalts. Since they have been generated by a calc-alkaline magma these rocks are not tholeiites. Owing to their main features they are calc-alkaline basalts or andesitic basalts. They represent exceptions, are not important and do not stand for an essential feature of this volcanic activity.

Trace element distribution. The trace element distribution within Upper Jurassic island arc volcanics is typical of calc-alkaline igneous rocks.

The nickel, cobalt, chromium, vanadium and scandium contents decrease within the sequence of volcanic rocks concomitantly with the SiO_2 increase (Tab. 6). This general decreasing tendency is however marked by some differences. Thus, while the Co, V and Sc contents

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decrease uniformly, the Ni and Cr ones decrease irregularly. The Ni and Cr contents of ankaramite are higher (Ni=470 ppm; Cr=1800 ppm) due to the accumulation of pyroxene and partly olivine crystals within the magma.

TABLE 6

Trace element distribution (ppm) in island arc volcanics

No.	Sample no.	Ni	Co	Cr	V	Sc	Y	Yb	Zr	Ba	Sr	Pb	Cu	Ga
1	39	470	65	1800	200	44	11.5	1.5	38	60	105	3	100	11
2	94	66	30	200	180	27	15	2.4	30	65	105	3	63	15
3	36	170	44	540	270	37	16	2	60	900	240	16	78	14
4	91	38	32	35	320	27	21	2.9	100	220	650	5	100	21
5	28	55	30	155	300	27	23	3	100	70	135	7	175	17
6	101	10.5	13	9	190	18	21	3	120	160	720	7	22	18
7	117	17	11.5	19	150	16	24	3	115	180	460	6	32	16
8	88	50	16	100	105	18	18	1.2	95	360	350	14	38	15
9	102	8.5	6.5	8.5	57	8	12	1.5	75	200	460	3.5	18	11
10	100	7	3	5	28	5.5	17	1	120	560	180	7.5	6	12
11	134	7.5	4	4	42	6.5	17	1	130	500	170	6.5	4	12
12	135	12	5	22	40	6	16	1.5	125	280	180	4.5	12	13

The Y and Yb contents do not vary within wide limits like in the case of ophiolites ; their maximum values (Y=24 ppm ; Yb=3 ppm) are two times less than the maximum values reported for the ophiolitic rocks. On the diagram of Figure 3, on which basaltic and andesitic rocks were plotted, it is to note that the positive correlations Y-Zr and Yb-Zr are no longer obvious, as it is the case of ophiolites. When considering the entire sequence of island arc volcanics, one notes a tendency of Zr increase related to the more acidic members of the series (Tab. 6).

The barium contents of the basic and intermediate rocks of the volcanic series are generally higher than those of ophiolitic rocks. On the diagram of Figure 4 the rocks are plotted mainly on the field of island arc volcanics, placed outside the field of abyssal tholeiites from the Azores islands, being marked by higher Ba values.

The Sr content of the basaltic and andesitic rocks is of 105-720 ppm, while that one of the acidic rocks is of 170-180 ppm. It is worth mentioning that the Cu content decreases gradually from basic to acidic rocks, varying between 175 and 4 ppm.

Origin of magmas and the geotectonic conditions under which the island arc volcanics were generated

In the previous chapters it has been shown that the volcanic which overlie unconformably the ophiolitic basement exhibit features typical of volcanic rocks, thus differing from the tholeiitic (ophiolitic)

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series. In outcrops, both rock series resemble as regards their composition and dark colour, no differences being reported so far. That is the reason why, between the years 1963-1978 the Upper Jurassic volcanic rocks have been generally assigned to the ophiolitic series and to the second evolution stage of Alpine initial magmatism. Nevertheless, it is enough to note that the ophiolites form submarine flows of basaltic rocks with intersertal texture, while the island arc volcanics constitute mainly pyroclastics alternations of basaltic, andesitic and acidic rocks and then the difference between the two rock series is obvious. Thus, Savu and Udrescu (1973) considered that these Upper Jurassic "ophiolites", with features typical of volcanics, have been generated by bilateral subduction processes ; the same opinion was later supported by Savu and Nicolae (1975) and Savu (1976).

According to Savu et al. (1978) the Jurassic-pre-Oxfordian ophiolites in the Bunești area represent ocean floor magmatites and the Upper Jurassic, possibly Lower Cretaceous, volcanics represent island arc volcanics ; the correlation with the above mentioned subduction processes leads to a complete image of the magmatites associated with the evolution of the Mureș Ocean, from its constitution till its closing, during the Lower Cretaceous (Savu, 1980 a, b). Our recent data, regarding the Visca-Luncoi area, support the opinion mentioned above. Thus, on the diagram of Figure 5 all the Upper Jurassic island arc volcanics are plotted on the field of sialic rocks, which excludes from the very beginning, according to the modern definition of the ophiolite (Coleman, 1977 a, b), the assignment of island arc volcanics to this category.

These volcanics are the products of Upper Jurassic island arc volcanic activity, which developed along two alignments occurring on the borders of the oceanic plate of the Mureș Zone (Savu, 1980 a, b ; Savu, 1983), as shown by the diagram of Figure 8 on which the basic rocks of the Upper Jurassic volcanic series are plotted within the field of plate margin or island arc volcanics. This conclusion is also accounted for by the diagrams on Figures 6 and 7, on which the basic rocks of this series are plotted on the field of island arc basalts. This is shown by a Ti-Zr diagram (Fig. 9) drawn up according to Pearce and Gale (1977), on which all the Upper Jurassic volcanic rocks occur in the field of island arc basalts and andesites.

Therefore, the Upper Jurassic volcanics in this region, as well as the other consanguineous rocks of the same age in the Mureș Zone should be considered island arc volcanics. The products of this island arc volcanic activity differ obviously from the rocks occurring in classical ophiolitic areas, such as the Alps, Apennines and Dinarides. However, they cannot be assigned to ophiolitic rocks, as their differentiates move off the ophiolite field to corner Q of a QLM diagram. Excepting the ankaramite, an augite-rich volcanic rock, all the island arc volcanic rocks constitute the field "b" of island arc volcanics, on the diagram (Savu, 1980 a, b).

In some previous studies (Savu, 1983), the bilateral subduction process of the Transylvanian and Apuseni Mts microplates below the Mureș Zone was described ; two island arcs were formed and their

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products occurring to the west of the winding line Zam-Godineşti-Almaş Sălişte-Vaţa de Sus-Prăvăleni are mainly located on the alignments situated along the plate margins. To the east of this boundary they lie

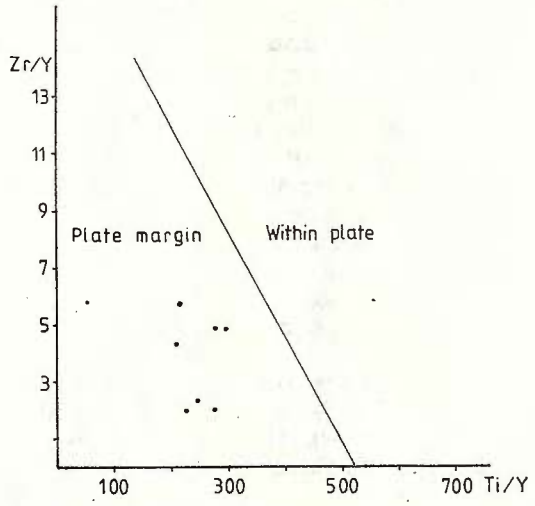


Fig. 8. — Zr/Y-Ti/Y diagram.

over the whole Mureş Zone and form a typical volcanic series, below which the basement ophiolites crop out in some inliers, like in the Visca-Luncoi area. Although the eastern area of the Mureş Zone is

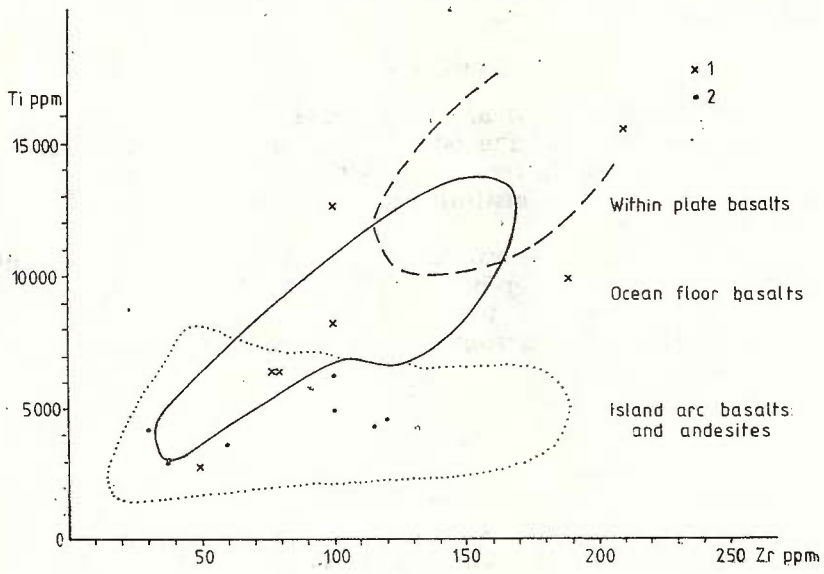


Fig. 9. — Ti-Zr diagram.
1, ophiolites ; 2, island arc volcanics.

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entirely covered by Upper Jurassic island arc volcanics, the alignments of the two main island arcs may be delimited most assuredly (Savu et al., 1984 ; Savu, 1983).

The Visca-Luncoi area is situated just to the north of the southern island arc located on the Căpîlnaş-Zam-Dănuleşti-Dealul Mare-Vălişoara-Almaşu Mare alignment and farther in the Trascău Mts. The axial area of this island arc coincides perfectly with an area of gravimetric minimum, reported by Andrei et al. (1971). It lies all over the island arc, that is over the volcanoes and the Upper Jurassic reef limestones occurring on this alignment.

Finally, the Upper Jurassic volcanics in the Băgara-Visca-Luncoi region, as well as the similar ones in other parts of the Mureş Zone, are island arc volcanics and cannot be assigned to the simatic series of ophiolitic rocks. Their sialic features show that the island arc volcanics resulted from the magmas generated by the oceanic crust melting on the two Benioff planes, marked by bilateral subduction processes (Savu, 1983).

According to some authors, the island arc volcanics would belong to the ophiolitic series ; this is the case of the Mureş Zone in the opinion of Cioflica et al. (1980). However, we consider — as usually (Savu, 1962 a, b ; 1980 a, b ; Savu et al., 1970) — that the ophiolitic series consist only of ocean floor rocks, similar to those in the Alps and Apennines, regions in which an ophiolite was described for the first time (Brongniart, 1913 ; Steinmann, 1927) ; the same is asserted by Coleman (1977 a, b). Otherwise, all island arc volcanics should be assigned to ophiolites independent of their position in the nappe or autochthon, as they usually originate in a more or less important orogenic movement (Savu, 1980 b) and exhibit similar petrological and geochemical features.

Conclusions

The rocks in this region are represented by tholeiitic (ophiolitic) rocks, Upper Jurassic submarine island arc volcanics, both assigned to initialites, Neokimmerian intrusions, banatites and Neogene volcanics.

The ophiolitic rocks constitute an ocean floor basaltic complex occurring in the basement.

The submarine or "pre-orogen" island arc volcanics represent a sialic calc-alkaline series different from the ophiolitic series.

The Neokimmerian and the banatitic (Laramian) rocks are represented by small acidic intrusions to which the main mineralizations in this area are related.

The Neogene volcanics (andesites) occur on very small areas.

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EXPLANATION OF PLATES

Plate II

Fig. 1. — Pillow lava in ocean floor basalts. Malu Valley.
Fig. 2. — Pillow lava of different size in ocean floor basalts. Malu Valley.

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Plate III

Fig. 1. — Elongated and slightly ovoid pillow lavas in ocean floor basalts. Malu Valley.

Fig. 2. — Elongated pillow lavas in ocean floor basalts. Malu Valley.

Plate IV

Fig. 1. — Ovoid or irregular segregations in the groundmass and crust of pillow lavas. Malu Valley.

Fig. 2. — Ovoid and irregular segregations in the vitreous crust of a basaltic pillow lava. Malu Valley.

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GEOLOGICAL MAP OF THE BÂGARA-VIȘCA-LUNCOI REGION

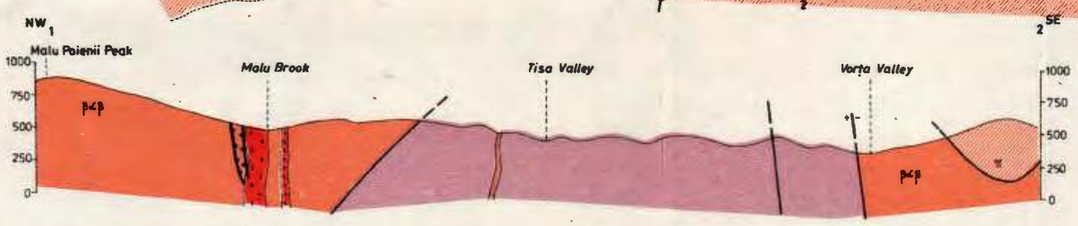
0 500 1000m

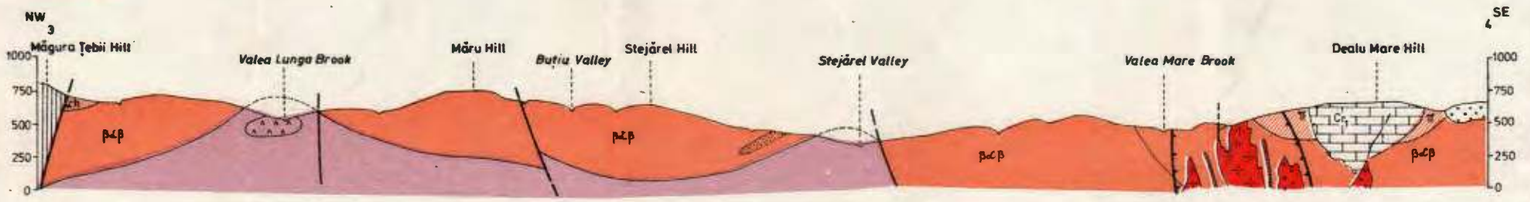
Măgura Tebii Hill
Malu Poienii Peak
898.6
Malu Peak
Scaunele Peak
Caraciu Lake
Cornet Hill
Piatra Hill
Poeni Peak
Holde Peak
Fruntii Hill
Cîrpinis Hill
Cristat Peak
Setea Peak
Pietrele Albe Peak
Sălișteu Hill
Priboi Hill
Bâdiș Hill
Stejărel Hill
Cuisu Peak
7036
Stejărel V.
Luncoiul de jos
Bâgara
Vișca
Cornetu Hill
Lunceșoara
Ursu Hill
Teiușu Peak
Podele
Dealu Mare Hill

LEGEND

- SARMATIAN PANNONIAN — Hornblende quartz andesites
- BADENIAN — Gravels, sandstones and clays
- BANATITIC OR LATE KIMMERIAN ROCKS — 1. Pyroxene diorites; 2. Quartz diorites and trondhjemites; 3. Quartz-diorite porphyrites; 4. Lamprophyres
- UPPER CRETACEOUS — Conglomerates and quartz sandstones
- UPPER JURASSIC LOWER CRETACEOUS — Stramberg limestones (J_3), limestones and conglomerate limestones (Cr_1)
- ISLAND ARC VOLCANICS UPPER JURASSIC LOWER CRETACEOUS — Pyroclastics ± flows of rhyolites, dacites, amphibole ± biotite quartz andesites; 1. Oligophyres; 2. Orthophyres (ol); Pyroxene-hornblende biotite andesites (ch); Basic tuffs and microagglomerates (b), agglomerates and flows of basalts and basaltic andesites (a); Ankaramites
- OPHIOLITES JURASSIC PREOXFORDIAN — Melagabbros and peridotites; Gabbros; Dolerites; Basalts, hyalobasalts, anamesites and variolites (pilow-lava) with scarce tachylyte intercalations and basaltic agglomerates

Fault
Geological boundary
Boundary of hydrometasomatic alteration areas
Vein sulphide mineralizations – pyrite ± oxides (a) – base metal sulphides (b)
Gallery
Geological section





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PETROLOGIA ROCILOR MAGMATICE

Project 195 : Ophiolites and Lithosphere of Marginal Seas

PETROLOGY AND GEOCHEMISTRY OF ALPINE OPHIOLITES FROM THE MEHEDINȚI PLATEAU (SOUTH CARPATHIANS) [1]

BY

HARALAMBIE SAVU [2], VASILICA NEACȘU [3], IRINA BRATOSIN [2], CONSTANȚA UDRESCU [2]

Ophiolites. Olistoliths. Tholeiitic magma. Ultramafic rocks. Peridotites. Subduction ; ocean floor. Modal composition. Major elements. Minor elements. Petrochemistry. Secondary transformations. Magmatic differentiation. South Carpathians-Sedimentary Danubian Domain (Severin Nappe included)-Cerna-Cazane Zone, Coșuștea-Balta-Baia de Aramă Zone.

Sommaire

Pétrologie et géochimie des ophiolites alpines du Plateau de Mehedinți (Carpathes Méridionales). Les olistolites de roches ultrabasiques et de mélange ophiolitiques du Plateau du Mehedinți ont été entraînées dans les formations de la nappe de Severin par obduction, étant rompues d'un complexe péridotitique de type alpin. Les roches ultrabasiques et basiques ont provenu d'un magma tholeiitique primaire, qui s'est différencié, engendrant ainsi une série ophiolitique de type „high-Ti". Les roches basiques de l'olistoplaque basaltique conservent les caractères généraux du magma tholeiitique, qui a entré en éruption sur le fond de l'Océan Carpathique (J_1-J_2). Du magma tholeiitique (basaltique) auquel correspond la plupart des roches basiques, s'est séparé un groupe de roches basiques différenciées, à deux directions d'évolution.

Introduction

Since now the ophiolitic rocks from the Mehedinți Plateau have not been the object of any petrological or geochemical study. A few chemical and spectral analyses have been carried on the ultramafic

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București 32.

[3] Întreprinderea de Prospecțiuni Geologice și Geofizice, str. Caransebeș 1, 78344 București 32.

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rocks by Mărunţiu et al. (1978) — which have not been published — and on the basic rocks by Cioflica et al. (1980).

Savu (1982) has already reported that the ophiolitic rocks from the Mehedinţi Plateau are allochthonous and occur either as olistoliths of ultramafic rocks and ophiolitic mélange (i.e. mélange in mélange) or as olistoplates of basic rocks included in the Jurassic olistostrome, to which belong also the Azuga Beds of the Severin Nappe. During the anchimetamorphism which acted on the Jurassic olistostrome, probably related to the Late Kimmerian movements, the ultramafic bodies were serpentinized and the basic rocks underwent several transformations, which altered the plagioclase and induced the advanced chloritization of clinopyroxene and glass.

Petrographic and mineralogical data regarding the ultramafic rocks

The structure of secondary mineral pseudomorphoses formed at the expense of the primary ones as well as the remnants of the latter prove that the serpentinized ultramafic rocks have mainly resulted from peridotites. With these associate in places serpentinite rocks formed at the expense of dunites and very rarely of pyroxenites. The first two rock types differ from each other due to the presence of an orthopyroxene and/or clinopyroxene besides olivine in peridotites and to the absence of these two minerals from dunites. Under the microscope, some rocks exhibit chromiferous spinels, primary magnetite and especially secondary magnetite, as well as other silicate minerals. The dunites which form separations in peridotites, occur either as thin layers, such as those of the rhythmic layering, or as somewhat larger ones.

a) *The dunites and peridotites,* which are closely related, include the following minerals : olivine, orthopyroxene, clinopyroxene, brown hornblende, spinels, magnetite and sulphides.

The olivine is very scarce ; it occurs as remnants of primary crystals which had been replaced by secondary minerals, generated during the serpentinization of rocks. It corresponds to a MgO rich variety of forsterite type. The olivine-rich serpentinized rocks exhibit a cellular structure (Pl., Fig. 1), deformed in places, which consists of a network of small veins made up of the chrysotile-lizardite association, in the mesh of which develops lizardite-antigorite associated with serpophite or only the latter in places. The serpophite occurs also in the axial zone of the veinlets in the cellular structure of rocks. During the substitution of olivine by serpentine, secondary magnetite formed ; it either occurs as a fine dust on the margins of pseudomorphoses after olivine or forms swarm-like concentrations in their central area, where it associates with isotropic serpophite or lizardite crystals. With the serpentine minerals the kämmererite, a chromiferous chlorite pleochroic in red and violet associates in places.

The orthopyroxene is usually bastitized and is substituted by serpentine minerals (Pl., Fig. 2). The orthopyroxene remnants, which are extremely scarce, point to a mineral belonging to the enstatite group ; orthopyroxene remnants with features similar to those of bron-

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zite occur in places. During the bastitization, iron oxides are generated, which arrange in rows parallel to the serpentine lamellae, that is parallel to the Z axis of the primary mineral. The rocks occurring at the springs of the Gradejnița Valley show that around the orthopyroxene, clinopyroxene did initially develop. As a result of bastitization of the former, the latter becomes an aureole round the bastite pseudomorphosis.

The clinopyroxene is the most resistant mineral during serpentinization and it is only rarely chloritized on margins (Pl., Fig. 3). The mineral exhibits variations in composition from diopside (c $\wedge$ Ng=38°) to titaniferous clinopyroxene (c $\wedge$ Ng=48°).

The brown hornblende is extremely scarce. It represents a primary (magmatic) remnant preserved during the anchimetamorphism of peridotitic rocks. The Lower Jurassic peridotites from the layered bodies in the Mureș Zone include the association olivine-clinopyroxene-brown hornblende-biotite (flogopite) in which the brown amphibole is a common mineral (Savu, 1962). The brown hornblende from the serpentinites occurring in the studied region shows the following optical properties : Ng=brown ; Nm=scarlet brown ; Np=brown yellow ; c $\wedge$ Ng=14°.

The spinels of these rocks occur as irregular grains, the features of which point to picotite and pleonaste. The former is a chromiferous variety and is the most frequent. The latter is extremely scarce ; it occurs as small crystals of dark green colour, sometimes with a chloritic reaction aureole on borders, formed during the serpentinization.

We note that the ultramafic rocks exhibit sometimes sulphides of pyrrhotite type, as well as isolated crystals of primary magnetite.

b) *The pyroxenites* consist of orthopyroxene, clinopyroxene, olivine, brown hornblende and spinels and are characterized by the prevalence of pyroxenes over olivine. According to the prevalence of one or another of the two pyroxenes, one distinguishes clinopyroxenites and orthopyroxenites, the component minerals of which do not differ qualitatively from those of peridotites.

c) *The Jurassic basic rocks* associated as exotic blocks within the olistoliths of ophiolitic mélange, are represented by gabbro-dolerites and basalts. The gabbro-dolerite which occurs at the springs of the Hoanca Valley is a massive black rock, with ophitic to hypidiomorphic-granular texture, which consists of altered plagioclase, clinopyroxene and scarce xenomorphic magnetite. The plagioclase which was represented by tabular or sligthly elongated crystals, polysynthetically twinned, is now completely replaced by sericite and albite grains. The clinopyroxene forms xenomorphic crystals, sometimes twinned after (100), the crystallization of which followed the plagioclase, just like in the rocks of other tholeiitic series. The extinction angle c $\wedge$ Ng is of 50°, pointing to a Ti-augite. Because of its titaniferous character, possibly of mechanic deformations too, it does not exhibit simultaneous extinction. The rocks are crossed by quartz and calcite veinlets.

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Secondary transformations of ultramafic rocks

The secondary transformations which act on the ultramafic rocks took place on the floor of the Jurassic ocean during the anchimetamorphism and immediately after. They are represented by metasomatic processes induced by the residual solutions of tholeiitic magma. These are the most important processes and were reported from the bodies that lie on the Valea Seacă north of Isverna, at Gornovița, on the Coșuștea Valley and on the Ciolanul Mare peak. Here, at the periphery of the areas affected by metasomatosis, the serpentine rocks are replaced by talc and rodingites are generated in places (Gornovița). Innerwards the serpentinites are highly impregnated with quartz and epidote (Gornovița, Valea Seacă), so that in the centre of the metasomatism zone form panallotriomorphic rocks which consist of quartz and deformed chlorite lamellae. These are hard rocks and during the various tectonic manifestations they did not undergo lamination as the serpentinites did, but mylonitization and brecciation ; the salic mineral is triturated and then turned into a mortar which cemented the big fragments of crushed rock.

The talc-rich rocks (Gornovița) are in places completely substituted by talc in very fine lamellae, arranged on two perpendicular directions which form a fine network that still preserves in places clusters of serpentine lamellae or even remnants of the unaltered serpentinitic rock. The rocks are crossed by quartz veins, in which big asbestos fibers occur from one wall to the other. There are also small asbestos metasomatic veinlets with the fibers in the same position.

The rodingites are serpentinized ultramafic rocks with hydrogarnets (Ciolanul Mare peak, Coșuștea Valley). These minerals form isotropic grains with irregular contour (Pl., Fig. 4) grouped together in clusters or small aggregates. These rocks do also contain magnetite swarms or secondary iron oxides, resulted from the release of iron from olivine and of pyroxenes during serpentinization, when Mg took part in the constitution of the serpentine mineral network.

It is to note also the rocks which consist of talc and hydrogarnets (Coșuștea Valley). They seem to have been rodingites subsequently replaced by talc and consist of a groundmass made up of the same fine talc lamellae and serpentinite remnants, crossed by asbestos veinlets including isolated or clustered hydrogarnet crystals with irregular contour.

The listwanites occur in certain hydrometasomatic alteration zones (Camena Valley). They consist of serpentinite, the mass of which contains numerous magnesite clusters. Veinlets of the same mineral cross the rocks ; there are also very thin asbestos veinlets with fibers perpendicular to their walls.

Geochemistry of ultramafic rocks

In order to define the petrochemical and geochemical features of the ultramafic rocks, 25 samples have been analysed chemically and by emission spectrography ; the results are shown in Tables 1 and 2.

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TABLE 1

Chemical composition of serpentinized ultramafic rocks

Number	1	2	3	4	5	6	7	8	9	10
Number of sample	9	10	41	75	52	29	77	35	12	14
Location	Camena Valley Podeni	Camena Valley Podeni	Coşuştea Valley Izverna	Obîrşia Cloşani	Valea Seacă Sălişte	Grădejniţa Valley Podeni	Obîrşia Cloşani	Giurgiani Valley Isverna	Valea Mare Gornenţi	Valea Mare Gornenţi
SiO_2	36.49	37.00	37.26	38.30	38.59	38.59	38.68	38.70	38.91	38.94
Al_2O_3	8.40	9.30	0.83	1.53	3.05	3.05	1.51	3.05	1.19	2.06
Fe_2O_3	3.08	3.80	4.33	7.40	6.43	6.05	6.44	6.05	5.40	4.59
FeO	3.28	2.38	2.69	2.10	1.51	1.39	1.09	1.39	2.25	1.36
MnO	0.25	0.15	0.05	0.10	0.12	0.12	0.07	0.12	0.12	0.11
MgO	34.67	33.46	33.00	37.30	38.20	36.10	38.50	36.10	38.66	38.73
CaO	0.42	1.17	5.03	0.06	1.80	1.16	0.04	1.16	0.11	0.12
Na_2O	0.019	0.040	0.012	0.018	0.019	0.003	0.013	0.003	0.026	0.611
K_2O	0.08	0.12	0.06	0.06	0.07	0.04	0.06	0.04	0.07	0.04
TiO_2	0.52	0.28	0.04	0	0.22	0.20	0	0.20	0	0.08
P_2O_5	0.06	0	0.08	0.04	0	0	0.08	0	0.06	0
CO_2	—	—	5.55	—	—	—	—	—	—	—
S	0.061	0.044	0.042	0.062	0.056	0.050	0.15	0.050	0.15	0.045
Fe(S)	0.05	0.04	0.04	0.05	0.05	0.04	0.13	0.04	0.13	0.04
H_2O^+	12.23	11.54	10.98	12.27	11.90	12.56	12.25	12.56	12.65	13.34
Cr_2O_3	0.32	0.32	0.30	0.26	0.35	0.45	0.24	0.45	0.36	0.26
NiO	0.16	0.18	0.15	0.22	0.25	0.24	0.22	0.24	0.29	0.22
Total	100.09	99.82	100.44	99.77	100.89	100.15	99.47	100.15	100.37	100.84

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Table 1 (continued)

Number	11	12	13	14	15	16	17	18	19	20
Number of sample	63	19	38	30	71	21	25	72	74	51
Location	Valea Seacă Sălişte	Grădejniţa Valley Podeni	Giurgiani Valley Isverna	Grădejniţa Valley Podeni	Gornoviţa	Grădejniţa Valley Podeni	Grădejniţa Valley Podeni	Gornoviţa	Ponoare	Valea Seacă Sălişte
SiO_2	38.96	38.97	38.98	39.00	39.02	39.12	39.18	39.30	39.40	39.60
Al_2O_3	1.71	3.50	2.56	2.25	3.54	1.69	1.48	1.49	3.70	1.28
Fe_2O_3	6.61	4.97	5.45	6.14	4.95	6.98	5.48	6.27	5.63	5.60
FeO	1.60	2.51	1.29	1.36	2.49	1.82	1.72	1.26	2.26	1.61
MnO	0.15	0.20	0.12	0.13	0.12	0.15	0.13	0.10	0.14	0.11
MgO	37.90	33.10	36.20	36.20	35.50	36.92	37.80	38.63	32.80	38.46
CaO	0.20	3.94	0.99	1.94	0.38	0.04	0.20	0.59	3.92	0.07
Na_2O	0.014	0.010	0.019	0.02	0.008	0.007	0.02	0.021	0.034	0.024
K_2O	0.06	0.02	0.09	0.06	0.04	0.05	0.04	0.02	0.03	0.04
TiO_2	0	0.27	0.09	0.08	0.08	0	0	0.10	0.18	0.40
P_2O_5	0.04	0.06	0.06	0.04	0	0.03	0.04	0.04	0	0.05
CO_2	—	—	—	—	—	—	—	—	—	—
S	0.062	0.07	0.062	0.048	0.062	0.11	0.088	0.060	0.081	0.042
Fe(S)	0.05	0.06	0.05	0.04	0.05	0.09	0.07	0.05	0.07	0.04
H_2O^+	11.75	11.13	12.93	11.95	12.82	12.25	12.71	12.40	11.15	12.76
Cr_2O_3	0.23	0.47	0.33	0.32	0.32	0.33	0.26	0.26	0.25	0.25
NiO	0.22	0.15	0.21	0.22	0.20	0.23	0.23	0.23	0.16	0.20
Total	99.55	99.44	99.43	99.79	99.58	99.72	99.45	100.82	99.80	100.53

Table 1 (continued)

Number	21	22	23	24	25
Number of sample	65	22	11	15	8
Location	Gornovița	Grădejnița Valley Podeni	Camena Valley Podeni	Valea Mare Gornenți	Camena Valley Podeni
SiO_2	39.78	39.78	39.90	40.10	40.60
Al_2O_3	1.69	2.12	0.96	1.33	1.30
Fe_2O_3	4.71	4.62	6.05	6.16	5.48
FeO	1.44	1.59	1.68	1.60	1.92
MnO	0.09	0.10	0.07	0.11	0.07
MgO	37.65	38.57	37.50	38.00	37.03
CaO	0.30	0.07	0.44	0.70	0.11
Na_2O	0.02	0.003	0.013	0.021	0.02
K_2O	0.05	0.04	0.08	0.07	0.11
TiO_2	0.09	0.14	0.10	0.08	0
P_2O_5	0	0	0	0.06	0
CO_2	—	—	—	—	—
S	0.054	0.10	0.15	0.085	0.063
Fe(S)	0.05	0.08	0.13	0.07	0.05
H_2O^+	13.17	12.49	12.74	11.90	12.55
Cr_2O_3	0.28	0.33	0.51	0.36	0.29
NiO	0.20	0.22	0.32	0.22	0.24
Total	99.57	100.26	100.64	100.86	99.83

TABLE 2

Minor elements (ppm) of ultramafic rocks

No.	No. of sample	Cr	Ni	Co	V	Sc	Cu	Ga
1	9	2200	1300	83	144	30	15	35
2	10	2200	1400	97	100	18	25	3
3	41	2100	1200	55	28	4	7.5	1
4	75	1800	175	92	30	6	11	1.5
5	52	2400	2000	115	42	6	9	1.5
6	29	1650	1500	78	30	5	11	2
7	77	1650	1750	100	30	6	7	1
8	35	3100	1900	130	52	9	47	2
9	12	2500	2300	120	35	6	13	1.5
10	14	1800	1750	82	34	7	17	1.5
11	63	1600	1750	95	32	5.5	9.5	1
12	19	3200	1300	90	190	22	7	1
13	38	2300	1650	90	43	7.5	33	2
14	30	2200	1750	115	46	8	10	1.5
15	71	2200	1600	82	54	9	9.5	2
16	21	2300	1750	100	44	8	6	2
17	25	1800	1800	105	35	7	11	1.5
18	72	1800	1800	95	26	5	11	1
19	74	1800	1750	92	30	6	11	1.5
20	51	1700	1550	90	26	5	8	1
21	65	1900	1550	95	27	5.5	6.5	1
22	22	2300	1750	100	44	8	6	2
23	11	3500	2500	140	31	6	9.5	1
24	5	1800	1750	82	34	7	17	1.5
25	8	2000	1900	100	33	6	13	1

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a) *Petrochemistry.* As one may infer from Table 1, the chemically analysed samples represent homogeneous ultramafic rocks, the main oxides of which vary within restricted limits.

The high water content of these rocks, which varies between 10.98 and 13.24%, points to the fact that they are all serpentinized rocks. Sample no. 3 contains some calcite proved by the amounts of 5.03% CaO and 5.55% CO_2. There is no direct correlation between the sulphur and NiO amounts determined by analysis, which show that the nickel may be included in the network of both pyrrhotite and olivine.

By taking into account the different rock components, such as Al_2O_3, MgO, CaO, SiO_2 and the FeO(tot)/Fe(tot)+MgO ratio which were considered in order to plot the rocks on two significant diagrams (Savu, 1985 — Figs. 1 and 2), it is to note that : (1) on both diagrams the rocks are plotted in the field of ultramafic cumulates ; (2) most of these rocks are plotted round the point of average composition of metamorphosed dunites (Fig. 1) ; in Figure 2 the same rocks enter the field of metamorphosed peridotites.

The values of the Niggli parameters vary between the following limits : si=58.41-65.49 ; al=0.82-8.86 ; fm=88.93-98.60 ; c=0.04-8.87 ; alk=0.03-0.19; k=0.33-0.90; mg=0.79-0.92; Q=5.93-18.77; L=0.20-6.42; M=83.24-98.51. According to them, all the rocks correspond to a peridotite magma. These data show that the obducted ultramafic rock olistoliths proceeded from the fourth complex of the ophiolitic series, formed on the floor of the Carpathian Ocean during the Jurassic (J_1-J_2), namely the peridotite complex. The ultramafic rocks of this complex have been generated as cumulates by the tholeiitic magma

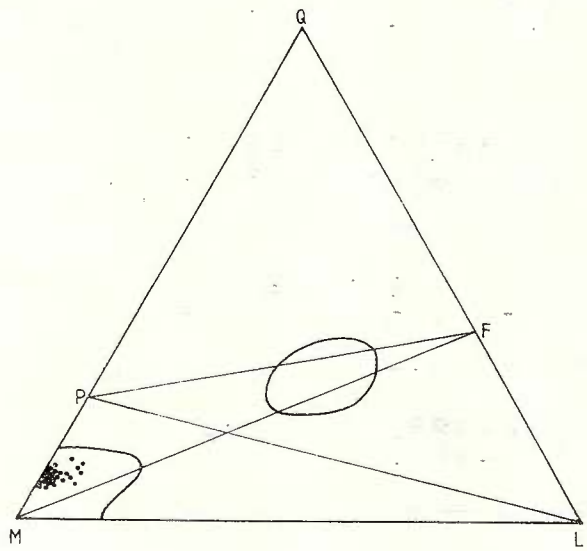


Fig. 1. — QLM diagram.

which had been formed as a pyrolith (Green, Ringwood, 1968) in the upper mantle. The insedimentation of the ultramafic rocks as olistoliths in the Jurassic olistostrome was followed by anchimetamorphic processes and serpentinization. The plotting of these rocks on the QLM

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diagram (Fig. 1) of Burri and Niggli (1945) accounts for their belonging to an Alpine ophiolitic series ; all the ultramafics from the Mehedinți Plateau are situated in the field of ultramafic rocks belonging to the Alpine ophiolitic series from the Apennines, Alps and Dinarides.

b) *Minor element distribution.* The minor elements from the ultramafic rocks are Cr, Ni, Co, V, Cu and Ga, according to the decreasing order of their contents (Tab. 2). As the chemical analyses have proved the ultramafic rocks exhibit a high homogeneity of minor element distribution, which show contents varying within restricted limits.

The Cr and Ni contents are higher than the other ones and they have been included in the olivine network during the crystallization of silicates. Cr may be also present in spinels and Ni in sulphides. The Cr contents vary between 1700 and 2500 ppm, with the exception of three samples in which its values are of 3100 and 3500 ppm ; rare chromite crystals occur in these rocks. The Ni contents oscillate between 1200 and 2500 ppm. The average values of 2152 ppm Cr and 1720 ppm Ni respectively enter the field of average values stated by Turekian and Wedepohl (1961), Vinogradov (1962) and Goles (1967) regarding the variation of these elements in the ultramafic rocks, which exhibit 1600-2400 ppm in the case of Cr and 1500-2000 ppm in the case of Ni. The Cr/Ni ratio is bigger or equal to 1, except for the three rocks richer in Cr which show a higher ratio. On the diagram of Figure 2, drawn up after Malpas and Stevens (1977), most of the rocks enter the field of Alpine type ultramafics, being situated in the neighbourhood of the boundary which delimits this field from that one of layered intrusions ; only four rocks occur in the latter field.

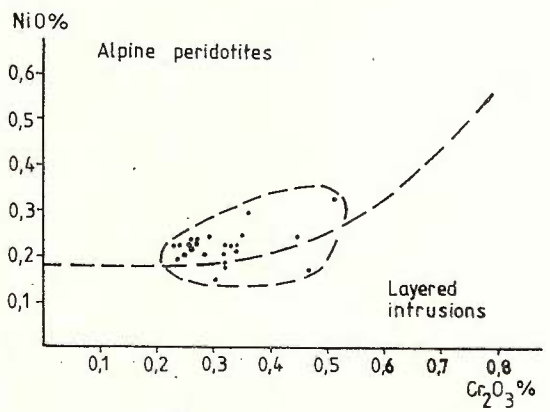


Fig. 2. — NiO-Cr_2O_3 diagram.

The Co contents vary between 55 and 140 ppm ; the average value of 97 ppm is close to the average of 110 ppm reported by Goles (1967) for similar rocks.

The V contents represent 26 to 54 ppm and the average content is of 36 ppm, very close to the average of 40 ppm reported by Turekian and Wedepohl (1961) and Vinogradov (1962). An exception is re-

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presented by three samples which show V contents of 100 to 190 ppm, values which have not been considered for calculating the average value. These three samples do also exhibit higher Sc contents (18-30 ppm), while in the case of the other rocks the Sc values vary between 4 and 9 ppm, with an average value of 6.5 ppm. This is lower than the average of 15 ppm established by Turekian and Wedepohl (1961) and of 16 ppm Sc reported by Goles (1967).

The Cu contents are of 6 to 47 ppm and the Ga ones are extremely low (1-3.5 ppm) pointing to the low Al_2O_3 contents of these rocks.

Geochemistry of basic rocks

In order to determine the geotectonic conditions under which the ophiolitic series was formed and from which the igneous melanocrate rock olistoliths from the Mehedinţi Plateau were scraped as well as the magmatic evolution of this series, the basic rocks occurring in the north of this region have been analysed, too (Tab. 3). They represent a basaltic complex (O_1), generally in pillow lava facies, which formed on the floor of the Lower Jurassic Carpathian Ocean and where from they were obducted as slabs in the Jurassic olistostrome and in the Azuga Beds respectively. They consist of anchimetamorphic lava flows which include a wide range of basic rocks such as hyalobasalts, variolites, basalts, anamesites and sills or dikes of dolerites and porphyritic dolerites. With the lavas associate tuffs and anchimetamorphic basalt agglomerates with interbedded pelitic schists and jaspers in places (Savu, 1985, Pl. II).

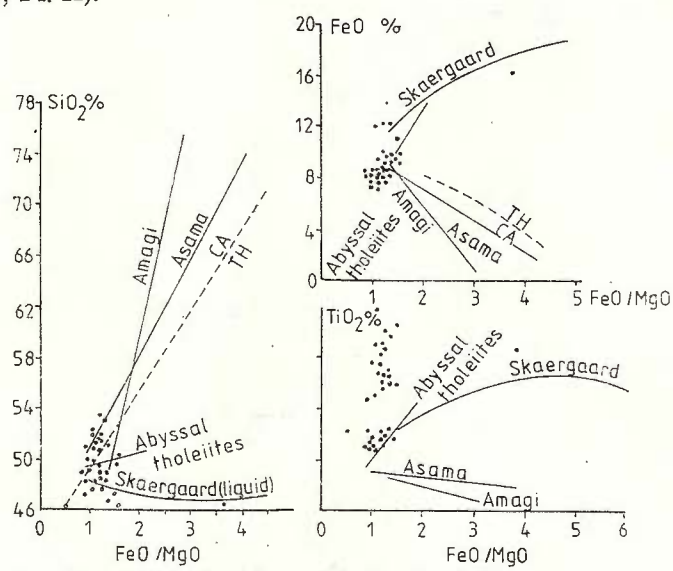


Fig. 3. — SiO_2, FeO(tot), TiO_2-FeO(tot)/MgO diagrams.

a) *Petrochemistry*. As shown by Table 3, the rocks of this basaltic complex are SiO_2 saturated tholeiitic rocks, fact also proved by the diagrams of Figure 3, drawn up according to Miyashiro (1975). The

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TABLE 3

Chemical composition of basic rocks

Non-differentiated basic rocks										
Number	1	2	3	4	5	6	7	8	9	10
Number of sample	18*	111	117	101	78	89	84	116	105	102
Rock type	Altered basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Dolerite	Basalt
Location	Grădejniţa Valley Podeni	Măgura Valley	Ghinii Valley	Brebina Valley	Bradul Brook	Brebina Valley	Brebina Valley	Turcu Valley	Băroaia Valley	Băroaia Valley
SiO_2	35.38	44.39	44.68	46.07	47.00	48.26	48.38	49.07	49.36	49.72
Al_2O_3	11.55	15.14	16.29	16.04	19.16	15.24	16.15	15.15	15.79	15.25
Fe_2O_3	3.87	2.47	1.84	2.16	2.24	1.89	1.55	1.99	2.75	1.50
FeO	5.84	7.11	6.47	8.98	5.89	6.18	6.39	6.03	6.32	6.54
MnO	0.52	0.16	0.19	0.19	0.17	0.15	0.19	0.13	0.16	0.17
MgO	19.20	8.45	8.09	7.85	9.10	6.56	8.58	8.17	7.55	7.18
CaO	13.89	7.85	9.87	9.06	4.63	11.51	9.07	11.36	10.77	10.38
Na_2O	0.02	3.35	3.48	2.59	2.50	3.07	2.88	2.62	2.06	3.77
K_2O	0.12	0.03	0.43	0.22	3.63	0.39	0.33	0.45	0.55	0.12
TiO_2	1.54	1.25	1.12	1.42	1.54	1.48	1.29	1.22	1.46	1.13
P_2O_5	0.22	0.14	0 17	0.12	0.12	0.18	0.16	0.12	0.18	0.12
CO_2	—	3.28	1.94	0.59	—	—	—	—	—	0.74
S	0.050	0.37	0.17	0.074	0.049	0.051	0.052	0.052	0.14	0.052
Fe(S)	0.04	0.32	0.15	0.06	0.04	0.04	0.045	0.045	0.12	0.045
H_2O^+	8.29	5.12	4.56	4.73	4.82	4.48	4.38	3.42	3.00	2.73
Total	100.57	99.43	99.42	100.15	100.88	99.48	99.44	99.82	100.21	99.44

* Sample 18 includes 0,03 Cr_2O_3 and 0,01 NiO

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Table 3 (continued)

Non-differentiated basic rocks					Differentiated basic rocks					
No	11	12	13	14	15	16	17	18	19	20
No. of sample	92	86	85	80	79	109	110	98	81	112
Rock type	basalt	basalt	basalt	basalt	basalt	porphyritic dolerite	anamesite	variolite	basaltic tuff	basalt
Location	Dragu Valley	Brebina Valley	Brebina Valley	Bradu Brook	Bradu Brook	Măgura Valley	Măgura Valley	Brebina Valley	Brebina Valley	Măgura Valley
SiO_2	49.94	50.58	50.79	50.89	42.38	46.32	46.68	47.06	47.68	47.70
Al_2O_3	16.30	15.44	15.40	14.97	14.15	11.90	15.65	15.84	15.80	14.30
Fe_2O_3	1.68	2.08	1.80	2.85	0.96	11.63	2.42	2.22	2.65	2.24
FeO	5.39	5.82	5.60	5.89	7.46	5.10	7.15	6.92	5.75	7.17
MnO	0.18	0.18	0.18	0.16	0.32	0.25	0.13	0.11	0.15	0.17
MgO	7.33	6.89	7.68	7.59	9.55	4.21	6.85	6.04	7.91	7.40
CaO	9.51	10.07	9.54	7.85	17.75	7.27	12.40	9.18	8.66	12.74
Na_2O	3.55	2.89	3.08	3.57	0.24	3.90	2.04	2.75	3.38	1.49
K_2O	0.69	0.19	0.64	0.69	0.08	0.30	0.11	0.23	0.32	1.40
TiO_2	1.33	1.54	1.35	1.38	2.22	3.16	2.66	2.48	3.24	2.64
P_2O_5	0.16	0.14	0.24	0.16	0.42	0.40	0.20	0.24	0.16	0.18
CO_2	—	—	0.40	—	—	2.03	—	1.80	0.92	—
S	0.051	0.052	0.047	0.049	0.054	0.047	0.08	0.046	0.054	0.057
Fe(S)	0.04	0.045	0.04	0.04	0.05	0.04	0.07	0.04	0.05	0.05
H_2O^+	3.55	4.00	3.69	3.35	3.79	4.03	4.40	4.67	3.66	3.30
Total	99.70	99.91	100.48	99.44	99.42	100.59	100.84	99.62	100.29	100.83

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Table 3 (continued)

Differentiated basic rocks															
No	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
No. of sample	103	114	82	104	97	113	108	83	94	96	107	95	87	99	100
Rock type	dolerite	hyalo-basalt	basalt	dolerite	basaltic tuff	basalt	aname-site	hyalo-basalt	basaltic tuff	basaltic tuff	basalt	aname-site	basaltic tuff	basalt	basalt
Location	Băroaia Valley	Măgura Valley	Brebina Valley	Băroaia Valley	Brebina Valley	Măgura Valley	Măgura Valley	Brebina Valley	Brebina Valley	Brebina Valley	Măgura Valley	Brebina Valley	Brebina Valley	Brebina Valley	Brebina Valley
SiO_2	48.18	48.60	48.82	48.98	49.54	49.75	50.63	50.80	51.34	51.38	51.93	52.19	52.84	52,59	53.44
Al_2O_3	14.19	14.45	14.30	15.28	16.15	14.40	15.00	16.44	14.50	14.15	14.70	14.18	16.30	14,54	15.40
Fe_2O_3	3.43	2.04	1.74	1.03	2.78	2.71	1.61	1.45	2.17	1.48	2.15	2.29	3.66	1,91	1.64
FeO	6.02	7.57	7.93	6.60	5.53	7.07	6.61	6.59	5.55	6.38	5.56	5.03	4.62	5,85	6.11
MnO	0.17	0.17	0.16	0.18	0.11	0.20	0.12	0.17	0.15	0.12	0.14	0.12	0.12	0,11	0.14
MgO	8.22	7.65	7.41	7.84	6.74	6.48	6.78	7.81	6.69	6.30	6.72	6.78	6.07	7,28	6.28
CaO	9.38	8.29	10.10	9.99	8.73	8.74	7.64	6.79	9.34	10.66	6.65	9.37	6.20	8,25	6.85
Na_2O	3.28	3.62	1.83	2.59	3.07	4.18	4.46	4.10	3.83	2.55	4.47	2.19	4.13	2,15	3.97
K_2O	0.47	0.16	0.14	0.47	1.24	0.13	0.58	0.35	0.27	0.13	0.58	1.15	0.87	0,80	0.26
TiO_2	2.85	3.50	3.36	2.93	2.36	3.64	3.20	3.90	2.52	2.72	3.16	2.28	2.52	2,66	3.04
P_2O_5	0.16	0.24	0.22	0.26	0.18	0.24	0.28	0.14	0.34	0.24	0.26	0.24	0.16	0,18	0.20
CO_2	—	—	0.29	—	0.10	—	1.08	—	—	—	—	—	0.10	—	0.26
S	0.076	0.057	0.18	0.093	0.056	0.26	0.11	0.077	0.096	0.077	0.13	0.074	0.076	0,057	0.057
Fe(S)	0.06	0.05	0.15	0.08	0.05	0.22	0.09	0.07	0.08	0.07	0.11	0.06	0.07	0,05	0.05
H_2O^+	2.94	3.26	4.16	3.11	3.66	2.60	3.13	0.99	3.07	3.95	2.91	3.47	2.64	3,91	3.06
Total	99.42	99.66	100.79	99.43	100.29	100.62	100.72	99.67	99.94	100.21	99.47	99.43	100.37	100,33	100.75

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tholeiitic nature is clearly shown by the diagrams FeO(tot)-FeO(tot)/MgO and TiO_2-FeO(tot)/MgO, while on the diagram SiO_2-FeO(tot)/MgO only a few rocks enter the field of calc-alkaline rocks.

If one takes into account the variation of the two oxides — FeO(tot) and TiO_2 — which are typical of the differentiation of tholeiitic magmas (Fenner, 1929), the basic rocks from this region divide into non-differentiated tholeiitic rocks and differentiated tholeiitic rocks. These two groups and their petrochemical features are clearly shown when comparing their most mobile components during differentiation, as follows :

	FeO(tot)%	TiO_2%	Na_2O%	SiO_2%
Non-differentiated rocks	6.95—11.00	1.12—1.54	2.06—3.77	44.39—50.58
Differentiated rocks	7.15—15.61	2.22—3.90	1.49—4.47	49.94—53.44

From this table, one may infer that, as compared to the non-differentiated rocks, the differentiated ones exhibit an obvious enrichment in the four chemical elements mentioned above.

The differentiated basic rocks, just like the sheeted dike complex from the Mureş Zone (Savu et al., 1985), exhibit a FeO(tot) and TiO_2 enrichment of magmas in one direction and a SiO_2 and Na_2O enrichment in the other direction.

The slight differentiation of the tholeiitic series followed the line : tholeiitic non-differentiated magma → tholeiitic differentiated magma $\begin{cases} \text{Si and Na enriched magma} \\ \text{Fe and Ti enriched magma} \end{cases}$

As FeO(tot) enrichment progresses, the MgO content of magma increases as shown by the close values of the FeO(tot)/MgO and FeO(tot)/FeO(tot)+MgO ratios in both rock groups.

Because of the fact that the rocks are anchimetamorphosed, their plagioclase is only decalcified fact pointed out by the normal Na_2O content of the non-differentiated tholeiitic rocks. The Na_2O contents, which exceed 4%, of the differentiated tholeiites show that these rocks were represented by spilites, resulted from the differentiation of tholeiitic magma, just like the spilites from the sheeted dike complex in the Mureş Zone which exhibit a high value of this component. On the diagram of Figure 4, drawn up according to Irvine and Baragar (1971), the non-differentiated rocks occur in the field of SiO_2 saturated tholeiitic rocks, just like on Miyashiro's diagrams (1975) ; some of the differentiated rocks enter the calc-alkaline field due to their higher Na_2O content, although most researchers who studied the Alpine ophiolitic rocks from the Mehedinţi Plateau had considered them the most characteristic ocean floor tholeiitic series. This proves that the series has undergone differentiation processes, Na_2O enrichment

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respectively, which generated the spilites. Part of this Na_2O enrichment may be also due to anchimetamorphic processes. However, their influence was less important as they were too weak.

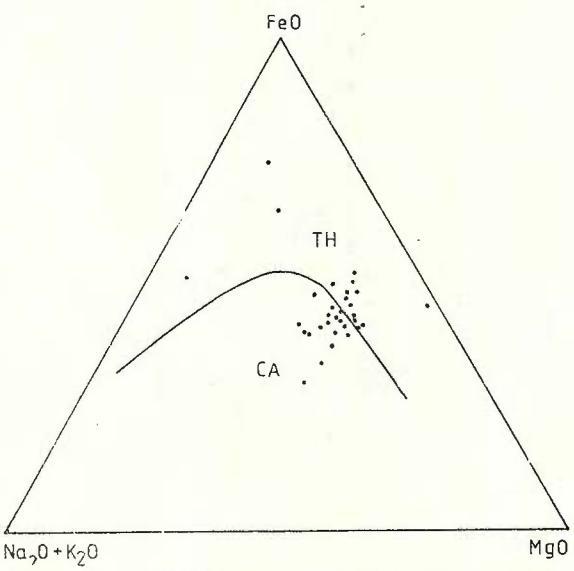


Fig. 4. — FeO(tot)-MgO-Na_2O+K_2O diagram.

The ophiolitic series from which proceeded the basic and ultramafic rock olistoliths from the Mehedinți Plateau was an ophiolitic series belonging to the "high-Ti ophiolites" group, as it is obvious on the diagram of Figure 5, drawn up according to Serri and Saitta (1980). On

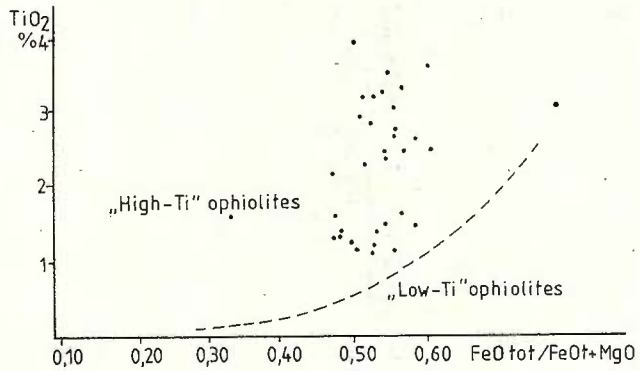


Fig. 5. — TiO_2-FeO(tot)/FeO(tot)+MgO diagram.

this diagram all the rocks enter the field of this type of ophiolitic series, thus resembling the basic rocks from median oceanic ridges. It is to note also on the diagram the two rock groups of the basaltic complex, namely the non-differentiated tholeiites and the differentiated

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TABLE 4

Minor elements (ppm) of non-differentiated basic rocks

No.	No. of sample	Ni	Co	Cr	V	Sc	Yb	Y	Zr	Sr	Ba	Pb	Cu	Ga	Sn
1	18	105	37	230	180	22							34	5.5	
2	111	85	20	240	120	26	1	13	60	120	15	<2	41	14	<2
3	117	75	24	190	135	28	1	12	57	150	55	<2	81	15	<2
4	101	75	25	180	180	34	1.5	16	82	130	25	<2	66	23	<2
5	78	180	33	340	180	30	1.5	12	50	46	410	<2	64	15	<2
6	89	80	35	200	230	37	1.8	16	82	125	23	3	90	16	<2
7	84	125	30	360	215	31	1.1	15	67	90	43	<2	82	15	<2
8	116	56	19	200	135	26	1.1	13	50	90	77	2.5	44	13	<2
9	105	73	22	155	160	23	1.4	14	64	155	45	2.5	47	17	<2
10	102	77	22	210	145	24	1.2	13	65	160	36	2	42	14	<2
11	92	77	24	260	170	31	1.7	15	70	115	130	<2	54	17	<2
12	86	60	28	74	280	28	1.9	17	95	175	30	<2	55	15	<2
13	85	100	35	180	280	39	1.8	19	82	175	55	2	81	14	<2
14	80	96	24	110	180	28	1.8	17	82	190	60	2	60	16	<2
X min		56	19	74	120	22	1	12	50	46	15	<2	41	13	<2
X max		180	37	360	280	37	1.9	17	95	290	130	3	90	23	<2
$\overline{X}$		90	27	209	185	29	1.5	15	70	148	50		60	16	

TABLE 5

Minor elements (ppm) of differentiated basic rocks

No.	No. of sample	Ni	Co	Cr	V	Sc	Yb	Y	Zr	Sr	Ba	Pb	Cu	Ga	Sn
15	79	95	45	260	200	33	1.4	22	95	75	30	2	17	8	<2
16	109	85	22	280	120	24	1.2	10	46	215	16	<2	49	12	<2
17	110	85	50	230	260	35	1.5	20	87	100	28	2.5	65	15	<2
18	98	125	32	280	200	34	1.7	21	80	55	40	<2	72	16	<2
19	81	85	40	165	260	40	2.1	24	85	200	62	<2	75	13	<2
20	112	80	54	135	300	35	2	24	75	130	60	2	55	13	<2
21	103	85	46	130	300	38	1.7	23	95	330	67	2.5	60	10	<2
22	114	80	50	65	320	36	2.4	24	120	185	55	<2	48	11	2
23	82	55	50	22	320	37	2.6	28	125	240	37	2	60	13	2
24	104	140	48	210	300	34	1.9	23	100	140	60	2.5	48	13	2
25	97	100	36	270	290	36	1.6	21	85	90	95	2	60	15	<2
26	113	80	48	95	340	37	3	31	135	150	62	4	55	14	<2
27	108	95	48	125	330	36	2.1	23	95	70	50	<2	52	14	<2
28	83	76	50	130	300	40	2	25	110	165	52	2	75	13	2,5
29	94	115	43	190	250	34	1.6	23	90	270	42	<2	60	11	<2
30	96	110	46	200	320	42	2.3	22	115	180	20	2.5	65	13	<2
31	107	100	55	140	340	38	2.1	24	115	55	55	3	55	12	<2
32	95	110	50	200	250	37	1.6	18	90	165	100	<2	65	12	<2
33	87	62	17	185	280	37	1.9	24	100	200	75	<2	44	14	<2
34	99	105	48	185	240	41	1.8	21	90	100	80	<2	62	10	2
35	100	85	48	150	320	42	1.8	25	130	240	46	<2	60	10	<2
X min.		55	17	22	120	24	1.2	10	46	55	16	<2	17	8	<2
X max.		140	55	280	340	42	3	31	130	330	100	4	75	16	2.5
$\overline{X}$		93	44	174	278	36	1.9	23	98	160	54		57	12.5	

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tholeiites, which proves that within a "high-Ti ophiolite series" there are differentiations as regards the TiO_2 content. The magma which generated this ophiolitic series was a primary magma, formed in the upper mantle by differential melting of the ultramafic substratum and not a secondary magma, generated by another tholeiitic magma. As far as we assume that this primary magma has supplied the ultramafic cumulates studied in the previous chapter then the "high-Ti ophiolite" character of this series could be due to the extraction of Mg and Fe from the magma, elements which may enter the network of olivine and pyroxene in the cumulates, as well as to the enrichment of this magma in Ti which lacks from the olivine network.

The two subgroups of differentiated tholeiitic rocks were formed during the evolution of this "high-Ti" ophiolitic magma during the Lower Jurassic spreading process, when, just like in the Mureș Zone, the Fe and Ti as well as the Si and Na-rich magmas were differentiated and spilites were generated.

b) *Minor element distribution.* By means of emission spectrography the minor elements from Tables 4 and 5 have been determined in the basic rocks. Their distribution will be referred to the groups of tholeiitic rocks, delimited in the previous chapter.

Except for the vanadium, the siderophyle elements Ni, Co and Cr vary within close limits in the two groups of rocks. The vanadium shows differences which increase obviously (200-340 ppm) in the case of differentiated rocks, as compared to the non-differentiated tholeiites that exhibit variation limits between 120 and 280 ppm. The high V content of the first group rocks is in agreement with the FeO(tot) and Ti enrichment of the differentiated magma, a main characteristic of the evolution of tholeiitic magmas.

The distribution of scandium may be correlated with the distribution of vanadium and both elements show the tendency of increasing in the differentiated rocks (Tab. 5).

As shown by Table 5, Yb, Y and Zr exhibit a slight increasing tendency in the differentiated rocks, which may be compared to the evolution of the Alpine tholeiitic magma from the Mureș Zone.

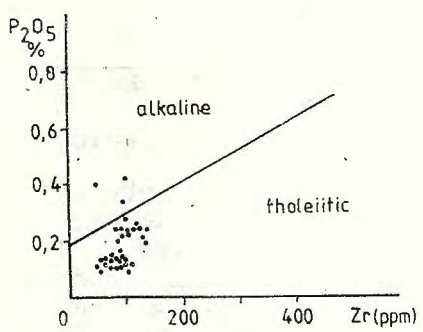


Fig. 6. — P_2O_5-Zr diagram.

On the Zr-P_2O_5 diagram of Figure 6, drawn up according to Beccaluva et al. (1977), the basic rocks from the Mehedinți Plateau are plotted on the field of tholeiites except for three samples, which

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show a high phosphorous content. They are differentiated rocks which tend to the field of alkaline rocks.

The strontium values do not show great differences from one group of rocks to the other, its average value being of 150 ppm in the non-differentiated rocks and of 160 ppm in the differentiated ones. According to these close values of Sr and by taking into account the diagram of Hart et al. (1970), one may infer that the magma which generated the series of ophiolitic rocks was formed in the upper mantle, at a depth of about 100 km.

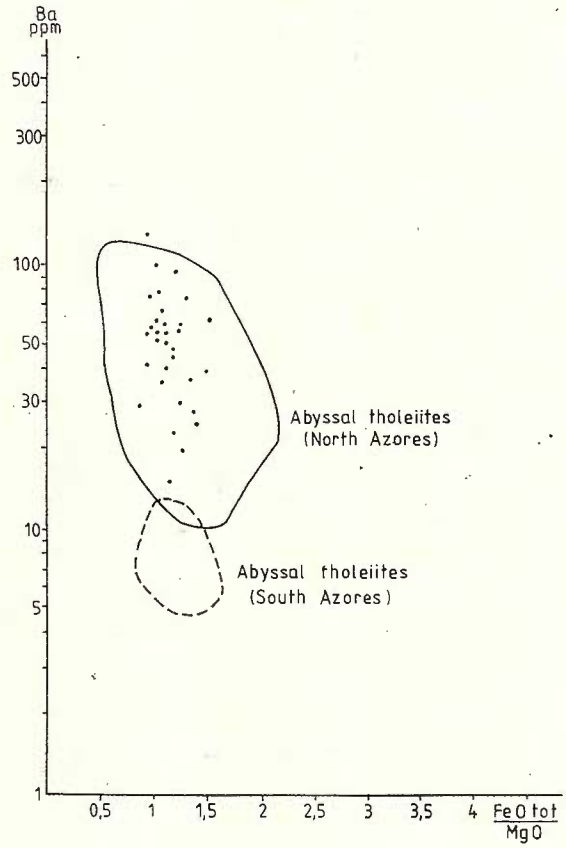


Fig. 7. — Ba-FeO(tot)/MgO diagram.

The Ba contents are quite similar in the two groups of rocks. Ba varies between 15 and 130 ppm in the non-differentiated tholeiites and between 16 and 100 ppm in the differentiated ones. As proved by the diagram of Figure 7, drawn up according to Miyashiro (1975), all the ophiolitic basic rocks from the Mehedinți Plateau enter the field of abyssal tholeiites from "North Azores", pointing to their belonging to an ocean floor basalt complex.

The other minor elements Pb, Cu, Ga and Sn are not relevant from petrogenetic point of view. It is to note the very low Sn and Pb

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contents, generally below the detection limit ; the same may be noted in the case of La and Nb (Tab. 4 and 5).

All over the series, the copper contents are very close, varying between 17 and 90 ppm. Similarly, the gallium values do not differ much in the two groups. In the non-differentiated rocks they vary between 13 and 23 ppm, and in the differentiated ones it is to note a decrease of Ga contents, between 8 and 16 ppm.

Origin of ophiolitic magma

The data mentioned above demonstrate that the Alpine allochthonous ophiolites from the Mehedinți Plateau have been generated by a SiO_2 saturated tholeiitic magma formed as a pyrolith in the upper mantle, at a depth of about 100 km. This magma erupted on the floor of the Carpathian Ocean, along the spreading centre, as shown by the diagrams of previous figures and mainly by the diagram of Figure 8, drawn up according to Pearce (1975) ; except for three rocks, the basic rocks enter the field of ocean floor basalts.

The primary tholeiitic magma gets differentiated at depth and generates the ultramafic cumulates of Alpine type (Fig. 1), the non-differentiated rocks and the slightly differentiated rocks, out of which some tend to become Fe, Ti and V enriched and others Si, Na, P, lantanides and Zr enriched. These trends point to the differentiation line of the tholeiitic magma which generated the sheeted dike complex

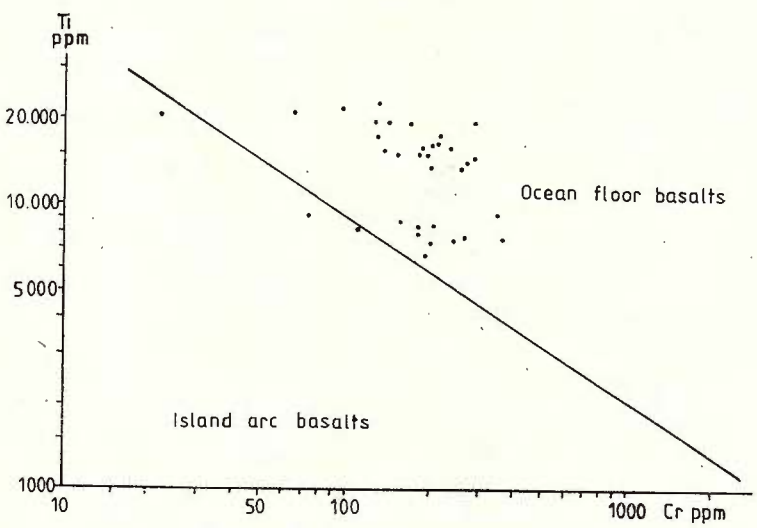


Fig. 8. — Ti-Cr diagram.

from the Mureș Zone (Savu et al., 1985). However, in the upper — basaltic — complex (O_1) of the ophiolitic series, as it is the case of the basaltic rocks in the Mehedinți Plateau, these two differentiation trends are less obvious.

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Conclusions

The following main conclusions are to be noted :

1. The olistoliths of ultramafic rocks and ophiolitic mélange from the Mehedinți Plateau were obducted from a peridotite complex of Alpine type.

2. The ultramafic and basic rocks were generated by a primary tholeiitic magma, which got differentiated and led to an ophiolitic series of "high-Ti ophiolite" type.

3. The basic rocks of the basalt slabs still preserve the general features of the tholeiitic magma which erupted on the floor of the Carpathian Ocean.

4. Besides the tholeiitic non-differentiated rocks, the main group in the region, one distinguishes another group of differentiated basic rocks with two evolution trends.

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EXPLANATION OF PLATE

Fig. 1. — Serpentinite characterized by cellular structure flattened during Late Kimmerian movements which led to the serpentinization of rocks. Hoanca Valley, N ||, × 30.

Fig. 2. — Serpentinite including bastitized orthopyroxene crystal. Giurgiani Valley. N ||, × 30.

Fig. 3. — Serpentinite with clinopyroxene remnants. Giurgiani Valley. N ||, × 30.

Fig. 4. — Rodingite. Gornova. N ||, × 30.

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STRUCTURAL, PETROLOGICAL AND METALLOGENETIC STUDY OF THE LARAMIAN INTRUSIONS LOCATED ON THE ARMENIŞ-LĂPUŞNICEL ALIGNMENT (BANAT) [1]

BY

HARALAMBIE SAVU [2], CONSTANŢA UDRESCU [2], VASILICA NEACŞU [2]

Banatites. Laramian igneous rocks. Calc-alkaline rocks. Petrochemistry. Magmatic differentiation. Petrological association. Minor elements. Ba. Sr. Porphyry copper. South Carpathians-Getic and Supragetic crystalline domains-Semenic and Western Ţarcu Mts.

Sommaire

Etude structurale, pétrologique, géochimique et métallogénétique des intrusions laramiennes sur l'alignement d'Armeniş-Lăpuşnicel (Banat). Les roches banatitiques situées entre Armeniş, Teregova, Pîrvova et Lăpuşnicel forment le troisième alignement de magmatites laramiennes de Banat. Au point de vue pétrochimique, ces roches constituent une série calco-alcaline, provenue d'un magma sialique et formée à la suite des processus de subduction, dans la partie inférieure de l'écorce terrestre. La ligne de différenciation de cette série pétrologique est représentée par l'association quartzdiorites-granodiorites-aplites. Les teneurs en éléments mineurs correspondent en général aux roches quartzdioritiques et granodioritiques. On remarque des teneurs plus élevées en Ba et Sr que dans d'autres séries magmatiques caractérisées par la même association pétrographique. Au niveau actuel d'érosion on trouve dans certains corps banatitiques de faibles concentrations de type "porphyry copper".

Introduction

The igneous bodies which occur in the banatitic (Laramian) province located in the west of Romania have been the object of geological studies since the last century (Cotta, 1865). They are of interest due to the petrological and geochemical features of banatites, as well as to

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[2] Institutul de Geologie şi Geofizică, str. Caransebeş 1, 78344 Bucureşti.

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the fact of being associated with hydrothermal, pneumatolytic mineralizations and metasomatic contact metalliferous concentrations.

The authors' investigations carried on the banatites in the Semenic Mts, initiated several years ago (Savu, 1962, 1964), have been extended to all the intrusions occurring on the Armeniş-Lăpuşnicel alignment which are less known. The present study is meant to complete the knowledge on the rocks in this area from structural, petrological, geochemical and metallogenetic view points. Data from reports drawn up in 1981 and found in the archives of IGG and IFLGS have been considered.

The first notes on the banatites in the Semenic Mts belong to Streckeisen (1932), then the data supplied by Hurduzeu (1962), Paraschivescu and Serghie (1963) and the recent ones of Hann (1973), Russo-Săndulescu and Berza (1979) are to be considered.

In 1962 and 1964 Savu drew up two detail maps (scale 1 : 10,000) of the eastern and south-eastern areas of the Semenic Mts, which include the crystalline schists belonging to the Dalslandian Sebeş-Lotru and Miniş series and the banatitic bodies located on the third Armeniş-Lăpuşnicel alignment, also figured on the appended map (Pl. I). The first map (1962) includes the crystalline schists and the banatitic rocks occurring between Armeniş and Luncaviţa and the second one (1964) those between Luncaviţa and Mehadica. In order to draw up the geological map on the scale of 1 : 50,000, sheet Pîrvova, published in 1974 by the Institute of Geology and Geophysics in Bucharest, Savu studied both the banatites and the crystalline schists occurring in the area of Mehadica, Pîrvova and Lăpuşnicel localities and got the map of the entire alignment (III) of Laramian rocks. The banatites in the northernmost area have been figured on the geological map, scale 1 : 50,000, sheet Văliug, published by the Institute of Geology and Geophysics in 1976.

Giuşcă, Cioflica and Savu (1966) have shown in their study on the banatitic (Laramian) province in Romania that in the Banat region the Laramian rocks occur on three characteristic alignments, out of which the eastern one is the less important, constitutes the object of the present study and is the third. The metallogenetic processes associated with the banatites on this alignment were studied by Savu et al. (1978) according to whom on this alignment is superposed a metallogenetic district characterized by pyrite or pyrite $\pm$ chalcopyrite (Savu, 1962) or pyrite and pyrrhotite mineralizations (Savu, Hann, 1981). According to Gunesch et al. (1978), Vlad (1979), Vlad and Gheorghiţescu (1980), Cioflica and Vlad (1980) the postmagmatic alteration maps and the distribution of pyrite and chalcopyrite depositions in the banatitic rocks would point to the occurrence of some mineralizations of porphyry copper type.

Distribution of Banatitic Bodies and Their Structure

The banatitic rocks in this area occur between Armeniş and Lăpuşnicel and form the third Laramian rock alignment in the Banat region, located in the east of the crystalline schist Semenic massif

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which is bordered eastwards by the Caransebeş-Mehadia Neogene sedimentary basin (Pl. I). These Laramian intrusions occur in the valleys Frîncu, Timiş, Teregova, Lazu, Luncavița, Verendin (Valea Satului), Mehadica (Belenicia) and Terova, as well as in the interfluves among them.

The banatitic bodies are located in the crystalline schists of the Dalslandian Sebeş-Lotru and Miniş series. From structural point of view, the crystalline schists of these two series constitute a virgation structure (Savu, 1975), the folds of which are gradually curving and sink from the east SSW-wards. Within the area of occurrence of the rocks belonging to the third alignment one encounters, the eastern end of the structures which form the virgation mentioned above. As the third banatitic alignment trends NNE-SSW, its intrusions cross unconformably the former Dalslandian structures (Pl. I).

The banatitic instrusions of this alignment occur as apophyses, irregular bodies, dykes and veins.

1. The most important apophyses and banatitic bodies are the quartz diorite ones located on the Frîncu and Lazu brooks, which horizontally are of oval or irregular shape. The biggest body occurs on the Lazu brook ; it is almost 1 km long and 0.5 km wide, while the smallest body, located at the springs of the same valley, is of only 200 m long and 80 m wide. The contact plane between these bodies and the adjoining crystalline schists sinks either below these bodies, when they are of laccolith shape and have been highly eroded, just like in the case of the bodies located downstream the Lazu brook, or outside the bodies below the crystalline schists (Pl. II, Fig. 1), when the bodies crop out on smaller areas and correspond to the apophyses of one or several important bodies, located at depth. Around these bodies there is usually a contact metamorphism aureole.

2. The dykes consist mainly of quartz-diorite porphyrites. They are almost vertical, longer and thinner than the ones mentioned at point 1. The most important dykes are those occurring to the north and south of the Verendin locality. They are situated along a N 10°E trending fault. The biggest one lies north of Verendin ; it is 1,6 km long and its thickness is of about 100 m. Quartz-diorite porphyrite dykes occur all over the area (Pl. I).

3. The veins are types of occurrences characteristic mainly of lamprophyres, but veins made up of quartz-diorite porphyrites or granodiorite porphyries may also be encountered. They are only a few meters thick. Aplite veins, a few centimeters thick are also present. They cross the porphyritic quartz diorite body on the Mehadica Valley (Pl. II, Fig. 2) and the quartz-diorite porphyrite dyke on the Verendin Valley (Pl. III, Fig. 1).

As regards the dykes and the veins, the contacts are usually plane, vertical or strongly inclined, according to the position of the fault on which the igneous body was emplaced. There are several places in which one encounters the proofs of the emplacement of the banatitic bodies on faults. On the Verendin Valley, in the western contact area of the quartz-diorite porphyrite dyke situated to the south of the locality bearing the same name, there is a tectonic breccia, 10 m

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thick, consisting of crystalline schists fragments with the diameter of 10-30 cm (Pl. III, Fig. 2). The breccia fragments are displaced and in the neighbourhood of the contact area with the dyke they are cemented by the igneous matter migrated from the igneous body during its emplacement. Thus, an eruptive breccia, according to Balk (1937), is generated. The crystalline schists of the breccia are included within the body. Another example of this kind was observed on the Teregova Valley, where one encounters a quartz-diorite porphyrite vein, 8 m thick, which trends N 20° E/60°N. In the north-western contact area of the vein, the crystalline schists are strongly brecciated on about 30 cm in thickness.

The sketch map drawn up by Gunnesch et al. (1979) presents only one fracture which crosses the region and corresponds to a major terrestrial discontinuity line, reported by geophysical prospecting (Cristescu, 1975) between Caransebeș and Dubova. This discontinuity line may stand for the major fracture which borders the Neogene Caransebeș-Mehadia basin westwards and thus it seems to belong to the Early Tortonian. Along the banatitic alignment, except for the fault occurring on the Verendin Valley on which the two dykes mentioned above were emplaced, there are no signs of a single fault along alignment III, as far as north of Armeniș this banatitic alignment bends NE-wards, somehow parallel to the Getic Nappe plane (Savu, Hann, 1981) ; thus, it is intersected, probably at Sadova Veche, by the western border of the Neogene Caransebeș-Mehadia basin, that is the Caransebeș-Dubova discontinuity line. Therefore the banatitic bodies occurring on alignment III are considered to have been emplaced on a Laramian fracture system, almost parallel, partly welded by the banatitic magma. In this region there are also other fracture systems, trending NW-SE and NE-SW, which have not been ways of access for banatitic magmas. These fractures may also be post-Laramian.

As concerns the trending of the igneous bodies, most of them are parallel to the alignment (N10°-20°E). There are a few cases in which the banatitic bodies may trend ENE-WSW or even E-W.

According to the occurrence of the rock types on alignment III, from the appended map (Pl. I) one may infer that the most widespread are the quartz-diorite porphyrites and the quartz diorites. The former occur along the entire alignment III, while the latter are more frequent in its middle and northern areas.

The banatitic rocks, mainly the quartz-diorites and quartz-diorite porphyrites, include two types of enclaves : crystalline schist xenoliths and autoliths. Some quartz diorite bodies situated on the Frîncu brook and the Verendin Valley contain separations of granodiorite nature, while some quartz-diorite porphyrite bodies (Verendin) and the porphyritic quartz diorite body on the Mehadica Valley include aplite veins, a few cm thick. In the first instance, the aplite veinlets occur on transversal fissures. Many bodies also include quartz veins associated or not with pyrite.

The granodiorite porphyries (quartz porphyries) constitute small size dykes and veins. They usually occur in the northern area of the alignment, mainly in the Timiș Valley.

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The lamprophyres (kersantites) are scarce ; they form two veins, one of them radially altered and located to the south of this area, west of Pîrvova, on the Terova Valley and the other one on the Cerbul brook.

Petrographic and Mineralogical Data

The banatitic rocks in this region belong to the following types : quartz diorites, porphyritic quartz diorites, leucodiorites, granodiorites, quartz-diorite porphyrites, granodiorite porphyries, aplites and lamprophyres. They have been described in detail in other studies (Savu, 1962, Savu et al., 1981).

The rock texture is hypidiomorphic-grainy or porphyritic, while the structure is massive. The groundmass of porphyritic rocks varies, as regards its crystallinity, from grainy in porphyritic quartz diorites to fine-grainy in porphyrites and porphyries. The lamprophyres exhibit a particular structure as compared to the other banatitic rocks. Their colour varies from dark grey to leucocratic types. The rocks consist of quartz, plagioclase (An_{40-28}), hornblende, biotite and orthoclase as main minerals. The porphyritic quartz diorites on the Mehadica Valley contain plagioclase phenocrysts with a diameter of 10-15 mm. Usually the plagioclase shows zoned structure and polysynthetic twins after albite, albite-Karlsbad and seldom pericline laws.

The hornblende is represented by a common variety with the following optical features : *Ng*=green ; *Nm*=brown green ; *Np*= =yellowish ; $c \wedge Ng = 20°\text{-}23°$. In the porphyrites it forms large phenocrysts with twins after (100). In lamprophyres the amphibole is darker and its pleochroism is : *Ng*=green ; *Nm*=light brown green ; *Np*= =yellowish.

The biotite occurs in most rocks and in some of them it replaces the amphibole. In the granodiorite porphyrites it forms idiomorphic phenocrysts, besides the quartz and plagioclase phenocrysts. The biotite crystals contain prehnite and rutile segregations.

The orthoclase occurs only in the most acid rocks. It usually appears as xenomorphic crystals with perthitic structure which fill the interstices among the other minerals ; the angle (—) 2V is somewhat smaller than the usual one.

The accessory minerals of banatitic rocks are apatite, titanite and zircon.

Epidote (pistacite) and chlorite are generated at the expense of melanocrate minerals, while sericite occurs at the expense of plagioclase and orthoclase.

The melanocrate segregations or autoliths (Didier, 1964) are those formations of enclave type present in banatitic rocks and especially in plutonic ones. The autoliths are generated during the initial crystallization stages of magma and consequently they consist of the main minerals which build up the host rock, their granulation being finer than the one of the latter. Thus, they are influenced by the magma flow currents during the emplacement of the banatitic body and they

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show disc shapes or are fusiform (Balk, 1937). An autolith of this type located in the porphyritic quartz diorite body in the Mehadica Valley exhibits the trending (L_1)=N50°E/50°N, which points out the trending and the angle under which the magma intruded.

As far as the autoliths depend on the composition of the host rock, they may be divided into hornblende autoliths, biotite autoliths or melanocrate minerals autoliths. The autoliths of the quartz diorites consist of amphibole and plagioclase, which are similar to the most developed minerals in the rock. Therefore, from the granulation point of view, the autoliths are small microdiorite enclaves and they have often been mistaken for these rocks. The autoliths of the leucocratic quartz diorites, which consist of plagioclase, quartz and biotite, possibly hornblende, occur as small size aggregates made up of fine biotite lamellae and small plagioclase crystals. In some other instances, biotite is accompanied by fine green hornblende crystals.

Contact Metamorphism

The contact metamorphism has acted on the crystalline schists of the Sebeş-Lotru Series and occurred at the expense of gneisses, micaschists and migmatite hornfelses as well as rocks characterized by different grades of thermic metamorphism. This metamorphism is superposed on the effects of Dalslandian regional metamorphism which took place in the kyanite, staurolite and kyanite and staurolite zones (Savu, 1969, 1970). The thickness of the contact area varies from 30 m to 800 m, the widest area being located in the Lazu brook, where the banatitic intrusions are bigger and grouped into several bodies in the same area. The effects of the contact metamorphism are stronger near the intrusions and in the crystalline schists xenoliths of these bodies. Farther from the intrusions, the effects of the thermic metamorphism diminish due either to the decreasing intensity of the main controlling factor, namely the temperature, or to the crystalline schists which are metamorphic rocks formed under the conditions of the metamorphic zones mentioned above, at temperatures of about 550°C and 700°C, and have been less altered. On the other hand, although the adjoining rocks have been less metamorphosed regionally — as for example those on the Alibeg brook, on the IInd banatitic alignment, where the crystalline schists of the Miniş Series, metamorphosed under the conditions of the biotite zone — they are altered at the contact of a small quartz diorite intrusion in andalusite and cordierite hornfelses, diopside hornfelses and amphibole hornfelses (Savu, 1970).

Within the area of banatitic intrusions which form the IIIrd alignment, the paragneisses and micaschists metamorphosed in the contact area, the following transformations are to be noted. The quartz recrystallizes in fine grains characterized by slightly rolling extinction; the rocks also contain quartz veinlets which start from the intrusive body. The plagioclase and the potash feldspar are also recrystallized. A part of the last mineral enters the rock concomitantly with the quartz, as orthoclase with microperthitic structure. Muscovite and biotite recrystallize in a finer aggregate which consists of the lamellae of the two micas. The aggregates preserve sometimes the contours

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of the replaced mica crystals, usually differently oriented, and form aggregates covered by recrystallized feldspars. The mica-rich bands of the crystalline schists contain, as a consequence of recrystallization, small andalusite grains, slightly pleochroic in rosy shades. Some sericite pseudomorphoses with clear-cut contours seem to represent replaced cordierite crystals. In some instances, the almandine crystals recrystallize in an aggregate built of fine biotite lamellae.

The contact rocks usually include a brown reddish biotite which is the most typical mineral of these hornfelses. It occurs as isolated lamellae or grouped in swarms, the trending of which does no longer correspond to the former foliation plane of the rock, which may be slightly recognized in places. The hornfelses also include zoisite clusters or pistacite in places. Big apatite crystals have also been reported. Other extremely fine crystals included in recrystallized feldspars or in andalusite probably represent a brown spinel. The migmatites, which are feldspar-rich rocks, show a slight recrystallization of these minerals and of pre-existing micas. In the areas far from the igneous bodies, the primary components of the crystalline schists are not altered, except for the biotite in which sagenite is recognized.

The characteristic paragenesis of the hornfelses generated next to the banatitic bodies is the following : plagioclase-quartz-andalusite (cordierite)-biotite (-muscovite). This paragenesis shows that the contact metamorphism took place in the amphibole hornfelses facies (Turner, Verhoogen, 1960), next to the intrusions and in the crystalline schist xenoliths and that its intensity decreased as the distance from the intrusive body increased.

Petrochemistry of Banatitic Rocks

In order to state the petrochemical features of the banatites occurring on the IIIrd alignment, 15 samples, which represent all the characteristic petrotypes in this area, have been chemically analysed. Table 1 includes the results of these analyses and points to the following main features of banatitic rocks chemistry. SiO_2 content is of 56.87% in lamprophyres and reaches 57.37% to 61.20% in quartz diorites, 65.75% in granodiorites and 74.71% in aplites which are the last differentiates of this petrological sequence. The slight decrease of the FeO, Fe_2O_3, MgO and CaO contents is also noted from lamprophyres to aplites. Both Na_2O and K_2O contents show close values for the three rock groups. An exception are some rocks, such as aplite, the K_2O of which represents 5.64%, and the granodiorite occurring on the Frîncu brook, with a Na_2O content of 4.30%. These data show that the banatitic rocks located on the IIIrd alignment constitute a petrographic sequence with chemically similar members, represented by the quartz diorite-granodiorite-aplite sequence.

The banatitic bodies show a gradual transition from quartz diorites to granodiorites, so that they include several acid segregations which cannot be mapped. It is to mention that in some segregations the K_2O content required for the granodiorite composition is not present in the potash feldspar which is absent, but in the biotite which

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TABLE 1

Chemical Composition

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sample	41	24	27	19	32	15	22	25	14	10	5a	36	37	3	31
Rock type	lampro-phyre	quartz diorite	quartz diorite	quartz diorite	quartz diorite	quartz diorite	granodio-rite por-phyry	grano-diorite	grano-diorite	grano-diorite	grano-diorite	grano-diorite	grano-diorite	grano-diorite	aplite
Location	Teregova Valley	Mehadica Valley	Mehadica Valley	Cerbul brook	Verendin Valley	Teregova Valley	Poiana brook	Mehadica Valley	Lazul brook	Lazul brook	Lazul brook	Verendin Valley	Luncavița Valley	Frincul Valley	Verendin Valley
SiO_2	56.87	57.37	59.23	59.96	60.75	60.80	61.20	61.52	61.55	61.55	63.50	63.70	63.85	65.75	74.71
Al_2O_3	17.48	16.80	16.80	15.90	17.50	17.75	17.10	17.35	17.60	17.44	16.80	17.40	16.65	17.19	12.34
Fe_2O_3	3.74	3.20	3.20	2.87	3.08	0.59	1.94	2.52	2.58	1.98	—	1.76	1.54	1.37	0.77
FeO	2.76	2.52	2.75	2.84	2.18	4.66	2.37	2.23	2.49	2.44	2.90	2.35	1.71	1.69	0.52
MnO	0.16	0.13	0.13	0.12	0.10	0.08	0.14	0.11	0.12	0.10	0.06	0.10	0.07	0.08	0.03
MgO	3.02	2.74	2.59	3.54	2.09	3.04	1.88	2.07	2.09	2.16	1.72	1.93	1.94	18	0.44
CaO	4.68	5.76	5.52	5.38	5.58	5.74	5.15	5.00	4.68	5.24	4.94	4.56	4.75	4.28	1.18
Na_2O	3.70	3.67	3.65	3.45	3.99	3.68	3.69	3.75	3.85	3.75	3.78	3.90	3.81	4.30	3.59
K_2O	2.07	2.25	2.33	2.66	2.33	1.69	2.42	2.06	2.53	2.41	2.22	2.23	1.46	1.95	5.64
TiO_2	0.66	0.63	0.63	0.57	0.51	0.88	0.55	0.47	0.65	0.55	0.64	0.50	0.55	0.35	0.21
P_2O_5	0.35	0.47	0.42	0.35	0.31	0.26	0.28	0.26	0.37	0.34	0.31	0.34	0.33	0.33	0.13
CO_2	1.33	1.88	2.02	—	—	—	—	—	—	—	—	—	—	—	—
S	0.09	0.06	0.10	0.06	0.12	0.11	0.46	0.10	0.08	0.41	1.54	0.57	1.35	0.05	0.05
Fe(S)	0.08	0.05	0.09	0.05	0.10	0.10	0.40	0.09	0.07	0.36	1.34	0.41	1.17	0.04	0.05
H_2O^+	3.02	2.45	1.27	1.86	0.83	0.75	1.92	1.88	0.81	0.81	1.07	1.23	1.30	0.88	0.49
Total	100.00	99.98	100.65	99.47	99.46	100.12	99.50	88.41	99.47	99.53	00.82	100.87	100.48	99.44	100.14
σ	20.88	20.84	20.87	21.84	26.49	15.99	24.38	28.93	21.15	24.89	120.34	27.00	23.34	26.83	41.66

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replaces the amphibole of the quartz diorite. Therefore the map representation (Pl. I) of some of these bodies as consisting of quartz diorites should be regarded as the preponderance of these rocks.

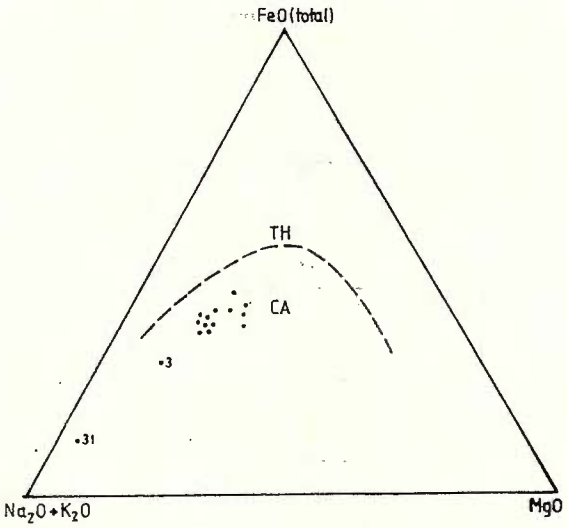


Fig. 1. — FeO(tot)-MgO-Na_2O+K_2O diagram.

The banatitic rocks constitute a calc-alkaline petrological sequence, as shown by the diagram of Figure 1, drawn up according to Irvine and Baragar (1971), on which all the banatites occur below the line which delimits the calc-alkaline and the tholeiitic rocks. The Niggli parameters (Burri, 1959), according to which the magma types corresponding to the banatitic rocks and the direction of variation (Tab. 2) have been stated, point to a calc-alkaline series, too. The most typical magma types of this sequence are the quartz-diorite and granodiorite magmas, at which add the peleeite magmas of the same petrochemical group and a leucogranitic magma.

According to the magmatic parameters of the Laramian rocks, which show close values, the banatites enter a small field on the QLM diagram, within the acid magmas domain. The lowermost area of this field includes quartz diorites and lamprophyres, then follow the six rocks of granodioritic type, the most acid being the aplite, which stands out obviously within the main field of banatitic rocks.

The magma types defined on the IIIrd alignment show that the primary magma was of quartz diorite composition. Its differentiation followed the evolution trend of calc-alkaline magmas to ultraacid magmas, such as the leucogranitic magma which generated the aplites, as shown by the diagram of Figure 2. The quartz diorite magma has also generated the more basic residual magmas, as for example the peleeitic magma which generated the lamprophyres.

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TABLE 2

Niggli Parameters

No	Sample	Si	al	fm	c	alk	k	m/g	cfm	ti	p	w	Qz	Q	L	M	Magma type
1	41	189.60	34.41	32.48	16.75	16.36	0.26	0.46	0.51	1.72	0.50	0.55	+ 24.16	41.40	44.39	14.21	pelecitic
2	24	192.99	33.33	29.21	20.72	16.74	0.28	0.47	0.71	1.67	0.75	0.53	+ 26.03	41.58	43.38	15.04	quartz-dioritic
3	27	201.69	33.74	29.11	20.12	17.03	0.29	0.45	0.69	1.69	0.65	0.50	+ 33.57	42.87	42.85	14.28	quartz-dioritic
4	19	198.94	31.09	33.04	19.09	16.78	0.34	0.52	0.57	1.47	0.49	0.49	+ 31.82	42.15	41.12	16.73	quartz-dioritic
5	32	209.07	35.58	25.42	20.58	18.42	0.27	0.42	0.81	1.05	0.43	0.56	+ 35.39	43.42	44.39	12.19	quartz-dioritic-granodioritic
6	15	201.14	34.68	29.55	20.35	15.42	0.23	0.50	0.69	2.14	0.32	0.10	+ 40.46	43.92	42.45	13.63	quartz-dioritic
7	22	225.48	37.17	23.62	20.36	18.85	0.30	0.44	0.86	1.54	0.40	0.43	+ 50.08	45.74	43.78	10.48	granodioritic
8	25	223.21	37.18	25.54	19.39	17.89	0.26	0.44	0.76	1.24	0.35	0.50	+ 51.65	46.06	43.46	10.48	granodioritic
9	14	219.04	36.96	26.08	17.88	19.08	0.30	0.42	0.68	1.81	0.57	0.49	+42.72	44.62	44.81	10.90	granodioritic
10	10	220.57	36.88	24.49	20.18	18.45	0.29	0.47	0.82	1.50	0.51	0.43	+ 46.77	45.27	43.87	10.86	granodioritic
11	5a	251.54	39.27	19.85	20.89	19.99	0.28	0.51	1.05	1.99	0.50	—	+72.58	48.72	42.96	8.32	granodioritic
12	36	239.44	38.59	23.62	18.32	19.47	0.37	0.77	0.77	1.35	0.54	0.42	+ 61.56	47.48	41.75	10.77	granodioritic mg>
13	37	254.66	39.19	22.06	20.36	18.39	0.20	0.52	0.92	1.67	0.55	0.44	+ 81.10	50.09	40.12	9.79	granodioritic
14		269.24	41.52	17.63	18.83	22.02	0.23	0.41	1.06	1.10	0.56	0.42	+ 81.16	50.00	42.20	7.80	granodioritic
15	31	433.17	42.27	9.68	7.24	40.81	0.51	0.39	0.74	1.07	0.45	0.56	+169.93	55.72	40.32	3.95	leucogranitic

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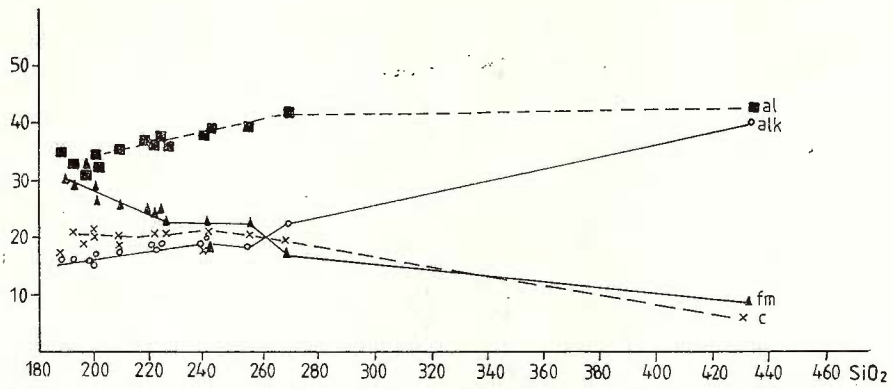


Fig. 2. — Differentiation diagram of banatitic rocks.

Distribution of Minor Elements

In order to state the distribution of minor elements in the banatitic rocks, the 15 samples from Table 1 and other 10 ones have been studied by emission spectroscopy. The data regarding these 25 samples are presented in Table 3 which includes the main types of banatitic rocks. As shown above, the banatitic rocks located on this alignment constitute a typical calc-alkaline sequence, the elements of which are much similar as regards their petrographic and, mainly, chemical features. The same may be said of the distribution of minor elements, which in most (70%) of the rocks belonging to this series show close values. Here it is to mention the quartz diorites, quartz-diorite porphyrites and most of the granodiorites. Apart from this main group stand some basic banatites, such as the quartz diorite (no. 15), the quartz diorite porphyrite (no. 33) and the autolithic melanocrate segregation (no. 19) in one direction and some acid rocks (granodiorites nos. 1, 3 and 5 and the aplite no. 31) in the other direction. This feature of the banatitic sequence is pointed out by the behaviour of Ni, Co, Cr, V and Sc, which are characteristic of the melanocrate minerals of igneous rocks. On the correlation diagram of Figure 3 most of the banatitic rocks group into characteristic fields, located on the positive correlation lines Ni/Co=1, Cr/Ni=0.6 and V/Sc=10. Near these correlation lines are plotted, at higher or lower values, the basic and acid rocks of the mentioned sequence.

Ytrium and yterbium show contents characteristic of quartz-diorite and granodiorite rocks mentioned in geological literature. On the diagram of Figure 4, all the rocks analysed group round the positive correlation line Y/Yb=10. Contents typical of the same rock groups are reported for Zr of the Laramian magmatites.

Ba contents vary between 340 and 960 ppm, the values exceeding 500 ppm are predominant. As compared to the Ba contents reported from the rocks at Săvîrşin (Savu et al., 1966), the Ba values shown by the rocks occurring on the IIIrd alignment in Banat are somewhat higher.

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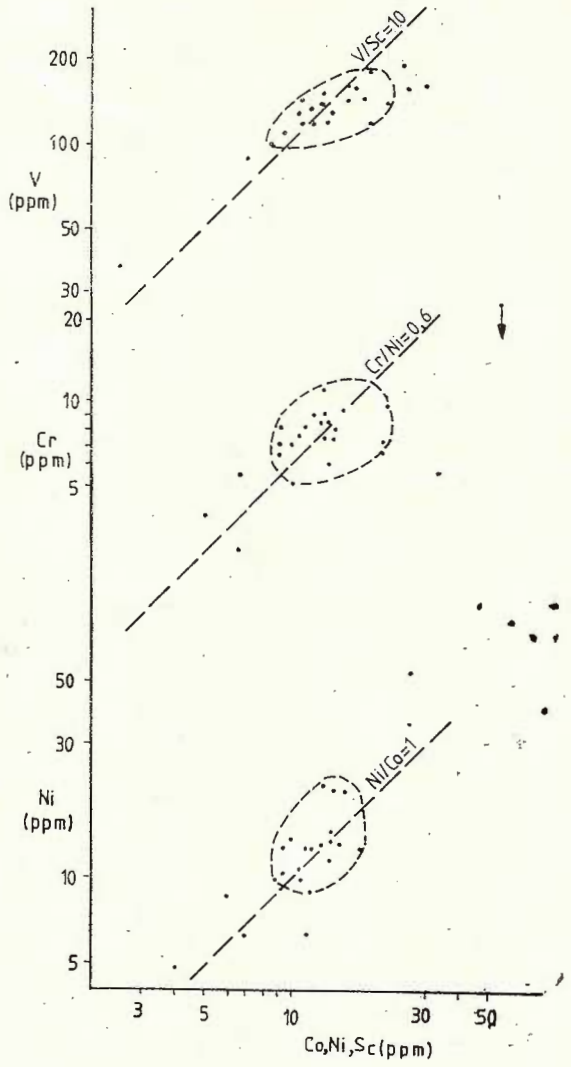


Fig. 3. — Diagram of Ni/Co, Cr/Ni and V/Sc ratio variation.

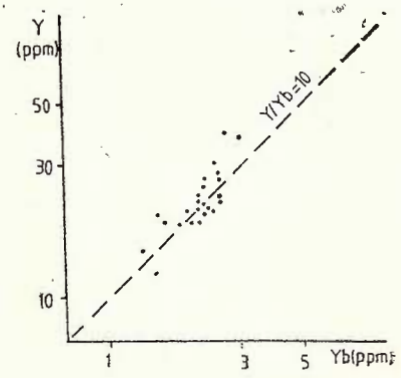


Fig. 4. — Y-Yb diagram.

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Strontium contents vary between 270 and 900 ppm in quartz diorites and granodiorites, being similar to those reported for the Săvîrșin banatitic massif. The Sr content of aplites is lower — 150 ppm.

The Cu and Mo contents of the banatitic rocks occurring on the Lazu brook, Verendin and Luncavița valleys are relevant from metallogenetic view point. The copper contents are normal in several rocks of this series, while in some magmatites it concentrates and reaches 120 to 260 ppm (Tab. 3). The contents are characteristic of the rocks in which chalcopyrite is dispersed as slight concentrations of porphyry copper type. Although molybdenum may not be detected (< 2 ppm) in most of the rocks, it shows significant contents (11 and 38 ppm) in the granodiorites nos. 10 and 37, from which the highest copper contents have been reported (Tab. 3).

Origin of Banatitic Magmas

The banatitic rocks have resulted from a SiO_2-rich magma (Giușcă et al., 1966), generated under subduction conditions (Rădulescu, Săndulescu, 1973). The sialic origin of the magmas is pointed out by the projection of rocks on the diagram of Figure 5, drawn up according to Gottini (1969); with no exception, they enter the field of sialic magmas. This origin is also supported by the reduced chalcophile elements contents and the high Ba and Sr ones.

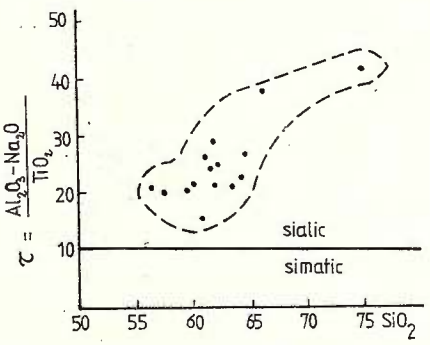


Fig. 5. — τ-SiO_2 diagram.

There has always been the question why the Laramian rocks in the Banat region do not exceed the Getic Nappe plane south-eastwards. It has been supposed that this plane was represented by the Benioff plane of Alpine subduction. Subduction processes took place along the South Carpathians and during the previous tectonomagmatic cycles (Savu et al., 1973); in all these instances the Benioff plane occurred at the limit between the mobile zone of the South Carpathians and the Moesian Platform with its old Precambrian core, subducted below the South Carpathians, namely outside the Danubian Autochthon, approximately in the area covered at present by the Pericarpathian Depression. Therefore, during the Alpine cycle, as well, the subduction plane occurred along the outer border of the Danubian Autochthon, which is

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TABLE 3

Minor Elements (ppm) in Banatitic Rocks

No.	Sample	Rock type	Location	Pb	Cu	Ga	Sn	Ni	Ca	Cr	J	Sc	Y	Yb	Zn	Mo	Ba	Sr
1	41	Iamprophyre	Teregova Valley	4.5	16	15	2	6.5	11.5	3	120	13.5	27	2.2	145	<2	620	850
2	24	quartz diorite	Mehadica Valley	9	17	18	2	13	11	11	150	13	18.5	1.8	140	<2	500	650
3	27	quarz diorite	Mehadica Valley	11.5	40	18	2	15	14	9	155	17	21	2.1	145	<2	520	450
4	19	quartz diorite	Cerbul brook	7.5	7.5	15	2.5	21	15.5	6.5	120	19	19	1.6	140	<2	650	460
5	32	quartz diorite	Verendin Valley	9.5	7.5	19	2	14	10	8	145	11	21	2.3	170	<2	550	600
6	15	quartz diorite	Teregova Valley	7	24	20	4	33	26	5.5	150	26	38	2.6	150	<2	340	270
7	22	granodiorite porphyry	Poiana brook	30	16	17	2	10	9	5	100	8.5	23	2.5	195	<2	600	670
8	25	granodiorite	Mehadica Valley	13	14	18	2	10.5	9.5	7.5	110	9.5	12.5	1.5	120	<2	700	650
9	14	granodiorite	Lazul brook	11	19	22	2.5	11	11	8	130	10.5	27	2.5	175	<2	570	500
10	10	granodiorite	Lazul brook	7	210	17	<2	13	12	8.5	120	12	20	2.2	135	11	440	350
11	5a	granodiorite	Lazul brook	11.5	34	18	2	6.5	7	5.5	90	7	18.5	2.1	160	<2	880	750
12	36	granodiorite	Verendin Valley	9	120	21	2	13	9.5	8.5	140	13	23	2.2	140	2.5	650	600
13	37	granodiorite	Luncaviţa Valley	6	260	18	2.5	9	12	6.5	135	12	19	2.0	140	38	500	580
14	3	granodiorite	Frîncul brook	27	6.5	19	2	9	6	7	75	5	23	2.5	170	<2	960	440
15	31	aplite	Verendin Valley	14	7.5	15	<2	5	4	4	37	2.5	15	1.3	110	<2	680	150
16	16	quartz-diorite porphyrite	Teregova Valley	18	21	16.5	2	21	14	7	145	16	21	2.3	140	<2	680	520
17	18	quartz-diorite porphyrite	Teregova Valley	55	19	14.5	2.5	22	13	9.5	160	16	21	1.9	140	<2	530	700
18	17	melanocrate segregation	Teregova Valley	30	17	16	<2	55	26	22	160	30	24	2.1	135	<2	620	450
19	23	quartz-diorite porphyrite	Mehadica Valley	10	46	15	2.5	12	14	9	130	14	23	2'1	130	2	500	490
20	8	quart-diorite	Lazul brook	7	32	18	<2	10	11	1	120	11	22	2.2	155	<2	530	900
21	7	quartz-diorite porphyrite	Lazul brook	6	120	16	2.5	13.5	15	6	145	18	28	2.5	190	3	580	580
22	33	quartz-diorite porphyrite	Verendin Valley	4.5	80	17	2.5	14	14	7.5	190	25	37	3.0	230	<2	380	800
23	1	granodiorite	Frîncul brook	23	5.5	13.5	<2	9	4.5	8	48	3.5	20	1.5	140	<2	850	300
24	40	quartz-diorite porphyrite	Pîrvova	11	16	15	2.5	13.5	16	7.5	180	19	26	2.2	150	<2	650	380
25	20	quartz diorite	Teregova Valley	6	34	15	2.5	13	18	9	140	22	30	2.4	180	<2	380	350

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proved by the presence of the Pericarpathian Depression which acted by that time as a sedimentation trough along the Benioff plane (Fig. 6).

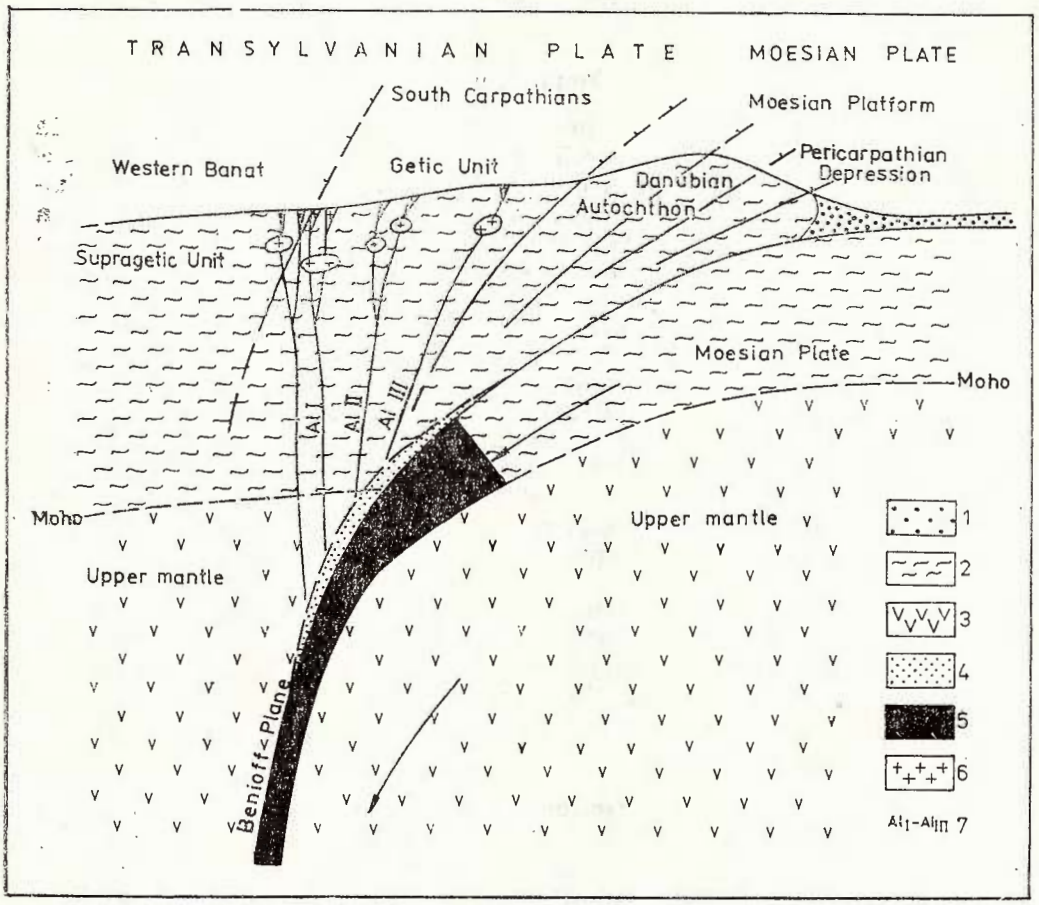


Fig. 6. — Geotectonic sketch of the South Carpathians during the emplacement of banatitic rocks (Upper Cretaceous-Paleocene).

1, sedimentary rocks in the Precarpathian Depression ; 2, sialic plates ; 3, upper mantle ; 4, source area of banatitic magmas ; 5, subducted oceanic crust ; 6, intermediary magmatic chambers ; 7, banatitic rock alignments.

The thrusting plane of the Getic Nappe, as well as the one which delimits it from the Supragetic Unit, are geotectonically subordinate but they are of peculiar interest from petrogenetic point of view, as far as in the area between these two crustal fractures occurs the magmatic basin out of which migrated the magmas which would generate the banatitic bodies (Fig. 6). In some zones the melting is possible to have affected the sialic layer too ; this could account for the occurrence in the same area (Giuşcă et al., 1966) or in the same Laramian magmatite massif (Russo-Săndulescu, Berza, 1979) of some basic

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and acid rocks. The magma ascension to the surface followed different third order parallel fracture systems and the three Laramian alignments in the Banat region were formed. According to this model, banatitic intrusions and associated mineralizations may occur in the Danubian Autochthon.

Metallogenesis

Regionally, the Laramian rocks of the banatitic province in Romania occur as far as Yugoslavia, Bulgaria, Turkey and even Himalaya and constitute a typical metallogenetic province. It is a calc-alkaline igneous province, the rocks of which were generated by subduction and one of its characteristic metals is the copper which occurs as porphyry copper mineralizations (Jancovic, 1980, Sillitoe, 1980). Copper concentrations of this type occur on the western first alignment made up of Laramian rocks and located in the Banat region, at Moldova Nouă (Ianovici et al., 1977, Cioflica, Vlad, 1980).

As regards the third banatitic alignment, the occurrence of pyrite-associated copper has been previously mentioned (Savu, 1962). By taking this into account and by analysing the composition of the rocks in this area and the features of the autometamorphic alteration processes, Gunesch et al. (1978) and Vlad (1979) considered that the quartz diorite bodies in this area might include copper mineralizations. Our investigations, in 1980-1981, pointed out two mineralization types with copper.

The late magmatic, pneumatolitic and hydrometasomatic processes lead to the sulphide impregnation of rocks and the generation of slight porphyry copper concentrations, as well as to the hydrometasomatic alteration of banatites and the constitution of impregnation mineralizations in the altered rocks or the constitution of veinlets and fissures filled by metallic minerals.

A) **Porphyry copper concentrations.** Mineralizations of this type of the banatitic rocks have been reported on the Lazu brook, Mehadica Valley and Luncavița Valley, but the most important one occurs on the Lazu brook. The rocks including these mineralizations do not show hydrothermal alteration, but high temperature metasomatic processes, such as amphibole biotitisation, the generation of olive green biotite and the quartz enrichment of rocks take place. The metallic mineral associations from sulphide and magnetite impregnated quartz diorites are the following : (1) pyrite-magnetite ; (2) pyrite-magnetite-chalcopyrite ; (3) magnetite-chalcopyrite.

These mineral associations were constituted in the banatitic rocks during the final consolidation stage out of late magmatic solutions, while the constitution of a certain association depended on the Cu, Fe, S and O concentration in these solutions (Betehtin, 1950). The porphyry copper mineralization is copper poor at least at the present-day erosion level. It usually impregnates the quartz diorites, in which the metal-bearing minerals are located within interstitial spaces of the plagioclase and quartz crystals, generally in the biotite filled spaces. In some instances the pyrite grains may be included in the other

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silicates as well. As shown by the microscopic study of the rocks, the granulation of these metallic minerals varies, generally below 2 mm.

Pyrite. This mineral occurs as xenomorphic grains, usually pierced by silicate inclusions. The xenomorphic pyrite crystals may have a diameter of 2 mm, but they are often of small dimensions. The pyrite includes sometimes very fine chalcopyrite patches.

Chalcopyrite. This sulphide occurs usually as grains or irregular patches, smaller than the pyrite and magnetite ones, their diameter being of less than 0.5-0.3 mm. The xenomorphic chalcopyrite crystals are clearer than the pyrite ones as the silicate inclusions are smaller and rarer, being present on the borders of the patches.

Magnetite. This mineral occurs only rarely as hypidiomorphic crystals. Generally, they are irregular and show several big silicate inclusions, so that in places the mineral is of skeletal shape.

B) **Hydrothermal alterations and sulphide mineralizations.** By the time the banatitic bodies consolidated and the typical cooling fissure systems were generated together with some primary fractures, pneumatolytic vapours and hydrothermal solutions came upwards through these fissures. The hydrothermal solutions are of low temperature and the component minerals of the rocks are no longer in equilibrium with them, and therefore they are altered to secondary minerals. The secondary mineral parageneses will depend on the temperature of the solutions and on the composition of primary rocks. Quartz, pyrite and possibly chalcopyrite deposit out of the solutions, pointing to the generation of these mineralizations during the mesothermal stage. The rocks of numerous banatitic bodies in this region have undergone hydrometasomatic alteration and have been sulphide, mainly pyrite, impregnated.

a) *Hydrometasomatic alterations.* All rock types have undergone this type of alteration and some examples should be given.

1. Quartz diorites. The initial quartz of these rocks has not been affected by the hydrothermal process. The plagioclase has been turned into an aggregate including the paragenesis albite-epidote (zoisite)-sericite, the crystals preserving their initial shape, their zoned structure and typical polysynthetic twins being no longer distinguishable. The altered crystals consist of albite and abund in sericite lamellae, epidote or zoisite nests and calcite patches in places ; sometimes the plagioclase is wholly replaced by sericite lamellae. The melanocrate minerals are entirely replaced by pennine associated with pistacite in places ; the sphene crystals and grains impregnate the rock in small amounts. There are also wide calcite patches. The hydrothermal alteration, on the whole, generates the following typical parageneses in quartz diorites : epidote-chlorite-albite-sericite-calcite-pyrite. This paragenesis is characteristic of the propylitic alteration facies (Meyer, Hemley, 1967).

2. Quartz-diorite porphyrites. The alteration of these rocks is approximate, just like in the case of quartz diorites. The plagioclase of the groundmass and phenocrysts is decalcified and albitized. The plagioclase phenocrysts undergo these processes on borders only, while inside they are fresh and show polysynthetic twins. The elongated hornblende

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crystals are replaced by olive green biotite and short chlorite lamellae usually associated with isometric pistacite grains, which form dense masses. This rock does also include fine tourmaline grains. Epidote occurs in the rock mass too, forming dense aggregates concomitantly with the alteration of melanocrate minerals into chlorite and the generation of a fine iron and titanium oxide powder. The rock also contains pistacite nests and radial intergrowths of fibrous amphibole.

3. Sericitisation is the main hydrothermal process in acid rocks.

b) *Sulphide hydrothermal mineralizations.* They take place during a stage subsequent to the one characterized by porphyry copper deposits, including therefore the hydrothermal alterations mentioned above. These hydrothermal mineralizations take place in the main banatitic body located on the Lazu brook (Pl. I).

Nevertheless, the area on the Lazu brook including banatitic intrusions, which contains both slight porphyry copper concentrations and hydrothermal alterations with pyrite impregnations, represents the marian area with poor mineralizations related to the Laramian magmatic activity.

Conclusions

The banatitic rocks occurring in the area of the localities Armeniș, Teregova, Pîrvova and Lăpușnicel form the third Laramian igneous rock alignment in the Banat region.

Petrochemically, they represent a calc-alkaline sequence resulted from a magma generated by subduction processes.

The differentiation line is represented by the quartz diorites-granodiorites-aplites assemblage.

The minor elements contents correspond to quartz-dioritic and granodioritic rocks mentioned in literature. It is to note Ba and Sr contents higher than those reported from igneous sequences characterized by the same petrographic assemblage.

At the present-day erosion level, some banatitic bodies and especially those located on the Lazu brook contain slight copper and molybdenum concentrations of porphyry copper type.

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EXPLANATION OF PLATES

Plate II

Fig. 1. — Contact area between the crystalline schists of the Sebeș-Lotru Series and the porphyritic quartz diorite body in the Mehadica Valley, trending N 60°E/22°N.

Fig. 2. — Aplite vein in porphyritic quartz diorites in the Mehadica Valley.

Plate III

Fig. 1. — Network of aplite veins which cross the dyke of quartz-diorite porphyrites in the Verendin Valley (Valea Satului stream).

Fig. 2. — Magmatic breccia in the western contact area of the quartz-diorite porphyrite dyke in the Verendin Valley (Valea Satului stream).

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H. SAVU

DISTRIBUTION OF BANATITIC ROCKS AND OF SULPHIDE MINERALIZATIONS ALONG THE ARMENIŞ-PIRVOVA-LAPUŞNICEL ALIGNMENT

0 1 2 km

Pietroasa ravine

Armeniş

Bibon ravine

Frîncu ravine

Timiş

Teregova v.

Teregova

Timiş

SEMENIC CRYSTALLINE MASSIF

CARANSEBEŞ - MEHADIA BASSIN

STAUROLITE AND DISTHENE ZONE

STAUROLITE ZONE

Luncavita

Luncavita v.

STAUROLITE ZONE

ALMANDIN ZONE

Verenain

ALMANDINE ZONE

BIOTITE ZONE

Craiova v.

STAUROLITE ZONE

STAUROLITE AND DISTHENE ZONE

Mehadica

Mehadica v.

ALMANDINE ZONE

STAUROLITE ZONE

Pîrvova

LEGEND

- Neogene sedimentary deposits
- λ Lamprophyres
- γδiII Granodioritic porphyries
- Qδi II Quartz-dioritic porphyrites
- γδi Granodiorites
- Qδi II Porphyritic quartz diorites
- Qδi Quartz diorites
- Contact zone
- a, b Sebeş-Lotru Series (a) and Miniş Series (b)
- Metamorphism isograde
- Anticline
- Syncline
- Fault
- Reverse fault
- oPy Sulphide mineralization

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

Project 195 : Ophiolites and Litosphere of Marginal Seas

PETROLOGY AND GEOCHEMISTRY OF THE SHEETED DYKES COMPLEX IN THE MUREŞ ZONE, DUMBRĂVIŢA-BAIA-BĂTUŢA-JULIŢA REGION (APUSENI MOUNTAINS) [1]

BY

HARALAMBIE SAVU [2], CONSTANŢA UDRESCU [2], VASILICA NEACŞU [2]

Sheeted dykes. Tholeiitic magma. Magmatic differentiation. Major elements. Minor elements. Petrochemistry. Geochemistry. Gabbro. Vanadiferous. titanomagnetite. Apuseni Mountains. South Apuseni Mountains-Zarand (Drocea) Mountains.

Sommaire

Pétrologie et géochimie du complexe de "sheeted dikes" de la zone de Mureş, région de Dumbrăviţa-Baia-Bătuţa-Juliţa (monts Apuseni). Le complexe de sheeted dikes est généré par un magma tholeiitique primaire, formé dans le manteau supérieur, à une profondeur de presque 100 km. Grâce aux processus de différenciation qui ont eu lieu dans le bassin magmatique situé au-dessous de la zone de speading, ce magma primaire non-différenciée a évolué vers des magmas différenciés basiques et des magmas différenciés acides, à caractère trondhjénitique. Au point de vue géochimique, les trois groupes de roches résultées du magma tholeiitique primaire se caractérisent par des teneurs spécifiques de différents éléments mineurs. Les roches basiques non-différenciées présentent des caractéristiques pétrochimiques et géochimiques voisines de celles des séries tholeiitiques classiques. Les roches différenciées basiques s'enrichissent en Fe, Ti, V et P, éléments s'accumulant dans les gabbros à titanomagnétite vanadifère, ce qui constitue le principal processus métallogénétique de ces magmas tholeiitiques. Les roches différenciées acides s'enrichissent en Si, Na, Yb, Y, La et Zr. Puisqu'elles s'enrichissent en éléments majeurs et mineurs, elles ne peuvent pas être utilisées pour la détermination des conditions géotectoniques favorables à la formation du complexe, indifféremment s'il s'agit des roches effusives, hipoabyssales ou plutoniques.

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[2] Institutul de Geologie şi Geofizică, str. Caransebeş nr. 1, 78344, Bucureşti 32.

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Introduction

Many classical series of ophiolitic rocks consist of three characteristic complexes, of which the median one is a sheeted dyke complex (Coleman, 1977 a, b ; Thayer, 1977). The petrographic constitution and the chemical composition of this complex is rather uniform ; this complex shows some peculiarities caused by the local conditions in which the oceanic zone and the magma which it generated developed.

A sheeted dyke complex has been recently pointed out (Savu, 1983) as a particular formation and described from the structural, petrographic and geotectonic points of view (Savu, 1985 — in this volume) ; it is part of the Alpine series of ophiolitic rocks in the Mureş Zone (Apuseni Mountains). The present paper, which comprises the results of our researches on this complex in the Dumbrăviţa-Baia-Bătuţa-Julita region, is a contribution to its knowledge also in point of petrochemistry and geochemistry. The paper is based mainly on the results included in our report of this year (Savu et al., 1982 b), elaborated in the period 1981-82.

We underline the fact that separate data on the chemical composition, the content of trace elements and the genesis of some rocks described in this paper were presented on several occasions, but no unitary study on the sheeted dyke complex has been worked out so far, especially because it was pointed out as a particular formation only last year. A special investigation has been recently carried out on the gabbro body at Julita (Savu et al., 1982 a).

General Considerations on the Sheeted Dyke Complex

The investigated region is marked by the presence of two magmatic complexes : (a) the ocean floor basalt complex (O_1) and (b) the sheeted dyke complex (O_2).

The basalt complex (O_1), usually in pillow lava facies, which represents the upper complex of the ophiolitic series, in this region as well as along the whole NW ridge of the Mureş Zone, is tectonically situated between the sheeted dyke complex and the Lower Cretaceous flysch deposits, which are overthrust by the ophiolitic series. That is why it appears here as a strip lying between the two mentioned units, as can be seen on the map drawn up by Savu (1985, Pl. I — in this volume).

The sheeted dyke complex (O_2) covers most of the investigated region (Savu, 1985, Pl. I — in this volume) ; it consists of a succession of parallel dykes (100%) set close to one another. The dykes strike N 70°-80° W and dip by 70°S-80°N. This direction differs a little from the general trend of the Mureş Zone. The thickness of the dykes ranges between 0.5 and 2 m, seldom 5-10 m. They consist mainly of intergranular basalts, dolerites and spilites, but, in the central and northeastern parts of the region there occur also dykes of gabbros, granophyres and pegmatoid quartzdiorites, which are in their turn crossed by dykes of dolerites, basalts, gabbroporphyrites and vein-like hyalobasalts. The hyalobasalt dykes (veins), that cross also the granophyres,

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range between 1-5 cm in thickness. Dykes of albitic felsites and albitic plagiogranites are seldom found in this complex. The albitic plagiogranites contain xenoliths of basic rocks, metamorphosed at the contact into amphibole hornfelses.

The basic rock dykes show on one or both margins a narrow chilled zone, consisting of hyalobasalt, while inside they consist of dolerites or normal basalts. There are also cases in which the margins of some dykes of basalts or dolerites are brecciated. On the margins of the very thin hyalobasalt dykes there are planar textures, parallel to their walls, in which the very fine magnetite crystals are disposed in parallel bands, that alternate with clear bands formed only of devitrified glass. Inside these dykes the rare plagioclase microcrystals and the microphenocrysts floating in the devitrified glassy mass tend to be parallel to the direction of the magma movement. Some basalt and dolerite dykes are albitized on the margins.

Regarding petrography, it is noticed that within all the rocks plagioclase is the first mineral to crystallize, while magnetite is the last. That is why the characteristic textures are intergranular, ophitic and hypidiomorphic granular. Usually plagioclase prevailing in the ophiolitic rocks is a labrador (An_{50-60}), while in spilites and felsites it is an albite (An_{8-10}). Clinopyroxene, the melanocrate mineral common in the rocks of this complex, with some exceptions, is an augite and seldom a diopside.

We mention as peculiar rocks the ferrogabbros, i.e. the gabbros with vanadium titanomagnetite (20-25%), in which the succession of crystallization is : plagioclase (An_{55}) — clinopyroxene — xenomorphic magnetite. It is worth underlining also the presence of albitic felsites, which consist of a compact mass of thin albite crystals, as intergrowths in the form of garlands or spherulites, within which there occur thin and elongated titanaugite crystals ($c \wedge Ng = 47°$), also in garlands. Granophyres are peculiar rocks too.

A general remark on the rocks of this complex is that they were subjected to the ocean floor metamorphism. Plagioclase is frequently saussuritized or albitized, while pyroxene is replaced by uralite, epidote, actinolite and chlorite with the separation of iron and titanium oxides.

Petrochemistry

The petrochemical characterization of the rocks within the sheeted dyke complex is based on 35 analyses of samples comprising all the representative rocks in the region. Taking into consideration the petrochemical and geochemical peculiarities of the analysed rocks, they were separated in the following groups, including also their oxide contents (Table 1) : (1) undifferentiated basic rocks and (2) differentiated rocks which, in their turn, are separated in (a) differentiated basic rocks and (b) differentiated acid (albitic) rocks. These rock groups are characterized by the following oxide contents (Table 2).

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TABLEO 1

Chemical Composition of Ophiolitic Rocks

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	11	16	17
Sample no.	9	78	86	92	35	90	74	75	59	40	69	79	82	25	96	33	127
Rock type	basalt	dole-rite	dole-rite	dole-rite	dole-rite	dole-rite	gabbro	gabbro	dole-rite	dole-rite	dole-rite	gabbro	gabbro	mag-netite gabbro	mag-netite gabbro	mag-netite gabbro	dole-rite
Location	Govi-decea Brook	Bătuţa	Bătuţa quarry	Bătu-ţa quarry	Gru-neţul Mic	Bătuţa quarry	Vălcu-ţa Valley	Vălcu-ţa Valley	Valea Mare (Bălcescu)	Calu Valley	Vălcu-ţa Valley	Bătuţa	Bătuţa	Grune-ţul Mare	Grune-ţul Mare	Gru-neţul Mic	Juliţa quarry
SiO_2	49.27	49.48	49.49	49.49	49.58	49.59	49.66	49.79	49.88	49.96	50.26	50.78	51.48	43.20	45.34	46.88	47.18
Al_2O_3	12.87	14.00	14.62	13.70	13.50	14.59	14.41	14.78	15.10	13.91	13.94	15.18	15.95	11.05	11.95	10.87	12.79
Fe_2O_3	4.80	2.79	3.32	3.70	3.93	2.91	3.22	2.62	2.51	2.90	4.36	2.95	1.36	4.79	5.56	5.46	4.35
FeO	7.12	8.18	7.67	8.10	9.01	8.44	9.32	7.61	7.38	7.95	8.14	6.42	5.10	14.84	13.22	13.67	10.61
MnO	0.23	0.19	0.21	0.19	0.22	0.20	0.22	0.15	0.22	0.19	0.20	0.14	0.14	0.28	0.30	0.31	0.20
MgO	6.75	7.46	7.70	7.22	6.82	7.24	5.88	7.88	8.47	7.26	6.10	8.36	8.65	5.86	6.07	3.22	5.69
CaO	9.15	11.36	8.85	10.59	9.86	10.36	10.10	11.45	11.20	11.01	8.17	11.38	11.79	8.36	8.26	7.60	8.45
Na_2O	3.70	2.28	3.62	3.64	2.79	2.92	3.18	2.35	2.71	2.66	3.67	2.29	2.52	2.31	2.88	3.79	3.89
K_2O	0.59	0.07	0.37	0.19	0.12	0.14	0.18	0.09	0.20	0.25	0.28	0.06	0.09	0.17	0.33	0.19	0.41
TiO_2	2.35	1.29	1.65	1.72	2.17	1.88	2.14	1.38	1.18	1.64	2.13	0.98	0.60	6.95	3.88	3.72	3.18
P_2O_5	0.24	0.20	0.19	0.22	0.24	0.26	0.32	0.16	0.14	0.24	0.32	0.14	0.08	0.06	0.12	1.64	0.34
S	0.051	0.14	0.069	0.12	0.16	0.21	0.15	0.10	0.050	0.13	0.11	0.08	0.069	0.075	0.10	0.21	0.15
Fe(S)	0.04	0.12	0.06	0.10	0.14	0.18	0.13	0.09	0.04	0.11	0.09	0.07	0.06	0.06	0.09	0.18	0.13
H_2O+	2.29	1.87	2.20	2.39	1.76	1.88	1.67	0.98	1.69	1.54	2.74	1.47	1.65	2.10	1.55	1.70	2.56
Total	99.45	99.43	100.02	100.74	100.30	100.80	100.58	99.42	100.77	99.75	100.51	100.28	99.67	100.10	99.65	99.44	99.93

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(continued)

No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Sample no.	71	100	91	31	68	113	45	26	107	60	121	105	61	17a	7	116	110	43
Rock type	Vein-like hyalo-basalt	gabbro	dole-rite	mag-netite gabbro	quartz dole-rite	spilitic hyalo-basalt	dole-rite	porph-yric dole-rite	vein-like hyalo-basalt	spilitic vein-like hyalo-basalt	spilite	spilite	grano-phyr	grano-phyr	albitic quartz-diorite	grano-phyr	felsite	plagio-granite
Location	Vălcu-ța Valley	Gru-neț-ul Mare	Bătuța quarry	Grune-țul Mic	Vălcu-ța Valley	Babei Valley	Gru-neț-ul Mic	Gru-neț-ul Mare	Frun-ții Valley	Valea Mare (Bălces-cu)	Babei Valley	Frun-ții Valley	Valea Mare (Băl-cescu)	Babei Valley	Vălcu-ța Valley	Babei Valley	Ripii Hill	Calu Valley
SiO_2	47.92	48.28	48.40	48.52	49.17	49.22	49.43	49.48	49.68	50.71	51.54	51.76	55.95	58.88	59.06	59.45	62.39	75.53
Al_2O_3	12.70	12.44	11.50	11.75	11.74	11.86	13.20	12.94	12.24	11.80	13.42	12.39	13.44	12.94	14.14	12.99	11.30	11.35
Fe_2O_3	5.92	2.46	4.56	3.99	7.04	6.11	11.12	3.27	3.59	5.53	7.69	5.96	4.20	2.78	2.79	5.37	4.29	3.65
FeO	9.60	13.50	11.32	12.22	10.03	10.36	3.60	9.93	12.55	9.20	6.93	9.64	8.39	9.27	6.66	6.33	4.79	0.64
MnO	0.19	0.30	0.25	0.28	0.28	0.27	0.25	0.22	0.29	0.23	0.16	0.28	0.17	0.18	0.09	0.14	0.12	0.01
MgO	6.21	4.95	5.61	5.85	4.76	4.48	6.00	6.18	5.01	4.73	3.94	2.59	2.88	1.89	2.95	1.70	2.99	0.30
CaO	8.37	7.48	7.86	8.78	7.93	7.55	9.70	10.08	8.61	6.84	6.49	7.03	4.60	4.38	6.39	5.08	4.81	1.58
Na_2O	3.64	3.29	3.27	3.07	2.93	2.98	2.73	2.47	3.36	4.58	4.55	4.65	4.98	5.67	4.76	5.58	5.0⁻	5.71
K_2O	0.11	0.37	0.07	0.18	0.08	0.17	0.10	0.08	0.19	0.05	0.08	0.10	0.16	0.19	0.23	0.17	0.39	0.05
TiO_2	2.39	4.47	3.14	3.40	3.56	3.52	2.40	2.47	2.96	2.65	2.53	2.68	2.18	1.58	1.50	1.62	1.93	0.34
P_2O_5	0.28	0.36	0.36	0.12	0.42	0.44	0.34	0.36	0.26	0.42	0.48	0.88	0.36	0.74	0.48	0.30	0.28	0.12
S	0.069	0.15	0.27	0.11	0.21	0.18	0.15	0.23	0.11	0.19	0.059	0.076	0.058	0.038	0.049	0.059	0.11	0.051
Fe(S)	0.06	0.13	0.23	0.09	0.18	01.6	0.13	0.20	0.09	0.16	0.05	0.07	0.05	0.03	0 04	0.05	0.09	0.04
H_2O^+	2.69	1.31	2.84	1.81	2.32	2.17	1.67	1.59	1.37	2.45	1.98	1.38	2.04	0.96	1.22	0.82	1.15	2.29
Total	100.14	99 9.4	99.68	100.17	100.65	99.47	100.82	99.50	100.31	99.54	99.89	99.48	99.44	99.52	100.35	99.65	99.71	99.45

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The comparison of the analyses of the three rock groups shows that the undifferentiated basic rocks are similar to the basic rocks from the classical, normal tholeiitic series ; they correspond to the tholeiitic basalts from the median ridges of the present oceans. In

TABLE 2

Variation of Oxides (%) in the Ophiolitic Rocks

Oxides	Undifferentiated basic rocks	Differentiated basic rocks	Differentiated acid rocks
SiO_2	49.27—51.48	43.20—51.54	51.76—75.53
Al_2O_3	12.87—15.95	10.87—13.42	11.30—14.14
Fe_2O_3	1.36—4.80	2.46—11.12	2.78—6.96
FeO	5.10—9.32	3.60—14.84	0.64—9.64
MgO	6.10—8.65	3.22—6.21	9.30—2.99
CaO	0—17—11.79	6.49—8.79	1.58—7.03
Na_2O	2.28—3.67	2.31—4.58	4.65—5.71
K_2O	0.06—0.59	0.05—0.41	0.05—0.39
TiO_2	0.60—2.35	2.39—6.95	0.34—2.68
P_2O_5	0.08—0.32	0.06—1.64	0.12—0.88

the group of the differentiated basic rocks, which comprises the titanomagnetite gabbros (ferrogabbros), in a few dolerites, vein-like hyalobasalts (hyaloferrobasalts) and a few spilites, are noticed higher iron oxide, TiO_2, Na_2O and P_2O_5 contents than in the normal tholeiitic rocks, a fact characteristic of the differentiation of the tholeiitic magmas. The iron content increase in the differentiates of the tholeiitic magmas was pointed out by Fenner (1929). These contents increase, causing the decrease of the MgO, CuO, Al_2O_3 and SiO_2 contents. This rule is also valid in the case of the four vein-like hyalobasalts (71, 113, 107, 60), a reason why, in a previous paper (Savu, 1972) they were considered as magnetite basalts which would probably originate in a ferrobasaltic magma, differentiated from the tholeiitic one, namely the magma that gave rise to the dykes of titanomagnetite gabbros. As compared to the undifferentiated tholeiites, the differentiated acid rocks are marked by higher SiO_2, Na_2O and P_2O_5 contents. It is worth mentioning the fact that K_2O within the whole rock series shows values lower than 0.4%, while Na_2O, higher than 2.5%, which agrees with what was established by Miyashiro (1975) for the abyssal or ocean floor tholeiitic basalts.

The magma types to which the rocks of the sheeted dyke complex correspond, depending on the magmatic parameters (Burri, 1959), are represented by prevailingly gabbroid magmas, as well as by eucritic, hawaiitic, leucogabbroidic and trondhjemitic magmas (Table 3). They are rocks of simatic origin, as results from the diagram in Figure 1, drawn according to Gottini (1969).

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TABLE 3

Niggli Parameters

No.	Sample no.	Si	al	fm	c	alk	k	mg	c/fm	ti	p	w	Qz	Magma type
Undifferentiated Basic Rocks														
1	9	119.66	18.48	48.13	23.77	9.62	0.08	0.51	0.49	4.30	0.20	0.37	−18,82	hawaiitic
2	78	115.36	19.18	47.28	28.32	5.22	0.02	0.54	0.60	2.22	0.14	0.24	− 5,52	hawaiitic
3	86	116.62	20.27	48.58	22.36	8.79	0.06	0.56	0.46	2.90	0.27	0.28	−18,54	gabbroid
4	92	114.70	18.65	46.62	26.28	8.45	0.03	0.54	0.56	2.97	0.17	0.26	−18,10	gabbroid
5	35	117.82	18.84	49.43	25.15	6.58	0.03	0.48	0.51	3.91	0.20	0.28	− 9,50	gabbroid
6	90	115.90	20.05	47.21	25.90	6.84	0.03	0.53	0.55	3.34	0.22	0.23	−11,46	gabbroid
7	74	119.31	20.35	45.98	25.96	7.72	0.03	0.46	0.56	3.86	0.32	0.23	−11,57	gabbroid
8	75	114.52	20.01	46.42	28.18	5.39	0.02	0.58	0.60	2.43	0.22	0.23	− 7,04	gabbroid
9	59	111.88	19.93	46.91	26.94	6.22	0.04	0.60	0.57	1.99	0.19	0.24	−13,60	gabbroid
10	40	117.55	19.24	46.57	27.73	6.46	0.05	0.55	0.59	2.88	0.34	0.24	− 8,29	gabbroid
11	69	125.50	20.46	48.39	21.81	9.34	0.04	0.47	0.45	3.99	0.33	0.33	−11,86	gabbroid
12	79	116.79	20.55	46.29	27.98	5.18	0.02	0.62	0.60	1.74	0.19	0.29	− 3,93	gabbroid
13	82	120.30	21.97	42.75	29.47	5.01	0.02	0.70	0.69	1.12	0.11	0.19	− 2,94	gabbroid
Differentiated Basic Rocks														
14	25	101.01	15.24	58.34	20.96	5.46	0.04	0.35	0.35	12.22	0.08	0.22	−20,82	eucritic
15	96	104.48	16.26	56.45	20.37	6.92	0.07	0.36	0.36	6.75	0.16	0.27	−23,20	gabbroid
16	33	120.29	16.44	52.92	20.95	9.69	0.03	0.23	0.39	7.15	1.75	0.27	−18,47	gabbroid
17	127	113.76	18.23	50.23	21.86	9.68	0.06	0.40	0.43	5.76	0.34	0.27	−24,96	gabbroid
18	71	114.11	17.87	52.20	21.35	8.56	0.02	0.42	0.40	4.27	0.25	0.35	−20,13	gabbroid
19	100	122.00	18.58	52.55	20.28	8.59	0.06	0.35	0.38	8.45	0.39	0.14	−12,36	gabbroid
20	91	121.40	17.02	53.83	21.11	8.04	0.01	0.38	0.39	5.93	0.39	0.26	−10,76	gabbroid
21	31	114.96	16.43	53.98	22.60	7.28	0.03	0.38	0.41	6.11	0.17	0.21	−14,16	gabbroid
22	68	124.89	17.60	53.45	21.60	7.35	0.02	0.34	0.40	6.80	0.48	0.39	− 4,61	gabbroid
23	113	128.71	18.32	52.70	21.21	7.77	0.03	0.33	0.40	6.94	0.53	0.34	− 2,37	gabbroid
24	45	119.45	18.57	49.75	25.11	6.57	0.02	0.43	0.50	4.35	0.34	0.74	− 6,83	hawaiitic
25	26	120.47	18.63	49.18	26.26	5.93	0.02	0.46	0.53	4.49	0.38	0.23	− 3,25	hawaiitic
26	107	122.05	17.77	51.37	22.59	8.27	0.03	0.56	0.44	5.48	0.23	0.21	−11,03	gabbroid
27	60	134.08	18.42	50.43	19.34	11.81	0.01	0.37	0.38	5.32	0.51	0.35	−13,16	gabbrodioritic
28	121	139.39	21.32	47.79	18.82	12.07	0.01	0.33	0.39	5.13	0.62	0.50	− 8,89	gabbroid
Differentiated Acid Rocks														
29	105	143.43	20.29	46.14	20.92	12.65	0.01	0.23	0.45	5.63	1.13	0.36	− 7,17	gabbrodioritic
30	61	173.04	24.42	45.08	15.23	15.27	0.02	0.29	0.34	5.13	0.48	0.31	+ 11,96	leukogabbroid-gabbroid
31	117a	191.11	24.83	41.65	18.18	15.34	0.02	0.22	0.44	3.85	1.05	0.22	+ 29,75	leukogabbroid-gabbroid
32	72	184.32	25.94	37.93	21.34	14.79	0.03	0.36	0.56	3.56	0.71	0.28	+ 25,16	leukograbbroid
33	116	194.31	25.12	39.15	17.78	17.95	0.02	0.21	0.45	3.96	0.39	0.43	+ 22,51	leukogabbroid
34	110	216.96	23.19	40.93	17.99	17.89	0.04	0.37	0.44	5.07	0.17	0.44	+ 45,40	leukogabbroid
35	43	425.00	37.67	21.27	9.66	31.39	0.00	0.11	0.45	1.48	0.40	0.84	+ 199,44	trondhjemitic

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The above statements reveal that the magmas which generated the rocks of the sheeted dyke complex were pre-eminently of tholeiitic nature, as can be seen on a FeO-MgO-Na_2O+K_2O diagram,

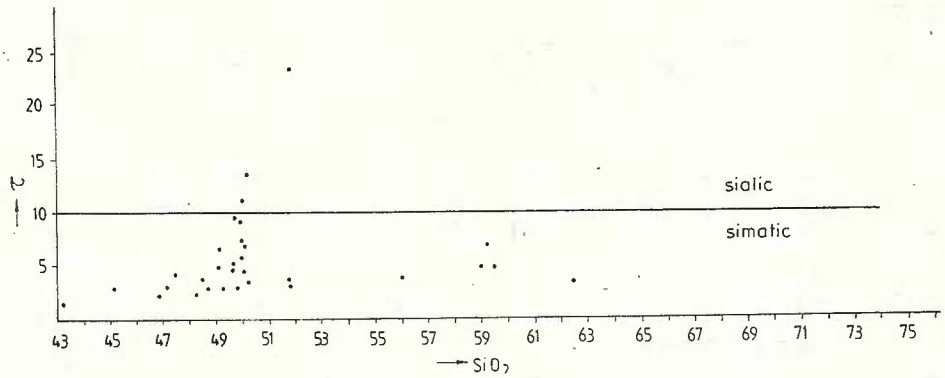


Fig. 1. — T-SiO_2 diagram.

drawn according to Irvine and Baragar (1971), where both the differentiated and the undifferentiated rock groups are plotted in the field of the tholeiitic magmas (Savu, 1985, Fig. 4). This diagram also clearly indicates the trend of the differentiation of the tholeiitic magmas, the residual ones getting gradually enriched in iron oxides and then in alkalies. By this peculiarity the differentiation line of the sheeted dyke complex is very close to that of the Skaergaard magmas, the basic rocks being distributed on the diagram along a line parallel to the FeO(tot)-MgO side (Miyashiro, 1974, 1975).

The value of the FeO(tot)/MgO ratio within the undifferentiated basic rocks ranges between 0.74 and 1.99, as is required by the rocks of the abyssal tholeiitic or ocean floor series, namely that this value should be lower than 2 (Miyashiro, 1975).

Although the differentiated rocks of the sheeted dyke complex show many characteristics of tholeiitic rocks, due to the fact that during the differentiation of magmas an enrichment in FeO(tot) takes place to the detriment of other oxides, among which MgO, they show the value of the FeO(tot)/MgO ratio higher than 2. These conclusions are well illustrated on the diagrams in Figure 2, drawn according to Miyashiro (1975), where one can also see the trends of the tholeiitic magma evolution in the Mureş Zone as compared with the abyssal tholeiitic magmas and the magmas of Skaergaard.

On the Si-FeO(tot)/Mg diagram the rocks of the sheeted dyke complex are plotted, with three exceptions, in the field of the tholeiitic magmas, being distributed in the space between the curve of the abyssal tholeiites and that of the Skaergaard magmas. On the FeO(tot)-FeO (tot)/Mg diagram all the rocks of the complex are distributed along the same variation curves as in the previous diagram, which is also true of the TiO_2-FeO(tot)/MgO diagram. Concerning the latter diagram

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we point out sample 25, a titanomagnetite gabbro, in which TiO_2 represents 6.95%, being therefore plotted outside the diagram.

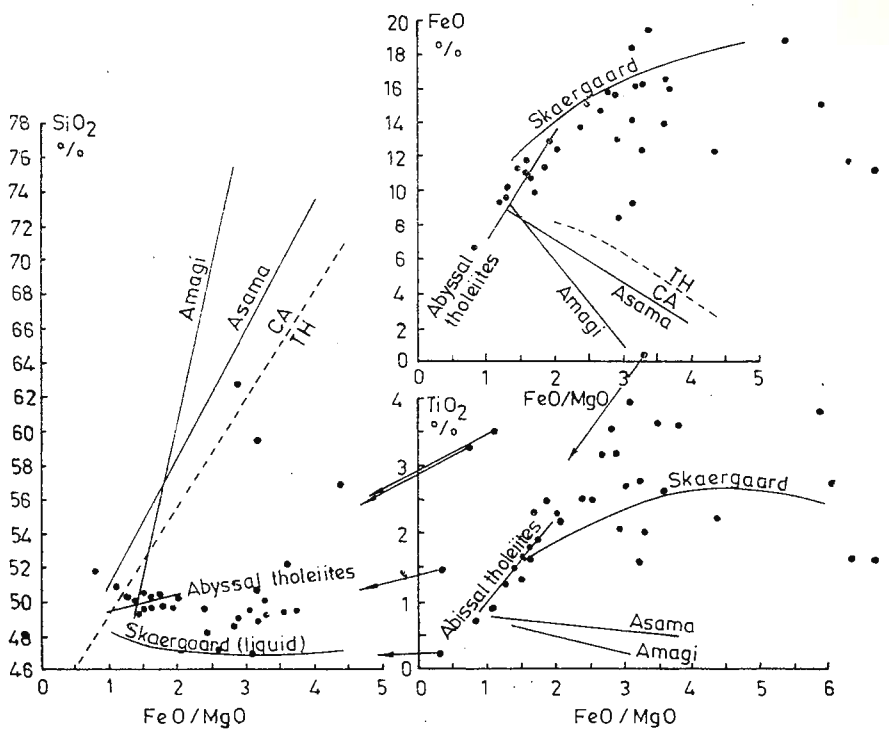


Fig. 2. — SiO_2-FeO(tot)/MgO, FeO(tot)-FeO(tot)/MgO, TiO_2-FeO(tot)/MgO diagram.

It follows from the above statements that during the evolution of the tholeiitic magma that generated the sheeted dyke complex a differentiation process took place, as follows :

Primary tholeiitic magma → Gabbroid magmas ↗ Trondhjemitic magma rich in Si, Na, P
↘ Gabbroid magma rich in Fe, Ti, V

The differentiation of the tholeiitic magma took place at depth (Savu, 1962 ; Savu et al., 1970) in the upper mantle, where it formed as a pyrolite (Green, Ringwood, 1966) by the melting of the ultramafic stratum, beneath the spreading zone (Savu, Manea, 1982).

This differentiation trend, which is characteristic of the tholeiitic magmas, takes place throughout the ophiolitic series of the Mureș Zone, but is also found at the level of a single gabbroic body, such as those at Julița (Savu et al., 1982) and Almășel (Savu, 1962).

By the high Ti content, characteristic of the whole series of ophiolitic rocks in the Mureș Zone, except for the acid differentiates, this series belongs to the "high-Ti ophiolite" group, as can be noticed on the diagram of Figure 3, drawn according to Serri (1980). The

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latter author established that the ophiolitic series showing a high titanium content are quite similar to the basic rocks of the median ridges in the present "normal" oceans (Serri, Saitta, 1980). This fact,

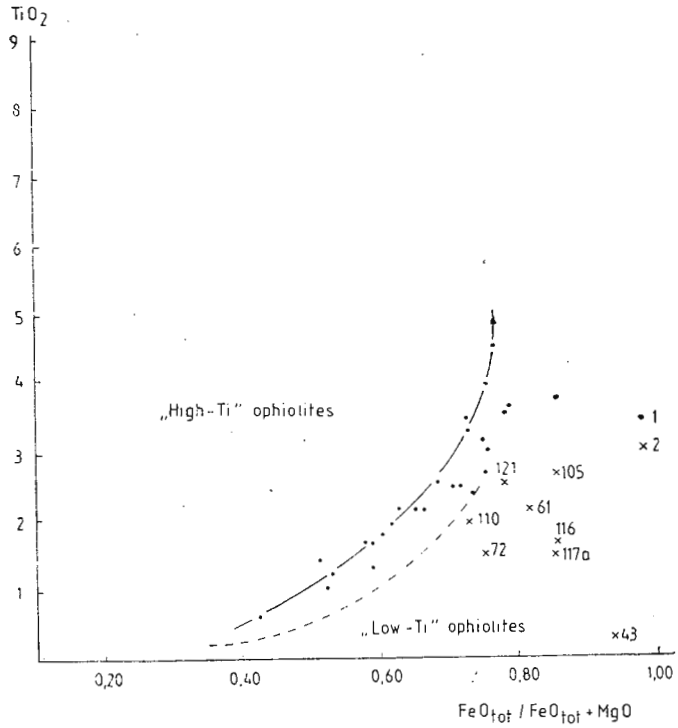


Fig. 3. — TiO_2-FeO(tot)/FeO(tot)+MgO diagram.
1, undifferentiated and differentiated basic rocks; 2, differentiated acid rocks.

correlated with the "high-Ti ophiolite" character of the tholeiitic rock series in the Mureș Zone, shows that the latter formed under conditions of the spreading of the Mureș ocean floor.

Distribution of Trace Elements

In order to characterize the sheeted dyke complex from the geochemical point of view, the trace elements presented in Table 4 were determined by emission spectrography. The rocks in this table are grouped, as above, into undifferentiated basic rocks and differentiated basic and acid rocks.

a) The group of undifferentiated basic rocks. The distribution of trace elements in this rock group is a characteristic of the tholeiitic rock series, such as the series of the ocean floor basalts. Of the group of siderophile elements Co and V show values ranging within restricted limits (Co=32-52 ppm ; V=200-380 ppm). Restricted values of the variation limits are also noticed in the case of Sc (31-40 ppm). Nickel and chromium show somewhat wider variation limits (Ni=40-100 ppm; Cr=57-240 ppm).

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TABLE 4

Distribution of Trace Elements (ppm) in Ophiolitic Rocks

No.	Sample no.	Ni	Co	Cr	V	Sc	Y	Yb	Zr	Ba	Sr	Pb	Cu	Ga	Sn
					Undifferentiated Basic Rocks										
1	9	65	48	90	320	40	55	6,5	200	43	300	undt	30	15	2
2	78	42	45	57	260	35	23	4,2	80	12	100	undt	30	11	undt
3	86	90	46	230	280	34	34	4	140	65	230	2,5	25	16	undt
4	92	87	36	240	270	34	35	5	120	32	150	ndt	29	15	undt
5	35	60	44	140	230	36	43	5,7	160	23	125	3	43	19	undt
6	90	67	46	215	280	38	29	4,3	130	30	240	11	34	12	undt
7	74	40	44	65	340	39	48	6,5	155	50	140	3	23	17,5	undt
8	75	85	36	240	300	32	20	2,8	75	20	120	undt	30	14	undt
9	59	100	52	340	280	40	28	4	110	37	140	undt	6	14	undt
10	40	60	44	155	240	38	35	5	120	28	130	undt	37	15	undt
11	69	57	38	120	280	31	46	5,2	200	38	135	undt	90	17	2
12	79	75	40	120	200	35	18	2,2	52	13	95	undt	45	14	undt
13	82	95	32	190	200	34	14	2	37	12	126	60	35	10	undt
					Differentiated Basic Rocks										
14	25	34	55	2	900	31	30	6	105	25	140	undt	5,5	16	7
15	96	42	50	8	770	35	36	4,8	120	37	175	undt	53	17	2
16	33	8,5	55	1,5	180	38	155	10,5	270	36	140	3	25	26	2
17	127	46	43	70	460	40	72	7,3	215	48	80	undt	23	18	2
18	71	40	45	20	310	36	48	6	160	34	165	undt	31	17,5	2
19	100	28	41	11	310	32	73	6,4	260	44	150	14	19	15	3
20	91	33	37	17	370	34	60	7,3	230	27	120	3,5	33	12	2
21	31	37	57	18	410	42	52	5,3	160	18	75	undt	20	18	2,5
22	68	34	55	7	380	41	87	9	280	24	120	2	37	21	3,5
23	113	29	43	1,5	380	32	70	7,4	220	38	125	undt	26	17	2
24	45	50	55	85	350	41	60	6	230	21	125	3	48	22	undt
25	26	65	38	130	320	35	55	6,5	170	19	95	undt	25	17	2
26	107	32	46	15	360	30	57	6	235	32	125	5	24	19	3
27	60	33	44	16	340	34	70	7	280	25	120	undt	27	18	2,5
28	121	15,5	36	4	260	30	65	6,7	220	34	155	4	4	22	2
					Differentiated Acid Rocks										
29	105	4	22	2	62	23	931	0,5	400	22	80	4,5	4,5	23	2,5
30	61	3,5	15	2,5	50	20	110	5,5	270	80	100	undt	4	26	undt
31	117a	4	12	ndt	16	18	125	8	380	60	60	2	5	30	2
32	72	15	13	9	100	23	85	8,5	240	66	130	2	8,5	25	2,5
33	116	4	16	1,5	18	20	105	11	440	60	155	2	4,5	26	3
34	110	13	19	6,5	150	23	65	6,3	380	30	50	7	23	21	2
35	43	5	6	5	12	7,5	150	18,5	805	18	44	4	8	25	3
Detection limits				1								2			2

La, whose detection line is of (30 ppm), was determined only in samples nos. 116 (34 ppm) and 43 (42 ppm).

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Among the lanthanides the Y and Yb contents were determined, which range within the following limits: Y=14-55 ppm; Yb=2-65 ppm. The variation of the contents of these elements is in positive correlation with that of Zr, which ranges between 37-200 ppm. Lanthanum could not be determined in any of the undifferentiated basic rocks, its contents being lower than the detection limit of this element, which is of 30 ppm.

The low Ba contents (12-65 ppm) are characteristic of the abyssal tholeiites (Miyashiro, 1975), for the ocean floor basalts respectively (Hart et al., 1972 ; Savu, Udrescu, 1981). Close Ba values were found also in the upper complex (O_1) of the ocean floor basalts of the Mureş Zone, investigated by us in the Roşia Nouă Zone (Savu et al., 1970).

Strontium ranges between 95-300 ppm, these being also close values to those of the ocean floor basalt complex. The contents of the other elements determined in the undifferentiated basic rocks are also close to those obtained in the rocks making up the series of tholeiitic basic rocks.

On the whole the undifferentiated ophiolitic rocks of the sheeted dyke complex resemble very much, also with respect to geochemistry, the rocks of the ocean floor basalt complex (O_1) in the Mureş Zone. This can be very well explained, if we take into account the fact that the dykes of the lower complex (O_2) constituted the channels of magma ascension, giving rise to the pillow lava basalts of the upper complex.

b) Group of differentiated basic rocks. The rocks in this group show some peculiarities in comparison with the undifferentiated basic ones. Thus Ni, and especially Cr show low contents, ranging within the following limits : Ni=8.5-65 ppm ; Cr=1.5-130 ppm ; in the latter case the values close to the lower limit prevail. Vanadium increases (180-460 ppm), being concentrated to a great extent in the gabbros with vanadium titanomagnetite (770-900 ppm). Cobalt presents the same values as in the case of the undifferentiated rocks (Co=36-57 ppm). Sc shows a similar behaviour, ranging between 30-42 ppm.

As compared to the undifferentiated rocks, the contents of Y and Yb in the differentiated basic rocks increase, as the Zr content increases, varying within the following limits : Y=30-155 ppm ; Yb=4.8-10.5 ppm. The Zr content also increases a little, ranging between 105-280 ppm. The lowest Zr values were determined in the gabbros with vanadium titanomagnetite.

The low Ba values are typical of the differentiated basic rocks of the complex, which demonstrates their character of ocean floor basic rocks. On the diagram of Figure 4, drawn according to Miyashiro (1975) it is found that the basic undifferentiated rocks are plotted in the field of the abyssal tholeiites in the northern part of the Azores, while the differentiated ones are plotted outside this field, exhibiting equal Ba contents, but much higher values of the FeO(tot)/MgO ratio.

The other trace elements determined in this rock group show similar values to those in the undifferentiated rocks, except for Sn which slightly increases in the differentiated rocks.

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c) Group of differentiated (albitic) acid rocks. The distribution of the trace elements in the rocks of this group is characteristic of the acid trondhjemitic rocks. Thus Ni, Co, Cr and V show lower con-

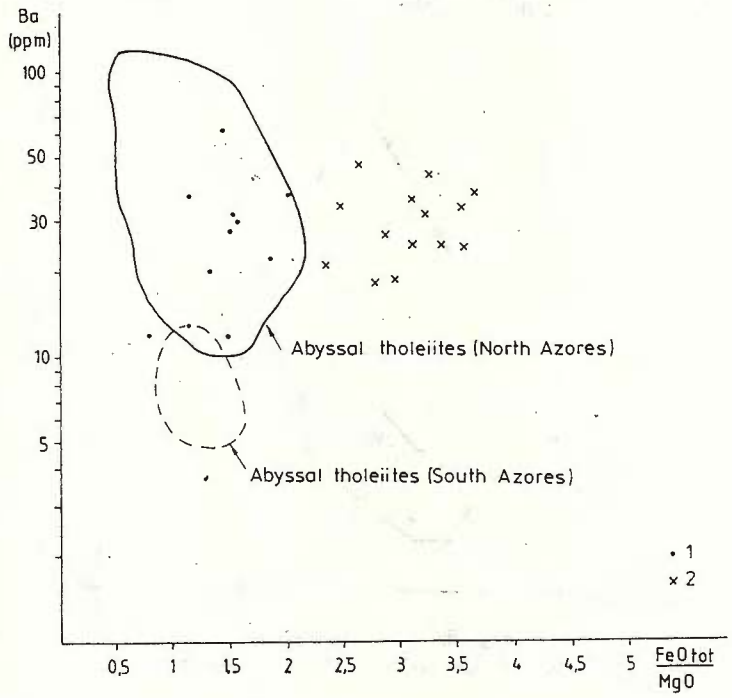


Fig. 4. — Ba — FeO(tot)/MgO diagram.
1, undifferentiated and differentiated basic rocks; 2, differentiated acid rocks.

tents as compared to those of the previous rock groups (Ni=3.5-15 ppm; Co=6-22 ppm; Cr=undetermined — 9 ppm; V=12-150 ppm). Scandium, although showing lower contents than in the two basic rock groups (7.5-23 ppm), has nevertheless higher values than in the classical calc-alkaline acid rock series known in the relevant literature.

Ytium and yterbium, and especially zirconium, concentrate in the acid rocks resulted from the differentiation of the tholeiitic magma. Lanthanum, formed below the detection limit in all the rocks of the sheeted dyke complex, shows detectable values (34-42 ppm) in a granophyre and the albitic plagiogranite.

Barrium is also characteristic of the trondjhemitic rocks, showing low values (18-80 ppm) corresponding to the low K_2O values.

Of the other analysed trace elements one should mention Cu, exhibiting somewhat lower contents and Ga, having slightly higher contents than in the anterior rock groups. Sn shows the same values as in the basic differentiated rocks.

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Origin of the Sheeted Dyke Complex

The presence of the sheeted dyke complex in the structure of the Alpine ophiolitic series of the Mureș Zone demonstrates that it undoubtedly formed under ocean floor conditions — in the sense es-

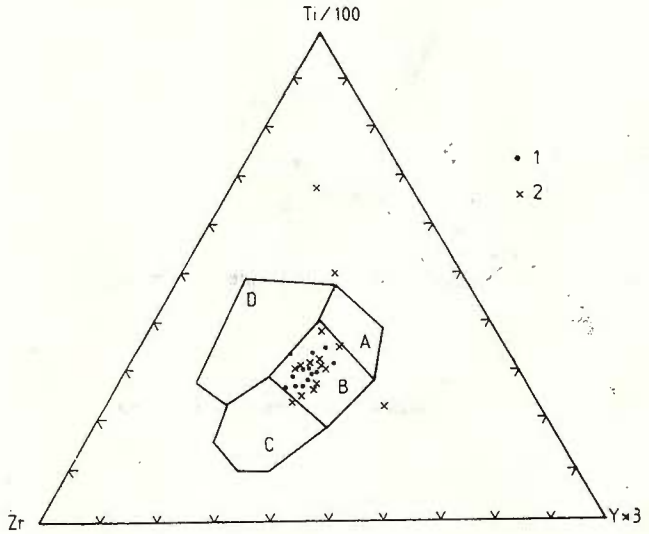


Fig. 5. — Ti/100-Y×3-Zr.
1, undifferentiated rocks ; 2, differentiated rocks.

tablished by Coleman, 1977, a, b — during the spreading of the Mureș ocean (Savu, 1980, 1983). This complex originated in a tholeiitic magma that formed in the upper mantle, as indicated by the Sr content of the rocks (Hart et al., 1970), at the depth of about 100 km beneath the spreading zone. The geotectonic conditions under which the tholeiitic magmas existed on the Mureș ocean floor can be clearly seen on the diagram in Figure 5, drawn according to Pearce and Cann (1973), on which all the undifferentiated and differentiated rocks are plotted in the B field of the ocean floor basalts. During the spreading of the Mureș ocean the tholeiitic magma in the magmatic chamber beneath the spreading zone is marked by an ascending movement, filling successively the trough formed and constituting thus a succession of sheeted dykes.

The basalts and dolerites in the dykes originating from the undifferentiated (primary) tholeiitic magma remain in the field characteristic of this magma type and preserve the character of ocean floor basalts from the upper complex of the series (Figs. 4, 5). During the ocean floor spreading that took place for millions of years, the magma at depth gradually differentiated, resulting in three groups of undifferentiated and differentiated basic and acid rocks. It is worth noting that while the undifferentiated rocks and a great part of the differentiated basic ones remain in the primary magma tholeiitic domain

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(Fig. 6, according to Beccaluva et al., 1977), the differentiated rocks, that gradually enrich in P_2O_5, and especially in TiO_2, pass to the alkaline domain, in spite of the fact that they do not belong to such a series.

The enrichment in TiO_2 of the differentiated basic rocks and in Zr of the acid ones, as well as the decrease of the content of the

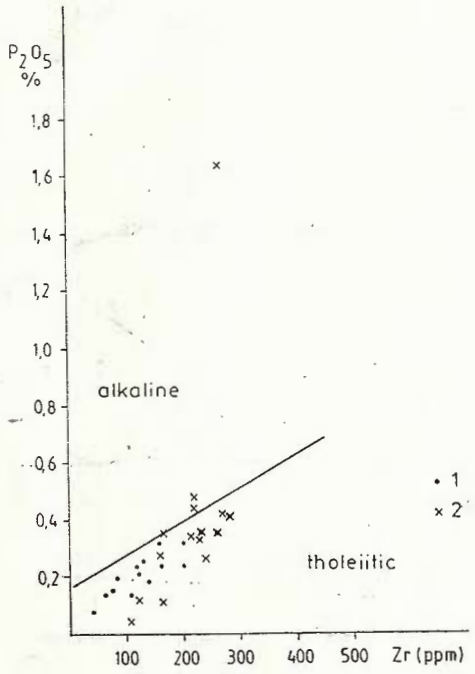


Fig. 6. — P_2O_5-Zr diagram. 1, undifferentiated rocks ; 2, differentiated rocks.

other elements (Cr) lead to the shift of some of them from the normal ocean floor domain to the withinplate basalt domain (Fig. 7, according to Pearce and Gale, 1977), or to the domain of the island arc basalts (Fig. 8, according to Pearce, 1975). If we accept that the magmas differentiated at depth can consolidate depending on the conditions of their emplacement, either as gabbros or dolerites on the one hand or as basalts on the other hand, one can explain why some basalts of the ocean floor tholeiitic series can be plotted on such diagrams in one of the two mentioned fields ; this makes difficult the geotectonic setting of such a basic rock series and even leads to erroneous conclusions (see Nicolae, 1983). This is obvious especially when, in the investigated zone, only the basalt complex is exposed, as is the case at Pătîrș, where the spilites, rocks that clearly belong to the differentiated magmas, alternate with ocean floor basalt flows. That is why good results will be obtained in such cases only from the undifferentiated rocks coming from the original magma, unaffected by other factors.

This conclusion is supported by the basalt dykes and especially by the four hyalobasalt veins (nos. 60, 71, 107, 113) which are plotted

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in the field of the differentiated basic rocks, some of them being rich in Na_2O, therefore spilitic. All the rocks in these veins show iron contents higher than those in the undifferentiated (normal) basalts,

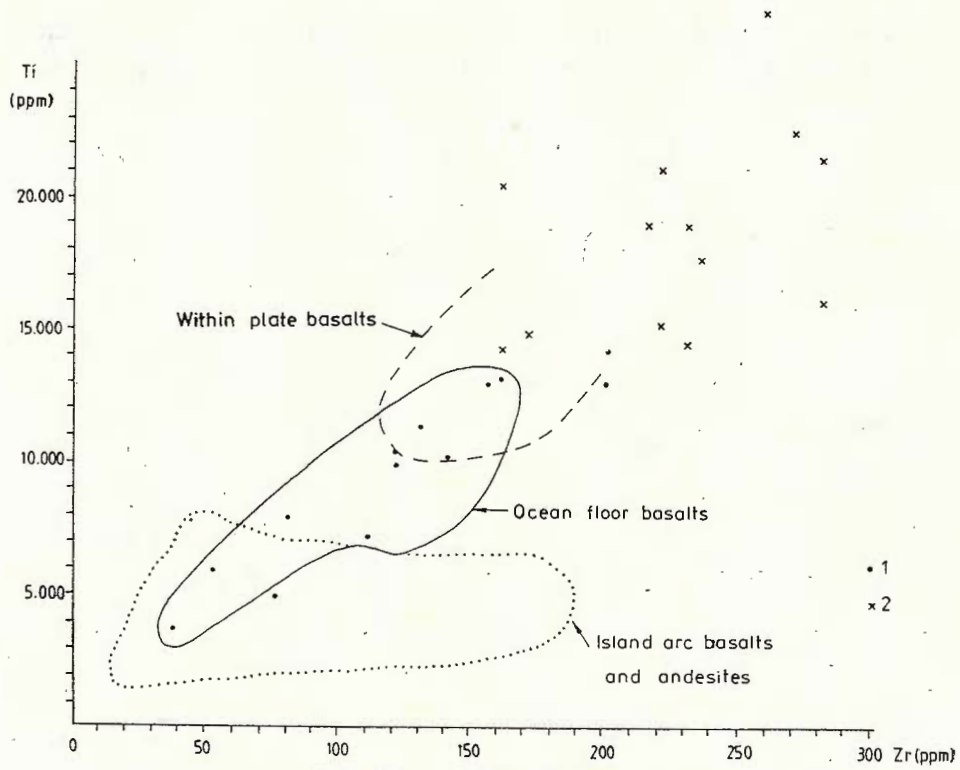


Fig. 7. — Ti-Zr diagram.
1, undifferentiated rocks ; 2, differentiated rocks.

which are close to those in the gabbros with vanadium titanomagnetite (Savu, 1972). This is clearly seen if we compare the FeO(tot) value, which ranges between 14.67% and 19.21% in the titanomagnetite gabbros (ferrogabbros), while in the vein-like hyalobasalts (hyaloferrobasalts) it ranges between 14.38% and 16.06% ; in the undifferentiated basalts this value varies between 6.38% and 12.72%, its mean being of about 10%.

The great amount of iron oxides in the magnetite hyalobasalt, ranging within the following limits : Fe_2O_3 = 5.92-6.11% ; FeO = = 9.60-10.30% brings this rock close to the iron basalts (Steenstrup, 1882) of Greenland, where the iron oxides range within the limits : Fe_2O_3 = 1.64-6.89% ; FeO = 11.14-14.27%. The essential difference is that in the latter case iron is in native state. It is worth noting a tendency of enrichment in FeO of the sheeted dykes of the ophiolitic series from the Macquarie Island (Griffin, Varne, 1980).

As shown above, the differentiation succession took place from tholeiitic magmas to trondhjemitic magmas, the last products being the

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aplitic plagiogranites with albite, a fact also noticed by Thayer (1977). Therefore the magmas followed during their differentiation the enrichment in Fe, Ti and V in one sense (Kennedy, 1948) and in SiO_2,

PETROLOGY OF SHEETED DYKES — DUMBRĂVIȚA—JULIȚA REGION

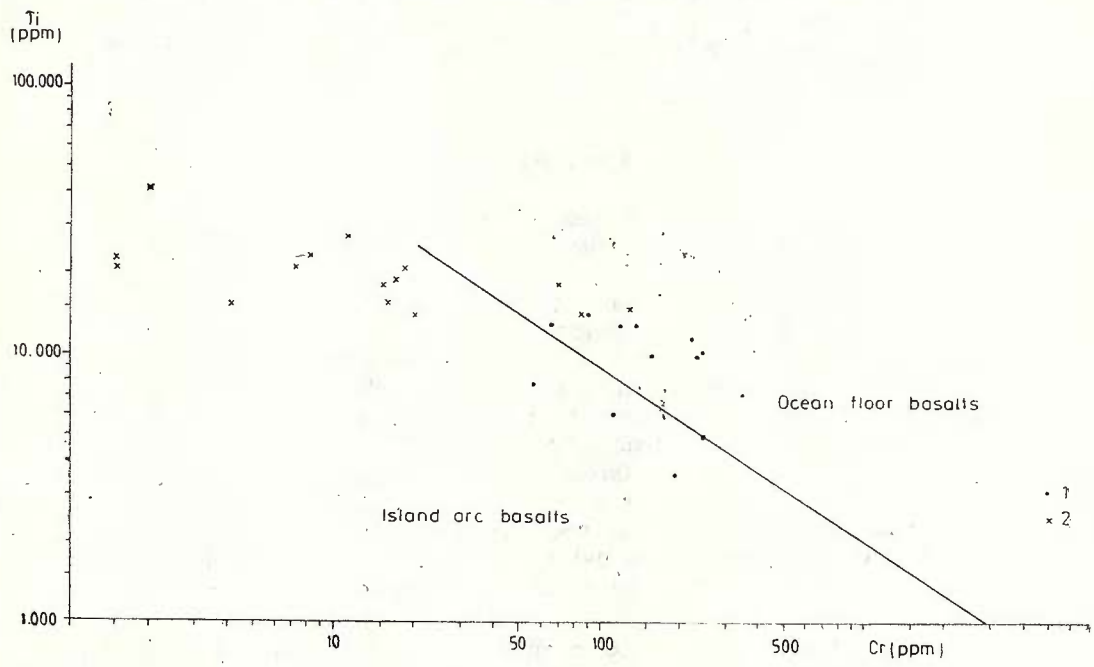


Fig. 8. — Ti-Cr diagram.
1, undifferentiated rocks ; 2, differentiated rocks.

Na_2O and volatiles in another sense. The first differentiation direction leads to the formation of the cumulates of titanomagnetite gabbros discussed above. The second differentiation trend leads to the formation of some magmas that gradually enrich in the mentioned components, giving rise to the following rock sequence : albitized basalts — spilites — granophyres — albitic plagiogranites. This succession also explains the genesis of spilitic rocks that alternate with basaltic lava flows in the O_1 complex of the ocean floor basalts or the formation of the spilite dykes alternating with the basalt or dolerite dykes within the sheeted dyke complex (O_2).

The differentiation at depth takes place simultaneously in both senses, as it is found that the basalt and hyalobasalt dykes or veins enriched in iron cross in a parallel direction also the granophyre dykes. This shows that the emplacement of the dykes within the O_2 complex took place alternatively, their magmas coming from different parts of the magmatic chamber beneath the spreading centre, possibly from different magmatic chambers (Coleman, 1977).

From the metallogenetic point of view it is found that, if the differentiated basic magmas are connected with liquid-magmatic concentration of vanadium titanomagnetite gabbros, the acid differentiated

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rocks are likely to associate with the hydrothermal mineralizations of pyrite and chalcopyrite in quartz and calcite gangue that form veins and stockworks, such as those at Pătîrș and Roșia Nouă (Savu et al., 1982). The latter may be hosted both in the sheeted dyke complex — as at Dumbrăvița-Baia (Savu, 1985, Pl. I, in this volume) — and in the ocean floor basalt complex above it. They circulated either on the separation plane of the dykes or on primary fractures, formed since the spreading stage of the Mureș ocean.

Conclusions

1. The sheeted dyke complex originated in a primary tholeiitic magma, formed in the upper mantle at the depth of about 100 km.

2. Due to the differentiation processes that took place in the magmatic chamber situated beneath the spreading zone, the undifferentiated primary tholeiitic magma changes into basic differentiated magmas and differentiated acid ones of trondhjemitic character.

3. From the geochemical point of view the three rock groups which derived from the primary tholeiitic magma are marked by specific contents of the various trace elements.

4. The undifferentiated basic rocks show petrochemical and geochemical characteristics similar to those of the classical tholeiitic series.

5. The differentiated basic rocks enrich in Fe, Ti, V and P, elements that concentrate in the gabbros with vanadium titanomagnetite (ferrogabbros), constituting the main metallogenetic process of these tholeiitic magmas.

6. The differentiated acid rocks enrich in Si, Na, Yb, Y, La and Zr.

7. As the differentiated basic or acid rocks enrich very much in some major or trace elements, they cannot be of use for establishing the geotectonic conditions in which they formed, no matter what they are : effusive, hypabyssal or intrusive rocks.

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CONTRIBUȚII LA STUDIUL PROCESELOR DE TRANSFORMARE POSTMAGMATICĂ ASOCIATE CORPULUI INTRUZIV MONZODIORITIC DIN PARTEA CENTRALĂ A CALDEREI CĂLIMANI [1]

DE

IOAN SEGHEDI [2], ALEXANDRINA MEDEȘAN [2], ALLA ZĂMÎRCĂ [2]

Monzodiorite. Mineral assemblage. Caldera. Postmagmatic alterations. Albitisation. Biotitisation. Actinolitisation. Argillisation Turmalinisation. East Carpathians-Neogene Eruptive-Călimani.

Abstract

Contributions to the Study of Postmagmatic Alteration Processes Associated with the Monzodiorite Intrusive Body in the Central Area of the Călimani Caldera. The postmagmatic alteration processes, controlled by a NW-SE trending fracture, affected the eastern part of the monzodiorite intrusive body. The following assemblages (zones) do occur : albite, biotite, actinolite, argillic, quartz + sericite + turmaline. Outside this area with superposed alterations, subordinate propylitisations and zeolite ± (quartz, calcite) depositions in fissures are noticed. Chemical and geochemical studies reveal that the hydrometasomatic alteration zones have high contents of Na_2O ; K_2O, Cu ; MgO, Mo, Zn ; H_2O^+, Li ; B_2O_3, Sn, exceeding their medium contents in the fresh rocks. The computer processing of data pointed to relationships among the different elements, which had been assigned to the different alteration processes. The most significant are the correlations requiring the boron supply : Sn-B, La-B.

Procesele de transformare hidrotermală din cadrul calderei Călimani au fost examinate anterior de Teodoru, Teodoru (1966), Balintoni (1970) și Stanciu, Medeșan (1971, a, b).

Teodoru, Teodoru (1966) disting în cadrul calderei Călimani două faze principale de desfășurare ale proceselor hidrotermale. Primele manifestări hidrotermale de temperatură ridicată afectează andezitele

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[2] Institutul de Geologie și Geofizică, str. Caransebeș nr. 1, București.

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cu amfiboli şi piroxeni şi microdioritele şi sînt reprezentate prin : cloritizări, propilitizări, sericitizări, biotitizări şi turmalinizări. Autorii prezintă aceste manifestări hidrotermale pe o hartă geologică, sub forma unor aureole situate în partea de est a intruziunii microdioritice. A doua fază de hidrotermalism se asociază în principal cu roci vulcanice extrusive şi efuzive şi este reprezentat prin silicifieri, argilizări, opalizări, alunitizări, ce ulterior sînt însoţite de depuneri de sulf şi limonit. Această sistematizare este în conformitate cu interpretarea activităţii eruptive din munţii Călimani de nord după Cosma et al. (1964).

Balintoni (1970) consideră sulful legat genetic de andezitele cu biotit, hornblendă şi cuarţ. Punerea în loc a sulfului a generat transformări de tip special (cuarţite secundare, alunitizări), care însă s-au suprapus pe un fond transformat hidrotermal (propilitizare, cloritizare).

Stanciu şi Medeşan (1971, a, b) au studiat de asemenea transformările postvulcanice din aria acumulărilor de sulf. Autorii consideră că subsecvent manifestărilor vulcanice prin care s-au pus în loc andezite cu piroxeni şi precedînd andezitele cu biotit, hornblendă şi cuarţ s-a format o importantă arie geotermală. În ordinea desfăşurării transformărilor din această arie, au avut loc alterări slabe, cloritizări, argilizări şi silicifieri, care formează uneori în această ordine zone cu aranjamente simetrice. Ulterior, are loc depunerea sulfului nativ şi a sulfurilor de fier (mineralizaţie epitermală de tipul înlocuire prin impregnare).

În urma cercetărilor efectuate în ultimii ani, am propus o nouă schemă evolutivă a activităţii magmatice a compartimentului superior din cadrul calderei Călimani (Seghedi, 1982). Activitatea vulcanică s-a desfăşurat pe parcursul mai multor stadii în următoarea succesiune : I. Stadiul stratovulcanic — care se subdivide în trei substadii : I. a. substadiul preponderent exploziv precalderă caracterizat printr-un volum mare de piroclastite grosiere cu intercalaţii de lave. Petrografic se caracterizează prin prezenţa andezitelor bazaltice, andezitelor piroxenice şi andezitelor cu hornblendă şi piroxeni ; I. b. substadiul preponderent efuziv precalderă este reprezentat prin curgeri de lave groase, stratificate cu intercalaţii subţiri de piroclastite, constituite din andezite cu piroxeni ± hornblendă, aparţinînd mai multor centre vulcanice. În urma punerii în loc a acestei importante mase efuzive, considerăm că s-a produs un proces de colaps, care a generat actualul aspect morfologic semicircular al calderei ; I. c. substadiul efuziv-exploziv postcalderă se caracterizează printr-o activitate restrînsă ca volum şi suprafaţă la interiorul calderei. Este reprezentat prin curgeri de lave, piroclastite, şi intruziuni minore aparţinînd mai multor centre vulcanice. Din punct de vedere petrografic au fost separate andezite piroxenice bazaltoide, andezite piroxenice, andezite cu hornblendă şi piroxeni.

II. Stadiul intruziv se caracterizează printr-o intruziune mare, alungită NE-SE, în centrul calderei, alcătuită din monzodiorite, diorite, micromonzodiorite. Ulterior apar intruziuni minore de andezite piroxenice cu hornblendă, biotit şi cuarţ şi de micromonzodiorite cuarţifere porfirice.

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III. Stadiul efuziv final este reprezentat de domuri extrusive ale andezitelor cu biotit, hornblendă și cuarț, situate la marginea sau la exteriorul calderei.

Potrivit acestei scheme activitatea postvulcanică din cadrul calderei Călimani, prezintă două momente succesive mai importante.

Primul moment este cel legat de activitatea postvulcanică caracteristică vulcanismului postcalderă. Spațial aparține centrelor presupuse de erupție de la vîrful Negoiul Românesc și vîrful Iancului, caracterizate prin prezența unor importante mase de piroclastite asociate cu rare intercalații de lave. Petrografic predomină andezitele piroxenice, subordonat andezitele cu hornblendă și piroxeni. Procesele de alterare din aceste centre vulcanice, ce conduc la importante acumulări de sulf, au fost studiate de autorii menționați anterior.

Alt moment hidrotermal important este asociat intruziunii subvulcanitelor monzodioritice, din centrul calderei. Rocile intrusive metamorfozează termic toate produsele andezitice preexistente de la contact, generînd o aureolă de corneene în faciesul corneenelor cu amfiboli (fig. 1). Studiul mineralogic și geochimic al neoformațiunilor postmagmatice metasomatice asociate intruziunii monzodioritice constituie obiectul lucrării de față.

Transformări postmagmatice asociate intruziunii monzodioritice

Cercetările de teren indică faptul că principalele transformări postmagmatice se localizează în partea estică a intruziunii și sînt controlate de o fractură NW-SE, ce pornește din versantul drept al văii Dumitrelul, pînă în creasta Iancului. În partea de vest a intruziunii nu au fost întîlnite transformări post-magmatice semnificative.

Majoritatea transformărilor se prezintă ca fenomene suprapuse în spațiu.

Rocile intruzive transformate sînt reprezentate îndeosebi de micromonzodiorite porfirice. Transformările hidrometasomatice afectează de asemenea și andezitele preexistente, precum și zonele de metamorfism termic, de la contactul cu acestea. Corpul și dykul de andezite piroxenice cu hornblendă, biotit și cuarț, din extremitatea sud-estică a intruziunii nu sînt afectate hidrometasomatic.

Falia NW-SE reprezintă principala zonă de acces a soluțiilor hidrotermale, de-a lungul căreia transformări hidrometasomatice, succesive, se distribuie în următoarele asociații :

Asociația (zona) cu albit

În această asociație plagioclazii inițiali se transformă în albit. Calciul din plagioclazi este levigat, sau poate rămîne uneori sub formă de epidot (pistațit sau clinozoizit).

Asociația (zona) cu biotit

Această asociație se caracterizează prin dezvoltarea biotitului de neoformație, care impregnează masa rocilor, pseudomorfozează total mineralele melanocrate primare (piroxeni, hornblendă) și înlocuiește

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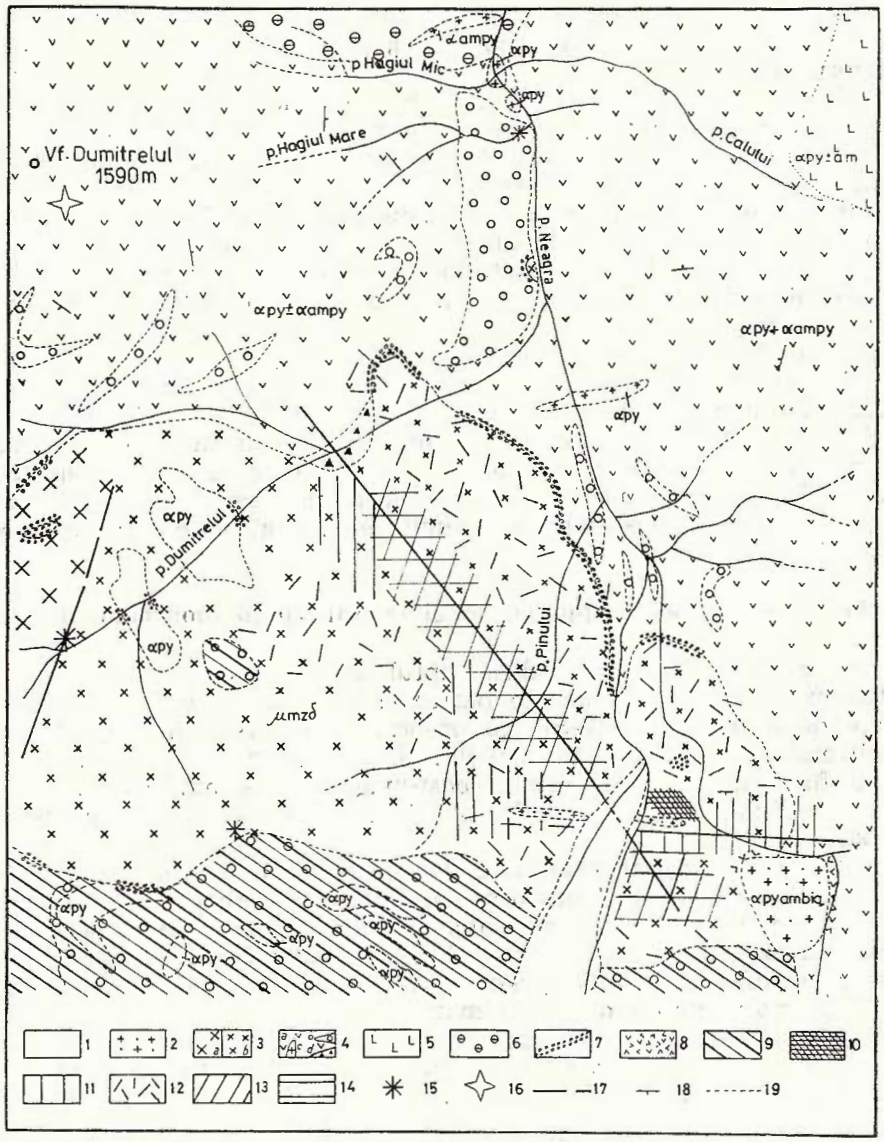


Fig. 1. — Schiță geologică în partea centrală a calderei Călimani.
1, aluviuni ; 2, andezite piroxenice cu hornblendă, biotit și cuarț (αpy am bi q), corp intruziv dyke ; 3, monzodiorite, diorite (mzδ, δ) a, micromonzodiorite (μmzδ) b, stock intruziv ; 4, andezite cu piroxeni (αpy), andezit cu hornblendă și piroxeni αam py), curgeri de lave (a), brecii vulcanice autoclastice și brecii piroclastice (b), corpuri intruzive (c) brecii intruzive (d) ; 5, andezite cu piroxeni ± hornblendă (αpy ± am) curgeri de lave ; 6, andezite piroxenice (αpy), subordonat andezite cu piroxeni și hornblendă (αpy am), brecii piroclastice ; 7, corneene cu piroxeni ± hornblendă ± biotit ; 8, brecii vulcano-tectonice ; — Transformări postvulcanice din aria acumulărilor de sulf ; 9, silicifiere, argili-

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plagioclazii (primari sau albitizați). Biotitul formează agregate glomeroporfirice cu conture neregulate sau apare în filonașe împreună cu cuarț și feldspat potasic.

Asociația (zona) cu actinolit

Distribuția spațială a acestei asociații depășește cadrul asociațiilor cu albit și biotit. Actinolitul este mineralul principal. Se dispune pe fisuri milimetrice pînă la centimetrice, formează aglomerări sau impregnează masa rocilor proaspete, ori afectate anterior de albitizare și biotitizare. Se asociază îndeosebi cu epidot, cuarț, albit, biotit, magnetit, pirită, mai rar calcit și feldspat potasic. Procesul de actinolitizare afectează și produsele andezitice din jurul intruziunii.

Asociația (zona) argilică

Se caracterizează prin participarea largă a mineralelor argiloase, care se suprapun celorlalte asociații de transformare. Se remarcă distribuția procesului de argilizare pe direcții perpendiculare pe falia principală NW-SE, sugerînd un control structural pe fracturi orientate în această direcție.

Asociațiile mineralogice principale sînt :
— illit — cuarț
— illit — montmorillonit — caolinit — cuarț
— montmorillonit — illit — cuarț

Mineralele argiloase au fost determinate prin difracție de raze X pe fracția < 2 μm cu următoarele precizări : termenul illit — l-am utilizat pentru mineralele argiloase la care $d_{(100)}$ este aproximativ la 10 Å ; termenul montmorillonit pentru $d_{(100)}$ între 15-15,5 Å iar

zare, cloritizare. Zone de transformare metasomatică asociate subvulcanitelor ; 10, zone cu cuarț + sericit + turmalină ; 11, zona argilică ; 12, zona cu actinolit ; 13, zona cu biotit ; 14, zona cu albit ; 15, depuneri de zeoliți ; 16, centre presupuse de erupție postcalderă ; 17, fracturi ; 18, direcția curgerilor de lave ; 19, limită geologică.

Esquisse géologique de la partie centrale de la caldeira de Călimani.
1, alluvions ; 2, andésites pyroxéniques à hornblende, biotite et quartz (α py am bi q), corp intrusif dyke ; 3, monzodiorites, diorites (mz δ, δ), a. micromonzodiorites (μmzδ), b, stock intrusif ; 4, andésites à pyroxènes (α py), andésite à hornblende et pyroxènes (α am py), coulées de lave (a), brèches volcaniques autoclastiques et brèches pyroclastiques (b), corps intrusifs (c) brèches intrusives (d) ; 5, andésites à pyroxènes ± hornblende (α py), ± am coulées de lave ; 6, andésites pyroxéniques (α py), subordonné andésites à pyroxènes et hornblende (α py am), brèches pyroclastiques ; 7, cornéennes à pyroxènes ± hornblende ± biotite ; 8, brèches volcano-tectoniques ; — Transformations postvolcaniques de l'aire des accumulations de souffre ; 9, silicification, argilisation, chloritisation. Zone de transformation métasomatique associée aux subvolcanites ; 10, zone à quarz + séricite + tourmaline ; 11, zone argilique ; 12, zone à actinolite ; 13, zone à biotite ; 14, zone à albite ; 15, dépôts de zéolites ; 16, centres supposés d'éruption postcaldeira ; 17, fractures ; 18, direction des coulées de lave ; 19, limite géologique.

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termenul caolinit pentru mineralele argiloase avînd $d_{(100)}$ aproximativ la 7 Å.

Cuarţul alcătuieşte fie o masă de impregnaţie microcristalină, cu conture neregulate, fie se dispune pe fisuri fine sau în geode, unde ia forma unor cristale idiomorfe submilimetrice, rar centimetrice, asociate uneori cu pirită, hematit. În cîteva situaţii se remarcă silicifierea rocilor, datorită abundenţei crescute a cuarţului de înlocuire.

Acolo unde argilizarea se suprapune asociaţiilor cu albit, biotit, actinolit, se remarcă prezenţa relictelor de minerale caracteristice acestora : biotitul este înlocuit de illit, clorit şi minerale opace (hematit în principal). Actinolitul este înlocuit prin montmorillonit, illit, hematit, cuarţ, rar leucoxen.

Asociaţia (zona) cu cuarţ + sericit + turmalină

Această asociaţie se suprapune pe rocile intrusive monzodioritice alterate anterior cît şi peste produse andezitice din apropierea contactului cu rocile intrusive, caracterizîndu-se prin prezenţa sporadică a turmalinei în asociaţie cu illit şi cuarţ. Pe creasta Iancului prezenţa asociaţiei cuarţ, sericit şi turmalină (ce ajunge pînă la 25% din volumul rocii), indică o intensitate mare a procesului hidrotermal, sugerînd existenţa unei importante zone de brecifiere. Cuarţul predomină, are conture neregulate sau este granular. Turmalina se prezintă sub forma unor agregate granulare, rozete şi mai rar sub formă de cristale prismatice alungite, de dimensiuni milimetrice, bine individualizate. Culoarea neagră-verzuie precum şi proprietăţile optice sugerează prezenţa varietăţii schorlit. Deseori intensitatea culorii cristalelor se reduce pînă la transparenţă, din centru spre exterior, reflectînd reducerea conţinutului în fier, de la interior spre margine, în timpul creşterii cristalelor.

Propilitizarea micromonzodioritelor a fost întîlnită mai ales în cursul mijlociu al văii Dumitrelu şi într-un foraj executat pe această vale, în afara arealului cu asociaţiile menţionate anterior. Mineralele melanocrate primare ale rocii (piroxeni şi hornblendă) sînt înlocuite cu pennin şi clinoclor subordonat calcit, cuarţ şi sfen. Plagioclazii sînt de obicei sericitizaţi sau slab argilizaţi. Uneori cristale de calcit înlocuiesc şi cristalele de plagioclaz.

Depuneri pe fisuri :

a) filonaşe cu cuarţ, calcit, gips, pirită, blendă, galenă, în forajul 26.165 şi la contactul cu andezitele piroxenice pe valea Neagra ;

b) filonaşe şi cuiburi cu zeoliţi, însoţiţi de cuarţ, calcit, subordonat dolomit, epidot, prehnit, pirită, hematit. Zeoliţii hidrotermali apar la marginea corpului intrusiv sau chiar în roci adiacente pînă la aproximativ un kilometru în jurul zonelor intens transformate hidrometasomatic.

Chimismul produselor de transformare hidrotermală

Suprapunerea proceselor de transformare în cadrul aceluiaşi areal, dar prezentînd intensităţi diferite a determinat gruparea probelor analizate după criterii mineralogice şi chimice ţinînd cont de procesul de

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transformare care le-a afectat cel mai intens. În tabelele 1 şi 2 probele de micromonzodiorite 1-9 sînt preponderent albitizate ; de la 10-15 preponderent biotitizate ; de la 16-24 preponderent actinolitizate. Probele 25, 26 reprezintă exclusiv asociaţia cu cuarţ + sericit + turmalină. Probele 27-33 sînt corneene afectate hidrotermal. Nu a fost separată o grupare reprezentativă procesului de argilizare, deoarece rocile, anterior argilizării au fost albitizate, biotitizate, actinolitizate.

Pentru comparaţie în tabelul 3 sînt prezentate analizele unor monzodiorite proaspete.

Caracterele distribuţiei elementelor majore (oxizi %) pe roci preponderent albitizate, preponderent biotitizate şi preponderent actinolitizate sînt prezentate în figura 2 comparativ cu intervalele compoziţiei chimice a rocilor proaspete (marcate în partea stîngă a figurii). În primul rînd sînt de remarcat valorile ridicate mult peste cele ale rocilor proaspete, ale Na_2O pentru rocile preponderent albitizate (3,58-7,92%), ale K_2O pentru roci preponderent biotitizate (3,36-4,82%) şi ale MgO — pentru rocile preponderent actinolitizate (6,30-14,80%).

Valorile SiO_2 sînt în general mai ridicate la rocile biotitizate şi albitizate şi asemănătoare cu a rocilor proaspete la rocile actinolitizate.

Al_2O_3 prezintă valori mai scăzute cu 2-5 procente de greutate, faţă de rocile proaspete. Conţinutul de H_2O^+ este mult ridicat faţă de rocile proaspete.

Se observă o alură asemănătoare a distribuţiei Al_2O_3 şi H_2O^+ legat de toate procesele de transformare, sugerînd suprapunerea proceselor de argilizare.

Fe_2O_3 şi FeO arată o mobilitate legată îndeosebi de procesele de argilizare, ce afectează metasomatitele preexistente.

Se constată levigarea CaO în toate procesele hidrotermale. De obicei cu creşterea conţinutului de H_2O^+ scade şi conţinutul de CaO şi MgO (exceptînd grupul rocilor actinolitizate).

Analizele celor două roci intens transformate din asociaţia cu cuarţ + sericit + turmalină, prezintă valori mari ale SiO_2 (70,85-74,56%) şi o levigare puternică a Fe_2O_3, FeO, CaO, Na_2O şi MgO, concomitent cu un aport de B_2O_3 (pînă la 3,62%).

Corneenele hidrotermalizate indică schimbări nesemnificative ale valorilor SiO_2, MgO, CaO, Fe_2O_3, comparativ cu rocile proaspete. Concomitent se observă o creştere a valorilor Na_2O, K_2O, H_2O^+ indicînd influenţa îndeosebi a proceselor de albitizare şi biotitizare şi în mai mică măsură a argilizării.

Distribuţia elementelor minore pe principalele procese hidrometasomatice, comparativ cu rocile proaspete se prezintă astfel :

— Ni, V, Cr urmăresc comportarea generală a Fe_2O_3 şi FeO, fără a suferi schimbări mari faţă de conţinuturile din rocile proaspete.

— Se observă o uşoară creştere a Ba în rocile albitizate şi parţial în cele biotitizate şi o uşoară scădere caracteristică celorlalte procese. Sr în general este levigat urmărind comportarea CaO.

— Zn, Zr, Y, Yb, La, Sc, Be, Ga, prezintă uşoare variaţii faţă de conţinutul mediu în rocile proaspete.

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TABELUL 1

Analize chimice ale rocilor transformate hidrometasomatic

Nr. crt.	Nr. crt.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	TiO_2	P_2O_5	MgO	CaO	Na_2O	K_2O	H_2O	S	Fe	CO_2	Total
1	17	58,71	16,80	2,46	1,02	0,36	0,80	0,15	5,45	3,30	7,92	0,90	2,61	0,09	0,08	—	100,65
2	6	55,60	18,65	2,97	0,36	0,22	1,06	0,04	3,15	2,40	6,48	1,18	4,47	1,95	1,70	—	100,23
3	130	56,46	16,30	3,34	1,97	0,33	0,66	0,05	5,29	3,15	5,15	2,89	2,23	0,58	0,50	—	99,10
4	16	56,97	15,90	4,51	1,72	0,19	1,06	0,26	3,89	5,30	4,64	3,16	1,79	0,08	0,07	—	99,64
5	122	56,99	16,80	3,06	1,92	0,28	0,58	0,13	4,03	3,12	4,47	2,20	2,65	2,19	1,91	—	100,33
6	132	62,85	17,60	0,54	0,14	0,00	0,78	0,00	0,13	1,02	4,20	3,24	2,64	3,69	3,21	—	100,04
7	253	59,97	14,40	0,48	0,63	0,18	0,80	0,19	4,10	2,57	3,94	3,89	1,14	3,74	3,26	—	99,20
8	163	66,81	14,10	2,45	0,12	0,00	0,54	0,09	0,55	0,60	3,65	1,94	1,93	3,39	2,95	—	99,12
9	Z1	60,57	16,00	3,32	2,62	0,13	0,66	0,18	3,38	5,85	3,58	3,11	0,29	0,23	0,20	—	100,12
10	8	66,87	15,40	1,61	0,07	0,02	0,60	0,06	0,59	0,58	4,18	4,82	3,27	1,19	1,03	—	100,45
11	13	65,22	18,00	4,99	0,00	0,00	1,28	0,09	1,22	0,40	0,20	4,65	3,94	0,14	0,12	—	100,05
12	11	72,66	14,75	1,04	0,00	0,10	0,66	0,04	1,76	0,30	0,30	4,39	3,98	0,16	0,14	—	99,98
13	9	64,28	15,65	2,04	1,27	0,12	0,60	0,09	2,05	3,14	4,04	4,34	1,93	0,40	0,35	—	100,41
14	37	70,03	13,10	1,41	4,28	0,08	0,84	0,24	2,38	1,52	0,30	4,05	1,59	0,36	0,31	—	100,49
15	137	66,97	16,40	5,26	0,10	0,00	0,82	0,25	0,74	0,40	0,44	3,36	3,62	1,15	1,00	—	100,53
16	18	48,10	13,45	0,49	4,68	0,35	1,16	0,18	14,80	2,90	2,30	5,35	4,06	1,10	0,95	—	99,85
17	88	51,87	13,10	0,74	3,71	0,24	0,90	0,16	14,18	3,12	3,00	5,38	1,36	0,85	0,74	—	99,55
18	202	53,99	15,80	3,47	1,60	0,07	0,75	0,07	10,66	0,50	4,22	4,54	2,31	0,79	0,69	—	99,46
19	12	55,30	15,80	2,23	1,26	0,07	0,68	0,09	10,60	0,38	4,64	4,48	3,98	0,22	0,19	—	99,92
20	131	58,86	14,30	0,29	1,46	0,09	0,72	0,05	10,30	0,80	5,67	3,80	1,07	0,91	0,79	—	99,11
21	4A	54,46	16,65	2,41	1,44	0,18	0,96	0,13	8,56	2,22	4,64	2,74	4,39	1,80	1,57	—	100,15
22	15	58,25	16,35	3,44	0,72	0,34	1,08	0,19	6,30	0,43	3,46	2,56	5,52	1,25	1,09	—	100,98
23	7	66,61	16,10	3,30	1,95	0,26	1,26	0,24	5,25	4,80	4,52	3,32	2,21	0,87	0,76	—	100,59
24	P5	59,54	16,10	2,58	1,56	0,12	0,90	0,22	4,64	4,70	2,25	1,64	2,50	1,14	0,99	1,50	100,76
25	25	74,56	15,10	0,84	0,06	0,00	0,56	0,06	2,51	0,20	0,49	2,33	0,99	0,18	0,15	B_2O_3 2,74	100,77
26	T16	70,85	16,00	1,56	0,00	0,02	0,54	0,09	2,99	0,45	0,20	1,46	2,23	0,07	0,07	B_2O_3 3,62	100,15
27	174	51,10	17,30	3,20	2,55	0,37	0,89	0,20	5,40	0,70	3,65	1,02	0,93	0,17	1,05	0,96	99,59
28	28	55,48	16,00	4,70	2,82	0,15	0,70	0,19	6,20	7,20	3,09	1,40	1,54	0,22	0,19	—	99,88
29	1	55,92	16,40	3,88	3,17	0,29	1,34	0,24	3,93	5,22	3,74	3,50	1,76	0,24	0,21	—	99,84
30	22	56,13	16,20	5,14	2,96	0,06	1,22	0,22	3,66	7,50	3,96	2,02	1,05	0,14	0,12	—	100,38
31	26E	56,36	15,30	4,46	2,79	0,26	9,69	0,19	5,17	5,80	4,91	2,58	1,22	0,18	0,16	—	100,07
32	30	57,35	14,50	4,09	2,05	0,27	0,72	0,20	4,34	6,29	3,58	4,02	1,51	0,10	0,08	0,71	99,81
33	24	58,95	15,70	2,41	1,62	0,12	1,32	0,23	3,62	4,00	3,67	3,04	1,23	1,92	1,67	—	99,50

Între 1—9 roci preponderent albitizate; 10—15 roci preponderent biotitizate; 16—24 roci preponderent actinolitizate; 25—26 roci transformate în cuarț + sericit + turmalină; 27—33 corneene hidrotermalizate.

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TABELUL 2

Analize spectrale ale rocilor transformate hidrometasomatic

Nr. crt.	Nr. prob.	V	Zr	Cr	Ni	Co	Sc	Y	Yb	La	Nb	Mo	Li	Be	B	Pb	Cu	Zn	Go	Sn	Sr	Ba
1	17	165	190	65	14,5	5	18	23	2,4	23	<9	5	25	2,1	<30	18,5	17	60	16,5	3,5	310	365
2	6	115	105	17	6	7	18	9,5	1,2	35	<9	<2	36	1,1	<30	5	125	38	17	3	380	430
3	130	170	150	59	20	15	19,5	12,5	1,4	46	<9	6	—	1,9	<30	8	112	70	18	4	700	1050
4	16	145	140	39	20	13	16	16	2	22	<9	<2	26	1,9	<30	12	70	55	16	3	460	1050
5	122	165	140	29	17	19	22	30	2,9	50	<9	2,5	—	2,5	<30	10	240	70	21,5	3,5	430	1000
6	132	140	140	28	16,5	12,5	14	8	1	42	<9	2,5	—	2,2	<30	26	55,5	32	19	3,5	320	1250
7	253	110	205	35	15,5	17	17	23	2,5	46	<9	2,5	—	2,4	<30	20	100	100	20,5	5,5	290	950
8	163	87	160	59	32	27,5	12,5	16	1,8	42	<9	<2	—	1,5	40	7,5	22,5	37	14	2	160	1100
9	Z1	165	160	37,5	21	17,5	16,5	25	2,4	46	<9	2,5	—	2,5	<30	25,5	34,5	90	19	3	350	730
10	8	66	220	17,5	6	4,5	13	10	1,1	36	<9	4	32	1,2	41	29	130	<30	17	3	150	1400
11	13	160	150	37	5,5	<2	19	8	1,9	38	<9	3	30	1	230	24	100	<30	19	4,5	100	270
12	11	105	95	36	2,5	<2	11	12,5	2	43	<9	8,5	34	1,2	70	28	9	<30	16	4	44	570
13	9	105	210	27	10	7,5	14,5	22	2,4	38	<9	7,5	30	2	<30	11	420	40	17	3	240	1050
14	37	90	245	70	34	15	19	52	5,2	57	11	—	—	2	290	34	48	87	20	4,5	150	950
15	137	150	130	61	6	4	24	15	2,3	75	<9	<2	—	2,3	700	60	220	35	44	11	180	480
16	18	130	100	70	24	16	21	21	1,5	<20	<9	5	62	1,5	<30	11,5	48	95	13,5	10,5	175	900
17	88	195	105	115	17	9,5	15	14	1,7	22,5	<9	3	—	1,6	<30	25	8	115	20,5	8	200	480
18	202	160	175	50	11	6,5	18	17	1	30	<9	8	—	2	300	14	88	75	18,5	6	90	520
19	12	140	140	45	12	8	16	10	2	27	<9	5	26	1,1	100	15	28	<30	17,5	4,5	80	400
20	131	125	155	40	10,5	6,5	14	14	1,3	26,5	<9	42	—	2	<30	16	9	90	19	8,5	205	460
21	4A	160	125	31	16	16,5	16	15	1,7	32	<9	2	20	2,7	<30	13	170	90	21	2,5	260	370
22	15	105	105	48	10,5	6	15	13	1,7	35	<9	2	34	1	290	42	3,51	100	11	2,5	110	340
23	7	180	140	34	15,5	13	21	25	2,5	30	<9	3,4	17	2	30	30	170	85	20	2,5	480	1300
24	P5	115	170	62	22	14	16	23	2,1	35	<9	<2	20	2,4	<30	20	33	80	18,5	3	240	1050
25	25	120	230	30	7	3,5	10,5	29	4,6	53	<9	—	—	2,3	8500	16	7	38,5	22	2,7	90	280
26	T 16	150	285	16	6,5	<2	17	37	4,4	55	12	<2	18	3	>1%	25	16,5	33	23,5	28	90	210
27	174	250	110	18,5	11	21	30	28	3	26,5	<9	3,5	—	2	<30	,5	56,5	115	19	3	340	160
28	28	150	105	195	50	24	28	20	2,4	30	<9	<2	<10	1,6	<30	17	160	85	17	6	520	350
29	1	170	140	37	21	16,5	19	23	2,0	22	9	3	17	2	<30	20	230	120	19	2,5	340	850
30	22	150	130	42	33	30	17	19	2,1	<20	<9	<2	18	2	36	11	60	65	17,5	2	550	510
31	E26	165	105	62	25	16	15	26	2,3	38	<9	10	—	1,5	<30	34	105	135	18	6	380	700
32	30	125	120	35,5	21,5	12	12,5	16	1,8	42	<9	3,5	—	1,8	<30	15,5	64	75	17	4,5	550	1450
33	24	180	200	15	10,5	20	17	25,5	2,8	30	<9	<2	18	2,1	43	16,5	55	55	20	2	310	650

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TABELUL 3

Analize chimice și spectrale ale rocilor proaspete

Nr. crt.	Nr. prb.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O^+	TOTAL
1	GR1	59,23	0,60	18,33	1,25	3,93	0,05	3,91	4,91	2,68	2,76	0,38	1,00	99,23
2	146	57,40	0,78	19,30	1,07	3,87	0,15	4,13	5,79	2,77	2,63	0,35	1,00	99,69
3	280	54,10	0,71	19,51	2,28	3,23	0,10	4,85	6,17	2,63	2,91	0,38	1,41	99,65
4	320	55,52	0,84	18,81	2,16	4,64	0,10	4,42	6,68	2,05	2,71	0,42	0,81	99,61
5	347	57,24	0,77	19,60	3,41	2,95	0,12	3,53	5,79	2,55	2,55	0,36	0,90	100,29
Media		56,70	0,74	19,11	2,03	3,72	0,10	4,17	5,87	2,54	2,71	0,38	1,02	

Nr. crt.	Nr. prb.	V	Zr	Cr	Ni	Co	Mo	Be	B	Sc	Y	Yb	La	Nb	Pb	Cu	Zn	Ga	Sn	Sr	Ba	Li
1	GR1	200	195	37	19	18	<2	2,3	<30	21	23	2,2	30	10	10	90	80	21	2,5	330	650	23
2	146	190	180	65	16	17	<2	2	<30	24	34	2,5	38	9	11,5	43	45	21	2	550	800	—
3	280	195	150	70	28,5	20	5,5	2,4	<30	23	27	2,5	42	<9	23,5	×	75	21	3	560	760	—
4	320	180	120	39	21	18,5	<2	1,8	<30	18	21	1,8	25	<9	14	61	60	20	2,5	440	560	30
5	347	155	145	31	12,5	11	2	21	<40	15	25	2,2	24,5	<9	17	13	48	21,5	2,5	400	700	12
Media		184	158	48,40	19,40	16,9		2,1		20,2	26	2,2	31,9		17,2	51,75	71,6	20,9	2,5	456	694	21,6

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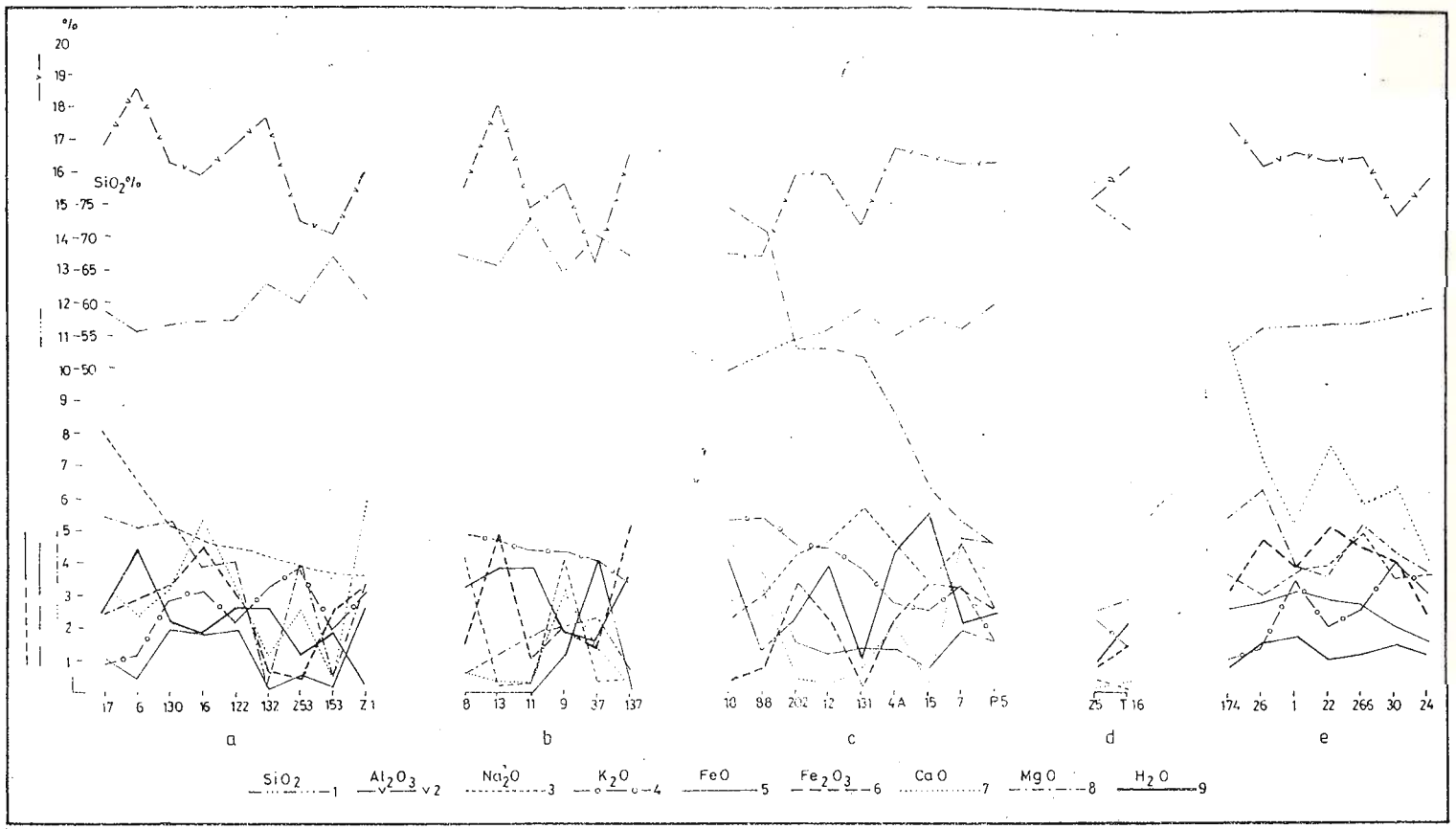


Fig. 2. — Variația elementelor majore în roci : a) albitizate; b, biotitizate ; c, actinolitizate ; d, turmalinizate ; e, corneene.

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— Li prezintă valori mai mari în roci transformate prin argilizare, cu conținutul cel mai ridicat în H_2O^+.

— Pb, dar mai ales Cu prezintă mari variații față de roca proaspătă. Valoarea maximă pentru Cu este în roci preponderent biotitizate de 420 ppm (proba 9).

— Mo prezintă uneori valori mai mari decît în rocile proaspete, valoarea maximă fiind de 42 ppm, în roci preponderent actinolitizate (proba 131).

— B prezintă frecvent valori ridicate față de rocile proaspete, suprapunîndu-se tuturor proceselor de transformare (40-300 ppm).

Rocile transformate intens în cuarț + sericit + turmalină, comparativ cu rocile proaspete, prezintă valori mai mici pentru Ni, Co, Cu, Zn, Sr, Ba, în general asemănătoare pentru Cr, V, Pb, mai ridicate pentru Y, Yb, La, Sn și mult mai ridicate în B.

Conținuturile în elemente minore al corneenelor alterate hidrotermal prezintă valori asemănătoare cu ale rocilor proaspete. Excepție fac Cu, Zn și uneori Mo și Ba (la probele cu conținut de K_2O ridicat). Se observă că, în general, cornificarea implică procese izochimice. Prezența elementelor minore cu conținuturi mai mari se datorește însă aportului de potasiu și sodiu al soluțiilor hidrotermale.

Pentru a urmări efectele rezultate din suprapunerea proceselor de transformare hidrometasomatică datele analitice au fost prelucrate de calculator stabilindu-se corelațiile existente și ecuațiile de regresie.

În figura 3 se prezintă perechile de elemente cu coeficientul de corelare corespunzător unui prag de semnificație $> 5\%$ pentru numărul de perechi de valori luate în calcul (Șarapov, 1968). Au fost excluse din interpretare cele două probe corespunzătoare asociației cuarț + sericit + turmalină, deoarece se șterge complet efectul transformărilor anterioare.

Corelațiile Sc-V, Ni-Cr, Co-Ni, FeO-Ni, caracteristice rocilor proaspete, se mențin și în rocile hidrotermalizate, datorită mai ales proceselor de levigare a elementelor feromagneziene.

Corelațiile pozitive CaO-Sr, CaO-V, CaO-Co, CaO-FeO exprimă de asemenea levigarea elementelor feromagneziene împreună cu Ca și Sr. Aceste corelații pot reprezenta îndeosebi procesele de albitizare și argilizare.

Corelația negativă K_2O-CaO și corelația pozitivă K_2O-Sn, sugerează legătura cu procesele de biotitizare.

Perechile de corelație în care este implicat MgO le-am atribuit procesului de actinolitizare : MgO-Zn, FeO-MgO pozitive și MgO-La negativă.

Corelații semnificative caracterizează procesele de transformare cu aport de bor și anume : Sn-B, La-B (fig. 4). Am luat în considerare aceste corelații, ținînd cont și de conținuturile în elemente minore din cele două probe transformate din asociația cuarț, sericit, turmalină.

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Perechile de corelații pozitive FeO-Y, FeO-Zn, Sn-Li, Li-B, Ga-B, Pb-B, La-Li, Yb-Li și negative Fe_2O_3-Li și Li-Be nu au putut fi atribuite unor procese specifice de transformare, rămînînd să-și găsească explicația în contextul proceselor de transformare suprapuse.

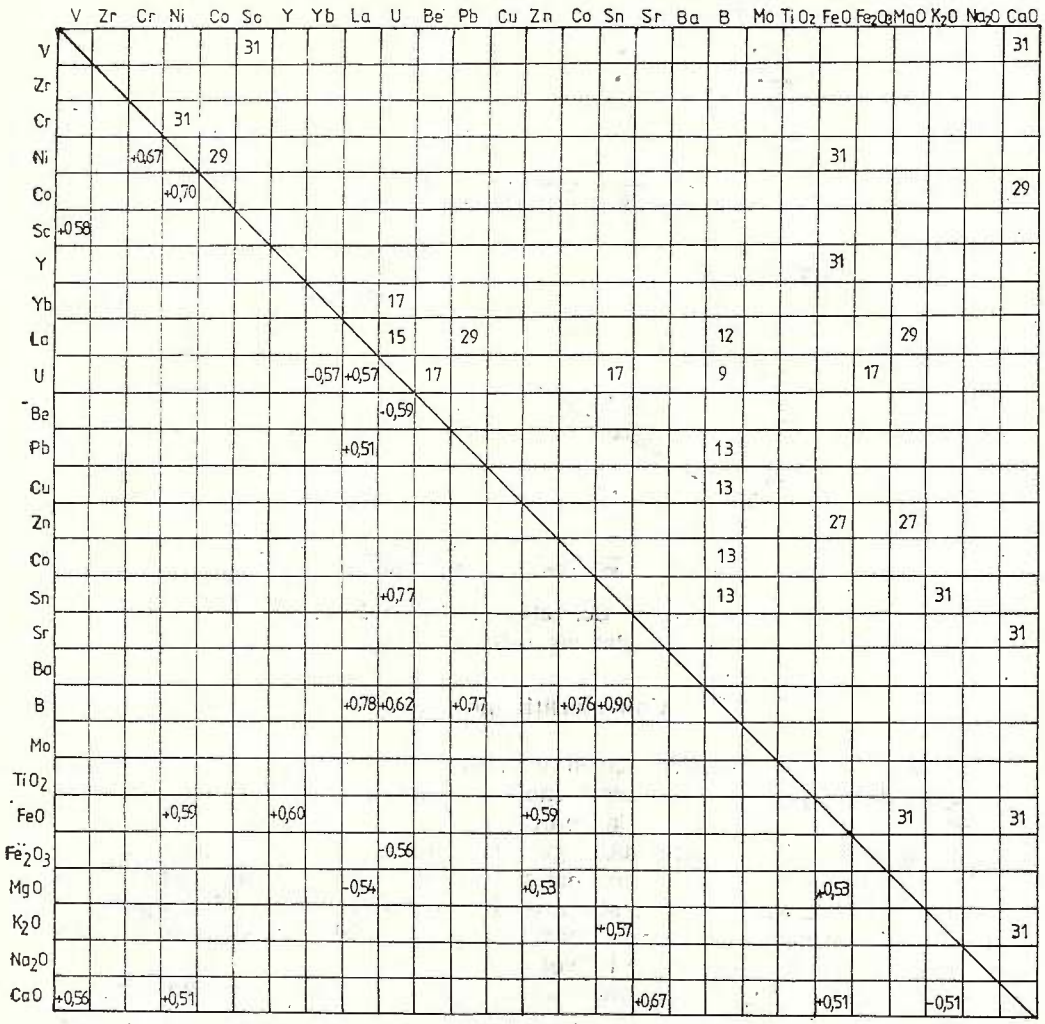


Fig. 3. — Corelarea elementelor majore și minore în roci transformate hidrometasomatic. Triunghiul SW prezintă coeficienții de corelație, triunghiul NE-numărul de perechi de valori intrate în calculul corelației.

Corrélation des éléments majeurs et mineurs en roches transformées hydrométasomatiquement. Le triangle SW présente des coefficients de corrélation, le triangle NE — le nombre de paires de valeurs employées dans le calcul de la corrélation.

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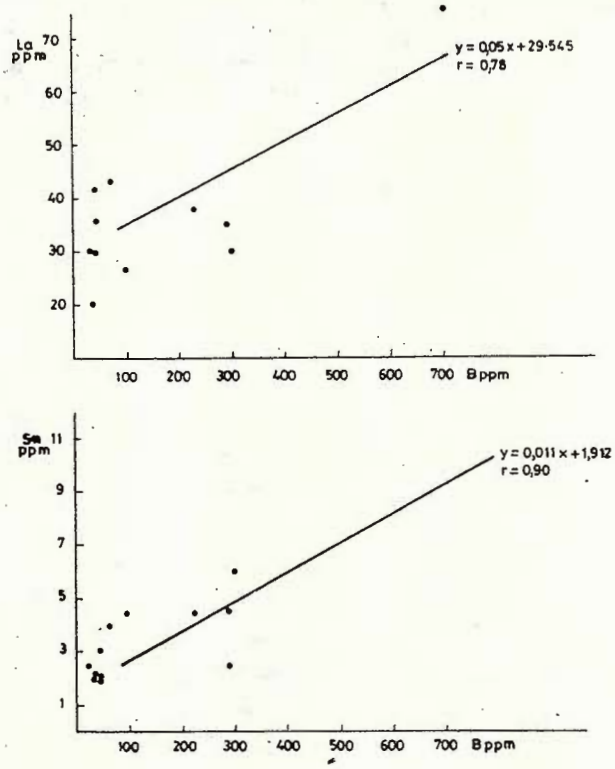


Fig. 4. — Corelațiile B-Sn și B-La.
Corrélations B-Sn et B-La.

Considerații genetice

Observațiile mineralogice și geochimice efectuate scot în evidență complexitatea proceselor hidrotermale asociate rocilor intruzive monzodioritice din cadrul calderei Călimani.

Manifestările hidrotermale, generate după punerea în loc a corpului intrusiv, au afectat cu intensitate diferită rocile preexistente atingînd în partea estică a acestuia o dezvoltare maximă. Suprapunerea mai multor procese de transformare pe acest areal sugerează o evoluție pulsatorie în timp a soluțiilor hidrotermale.

Migrarea soluțiilor hidrotermale s-a produs în principal de-a lungul unei fracturi NW-SE (între pîrîul Dumitrelul și creasta Iancului). Subvulcanitele au suferit de-a lungul acestei fracturi o serie de transformări determinate de influența unor soluții ce au generat următoarele procese :

Stadiul I

— Albitizarea datorită unor soluții alcaline sodice, la temperatură mare (metasomatoză sodică) ;

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— biotitizarea — datorită unor soluţii alcaline potasice, tot la temperatură mare (mteasomatoză potasică) ;

— actinolitizarea — produsă de soluţii preponderent magneziene cu caracter neutru la temperatură ridicată (metasomatoză magneziană);

— argilizarea desfăşurată în condiţii slab neutre spre acide, ce au favorizat metasomatismul de hidrogen (Meyer, Hemley, 1967). Temperaturile de omogenizare a incluziunilor de cuarţ din roci argilizate indică valori cuprinse între 285°-332° (Pomîrleanu în Seghedi et al., 1979), ceea ce sugerează temperaturi mai mari de 300° pentru procesele anterioare.

Se observă că în intervalul suprapunerii proceselor enunţate, soluţiile evoluează de la soluţii alcaline pînă spre slab acide, interval în care scade progresiv şi temperatura.

La exteriorul zonelor cu procese de transformare hidrotermală intensă se mai manifestă o serie de procese de slabă intensitate : propilitizare şi depuneri pe microfisuri de calcit, cuarţ, gips, ce însoţesc slabe mineralizări cu sulfuri de Pb-Zn, pentru care se apreciază existenţa unor condiţii de temperatură medie spre coborîtă.

Stadiul II

Observaţiile efectuate scot în evidenţă suprapunerea peste produsele stadiului I a unor soluţii acide de temperatură ridicată care favorizează un metasomatism de hidrogen şi bor. Migrarea acestor soluţii indică uneori o intensitate mare a procesului hidrotermal, care determină substituţia rocilor „iniţiale" cu cuarţ, sericit şi turmalină (creasta Iancului).

Legat de rocile intruzive monzodioritice, s-a constatat prezenţa unei faze hidrotermale constituită din depuneri în goluri şi fisuri de zeoliţi ± (calcit, cuarţ). Aceste depuneri au loc mai ales la contactul corpului intruziv cu produsele andezitice înconjurătoare pînă la aproximativ 1 km distanţă de zona intens hidrotermalizată. Temperaturile de omogenizare a incluziunilor fluide din cuarţuri ale acestei asociaţii indică un interval cuprins între 260°-195°C (Pomîrleanu, în Seghedi et al., 1979).

Lipsind relaţiile spaţiale, este greu de apreciat dacă această fază succede în timp stadiul I sau stadiul II.

În lanţul Călimani-Gurghiu-Harghita se mai cunoaşte o situaţie asemănătoare, exclusiv în ceea ce priveşte succesiunea stadiilor de transformare hidrotermală, în craterul Ostoroş (munţii Harghita). Aici într-un prim stadiu se produce o alteraţie biotitică şi argilică, iar într-un al doilea stadiu s-a format o brecie hidrotermală şi s-a depus asociaţia turmalină-cuarţ de substituţie şi turmalină ca ciment (Stanciu, 1976). Asociaţiile unor microelemente cu procesele de transformare sînt de asemenea similare ; aport de Li în procesul de argilizare şi de Sn în cel de turmalinizare (Stanciu în Peltz et al., 1975).

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CONTRIBUTIONS À L'ÉTUDE DES PROCESSUS DE TRANSFORMATION POSTMAGMATIQUE ASSOCIÉS AU CORP INTRUSIF MONZODIORITIQUE DE LA PARTIE CENTRALE DE LA CALDEIRA DE CĂLIMANI

(Résumé)

Les processus de transformation postmagmatique associés au corp intrusif monzodioritique de la partie centrale de la caldeira de Călimani se trouvent dans sa partie est et sont contrôlés par une fracture orientée NO-SE située entre le versant droit de la vallée de Dumitrelu et la crête de Iancului.

Les processus de transformation hydrométasomatique sont superposés, mais on peut distinguer les suivantes associations successives à : albite, biotite, actinolite, argilique, quartz + séricite + tourmaline. A l'extérieur de l'aréal des

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transformations mentionnées, les roches intrusives ont subi aussi, isolément, des processus de propilitisation. Le long des fissures apparaît rarement du gypse accompagné de sulfures de Pb et Zn, de quartz + calcite, alors que le long des fissures et dans des cavités, des zéolites ± (quartz, calcite).

Aux zones d'altération mentionnées correspondent du point de vue chimique des teneurs plus grandes de Na_2O, K_2O, MgO, H_2O^+, B_2O_3, qui dépassent les teneurs des roches fraîches (tableau 1).

Variation des éléments mineurs. Les processus de biotitisation, actinolitisation, argilisation et tourmalinisation ont engendré des augmentations de la teneur en Cu, Mo et Pb, Li, Sn et B (tableau 2).

L'analyse au calculateur des données obtenues a permis d'établir des corrélations linéaires entre des éléments attribués aux divers processus de transformation (fig. 3). Les plus significatives corrélations caractérisent les processus de transformation à apport de bore : Sn-B, La-B.

La genèse des roches hydrothermalisées peut être expliquée par les suivants stades d'évolution : le premier stade où les solutions évoluent en même temps avec la baisse de la température, en passant d'un caractère alcalin sodique (albitisation) et potassique (biotitisation) à un caractère neutre magnésien (actinolitisation), jusqu'à des solutions faiblement neutres voire acides qui ont favorisé la métasomatose d'hydrogène (argilisation) ; le deuxième stade évolue de nouveau d'une température plus élevée, les solutions acides favorisant une métasomatose d'hydrogène et de bore, qui affectent les roches transformées antérieurement. Si l'intensité du second processus est plus grande, apparaît l'association quartz+séricite+tourmaline. Les dépôts de zéolites+(quartz, calcite) le long des fissures et des cavités, qui sont présents jusqu'à une distance d'environ un kilomètre de la région intensément hydrothermalisée, constituent une phase à part. Faute de relations spatiales il est difficile de préciser si cette phase succède au premier stade ou au deuxième stade.

EXPLICAȚIA PLANȘELOR

Planșa I

Fig. 1. — Plagioclazi albitizați într-un monzodiorit cornificat cu clinopiroxeni de neoformație ; creasta Smidei ; N +, 35 ×.
Plagioclases albitisés dans un monzodiorite cornifié à clinopyroxènes de néoformation ; crête de Smidei ; N +, 35 ×.

Fig. 2. — Biotit de neoformație înlocuind marginal masa unui fenocristal de plagioclaz ; pîrîul Pinului ; N +, 35 ×. Bi-biotit.
Biotite de néoformation remplaçant en marge la masse d'un phénocristal de plagioclase ; ruisseau de Pinului ; N +, 35 ×. Bi-biotite.

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Planșa II

Fig. 1. — Actinolit depus pe fisură și impregnînd masa rocii ; creasta Pinului ; N ||, 35 ×. Ac-actinolit.

Actinolite déposé sur fissure et imprégnant la masse de la roche ; crête de Pinului ; N ||, 35 ×. Ac-actinolite.

Fig. 2. — Cristale radiare de turmalină în asociație cu cuarț și sericit ; creasta Iancului ; N +, 35 ×. Tm-turmalină, Q-cuarț, S-sericit.

Cristaux radiaires de tourmaline en association à quartz et séricite ; crête de Iancului ; N +, 35 ×. Tm-tourmaline, Q-quartz, S-séricite.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

CHERBELEZU AND SFÎRDIN GRANITOIDS. THEIR RELATIONSHIPS WITH THE ADJACENT ROCKS [1]

BY

NICOLAE STAN [2]

Granitoids. Crystalline schists. Precambrian. Cambrian. Permian. Vein rocks. Thermal contact metamorphism. Retromorphism. Dalslandian orogenesis. Caledonian orogenesis. Alpine orogenesis. South Carpathians-Crystalline Danubian Domain. Almăj Mountains.

Sommaire

Granitoïdes de Cherbelezu et Sfîrdin. Leurs relations avec les roches adjacentes. Soubassement de la région : 1. Schistes cristallins précambriens métamorphisés dans le faciès des amphibolites, zone à disthène faiblement rétromorphe (série d'Ielova et formation de Poiana Mraconia) ; 2. Schistes cristallins cambriens métamorphisés en faciès des schistes verts, zone à grenat ou possible en faciès des amphibolites (série de Corbu) ; 3. Granodiorites cambriennes-siluriennes, massives, faiblement gneissiques ou cataclasées ; 4, Roches métamorphiques de contact thermique à andalousite, staurotide, biotite et muscovite ; 5. Roches filoniennes : aplites, quartz hydrothermaux, lamprophyres. Couverture sédimentaire : Carbonifère, Permien, Mésozoïque et Néogène. Tectonique : 1. Métamorphisme de la série d'Ielova et de la formation de Poiana Mraconia pendant l'orogenèse dalslandienne ; 2. Métamorphisme de la série de Corbu durant la première phase de l'orogenèse calédonienne ; 3. Chevauchement de la formation de Poiana Mraconia sur la série de Corbu au cours de la seconde phase de l'orogenèse calédonienne et rétromorphisme de la série de Corbu ; 4. Intrusion postcinématique des granitoïdes au cours de la troisième phase de l'orogenèse calédonienne ; 5. Métamorphisme de contact thermique ; 6. Division de la région en horsts et grabens (anté-hercynien, hercynien et alpin) ; 7. Déplacement en bloc des dépôts permiens vers la série de Corbu ; un nouveau rétromorphisme de la série de Corbu y compris celui des roches de contact thermique pendant la phase finale des mouvements hercyniens et/ou au début des mouvements alpins.

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[2] Institutul de Geologie şi Geofizică, str. Caransebeş 1, 78344 Bucureşti.

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1. Introduction

The Cherbelezu and Sfîrdin granitoids form two plutonic bodies trending north-southwards in the Almăj Mts. They develop on a length of 25 km and a maximum width of 8 km. The granitoids occupy a surface of about 130 sq.km.

The Cherbelezu Granitoid, situated in the south, is separated from the Sfîrdin Granitoid by a strip of crystalline schists which do not exceed 2 km in width.

The eastern border of the granitoid massifs is at 15-25 km west of the localities of Mehadia, Băile Herculane, Topleț.

In the north, the Sfîrdin Granitoid is delimited by the Satul Valley at 3-5 km south of the village of Iablanița ; in the south, the Cherbelezu Granitoid is delimited by the Corbul Valley. These mountainous massifs are furrowed inside by deep valleys, with abundant water supplies, generally trending W-E or N-S. The hydrographic network is mostly tributary to the Cerna Valley and less to the Danube ; the most important streams are : Sfîrdinul Mare, Sfîrdinul Mic, Iardașița, Ieșelnița, Pîrîul Pietros, Pîrîul Negru, and Secărstița. The interfluves are flattened and mostly overlain, unfavourable for geologic observations. The heights of the plateau generally range from 650 to 900 m, with some exceptions — Mala Cîrșa, Velica Cîrșa, Cherbelezu or Movila lui Grecu summits — where they exceed 1000 m. The minimum heights are of about 300-400 m.

2. History of Researches

The granitoids known nowadays as Cherbelezu and Sfîrdin granitoids are found in the relevant literature beside the crystalline schists and sedimentary rocks from the Banat in papers printed in the second half of the 19th century. Those papers are due to Böck, Foetterle and Schafarzik.

According to Murgoci (1905, 1910) the granitoids in the southeast and east of the Banat belong to the tectonic unit of the Danubian Autochthon.

Streckeisen (1931) and Codarcea (1937, 1940) designated the main geologic and tectonic units of the Banat within the Danubian Autochthon on geological maps including the South Carpathians or the Almăj Mts, therefore the Cherbelezu and Sfîrdin granitoids as well.

Geologic studies on the South Banat, with special references to the crystalline schists and the intrusive metabasites have been subsequently studied thoroughly by Codarcea et al. (1961), Codarcea, Codarcea (1968) and Bercia, Bercia (1975, 1980).

The granitoids of Cherbelezu and Sfîrdin began to be investigated more deeply relatively late, after the year 1960. Codarcea and Pavelescu (1962) consider the Sfîrdin Granitoid of magmatic-metamorphic-metasomatic origin. In 1963, Codarcea and Pavelescu studied the origin of the South Carpathians granitoid massifs and inferred that the sialic magmatism of the Danubian Autochthon had developed during a period of time corresponding to the Caledonian foldings, as synkinematic and

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paulo-postkinematic intrusions. Bîrlea and Bîrlea (1964, 1965) prospected the alluvia of the valleys intruding the Ogradena, Cherbelezu and Sfîrdin granitoids. The geological map drawn up by them renders evident the graben which separated the Cherbelezu Granitoid from the Sfîrdin Granitoid. From the petrochemical point of view the Ogradena Granitoid was studied by Anastasiu (1976). Tiepac (1967) registered the radioactivity of the Cherbelezu Granitoid on some profiles. K/Ar or Rb/Sr radiometric age determinations on samples from the Cherbelezu and Sfîrdin granitoids or from the adjacent crystalline schists were carried out by Soroiu et al. (1970), Mînzatu et al. (1974), Mînzatu et al. (1975), Pavelescu et al. (1975). Minute geological researches on the Cherbelezu and Sfîrdin granitoids were made by Stan et al. (1981) and Stan et al. (1982).

3. Geological Structure

The region belonging to the great tectonic unit of the Danubian Autochthon consists of a basement, represented by metamorphites and Precambrian-Lower Paleozoic intrusions, and by Permo-Carboniferous, Mesozoic and Neogene sedimentary rocks. The sedimentary deposits form the basement cover.

3.1. *Metamorphic-Intrusive Basement. Associated Vein Rocks*

The basement is constituted of crystalline schists, intrusive metabasites, granodiorites, contact metamorphic rocks and vein rocks.

3.1.1. *Crystalline Schists*

The crystalline rocks including the Cherbelezu and Sfîrdin granitoids are represented by the Ielova Series, Poiana Mraconia Formation and Corbu Series.

The Ielova Series and the Poiana Mraconia Formation belong (acc. to Bercia, Bercia, 1975) to the Almăj Unit (Middle Precambrian) and the Corbu Series to the Ogradena Unit (Lower Cambrian-Upper Precambrian). Kräutner (1980) assigned the Ielova Series and the Poiana Mraconia Formation to the Carpian Supergroup (Upper Precambrian A) and the Corbu Series to the Marisian Supergroup (Upper Precambrian B-Cambrian).

Ielova Series (Bercia, Bercia, 1975 ; synonyms : Rudăria-Berzasca Zone, Streckeisen, 1931 ; Ielova Zone, Codarcea, 1940) had been mapped and described by Gheruci and Teodoreanu (1968) in an area extending eastwards up to the boundary with the Sfîrdin Granitoid.

Our researches included only a narrow strip of the above-mentioned series, trending N-S, lying between the Poiana Mala spring area of the Sfîrdinul Mic Valley. The zone consists mostly of amphibolites and amphibolic gneisses with or without biotite ; paragneisses occur subordinately. The minerals which are to be found in these rocks are : green hornblende, plagioclase feldspar, biotite, garnet, muscovite, sphene, apatite, zircon, epidote, chlorite, sericite, and calcite. Mărunţiu (1976) pointed out the presence of kyanite as well. In places, the Ielova Series is weakly retromorphosed.

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Poiana Mraconia Formation (Kräutner, 1980 ; synonyms : Cătrămăț Series, Streckeisen, 1931 ; Poiana Mraconia Zone, Codarcea, 1940 ; Poiana Mraconia Series, Bercia, Bercia, 1975) delimits the western limb of the Cherbelezu Granitoid. Further on it develops towards W-E, between the two granitoid massifs ; then it extends northwards, on the eastern limb of the Sfîrdin Granitoid. The Mraconia Formation develops more westwards, besides the study area, where it is partly overlain by Mesozoic sedimentary deposits.

In the study area this geological subunit consists mainly of amphibolic rocks — like the Ielova Series. Unlike the latter, significant intercalations of gneisses are found in amphibolites, represented by gneisses with hornblende (with or without biotite). Quartzites and feldspathic quartzites occur more rarely and micaschists are found only in places. The minerals which enter into the composition of the Poiana Mraconia Formation are : green hornblende, plagioclase, microcline, biotite, muscovite, and quartz, more rarely garnet and very rarely kyanite and staurolite. Sphene, zircon, apatite, rutile and tourmaline are accessory minerals.

Gneisses intercalations are frequently to be found in amphibolites on the right-hand tributaries of the Ieșelnița Valley and the spring area of the Perilor Valley. Feldspathic quartzites are individualized on larger areas towards the spring area of the Corbul Valley. Micaschists with garnet, staurolite and kyanite occur on the western limb of the Scorțari Summit.

The Poiana Mraconia Formation is more or less retromorphosed. The crystalline schists, with a N-S trend, included into the Sfîrdin granitoids, are strongly metamorphosed. In this area the tectonized amphibolites and amphibolic gneisses have a conspicuous schistous texture. The primary minerals are changed into actinote, tremolite, epidote, zoisite, chlorite, sericite, calcite. The younger shear cleavage, intersecting the old lineation, is often observed in slides. Macroscopically two clear lineations, almost perpendicular to each other, are also visible in the retromorphosed rocks.

In conclusion, both the Poiana Mraconia Formation and the Ielova Series originate in metamorphosed effusive basic rocks, closely associated to the clay-gritty or gritty-quartzitic, in places feldspathic, sedimentary material. Considering the primary mineralogic paragenesis (acc. to Bercia, Bercia, 1975, 1980), the prograde regional metamorphism took place, in both units, under the conditions of the almandine amphibolite facies (kyanite-almandine-muscovite subfacies). More often the rocks, especially those belonging to the Poiana Mraconia Formation, are retromorphosed and included into the greenschist facies. The metamorphic ages of the Ielova Series and of the Poiana Mraconia Formation are not yet proved. They are supposed on the basis of the correlation of the mentioned geological units with other units in the South Carpathians, whose palinological and paleontological data and the radiogene ages are known.

The Corbu Series (Bercia, Bercia, 1975 ; synonyms : Predeal Zone, Streckeisen, 1931 ; Corbu Phyllites Zone, Codarcea, 1937, 1940) has been thoroughly mapped and described by Gheruci et al. (1963),

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Gheruci and Serafimovici (1964, 1967). It develops in the eastern part of the area, after a N-S and NNE-SSW trend, as a narrow strip which does not exceed 1 km in width, at the direct contact with the Sfîrdin and Cherbelezu granitoids.

Petrographically, this series consists mainly of sericite-chlorite schists, within which relics of muscovite and biotite may be observed. The transition towards less retromorphosed, quartz micaceous rocks — in places associated with garnet — may be followed in slides. The chlorite-sericite-micaschists are closely associated with strips — with thicknesses of the metres order — of schists with albite porphyroblasts (Iardaşiţa, Iloca, Tustinele valleys), crystalline limestones (Iardaşiţa, Corbul and Perilor valleys), chlorite calc-schists (north of the Teiul Moşului), actinolite schists, in places with hornblende relics (Satul, Iloca, Corbul valleys and Perilor Ravine). Other intercalations, more rarely found, are represented by slightly retromorphous micaschists (Satul Valley) as well as by partly retromorphous amphibolites (spring area of the Iardaşiţa Mică Valley). Quartzites, epidote schists, graphite schists are more or less spread within the Corbu Series ; they do not form well-individualized entities.

The minerals entering into the composition of this strongly retromorphosed series are : chlorite, sericite, quartz, then albite-oligoclase, calcite, graphite, epidote, actinote ; the relict minerals are represented by muscovite, biotite, hornblende and garnet and the accessory minerals by apatite, rutile-sagenite, zircon, opaque minerals, and very seldom tourmaline.

The rock structure is schistous with a satinated aspect. Microscopically one may often observe in the same sample two lineations — l_1 and l_2.

The microscopic study of the crystalline rocks belonging to the Corbu Series points out that they are the result of the metamorphosis of detrital sediments closely associated with a basic volcanic material. At present those rocks are mostly metamorphosed in the greenschist facies, albite-muscovite-chlorite subfacies. Initially, if we consider the relict minerals, the sedimentary rocks have been metamorphosed at least at the level of the biotite-garnet isograde. There is no information on the initial chemical composition of the plagioclase changed into albite. However, the prograde metamorphism of the Corbu Series might have developed at the level of the amphibolite facies, exceeding the intensity of the greenschist facies.

The premetamorphic age of the mentioned geological subunit is considered Lower Cambrian (Codarcea, Codarcea, 1968) by comparison with the rocks forming the upper complex of the Crnajka syncline (Yugoslavia) from which the Archaeociatidae have been reported. This assumption is supported also by the phytoplanktonic association identified by Adina Visarion in the diabase-phyllitoid sequence of the Corbu Series (Savu et al., 1978). It is very likely that most of the "Corbu Series" might represent the retromorphous facies of the Neamţu Group (Gunnesch, Gunnesch, 1978 ; Stan et al., 1981 [3]).

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3.1.2. *Intrusive Metabasites*

Metabasites are represented by gabbros-peridotites intensely serpentinized. In the south, the tectonized peridotites are located on an overthrust and faulting zone, between the Poiana Mraconia Formation and the Cherbelezu Granitoid. Inside the granitoids there occurs a small lens of about 1.5 km, trending N-S. On the Perilor Ravine the tectonized serpentinites, with laminated structures and slickensides, are penetrated by the Cherbelezu granitoids with a massive structure. To the north the rocks are to be found only as fragments on the Tustinele Mici Valley.

Metabasites consist of asbestos-chrysotile, antigorite-chlorite, talc, and carbonate, rare crystals of olivine and rhombic pyroxene besides chromite and magnesite.

The age of those basic intrusions is considered to be ante-Permian by Streckeisen (1931) and Codarcea (1937), and Devonian-Carboniferous by Bercia, Bercia (1975).

3.1.3. *Cherbelezu and Sfîrdin Granitoids*

Granitoids occupy about 70 per cent of the study area. To the west they come into contact with the crystalline schists of the Ielova Series and of the Poiana Mraconia Formation. To the east they are directly connected with the Corbu Series. In the south the contact with the Corbu Series and the Poiana Mraconia Formation is marked by a fault trending WNW-ESE and in the north the Sfîrdin Granitoid is overlain by Jurassic and Neogene sediments. The two massifs are distinguished as well-outlined areals by the crystalline schists of the Poiana Mraconia Formation.

The Cherbelezu granitoids are highly homogeneous from qualitative mineralogical point of view. The mineralogic composition is relatively simple : quartz, oligoclase-andesine, microcline, microcline-perthite, biotite$\pm$muscovite. The petrochemical studies indicate for the Cherbelezu, and Sfîrdin granitoids granodioritic-adamellitic features (Stan et al., 1981, 1982).

The structures and textures are more various. From this point of view one may take into account, on the one hand, the textures referring to the sizes of the component minerals and, on the other hand, the structures concerning the arrangement of the minerals. In this respect, macroscopically one may observe microgranular, macrogranular, pegmatoid, porphyric textures, the last ones with feldspar megacrysts, and massive or oriented structures. The oriented structures are primary, slightly gneissic, and secondary, the latter subsequent to the granitic rocks, due to the displacement movements or to the disjunctive movements. The secondary textures are typical of the proper metagranites and cataclasites. All the primary and secondary structural-textural facies, which in places overlap one another and display gradual transitions between them, cannot be strictly delimited in cartographic respect ; however, on the map they have been indicated by marks.

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The Cherbelezu granitoids display more varied textures and the mineralogical elements are generally more crystallized as compared to the Sfîrdin Granitoid.

The microgranular granitoids crop out on a restricted area north of the Cherbelezu Summit, in the spring area of the Pîrîul Negru Brook and the Pietroasa Brook. The sizes of the mineralogical components are of 1-2 mm. The structure is massive, equigranular, quite seldom oriented.

The macrogranular granitoids have the widest spreading within the Cherbelezu granitoids. The structures are massive, slightly oriented, gneissic. Most of the mineralogical components have sizes up to 0.5-0.7 cm.

The pegmatoid granitoids are to be found in the area of the Cherbelezu Summit, on the Ieşelniţa Valley, as well as on the main left-hand tributary of the Corbul Valley. The structures are mostly massive; however, gneissic, slightly oriented structures can be observed, too. The minerals frequently reach up to 1-1.5 cm in length.

The porphyric granitoids with alkaline feldspar megacrysts lie in the central and northern part of the massif. They are often found on the Valea Pietroasă Valley on the Pîrîul Negru Brook and more seldom in the spring zone of the Iadaşiţa Valley. As a matter of fact they are macrogranular or pegmatoid granitoids with alkaline feldspar megacrysts. The alkaline feldspars generally reach 2-3 cm in length ; in places they reach 5-7 cm and only exceptionally 10 cm. Megacrystals are often oriented : N20-35°E.

The cataclased granitoids occupy most of the eastern border of the Cherbelezu and Sfîrdin granitoids. The maximum width of the metagranites is of 300-400 m ; however, more frequently they do not exceed 100-200 m. The textures obviously trend approximately N-S, with slight E or W deviations of 15-20°.

Granitoid rocks, intensely tectonized and broken, resulting from the disjunctive movements, with a N-S or E-W trending, have been identified on the Ieşelniţa Valley or on its tributaries in the upper basin. The cataclased zones do not exceed some metres in width.

3.1.4. *Thermal Contact Rocks*

Minerals specific to the thermal metamorphism — represented by andalusite, biotite, muscovite, quartz, beside staurolite and garnet — are formed, in certain sectors, at the contact between the granitoid rocks and the crystalline schists, intruded by them.

More often such rocks are found on the eastern flank of the region in the crystalline schists belonging to the Corbu Series, situated closely nearby the granitoid rocks. The contact rocks crop out on a narrow strip with a N-S trend and a thickness of about 100-200 m.

On the western flank the thermal metamorphism have been identified much more rarely in two small sectors : on the Sfîrdinul Mic Valley, at the contact of the Sfîrdin Granitoid with the Ielova Series, and in the spring area of the Terleţu Brook, at the contact of the Cherbelezu Granitoid with the Poiana Mraconia Formation. In the east, the contact rocks, formed at the expense of the Corbu Series,

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mostly display schistous structures. That aspect is given by paleominerals which occupy 90-95% of the rock volume. However, the neominerals develop as porphyroblasts,very often without preferential trending. They intersect the older lineation of the rock under different angles. Andalusite, more seldom staurolite and quartz, contain fine-grained paleomineral inclusions. The more recent thermic contact minerals are generally less altered than the older minerals ; sometimes the contact minerals are remarkably fresh. All this proves the later increase of andalusite, staurolite and micas at the expense of already metamorphosed rocks.

The schistous texture of the thermic contact metamorphites grows indistinct in places and even display a tendency to become massive as the contact minerals become more abundant. On the Satul Valley the andalusite, biotite and muscovite porphyroblasts are so numerous that they represent 70-80% of the rock volume. The andalusite porphyroblasts with a poikilitic structure reach there sizes of 0.5-1 mm.

Slightly schistous, almost massive structures are displayed also by the granitoids from the western part. On the Terleţu Valley, for instance, the porphyroblasts of andalusite (1-1.5 mm), biotite, muscovite and quartz occur in significant amounts, representing up to 90% of the rock volume.

The thermic contact minerals identified in the Corbu Series show also other significant aspects within the tectonic evolution : andalusite, staurolite and micas in places underwent mineralogical alterations. For example, andalusite is partly or totally sericitized. The rocks display sericite spots. Andalusite may be impregnated with iron oxides. Staurolite is generally less affected by sericitization as against andalusite; muscovite is considerably less sericitized. Biotite is incipiently chloritized.

Besides the above-mentioned chemical alterations, mention should be made of the purely mechanical effects underwent by neoporphyroblasts : contorsion, goffering and, in places, breaking of the micas ; rolling and fissuring of andalusite and staurolite. The effects of the mechanical movements are pointed out, on the one hand, by the L internal lineations of staurolite and andalusite, unconformably with the L_e external lineations of the rock and, on the other hand, by the pressure shadows occurring at the end of the minerals. Along the same line it is worth mentioning that the fissures found in andalusite are filled with minerals from the rock groundmass.

The chemical alterations as well as the mechanical deformations displayed by the thermic contact minerals represent the effect of subsequent tectonic movements, superimposed to the Corbu Series.

Garnet can hardly not considered exclusively as a contact mineral as there are no evident proofs in this respect. It may be the result of the prograde regional metamorphism or, in view of its frequent association with the mentioned neominerals, it has probably been formed at the contact. In most cases garnet is fresh ; very seldom it is incipiently chloritized.

In conclusion, andalusite, some of the micaceous minerals, staurolite and probably garnet have been formed subsequently to the pro-

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grade regional metamorphism of the Ielova Series, Poiana Mraconia Formation and Corbu Series. Those minerals underwent chemical and mechanical alterations as a result of a recent metamorphism which had affected the Corbu Series. The thermic contact minerals of the Ielova Series and the Poiana Mraconiei Formation, situated in the western part, are undeformed and the chemical alterations are very weak and unsignificant.

3.1.5. *Vein Rocks*

The veins penetrating both the granitoids and the crystalline rocks occur mainly in granitoids, particularly towards the periphery. They are represented by hidrothermal quartz, aplite, pegmatite, porphyric-granodiorite, porphyric-diorite±quartz and lamprophyres. They have reduced sizes : up to 400-500 m long (exceptionally up to 1000 m) and some metres thick. Most of the veins have generally a N-S trending and only seldom a E-W trending.

3.2. *Sedimentary Cover*

The sedimentary rocks overlie transgressively and unconformably the crystalline-granitic basement. According to Codarcea (1940) the sedimentary formations are represented by Carboniferous, Permian, Jurassic, Neogene and Quaternary.

Carboniferous crops out in the Mişelep Hill and extends to the north on the Teiul Moşului branch, where it is crushed in the Cherbelezu granitoids and strongly tectonized. It consists of microconglomerats, sandstones and clay-gritty shales.

Permian occurs in the eastern part on an alignment trending N-S. It has a characteristic grey-brick red colour and consists of an alteration of conglomerates with elements of granite and crystalline, microconglomerates, sandstones, clays and acid volcanic tuffits with intercalations of decimetric dacite-keratophyre ignimbritic flows. That volcano-sedimentary complex is slightly metamorphosed.

Jurassic is represented by limestones, conglomerates, microconglomerates and coaly black shales.

White-grey, schistous limestones occur in the middle basin of the Sfîrdinul Mic Valley, on a surface of about 1.5 sq.km.

Conglomerates, consisting of quartz elements, form the crystalline of the Poiana Mraconia Formation.

Neogene transgressively overlies the northern part of the Sfîrdin Granitoid massif. It is represented by conglomerates, pebbles, sands, sandstones, and marls. Centimetric intercalations of coal have been reported from marls and clays from the left side of the Sfîrdinul Mic Valley.

Quaternary forms alluvial plains south of the village of Iablanița.

4. Geological and Tectonical Evolution

The oldest crystalline formations constituting the crystalline basement belong to the Ielova Series and the Poiana Mraconia Formation. The prograde regional metamorphism of the mentioned geological units

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is considered to have occurred during the Dalslandian orogenesis (Upper Precambrian A ; Savu et al., 1978 ; Kräutner, 1980). The metamorphism developed at the level of the amphibolite facies, kyanite-almandine-muscovite subfacies (Bercia, Bercia, 1975, 1980).

Next in the chronologic succession comes the Corbu Series, whose pre-metamorphic Lower Cambrian age is endorsed by Savu et al. (1978) on the basis of palynologic data. Therefore, the metamorphism is of post-Lower Cambrian age. Since in the South Carpathians the age of the crystalline schists metamorphism, paleontologically proved, is ante-Silurian (Stănoiu, 1971), it is considered that the metamorphism of the Corbu Series took place in the post-Lower Cambrian—ante-Silurian time span (Caledonian orogenesis, event I). In view of the relict minerals, the prograde metamorphism of the Corbu Series developed at the level of the greenschist facies, possibly the amphibolite facies.

The metamorphism of the Corbu Series was followed by the thrust of the Poiana Mraconia Formation over the Corbu Series. That major tectonic line, including the intrusive metabasites too, was pointed out by Streckeisen (1931). The above-mentioned tectonic event determined the first intense retromorphism of the metamorphites of the Corbu Series — the lamination and tectonization of the intrusive metabasites too — as indicated by the existence of phyllonite in the Corbu Series and the change of the primary minerals into secondary minerals: sericite — chlorite — epidote — calcite — actinote. The overthrust took place after the regional metamorphozation of the Corbu Series and before the granitoid intrusion in the post-Lower Cambrian-ante-Silurian time span (Caledonian orogenesis, event II). The intrusive metabasites were emplaced towards the end of the thrust dynamic movements or they were dredged, pushed and crashed mechanically by the Poiana Mraconia Formation when extending eastwards. In this last case the metabasites have already been intruded in the crystalline schists. The second hypothesis is more likely.

The Cherbelezu and Sfîrdin granitoids penetrate the adjacent crystalline schists belonging to the Ielova Series, the Poiana Mraconia Formation and the Corbu Series ; they also intercept the intrusive metabasites. Their N-S trending in the northward extension of the Poiana Mraconia tectonic line indicates their ascent towards the surface on that tectonic zone of weak resistance. The northern extension of the thrust line is also pointed out by relics of intrusive metabasites identified on the Tustinele Mici Valley. It is very likely that tectonic zone extended much northwards under the sedimentary cover of the Mehadia basin up to Ilișovii because there the crystalline schists are found beside metabasites.

The post-kinematic intrusion of the granitoids in the crystalline schists determined, particularly in the Corbu Series, the formation of the thermic contact minerals. The presence of the staurolite and andalusite porphyroblasts shows that the metamorphism has occurred at high pressures (cca 3 kb), corresponding to a depth of 6-7 km. At pressures of 3 kb, under the conditions of contact metamorphism, instead of cordierite, staurolite occurs beside andalusite (Winkler, 1966). Within the Corbu Series, retromorphosed at the level of the green-

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schist facies, an increase of the metamorphic degree took place nearby the granitoids, as shown by the contact minerals, such as : andalusite, staurolite, biotite and probably garnet. That is the third metamorphism superimposed to the Corbu Series.

The granitoid structures, slightly oriented and poorly gneissic, are primary, formed during the cooling of the magmas. The potash feldspar megacrysts trend approximately N20-30°E. There is a slight angular unconformity of 10-15° between the general trending of the mineralogical elements from granitoids and the general trending of the adjacent crystalline schists, which indicates once more the post-kinematic character of the granitoid rocks.

The oldest radiogene ages, determined by Rb/Sr and K/Ar methods, are of 393 m.y. for the Cherbelezu Granitoid (Tiepac, in Mînzatu et al., 1974) and 372 m.y., respectively, for the Sfîrdin Granitoid (Mînzatu et al., 1974). These values indicate the Silurian-Devonian boundary on the chronologic scale. In view of the above-mentioned data the granitoids may be considered of ante-Devonian age. Provided that the radiogene ages are real, the intrusion of the granitoids will have to be considered at the Silurian-Devonian boundary. In case that those ages are not real, that is they are older, the granitoids emplacement has to be estimated within a larger time interval, namely ante-Devonian-post-Lower Cambrian, at any rate subsequent to the prograde metamorphism of the Corbu Series and the thrust of the Poiana Mraconia Formation over the Corbu Series (Caledonian orogenesis, event III : Middle Cambrian ?, Upper Cambrian ?).

After the intrusion of the granitoid rocks and the location of the vein rocks, the disjunctive dislocations played an important part, dividing the region into several horsts and grabens. The intense and long-time erosion of the horsts has exposed the granitoid rocks. The faults trenchantly separating the granitoids from the adjacent schists can sometimes be observed in the field, other times they can be presumed from the geological background. Mention should be made of the granitoid apophyses from the crystalline schists next to the plutons, to the east and west, which are very rarely found. However, they occur frequently in the crystalline constituting the Patru Pene Graben, which separates the Sfîrdin Granitoid (to the north) from the Cherbelezu Granitoid (to the south). That is explained by the fact that the crystalline schists of Patru Pene area is more uplifted and, consequently, more eroded as compared to the other compartments of crystalline schists in which the granitoid veins are missing. As a matter of fact the Cherbelezu and Sfîrdin granitoids represent two large bodies belonging to a unique batholitic body, homogeneous in petrochemical respect. The Cherbelezu Granitoid, usually with pegmatoid textures with alkali feldspar megacrysts, is more intensely eroded, therefore more uplifted as compared to the Sfîrdin Granitoid, which displays a more homogeneous, equigranular texture generally with smaller crystals.

Within each intrusive body the faults are pointed out by the cataclastic structures of the granitoid rocks. The configuration of the hydrographic network indicates also the existence of older faults e.g. : the

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Sfîrdinul Mare Brook flows about 5-6 km to N-S and then suddenly changes its course to E. The fault on which the Sfîrdinul Mic flows in the spring area was followed on a length of about 2 km and measured : N20-25E/55-70S. It is assumed that several of the main valleys intruding the granitoid massifs are tectonic valleys. The faults are of ante-Hercynian, Hercynian and Alpine ages. The granitoids cropped out before the Permian as the Permian deposits include elements of granitoid rocks. Eastwards, the Permian deposits come into tectonic contact with the Corbu Series. Towards the end of the Permian, but especially at the beginning of the Mesozoic the volcano-sedimentary Permian deposits have been pushed westwards. As a result the Corbu Series has been pressed between the rigid granitoid block (to the west) and the Permian deposits (to the east). Consequently, the Corbu Series underwent a new retromorphism : staurolite, but especially andalusite changed into sericite and garnet, to a less extent, into chlorite ; micas formed during the contact metamorphism folded or broke. The schists of the Corbu Series were straightened out vertically or contorted ; the Carboniferous deposits on the Teiul Moşului branch were crashed within the granites and the granitoids nearby the Corbu Series broken tectonically (cataclased or laminated). The Poiana Mraconia Formation, situated on the eastern flank of the Sfîrdin Granitoid, is strongly retrometamorphosed. As a result of those Alpine and pre-Alpine drive two, in places even three, superposed lineations can be observed macroscopically and microscopically both in the Corbu Series and in the Poiana Mraconia Formation. After those events a great fault of about 17 km, trending N-S, marked the boundary between the Corbu Series and the Permian deposits. The results of those Hercynian and Alpine tectonic movements are also pointed out by the radiometric ages obtained on granitoid rocks and crystalline schists (Mînzatu et al., 1974, 1975 ; Soroiu et al., 1970 ; Pavelescu et al., 1975). The Cherbelezu and Sfîrdin granitoids seem to be the strongest eroded granitoids in the South Carpathians. Both granitoids, especially the Cherbelezu one, display generally concentrical structures. The pegmatoid or macrogranular facies crop out in the centre whereas the medium or microgranular facies towards their periphery.

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[3] Provided that the "Corbu Series" represents the whole retromorphous facies of the Neamţu Group the premetamorphic age of that geological unit should be considered Lower Cambrian, that is the age indicated palynologically for the "Corbu Series". Even if the age of the Corbu Series and that of the Neamţu Group are different it is hardly admitted that the retromorphism caused by the thrust of the Mraconia Formation over the adjacent crystalline schists affected only the Corbu Series and that the Neamţu Group was not, in the adjacent zone, retromorphosed as well. The boundary between the above-mentioned units is, in this case, concealled by the retromorphism and therefore difficult to mark. However, we consider that the "Corbu Series" includes a part of the Neamţu Group.

As the matter is still doubtful we use conventionally the denomination "Corbu Series".

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PETROCHEMICAL STUDY OF THE CHERBELEZU AND SFÎRDIN GRANITOIDS AND THE ASSOCIATED VEIN ROCKS [1]

BY

NICOLAE STAN [2], CONSTANȚA UDRESCU [2], ELENA COLIOS [2]

Granodiorites. Adamellites. Vein rocks. Hydrothermal quartz. Aplite. Pegmatite. Lamprophyre. Major elements. Minor elements. Rare elements. Petrochemistry. South Carpathians-Crystalline-Danubian Domain-Almăj Mountains.

Sommaire

Etude pétrochimique des granitoïdes de Cherbelezu-Sfîrdin et des roches filoniennes associées. Granitoïdes de Cherbelezu : quartz (25 à 35%), oligoclase-andésine (25 à 40% ; An 20 à 30), feldspath alcalin (20 à 35%, microcline, microcline-perthite, perthite) biotite (3 à 7%) ± muscovite, zircon, apatite, sphène, orthite. Granitoïdes de Sfîrdin : quartz (20 à 30%), oligoclase-andésine (30 à 45% ; An 20-35), feldspath alcalin (25 à 40%, microcline, microcline-perthite, perthite) biotite (5 à 15%) ± muscovite, sphène, apatite, zircon, épidote, orthite, monasite. Sur le diagramme *Q-A-P* les granitoïdes de Cherbelezu et Sfîrdin s'inscrivent dans les champs des granodiorites et des adamellites (composition normate). Les granitoïdes de Sfîrdin sont plus riches en éléments ferromagnésiens, CaO et K_2O et plus différenciées que les granitoïdes de Cherbelezu. Tous les deux types de granitoïdes tiennent des valeurs plus grandes de Be, Sn, Pb, Ga et des valeurs plus petites de Zr, Y, Yb, La, Nb par rapport aux granitoïdes étalon considérées selon Kraft et Schindler (1961). Roches filoniennes : quartz hydrothermaux, aplites, pegmatites, diorite-porphyres ± quartzifères, granodiorite-porphyres, lamprophyres à hornblende et lamprophyres à augite. Dans la suite filonienne d'acide à basique le taux de SiO_2 diminue ; en même temps la valeur des éléments ferromagnésiens et de CaO augmente. Y, Yb, La, Be, Nb, Sn, Ga, Pb sont en petites quantités dans toutes les roches filoniennes. Les quantités de Ni, Co, Cr, V et Sc accroissent allant des roches acides aux roches basiques. Ba et Sr ont des valeurs très grandes pour toutes les roches filoniennes excepté les aplites.

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București.

[3] Întreprinderea de Prospecțiuni Geologice și Geofizice, str. Caransebeș 1, 78344 București.

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1. Introduction

The Cherbelezu and Sfîrdin granitoids form, within the Danubian Autochthon of the Almăj Mts, two intrusive bodies lying on a surface of about 130 sq. km. They are situated west of the Cerna Valley, about 15-25 km from the localities of Mehadia-Băile Herculane-Topleț-Orșova.

The Cherbelezu massif, especially its southern part, was studied in petrographic respect by Codarcea (1937). The Sfîrdin massif was mapped by Codarcea and Pavelescu (1962). Bîrlea and Bîrlea (1964-1965) presented briefly both the Cherbelezu Granitoid and the Sfîrdin Granitoid. Stan et al. (1981, 1982) carried out petrological researches on both granitoids.

2. Petrography of the Granitoid Rocks

The Cherbelezu-Sfîrdin granitoids display primary structures (massive or vaguely gneissic) and secondary structures (cataclastic or laminar). The primary structures can be divided, according to the size of the crystals, into micro-, medium- and macrogranular, pegmatoid, porphyric with alkali feldspar megacrysts.

The Cherbelezu granitoids display more various structures as compared to the Sfîrdin granitoids. The pegmatoid facies with or without alkali feldspar megacrysts is generally found in the central and northern part of the massif. Granitoids with microgranular structure occur in the spring zone of the Pîrîul Pietros and Pîrîul Negru brooks. The southern and eastern part of the massif consists mostly of granitoids with massive, macrogranular structures. The poorly gneissic structures are developed in the eastern zone and the cataclastic structures on the eastern border of the granitoid, nearby the contact with the crystalline schists.

Microscopic observations: the Cherbelezu granitoids are sensibly less varied as regards the mineralogical composition. They consist of quartz, plagioclase, alkali feldspar, biotite$\pm$muscovite and accessory minerals.

Quartz (25-35%) generally displays xenomorphous contours and a limpid extinction, and a slightly undulatory extinction in the massive or poorly gneissic granitoids. In metagranites or cataclased granites quartz occurs as bands trending to certain directions; it is strongly deformed and crashed.

Plagioclase (25-40%) shows idiomorphous contours, zonary structures or polysynthetic twins. Its chemical composition corresponds to an oligoclase-andesine (An_{20-30}). It is often poorly sericitized or kaolinized. In laminated granitoids plagioclase is sometimes bent or broken and it is always less affected than quartz.

Alkali feldspar (20-30%) is in most cases quantitatively subordinated to plagioclase feldspar and represented by microcline, microcline-perthite or perthite. The Karlsbad twins and the quadrille structure are

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the most frequent ones. Alkali feldspar may include all the other minerals : quartz, plagioclase, micas ; poikilitic structures are frequently found. Plagioclases are often found as inclusions after the cleavage or twin planes. As against plagioclase feldspar alkali feldspar is fresh, unalterde. Likewise, the microcline is very poorly or not affected by the mechanical processes of crashing.

Biotite (3-7%) is mostly fresh, strongly pleochroic ; sometimes it is incipiently altered into chlorite. The biotites from the tectonized or cataclased granitoids are most frequently chloritized. Chlorite contains fine needles of sagenite and magnetite powder.

Muscovite (0-5%) occurs as colourless sheets, usually in association with biotite. Very seldom it is poorly sericitized.

Accessory minerals (0.05%) are represented by zircon, apatite, sphene, orthite ; a garnet crystal has been observed only in one thin section.

The Sfîrdin granitoids may be classified, according to the size of the components, into medium-grained granitoids and coarse-grained granitoids. In most cases the structures are massive ; the gneissic structures are less obvious both as regards the areal extension and as intensity. The schistous and cataclastic structures from the Sfîrdin granitoids are also to be found.

The medium-grained granitoids have been reported from the Satul Valley ; the rock structure is massive.

The coarse-grained pegmatoid granitoids represent most of the Sfîrdin granitoids.

The laminated granitoids crop out in the lower basins of the Iloca and Sfîrdinul Mare valleys. The cataclased granitoids occur also on narrow zones nearby the faults with a N-S trend, both in the west and the east of the granitoid pluton.

Microscopic observations : the mineralogical composition of the Sfîrdin Granitoid is almost as monotonous as that of the Cherbelezu Granitoid which, however, it resembles very much. The main constituting minerals are represented by quartz, plagioclase, alkali feldspar, biotite±muscovite. Hornblende crystals have been reported from some thin sections.

Quartz (20-30%) displays xenomorphous contours, breaks and inclusions. In cataclased granitoids it is strongly deformed, crashed and oriented.

Plagioclase (30-45%) is an oligoclase-andesine ($An_{20-35}\%$) twinned on the albite law, more seldom zoned or partly altered into sericite and zoisite.

The myrmekitic structures, plagioclase quartz-feldspar, are quite frequently found.

Alkali feldspar is represented by microcline, perthite and microcline-perthite. Karlsbad twins, quadrille structures, as well as the albite-potash feldspar intergrowth occur usually. The poikilitic structure, very

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TABLE 1

Chemical composition of the Cherbelezu granitoid rocks

No.	Sample no	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O	CO_2	S	Fe(S)	Total	Location
1	106	73.98	0.05	14.41	0.54	0.23	0.08	0.08	0.86	4.30	4.15	0.00	0.26	0.56	0.06	0.05	99.61	Ieşelniţa Valley
2	199	73.21	0.06	15.50	0.36	0.15	0.00	0.13	1.35	3.48	4.73	0.05	0.76	0.00	0.04	0.03	99.85	Tustinele Valley
3	48	72.50	0.15	15.91	0.58	0.46	0.04	0.53	1.55	2.64	4.90	0.04	0.55	0.00	0.06	0.05	99.06	Iardaşiţa Valley
4	24	72.47	0.19	15.66	0.58	0.54	0.03	0.55	1.20	2.59	4.84	0.10	0.36	0.42	0.07	0.06	99.76	Valea Pietroasă Valley
5	52	72.42	0.20	15.81	0.71	0.43	0.05	0.58	1.75	2.94	4.68	0.02	0.71	0.00	0.06	0.05	100.41	Iardaşiţa Valley
6	31	72.03	0.22	15.70	0.87	0.31	0.02	0.57	1.42	2.90	4.75	0.04	0.76	0.81	0.05	0.04	100.49	Pîrîul Negru Brook
7	25	72.00	0.21	16.46	0.66	0.36	0.02	0.65	1.22	2.83	4.52	0.04	0.36	0.43	0.05	0.04	99.85	Valea Pietroasă Valley
8	45	71.51	0.25	15.81	0.92	0.36	0.02	0.76	1.83	2.52	4.72	0.10	0.32	0.58	0.06	0.05	99.73	Pîrîul Negru Brook
9	87	71.46	0.30	15.90	0.76	1.08	0.05	0.95	1.38	2.56	4.25	0.14	0.69	0.12	0.04	0.03	99.71	Pîrîul Negru Brook
10	147	71.44	0.14	15.86	0.82	0.44	0.06	0.40	1.57	4.07	4.07	0.04	0.47	0.17	0.04	0.03	99.62	Corbul Brook
11	49	71.32	0.10	16.75	0.66	0.22	0.03	0.51	1.83	2.83	4.66	0.06	0.74	0.00	0.05	0.04	99.80	Iardaşiţa Valley
12	246	71.31	0.30	15.47	1.00	0.57	0.04	0.62	1.64	2.77	4.43	0.12	1.26	0.00	0.03	0.02	99.85	Iardaşiţa Valley
13	27	71.21	0.20	16.46	0.92	0.49	0.04	0.62	2.23	2.02	4.76	0.08	0.33	0.49	0.05	0.04	99.94	Valea Pietroasă Valley
14	109	71.21	0.16	15.41	0.93	0.84	0.04	0.78	1.59	4.06	4.04	0.14	0.73	0.50	0.04	0.03	100.50	Ieşelniţa Valley
15	38	71.19	0.25	16.20	0.69	0.50	0.02	0.58	1.81	2.70	4.81	0.06	0.46	0.33	0.05	0.04	99.70	Pîrîul Negru Brook
16	139	70.71	0.24	14.91	1.15	0.78	0.05	0.98	1.41	3.80	3.97	0.16	1.05	0.65	0.06	0.05	99.97	Corbul Valley
17	29	70.66	0.23	16.85	0.93	0.34	0.03	0.57	2.10	2.25	4.76	0.06	0.33	0.45	0.05	0.04	99.65	Pîrîul Negru Brook
18	47	70.65	0.25	16.61	0.98	0.64	0.04	0.81	1.54	2.98	4.14	0.12	0.66	0.25	0.05	0.04	99.76	Cherbelezu Summit
19	21	70.47	0.18	15.71	0.59	0.63	0.04	0.63	1.99	3.64	4.15	0.12	0.48	1.07	0.07	0.06	99.83	Pietroasa Summit
20	41	70.45	0.26	16.01	0.87	0.63	0.03	0.81	2.20	2.01	4.92	0.10	0.76	0.48	0.05	0.04	99.62	Pîrîul Negru Brook
21	30	69.81	0.25	16.49	1.06	0.37	0.03	0.85	1.33	3.14	4.81	0.14	0.86	0.38	0.05	0.04	99.61	Pîrîul Negru Brook

Analyst: E. Colios

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TABLE 2

Chemical composition of the Sfîrdin granitoid rocks

No.	Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O^+	CO_2	S	Fe(S)	Total	Location
1	189	63.32	0.57	17.56	1.29	2.26	0.05	2.26	3.54	3.87	3.85	0.23	1.11	0.00	0.04	0.03	99.98	Iloca Valley
2	165	64.17	0.60	16.96	1.41	2.10	0.06	2.20	2.70	3.95	3.91	0.28	1.17	0.00	0.05	0.04	99.60	Sfîrdinul Mare Valley
3	243	64.60	0.48	17.50	1.02	1.91	0.05	2.20	2.24	3.77	3.98	0.20	1.79	0.00	0.05	0.02	99.79	Sfîrdinul Mare Valley
4	208	64.71	0.39	17.35	1.16	2.04	0.07	2.12	2.98	3.67	4.06	0.26	0.99	0.00	0.04	0.03	99.87	Satul Valley
5	182	64.76	0.60	16.06	1.26	2.52	0.06	2.38	2.96	3.78	4.12	0.25	1.46	0.00	0.05	0.04	100.30	Iloca Valley
6	219	64.96	0.48	17.87	0.88	2.10	0.05	2.02	2.79	3.60	4.06	0.24	0.82	0.00	0.04	0.03	99.94	Sfîrdinul Mare Valley
7	242	65.30	0.55	17.76	1,23	2.07	0.05	2.23	2.31	3.67	3.78	0.24	1.33	0.00	0.03	0.04	99.59	Sfîrdinul Mare Valley
8	300	65.39	0.53	16.70	1.01	1.70	0.04	1.98	2.35	4.53	3.67	0.20	1.63	0.00	0.07	0.06	99.86	Sfîrdinul Mic Valley
9	217	66.22	0.55	16.59	1.23	1.88	0.05	2.09	1.00	3.83	3.71	0.20	2.26	0.00	0.04	0.03	99.68	Sfîrdinul Mare Valley
10	174	66.55	0.36	16.57	0.71	1.96	0.06	1.62	2.68	3.11	4.12	0.20	1.13	0.64	0.04	0,03	99.78	Iloca Valley
11	215	67.06	0.58	16.00	1.05	2.02	0.05	1.64	2.02	3.72	3.75	0.20	1.53	0.00	0.04	0.03	99.69	Ramnițu Ravine
12	180	67.20	0.44	16.19	1.26	1.38	0.05	1.79	1.86	3.46	4.19	0.18	1.66	0.00	0.04	0.03	99.73	Iloca Valley
13	214	67.27	0.51	16.25	0.93	1.65	0.04	1.52	2.04	3.96	3.88	0.20	1.24	0.00	0.04	0.03	99.57	Romnița Ravine
14	178	67.37	0.34	15.90	1.03	1.24	0.04	1.70	1.80	4.33	3.88	0.15	1.80	0.00	0.03	0.02	99.63	Iloca Valley
15	185	67.63	0.46	16.44	1.16	1.74	0.05	1.81	1.77	3.98	3.76	0.21	1.15	0.00	0.04	0.03	00,23	Iloca Valley
16	267	67.87	0.33	16.70	0.98	1.22	0.04	1.24	1.67	4.68	3.77	0.16	1.10	0.35	0.03	0.02	100.16	Sfîrdinul Mare Valley
17	210	68.22	0.42	15.97	0.93	1.79	0.04	1.69	1.66	3.47	3.75	0.18	1.34	0.00	0.03	0,02	99.78	Satul Valley
18	273	68.34	0.45	16.24	0.77	1.62	0.04	1.34	1.63	3.71	3.72	0.18	1.55	0.00	0.04	0:03	99.66	Sfîrdinul Mic Valley
19	295	68.67	0.43	16.20	0.71	1.28	0.03	1.18	1.44	4.26	3.98	0.16	1.29	0.00	0.05	0.04	99.72	Sfîrdinul Mic Valley
20	251	68.78	0.38	15.84	0.82	1.54	0.05	1.43	1.53	3.77	3.76	0.18	1.55	0.00	0.04	0.03	99.70	Sfîrdinul Mare Valley
21	212	68.86	0.38	16.19	0.82	1.14	0.03	1.22	0.08	4.50	3.98	0.16	1.65	0.00	0.04	0.03	100.08	Ramnițu Ravine
22	252	69.17	0.34	15.94	0.79	1.12	0.02	1.10	1.42	4.42	2.91	0.29	1.19	0.00	0.04	0.03	99.78	Sfîrdinul Mare Valley
23	254	69.43	0.32	15.93	0.92	1.23	0.03	1.25	1.63	3.83	3.80	0.16	1.15	0.00	0.05	0.04	99.77	Sfîrdinul Mare Valley
24	264	69.80	0.38	15.82	0.75	0.96	0.04	0.90	1.43	4.30	3.86	0.07	1.37	0.00	0.03	0.02	99.83	Sfîrdinul Mic Valley
25	244	70.22	0.31	15.54	0.70	1.09	0.05	1.10	1.35	4.07	3.81	0.16	1.20	0.00	0.03	0.04	99.67	Cîrșa Brook
26	167	70.56	0.30	16.70	0.54	0.98	0.05	1.20	1.45	3.90	3.67	0.18	0.53	0.20	0.06	0.05	100.37	Sfîrdinul Mare Valley
27	170	70.71	0.24	15.30	0.83	0.61	0.03	0.90	1.26	4.38	4.04	0.13	1.26	0.00	0.04	0.03	99.76	Sfîrdinul Mare Valley
28	169	70.72	0.29	16.10	0.56	0.79	0.03	0.94	1.17	4.06	3.87	0.10	0.92	0.11	0.05	0.04	99.74	Sfîrdinul Mare Valley
29	204	70.74	0.22	14.98	0.98	1.06	0.06	0.71	1.71	3.40	4.26	0.14	1.21	0.00	0.04	0,03	99.54	Satul Valley
30	304	71.62	0.20	15.67	0.50	0.69	0.03	0.55	1.25	4.00	4.29	0.10	0.74	0.00	0.06	0.05	99.75	Sfîrdinul Mic Valley

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frequently present, is a result of the inclusions of quartz, biotite, muscovite and especially plagioclase ; plagioclase is mostly sericitized, displaying an albitic reaction rim.

Biotite (5-15%) is usually unaltered. In the cataclased or laminated zones of the granitoid, biotite is wholly or almost wholly chloritized, contorted, often broken.

Muscovite (0-0.5%) occurs usually in association with biotite.

Green hornblende (c/ng = 18-20°) was found accidentally in some thin sections (2-3%).

Accessory minerals are represented by sphene, apatite, zircon, epidote, very rarely orthite and monazite.

3. Chemism of the Granitoid Rocks

The values of oxides for the Cherbelezu and Sfîrdin granitoids are rendered in Tables 1 and 2.

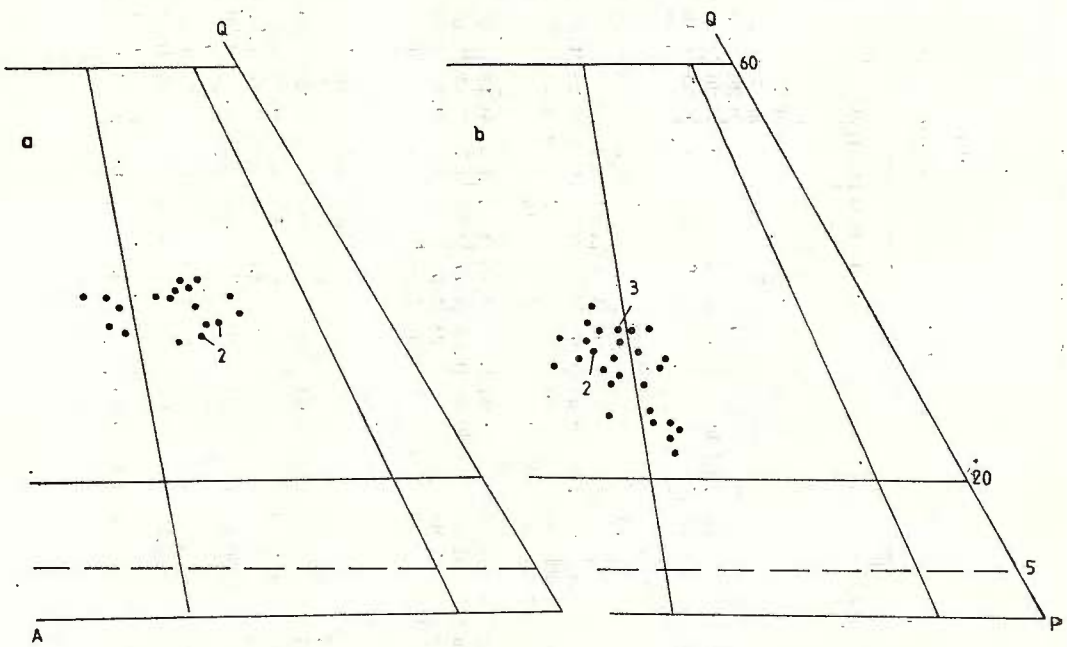


Fig. 1. — *Q-A-P* diagram (normative composition) : a, Cherbelezu granitoids ; b, Sfîrdin gronitoids.

On the *Q-A-P* diagram (proposed by Streckeisen, 1974) the Cherbelezu granitoids are plotted in the granodiorite and adamellite fields (Fig. 1 a) ; most of the Sfîrdin granitoids occur in the adamellite field and to a less extent in the granodiorite area (Fig. 1 b).

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3.1. *Major Elements*

The variation limits of the main oxides of the granitoid rocks are, as follows :

Elements	Cherbelezu (21 samples)	Sfîrdin (30 samples)
SiO_2	69.81—73.89%	63.32—71.62%
Al_2O_3	14.41—16.57%	14.98—17.87%
Fe_2O_3	0.36—1.15%	0.50—1.41%
FeO	0.15—1.08%	0.61—2.52%
MgO	0.08—0.98%	0.55—2.26%
CaO	0.86—2.23%	1.08—3.54%
Na_2O	3.97—4.92%	3.67—4.29%
K_2O	2.02—4.30%	3.11—4.68%

The variation intervals of oxides are narrow or highly narrow as shown by the monotony of the mineralogical composition of the Cherbelezu and Sfîrdin granitoid rocks. However, in view of the chemism, the two massifs display specific features. The main differences between the Cherbelezu and the Sfîrdin granitoids are : 1. SiO_2 shows higher values and its variation interval is more reduced in case of the Cherbelezu granitoid because it generally has more quartz in more constant amounts. 2. The Sfîrdin Granitoid is richer in ferro-magnesian elements and the values of the variation intervals are larger. It is worth mentioning the more significant participation of biotite in the Sfîrdin Granitoid as well as its quantitative variation from one zone to another. 3. The Sfîrdin granitoids are more potassic, not because of their higher content in potash feldspar but particularly due to the biotite participation in greater amount. 4. The Cherbelezu granitoids contain more sodium and less calcium as the plagioclase feldspar is, in that case, more acid. All this is briefly presented on the diagram of Figures 2 and 3.

3.2. *Trace Elements*

The trace elements contents of the granitoid rocks determined by the emission spectrography method are presented in Tables 3 and 4.

Variation diagrams according to the Nockolds differentiation index have been drawn up for some trace elements. Thus, the trace elements from the Ni, Co, Cr, V, Sc series, wtih great affinities for the substitution of the ferro-magnesium elements in the crystallographic network of the femic minerals indicate, for the twot ypes of rocks, specific

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values and tendencies. In the Cherbelezu granitoids the contents in the above-mentioned elements are low and in a linear disposition as against the differentiation index, whereas in the Sfîrdin granitoids

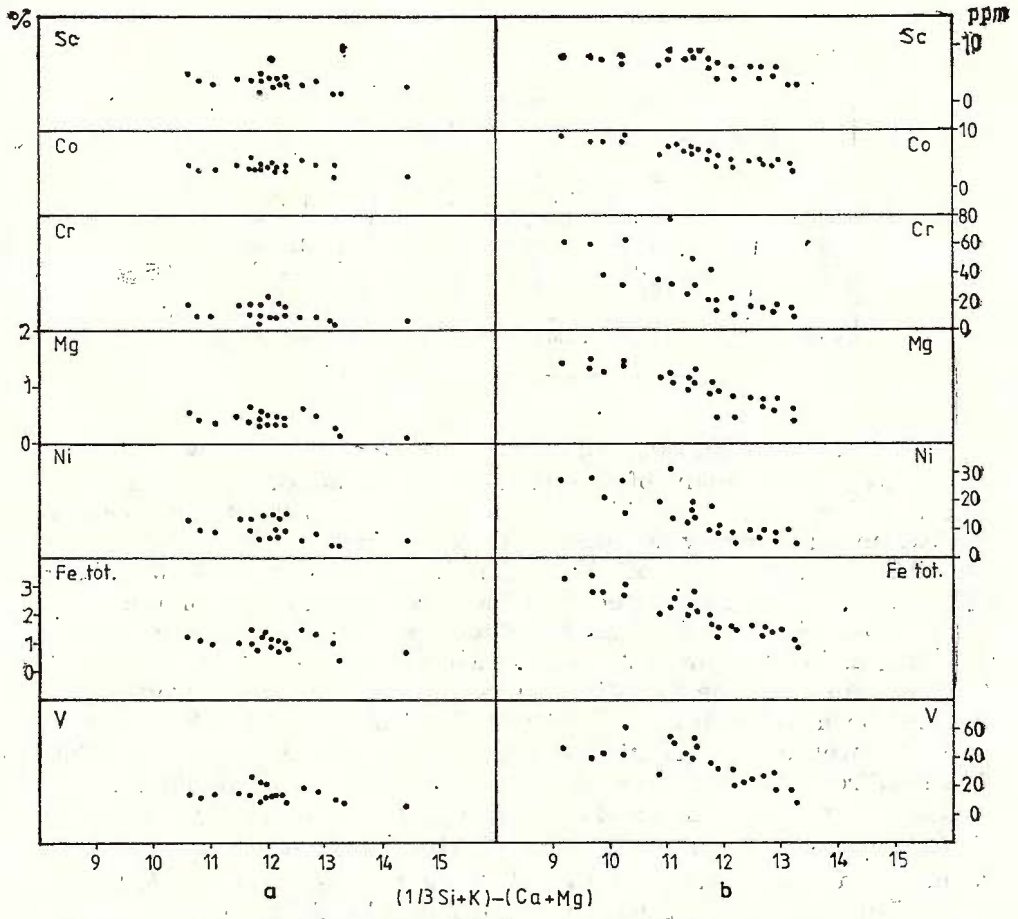


Fig. 2. — Sc, Co, Cr, Ni, V variation diagram : a, Cherbelezu granitoid ; b, Sfîrdin granitoid.

the values of the trace elements are generally higher with a clear tendency of decrease of contents concurrently with the increase of the rock acidity (Fig. 2). The Ba contents are higher in the Sfîrdin granitoids than in the Cherbelezu ones. Ba usually substitutes K and the Sfîrdin granitoids have a higher quantity of K than the Cherbelezu granitoids (Fig. 3). The quantity of Sr and of Ca decreases during the differentiation process in the Cherbelezu granitoid rocks. In the Sfîrdin granitoid the Sr contents are quite uniform and are not correlated with the Ca values which decrease concomitantly with the increase of the Nockolds index (Fig. 3).

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TABLE 3

Trace elements (ppm) in the Cherbelezu granitoid rocks

No.	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Y	Yb	La	Zr	Be	Nb	Ba	Sr	Li
1	106	150	6.5	28	12	5	<2	4	3.5	2	9	5,0	<30	45	10.5	23	140	42	9
2	199	105	4	23	2.5	3.5	<2	5	6.5	2	5	<0.5	<30	66	5	<10	460	270	6
3	48	34	6	20	2.5	6.5	3	7	11.5	6.5	6.5	0.6	<30	82	3.2	10	430	260	36
4	24	60	5.5	22	3	7.5	2.5	7.5	11.5	3.5	10	<0.5	<30	110	5.7	16	800	550	11
5	52	65	6	21	4	7	3	6.5	10.5	2	6.5	<0.5	<30	82	5.3	<10	600	360	60
6	31	65	9.5	23	3.5	8.5	<2	7	8	2.5	10	<0.5	<30	90	5.8	14	950	580	32
7	25	50	6	22	3	15	3	13.5	7.5	3	10.5	<0.5	<30	130	6.5	14	650	470	29
8	45	41	8	22	3	13	3	14	13.5	3	10	<0.5	<30	95	4	12	900	800	44
9	87	36	6.5	19	2	11.5	4.5	13.5	25	3	10.5	0.6	<30	105	3	<10	1100	360	32
10	147	130	7.5	24	7	3.5	3	5	7	2	7.5	<0,5	<30	79	8	12.5	460	150	20
11	49	55	6.5	24	2.5	6.5	2.5	6	7.5	2	7	<0,5	<30	78	4	11	530	340	15
12	246	57	6	16	2.5	9.5	3	12	22	3.5	7.5	0.6	<30	95	5	17.5	700	570	32
13	27	31	5	20	2	9	<2	7.5	9.5	3	11	0.6	<30	92	3.8	12	550	800	44
14	109	155	8.5	27	9	7.5	3.5	8	17	3	10	0.6	<30	84	7.2	11	440	165	26
15	38	70	5.5	23	4	9.5	2.5	10	12.5	3	9	<0.5	<30	90	5.2	10	700	470	35
16	139	105	9	22	6.5	6	4	7	16	2	8.5	0.5	<30	76	5.2	11	720	240	9
17	29	38	7.5	22	2	8.5	2.5	9	15	2.5	10	0.5	<30	80	3.2	20	650	850	50
18	47	34	7	22	3	13.5	3	17	20	4	13	0.6	<30	80	3.8	<10	700	620	38
19	21	72	6.5	24	8	13	3	17	15	3	10.5	0.6	30	137	8.5	28	850	470	7
20	41	38	12	22	3	12.5	3	17	16.5	3.5	9.5	0.5	<30	100	4.4	14	550	800	16
21	30	60	10	21	4	14	3	22	16	3.5	12	<0.5	<30	110	4.7	18	800	650	16

Analyst : C. Udrescu

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TABLE 4

Trace elements (ppm) in the Sfîrdin granitoid rocks

No.	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Y	Yb	La	Zr	Be	Nb	Ba	Sr	Li
1	189	40	10	24	3.5	27	8.5	57	44	7.5	12	0.6	42	125	3.2	<10	750	270	58
2	165	54	16.5	26	4	23	7	45	48	8.5	16	<0.5	37	195	4	<10	850	300	38
3	243	53	4	20	4.5	26	9	60	60	7.5	12	0.6	48	170	7	10	1200	480	40
4	182	36	12	27	4	27	7.5	55	40	7.5	10	0.5	32	150	4.8	<10	900	550	38
5	219	48	6.5	23	4	20	7.5	37	42	7	9	0.6	38	160	8	<10	1050	450	20
6	242	38	6.5	23	3.5	15	7.5	29	42	7	10	0.9	30	175	8	11	900	320	55
7	300	55	0	38	3.5	29	6.5	75	54	7	14	0.5	60	210	5.6	<10	1350	600	17
8	217	58	11	23	4	15	5.5	28	52	8.5	15.5	1.1	48	180	6.6	11	1000	320	22
9	174	90	8	25	7.5	15	6	38	36	7	9	0.5	30	130	7.2	<10	750	440	55
10	215	55	12	24	4	13	6.5	30	50	8.5	17	1	50	185	5.5	<10	900	420	42
11	180	46	18	23	7	18	5	32	26	6	10.5	0.7	<30	110	5.8	<10	600	290	21
12	214	60	7	24	4	12	6	24	42	7	13	1.2	38	155	7.2	10	1000	270	52
13	178	46	8.5	23	3.5	17	6	40	33	5.5	9	0.5	50	170	3.8	<10	1150	460	16
14	185	40	9	29	5.5	18	6	48	40	8	15	0.7	36	140	3.4	<10	800	280	50
15	267	58	6	19	7.5	8	4	14	25	5.5	8.5	0.7	<30	115	8	10	1200	400	52
16	210	60	10	22	4	13	6	27	48	8	9	0.7	50	170	10	13	1200	550	46
17	273	40	5.5	16	3	8	4.5	19	34	7	13	0.8	36	105	5	<10	850	270	50
18	295	55	11	34	7	8	4.5	28	36	5	14	0.7	55	150	6.7	<10	700	210	80
19	251	50	7.5	24	4.5	8	5	18	33	6	10	0.9	32	135	8	14	700	250	50
20	212	67	6	26	8.5	7	4	14	28	5.5	8.5	0.7	<30	115	8	14	900	230	46
21	252	65	4	27	5	6.5	3.5	12.5	22	5	10	0.7	30	110	7.5	14	850	330	75
22	254	55	5	21	5.5	7.5	4.5	19	29	5.5	10	0.7	34	110	8	10	900	230	85
23	264	60	5.5	21	7	5	3.5	10	15	4	8.5	0.8	<30	80	8.5	16	720	230	90
24	244	57	4.5	17	5.5	7.5	4	13	26	4	9	0.8	<30	110	75	13	600	210	100
25	167	65	6.5	34	8	8	4.5	16	19	4	10	0.9	30	120	8.5	<10	640	240	90
26	170	60	6	30	8	9	3.5	13	16	2.5	9	0.5	<30	100	4.8	<10	750	260	95
27	169	55	6.5	30	10	8	4	15	16	3.5	11	0.8	34	115	9.5	10	600	220	95
28	204	95	6.5	22	4	5	3	8	20	3.5	14	1	<30	180	11.5	19	1150	440	16
29	304	105	7.5	27	8.5	4	2	6	5.5	2.5	7	<0.5	30	120	12.5	17	650	400	15

Analyst: C. Udrescu

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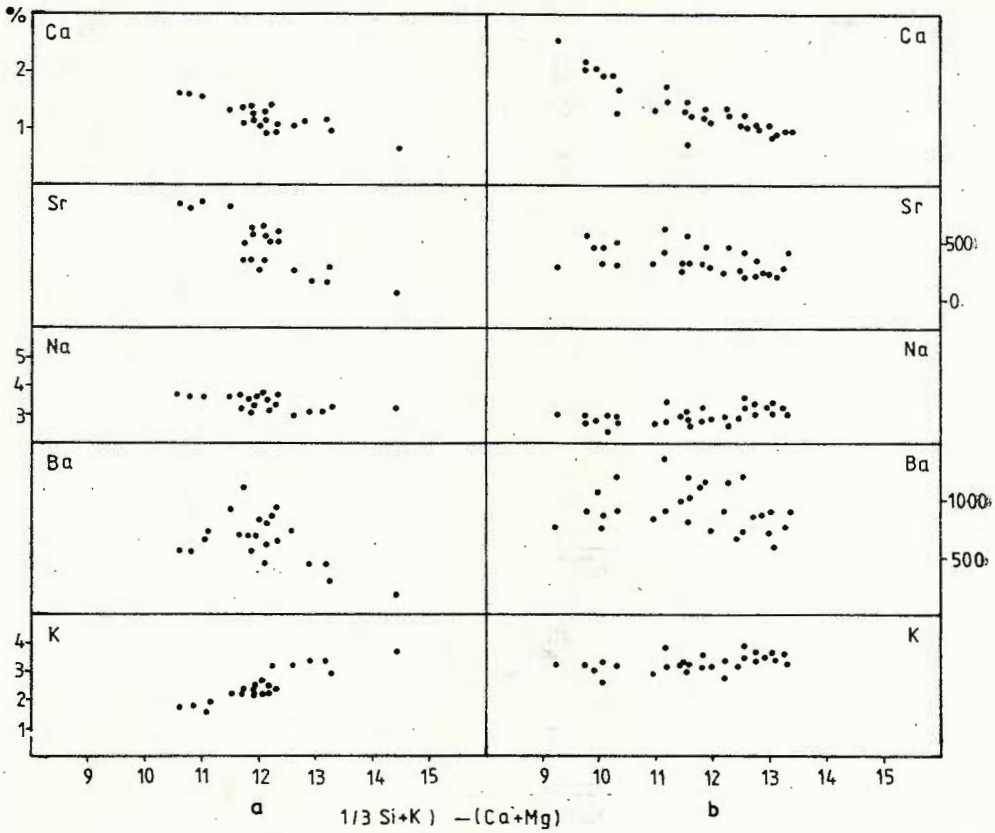


Fig. 3. — Sr, Ba variation diagram : a, Cherbelezu Granitoid ; b, Sfîrdin Granitoid.

The variation domains and the average values of the felsiphile trace elements are rendered on the diagram on Figure 4 for both types of granitoid rocks. These values are compared with the average values of the granitoids advocated by Kraft and Schindler (1961). On the double logarithmic diagram the ordinate represents the axis of the contents for the standard granitoid rocks and the abscissa the axis of the contents for the Cherbelezu and Sfîrdin granitoid rocks. The values of the trace elements for the standard granitoid rocks are plotted on the 45° diagonal intersecting the origin. The variation domains of the trace elements from the Cherbelezu and Sfîrdin granitoids are mentioned beside the standard values (for comparison). The arrows indicate the average values for the Cherbelezu and Sfîrdin granitoids. The values to the right of the diagonal represent higher values and those to the left — lower values as against the standard granitoids.

The diagram in Figure 4 points out high values of Be, Sn, Pb and Ga and low values of Zr, especially Y, in the Cherbelezu and Sfîrdin granitoids as compared to the standard granitoids. The contents

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in Yb, La and Nb are highly reduced, many of them beyond the detection limit. Zr, Y, Yb, La and Nb accumulate especially in the trace elements network : zircon, apatite, sphene ; the accessory minerals are very rarely found in the Cherbelezu and Sfîrdin granitoids.

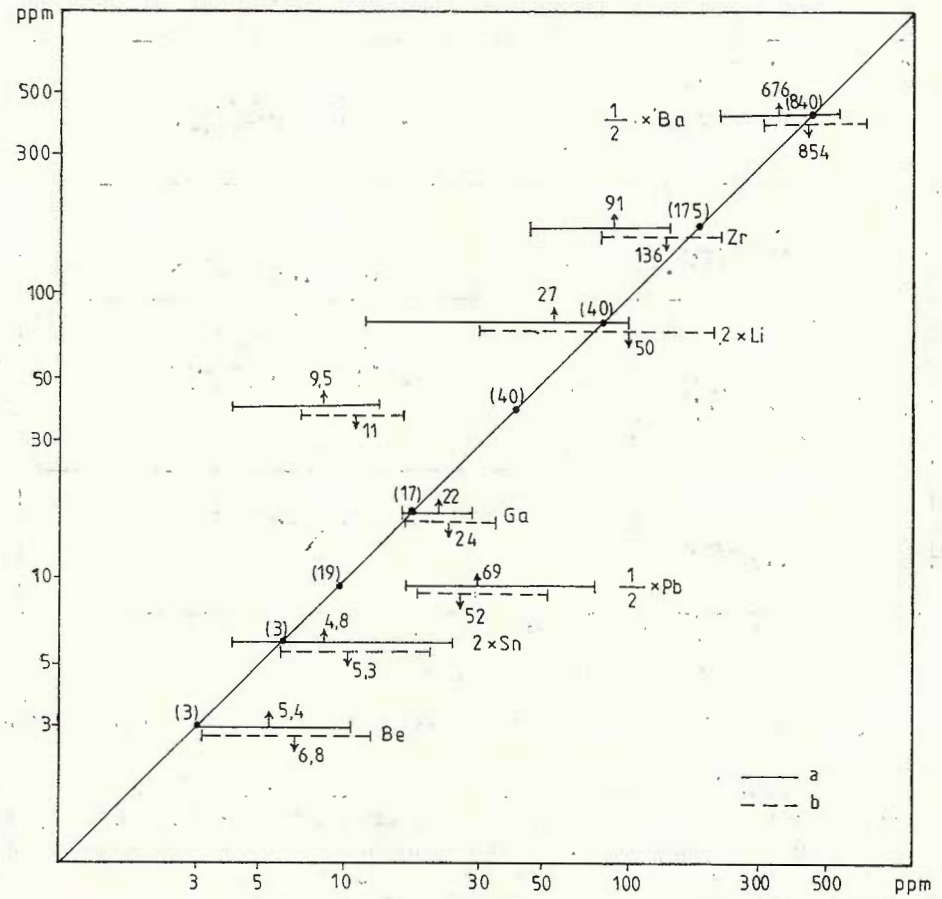


Fig. 4. — Diagram for the comparison of the trace elements contents (ppm) in the Cherbelezu and Sfîrdin granitoid rocks with the average values of the trace elements from the standard granitoid rocks (after Kraft and Schindler, 1961). a, Cherbelezu granitoids ; b, Sfîrdin granitoids.

4. Petrography of the Vein Rocks

The vein rocks penetrate both the granitoid rocks and the adjacent crystalline rocks. They are, however, located above all in granitoids, especially towards the periphery.

The vein rocks are represented by hydrothermal quartz, aplites, pegmatites, porphyric-granodiorites, porphyric-quartz diorites and lamprophyres. The vein rocks are reduced, their length is usually of

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maximum 400-500 m, exceptionally 1,000 m and the thickness reaches some metres. Their trend is variable, most of them generally trend N-S.

Hydrothermal quartz is white-milky and displays a chippy breaking. Limonitic films are seldom observed on fissures. They consist of quartz (98-99%) and iron oxides. The rocks structure is allotriomorphous-massive. Quartz occurs as a vein sequence grouped north of the Cherbelezu Summit.

Aplites display a white-yellowish colour with pink hues and saccharoid textures. They are constituted of quartz (45-50%), oligoclase (50-60%), alkali feldspar (2-7%), very little muscovite±biotite, chlorite and opaque minerals. The texture is allotriomorphous and the structure is massive, slightly oriented.

Pegmatites are found only exceptionally. A significant vein (of about more than 1 km long and 2 m thick) occurs on the main tributary of the Ieşelniţa Valley. Pegmatites consist of quartz and albite-oligoclase (90-95%) ± muscovite ± biotite ± potash feldspar, iron oxides.

Porphyric-diorite ± quartz and porphyric-granodiorite are of a grey-green colour and display porphyric textures. The mineralogic composition is : plagioclase (20-25%), quartz (0-10%), hornblende (0.5-5%), biotite (0.5%), orthoclase (0-0.5%). The rock texture is of porphyric type. The accessory minerals are represented by apatite, zircon, sphene, opaque minerals. The rocks are more or less altered :plagioclase is sericitized or substituted, in variable amounts, by calcite ; hornblende and biotite are altered into chlorite or poorly opacitized. The rock matrix (50-65%) — entirely crystallized — has a panidiomorphous texture. No clear delimitation can be made between porphyric-granodiorite and porphyric-diorite ± quartz because of the intense alteration of the rock. Sometimes the phenocrysts and the matrix are homogenized in a sericite-chlorite-calcite aggregate within which relics of the primary minerals can hardly be observed.

Lamprophyres are divided, according to their mineralogical composition, into hornblende-bearing lamprophyres and biotite-bearing lamprophyres with augite.

Hornblende-bearing lamprophyres, of a dark colour, show an aphanitic or fine-grained texture. The mineralogical composition includes hornblende (20-55%), plagioclase (10-30%), orthoclase feldspar (5-20%), augite-diopside (0-3%), biotite (0-1%). The accessory minerals are represented by sphene, apatite and opaque minerals. The microscopic texture is panidiomorphous-inequigranular, more seldom panidiomorphous equigranular.

Biotite-bearing lamprophyres with augite have been identified only in one zone in the southern part of the Cherbelezu Granitoid, on the left-hand tributary of the Corbul Valley. The rock displays large-sized biotite phenocrysts (2-4 cm) included in a black, aphanitic matrix. Under the microscope several minerals have been identified, as follows : biotite (30-60%), augite (15-20%), orthoclase feldspar (5-15%), apatite, calcite, sphene, epidote, opacite.

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Biotites are titaniferous, with zonary structures forming phenocrysts. Pyroxene is an augite-diopside. The rock texture is porphyric-panidiomorphous.

5. Chemism of the Vein Rocks

The oxide values for the vein rocks are presented in Table 5.

5.1. *Major Elements*

Aplites present high and constant SiO_2 values (73.95-77.81%) and a high content in quartz. The SiO_2 percentage is higher than in the granitoid rocks. The amount of SiO_2 decreases very much in porphyric-diorites and porphyric-granodiorite, the limit intervals being 58.16-63.09%. The rocks contain little quartz or are deprived of it. Lamprophyres have the lowest amount of SiO_2 : 49.16-54.46%. In the biotite-lamprophyre with augite the content in SiO_2 is still lower : 37.92%.

The ferromagnesian elements are missing in aplites or occur in minimum amounts, thus the absence or the minor participation of the femic minerals in those rocks are pointed out. The percentage of the ferromagnesian elements increases progressively in the vein sequence (porphyric-granodiorite, porphyric-diorite $\pm$ quartz — hornblende-bearing lamprophyres — biotite-bearing lamprophyres with augite) concurrently with the increase of the contents of the femic minerals.

In aplites the CaO value is subunitar, ranging from 0.52% to 0.71% ; in granodiorites and porphyric-diorites $\pm$ quartz, CaO varies between 3.50-4.50% and in hornblende-bearing lamprophyres it increases (6.57-9.0%). The maximum value (14.24%) is found in the biotite-bearing lamprophyres with augite. Some of the Ca amount enters into the mineralogical composition of hornblende, pyroxene and plagioclase feldspar and another is found in the carbonates substituting the other minerals. In that case the chemical analyses indicate a high percentage of CO_2 (samples 110, 150, 271, Table 5). The very large amount of CaO found in the biotite-bearing lamprophyre (sample 151) must be ascribed to the presence of the diopside augite, and the large amount of titanium (4.07%) to the titaniferous biotites.

Na_2O/K_2O ratio in aplites is always > 1 as albite-oligoclase predominates in quantitative respect as against potash feldspar. The mentioned ratio is also > 1 in case of porphyric-diorites $\pm$ quartz and porphyric-granodiorites. The sodium plagioclase occurs in significant amounts as compared to the orthoclase feldspar or the biotite which are found in small amounts. K_2O amount in lamprophyres is larger than Na_2O amount as lamprophyres include relatively large amounts of orthoclase or high contents in biotite. Concomitantly, the sodium percentage in the plagioclase feldspar decreases, being replaced mostly by calcite.

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TABLE 5

Chemical composition of the vein rocks

No.	Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	H_2O	CO_2	S	Fe(S)	Total	Location
1	78	76.68	0.00	14.31	0.39	0.00	0.01	0.71	3.16	4.42	0.00	0.59	0.00	0.05	0.04	0.04	100.38	Ieşelniţa Valley
2	92	75.01	0.10	14.66	0.55	0.04	0.20	0.52	3.44	4.60	0.08	0.15	0.26	0.04	0.03	0.03	99.72	Ieşelniţa Valley
3	50	75.78	0.06	14.26	0.52	0.00	0.03	0.08	0.55	3.98	4.02	0.08	0.33	0.00	0.04	0.04	99.78	Iardaşiţa Valley
4	10	63.09	0.42	16.01	1.34	1.52	0.07	2.00	3.50	2.93	4.85	0.40	1.23	2.37	0.05	0.04	99.95	Ieşelniţa Valley
5	111	58.16	0.50	15.71	2.22	2.70	0.09	5.93	4.56	3.60	4.35	0.28	1.57	0.16	0.06	0.05	99.94	Ieşelniţa Valley
6	43	1.00	0.98	15.15	4.50	4.10	0.15	6.73	8.04	3.87	3.05	0.54	1.40	0.33	0.09	0.08	100.01	Secărştiţa Valley
7	150	49.16	1.20	12.99	2.80	3.34	0.13	3.87	9.00	5.35	1.85	1.52	2.44	5.52	0.14	0.12	100.42	Left tributary
8	151	37.92	4.07	13.00	5.54	4.60	0.15	1.14	14.24	3.55	0.56	0.56	2.07	2.25	0.18	0.15	99.98	Corbul Valley
9	307	73.95	0.06	16.15	0.36	0.06	0.00	0.00	0.69	3.78	4.06	0.08	0.84	0.00	0.05	0.04	100.12	Corbul Valley
10	302	59.99	0.79	15.75	3.20	2.50	0.10	4.36	4.29	3.23	3.92	0.18	2.12	0.00	0.11	0.09	99.63	Sfîrdinul Mare Valley, spring area
11	271	54.46	0.89	15.59	1.81	3.85	0.12	3.89	6.57	4.24	0.00	0.24	4.04	4.57	0.04	0.03	100.34	Sfîrdinul Mare Valley Sfîrdinul Mic Valley, spring area

a) aplites : 78, 92, 50 porphyric-diorites ± quartz, 110 : porphyric-diorites, 111 ; 111 ; hornblende lamprophyres : 43, 150 ; biotite lamprophyres + augite-diopside, 151 (Cherbelezu granitoids zone).

b) aplites : 307, porphyric-diorites, 302 ; hornblende lamprophyres, 271 (Sfîrdin granitoids zone).

Analayst : E. Colios.

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TABLE 6

Trace elements in the vein rocks

No	Sample no.	Pb	Cu	Ga	Sn	Ni	Co	Cr	V	Sc	Y	Yb	La	Zr	Be	Nb	Ba	Sr	Li
1	78	190	12	25	9	2.5	<1	3.5	3.5	2	10	0.8	<30	38	9	22	53	50	<3
2	50	35	6	26	3	2	<2	3	5	2	5	0.5	<30	18	8.5	12.5	38	40	6.5
3	92	105	5	36	26	4	<2	4	5	3.5	18	2	<30	26	10	20	68	17	<3
4	110	24	10	22	2	18	5.5	13	42	4.5	10.5	0.6	60	130	3	<10	2100	3000	18
5	111	20	21	20	2	95	20	190	120	17	18	0.8	42	100	3	<10	1700	1000	32
6	43	14	22	18	2	78	38	280	190	25	23	2.9	44	140	3.2	<10	2200	2200	56
7	150	38	26	18	4.5	75	16	105	110	14	19	0.8	65	175	4.3	<10	4000	550	48
8	151	10	40	16.5	<2	110	48	180	300	39	20	1.5	62	230	1.3	23	2700	1700	50
9	307	38	5	31	5	2	<2	2.5	3	3	13	1	<30	26	8.5	21	37	15	14
10	302	12	46	25	2	55	13	125	65	11.5	20	1.4	58	150	2.9	<10	1300	970	12
11	271	3	45	15	2	105	18	220	105	19	12	1.7	34	145	7	<10	340	120	140

a) aplites; 78, 92, 50, porphyric-diorites ± quartz, 110; porphyric-diorites, 111; hornblende lamprophyres: 43, 150; biotite lamprophyres + augite-diopside, 151 (Cherbelezu granitoids zone).

b) aplites, 307; porphyric-diorites, 302; hornblende lamprophyres, 271 (Sfîrdin granitoids zone).

Analyst: C. U d r e s c u.

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5.2. *Trace Elements*

The results of the trace elements for the vein rocks are rendered in Table 6.

Certain trace elements, i.e. Y, Yb, La, Be, Nb, Sn, Ga, Pb, are found as small or very small amounts in all types of vein rocks.

The Ni, Co, Cr, V, and Sc values are very small in aplites. In porphyric-diorites±quartz and lamprophyres the amount of the mentioned elements increases proportionally to the amount of femic minerals. Ba and Sr are found as large amounts in porphyric-diorites± ±quartz, porphyric-granodiorites and lamprophyres, rocks usually intensely altered, sericitized and calcitized. Ba replaces K in potash feldspar and especially K in biotite.

Li occurs in small amounts in aplites and in larger amounts in the other vein rocks. It is usually found in the biotite network and more seldom in the crystalline network of other ferromagnesian minerals.

6. Conclusions

The Cherbelezu and Sfîrdin granitoids, similar in petrochemical respect, are the result of the consolidation of a unique magmatic batholit of sialic origin.

The pegmatitic, aplitic vein rocks and the hydrothermal quartz are the result of the differentiation of those calc-alkali magmas with alkali trending, in the final stages : porphyric-diorites±quartz as well as porphyric-granodiorites are the result of those differentiations as well. As regards lamprophyres they might have a different origin — a simatic one.

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N. STAN

GEOLOGICAL MAP
OF THE CHERBELEZU AND SFIRDINU MASSIFS

0 1 2 km

LEGEND

SEDIMENTARY ROCKS

QUATERNARY — a. Colluvial deposits ; b. alluvial deposits

NEOGENE — Conglomerates, sands, marls, sandstones

JURASSIC — a. Conglomerates, microconglomerates ; b. carbonatic rocks

PERMIAN — Conglomerates, sandstones and ignimbritic flow rocks

CARBONIFEROUS — Microconglomerates, sandstones, marls

VEIN ROCKS

(A) Aplites ; (Q) hydrothermal quartz ; (σπ) porphyric-diorites ± quartz and porphyric-granodiorites ; (λ) lamprophyres

THERMIC CONTACT ROCKS

Schists with andalusite, staurolite, biotite (garnet)

BIOTITE GRANITOID ROCKS

CHERBELEZU : Granodiorites and — SFÎRDIN : Granodiorites and

A) Massive textures

(a) Microgranular
(b) Macrogranular
(c) Pegmatoid
(d) Porphyric with alkali feldspar megacrysts

(e) Medium - grained
(f) Macrogranular

B) Oriented textures

Cataclased granitoids

Weakly gneissic granitoids

INTRUSIVE METABASITES

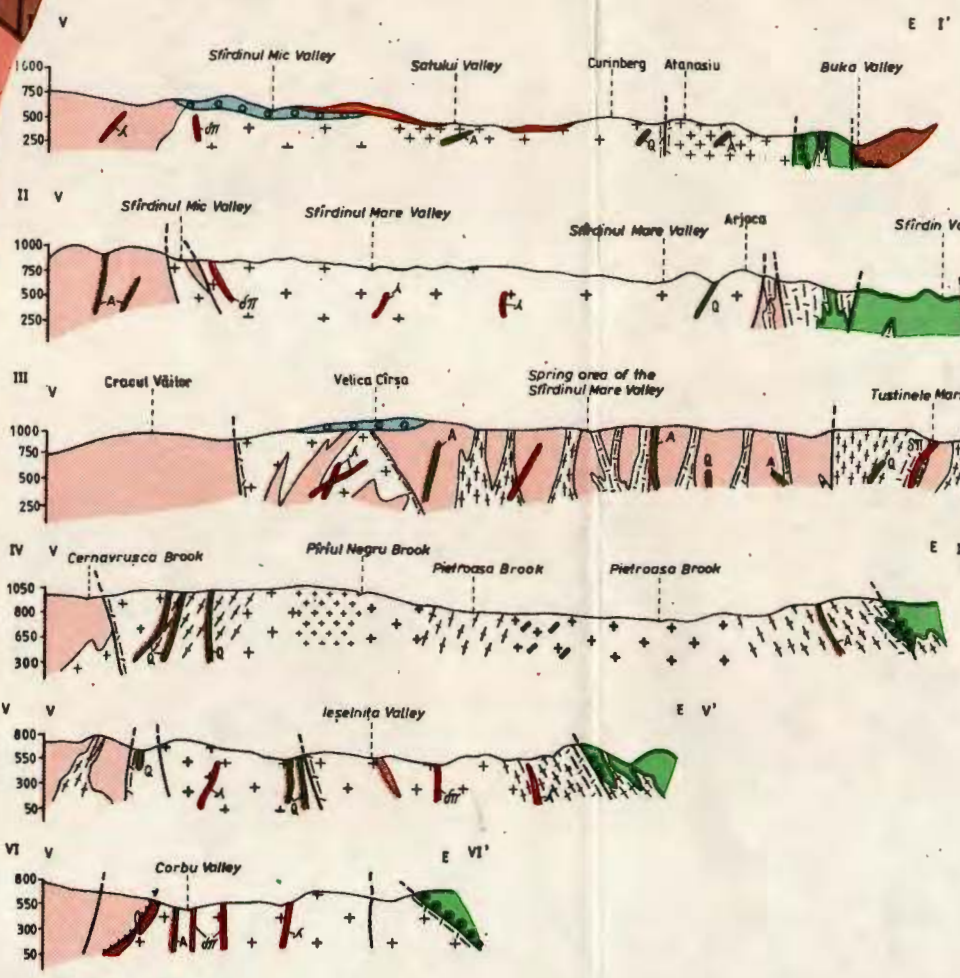
Peridotites and gabbro serpentinitized

CRYSTALLINE SCHISTS

Corbu Series : greenschists facies : biotite - garnet isograde (intensely retromorphosed series : chlorite - sericite isograde)

(a) Ielova Series and Poiana Mraconia Formation : almandine - amphibolite facies, kyanite - almandine - staurolite subfacies ;
(b) Neamțu Group : almandine - amphibolite facies, almandine - staurolite subfacies. Weakly retromorphosed crystalline units

(4) Chemical and spectral analyses



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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

THE MĂDĂRAȘUL MARE RHYODACITE (HARGHITA MOUNTAINS) [1]

BY

CONSTANTINA STANCIU [2], CONSTANȚA UDRESCU [2], MARGARETA DAVID [3]

Rhyodacites. Hornblende pyroxene andesites. Microdiorite. Vein rocks. Major elements. Minor elements. Petrochemistry. East Carpathians-Neogene eruptive-Harghita.

Sommaire

Rhyodacite de Mădărașul Mare des monts Harghita. La rhyodacite de Mădărașul Mare, à texture eutaxitique, se localise dans le compartiment supérieur pliocène des monts Harghita ; la roche apparaît sous forme de filons d'épaisseurs de 1 m, 1,40 m et 230 m qui traversent les laves constituées d'andésites à hornblende verte et de pyroxènes. La comparaison des analyses chimiques des rhyodacites et des andésites+microdiorites hôte relève de grandes différences et l'absence des termes intermédiaires.

A fine-banded, light-coloured rhyodacite, clearly distinct as against the dark and massive andesitic mass including it, was first observed in a borehole in the spring area of the Cocoizaș Brook, left-hand tributary of the Mădărașul Mare Valley (the Harghita Mountains), in 1980 (Stanciu et al., 1984). At present, it is considered as a local product with the highest acidity in the Călimani-Gurghiu-Harghita volcanic chain (SiO_2 — 67.70-69.01%).

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București.

[3] Întreprinderea de Prospecțiuni Geologice și Geofizice, str. Caransebeș 1, 78344 București.

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1. Geological Setting

In the axial part of the North Harghita Mts, Setel et al. (1974) pointed out a caldera (Fig. 1), within which an activity of mining prospections with galleries and drillings was carried out, aiming at the knowledge of the alteration and mineralization products of "porphyry" type.

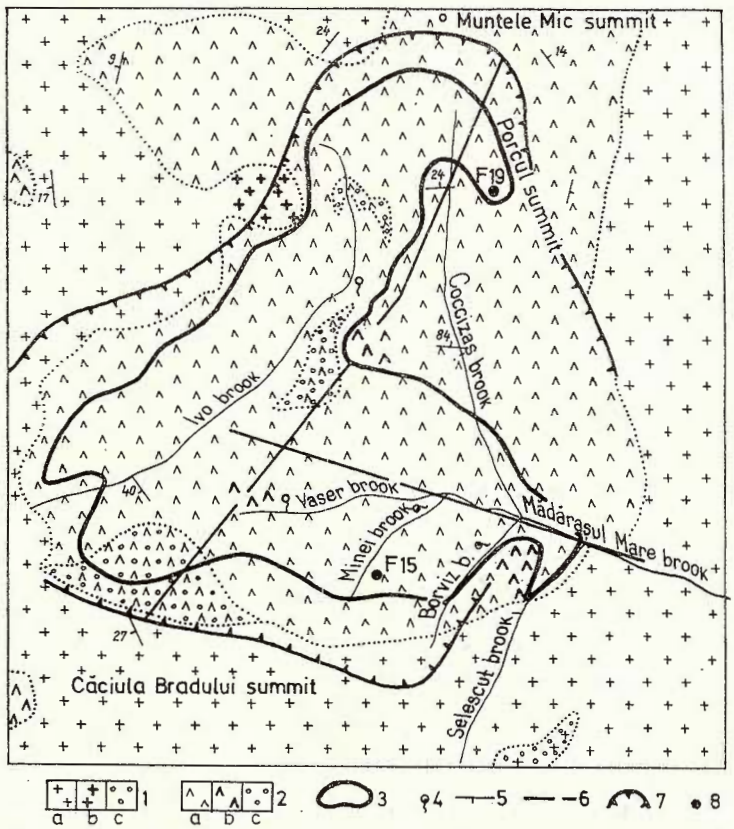


Fig. 1. — Geological map of the Mădărașul Mare-Ivo region, scale 1 : 50 000 (acc. to Setel et al., 1974)

1, pyroxene andesite ; 2, hornblende + pyroxene andesite ; 1-2 a, lavas ; 1-2 b, holocrystalline rocks ; 1-2 c, agglomerates ; 3, hydrothermal alteration area ; 4, mineral springs ; 5, position of parting surfaces of lava flows ; 6, fault ; 7, caldera border ; 8, location of borehole.

On the basis of regional considerations (after Rădulescu et al., 1964) the region belongs to the stratovolcanic upper compartment, overlying the volcano-sedimentary plateau of the lower compartment, developed on a prevolcanic basement.

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The petrographical, mineralogical and geochemical research of the mine workings and drillings (Stanciu, 1982 ; Stanciu et al., 1984) indicates that successive magmatic phenomena built up a complex structure consisting of the andesites of the stratovolcano penetrated by microdiorites, which generated important postmagmatic processes.

The first volcanic activity, with a mixed character, gave rise to the main andesitic mass constituted of lavas, subordinated pyroclastics and bodies. The andesite with pyroxenes (I) and/or green hornblende represents the fundamental petrographic type. The intrusive activity developed subsequently within the stratovolcanic complex, generating microdiorites with pyroxenes or hornblende and, in places, quartz, which form an assemblage of small bodies. The end of the volcanic activity corresponds to the eruptions of pyroxene andesites (II), which pierce or overlie the previous products.

2. Rhyodacites

2.1. *Location.* In the borehole no. 19 (644.50 m deep), south of the Porcul Mts, two rhyodacite bodies have been intercepted. Plate I represents the borehole column ; the right-hand, narrow column indicates the position of the rocks pointed out by the direct observation of the drill cores, whereas the left-hand, large column shows the interpretation of data.

The zone penetrated by the borehole 19, situated at the northern periphery of the area with hydrothermal activity, consists of a succession of fresh volcanic products : a packet of andesitic lavas (a), represented, in the lower part (644.50-530 m), by andesites with partly opacitized green hornblende and pyroxenes ; a level of andesitic pyroclastics (b), intercepted from surface on a thickness of 54 m ; and two vein bodies of rhyodacites (c) piercing the andesitic mass.

Rhyodacites are to be found in a 40 m thick interval, situated at a depth of 527-487 m ; they are much more developed on an interval of 230 m, from the depth of 388 m up to 150 m.

The viscous, acid magma intruded abruptly, at the contact giving rise to the brecciation of the pre-existent andesites and particularly to an explosion breccia, individualized in the lower part of the main rhyodacite body, in an interval of 18 m, and even within its mass, at the depth of 240-200 m.

In a borehole (no 15) situated in the southernmost part of the hydrothermal area, in the right bank of the Mina Brook, an 1 m thick vein has been intercepted at a depth of 255 m, which penetrates a body of andesites with pyroxene and hornblende.

2.2. *Petrographical and Mineralogical Data.* Macroscopically, rhyodacite occurs as a nonhomogeneous rock, with eutaxitic texture (Pl. II, Figs. 1, 2) determined by the alteration of fine, linear bands

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(with thicknesses varying from submillimetric to maximum 3 cm), with clear contacts between them ; their colour varies from white to dark grey, the light hues prevailing. This parallelism, continuously observed, points out the laminar flow of the magma which, referred to the borehole axis, indicates that the intrusion have generally taken place according to an inclined plane, which becomes vertical only in the lower part of the main vein. The structure of the rock is aphanitic, phenocrysts of hornblende and biotite being only accidentaly found (a grain of quartz has been observed in one sample). The rock break is conchoidal and the lustre is often glassy.

The microscopic study points out a variation of composition, structure and colour of bands (Pl. III, Fig. 1). Besides their general parallel disposition one may also observe an anastomosed structure, short undulated strips pinching out or blending one another. The rock is mostly constituted of glass, occurring as bands of grey, brown or reddish colour contrasting with the scarce colourless, crystallized bands. There is a clear or gradual transition from the exclusively vitreous material to zones including crystallites either as minute centres or as better-individualized forms, the latter occurring as globulites or longulites. The globulites are small, spheroidal nuclei disseminated in the amorphous mass or agglomerated in linear and long or undulated and short felts forming clearly differentiated bands. Both the composition of the globulites and that of the longulites cannot be studied thoroughly because of their reduced sizes but they are likely to be constituted of feldspar and silicas. In the bands including crystals one can observe a linear disposition as against the flow direction this being the order of both the microlites from the bands with pilotaxitic structure and of the phenocrysts of plagioclase, hornblende, pyroxenes or biotite (Pl. III, Fig. 2).

Well individualized are the colourless bands, entirely crystallized, with a microgranular groundmass and with more phenocrysts than the hyaline or cryptocrystalline adjacent zones (Pl. III, Figs. 3, 4).

The phenocrysts occur in a reduced number ; in thin sections in which they occur their percentage is of maximum 10-15%. The plagioclase (oligoclase-andesine) phenocrysts are the most frequent ones, generally constituted of two zones : an internal part, usually rounded and dark, of small crystals of mafic minerals, particles from the groundmass, secondary minerals, surrounded by an external part, fresh and much more developed. Some crystals display a progressive change in the composition from the centre to the margin of the crystals. The mafic minerals are subordinate. The green hornblende, with frequent opacite rims, is the most common presence. A cluster of resorbed, green hornblende is surrounded by a belt of plagioclases in comparison with which the microlites from the groundmass are ordered, parallel to the glomeroporphyry contour. Other acicular microphenocrysts of amphibole are indicated by the pseudomorphoses of iron oxides. Pyroxene (probably augite) is entirely carbonated as against the fresh state

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of the other mafic elements. The biotite blades display, in places, a strong pleochroism, from brown yellow to dark brown almost opaque.

In rhyodacite several parallel fissures can be observed, which coincide with flow surfaces of the magma and are filled with calcite ± ± pyrite ; they are intersected by other breaks including also quartz and zeolites, besides calcite. The mentioned hydrothermal depositions are proper to rhyodacites being not found in the host andesites.

The explosion breccia formed during the acid magma ascent towards surface. The explosion phenomena gave rise to gaps in which fragments from the andesitic walls as well as from the rhyodacitic consolidated parts have been thrown. Angular and subangular fragments (with variable sizes up to 10 cm) are cemented with a nonsorted matrix consisting of eruptive material (Pl. III, Fig. 3).

2.3. *Chemical Data.* Besides the chemical analyses of rhyodacite we shall also present the analyses referring to andesites and microdiorites forming the Ivo-Mădăraşul Mare eruptive structure with a view to comparing their results as well as because in a previous paper only the average values and the variation limits of the contents have been given.

There are 33 analyses on silicates (Table 1) and 37 spectral analyses (Table 2).

The projection on the *QAP* diagram (Streckeisen, 1967) of the CIPW norms (Fig. 2) confirms the andesitic or dioritic origin of the main eruptive products, most of the projections occurring in the normal field of these petrographic types. The veins of acid rocks analysed are projected in the left-hand side of the dacite field or even at the boundary with the rhyolite field, so that the denomination used by us — rhyodacite — is proper. In the Mădăraş area no intermediary types between the mentioned rock groups have been found, as pointed out by the diagram, too.

The clear delimitation of the projection of the andesitic and microdioritic rocks, on the one hand, and of the rhyodacitic rocks, on the other hand, appears also on the ternary diagram Mg, Fe_{tot}, Alk and Ca, Na, K (Figs. 3, 4). It is obvious the presence of two distinct groups of points so that it is impossible to draw a differentiation line from basic to acid. This situation showing the lack of intermediary terms (according to petrographic remarks) excludes the interpretation of rhyodacites as local acid differentiates. On the other hand their consanguinity with the other Neogene magmatites in the region is likely; they might represent a late acid differentiate from the magmatic chamber in a time span impossible to be specified, but undoubtedly subsequent to the consolidation of andesites and microdiorites.

A comparison of the variation limits and of the average values of the trace elements — Ni, Co, Cr, V, Sc, Ba, Sr, Zr, Li (Fig. 5) —

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TABLE 1

Chemical composition (%) of the eruptive rocks in the Mădărașul Mare-Ivo structure (Harghita Mountains)

No	Location *		SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	H_2O^+	Fe(S)	S	Total	Fe_2O_3 Total
	Pyroxene andesite I																		
1	m 81	F 15	53.36	17.42	1.03	3.91	0.15	4.70	8.68	3.00	0.92	0.74	0.63	2.12	2.18	0.73	0.84	100.41	6.41
2	m 256	F 15	55.53	17.60	0.83	4.57	0.11	4.34	7.87	3.05	1.32	0.67	0.22	0.66	0.67	0.57	0.66	99.67	6.72
3	m 102	F 18	56.07	17.90	1.99	3.33	0.10	4.91	8.17	2.78	1.21	0.69	0.13	0.20	1.81	0.30	0.35	99.94	6.12
4	m 289	F 15	56.09	17.50	0.85	4.63	0.12	4.79	7.81	3.00	1.10	0.73	0.47	0.45	1.67	0.43	0.50	100.14	6.60
5	m 172	F 18	57.06	18.00	2.30	3.45	0.12	4.72	7.98	3.15	1.32	0.64	0.12	0.43	0.65	0.08	0.092	100.12	6.24
6	m 74	F 18	57.64	16.30	0.99	3.93	0.07	6.00	7.72	2.66	1.44	0.58	0.19	0.20	1.42	0.25	0.29	99.688	5.71
7	m 96	F 19	58.50	18.10	2.79	2.87	0.16	3.66	6.75	3.02	1.63	0.59	0.19	0.50	0.63	0.19	0.22	99.80	6.25
	Pyroxene andesite II																		
8	m 28	F 9	56.47	16.86	2.31	3.76	0.17	5.76	8.28	3.04	1.42	0.65	0.10	0.45	0.73	0.04	0.05	100.09	6.55
9	No 16	v. Ivo	57.87	18.87	2.80	3.17	0.12	3.38	6.70	3.42	1.75	0.74	0.15	0.42	0.87	0.05	0.06	100.37	6.39
10	m 110	F 32	57.97	17.59	2.33	4.13	0.07	4.64	6.63	2.79	0.45	0.58	0.20	0.25	2.07	0.09	0.10	99.89	7.05
11	m 400	F 32	58.56	16.40	1.10	3.90	0.25	4.98	6.36	2.88	1.13	0.55	0.12	1.21	2.14	0.05	0.06	99.69	5.50
12	m 213	F 30	58.65	17.10	0.76	3.48	0.11	4.02	7.24	2.42	1.50	0.58	0.14	1.22	1.64	0.39	0.45	99.70	5.19
	Hornblende pyroxene porphyry microdiorite																		
13	m 41	F 2	54.88	17.55	2.21	4.38	0.19	3.95	8.43	3.10	0.72	0.84	0.094	0.77	1.95	0.32	0.37	99.754	7.54
14	m 71	F 11	55.99	18.05	2.81	3.20	0.15	4.17	7.88	3.18	1.55	0.79	0.11	1.07	0.88	0.16	0.19	100.18	6.59
15	m 39	F 2	56.08	17.55	2.18	4.33	0.17	4.03	8.01	3.00	1.08	0.86	0.10	0.71	1.47	0.22	0.25	100.04	7.30

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16	m 561	F 30	56.15	17.68	1.10	4.70	0.09	5.33	8.47	2.55	1.20	0.67	0.16	0.48	1.26	0.23	0.26	100.33	6.65
17	m 489	F 32	56.29	18.11	1.24	5.07	0.11	3.88	7.58	2.23	0.51	0.62	0.14	1.10	2.71	0.08	0.09	99.76	6.98
18	m 581	F 32	56.45	18.36	1.37	4.87	0.24	4.15	7.86	2.50	0.57	0.62	0.14	0.76	1.85	0.05	0.06	99.85	6.85
19	m 315 Gal VIII/Lat 685		56.80	17.80	3.28	3.08	0.12	3.65	7.72	3.00	1.40	0.77	0.12	0.95	1.08	0.12	0.14	99.88	6.82
20	m 443	F 17	56.88	17.60	1.63	3.95	0.08	4.43	7.00	2.96	1.50	0.93	0.49	0.37	1.53	0.24	0.28	89.875	6.36
21	m 577	F 30	56.88	18.68	0.94	4.29	0.09	4.18	7.65	2.80	0.96	0.59	0.12	0.62	1.50	0.30	0.34	99.94	6.14
22	m 640	F 32	56.89	18.53	1.00	4.26	0.08	4.19	8.05	2.74	1.63	0.62	0.12	0.23	0.94	0.15	0.17	99.63	5.94
	Hornblende pyroxene andesite																		
23	m 624	F 19	56.28	17.90	4.06	2.25	0.08	3.14	7.24	3.22	1.60	0.73	0.10	1.37	1.77	0.057	0.066	99.872	6.64
24	m 352	F 18	57.17	18.30	1.71	3.09	0.13	3.56	8.01	2.90	1.49	0.54	0.18	0.69	1.44	0.41	0.47	100.07	5.72
25	m 617	F 15	57.51	17.32	0.38	4.58	0.16	4.42	7.58	3.00	0.92	0.52	0.59	0.20	1.62	0.38	0.44	99.62	6.01
26	m 90	F 9	57.85	16.83	2.49	3.23	0.16	4.95	7.42	3.19	1.62	0.66	0.11	0.38	1.09	0.08	0.09	100.18	6.08
27	m 631	F 16	58.11	16.72	1.06	4.36	0.12	4.13	8.19	2.82	1.60	0.79	0.19	0.66	0.64	0.29	0.34	100.02	6.31
28	m 119	F 19	58.56	18.10	2.81	3.12	0.14	3.24	6.66	3.54	1.80	0.60	0.14	0.50	0.53	0.13	0.15	100.02	6.46
	Rhyodacite																		
29	m 188	F 19	67.70	15.70	1.70	1.88	0.18	0.52	2.92	3.67	2.88	0.28	0.10	1.08	0.94	0.087	0.10	99.737	3.91
30	m 191	F 19	67.81	16.00	1.70	1.52	0.14	0.40	2.95	3.79	2.93	0.28	0.12	0.87	1.13	0.13	0.15	99.93	3.58
31	m 264	F 19	68.88	15.14	1.51	1.66	0.11	0.55	2.69	4.22	3.01	0.24	0.14	0.61	1.01	1.045	0.052	99.86	3.41
32	m 520	F 19	68.97	14.89	1.11	1.65	0.07	0.67	2.62	3.55	3.08	0.24	0.13	1.53	1.09	0.052	0.060	99.72	3.01
33	m 255	F 19	69.01	14.84	1.51	1.64	0.06	0.58	2.64	4.25	3.00	0.22	0.14	0.91	0.81	0.047	0.054	99.714	3.40

* Symbols : F = drilling
Gal = gallery
Lat = lateral

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TABLE 2

Trace elements contents (ppm) in the eruptive rocks of the Mădăraşul Mare-Ivo structure (Harghita Mountains)

No	Location *		Pb	Cu	Zn	Bi	Sn	Mo	Ga	Ni	Co	Cr	V	Sc	Y	Yb	Ba	Sr	Li	B	Zr
	Pyroxene andesite I																				
1	m 750	Gal. X	3	38	80	ndt.	ndt.	ndt.	15	46	14	140	120	16.5	9.5	1.3	230	320	6.5	57	90
2	m 740	Gal. X	ndt.	6.5	80	ndt.	2	ndt.	17	20	12	28	150	18	16	1.7	550	380	5.5	ndt.	135
3	m 730	Gal. X	3	17	65	ndt.	2	4	17	20	14	40	135	16.5	17	1.6	450	340	7	ndt.	140
4	m 81	F 15	16	19	55	ndt.	2.5	2	20	14	14.5	62	185	32	22	2.3	420	78	7.5	480	130
5	m 256	F 15	5	11	60	ndt.	2.5	ndt.	16	8	13	15	110	23	22	2.0	290	440	9	32	145
6	m 102	F 18	ndt.	5.5	80	ndt.	ndt.	ndt.	13	9	13	45	115	22	15	1.3	270	260	3	ndt.	95
7	m 289	F 15	13	14	46	ndt.	2.5	ndt.	17	14	13	16	95	20	19.5	1.6	270	340	8.5	30	125
8	m 172	F 18	4.5	9.5	80	ndt.	ndt.	ndt.	14	8.5	14	24	100	21	16	1.4	300	300	ndt.	ndt.	125
9	m 74	F 18	2	14	42	ndt.	ndt.	ndt.	13	10	20	160	110	21	16	1.6	300	220	3	ndt.	125
10	m 96	F 19	2.5	12	180	ndt.	ndt.	2	12	9.5	13	19	110	18	17	1.6	350	280	8.5	40	125
	Pyroxene andesite II																				
11	m 28	F 9	6	32	80	ndt.	2.5	ndt.	14.5	32	36	125	180	25	23	1.5	360	340	12	ndt.	
12	No 16	v. Ivo	8.5	28	76	ndt.	2.5	ndt.	18	13	24	10	140	14	19	1.5	300	280	12	ndt.	
13	m 110	F 32	43	18	60	ndt.	7.5	ndt.	21	17	12	80	135	16.5	14	1.3	250	430	ndt.	ndt.	
14	m 400	F 32	55	40	480	ndt.	3	ndt.	18	65	21	155	125	16	13.5	1.3	1000	340	10	ndt.	
	Porphyry microdiorite with pyroxenes and green hornblende																				
15	m 41	F 2	13	32	70	ndt.	5	ndt.	18	19	38	30	210	22	23	2.4	225	210	14	72	160
16	m 71	F 11	4.5	22	60	ndt.	2	ndt.	13	15.5	38	17.5	155	22	25	1.6	320	310	8.5	ndt.	
17	m 39	F 2	8.5	32	50	ndt.	4	ndt.	20	17	34	28	175	20	22	2.3	260	210	13	38	160

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18	m 489	F 32	16	46	73	ndt.	7	ndt.	19	9	13	23	92	16.5	17	1.5	200	340	16	ndt.	
19	m 581	F 30	29	19	90	ndt.	4.5	ndt.	18	16	22	100	160	22	15.5	1.5	420	340	7.5	ndt.	
20	m 315	Gal.VIII/Lat.685	9	28	75	ndt.	4.5	ndt.	19	11	34	15	125	16	20	2	345	420	11	30	170
21	m 443	F 17	4.5	5.5	32	ndt.	3	2	18	8	6.5	52	48	12	18	1.5	400	320		ndt.	100
22	m 577	F 30	3.5	8.5	75	ndt.	2.5	ndt.	22	13	27	37	125	19	18	1.7	185	280		54	
23	m 640	F 32	17	31	53	ndt.	6	ndt.	20	8.5	15	23	145	20	17	1.8	460	410	ndt.	ndt.	
	Andesite with pyroxenes and green hornblende																				
24	m 982	Gal. X	36	15	70	ndt.	ndt.	ndt.	14	21	12	57	130	16	13	1.5	350	300	6	ndt.	125
25	m 612	F 19	2.5	30	58	ndt.	ndt.	ndt.	14.5	11	9	5.5	130	14	9	1	350	330	10.5	ndt.	80
26	m 624	F 19	2	28	95	ndt.	ndt.	ndt.	19.5	11	13	13	150	25	15	2.1	360	370	15	ndt.	95
27	m 352	F 19	6	2.5	110	ndt.	ndt.	ndt.	14	6	8.5	15	60	18	15	1.5	400	460	12	ndt.	140
28	m 617	F 15	48	15	200	ndt.	2	ndt.	17	6	12	50	92	19	22	1.8	350	420	12	30	160
29	m 90	F 9	4	18	55	ndt.	2.5	ndt.	15	12	31	62	180	23	22	1.5	410	270	18	ndt.	
30	m 631	F 16	17	360	75	ndt.	2.5	2	18	7.5	12	45	75	17	20	1.7	320	420	8	ndt.	110
31	m 119	F 19	2.5	11	83	ndt.	ndt.	ndt.	12.5	11.5	12	11	88	13	17	1.7	400	270	19	ndt.	140
	Rhyodacite																				
32	m 276	F 15	2	12	ndt.	ndt.	4.5	ndt.	14	6	3.5	1.5	5	2	17	2.1	1200	340	12	100	280
33	m 188	F 19	8	6	58	ndt.	ndt.	2	12	2.5	4	1.5	9.5	2	17	1.7	550	220	40	34	290
34	m 191	F 19	8.5	9	65	ndt.	ndt.	2	12	3.5	4.5	3	15	2.5	19	1.7	480	200	25	36	300
35	m 264	F 19	10	7	70	ndt.	ndt.	2	12	2.5	3	3.5	8	2.5	17	1.9	600	200	27	40	290
36	m 520	F 19	8.5	5	47	ndt.	ndt.	2	11	2.5	3	1.5	5	3	17	2	600	220	95	35	270
37	m 255	F 19	10	9	83	ndt.	ndt.	3	11	3.5	3	3.5	5	2.5	15	1.5	650	230	24	42	280
Limits of detection			2	30	3	2	2												3	30	

* Symbols: ndt.=not detected; F = borehole; Gal = gallery; Lat = lateral.

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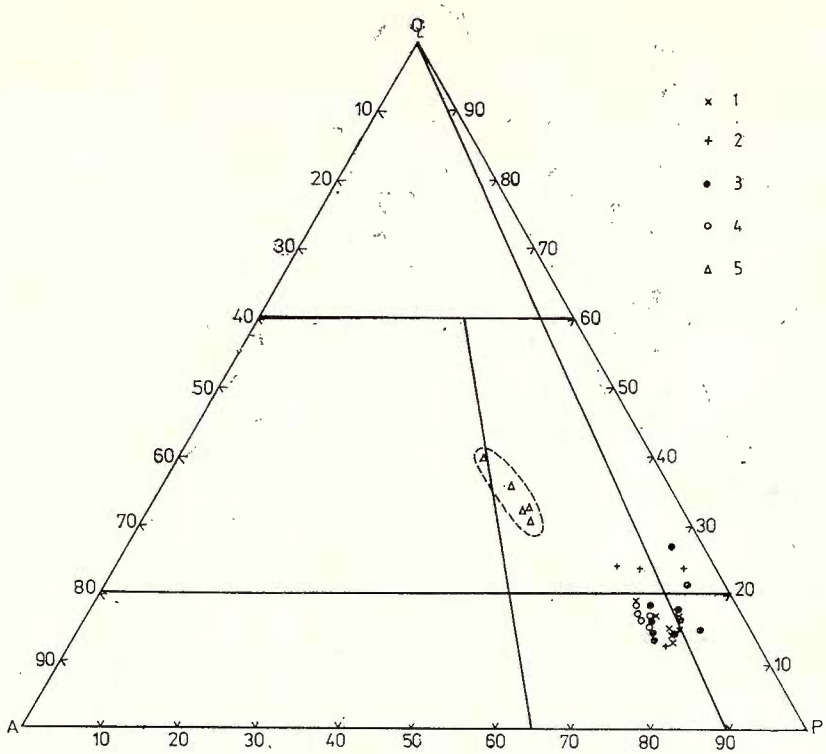


Fig. 2. — QAP normative diagram
1, pyroxene andesite I ; 2, pyroxene andesite II ; 3, porphyry microdiorite with pyroxene and green hornblende ; 4, andesite with pyroxenes and green hornblende ; 5, rhyodacite.

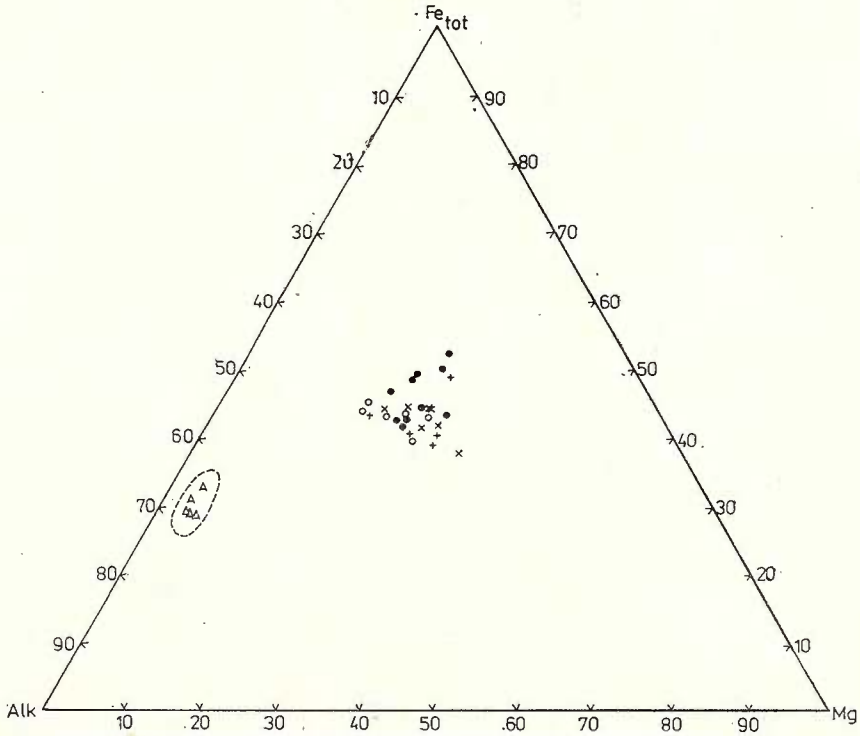


Fig. 3. — Mg, $Fe_{tot.}$ Alk diagram. See legend of Fig. 2.

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indicates also a clear differentiation of rhyodacites as compared to andesites and microdiorites, lower values of Ni, Co, Cr, V, Sc — elements specific to the ferromagnesian minerals — and high values of Ba, Zr, Li — elements enriched in the acid rocks — being obvious. For andesites-microdiorites, the variation domain of the trace elements mostly cor-

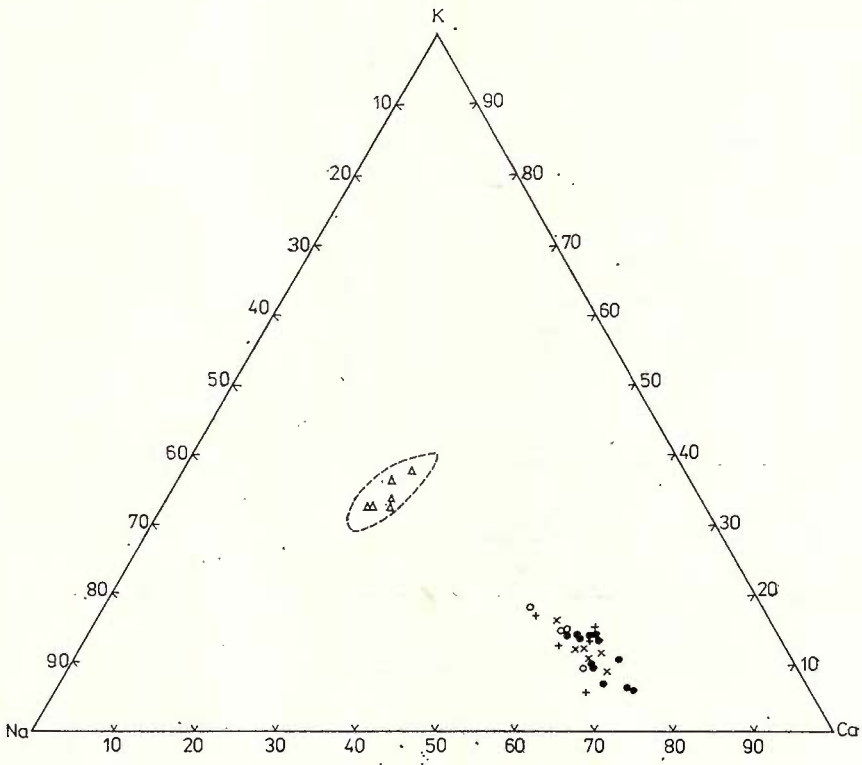


Fig. 4. — Ca, Na, K diagram. See legend of Fig. 2.

responds ; however a more basic character of the andesites with pyroxenes II (high average values of Ni, Cr, V) is observed. Figure 6 shows the correlation diagrams Cr-Ni, Ni-Co, V-Sc, and V-Ni (average values). These diagrams also indicate the different position of rhyodacites : lower contents of Cr, Ni, Co, V, Sc, and much lower values of the ratios Cr/Ni, V/Sc, V/Ni as compared to andesites and microdiorites. It is only on the Ni-Co diagram that the rhyodacites have the same Ni/Co = 1 ratio as the andesites but for much lower values of those elements. The trace elements contents in the Mădăraș rhyodacites are close to the values known in the relevant literature for the rhyolitic rocks (Ewart et al., 1968).

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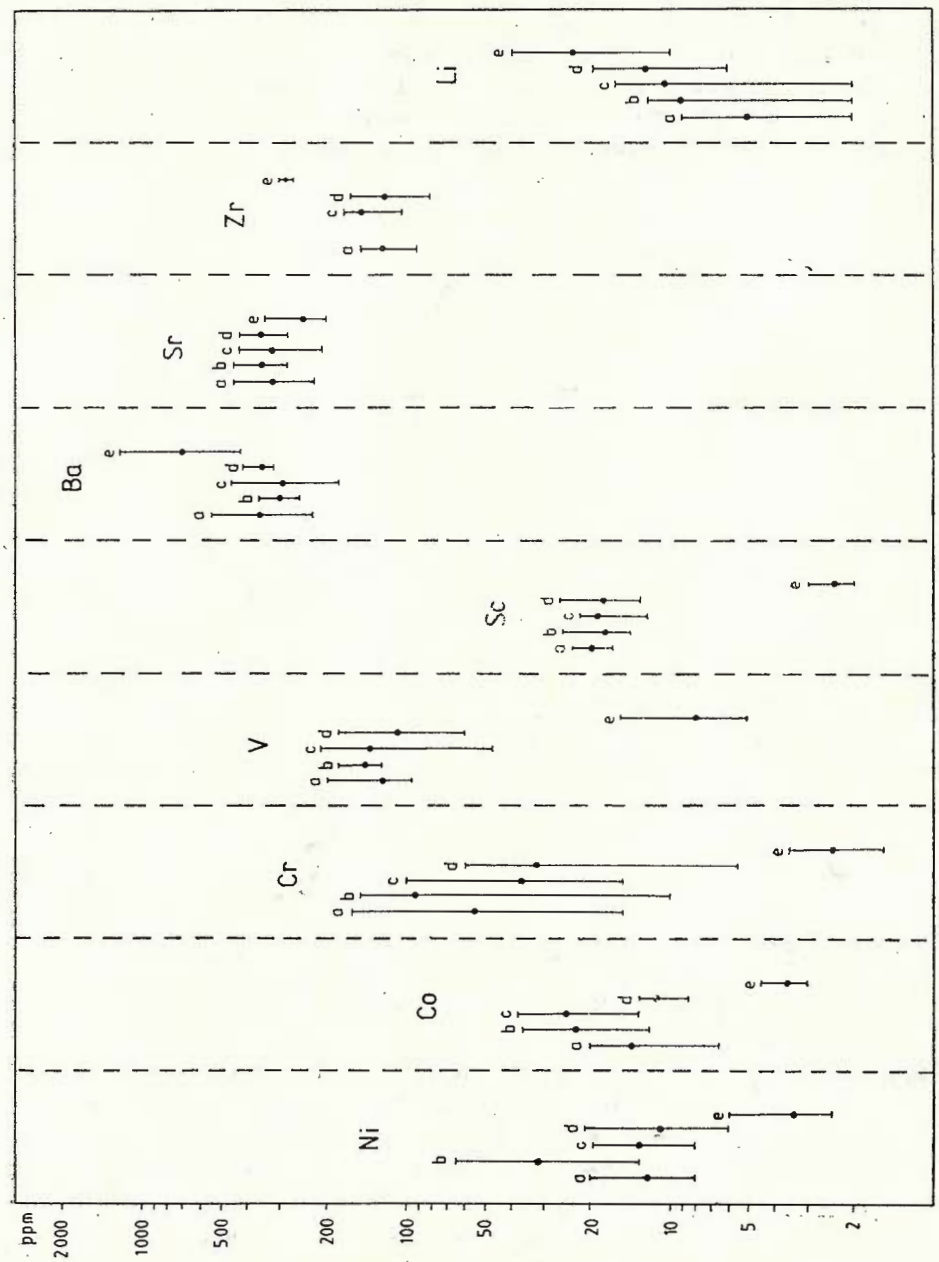


Fig. 5. — Variation limits and average values of the Mădăraşul Mare-Ivo structure petrographic type. a, pyroxene andesite I ; b, pyroxene andesite II ; c, porphyry microdiorite with pyroxene and green hornblende ; d, andesite with pyroxenes and green hornblende; e, rhyodacite. The vertical lines represent the variation limits and the central points represent the average values.

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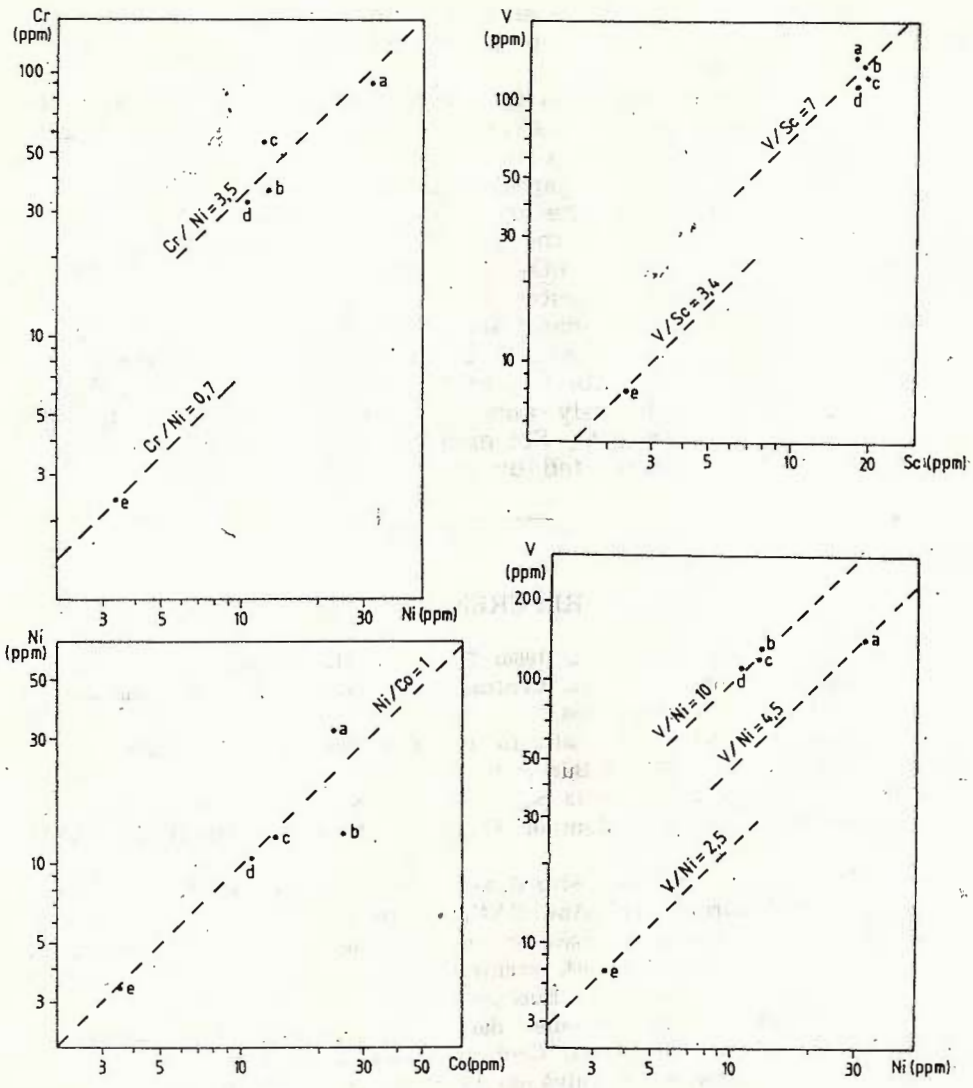


Fig. 6. — Cr-Ni, Ni-Co, V-Ni correlation diagram. See legend of Fig. 5.

3. Conclusions

The rhyodacite veins with eutaxitic texture at Mădărașul Mare constitute a particular volcanic formation entirely new for the Călimani-Gurghiu-Harghita volcanic chain; the rhyodacitic intrusion is situated within the stratovolcanic andesitic complex of the Pliocene upper compartment, subsequently to the eruption of andesites + pyroxenes and/or green hornblende.

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The similitude of texture and partly of composition between the Mădărașul Mare rhyodacite and the Vlădeasa banatitic rhyolites is obvious (Ștefan, 1980).

In the Harghita Mts, also in the upper compartment, there are to be found other acid products, as well, such as : fissure granophyre (a) occurring in the same area as rhyodacite (Stanciu, 1982) ; Dănești dacitic dome (b) (Raczkebel area) with 66.23% SiO_2 (Peltz, 1985) ; pumice stone levels (c) in the pyroclastic volcanoes east of the Olt Valley, south-eastern part of the Harghita Mts ; andesites+amphiboles and biotite (d) with 60-67% SiO_2, which represent an acid domain, too (c and d, according to Rădulescu, 1973).

The existence of acid manifestations, independent and minor (except for andesite+amphibole and biotite) individualizes the upper compartment of the Harghita Mts from that of the Gurghiu and Călimani Mts, almost exclusively andesitic (only in the Fîncel-Lăpușna caldera in the Gurghiu Mts, Solomon — 1975 — described a dacite with SiO_2=61.37%, intercepted by one drilling).

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EXPLANATION OF PLATES

Plate II

Fig. 1. — Eutaxitic rhyodacite. Linear parallel bands intersected by a calcite fissure. Borehole 19, m 297.

Fig. 2. — Eutaxitic rhyolite. Narrowed bands. Borehole 19, m 387.

Fig. 3. — Explosion breccia with rhyodacite dark-coloured fragments and andesite light-coloured fragments. Borehole 19, m 223.

Plate III

Fig. 1. — Eutaxitic rhyodacite. Alternation of linear parallel bands with phenocrysts of plagioclase (a) and biotite (b) trending towards the flow direction. Borehole 19, m 260 N || ; × 40.

Fig. 2. — Eutaxitic rhyodacite. Crystals of plagioclase and opacitized amphiboles conformably to the flow direction. Borehole 19. m 340 N || ; × 30.

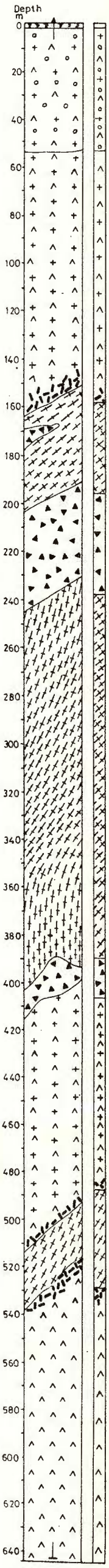
Fig. 3. — Eutaxitic rhyodacite. Contact between a vitreous band with oriented phenocrysts and a crystallized band. Borehole 19. m 250 N || ; × 50.

Fig. 4. — Eutaxitic rhyodacite. Crystallized band (microgranular matrix with plagioclase phenocrysts) in contact with isotropic vitreous bands. Borehole 19, m 270 ; N + ; × 40.

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COLUMN OF BOREHOLE 19



LEGEND

- Soil
- Brecciations
- Explosion breccia
- Rhyodacite
- Hornblende + pyroxene andesite a, lavas; b, pyroclastics
- Andesite with partly opacitized green hornblende; lavas
- Borehole axis

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PETROLOGICAL STUDY OF THE BANATITIC ERUPTIVE ROCKS IN THE EASTERN PART OF THE GILĂU MOUNTAINS [1]

BY

AVRAM ŞTEFAN [2], CONSTANTIN LAZĂR [2], ION ÎNTORSUREANU [2], ADOLF HORVATH [2], IOANA GHEORGHIŢĂ [2], IRINA BRATOSIN [2], ANA ŞERBĂNESCU [2], ERNA CĂLINESCU [3]

Banatites. Laramian magmatites. Andesites. Dacites. Granodiorites. Rhyolites. Lamprophyres. Modal composition. Petrochemistry. Major elements. Minor elements. Magmatic differentiation. Apuseni Mountains — Neocretaceous — Paleogene magmatites — Gilău.

Sommaire

Etude pétrologique des roches éruptives banatitiques de la partie est des monts Gilău. Les schistes cristallins et les roches granitoïdes du massif de Gilău ainsi que les dépôts permiens et sénoniens du versant orientale sont traversés par de nombreux corps de roches banatitiques. Toutes ces formations sont recouvertes transgressivement par des dépôts paléogènes. Bien qu'ils présentent d'habitude des dimensions petites, les corps éruptifs, consolidés en des conditions subvolcaniques, se caractérisent souvent par une non-homogénéité structurale, accompagnée parfois d'une variation de la composition minéralogique. Par suite des recherches de terrain et de laboratoire on a pu séparer les suivants types de roches (mentionnés d'après leur succession de mise en place) : andésites à pyroxènes et amphiboles, andésites amphiboliques, andésites quartzifères à amphiboles et biotite — appartenant au premier cycle — et andésites quartzifères-porphyres quartzdioritiques-diorites quartzifères, dacites-porphyres granodioritiques-granodiorites, granites, microgranites, porphyres granitiques, rhyolites, rhyolites alcalines, aplites — pendant le deuxième cycle principal. Le magmatisme banatitique de la région s'achève par des éruptions d'andésites pyroxéniques±olivine et lamprophyres. La masse principale des roches banatitiques a été générée d'un magma quartzdioritique-granodioritique, tandis que les andésites pyroxéniques±olivine et lampro-

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[2] Institutul de Geologie şi Geofizică, str. Caransebeş 1, 78344 Bucureşti.

[3] Întreprinderea de Prospecţiuni Geologice şi Geofizice, str. Caransebeş 1, 78344 Bucureşti.

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phyres proviennent d'un magma à composition différente — fait relevé à la suite des observations microscopiques corroborées avec l'interprétation des résultats des analyses chimiques et spectrales.

Introduction

The present paper represents a synthesis of the data obtained during 1979-1982 concerning the banatitic eruptive rocks from the eastern part of the Gilău Mts. Data on the metamorphic formations are not included in this paper and for this reason the crystalline schists and the associated granitoids are shown unitary on the geological map (Pl. I), only some tectonic elements being drawn up. At the periphery of the Gilău crystalline massif, towards its northern and eastern part, at the contacts with Cretaceous and Paleogene deposits, our thorough researches pointed out several new elements, illustrated on the geological map, scale 1 : 50.000, Iara Valley sheet (Hârtopanu et al., 1982).

It is to be mentioned that the thermal metamorphism as well as the pyrohydrometasomatic alterations, partly known (Gheorghițescu et al., 1979), are not presented in this paper.

Ilie (1946) is the first researcher who assigned the eruptive rocks from the Băișoara-Săcel Mountain area to the laramides known as banatites. Studies or references on banatites from the Gilău Mts belong to several researchers, as follows : Saulea (1953), Borcoș, Borcoș (1962), Hanomolo, Hanomolo (1962), Moțoi, Moțoi (1963), Vlaicu, Tătărâm (1963), Boștinescu, Mătieș (1965), Ghenescu (1965), Niță Pion (1965), Risa (1970), Mureșan (1971, 1974, 1980), Lazăr et al. (1972, 1981, 1982), Kecseti (1974), Căpraș, Berner (1975), Întorsureanu (1976), Solomon et al. (1977), Întorsureanu, Gheorghițescu (1978), Întorsureanu et al. (1979), Gheorghițescu et al. (1979), Lazăr, Întorsureanu (1982). Likewise, data on the banatitic rocks occurring in the above-mentioned region are found in the synthesis papers (Giușcă et al., 1967 ; Ianovici et al., 1976).

Geological Setting

The northeastern part of the Gilău Mts, mostly consisting of crystalline schists and granitoid rocks, comes into contact with the Cretaceous and Tertiary deposits of the Transylvania Basin.

The Upper Precambrian-Lower Paleozoic crystalline formations (Giușcă et al., 1967 ; Ianovici et al., 1976) belong to the Someș, Baia de Arieș, Codru, Biharia, Muncel, and Păiușeni series.

The granitoid rocks of the Muntele Mare pluton display a large structural-textural variety and a mineralogical nonhomogeneity. Eastwards the pluton pegmatitic rocks do occur.

The Permian, Cretaceous, Paleogene and Quaternary sedimentary formations have a more reduced development as compared to the above-mentioned ones. The detrital formations in the Ierții Valley have been assigned to the Permian (Borcoș, Borcoș, 1962). The Senonian deposits

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display both flysch-like facies and Gosau facies (Pion, 1965 ; Mureşan, 1980). The cover of the Paleogene deposits transgressively overlies both the Senonian and crystalline formations and the Laramian magmatites (Lazăr et al., 1972 ; Întorsureanu et al., 1979). The Quaternary deposits include alluvia, terraces, alluvial fans, detritus, etc.

The above-presented formations belong to several tectonic units. The Alpine structural assemblage has been completed by an important ruptural tectonics on the eastern and northern border. Among the numerous fractures two systems are to be distinguished. The fractures generated by the Laramian diastrophism with a NW-SE and NE-SW trending played a part in the development of the banatitic magmatism, too. The younger fractures with a N-S and E-W trending, often intersecting the former ones, led to significant sinkings and wrench folds of the formations.

Laramian Magmatites (Banatites)

In the eastern part of the Gilău Mts the banatitic rocks are spread all over the investigated region ; however, three main zones could be distinguished : Căpuş, Băişoara, Măguri-Răcătău. Most of the rocks appear as subvolcanic bodies, the part played by the structural and tectonic elements in the distribution of magmas being obvious.

Taking into account the mineralogical composition of the rocks and the evidence given by the chemical and spectral analyses several varieties of andesites have been separated on the map, followed by quartz-diorites and granodiorites, highly widespread and with a large structural variation.

In the region of interest, the banatitic magmatism ends with rhyolites, alkali rhyolites and granitic porphyries, as late differentiates of the granodioritic magma, on the one hand, and with pyroxene andesites (in places with olivine) beside lamprophyres, on the other hand.

Description of the Banatitic Rocks

Andesites

Most of the researchers dealing with the banatitic rocks in the Gilău Mts described the andesites as a whole, no attempt to separate them being made. Mureşan (1974, 1980) is the first researcher who distinguished several varieties of andesites (mostly confirmed by our researches, as well). It is worth mentioning that the field relationships do not allow either strict determination of the emplacement succession of different andesite types or a close comparison with similar rocks of the Vlădeasa massif. On the other hand one is not always sure whether there are lava flows or enrooted bodies, especially when the andesites crop out only as a result of the partial erosion of the transgressive cover of Paleogene deposits. Finally, in case of the intensely altered andesites their assigning to one or another variety is very difficult.

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Andesites with Pyroxenes and Amphiboles

The andesitic rocks with pyroxenes and amphiboles, cropping out from under the Paleogene deposits on the streams south of Căpuşul Mare, are likely to constitute lava flows resembling those with which the volcanism starts in the Vlădeasa eruptive massif (Ştefan, 1980). As in the Vlădeasa massif, andesitic pyroclastics have been found neither in the base of the lava flows nor overlying them (Mureşan, 1980).

Macroscopically, the grey-blackish or brown-reddish rock is massive, with a striking porphyritic texture and a breccious aspect due to supergene alteration.

Microscopically, the rock consists of a groundmass within which the acicular plagioclase microlites have sometimes a parallel disposition, moulding the phenocrysts (pilotaxitic texture). More often the groundmass is hyaloaplitic. In other cases, an incipient arrangement of the matrix as allotriomorphic grains including plagioclase microlites gives rise to micropoikilitic textures. Phenocrysts are represented by plagioclases (An_{37-50}), pyroxenes and amphiboles. Femic minerals, sometimes opacitized, other times chloritized or calcitized, are usually distinguished only after the crystallographic contours. The grains of opaque minerals occur both within the old contours of femic minerals and in the groundmass where they are probably primary (at least partially). The large phenocrysts of plagioclases are twinned and zoned, meanwhile the medium ones are only twinned. Both of them are often pseudomorphosed by calcite, other times by sericite or albite. Often are present vugs filled with carbonates surrounded by fibrous chlorite. The rock, as a whole, is cross-cut by fissures filled either with opal or chalcedony or chlorite and carbonates. Mureşan (1980) determined also α-christobalite along fissures. The argillic alteration is rather strong and affects particularly the groundmass.

In the vicinity of the Gilău dam the grey-blackish or brown andesitic rocks show the same chemical composition; nevertheless, they have been consolidated under subvolcanic conditions.

Under the microscope, the relatively fresh rock is constituted of a microcrystalline groundmass (micropoikilitic or microgranular) including phenocrysts of plagioclase, femic minerals (pyroxenes and amphiboles) and, in places, rare phenocrysts of highly corroded quartz. Apatite and opaque minerals occur as accessory minerals. Plagioclase (An_{50-56}) is twinned and, in places, zoned. For the smaller and non-zoned phenocrysts the contents in anorthite are of 36-40%. Pyroxenes are often bastitized, amphiboles are replaced by chlorite and calcite, meanwhile plagioclases are pseudomorphosed by calcite or sericite.

Amphibole Andesites

A white-yellowish rock, poor in phenocrysts, generally difficult to be distinguished due to hydrothermal and supergene alteration, crops out west of Ocolişel, in both sides of the Vadu Valley. This rock

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includes angular fragments of Senonian siltites and comes into vertical contact with a much fresher andesitic body.

Microscopically, the intensely altered andesite consists of a groundmass (80%) within which plagioclase acicular microlites, with a parallel trending (primary pilotaxitic texture), are hardly distinguished. They are included into nuclei of glass slightly individualized and wtihout crystallographic contours (micropoikilitic textures). Amphiboles are entirely opacitized and plagioclases are converted into calcite and albite. The rock groundmass is highly replaced by clay minerals and carbonates.

Other two andesite occurrences with a similar composition but much fresher appear as thin dykes which penetrate the crystalline schists of the Baia de Arieş Series in the Ierţii and Iara valleys. Microscopically, the rocks display a brown, fresh groundmass, with a hyalopilitic texture : the phenocrysts (20%) of twinned and zoned plagioclases (An_{50-55}) as well as those of common hornblende are fresh.

Quartz Andesites with Amphiboles and Biotite

In the northernmost part of the area, in the Cerhat Hill, near the locality of Dumbrava, a light grey massive rock, with a porphyritic texture, crops out in some quarries. Under the microscope, the rock consists of phenocrysts of plagioclase, quartz and biotite, as well as apatite and iron oxides included in a microcrystalline groundmass. Plagioclase (An_{40-48}) is twinned and recurrently zoned. Green hornblende is often replaced by calcite which is also found in the groundmass. Biotite, obviously intramagmatic is corroded and displays, in places, an opacitized rim. Quartz is omnipresent and intensely corroded. This andesite includes fragments of microdiorites, strongly carbonated, as well as of siltites and quartzites.

Quartz Andesites — Quartz-Diorite Porphyries and Quartz Diorites — Quartz Monzodiorites

The rocks belonging to this family display a generally uniform composition but a large textural variation due to the body sizes and the position of the rocks within it. It is very obvious the close spatial and composition connection between these rocks and those assigned to the dacite-granodiorite family which succeed the former ones in time. It is especially in case of the large-sized bodies (Miei Brook, Vadul Valley) that the variation of rock composition and texture may be followed gradually from quartz-diorite porphyries, at the periphery, through porphyry microdiorites to granodiorite porphyries and granodiorites, towards the central zone of the intrusion. In the small-sized bodies, as dykes and sills, the separation of the two rock types is easier, the quartz andesites or the quartz-diorite porphyries, of a darker colour, being consolidated earlier than the dacites or granodiorite porphyries of a light colour and richer in quartz. No xenoliths from one rock into another have been observed. In dacites the parallel trending of plagioclase along the contact with the penetrated andesites is obvious.

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Quartz andesites and quartz-diorite porphyries are massive rocks of a blackish colour, in places greenish, and display a porphyritic character. Plagioclase phenocrysts and femic minerals are distinguished macroscopically, biotite being very easily recognized. Quartz occurs rarely as phenocrysts.

Under the microscope, the andesitic rock shows a groundmass different from that of dacites, within which plagioclases, a little quartz and femic minerals, generally substituted by chlorite, are distinguished. The groundmass granulation varies from cryptocrystalline to fine-grained, still aphanitic, but with a microdioritic aspect under the microscope. The plagioclase and hornblende phenocrysts are omnipresent unlike pyroxene, biotite and quartz which have a discontinuous occurrence. Thus, a 1.5 m thick sill, penetrating the chlorite schists of the Biharia Series, in the left-hand side of the Vadul Valley, consists of andesite with phenocrysts of green hornblende, pyroxenes and plagioclases towards the upper part and frequent quartz phenocrysts towards the base. Above it, after a metre of schists, in another 50 cm thick sill, andesite includes only plagioclase and hornblende phenocrysts ; in all cases the groundmass is identical. It is difficult to establish a rule of the phenocrysts distribution within the quartz andesites ; however, one may estimate that while pyroxene is frequently found in the Băişoara and Cacova bodies, in the Iara Valley-Someşul Rece Valley, where dacites occur rarely, the quartz-diorite porphyries are generally devoid of pyroxenes and consist more frequently of quartz phenocrysts. The composition of the plagioclases belonging to this family of rocks is variable. Thus, there occur twinned and recurrently zoned plagioclase phenocrysts with contents of 28-38% An as well as more basic ones (46-50% An). Pyroxene and hornblende are usually pseudomorphosed by chlorite, calcite or quartz, sometimes sphene and iron oxides being separated, whereas biotite may remain fresh.

Nearby the larger bodies of granodiorite porphyries or granodiorites, the quartz andesites and quartz-diorite andesites are secondary biotitized. The automorphous propylitization, characteristic of this rock group, is followed within the granodiorite bodies by neoformation of actinolite with divergent disposition and limited to the primary contours of femic minerals. Neominerals of the epidote group are plentiful in the metasomatic aureole of the hypabyssal bodies and also late zeolites replacing the plagioclases or filling the fissures. The fissures filled with quartz, usually crossing the rocks, occur more frequently in the Băişoara zone. Sericite and clay minerals often substitute the plagioclase phenocrysts and the groundmass. Albite has often been observed along the cleavage planes and fissures in the plagioclase phenocrysts, slightly pseudomorphosed by calcite and sericite.

Quartz diorites and quartz monzodiorites appear either as isolated small bodies (Răcătău Valley, Agîrbiciu Valley) or as peripheric facies of the granodioritic bodies (Miei Brook, Vadul Valley). They differ from the underlying granodiorites by a higher percentage of femic minerals (C.I. = 15-25) and a smaller amount of orthoclase. The

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percentage in quartz and potash feldspar varies very much in the peripheric facies of the granodiorite body from the Vadu Valley, thus diorites and tonalites are found beside quartz-monzodiorite and granodiorite rocks.

The quartz monzodiorites in the Agîrbiciu Valley, reported by Rișa (1970), have a narrow spreading. They are massive, phaneritic rocks, with massive structure and hipidiomorphic-granular texture. The rock consists of plagioclase (andesine-labrador), twinned and zoned, often corroded by granophyric intergrowths, to which quartz, amphiboles, biotite, apatite, and opaque minerals are added. Chlorite, calcite, sericite, and albite occur as newly-formed minerals.

The quartz monzodiorite body in the Răcătău Valley also displays structural and composition varieties. Thus, the porphyritic, marginal facies is characterized by a microgranular groundmass of andesine and quartz, as well as biotite, pyroxenes and opaque minerals. Twinned and zoned plagioclases and rhombic and monoclinic pyroxenes corroded by biotite occur as phenocrysts. Towards the middle of the body, the rock becomes almost equigranular, being made up of plagioclases (replaced by sericite and epidote), biotite (often chloritized), very few pyroxenes and a large amount of green hornblende.

Dacites — Granodiorite Porphyries — Granodiorites

The rocks belonging to the above-mentioned family have an identical composition but a different texture. The dacite-granodiorite porphyries-granodiorites are widespread as sills, dykes and apophyses of hypabyssal, well-crystallized larger bodies. The texture variation of the rocks within the larger bodies is obvious both macroscopically and microscopically. Insignificant variations of the mineralogical composition of the granodiorite porphyry bodies occur quite often. A gradual increase of the content in femic minerals, from the centre towards the periphery, from granodiorite porphyry, through dacite and then towards dark-coloured quartz andesite is observed in the bodies of the Cetate Valley and Cheile Băișoarei.

Macroscopically, the dacitic and granodioritic rocks display a grey-whitish colour, in places spotted. The rock structure is massive and the texture is porphyritic or grainy, almost equigranular. Plagioclase, quartz, hornblende and biotite, as well as orthoclase (in the phaneritic rocks) can be observed macroscopically.

Microscopically, the rocks show variable textures of the groundmass (55-70%) which, together with the phenocrysts (in case of porphyritic rocks) determine the rock varieties of the family. Dacites display a cryptocrystalline to microcrystalline groundmass. The groundmass of the granodiorite porphyries, generally aphanitic, occurs well crystallized under the microscope. The small-grained, almost isometric quartz and the potash feldspar microlites often give a slab-like aspect to the groundmass. In many dykes the quartz-feldspathic groundmass shows granophyric character.

The phenocrysts of plagioclase, quartz and biotite (always present), amphibole (in places absent) and pyroxene (sporadically found),

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occur both in dacites and in granodiorite porphyries. Apatite, iron oxides, titanite, and more rarely zircon occur as accessory minerals.

Plagioclase feldspar (10-25%), twinned and recurrently zoned, in places surrounded by a rim of potash feldspar, displays a variable content of anorthite from one body to another. Thus, contents of 33-34% An have been recorded in the Buru Hill dacites, 34-37% An in the Fînațe Valley granodiorite porphyries, 37-38% An in similar rocks of Cheile Băișoarei, and 39-47% An in the Cetate Valley body. The rocks with intermediary facies between dacites and granodiorite porphyries, including xenoliths of quartz micromonzodiorites exposed in the Valea Fetii quarry, contain a plagioclase with 48-52% An. Very often plagioclases are pseudomorphosed by clay minerals and sericite, albite, calcite, epidote or zeolite (Ierții Valley, Buru Hill).

Hornblende and especially biotite, with inclusions of plagioclase or apatite, are frequently substituted by chlorite, calcite and epidote, sometimes iron oxides and titanite being separated.

Close by the granodiorite bodies secondary biotite occurs in dacites — a proof of the earlier consolidation of the dykes of dacitic rocks as against granodiorites developed towards depth (Lazăr et al., 1972). The presence of secondary biotite in the Măguri-Răcătău granodiorite porphyry body suggests a deep-seated granodioritic intrusion.

In the central zone of the body situated in the Vadul Valley the granodioritic rocks display a granular texture slightly porphyritic. They consist of plagioclase (An_{34-40}), twinned and recurrently zoned, hornblende, biotite, quartz, orthoclase ; apatite and iron oxides occur as accessory minerals. In these rocks hornblende is frequently corroded by biotite, a phenomenon more developed in the deep-seated rocks intercepted by drillings in the central zone of the Mașca-Băișoara granodiorite bodies.

Rhyolites. Alkali Rhyolites, Granite Porphyries, Porphyritic Microgranites, Granites and Aplites

The rocks of this family represent the late differentiates of the granodioritic magma, which generated the large series of the above-described rocks. As regards the rhyolites with transitions towards rhyodacites, found in the basins of the Șatra, Agîrbiciu-Rișca and Stolna valleys, we are not sure that their emplacement has taken place after the consolidation of the granodiorites of the second (main) cycle. They might have been emplaced before the quartzdiorites-granodiorites and their porphyritic varieties, thus being compared to the Vlădeasa and Bihor rhyolites of the first cycle of the banatitic magmatism. There have been described as rhyodacites (Întorsureanu et al., 1979) all the rocks from the sills and dykes, generally felsitic, assigned to rhyolites (Hanomolo, Hanomolo, 1962 ; Kecseti, 1974 ; Moțoi, Moțoi, 1963 ; Mureșan, 1971, 1974), tuffites (Niță Pion, 1965), andesites or intensely hydrothermalized dacites (Rișa, 1970). The rocks with such a composition and texture underwent an intense automorphous and supergene alteration and therefore they are inadequate for chemical analyses. For this reason as well as in the absence of

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field evidence we present them for the moment together with the other rhyolites. They are rocks of a white-yellowish colour, with earthy aspect, and with spots or cavities filled with limonite. Many of them have very few small phenocrysts which, in places, are lacking. Quartz phenocrysts are very rarely recognized beside feldspars and baueritized biotite. Plagioclases often display a negative relief and, due to their strong alteration, they may be mistaken for the potash feldspars, mentioned by Moţoi and Moţoi (1963) in a percentage of 4-8% but not identified by us positively.

Microscopically, the rock consists mostly (95%) of a felsitic or granophyric quartz-feldspathic mass. The banded rocks emphasize an eutaxitic character of the groundmass, grey strips, rich in potash feldspar, alternating with limpid, quartzose ones. Among phenocrysts, biotite — almost omnipresent — is usually baueritized. Twinned plagioclase, generally with an albitic composition, is sometimes richer in anorthite (25-34% An) and, in this case, the untwinned feldspars, with a negative relief and invaded by sericite, are probably potassic.

Typical rhyolites with quartz phenocrysts occur nearby Păniceni and north of the Vadul Valley, piercing the mentioned granodioritic body. Microscopically, the rock has a cryptocrystalline groundmass (80-90%), more rarely microgranular, frequently sericitized. Oligoclase, often sericitized or argillized, corroded quartz and chloritized or baueritized biotite, with apatite inclusions, occur as phenocrysts.

Granite porphyries from the dyke penetrating the Ierţii Valley granodiorite contain the same phenocrysts (quartz, biotite and zoned plagioclase) and the quartz-feldspathic groundmass is microgranular.

The obvious increase of the groundmass granulation gives rise to porphyritic microgranites (south of Cacova).

Alkali rhyolites crop out in the Cetăţeaua Hill and the basins of the Iara and Someşul Rece valleys.

In the Cetăţeaua Hill, the white-yellowish rock is massive, often banded in places cavernous, showing a porphyritic texture.

Under the microscope, the rock consists of a groundmass (90%) sometimes with an eutaxitic aspect, other times uniformly cryptocrystalline or showing quartz-feldspathic spherulitic aggregates. The fresh phenocrysts of potash feldspar (—2V = 36°) are often Karlsbad twinned, more rarely Baveno twinned. Plagioclase is entirely replaced by cryptocrystalline silica. Biotite is absent and quartz is intensely corroded. The lenticular or round vugs are filled with opal or chalcedony.

Alkali rhyolites from the basin of the Iara and Someşul Rece valleys often show a granoporphyric or microgranitic groundmass, with sericitized feldspars. The rock composition is similar to that of the Dumbrava rocks, to which biotite is added, in places, and the amount of phenocrysts increases up to 20%.

Granites, found only in the boreholes in the Cacova zone, as well as the rare veinlets of granitic and micropegmatitic aplites were thoroughly described by Lazăr et al. in 1972 and we do not deal with them any more.

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Pyroxene Andesites ± Olivine

The rocks belonging to this family are found exclusively in the northern part of the region, west of the Căpuşul Mic, and generally represent enrooted bodies of shallow emplacement. On the map, one may observe their alignment with a NW-SE trending, being exposed, together with the Senonian deposits penetrated by them, along a system of fractures extending southwards up to Agîrbiciu. The rocks display a chippy fracture, are massive and black coloured when fresh or brick-red when limonitized.

In the right-hand side of the Şatra Valley, at the western contact of the andesitic bodies, as well as in the Cionca Hill, north of Căpuşul Mic, there occurs a narrow breccia zone, intercepted by a borehole in which, beside pyroxene andesites, clearly predominating, fragments of Senonian sedimentary rocks and crystalline rocks are also found ; rhyolite fragments occur very rarely. The identification of the primary character of the breccia is difficult due to the bentonitization of the glassy matrix of the pyroxene andesite. The formation of the montmorillonitic bentonite seems to be closely related to hydrothermal solutions generated either by the andesite or by some rhyolitic bodies probably deep-seated which, more northwards, in the Cetăţeaua Hill, penetrate pyroxene andesites.

In this zone, the texture of the andesites varies from one body to another and even within the same body. Thus, in the Căpuşul Mic bodies the rocks are obviously porphyritic, the phenocrysts representing up to 50% of the rock volum. On the contrary, in the Cetăţeaua Hill body and particularly at its periphery, the porphyritic character of the rock is hardly visible, the glassy and breakable rock being very similar with a hornfels. Microscopically, it consists of acicular microlites or fine sticks of plagioclases, with an obvious trending (fluidal structure), floating in a vitreous or crpytocrystalline mass, intensely opacitized. Towards the centre of the body rare plagioclase phenocrysts appear, and the groundmass becomes coarser, suggesting intergranular textures by the disposition of the augite, hypersthene and plagioclase crystals. The dusty iron oxides intensely impregnate the rock. The Cetăţeaua Hill andesitic body is the result of at least two successive phases as on its south-western side the red-brick andesites seem to be penetrated by grey andesites ; they differ from the last ones by the intense limonitization degree of the femic and opaque minerals or by the presence of alveoles filled with carbonates and chlorite. The limonitized andesites, included as xenoliths in the alkali rhyolites, are biotitized and the iron hydroxides are converted into magnetite. Biotite and adularia are to be found in the andesites at the periphery of the body in the Cetăţeaua Hill. The opal-bearing fissures occur quite frequently.

In the right side of the Dumbrava Valley, the olivine-bearing pyroxene andesites, obviously porphyritic, include numerous xenocrysts beside their phenocrysts (olivine, augite, hypersthene, and more rarely plagioclase). Thus, the fissured crystals of quartz and plagioclase (An_{36-52}), twinned and zoned, intensely corroded by the ground-

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mass, are not characteristic of the rock which includes them. Other xenocrysts, entirely opacitized, suggest an amphibole with poikilitic inclusions of tiny plagioclase crystals, in places. Olivine is sometimes corroded by pyroxene and the isolated crystals are pseudomorphosed by antigorite. Monoclinic pyroxenes, much more abundant than hypersthene, are generally fresh and very seldom substituted by serpentinic minerals and carbonates. Mureşan (1980) mentioned xenoliths of crystalline schists in the olivine-bearing andesites. At Căpuşul Mic the pyroxene andesites are much richer in phenocrysts (50-52%), represented by plagioclase, twinned and slightly zoned, and hypersthene and augite, in places slightly opacitized. The microcrystalline groundmass consists of plagioclase, pyroxene and opaque minerals. Secondary biotite appears both in the groundmass and as pseudomorphoses after pyroxenes. Plagioclases are sometimes substituted by zeolites.

Lamprophyres

Rişa (1970) is the first researcher who mentioned banatitic lamprophyres in the investigated area. Other researchers (Moţoi, Moţoi, 1963, and Mureşan, 1971, 1980) described them as diabases, older than the banatitic rocks. Four lamprophyre dykes were identified by us in the Şatra Valley head water basin, two of them piercing the granodiorite porphyries, and another one situated in the Calul Valley.

Lamprophyres are grey-blackish, massive rocks, usually with numerous cavities filled with chlorite, quartz and especially calcite.

Microscopically, the rock displays an intergranular character and consists of plagioclase sticks chaotically distributed, with interstices filled with chlorite and quartz. Grains of opaque minerals occur frequently. Phenocrysts are represented by pyroxenes and amphiboles, often completely pseudomorphosed by chlorite and calcite. In other lamprophyre varieties plagioclase phenocrysts do occur.

The black, massive, porphyry-like rock from the dyke which penetrates the micaschists of the Someş Series, at the confluence of the Ursul Valley with the Calul Valley, has an unusual mineralogical composition. The large crystals (up to 1 cm) of twinned and zoned plagioclases, but particularly those of quartz are strongly corroded by the fine-grained mass, indicating their xenolithic origin. The small phenocrysts (2-3 mm) of monoclinic pyroxene are generally fresh, more rarely calcitized, and do not display any reaction with the intergranular or intersertal groundmass. The biotite presence determined us to assign it to lamprophyres, although quartz is missing in the plagioclase interstices. Chlorite and especially calcite intensely pseudomorphose primary minerals making difficult the identification of the varieties (spessartites, kersantites and camptonites).

Petrochemical and Geochemical Features of the Banatitic Rocks of the Gilău Mountains

The present paper is based on 79 complete chemical analyses of silicates [4] (Tab. 1), among which 10 have already been mentioned in a previous paper (Lazăr et al., 1972). Aiming at a unitary characterization

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TABLE 1

Chemical analyses

No	Sample no	Rock type and samping point	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	Cl	PC	S	Fe(S)	H_2O^+	H_2O^-	Total
1	9409	Rhyolite, Calul Valley	79.88	0.14	12.30	0.19	0.08	traces	0.15	0.06	0.32	4.85	—	—	—		—	—	1.63	—	99.61
2	7655	Rhyolite, Cetăţeaua Hill, Dumbrava	78,72	0.10	9.30	0.62	0.08	—	0.65	1.19	2.80	4.40	0.66	0.73	—		0.04	—	1.05	0.58	100.92
3	8705	Rhyolite, Calul Valley	78.05	0.16	11.75	0.68	0.08	0.02	0.20	0.30	1.91	4.36	0.05	—	—		0.05	0.04	1.60	—	99.95
4	989HA	Rhyolite, Rişca Valley	77.19	0.14	12.21	0.45	0.10	0.05	0.17	0.17	0.15	6.82	0.03	—	—		0.11	0.10	1.83	—	99.82
5	573	Rhyolite, Cetăţeaua Hill, Dumbrava	76.70	0.12	12.69	—	1.14	0.02	0.04	0.35	3.08	4.55	0.01	—	—		0.03	—	0.96	—	99.69
6	1408B	Rhyolite, Cetăţeaua Hill, Dumbrava	76.07	0.15	12.85	1.17	0.21	0.04	0.54	0.43	2.86	4.14	0.05	0.10	—		0.02	—	1.48	0.08	100.19
7	1757A	Granitic aplite, Horiz. — 120, Băişoara	74.77	0.10	12.75	1.24	0.12	0.03	0.50	1.40	2.29	5.56	0.02	0.20	—	0.75	0.03	—	—	0.55	100.31
8	606	Rhyolite, Stolna Valley	73.76	—	15.55	—	0.44	0.03	0.15	0.40	3.74	4.00	0.03	—	—		0.03	—	1.53	—	99.66
9	8198	Rhyolite, Vadul Valley	73.04	0.24	14.90	0.67	0.10	0.02	0.89	1.28	3.17	4.11	0.04	—	—		—	—	1.08	—	99.54
10	2034	Rhyolite, Vadul Valley	72.59	0.30	14.75	1.10	0.35	0.03	0.83	0.99	3.40	4.07	0.14	0.58	—		—	—	0.69	—	99.82
11	7910	Rhyolite, Măguri-Răcătău	72.25	0.14	13.81	2.34	0.15	0.02	0.35	0.63	2.20	5.40	0.05	0.90	—		0.05	—	1.28	0.71	100.28
12	84	Granite, F. 31745, Băişoara	69.68	0.18	15.29	0.77	1.31	traces	0.65	3.90	2.96	4.09	0.06	0.19	0.17	0.08	0.08	—	0.03	0.42	99.78
13	7720	Rhyolite, Satul Valley, Păniceni	68.93	0.38	14.50	1.02	1.13	0.09	1.00	1.78	3.92	3.24	0.10	2.30	—		0.06	—	1.43	—	99.88

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14	1367	Dacite, Măguri-Răcătău	68.18	0.48	14.52	1.59	1.45	0.06	1.28	2.90	3.66	3.05	0.15	0.75	—		0.04	0.03	1.31	—	99.45
15	7796	Granodiorite porphyry, Valea Mare, Căpuşul Mic	67.53	0.40	15.50	2.77	1.32	0.08	1.55	3.25	3.98	2.70	0.14	0.25	—		0.05	—	0.71	—	100.33
16	7706C	Dacite, Pănieeni	66.48	0.30	14.35	1.63	1.37	0.03	1.26	2.45	4.20	3.60	0.09	2.13	—		0.04	—	1.57	0.45	99.95
17	2167	Granodiorite porphyry, Negruţa Brook	66.45	0.62	16.00	0.90	1.82	0.05	2.37	2.91	3.37	2.49	0.19	—	—		0.07	0.06	2.27	—	99.57
18	87	Granodiorite, F. 93, Băişoara	66.42	0.53	15.90	1.32	2.59	0.10	1.69	3.76	3.37	2.78	0.22	—	—		—	—	0.83	—	99.51
19	7776C	Granodiorite porphyry, Finaţe Brook	66.19	0.40	15.85	1.66	2.47	0.10	1.45	3.36	3.80	3.00	0.11	1.20	—		0.06	—	0.78	0.49	100.36
20	195	Granodiorite porphyry, Ierţii Valley	66.18	0.40	16.90	1.18	2.10	—	1.94	4.45	2.96	2.65	0.12	—	0.13		—	—	0.02	0.71	99.74
21	11	Granodiorite porphyry, F. 93, Băişoara	66.17	0.60	15.73	1.17	2.31	0.07	1.53	3.98	3.33	3.10	0.33	0.37	—		traces	—	0.89	—	99.58
22	2156	Dacite, Moara Căpriţei Brook	65.92	0.54	15.03	1.83	1.57	0.08	1.62	3.75	3.27	2.98	0.19	1.13	—		0.07	0.06	1.47	—	99.51
23	1402 A	Granodiorite porphyry, Măguri-Răcătău	65.86	0.51	15.61	1.80	1.32	0.07	1.95	3.16	3.27	2.95	0.16	1.15	—		0.05	0.04	2.22	—	100.12
24	1589	Granodiorite, Ierţii Valley, Băişoara	65.71	0.63	15.78	1.13	2.50	0.09	1.81	4.53	3.18	3.06	0.21	—	—		0.17	0.15	0.95	—	99.90
25	7776	Granodiorite porphyry, Finaţe Brook	65.60	0.47	16.40	2.30	1.96	0.11	1.71	3.01	3.77	2.55	0.14	0.42	—		0.17	—	1.09	—	99.72
26	87 J	Granodiorite F. 94, Băişoara	65.38	0.56	15.79	1.03	2.76	0.05	1.98	4.32	3.52	3.27	0.17	—	—		0.05	0.04	0.71	—	99.66
27	22	Dacite, Cheile Băişoarei Valley	65.25	0.42	15.96	1.94	2.28	0.07	1.45	4.24	3.49	3.59	0.14	—	—		—	—	1.25	0.53	100.61
28	40	Granodiorite porphyry, Cetăţii Valley	65.21	0.37	14.28	2.38	1.96	0.06	1.96	5.18	4.00	2.90	0.10	0.78	—		0.17	—	0.83	0.36	100.37

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(continuep)

No	Sample no	Rock type and sampling point	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	Cl	PC	S	Fe(S)	H_2O^+	H_2O^-	Total
29	126	Dacite, Lita Valley Horizon 545	65.02	0.37	15.62	2.39	2.19	0.11	1.09	4.99	3.34	3.54	0.14	—	—		—	—	1.14	0.61	100.60
30	45	Dacite, Iara Valley	64.78	0.43	16.51	1.61	2.25	0.06	1.40	5.40	3.49	3.21	0.17	—	—		—	—	0.79	0.50	100.60
31	39	Granodiorite porphyry, F. 7, Cetate Valley	64.55	0.56	14.70	2.26	1.84	0.06	2.01	5.04	4.00	3.00	0.12	0.97	—		0.07	—	0.73	0.46	100.36
32	369	Dacite, Iara Valley	64.41	0.38	18.03	1.11	1.94	—	1.50	5.37	3.45	2.74	0.14	—	—		—	—	0.73	0.10	99.90
33	1404A	Granodiorite porphyry, Măguri-Răcătău	64.10	0.50	16.40	1.88	1.75	0.03	2.00	2.55	2.55	3.01	0.10	1.34	—		0.04	—	3.02	2.00	100.28
34	8500	Granodiorite porphyry, Cheile Băișoarei Valley	63.96	0.51	15.37	1.25	1.96	0.10	2.00	5.06	2.37	2.65	0.17	1.41	—		0.07	0.06	2.57	—	99.51
35	8036	Granodiorite porphyry, Cetate Valley	63.80	0.46	16.90	2.46	1.73	0.09	1.86	3.35	4.04	2.74	0.15	0.94	—		0.04	—	1.16	—	99.72
36	84 H	Dacite, Iara Valley	63.79	0.62	15.94	0.83	2.77	0.21	1.63	4.19	2.60	2.60	0.20	1.62	—		0.11	0.10	2.40	—	99.61
37	8485	Granodiorite porphyry, Iara Valley	63.31	0.71	15.77	1.50	2.56	0.09	2.31	3.83	3.28	3.03	0.18	0.71	—		0.06	0.05	2.31	—	99.70
38	8241 G	Granodiorite porphyry, Iara Valley	63.17	0.70	15.99	1.79	2.62	0.11	2.95	5.07	3.07	2.55	0.12	—	—		0.38	0.33	1.17	—	100.02
39	7980	Quartz andesite, Carpeni Brook	63.16	0.50	14.60	1.85	0.86	0.06	1.20	4.69	3.80	3.60	0.14	2.61	—		0.05	—	1.49	2.03	100.64
40	1405	Granodiorite porphyry, Măguri-Răcătău	63.00	0.71	16.36	2.50	1.80	0.15	2.04	3.23	4.36	2.83	0.18	1.10	—		0.04	—	1.67	0.33	100.26
41	620	Dacite, Fetei Valley, Stolna	62.70	0.62	16.75	2.21	1.71	0.07	2.22	3.83	3.03	2.68	0.17	1.88	—		0.04	—	2.10	—	100.01

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42	8393	Dacite, Ierţii Valley	62.67	0.66	16.48	1.38	2.98	0.08	2.30	5.21	2.98	3.06	0.30	0.72	—		0.12	0.10	1.21	—	100.25
43	2035	Quartz microdiorite, Vadul Valley	62.61	0,72	16.64	1.93	2.60	0.11	2.53	5.74	3.00	2.62	0.14	0.31	—		—	—	0.78	—	99.73
44	52	Quartz andesite, Iara Valley	62.59	0.43	15.44	2.26	3.37	0.07	1.95	5.99	3.23	3.21	0.51	—	—		—	—	1.04	0.69	100.32
45	85 J	Quartz andesite, F. 94 Băişoara	62.30	0.56	17.78	0.73	2.92	0.03	2.26	5.60	3.98	1.90	0.27	—	—		0.29	0.25	0.69	—	99.56
46	8016	Quartz andesite, Stolna Valley	62.29	0.50	14.55	1.74	2.04	0.06	2.70	4.62	2.50	3.10	0.13	2.30	—		0.05	—	2.37	1.40	100.35
47	178	Quartz andesite, Ierţii Valley	62.09	0.52	16.65	1.60	1.93	0.09	3.33	7.02	3.86	2.39	0.16	0.22	—		—	—	0.38	0.38	100.62
48	1223	Quartzdiorite porphyry, Plopi Valley	61.93	0.72	15.98	1.95	2.60	0.10	2.40	3.75	2.88	3.25	0.17	0.79	—		0.04	0.03	3.09	—	99.68
49	7915	Quartz andesite, Someşul Rece Valley	61.63	0.50	14.40	0.01	2.16	—	1.96	4.76	3.80	3.50	0.15	3.10	—		0.03	—	1.88	0.59	100.53
50	4G	Pyroxene andesite, F. 8, Căpuşul Mic	61.47	0.50	16.30	1.94	1.55	0.12	1.98	5.44	3.58	2.25	0.17	2.13	—		0.10	0.09	1.99	—	99.61
51	2034B	Olivine-bearing andesite, Căpuşul Mic	61.21	0.63	15.72	1.88	3.01	0.11	3.76	6.07	4.00	1.23	0.16	—	—		0.11	0.10	1.60	—	99.59
52	7660	Pyroxene andesite, Cerhat Hill, Dumbrava	61.20	0.50	15.00	1.95	1.49	0.06	2.06	4.83	3.60	2.70	0.13	2.87	—		0.04	—	2.05	2.28	100.76
53	1320	Quartz monzodiorite, F. 31783, Băişoara	60.61	0.88	17.36	0.64	4.05	0.08	3.06	6.01	3.23	2.41	0.13	—	—		0.06	—	0.42	0.07	99.31
54	8199	Quartz monzodiorite, Vadul Valley	60.47	0.81	17.50	1.94	3.26	0.11	2.82	6.24	3.17	1.77	0.18	0.48	0.28		—	—	0.80	—	99.55
55	1407A	Quartz andesite, Cerhat, Hill, Dumbrava	59.60	0.50	16.89	2.61	1.66	0.14	2.52	3.40	3.55	2.12	0.20	2.00	—		0.02	—	0.88	0.33	99.97

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(continued)

No	Sample no	Rock type and sampling point	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	Cl	PC	S	Fe(S)	H_2O^+	H_2O^-	Total
56	1821	Quartz monzodiorite, Horiz.—80, Băişoara	59.46	0.45	17.25	3.96	1.74	traces	3.70	6.44	3.22	2.12	0.20	0.54	—		—	1.05	0.26	0.25	100.61
57	1406	Andesite, Gilău	58.90	0.70	18.27	2.90	1.84	0.14	2.12	4.90	3.50	2.20	0.15	1.20	—		traces	—	2.18	1.28	100.28
58	1842B	Porphyritic quartz micromonzodiorite, Răcătău V.	58.72	0.90	18.02	2.14	4.31	0.13	3.57	6.55	1.98	3.46	0.20	—	—		0.08	0.07	0.20	—	100.33
59	86 J	Quartz micromonzodiorite, F. 94, Băişoara	58.59	0.82	16.90	1.98	3.73	0.14	2.86	6.01	3.70	2.54	0.35	—	—		0.24	0.21	1.46	—	99.53
60	585	Andesite, Hîrtoape Brook, Căpuşul Mare	58.50	0.74	16.55	1.82	5.40	0.10	1.81	7.31	2.92	1.60	0.20	2.88	—		0.04	—	2.26	—	100.27
61	1757	Quartz monzodiorite, Horiz. — 120, Băişoara	58.25	0.77	17.28	0.54	5.63	traces	4.36	5.91	3.23	2.53	0.19	—	0.35		—	—	0.23	0.34	99.61
62	11G	Andesite, Gilău	58.02	0.68	17.13	1.81	4.00	0.10	3.78	6.83	1.68	3.55	0.27	1.38	—		0.07	0.06	0.48	—	99.84
63	1736	Quartz monzodiorite, Horiz. — 160, Băişoara	57.59	0.64	17.25	0.30	4.79	traces	4.51	7.50	3.70	1.97	0.12	—	0.26		0.65	—	0.97	0.47	100.00
64	7944	Quartz monzodiorite, Agîrbiciu Valley	57.55	0.55	15.10	2.08	2.95	0.08	4.55	7.01	3.60	1.50	0.14	2.66	—		0.07	—	0.65	0.70	100.19

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65	2029B	Pyroxene andesite, Căpuşul Mic	57.28	0.84	18.89	4.09	2.51	0.12	2.12	6.89	3.82	1.55	0.19	—	—		0.05	0.04	1.15	—	99.54
66	1755	Quartzdiorite porphyry, Horiz. — 50, Lita V.	57.16	0.93	16.76	1.88	3.60	0.09	5.67	4.48	3.23	2.28	0.24	0.37	—		0.10	0.09	2.89	—	100.13
67	1849B	Quartz monzodiorite, Răcătău Valley	56.64	0.90	17.93	1.69	4.25	0.13	4.13	6.45	1.58	3.61	0.24	—	—		0.44	0.38	1.30	—	99.67
68	1408A	Pyroxene andesite, Cetăţeaua Hill	56.60	0.70	19.20	4.83	1.82	0.13	3.40	6.40	3.70	1.30	0.15	0.20	—		0.03	—	0.90	0.41	99.77
69	244	Quartz monzodiorite, Miei Brook	56.52	0.70	20.44	1.75	3.19	traces	2.67	7.59	2.96	1.71	0.18	0.29	0.28		—	1.05	1.57	0.25	100.08
70	2041B	Andesite, Gilău	56.46	1.44	18.16	5.58	0.53	0.10	3.48	6.58	3.48	1.77	0.27	—	—		0.05	0.04	1.93	—	99.87
71	1407	Pyroxene andesite, Cetăţeaua Hill, Dumbrava	55.90	1.00	18.60	2.50	4.40	0.30	2.56	6.20	4.13	1.33	0.20	1.60	—		0.04	—	0.88	0.33	99.97
72	8042A	Pyroxene andesite, Cetăţeaua Hill, Dumbrava	55.68	0.71	17.49	2.32	4.09	0.08	4.05	7.57	3.60	1.50	0.20	1.42	—		0.04	—	0.56	0.80	100.11
73	7874	Pyroxene andesite, Căpuşul Mic	55.66	0.82	18.75	3.70	3.45	0.18	3.17	6.58	3.68	1.55	0.22	1.38	—		0.03	—	0.82	—	99.99
74	7680	Lamprophyre, Valea Mare, Căpuşul Mic	55.36	0.05	15.15	2.44	3.30	0.11	4.66	7.80	2.84	0.25	0.11	4.95	—		0.04	—	3.00	1.00	100.25
75	8402	Lamprophyre, Calul V.	55.06	1.01	15.05	3.23	3.10	0.12	6.05	4.73	3.38	3.40	0.31	1.40	—		traces	—	2.68	—	99.25

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(continued)

No	Sample no	Rock type and sampling point	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	Cl	PC	S	Fe(S)	H_2O^+	H_2O^-	Total
76	8500E	Porphyritic quartz micromonzodiorite, Cheile Băişoarei Valley	54.89	0.85	15.74	2.72	4.07	0.19	6.70	6.32	2.95	2.01	0.20	—	—		0.12	0.10	2.96	—	99.82
77	1743	Andesite, Horiz. — 120, Băişoara	54.79	0.81	20.87	0.77	5.55	traces	4.05	7.40	2.85	0.54	0.12	—	0.21		—	—	0.98	0.47	99.41
78	1404B	Porphyritic quartz micromonzodiorite, Măguri-Răcătău	53.00	1.02	18.41	3.45	2.80	0.14	2.95	4.52	4.10	2.83	0.18	2.85	—		—	—	3.00	—	100.25
79	7691	Lamprophyre, Valea Mare, Căpuşul Mic	52.79	0.58	14.47	3.30	2.75	0.09	5.23	7.57	3.00	1.00	0.10	5.56	—		0.04	—	2.10	1.52	100.10

Analysts: Simina Bunea — no. 40, 55, 57, 71, 78; Erna Călinescu — no 1, 3, 4, 9, 10, 14, 17, 18, 21, 22, 23, 24, 26, 34, 36, 37, 38, 42, 43, 45, 48, 50, 51, 54, 58, 59, 62, 65, 66, 67, 70, 75, 76; Elena Colios — no. 5, 8, 13, 15, 25, 35, 41, 60, 73, 74; Maria Cristea — no. 12, 20, 32, 53, 61, 63, 69, 77; Maria Dumitrescu no. 27, 29, 30, 44, 47; Aurelia Movileanu — no. 2, 11, 16, 19, 28, 31, 39, 46, 49, 52, 64, 72,79; Georgeta Nedeleu no. 7, 56; Giovana Zăvoianu — no. 6, 33, 38; Analyses no. 12, 20, 32, 53, 61, 63, 69, 77, 7, 56 after published data (Lazăr et al., 1972).

F = borehole

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of all rock varieties, we consider these analyses representative for all petrotypes of banatitic rocks occurring in the study area. Analyses with high contents of CO_2 and H_2O had to be introduced in the table especially for the andesite samples, dacite and rhyolite sills and dykes, usually showing automorphous transformations.

Based on the primary data the Peacock diagram (Fig. 1) has been drawn up, which obviously shows an alkali-calcic index of 61, situated at the limit admitted for the calc-alkali magmas but exceeding the variation interval (56.75-59.33) established for the banatitic rocks in Romania (Giuşcă et al., 1966).

Aiming at the process of magmatic differentiation some diagrams have been drawn up on the basis of the Niggli parameters. The differentiation diagram (Fig. 2) points out the evolutive and continuous character of the value change for the main parameters as against the increase of the silica content. The concentration of the representative points in the domain of the *si* = 170-275 values, wherein the isophale points *(al=fm, alk=c, alk=fm)* are also situated, proves the quartz-diorite character of the magma generating the banatitic rocks. The *fm : al* diagram (Fig. 3a) indicates also a high differentiation degree as well as the consanguinity of most of the analysed rocks. The disposition of the representative points on the *alk : al* diagram (Fig. 3a) shows a positive correlation, the rocks being located in the field corresponding to the subunitary values of the *alk : al* ratio and concentrated especially in the intermediary domain and poor in alkali ; alkali rhyolites and aplites are plotted particularly in the alkali field. *QLM* diagram (fig. 4) points out the disposition of points in the saturated rock field.

For the systematics of the banatitic rocks the CIPW parameters have been calculated on the basis of which the *QAP*-normative diagram was drawn up (Streckeisen, 1967, 1979). This diagram (Fig. 5a) shows the granodioritic-quartz-monzodioritic character for 80% of the analysed rocks, the disposition of the petrotypes within the limits of the characteristic fields being obvious. Some andesites and rhyolites which underwent a higher alteration degree are exceptions to this rule. The position of such rocks is close to the corresponding fields provided that the contents in CO_2 (Fig. 5a — insets) for rocks without any late supply of solutions are not taken into account. The data provided by the planimetric measurements of granular rocks has been plotted on the *QAP*-modal diagram (Fig. 5b) and the comparison of the two diagrams points out a good correspondance and an artificial increase of the "A" values for rocks rich in biotite.

The contents in trace elements have been spectrographically determined for most of the rocks chemically analysed (Tab. 2). The study of the analytical data points to values comparable with those known in similar petrotypes of the banatitic province in the Apuseni Mountains (Ştefan, 1980). Nevertheless several particularities of the analysed rocks are observed : higher contents of Ni in the quartz-diorites and of V in the granodiorite porphyries ; Sr higher values in the rhyolites of Vadul Valley and in the andesites of Lita Valley ; higher content of Ba in the rhyolites of Vadul Valley and in the dacites and granodiorite

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TABLE 2

Trace elements in the banatitic rocks (ppm)

Nr.	Sample number	Pb	Cu	Zn	Sn	Ga	Ni	Co	Cr	V	Sc	Y	Yb	La	Zr	Sr	Ba	Li
1	8409	21	5		<2	10	<2	<2		14	<2	23	2.9		70	20	620	
2	7655 B	28	5		<2	13	<2	<2	<1	<4	2	21	2.9	<30		12	820	
3	8705	12	4	<30	4	11	<2	<2		5.5	<2	12	<1	<30	56	90	760	
4	989 H	19	5	<30	3	11	<2	<2		<4	<2	10	1	<30	46	48	930	
5	573	30	4.5		<2	17	<2	2	3.5	4	5	17	1	50		<10	1250	26
6	1408 B	36	8		<2	13	<2	<2	2	4	3	20	4.2	37		22	950	20
7	606	70	4.5		3	17	<2	4.5	3	<4	3.5	<10	<1	<30		63	630	36
8	8198	8.5	10	<30	10	16	<2	<2		22	4	10	1.4	46	140	378	1300	
9	2034	68	28		6.5	16	<2	<2		26	<2	10	1		120	440	2100	
10	7910	47	4		3.5	13	3.5	3	5	15	3	18	3.4	30		40	680	30
11	7720	22	11		<2	17	3	4	5.5	19	5.5	21	3.2	35		120	550	8
12	1367	12	6	<30	4.5	13	5.5	5.5	17	50	7.5	17	1.7	37	170	320	800	
13	7796	30	20		2.5	18	6	7	9	67	9	21	2.4	<30		180	600	18
14	7706 C	17	8		3.5	16	4.5	6	5	35	5	22	3.6	30		200	600	22
15	2163	5.5	3	36	4	15	6	<2	16	60	8.5	17	1.2	37	100	400	725	
16	87/F-93	20	5	51	<2	18	6.5	7	12	60	9.5	22	2.5	40	120	340	565	
17	7776 C	24	8		3.5	17	12	17	9	52	8.5	24	2.6	30		280	560	26
18	11/F-93	23	8	97	<2	18	6	7	14	60	9	17	1.9	35	140	340	680	
19	2156	16	7	165	2	16	8.5	6	22	72	12	20	1.7	57	180	250	530	
20	1402	8	6	38	2	11	15	5	22	67	10	17	1.5	44	130	270	560	
21	1589	10	26		<2	23	3		13	69	13	19	1.8		145	240	500	
22	7776	18	21		<2	16	11	12	10	82	11	26	2.3	35		310	720	26
23	87 J	3	16	60	4	17	9	6	25	75	9	15	1.5	44	135	390	650	
24	22	31	13	78	3	24	6	9	14	80	9	20	2.2	48	195	470	760	
25	40	29	8		3	15	4.5	11	7.5	68	8.5	21	2.9	30		340	600	22
26	126	18	3.5	55	2	21	4.5	9.5	10	80	8.5	19	2	48	175	530	1050	
27	45	16	14	65	3	23	5	8	15	84	9.5	19	2.3	48	180	360	900	
28	39	25	9		3	18	6	9.5	8	75	8.5	23	2.6	<30		440	620	26
29	1404 A	27	14		3.5	16	2.5	10	12	60	8.5	20	2.5	<30		270	400	
30	8500	4.5	<3	<30	4	10	4	<2	14	30	6	11	1	37	80	500	1000	
31	8036	30	15		<2	18	6	9	8	100	5.5	18	2	32		400	750	20
32	84 H		5	450	3	15	5	6		45	8	15	1	30	125	540	1100	
33	8485	12	5	60	2.5	17	12	9	26	100	15	22	1.5	57	180	575	900	
34	8241 G	9	20	55		16	27	13	58	85	13	19	1.9	32	167	280	500	

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35	7980		9.5	15			<2	10	5.5	8.5	13	60	6.5	18	2.5	<30		330	800	15
36	1405		25	12			4	17	7.5	9.5	15	60	7.5	19	2.8	30		250	380	53
37	620		19	15			<2	16	7	10	8	125	11	17	1.8	46		450	550	
38	8393		12	6.5	43			17	8	7	24	92	16	21	2	46	195	290	650	
39	2035		29	6.5	78			17	7	8.5	17	100	14	20	2	42	160	370	750	
40	52		57	6	85		2.5	25	6.5	10	4	130	13	19	2.3	57	90	440	800	
41	85 J		2	30	<30		2	18	9.5	5	12	118	16	30	3	57	185	360	440	
42	8016		38	12			<2	15	7	8	11	55	8	21	2.8	34		280	750	45
43	178		15	6	80		45	23	23	6.5	140	125	14	16	2.6	40	155	400	700	
44	1223		12	7	47		2	17	8	7	17	100	14	23	2	44	105	330	700	
45	7915		27	10			3.5	15	7	9.5	9	75	10	18	2.7	30		330	530	90
46	4 G		4	12	55		3.5	15	8	9.5	21	67	11	18	1.7	30	170	560	750	
47	2034	B	9	60			<2	14	42	17	120	73	12	15	2.4		145	345	500	
48	7660		33	14			3	16	6.5	8	4	55	6	18	2.6	40		460	720	30
49	8199		18	7	91			18	9.5	8.5	20	133	15	22	2	42	150	380	560	
50	1406		19	20			<2	16	9.5	16	19	110	13	21	2.9	30		300	450	32
51	1842	B	19	16	85		2	21	9	17	16	135	18	25	2	<30	150	420	630	
52	86 J		7	100	46		8	17	13	12	17	120	9	19	1.5	52	140	390	650	
53	585		25	27			2	17	10	16	22	145	17	28	2	42		240	410	18
54	11 G		13	14	90		3.5	18	13	14	33	100	18	21	1.6	39	170	630	600	
55	7944		9	26			3	14	56	21	85	110	15	23	2.5	<30		360	440	36
56	2029	B	9	12			<2	17	6.5	30	8	95	16	17	2.4		160	470	550	
57	1755		16	20	44		2	11	64	14	220	130	20	16	1.3	<30	105	900	410	
58	1849	B	10	45	90		4	21	10	16	10	150	19	23	1.8	<30	145	390	425	
59	2041	B	5.5	75			4	13	12	16	42	53	11	10	1		90	500	440	
60	8042	A	15	14			<2	16	8	20	4	120	15	21	2.2	<30		480	480	5
61	7874		18	13			<2	21	6.5	17	11	170	17	27	2.2	42		410	410	12
62	7680		12	45			<2	14	46	23	170	155	21	20	1.5	<30		320	220	66
63	8500	E	11	3	165		4.5	10	30	12	160	100	15	13	1	30	60	440	550	
64	8402		8.5	10	<30		10	16	<2	<2		21	4	10	1.4	46	170	378	1300	
65	1404	B	32	12			2.5	18	9	14	15	95	12	25	2.8	30		300	380	56
66	7691		35	35			<2	16	38	26	160	115	18	15	2.5	<30		250	310	40

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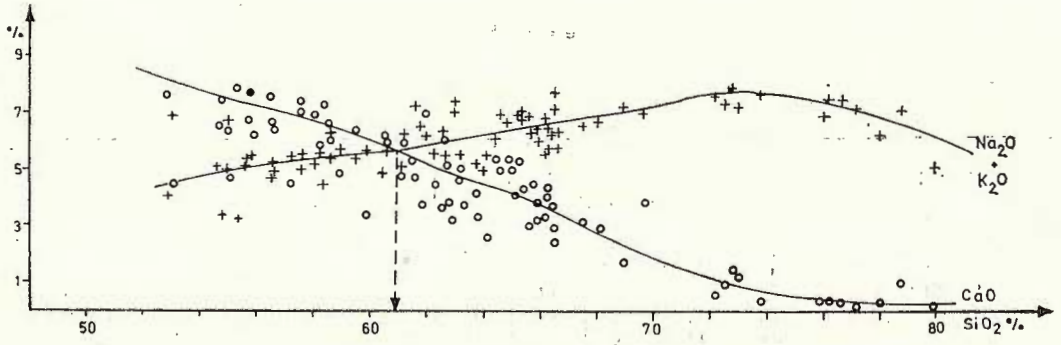


Fig. 1. — Peacock diagram.

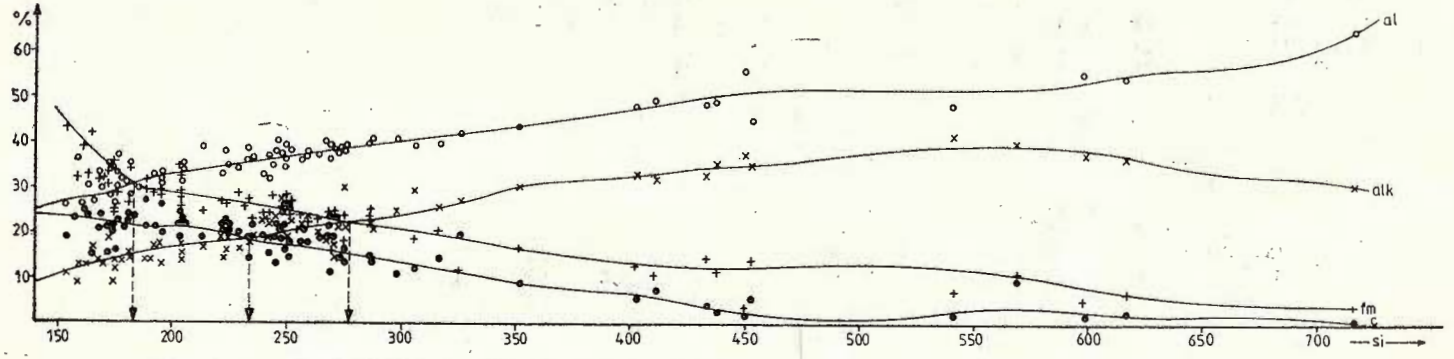


Fig. 2. — Differentiation diagram of the banatites in the eastern part of the Gilău Mountains.

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porphyries in the Lita Valley ore deposit and in the surrounding area. The Ba high values in the lamprophyre of Calul Valley may be associated to the feldspar xenocrysts. The contents in Sr and Ba in the

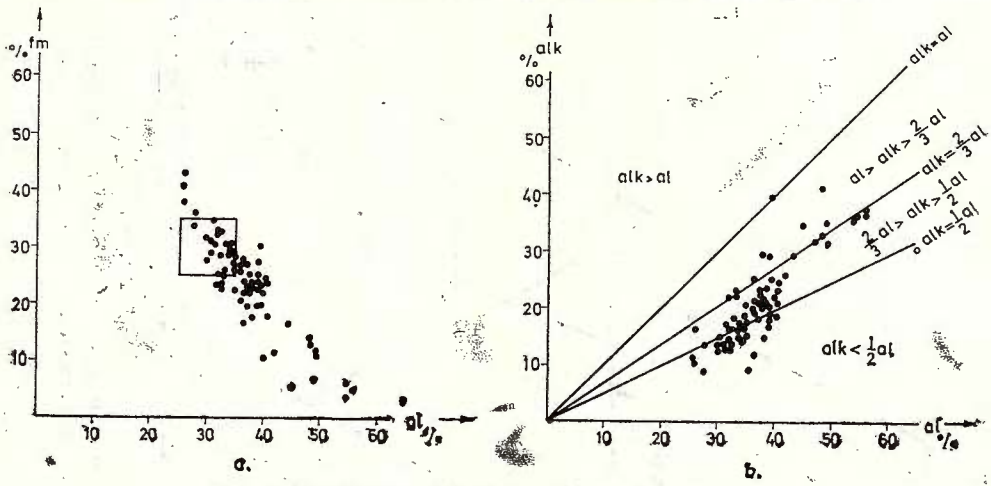


Fig. 3. — *fm : al* (a) and *alk : al* (b) diagram.

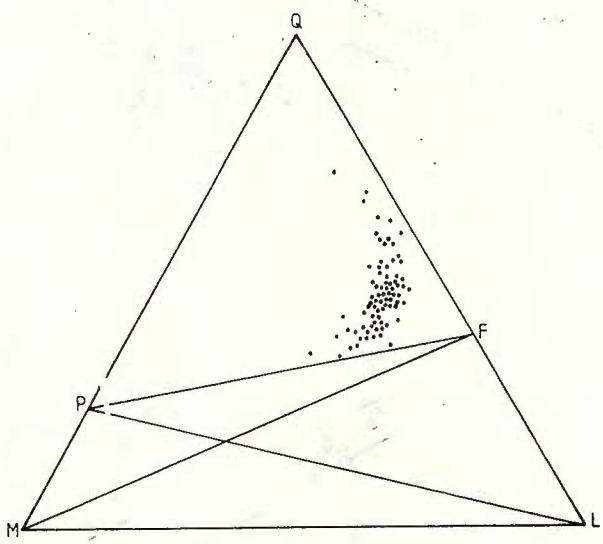


Fig. 4. — *QLM diagram.*

olivine-bearing pyroxene andesites of Cionca Hill point to the xenolithic character of the twinned and zoned plagioclases, and the Ba high values of some pyroxene andesites are due to the late circulation of the solutions associated with bentonite and adularia neoformations.

The variation of the trace element contents as compared to that of the main elements, to which they are geochemically linked, is presented on the differentiation diagrams as against Nockolds--Allen

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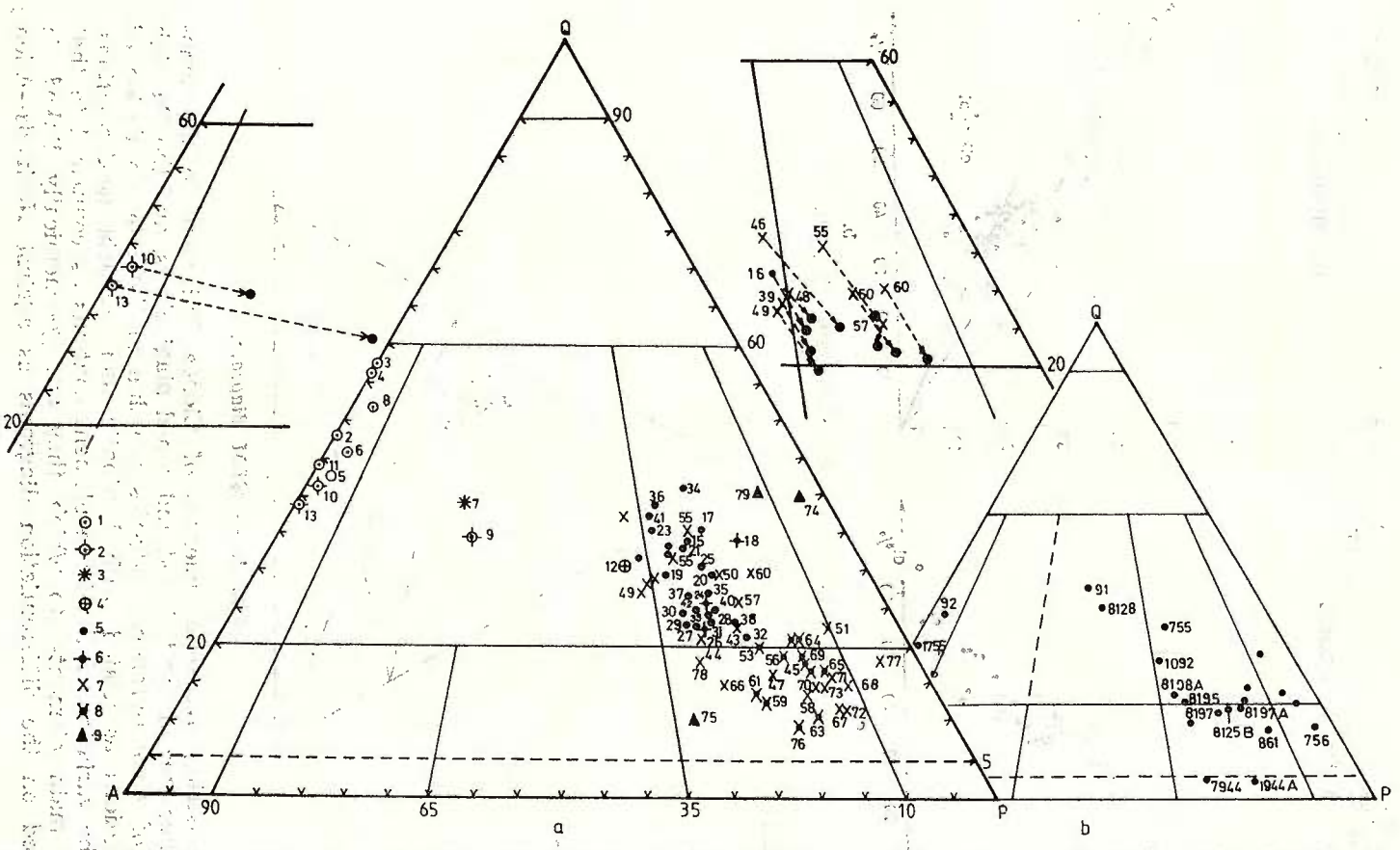


Fig. 5. — *QAP* normative (a) and modal (b) diagram of the banatites in the eastern part of the Gilău Mountains. 1, alkali rhyolites ; 2, rhyolites ; 3, aplites ; 4, granites ; 5, granodiorite porphyries-dacites ; 6, granodiorites ; 7, andesites, quartz-diorite porphyries ; 8, quartz diorites, quartz monzodiorites ; 9, lamprophyres.

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index (1953). Thus, Ni, Co, Sc, Cr (Fig. 6) display a poor correlation with Mg, Fe and Ti ; it is only in case of V that the positive correlation is more obvious. On the diagram of Figure 7, the variation of the Sr and Ba contents, parallel to that of the Ca and K contents, indicates a good correlation which, like in case of V, is partly concealled by

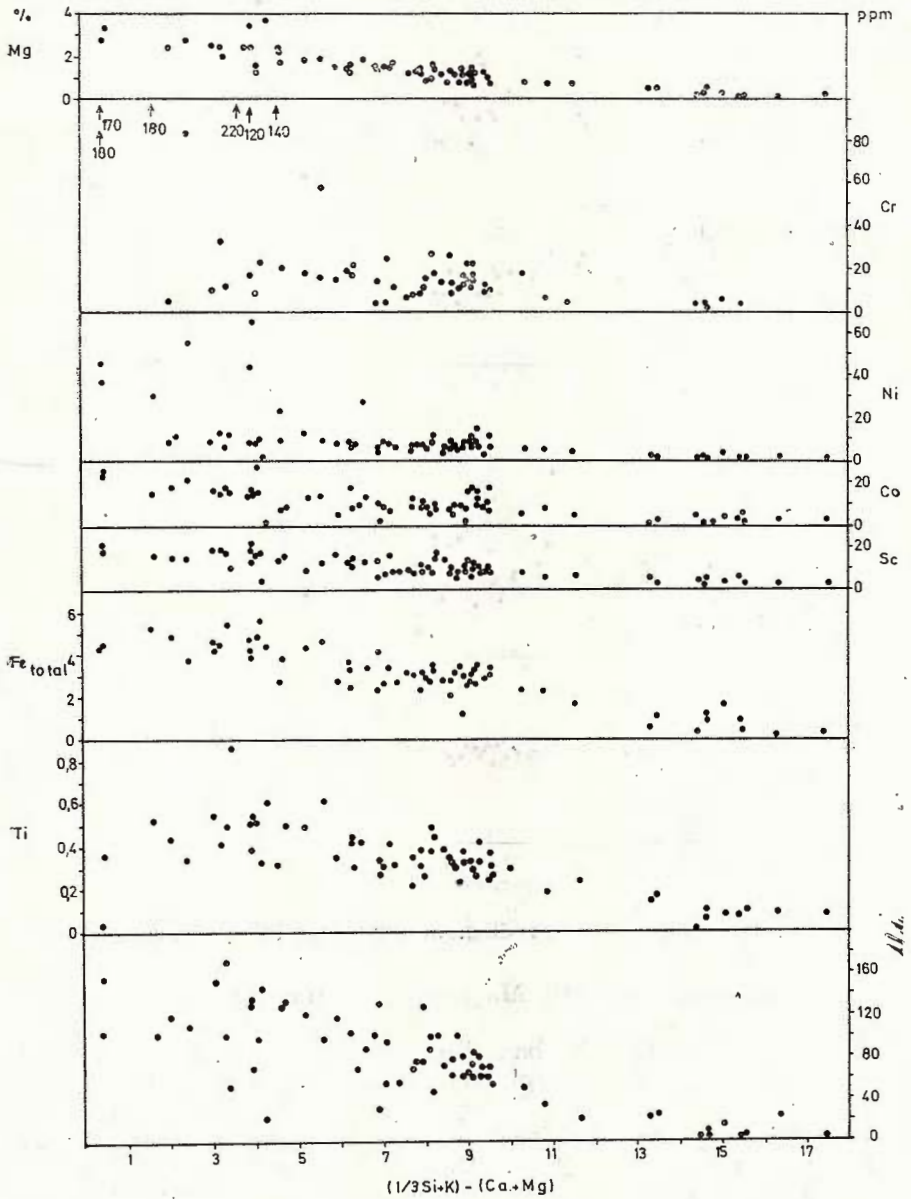


Fig. 6. — Variation of the contents in Mg, Fe, Ti and Cr, Ni, Co, Sc, V as against Nockolds-Allen index.

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the dispersion of the trace element contents. The Cr : Ni and Ni : Co diagrams (Fig. 8a and 8b) point out a weak positive correlation between these pairs of elements whereas the V : Sc diagram (Fig. 8c) shows a positive correlation of the two elements for all rocks taken into account, except the alkali rhyolites characterized by low contents.

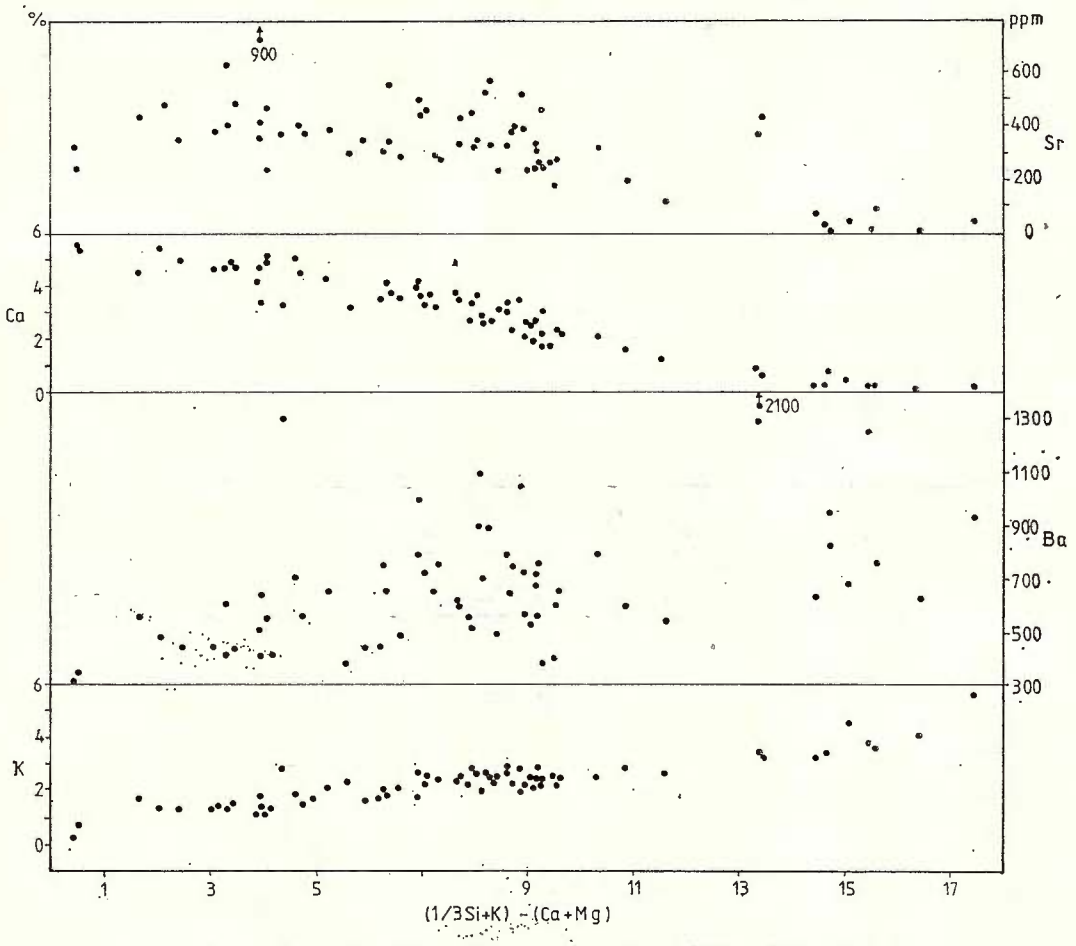


Fig. 7. — Nockolds-Allen diagram for some lithophilic elements.

Evolution of Banatitic Magmatism in the Gilău Mountains

In the Gilău Mts the banatitic magmatism started probably with flows of pyroxene and amphibole andesitic lavas of Căpuşul Mare which are not accompanied by pyroclastics as mentioned by Mureşan (1971, 1980). In contrast with Mureşan, our results are contradictory with the existence of rhyolitic tuffites and tuffs interbedded in the Senonian formations. Thus, in the Fetei Valley quarry only the dacites-granodiorite porphyries (quartz andesites — Mureşan, 1980), with

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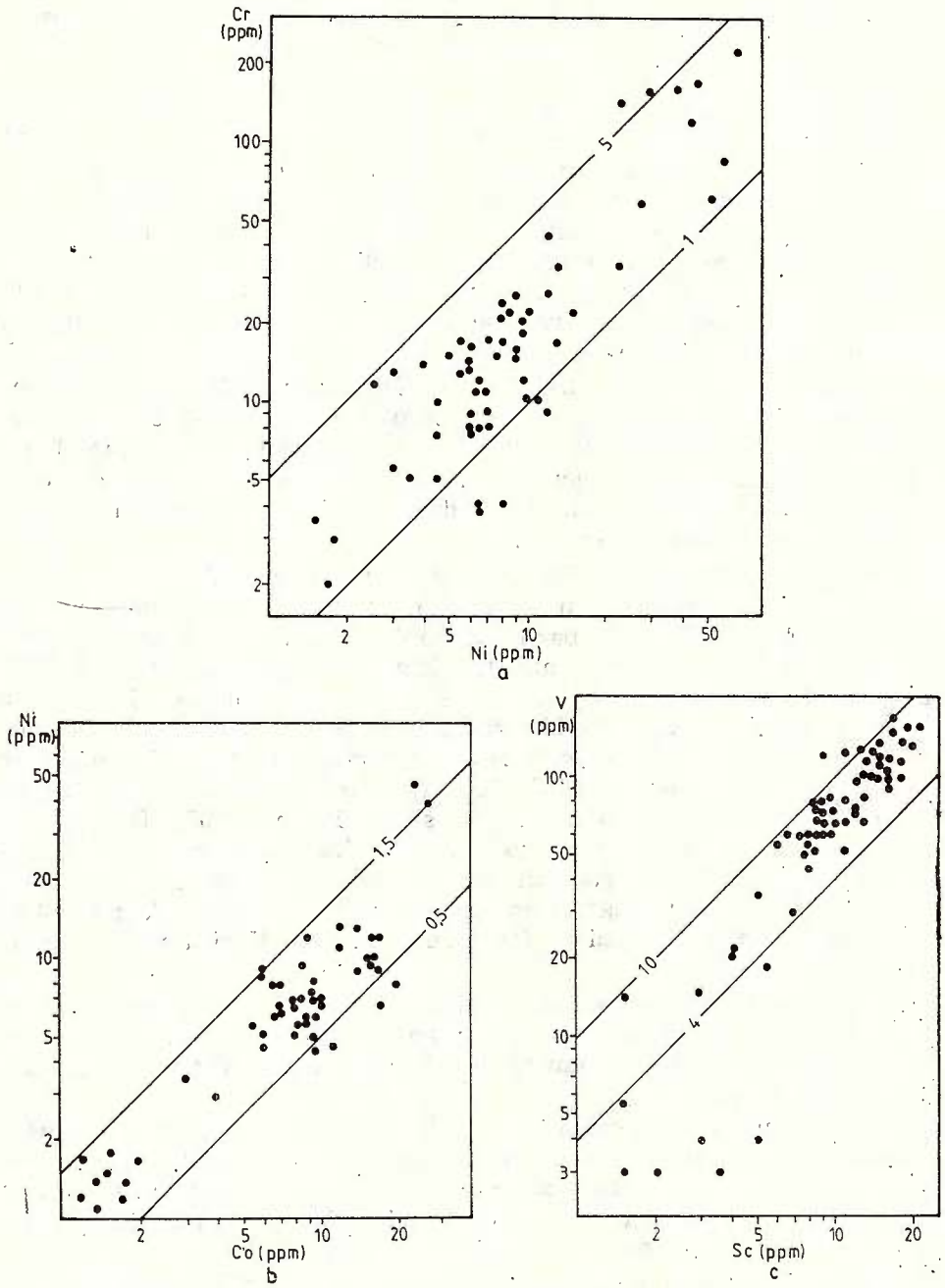


Fig. 8. — Cr-Ni (a), Ni-Co (b) and V-Sc (c) correlation diagrams.

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numerous enclaves of porphyritic microdiorites, are exposed. In the Sărăţii Valley, 50 m upstream of the dacite intrusive body, in the zone where Mureşan reported tuffites intercalated in Senonian deposits, whitish quartz-feldspathic micaceous sandstones intensely hydrothermalized crop out.

After the pyroxene+amphibole andesites, amphibole andesites were probably emplaced, penetrated, in the Vadul Valley, by quartz andesites — quartz-diorite porphyries with which the second banatitic magmatic cycle began. For the time being we consider that the hornblende+biotite quartz andesites with certain dacitic particularities (the presence of porphyritic microdiorite xenoliths) follow the amphibole andesites of the first cycle. It is not out of question that the felsitic rhyodacite-rhyolites should represent the final term of the banatitic magmatism of the first cycle.

In the second cycle, the quartz andesites-quartzdiorite porphyries are followed by dacites-granodiorite porphyries-granodiorites ; they do not occur in association with pyroclastics as stated by Mureşan (1971, 1980) ; it is either a contact breccia (Gilău borehole) or false pyroclastic aspects as a result of the hydrothermal and particularly supergene alteration (Sărăţii Valley).

Granites, aplites, rhyolites and alkali rhyolites end the main cycle of the banatitic magmatism in the Gilău Mts. Penecontemporaneous to the alkali rhyolites and partly probably after their consolidation the pyroxene andesites±olivine and the lamprophyres are emplaced. The pyroclastics and rhyolitic tuffites mentioned by Mureşan (1980) have not been found at Căpuşul Mic and in the Sărăţii Valley and we consider that in the first case it is about some breccias (of contact or explosion) and in the zone of the locality of Stolna what was considered as pyroclastics represents a lateritic soil (Tătărîm, 1963). It is worth mentioning that the very diverse petrographic origin, the limited extension, as well as the position of the explosive products in the succession of the Gilău magmatism, presented by Mureşan, do not allow the correlation with similar formations in the Vlădeasa and Bihor massifs.

Our data on the banatitic rocks of the Gilău Mts corroborated with those available for the Bihor and Vlădeasa massifs lead to a unitary image on the evolution of the Laramian magmatism in the Apuseni Mountains.

The banatitic magmatism of cycle I, widespread in the Vlădeasa massif, where it has a volcanic character, has an incomplete evolution and occurs only under subvolcanic conditions in the Bihor massif. Along the northeastern border of the Gilău Mts the Laramian magmatism starts with flows of pyroxene and amphibole andesites.

Dacites, which followed the andesites, are widespread in the Vlădeasa Mts and occur sporadically in the Bihor Mts ; they are probably lacking in the Gilău Mts.

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Finally, the rhyolites, which end the banatitic magmatism of the first cycle, have a wide development and diversity in the Vlădeasa massif and are represented by rhyodacites and rhyolites in the Bihor massif. It is possible that the Gilău rhyolites-rhyodacites might belong to the same cycle (I).

The second, main cycle, displaying no volcanics activities, starts, in all the three areas, with quartz andesites-quartzdiorite porphyries or quartz diorites or quartz monzodiorites. There follow dacite-granodiorite porphyries or granodiorites. The cycle ends with granites and their alkali differentiates (microgranites, aplites, alkali rhyolites).

After the consolidation of the granodioritic magma (with a poor quartzdioritic character in the Gilău massif) from the reservoir which generated the wide range of banatites, along the deep fractures from another source, andesites, basalts and lamprophyres (in the Bihor Mts), lamprophyres (in the Vlădeasa Mts) and pyroxene andesites ± olivine as well as lamprophyres (in the Gilău Mts) were emplaced.

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EXPLANATION OF PLATES

Plate II

Fig. 1. — Porphyritic microdiorite, Răcătău Valley. N || ; × 10.

Fig. 2. — Quartz monzodiorite. Borehole 94 Băişoara. N + ; × 10.

Fig. 3. — Twinned plagioclases in quartz monzodiorite, Agîrbiciu Valley. N + ; × 10.

Fig. 4. — Quartz micromonzodiorite, Vadu Valley. N + ; × 10.

Plate III

Fig. 1. — Quartzdiorite porphyry, Ierţii Valley. N + ; × 10.

Fig. 2. — Quartzdiorite porphyry — quartz andesite, Gilău — dam. N + ; × 10.

Fig. 3. — Granodiorite porphyry-dacite, Ierţii Valley. N. +, × 10.

Fig. 4. — Granodiorite porphyry, Ierţii Valley. N + ; × 10.

Plate IV

Fig. 1. — Granite porphyry, Ierţii Valley. N + ; × 10.

Fig. 2. — Dacite, Ierţii Valley. N + ; × 10.

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Fig. 3. — Bavene twin in alkali rhyolite, Cetățeaua Hill. N +; × 10.
Fig. 4. — Plagioclase feldspar phenocrysts from pyroxene andesite with benthonitized groundmass. Borehole 8 Căpușu Mic. N +; × 10.

Plate V

Fig. 1. — Marginal facies in pyroxene andesite body, Cetate Hill. N +; × 10.
Fig. 2. — Olivine in pyroxene andesite, Căpușu Mic. N +; × 10.
Fig. 3. — Lamprophyre, Calul Valley. N +; × 10.
Fig. 4. — Corroded quartz in lamprophyre. N +; × 10.

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GEOLOGICAL MAP OF THE EASTERN PART OF THE GILĂU MOUNTAINS

0 1500 3000m

LEGEND

QUATERNARY — Alluvia and proluvial deposits

PALEOGENE — Marls, limestones, calcareous sandstones, shales, sands, pebbles, conglomerates, epiclastics

LARAMIAN MAGMATITES (BANATITES):

- Lamprophyres
- Pyroxene andesites ± olivine; Rhyolites, alkali rhyolites, granitic porphyries
- Dacites - granodiorite porphyries (a); granodiorites (b)
- MAASTRICHTIAN-PALEOCENE — Quartz andesites - quartz diorite porphyries (a); quartz diorites - quartz monzodiorites (b)
- Amphibole- and biotite-bearing quartz andesites
- Amphibole andesites
- Pyroxene- and amphibole-bearing andesites

UPPER CRETACEOUS — Shales, marls, limestones, sandstones, conglomerates

PERMIAN — Siltites, sandstones, microconglomerates; conglomerates

LOWER PALEOZOIC-UPPER PRECAMBRIAN — Crystalline formations, migmatites, granitoid rocks, pegmatites

Hornfelses

CONVENTIONAL SIGNS

- Normal lithological limit
- Geological limit
- Unconformity limit
- Upthrow fault
- Fault
- Bed position; foliation
- Quarry

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CONTRIBUTIONS TO THE KNOWLEDGE OF THE METAMORPHIC HISTORY OF THE ARGESTRU SERIES ROCKS IN THE PUCIOSUL BROOK (EAST CARPATHIANS) [1]

BY

ION BALINTONI [2]

Metamorphic facies. Greenschist facies. Almandine amphibolites. Gneiss. Paragenesis. Mineral association. Neoformation minerals. Lambeaux de rabotage. Mylonitization. Sub-Bucovinian Nappe. East Carpathians-Crystalline-Mesozoic Zone. Bistrița Mountains.

Sommaire

Contributions à la connaissance de l'histoire métamorphe des roches attribuées à la série d'Argestru sur le ruisseau Puciosul (Carpathes Orientales). La série d'Argestru a été décrite comme une séquence de roches d'âge paléozoïque moyen faiblement métamorphisée au cours de l'orogenèse hercynienne. Une nouvelle analyse détaillée des associations de minerai contenus par ses roches a mis en évidence la coexistence de deux paragenèses : l'une s'inscrivant dans le faciès des amphibolites à almandin, à caractère relique (oligoclase, almandin, biotite, hornblende) et l'autre de néoformation, spécifique à la zone du chlorite du faciès des schistes verts (chlorite, actinote, albite, épidote, séricite). Sur base de la paragenèse relique, les roches de la série d'Argestru ont été parallélisées à celles de la série de Bretila, en constituant son soubassement ; on peut conclure donc qu'elles représentent une séquence de la partie supérieure de la série de Bretila, rabotée et milonitisée dans la base de la nappe subbucovinienne. Les transformations regressives de la paragenèse plus ancienne ont commencé au cours de l'orogenèse hercynienne et ont continué pendant la mise en place des nappes de charriage alpin.

I. Introduction

In 1970, Bercia and Bercia individualized a lithostratigraphic unit — "the phyllonitized detrital complex" — in the region lying between Vatra Dornei and Iacobeni. This phyllonitized detrital complex occurs

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București.

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both in a normal position (under the Mesozoic of the Bretila-Iacobeni autochthonous unit) and in an allochthonous position (between the Mesozoic of the Bretila-Iacobeni Unit and the Bistriţa Nappe). For the latter the denomination "Argestru Unit" was used. Bercia et al. (1971), used the denomination "Argestru Series" for the phyllonitized detrital series and the "Argestru planing slice" for the Argestru Unit ; concomitantly, the content of the Argestru Series was much enlarged, including also the conglomerates reported by Savul (1972) from the surroundings of Şaru Dornei as well as the apparently poorly metamorphosed rocks outcropping in the Bărnărel Brook basin. A typical profile of the Argestru Series is considered that exposed in the escarpment on the right side of the national highway Cîmpulung Moldovenesc-Vatra Dornei, upstream of the confluence of the Puciosul Brook with the Bistriţa River, towards the Mestecăniş Pass. In the synthesis paper published in 1976 Bercia et al. maintained their opinion on the lithostratigraphic content of the Argestru Series and on the properties of the tectonic unit with the same name.

According to Bercia, Bercia (1970), Bercia et al. (1974), and Bercia et al. (1976) several stages can be distinguished within the geological evolution of the Argestru Series : 1. low-grade metamorphism under the conditions of the greenschists facies or even anchimetamorphism in the Hercynian orogenesis ; 2. intense dynamic metamorphism (phyllonitization) in connection with the Alpine overthrusts ; 3. postphyllonitization recrystallization (postkynematic) with formation of biotite and, in places, of hornblende ; 4. appearance of a fracture cleavage intersecting the foliation generated during the phyllonitization and, in places, of biotite grown after the phyllonitization. The enrichment of the knowledge of the Crystalline-Mesozoic Zone of the East Carpathians after 1976 modified the previous concepts, the problems related to the Argestru Series inclusively. In the area between Vatra Dornei and Iacobeni, the Argestru Series lies between the Iacobeni Nappe and the Sub-bucovinian Nappe (Săndulescu et al., 1981). The upper part of the Iacobeni Nappe comprises the Bretila Series (Balintoni, 1981), not the Rebra Series as previously considered (e.g. Bercia et al., 1976). Since 1977, Balintoni and Gheuca have found out that the rocks occurring in the Bărnărel Brook, which seem to be weakly metamorphosed, represent the upper part of the Rebra Series — intensely mylonitized and retromorphosed during the Hercynian orogenesis — which enter into the constitution of the basement of the Bucovinian Nappe (Rodna pre-Alpine nappe from the basement of the Bucovinian Nappe according to Balintoni, in Săndulescu et al., 1981). Therefore, the rocks from the Bărnărel Basin assigned to the Argestru Series have an upper structural position as compared to the Argestru Series at Iacobeni ; they are linked to the Rebra Series, not to the Bretila Series, and do not belong to a Middle Paleozoic lithostratigraphic sequence with an initial Hercynian metamorphism. As regards the conglomerates reported by Savul (1927) in the vicinity of Şarul Dornei, Balintoni et al. (1982) pointed out that they are situated between the Şaru Dornei and Iacobeni Alpine nappes, therefore they have a lower structural position as against the Argestru Series at Iacobeni and display all the

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features of a Permian formation weakly metamorphosed dynamically. On the other hand, nearby Şaru Dornei there is an association of highly mylonitized mesozonal rocks, planed in the base of the Sub-bucovinian Nappe. Balintoni et al. (1982) described these rocks under the name of "Chirileni overthrust slice" as they are considered to be pulled out from the upper part of the Bretila Series — the uppermost lithostratigraphic unit of the Iacobeni Nappe. Consequently, south of Vatra Dornei there is a tectonic equivalent of the Argestru planing slice ; however, it is not a lithostratigraphic correspondent of the Argestru Series as considered by Bercia et al. (1976). Finally, along the right side of the Bistriţa, from Vatra Dornei up to Ciocăneşti, between the Sub-bucovinian and Iacobeni nappes, Balintoni (1981) reported only *in situ* rocks, in different stages of mylonitization, belonging both to the Bretila Series and to the Negrişoara Series (here the base of the Sub-bucovinian Nappe). In the autumn of 1981, the profile in the Puciosul Brook, regarded as a lithostratotype of the Argestru Series, was investigated. The results will be presented further on.

II. Outcrops

The Argestru Series is visible in the right side of the Puciosul Brook, in the escarpment of the national highway Cîmpulung Moldovenesc-Vatra Dornei. The outcrops begin at the confluence of the Puciosul Brook with its right-hand tributary — Tolovanul — and continue upstream on about 80 m. The contact of the Argestru Series with the base of the Sub-bucovinian Nappe, represented here by rocks of the Tulgheş Series, is low-dipping and occurs at some metres above the highway. Quartz-feldspathic and chlorite-amphibolic rocks, and subordinately quartzites, crop out. The rocks have a brick-red or greenish-satinated, sometimes blackish colour. They are fine-grained and easily crumbled. The satinated lustre of the amphibolic rocks is partly due to the frequent slickenslides, no matter how much a sample is fragmented. At the lower part of the Argestru Series the relationships are not visible because the right side of the Puciosul Brook, under the road, is covered with grass.

III. Macroscopic Structures

A minute study of the lithologic entities pointed out by the colour contrast and of foliations indicates that the rocks of the Argestru Series in the Puciosul Brook are strongly folded ; folds with metric amplitude are grafted on folds with higher amplitudes, whose sizes cannot be estimated because their flanks stop in the thrust plane of the Sub-bucovinian Nappe. These folds are recumbent, their axial planes being parallel to the thrust plane of the Sub-bucovinian Nappe and their hinges are very sharp. The profile along the road is perpendicular to the hinges of the folds. The impression of low-dipping stratification (e.g. Bercia et al., 1971) is given by the plane-axial foliation of the folds, after which a partial transposition of the pre-existent banding is achieved. All this points out that two sets of penetrative S

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planes may be distinguished on the outcrop scale : an older set (S_1), given by the lithologic contrast and involved in folding, and a younger set (S_2), parallel to the axial planes of the recumbent folds. It is not certain whether the S_1 foliation is or is not parallel to the primary rocks stratification which provided the Argestru Series metamorphics. The hinges of the recumbent folds have a NW-SE trend, corresponding to the strike of the major Alpine structural elements of the Crystalline-Mesozoic line of the East Carpathians. The above-mentioned characteristics of the folds as well as certain microscopic evidence, which will be presented further on, make us consider that they and the S_2 plane-axial foliation are related to the emplacement of the Meso-Cretaceous thrust nappes.

IV. Mineral Associations and Parageneses

The study of the thin sections indicated the coexistence of two distinct, successive parageneses, within the same mineral associations, belonging to two completely different thermodynamic conditions : a relict paragenesis, specific to the almandine-amphibolite facies, constituted mainly of oligoclase, biotite, muscovite, almandine, titaniferous brown hornblende, and a neoformation paragenesis, typical of the chlorite, neoformation muscovite, actinolite, albite, clinozoisite or epidote, sphene. The mineral associations and parageneses visible in the rocks, which underwent an incomplete mineralogical alteration during the formation of the S_2 foliation, are presented below :

In gneisses :

(1) Q + Pl + Bi + M + Alm + Cl + Ep + Ser + Ti/T + Zr + Ap + Op + + Ort + Hem + Cal[3]

(2) Q + Pl + Bi + M + Cl / Ep + R + T + Zr + Ap + Op + Hem

In quartzites :

(3) Q + (Pl) + Bi + M + Cl/R + Ilm + Gf + T + Zr + Ap + Op + + Hem + Cal

In amphibolites :

(4) Brown Ho + Ho act + Act + Ab + Clz + Bi + Cl/Ti + Cal

(5) Brown Ho + Ho act + Act + Ab + Clz + Bi + Cl + M + Q/Ti + + Hem + Cal + T + Ap

The oblique line separates the main minerals from the accessory ones ; the underlined minerals belong to the second paragenesis. The mineral in brackets may not occur in association. The minerals of the relict parageneses are maintained only in certain parts of the rocks with

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a reduced extension, hardly observable. More often the alterations are complete, the neoformation parageneses replacing entirely the pre-existent parageneses.

V. Direction of the Mineralogical Alterations

In all cases the structural relationships show that the altered minerals belong to the almandine amphibolite facies, on their account being formed the minerals established in the chlorite zone of the greenschist facies. There are numerous evidences in this respect. Thus, the minerals of the almandine amphibolite facies are intensely deformed and fragmented by the S_2 foliation, the fragments being removed ; the neoformation minerals are aligned after S_2 ; biotite and garnet substitution by chlorite may be observed in different stages ; chlorite formed on biotite represents a pennine with abnormal birefringence colours, typical of such relationships ; in the biotite which is to be chloritized one may observe the separation of titanium as sagenite ; brown hornblende is found only as small spots filled with rutile in the middle of the larger, actinolitized crystals ; small actinolite prisms come from the tearing of the crystals of actinolitized hornblende as a result of their crossing by the S_2 foliation ; often the porphyroblastic albite crystals are packed with clinozoisite.

Some gneisses, although penetrated by S_2, display only incipient changes of the high-grade metamorphosed paragenesis, even the recrystallized deformed quartz being hardly visible. Amphibolites responded more promptly and completely to the transformations imposed by the penetration of the S_2 foliation. In amphibolites plagioclase is always albitized and, generally, recrystallized after S_2. The amphibolite minerals showed more elasticity to deformations than the gneiss minerals, probably due to the predominance of minerals displaying good cleavage properties. As there are no structural relationships to allow speculations on the presence of minerals previous to those of high-grade metamorphism the only sense of the mineralogical alterations, indicated by all the available observations, is that from parageneses characteristic of the almandine amphibolite facies towards the stable parageneses in the chlorite zone of the greenschist facies. In case of metamorphic rocks the mineralogical alterations always imply more than a starting mineral and a resultant one, so that the reactions we shall propose further on, on the basis of microscopic evidence, have a purely qualitative character.

In gneisses, biotite is chloritized and plagioclase sericitized due to the fastening on the latter of the potash component lost by biotite. This process may be linked to albitization and epidotization of plagioclase. When sericitization is not possible, mainly due to small amounts of plagioclase, biotite gives rise to ferriferous muscovite, chlorite and some of the iron remains outside the neoformation silicates. Titanium from biotite individualizes as rutile. When almandine is included into the chloritization reaction, titanium crystallizes as sphene due to calcite resulting from the garnet chloritization. In gneisses epidote, formed at the expense of plagioclase which is albitized, takes the iron from the

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surplus resulting from the femic minerals alteration. In amphibolites clinozoisite is poorer in iron than epidote because the iron from hornblende is entirely included in its alteration products. Brown hornblende of amphibolites is actinolitized and titanium is separated first as rutile and then as sphene concurrently with the development of processes and calcite released by hornblende and plagioclase takes part in reactions. Biotite alterations in amphibolites are similar to those occurring in gneisses. Opaque minerals are almost entirely oxidated and pass into hematite, like the iron surplus coming from the silicates alternations, and give a brick-red colour to the rocks. The abundance of hematite indicates that the reactions have taken place under oxidizing circumstances. It is worth mentioning that the rocks of the Rusaia Series, which represent a Middle Paleozoic sequence transgressively overlying the Bretila Series, metamorphosed during the Hercynian orogenesis, are magnetite-bearing rocks not hematite-bearing rocks.

VI. **Metamorphic Evolution of the Rocks Assigned to the Argestru Series**

The relict parageneses visible in the rocks assigned to the Argestru Series in the Puciosul Brook are pre-Hercynian and resemble the so-called Bretila Series in the Iacobeni Nappe. The main alteration of these parageneses is synchronous with the generation of S_2 foliation, which occurred during the Meso-Cretaceous overthrusts. It is hard to say that the rocks of the "Argestru Series" underwent incipient mineralogical alterations connected with the Hercynian regional retromorphism, they being concealed by the strong Meso-Cretaceous alterations. The very fine-grained rocks are due to mylonitizations concomitantly with their penetration by the S_2 foliation. An albite recrystallization especially in amphibolites took place subsequently to the mentioned foliation. One may infer that during the emplacement of the nappes constituting the Meso-Cretaceous structural basement of the Crystalline-Mesozoic Zone of the East Carpathians nearby the lower Alpine thrust planes there occurred thermodynamic conditions similar to those from the chlorite stability zone, pointing out an Alpine metamorphism. The Suhărzelu Mesozoic rocks, representing the cover of the Iacobeni Nappe, are in favour of this point of view. The pelitic rocks of the carbonatic rock association point to neoformation chlorite and sericite. The existence of Alpine biotite, hornblende, almandine, and oligoclase in the central part of the Crystalline-Mesozoic Zone of the East Carpathians cannot be accepted. The Mesozoic and Permian formations in a structural position lower than those of the Iacobeni Nappe (the Permian conglomerates on the Șaru Dornei Nappe and the Mesozoic in the Barnar Valley) indicate only a weak dynamic metamorphism. The same situation appears in the upper parts of the old crystalline series overlapped by the Alpine thrust nappes ; it points only to retromorphous alterations towards the chlorite stability zone. Another example is the Rusaia Series (Middle Paleozoic), which overlies also the Brătila Series of the Iacobeni Nappe and whose metamorphism does not exceed the chlorite stability zone (chlorite, stilpnomelane, chloritoid

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in parageneses). Consequently the rocks assigned to the Argestru Series in the Puciosul Brook (Bercia et al., 1971 ; Bercia et al., 1976) represent in fact rocks of the Bretila Series, strongly mylonitized and retromorphosed. They have an allochthonous position like the Chirileni thrust slice near Șaru Dornei. The problems concerning the rocks assigned also to the Argestru Series between the Chiril and Argestru brooks, in the left-hand side of the Bistrița, are identical with those of the rocks in the Puciosul Brook. Therefore the Argestru Series, as a whole, represents the upper part of the Bretila Series of the Iacobeni Nappe, strongly affected dynamically in the base of the Sub-bucovinian Nappe. In some places this part of the Bretila Series has been pulled off the substratum and tectonically transported, reaching an allochthonous position. Accordingly, if the Argestru Series is not a lithostratigraphic unit, the Argestru planing slice maintains its initial significance given by Bercia, Bercia in 1970. The fact that the Argestru Series has no lithostratigraphic equivalent in the Rusaia or Repedea series (Middle Paleozoic in age), transgressively overlying the Bretila Series, constitutes a further argument against the hypothesis that the Argestru Series might represent a Middle Paleozoic formation initially metamorphosed during the Hercynian orogenesis. It is worth mentioning that the oxidizing environment in which the paragenetic alterations occurred under the thrust plane of the Sub-bucovinian Nappe during the Meso-Cretaceous paroxismal tectogenesis differentiate this type of metamorphism from the Hercynian regional retromorphism which had taken place under reducing conditions. It is to be mentioned that the upper part of the Bretila Series displays pre-Triassic alterations extensive and supergene in oxidizing regime with iron separation from decomposed silicates as a limonitic, red powder which impregnates the mass of altered rocks. The evolution of the rocks assigned to the Argestru Series in the Puciosul Brook would be briefly, as follows : pre-Hercynian metamorphism (one or several) in the almandine amphibolite facies (S_1 foliation belongs to this stage) as part of the Bretila Series ; Hercynian regional retromorphism, hardly observable mineralogically and structurally ; pre-Triassic oxidation, more or less obvious, of the ferromagnesian silicates, probably in connection with the Permian oxidizing regime of rock alteration ; regressive alteration of pre-existent minerals under thermodynamic conditions similar to those in the chlorite zone, synchronous with the rocks mylonitization, their close folding and formation of the S_2 plane-axial foliation, in relation to the Meso-Cretaceous overthrustings ; concomitantly, the upper part of the Bretila Series has been detached from the substratum in some places and planed in the base of the Sub-bucovinian Nappe ; partial recrystallization of albite and quartz after S_2.

VII. Inferences

1. Separation of the Argestru Series as an independent lithostratigraphic unit is not justified.

2. The denomination "Argestru planing slice" may be used for the "lambeaux de rabotage" in the base of the Sub-bucovinian Nappe.

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3. Below the thrust plane of the Sub-bucovinian Nappe, thermodynamic conditions similar to those in the chlorite zone of the greenschist facies occurred during the emplacement of the mentioned nappe. Therefore it is an Alpine metamorphism associated to the Meso-Cretaceous overthrustings.

4. Up to now no Alpine parageneses of a metamorphic grade superior to that in the chlorite zone of the greenschists facies have been rendered evident. Minerals such as hornblende, oligoclase, biotite and almandine belong, in all cases, to some pre-Alpine, even pre-Hercynian relict parageneses.

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EXPLANATION OF PLATES

Plate I

Fig. 1. — N || × 85 ; biotite deformed in gneiss.
Fig. 2. — N || × 25 ; biotite deformed in amphibole.

[3] Q=quartz ; Pl=plagioclase ; Bi=biotite ; M=muscovite ; Alm=almandine ; Cl=chlorite ; Ep=epidote ; Ti=titanite ; T=tourmaline ; Zr=zircon; Ap=apatite; Op=opaque minerals ; Ort=orthite ; Hem=hematite ; R=rutile ; Ilm=ilmenite ; Gf=graphite ; Cal=calcite ; Ho=hornblende ; Act=actinolite ; Ab=albite ; Clz= =clinozoisite ; Ser=sericite.

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Fig. 3. — N || × 10 ; biotite deformed with chlorite alteration in amphibolite.
Fig. 4. — N || × 10 ; brown hornblende, marginally actinolitized, surrounded by thin actinolite needles.

Plate II

Fig. 1. — N || × 10 ; albite packed with clinozoisite in amphibolite.
Fig. 2. — N || × 10 ; albite packed with clinozoisite in amphibolite.
Fig. 3. — N + × 2.5 ; cataclastic structure in gneiss with almandine fragments.
Fig. 4. — N || × 10 ; fragment of almandine in gneiss.

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D. S. Inst. Geol. Geofiz. vol. LXIX/1 (1982). Pag. 257-278

1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

PETROLOGIA ROCILOR MAGMATICE

ROCILE AMFIBOLICE DE LA IACOBENI (CARPAȚII ORIENTALI), CU PRIVIRE SPECIALĂ ASUPRA GENEZEI LOR [1]

DE

VIOREL MACALEȚ [2]

Amphibole rocks. Epidote amphibolites. Epidote gneisses. Greenschist facies. Pelitic rocks. Modal composition. Petrochemistry. Magma. Major elements. Minor elements. Magmatic differentiation. East Carpathians-Crystalline-Mesozoic Zone-Bistrița Mts.

Abstract

The Amphibole Rocks at Iacobeni (East Carpathians), with Special View on Their Genesis. The petrography and chemistry of amphibole rocks which crop out on the right bank of the Bistrița Aurie river, between the brooks Suhărzelul Mare and Haju, are discussed. They are represented by epidote amphibolites, epidote gneisses and amphibole gneisses which constitute the main petrographic component of two bands occurring in the two anticlinal flanks trending approximately north-southward. The present-day metamorphism grade corresponds to the quartz-albite-epidote-almandine subfacies of the greenschist facies. The geochemical study has proved that the epidote amphibolites and the epidote gneisses have probably resulted from lavas and tuffs corresponding to magmas of gabbrodiorite, gabbroid and leucogabbroid nature; the genesis of amphibole gneisses is also accounted for by the presence of pelitic sedimentary material.

Amfibolitele din versantul drept al Bistriței Aurii, de la Iacobeni, au atras atenția cercetătorilor încă din secolul trecut, datorită mai ales mineralizațiilor de fier care le sînt asociate. Lucrările lui Savul (1940), Savul, Mastacan (1955), Kräutner (1966), ca și rezultatele prospecțiunilor geologice și geofizice și ale lucrărilor de explorare efectuate în zonă, concretizate într-o serie de rapoarte de către Costescu (1953), Mastacan, Bîgu (1954), Mușat et al. (1974), Macaleț, Lăzăroiu (1976), aduc

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[2] Institutul Politehnic București.

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contribuții importante privind petrografia și mineralogia rocilor amfibolice, cît și a rocilor cu magnetit legate de acestea.

Lucrarea de față își propune să prezinte o parte a rezultatelor cercetărilor efectuate pe baza datelor și probelor culese de autor în campania de teren a anului 1975.

Zona Suhărzelul Mare-Haju (fig. 1) este constituită în cea mai mare parte dintr-un fond de roci terigene metamorfozate, reprezentate

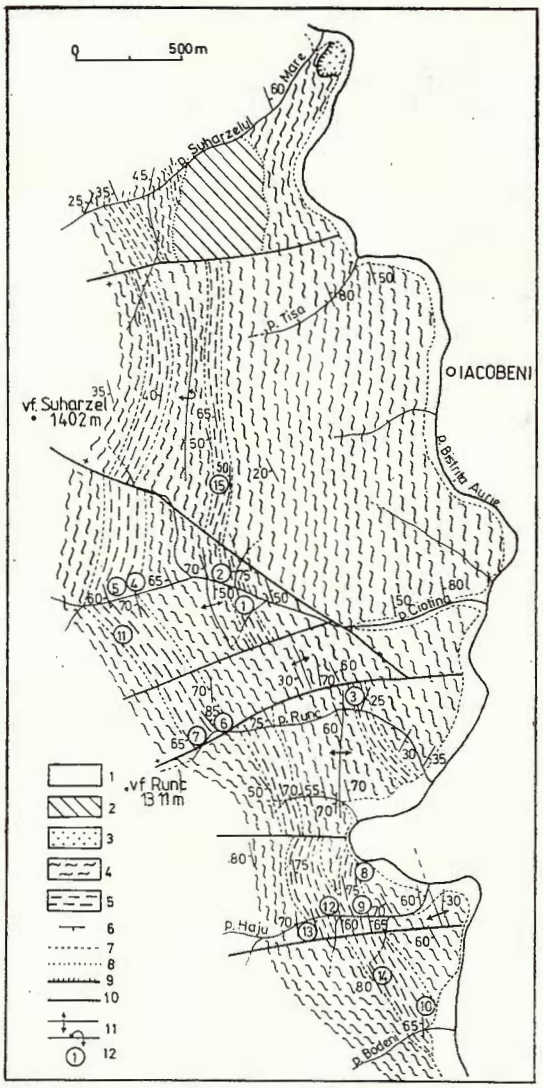


Fig. 1. — Schiță geologică a zonei Suhărzelul Mare-Haju
Formațiuni sedimentare. 1, Cuaternar : aluviuni ; 2, Triasic : calcare și conglomerate. Formațiuni metamorfice. 3, Seria de Tulgheș : cuarțite negre și șisturi grafitoase. Seria de Rebra. 4, micașisturi și paragnaise muscovito-biotitice ± ± granat ; 5, amfibolite ; 6, foliație ; 7, limită normală ; 8, limită de transgresiune ; 9, pînză de șariaj ; 10, falie ; 11, axe de cute ; 12, probă.

Esquisse géologique de la zone de Suhărzelul Mare-Haju.
Formations sédimentaires. 1. Quaternaire : alluvions ; 2, Trias : calcaires et conglomérats. Formations métamorphiques. 3, série de Tulgheș : quartzites noirs et schistes graphiteux. Série de Rebra : 4, micaschistes et paragneiss muscovite-biotitiques ± grenat ; 5, amphibolites ; 6, foliation ; 7, limite normale ; 8, limite de transgression ; 9, nappe de charriage ; 10, faille ; 11, axes de plis ; 12, échantillon.

prin micașisturi și paragnaise muscovito-biotitice ± granat și șisturi muscovitice cu porfiroblaste de albit. În aceste șisturi terigene se intercalează, în partea inferioară, roci metaeruptive bazice, constituite din amfibolite cu epidot, gnaise epidotice și amfibolice, iar în partea supe-

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rioară roci metaeruptive acide, reprezentate prin gnaise porfiroide cloritoase de tip Pietrosul și gnaise muscovitice (Macaleț, Lăzăroiu, 1976). Din punct de vedere stratigrafic, se încadrează în zona central-vestică a unității mezometamorfice din cristalinul munților Bistriței (Rădulescu, 1969), aparținînd seriei de Vatra Dornei-Iacobeni (Bercia et al., 1967), sau complexului superior al seriei de Rebra — Rb3, iar din punct de vedere tectonic face parte din pînza de Iacobeni (Bercia et al., 1976). Recent, Balintoni (1981) consideră că formațiunile precambriene din pînza de Iacobeni pot aparține seriei de Bretila, folosind ca principal argument asociațiile de roci, asemănătoare cu acelea din munții Rodnei. La sud de confluența pîrîului Suhărzelul Mare cu Bistrița Aurie aflorează, pe o suprafață redusă, formațiunile seriei de Tulgheș, aparținînd pînzei de Rodna-Mestecăniș (Bercia et al., 1976).

Petrografia rocilor amfibolice

Rocile amfibolice formează componenta petrografică principală a două benzi aproape paralele, conținînd numeroase intercalații lenticulare de șisturi și gnaise micacee cu granat ± magnetit puternic retromorfozate. Banda vestică poate fi urmărită continuu de la pîrîul Suhărzelul Mare pînă la sud de pîrîul Haju, pe o lungime de circa 8 km și o lățime cuprinsă aproximativ între 150 și 350 m ; între Suhărzelul Mare și Ciotina are direcția aproximativ nord-sud, iar la sud de pîrîul Ciotina are direcția NW-SE. A doua bandă se dezvoltă la est de prima, la o distanță care variază între 300 și 750 m și se urmărește, cu unele întreruperi, de la pîrîul Suhărzelul Mare pînă la sud de gura pîrîului Runc, pe o lungime de aproape 6 km. Cele două benzi de roci amfibolice, separate cartografic, sînt situate pe flancurile unei structuri anticlinale a cărei zonă axială, cu direcția aproximativ nord-sud, este întreruptă de o serie de falii transversale și, mergînd de la nord spre sud, deplasată progresiv către est, încît în dreptul pîrîului Haju ajunge în valea Bistriței ; unele compartimente sînt basculate în plan vertical, uneori cu pînă la 25-30°. În această interpretare, mineralizațiile de fier sînt legate de rocile amfibolice de pe flancul vestic al anticlinalului, fiind situate mai ales în partea lor bazală.

Amfibolitele cu epidot formează aproape în întregime banda estică și partea bazală a benzii vestice ; de asemenea, se întîlnesc sporadic și în partea superioară a benzii vestice — în zona de izvoare a pîrîului Runc. Sînt roci de culoare cenușie închisă — verzuie, microgranulare pînă la mediu granulare, mai mult sau mai puțin șistoase, prezentînd uneori o rubanare accentuată. Sînt constituite din amfiboli, feldspați, epidot, clinozoizit, cuarț, calcit, clorit, sericit, biotit ; accesoriu apar granatul, magnetitul, sfenul și apatitul.

Amfibolii pot apărea răspîndiți relativ uniform în toată masa rocii, dar de cele mai multe ori formează benzi paralele în care, împreună cu epidotul și clinozoizitul, sînt mineralele principale. Amfibolii aparțin în mod indiscutabil la două generații : un amfibol mai vechi, reprezentat prin hornblendă verde și unul mai nou, format pe seama hornblendei preexistente, reprezentat prin hornblendă actinolitică. Hornblenda verde se conservă doar în puține locuri, sub formă de cristale

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alungite (pînă la 3-4 mm), de obicei rupte și împrăștiate în masa rocii. De cele mai multe ori hornblenda preexistentă a fost recristalizată în cea mai mare parte sau complet, trecînd într-o hornblendă actinolitică sub formă de cristale lung prismatice sau aciculare dispuse liniar sau radiar ; lungimea obișnuită a prismelor de actinolit este cuprinsă între 1 și 5 mm, raportul lungime-grosime fiind în general de 10/1. Uneori, hornblenda actinolitică apare slab cloritizată.

Feldspații sînt reprezentați, de asemenea, prin două generații, feldspatul original fiind de obicei complet degradat, foarte rar observîndu-se urme de macle polisintetice. Pe fondul feldspaților preexistenți pot fi urmărite, în secțiuni diferite, toate stadiile începînd de la o recristalizare, foarte slabă a albitului, sub formă de pete limpezi, pînă la o recristalizare aproape completă, cînd s-au format cristale de albit ușor anizometrice, putînd ajunge pînă la 1 mm lungime ; cristalele sînt nemaclate sau formate, în general, din doi indivizi asociați după legea albitului. Conținutul de anortit este de 4—6%.

Epidotul și clinozoizitul apar atît în interstițiile dintre prismele de amfiboli, cît și în masa cristalelor de feldspat transformate. S-au format pe seama amfibolilor și plagioclazilor mai bazici preexistenți. Cantitativ, pot ajunge aproximativ egale cu hornblenda actinolitică.

Cuarțul se găsește de cele mai multe ori sub formă de granule (0,3-0,5 mm) în benzile leucocrate, împreună cu feldspat și calcit și mai rar răspîndit uniform în toată masa rocii, sau formînd lentile mici (1-2 mm) cu structură microgranulară.

Calcitul se găsește împreună cu epidotul, clinozoizitul și cuarțul atît în interstițiile dintre cristalele de hornblendă, cît mai ales format pe seama feldspatului preexistent.

Cloritul apare în special între cristalele de amfiboli, sub formă de lamele slab individualizate și pe fisuri. Uneori este concrescut cu biotitul. Biotitul se întîlnește sporadic, izolat sau concrescut cu cloritul. Sericitul se întîlnește uneori în spațiile dintre cristalele proaspete de albit, formînd o masă pîsloasă, fină.

Granatul (almandin-spessartin) apare frecvent în amfibolitele din baza aliniamentului vestic, sub formă de granule izometrice de 0,01-0,03 mm, răspîndit relativ uniform, putînd depăși uneori 15% din masa rocii. Magnetitul are, în general, aspect scheletiform evidențiind cîteodată clivajele hornblendei mai vechi.

Gnaisele epidotice au răspîndire mare în partea superioară a aliniamentului vestic. Sînt roci de culoare cenușie închisă-verzuie, relativ grosier-granulare, cu textură masivă sau ușor rubanată. Șistozitatea este slabă sau poate lipsi. Privite la microscop evidențiază întreaga gamă de transformări de la o rocă constituită dintr-o masă clorito-carbonatică cu puțin cuarț, epidot și magnetit, pînă la roci aproape în întregime recristalizate, formate din feldspat, epidot, clinozoizit, biotit, clorit, cuarț, calcit, hornblendă, sericit ; accesoriu apar apatitul și magnetitul.

Feldspatul preexistent nu poate fi recunoscut, iar feldspatul recristalizat este constituit din albit (3-4% An) sub formă de granule limpezi răspîndite uniform sau formînd aglomerări de cristale cimentate cu calcit. Dimensiunea granulelor poate ajunge la 1-1,5 mm. Epi-

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dotul și clinozoizitul se găsesc în cantitate mai mare decît albitul și formează, în general, benzi și cuiburi. Dimensiunile sînt comparabile cu ale albitului. Biotitul formează lamele vizibile uneori și cu ochiul liber. Apare independent sau concrescut cu cloritul, putînd ajunge pînă la 5%. Cloritul este, în unele părți alături de calcit, mineralul, principal. Calcitul se găsește uneori în cantitate mare, între granulele de feldspat și epidot sau în asociație cu cloritul. Hornblenda se recunoaște cu greu, fiind înlocuită prin clorit, epidot, calcit, fără recristalizarea actinolitului. Sericitul poate fi întîlnit uneori între granulele de albit. Cuarțul se găsește în cantitate redusă, nedepășind 2-3%.

Gnaisele amfibolice formează unele intercalații în cuprinsul aliniamentului estic de roci amfibolice, mai ales la nord de pîrîul Ciotina. Sînt roci dure, slab șistoase, avînd culoare cenușiu-verzuie. Perpendicular pe foliație se vede o alternanță de benzi formate preponderent din amfiboli cu benzi în care pe lîngă amfiboli sînt și minerale leucocrate. Sînt formate dintr-o masă microgranulară cuarțo-feldspatică în care se dezvoltă agregate aciculare sau prisme alungite, izolate, de amfibol și foițe de biotit. Subordonat cantitativ se găsește granat, epidot, clinozoizit și calcit.

Feldspatul este puternic alterat, rar observîndu-se urme de macle polisintetice ; prezintă slabe tendințe de recristalizare, avînd dimensiuni cuprinse între 0,5 și 1 mm. Cuarțul este subordonat cantitativ feldspatului, prezentînd extincție ondulatorie ; nu depășește 0,5 mm. Amfibolul este în cea mai mare parte un actinolit cu grosimi de 0,1-0,2 mm și lungimi de pînă la 3 mm, fiind în proporție de 10-30% ; rar se întîlnesc și prisme scurte de hornblendă verde. Biotitul este puternic cloritizat, foițele prezentînd o orientare mai slabă decît cristalele de actinolit. Granatul se întîlnește rar, sub formă de idioblaste de 0,5-2 mm, fiind puternic fisurat și cloritizat. Epidotul și clinozoizitul formează granule izolate, agregate granulare sau cristale prismatice. Calcitul apare în jurul și în masa feldspatului. Ca minerale accesorii apar foițe neregulate de hematit, de ordinul sutimilor de milimetru, dispuse concordant cu orientarea celorlalte minerale.

Paragenezele minerale actuale ale rocilor amfibolice descrise sînt rezultatul unei evoluții metamorfice îndelungate, care cuprinde cel puțin trei faze : un metamorfism regional progresiv în condițiile faciesului almandin-amfibolitic, urmat de un metamorfism distructiv, cînd rocile au fost transformate în șisturi verzi constituite în principal din clorit, calcit, epidot și, în cantitate mai mică, din cuarț, albit, actinolit, magnetit ; ulterior, aceste roci au suferit un nou metamorfism progresiv în timpul căruia au recristalizat actinolitul, albitul, biotitul, și granatul almandin-spessartin. În timpul acestui ultim metamorfism, care corespunde subfaciesului cuarț-albit-epidot-almandin al faciesului șisturilor verzi, nu s-a realizat un echilibru mineralogic complet, rămînînd sub formă de relicte ale metamorfismului preexistent, feldspat plagioclaz, hornblendă și granați. Aceste faze corespund mișcărilor precambriene, hercinice și, respectiv, alpine (după Bercia et al., 1976).

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Geneza rocilor amfibolice

Originea amfibolitelor reprezintă una dintre cele mai importante şi controversate probleme ale petrologiei metamorfitelor, atît din punctul de vedere al materialului din care au luat naştere, cît şi al evoluţiei metamorfice a terenurilor cristalofiliene. Numeroşi autori au abordat diferitele aspecte ale originii şi evoluţiei amfibolitelor, fără însă a se putea stabili măcar un criteriu riguros de discriminare, în particular în regiunile care au suferit un grad avansat de metamorfism, unde, în general, se admite că există o convergenţă mineralogică şi structurală a rocilor de diferite origini dar cu compoziţie chimică similară, chiar în condiţiile unui metamorfism izochimic. Sub denumirea de amfibolite sînt incluse, în general, toate rocile mai mult sau mai puţin cristaloblastice care sînt formate în special din amfiboli şi plagioclazi. Roci cu o asemenea constituţie mineralogică ar putea rezulta fie prin metamorfozarea în condiţii medii şi superioare de temperatură şi presiune a doleritelor, bazaltelor şi tufurilor bazice, pe de o parte, dînd naştere ortoamfibolitelor, fie prin metamorfozarea şisturilor calcaroase sau dolomitice, pe de altă parte, dînd naştere paraamfibolitelor, întrucît numai aceste roci sedimentare au o compoziţie primară apropiată de a amfibolitelor tipice (Leake, 1964). Sînt totuşi unii autori care au contestat identitatea chimică a unor roci sedimentare cu rocile magmatice bazice (Moine, 1969), sau au inclus metatufurile bazice în cadrul paraamfibolitelor (Van de Kamp, 1970). Engel, Engel (1951) au arătat că amfibolite hornblendice aproape identice, în care andezinul este de obicei un constituent major, se pot forma prin : metasomatismul, asemănător cu skarnificarea sedimentelor carbonatice ; reconstituirea fără schimburi chimice apreciabile a tufurilor şi marnelor, a maselor gabbroice, sillurilor doleritice şi curgerilor de bazalte. Dacă în condiţiile unui metamorfism de intensitate mai scăzută stabilirea genezei amfibolitelor poate să nu ridice probleme deosebite, în condiţiile faciesurilor cele mai avansate aceasta poate să fie dificilă, dacă nu chiar imposibilă.

Cartarea amănunţită a terenurilor cristalofiliene poate uneori conduce, ea singură, la separarea ortoamfibolitelor de paraamfibolite dacă pot fi distinse o serie de caractere cum sînt : forma de zăcămînt (Eskola, 1914 ; Gjelsvik, 1952 ; Savul, Mastacan, 1940 ; Taylor, 1955 ; Nelson, 1969 ; Taylor, Morgan, 1972 ; Graham, 1976 ; Hurst, Jones, 1973 ; Satynarayana, 1974 ; Wit, Strong, 1975), asociaţiile de roci (Manolescu, 1937 ; Pavelescu, 1953 ; Ghica Budeşti, 1940 ; Gjelsvik, 1952 ; Moine, 1969 ; Nelson, 1969 ; Holdus, 1971 ; Harker, 1974 ; Satynarayana, 1974), şi natura contactelor cu rocile gazdă (Gjelsvik, 1952 ; Miyashiro, 1958 ; Nelson, 1969 ; Holdus, 1971 ; Morgan, 1972 ; Fairley, 1973). În rocile care au suferit un grad scăzut sau mediu de metamorfism şi mai rar în cazul rocilor puternic metamorfozate pot fi recunoscute unele caractere primare, cum sînt structurile şi texturile relicte. Astfel sînt citate structuri magmatice relicte — ofitice (Taylor, Morgan, 1972 ; Wilson, Leake, 1962 ; Smulikovski, 1974), doleritice şi gabbroice (Eskola, 1914 ; Moine, 1969), porfirice (Eskola, 1914 ; Morgan, Taylor, 1970 ; Barron, 1976), structuri sedimentare relicte (Van de Kamp, 1971). Printre texturile magmatice relicte cele mai citate sînt textura masivă (Taylor, Morgan, 1972 ; Harker, 1974), pillow (Hurst, Jones, 1973), amigdaloidă (Eskola, 1914 ; Hurst, Jones, 1973 ; Barron, 1976), iar dintre cele sedimentare sînt citate stratificaţia (Van de Kamp, 1971), uneori chiar stratificaţia încrucişată (Satynarayana, 1974) şi rubanarea (Wilcox, Poldervaart, 1958 ; Walker et al., 1960).

Dacă pot fi identificate, un rol important în stabilirea naturii originale a materialului din care prin metamorfism au rezultat amfibolitele îl au mine-

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ralele relicte, mai ales cele magmatice (Gjelsvik, 1952 ; Smulikovski, 1974). De asemenea, din numeroase lucrări (Moine, 1969 ; Nelson, 1969 ; Holdus, 1971 ; Satynarayana, 1974 ; Wit, Strong, 1975 ; Bercia, 1975) rezultă importanța pe care pot să o aibă paragenezele minerale actuale în stabilirea genezei amfibolitelor. Astfel se poate trage concluzia că paraamfibolitele, spre deosebire de ortoamfibolite, conțin aproape întotdeauna diopsid ca mineral principal, feldspatul plagioclaz participă în cantități mai mici, iar feldspatul potasic poate, în unele cazuri, deveni un constituient major. O caracteristică a paraamfibolitelor ar putea fi și prezența calcitului în cantitate mai mare în asociații de minerale stabile, iar a ortoamfibolitelor cantitatea în general mai ridicată a mineralelor opace oxidice (magnetit și ilmenit).

Rocile amfibolice descrise de noi sînt concordante cu șisturile din culcuș și acoperiș, fiind cutate împreună cu acestea ; contactele sînt, în general, nete, dar și gradate pe grosimi de cîțiva metri datorită interstratificării cu șisturi micacee. Singurul aspect textural relict poate fi considerat aspectul relativ masiv al majorității gnaiselor epidotice ; rubanarea, mai ales a amfibolitelor cu epidot, este probabil consecința diferențierii metamorfice, și nu a unei stratificații inițiale. Aceste aspecte, ca și asocierea cu roci tipice de geosinclinal (metapelite, metagrauwacke) și lipsa în apropiere a șisturilor calcsilicatice și marmurelor, luate la un loc, pot fi argumente în favoarea formării rocilor amfibolice pe seama unor roci magmatice extrusive, reprezentate prin curgeri de lave și tufuri stratiforme și concordante cu rocile gazdă.

Dacă în condițiile metamorfismului de grad scăzut și mediu originea unor tipuri de amfibolite poate fi recunoscută în urma găsirii unuia sau mai multor caractere dintre cele arătate pînă acum, în condițiile metamorfismului cel mai ridicat, uneori și mediu, datele chimice sînt singurele care pot fi folosite pentru distingerea amfibolitelor formate pe seama rocilor magmatice bazice de acelea formate prin metamorfismul unor roci sedimentare. În mod curent, multe lucrări au arătat că nu există nici o diferență chimică între ortoamfibolite și paraamfibolite. Totuși, în general, se admite că analiza globală a unui amfibolit permite repartizarea lui cu anumită încredere unei origini magmatice sau sedimentare ; excepții se întîlnesc cînd un sediment a provenit direct din unele roci magmatice fără schimbări chimice importante.

Privind *elementele majore*, părerea cvasigenerală este că ortoamfibolitele se caracterizează prin conținuturi mai ridicate de Na, Fe, Ti, Al și Mg și prin conținuturi mai scăzute de K și Si, pe cînd paraamfibolitele sînt bogate în Ca, K, Si și sărace în Ti, Na și Al (Gjelsvik, 1952 ; Nelson, 1969 ; Moine, 1969 ; Van de Kamp, 1971 ; Holdus, 1971 ; Satynarayana, 1974), în concordanță cu concentrațiile acestor elemente în rocile sursă, așa cum rezultă din tabelul 1 (din Turekian et al., 1961). În tabelul 2 sînt date rezultatele analizelor a 15 probe prelevate din rocile amfibolice de la Iacobeni, iar în tabelul 3 parametrii Niggli corespunzători. O primă concluzie care se desprinde este că amfibolitele cu epidot corespund magmelor neutre-bazice, iar gnaisele epidotice magmelor bazice, toate încadrîndu-se în tipurile de magme gabbrodioritice, gabbroide sau leucogabbroide ; excepție face proba de gnais amfibolic (15) care corespunde unei magme neutre dioritice. Caracterul tuturor este puternic calcoalcalin.

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În continuare vom discuta chimismul amfibolitelor analizate, folosind o serie de reprezentări grafice propuse de diverși autori.

În tetraedrul de concentrație al lui Niggli, care grupează parametrii *al, alk, c* și *fm*, toate probele se proiectează în domeniile magmatice ale secțiunilor III, IV și V — figura 2, doar proba 14 proiectîndu-se în secțiunea VII. Este de remarcat faptul că dacă amfibolitele cu epidot au valori ale raportului *c : fm* variabile și în general mai mici (de la 0,28 la 0,95) gnaisele epidotice au valori mai mari și constante (0,87-0,96).

TABELUL 1

Concentrațiile elementelor majore în principalele tipuri de roci; conținuturile sînt date în ppm (din Turekian, 1961)

Elemente majore	Roci bazaltice	Argile	Gresii	Roci carbonatice
Si	230.000	73.000	368.000	24.000
Al	78.000	80.000	25.000	4.200
Fe	86.500	42.000	9.800	3.800
Mg	46.000	15.000	7.000	47.000
Mn	1.500	850	—	1.100
Ca	76.000	22.100	39.100	302.300
Na	18.000	9.600	3.300	400
K	8.300	26.000	10.700	2.700
Ti	13.800	4.600	1.500	400
P	1.100	700	170	400

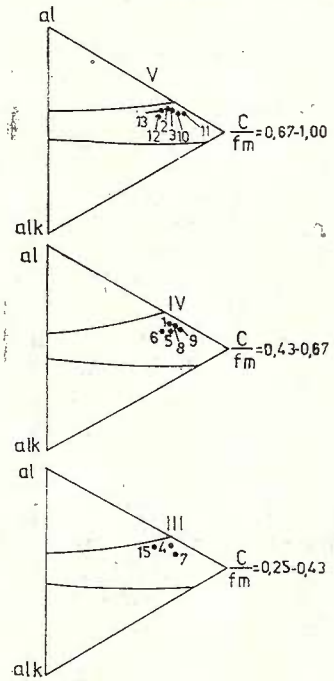


Fig. 2. — Proiectarea rocilor amfibolice în tetraedrul de concentrație al lui Niggli.
Projection des roches amphiboliques dans le tétraèdre de concentration de Niggli.

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TABELUL 2

Rezultatele analizelor chimice

Nr. probei	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_3 %	CO_2 %	S %	H_2O^+	H_2O^-
1	49,30	16,54	4,08	8,29	0,50	2,70	9,10	2,58	0,92	1,85	0,28	2,42	0,05	0,60	0,50
2	45,80	18,45	9,48	7,58	0,33	1,40	8,96	2,37	0,90	2,50	0,51	0,92	0,04	0,50	0,36
3	44,97	17,50	7,89	6,15	0,30	3,00	12,60	2,30	0,34	2,65	0,35	1,40	0,08	0,36	0,27
4	45,38	18,90	7,25	6,72	0,60	6,20	6,30	1,40	0,80	1,75	0,36	1,49	0,04	0,10	2,80
5	45,80	18,10	7,33	5,58	0,24	3,80	9,70	2,02	0,72	2,05	0,23	2,24	0,04	0,78	1,68
6	50,40	16,00	6,58	5,29	0,28	4,30	7,42	3,34	0,94	2,65	0,45	0,26	0,07	0,12	1,40
7	50,13	16,10	4,86	6,72	0,27	6,80	8,06	2,07	0,38	1,42	0,12	1,14	0,08	0,30	1,79
8	48,05	16,73	4,95	7,72	0,23	5,20	8,52	1,86	0,60	2,12	0,35	2,11	0,04	0,63	0,94
9	45,96	17,18	4,63	7,29	0,43	7,00	9,80	1,93	1,11	1,92	0,15	0,70	0,15	0,16	1,40
10	44,16	17,80	4,31	6,15	0,26	4,00	14,10	1,67	0,90	2,16	0,42	3,08	0,05	0,40	0,76
11	37,50	17,25	9,20	4,50	0,60	4,20	15,50	1,80	0,40	2,20	0,15	3,80	—	0,40	2,50
12	42,40	19,10	6,21	3,72	0,17	3,50	10,78	3,88	1,61	1,85	0,35	4,79	0,05	0,33	1,48
13	41,50	19,98	5,72	3,00	0,14	4,10	11,20	2,54	1,16	1,85	0,16	4,88	0,09	0,65	2,90
14	37,84	18,70	7,48	5,57	0,16	2,40	16,60	1,02	1,08	2,20	0,38	6,90	0,05	0,35	2,55
15	51,40	19,40	9,00	1,90	0,50	5,00	5,60	3,10	1,30	0,65	0,50	0,30	—	0,35	1,95

Probele 1—3, amfibolite cu epidot din banda estică ; 1, versantul drept al pîriului Ciotina ; 2, malul sting al pîriului Ciotina ; 3, versantul sting al pîriului Runc.

Probele 4—10, amfibolite cu epidot din banda vestică : 4 şi 5, versantul sting al pîriului Ciotina ; 6, versantul sting al pîriului Runc ; 7, zona de izvoare a pîriului Runc ; 8, drumul de pe malul drept al Bistriţei, la cca 600 m amonte de confluenţa cu pîriul Haju, (din fragmente) ;9, versantul sting al pîriului Haju ; 10, drumul de pe malul drept al Bistriţei, la cca 150 m amonte de confluenţa cu pîriul Bodeni.

Probele 11—14, gnaise epidotice : 11, versantul drept al pîriului Ciotina ; 12, versantul sting al pîriului Haju ; 13, versantul drept al pîriului Haju ; 14, interfluviul dintre pîriul Haju şi pîriul Bodeni.

Proba 15, gnais amfibolic din versantul sting al pîriului Ciotina.

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TABELUL 3

Valorile parametrilor Niggli, corespunzătoare analizelor din tabelul 2

Nr. probei	*si*	*al*	*fm*	*c*	*alk*	*k*	*c/fm*	*mg*	*p*	ti	qz
1	133	25,7	38,7	26,2	8,25	0,2	0,67	0,28	0,32	3,72	0
2	122,6	29,67	37,13	25,7	7,65	0,20	0,69	0,15	0,57	4,98	—8,0
3	106,64	24,84	37,33	32,03	5,78	0,08	0,85	0,28	0,35	4,69	—16,48
4	112	27,70	51,18	16,54	4,59	0,27	0,28	0,44	0,36	3,25	—6,36
5	115,57	27,05	40,57	26,90	6,16	0,18	0,64	0.35	0,24	3,93	— 9,07
6	134,16	25,58	43,11	21,03	10,22	0,15	0,48	0,39	0,50	5,27	— 6,72
7	124,50	23,68	49,32	21,47	5,51	0,10	0,43	0,51	0,12	2,68	2,46
8	121,74	25,33	45,98	23,13	5,53	0,17	0,50	0,43	0,38	4,03	— 0,38
9	105,35	23,25	46,76	24,06	5,91	0,27	0,51	0,51	0,14	3,30	—18,29
10	108,02	25,97	35,62	33,02	5,47	0,26	0,92	0,41	0,44	3,96	—13,46
11	81	22,2	38,7	37,2	4,0	0,12	0,96	0,36	0,12	3,5	—35
12	103,68	27,83	32,22	28,19	11,74	0,21	0,87	0,39	0,36	3,37	—43,28
13	103,57	29,50	32,62	29,03	7,93	0,22	0,91	0,46	0,16	3,44	—28,15
14	89,95	26,47	27,40	42,19	3,92	0,41	1,53	0,31	0,38	3,92	—26,03
15	136	30,8	43,6	16	10	0,22	0,36	0,46	0,55	1,2	—4

În figura 3 este arătată corelația parametrilor *c* și *mg* în doleritele de Karroo, ca o serie tipică de roci magmatice bazice și în amestecuri de pelite — calcare — dolomite, iar în figura 4, considerînd aceleași roci, este dată o diagramă triunghiulară în care sînt reprezentate valorile 100 *mg*, *c* și *al-alk* recalculate în procente (după Leake, 1964).

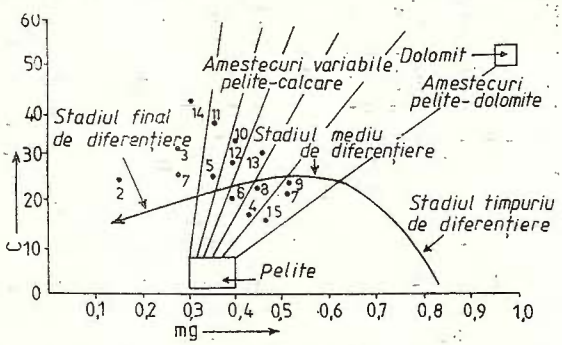


Fig. 3. — Diagrama *c : mg* (după Leake, 1964).
Diagramme *c : mg* (selon Leake, 1964).

Deși corelația parametrilor considerați este variabilă în timpul diferențierii magmatice, depinzînd de stadiul acesteia și suprapunîndu-se în mare parte peste direcțiile date de amestecurile pelite-calcare-dolomite, se vede că acestea din urmă intersectează la un unghi destul de mare direcția rocilor magmatice. În ambele diagrame propuse de Leake, cele mai multe dintre analizele noastre urmează îndeaproape direcția magmatică, de la stadiul mediu pînă la stadiul final de diferențiere.

În diagrama *si:c+alk* (Burri, 1959) — figura 5, toate cele 15 probe se proiectează în cîmpul rocilor magmatice, evidențiind în modul cel

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mai clar o diferențiere compoziţională în funcţie de parametrul *si*; astfel gnaisele epidotice sînt în partea inferioară (*si* = 81-103), amfibolitele cu epidot imediat peste acestea (*si* = 105-134), iar gnaisul amfi-

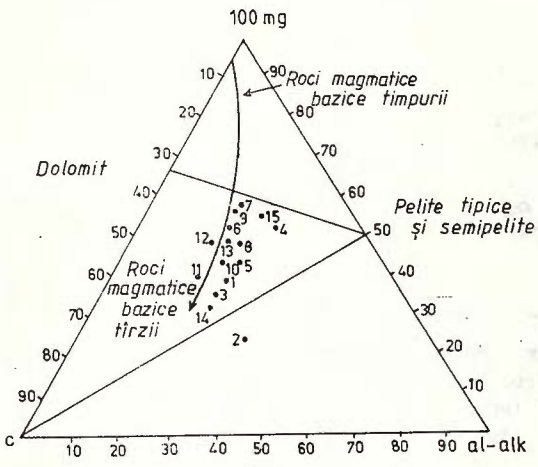


Fig. 4. — Diagrama 100 *mg* : *c* : *al-alk* (după Leake, 164). Diagramme 100 *mg* : *c* : *al-alk* (selon Leake, 1964).

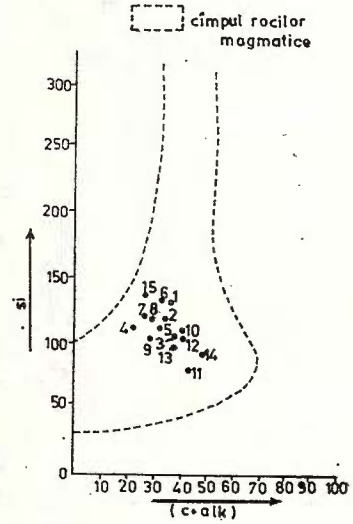


Fig. 5. — Diagrama *si* : *c*+*alk* (după Burri, 1959). Diagramme *si* : *c*+*alk* (selon Burri, 1959).

bolic în partea cea mai de sus (*si* = 136). De asemenea, valorile *c*+*alk* sînt mai mari în gnaisele epidotice decît în amfibolitele cu epidot.

În diagrama *c* : *al-alk* propusă de Evans şi Leake, 1960 (din Holdus, 1971) figura 6, cu excepţia probelor 4 şi 15, toate celelalte se proiec-

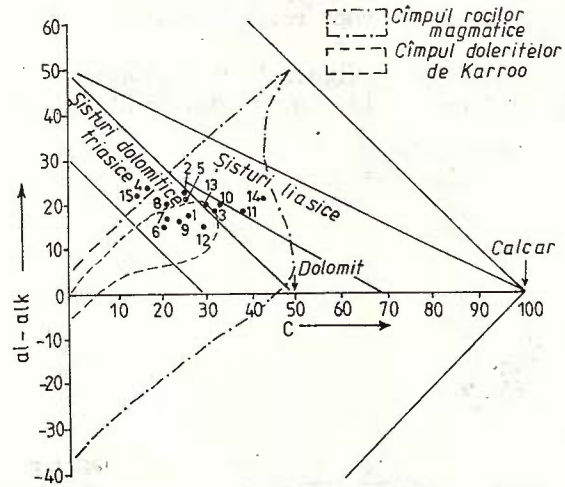


Fig. 6. — Diagrama *c* : *al-alk* (după Holdus, 1971). Diagramme *c* : *al-alk* (selon Holdus, 1971).

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tează în cîmpul rocilor magmatice, care însă se suprapune, în cea mai mare parte peste domeniul rocilor sedimentare.

Grupînd parametrii *al*, *fm*, *c* și *alk* și raportîndu-i la valoarea parametrului *si*, Simonen, 1953 (din Holdus, 1971) separă cîmpurile rocilor vulcanogene și ale sedimentelor calcaroase, argiloase și arenacee — figura 7. Pe această diagramă, cele mai multe dintre amfibolitele

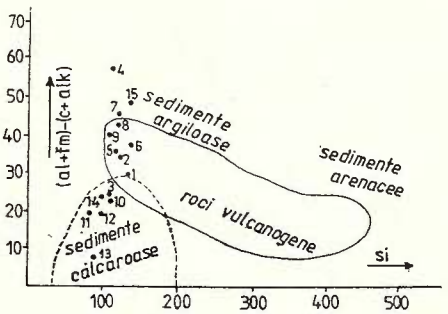


Fig. 7. — Diagrama *si : (al+fm) — (c+alk)*, din Holdus, 1971).
Diagramme *si : (al+fm) — c+alk)*, (de Holdus, 1971).

cu epidot se proiectează în cîmpul rocilor vulcanogene sau în apropierea lui, mai ales către sedimentele argiloase, iar proba 15, de gnais amfibolic, în domeniul sedimentelor argiloase, aproape de cîmpul vulcanogen ; toate gnaisele epidotice se proiectează în cîmpul sedimentelor calcaroase și, cu o singură excepție (proba 13) în apropierea rocilor vulcanogene. De asemenea, se observă că amfibolitele cu epidot au valori mai mari pentru ambii parametri luați în discuție, pe cînd gnaisele cu epidot au valorile respective mai mici, punctul de tangență între cele două tipuri de roci corespunzînd raportului *si : [(al+fm)-(c+alk)]* = 105 : 23.

În diagrama *ti : mg* — figura 8, majoritatea rocilor amfibolice de la Iacobeni se proiectează în cîmpul amfibolitelor magmatogene care

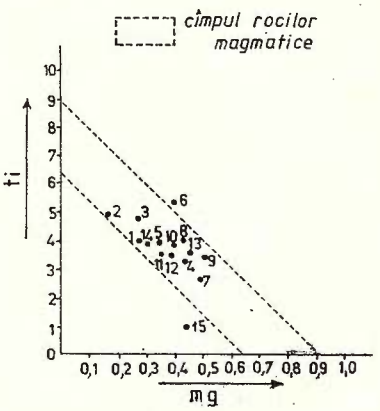


Fig. 8. — Diagrama *ti : mg* (din Bercia, 1975).
Diagramme *ti : mg* (de Bercia, 1975).

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satisfac relaţia : $ti+10\ mg = 6{,}5\text{-}9$ (din Bercia, 1975) ; probele 1 şi 2 sînt la limita valorii 6,5, iar proba 15 sub această valoare.

Discutînd variaţiile distribuţiei Ti în metabazite, Misra (1971) propune două diagrame. Prima diagramă — figura 9 dă variaţia con-

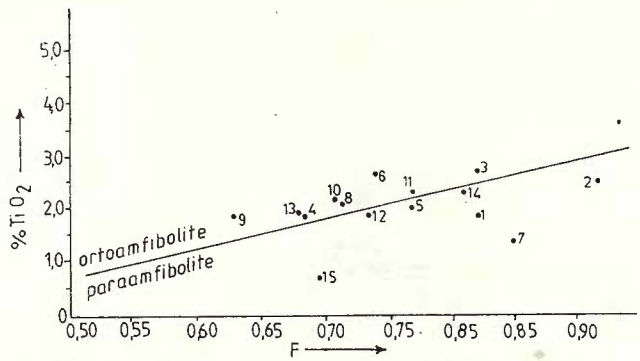


Fig. 9. — Diagrama $TiO_2 : F$ (după Misra, 1971).
Diagramme $TiO_2 : F$ (selon Misra, 1971).

ţinutului de Ti în funcţie de F, $F=(FeO+Fe_2O_3) : (FeO+Fe_2O_3+MgO)$, autorul subliniind că în rocile magmatice şi derivatele lor metamorfice TiO_2 arată schimbări sistematice cu F, putîndu-se trasa o linie care să separe cîmpurile pentru ortoamfibolite şi paraamfibolite. În cea de a doua diagramă este dată variaţia TiO_2 în funcţie de MnO, cu separarea

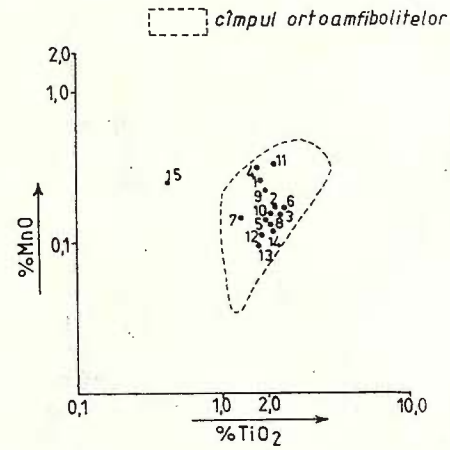


Fig. 10. — Diagrama $TiO_2 : MnO$ (după Misra, 1971).
Diagramme $TiO_2 : MnO$ (selon Misra, 1971).

cîmpului ortoamfibolitelor — figura 10. Dacă în prima diagramă gnaisele epidotice şi doar majoritatea amfibolitelor cu epidot evidenţiază tendinţele manifestate de ortoamfibolite, în diagrama a doua toate aceste roci se plasează în cîmpul ortoamfibolitelor. Proba de gnais amfibolic (15) se proiectează net în afara cîmpului ortoamfibolitelor.

În cadrul unor discuţii generale care intenţionează să arate că nu există nici o convergenţă chimică între rocile magmatice şi dife-

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ritele tipuri de roci sedimentare în timpul unui metamorfism izochimic, Moine (1969) și La Roche (1972) propun o serie de diagrame de un deosebit interes pentru stabilirea originii rocilor premetamorfice, prin faptul că sînt mai bine delimitate cîmpurile compoziționale corespunză-

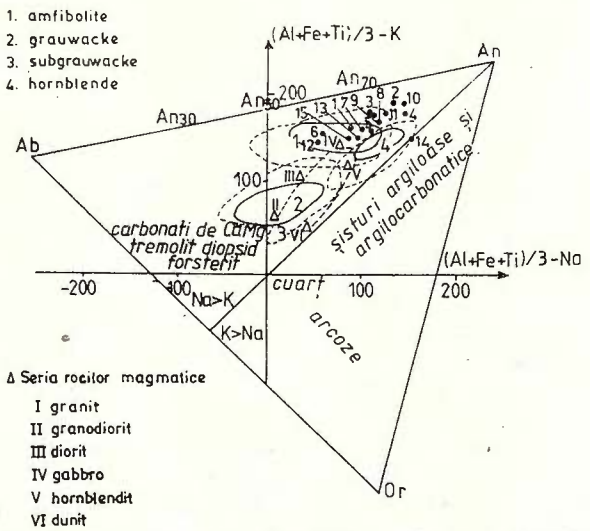


Fig. 11. — Diagrama (Al+Fe+Ti)/3 — K : (Al+Fe+Ti)/3 — Na (după Moine, 1969).
Diagramme (Al+Fe+Ti)/3 — K : (Al+Fe+Ti)/3 — Na (selon Moine, 1969).

toare. În diagrama din figura 11 (simplificare după Moine, 1969) este redată comportarea diferențială a Al, Na, și K din rocile magmatice și sedimentare, luînd în considerație și caracterul siderofil al primelor ; astfel, sînt prezentate variațiile valorilor (Al+Fe+Ti)/3 — K în funcție de (Al+Fe+Ti)/3 — Na, calculate în miliatomi-gram la 100 grame rocă sau mineral. Pe diagramă sînt trecute și pozițiile medii ale principalelor roci magmatice. Din această diagramă se vede că nu există nici o convergență chimică între amfibolite și rocile argilo-carbonatice (marne), pe cînd cîmpurile amfibolitelor și grauwackelor se suprapun parțial. Pentru separarea amfibolitelor de grauwacke este folosit raportul (Al+Fe+Ti) : (Ca+Mg) — figura 12 (simplificare după Moine, 1969). Cu excepția probei 14, care este la limita dintre domeniul sodic și cel potasic, toate celelalte probe se proiectează în domeniul în care Na>K, în majoritate în cîmpurile amfibolitelor. Compoziția plagioclazilor se întinde pe un interval cuprins între 50 și 70% An, aproximativ în dreptul magmelor dioritice și gabbroice.

La Roche (1972) propune o reprezentare triunghiulară destinată examinării compoziției globale a rocilor, numită „triunghiul rocilor totale“ — figura 13, în cele trei colțuri găsindu-se SiO_2 (cuarț), suma Fe_2O_3 + TiO_2 + CaO (oxizi, sulfuri, carbonați) și Al_2O_3 (gibbsit, corindon). Rocile magmatice se dispersează puțin în această diagramă, con-

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turînd un fel de dorsală, iar formațiunile sedimentare se proiectează de o parte și de alta ; tendințele diferențierii sedimentare sînt oblice față de tendințele magmatice și acoperă în parte linia magmatică. Toate

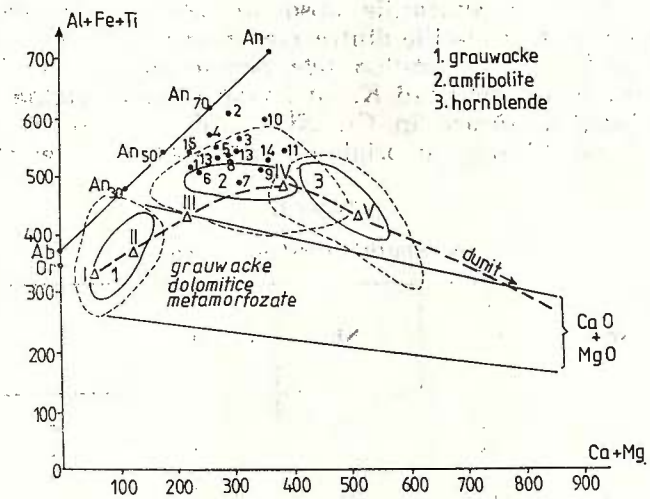


Fig. 12. — Diagrama (Al+Fe+Ti) : (Ca+Mg), (după Moine, 1969).

Diagramme (Al+Fe+Ti) : (Ca+Mg), (selon Moine, 1969).

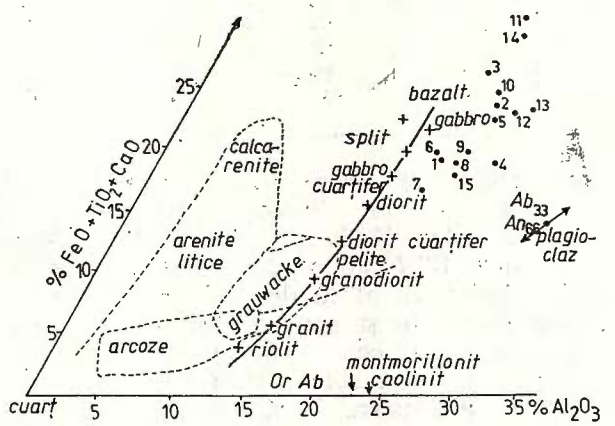


Fig. 13. — „Triunghiul rocilor totale“ (după La Roche, 1972).

„Triangle des roches totales“ (selon La Roche, 1972).

probele de la Iacobeni se proiectează departe de cîmpurile sedimentare, urmărind linia magmatică, în majoritate de la gabbro cuarțifer la gabbro și bazalt.

Atenția multor cercetători a fost îndreptată și în direcția studiului *elementelor minore* pentru aprecierea genezei amfibolitelor. Totuși,

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atît pelitele carbonatice cît și rocile magmatogene bazice prezintă o variație relativ largă a concentrației elementelor minore și din această cauză nu poate fi evidențiat nici un criteriu sigur de discriminare. La fel ca și în cazul elementelor majore și pentru elementele minore mai semnificative decît concentrațiile absolute par a fi corelațiile dintre aceste elemente, sau corelațiile dintre elementele minore și cele majore. Se poate astfel spune că amfibolitele bogate în Cr, Ni, Ti și avînd valori scăzute ale parametrului *K*, au aproape sigur origine magmatică, pe cînd amfibolitele sărace în Cr, Ni, Ti, dar cu valori ridicate ale paramtrului *k* pot fi sau de origine magmatică, sau de origine sedimentară (Leake, 1964). De asemenea, o serie de autori au arătat că studiul repartiției Sr (Wilcox, Poldervaat, 1958 ; Fabries, 1963) sau ale rapoturilor K : K/Rb, Ca : Ca/Sr (Condie, 1967) și $^{87}Sr : {}^{86}Sr$ (James, Faure, 1972 ; Jones, 1973) poate aduce unele clarificări în problema amfibolitelor. În afară de probele 11 și 15, pe toate celelalte probe au fost efectuate și analize spectrale informative, conținuturile mai semnificative fiind cele de Cr, Ni, Co și V, date în tabelul 4. Diagrama din figura 14 arată corelațiile dintre *mg* pe de o parte și Cr, Ni, Co și V pe de altă parte. Fără a ține cont de valorile absolute ale acestor conținuturi, în general reduse, singura concluzie care se poate desprinde este că Cr și Ni au valori mult mai mici în amfibolitele cu epidot din banda estică (probele 1, 2 și 3), în care și parametrul *mg* este mai mic, decît în majoritatea rocilor din banda vestică ; aceeași tendință, dar mai slabă, prezintă și conținuturile de cobalt.

TABELUL 4

Conținuturile în elemente minore

Nr.	Cr	Ni	Co	V
1	12	6	9	80
2	6	5	8	35
3	12	4	8	55
4	50	20	9	55
5	50	35	13	65
6	15	4	9	80
7	15	16	13	65
8	38	7	9	75
9	70	25	13	75
10	38	15	8	40
12	55	18	8	75
13	50	18	8	70
14	40	40	12	50

Comparînd conținuturile diferitelor elemente în rocile amfibolice descrise cu conținuturile medii în rocile magmatice bazice se constată următoarele. Amfibolitele cu epidot sînt mai sărace în magneziu și calciu și mai bogate în aluminiu ; conținutul în Si este asemănător și puțin variabil. Gnaisele epidotice sînt mai sărace în Si și Mg și mai

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bogate în Al şi Ca, iar gnaisele amfibolice conţin mai mult Si şi Al şi mai puţin Ca. În diagramele prezentate, majoritatea amfibolitelor cu epidot manifestă tendinţe clare de ortoamfibolite, cu excepţia celor din banda estică, care se situează uneori la limita domeniilor acestora,

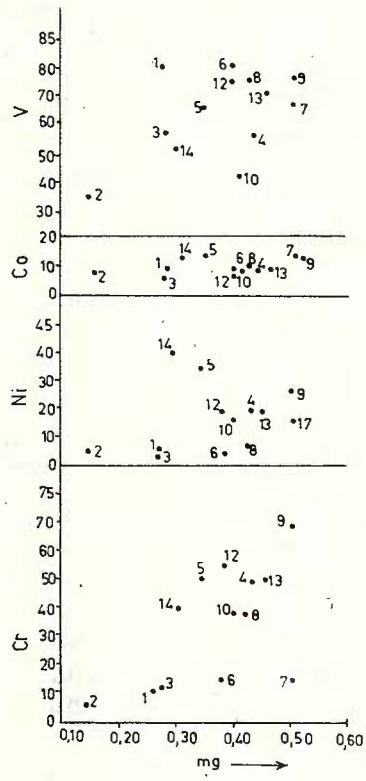


Fig. 14. — Corelaţiile dintre mg şi Cr, Ni, Co, V.
Corrélations entre mg et Cr, Ni, Co, V.

mai ales spre sedimentele argiloase ; acest aspect, împreună cu valoarea mai mică a lui *mg* şi conţinuturile mult mai reduse de Cr şi Ni, diferenţiază aceste amfibolite de amfibolitele din banda vestică. Gnaisele epidotice se proiectează de cele mai multe ori în cîmpurile ortoamfibolitelor, uneori către sedimentele calcaroase, iar gnaisele amfibolice de obicei în afara domeniilor magmatice, în special în domeniul sedimentelor argiloase. Deosebirile dintre cele trei tipuri de roci sînt accentuate şi de tendinţele diferite manifestate de diverşi parametri : astfel, în amfibolitele cu epidot parametrul *si* este mai mare, suma *(c+alk)* mai mică, iar valorile *(al+fm) — (c+alk)* mai mari ; gnaisele epidotice au valori scăzute ale parametrului *si*, mai mari pentru *(c+alk)* şi mai mici pentru *(al+fm) — (c+alk)* ; gnaisele amfibolice se diferenţiază prin valoarea mai mare a parametrului *si*. Diagramele care permit acest lucru dau o compoziţie a feldspatului plagioclaz iniţial corespunzătoare aproximativ labradoritului (50-70% An).

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Concluzii

În versantul drept al Bistriței Aurii, între pîrîul Suhărzelul Mare și pîrîul Haju, se dezvoltă două benzi formate în principal din roci amfibolice — amfibolite cu epidot, gnaise epidotice și gnaise amfibolice — cu numeroase intercalații lenticulare de șisturi micacee ± magnetit. Ele sînt situate pe flancurile unei structuri anticlinale cu direcția aproximativ nord-sud, afectate de o serie de falii transversale, unele compartimente fiind basculate în plan vertical cu pînă la 25-30°. Amfibolitele cu epidot formează aproape în întregime aliniamentul estic și partea bazală a celui vestic, iar gnaisele epidotice au o răspîndire mai mare în partea superioară a aliniamentului vestic ; gnaisele amfibolice apar sub formă de intercalații în cuprinsul aliniamentului estic și mai rar în cel vestic.

Paragenezele minerale actuale ale rocilor amfibolice sînt rezultatul unei evoluții metamorfice îndelungate, care cuprinde cel puțin trei faze : un metamorfism regional progresiv de intensitate ridicată, care a atins condițiile faciesului almandin — amfibolitic, urmat de o perioadă de retromorfism peste care s-a suprapus un nou metamorfism progresiv cu dezvoltare limitată, în timpul căruia au recristalizat amfibolii, albitul, biotitul și granatul almandin — spessartinic. În timpul acestui ultim metamorfism, care corespunde subfaciesului cuarț — albit — epidot — almandin al faciesului șisturilor verzi, nu s-a realizat un echilibru mineralogic complet, rămînînd sub formă de relicte ale metamorfismului mai vechi feldspat plagioclaz, hornblendă și granați.

Forma și natura contactelor cu rocile înconjurătoare și asociațiile petrografice sînt indicii că rocile amfibolice s-au format pe seama unor roci magmatice extrusive, reprezentate prin curgeri de lave și tufuri. Datorită evoluției geologice îndelungate, atît paragenezele, cît și structurile și texturile actuale nu dau indicații asupra materialului premetamorfic.

Studiul chimic efectuat a evidențiat că amfibolitele cu epidot și gnaisele epidotice corespund în cea mai mare parte ortoamfibolitelor rezultate din roci magmatice neutre-bazice (amfibolitele cu epidot) și bazice (gnaisele epidotice), toate încadrîndu-se în tipurile de magme gabbrodioritice, gabbroide și leucogabbroide ; doar gnaisele amfibolice ar corespunde unei magme neutre, dioritice. Caracterul tuturor este puternic calcoalcalin, cu $Na \geqslant K$.

Diferențele în chimismul amfibolitelor cu epidot și al gnaiselor epidotice sînt, în primul rînd, efectul constituției mineralogice a rocilor magmatice inițiale, mai ales în privința raportului dintre mineralele melanocrate și cele leucocrate ; amfibolitele cu epidot s-au format din roci care inițial erau constituite preponderent din piroxeni și hornblendă, în general bogați în Fe, feldspatul plagioclaz participînd în cantitate subordonată, pe cînd rocile din care s-au format gnaisele epidotice conțineau feldspați plagioclazi în cantitate mare.

Pentru explicarea chimismului gnaiselor amfibolice trebuie admisă și participarea materialului sedimentar pelitic.

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Diferențele chimice între amfibolitele cu epidot din cele două benzi, evidențiate în principal prin valorile diferite ale parametrului *mg* și conținuturile de Cr și Ni, sînt probabil rezultatul unor variații laterale și nu al aparținerii lor de orizonturi stratigrafice diferite.

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ROCHES AMPHIBOLIQUES D'IACOBENI (CARPATHES ORIENTALES) ET LEUR GENÈSE

(Résumé)

Les roches amphiboliques, affleurent sur le versant droit de Bistrița Aurie, entre le ruisseau de Suhărzelul Mare, sur les deux flancs d'une structure anticlinale à direction nord-sud, appartenant au même horizon stratigraphique. Dans

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la masse des roches amphiboliques, représentées par des amphibolites à épidote, gneiss épidotiques et gneiss amphiboliques, il y a de nombreuses intercalations lenticulaires de schistes et gneiss micacés ± magnétite. Les amphibolites à épidote se développent principalement dans le versant est et la partie inférieure du versant ouest, alors que les gneiss à épidote ont une grande distribution dans la partie supérieure du versant ouest ; les gneiss amphiboliques apparaissent sous forme d'intercalations, surtout dans le versant est. Les aspects minéralogiques, structuraux et texturaux actuels des roches amphiboliques sont le résultat d'une évolution métamorphique prolongée à plusieurs phases : un métamorphisme régional progressif dans les conditions du faciès almandin amphibolitique, suivi d'intenses processus de rétromorphisme, sur lequel se superpose un nouvel métamorphisme progressif à développement limité, durant lequel amphiboles, albite, biotite et grenat almandin-spessartinique ont recristallisé. Au cours du dernier métamorphisme, qui correspond au sous-faciès quartz-albite-épidote-almandin du faciès des schistes verts, on ne s'est pas réalisé un équilibre minéralogique complet, elles se conservant sous forme de relictes du métamorphisme plus ancien (feldspath plagioclase, hornblende et grenat). Cette évolution complexe a mené à la destruction des caractères structuraux et texturaux prémétamorphiques des roches initiales, en rendant difficile la détermination de leur genèse.

La forme et la nature des contacts avec les roches environnantes et l'association avec les roches typiques de géosynclinal (métapélites, métagrauwackes) sont des arguments pour la formation des roches amphiboliques au dépens des roches magmatiques extrusives représentées des coulées de lave et des tufs.

Une grande partie de l'article est affectée à l'étude chimique comparative, employant un bon nombre de compositions chimiques moyennes correspondantes aux divers types de roches et diagrammes de variation des contenus, proposés par d'autres auteurs. Cet étude a relevé que les amphibolites à épidote et les gneiss épidotiques correspondent spécialement aux ortoamphibolites résultées des roches magmatiques neutres-basiques (amphibolites à épidote) et basiques (gneiss épidotiques), toutes appartenant aux types de magmas gabbrodioritiques, de gabbroïdes et leucogabbroïdes ; les gneiss amphiboliques corresponderaient à un magma neutre, dioritique. Leur caractère est fortement calcoalcalin.

Les différences du chimisme des amphibolites à épidote et des gneiss épidotiques sont premièrement l'effet de la constitution minéralogique des roches magmatiques initiales, surtout pour ce qui est du rapport entre les minerais mélanocrates et ceux leucocrates ; les amphibolites à épidote se sont formées des roches qui initialement étaient constituées dans la majeure partie des pyroxènes et des amphiboles, en général riches en Fe, le feldspath plagioclase participant en quantité subordonnée, bien que les roches d'où ont engendré les gneiss épidotiques comportaient du feldspath plagioclase en grande quantité. Les diagrammes illustrant cet état des choses indiquent une composition du feldspath plagioclase des roches basiques initiales correspondante au labradorite (approximativement de 50 à 70% An). Pour expliquer le chimisme des gneiss amphiboliques il faut également prendre en considération la participation du matériel sédimentaire pélitique.

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EXPLICAȚIA PLANȘELOR

Planșa I

Fig. 1. — Amfibolit cu epidot. Valea Ciotina. N +; × 60.
Amphibolite à épidote. Valea Ciotina. N +; × 60.

Fig. 2. — Amfibolit cu epidot. Valea Ciotina. N +; × 25.
Amphibolite à épidote. Valea Ciotina. N +; × 25.

Fig. 3. — Magnetit scheletiform în amfibolit cu epidot. Valea Ciotina. N +; × 60.
Magnétite squelettiforme en amphibolite à épidote. Valea Ciotina. N +; × 60.

Fig. 4. — Cristale relicte de hornblendă și feldspat plagioclaz în amfibolit cu epidot. Valea Runcu. N +; × 25.
Cristaux relictes de hornblende et feldspath plagioclase en amphibolite à épidote. Valea Runcu. N +; × 25.

Planșa II

Fig. 1. — Gnais epidotic. Valea Ciotina. N +; × 25.
Gneiss épidotique. Valea Ciotina. N +; × 25.

Fig. 2. — Gnais epidotic (bandă melanocrată). Valea Haju. N +; × 60.
Gneiss épidotique (bande mélanocrate). Valea Haju. N +; × 60.

Fig. 3. — Cristale de albit cimentate cu calcit, în gnais epidotic. Valea Haju. N +; × 60.
Cristaux d'albite cimentés avec du calcite, en gneiss épidotique. Valea Haju. N +; × 60.

Fig. 4. — Gnais amfibolic. Valea Ciotina. N +; × 60.
Gneiss amphibolique. Valea Ciotina. N +; × 60.

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METAMORPHIC HISTORY OF THE UZUM BAIR FORMATION [1]

BY

ANTONETA SEGHEDI [2], VERONICA URICARU [3]

Micaschists. Gneisses. Pegmatites. Polymetamorphism. Amphibolitic facies. Metamorphic conditions. Precambrian. Dobrogea-North Dobrogea-Tulcea and Consul-Niculiţel Zone.

Sommaire

Evolution métamorphique de la formation d'Uzum Bair. La formation d'Uzum Bair affleure dans l'unité de Tulcea de la Dobrogea du Nord et elle est constituée de micaschistes à disthène, comportant des bandes de paragneiss et pegmatites à muscovite et grenat. Les roches ont été antérieurement considérées en tant que cornéennes au profit des dépôts siluriens. La formation d'Uzum Bair est polymétamorphe, une étape de métamorphisme du faciès des amphibolites à almandin étant suivie de deux événements métamorphiques successives, marquées par une paragenèse à muscovite-biotite, sur laquelle se superpose une nouvelle génération de muscovite. La formation d'Uzum Bair comprend des roches à une évolution métamorphique fort complexe de l'unité de Tulcea et représente probablement le Précambrien de cette unité.

The Uzum Bair Formation is exposed on a restricted area within the Tulcea Unit (North Dobrogea), on the northern slope of the Uzum Bair Hill (Figure). Atanasiu (1940) described here biotite micaschists, while Murgoci (1914) considered them sericite schists and phyllitic hornfelses. Ianovici et al. (1961) assigned the same rocks to the phyllite-quartzitic series (Cambrian?-Ordovician) ; Mirăuţă (1966) described them as aluminium silicate-bearing micaceous hornfelses, formed at the ex-

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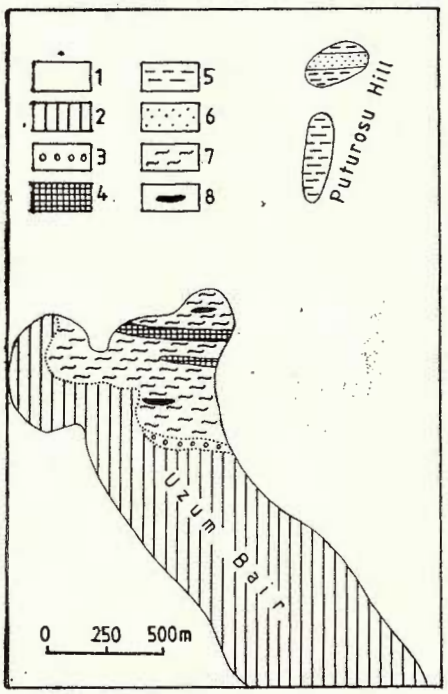
[2] Institutul de Geologie şi Geofizică, str. Caransebeş 1, 78344 Bucureşti.

[3] Întreprinderea de Prospecţiuni Geologice şi Geofizice, str. Caransebeş 1, 78344 Bucureşti.

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pense of Silurian phyllites under the termal influence of synkinematic granites.

The Uzum Bair Formation consists of kyanite-bearing micaschists, thinly interlayered with biotite gneisses and muscovite-garnet- and



Geological sketch of the Uzum Bair-Puturosu hills.
1, loess ; 2, Ladinian-Carnian limestones ; 3, red arkosic conglomerates ; 4, rhyolites ; 5, black slates ; 6, black quartzites and phyllites ; Uzum Bair Formation ; 7, kyanite-bearing micaschists, paragneisses ; 8, pegmatites.

tourmaline-bearing pegmatites. These rocks are intruded by several dykes of mylonitic rhyolites, taken as granites (Mirăuţă, 1966). The loess deposits on the northern slope of the Uzum Bair Hill obscure the relationships with the Silurian deposits. Southeastwards, the micaschists are reddish due to the overlying red conglomerates and arkosic sandstones ascribed to the Permian in Verrucano facies (Murgoci, 1914), to the Werphenian (Atanasiu, 1940 ; Ianovici et al., 1961 ; Mutihac, 1964) or to the Ladinian-Carnian (Mirăuţă, 1966). To the southwest the micaschists are unconformably overlain by mainly carbonatic Ladinian-Carnian deposits (Mirăuţă, 1966).

The Uzum Bair Formation is polymetamorphic : it was subjected to a medium-grade, medium-pressure type metamorphism, followed by two successive stages of low-grade metamorphism.

Garnet (in pegmatites) and kyanite (in micaschists) are relics of an early metamorphic event. Garnet is altered to chlorite, while kyanite is usually completely altered to grey pinitic aggregates with oriented plates of opaque inclusions. Kyanite relics are scarcely preserved in the pinitic matrix (Pl. I, Fig. 1).

The dominant metamorphic foliation (S_2) results from alternating layers of quartz and fine-grained muscovite or biotite. When crossing

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the pinitic aggregates the phyllosilicate layers obviously result at the expense of the latter. S_2 foliation is strongly crenulated (Pl. I, Figs. 2, 3) and deformed by symmetrical microfolds (Pl. II, Figs. 1, 2); locally a new generation of muscovite lamellae grows axial-planar to these microfolds (Pl. II, Fig. 2). This new generation of muscovite occurs as large, oriented, sometimes poikiloblastic flakes, mainly when they grow at the expense of some pinitic aggregates with unknown origin, due to the complete lack of any metamorphic relics.

Structural and mineralogical features of the Uzum Bair micaschists reveal a more complex metamorphic and deformational history than a contact metamorphism superposed over low-grade metamorphic rocks (quartzites and phyllites) of the Rediu Formation. Anyway, the nearest granite bodies of the Tulcea Unit crop out 4 km southwards, in the Cazalgic Bair Hill, the geophysical evidence suggesting their northeastward extension (Ştefan, Popovici, 1970). The following statements may be used to ascribe the Uzum Bair Formation to the Precambrian: Lower Paleozoic formations of the Tulcea Unit exhibit a very low-grade metamorphism; a possible progressive southward increase in their metamorphic grade (not supported by field evidence) could not account for the superposed metamorphic events in the Uzum Bair Formation; meanwhile, black slates of the Rediu Formation are exposed in the Puturosu Hill, 300 m north of micaschists. K-Ar ages of the Monument phyllites (Giuşcă et al., 1967), if not resetted, point to a Lower Cambrian metamorphic event in the Tulcea Unit. If the last metamorphic event within the Uzum Bair Formation is at least Cambrian, amphibolite facies minerals could have resulted during the Precambrian.

The relationships between the Uzum Bair and Rediu formations (Patrulius et al., 1973), are hidden under the loess cover. The occurrence of the micaschists in the vicinity of Silurian slates could be explained either as the uprise of the micaschists along an EW trending fault (Mirăuţă, 1966) or as a result of EW folding (Uzum Bair Formation lying in an anticline core while the Rediu Formation is exposed in a syncline). Since the Paleozoic structures in the Horia and Rediu hills have EW trends and plunge eastward (Mirăuţă, 1966), a tectonic contact between these formations seems more likely.

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EXPLANATION OF PLATES

Plate I

Fig. 1. — Kyanite relic in a pinitic matrix. N +, 30 ×.

Fig. 2. — Crenulation cleavage intensely deforming S_2 foliation and pinitic aggregates in micaschists. N ||, 20 ×.

Fig. 3. — Crenulation cleavages (S_3) deforming S_2 foliation N ||, 20 ×.

Plate II

Fig. 1. — F_3 microfolds deforming S_2 foliation.

Fig. 2. — Deformation of the S_2 foliation and blastesis of the muscovite lamellae parallel to the axial planes of the F_3 microfolds. N ||, 30 ×.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

PETROLOGIA ROCILOR SEDIMENTARE

NEW CHEMICO-MINERALOGICAL DATA ON THE BAUXITES IN THE GALBENA VALLEY BASIN (BIHOR MOUNTAINS) [1]

BY

VICTOR CORVIN PAPIU [2], GHEORGHE MANTEA [2], VASILE IOSOF [3], SILVIA MÎNZATU [2], CONSTANȚA UDRESCU [3], FLORICA POPESCU [2], VASILICA NEACȘU [3]

Ferric and ferrous bauxites. Neocomian. Oncoid limestone. Mineralogic composition. Clay minerals. Diaspore. Chemical composition. Major elements. Minor elements. Petrochemistry. Ore deposits genesis. Laterite. Apuseni Mountains-South Apuseni Mountains-Central Bihor massif.

Sommaire

Nouvelles données chimico-minéralogiques sur les bauxites du bassin de Valea Galbena (Monts du Bihor). Les bauxites karstiques d'âge crétacé inférieur (faciès wealdien) du bassin de Valea Galbena (Monts du Bihor, Roumanie) sont logées à la limite d'entre les calcaires néojurassiques récifaux (en mur) et les calcaires éocrétacés (en toit) de „l'Autochtone de Bihor". Ces roches sont constituées de diaspore, kaolinite, oxydes ferriques (hématite, goethite), chlorites ferrifères, à adjonctions subordonnées d'anatase et rutile. Ainsi que les autres bauxites de ce type du territoire de la Roumanie, les bauxites de Valea Galbena se séparent, vu la valeur du rapport $Fe_2O_3 : FeO$, en trois groupes : ferrique, ferro-ferrique et ferreux. La teneur en fer ferrique et total diminue allant des bauxites ferriques aux bauxites ferreuses, en rapport inverse avec la teneur en fer bivalent et en silice, composants dont la présence est redevable au magmatisme banatitique. Génétiquement, on admet que les bauxites ferriques correspondent au sédiment primaire, formé par précipitation en des eaux karstiques, tandis que le caractère chimico-minéralogique des bauxites ferreuses est secondaire, dû au faible métamorphisme thermique et à l'apport de la silice hydrothermale.

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București.

[3] Întreprinderea de Prospecțiuni Geologice și Geofizice, str. Caransebeș 1, 78344 București.

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This paper presents the chemico-mineralogical and petrographical features of the bauxites in the western part of the Central Bihor area, rendered evident by the authors of this work (Mantea et al., 1981).

Among the previous researches mention should be made of those carried out by Peters (1861), Szontagh, Palfy and Rozlozsnik (1911) as well as of the prospecting and exploration workings on the bauxite deposits effectuated lately by IFLGS and Puricel et al. (1975). Recent studies on the qualities of the central Bihor bauxites and those referring to the stratigraphical and structural survey of the carbonatic formations in the hanging wall and foot wall of the bauxites belong to Papiu et al. (1968) and Mantea et al. (1980, 1981). Papiu et al. (1970) pointed out petrological considerations on two samples from the Galbena Valley collected by Bleahu.

I. Geological Setting

The formations entering into the geological constitution of the area under study are represented by Paleozoic and Mesozoic rocks which define major structural units of the northern Apuseni Mountains: the Bihor Autochthon and the Finiş-Ferice-Gîrda and Arieşeni units (Codru Nappes System). The Bihor Autochthon is formed exclusively of Mesozoic formations constituted especially of carbonatic deposits and shows the following lithostratigraphic sequence : Wetterstein-type limestones (Upper Illyrian-Cordevolian), Scărița Beds (Upper Triassic, defined by Patrulius in Ianovici et al., 1976), detrital formation in Gresten Facies (Hettangian-Lower Sinemurian), Gresten Limestone (Upper Sinemurian-Domerian), marly formation in Fleckenmergel Facies (Toarcian), Mediojurassic limestones in Fleckenkalk Facies, Neojurassic limestones comprising light-coloured, reefal, massive limestones of Stramberg Facies (Farcu Limestone — Oxfordian-Lower Tithonian) at the lower part, and grey-blackish, layered, oncoid-bearing limestones of 'lagoonal' facies (Albioara Limestones — Upper Tithonian). Neocomian bauxites, Eocretaceous limestones of "back-reef" facies displaying three microfacial separations : limestone with fenestral lamination, miliolid-bearing limestone and orbitolinid-bearing limestone, at the upper part ; the Eocretaceous succession ends with Ecleja Beds and is referred to the Berriasian-Bedoulian time-span.

The Finiş-Ferice-Gîrda Unit has been recognized in the left side of the Galbena Valley as well as in the Bulzul Valley and displays a succession of quartzitic sandstones, conglomerates, clay shales and schistous dolomites (Werfen Formation — Spathian-Lower Anisian), and an alternation of dolomites and dolobreccias with black micritic limestones and clay shales (Lower Anisian-Illyrian).

The Arieşeni Unit consists of Permian red-brick red detrital deposits, associated with quartziferous porphyries and overlies the Bihor Autochthon and the Finiş-Ferice-Gîrda Nappe. Both the Bihor Auto-

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chthon and the units of the Codru Nappes System are affected by a disjunctive tectonics which determines the appearance of compartments uplift in N-E and sunk in S-W. This ruptural tectonics reveals a "Saxon"-type structure due particularly to the competent character of the limestones, a main component of the Mesozoic formations.

II. Occurrence and Morphology of the Bauxite Deposits

Bauxites appear as lenses situated at the boundary between the Terminal Jurassic and Lower Cretaceous limestones. They lie on a bed consisting of Albioara-type oncoid limestones and are overlain by Eocretaceous dismicritic limestones. Bauxites are encompassed in karstic depressions which occurred as a result of a superficial corrosion. The bauxite bodies are lenticular, plane-convex or cone-shaped, and have an irregular surface. Endokarstic cavities, with a discoidal shape, of reversed horn (Aston type) or with a lobate or branched outline and vertical walls (Caguanes type) have also been found (Jimenez, 1967 ; Pop, Mîrza, 1977). The bauxite lenses have a diameter of 30-40 m and a thickness of 2-2.5 m.

The contact surface between the Neojurassic and Eocretaceous limestones is not uniformly even. As bauxites are arranged not only on the upper part of the Tithonian but also irrespective of it, the complex character of the Neocimmerian tectonic movements should be admitted in the sense that they no longer had an epirogenetic character. The dezaggregation processes of the primary bauxites led to the appearance of bauxitiferrous materials, located both around the ore deposits and at appreciable distances.

III. Petrographical Features

After colour, the bauxites in the Galbena Valley basin are divided into red, cherry-coloured and brown-cherry-coloured bauxites. The cherry-coloured and red bauxites appear generally fresh and are similar to the bauxites of type 1 (Bihor 1) of the Galbena Valley (Papiu et al., 1970). The collomorphous, diasporic strongly ferruginous mesostasis makes difficult the recognition of the oöidal structure and only in cases when oöids have a diasporic peripheric crust. The oöids display various sizes ranging between 1.5 mm ∅ and 0.1 mm ∅, in places smaller, of a circular shape, oval or even deformed (spastoidized). The mesostasis-oöid ratio varies from 1 : 1 to 1 : 2. Generally, oöids have a simple composition, deprived of a concentric structure specific to the bauxites in the Pădurea Craiului Mts. The monomineral oöids are generally hematitic, with sizes ranging between 2.5 mm ∅ and 0.5 mm ∅. In places, hematite is found as angular grains. Fissures of circular contraction on which diaspore deposited are observed within the men-

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tioned oöids. The monomineral, diasporic oöids are very rare and of reduced sizes (about 0.4 mm ∅). The bimineral oöids usually display a hematitic centre and a collomorphous, diasporic peripheric crust, the reversed situations (diasporic-collomorphous centre and hematitic periphery), being more seldom found. The complex oöids, with a diaspore mass, with 2-3 hematitic nuclei, are also rare. In cases of local deferrization a slight recrystallization of the mesostasis occurs and the oöid diaspore is in a phase of transition from the collomorphous state to the cryptocrystalline one. The leached iron concentrates on fissures in the form of hematite or fibro-radial goethite. Fragments of oöids and of bauxites, intraformationally reworked, become visible also due to the deferrization. Grains of rutile, found on fissures and oöids, as well as of gibbsite developed in geode-shaped spaces, have been recognized. In places, the fissures with anastomosing aspect are filled with limpid, crystallized diaspore related to gibbsite and rutile and sometimes with anatase. When these fissures are larger, drusy, their walls are lined with prismatic, fine diaspore proliferating towards the centre filled with kaolinite. Other fissures are filled only with calcite. The rock fissuration took place after an approximately parallel system, probably as a result of mechanic pressures with one way action. The fine-crystallized diaspore fills some fissures.

Sometimes the brown-reddish bauxites display a constitution analogous to that of the cherry-coloured-reddish bauxites with small differences (in which case they correspond to the ferroferric type). Mesostasis, also diaspore-ferruginous, is less opaque. The oöidal structure is well represented by the same types of oöids, similar to those from the cherry-coloured bauxites. The fissures are frequently filled with light green-bluish, up to colourless chlorite related to a less extent to diaspore and rutile ; in places these fissures are filled with hematite resulting from the deferrization process. Provided that this process affects relatively uniformly the rocks, the colour becomes red through the decolouring of the mesostasis. Within oöids, hematite is also involved on the surrounding fissures, microscopically occurring in the form of prolongations joining the hematite mass.

IV. Chemico-Mineralogical Constitution

Our study was effectuated on the basis of analyses on 12 bauxite samples whose origin is indicated in Table 1 and the annexed geological map.

The determinations consisted of complete chemical (Table 2), roentgenographic and thermodifferential analyses ; the determination of the mineralogical constitution was made on the basis of the correlation of the mentioned data. Table 4 presents variation and average values and Table 5 shows the results of the spectrographic analyses carried out on minor elements.

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TABLE 1

Origin of the samples in the Galbena Valley area

Sample no.	
1. 4A = Măgura Seacă 2. 366 = Banciul Valley 3. 4 = Măgura Seacă	Ferric bauxites
4. 2A = Poiana Plaiului 5. 85 = Galbena Valley 6. 95 = Poiana Florilor 7. 2 = Poiana Plaiului	Ferroferric bauxites
8. 86 = Poiana Florilor 9. 1 = Bulzul Valley 10. 196 = Zăpodie 11. 3 = Bulzul Valley 12. 3A = Bulzul Valley	Ferrous bauxites

TABLE 2

Chemical composition of the bauxites in the Galbena Valley area

	Ferric			Ferroferric				Ferrous				
Sample/ element	4a	366	4	2 a	85	95	2	86	1	196	3	3 a
SiO_2	1.60	2.70	1.80	4.60	1.60	2.90	5.40	3.30	4.85	5.60	9.40	5.90
Al_2O_3	40.20	56.90	52.50	55.30	59.50	61.35	55.00	51.00	55.19	52.10	52.90	58.10
Fe_2O_3	43.53	26.48	30.06	23.89	24.64	20.41	23.21	29.79	21.97	22.25	17.35	14.02
FeO	0.31	0.37	0.67	0.71	0.82	0.76	1.19	2.12	2.44	4.64	4.27	5.52
MnO	0.03	0.08	0.03	0.02	0.02	0.02	0.02	0.09	0.04	0.08	0.03	0.04
MgO	0.09	0.52	0.11	0.25	0.05	0.07	0.29	0.18	0.31	0.25	0.64	0.38
CaO	0.16	0.11	0.12	0.10	0.09	0.11	0.11	0.17	0.10	0.14	0.25	0.15
Na_2O	0.11	0.11	0.11	0.07	0.09	0.10	0.05	0.10	0.08	0.09	0.06	0.10
K_2O	0.03	0.02	0.04	0.04	0.01	0.01	0.03	0.01	0.02	0.01	0.02	0.02
TiO_2	2.20	2.80	2.60	2.74	2.80	3.08	2.74	3.08	2.60	2.80	2.64	2.72
P_2O_5	0.16	0.02	0.08	0.03	0.04	0.02	0.04	0.04	0.04	0.04	0.06	0.02
S	0.10	0.06	0.08	0.06	0.07	0.09	0.06	0.05	0.05	0.08	0.06	0.05
Fe(S)	0.09	0.05	0.07	0.05	0.06	0.08	,05	0.04	0.04	0.07	0.05	0.04
H_2O^+	12.20	10.59	12.57	12.31	10.80	11.20	11.67	9.84	11.84	11.41	12.86	12.81
Total	100.81	100.79	100.84	100.17	100.79	100.20	99.86	99.72	99.57	99.56	100.59	99.62
Fe_2O_3T	44.00	26.95	30.90	24.75	25.65	21.36	24.60	32.20	24.75	27.90	22.16	20.21
Fe_2O_3/FeO	37.9	32.5	20.2	15.1	13.5	12.05	8.8	6.3	4.4	2.2	.1.8	1.1
Al_2O_3/SiO_2	25.1	21.8	29.2	12.0	33.0	21.2	10.2	15.4	11.4	9.30	5.6	9.8

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TABLE 3

Mineralogical composition of the bauxites in the Galbena Valley area

Sample element	Ferric			Ferroferric				Ferrous				
	4 a	366	4	2 a	85	95	2	86	1	196	3	3a
Diaspore	45.7	64.3	60.1	60.6	68.3	69.4	59.5	55.9	60.5	56.6	53.5	63.5
Kaolinite	2.9	5.2	2.7	8.7	2.5	4.9	9.6	3.5	6.3	4.1	10.8	3.3
Chlorite	0.9	1.0	1.9	2.0	2.3	2.2	3.4	6.0(7)	6.9	13.2(14)	12.1(14)	15.7(14)
Hematite	5.0	26.4	4.0(7)	12.0(7)	24.6	20.3	13.0	29.6	21.7	21.8	2.0	6.0
Goethite	42.3	—	28.6	12.9	—	—	12.0	—	—	—	15.3	8.2
Pyrite	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Anatase	2.2	2.8	2.6	2.7	2.8	3.1	2.7	3.1	2.6	2.8	2.6	2.7
Fe_2O_3/FeO	37.9	32.5	20.2	15.1	13.5	12.0	8.8	6.3	4.0	2.2	1.8	1.1

(7) = septechlorite (7Å)
(14) = chlorite 14 Å

TABLE 4

Variation limits and averages of the bauxites in the Galbena Valley area

Sample element	Ferric (3 samples)		Ferroferric (4 samples)		Ferrous (5 samples)	
	Variation limit	Average	Variation limit	Average	Variation limit	Average
SiO_2	1.6— 2.7	2.0	1.8— 5.4	3.7	3.3— 9.4	5.8
Al_2O_3	40.2—56.9	49.9	55.0—61.3	57.8	51.0—58.1	53.4
Fe_2O_3	26.5—43.5	33.3	20.4—24.6	23.0	14.0—29.8	21.1
FeO	0.31—0.67	0.45	0.7— 1.2	0.87	2.1— 5.5	3.8
Fe_2O_3T	26.9—44.0	33.9	21.6—25.6	24.1	20.2—32.2	25.4
TiO_2 (anatase)	2.2— 2.5	2.5	2.7—3.1	2.8	2.6— 3.1	2.8
Diaspore	45.7—64.3	56.7	59.5—69.4	64.4	53.4—63.5	58.0
Kaolinite	2.7— 5.2	3.9	2.5—9.6	6.4	3.3—10.8	5.6
Hematite+	26.4—47.3	35.4	20.6—25.2	23.8	14.2—21.8	20.9
Goethite	0.9— 1.9	1.3	2.0—3.4	2.5	6.0—15.7	10.8
Fe_2O_3/FeO	37.9—20.2	30.2	15.1— 8.8	12.5	6.3— 1.1	3.1
Al_2O_3/SiO_2	39.2—21.8	25.4	10.2—33.0	19.0	5.6—15.4	10.3

1. *Geochemical features* (Fig. 1). The bauxites under discussion, like those in the Apuseni Mountains, fall into three geochemical groups according to the value of the $Fe_2O_3 : FeO$ ratio, as follows : ferric bauxites (more than 20 ; 3 samples), ferroferric bauxites (20-8 ; 4 samples) and ferrous bauxites (less than 8 ; 5 samples).

As in case of other bauxites, besides water, silica and the oxides of the triad specific to bauxites, Al-Fe-Ti represent the only supra-unitary chemical components, the other elements being subunitary. Their variation limits are those characteristic of all the karstic bauxites.

Between 0.1-1% almost in all samples occur magnesium (MgO) related to chlorite, calcite (CaO) correlable with the calcareous rocks

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TABLE 5

Minor elements contents (ppm) in the bauxites of the Galbena Valey area

	Sample no.	Ga	Sn	Ni	Co	Cr	V	Sc	Nb	Zr	Be	Mn	Ba	Sr	Li	Pb	Cu
Ferric bauxites	4a	43	6.5	165	22	260	520	26	56	560	7.3	290	13	<10	<10	82	19
	366	44	9	85	12.5	340	360	53	97	770	10.5	660	24	<10	<10	97	17.5
	4	36	8.5	112	18	260	450	29	65	670	9	310	17	10	18	58	22
Ferroferric bauxites	2 a	52	10	145	44	400	375	49	72	760	7.2	270	38	16	63	72	12
	85	51	8	84	9	310	420	44	62	660	7	22	18	13	<10	80	17
	95	50	9	110	13	440	265	51	105	750	9.5	185	25	<10	37	72	10
	2	44	11	163	39	405	370	44	84	880	6.3	200	35	18	72	97	22
Ferrous bauxites	86	45	8	110	11	320	370	45	63	650	6.5	680	56	12.5	68	110	10
	1	44	10	116	10.5	325	640	55	75	770	7	440	68	33	62	97	18
	196	48	9	120	13.5	290	410	51	84	680	6.2	700	70	13	88	125	10
	3	45	8	120	12	240	410	53	69	780	6.2	275	110	24	86	47	9.5
	3 a	52	10	96	23	280	330	56	57	700	9	435	35	12	83	52	10.5
$\bar{X}$ Ferric bx		41	8	120.7	17.5	287	443	36	72.7	667	8.9		18	<10		79	19.5
$\bar{X}$ Ferroferric bx		49	9.5	125.5	26.2	388	357	47	80.7	762	7.5		29	14.2		82.7	15.2
$\bar{X}$ Ferrous bx		46.8	9	112.4	14	291	432	52	69.6	716	7		67.8	18.9		86	11.6

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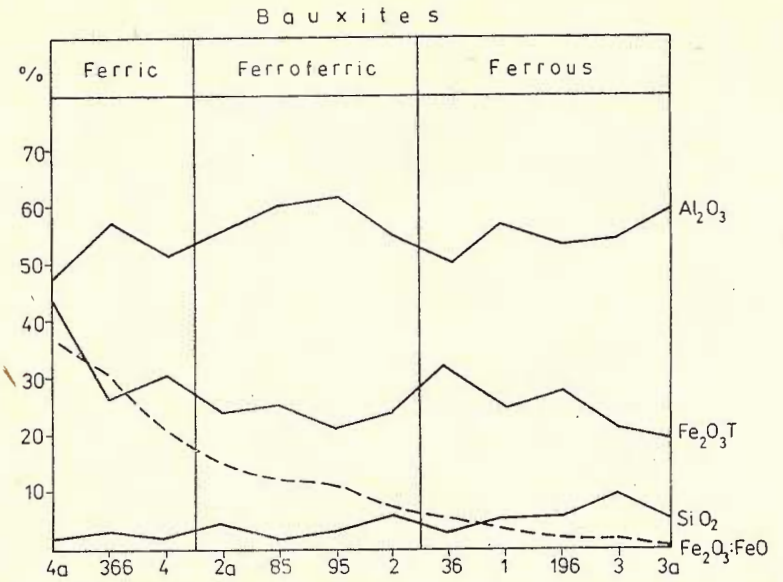


Fig. 1. — Correlation between alumina, total iron, silica and Fe_2O_3:FeO ratio.

including bauxites (comprised into gels or diagenetically or hypergenetically). In half of the samples sodium (Na_2O) retained probably absorptivily in the aluminium gels represents about 0.1%. The other components are found in percentages of thousands order : MnO, P_2O_5 (with one exception), K_2O (practically indicating the lack of illites) and sulphur whose presence, in all samples, indicates the existence of pyrite, being correlable with an equivalent percentage of Fe(S).

As regards the main components of bauxites several conclusions are inferred.

Alumina, originating first in diaspore (obvious direct correlation) and then in clay minerals, shows variation limits of the same order silica, whose values vary from 1.6 to 9.4%, a gradual decrease of the ferric alumina (50%), followed by the ferrous one (53%), and culminates with the ferroferric type (58%). Without any detail correlation with silica, whose values vary from 1.6 to 9.4%, a gradual decrease of the value of its module ($Al_2O_3 : SiO_2$) from the ferric (average 25.4) through the ferroferric (average 19.0) to the ferrous ones (average 10.3) can be recognized, favourable values in the dressing process.

There is an obvious reversed ratio between alumina and the content in total iron (Figs. 1 and 2), like in the Neocomian bauxites in the Pădurea Craiului Mts, as well as between the ferric iron (Fe_2O_3) and the content in diaspore — the principal aluminous mineral (Fig. 4). The amount of total iron is with ten units higher in the average of the ferric bauxites as against in that of the ferroferric ones, whose content is close to that of the ferrous bauxites (34%-24%-25.4%) ; it would roughly suggest a reversed ratio between total iron and silica.

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A reversed ratio is, however, obvious between the trivalent and bivalent forms of the iron. In the ferric bauxites the content in ferric iron almost superposes the total iron content ; in the ferroferric bauxites

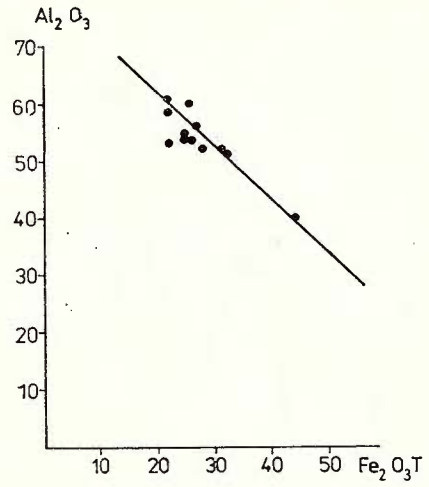


Fig. 2. — Binary diagram with the correlation between alumina and total iron.

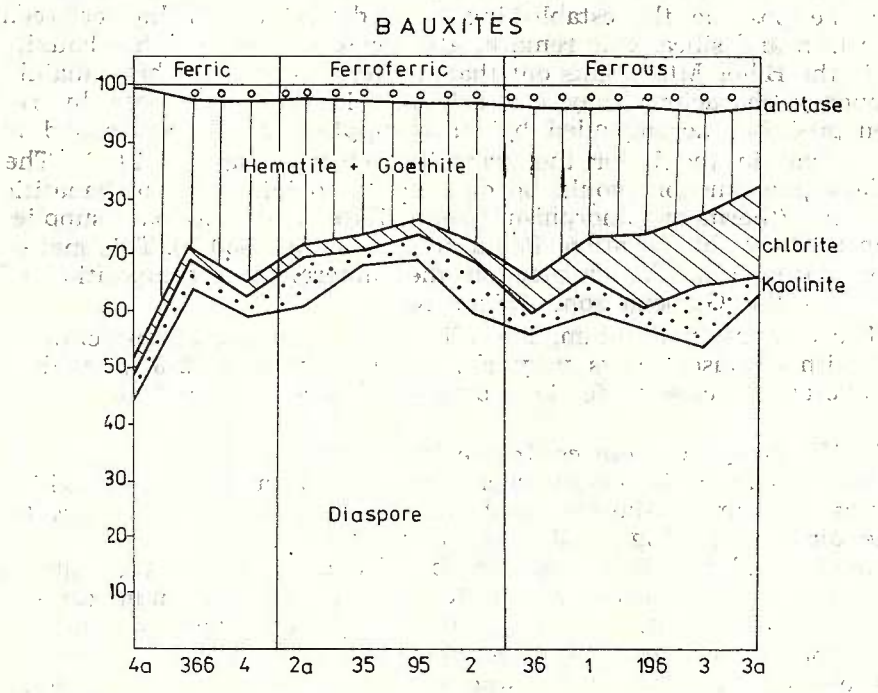


Fig. 3. — Cumulative diagram with the mineralogical constitution

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it is lower and in the ferrous ones obviously subordinate by the sensible increase of the ferrous iron percentage. This observation correlated with the increase in the same direction of the content in silica (Fig. 1)

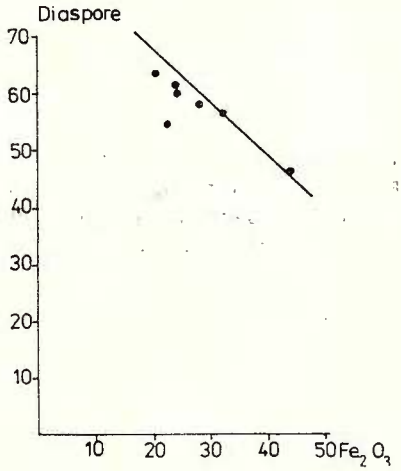


Fig. 4. — Binary diagram : diaspore-total iron.

is reflected in the mineralogic constitution, that is in the decrease of hematite and goethite from the ferric to the ferrous bauxites, compensated by the increase of the content in chlorite. All the mentioned data make possible the establishing of a direct relationship between ferrous iron and silica. Our remark, also made in case of other bauxite zones in the Bihor Mts, points out that the ferrous bauxites have mainly a secondary character ; they can originate in the ferric ones by reduction processes accompanied by silica supplies, which correspond to the fact that in the latter the prevailing chlorites are of 14 Å. The secondary phenomenon would be due, in our opinion, to the banatitic magmatism (thermometamorphism and silica hydrothermal supplies accompanied by chloritization, Papiu et al., 1980 a, 1980 b). This matter will be resumed in the chapter on the mineralogical composition of bauxites in the Galbena zone (Bihor Mts).

The content in titanium, like all karstic bauxites, almost entirely linked with anatase, shows very close values (between 2-3%), with a lower average in case of ferric bauxites (2.5% as against 2%).

2. *Mineralogical features.* In the Bihor Mts (Tables 3, 4) the composition of bauxites is mainly represented by diaspore (Fig. 3) which fixes most of alumina, the curves of alumina and diaspore being parallel on the diagram in Figure 3. This mineral has the same order of magnitude in all the three types of bauxite and displays the highest average in case of ferroferric bauxites (64.4%), the maximum content representing almost 7%, a figure which brings it together with a sample from the Galbena area, mentioned by us in a previous paper. Unlike one of the two samples studied in that paper, as in the other bauxites in the Bihor Mts, boehmite has not been recognized in the

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analysed samples, which corresponds to the slightly metamorphic character of these rocks. Figure 3 also indicates the reserved relationships between the iron oxides and chlorite, as well as the independence of the content in kaolinite as against the other minerals. The content in

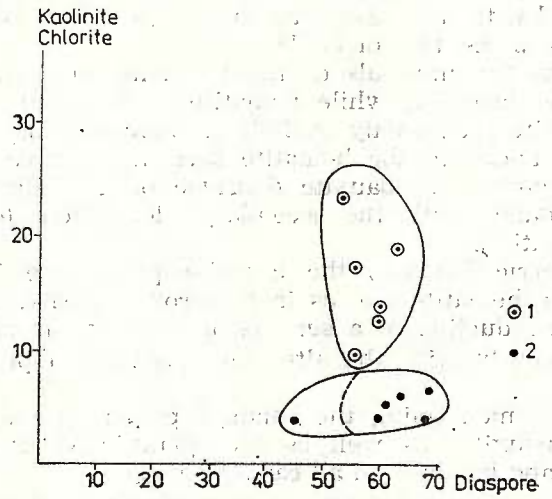


Fig. 5. — Binary diagram with the diaspore-(kaolinite+chlorite) correlation.
1, ferrous bauxites ; 2, ferric and ferroferric bauxites.

iron oxides decreases whereas chlorite increases (synchronously with silica and bivalent iron), the highest amounts of iron oxides (and lower amounts of chlorite) being found in the ferric bauxites and the highest percentages of chlorite and lower ones of oxides occurring in the ferrous bauxites.

A comparative binary diagram between the content in diaspore and that in clay minerals (kaolinite+chlorite) (Fig. 5) correlated with Table 3 indicates :

— for similar diaspore contents (55-70%) correspond fairly various percentages of clay (5-25%) ;

— ferric and ferroferric bauxites concentrate in a restricted field : 60-70% diaspore (with two exceptions) and 3-7% clay minerals (with one exception), whereas in case of ferrous bauxites for a variation domain quite restricted in case of diaspore (53-63%), the spreading of the values of the clay minerals is higher and superior to the ferric and ferroferric ones (9-24%). In our opinion it would point to the correlation of the chemico-mineralogical constitution of bauxites with the silica amount intruded secondary in the rock concomitantly with the iron reduction process and the decrease of diaspore percentage or, in other words, the metamorphic derivation of chlorite from ferric (primary) bauxites from alumina and iron of the primary sediment and from hydrothermal silica. The same conclusion can also be inferred from the cumulative diagram illustrated in Figure 3.

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The process is similar for all bauxites in the Bihor Mts and has been presented in the above-mentioned papers. Chlorites from the Bihor bauxites have, therefore, two origins : in sedimentogene chlorite (septechlorites) in ferric and ferroferric bauxites, also some ferrous ones, and in chlorite of 14 Å only in ferrous bauxites, the minerals whose genesis is linked with the weak banatitic metamorphism (ferrous samples with the highest percentage of Fe^{++}).

As regards the minerals of the trivalent iron, mentioned should be made of the fact that while hematite is found in all the samples analysed, geothite occurs only in half of them and in amounts which, in some cases, added to the hematite percentages give values close to the hematite contents in bauxite deprived of goethite ; it points to a perfect concordance with the secondary derivation (exogene of the goethite in hematite).

In two ferric bauxites the goethite percentage is 8 or 7 times higher than the hematite one as in a ferrous bauxite. The question is whether the introduction of a surplus of ferric hydroxide of rock took place simultaneously with the alteration (hydration) process : hematite — goethite.

It is worth mentioning the smallest percentages of clay minerals in the ferric bauxites as well as the quantitative independence between chlorite and kaolinite in all cases (Fig. 3).

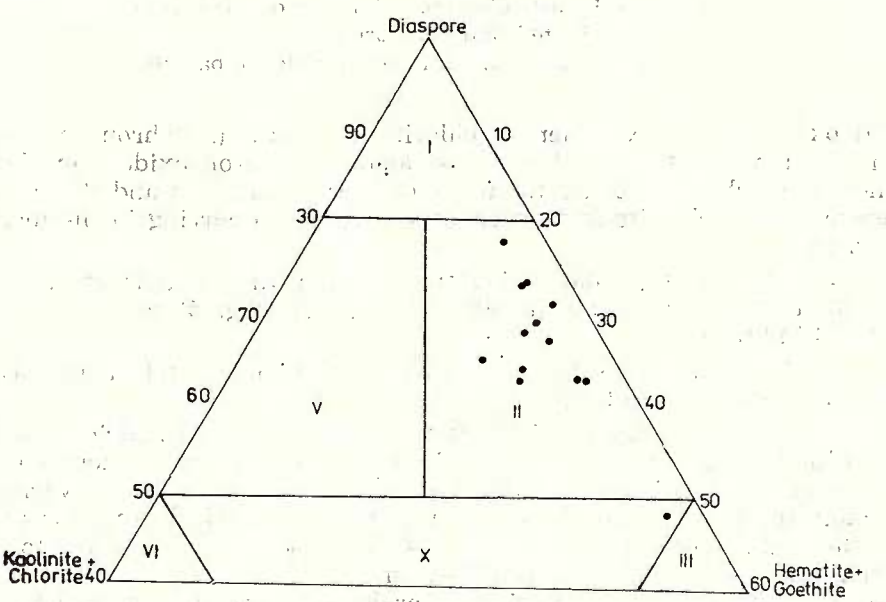


Fig. 6. — Ternary diagram : diaspore — (kaolinite+chlorite)-(hematite+goethite).

The content in anatase has been discussed in the chapter on chemism (TiO_2) as well as the presence and significance of pyrite (0.1%, subordinately 0.2%) in all bauxites under discussion.

In a ternary diagram on the contents in diaspore — clay minerals — hematite + goethite (Fig. 6) all rocks are referred to the ferri-

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ferrous bauxite (Ch. II), with one exception, which contains much iron, at the limit with bauxitic ferrolites.

A chemico-mineralogical comparison between the bauxites in the Galbena Valley area of the Bihor Mts and other bauxites on which several studies had been made leads to the significant analogies both constitutional and genetical. It is to be mentioned that the rocks presented here contain higher quantities of bivalent iron and are less siliceous. However, these differences are of a less importance.

V. Distribution of Minor Elements

The analytical data referring to the minor elements — Ga, Sn, Co, Cr, V, Sc, Nb, Zr, Be, Mn, Ba, Sr, Li, Pb, Cu — determined by emission spectroscopy are presented in Table 5. This table also includes the values of the arithmetical mean ($\bar{x}$) of the contents of minor elements in the three bauxite types : ferric, ferroferric and ferrous.

A comparison of the average values indicates that they are very close in all the three bauxite types, the differences being insignificant.

In case of Ba, Sr and Li there is a gradual increase of the contents from the ferric bauxites to the ferrous ones concomitantly with the increase of the participation of the clay minerals. The dependence

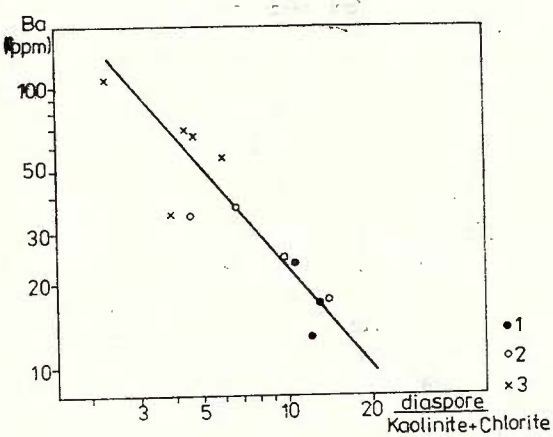


Fig. 7. — Binary correlation : Ba — (diaspore : kaolinite+chlorite).
1, ferric bauxites ; 2, ferroferric bauxites ; 3, ferrous bauxites.

of the Ba and Li contents on the amount of clay minerals is illustrated graphically on the diagrams in Figures 7 and 8 in which the Ba and Li values occur on the ordinate and the values of the diaspore/kaolinite+ +chlorite ratio on the abscissa.

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On the Cr-Be diagram (Fig. 9) the bauxites of study are plotted in the domain of the karstic bauxites, in a field mostly superposed on the field of the Central Bihor bauxites, the other part of the field being situated at lower Cr values. In the right-hand part of the diagram the field of the bauxites in the Galbena Valley is detailed, taking into account the chemico-mineralogical types.

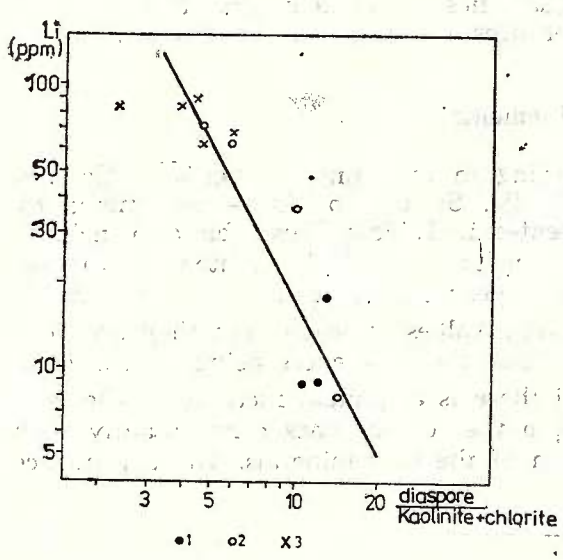


Fig. 8. — Binary correlation : Li-(diaspore : kaolinite + chlorite).

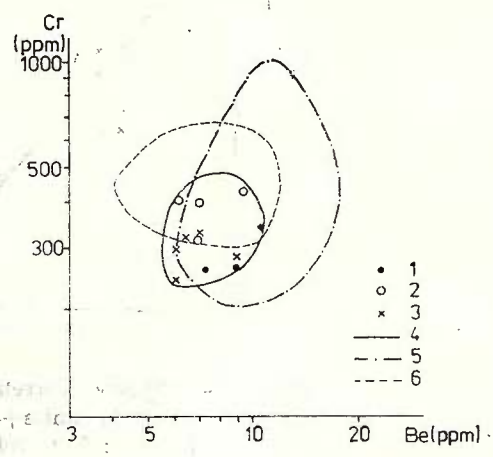


Fig. 9. — Comparative binary diagram with Cr-Be correlation (according to Schroll, 1964)

1, ferric bauxites ; 2, ferroferric bauxites ; 3, ferrous bauxites ; 4, Galbena Valley ; 5, Pădurea Craiului ; 6, Central Bihor.

A comparison of the bauxites in the study area with those in the Central Bihor (Table 6) reveals that although the variation domains of the minor elements from the bauxite in the Galbena Valley are generally included within those of the Central Bihor bauxites the average contents in Ga, Sn, Cr, and Zr are lower and those in Ni, V, Nb, Be are higher in the bauxites of the Galbena Valley.

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TABLE 6

Comparative table of the minor elements contents (ppm) in the bauxites of the Galbena and Central Bihor areas

Element	GALBENA						CENTRAL BIHOR			
	Ferric (n = 3)		Ferroferric (n = 4)		Ferrous (n = 5)		Ferric (n =18)		Ferrous (n = 9)	
	Δ	$\overline{X}$	Δ	$\overline{X}$	Δ	$\overline{X}$	Δ	$\overline{X}$	Δ	$\overline{X}$
Ga	36 — 44	41	44 —52	49	44 — 52	46.8	48 — 83	61	52 — 64	59
Sn	6.5— 9	8	8 —11	9.5	8 — 10	9	15 — 31	20.4	15.5— 25	18.9
Ni	85 —165	121	84 —163	125	96 —120	112	44 — 295	107	49 — 110	70
Co	12.5— 22	17.5	9 — 44	26	10,5— 23	14	6 — 95		4,5— 13	8
Cr	260 340	287	310 —440	388	240 —325	291	330 — 680	431	370 — 480	426
V	60 —520	493	265 —420	357	370 —640	432	270 — 560	394	280 — 550	392
Sc	26 — 53	36	44 — 51	47	45 — 56	52	30 — 59	45.2	39 — 57	45.5
Nb	56 — 97	73	62 —105	81	63 — 84	69.2	24 — 75	52.2	40 — 70	54.3
Zr	560 —770	667	660 —880	762	650 —780	716	570 —1200	849	550 —1070	822
Be	7.3— 10.5	8.9	6.3— 9.5	7.5	6.2— 9	7	4.7— 11	6.6	4.5— 5.7	5.4
Mn	290 —660		22 —270		275 —700		95 — 720		170 — 440	
Ba	13 — 17		18 — 38		35 —110		14 — 145		17 — 120	
Sr	<10 — 10		<10 — 18		12 — 33		25 — 81		31 — 96	
Li	<10 — 18		<10 — 72		62 — 88		5 — 33		13 — 39	
Pb	58 — 97	79	72 —97	83	52 —125	86	17.5— 290		26 — 150	
Cu	17.5— 22	19.5	10 — 22	15	9.5— 18	11.6	7.5— 90		6 — 31	

Δ = variation domain

$\overline{X}$ = arithmetical mean

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VI. Genetic Inferrences

Genetically, employing also our theory on the way of formation of the Neocomian bauxites in the Apuseni Mts, we consider that the bauxite in the Galbena Valley (Bihor Mts) occurred as a result of processes of precipitation at surface of a paleokarst in wealdian facies, after the exondation at the end of the Jurassic (related to the last Kimmerian orogenic recrudescences, Papiu et al., 1970 b). The chemico-mineralogical differences between the ferric and ferrous bauxites have a post-sedimentary origin, being correlable with the thermal and hydrothermal influences of the Vlădeasa banatitic magmatic masses. Therefore, in our opinion, only the ferric bauxites and partially the ferroferric ones correspond chemically to the primary sediments, the characters of the ferrous bauxites being acquired after the iron reduction (Fe^{3+}-Fe^{++}) and the introduction of the juvenile silica. No deferrization processes have been observed in case of the study bauxites. All this differentiates the Bihor bauxites from the Pădurea Craiului bauxites in which all the chemico-mineralogical features are primary, sedimentogene or diagenetic at the most (except those in the Meziad zone also weakly metamorphosed ; Papiu et al., 1981).

The primary material is considered to be a laterite, possibly of magmatic origin, basic or intermediary rocks ; the study of minor elements seems to confirm it according to the diagram from Ozlü (1978) whose irons have been solubilized in very acid waters or passed as stabilized colloidal solutions through "protection colloids" of organic nature. From these the primary allitic gel precipitated by mixture with karstic waters.

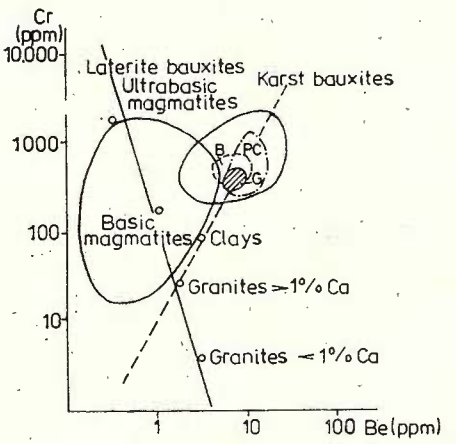


Fig. 10. — Position of bauxites in the Romanian territory on the Ozlü diagram (1978) indicating the probable character of the magmatic mother rocks according to the content in Cr and a coefficient of accumulation calculated on the basis of the contents in Ga, Cr, V, Ni, Zr.

Ozlü diagram (1978) (Fig. 10) shows clearly the genetic position of the central Bihor bauxites (Galbena Valley) nearby the field of basic magmatic rocks and its position in comparison with other bauxites in the Romanian territory.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

GEOCHIMIE

STUDIUL CUARŢITELOR HIDROTERMALE DINTRE SEINI ŞI VALEA FIRIZEI, JUDEŢUL MARAMUREŞ [1]

DE

VASILE MANILICI [2], AURELIA DUMITRESCU [2], MARIAN RĂDUŢ [3], VIOREL MACALEŢ [2], IOAN KALMAR [4], OSCAR EDELSTEIN [4]

Quartzites. Opal. Quartz andesite. Hydrothermal transformations. Mineralogical sequence. Mineralogical composition. Neoformation quartz. Major elements. Adularia. Paleogeothermometry. Dilatometry. East Carpathians-Neogene-Quaternary Eruptive-Gutîi.

Abstract

The Study of Hydrothermal Quartzites Occurrign between Seini and the Firiza Valley. North and west of Baia Mare, Maramureş district, one notes the occurrence of quartzites constituted of the Sarmatian Seini andesites and of the Pannonian Piscuiatu quartz andesites. The silicification processes which had generated them took place between the emplacement of these volcanics and the mineralization processes related to the two andesite types. The quartzites crop out either inside or between the mining fields and enter the area of adularization, sericitization and kaolinization processes of volcanics. They are crossed by natural fissures parallel to the neighbouring base metal veins, which proves they had formed prior to the mineralization processes. It is also to note the presence of opal veins which preceded the mineralizations, too. The dilatometric study points to the formation of quartzites at a temperature of 418-126°C ; the same temperature was reported for the constitution of opal.

Rolul metalogenetic al cuarţitelor hidrotermale este bine stabilit de Nakovnik (din Kurek, 1954), fiind verificat în Kazahstan, Urali, Peru, Mexic, Bolivia etc., formarea lor înglobîndu-se în cortegiul mani-

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[2] Institutul Politehnic Bucureşti, Splaiul Independenţei nr. 313, Bucureşti.

[3] Ministerul Geologiei, str. Mendeleev, nr. 34-36, Bucureşti.

[4] Întreprinderea de Prospecţiuni şi Explorări geologice, str. Victoriei nr. 146, Baia Mare.

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festărilor postmagmatice răspunzătoare de formarea mineralizațiilor filoniene polimetalice ori auro-argintifere. În regiunea minieră Baia Mare, acest rol se verifică bine la mineralizațiile legate de andezitele ponțiene de Jereapăn de la Șuior, Cavnic, Jereapăn, Băiuț și Văratec, inclusiv cele care formează obiectul lucrării de față, legate de andezitele sarmațiene de Seini de la Ilba și Nistru, ca și cele legate de andezitele cuarțifere, pannoniene de Piscuiatu, de la Tyuzoșa și Săsar.

Spre deosebire de situația din zona Cavnic, Jereapăn, Băiuț și Văratec, unde procesul de silicifiere s-a manifestat mai intens, iar cuarțitele au extindere mare, în zona Seini-valea Firizei procesul de silicifiere a avut amploare mai redusă, iar ivirile de cuarțite au dimensiuni mai reduse. Printre cele mai importante iviri de cuarțite legate de andezitele de Seini citām cele de la Beneci, valea Mesteacănului, valea Ardeleană, valea Cicărlăului și afluentul acesteia Baba Griga, din zona Ilba, Piatra Handalului și creasta dintre valea Nistrului și valea Roșie din zona Nistru, Calvaria și creasta dintre valea Roșie și valea Băiței de la Băița, inclusiv Bangău de la obîrșia văii Băița. Cuarțitele pannoniene, legate de andezitele cuarțifere de Piscuiatu, sînt mai slab reprezentate, identificîndu-se la Poprad și Murgău.

Cu excepția cuarțitelor de la Bangău, alcătuite din stînci izolate de 5-10 m înălțime, răspîndite pe o suprafață de circa 250/100 m, alungită pe direcția N-S, celelalte au dimensiuni reduse, prezentîndu-se în majoritatea cazurilor sub formă de blocuri răspîndite pe suprafețe de ordinul zecilor de metri pătrați. Explicația acestei stări de lucruri trebuie căutată în amploarea redusă a procesului de silicifiere.

Urmărirea aliniamentelor după care s-a produs silicifierea arată că acestea sînt orientate în zona Băița-Nistru pe direcția NE-SW, paralele cu filoanele metalifere, excepție făcînd ivirea de deasupra gurei galeriei Cîmpurele, orientată pe direcția N 40° W. În zona Ilba această orientare este mai greu de urmărit din cauza dimensiunilor reduse ale ivirilor, cît și a acoperirii terenului. La Poprad silicifierea pare să aibă orientarea N-S, iar la Murgău NNE-SSW.

Toate ivirile de cuarțite sînt localizate în ariile de sericitizare și caolinizare a vulcanitelor, ceea ce confirmă concluziile lui Nakovnik (din Kurek, 1954) conform cărora rocile sericitizate și caolinizate reprezintă faciesuri marginale ale cuarțitelor secundare.

Modul de prezentare al cuarțitelor din zona Seini-valea Firizei nu diferă de cel al cuarțitelor ponțiene din munții Gutîiului (Manilici et al. sub tipar). Roca, de regulă masivă, fin granulară, prezintă local goluri milimetrice-centimetrice, tapițate uneori cu cristale aciculare de cuarț în stadiul inițial de dezvoltare. Este posibil ca unele dintre aceste goluri să fi fost create prin levigarea sulfurilor. În sprijinul acestei ipoteze pledează culoarea roșcată a rocii din apropiere, contrastînd cu cea cenușie-deschisă, ori albicioasă proprie acestor roci. Un aspect deosebit îl prezintă varietatea cenușie compactă, cu structură criptocristalină de la Bangău ; varietăți asemănătoare identificîndu-se și la Murgău. Cuarțitele formate pe seama tufurilor andezitice prezintă totdeauna textură fină, compactă.

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Compoziția mineralogică a cuarțitelor

Examenul mineralogic al cuarțitelor cercetate arată că acestea sînt alcătuite în principal din cuarț, care la cuarțitele propriu-zise poate atinge 95-98% din masa rocii (pl. I, fig. 3), în funcție de gradul de silicifiere al rocii inițiale. În stadiul incipient de transformare silicioasă, andezitul este diaclazat (pl. IV, fig. 2) sau chiar brecifiat și cimentat cu cuarț de neoformație, local putîndu-se observa chiar un început de înlocuire metasomatică a rocii de proveniență. În acest stadiu cuarțul de neoformație alcătuiește circa 10-20% din masa rocii.

Totdeauna roca supusă procesului de silicifiere, atît în cazul andezitelor de Seini cît și al celor de Piscuiatu, are de regulă fenocristalele de feldspat plagioclaz pseudomorfozate de adular triclinic, fenomen observat încă de Giușcă (1960). În ambele cazuri, resturile de plagioclaz neadularizat sînt decalcifiate (albitizate) și parțial sericitizate. Această situație arată că atît în cazul andezitelor de Seini cît și al celor de Piscuiatu procesul de adularizare este anterior celui de silicifiere. Absența unor resturi de minerale melanocrate proaspete în roca supusă procesului de silicifiere, arată că în timpul acestui proces componentele respective erau cloritizate.

Printre primele componente înlocuite de cuarțul de neoformație se numără adularul triclinic care pseudomorfozează feldspații plagioclazi, în stadiul inițial de silicifiere roca fiind alcătuită din plagioclaz decalcifiat, adular triclinic și pseudomorfoze de clorit după minerale melanocrate în care se dezvoltă treptat cuiburi de cuarț criptocristalin. Ulterior cuarțul înlocuiește în continuare cloritul ce pseudomorfozează mineralele melanocrate, inclusiv plagioclazul neînlocuit de adular. Diaclazele noi, formate pe parcurs, sînt umplute cu cuarț microcristalin avînd o granulație mai mare decît a cuarțului precedent. Ultima componentă a cuarțitului care este înlocuită de cuarțul de neoformație este pasta rocii. În acest ultim stadiu de silicifiere roca este alcătuită din cuarț criptocristalin, resturi de adular triclinic, resturi de pastă amorfă cu microlite feldspatice (pl. I, fig. 2) și concrețiuni de minerale opace, avînd de regulă dispoziție capricioasă (pl. I, fig. 4).

În toate stadiile de înlocuire, raporturile spațiale dintre cuarțul de neoformație și componentele rocii supuse procesului de silicifiere sînt sinuoase (pl. I, fig. 1), evidențiind înlocuirea metasomatică.

Cuarțul, în calitate de componentă principală a cuarțitelor formate pe seama andezitelor de Seini, este însoțit local de calcedonie, sericit, clorit, pirită, hematit și limonit, la cele de la sud de Piatra Handalului identificîndu-se și sfen.

La cuarțitele de la Poprad și Murgău formate pe seama andezitelor cuarțifere de Piscuiatu, la componentele proprii cuarțitelor formate pe seama andezitelor de Seini se adaugă și cuarțul primar, sub formă de fenocristale cu coroziunile specifice. Adularul prezent în aceste roci are aceleași particularități ca și cel din cuarțitele sarmațiene, pseudomorfozînd atît feldspatul plagioclaz cît și pasta rocii, fiind asociat local cu clorit. Asemenea relații mineralogice arată că și în cazul andezitelor cuarțifere de Piscuiatu, procesul de silicifiere care a generat cuarțitele pannoniene este precedat de un proces de adularizare.

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Ca şi la cuarţitele formate pe seama andezitelor de Seini, adularul triclinic este bine reprezentat numai în rocile din stadiul incipient de silicifiere, în fazele ulterioare el fiind treptat înlocuit de cuarţul de neoformaţie. Acest lucru este uşor de verificat atît cu ocazia observaţiilor microscopice cît şi cu ajutorul analizelor chimice (tab. 1).

TABELUL 1

Compoziţia chimică a cuarţitelor

Elemete analizate	1	2	3	4	5	6	7	8	9
SiO_2	59,72	88,86	83,40	95,03	97,10	96,00	66,40	94,55	97,02
TiO_2	0,50	0,28	0,41	0,60	0,03	1,05	lipsă	lipsă	0,03
Al_2O_3	21,34	3,55	6,69	0,30	0,75	0,80	4,12	0,90	0,70
Fe_2O_3	1,66	1,61	2,48	1,46	0,23	0,18	11,16	0,95	0,31
FeO	0,76	0,54	0,46	0,54	0,11	0,36	0,85	0,36	0,11
CaO	0,31	1,40	1,68	1,27	0,40	0,50	1,74	0,63	0,38
MgO	0,55	0,15	0,10	0,20	0,60	0,58	0,72	0,80	0,56
MnO	0,03	urme	urme	lipsă	0,04	0,02	urme	lipsă	0,02
Na_2O	0,92	0,12	0,10	0,14	0,03	0,04	0,24	0,14	0,08
K_2O	12,02	0,77	3,32	0,02	0,26	0,24	7,00	0,12	0,26
P_2O_5	0,11	0,02	0,06	0,01	0,08	0,02	0,93	lipsă	0,02
S	—	1,71	urme	urme	0,06	0,05	0,45	0,36	0,05
SO_3	0,09	—	—	—	lipsă	lipsă	—	—	lipsă
H_2O^{-105}	0,35	0,28	0,18	0,09	0,11	0,07	0,38	0,10	0,20
H_2O^{+105}	1,72	0,86	1,20	0,63	0,64	0,66	5,34	0,26	0,83
CO_2	—	lipsă	lipsă	lipsă	—	—	0,94	0,36	—
P. C.	—	—	—	—	0,75	0,73	—	—	1,03
	100,08 %	100,15 %	100,08 %	100,29 %	101,19 %	101,30 %	100,27 %	99,53 %	101,60 %

Proveniența probelor: 1, dealul Tarda-Seini; 2, Valea Cicîrlăului; 3, Beneci; 4, Piatra Handalului; 5, Piatra Handalului S; 6, Bangău; 7, 8, Poprad; 9, Murgău.

Analişti: 1, F. Popea; 2, 3, 4, A. Dănescu; 5, 6, 9, G. Zăvoianu; 7, 8, A. Dănciulescu.

În ambele tipuri de cuarţite, structura rocii de proveniență poate fi uşor recunoscută în stadiul incipient de transformare silicioasă, ea fiind treptat ştearsă în fazele următoare. Menţionăm totuşi păstrarea texturii stratificate la cuarţitele formate pe seama tufurilor vulcanice.

O caracteristică a cuarţului de neoformaţie din componenţa cuarţitelor dintre Seini şi valea Firizei, recunoscută de altfel şi la cuarţitele ponţiene formate pe seama andezitelor de Jereapăn (Manilici et al., sub tipar), este extincţia ondulatorie, bine vizibilă la toate secţiunile examinate. Această particularitate ne dă posibilitatea de a ne face o idee asupra formei de depunere a silicei în cadrul procesului de silicifiere. Avînd în vedere că această extincţie caracterizează cuarţul granular format pe seama gelului de silice, putem conchide că şi la formarea cuarţitelor din această regiune, silicea a fost depusă sub formă de gel.

Pentru verificarea unor eventuale resturi de gel silicios în cuarţitele cercetate, au fost efectuate de către V. Drăghici de la Institutul de geologie şi geofizică 5 analize prin absorbţie în infraroşu asupra

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unei probe de opal din cariera Cicărlău (nr. 1) și a patru probe de cuarțite de la : Beneci (nr. 2), zona galeriei Apolo (nr. 3), Poprad (nr. 4) și Murgău (nr. 5), ale căror rezultate sînt reprezentate în fig. 1. Se

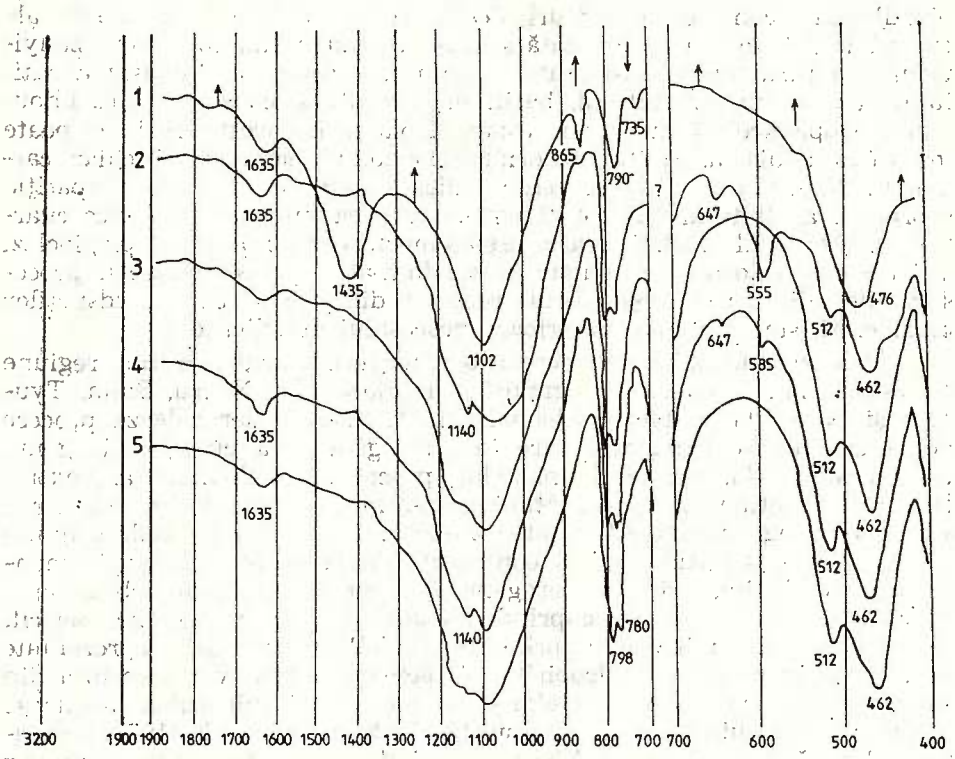


Fig. 1. — Curbe de absorbție în infraroșu ale unor probe de : opal din cariera Cicărlău (nr. 1), cuarțitelor de la Beneci (nr. 2), din zona galeriei Apolo de la Băița (nr. 3), Poprad (nr. 4) și Murgău (nr. 5).

Courbes d'absorbtion en infrarouges de quelques échantillons de : opale de la carrière de Cicărlău (no. 1), quartzites de Beneci (no. 2) de la zone de la galerie d'Apolo à Băița (no. 3), Poprad (no. 4) et Murgău (no. 5).

vede că la cuarțitele cercetate întreaga masă de silice este reprezentată prin cuarț, ceea ce arată că timpul scurs de la formarea lor a fost suficient pentru transformarea întregii cantități de gel silicios în cuarț, în timp ce opalul amorf, fără urme de cuarț vizibile microscopic, este lipsit de liniile de absorbție specifice cuarțului de 512, 697 și dipolul 780-798 cm^{1-} bine reprezentate la cuarțite. La probele de cuarțit de la Beneci (nr. 2), Poprad (nr. 4) și Murgău (nr. 5) se individualizează bine adularul prin liniile de absorbție de : 595 și 647 cm^{1-}, mineral vizibil de altfel și la microscop. La proba de opal din cariera Cicărlău (nr. 1) sînt bine individualizate linia de absorbție de 1435 cm^{1-} specifică calcitului, inclusiv liniile 735 și 965 cm^{1-} specifice sideritului, minerale care se identifică și microscopic.

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Comparînd compoziţia mineralogică a cuarţitelor dintre Seini şi valea Firizei cu a celor din Kazahstan, descrise de Nakovnik (din Kurek, 1954), se constată ca şi în cazul celor din partea de est a masivului Gutîi (Manilici et al., sub tipar), lipsa alunitului, diasporului şi pirofilitului, considerate alături de cuarţ ca minerale principale ale cuarţitelor. Totodată se constată şi lipsa corindonului, topazului, zunyitului şi a turmalinei considerate ca minerale accesorii, inclusiv a rutilului, lazuritului, ilmenitului, baritinei şi rutilului considerate ca impurităţi. După acelaşi autor, în cazuri izolate, în aceste roci se poate identifica adularul, albitul, fluorina, cloritoidul, spinelul şi chiar carbonaţi. În cazul nostru frecvenţa ridicată a adularului ca şi apariţia sporadică a albitului nu pot fi considerate ca minerale specifice cuarţitelor. Adularul triclinic care pseudomorfozează feldspaţii plagioclazi şi care este înlocuit de cuarţul de neoformaţie depus în cadrul procesului de silicifiere, ca şi albitul rezultat din decalcifierea feldspaţilor plagioclazi, sînt minerale anterioare procesului de silicifiere.

Procesul de silicifiere care a dat naştere cuarţitelor din regiune nu este izolat. În cuprinsul cîmpurilor miniere Ilba, Nistru, Băiţa, Tyuzoşa şi Săsar, la contactul filoanelor metalifere se semnalează procese de silicifiere asemănătoare, care însă nu generează cuarţite de genul celor descrise. La contactul filoanelor, procesul de silicifiere are extindere redusă, atingînd rareori lăţimi de 2-3 metri, iar gradul de înlocuire silicioasă atinge numai întîmplător 30-35%. Din punct de vedere mineralogic, rocile silicifiate de la contactul filoanelor din cîmpurile menţionate, se disting printr-o parageneză de neoformaţie deosebită de a cuarţitelor prezentate, ce cuprinde : cuarţ, adular monoclinic, sericit, clorit, calcit, caolinit, montmorillonit, beidellit şi sulfuri, reprezentate de regulă prin pirită şi calcopirită. Caracterul distinctiv al acestora din urmă îl imprimă calcitul, adularul monoclinic şi mineralele argiloase asociate cuarţului, parageneză sesizată de Stanciu et al. (1970) în cuprinsul zăcămîntului de la Nistru, cît şi de Manilici în cîmpul minier Băiţa-Nistru (Manilici, sub tipar). Faptul că majoritatea acestor minerale nu se întîlnesc în cuarţitele propriu-zise, cît şi faptul că acestea sînt traversate adesea de filonaşe cu umplutură de cuarţ, adular monoclinic şi pirită, parageneză specifică culcuşului şi acoperişului filoanelor polimetalice, arată că procesele de silicifiere respective au fost realizate în perioade diferite de timp.

Compoziţia chimică a cuarţitelor cercetate

Pentru caracterizarea chimismului cuarţitelor au fost analizate 7 probe din aceste roci surprinse în diverse stadii de silicifiere, prezentate în tabelul 1. Ţinînd seama de proveniența cuarţitelor, pentru urmărirea transformărilor în cadrul procesului de silicifiere se prezintă şi o analiză de andezit de Seini adularizat din dealul Tarda (Rădulescu, 1958) — proba nr. 1 — şi o analiză de andezit cuarţifer, de Piscuiatu, în stadiul incipient de silicifiere — nr. 7.

În cazul cuarţitelor formate pe seama andezitelor de Seini, procesul de silicifiere al rocii adularizate evoluează în sensul îmbogăţirii în SiO_2, care se realizează pe seama reducerii conţinutului de Al_2O_3,

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MgO, Na_2O și mai ales K_2O. Chiar în faza incipientă de silicifiere se remarcă faptul că mărirea conținutului de SiO_2 atrage după sine diminuarea în principal a conținutului de Al_2O_3 și K_2O, ceea ce concordă cu observațiile microscopice care arată că în această etapă este înlocuit de preferință adularul. Diminuarea într-o proporție mai mică a conținutului de Fe_2O_3 în această primă etapă se explică prin prezența hematitului și a cloritului, inclusiv a limonitului care pare să fi fost prezent din prima etapă a metasomatozei silicioase. Menținerea într-o proporție ridicată a conținutului de CaO poate fi explicată prin prezența acestuia în albit și în clorite. TiO_2 se menține la conținutul său inițial pînă în faza finală a procesului de silicifiere, cînd conținutul său scade brusc (proba nr. 5), el concentrîndu-se foarte probabil în ilmenit. Un conținut ridicat de TiO_2 se înregistrează la cuarțitul de la Bangău (proba nr. 6), unde depășește conținutul mediu al andezitelor nesilicifiate. Acest lucru este greu de explicat, întrucît în această rocă nu se identifică microscopic minerale titanifere. După toate probabilitățile, această componentă se concentrează în incluziunile pulverulente, submicroscopice, care impregnează mai ales cuarțitele din stadiul final de silicifiere, TiO_2 provenind din piroxenii titaniferi ai andezitului inițial.

La cuarțitele formate pe seama andezitelor cuarțifere, de Piscuiatu (probele 8, 9), se urmărește aceeași evoluție a procesului de silicifiere. Față de cuarțitele formate pe seama andezitelor de Seini, acestea se caracterizează printr-un conținut mai scăzut de TiO_2.

Analizele chimice prezentate explică bine compoziția mineralogică a cuarțitelor, inclusiv deosebirile față de cuarțitele secundare prezentate de Nakovnik. Astfel lipsa alunitului din cuarțitele de la Baia Mare se explică prin conținutul scăzut, respectiv lipsa ionului de SO_3^{2-} iar conținutul scăzut în Al_2O_3 explică lipsa corindonului și andaluzitului ; conținutul scăzut în apă al cuarțitelor monominerale, împreună cu conținutul scăzut de alumină, explică absența diasporului, pirofilitului și zunyitului.

Analizele spectrale efectuate de Ana Șerbănescu de la I.G.G. arată că atît cuarțitele cît și opalul se caracterizează prin lipsa elementelor minore. La cuarțitele sarmațiene se remarcă, atît în stadiul intermediar cît și în cel avansat de silicifiere, Ba care atinge 300 ppm și Ag care nu depășește însă 10 ppm. Remarcăm faptul că conținutul acestora rămîne totdeauna inferior celor din roca gazdă a filoanelor de la Nistru (Stanciu et al., 1970), respectiv a celor de la Săsar (Borcoș et al., 1972). Asemenea diferențe pledează în favoarea ideii formării cuarțitelor într-o etapă diferită de aceea a punerii în loc a mineralizațiilor legate de vulcanismul sarmațian și pannonian.

Alte forme de silice cunoscute în regiune

În cadrul cercetărilor sale din zona Ilba, Amalia Szöke (1965) semnalează apariția unor opaluri în cuprinsul carierei din localitate. Cu ocazia cercetărilor noastre, asemenea roci le-am identificat în cariera Cicărlău și pe valea Handalului din cuprinsul andezitelor de Seini, inclusiv în cuprinsul andezitelor cuarțifere de pe valea Băiței, valea Ulmoasa și între valea Vălinilor și valea Serini. În toate ivirile întîl-

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nite, opalul alcătuieşte umplutura fisurilor ce străbat andezitele de Seini, cele de Piscuiatu, inclusiv cele de Ilba, ceea ce ne duce la ideea depunerii acestora în trei trepte diferite. Poziţia fisurilor cu umplutură de opal variază de la o ivire la alta, iar grosimea filonaşelor respective oscilează între 1 şi 10 cm, atingînd în cariera Cicărlău chiar 20 cm. Ivirea de pe malul stîng al văii Băiţei, din aval de localitatea cu acelaşi nume, exploatată în trecut, pare să aibă dimensiuni mai mari.

Macroscopic se recunosc frecvent transformări ale opalului în calcedonie. Ca şi la cuarţite, în asociere cu silicea nu se remarcă prezenţa adularului, fapt confirmat de altfel şi de absorbţia în infraroşu (nr. 1, fig. 1).

Spre deosebire de cuarţite, la care trecerea de la cuarţitul propriuzis la roca de provenienţă se realizează prin tipuri intermediare în care conţinutul de cuarţ scade treptat pînă la roca neafectată de procesul de silicifiere, filonaşele de calcedonie au limite nete. La contactul acestor filonaşe roca gazdă nu prezintă fenomene de transformare hidrotermală, ea putînd să apară fie proaspătă, ca în cariera Cicărlău, fie cloritizată ori sericitizată în etapele anterioare de metamorfism hidrotermal, cum este cazul pe valea Ulmoasa. Considerăm că aceste deosebiri pot fi explicate prin starea deosebită a silicei în cele două situaţii. Fără îndoială că soluţiile care au generat corpurile cuarţitice au avut un pronunţat caracter electrolitic, în timp ce opalul s-a format pe seama unor geluri silicioase.

Încadrarea formării cuarţitelor în evoluţia proceselor tectono-magmatice şi metalogenetice

Numeroasele studii efectuate în partea de vest şi centrală a lanţului Oaş-Gutîi în ultimii 30 de ani, au permis stabilirea evoluţiei vulcanismului, a transformărilor hidrotermale şi a formării mineralizaţiilor, fără să fi adus date asupra perioadei de formare a cuarţitelor din regiune. Astfel Giuşcă (1960) atrage atenţia asupra procesului de adularizare, iar Giuşcă et al. (1965) stabilesc raporturile dintre adularizare şi alte tipuri de transformări hidrotermale, scoţînd în evidenţă legătura acestora cu cele de mineralizare.

Mai recent, Borcoş et al. (1972, 1973) aduc precizări asupra evoluţiei vulcanismului neogen din Munţii Oaş-Gutîi, realizînd o încercare de corelare între manifestările vulcanice, transformările hidrotermale şi procesele metalogenetice pentru intervalul dintre Tortonian superior şi Ponţian. Stanciu et al. (1970) urmăreşte natura transformărilor hidrotermale şi chimice ale andezitelor de Seini de la contactul filoanelor din cîmpul minier Nistru, iar în alte două lucrări (1972, 1973), plecînd de la schema evoluţiei vulcanismului elaborată de colectivul Borcoş (1972), se ocupă de analiza sistematică a proceselor de alteraţie hidrotermală din partea de vest şi centrală a regiunii.

În ultima perioadă, Borcoş et al. (1979), sintetizînd rezultatele cercetărilor geologice şi geofizice din întreaga regiune, propun o imagine a structurii de adîncime a masivelor Oaş-Gutîi, cu ajutorul căreia explică procesele vulcanice, metalogenetice şi metamorfismul hidrotermal din regiune.

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Conform schemei elaborate de autorii amintiți, vulcanismul din lanțul Oaș-Gutîi împreună cu celelalte procese însoțitoare s-au desfășurat în trei cicluri : primul, Tortonian inferior-Buglovian, caracterizat prin erupții riolitice, al doilea, Volhinian-Pannonian, generînd andezitele de Seini, dacitele de Ulmoasa și andezitele cuarțifere de Piscuiatu, iar al treilea, Ponțian, cînd au fost puse în loc andezitele piroxenice de Jereapăn. În perimetrul cercetat, dintre Seini și valea Firizei, formarea cuarțitelor hidrotermale a fost realizată în două etape : prima în Sarmațian, legată de punerea în loc a andezitelor de Seini, iar cea de a doua legată de punerea în loc a andezitelor cuarțifere, de Piscuiatu. În aria de răspîndire a andezitelor de Jereapăn din zona Dealul Crucii-valea Firizei nu se semnalează prezența cuarțitelor.

Cercetările întreprinse de Stanciu et al. (1972, 1973), cele efectuate de Manilici în zona Băița-Nistru (Manilici, sub tipar), inclusiv cele din cadrul lucrării de față, scot în evidență atît în andezitele de Seini, cît și în cele cuarțifere de Piscuiatu, cîte o fază de transformări care au avut loc înainte de punerea în loc a mineralizației sarmațiene, respectiv pannoniene, cîte una sincronă cu aceste mineralizații și în sfîrșit cîte o fază posterioară acestor mineralizații. În lumina acestor cercetări, primele transformări la care au fost supuse andezitele de Seini după punerea lor în loc a fost propilitizarea. Ulterior această transformare este urmată de adularizarea de preferință a feldspaților plagioclazi, apoi a celorlalte componente ale rocii care sînt înlocuite de adular triclinic. Procesul de adularizare are caracter general, fiind precedat de o diaclazare sau chiar brecifierea andezitului, cum este cazul în zona Seini-Ilba. Mai tîrziu, prin schimbarea raportului K/H în favoarea acestuia din urmă (Giușcă, 1960), începe sericitizarea resturilor de feldspat plagioclaz decalcifiat, urmată de sericitizarea cloritului ce pseudomorfozează piroxenii primari. Acest proces are și el caracter general, roca dobîndind culoare albicioasă.

Mai tîrziu, roca transformată succesiv în etapele anterioare, este din nou diaclazată sau chiar brecifiată sub influența unor noi solicitări tectonice, pe fracturile noi create insinuîndu-se soluțiuni hidrotermale silicioase care le cimentează prin depunerea cuarțului de neoformație, În același timp, noile soluții circulînd o perioadă îndelungată de timp prin sistemul de fisuri format, produc înlocuirea treptată a componentelor mineralogice ale andezitelor de Seini, generînd cuarțitele sarmațiene. În regiunile clasice de formare a cuarțitelor secundare, s-a observat că acestea sînt legate de vulcanismul acid ori intermediar, reprezentînd formațiuni de suprafață, respectiv din apropierea acesteia. Ele se dezvoltă îndeosebi în zona coșurilor, cum este cazul la Piatra Handalului, în jurul acestora, inclusiv în jurul izvoarelor termale, reprezentînd manifestări postvulcanice tipice.

După formarea cuarțitelor, întregul complex de roci hidrotermalizate, a fost supus unor noi solicitări tectonice responsabile de formarea fracturilor filoniene pe care s-au instalat filoanele de la Ilba, Nistru și Băița, inclusiv fisurarea cuarțitelor care sînt afectate de sisteme de fisuri paralele cu filoanele. Punerea în loc a mineralizației este însoțită și ea de fenomene de transformare hidrotermală constînd din sili-

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cifieri + adularizări, sericitizări, argilizări, caolinizări şi carbonatări care s-au manifestat la contactul filoanelor.

În Pannonian, în lumina datelor de care dispunem (Stanciu, 1972), după punerea în loc a andezitelor cuarţifere de Piscuiatu, se realizează aceleaşi transformări hidrotermale, care s-au desfăşurat în aceeaşi ordine ca şi cele din Sarmaţian, procesele de silicifiere din această etapă generînd cuarţitele de la Poprad şi Murgău. Faptul că şi în cazul andezitelor cuarţifere, în momentul începerii procesului de silicifiere, feldspaţii plagioclazi erau practic complet înlocuiţi de adularul triclinic, arată că procesul de silicifiere succede celui de adularizare. După formarea cuarţitelor pannoniene are loc, ca şi în Sarmaţian, fracturarea şi fisurarea rocilor hidrotermalizate, pe fracturile mai importante instalîndu-se mineralizaţiile de la Tyuzoşa, Săsar, Borzaş şi Valea Roşie. Şi în acest caz sistemele de fisuri ce afectează cuarţitele sînt paralele cu filoanele metalifere, ceea ce demonstrează că procesul de mineralizare este mai nou decît cel de silicifiere.

Procesul de mineralizare legat de punerea în loc a andezitelor pannoniene, de Piscuiatu, este şi el însoţit de transformări hidrotermale ca silicifieri, sericitizări, argilizări şi carbonatări, realizate la contactul filoanelor metalifere de la Tyuzoşa, Săsar, Borzaş şi Valea Roşie, însă silicifierile respective se deosebesc prin extindere redusă şi asocierea cuarţului de neoformaţie cu adular monoclinic.

Date de microtectonică

Pentru stabilirea vîrstei cuarţitelor în raport cu a filoanelor metalifere din cîmpurile miniere apropiate, s-au efectuat, ca şi în partea de est a munţilor Gutîi, măsurători de fisuri naturale în ivirile de cuarţite şi în cîmpurile miniere învecinate. Asemenea cercetări s-au efectuat în ideea că solicitările tectonice din perioada premergătoare punerii în loc a mineralizaţiilor trebuie să fi afectat şi cuarţitele, în ipoteza că formarea acestora a fost realizată înainte de punerea în loc a mineralizaţiilor. În acest caz era normal ca ele să fie străbătute de aceleaşi sisteme de fisuri ca şi rocile gazdă ale filoanelor. În caz contrar, dacă formarea lor ar fi fost realizată odată cu formarea mineralizaţiilor, însemna că aceste cuarţite să fie străbătute numai de sisteme de fisuri paralele cu fracturile ce afectează filoanele, sau de alte sisteme, în cazul formării lor într-o etapă posterioară mineralizaţiei.

La efectuarea acestor cercetări s-au întîmpinat unele dificultăţi datorită faptului că ivirile de cuarţite avînd dimensiuni reduse, iar stîncile în loc fiind, de regulă rare, în majoritatea cazurilor nu s-a putut realiza un număr suficient de măsurători pentru întocmirea unor diagrame comparabile cu cele din cîmpurile miniere învecinate, aşa cum s-a realizat în zona Jereapăn (Manilici et al., sub tipar).

În diagrama corespunzătoare cuarţitelor de la Beneci, asemănătoare diagramei andezitelor brecifiate de pe valea Seinelului, polii fisurilor naturale, cu căderi de 70-90°, se dispun sub formă de ghirlandă concentrică, fără individualizarea unor maxime proeminente. Diagrame de acest gen, specifice zonelor de brecifiere (Gurău et al., 1970, 1975),

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arată că formarea cuarțitelor este legată de procesul de brecifiere și că solicitările tectonice au rămas active în tot timpul procesului de silicifiere.

Cuarțitele de pe cursul superior al văii Ardelene sînt străbătute de fisuri cu orientarea NE-SW, paralele cu filoanele Firizan, Aluniș și Fața Mare, iar cele de pe creasta dintre valea Moșu Haza și valea Cicărlăului sînt străbătute și ele de fisuri fie cu orientarea NE-SW, paralele cu filonul Ramura Venerei, fie cu orientarea NW-SE, paralele cu filonul Venera din apropiere. Aceeași situație se constată și la cuarțitele de pe cursul superior al văii Cicărlăului, care sînt străbătute, de asemenea, de fisuri cu orientarea NE-SW, paralele cu filoanele din mina 9 Mai de la Nistru, respectiv cu cele ce străbat andezitele de pe cursul superior al acestei văi.

La breciile silicifiate de la Piatra Handalului, cu toată împrăștierea mare a polilor fisurilor naturale, specifică zonelor de brecifiere, se remarcă o slabă predominare a celor cu orientare NE-SW, paralele cu filoanele din cîmpurile miniere 9 Mai și 11 Iunie de la Nistru. O situație mai clară se întîlnește la cuarțitele de la sud de Piatra Handalului, străbătute exclusiv de fisuri cu orientarea NE-SW, paralele cu filoanele din cîmpul minier 9 Mai.

Fisurile ce străbat cuarțitele de la Calvaria, din apropierea confluenței dintre Valea Roșie și valea Băiței, se remarcă predominarea fisurilor cu orientarea ENE-WSW, paralele cu filoanele Tarnița și Lăpușna. Aceeași situație se constată și la cuarțitele de pe creasta dintre valea Roșie și valea Băiței, la care pe maximele de concentrare ale polilor fisurilor naturale ce le străbat se proiectează polii filoanelor Tarnița și Lăpușna.

Toate aceste observații arată că în perioada de formare a fracturilor pe care s-au instalat filoanele de la Ilba, Nistru și Băița cuarțitele existau, de vreme ce fisurile naturale ce le străbat sînt paralele cu filoanele metalifere. Deci procesul de silicifiere care a generat cuarțitele este anterior procesului de mineralizare legat de andezitele sarmațiene de Seini.

Cuarțitele de la Poprad, legate de andezitele cuarțifere de Piscuiatu, apar străbătute predominant de fisuri cu orientarea NW-SE, paralele cu filoanele din mina Sofia. Prin urmare și în perioada de formare a fracturilor pe care s-au instalat filoanele de la Săsar, cuarțitele de la Poprad erau formate. Cu alte cuvinte și procesul de silicifiere care a generat cuarțitele pannoniene, este anterior procesului de mineralizare legat de andezitele de Piscuiatu.

Date paleogeotermometrice

În cadrul lucrării de față s-a urmărit, ca și la cuarțitele ponțiene din partea de est a munților Gutîi (Manilici et al., sub tipar), temperatura de formare a cuarțitelor sarmațiene și pannoniene dintre Seini și valea Firizei, inclusiv temperatura de formare a depunerilor de opal din același perimetru.

Întrucît nici la cuarțite, care prezintă o structură micro- sau chiar cripto-cristalină și conțin numeroase incluziuni fine submicroscopice,

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nici la opaluri nu se poate aplica metoda omogenizării, determinarea temperaturii de formare a acestora s-a realizat prin aplicarea metodei dilatometrice care permite obținerea unor rezultate comparabile. Rezultatele obținute sînt consemnate în tabelul 2 și figurile 2, 3 și 4.

Se vede că procesul de silicifiere a fost realizat între 418 și 137°C. Remarcăm faptul că la unele probe s-a obținut un singur interval de

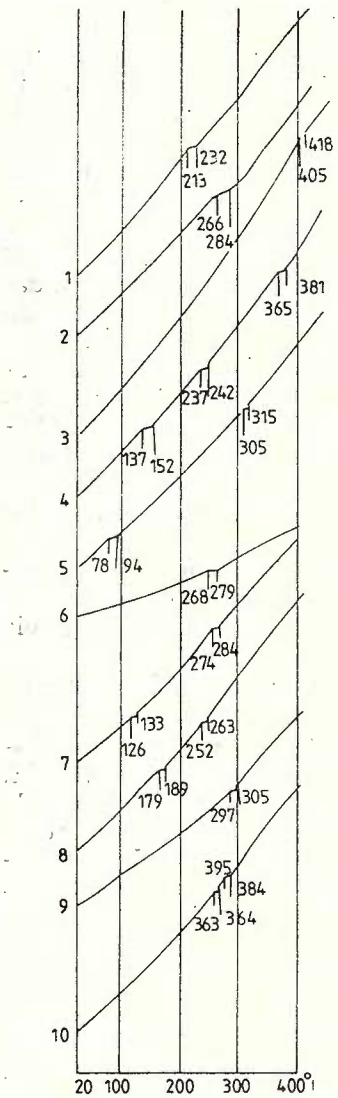


Fig. 2. — Temperaturile de formare ale cuarțitelor de la : Beneci (nr. 1), valea Ardeleană (nr. 2), Piatra Handalului (nr. 3, 4), creasta dintre valea Galbenă și valea Handalului (nr. 6, 7), Bangău (nr. 8), Poprad (nr. 9) și Murgău (nr. 10), determinate dilatometric.
Températures de formation des quartzites de : Beneci (no. 1), Valea Ardeleană (no. 2), Piatra Handalului (no. 3, 4), crête entre Valea Galbenă et vallée de Handalului (no. 6, 7), Bangău (no. 8), Poprad (no. 9) et Murgău (no. 10), déterminées dilatométriquement.

formare, în timp ce la altele două sau chiar trei intervale, situate la nivele diferite de temperatură. În majoritatea cazurilor se observă o bună corelare între generațiile de cuarț de neoformație ce alcătuiesc

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roca și numărul intervalelor de temperatură. Astfel, probele cu un singur interval de formare (nr. 1, 3, 6 și 9) sînt alcătuite din cuarț cu granulație omogenă, precipitat într-o singură generație. O situație aparte

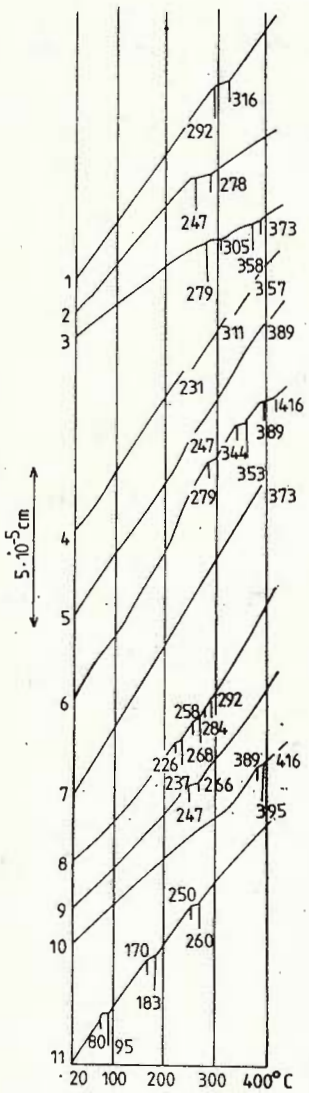


Fig. 3. — Temperaturile de formare ale opalului de la: Cariera Cicărlău (nr. 1-7), Ulmoasa (nr. 8), valea Băiței (nr. 9), valea Vălinelor (nr. 10) și Tarna Mare (nr. 11), determinate dilatometric.

Températures de formation de l'opale de : carrière de Cicărlău (no. 1-7), Ulmoasa (no. 8), vallée de Băița (no. 9), vallée des Vălinelor (no. 10) et Tarna Mare (no. 11) déterminées dilatométriquement.

se înregistrează la proba nr. 2 de pe valea Ardeleană, care cu toate că are o compoziție mineralogică mai complexă, conținînd resturi de feldspat plagioclaz într-o masă de adular triclinic ce-l pseudomorfozează, cuarț de neoformație care înlocuiește sticla vulcanică împreună cu feldspații, întregul ansamblu fiind străbătut de filonașe cu umplutură de cuarț și adular monoclinic, prezintă totuși un singur interval de for-

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mare. Este posibil ca această situaţie să fie datorită fie analizării unei probe lipsite de filonaşe de cuarţ cu adular monoclinic, fie că mineralele din umplutura acestor filonaşe împreună cu cuarţul ce pseudomorfozează întreaga rocă au cristalizat la aceeaşi temperatură.

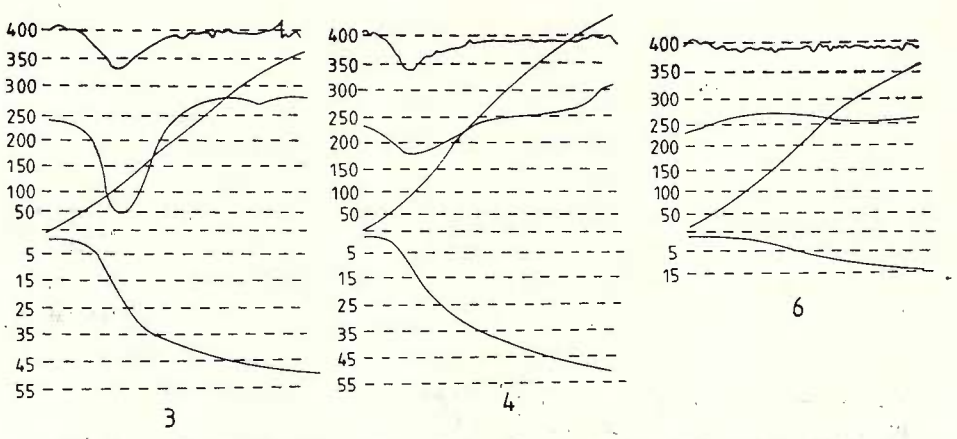


Fig. 4. — Curbe termice diferenţiale ale opalurilor din cariera Cicărlău.
Courbes thermiques différentielles des opales de la carrière de Cicărlău.

La probele cu două intervale de formare (nr. 7 şi 8) se identifică microscopic cîte două generaţii de cuarţ de neoformaţie ; cel din prima generaţie care înlocuieşte masa principală a rocii s-a format la unul din intervale — probabil cel superior — în timp ce cel din a doua generaţie alcătuieşte umplutura filonaşelor ce străbat roca. Nu s-au putut efectua determinări separate pe generaţii din cauza grosimii reduse a filonaşelor şi desimii acestora.

La Piatra Handalului se remarcă chiar patru intervale de formare, ceea ce arată că procesul de silicifiere a avut caracter discontinuu, fiind legat după toate probabilităţile de fisurarea succesivă a rocii în curs de formare, fiecare din aceste fisurări deschizînd noi căi de circulaţie pentru noi valuri de soluţii hidrotermale ce se găseau la un nivel energetic diferit de al celorlalte.

În cadrul lucrării de faţă nu s-au putut obţine date asupra temperaturii de formare a adularului triclinic. Judecînd după rezultatele obţinute la cuarţitul de la Murgău (nr. 10) el pare să se fi format în jurul temperaturii de 400°C. Formarea caolinitului (proba nr. 5) a fost realizată sub 100°C.

Formarea opalului a avut loc la temperaturi comparabile cu ale cuarţitelor. Admiţînd că ultimul interval obţinut la proba de la Tarna Mare corespunde opalului, rezultă că formarea acestuia poate avea loc între 416 şi 80°C. Ca şi la cuarţite, se remarcă unul pînă la trei intervale de formare, corespunzînd la tot atîtea etape de consolidare a gelurilor silicioase, ce se verifică de altfel şi microscopic. Procesul de cristalizare a gelului silicios care duce la formarea calcedoniei pare să nu aibă un interval de temperatură de formare.

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TABELUL 2

Temperaturile de formare ale cuarțitelor și opalurilor, determinate dilatometric

Nr. crt.	Roca și proveniența	Minerale de neoformație	Temperatura °C
1	2	3	4
	A) *Cuarțite hidrotermale*		
1	Brecie andezitică adularizată și silicifiată, Beneci	adular triclinic, cuarț clorit	232—213
2	Piroclastit andezitic adularizat și silicifiat, valea Ardeleană,	cuarț, adular triclinic și monoclinic	284—266
3	Tuf andeziti silicifiat, Piatra Handaluluiic	cuarț	418—405
4	Piroclastit silicifiat, Piatra Handalului	cuarț, 3 generații	381—365 242—237 152—137
5	Andezit silicifiat, creasta dintre valea Băiței și valea Roșie	cuarț, caolinit	313—305 78—94
6	Cuarțit, creasta dintre valea Galbena și valea Handalului	cuarț	279—268
7	Cuarțit, creasta dintre valea Galbena și valea Handalului	cuarț	284—274 133—126
8	Cuarțit, Bangău	cuarț	263—252 189—179
9	Brecie andezitică adularizată, cimentată cu cuarț + adular monoclinic, Poprad	cuarț, adular triclinic, adular monoclinic	305—297
10	Cuarțit, Murgău	cuarț, adular triclinic	395—384 374—363
	B) *Opaluri*		
1	Opal cenușiu, cariera Cicărlău	opal, calcedonie	316—292
2	Opal albicios, cariera Cicărlău	opal, calcedonie	274—247
3	Opal negru, cariera Cicărlău	opal, calcedonie 5% siderit	373—358 305—279
4	Opal cenușiu verzui, cariera Cicărlău	opal, calcedonie 65%	357, 331 231
5	Opal alb lăptos, cariera Cicărlău	opal	389, 247
6	Opal, cariera Cicărlău	calcedonie 80%, cuarț + opal	416—389 353—344 300—279
7	Opal, cariera Cicărlău	opal, calcedonie 50%, limonit	373
8	Opal roșu, valea Ulmoasa	opal, cuarț, adular monoclinic	292—284 268—258 237—226
9	Opal negru, valea Băiței	opal	416 395—389 266—247
10	Opal roșu, valea Vălinelor	opal	416 395—389
11	Cuarțit cu opal, Tarna Mare	cuarț, opal	260—250 183—170 95—80

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La unele probe (nr. 4 şi 5) nu s-au înregistrat intervale de temperatură, ci numai decrepitări, acestea fiind determinate foarte probabil de incluziuni mai mari de fluide, separate în timpul consolidării.

Din datele de literatură (Todor, 1972), se ştie că eliminarea apei din masa opalului se realizează între 100 şi 150°C, putînd continua în unele cazuri pînă la 300°C. Se poate pune întrebarea dacă în cazul opalului pierderea apei nu poate cauza perturbări pe curba dilatometrică, interpretate de noi ca fiind determinate de stabilirea echilibrului de presiune dintre masa mineralului şi incluziunile fluide.

Pentru a stabili cauza reală a perturbărilor de pe curbele dilatometrice, considerate de noi ca reprezentînd temperatura de formare a opalului, au fost executate, de către I. Constantin de la Institutul politehnic Bucureşti, trei analize termice diferenţiale ale căror rezultate sînt prezentate în fig. 4, spre a verifica dacă intervalele de temperatură la care are loc pierderea apei coincid cu palierele de pe curbele dilatometrice. Diagrama nr. 3 corespunzătoare opalului negru din cariera Cicărlău, la care dilatometric s-au obţinut două intervale de formare : 373-358 şi 305-279°C, arată că pierderea apei se realizează între 100 şi 200°C, interval în care se pierde 3,33% din greutate, în timp ce între 200 şi 360°C se înregistrează o pierdere de numai 0,83% din greutate.

O situaţie asemănătoare se întîlneşte la proba de opal verzui nr. 4 care prezintă decrepitări la 357, 311 şi 231°C. La această probă pierderea de apă este mai uniformă, pînă la 200°C înregistrîndu-se o pierdere în greutate de 2,26%, iar între 200 şi 300°C o pierdere de 1,61%.

La nici una din aceste două probe nu se observă vreo legătură între pierderea apei şi stagnarea dilataţiei, respectiv decrepitarea probei, ceea ce arată că aceste două fenomene sînt independente.

Proba de calcedonie cu resturi de opal (nr. 6) care prezintă dilatometric trei intervale de formare : 416-389, 353-344 şi 300-279°C, prezintă la analiza termică o situaţie diferită. Fiind vorba de o rocă alcătuită în cea mai mare parte din silice cristalizată, pierderea în greutate este nesemnificativă (1,71%), repartizată uniform între 100 şi 370°C, fiind determinată de eliminarea apei din resturile de opal. Nici la această probă nu se observă vreo perturbare pe curba pierderii de greutate la intervalele corespunzătoare palierelor de pe curba dilatometrică.

Datele prezentate diferă în parte de cele publicate anterior de Manilici et al. (1978).

Concluzii

Între Seini şi valea Firizei se identifică cuarţite hidrotermale sarmaţiene, legate de andezitele piroxenice de Seini şi pannoniene, legate de andezitele cuarţifere de Piscuiatu. Formarea lor se încadrează în cortegiul transformărilor hidrotermale realizate după punerea în loc a vulcanitelor respective, care preced mineralizaţiile sarmaţiene şi pannoniene. În ambele cazuri, succesiunea transformărilor respective este în linii generale următoarea : propilitizare → adularizare → sericitizare → silicifiere → mineralizare. Punerea în loc a opalurilor, care nu produc fenomene de transformare hidrotermală în roca înconjurătoare,

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este mai greu de stabilit, ea încadrîndu-se probabil printre aceleași manifestări, anterioare proceselor de mineralizare. Ca și în alte regiuni, ca la Banska Steavnița și Kazahstan, cuarțitele din munții Gutîiului apar localizate în aria de răspîndire a zăcămintelor metalifere ; local, cum este cazul filonului Laurențiu de la sud de Piatra Handalului, ele alcătuiesc chiar roca gazdă a filonului.

Principala componentă mineralogică a cuarțitelor din regiune este cuarțul de neoformație, asociat rareori cu sericit, clorit, hematit ori limonit. Adularul triclinic, format într-o etapă anterioară și care este frecvent în rocile din stadiul incipient de silicifiere, dar care este înlocuit treptat de către cuarțul de neoformație, după cum o demonstrează și analizele chimice, nu poate constitui o componentă caracteristică cuarțitelor.

Cuarțitele de la Beneci sînt străbătute de fisuri cu poziții foarte diferite, fără să se concentreze pe direcții privilegiate, situație specifică zonelor de brecifiere, pe cînd cele din cîmpurile miniere Ilba, Nistru, Băița și Săsar sînt străbătute în principal de fisuri paralele cu filoanele din cîmpurile respective. Aceasta arată că fisurarea cuarțitelor s-a produs sub influența acelorași solicitări tectonice care au determinat și formarea fracturilor pe care s-au instalat filoanele metalifere sarmațiene și pannoniene. Rezultă că procesele de silicifiere care au dat naștere cuarțitelor sînt anterioare proceselor de mineralizare.

Procesele de silicifiere din perioadele de mineralizare, de la contactul filoanelor metalifere, au amploare mai redusă și nu generează cuarțite propriu-zise. Cuarțul de neoformație din rocile silicifiate de la contactul filoanelor este constant asociat cu adular monoclinic, ceea ce reprezintă un caracter distinctiv al acestor două etape de silicifiere.

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ÉTUDE DES QUARTZITES HYDROTHERMAUX ENTRE SEINI ET LA VALLÉE DE FIRIZEI

(Résumé)

Dans la région étudiée, les quartzites hydrothermales sont liées aux andésites sarmatiennes de Seini qu'aux andésites quartzifères pannoniennes de Piscuiatu. Tout comme les quartzites pontiens de Jereapăn, ceux d'entre Seini et la vallée de Firizei sont localisés dans les volcanites adulairisées, séricitisées et kaolinitisées de la zone des champs miniers ou bien de leur voisinage.

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Ils sont des roches cripto- ou microcristallines constituées de quartz, séricite, chlorite, calcédoine, hématite, pyrite, limonite et localement sphène. L'adulaire triclinique, bien représenté dans les quartzites du stade incipient de silicification et peu à peu remplacé par le quartz de néoformation généré pendant le processus de silicification, ne peut pas être considéré comme un minerai spécifique aux quartzites, puisque son dépôt s'est produit avant le processus de silicification.

La plus grande partie du quartz composant ces roches se caractérise par une forte extinction ondulatoire, ce qui dénote qu'il a été précipité surtout sous forme de gel. La composition chimique des quartzites est présentée dans le tableau 1. Elle explique la composition minéralogique déterminée microscopiquement, y compris l'absence de l'alunite, l'andalousite, le diaspore et le corindon, spécifiques aux quartzites secondaires de Kazakhstan. Les observations de terrain et microscopiques relèvent que la formation des quartzites, autant ceux liés aux andésites de Seini que ceux liés aux andésites de Piscuiatu a eu lieu avant les processus de minéralisation. En grand, la succession des transformations hydrothermales est la suivante : propilitisation adulairisation séricitisation silicification minéralisation.

La mise en place de la minéralisation liée aux andésites de Seini à Ilba, Nistru et Băița tout comme celle liée aux andésites quartzifères de Piscuiatu, de Tyazoșa, Ludovica, Wilhelm, Sofia et Valea Roșie est accompagnée des processus de chloritisation, silicification±adulairisation, argilisation et carbonisation. La silicification de cette étape, accompagnée des dépôts d'adulaire monoclinique, est faible et n'engendre pas des quartzites proprement-dites.

Pour établir le rapport d'âge entre quartzites et filons métallifères des champs miniers susmentionnés, on a mesuré la position des fissures naturelles des affleurements de quartzites, logés dans les roches-hôte des filons, y compris celles des zones d'entre les champs miniers. Ces mesurages ont mis en évidence que les quartzites de Beneci, de la partie ouest du périmètre, sont traversés par des fissures naturelles ayant des positions très variées et n'arrivant pas à des maximums bien individualisés, situation spécifique **aux zones de bréchification.** Les quartzites des champs miniers d'Ilba, Nistru, Băița et Săsar sont traversés par des fissures parallèles aux filons métallifères, respectivement aux fissures traversant la roche-hôte des filons. Cela montre que la formation des fissures affectant les quartzites a été déterminée par les mêmes causes tectoniques qui ont produit des fractures filoniennes. Il en résulte que les processus de silicification responsables de la formation des quartzites sont antérieurs aux processus de minéralisation de la région.

Outre les quartzites, dans le périmètre étudié apparaissent encore des opales qui constituent le remplissage des filons traversant les andésites de Seini non affectées hydrothermalement, ainsi que les andésites quartzifères de Piscuiatu. A la différence des quartzites, chez lesquels peuvent être poursuivis des passages graduels vers la roche non silicifiée, les opales présentent des limites nettes envers la roche-hôte ; au contact des filons d'opale il n'y a pas des processus de métamorphisme hydrothermal. Leur mise en place a été aussi réalisée d'après toutes les probabilités, avant les processus de minéralisation liés aux andésites de Seini et de Piscuiatu.

Les températures de formation des quartzites, déterminées par la méthode dilatométrique proposée par Bolgiu et Manilici (1976), montrent que les processus de silicification engendrant les quartzites ont été réalisés entre 418 et 126°C

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(tableau 2). La formation des opales de la région a eu lieu approximativement entre les mêmes limites de température. Pour vérifier si les perturbations des courbes dilatométriques ne sont pas déterminées par la perte de l'eau de la masse de l'opale durant le réchauffement ont été effectuées trois analyses thermiques différentielles (fig. 4). On aperçoit, vu ces courbes, qu'il n'y a aucune liaison entre les perturbations des courbes dilatométriques et celles de la perte de l'eau.

EXPLICAȚIA PLANȘELOR

Planșa I

Fig. 1. — Cuarțit cu resturi de andezit de Seini adularizat. Valea Seinelului. N +, 78 ×.
Quartzite à restes d'andésite de Seini adulairisés. Vallée du Seinului. N +, 78 ×.

Fig. 2. — Cuarțit Beneci. N +, 78 ×.
Quartzite de Beneci. N +, 78 ×.

Fig. 3. — Cuarțit cu resturi de adular triclinic de la S de Piatra Handalului. N+, 78 ×.
Quartzite à restes d'adulaire triclinique au S de Piatra Handalului. N +, 78 ×.

Fig. 4. — Cuarțit Murgău. N +, 50 ×.
Quartzite de Murgău. N +, 50 ×.

Planșa II

Fig. 1. — Andezit de Seini adularizat cu pseudomorfoze de adular triclinic brecifiat și silicifiat, cimentat de cuarț + adular monoclinic. Piatra Handalului. N +, 78 ×.
Andésite de Seini adulairisée à pseudomorphoses d'adulaire triclinique, bréchifiée et silicifiée, cimentée de quartz + adulaire monoclinique. Piatra Handalului. N +, 78 ×.

Fig. 2. — Andezit de Seini adularizat cu pseudomorfe de adular triclinic după feldspați plagioclazi prezentînd un început de silicifiere și adularizare cu depunere de adular monoclinic din perioada de mineralizare. Contactul fil. 290 — Fătuțoaia. N +, 78 ×.
Andésite de Seini adulairisée à pseudomorphoses d'adulaire triclinique après feldspaths plagioclases qui présentent un commencement de silicification et d'adulairisation à dépôt d'adulaire monoclinique durant la période de minéralisation. Contact fil. 290 — Fătuțoaia. N +, 78 ×.

Fig. 3. — Gangă de cuarț cu adular monoclinic larg cristalizat. Valea Seișina. N +, 156 ×.
Gangue de quartz à adulaire monoclinique largement cristallisé. Vallée Seișina. N +, 156 ×.

Fig. 4. — Gangă de cuarț cu adular monoclinic larg cristalizat de pe filonul 3, Valea Roșie. N +, 78 ×.

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Gangue de quartz à adulaire monoclinique largement cristallisé du filon 3, Valea Roșie. N +, 78 ×.

Planșa III

Fig. 1. — Gangă de cuarț cu adular monoclinic. Filonul Țiger. N +, 78 ×.
Gangue de quartz à adulaire monoclinique. Filon de Țiger. N +, 78 ×.

Fig. 2. — Depuneri de opal și calcedonie. Cariera Cicărlău. N ||, 78 ×.
Dépôts d'opale et calcédoine. Carrière de Cicărlău. N ||, 78 ×.

Fig. 3. — Opal în stadiul avansat de transformare în calcedonie. Cariera Cicărlău. N ||, 78 ×.
Opale en stade avancée de transformation en calcédoine. Carrière de Cicărlău. N ||, 78 ×.

Fig. 4. — Opal limonitic. Valea Ulmoasă. N ||, 78 ×.
Opale limonitique. Valea Ulmoasă. N || 78 ×.

Planșa IV

Fig. 1. — Andezit cuarțifer silicifiat și adularizat din acoperișul filonului Wilhelm. N +, 50 ×.
Andésite quartzifère silicifié et adulairisé du toit du filon Wilhelm, N +, 50 ×.

Fig. 2. — Brecie andezitică de Piscuiatu adularizată și silicifiată cimentată cu cuarț și adular monoclinic. Poprad. N +, 50 ×.
Brèche andésitique de Piscuiatu adulairisée et silicifiée cimentée à quartz et adulaire monoclinique. Poprad. N +, 50 ×.

Fig. 3. — Opal limonitic străbătut de filonașe cu umplutură de cuarț ± adular monoclinic. N ||, 78 X.
Opale limonitique traversé par des filonets de remplissage de quartz ± ± adulaire monoclinique. N ||, 78 ×.

Fig. 4. — Depuneri ritmice de opal și calcedonie. Cariera Cicărlău. N +, 78 ×.
Dépôts rhytmiques d'opale et calcédoine. Carrière de Cicărlău. N +, 78 ×.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

Rb, Sr AND K DISTRIBUTION IN YOUNG VOLCANICS FROM THE CĂLIMANI-HARGHITA AND PERȘANI MOUNTAINS. PETROGENETIC IMPLICATIONS [1]

BY

SERGIU PELTZ [2], GABRIELA GRABARI [2], ANCA TĂNĂSESCU [2], ELEONORA VĂJDEA [2]

Andesites. Basalts. Dacites. Rhyolites. Rb, Sr, K. *Analytical methods. Geochemical distribution. Chemical classification. Magmatic differentiation. Calc-alkaline series. Subduction. Lithospheric crust. Geotectonic model. Plate tectonics. East Carpathians-Neogene-Quaternary eruptive-Călimani, Harghita, Perșani.*

Sommaire

Distribution de Rb, Sr *et* K *dans les volcanites jeunes des monts Călimani-Harghita et Perșani. Implications pétrogénétiques.* L'étude de la distribution de Rb, Sr et K se base sur 148 d'échantillons représentant tous les types de roches volcaniques jeunes des monts Călimani-Harghita et Perșani (Carpathes Orientales). Les volcanites appartiennent à la suite calco-alcaline basalte-andésite-dacite-rhyolite ; on remarque la présence des andésites fortement potassiques, des dacites fortement potassiques (sporadiquement) et des banakites. L'étude a été initiée dans le but d'apporter des contributions détaillées à la caractérisation géochimique des volcanites et à la confirmation de quelques points de vue sur leur genèse. A partir des valeurs de Rb, Sr, K, Rb/Sr, K/Rb, K/Sr on révèle les différences existentes entre les basaltes pléistocènes de Perșani et l'association néogène andésite-dacite-rhyolite de Călimani-Harghita. En comparaison des andésites et des dacites, les basaltes présentent des valeurs plus petites de Rb, Rb/Sr, K/Sr et des valeurs plus grandes de K/Rb Ce. fait dénote que le magma parental provenu du manteau n'a pas subi des modifications, grâce à l'apport du matériel lithosphérique. Les teneurs rapprochées de Rb, Sr, K, en différentes variétés d'andésites, relèvent l'appartenance à un fond homogène de magma. Les valeurs plus petites de K/Rb et celles plus grandes de K/Sr et de Rb/Sr par rapport aux basaltes, peuvent être expliquées par le mécanisme de la formation du magma

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București.

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andésitique, grâce à l'apport du matériel de la lithosphère au matériel basaltique initial. Les volcanites fortement potassiques de Drăgoiasa (Călimani, NE) et de Tușnad-Malnaș (Harghita, SE) proviennent de divers magmas. Le magma de type Drăgoiasa a engendré des volcanites exclusivement acides à teneur élevée de Rb, K, Rb/Sr, K/Sr ; cela indique un magma différencié, à la constitution duquel un rôle important revient au matériel sédimentaire. Le magma de type Tușnad-Malnaș a donné des volcanites intermédiaires et acides fortement potassiques à valeurs élevées de K, Sr ; il a été généré à la fin du processus de subduction au dépens du magma andésitique avec un apport des composantes de la croûte lithosphérique. En même temps a eu lieu un processus d'assimilation du matériel lithosphérique en chambres magmatiques intermédiaires.

1. Introduction

These last 15 years several studies have been carried out on the distribution of minor elements Cu, Pb, Zn ; Ni, Co, Cr, V, Sc ; Sr, Ba ; U, Th, K in the volcanics from the Călimani-Harghita and Perșani Mts. The investigations aimed at a better geochemical characterization of the products of the Carpathian young volcanism.

The results of recent petrological studies on the volcanic associations from different regions of the Earth have proved the special importance of Rb, Sr and K in the research of geochemical features of volcanics, and mainly in elucidating the relationship between the tectonic background and the genesis of magmas.

As regards the petrological importance of Rb, Sr and K, one notes that due to its big and closed ionic radius, Rb is related to K minerals (Rb^+=1.47 ; K^+=1.33) and is also concentrated in the products of magma differentiation ; the ionic radius of Sr is intermediate between Ca and K (Sr^{2+}=1.18, Ca^{2+}=0.99) and it is related to plagioclases and K-feldspar. These minerals play an important part in processes of generation and differentiation of calcalkaline magmas.

The Călimani-Harghita Mts, as volcanic calcalkaline area generated within an intracontinental geological background by subduction processes, exhibit at least partly different features as compared to the Pacific island arc associations and Andine continental margin ones. Owing to the geochemical-petrogenetic features of Rb, Sr and K, the study of their distribution will point to the nature and significance of these differences or similarities.

In 1973 Peltz et al. wrote a note on the results of the investigations carried out on the K, U and Th distribution in view of the geochemical characterization of the petrotypes from the Călimani--Harghita and Perșani Mts.

A former estimation of Rb, Sr and K distribution in the Călimani-Harghita volcanics was made by Bencini and Peccerillo (1977) on 39 analyses. By comparing the data reported for the Călimani-Harghita to those regarding some other calcalkaline series, the authors conclude that under the peculiar tectonic conditions from the East Carpathians were generated magmas similar to the island arc ones.

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The authors of the present note intend to use more complete and representative data (148 analyses) in order to achieve a detailed geochemical characterization of young volcanics from the Călimani-Harghita and Perșani Mts as well as to substantiate some view points on their genesis.

2. Geological background

The Călimani-Gurghiu-Harghita area represents the maximum development region of young volcanism situated inside the Carpathians. The volcanic activity started during the Upper Malvensian and continued intensely during the Pontian and the Pliocene. The volcanic edifice consists of two structural compartments : volcano-sedimentary (lower) and stratovolcanic (upper). The two compartments are built up of different types of andesites, subordinately basaltic andesites and dacites. According to the chemical classification, besides andesites there are low-Si andesites, high-K or low-K andesites, high-K dacites and rhyolites.

The volcanic activity took place in central volcanoes of varied dimensions ; it is worth mentioning the presence of volcanic edifices of caldera type and with well preserved craters. The superstructure and infrastructure of the volcanic edifice are characterized by the occurrence of several igneous bodies. The volcanoes and the igneous bodies lie on mainly northwest-southeast trending alignments. The eruptive activity from the Călimani-Harghita area as well as all over the Carpathians was generated by subduction processes (Bleahu et al., 1973 ; Boccaletti et al., 1973 ; Rădulescu, Săndulescu, 1973). Due to their geochemical features, the volcanics from this area resemble the island arc calcalkaline associàtions (Boccaletti et al., 1973).

The basaltic volcanism developed during the Pleistocene, at the extremity of the East Carpathian volcanic chain, on the western area of the Perșani Mts (Racoșu de Jos-Comana). It was of mixed, mainly effusive nature ; the volcanoes are of small dimensions. According to the mineralogical and chemical classifications all the products are basalts. The petrochemical study points to the slightly alkaline character of the basalts from this area.

According to Rădulescu, Săndulescu (1980), Rădulescu (fide Rădulescu et al., 1981), the Perșani basaltic volcanism belongs to a magmatic activity which had been generated under intraplate conditions, after the alpine consolidation.

3. Analytical methods

Rb and Sr have been determined by means of non-dispersive XRF spectrometry (power dispersive) and utilizing a Si(Li) detector (190 eV at 5.9 Kev). The X-rays were stimulated by a Cd-109 source of 5 mCi.

The sampled material was a fine powder (3 g) stored in a plastic box with a Mylar sheet on the bottom. AGV-1 and BCR-2 standards have been used (Grabari, 1977). The detection limits were stated at 10 ppm for Rb and Sr. Within the field of 10-50 ppm, the errors are

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TABLE 1

Volcanic rocks from the Călimani-Gurghiu-Harghita and Perșani Mts. Analytical data

No	SiO_2 %	K_2O %	Rbppm	Srppm	Rb/Sr	K %	K/Rb	K/Sr
				Low-K tholeiite				
1	51.43	0.44	20.29	244.7	0.0829	0.3	178	15
				Basalt				
2	49.20	1.32	41.11	255.2	0.1611	1.1	267	43
3	51.29	1.49	46.29	331.6	0.1395	1.2	280	39
4	51.88	0.76	19.32	238.4	0.0810	0.6	362	29
				Low-Si andesite				
5	52.90	1.13	34.07	248.8	0.1369	0.9	279	38
6	53.07	0.94	27.10	272.0	0.0996	0.8	295	29
7	53.11	0.75	24.65	235.4	0.1047	0.6	252	26
8	53.16	0.68	14.51	246.7	0.0588	0.6	385	22
9	53.36	1.12	37.42	290.5	0.1287	0.9	249	32
10	53.40	1.58	37.78	429.1	0.0880	1.3	344	30
11	53.53	1.13	35.70	277.5	0.1286	0.9	252	32
12	53.80	0.88	45.57	416.9	0.1093	0.7	100	17
13	53.87	1.01	27.57	268.2	0.1027	0.8	290	29
14	53.88	1.04	27.42	288.5	0.0950	0.9	328	31
15	54.30	1.16	42.98	236.8	0.1814	1.0	232	42
16	54.50	1.15	32.92	298.3	0.1103	1.0	303	33
17	54.64	1.37	30.18	396.0	0.0762	1.1	377	28
18	55.04	1.11	39.02	250.4	0.1557	0.9	256	39
19	55.10	0.96	32.39	338.3	0.0957	0.8	277	26
20	55.61	1.32	36.31	287.4	0.1263	1.1	300	38
21	55.80	1.55	42.06	372.6	0.1131	1.1	309	39
22	55.90	1.49	70.22	240.1	0.2921	1.2	142	51
				High-K, low-Si andesite				
23	52.76	1.94	71.71	269.5	0.2289	1.6	261	59
24	52.85	2.02	57.72	251.2	0.2294	1.7	294	67
25	53.88	1.76	48.28	302.8	0.1599	1.5	310	49
26	54.70	2.06	31.00	303.5	0.1021	1.7	548	56
				Low-K andesite				
27	61.03	0.81	34.31	195.4	0.1755	0.7	204	35

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No	SiO_2%	K_2O%	Rbppm	Srppm	Rb/Sr	K%	K/Rb	K/Sr
				Andesite				
28	56.05	1.32	34.05	316.9	0.1077	1.1	322	34
29	56.10	1.29	35.37	248.4	0.1423	1.1	310	44
30	56.14	1.19	27.20	245.1	0.1109	1.0	257	28
31	56.30	1.15	34.94	266.0	0.1313	1.0	286	37
32	56.31	0.93	30.88	240.4	0.1284	0.8	218	33
33	56.38	1.26	36.70	266.7	0.1381	1.0	285	37
34	57.12	1.32	35.07	279.2	0.1256	1.1	313	39
35	57.50	1.25	21.20	262.0	0.0809	1.0	471	38
36	57.50	1.69	58.24	290.5	0.2004	1.4	240	48
37	57.93	1.84	52.68	506.4	0.1040	1.5	289	29
38	58.30	1.30	59.07	204.4	0.2890	1.1	183	52
39	58.40	1.58	33.69	356.0	0.1789	1.3	204	36
40	58.58	1.66	67.42	301.3	0.1905	1.4	243	46
41	58.78	1.16	58.00	272.3	0.1395	0.9	236	33
42	58.78	1.48	32.69	364.0	0.0898	1.2	267	32
43	58.80	1.68	63.68	311.9	0.2041	1.4	220	44
44	58.91	1.37	38.53	275.4	0.1399	1.1	296	41
45	59.32	1.20	39.14	371.3	0.1054	1.0	255	26
46	59.62	1.88	63.73	496.6	0.1283	1.6	251	32
47	59.80	1.80	50.52	586.0	0.0862	1.5	297	25
48	60.60	1.88	50.75	282.7	0.2148	1.6	263	56
49	61.48	1.61	57.13	188.8	0.3025	1.3	227	68
50	62.70	1.27	45.20	306.6	0.1473	1.0	221	32
				High-K andesite				
51	56.61	3.20	40.32	2054.0	0.0196	2.7	670	13
52	57.50	2.08	53.73	1700.0	0.0316	1.7	317	1
53	60.11	2.56	93.18	392.0	0.2376	2.1	225	53
54	60.16	2.05	57.83	503.3	0.1149	1.7	293	33
55	61.87	2.33	68.76	653.9	0.1051	1.9	276	29
				Banakite				
56	56.78	4.05	52.88	2860.0	0.0185	3.4	642	11
57	57.92	4.09	61.66	3000.0	0.0205	3.4	551	11
				Dacite				
58	63.80	1.67	62.29	242.3	0.2570	1.4	225	57

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No	SiO_2 %	K_2O %	Rbppm	Srppm	Rb/Sr	K %	K/Rb	K/Sr
High-K dacite								
59	64.84	3.22	85.84	1700.0	0.0503	2.7	315	15
60	65.04	3.25	54.16	2900.0	0.0186	2.7	498	9
61	67.27	3.13	125.0	259.2	0.4825	2.6	207	100
62	68.04	3.31	132.7	294.6	0.4504	2.7	203	19
Rhyolite								
63	72.90	2.35	70.72	158.5	0.4460	1.9	276	122

Petrotype acc. to mineralogical composition : basaltic andesite = no. 1, 2, 3, 4, 9, 12, 23, 24, 25 ; pyroxene andesite = no. 7, 8, 11, 13, 15, 17, 18, 27, 29, 31, 32, 33, 34, 38, 42, 46, 51, 52, 53 ; pyroxene-hornblende andesite = no. 6, 10, 14, 16, 19, 22, 26, 28, 30, 39, 40, 44, 45, 47, 50, 58 ; hornblende andesite = no. 20, 21, 35, 36, 37, 41, 43, 48, 49, 55 ; hornblende-biotite andesite = no. 54 ; pyroxene-hornblende ± biotite ± quartz andesite = no. 56, 57, 59, 60 ; dacite = no. 61. 62. 63.

of about 10% ; in the case of higher concentrations the errors decrease at less than 5%. K was determined by gamma spectrometry. The measuring chain consists of a scintillation well-type detector with NaI (Tl) crystals and a 400 canals analyser SA-40B "INTERTECHNIQUE".

The ground samples averaged from about 2 kg of rock were introduced in identical precincts ; each sample (=0.5 kg) was measured for one hour. In order to standardize the width of the analyser canal the radioactive isotope Cs^{137} was used. The calculated error of K determination = 5%.

4. Results and discussions

In order to study the Rb, Sr and K distribution in the volcanics from this area, 148 samples representing 128 andesites and dacites from Călimani-Harghita and 20 basalts from Perşani have been analysed. Following their areal distribution, these samples represent the petrotypes, the eruption phases and the volcanic units. Table 1 includes the individual values of Rb, Sr, K as well as of Rb/Sr, K/Rb and K/Sr of 63 samples. Out of the 148 samples, only these ones have been analysed chemically and were classified according to the SiO_2-K_2O relationship (Fig. 1). As far as only some samples were defined according to their chemical composition, the present note will consider the petrotypes analysed and they will be defined by taking into account

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the mineralogical and chemical classifications. Table 2 presents the average values characteristic of the Călimani-Harghita and Perșani petrotypes, delimited according to the two classifications.

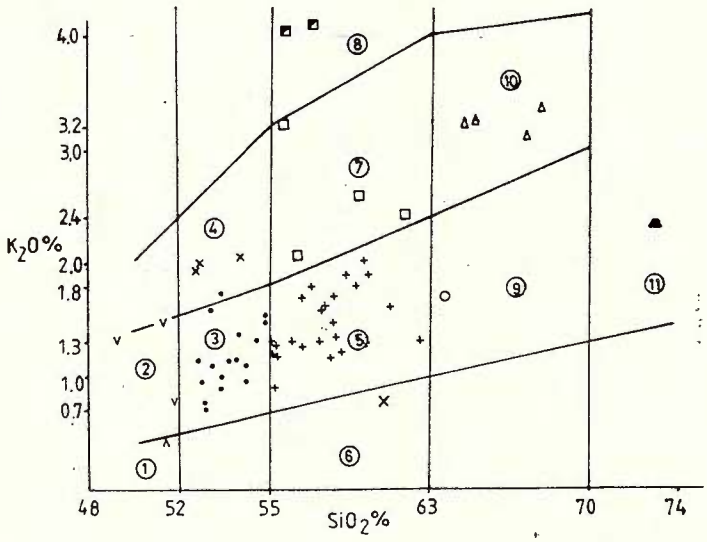


Fig. 1. — SiO_2-K_2O diagram of classification of analysed samples (acc. to Taylor, 1969, Peccerillo, Taylor, 1976).

1, tholeiite ; 2, basalt ; 3, low-Si andesite ; 4, low-Si, high-K andesite ; 5, andesite ; 6, low-K andesite ; 7, high-K andesite ; 8, banakite ; 9, dacite ; 10, high-K dacite ; 11, rhyolite.

In order to give a complete account of the Rb, Sr and K distribution in the volcanics from this region, Table 2 presents the average values of 15 samples of andesite tuffs. The chemical heterogeneity as well as the secondary alterations entail different values, generally lower as compared to massive rocks. The relatively few data we dispose of, show that the geochemical studies imply a proper use of Rb, Sr and K analyses of tuffs.

The graphic representation of the differentiation of the rocks analysed is based on the relationships between SiO_2 and Rb, Sr, K/Rb (Fig. 2a, b, 3). It is to note the grouping and the different positions of : basalts, low-Si andesites, andesites, high-K andesites+banakites+dacites ; the rhyolite appears in extreme position.

The comparative study of average contents (Tab. 2) points to the Rb, Sr, K increase from basalt to andesite and the high increase of contents of high-K volcanics.

The high Sr contents group the high-K rocks from the Tușnad-Malnaș region (high-K andesite, banakite, high-K dacite) in a special position. At the same time, one notices that excepting some samples

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TABLE 2

Volcanic Rocks from the Călimani-Gurghiu-Harghita and Perşani Mts. Averages.

Petrotype acc. to mineralogical classification	Rb ppm	Sr ppm	Rb/Sr	K%	K/Rb	K/Sr
Basaltic andesite (n = 16)	46.2	279.6	0.1674	1.4	304.7	50.4
Pyroxene andesite (n = 34)	49.4	289.0	0.1709	1.4	283.0	48.0
Pyroxene - hornblende andesite (n=22)	42.1	299.0	0.1408	1.0	237.0	33.0
Hornblende andesite (n = 19)	48.0	335.0	0.1433	1.2	250.0	36.0
Pyroxene-hornblende ± biotite ± quartz andesite (n = 14)	50.3	2410.0	0.0209	2.9	576.0	12.0
	60.5	495.0	0.1222	1.7	281.0	34.0
Dacite (n = 9)	109.1	269.0	0.4056	2.6	238.0	97.0
Tuffs (n = 15)	37.1	276.0	0.1344	0.9	242.0	33.0
Petrotype acc. to chemical classification	**Rb ppm**	**Sr ppm**	**Rb/Sr**	**K%**	**K/Rb**	**K/Sr**
Basalt (Călimani) (n = 3)	35.6	275.0	0.1294	1.0	281.0	36.0
Basalt (Perşani) (n = 20)	37.8	777.0	0.0486	1.2	317.0	15.0
Low-Si andesite (n = 18)	35.4	300.0	0.1180	0.9	254.0	30.0
High-K, low-Si andesite (n = 4)	49.7	281.0	0.1769	1.6	322.0	57.0
Andesite (n = 23)	45.0	314.0	0.1433	1.2	267.0	38.0
High-K andesite	47.0	1877.0	0.0250	2.2	468.0	12.0
	73.3	516.0	0.1420	1.9	259.0	37.0
Banakite (n = 2)	57.3	2930.0	0.0195	3.4	593.0	12.0
High-K dacite (n = 4)	70,0	2300,0	0,0304	2,7	386,0	12.0
	128.8	277.0	0.4650	2.7	209.0	97.0

of high-K volcanics all the other ones, although differentiated in the SiO_2 field, cover a relatively reduced area of K/Rb (200-400, Fig. 3).

The Sr-Rb diagram (Fig. 4 mineralogical classification, Fig. 5 chemical classification) marks clearly the special position of some pyroxene-hornblende±biotite±quartz andesites, banakites and high-K dacites from the Tuşnad-Malnaş region (Sr > 1000 ppm) as well as some dacites from the Drăgoiasa region (Rb > 70 ppm). One may also note some differentiations of Rb and Sr contents of andesites. Of peculiar interest is the Rb value of the Drăgoiasa rhyolite (Fig. 5) comparable to that one of the high-K dacites ; the Sr content is inferior to that one of andesites.

On the K-Rb diagram (Fig. 6, K ppm-Rb, mineralogical classification, Fig. 7 K%-Rb, chemical classification), excepting the Tuşnad-Malnaş volcanics, the other ones are plotted on the field between the lines K/Rb=200 and K/Rb=500.

The Sr and Rb contents and K/Rb and Rb/Sr ratios are very different in high-K volcanics as compared to the other volcanics which are characterized by smaller differences between petrotypes or within the same petrotype (Fig. 8, 9). According to the relationships between the above mentioned values, the exactly opposite positions of most volcanics from the Drăgoiasa and Tuşnad-Malnaş regions are illustrated.

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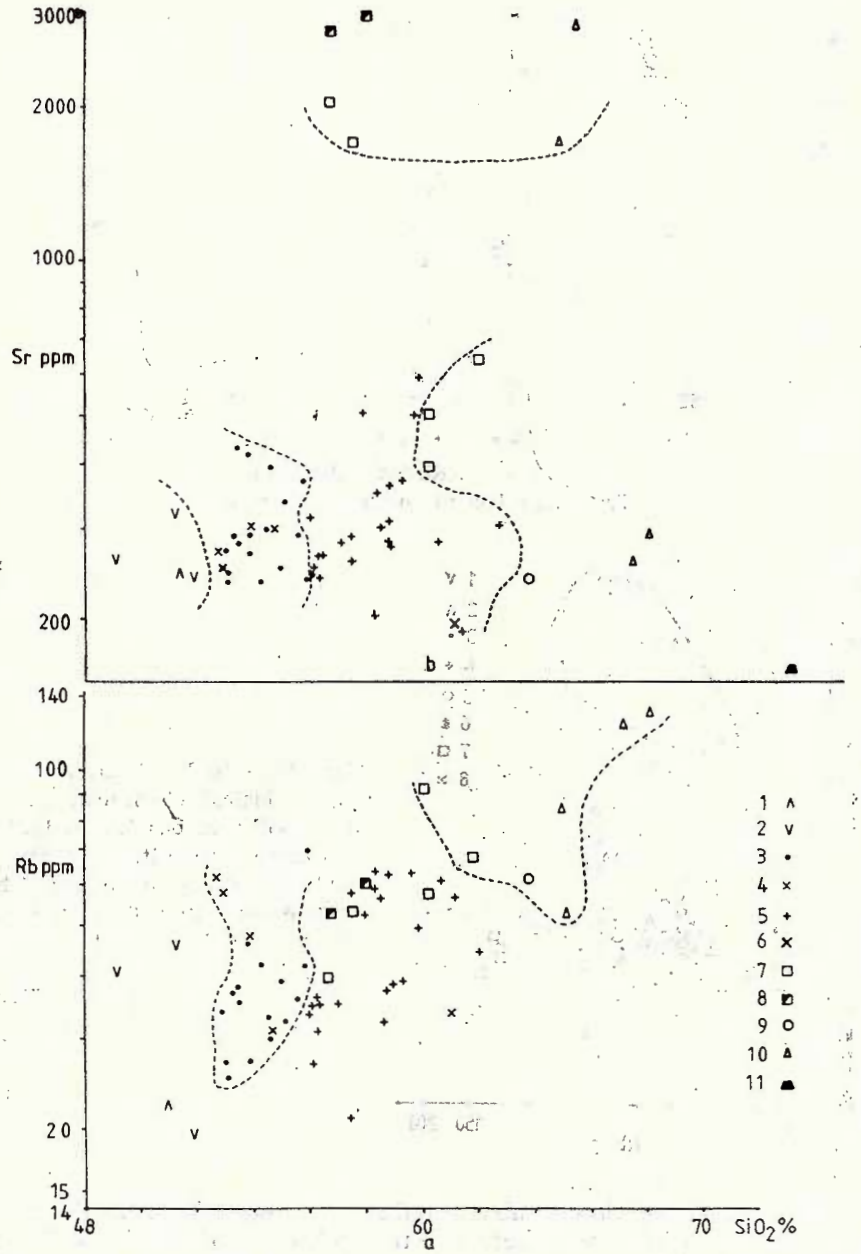


Fig. 2. — Rb-SiO_2 (a) and Sr-SiO_2 (b) diagrams.
The same legend as for Figure 1.

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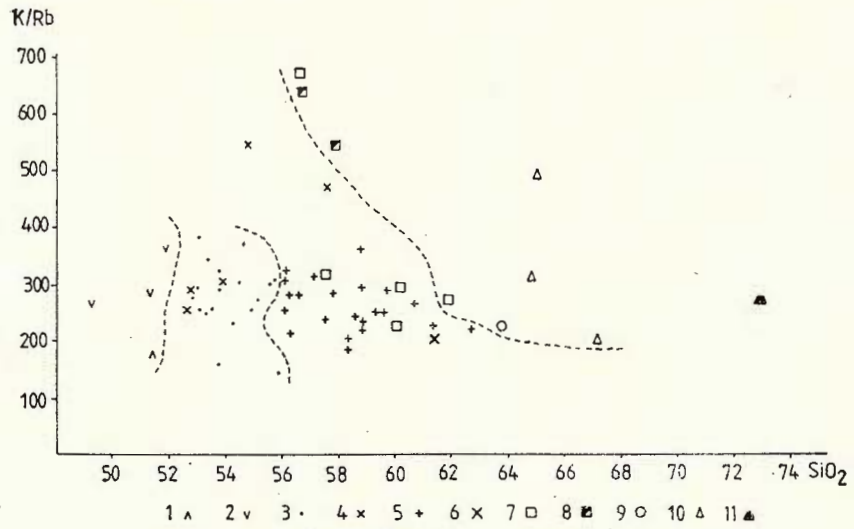


Fig. 3. — K/Rb-SiO_2 diagram.
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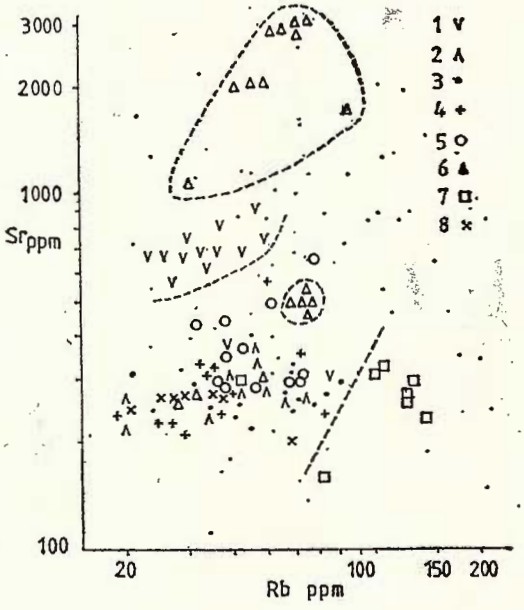


Fig. 4. — Sr-Rb diagram (mineralogical classification).
1, basalt; 2, basaltic andesite; 3, pyroxene andesite; 4, pyroxene and hornblende andesite; 5, hornblende andesite; 6, biotite andesite; 7, andesite tuff; 8, dacite.

The facts mentioned above point out that the Rb, Sr and K contents reveal differences between the volcanics of the basaltic andesite-andesite-dacite-rhyolite association from the Călimani-Harghita Mts. It is also to note the important differences between andesites and high-K volcanics (andesites-|-dacites) from the Tuşnad-Malnaş region and between the latter and the Drăgoiasa dacites.

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Although the andesites cover an area of some thousands of km and they have been generated during several eruption stages between the Malvensian and the Pliocene, they are relatively homogeneous, which points to a single genetic mechanism of the parental magma.

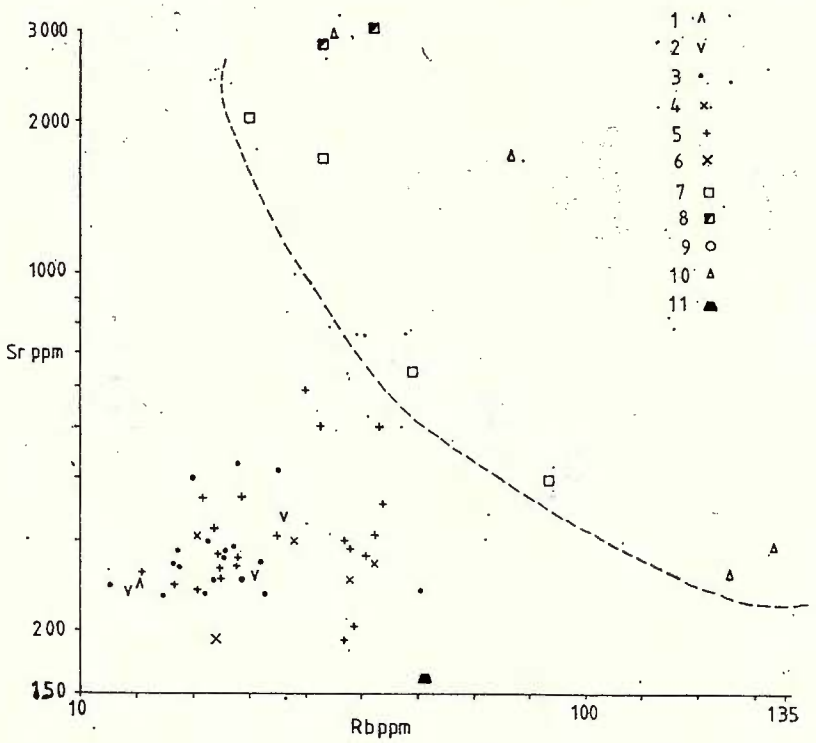


Fig. 5. — Sr-Rb diagram (chemical classification).
The same legend as for Figure 1.

The high Sr and K contents of the Tușnad-Malnaș volcanics and the Rb and K contents of the Drăgoiasa dacites point to the different chemistry of magmas as compared to that one of andesites and basalts. The participation of lithosphere and mantle supply in the constitution of the Drăgoiasa and Tușnad magmas could account for their peculiar composition.

The Sr and K increase in the Tușnad-Malnaș volcanics could have been also caused by other factors, such as the assimilation of sedimentary material in intermediate magmatic chambers which succeeded to the generation of andesite parental magma by means of subduction processes. This view point is similar to that one previously presented by Peltz et al. (1973 a, b) and Rădulescu (1973), Rădulescu, Dimitriu (1973).

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The petrogenetic remarks inferred from the study of Rb, Sr and K distribution in the Călimani-Harghita and Perşani volcanics are in agreement with those pointed out by the study of REE distribution

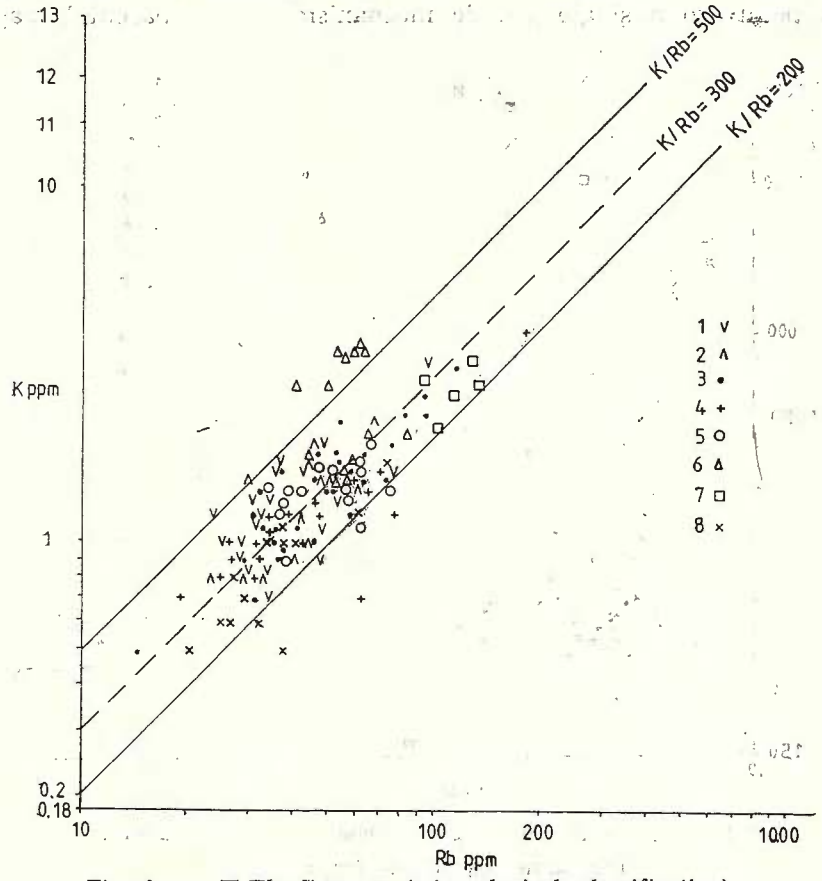


Fig. 6. — K-Rb diagram (mineralogical classification). The same legend as for Figure 4.

in similar rocks from the same volcanic regions (Peltz, Stoian, this volume).

The comparison of Rb, Sr and K contents reported for the volcanics from Călimani-Harghita, New Zealand (Pacific island arc, Ewart, Stipp, 1968, fide Bencini, Peccerillo, 1977) and Chile (Andine continental margin, Siegers et al., 1969, Pichler, Zeil, 1972, fide Bencini, Peccerillo, 1977) points to : a) close Rb contents=43, 40, 42 and Rb/Sr ratios= =0.15, 0.17, 0.14 ; b) different Sr contents especially between Călimani-Harghita and New Zealand on one hand and Chile on the other (297, 271, 743) as well as different K/Rb ratios (292, 325, 397).

Although generated by subduction processes on different geological backgrounds (intracontinental, island arc, continental margin) the calcalkaline volcanics show more similarities than differences. As men-

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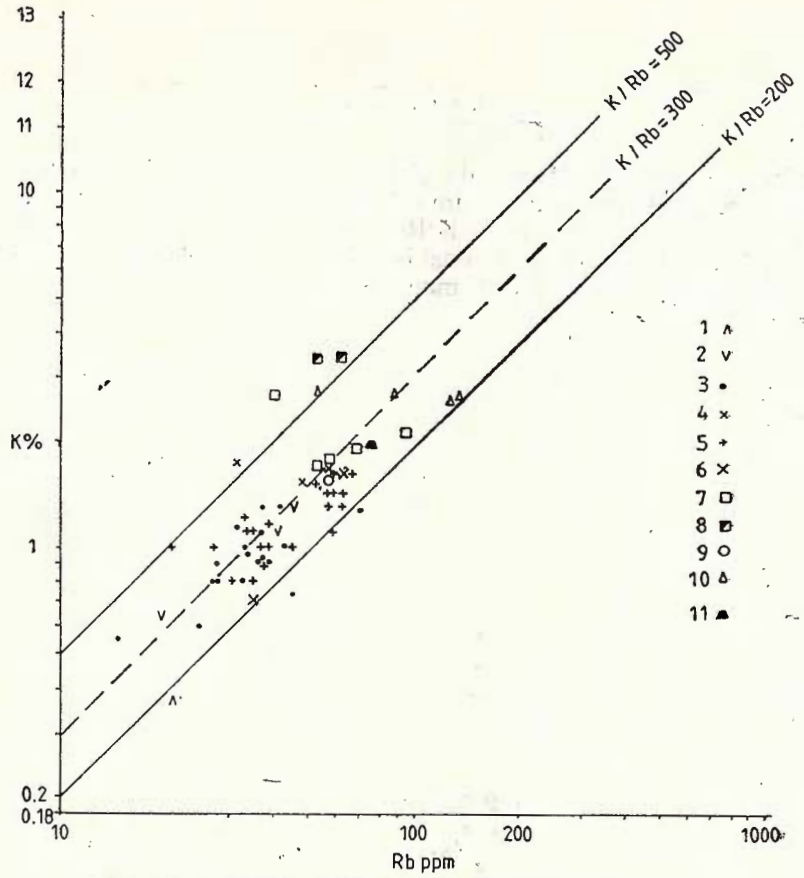


Fig. 7. — K-Rb diagram (chemical classification).

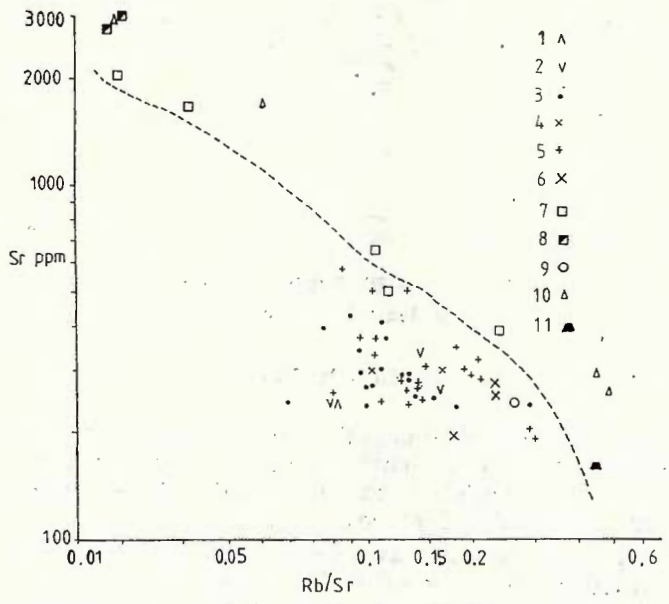


Fig. 9. — Sr-Rb/Sr diagram.
The same legend as for Figure 4.

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tioned by Bencini and Peccerillo (1977), the K/Rb ratio shows clearly the difference between the Călimani-Harghita volcanics and the New Zealand and Chile ones. As K/Rb ratio is lower in the Călimani-Harghita, it could be used to consider the role of sedimentary material in the generation of parental magmas.

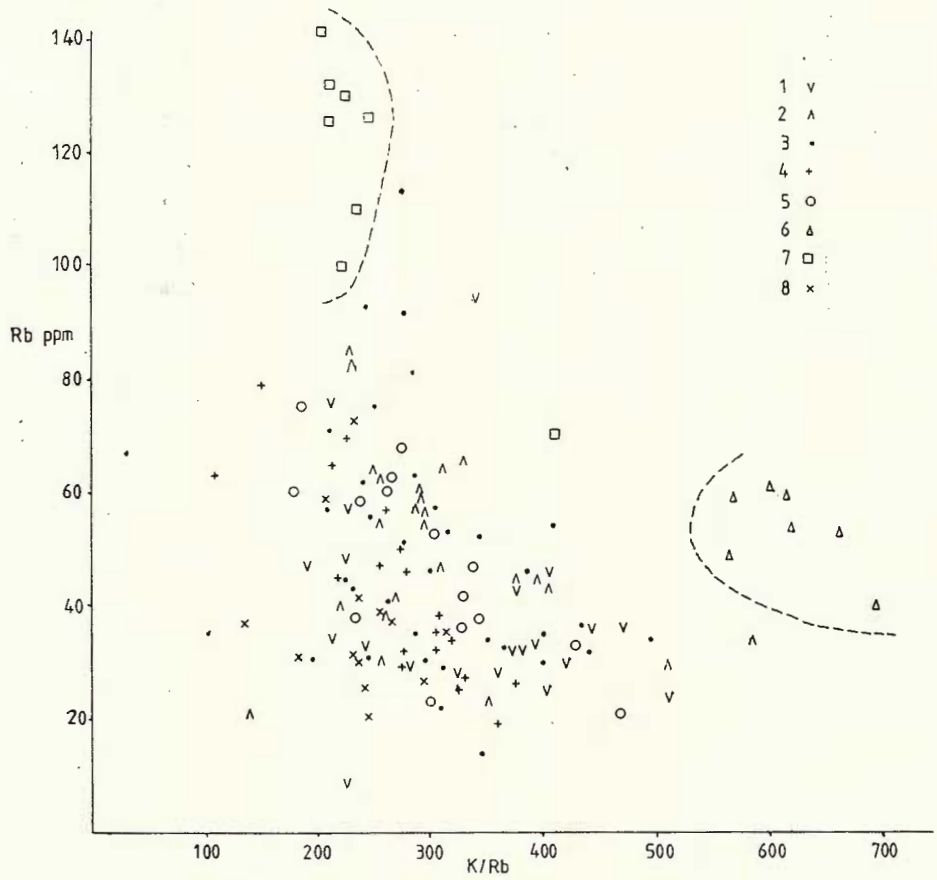


Fig. 8. — Rb-K/Rb diagram.
The same legend as for Figure 1.

5. Conclusions

The Călimani-Harghita-Perşani volcanic chain consists of the calc-alkaline basalt-andesite-dacite-rhyolite series. The products of this association occur in association with subordinate high-K volcanics, which show in places shoshonite features.

In the light of present-day geodynamic principles the Călimani-Harghita volcanics are considered to have been generated by subduction processes within an intracontinental geological background and the Perşani basalts are posterior to the consolidation of lithosphere plates.

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The study of Rb, Sr and K distribution points to differences among basalts, andesites, high-K andesites + high-K dacites. According to some petrogenetic view points (Taylor, 1968 ; Sighinolfi, 1969 ; Jakeš, White, 1970 ; Armstrong, 1971 ; Dupuy et al., 1977) and to the conclusions of the study of REE distribution (Peltz, Stoian, this volume), the young volcanics from the Călimani-Harghita and Perșani Mts are considered to have been generated by four different magmas as follows.

The Perșani Pleistocene basalts represent the products of REE enriched garnet peridotite magma. As compared to the Călimani-Harghita andesites and dacites, Rb=37.8, Rb/Sr=0.0486, K/Sr=15 are smaller ; K/Rb ratio=317, exceeds K/Rb ratio=292 of andesites. This shows that the parental magma generated by the mantle has not been changed by processes of involvement of lithospheric material.

The Călimani-Harghita andesites which have erupted on a Carpathian area 125 km long, during a time interval between the Upper Malvensian and the end of Pliocene, as well as during several stages, have been generated by a relatively homogeneous magma. This characteristic is pointed out by the following values : Rb ppm=43.3 ; Sr ppm=298 ; $K^0/_0$=1.2 ; Rb/Sr=0.146 ; K/Rb=281 ; K/Sr=41. The less K/Rb ratios and the higher K/Sr and Rb/Sr ones as compared to basalts point to the generation of andesite magma by processes of involvement of sediments.

The Drăgoiasa acid volcanics (dacites, subordinately rhyolites) and the Tușnad-Malnaș high-K volcanics (high-K andesites, banakites, high-K dacites) have been generated by different magma types which do also differ from andesite and basaltic magmas. Thus, the Drăgoiasa parental magma has generated only acid volcanics with Rb ppm=109 ; Sr ppm=269 ; $K^0/_0$=2.6 ; Rb/Sr=0.4056 ; K/Rb=238 ; K/Sr=97. The high Rb contents point to a differentiated magma ; the high-K content correlated with high Rb/Sr and K/Sr ratios reveal the involvement of the material from the crust during the subduction process.

The Tușnad magma has generated intermediate and acid high-K volcanics ; it exhibits the highest average values all over the Călimani-Harghita area, Sr ppm=2930 and $K^0/_0$=3.4. These data reveal a parental magma constituted during the final stages of the subduction process from an andesite magma and an important amount of sedimentary material from the lithosphere crust. One should also consider the assimilation of sedimentary material in intermediate magmatic chambers which succeeded to the generation of the parental magma.

The geochemical features of some volcanics from the Călimani-Harghita area related to Rb, Sr and K distribution confirm Armstrong's (1971) view on the role of the involvement of sediments in the magma genesis.

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D. S. Inst. Geol. Geofiz. vol. LXIX/1 (1982). Pag. 339-349

1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

REE DISTRIBUTION IN YOUNG VOLCANICS FROM THE CĂLIMANI-HARGHITA AND PERȘANI MOUNTAINS[1]

BY

SERGIU PELTZ[2], MARIA STOIAN[2]

Andesites. Dacites. Intraplate basalts. Pliocene. Pleistocene. REE. Geochemical distribution. Magmatic differentiation. Parental magmas. Subduction. Plate tectonics. Petrogenetic model. East Carpathians-Neogene-Quaternary eruptive-Călimani, Harghita, Perșani.

Sommaire

Distribution des terres rares dans les volcanites jeunes des monts Călimani-Harghita et Perșani. La, Ce, Sm, Eu, Lu ont été déterminés par l'analyse d'activation à neutrones thermiques de 28 échantillons représentant les volcanites de la série calcoalcaline des Carpathes Orientales : andésites basaltiques, andésites, dacites — de subduction — d'âge pannonien-pliocène des monts Călimani-Harghita ; basaltes — d'intraplaque — d'âge pléistocène des monts Perșani. Eu égard au fond réduit de données analytiques, les auteurs ont étudié la distribution géochimique des terres rares pour contribuer à la caractérisation géochimique des volcanites et à l'évaluation préliminaire de certaines hypothèses actuelles concernant leur genèse. Les valeurs T. R. faibles, La/Sm, Σ T. R. indiquent des différences entre des basaltes et des andésites et entre ceux-ci et les dacites. De grandes différences apparaissent aussi entre les volcanites fortement potassiques de la région de Tușnad-Malnaș (Harghita du Sud) et les autres volcanites. Les dacites fortement potassiques de la région de Drăgoiasa (Călimani de nord-est) se différencient beaucoup des volcanites fortement potassiques de Tușnad-Malnaș. Compte tenu de quelques points de vue des modèles pétrogénétiques de Thorpe et al. (1976), Peccerillo, Taylor (1976), Dupuy et al. (1977) on doit admettre que les volcanites des monts Călimani-Harghita et Perșani ont été générées par quatre magmas parentaux à caractères distincts. Le magma parental des basaltes de Perșani a été de type péridotite granatifère, enrichi en T. R. La variation entre la participation du matériel représentant la lithosphère soumise à la subduction et le matériel du manteau de type pyroxénite

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[2] Institutul de Geologie și Geofizică, str. Caransebeș 1, 78344 București.

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granatifère a conditionné la genèse des magmas parentaux : andésitique, de type Drăgoiasa, acide fortement potassique — de type Tuşnad-Malnaş — intermé-+acide fortement potassique.

1. Introduction

The last decade is characterized by the elaboration, according to plate tectonics concepts, of some models regarding the genesis of East Carpathian young volcanics. Corresponding to these models, there are some view points on the genesis of magmas which have generated the volcanics of this area. However, the geochemical proofs of the petrogenetic view points are not of the same importance as the tectonic ones. That is why, at present the emphasis is laid on the geochemistry of volcanics, especially on the distribution of those elements which are very important for elucidating the petrogenetic problems.

Out of the trace elements many scientists are taking into account the rare earth elements in order to substantiate the petrogenetic models. We dispose of 28 analyses which represent the andesites and dacites from the Călimani-Gurghiu-Harghita area and the basalts from the Perşani area. The authors of the present note are going to use these data in view of the study of rare earth distribution which contributes to the geochemical characterization of volcanics and to the estimation of several present-day hypotheses regarding their genesis.

Peccerillo and Taylor (1976) study the REE distribution in 6 samples of volcanic rocks from the Călimani-Harghita area. Due to the reduced number of samples examined, the results of the investigation are considered by the authors as preliminary. The petrogenetic view points will be reconsidered later on.

The studies concerning the trace element distribution in the young volcanics from the Călimani-Harghita and Perşani Mts, published by Peltz et al. (1972, 1973 a, b), aimed at both the geochemical characterization and the substantiation of several view points on the features of parental magmas. The investigation was centred on the distribution of trace elements Cu, Pb Zn ; Ni, Co, Cr, V ; U, Th, K.

2. Geological framework

The Călimani-Gurghiu-Harghita chain represents the area of maximum development of young volcanism inside the East Carpathians ; it covers a unitary area of about 6,400 sq km. The andesite volcanism prevailed in the whole area and manifested under different forms — effusive, explosive and subordinately intrusive (dome, dike, sill).

The structure of the volcanic edifice consists of two units. Each one was formed during independent evolution stages of volcanism and under characteristic lithogenetic conditions. The volcanic petrotypes are generally represented by pyroxene andesites and pyroxene-hornblende andesites. The dacites crop out in the eastern part of the Călimani Mts and in some areas of the Harghita Mts, being prevalent in the southern

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areas. The areal extent of basaltic andesites is typical of the Călimani Mts.

The volcanic activity took place in central volcanoes of different dimensions. The upper compartment is characterized by the occurrence of complex edifices of caldera type, as well as of volcanic edifices with well preserved crater. The volcanoes and the igneous bodies lie on mainly NW-SE trending alignments.

The volcanic activity started during the Upper Malvensian and went on during the Pontian and the Pliocene. In this area, it was generated by subduction processes (Bleahu et al., 1973; Boccaletti et al., 1973; Rădulescu, Săndulescu, 1973). Due to their geochemical features, the volcanics resemble the island arc calcalkaline associations (Boccaletti et al., 1973).

The basaltic volcanic activity took place during the Pleistocene in the south-westernmost part of the East Carpathian volcanic chain. The volcanic products from the Perșani Mts occur between the localities of Racoșu de Jos (Fig. 1) and Comana. The volcanic activity was of mixed, mainly effusive nature. The small volcanoes lie on a SSW-NE trending alignment.

According to Rădulescu and Săndulescu (1980), the basaltic volcanic activity from the Perșani Mts belongs to the magmatic activity posterior to the alpine consolidation, under intraplate conditions.

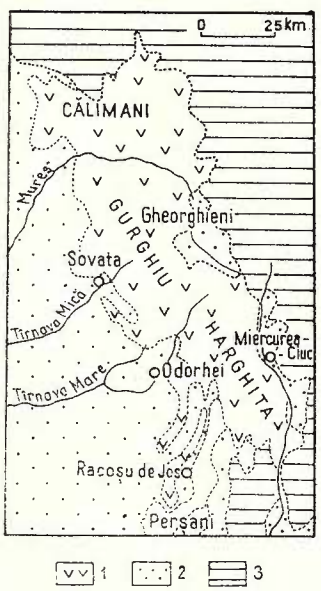


Fig. 1. — Location of the Călimani-Harghita-Perșani volcanic area (acc. to the tectonic sketch map of Romania, scale 1 : 2,500,000, drawn up by Dumitrescu and Săndulescu). 1, young volcanics in the Călimani-Harghita and Perșani Mts; 2, rocks of the Transylvanian Depression and of the Gheorghieni, Ciuc, Sfîntu-Gheorghe and Baraolt depressions; 3, rocks of the Transylvanian, Central, Ceahlău nappes as well as of the Transcarpathian Zone.

3. Analytical methods

La, Ce, Sm, Eu, Lu have been determined by means of thermic neutron activation, the non-distructive variant, which is one of the most frequently used methods all over the world in view of quantitative measurement of low clarke elements.

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As regards the complex gamma spectra, there are instances in which two or more photopeaks influence one another (as they are very close as concerns the energy) leading to an inaccurate identification of energy and to important errors in connection with the areas designed by usual methods. In order to do away with these drawbacks, the samples were measured at three different "cooling" times (T_1=5-8 days; T_2=12-15 days ; T_3=30-40 days) and the concentrations were calculated by taking into account only the photopeaks without interferences.

The activity of ^{140}La and ^{153}Sm was measured at T_1, of ^{177}Lu at T_2 and of ^{141}Ce and ^{152}Eu at T_3.

The rock samples were finely ground (grains of 400 mesh), dried at 105°C and then tightly wrapped in pure aluminium sheets. The sampled quantity was of about 200 mg.

The activity of ^{410}La and ^{153}Sm was measured at T_1, of ^{177}Lu the IFIN reactor with a flow of thermic neutrons of $5\times10^{12}n/cm^2s$ during 7 hours. The activity of samples was measured by a high resolution gamma spectrometry equipment, with Ge(Li) detector of coaxial type, active volume of 22 cm^3, power resolution of 3.8 Kev for 1332.5 Kev a ^{60}Co line. The signals of the detector were processed by means of the Canberra electronic equipment and the 800 canal analyser of SA-43 INTERTECHNIQUE type.

The accuracy of the concentrations determined is of : 5-7% in the case of Ce, Lu, Sm, Eu and of 10% in the case of La. The sensitivity of this method is : La — 1 ppm, Ce — 0.5 ppm, Sm — 0.8 ppm, Eu — 0.1 ppm, Lu — 0.5 ppm.

4. Results

According to their chemical features, the rare earth elements (REE) divide into : light rare earth elements (LREE) and heavy rare earth elements (HREE). Further on we are going to study the analytical data regarding some light rare earth elements and Lu. Table 1 includes the REE contents of the 28 samples analysed, the rock type corresponding to the mineralogical and chemical classification, the location. Table 2 includes the REE contents reported by Peccerillo and Taylor (1976).

The content means have been calculated by taking into account the individual values (Table 3). They have been chondrite normalized as follows : La=0.300 ; Ce=0.840 ; Sm=0.210 ; Eu=0.074 ; Lu=0.031 (Peccerillo and Taylor, 1976). Concomitantly ΣLREE and La/Sm of all petrotypes classified according to the mineralogical composition have been stated : basalt, ΣREE=50.3 ; La/Sm=8 ; basaltic andesite, ΣREE=40.3 ; La/Sm=5 ; pyroxene andesite, ΣREE=44.6 ; La/Sm=5 ; pyroxene-hornblende andesite, ΣREE=38.2 ; La/Sm=5.75 ; hornblende andesite, ΣREE=52.7 ; La/Sm=7 ; pyroxene-hornblende±biotite±quartz andesite, ΣREE=245 ; La/Sm=10.5 ; dacite, ΣREE=72.9 ; La/Sm=4.75.

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TABLE 1

REE in Volcanics from the Călimani-Harghita and Perșani Mountains

No.	Sample	Petrotype		Location	La	Ce	Sm	Eu	Lu
		Mineralogical composition	Chemical composition						
1	2	Basalt	Basalt	Bogata	15.0	23.3	2.1	1.12	0.21
2	7	Basalt	Basalt	Bogata	13.1	24.6	2.2	1.15	0.19
3	17	Basalt	Basalt	Racoșu de Jos	27.8	38.2	2.5	1.35	0.18
4	40	Basalt	Basalt	Racoșu de Jos	18.7	17.3	2.4	0.89	0.22
5	45	Basalt	Basalt	Comana	21.8	33.6	2.8	1.23	0.21
6	277	Basaltic andesite	Basalt	Poiana Negrii	18.3	19.5	3.5	0.94	0.23
7	153	Basaltic andesite	Basalt	Sărmaș	14.2	20.5	2.6	0.80	0.36
8	213	Pyroxene andesite	Andesite	Dornișoara	10.7	14.3	3.4	0.89	0.29
9	253	Pyroxene andesite	Andesite	Pietrele Roșii	16.3	21.7	3.2	0.98	0.26
10	233	Pyroxene andesite	Andesite	Rățitiș	15.6	33.7	2.4	1.09	0.32
11	141	Pyroxene andesite	High-K andesite	Puturos	16.6	34.2	2.8	1.58	0.30
12	167	Pyroxene andesite	Low-K andesite	Zebrac	13.2	31.2	2.8	0.81	0.33
13	140	Pyroxene andesite	Andesite	Șumuleu	15.1	23.3	2.9	0.88	0.38
14	124	Pyroxene andesite	Andesite	Suseni	14.0	24.0	2.8	0.77	0.39
15	53	Pyroxene andesite	Andesite	Juhod	15.4	24.0	3.1	0.95	0.21
16	256	Hornblende-pyroxene andesite	Andesite	Gura Haitii	16.6	25.3	3.2	1.03	0.23
17	165	Hornblende-pyroxene andesite	Andesite	Zebrac	5.6	6.8	1.5	1.01	0.20
18	199	Hornblende-pyroxene andesite	Low-Si andesite	Răstolița	7.8	8.2	2.5	0.93	0.27
19	123	Hornblende-pyroxene andesite	Andesite	Groapa Mare	27.6	40.7	3.0	0.84	0.21
20	207	Hornblende andesite	Andesite	Dornișoara	7.5	6.5	2.5	0.91	0.25
21	133	Hornblende andesite	Andesite	Șumuleu	11.1	15.6	2.5	1.26	0.42
22	130	Hornblende andesite	Andesite	Răchițiș	15.8	19.6	2.7	0.85	0.33
23	78	Hornblende andesite	Low-Si andesite	Creanga Mică	35.6	48.6	3.6	1.16	0.18
24	75	Hornblende andesite	Low-Si andesite	Creanga Mică	36.1	45.7	4.2	1.18	0.15
25	107	Pyroxene-hornblende ± biotite ± quartz andesite	High-K dacite	Bicsad	61.1	143	4.3	2.60	0.22
26	103	Pyroxene-hornblende ± biotite ± quartz andesite	High-K dacite	Malnaș	83.5	183	9.4	2.90	0.22
27	257	Dacite	High-K dacite	Drăgoiasa	20.0	71.9	4.8	1.30	ndt*
28	258	Dceti	High-K dacite	Drăgoiasa	13.5	31.6	2.3	0.72	ndt*

* not detected.

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TABLE 2

REE in Volcanics from the Călimani-Harghita Mountains (acc. to Peccerillo and Taylor, 1976)

No.	Petrotype (acc. to Taylor, 1969)	La	Ce	Sm	Eu	Lu
1	Basalt, Sălard, Călimani Mts.	20	44	3.28	0.90	0.28
2	Low-Si andesite, Iuhod, Gurghiu Mts.	20	43	3.60	1.15	0.33
3	Andesite, Pinul, Călimani Mts	18	42	3.27	0.85	0.27
4	High-K andesite, Bixad, Harghita Mts.	75	163	7.60	1.98	0.09
5	Dacite, Voivodeasa, Călimani Mts.	12.7	29	1.49	0.52	0.18
6	Rhyolite, Drăgoiasa, Călimani Mts.	18.7	39	2.56	0.67	0.05

TABLE 3

Mean REE Contents in Volcanics from the Călimani-Gurghiu-Harghita Mountains

Petrotype acc. to mineralogical classification	La	Ce	Sm	Eu	Lu
Basalt	19.2	27.4	2.4	1.14	0.20
Basaltic andesite	16.2	20	3.0	0.84	0.29
Pyroxene-andesite	14.6	25.8	2.9	0.99	0.31
Pyroxene-hornblende andesite	14.4	20.2	2.5	0.95	0.22
Hornblende andesite	21.2	27.2	3.1	1.07	0.26
Pyroxene-hornblende ± biotite ± quartz andesite	72.3	163	6.8	2.75	0.22
Dacite	16.7	51.7	3.5	1.01	ndt*
Petrotype acc. to chemical classification					
Basalt	18.4	25.2	2.5	1.06	0.22
Andesite	16.7	21.2	2.7	0.88	0.31
Low-Si andesite	26.5	34.1	3.4	1.09	0.20
High-K dacite	44.5	107	5.2	1.88	0.22

* not detected.

4.1. *The Călimani--Harghita andesites and dacites*

The 23 samples analysed stand for the main types of andesites and dacites from the Călimani-Gurghiu-Harghita belt. By considering the way the samples represent the three massifs, their different units and petrotypes, one may state that the remarks and the conclusions inferred are of preliminary nature.

La contents vary within wide limits and for most petrotypes (Tab. 1) they exceed the mean value of andesites = 11.9 (Taylor, 1968). At the same time, they are lower than the values mentioned by Peccerillo and Taylor (1976) for 3 samples from this area (nos. 1, 2, 3, Tab. 2). It is to note the variation of La within the same petrotype irrespective of its mineralogical or chemical classification (Tab. 1). As regards this variation field, one notes the reduced contents which

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characterize the Călimani andesites and the higher ones of the Gurghiu andesites. The high-K dacite (pyroxene-hornblende±biotite± quartz andesite, according to the mineralogical classification) from the Tușnad-Malnaș area exhibits high La contents. Unlike this one, the high-K dacite from the Drăgoiasa area shows La contents similar to those ones characteristic of andesites (Tab. 1).

The distribution of Ce contents may be correlated with La distribution (Tab. 1). The highest or the lowest Ce contents are usually similar to La ones. Samples 141 and 167 from the Călimani Mts are an exception. As compared to La, the Ce of dacites shows high values in the samples from the Drăgoiasa region too. The Ce values of the Călimani-Harghita andesites are comparable to the mean value of andesites according to Taylor (Ce=24). The contents reported by us have been generally lower in the case of andesites and higher in the case of dacites, in opposition to those of Peccerillo and Taylor (Tab. 2).

Sm, Eu, Lu contents are less differentiated in andesites and dacites. The Sm and Eu means of the Călimani-Harghita andesites are comparable to mean values = 2.9 and 1.0 reported by Taylor (1968). There are only few instances in which our data are comparable to those of Peccerillo and Taylor (Tab. 1, 2).

When revising the rare earth element distribution one notes differences among basalts, andesites and dacites. The most important differences are between andesites and high-K dacites from Tușnad-Malnaș. The LREE show synthetically the differences among basalts, andesites and dacites and also obvious differences between the Drăgoiasa (Călimani) high-K dacites and the Tușnad-Malnaș (Harghita) ones. The La-Sm ratio of andesites points to a slight SiO_2 increase (La/Sm from 5.4 to 6.8). It is also to note the La/Sm=8 of the Perșani basalts and La/Sm=4.75 in the Drăgoiasa dacites (Tab. 1).

All these data reveal the peculiar geochemical features of the magmas which have generated the Perșani basalts, the Călimani-Harghita andesites and dacites. As concerns the parental andesite magma, one notes differences at least among the main eruption stages : basaltic andesite, pyroxene andesite, amphibole andesite.

Figure 2 shows the chondrite-normalized REE patterns for andesites and dacites. One notes the fractionation of LREE for all petrotypes and a stronger fractionation of HREE in the case of the Tușnad-Malnaș high-K dacites. As far as the pyroxene andesites are concerned, the line is less inclined in the field of HREE, pointing to a diminished fractionation. The Drăgoiasa high-K dacites exhibit a different fractionation tendency of LREE, although their contents are close to those of andesites.

The chondrite-normalized REE distribution diagram points to the following : a) the almost parallel aspect of REE patterns of the different eruption stage andesites which accounts for their common origin; b) differences between the REE pattern of andesites and that one of the Drăgoiasa dacite. This shows a peculiar genetic mechanism, that is the Drăgoiasa dacite had not been generated by the fractional crystallization of the parental andesite magma. It also corresponds to the geological data, according to which the dacite eruption had preceded

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the andesites which build up the lower compartment of the Călimani Mts ; c) differences between the REE patterns which represent the different types of andesites from Călimani-Harghita and high-K dacites from Tuşnad-Malnaş. The obviously different aspect of HREE

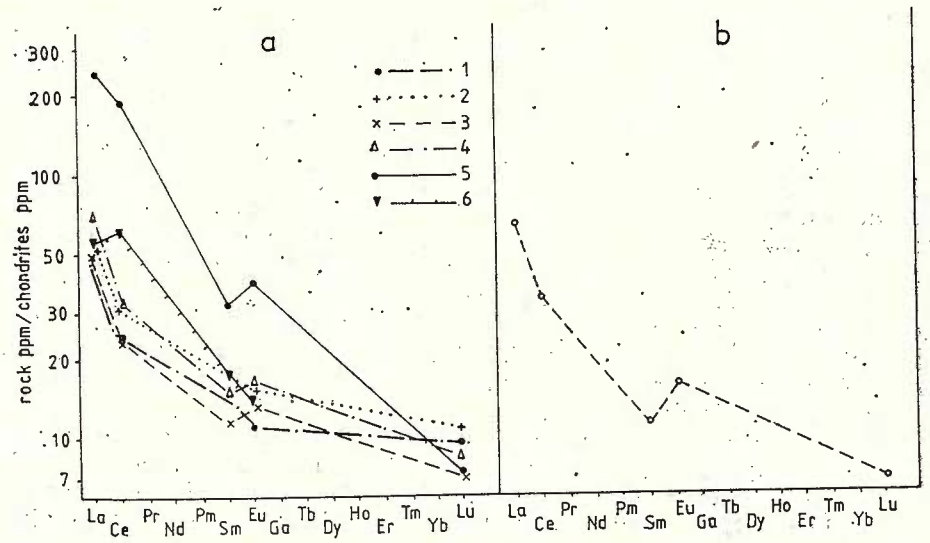


Fig. 2. — Chondrite normalized REE distribution in the mean composition of the volcanics in the Călimani-Harghita and Perşani Mts.
a, subduction volcanics ; b, intraplate volcanics ; 1, basaltic andesites ; 2, pyroxene andesites ; 3, pyroxene and hornblende andesites ; 4, hornblende andesites ; 5, biotite andesites ; 6, dacites.

Note : According to the chemical classification proposed by Peccerillo and Taylor the biotite andesites and the dacites are called high-K dacites.

field points to different magmas. The andesitic crust model (Taylor, 1968) is also accounted for by the high La and Ce contents of the Tuşnad-Malnaş dacites, which essentially alter the position and aspect of LREE patterns.

4.2. *The Perşani basalts*

At present we dispose of the first 5 LREE and Lu analyses of samples representing Pleistocene basalts from the Perşani Mts (Tab. 1). Due to the reduced number of samples, our remarks are purely informative.

The data of Table 1 (nos. 1-5) point to high La and Ce contents which are of the same order or higher than those reported for andesites. The Sm and Lu contents are smaller and the Eu ones are higher as compared to andesites.

The chondrite-normalized REE patterns for the analysed samples (Fig. 2b) exhibit the differentiation of contents both in the LREE field

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and in the HREE field. According to Manetti et al. (1979) the liquids resulted from the melting of garnet peridotite point to a high fractionation of HREE (also characteristic of the Perșani basalts). This is due to the fact that the garnet is a strong HREE discriminant, $D^{Yb}_{S/L} > D^{Tb}_{S/L}$ (Arth, 1976 fide Manetti et al., 1979). By taking into account the data above which point to poor LREE enrichment as compared to the mean of andesites and fractionation of REE, one may account for a LREE enriched melt of garnet peridotite type as parental magma of the Perșani basalts. This petrogenetic model corresponds to our data on the Ni, Co, Cr, V distribution in the Perșani basalts (Peltz et al., 1972).

5. Petrogenetic remarks and conclusions

Several petrogenetic models have been elaborated in order to study the geochemical features of the basalt-andesite-dacite-rhyolite calcalkaline volcanic association. Further on, we are going to consider only those ones which take into account the peculiar role of REE group as well as the geotectonic premises similar to the East Carpathian ones.

A multi-stage genetic model has been proposed by Thorpe et al. (1976) ; initiation of melting at the subduction zone and rise of magmas into the overlying mantle-wedge which thereby becomes richer in garnet-pyroxene components and large-ion lithophile (LIL) elements ; 2) partial melting of this LIL enriched garnet pyroxenite material to form andesitic magmas within the mantle-wedge ; 3) minor crystal fractionation during the rise through the crust. According to this genetic model, the subducted ocean crust undergoes subsolidus transformation, from amphibolite to eclogite. The partial melting of eclogite takes place at 100-150 km. The magmas generated are LREE enriched and react with the overlying mantle enriching it in garnet and pyroxene components. Thus, the garnet pyroxenite is the source of andesite magma. The LREE enrichment depends on the ratio of garnet to other silicate phases.

By studying the distribution of some trace elements, REE included, in the calcalkaline volcanics, Dupuy et al. (1977) conclude that all the andesites exhibit common features, but they differ from one zone to another due to their incompatible element content (K+associated elements, REE). These elements point to the higher contents characteristic of continental margin andesites. The andesites were generated in the upper mantle in the spinel or garnet areas. Under these conditions, the parental andesite magma gets lithophile elements enriched. Crustal contamination is also considered.

By taking into account the basic principles of the petrogenetic models of Thorpe et al., and Dupuy et al., one finds out the view points which illustrate the genesis of calcalkaline volcanics from the Călimani-Perșani area. It is worth mentioning that, by examining the REE distribution of 6 samples from the Călimani-Harghita area, Peccerillo and Taylor adopt a similar genetic model, at the same time. The rocks of the calcalkaline series are considered the product of partial melting of garnet pyroxenite composition ; this results from the reaction be-

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tween the primary melts of the undergoing oceanic slab and the peridotitic mantle overlying the Benioff zone. On the other hand, the Drăgoiasa and Tuşnad high-K dacites are known to have been generated by magmas which represent primary meltings of the subducted plate.

One should consider that the genetic models, including the above mentioned ones, are inferred from complex geotectonic and petrologic premises. Some of them have been mentioned by Rădulescu (1981). The author shows that at present it is agreed on the genesis of andesite magmas by fusion of ocean-type lithosphere in subduction areas. As compared to the magmas generated in the mantle, the andesite ones are of secondary nature as they have been generated by a material previously drawn in geological processes. Although andesite magmas result mainly from the melting of basic rocks generated by the mantle, they differ from the magmas generated in the mantle due to the sialic material contained. The study of the varying features of andesite magmas should envisage the composition of the subducted and melted lithosphere as well as the composition of the mantle.

The results of several petrogenetic studies have proved that the investigation of REE distribution contributes to solving up some problems related to the genesis of volcanics. Although we dispose of relatively few analytical data, as inferred from the results mentioned above, the REE behaviour in different petrotypes (basalts, andesites, dacites) points to their belonging to magmas with different features.

According to the petrogenetic models referred to, it is assumed that the volcanics which had built the Călimani-Perşani chain were generated by four magmas with different features : a) dacite magma which generated the acid volcanics cropping out in the north-easternmost part of the Călimani Mts (Drăgoiasa) ; they are characterized by the different REE fractionation as compared to all the other volcanics of this chain ; b) andesite magma which represents the source of the products that had built the largest part of the Călimani-Harghita area; c) dacite magma, the source of acid high-K volcanics from the Tuşnad-Malnaş region (different REE fractionation as compared to all the other volcanics of this area). It is worth mentioning that the Drăgoiasa and Tuşnad magmas have been generated during the initial and final stages of subduction volcanism, in the eastern extremities of the Călimani-Harghita chain ; d) basaltic magma, generated under different geodynamic conditions, in the Perşani Mts, represents a LREE enriched garnet peridotite melt. The different chemistry of the subducted and melted lithosphere induced the peculiar character of REE distribution in high-K dacites from southern Harghita. Variations of the geochemical features of andesite and dacite magmas have also been brought about by the variation of the ratio between the mantle garnet pyroxenite and the subducted lithosphere.

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1. MINERALOGIE-PETROLOGIE-GEOCHIMIE

BOOK REVIEWS

T. D. PERYT : *Coated Grains*, Springer Verlag, Berlin-Heidelberg-New York, 1983, 655 p., 359 figs.

The sedimentary particles known as "coated grains" (Wolf, 1960) have been scientifically observed since the last century. Their study gradually increased by the use of ever better methods, especially in the last two decades, when the ancient and recent carbonate formations have been systematically and intensively investigated.

The book edited by T. D. Peryt represents a review of the actual knowledge of this group of sedimentary grains, presented in synthesis articles and, especially, in the detailed and well-illustrated study of some new such particles originating from various recent marine and continental environments and old sedimentary formations. In the 52 papers grouped in 6 chapters (Approaches, Ooids, Rhodoids, Oncoids, Vadoids, Contrasted occurrence) various aspects of these grains are presented and discussed in a highly scientific manner : structures and ultrastructures, mineralogical and chemical composition, minor elements and carbon isotopes, formation environments, distribution, ecology, diagenetic evolution etc. ; the interpretation of their origin and environmental significance is based on them.

Concerning some problems (classification, genesis) there are, of course, differences of opinion, but the particular value of the book consists in the numerous and detailed data as well as in the interesting interpretations on the various types of coated grains investigated by the authors of the articles. Although it deals with a relatively narrow realm, the book is meant, in fact, for all the specialists working in the sendimentary field, as "coated grains" are significant with respect to environment and are found in a lot of ancient and recent sedimentary formations. Therefore we highly appreciate the idea of presenting in a single volume most of the knowledge on this interesting and fascinating chapter of sedimentary petrology, called "coated grains".

G. Pop

D. G. PERYT : *Geochemical Aspects of Radioactive Waste Disposal.* Springer Verlag, New York-Berlin-Heidelberg-Tokyo, 1984, 328 pp.

The remarkable development of the researches on nuclear energetics raised the problem of the storage of radioactive waste materials, whose siting is difficult due to their high radioactivity.

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Brookin's book deals with this problem from the geochemical point of view, with special regard to the geological conditions in which radioactive wastes can be stored. The book comprises 15 chapters (328 p.), the most important of them being : Radioactive Waste Management, Types of Radioactive Waste and the Multibarrier System, Geologic Sites : Generic Cases, Geologic Repositories : Specific Sites, Alternate Plans for Waste Disposal, Toxicity. The author also reviews the programmes of the Government and of the International Atomic Energy Agency (IAEA) concerning the investigations carried out in various countries for finding the best geological conditions of radioactive waste disposal. The main problem arisen is not only the high-level radioactivity, but also the long life of some elements (Am, Pu, Sr, Y).

The author shows that numerous rocks as well as the geologic conditions were studied in view of their use as storage sites. Thus salt deposits, basalts and granites were investigated. The hydrothermal factor is the most important in the author's opinion and therefore should be taken into account. Further on the author deals with the subseabed disposal of radioactive waste. Thus the oceanic zones, especially those in the Pacific Ocean and the large abyss round the Philippines, are investigated.

Other possibilities for the storage of radioactive wastes that should be considered are : the uninhabited oceanic islands, the ice sheet disposal, the well injection and the transmutation of radioactive elements. The storage on the ocean floor seems to be the most propicious of the mentioned possibilities.

A chapter of the book is devoted to the description of the toxicity of the waste material and the treatment and explanation of the geotoxicity index.

Brookin's book, the first of this kind in the relevant literature, represents a valuable contribution to the problem of the radioactive waste disposal under geological conditions.

I. Tiepac

J. O. NRIAGU, P. B. MOORE (eds.) : *Phosphate Minerals.* Springer Verlag, Berlin-Heidelberg-New York-Tokyo, 1984, 442 p., 83 figs.

It is a comprehensive work written by a group of 20 highly specialized contributors, giving an up-to-date overview of phosphorus minerals. They are systematically presented in 14 chapters covering all the main aspects of the mineralogy, geochemistry, genesis of phosphate minerals in various milieux, including the biological systems (it seems that it is the first mineralogy book in which the distribution of mineral compounds in human tissues is given) as well as effects of these rather widespread minerals or of phosphorus on the environment.

The first — the largest and, for mineralogists, the most interesting chapter —, written by one of the editors (J. O. Nriagu) gives short but rather comprehensive data on properties and modes of occurrence of some 300 P-bearing minerals, the most common of which belong to the apatite family. The next two chapters supplement these data with the nucleation and the growth of phosphate minerals (chapter 2) and their crystallochemical aspects (chapter 3, written by the second editor). Thermochemical data of phosphate ions, aqueous complex species and phosphate minerals are presented in chapter 4, with some results of experimental works. In chapters 5-8, the distribution of phosphate minerals in various milieux is given, such as in meteorites and lunar rocks (chapt. 5), in

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terrestrial-igneous and metamorphic-rocks (chapt. 6).; a special chapter (7) is devoted to space and time controls of the P-bearing minerals and rocks — it also includes a map showing the main phosphate deposits all over the world (reviewer : P. J. Cook) ; sedimentary rocks containing more than 18-20% P_2O_5 are called phosphorites — their mineralogy and geochemistry are accurately presented in chapter 8. Weathering of phosphate minerals (chapter 9) includes the specific assemblages resulted from guano reaction in limestones (brushite, whitlockite etc.) and on igneous rocks and soils (leucophosphite, variscite — strengite isomorphous series etc.) ; groundwater action on primary minerals gives millisite, crandallite, wavellite etc. A short review of the formation and stability of base metal phosphates in soils and sediments is given in chapter 10. Hydroxyapatite — the main compound found in bones and other calcified tissues — is fully characterized in chapter 11, and the next chapter deals with the occurrence and types of phosphate minerals in human tissues — bones and teeth — (mainly calcium hydroxyapatite). The last two chapters show some data on the phosphates in waste waters and the waste water treatment (13) and on phosphorus in the environment, emphasizing two aspects of the subject, i.e. the organophosphate compounds (chemical warefare agents called "nerve gases" and now used as a class of insecticids) and the release of the element P in the environment with a case history of such an incident.

Each chapter is followed by a specific and comprehensive reference list. The book has an useful subject index, allowing every topic to be easily found. This "round" work covers a large pluridisciplinary area of interest and gives accurate and basic information on phosphate minerals for mineralogists, geochemists, environmental scientists and biochemists, as well as for engineers and chemists. I recommend this book to be purchased by every library of mineralogy and ore deposits departments and institutes as a valuable source of information.

G. Udubaşa

J. W. MOORE, S. RAMAMOORTHY : *Heavy Metals in Natural Waters.* Springer Verlag, New York-Heidelberg-Tokyo, 1984, 268 p.

This new book in the Springer Series on environmental management provides an interdisciplinary approach to what is one of the main problems in the world : environment pollution. Eight most common heavy metals acting as strong pollutants (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn) were chosen for a comprehensive discussion (chapters 2-9) including the following topics for each metal : chemistry, production, uses and discharges, metal in aquatic systems (speciation in natural waters ; transport in natural waters ; metal in sediments), transformations (biological methylation — the most frequent process), residues (water, precipitation and sediments ; aquatic plants ; invertebrates ; fish) and toxicity (to aquatic plants and invertebrates ; fish ; humans), as well as references.

Chapter 10 (Impact of heavy metals in natural waters) includes (1) the physico-chemical impact on which the fate of metals in natural waters depends (methylation and reduction, increasing or decreasing toxicity as function of metal speciation, mobilization and transport of metals etc. ; there are six typical aquatic systems discussed : Ottawa River, Minamata Bay, Ruhr River, Rhine River, Danube River, Mississippi River) and (2) the biological impact on aquatic plants, on invertebrates and on fish with some examples such as Lake Päijänne, Finland and some fjords in Norway.

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Chapter 11 gives some basic ideas about "Monitoring and impact assessment approaches" (sub-title of the book) in order to solve the environmental problems due to "misuse or misunderstanding of technology". The program development must be based on the chemical (water and sediment analyses) and biological criteria (residue analyses in plants, invertebrates and fish, with special emphasis on differential effects (mainly toxicity and carcinogenicity) of some metals to Homo sapiens as compared to aquatic biota (e.g. nickel).

In the last chapter (12) — "Politics and environmental manager") the necessity of improving the balance of resource development, environmental protection and the quality of life is emphasized. Prevention (of hazards due to pollution) rather than treatment is the main role of environmental management.

The book gives an interdisciplinary review regarding heavy-metal pollution in natural waters; it is of use for a large number of scientists and should not be lacking in any great library. Scientists, engineers and environmental managers will welcome it; for geochemists and geologists it is an interesting approach to applied geochemistry and biochemistry.

G. Udubaşa

S. K. SAXENA: *Advances in Physical Geochemistry,* volume 3, Kinetics and Equilibrium in Mineral Reactions, Springer Verlag, Berlin, 1983, 99 figures, 273 pp.

Volume 3 of "Advances in Physical Geochemistry", entitled "Kinetics and Equilibrium in Mineral Reactions", edited by S. K. Saxena, comprises 8 papers written by well-known scientists from four continents, most of them being from the USA and the USSR. As indicated by the title itself, the mineral reactions are examined by means of the kinetic theory and the mineral equilibria, either by the study of the order-disorder phenomenon, that of the compositional zoning of crystals or by various geobarometry and geothermometry studies. Also various experiments on the equilibria of some classic mineral systems are examined.

The volume starts with an extremely interesting paper written by T. P. Loomis on the compositional zoning of the garnet and feldspar crystals, the author aiming at illustrating the basic physico-chemical processes that make possible the understanding of the zoning, suggesting also the trends of future research. Arguments are provided, supporting the idea that the kinetic inhibitors which preserve the primary magmatic crystals and the high metamorphic grade associations affect also the crystallization and the prograde metamorphism of these rocks. These "kinetic inhibitors" appear as zoned crystals and non-equilibrium associations.

The editor, S. Saxena, examines in his paper the possible relations existing between the exsolution processes in the calcium-ferro-magnesian pyroxenes and the cation order-disorder phenomenon in the non-equivalent crystallographic positions.

A. Lasaga introduces the notion of geospidometry, starting from the fact that by the use of thermodynamics, the dynamics or history of a rock becomes of secondary importance. The quantitative application of geospidometry implies that the chemical equilibrium criterion has been previously established.

In Chapter 4 Eugster and Ilton study the Fe-Mg distribution between a fluid phase and a solid coexisting solution, pleading for the necessity of obtaining some more additional data on the metamorphic fluids.

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Taking into account the fact that the knowledge of the metamorphic pressure is essential for establishing a correct tectonic model, Bohlem, Wall and Boetcher approach the barometric study of granulites, reviewing their own experimental data and presenting a synthesis of the geobarometers applicable to granulites.

The paper written by Aranovich and Podlaski is also concerned with geobarometry, being a study of the cordierite-garnet-sillimanite-quartz mineral equilibrium at the temperature of 700-750°C within the 4-8 kilobars pressure interval. The purpose of the authors was to determine very precisely the equilibrium compositions of the coexisting cordierite and garnet.

A similar mineral system (cordierite-garnet-biotite) is also discussed by the Soviet research workers Perchuk and Lavrentieva. Although the paper deals mainly with experimental processes, it can be of use as well to geobarometry specialists. The last paper, written by Powell, deals with the thermodynamics of complex phases ; the development of a quasichemical model for expressing the activity-composition relation in silicates is supported.

This volume benefits by a vast and well-selected list of references, a real work tool for the specialists.

It is of use to the research workers in our country, especially as a means of information and guidance concerning the physical space of the metamorphism conditions. It allows them to interpret and judge the non-equilibrium states, the reaction rims and the mineral zoning.

Unfortunately a large part of the book, devoted to experimental processes, by the content and its implications, is only partly accessible to the Romanian geologists, pleading at the same time for its necessity in the rich scientific activity of Romanian geology.

I. Hârtopanu

S. MATTHES : *Mineralogie (Eine Einführung in die spezielle Mineralogie, Petrologie und Lagerstättenkunde) — Mineralogy (An Introduction to the Special Mineralogy, Petrology and Mineral Deposits).* Springer Verlag, 1983, 417 pp., 157 figs., 2 tables.

A quarter of a century ago the Springer Publishing House edited a book of similar title and treatment of the subject (Correns, Einführung in die Mineralogie, 1968, second edition). We have made this remark in order to underline the utility of such works, in which mineralogy is regarded as an integrating science including crystallography, petrology, geochemistry and mineral deposit study.

The book consists of three main parts : Part I, "Special Mineralogy" (157 pp.) presents the most widespread minerals, their properties and distribution, stress being laid on their practical importance and fields of utilization.

Part II (Petrology and Mineral Deposits) is the largest one (pp. 159-371), being a concise but modern approach of the main rock and mineral deposit types ; a lot of experimental data are discussed in order to explain the genesis of magmas, while Schneiderhöhn's classification (ore formation) is used especially for the hydrothermal deposits. The chapter dealing with the sedimentary rocks and the associated deposits contains phase diagrams, including also those regarding the oxidation processes of the sulfide ores ; modern data on the classification

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and composition of sedimentary rocks with reference to the accumulation conditions of the various mineral substances (iron, salts etc.) are also used. This chapter comprises a brief presentation of the problems connected with all types of metamorphism as well, including the shock metamorphism (as a result of which the rocks called suevites form); examples of experimented metamorphic reactions, of graphic presentation of the metamorphic parageneses are given, while the classification of the metamorphic rocks (facies, isograde) as well as the structural-textural peculiarities of metamorphics, the ultrametamorphism and the formation of migmatites are discussed.

The last part, "Earth and Moon Composition and Structure", is a short review of the problems tackled in the book, containing a lot of data, some of which referring to meteorites.

The book ends with an extensive list of references arranged acording to the various problems discussed and a very useful alphabetical index.

Although this book is meant for students, it comprises up-to-date information from all the above-mentioned fields, thus being of use also to the research workers in the related fields by the rapid information it provides.

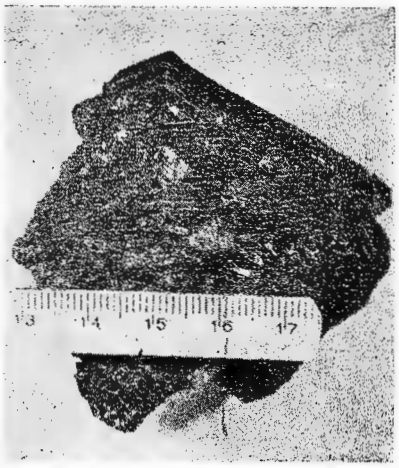
G. Udubaşa

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R. STRUSIEVICZ, E. STRUSIEVICZ. Rutil și andaluzit în pegmatitele din munții Plopiș.



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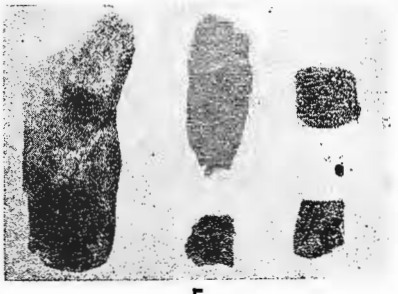
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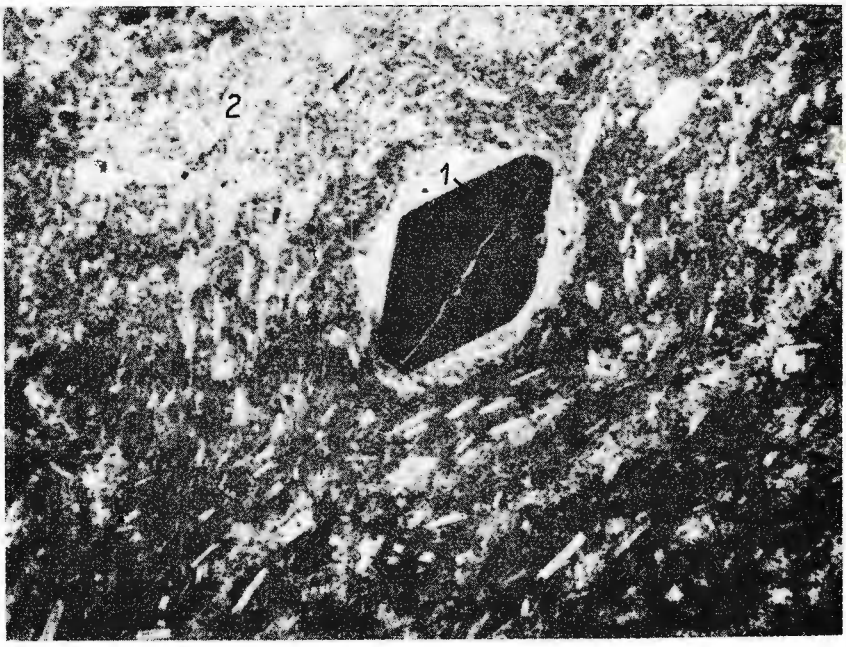


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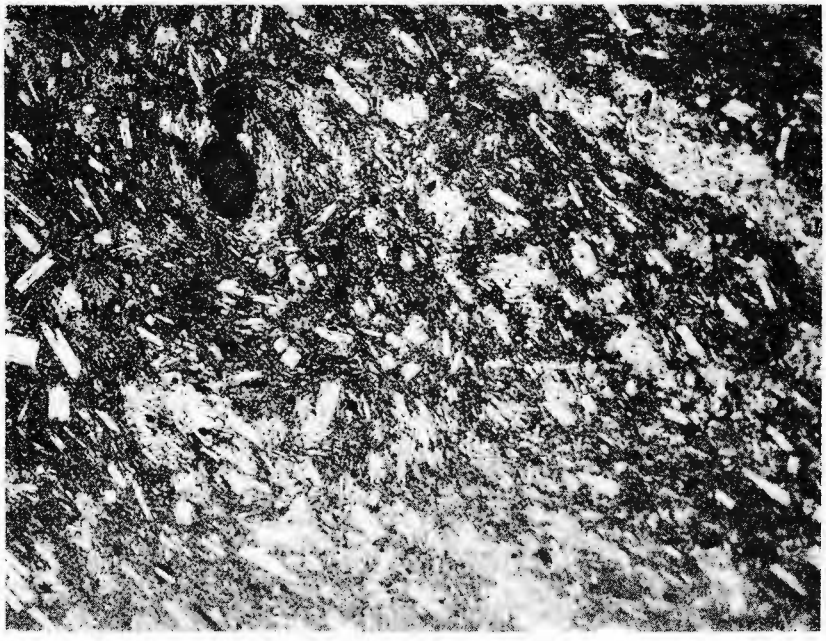


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H. SAVU et al. Ophiolites and Island Arc Magmatites-Băgara-Visca-Luncoi.



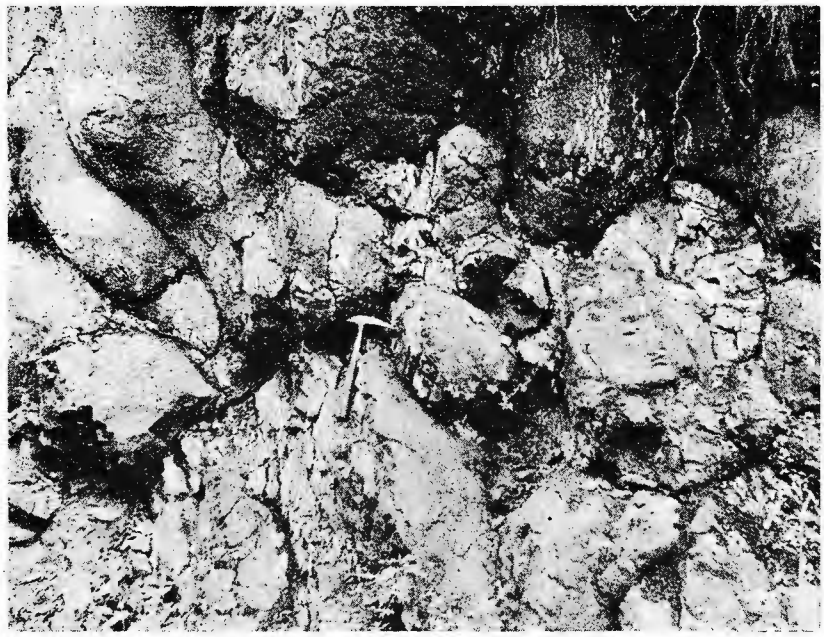
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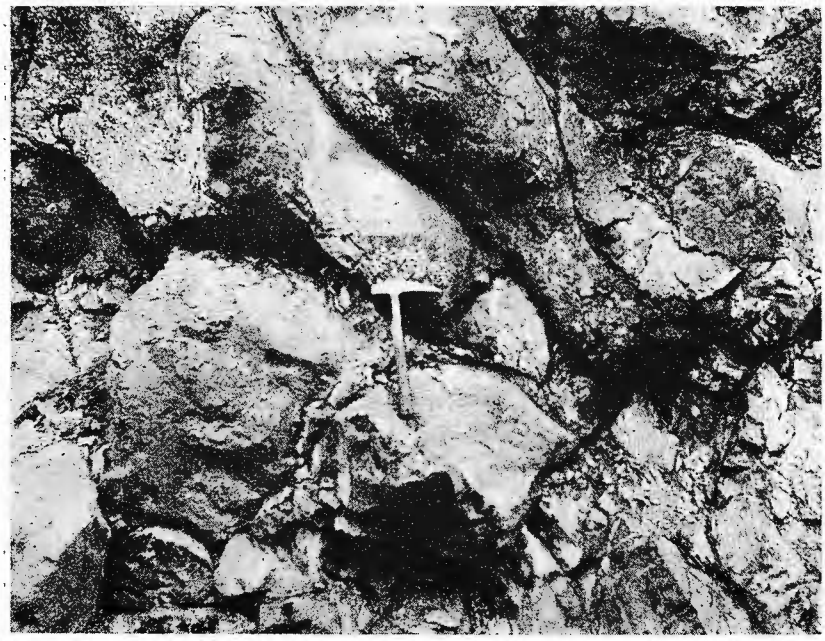
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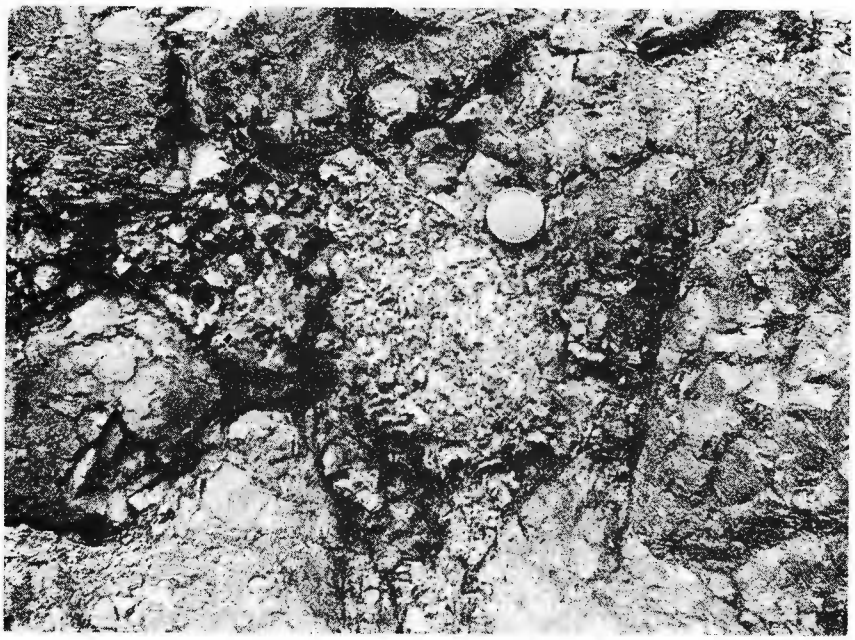
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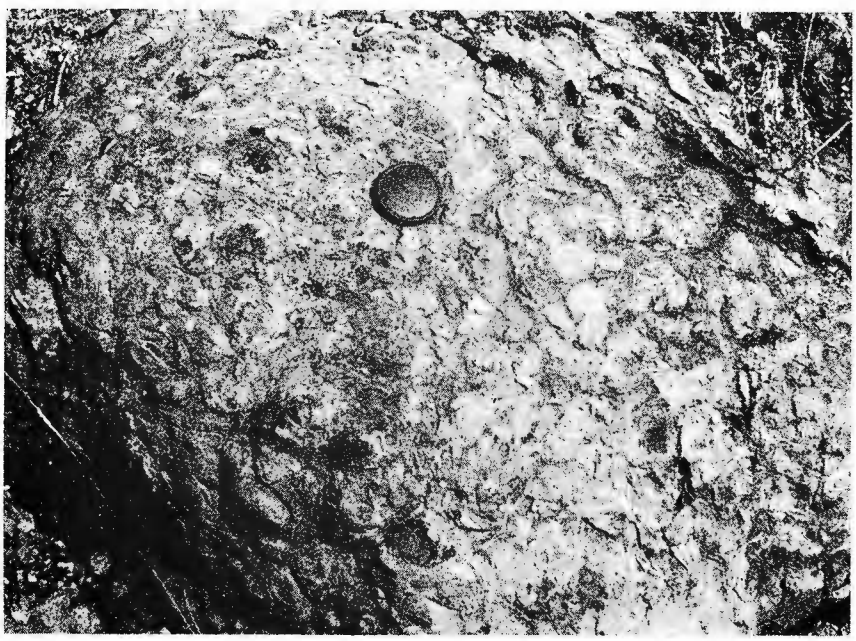
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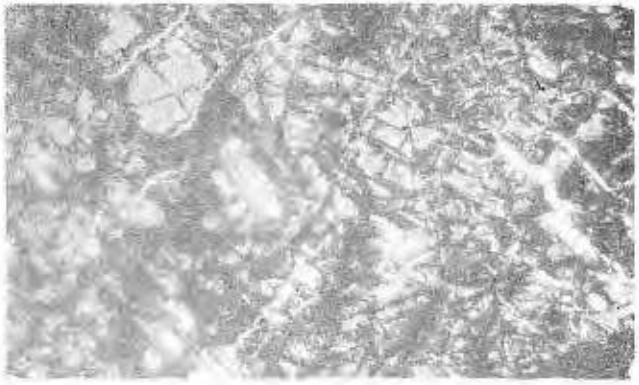
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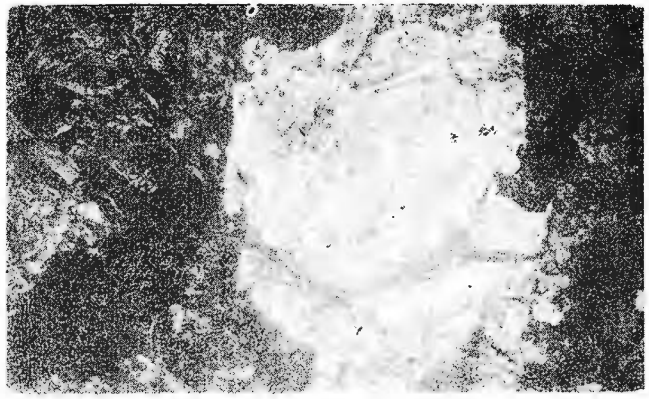
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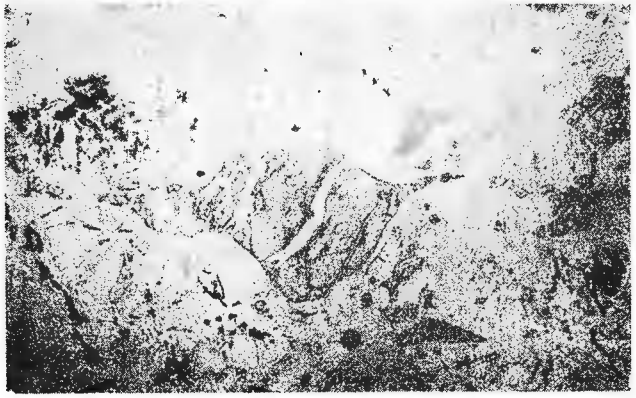
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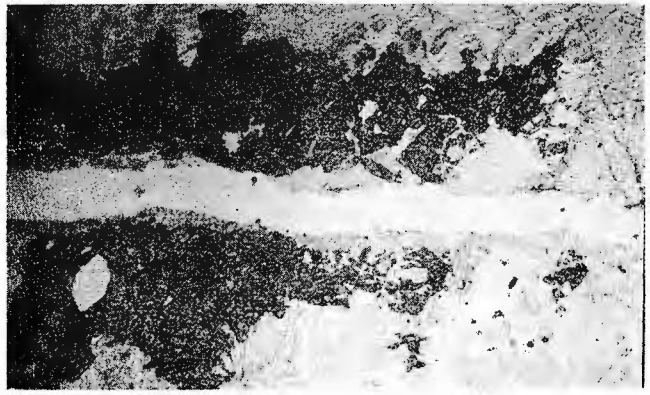
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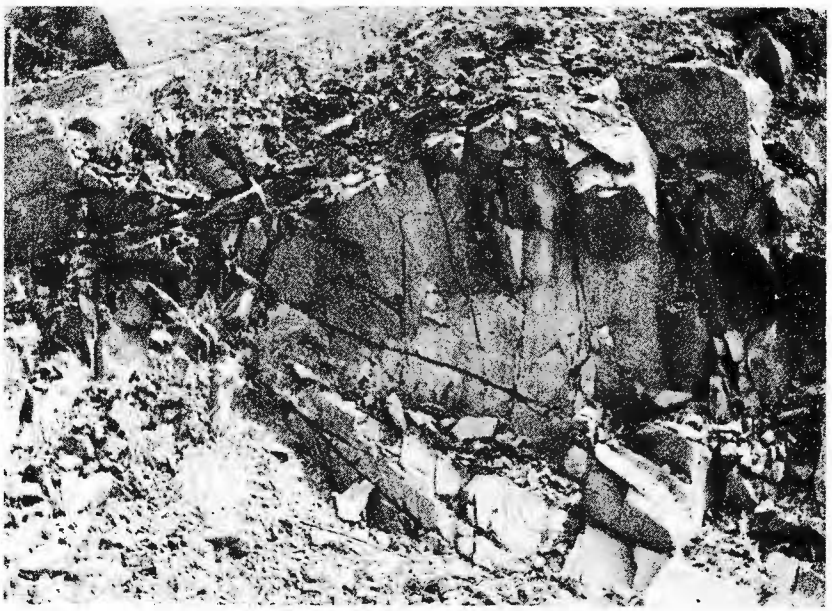
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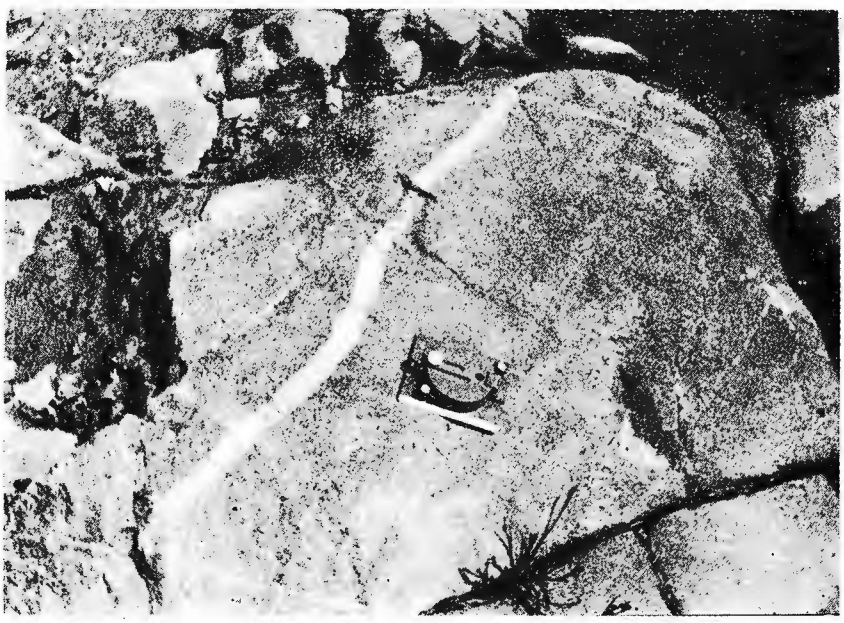
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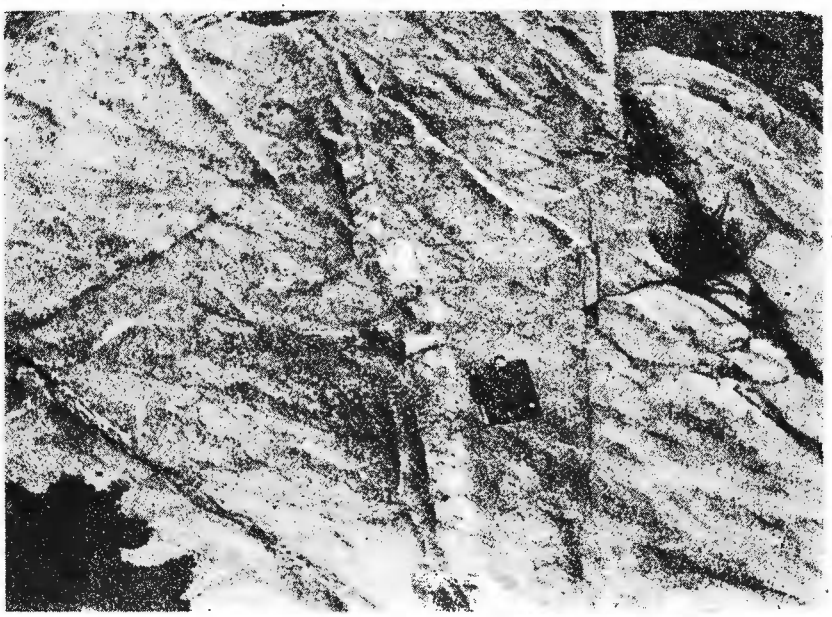
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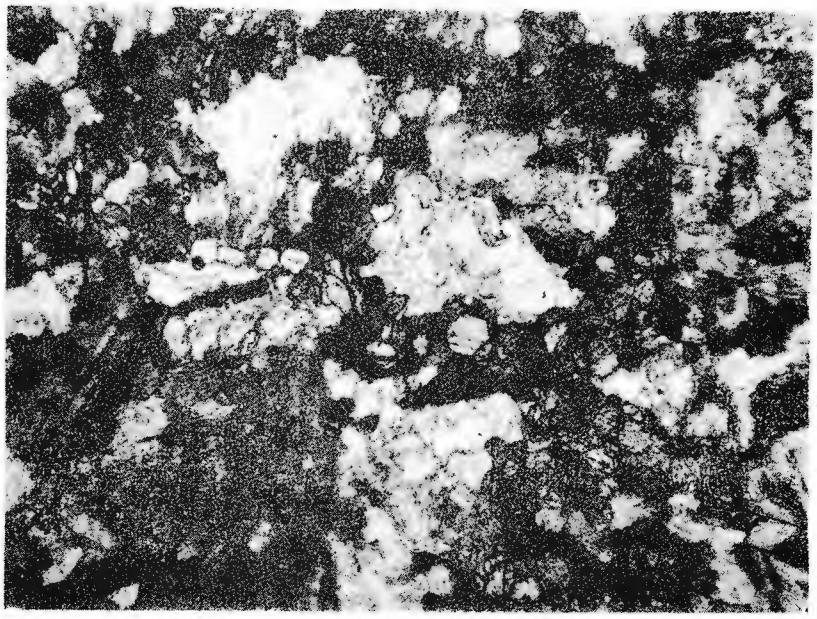


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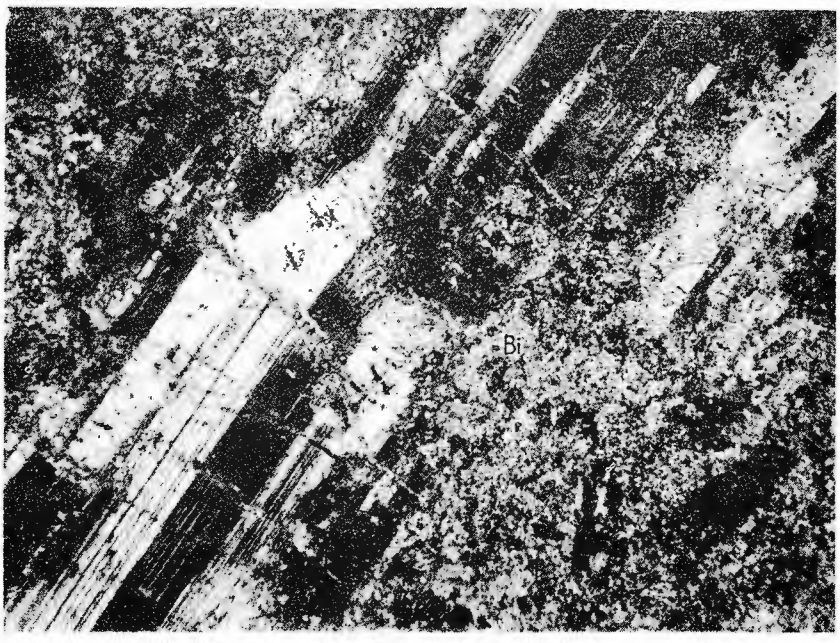


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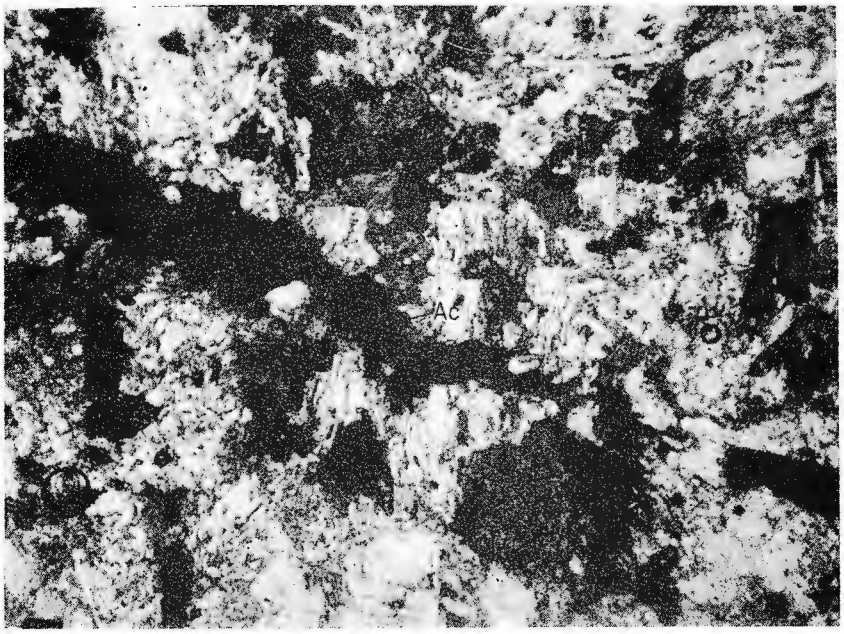


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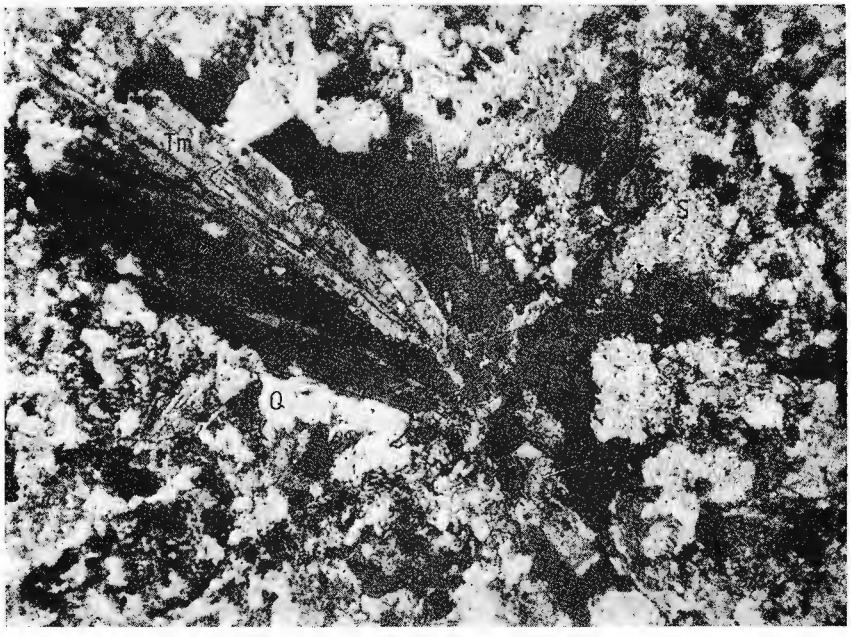


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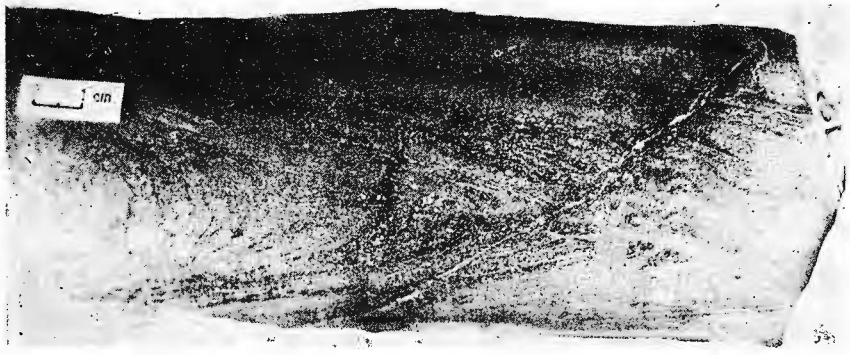


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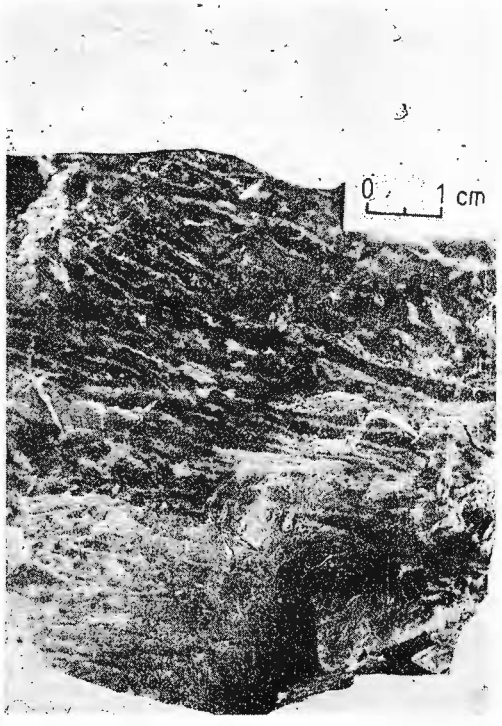


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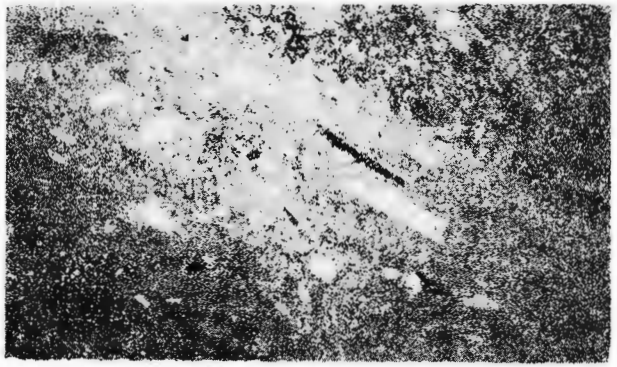
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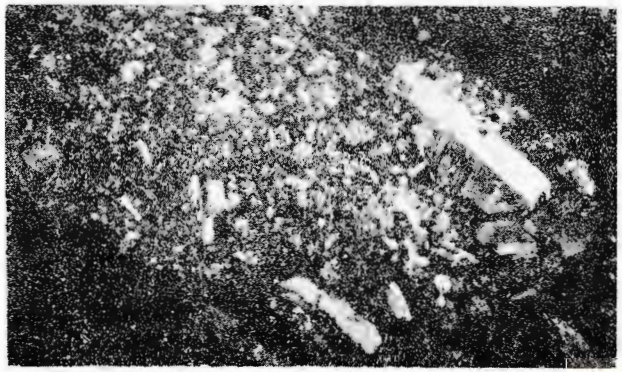
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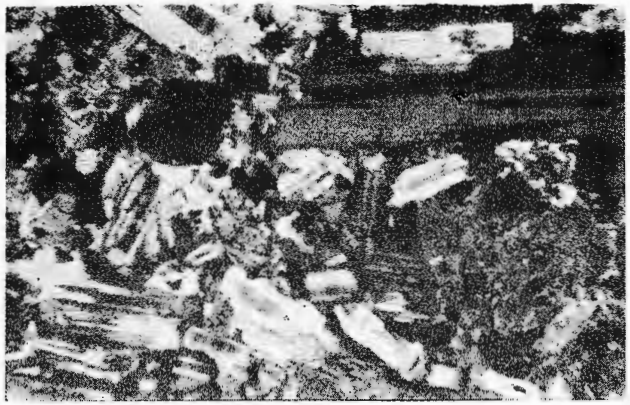


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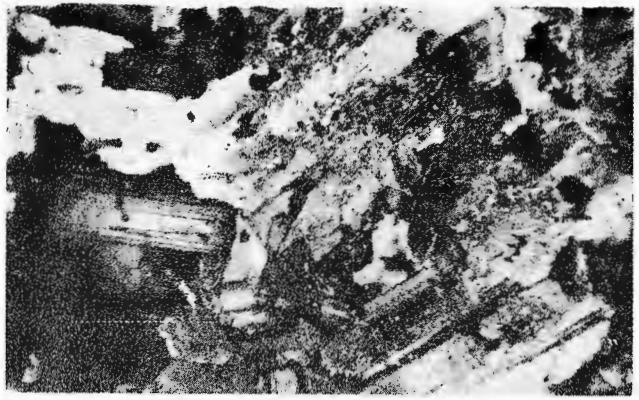


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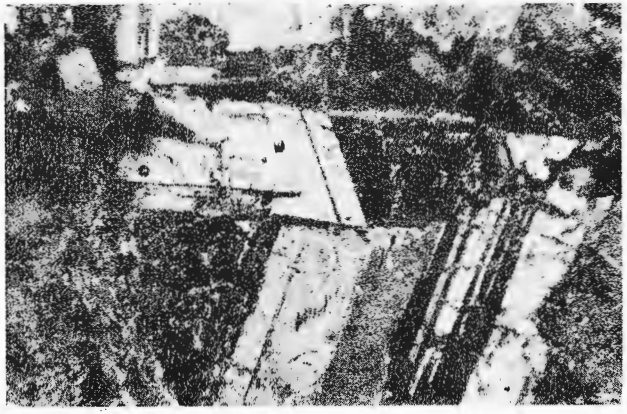
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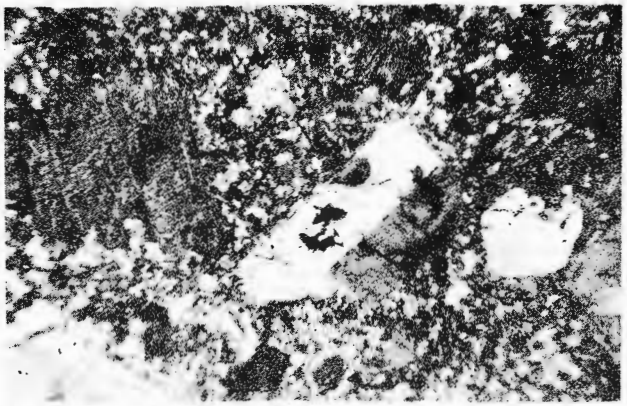


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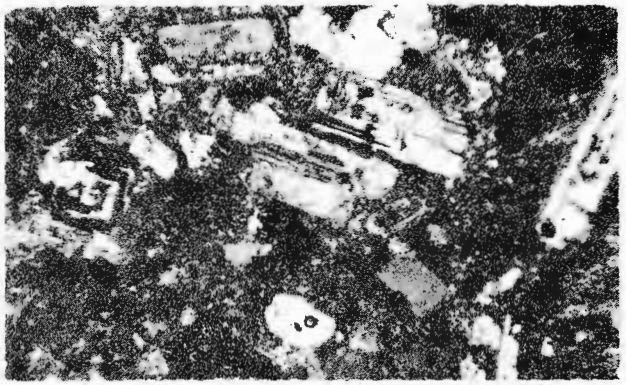


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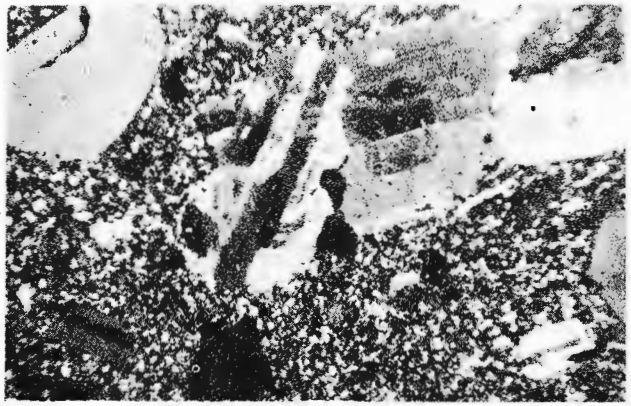
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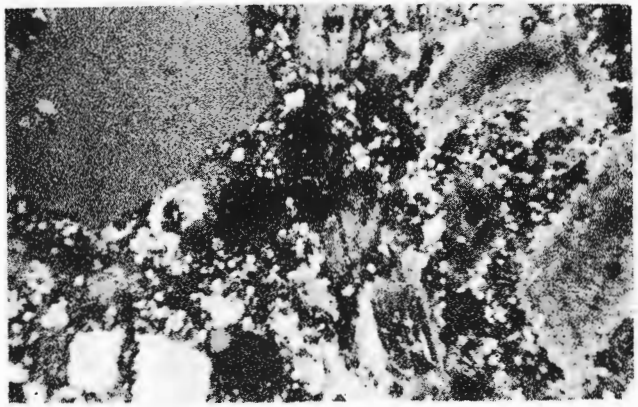


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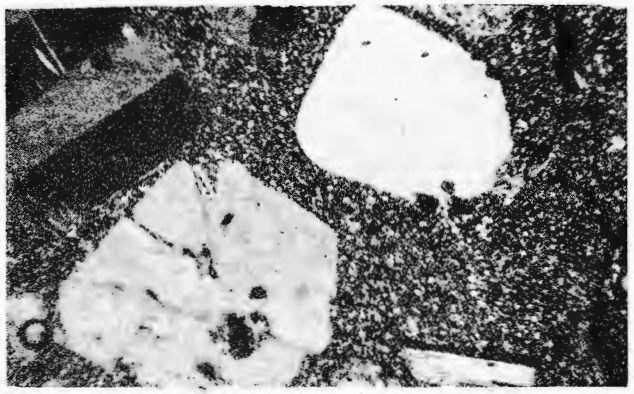


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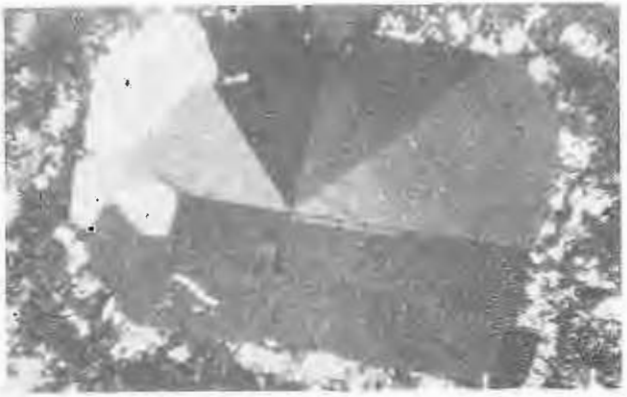
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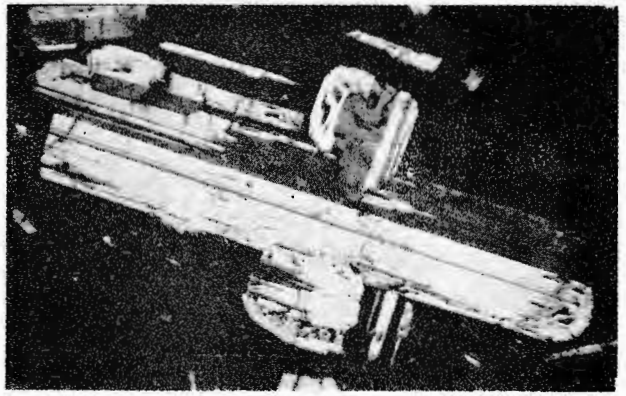
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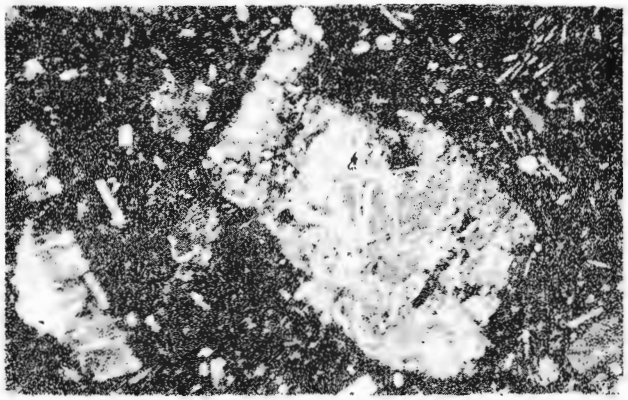


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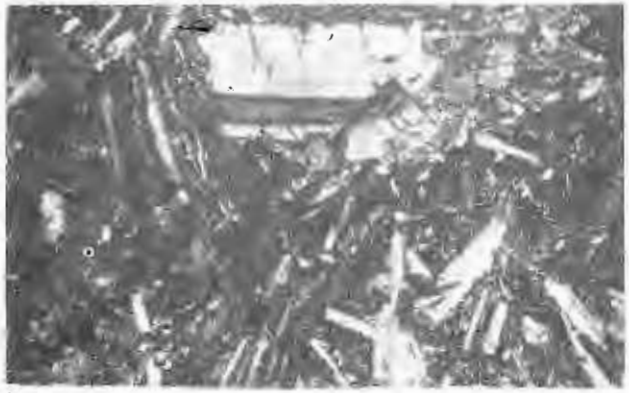
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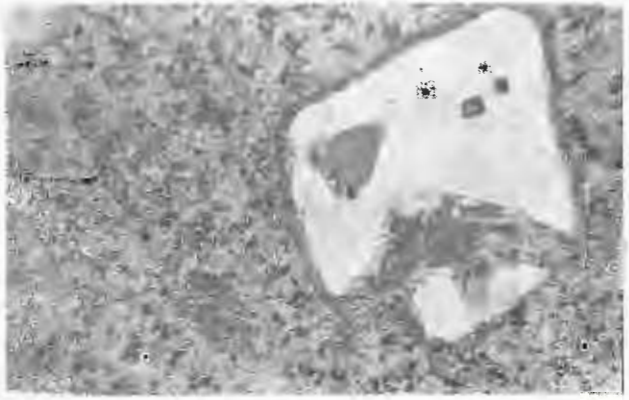
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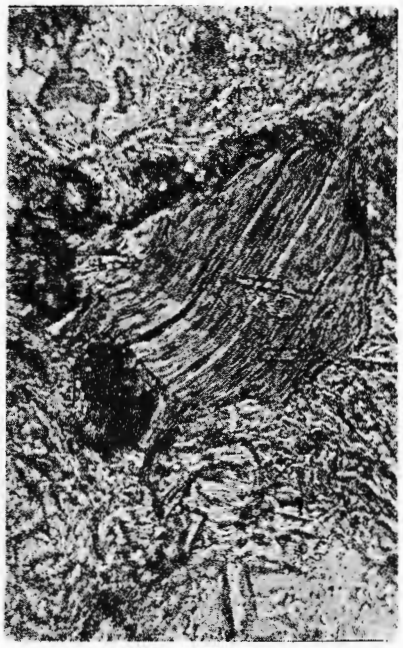


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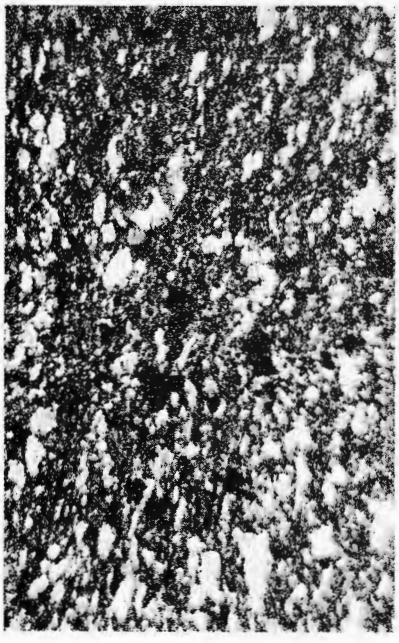
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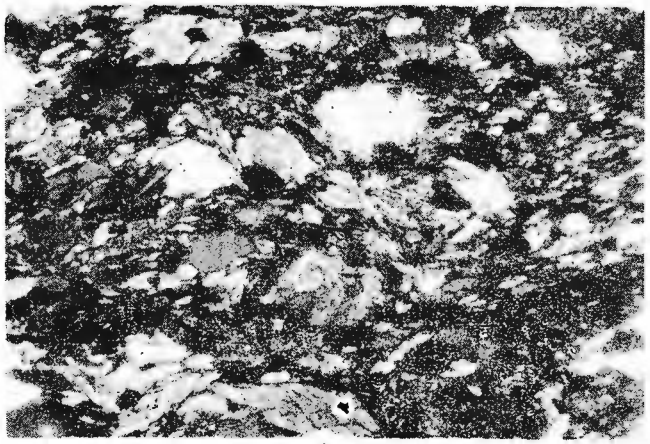
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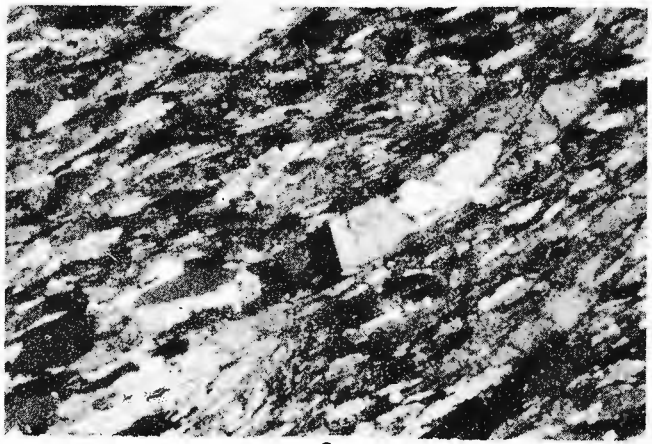
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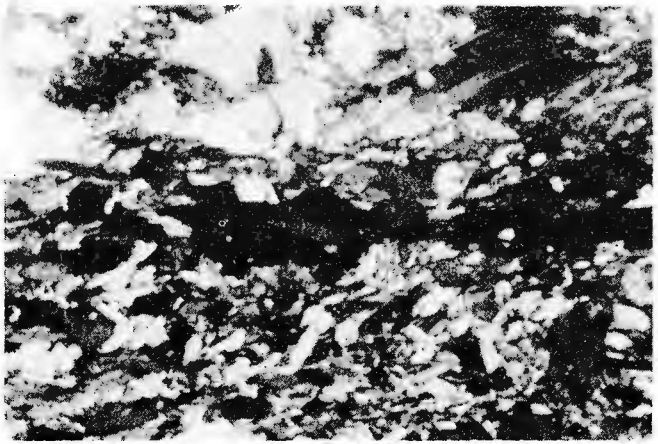
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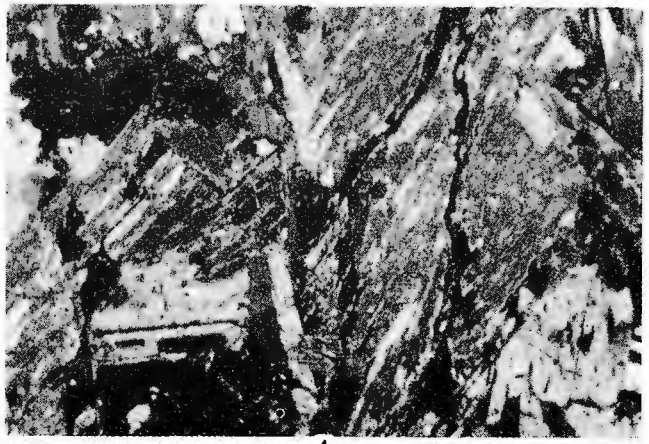
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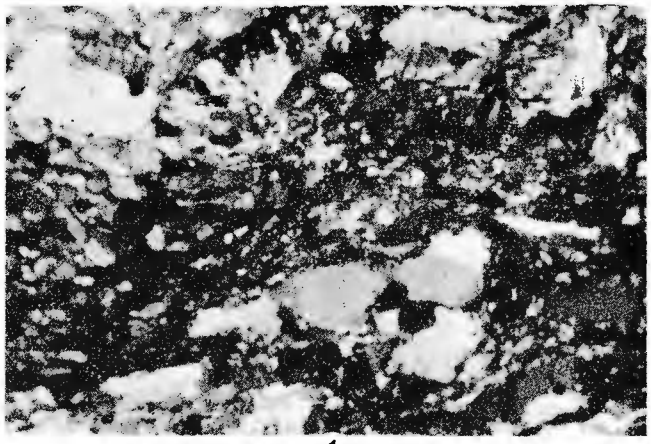


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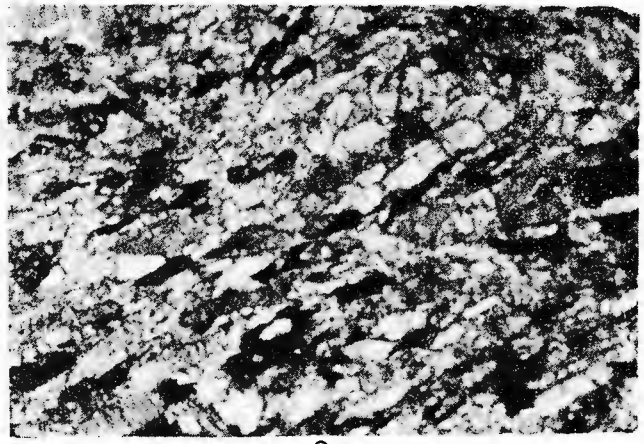


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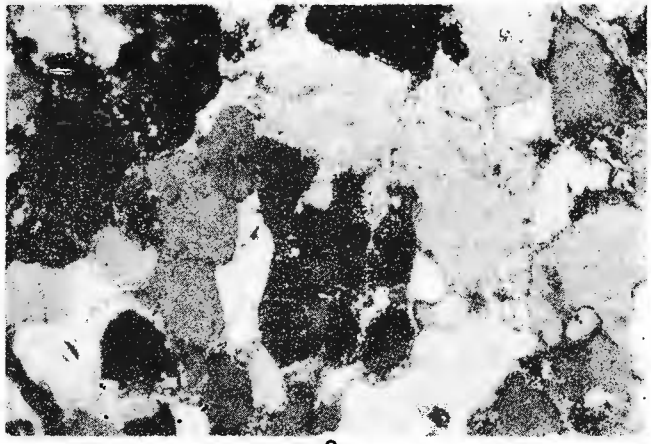
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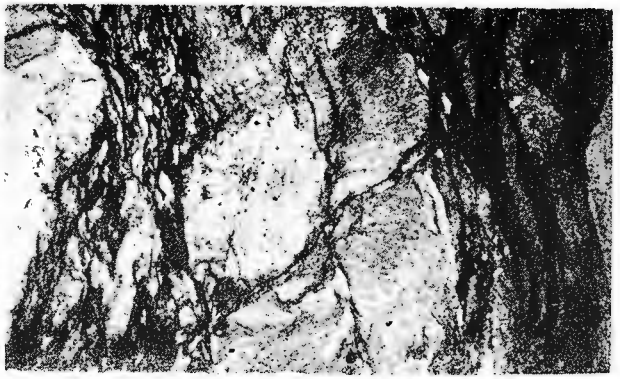


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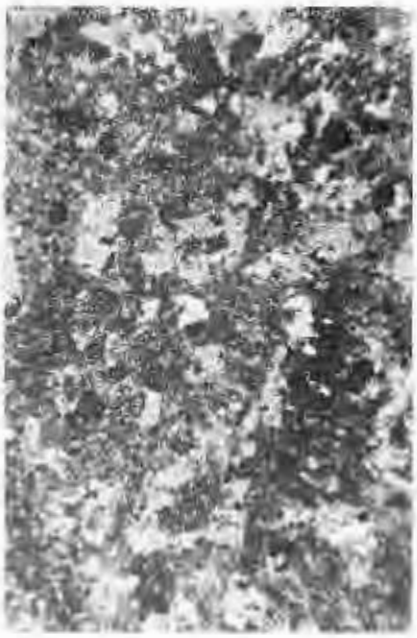


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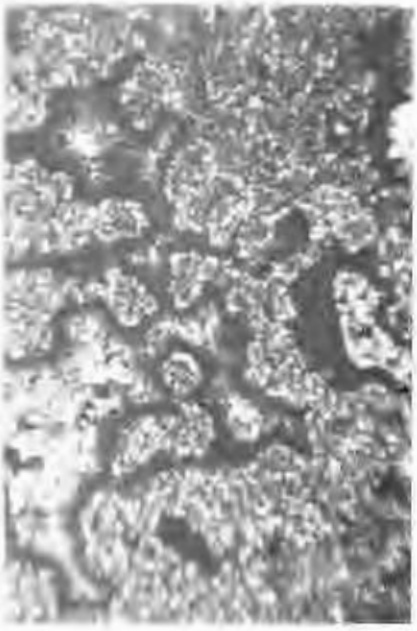
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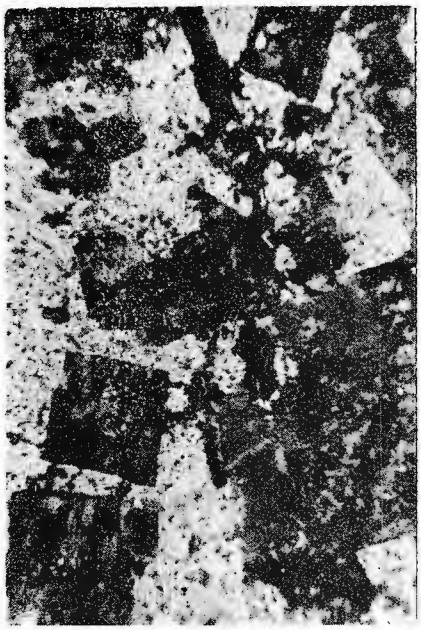


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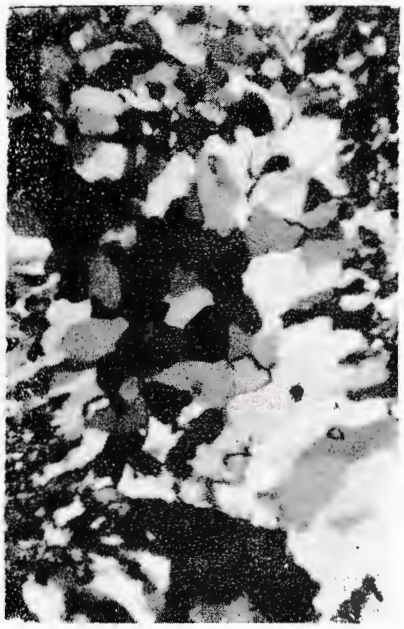


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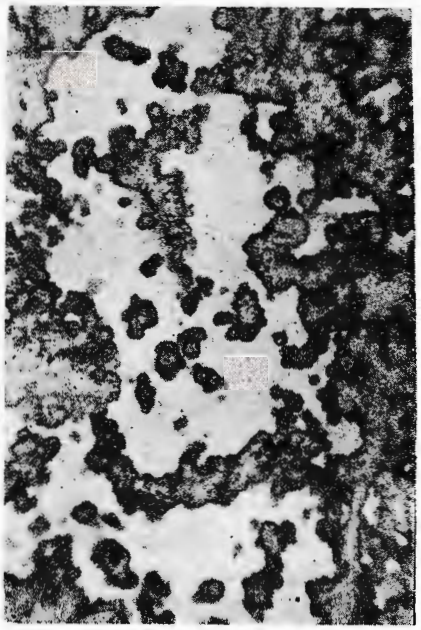


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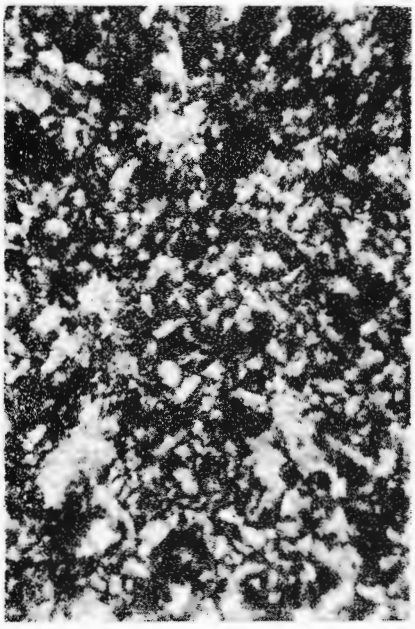
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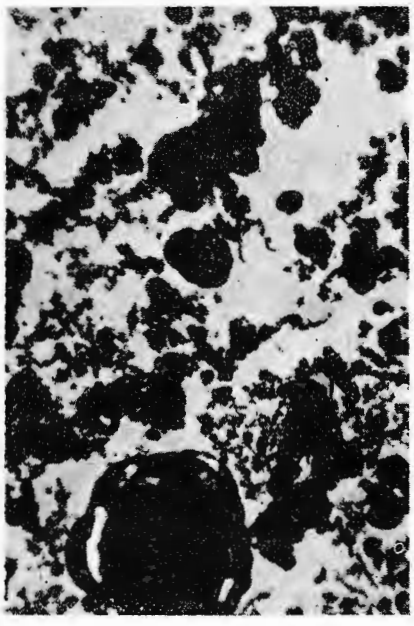
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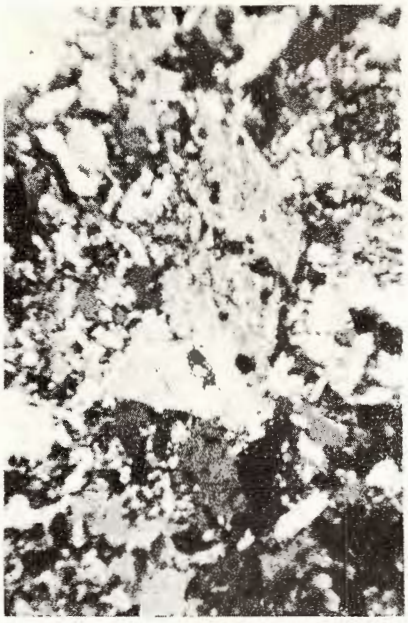


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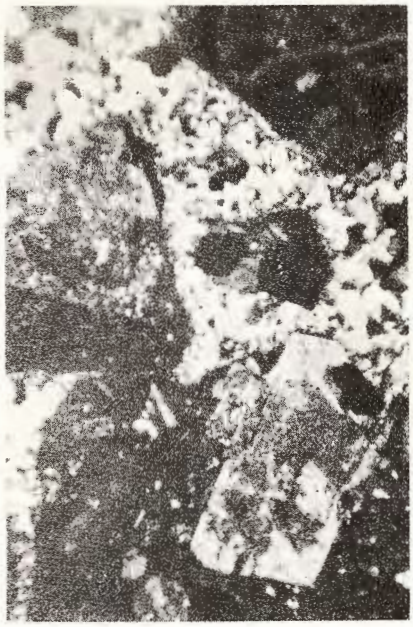


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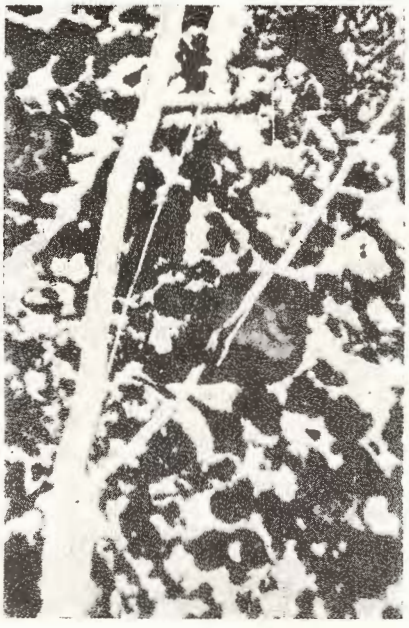
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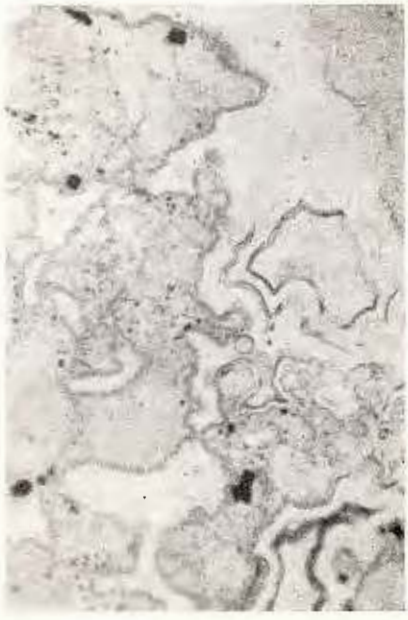
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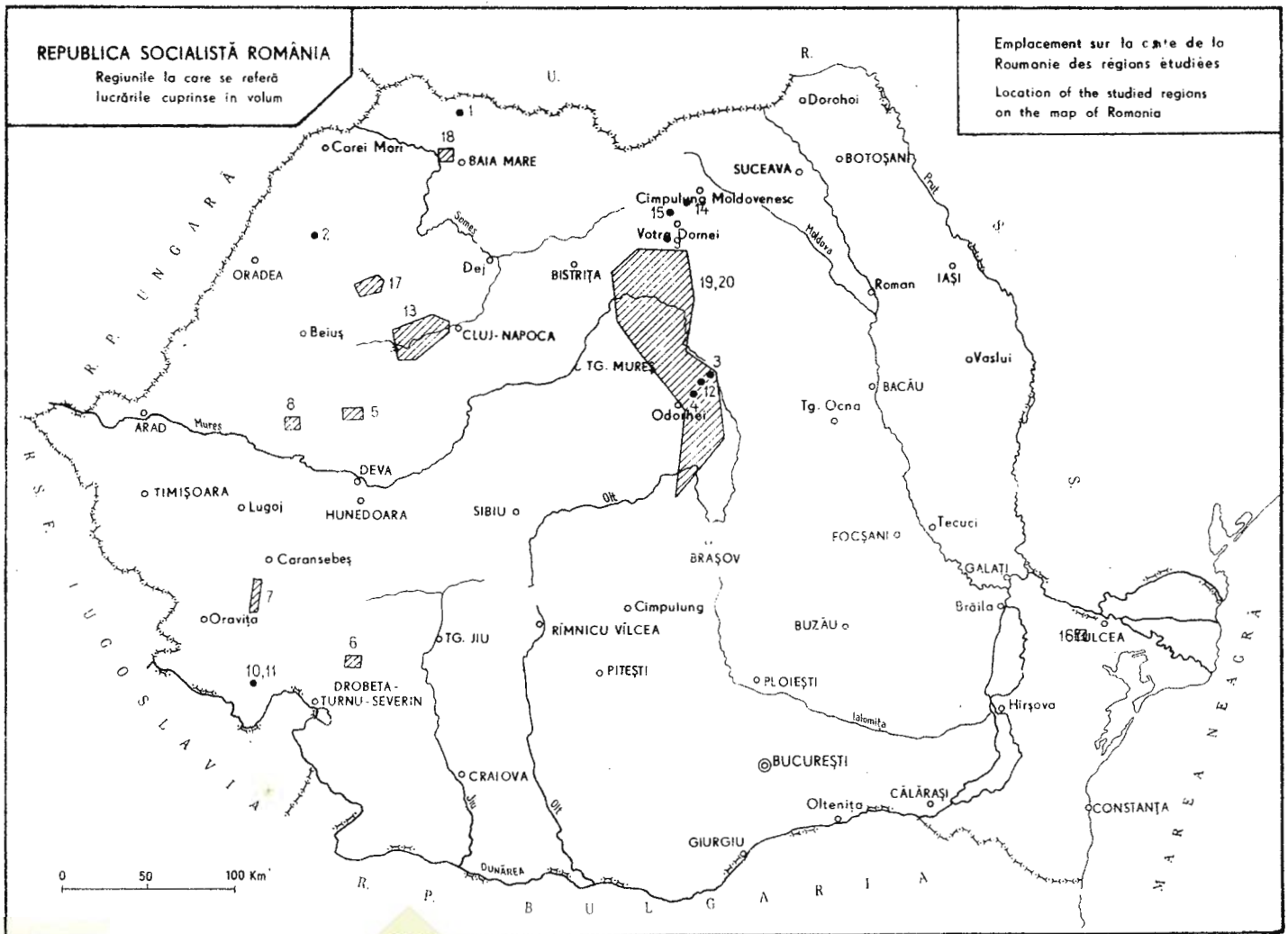


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„Comptes rendus des séances (Dări de seamă ale şedinţelor) ont été publiés le long des années dans le cadre des suivantes institutions":

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Comitetul Geologic t. XXXVII - LII / 1 (1953 - 1966)

Comitetul de Stat al Geologiei t. LII / 2 - LV / 1 (1967-1969)

Institutul Geologic t. LV / 2 - LX (1970 - 1974)

Institutul de Geologie şi Geofizică - à partir du tome LXI (1975)

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INSTITUT DE GÉOLOGIE ET DE GÉOPHYSIQUE

COMPTES RENDUS DES SÉANCES

TOME LXIX
1982

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