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ELISA LEONIDA ZAMFIRESCU
1887 — 1973

La 10 noiembrie 1987 s-au împlinit 100 de ani de la nașterea la Galați, a celei care a fost prima femeie inginer din Europa și care timp de 42 de ani a condus laboratoarele Institutului Geologic și ale Comitetului Geologic.

Tatăl său, Anastase Leonida, a fost ofițer de carieră, mama, Matilda Gill, fiica unui inginer de origine franceză, căsătorit cu o româncă din Reghin. A făcut parte dintr-o familie numeroasă, avînd 11 frați, dintre care cei ajunși la maturitate și-au afirmat personalitatea : astfel Dimitrie Leonida a devenit inginer energetician,o ilustră figură a tehnicii românești, un frate a devenit sculptor, unul general, trei surori profesoare. A făcut școala primară la Galați și liceul la Școala centrală din București.

Încă din liceu și-a format un ideal din a deveni inginer chimist, pe care l-a urmărit cu perseverență pînă la realizare. Nepoată de inginer, avînd un frate mai mare inginer energetician, profesor universitar, a avut ambiția să demonstreze că și fetele pot îmbrățișa o carieră tehnică. Avînd un bacalaureat clasic, face un prim pas prin a da examene de

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diferență pentru a absolvi și secția reală, la liceul Mihai Viteazul. Datorită prejudecăților vremii, la Școala de poduri și șosele, care mai tîrziu a devenit Școala politehnică din București, nu a fost admisă ca studentă. Înfruntînd toate piedicile, pleacă la Berlin în anul 1909 și se înscrie la Academia regală tehnică din Berlin, la școala de tradiție de la Charlottemburg devenind prima studentă a acestui așezămînt, pe care îl absolvă în 1912, devenind prima femeie ingineră din Germania, din Europa și implicit din România, unde avea să-și desfășoare activitatea profesională. Diploma sa, tradusă și legalizată, a fost redactată astfel : Domnișoarei Elisa Leonida, din Galați, titlul de inginer diplomat, după ce a depus examenul pentru diploma Facultății de chimie și metalurgie, conform regulamentului pentru examene de diplomă, la 20 ianuarie 1912, cu specialitatea chimie. A susținut examenul de absolvire obținînd mențiunea „bine". Charlottemburg 9 mai 1914. Semnată de rectorul Romberg și decanul facultății Hoffman.

Dar și la Berlin a avut de înfruntat prejudecățile și piedici din partea colegilor și a profesorilor, așa cum reiese din amintirile sale publicate în revista „Viața studențească" din 8 martie 1960, din care cităm : „În politehnică o studentă ? (politehnica din Charlottemburg). Cine a mai auzit așa ceva ? Unii profesori au îngăimat năuciți, proteste". Rectorul s-a simțit obligat să atragă ferm atenția noii studente ca nu cumva să dea prilej de nemulțumire, ea fiind... un caz aparte. Iar noii colegi, pentru care studenția însemna distracție și halbe cu bere, au împiedicat-o să participe la festivitățile tradiționale de matriculare. La cererea de înscriere, decanul Hoffman invocase ca argument, chemarea esențială a femeii, cei trei K — Kirche, Kinder, Kuche (biserica, copiii, bucătăria), iar în timpul studiilor, în laboratoare o ocolea, ignorîndu-i prezența. Profesorul Schubert, care preda un curs de mașini, mai combativ, plin de iritare, cînd a văzut-o în amfiteatru, a strigat : „la bucătărie, acolo-i locul femeilor, nu la politehnică". Cu răbdare, cu dîrzenie și cu silință a transformat prejudecățile, ostilitatea și privirile batjocoritoare, în admirația generală, și chiar a profesorului Hoffman care înmînîndu-i diploma a declarat printre altele — die Fleissigste der Fleissigsten — (cea mai silitoare dintre cei silitori).

Evenimentul absolvirii studiilor și obținerii titlului de inginer la Charlottemburg, de o femeie, a făcut vîlvă și a fost consemnat în toată presa europeană și în ziarele timpului care apăreau în România. Pentru a ilustra mentalitatea vremii și impresia făcută de acest eveniment, redăm cîteva fraze din ziarul „Minerva" apărut în iarna anului 1914, în care la rubrica „Cronica feminină" sub titlul „Prima romîncă inginer", printre altele se scrie : „Cine a spus că femeia nu e capabilă de muncă intelectuală intensă și serioasă s-a înșelat desigur. O compatrioată a noastră, d-ra Elisa Leonida, fiica colonelului Leonida, în loc să studieze literele sau medicina, sau mai rău, dreptul, a studiat ingineria la Charlottemburg. În inginerie, viitorul femeilor e mare. D-ra Elisa Leonida a trecut cu un strălucit succes examenul final, obținînd diploma de inginer. Dînsa este prima femeie inginer în țara noastră și din Germania. Transmitem felicitările noastre tinerei inginere și sperăm ca exemplul d-niei sale va fi urmat de cît mai multe fete din țara noastră, care, azi, se îngră-

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mădesc la facultatea de litere, sporind astfel proletariatul licenţelor în litere, candidate în viaţă la posturi de copiste sau dactilografe".

Reîntoarsă în patrie este angajată la Institutul Geologic, iniţial ca asistentă extrabugetară.

În timpul primului război mondial, cu riscul vieţii merge pe front unde îşi desfăşoară o intensă activitate în cadrul organizaţiei „Crucea roşie" ajutînd la alinarea suferinţelor soldaţilor răniţi. I se încredinţează chiar conducerea unor spitale de campanie în apropiere de Mărăşeşti şi este decorată cu ordine şi medalii româneşti şi străine. În anul 1918 se căsătoreşte cu C. Zamfirescu, inginer, doctor în chimie, fratele scriitorului Duiliu Zamfirescu. Căsătoria are loc în comuna Ghidiceni, unde soţii s-au cunoscut pe front.

Reîntoarsă în anul 1920, la Institutul Geologic, activează aici pînă la 1 mai 1963 ieşind la pensie la vîrsta de 75 de ani. Ca o trăsătură a caracterului său nobil, este de remarcat faptul că deşi avea dreptul de a cumula pensia cu salariul de la vîrsta de 52 de ani, renunţă la pensie, optînd numai pentru salariu, aducînd statului o economie de aproximativ 300 000 lei.

În anul 1948 se înfiinţează un Comitet de Stat al Geologiei şi o întreprindere de prospecţiuni şi laboratoare. Deşi îndeplinea condiţiile de pensionare îşi continuă activitatea, organizînd din micul laborator al Institutului Geologic, cu cîţiva chimişti, douăsprezece laboratoare avînd un personal numeros. Participă cu entuziasm la dezvoltarea acestei activităţi pe care o conduce cu competenţă şi îndrumă fondurile alocate de stat pentru dotarea cu aparatura cea mai modernă la acea oră. Astfel a adus un aport important la progresul economiei naţionale şi la afirmarea ştiinţei româneşti.

Sub conducerea sa, laboratoarele au realizat un volum de 85 000 analize, care poartă girul semnăturii sale pe buletine. Această cifră statistică este searbădă şi ar fi nesemnificativă dacă nu am aminti preocuparea inginerei chimist Elisa Leonida Zamfirescu, pentru elaborarea de metode de analiză, raţionalizări, introducerea de tehnici noi şi elaborarea de studii avînd ca scop cunoaşterea bogăţiilor subsolului patriei noastre.

În lunga sa activitate s-a preocupat de analize de ape potabile şi minerale, petrol şi gaze, cărbuni, bitumine solide, roci de construcţie şi de prepararea minereurilor. A executat numeroase studii de sinteză, unele publicate de Institutul Geologic, în seria „Studii economice". Dintre acestea menţionăm : Studiul extragerii potasiului din glauconite ; Studiul pentru valorificarea manganului din rodonite ; Studiul zăcămintelor de grafit din munţii Olteţului ; Studiul determinării germaniului în cărbuni şi minereuri ; Studiul pămînturilor decolorante din R.P.R. ; Valorificarea gazelor din craking ; Sinteza glicerinei plecînd de la propilenă ; Prepararea unui aditiv antioxidant pentru uleiuri plecînd de la etilenclorhidrină ; Aditivi pentru uleiurile minerale pe bază de răşini acrilice ; Studiul compoziţiei chimice a ţiţeiului în R.P.R. ; Studiul bauxitelor din Munţii Apuseni ; Studiul cromitelor de la Orşova ; Studiul diatomitelor din R.P.R. ; Studiul pămînturilor decolorante cu aplicaţii practice în in-

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dustria de petrol ; Metode elaborate pentru dozarea vanadiului în minereuri, zirconiului, cesiului, silicei în baritină și altele.

A studiat și a redactat norme și standarde de Stat pentru analize.

Mulți dintre specialiștii care aveau nevoie de rezultatele analizelor, de o îndrumare sau un sfat profesional o găseau de dimineață pînă seara la orele 20—21, în laborator, împărtășind din bogata sa experiență în domeniul compoziției chimice a substanțelor minerale, indicînd cele mai adecvate metode de analiză și moduri de valorificare a rezultatelor.

Dar printre multiplele sale preocupări, a dat o deosebită atenție formării personalului, ocupîndu-se atît de tineri chimiști, dar și de laboranți și muncitori, contribuind la ridicarea nivelului lor științific și profesional prin cursuri și îndrumări zilnice.

Ca profesoară de fizico-chimice la liceul Pitar Moș, din București, a reușit să se apropie sufletește de elevele sale, cărora le-a lăsat o amintire neștearsă și le-a insuflat dragostea pentru știință.

A făcut parte din Asociația internațională a femeilor universitare, aducînd o contribuție esențială privind cunoașterea activității femeilor din România. A ținut numeroase prelegeri de popularizarea științei. În calitate de președinte al Comitetului de luptă pentru pace din Institutul Geologic, luînd atitudine față de înarmarea atomică, adresează Comisiei de dezarmare de la Lancester House din Londra, un protest competent și justificat, insistînd asupra pericolului armei atomice. Această intervenție a fost comunicată oficial la ONU. În ziarul „Romînul American" nr. 14 din 8 martie 1960, apare un articol omagial privind viața și munca Elisei Leonida Zamfirescu, în care se referă și la viața sa exemplară de familie, ca soție și mamă a doi copii.

La 25 noiembrie 1973, în vîrstă de 85 de ani, a încetat din viață aceea care a fost prima femeie inginer din Europa, o ilustră personalitate științifică, care și-a dedicat întreaga viață slujindu-și cu dragoste Patria, contribuind prin munca sa la cunoașterea și valorificarea resurselor subsolului românesc.

Olteneanu Mihai

Întreprinderea de Prospecțiuni Geologice
și Geofizice București

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Prof. DAN GIUȘCĂ
Membru al Academiei Române
1904—1988

La 10 august 1988 s-a stins din viață la vîrsta de 84 ani profesorul Dan Giușcă, membru al Academiei Române. Dispariția neașteptată, în plină activitate științifică, a acestei personalități marcante a școlii române de geologie a lăsat un gol de neînlocuit în viața geologică a țării. Tristul eveniment a îndurerat profund pe toți cei care au pierdut prin personalitatea generoasă, cu deosebite calități umane, a profesorului Dan Giușcă, un dascăl îndrăgit, un colaborator prețios și un prieten atașat. Geologia românească a pierdut un deschizător de drumuri noi și un luptător plin de dăruire pentru afirmarea ei pe plan național și internațional.

Dan Giușcă s-a născut la 14 iulie 1904 în București, ca unic fiu al lui Dumitru și Mariei Giușcă, funcționari PTT. Învățămîntul mediu l-a urmat la liceele Lazăr și Sf. Sava și l-a absolvit în 1922 la liceul

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Matei Basarab din capitală. În 1925 obţine licenţa în ştiinţe fizico-chimice la Universitatea din Bucureşti, şi în 1927 dobîndeşte titlul de doctor în chimie la Universitatea din Cluj, pe baza unei teze de cristalochimie : „Efectul morfotropic al închiderii de cicluri spiranice".

Revenit la Bucureşti se dedică cristalografiei şi mineralogiei sub îndrumarea prof. Ludovic Mrazec, ca geolog asistent la Institutul Geologic al României şi din 1929 ca şef de lucrări la Catedra de mineralogie a Universităţii din Bucureşti. Pentru anii 1929 şi 1930 obţine prin concurs o bursă din partea statului, care-i asigură o specializare în mineralogie la Şcoala Politehnică din Zürich, unde lucrează cu Paul Niggli şi la Institutul pentru Cercetarea Silicaţilor din Berlin — Dahlem, pe lîngă W. Eitel.

Reîntors în ţară, Dan Giuşcă se dedică cu o deosebită pasiune atît activităţii didactice, cît şi cercetării teoretice cu aspecte aplicative directe. Această dublă preocupare i-a caracterizat activitatea pînă la sfîrşitul vieţii şi s-a materializat prin funcţionarea activă în paralel în corpul didactic al Universităţii Bucureşti şi succesiv în diverse instituţii cu profil geologic pe plan naţional. La începuturile acestui drum, în care s-a conturat din ce în ce mai pregnant personalitatea marcantă a profesorului şi a specialistului Dan Giuşcă, se situează căsătoria la 6 decembrie 1936 cu Constanţa Bănescu, absolventă a facultăţii de drept şi a conservatorului de stat din Bucureşti.

În învăţămîntul universitar Dan Giuşcă a fost atras de prof. Ludovic Mrazec, care remarcîndu-i valoarea i-a oferit încă din ultimul an de studenţie (1924) postul de custode al Laboratorului de Cristalografie, Mineralogie şi Petrografie al Universităţii din Bucureşti şi l-a numit în 1929 şef de lucrări la aceeaşi catedră. În 1937 a dobîndit titlul de conferenţiar de petrografie şi în 1948 a fost numit profesor universitar. După reforma învăţămîntului din 1948 a fost atestat ca doctor în ştiinţe geologice (1955) şi ca profesor de petrografie şi zăcăminte (1956). În 1960 i s-a încredinţat pregătirea doctoranzilor, iar în 1968 a obţinut titlul de doctor docent.

Profesorul Dan Giuşcă a fost activ 45 ani la catedra de Mineralogie-Petrografie pe care a slujit-o de fapt timp de peste o jumătate de veac. Spiritul său novator a pus bazele structurii moderne a învăţămîntului la această catedră, prin organizarea laboratoarelor şi a colecţiilor şi prin structura cursurilor sale care acoperă practic toate ramurile ştiinţelor geologice legate de domeniul proceselor endogene. În cursul anilor a prezentat prelegeri de cristalografie şi mineralogie, petrografie generală, petrografia României, petrologia rocilor endogene, petrografie şi geochimie, bazele fizico-chimice ale petrografiei, zăcăminte de minerale utile, metalografie, cursuri care s-au bucurat sistematic de adaptări în funcţie de progresele realizate pe plan mondial în ramurile respective.

După pensionarea în 1974 şi-a continuat activitatea didactică pînă la sfîrşitul vieţii ca profesor consultant pentru pregătirea doctoranzilor. În cursul a 28 de ani a îndrumat tezele de doctorat a 40 de specialişti din ţară şi a doi doctoranzi străini.

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În afara activităţii didactice profesorul Dan Giuşcă s-a remarcat printr-o remarcabilă muncă de cercetare ştiinţifică materializată în 107 lucrări publicate în ţară şi în străinătate şi în numeroase rapoarte de serviciu. De asemenea a colaborat activ în principalele instituţii cu profil geologic din ţară, atît în cadrul ministerelor de resort, cît şi al Academiei Române. Între 1929—1937 a lucrat deosebit de fructuos ca geolog asistent la Institutul Geologic al României, între 1937—1940 a funcţionat ca geolog la societatea „Mica", iar în 1948 revine la Institutul Geologic al României. În noile structuri organizatorice create după război a lucrat în cadrul „Intreprinderii de prospecţiuni şi laboratoare" (1945—1950) în conducerea „Intreprinderii de cercetări ceramice" (1946—1947), ca dispecer şi director în „Comitetul Geologic" (1950—1960), ca membru în „Comitetul Geologic" (1960—1966), în comitetul executiv al „Comitetului de Stat al Geologiei" (1966—1969), în consiliul departamentului geologic (1970—1972), în consiliul geologic al Ministerului Minelor, Petrolului şi Geologiei (1973).

Activitatea ştiinţifică s-a împletit astfel cu funcţiile de răspundere în orientarea şi organizarea pe plan naţional a cercetării, prospecţiunii şi explorării geologice. Îmbinarea armonioasă a vastelor cunoştinţe teoretice cu activitatea practică, pe care a ştiut s-o folosească în sprijinul cercetării fundamentale, a dus la punerea în evidenţă a noi resurse de substanţe minerale utile, dar şi la crearea unei generaţii de geologi care continuă tradiţia şcolii sale de geologie.

Din păcate, această activitate fructuoasă a fost curmată de legislaţia potrivnică intelectualităţii — care după 1970 a pregătit dezastrul economic şi cultural spre care s-a îndrpetat ţara — conform căreia prof. Dan Giuşcă a trebuit să se retragă din organismele operative ale geologiei româneşti.

În 1963 profesorul Dan Giuşcă a fost ales membru corespondent al Academiei Române, iar în 1974 devine membru titular. La Academie se remarcă în special prin susţinerea şi promovarea publicaţiilor secţiei de geologie şi prin reprezentarea geologiei româneşti peste hotare. A organizat şi coordonat, pînă la sfîrşitul vieţii, activitatea în cadrul programului de colaborare multilaterală cu academiile ţărilor socialiste (problema IX), contribuind şi în acest fel atît la afirmarea prestigiului geologiei româneşti, cît şi la accesul la viaţa ştiinţifică internaţională a geologilor competenţi din generaţiile mai tinere.

Înalta competenţă ştiinţifică a profesorului Dan Giuşcă s-a remarcat şi pe plan internaţional. A fost membru al Societăţii Geologice din Franţa, al societăţii franceze de cristalografie şi mineralogie, al asociaţiei geologice Carpato-Balcanice, al Comitetului de avizare a revistei „Tschermack s Mineralogische und Petrographische Mitteilungen", corespondent pentru asociaţia internaţională de vulcanologie, reprezentant naţional în comisia IX de colaborare între academiile ţărilor socialiste. A fost solicitat pentru conferinţe în Franţa, Germania, Anglia şi a examinat în calitate de expert lucrări geologice din Zambia şi Algeria.

Pe plan naţional a funcţionat ca membru în Consiliul naţional al geologilor din România, în Consiliul naţional de geodezie şi geofizică,

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vicepreşedinte al societăţii de ştiinţe geologice din România, preşedinte al filialei Bucureşti.

Pentru meritele deosebite în activitatea ştiinţifică, didactică şi practică la nivel naţional a fost distins cu „Premiul de stat", Medalia Muncii, Ordinul Muncii cl. a III-a, ordinul Stema Republicii cl. a IV-a, Meritul ştiinţific cl. a II-a.

Activitatea ştiinţifică a profesorului Dan Giuşcă a acoperit toate ramurile ştiinţelor mineralogice şi petrografice, inclusiv aspectele geochimice şi metalogenetice ale acestora. Domeniul de informare l-a constituit practic întregul teritoriu al ţării, în care era implicat prin funcţiile de coordonator pe plan naţional. În mod preferenţial s-a dedicat Dobrogei, Munţilor Apuseni, regiunii Baia Mare şi fundamentului Platformei Moldoveneşti.

Preocupările din diferitele ramuri s-au împletit armonios în vederea atingerii obiectivului urmărit. Reveniri în ultimii ani la problematici abordate în tinereţe atestă preocuparea permanentă de a aprofunda continuu înţelegerea fenomenelor geologice.

Domeniul cristalochimiei, cristalografiei şi apoi al mineralogiei în general a reprezentat una din preocupările preferenţiale în tot timpul vieţii ,de la debutul cercetării ştiinţifice prin descrierea în 1924 a unor forme noi ale cristalelor de celestină, pînă la ultima lucrare tipărită în 1986 despre structura atomică a mineralelor. Obiectul studiilor l-au format cu precădere mineralele din zăcămintele Transilvaniei, dar şi din alte părţi, ca şi substanţe sintetice sau organice. Însemnate pentru progresul ştiinţelor mineralogice au fost în special lucrări despre cristalochimia silicaţilor cu pămînturi rare şi scandiu, germanaţi şi titanaţi cu pămînturi rare, niobaţi ca şi studiul calcografic al sulfoarseniţilor de Pb, Ag, Tl de la Lengenbach (Elveţia), preluate în tratate clasice ca tratatul de zăcăminte al lui H. Schneiderhöhn şi mineralogia (reelaborată) a lui Dana.

Domeniul petrografic a constituit preocuparea de bază. Debutează cu studiul granitelor din Dobrogea şi extinde investigaţiile asupra granitoidelor din Carpaţii Meridionali şi Munţii Apuseni. În acest context contribuie cu L. Mrazec la argumentarea posibilităţii de formare a epidotului în momente tardive ale etapelor lichide magmatice. Rocile vulcanice banatitice şi neogene beneficiază de asemenea de contribuţii însemnate de ordin petrografic, geochimic, referitor la succesiunea punerilor în loc, la metamorfismul magmatic şi la transformările hidrotermale asociate. În acest sens trebuie remarcată în special recunoaşterea adularizării şi a semnificaţiei geologice a acesteia. În domeniul rocilor cristaline a contribuit la caracterizarea petrografică şi etapizarea evenimentelor metamorfice, atît în fundamentul Platformei Moldoveneşti şi al Dobrogei, cît şi în aria Carpatică. Modelul succesiunii ciclurilor metamorfice propus a ajuns în curînd la o accepţie generală şi în ţările învecinate.

În domeniul zăcămintelor activitatea a fost deosebit de fructuoasă şi a cuprins practic toate zăcămintele de minereuri metalifere din ţară. Abordarea problematicii prin împletirea aspectelor mineralogice, geochimice cu ideile genetice şi ansamblul geologic structural a creat o tra-

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diţie în studiul zăcămintelor din ţară, care a dus la punerea în evidenţă a noi resurse de minerale utile.

În domeniul geochimiei poate fi privit ca principalul părinte al Şcolii noastre de geochimie, pe care a creat-o atît prin învăţămîntul universitar, cît şi în instituţiile geologice cu caracter aplicativ. A publicat numeroase lucrări de geochimie referitoare la probleme regionale, elemente chimice, procese mineralo-petrogenetice şi metalogenetice.

Profesorul Dan Giuşcă şi-a dedicat viaţa muncii, progresului şi formării generaţiilor tinere de geologi. Personalitatea sa ştiinţifică s-a născut prin specializarea succesivă în numeroase domenii interdependente ale ştiinţelor geologice, pe un fond de inteligenţă şi putere de sintetizare remarcabile. La această înzestrare teoretică cu totul deosebită s-a adăugat o experienţă vastă din domeniul practicii. Figura lui generoasă va rămîne în amintirea noastră nu numai ca un reprezentant de seamă al intelectualităţii româneşti, ci şi ca personalitatea cea mai marcantă a mineralogiei şi petrografiei ultimei jumătăţi de veac.

Dispariţia prof. Dan Giuşcă reprezintă pentru geologia românească o pierdere imensă, care în perioada actuală de renaştere a spiritualităţii intelectuale şi a structurilor activităţii geologice se resimte în mod deosebit .Simţim un regret profund pentru faptul că nu i-a fost dat să trăiască reînnoirea actuală pe care a aşteptat-o din tot sufletul. Rămînem adînc îndatoraţi pentru tot ce a făcut pentru progresul geologiei româneşti, pentru generaţiile de geologi pe care le-a format şi pentru ameliorarea ,în măsura posibilităţilor, a declinului din viaţa geologică pe care în ultimii ani l-a trăit cu adîncă mîhnire. Amintirea profesorului, directorului, îndrumătorului ,colaboratorului şi în special a omului care a fost Dan Giuşcă, va persista adînc înrădăcinată în memoria celor care l-au cunoscut. Pentru generaţiile viitoare va rămîne prezent prin opera sa ştiinţifică care în mare parte va păstra valoarea în ciuda scurgerii anilor.

Din partea Institutului de Geologie şi Geofizică un pios omagiu !

Dr. H. G. Kräutner

Giuşcă D. (1937) Memoriu de titluri şi lucrări ; 13 p., Bucureşti.
Rădulescu D. (1939) Dan Giuşcă ; Rev. Roum. Géol. Géophys., Géogr., Géologie 33, p. 3—11.
Cioflică Gr. (1989). Acad. prof. Dan Giuşcă : Analele Univ. Bucureşti, 37, p. 93—95.
Anastasiu N. (1990) În amintirea Acad. Dan Giuşcă : Stud. şi cerc. geol. 34

Lista lucrărilor tipărite ale prof. Dan Giuşcă a fost publicată în *Rev. Roum. Géol., Géophys., Géogr., Géologie* 33, p. 9—11, (1989)

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GEOCHEMISTRY OF THE GRANITOID ROCKS IN THE ȚARCU MOUNTAINS [1]

by

PETRE ANDĂR [2]

Granites. Granite gneiss. Proterozoic. Quartz diorites. Leucogranite. Lower Paleozoic. Major elements. Minor elements. Magmatic differentiation. Granitisation. Metasomatism. Radiogenic heat. Statistical distribution. Correlation. Trend-surface analysis. Factor analysis. Țarcu Mountains. Transylvanian Alps.

Abstract

Vîrful Pietrii, Furcătura and Petreanu granitoid bodies are situated in the northwestern part of the Danubian Units in the metamorphites of the Petreanu-Rof tectonic window belonging to the Lower Danubian Unit. The mineralogical and petrographic differences between the granitoid rocks of the three mentioned bodies are reflected also by their chemical composition both for the major elements and for the trace elements. The statistical study (distribution, correlation, trend surface analysis, factors analysis) of the geochemical data revealed significant differences between the granitoid rocks in the Țarcu Mts. Unlike the Furcătura and Petreanu granitoid bodies, the areal distribution of the major chemical components of the Vîrful Pietrii granitoid rocks is controlled by the form of the granitoid body. Except for Li, Be, Yb and U, the average contents of all the other trace elements are almost two-four times lower in the Vîrful Pietrii leucogranites than in the Furcătura and Petreanu granitoid bodies. The granitoid rocks of the three bodies differ also by the frequency and intensity of the correlation between the trace element contents. As compared with other granitoid massifs of the Danubian Realm in the South Carpathians, Țarcu Mts granitoid bodies display average values of the lowest radiogene heat. The relationships with the surrounding rocks, structure, texture, mineralogical composition, origin of enclaves and the general aspect of the pluton point undoubtedly to the magmatic origin of the Vîrful Pietrii granitoid

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body. Nevertheles, the mineralogical, petrographical, structural and geochemical observations show significant differences between the Furcătura and Petreanu granitoid bodies suggesting different petrogenetic and evolution processes.

Résumé

Géochimie des roches granitoïdes des monts de Țarcu. Les corps granitoïdes de Vîrful Pietrii, Furcătura et Petreanu sont situés dans la partie NW de l'autochton danubien, dans les métamorphites de la fenêtre tectonique de Petreanu-Rof, appartenant au danubien inférieur. Les différences minéralogiques et pétrographiques entre les roches granitoïdes des trois corps se reflètent aussi dans leur composition chimique pour les éléments majeurs aussi bien que pour les éléments mineurs. L'analyse statistique (distribution, corrélation, analyse de tendance, analyse factorielle) des données géochimiques a indiqué d'importantes différences entre les roches granitoïdes des monts de Țarcu. A la différence des corps granitoïdes de Furcătura et Petreanu, la distribution aréale des components chimiques majeurs des roches granitoïdes du massif de Vîrful Pietrii est controlée par la forme du corps granitoïde. Excepté Li, Be, Yb et U les teneurs moyennes pour tous les autres éléments mineurs sont deux à quatre fois plus réduites dans les leucogranites du massif de Vîrful Pietrii par rapport aux corps granitoïdes de Furcătura et Petreanu. Les roches granitoïdes des trois corps diffèrent par la fréquence et l'intensité de la corrélation entre les contenus des éléments mineurs. A la différence d'autres massifs granitoïdes de l'autochton danubien des Carpathes Méridionales les corps granitoïdes des monts de Țarcu présentent des valeurs moyennes des plus réduites de la chaleur radiogène. Les rapports avec les roches environnantes, la structure, la texture, la composition minéralogique, la nature des enclaves et l'aspect général du pluton attestent l'origine magmatique du corps granitoïde de Vîrful Pietrii. En échange, les observations minéralogiques, pétrographiques, structurales et géochimiques indiquent d'importantes différences entre les corps granitoïdes de Furcătura et Petreanu en suggérant des processus pétrogénétiques et évolutions différentes.

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1. INTRODUCTION

The Vîrful Pietrii, Furcătura and Petreanu granitoid bodies lie in the north-western part of the South Carpathians, in the Țarcu massif, north of the Godeanu massif and west of the Retezat massif.

The relief is quite uneven. A characteristic feature of the relief is connected with its altitude which increases from the north, where it reaches ca 1400-1600 m, to the south (Sturu Summit, 1822 m ; Petreanu Summit, 1897 m ; Murgan Summit, 1964 m) attaining the maximum height in the Vîrful Pietrii (2198 m). The summits form a radial network with the centre in the Vîrful Pietrii.

On the whole, there is a close relationship between the relief and the petrographic constitution of the geological formations in the study region. Thus, the granitoid rocks led to the formation of a rough

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mountainous relief with steep slopes and peaked ridgees, with summits exceeding 2000 m high, whereas the surrounding metamorphic formations are characterized by mild forms of relief, with heights less than 1600 m.

The hydrographic network belongs to two hydrographic basins : the upper basin of the Bistra Bucovei River, whose tributaries drain the western part of the region, the northern and south-western parts of Vîrful Pietrii massif respectively, and the basin of the Rîul Mare River.

The glacial phenomena are represented by glacial circuses, glacial valleys and moraine deposits.

2. EARLIER GEOLOGICAL RESEARCHES

The first accounts on the geology of the north-western part of the Danubian Units date back in the years 1861-1862 and belong to Stur (1862). He described, in the north-western part of the Retezat massif, micaceous gneisses, amphibolites, etc. displaving a more obvious schisto-servations are recorded by Hauer and Stache (1863) on the map appended to their paper ; however, only gneisses are figured.

General geological data on the crystalline schists occurring in this area were given by B. von Inkey (1891), who divided them into three groups after Böch's classification (1879) : a lower group, consisting of granitic gneisses (I) ; an intermediary group, represented by micaschists, micaceous gneisses, amphibolites, etc. displaving a more obvious schistosity than the rocks from the first group (II) ; an upper group, with a more reduced schistosity, consisting of chlorite schists, graphite schists, phyllites, etc. (III).

The researches were continued by Schafarzik (1899), who described the crystalline schists in the Retezat massif and the Rîul Mare basin and divided them into three groups, according to Böch's classification. Thus, he considered the rocks from the Vîrful Pietrii massif muscovite gneisses, although he mentioned their morphology as stock ; he reached the conclusion that they form the lower part of the group II of crystalline schists. As regards the rocks of Petreanu massif, Schafarzik regarded them as biotitic orthogneisses derived from a granite by dynamometamorphic processes. Later on Schafarzik (1901) considered that the Petreanu massif consists mostly of eruptive rocks ; he also showed that the neighbouring crystalline schists display a contact metamorphism.

The geological researches in the study region were resumed in the period 1929-1933 by Gherasi who studied this area more than four decades. In 1937 Gherasi gave a detailed petrographic and tectonic description of the crystalline schists and of the granitoids in the upper part of the Rîul Mare basin, Țarcu and Godeanu Mts ; he also published the first geological map of the region. In this paper he rendered evident, for the first time, the Vîrful Pietrii granitic massif.

The first minute geological researches in the northern part of the Țarcu and Petreanu Mts were effectuated by Al. Codarcea and N. Gherasi (1944-1945), especially in connection with the water power stations designed to be carried out on Rîul Mare and Bistra Mărului. Their researches led to the separation of well-characterized metamorphic units

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and to the clearing up of their tectonics. Thus, on Bistra Mărului Valley, they distinguished an amphibolite zone, a zone with chlorite schists and quartzites, Vîrful Pietrii granite, Muntele Mic granite and Sucu granitized zone. The mentioned authors also separated the "Vidra Series" within the Paleozoic metamorphosed formations. In the Rîul Mare Valley they established the presence of five complexes that succeed from N to S as follows : muscovite chlorite-schists series, granitic gneisses complex, chlorite-biotite banded schists series, Petreanu granitic complex, and phyllite series.

The separated subdivisions were confirmed by subsequent geological researches effectuated in the area lying between the two rivers. Thus, Gherasi et al. (1968) described the stratigraphy and petrography of the crystalline schists in the north-western part of the Vîrful Pietrii massif; Gherasi and Dimitrescu (1968, 1970), Morariu (1982), Morariu, Morariu (1982) and Dimitrescu (1985) brought petrotectonic and lithostratigraphic contributions to the structure of the crystalline occurring in the northern part of the Retezat and Petreanu Mts.

The granitoid rocks from Vîrful Pietrii and Petreanu massifs were also studied by Codarcea and Pavelescu (1963) and Giușcă et al. (1969), who described the genesis of the granitoids occurring in the Danubian Units which they considered of magmatic origin and of Lower Paleozoic age, as well as by Soroiu et al. (1970-1972), who dated the Precambrian crystalline and eruptive formations of the South Carpathians by K/Ar absolute age measurements.

3. GENERAL GEOLOGICAL DATA

Recently, on the basis of all the geological data gathered in the last decades, Kräutner et al. (1981) and Berza et al. (1983) showed that the Danubian crystalline formations belong to two great tectonic units the Lower Danubian Unit and the Upper Danubian Unit — formed, in their turn, of several subunits.

The granitoid bodies from Vîrful Pietrii and Petreanu are situated in the north-western part of the outcropping area of the Danubian Units, in the metamorphites of the Petreanu-Rof tectonic window belonging to the Lower Danubian Unit. The mentioned granitoid massifs pertain to the suite of eruptive bodies that penetrate the Danubian crystalline formations in Romania, extending on a length of ca 160 km from the Danube up to the Latorița Basin.

The stratigraphy, petrography and structure of the lithostratigraphic units in the north-western part of the Danubian Unit were described by Schafarzik (1899, 1901), Gherasi (1937), Codarcea, Gherasi (1944, 1945), Gherasi, Medeșan (1968), Gherasi et al. (1968, 1975), Gherasi, Dimitrescu (1968, 1970), Morariu (1982), Morariu, Morariu (1982).

The results of these researches were reinterpreted by Kräutner (1980) and Kräutner et al. (1981), who pointed out that the Vîrful Pietrii and Petreanu granitoid bodies are located in the Precambrian polymetamorphic rocks of the Petreanu Group belonging to the Carpian Supergroup. According to the above-mentioned authors as well as to

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Dimitrescu (1985), the crystalline schists found in the Petreanu-Rof Unit, which are in direct relationships with the granitoid rocks, belong to the following lithostratigraphic units : Rof Formation, Nisipoasa Formation, Bodu Formation and Vidra Formation.

4. VÎRFUL PIETRII MASSIF

The Vîrful Pietrii granitoid massif forms an ellipsoid-shaped plutonic body, its axes having sizes of 15 × 11 km, and consequently it seems about circular. This massif lies between the Bistra Bucovei Valley, to the east, and the Bistra Mărului Valley, to the west, constituting the Bloju, Pietrii, Sturu, Murgan, Scărișoara, etc. mountains.

From the petrographic viewpoint, the Vîrful Pietrii massif consists of leucocrate granites, which occupy most of the surface, granodiorites, found sporadically only in the marginal zones of the massif, and quartz diorites, occurring as small bodies at the western margin of the massif. Enclaves of crystalline schists of different sizes are to be found both in the marginal zones and in the interior of the massif.

4.1. **Petrographical and Mineralogical Description**

4.1.1. *Dioritic Rocks*

In the west of the Vîrful Pietrii massif there are two small bodies of dioritic rocks known as the Bistra diorites (Gherasi, 1937).

The first diorite body is smaller and occurs in the Bistra Mărului Valley, about 500 m upstream the confluence with the Pecineaga Brook. The rocks are characterized by a medium-grained texture and an oriented structure.

The second diorite body is a bit larger and lies also in the Bistra Mărului Valley around its confluence with the Capra Foii Brook. The rocks are coarser than those of the first group ; they display a massive structure, particularly in the central part of the body, and an oriented structure in the marginal zone (Pl. I, Fig. 1).

Likewise, smaller outcrops of dioritic rocks (of some metres or tens of metres) appear in the granitic rocks in the Pecineaga Brook, Sturu Brook, Michi Brook, Bistra Mărului Valley and west of Vîrful Pietrii Summit in the Bloju Crest. In places these rocks occur in association with intercalations of crystalline schists e.g. in the Michi Brook and in the Bloju Crest.

The presence of the microcline, in places quite abundant and displaying an ocular character, determined the monzodioritic character of these rocks.

The dioritic rocks are penetrated lit-par-lit by granitic apophyses and veinlets which point out their relationships with the granitic rocks. This assemblage is locally cut by aplitic veinlets. All these field data point out that diorites were formed before the granitic rocks of the Vîrful Pietrii massif.

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The *QAP* diagram (Fig. 1) shows that they are grouped especially in the monzodiorite field and display slight variations both towards the quartz monzonites field and to the diorite field. Therefore, these rocks regarded as diorites (Gherasi, 1937 ; Gherasi et al., 1968) are mostly

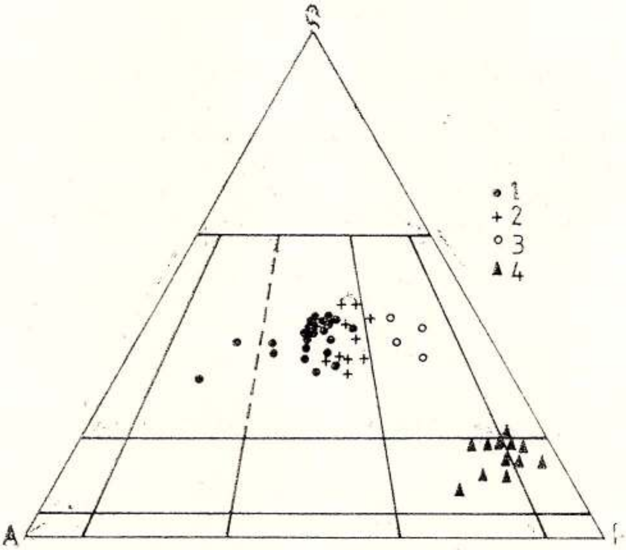

Fig. 1 — *QAP* diagram. 1, granites, central facies ; 2, granites, marginal facies ; 3 granodiorites ; 4 quartz diorites.

monzodiorites. The appearance of the monzonitic or dioritic rock-type is mainly determined by a larger or smaller quantity of potash feldspar as compared to that found in monzodiorites.

Under the microscope the rocks present a granular hipidiomorphic texture.

Plagioclase is entirely altered being filled with a fine aggregate of sericite, epidote and more rarely of albite. Shadows of polysynthetic twins are seldom observed.

Hornblende is represented by the common variety of a green colour. It occurs as well-developed, elongated, prism-like crystals with a good cleavage and frequently twinned after (100). They display a good pleochroism : Ng = green, Nm = light brown, Np = yellowish, c : Ng = 18°. Hornblende is less coloured on the margins. In places, it contains inclusions of quartz and altered plagioclase. In some zones of the dioritic bodies a fibrous hornblende is observed; its extinction angle c:Ng = 15-18° and it occurs especially as nests. The hornblende is of a light greenish colour, weakly pleochroic and is formed at the expense of a primary hornblende.

Quartz is usually found in small amounts as small grains. It is xenomorphic, with an undulatory extinction filling the space between the wider developed minerals (plagioclases and hornblende).

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Biotite occurs in variable amounts in different outcrops of monzodioritic rocks. It is found as irregular lamellas with the following pleochroism : Ng = Nm = brown ; Np = yellowish. It is often chloritized.

Potash feldspar is represented by microcline ; its spreading is not uniform. It usually occurs in small amounts, but locally it becomes more abundant and displays an ocular character. Potash feldspar is xenomorphous, inequigranular, with very irregular margins and always fresh. In places, it contains inclusions of altered plagioclase.

Accessory minerals are represented mostly by sphene and apatite and rarely by zircon.

Sericite, zoisite and epidote are secondary minerals formed especially by the hydrothermal alteration of plagioclase.

The main characteristics of the dioritic rocks in the Vîrful Pietrii massif can be presented as follows :

QAP modal values : $Q = 17.7\%$
$A = 9.8\%$
$P = 72.5\%$

chemical composition :

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O
56.20	0.81	16.54	2.57	4.30	0.22	5.13	6.43	3.15	3.08	0.41	1.09

QAP normative values : $Q = 7.5\%$
$A = 25.2\%$
$P = 67.3\%$

Niggli values

si	*al*	*fm*	*c*	*al*	*k*	*mg*
160.5	27.8	38.2	19.7	14.3	0.4	0.6

magma type : dioritic.

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4.1.2. *Granitic Rocks*

The Vîrful Pietrii granitoid massif is mostly constituted of a leucocrate granite, of a light grey-whitish colour, with an almost massive structure in the central part and an oriented or weakly oriented structure (Pl. I, Fig. 2) in the marginal zones. Macroscopically the schistous structure is pointed out by the muscovite orientation. In some zones this structure is more obvious and it reveals mechanic deformation phenomena in the rock, as in the Niermeș Valley nearby the confluence with the Bîrlova Brook, in the Strîmbu Mare Brook and in the Bistra Mărului upstream the confluence with the Bloju Brook. The marginal facies is not more than 500-600 m wide (on an average 300 m) from the margin of the granitic massif towards the interior.

These structural differences of the granitic rocks correspond to weak variations of textural and mineralogical composition. The differences

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between the central and marginal facies refer especially to the rock granulation and only to a less extent to the percentage of the component minerals.

Generally, in the central, massive facies, the rocks show a typical granitic, hipidiomorphic texture while in the marginal, schistous facies the granulation is smaller, locally displaying an aplitic character. At the same time the ratio between the calc-sodium feldspars and the potash feldspar increases slightly in the schistous facies. To all this one can add the presence of garnet and biotite in some marginal zones of the granitic massif. Garnet occurs as an accessory mineral only in the Bistra Mărului granites from the confluence with the Sturu Brook up to the confluence with the Bloju Brook. Biotite, practically lacking in the central part of the massif, occurs in the marginal zones e.g. south of Vîrful Pietrii.

A variety of more alkali granites with microcline occurs sporadically, on small surfaces, as in the Murgana Valley and the porphyroid ones at the confluence of the Pecineaga Brook with Bistra Mărului.

Mineralogically, the Vîrful Pietrii granitic rocks consist of quartz, plagioclase, microcline and muscovite, beside biotite especially in the peripheral zones. A characteristic of the Vîrful Pietrii granite is the lack of melanocrate minerals. The accessory minerals are also almost lacking, except for garnet, which occurs as small grains in the western margin of the massif, and sphene, which is very rarely found. As secondary minerals, resulting from the hydrothermal alteration of the primary minerals, especially of plagioclase, occur sericite, muscovite and more rarely epidote and chlorite.

Although the mineralogical composition is quite uniform in the granitic massif, as also pointed out by other researchers (Gherasi, 1937 ; Gherasi et al., 1968), certain variations can be observed as regards the percentage of the component minerals. Thus, the modal composition of the Vîrful Pietrii leucogranties indicates that :

— the quartz content displays a more obvious variation in the marginal facies than in the central one, the average values being, however, close ;

— the ratio between the plagioclase feldspars and the potash feldspars increases from the central part of the massif, where its values are almost equal to the unit, towards the periphery where it reaches 1.5 ;

— the variation of the muscovite content is quite uniform, the average content being a bit higher in the central facies.

The *QAP* diagram (Fig. 1) shows that the samples occur within the limits of the granitic rocks domain, the monzogranite field and more rarely in the syenogranite field. At the same time, one can observe that the rocks of the marginal facies show a more granodioritic tendency, their plotting field being situated in the close vicinity of the granodioritic rocks domain, whereas the rocks of the massif facies fall only in the granite domain. The plotting fields of the two facies are mostly superposed.

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Microscopically, the Vîrful Pietrii leucogranites display a hipidiomorphic texture, being constituted of quartz, plagioclase, potash feldspar and muscovite.

Quartz constitutes about 35—40% of the rock. It is inequigranular anhedral, irregularly disposed or occurring as nests in the central massive facies and as conformable bands or lenses elongated after a certain direction in the marginal facies. It is also found as small drop-like inclusions or on different fissures in feldspars. The crystal margins are very irregular displaying frequent interfingerings between them. The quartz grains are usually small-sized (0.05-0.5 mm), but larger-sized grains (0.8-1.5 mm) are also found. Regardless of their sizes, the quartz grains present an undulatory extinction. Both the undulatory extinction and the lack of inclusions in quartz indicate its recrystallization.

Plagioclase constitutes 25-35% of the granite mass, being spread especially in the marginal facies. Plagioclase crystals are anhedral up to subhedral and more rarely euhedral with a prism-like aspect. They are frequently ovoidal or elongated with curved outlines, lobated with a crystalloblastic aspect. When plagioclase comes into contact with potash feldspar a very sinuous, convex corrosion line can be observed. Plagioclase is usually altered, turbid, being filled with a fine aggregate consisting of muscovite, sericite, more rarely zoisite secondary mineral association or it is transformed into a clayey, thick mass, a characteristic feature of the plagioclase from the South Carpathians granites (Savu, 1970). Among these microlites muscovite occupies a significant part, its frequency being inversely proportional to that of zoisite.

Plagioclase crystals contain locally globular quartz inclusions. The plagioclase margins remain sometimes limpid and they show more albitic features. In places, fresher crystals are observed which contain very fine polysynthetic twins that show proof of the low anorthite contents in plagioclase. Polysynthetic twins are also recognized in altered crystals, locally only as traces. Associations of albite-Karlsbad twins are rarely observed in plagioclase. Very rarely, especially in the south of the massif, plagioclase shows a zonary texture emphasized by the different degree of alteration of the crystal zones.

It is difficult to determine the plagioclase composition because of their hydrothermal alteration which disturbed them. In some cases values of the extinction angle of 8-14° could be determined by the method of the sections perpendicular to [010], which would point to a plagioclase with 5-18°An.

In the marginal zones of the granitic massif plagioclase often shows cataclasis traces revealed by the fissured plagioclase crystals, torn, bent twins individuals, etc. In places, the fissures are filled with quartz (Pl. II, Fig. 1).

The myrmekite-type plagioclase-quartz intergrowths are very rarely found and they are quite poorly developed.

Potash feldspar constitutes 20—35% of the rock ; it is spread especially in the central part of the Vîrful Pietrii massif and is represented by microcline.

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Potash feldspar is anhedral, inequigranular, with highly irregular margins and almost always fresh.

It is developed interstitially as masses inside the plagioclase crystals or as borders around them. Often it occurs on fissures crossing the plagioclase. Larger crystals with an irregular, ameoboidal, ocular (Pl. II, Fig. 2) or tabular (Pl. II, Fig. 3) outline are often found, too. Microcline is often cross twinned. Microperthitic separations occur more rarely. The large crystals of potash feldspar include frequently euhedral crystals or anhedral grains of plagioclase and globular quartz (Pl. II, Fig. 2). Potash feldspar is very rarely zoned (Pl. II, Fig. 3). A reaction zone consisting of a very fine aggregate of quartz, sericite and altered plagioclase if often observed around the large microcline crystals. Very rarely, in the marginal zones of the granitic massif, potash feldspar is fissured ; these fissures are more often filled with secondary minerals, quartz and sericite.

The optical and structural variation domains of potash feldspar from granite were established on the basis of measurements of the optical axes angle and of the extinction angle $\gamma : b$ on the universal stage on 110 crystals from 32 thin sections.

The results of this study point out that there are no differences between the marginal and the central facies as regards angle 2V and the angle between Ng and the plane pole (010). The value of 2V varies between 73 and 88°, with the highest frequency (more than 60%) in the domain 82-84°. In all the studied feldspars the extinction angle $\gamma : b$ varies between 11 and 18°, the maximum frequences ranging from 16 to 18°.

The carried out measurements made possible the determination of the triclinicity degree and, consequently, of the textural state of potash feldspar. The Laves-Vishwanathan diagram (1967) shows that the potash feldspars from the Vîrful Pietrii granite have a high triclinicity and they can be regarded as a maximum microcline.

Muscovite constitutes up to 10% of the rock. It occurs in two distinct forms : as secondary mineral derived from the plagioclase alteration and as primary mineral spread in the whole rock.

Secondary muscovite from plagioclase is usually found as small, prismatic laths and more rarely as masses. Primary muscovite appears as isolated lamellas irregularly disposed or as nests in the central part of the granitic massif and as oriented suites or lens-shaped nests in the marginal zone of the massif. Muscovite crystals are usually small-sized and they fill the interstices between the other minerals, quartz and feldspars ; large-sized crystals are found as well. The latter contain locally drop-like quartz or biotite inclusions and are rarely surrounded by a reaction zone.

A deformation of the large-sized muscovite crystals is observed in the marginal zone of granite pointed out by their undulatory extinction and the bent lamellas (Pl. II, Fig. 4).

Biotite is very rarely found and is usually chloritized.

As *accessory minerals*, apatite and zircon are found sporadically in the whole granitic massif, while garnet occurs only in the west of the massif.

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The main features of the granitic rocks in the Vîrful Pietrii massif can be presented as follows :

QAP modal values : $Q = 39.8\%$
$A = 31.5\%$
$P = 28.7\%$

chemical composition :

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O
73.72	0.14	14.42	0.66	0.62	0.06	0.60	1.49	3.76	3.54	0.05	0.67

QAP normative values : $Q = 36.6\%$
$A = 22.4\%$
$P = 41.0\%$

Niggli values :

si	*al*	*fm*	*c*	*alk*	*k*	*mg*
410.5	47.3	10.9	8.9	32.9	0.4	0.5

magma type : engadinitegranitic-trondhjemitic.

4.1.3. *Granodioritic Rocks*

This petrographic type occurs sporadically in the marginal zone of the granitoid massif, as local variations of the main mass of granitic rocks without forming bodies or distinct zones within the massif. Such isolated, metrical occurrences are to be found in the Michi Brook, at the confluence with Bistra Mărului, and in the Pecineaga Brook.

The textural and structural features of the granodioritic rocks are similar to those of the granitic rocks the only differences being the percentage of the component minerals. It is of note the more frequent participation of biotite, which can reach 4-5% of the rock.

The *QAP* diagram (Fig. 1) indicates that the analysed rocks fall in the granodiorites field.

The general characteristics of the granodioritic rocks in the Vîrful Pietrii massif can be presented as follows :

QAP modal values : $Q = 38.9\%$
$A = 12.8\%$
$P = 48.3\%$

chemical composition :

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O
65.55	0.32	18.05	1.26	1.15	0.06	2.96	4.52	4.09	1.32	0.08	1.13

QAP normative values : $Q = 26.0\%$
$A = 9.0\%$
$P = 65.0\%$

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Niggli values :

si	*al*	*fm*	*c*	*alk*	*k*	*mg*
245.9	39.9	23.9	18.2	18.0	0.2	0.7

magma type : granodioritic.

4.1.4. *Pegmatites and Aplites*

The pegmatoid facies are almost lacking within the Vîrful Pietrii massif or at its periphery. They never form well-delimited veins or distinct bodies. Pegmatoid-like rocks are found as small amounts only in the Murgana Brook. The rock composition is identical with that of granites.

Unlike pegmatites, the aplitic rocks are more widespread. They occur as microcrystalline facies rich in quartz, feldspars, and muscovite, especially in the marginal parts of the massif. As already mentioned, the aplitic veins penetrate both the dioritic bodies and the surrounding schists.

4.1.5. *Crystalline Schists Intercalations*

Numerous crystalline schists intercalations are found in the Vîrful Pietrii plutonic body. They occur both in the marginal zone and towards the interior. The crystalline schists intercalations are very elongated, lenticular. Their sizes vary highly, usually exceeding the metre order, as those in the Pecineaga Valley or in the Michi Brook. Centimetric intercalations are more rarely found, especially in the marginal zones, e.g. in the Prodana Brook.

As concerns their relationships with granitic rocks, the crystalline schists intercalations are more often conformable, their foliation (schistosity) position coinciding with the granite foliation. However, in places, the foliation of the crystalline schists intercalations forms an angle of ca 10-30° versus the granite foliation, e.g. in the Loloaia Crest and the Tarnița Brook. This unconformity is explained by the fact that the crystalline schists intercalations represent blocks from the schistous cover of the granitic pluton, distributed by the ascent of the viscous magma.

For both types of intercalations the contact with the granitic rocks is clear.

The structural and textural features of the intercalations are proper to the crystalline schists and they are determined by their mineralogical composition. One can observe granoblastic, granolepidoblastic and lepidoblastic textures and a schistous structure.

In petrographic respect, the intercalations are represented by retromorphosed gneisses and muscovite- and biotite-bearing quartzites. The retromorphosed gneisses occur most frequently and they reach the largest sizes, e.g. those in the Pecineaga Valley, Michi Brook and in the Păltineț-Vîrful Pietrii Crest. Quartzites are less spread and form smaller occurrences at the mouth of the Sciomfu Mare Brook, near Murgan Summit,

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where they are found in association with micaschists, and in the Cununa Summit.

The crystalline schists intercalations are usually affected by granites ; the rocks display a migmatic character either because of biotitization and feldspathization (metablastic migmatites) or due to the intrusion of a granitic material onto the schistosity planes (metatectic migmatites). Such metablastic migmatites occur in the Pecineaga Valley, upstream its confluence with the Peceneguța Brook, and in the Izvorul Alb Brook, nearby the confluence with Bistra Mărului. Metatectic migmatites are found in the Loloaia Crest and nearby the Murgan Summit, where they are folded ; small quartz separations are observed in the folds axes.

The small-sized crystalline schists intercalations are strongly affected by the granitic intrusion and altered into biotite hornfelses, e.g. in the Niermeș Valley and in the margin of the forest road.

4.2. **Geochemistry of the Granitoid Rocks in the Vîrful Pietrii Massif**

4.2.1. *Petrochemical Features*

The petrochemical study of the granitoid rocks in the Vîrful Pietrii plutonic massif is based on 43 complete analyses of silicates which represent the following rock types : 37 granite samples, 1 granodiorite and 5 quartz diorite samples (Tab. 1). Only four analyses have been taken over from the literature : sample 1 for a quartz diorite (Gherasi, Medeșan, 1968) and samples 2, 3, 4 of granites (Gherasi, 1967 ; Zimmermann, Zimmermann, 1965).

As already pointed out by some researchers, e.g. Rittmann (1973), Streckeisen, Le Maître (1979), La Roche et al. (1980), Andreeva et al. (1981), etc. the data of the chemical analyses can be used in the classification of the magmatic rocks either directly (pure chemical classification) or calculating the normative composition (normative classification).

The projection of the results of the chemical analyses of the Vîrful Pietrii granitoids on the R_1R_2 diagram (Fig. 2) points out that most of the analysed granitic rocks fall in the granite field, namely in the silica-richer zone. Only few samples plot in other fields, especially in the granodiorite field. The dioritic rocks fall in the field of quartz diorites and diorites. This diagram shows a very good correspondence with the mineralogical classification.

With a view to establishing the rock denomination and classification according to chemico-mineralogical data the analysed granitoid rocks were plotted on a *QAP* diagram (Streckeisen, 1967) on the basis of the normative minerals values computed after Rittmann's method (1973). The plots of the rocks are wider spread than in case of modal determinations (Fig. 1), namely from the vicinity of the peak *P* up to the side *AQ* of

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TABLE 1

Chemical composition of granitoid rocks of the Vf Pietrii massif

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	1	259	303	197	220	239	149	4	227	232	113	250	108	3	263	257	114	288	101	285	184	119
	quartz diorite	quartz d[illegible]ite	quartz diorite	quartz diorite	quartz diorite	granodiorite	porhyroid granite	granite	granite	granite	granite	granite	granite	granite	muscovite granite	granite	granite	granite	granite	granite	granite	granite
SiO_2	[illegible]65	55.97	58.00	58.04	58.34	65.55	67.62	69.40	70.46	71.15	71.34	71.51	72.24	72.60	72.76	73.18	73.20	73.23	73.63	73.84	73.84	73.94
TiO_2	1.17	0.72	0.62	0.83	0.72	0.32	0.42	0.55	0.11	0.21	0.34	0.09		0.25	0.60	0.35		0.15	0.13		0.13	0.12
Al_2O_3	18.43	16.77	12.50	17.69	17.29	18.05	15.11	14.10	15.77	15.36	15.48	14.94	16.13	15.60	13.70	13.18	15.32	14.05	15.36	14.96	13.95	14.64
Fe_2O_3	3.07	1.72	4.94	1.49	1.63	1.26	1.27	1.84	0.58	0.95	1.09	0.75	1.05	0.83	0.74	0.52	0.89	0.28	0.66	0.39	0.66	0.54
FeO	5.31	4.31	3.59	4.56	3.73	1.15	2.04	1.57	0.55	0.78	1.65	0.48	0.49	0.70	0.43	1.00	0.64	0.86	0.72	0.28	0.68	0.64
MnO	0.24	0.30	0.10	0.34	0.13	0.06	0.15		0.06	0.05	0.07	0.06	0.05		0.04	0.03	0.05	0.04	0.04	0.05	0.08	0.02
MgO	5.82	6.03	5.30	4.45	4.05	2.96	1.39	0.70	0.75	0.91	0.95	0.95	1.30		0.30	0.50	0.40	0.20	0.20	1.00	0.94	0.29
CaO	6.86	6.49	6.30	6.07	6.42	4.52	3.36	1.75	2.75	1.34	1.31	2.98	0.70	1.65	1.82	2.38	1.54	2.10	0.98	0.84	1.50	0.91
K_2O	3.28	2.80	3.10	2.55	3.67	1.32	3.44	4.24	3.93	3.63	3.66	3.80	2.89	4.05	3.70	3.08	3.42	3.08	3.27	1.71	3.39	3.69
Na_2O	3.02	3.19	3.20	3.22	3.13	4.09	3.94	4.02	3.91	4.75	4.16	3.43	3.65	4.15	4.79	4.26	3.23	4.75	3.65	5.66	3.69	3.85
P_2O_5	0.87	0.31	0.25	0.39	0.25	0.08	0.17	0.22	0.03	0.06	0.05	0.03	0.03	0.07	0.05	0.03	0.03	0.06	0.04	0.04	0.01	0.04
H_2O	1.13	0.93	1.51	0.92	0.95	1.13	0.90	0.14	0.70	1.09	0.43	0.52	1.14		0.56	0.57	1.11	0.57	0.93	0.98	0.54	0.90
CO_2	0.35							1.00						0.60	0.20	0.30		0.20				
S															0.04	0.04		0.03				
Total	100.20	99.54	99.41	100.55	100.31	100.49	99.81	99.53	99.60	100.28	100.53	99.54	99.87	100.50	99.73	99.42	99.83	99.60	99.61	99.75	99.41	99.58
Fe_2O_3/FeO	0.58	0.40	1.38	0.33	0.44	1.10	0.62	1.17	1.05	1.22	0.66	1.56	2.14	1.19	1.72	0.52	1.39	0.33	0.92	1.39	0.97	0.84
FeO/MgO	0.91	0.71	0.68	1.02	0.92	0.39	1.47	2.24	0.73	0.86	1.74	0.51	0.38		1.43	2.00	1.60	4.30	3.60	0.28	0.72	2.21

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Table 1 - continued

	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
	256	127	26	86	63	2	11	137	48	289	151	99	209	195	87	162	145	54	267	7	172
	granite	granite	granite	granite	granite	granite	granite	granite	granite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite	leucogranite
SiO_2	73.99	74.22	74.34	74.39	74.42	74.42	74.48	74.55	74.63	74.75	74.77	74.78	74.80	74.85	74.99	74.99	75.02	75.34	75.85	76.22	78.07
TiO_2	0.10	0.10	0.09	0.11	0.08		0.16	0.08	0.08		0.05	0.10	0.11	0.07	0.06	0.11	0.07	0.04	0.25	0.06	0.11
Al_2O_3	14.55	14.56	14.39	14.28	14.32	14.47	14.46	14.13	14.33	13.78	14.42	14.58	14.14	14.23	14.43	13.43	13.99	13.50	13.90	13.86	11.81
Fe_2O_3	0.61	0.64	0.54	0.76	0.49	1.07	0.92	0.43	0.48	0.60	0.33	0.61	0.55	0.47	0.45	0.55	0.15	0.39	0.62	0.35	0.18
FeO	0.48	0.61	0.54	0.39	0.56	0.27	0.50	0.43	0.45	0.28	0.36	0.62	0.56	0.25	0.36	0.74	0.31	0.23	0.31	0.51	0.63
MnO	0.06	0.05	0.08	0.08	0.07	0.05	0.13	0.03	0.13	0.05	0.10	0.10	0.11	0.05	0.04	0.05	0.07	0.10	0.05	0.10	0.02
MgO	1.07	1.49	0.47	0.43	0.55	0.15	0.71	0.72	0.42	0.30	0.65	0.29	0.39	0.80	0.39	0.38	0.95	0.51	0.06	0.36	0.33
CaO	1.12	1.01	1.61	1.61	1.61	1.11	1.96	1.87	1.68	1.12	0.94	0.94	1.33	1.17	1.33	1.03	1.36	1.47	0.94	1.26	0.36
K_2O	3.63	3.22	3.35	3.64	3.72	4.08	2.67	3.26	3.54	3.39	3.03	3.40	3.77	3.62	3.79	3.40	4.09	3.29	3.19	3.69	4.87
Na_2O	4.02	3.55	3.65	3.19	3.08	3.88	2.67	3.37	2.95	4.23	3.99	3.70	3.19	3.98	2.97	3.86	3.54	3.07	3.59	3.44	2.89
P_2O_5	0.03	0.04	0.02	0.02	0.03	0.14	0.03	0.05	0.03	0.06	0.03	0.03	0.04	0.02	0.02	0.02	0.03	0.02	0.04	0.02	
H_2O	0.48	0.93	0.67	0.64	0.59	0.48	0.90	0.84	0.73	1.12	0.37	0.59	0.50	0.16	0.63	0.68	0.66	0.65	0.84	0.70	0.35
CO_2				tr.						tr.								tr.			
S				tr.																	
Total	100.14	99.52	99.75	99.54	99.52	100.12	99.59	99.76	99.45	99.69	99.34	99.74	99.64	100.43	99.46	99.45	100.34	99.31	99.64	100.57	99.62
Fe_2O_3/FeO	1.27	1.05	1.00	1.95	0.88	3.96	1.84	1.00	1.07	2.14	1.09	0.98	0.97	1.88	1.25	0.74	0.48	1.70	2.00	0.69	0.29
FeO/MgO	0.45	1.24	1.15	0.91	1.02	1.80	0.70	0.60	1.07	0.93	0.51	2.14	1.43	0.31	0.92	1.95	0.33	0.45	5.17	1.42	1.91

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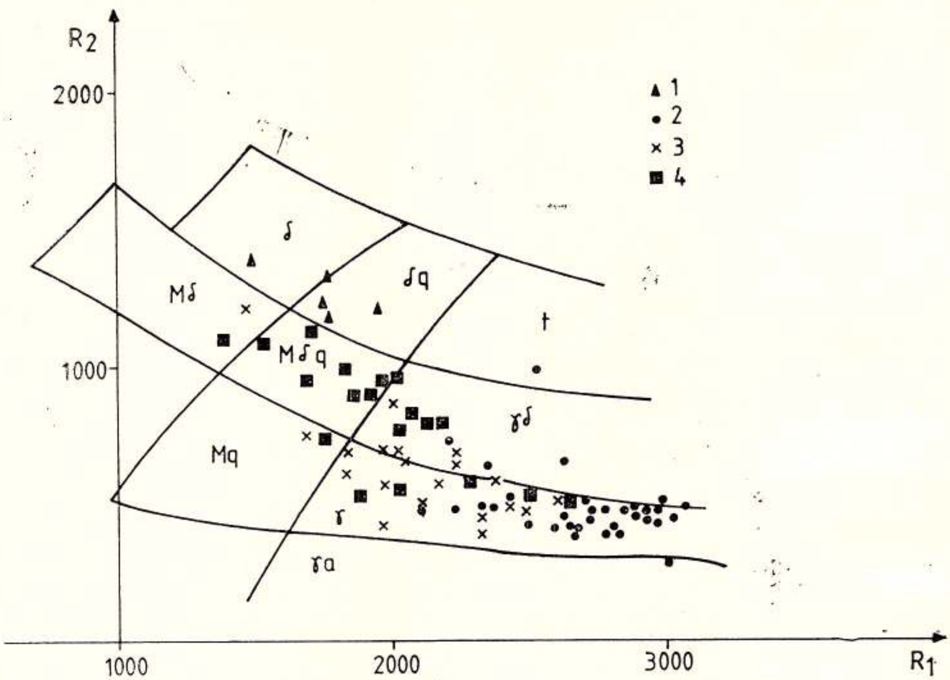

Fig. 2 — $R_1 - R_2$ diagram. 1, quartz diorites; 2, Vîrful Pietrii granites; 3, Furcătura granitoids; 4, Petreanu granitoids.

the diagram. This wide spreading of the plots makes possible the appurtenance of the analysed rocks to several fields of the diagram. Thus, the analysed samples of quartz diorites fall approximately near the same fields as in case of the modal mineralogical composition : quartz-monzonites, quartz monzodiorites, tonalites and quartz diorites. Quartz diorites associated with the Vîrful Pietrii granites confirm only partially this denomination, these rocks displaying a much more monzonitic character due to the presence in variable amounts of the microcline porphyroblasts. Most of the analysed granitic rocks plot in the granite field, monzogranite subfield, except for a few samples which fall in the granodiorite, tonalite and alkali granite field.

The projection of oxides on Tyrell diagram illustrates a differentiation process of the primary granitoid magma, the representative points of the rocks being inscribed along curves that characterize very well this phenomenon. Thus, the curves of the oxides Al_2O_3, Fe_2O_3 total, CaO and MgO show a descending character concomitantly with the passing from the dioritic rocks to more acid terms of the granitic rocks. This tendency of decrease of the oxide content concomitantly with the increase of the SiO_2 content of the rocks is more marked in case of Fe_2O_3 and MgO. K_2O curve shows a very weak tendency of increase towards higher contents in SiO_2, whereas Na_2O curve, which first has a more

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marked tendency of decrease than K_2O, decreases slightly at higher values of SiO_2.

The ratios Fe_2O_3/FeO and FeO/MgO vary similarly in the study granitoid rocks. The first ratio, although varies a lot, shows a significant tendency of increase concomitantly with the silica content.

The value of the alcalicalcic index (58) displays an obvious calc-alkaline character of this series.

The *FMA* diagram shows clearly a magmatic differentiation process, the plots being aligned along a line which starts approximately from the centre of the diagram and reaches the *F-A* side nearby the peak *A*. The change of the ratios between these chemical elements during the magmatic differentiation indicates in the mineralogical composition of the rocks a decrease of the melanocrate minerals up to their disappearance in the most acid terms of the granitoid series.

The *CNK* diagram also indicates a variation of the ratios between these elements simultaneously with the evolution of the magmatic differentiation process shown by the decrease of the calcium content and the increase of the alkali content.

The normative composition of the granitoid rocks, computed by the CIPW method, points to significant variations as regards the participation of different virtual minerals, particularly of quartz, orthose and albite. Moreover, one can observe that normative albite occurs always in a larger amount than orthose in the whole series of granitoid rocks.

The normative mafic components, represented by pyroxene and only once by olivine, vary within wide limits. The other normative components occur in variable percentages in the granitoid rocks.

The character of suprasaturated acid rocks of the Vîrful Pietrii granitoids is also pointed out by the *QLM* diagram, their plots occupying the field situated above the *PF* line with a slight tendency of approaching

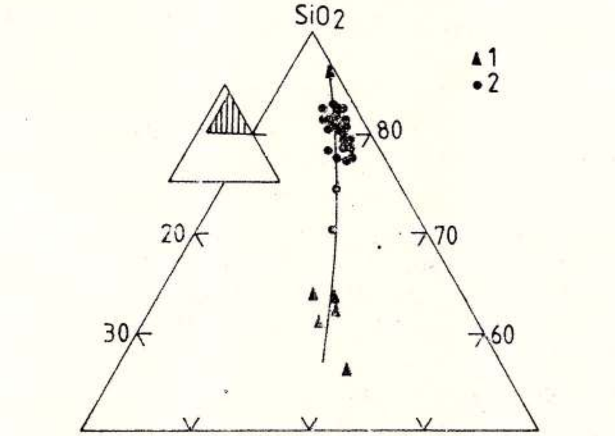

Fig. 3 — Korjinski diagram. 1, quartz diorites; 2, leucogranites.

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the Q peak of the diagram. Unlike granites, quartz diorites fall close to the PF line or even below it, indicating their character of slightly saturated or poorly nonsaturated rocks.

Korjinski (1968) classified the major elements, according to their behaviour during the magmatic processes, into inert components (SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3 total) and quite mobile components (especially alkalies), pointing out that the magma evolution is mostly influenced by the variation of the contents of mobile components. The distribution of the analysed granitoid rocks on the inert components diagram (Fig. 3) shows that the magmatic differentiation followed the evolution line of magmas with a normal alkalinity.

These features are also illustrated by the QBF diagram (Fig. 4), which indicates that the Vîrful Pietrii granitoids contain a much smaller

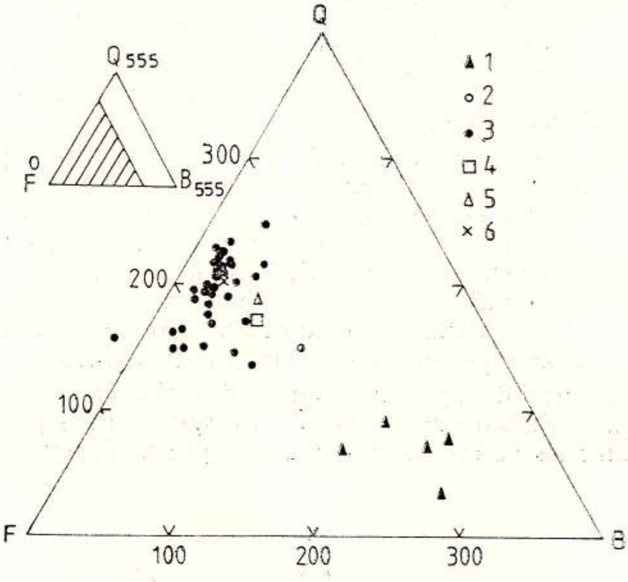

Fig. 4 — QBF diagram.

1, quartz diorites ; 2, granodiorites ; 3, Vîrful Pietrii granites ; 4, granites (Le Maître, 1978) ; 5, leucogranites (Didier, Lameyre, 1969) ; 6, leucogranites and granites (La Roche, Marchal, 1978).

amount of mafic components than the average of the granitoids comprised in the data base used by Le Maître (1976) and than the leucogranites of the French Central Massif (Didier, Lameyre, 1969), but they are identical with the leucogranites and granites of Alcantara, Spain (La Roche, Marchal, 1978).

4.2.2. *Statistic Distribution of the Major Elements*

One of the main problems of the contemporary geochemistry refers to the study of the distribution laws of the chemical elements in minerals and rocks. Numerous researches (Ahrens, 1953 ; Vistelius, 1960, 1964,

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1980 ; Rodionov, 1961, etc.) pointed out the geochemical significance of the distribution functions of the chemical elements contents showing that they represent one of the most significant genetic feature of the rock forming process — the phenomenon law.

The computed statistical parameters (Tab. 2) indicate a larger variation of the contents of major elements from granites in comparison

TABLE 2

Statistical parameters of major chemical components in granitoid rocks of the Vf. Pietrii massif

	quartz diorites					granites				
	$X_{min.}$	$X_{max.}$	$\bar{X}$	s	V	$X_{min.}$	$X_{max.}$	$\bar{X}$	s	V
SiO_2	50.65	58.34	56.20	3.24	6	67.62	78.07	73.72	2.39	3
TiO_2	0.52	1.17	0.81	0.21	26	0	0.60	0.14	0.13	78
Al_2O_3	12.50	18.43	16.54	2.34	14	11.81	16.13	14.42	0.98	7
Fe_2O_3	1.49	4.94	2.57	1.47	57	0.15	1.84	0.66	0.37	55
FeO	3.59	5.31	4.30	0.69	16	0.23	2.04	0.62	0.35	55
MnO	0.10	0.34	0.22	0.10	47	0	0.15	0.06	0.03	51
MgO	4.05	6.03	5.13	0.86	17	0	1.49	0.60	0.54	81
CaO	6.07	6.86	6.43	0.29	4	0.36	3.36	1.49	0.77	49
K_2O	2.55	3.67	3.08	0.43	14	1.71	4.87	3.62	0.65	18
Na_2O	3.02	3.22	3.15	0.08	3	2.67	5.66	3.76	0.55	15
P_2O_5	0.25	0.87	0.41	0.26	63	0	0.22	0.05	0.03	69

with those from quartz diorites. The lowest variations occur in case of the Na_2O, CaO and SiO_2 contents in quartz diorites and of the SiO_2 and Al_2O_3 in granites ; the highest variations are represented by the MnO, Fe_2O_3 and P_2O_5 contents in quartz diorites and P_2O_5, TiO_2 and MgO in granitic rocks.

Likewise, one can observe very low contents of ferromagnesian chemical elements in granitic rocks versus those in quartz diorites, in which they are three or five times higher, as shown also by the mineralogical composition of these rocks. The average contents of the alkaline elements are quite close in the two rock types and the Na_2O/K_2O ratio is constant.

The aspect of the frequency histograms indicates a homogeneous character of the study statistical population, they representing only one maximum of frequency. The weak left asymmetry of the frequency histograms drawn up on an arithmetical scale suggests a lognormal distribution of the study variables ; it is almost always confirmed by the numerical test. The only exception is the potassium distribution which is closer to the normal distribution, as also shown by the histogram or the test values.

The lognormal character of the statistic distributions of most of the major elements in the granitoid rocks is in favour of the prevailing of

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only one rock formation process, while the tendency towards normality of K_2O indicates two or several processes in the formation of the minerals containing this chemical component. This fact is mineralogically proved by the presence of neoformation microcline and muscovite, resulting from the autometamorphism as Savu (1970) pointed out for other granitoid massifs in the Danubian Realm, too.

4.2.3. *Major Elements Correlation*

Another main problem of the modern geochemical researches is represented by the study of the relationships between the chemical elements contents from minerals and rocks. Chayes (1960), Vistelius and Sarmanov (1961), Miller and Kahn (1962), Bodnarenko (1964) and others point out that the study of the correlation between the chemical elements contents of the geological formations is significant both theoretically, by its contribution to the proving of genetic hypotheses, and practically, by establishing quantitative relationships that can be used in the research and geological prospecting.

The values of the correlation coefficients (Tab. 3) indicate that the major chemical components of the study granitoid rocks display generally

TABLE 3

Correlation coefficients between major chemical components in leucogranites of the Vf. Pietrii massif

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O
TiO_2	-0.61									
Al_2O_3	-0.71	0.22								
Fe_2O_3	-0.65	0.61	0.56							
FeO	-0.63	0.68	0.26	0.44						
MnO	-0.14	-0.14	0.19	0.23	0.04					
MgO	-0.58	0.08	0.48	0.23	0.29	0.25				
CaO	-0.66	0.31	0.42	0.34	0.31	0.30	0.40			
K_2O	0.42	-0.25	-0.53	-0.20	-0.09	-0.03	-0.36	-0.27		
Na_2O	-0.38	0.53	0.26	0.13	0.16	-0.24	0.14	0.07	-0.27	
P_2O_5	-0.57	0.67	0.27	0.50	0.42	-0.11	0.02	0.22	-0.06	0.37

a weak correlation ($r < 0.4$), only about 35% of the computed correlation coefficients showing significant values ($r > 0.4$). Among the latter almost two thirds point to a satisfactory correlation ($0.4 < r < 0.6$) between the study variables and only one third shows a good correlation ($0.6 < r < 0.8$). The highest value of the correlation coefficient occurs between SiO_2 and Al_2O_3 ($r = -0.70$) and the lowest value between MgO and P_2O_5 ($r = 0.02$).

SiO_2, Al_2O_3 and Fe_2O_3 are the most frequently correlated variables, while MnO and Na_2O have almost no significant relationships with the other components. A significant petrogenetic aspect is that, except for

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K_2O, all the other correlation coefficients between SiO_2 and the other components have a negative sign pointing to a reverse variation of their contents in these rocks. This finding is in agreement with the development of the magmatic differentiation process during which a continuous decrease of the ferro-magnesian elements content takes place simultaneously with the increase of the silica and alkali contents.

4.2.4. *Areal Variability of the Major Elements Contents*

Whitten (1963), Krumbein and Graybill (1965), Baird et al. (1965), etc. showed that the areal distribution of the chemical elements contents constitutes an important feature with marked petrogenetic significances in the granitic rock formation process.

Polynominal trend-surface analysis was used for the areal variability research of the major elements contents.

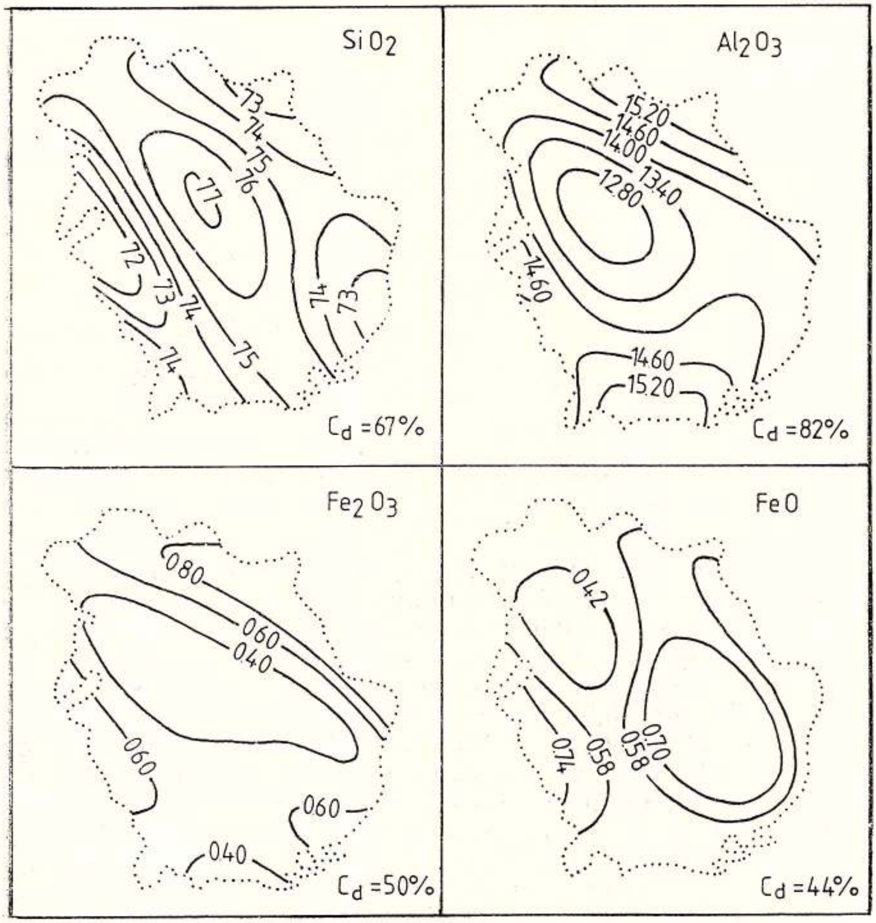

Fig. 5 — Areal distribution of SiO_2, Al_2O_3, Fe_2O_3 and FeO contents.

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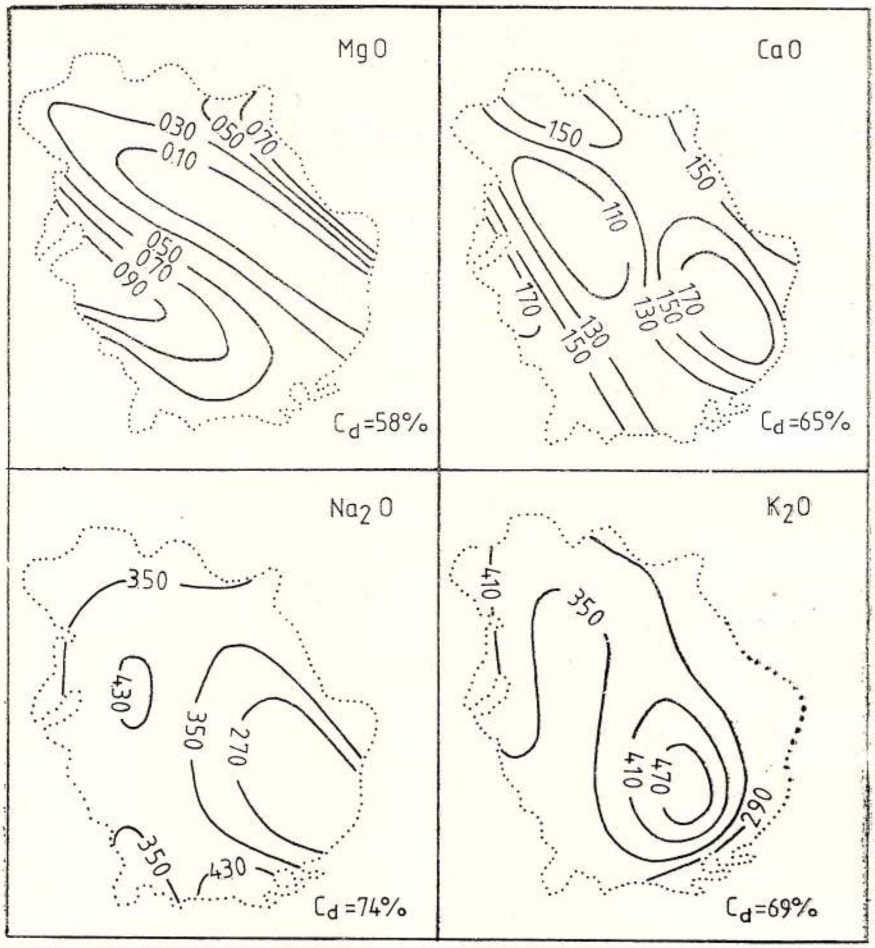

Fig. 6 — Areal distribution of MgO, CaO, Na_2O and K_2O contents.

In order to point out differences in the areal distribution of the major elements in Vîrful Pietrii granitoid rocks the computation of the trend surfaces was effectuated in two variants. The first variant took into account only the granitic rock data (Figs. 5, 6), and the second variant used also quartz dioritic rock data. The trend surfaces were computed only for eight major chemical components namely: SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O and K_2O. The computation of the trend surfaces for alkalies was based on a larger number of chemical analyses (n = 67) in comparison with the other major elements (n = 38).

A comparison of the two sets of trend surfaces computed for the two variants shows that there are no significant differences in the distribution of the major elements. The areal variation trends of the major elements in granitic rocks are slightly emphasized by taking into account the quartz diorite samples.

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SiO_2 displays a trend of the content increase from the massif margins towards its central part, with a maximum content zone disposed approximately along the massif long axis. The determination coefficients of the trend surfaces (C_d), which represent the strength of the fitted surfaces to the observed data values, point to a good enough fit.

Al_2O_3 shows a trend of the content increase approximately reverse versus SiO_2. The minimum zone of the alumina contents occurs also along the long axis of the massif. The high value of the determination coefficient indicates a greater degree of fit of the respective surfaces, and, therefore, the existence of a real factor which determined the distribution.

Fe_2O_3 and FeO possess similar trend surfaces, both as regards the aspect and their degree of fit. Both oxides show a trend of the content increase towards the southwestern part of the granitoid massif and the lowest determination coefficients, indicating that the computed surfaces are not representative, most of the variability of these components being associated with local variations and with higher-order surfaces.

MgO and CaO display a more marked similarity of the areal variation of their contents. The higher content zones are situated in the marginal parts of the granitoid body, parallel to its long axis. The determination coefficients of the computed trend surfaces have small values, in both cases pointing to their low representation.

Na_2O and K_2O have an entirely different variation both of the other oxides and between them. Thus, the high contents indicated by Na_2O constitute a quite large area in the west and north of the massif, while the higher K_2O contents form a more reduced maximum zone in the SE part of the granitoid massif. The determination coefficients of the computed trend surfaces display high values pointing to their high degree of fit.

The study of the trend maps points out, for all the major chemical components studied, the tendency of concentric increase or decrease of the contents according to the form of the granitoid massif.

4.2.5. *Factor Analysis*

The major chemical components differ between them according to their behaviour during the formation process of the granitoid rocks. The study of the relationships between these components can be effectuated by means of the factor analysis (Klovan, 1975).

The general aim of the factor analysis is to obtain simplified relationships within a group of data by means of statistical-mathematical methods. It can be used in the study of the relationships both between the variables (R-mode analysis) and between samples (Q-mode analysis).

The effectuation of the computations of the R-mode analysis on the matrix of geochemical data led to the estimation of the contribution of each variable (chemical component) to the total variation (loading of the factor).

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As shown in Table 4 and Figure 7, the most significant aspect is the major contribution, but in a contrary sense, of TiO_2, FeO, CaO, P_2O_5 and MgO on the one hand and of SiO_2 on the other hand in case of

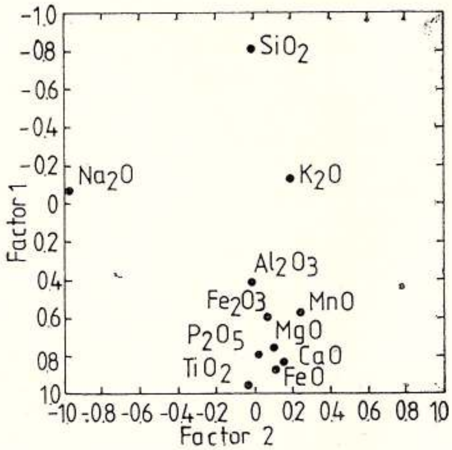

Fig. 7 — Diagram of rotated factors 1 and 2.

factor 1 ; the contribution of the other oxides is reduced. Factor 1 rotated justifies 46 per cent from the total variation, thus being the most significant one when explaining the rock variability. Factors 2, 3 and 4,

TABLE 4

Values of R-mode factors for granitoid rocks of the Vf. Pietrii massif

	F_1	F_2	F_3	F_4
SiO_2	-0.8138	-0.0119	-0.1624	-0.4487
TiO_2	0.9467	-0.0317	0.0772	0.0969
Al_2O_3	0.4145	-0.0116	0.3290	0.8208
Fe_2O_3	0.5957	0.0647	0.1666	0.4504
FeO	0.8712	0.1025	0.0790	0.2526
MnO	0.5778	0.2455	0.1269	0.1528
MgO	0.7591	0.1009	0.2198	0.3661
CaO	0.8329	0.1469	0.1848	0.3388
K_2O	-0.1360	0.1964	-0.9425	-0.2106
Na_2O	-0.0616	-0.9769	0.1709	-0.0042
P_2O_5	0.7845	0.0298	0.0768	0.2649
Sum. square	5.0858	1.1018	1.1966	1.5378
Var. explic.	46.23	10.02	10.88	13.98

each representing only 10-14 per cent from the total variation, are the result of only one chemical component : Na_2O for factor 2, K_2O for factor 3 and Al_2O_3 for factor 4.

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The contribution of each sample to the total geochemical variation within the granitoid massif was established by Q-mode analysis. It has been established that in case of factor 1 the most acid terms of the granitoid rocks series predominate, whereas factor 2 is mainly determined by the quartz diorite samples.

The results of the computations of Q-mode analysis and R-mode analysis can be used as a basis for a new petrochemical parameter which makes possible a better definition of the variation of the study granitoid rocks.

The effectuated analysis points out that the main chemical elements which characterize best the differentiation process of the magmas that generated the Vîrful Pietrii granitoid rocks are : TiO_2, FeO, CaO, SiO_2, P_2O_5 and MgO.

For the computations of a unique parameter including all the six chemical elements and giving a complete image only of the variation connected with the magmatic differentiation process, it has been considered to compute the loadings for the first Q-mode factor. The computed factor justifies more than 90 per cent of the geochemical variation of the rocks and the individual loadings of this factor can be regarded as indicators of the differentiation process. As the influence of the other chemical elements has been eliminated, the sample distribution in the matrix of the rotated factor is much more clear now (Fig. 8).

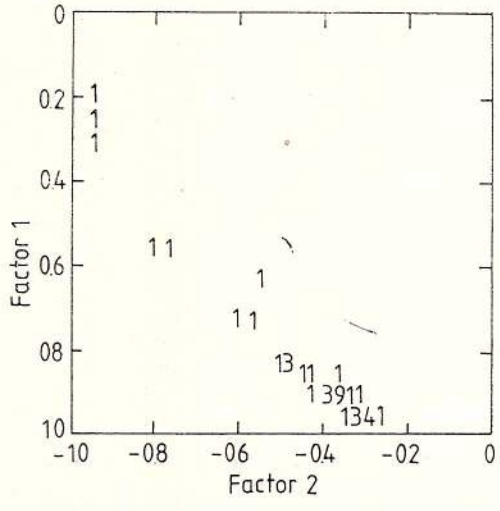

Fig. 8 — Diagram of rotated factors 1 and 2. (6 variables only).

With a view to recognizing in the field in the granitoid massif the petrochemical variations pointed out by this parameter, the individual loadings of the first Q-mode factor computed have been used in the computation and drawing up of a trend map (Fig. 9). The resulting trend

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map points out both a NW-SE trending parallel to the direction of the long axis of the granitoid pluton and zones with more rapid variations due to the presence of more basic differentiates at the periphery of the

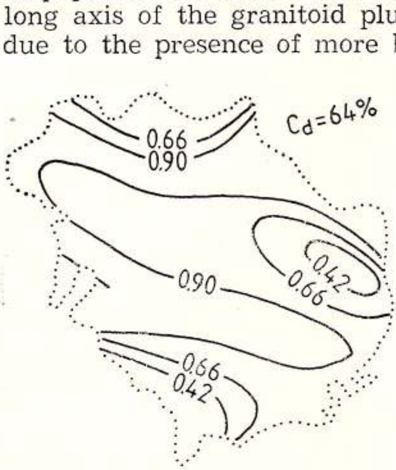

Fig. 9 — Areal variation of the petrogenetic index.

massif. The value of the determination coefficient points to a good degree of fit of the trend surface ; it indicates that this surface represents a result of the differentiation process, not something accidental.

4.2.6. *Content and Distribution of the Trace Elements*

For the pointing out of petrogenetic features, the Vîrful Pietrii granitoid rocks have been analysed spectrographically (Tab. 5) and by X-ray fluorescence (Tab. 6) and the results of the analyses have been statistically processed (Tab. 7).

Copper. The copper contents display very low values in the granitoid rocks, much lower than the average of 16 ppm established by Sandell and Goldich (1943) for the acid rocks. In the few analysed samples of quartz diorites the copper contents are higher and closer to the average of 38 ppm established for intermediary rocks. The greatest variation of the copper contents in the granitic rocks (V = 116) is worth mentioning.

Lead. Lead occurs in all studied samples and shows an increase of the contents from quartz diorites (5-8 ppm) to granitic rocks, where the average values of the lead contents is close to that established by Wedepohl (1956) for the acid rocks. Oftedal (1967) pointed out that the lead content is often constant in the uniform granitoid massifs, but Vîrful Pietrii pluton is not quite uniform as regards the lead content.

Gallium. The contents of gallium vary from 14 to 19 ppm in quartz diorites and from 14 to 28 ppm in granites, showing a slight increase in the latter. It is worth mentioning the poor variation of the gallium contents in granitoid rocks ; the contents are almost uniform (V ≐ 14).

Nickel. The variation of the nickel contents ranges between 3 and 12 ppm in granitic rocks and between 35 and 65 ppm în quartz diorites. In granites the average content of nickel coincides with that presented by Taylor (1965) ; in quartz diorites the average content of Ni is very

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TABLE 5
Trace elements contents in granitoid rocks of the Vf. Pietrii massif

No.	Sample no.	Cu	Pb	Ga	Ni	Co	Cr	V	Li	Be	Ba	Sr	Sc	Y	Yb	La
quartz diorites																
1	197	63	7	18	55	20	60	70		2.9	1080	480	19	30	3.2	62
2	220	26	8	19	50	17	48	46		5.5	2050	520	14	31	3.3	85
3	221		6	15	35	20	70	68	18		1000	650				
4	222		8	14	40	15	55	59	20		3000	670				
5	259	11	5	18	65	20	73	58		2.5	1070	650	17	29	3.1	42
granites																
6	7	6	23	16	6	2	11	4		7	530	160	4	13	1.5	<30
7	11	2	20	19	5	2	2	7		4.7	670	270	2.5	14	1.7	<30
8	17		18	15		3			25		1000	450				
9	26	3	19	15	3	2	6	4		6.5	720	205	1.5	11	1.5	<30
10	32		18	16		3		4	15		1100	500				
11	48	2	23	16	5	<2	4	5		6	850	250	1.5	15	2.2	<30
12	54	<1	28	15	3	2	4	3		5.7	310	87	2	37	4	<30
13	55		21	17	3				<1		600	150				
14	58		69	16		3			<1		750	350				
15	68		18	18	4				1		200	95				
16	76		18	20					3		120	50				
17	81		54			3		5	3,5		1100	400				
18	83	3	27	15	7	2	15	4		6	630	170	2	16	1.9	<30
19	86	3	23	17	4	2	10	2		5	600	190	2.5	20	2.2	30
20	87	4	28	14	4	2	7	2		2.8	400	125	2	21	2.4	<30
21	90		13	21				3	26		900	250				
22	99	2	23	17	5	2	4	4		6	1120	235	1.5	17	2.4	<30
23	101	3	16	16	3	2	8	4		4.2	820	215	2.5	21	1.3	<30
24	108	3	13	20					5		800	150				
25	110		15	17					10		700	370				
26	114	3	44						7		600	175				
27	119	3	14	18	4	2	7	4		4	1000	330	1.5	10	1.5	<30
28	123		25			2			8		700	350				
29	127	3	12	18	3	2	8	5		2,9	740	255	2	15	1.8	<30
30	133		18			2			14		700	275				
31	137	1	19	17	3	<2	6	4		3	950	200	2.5	15	2	<30
32	145	17	30	20	3	2	1	7		7	510	70	2	18	2	<30
33	149	5	10	17	12	9	18	33		5	1200	480	6	19	2.3	48
34	151	2	28	23	4	3	<1	7		6	480	128	2	20	2.2	<30
35	160		13			2		5	12		600	220				
36	162	48	22	22	4	2	1	5		9	730	115	3	42	5.3	32
37	172	2	17	20	3	2	<1	5		3	240	27	1	24	3	<30
38	173	3	15	28	5	3	3	5		10	580	56				
39	177		18			2			15		750	300				
40	181		18			2			3		600	270				
41	184	10	22	18	3	2	1	5		4	1220	265	2	12	1.7	30
42	190		13			2			4		300	150				
43	195	10	20	17	3	2	1	6		4	760	155	1.5	11	1.6	<30
44	204		24			2			4		280	150				
45	209	9	17	17	4	3	2	5		5	850	285	2	18	2.2	<30
46	227	20	25	17	4	2	3	5		5	800	200	1.5	20	2.7	<30
47	232		11	23		2		4	6		850	600				
48	235		21	15		[illegible]			16		650	170				
49	250	11	17	17	4	2	1	5		4	830	185	2.5	24	2.6	<30
50	256	9	21	21	3	2	1	4		6	440	130	2.5	25	2.8	<30
51	267		18	17					25		600	140				
52	285		15	17					4		400	70				
53	288		13	20					18		600	155				
54	289		18	19					5		800	140				
55	2[illegible]7		15	21					12		850	200				

Analysts : Viorica Mîndroiu and Constanta Udrescu

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TABLE 6

Contents and relations of some trace elements in granitoid rocks of the Vf. Pietrii massif

No.	Sample no.	Rb	Sr	Y	Zr	Nb	K/Rb	Ba/Rb	Rb/Sr
1	259	102	122	23.1	171	19.1	227	10.49	0.14
2	220	163	746	28.8	314	18.1	187	12.57	0.22
3	149	110	729	15.7	184	16.4	260	10.90	0.15
4	227	145	273	24.2	106	15.5	224	5.51	0.53
5	173	177	110	63.8	352	25.3	171	3.27	1.61
6	108	164	380	17.8	119	16.4	146	4.87	0.43
7	285	76.9	111	18.6	67.6	18.8	185	5.20	0.69
8	184	113	349	20.9	136	15.9	248	10.79	0.32
9	119	132	317	11.4	109	14.7	231	7.57	0.42
10	256	174	236	28.8	79.8	18.6	172	2.52	0.74
11	127	123	288	21.2	75.7	16.3	217	6.01	0.43
12	26	320	62.8	14.5	109	20.9	86	2.25	5.10
13	83	150	178	14.9	84	20.7	206	4.20	0.84
14	48	150	252	14.2	63.4	18.7	196	5.66	0.59
15	289	137	208	19.3	65.5	16.8	205	5.83	0.66
16	151	199	151	22.2	57.1	22.2	159	2.41	1.32
17	99	157	249	18.4	104	20.2	179	7.13	0.63
18	209	123	322	19.7	95.2	16.7	254	6.91	0.38
19	87	162	170	25.3	85.7	19.7	194	2.46	0.95
20	162	133	190	42.0	141	15.5	212	5.48	0.70
21	145	185	134	24.3	49.5	19.3	181	2.72	1.40
22	267	141	285	19.5	69.8	20.7	187	4.25	0.50

Analyst: Gabriela Grabari

close to the average value 50 ppm for diorites obtained by Vinogradov (1962).

Cobalt. Cobalt occurs in most of the analysed samples. Its variation limits range between 2 and 9 ppm in granitic rocks, and between 15 and 20 ppm in quartz diorites. Nevertheless the variation of the contents of cobalt and nickel is very weak both in granites and in quartz diorites (V = 29-34).

Chrome. There is a great variation of the chrome contents in the Vîrful Pietrii granitoid rocks (V=126). The highest chrome concentrations occur in quartz diorites (48-73 ppm), whereas in granitic rocks the variation limits range between 1 and 18 ppm.

Vanadium. The variation limits and the average contents of vanadium are almost identical with those of chrome both in granitic rocks and in quartz diorites.

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TABLE 7

Statistical parameters of trace elements distribution in granitoid rocks of the Vf. Pietrii massif

	granites (Taylor, 1964)	granites						quartz diorites			
		n	X_{min}	X_{max}	$\bar{X}$	s	V	n	X_{min}	X_{max}	$\bar{X}$
Cu	10	27	1	48	7	7.9	116	3	11	63	33
Pb	20	50	10	69	21.2	8.1	38	5	5	8	6
Ga	18	41	14	28	18.1	2.6	14	5	14	19	16
Ni	0.5	27	3	12	4.2	1.4	34	5	35	65	49
Co	1	38	2	9	2.4	0.7	29	5	15	20	18
Cr	4	25	1	18	5	6.9	126	5	48	73	61
V	20	30	2	33	5.5	2.6	50	5	46	70	60
Li	30	25	1	26	9.7	14.7	131	2	18	20	19
Be	3	25	2.8	10	5.3	1.8	34	3	2.5	5.5	3.6
Ba	600	50	120	1220	695	260.4	37	5	1000	3000	1640
Sr	285	50	27	600	218	151.8	68	5	480	670	584
Sc	7	24	1	6	2.3	1.1	45	3	14	19	17
Y	40	24	10	42	19.1	6.9	37	3	29	31	30
Yb	4	24	1.3	5.3	2.3	0.7	33	3	3.1	3.3	3.2
La	40	24	30	48	30.8	2.9	9	3	42	85	63
Nb	20	20	14.7	25.3	18.5			2	18.1	19.1	
Zr	180	20	49.5	352	108			2	171	314	
Rb	150	20	76.9	320	154			2	102	163	
U		170	0.9	13.4	3.9	2.4	61	14	1.6	10.5	4.6
Th		170	1.9	31.1	9.5	5.1	53	14	3.4	45.1	18.2
K		171	0.4	5.5	3.4	0.8	24	14	2.0	4.0	2.8

Lithium. The content of lithium is very low in granitic rocks and almost twice higher in quartz diorites. This is in agreement with the very small amount of melanocrate minerals in granitic rocks in which this mineral is concentrated by the substitution of magnesium in the crystalline network of the micas (Rankama, Sahama, 1950). In granites, the variation of the lithium content is the highest one from all analysed trace elements, the variation coefficient being the highest ($V = 131$).

Beryllium. In Vîrful Pietrii massif the contents of beryllium vary from 2.5 to 5.5. ppm in quartz diorites, higher values than the average established by Vinogradov (1962) for such rocks, and from 2.8 to 10 ppm in granitic rocks. The higher concentration of beryllium in the analysed granitoid rocks as compared with other granitoid bodies in the South Carpathians (Savu et al., 1972; 1973 b) is probably due to the higher amount of muscovite in those rocks, one of the minerals that can concentrate beryllium (Goldschmidt, Peters, 1932).

Barium. In granites, the contents of barium vary from 120 to 1220 ppm. The lowest contents of barium occur in some aplitic-like

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samples in the marginal zone of the massif. Generally, the barium concentration in granite does not vary too much (V = 37). The higher contents of barium in quartz diorites are due to the presence of both potash feldspars and of biotite, the latter the main barium-bearer in these rocks according to Rankama and Sahama (1950).

Strontium. Generally, strontium behaviour is similar to barium behaviour ; strontium concentration changes when the barium concentration decreases or increases. Like in case of barium, the highest contents of strontium occur in quartz diorites (480-670 ppm) and in granites they range between 27 and 600 ppm. Strontium behaviour in the study rocks points out its geochemical affinity for calcium and its concentration possibilities in minerals formed at the expense of this major element, as previously mentioned by Turekian and Kulp (1956) and Taylor and Heier (1960).

Scandium. Scandium contents vary from 1 to 6 ppm in granitic rocks, with an average value almost twice higher than that indicated by Goldschmidt (1937) for these rocks, and from 14 to 19 ppm in dioritic rocks, being obviously higher than in similar rocks in the Muntele Mic granitoid massif (Savu et al., 1973).

Rare earths. Among rare earths elements only Y, Yb and La have been analysed. Y and La have contents much higher than Yb both in granites and in quartz diorites. Nevertheless, there is a tendency of increase of their contents in quartz diorites in comparison with granites and a much more uniform variation of these trace elements in the former rocks.

Niobium. In the study rocks the variation of the niobium contents is very low, varying between 14.7 and 25.3 ppm. In Vîrful Pietrii granite the average content of niobium (Tab. 7) is less lower than the average value for all the granitic rocks in the Earth's crust (Taylor, 1964). The niobium contents in the study quartz diorites are similar to those in the granitic rocks.

Zircon. Zircon contents show higher variations in the study samples, ranging between 49.5 and 352 ppm. The average content of zircon in the Vîrful Pietrii granitic rocks is much lower than the average value (180 ppm) for all granitic rocks in the Earth's crust. The zircon contents of the study dioritic rocks are much higher than most of the granite samples. The lower concentration of zircon in the Vîrful Pietrii granite is in agreement with the fact that its distribution depends on the alkalinity of the meltings that generated the rocks.

Rubidium. In granitic rocks the rubidium contents vary from 76.9 ppm, in a sample taken off near by the granite contact with the surrounding schists, to 320 ppm. However, except for these extreme values, the contents of the other analysed samples do not show high variations. The average content of rubidium of the granitic rocks is identical with that calculated for the granitic rocks in the Earth's crust (Taylor, 1964). The rubidium contents of the two diorite samples analysed are included within the variation limits of the granitic rocks in the Vîrful Pietrii massif.

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Some of the ratios between the chemical elements have a very important petrogenetic significance. Among them the ratios K/Rb, Ba/Rb and Rb/Sr are most often used.

K/Rb ratio. The pair of alkaline metals, potassium and rubidium, represents a good example of close geochemical association in the petrogenetic processes due to their similarity as regards their chemical properties : ionic ray, electronegativity, ionic potential and binding energy. Due to the mentioned similarity rubidium substitutes potassium in small amounts in the crystalline structure of the potassium minerals. At the same time, Kolbe and Taylor (1966) pointed out that in granites rubidium prefers the mica crystalline structure instead of feldspar structure, a fact explained by the higher preference of Rb^+ ions for places with a greater coordination in the crystalline networks. Muscovite and biotite are the most significant rubidium bearers in common rocks. Potash feldspars are twice or three times poorer in Rb. It represents an example of the mineralogical influence over the chemical elements distribution. However, in the majority of granitic rocks potash feldspar contains most of the K and Rb contents due to its greatest abundance and it will control the K/Rb ratio.

The researches carried out (Taylor et al., 1956 ; Erlank, 1968) on the use of the K/Rb ratio in the interpretation of the geochemical processes showed that the K/Rb ratio is usually constant during the main stages of magmatic differentiation, pointing to a decrease only during the final stages of the magmatic differentiation or in the highly fractioned granitic rocks. The fractional crystallization of the silicate melting leads usually to an enrichment both in potassium and in rubidium in the liquid phase parallel with a relative slight enrichment in rubidium. Consequently, the differentiated magmatic rocks series tend to show a gradual decrease of the K/Rb ratio concomitantly with the increase of the potassium contents. Shaw (1968) calculated an average trend from a variety of magmatic rocks, giving the following values :

K/Rb	433	332	254	195
K	0.01	0.10	1.00	10.00

In the study granitic rocks the K/Rb ratio varies from 86 to 260 ppm, usually within the limits established for the magmatic rocks (115-460). The study quartz diorites show values of the K/Rb ratio similar to those of the granitic rocks. The Vîrful Pietrii granitoid rocks are relatively enriched in rubidium as compared with potassium ; the average value of the K/Rb ratio is 197, a value lower than the average value of the K/Rb ratio in the Earth's crust (240).

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Ba/Rb ratio. The lower contents of Rb as compared with K are a result of the very high Ba contents. Both rubidium and barium occur in large amounts in potash feldspar, when micas are absent or in small amounts and compete with potassium for the vacant places in the crystalline network of the minerals. Taylor (1965) and Nockolds (1966) showed that both potassium and barium are preferred to rubidium which is thus excluded when barium occurs in large amounts. This observation is also verified in case of the Vîrful Pietrii granite because the samples with higher K/Rb ratios have also the highest barium contents. These results are in agreement with the hypothesis according to which during the crystallization rubidium was generally maintained in liquid phase by barium and potassium and probably concentrated during the last phases of granite now eroded. It results that the Ba/Rb ratio can be successfully used as petrogenetic index impervious to different geological processes, e.g. fractional crystallization. In the Vîrful Pietrii granitic rocks the Ba/Rb ratio varies from 2.25 to 10.90, with an average value 5.3. Eliminating from the calculation of the average value the two higher values occurring in the porphyroid facies, the average value of the Ba/Rb ratio decreases to 4.7. In the study dioritic rocks the Ba/Rb ratio is much higher than in granites.

Rb/Sr ratio. Due to the different geochemical behaviour during the magmatic differentiation process, strontium being included into the early-crystallized minerals and rubidium, on the contrary, being concentrated in residual liquids, the Rb/Sr ratio shows ever higher values in the differentiated produces. In the Vîrful Pietrii granitoid rocks, the Rb/Sr ratio ranges between 0.14 in quartz diorites and 5.10 in granitic rocks, pointing to its increase concomitantly with the magma differentiation process. The average value of the Rb/Sr ratio in the study granitic rocks is 0.66 whereas in the study dioritic rocks the values are much lower.

Rb/Sr ratio is used as an indicator of the magma origin (Fairbridge, 1972). The small values (< 0.02) of this ratio point to the magma origin in the mantle, while the higher values (> 0.20) indicate magma formation by the melting of the rocks from the Earth's crust. Therefore, in the Vîrful Pietrii granitoid rocks the Rb/Sr ratio represents a further argument in favour of the lithogene origin of the primary granitoid magma.

The frequency histograms (Fig. 10) as well as the values of the numerical test indicate that most of the trace elements analysed display a lognormal statistical distribution characteristic of the trace elements distribution in rocks (Ahrens, 1953 ; Shaw, 1964 ; Rodionov, 1961). The

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only exception is barium whose normal statistical distribution indicates a geochemical behaviour different from the other trace elements.

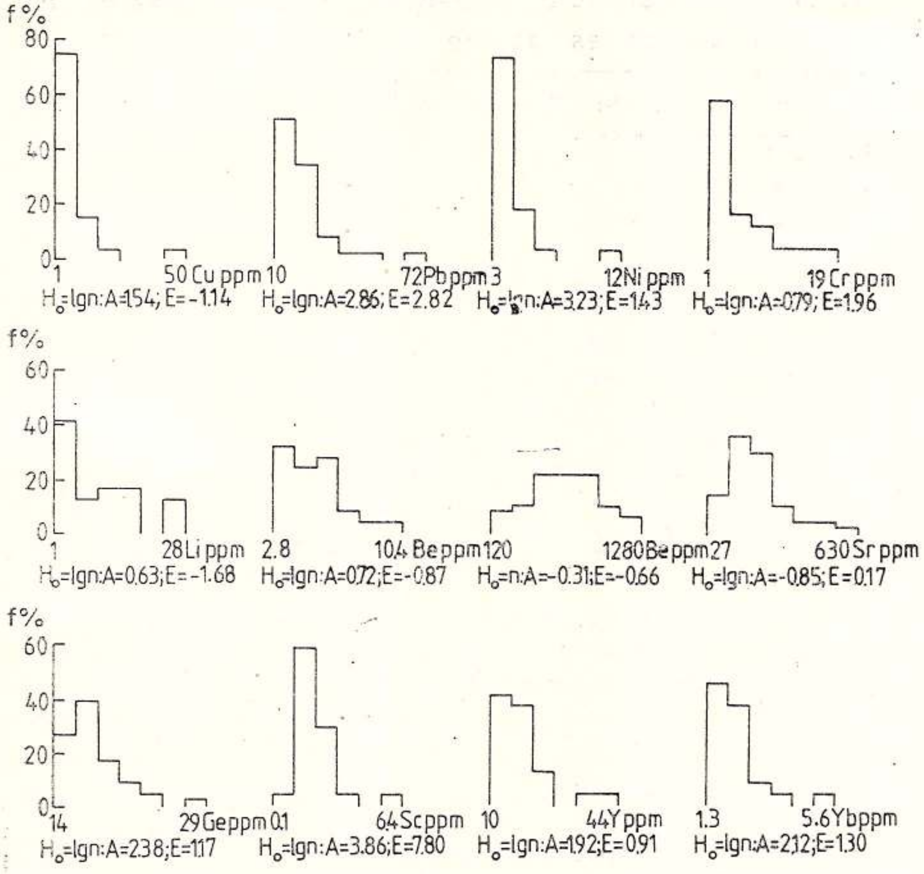

Fig. 10 — Frequency histograms of the trace elements in leucogranites.

4.2.7. *Correlation between Trace Elements*

The study of the correlation between the trace elements contents in granitoid rocks also represent a significant aspect of the geochemistry of these rocks. The coefficients of linear correlation (Tab. 8) computed according to the type of statistical distribution of the trace elements emphasize a weak correlation for most of the pairs of analysed trace elements ($r < 0.4$). Only about 15 per cent of the 90 coefficients computed show significant values and among them only in two cases their value indicates a very good correlation between the analysed trace elements e.g. Y/Yb and Co/La. The positive sign of these correlation coefficients points to a similar variation of their contents.

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TABLE 8

Correlation coefficients between trace elements in leucogranites of the Vf. Pietrii massif

	Cu	Pb	Ga	Ni	Co	Cr	V	Be	Ba	Sr	Sc	Y	Yb
Pb	0.04												
Ga	0.18	-0.31											
Ni	-0.03	-0.22	-0.05										
Co	-0.01	-0.10	0.02	0.64									
Cr	-0.35	-0.24	-0.48	0.49	0.22								
V	0.17	-0.26	0.19	0.50	0.72	-0.06							
Be	0.26	0.25	0.40	0.29	0.13	-0.01	0.12						
Ba	0.13	-0.04	-0.11	0.26	0.30	0.20	0.28	-0.02					
Sr	0.03	-0.03	-0.29	0.34	0.28	0.40	0.15	-0.16	0.73				
Sc	0.21	-0.04	-0.14	0.39	0.32	0.37	0.19	0.33	0.46	0.62			
Y	0.21	0.26	0.28	-0.01	0.07	-0.20	-0.06	0.25	-0.47	-0.47	-0.04		
Yb	0.24	0.24	0.29	-0.01	0.04	-0.25	-0.04	0.25	-0.36	-0.43	-0.12	0.92	
La	0.09	-0.52	0.01	0.66	0.88	0.34	-0.76	0.07	0.28	0.34	0.35	0.11	0.12

In other cases, the values of the correlation coefficients indicate a good relation between the pairs of trace elements taken into account : e.g. V/La, Sr/Ba, Co/V, Ni/La, Co/Ni, Sc/Sr.

In the mentioned cases, the correlation coefficients have the positive sign indicating a direct relation between the contents of the involved elements.

A satisfactory correlation, either positive or negative, also occurs between a series of trace elements : Pb-La, Ni-V, Cr-Ni, Y-Ba, Y-Sr, etc.

Among the study trace elements the most frequent correlations occur between Sr, Ba, La, Co and Ni, while other trace elements display almost no correlation, e.g. Cu, Be and Ga.

The correlation between the mentioned pairs of trace elements is due either to the possibilities of mutual isomorphous substitution or with the same major elements in the crystalline networks of the minerals, e.g. Sr-Ba, Co-Ni, Co-V, or to the identical response of these chemical elements versus a common petrogenetic process, such as the magmatic crystallization.

Several correlation diagrams have been drawn up in order to establish the existing relationships between some trace elements and the major elements which they can substitute isomorphically.

The Pb/K diagram indicates only a weak correlation between the potash contents and the lead ones in the study rocks, the samples occurring in an area almost parallel to one of the diagram axes.

Contrary to expectation, the Ba/K diagram shows a weak negative correlation between these elements, that is the distribution of the barium contents in the Vîrful Pietrii granitoid rocks is balanced negatively by

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the variation of the potash feldspar due to the autometamorphism processes.

The distribution of the study rocks on the Sr-Ca, Cu-Fe^{2+} and Cu-Mg diagrams illustrates the absence of any relation between the contents of the respective chemical elements.

4.2.8. *Variation of the Trace Elements Contents*

The different geochemical behaviour of the trace elements in the process of magma differentiation and crystallization was noticed by numerous researchers (Wager, Mitchel, 1951 ; Locardi, Mittempergher, 1967 ; Tauson, 1967, etc.).

The behaviour of the trace elements during the granitoid magma differentiation was followed by means of the variation diagrams, referring the contents of trace and major elements to the differentiation index 1/3 Si+K—(Ca+Mg). At the same time, the trace elements contents have been processed computing both the ratio between these elements and the ratios between the trace and major elements geochemically associated.

Gallium, although geochemically associated with aluminium (Shaw, 1964), has a quite limited variation domain which indicates that the contents of this chemical element have very close values in the granitoid rocks regardless of their acidity. The $Ga \times 10^3/Al$ ratio varies from 0.18 to 0.34.

The variation curves of Ni, Co, Cr and less of V are almost parallel to the Mg curve, indicating a gradual decrease of the contents of the mentioned elements concomitantly with the evolution of the magmatic differentiation process, and they differ slightly from the variation curve of Fe_{tot} which indicates a marked decrease of the iron contents in this rock series.

The behaviour of trace elements geochemically associated with Fe and Mg is revealed also by the variation of the ratios of these chemical elementes versus Fe_{tot}. Thus, the values, of the ratios $Co \times 10^3/Fe_{tot}$, $Ni \times 10^3/Fe_{tot}$, $Cr \times 10^3/Fe_{tot}$ and $V \times 10^3/Fe_{tot}$ decrease towards th acid terms of the series due to the more marked decrease of the contents of these trace elements versus Fe_{tot}. The Sr and Ca contents decrease gradually from quartz diorites to granites. The variation of the strontium contents in this rock series is in disagreement with Rankama and Sahama's opinion (1950), according to which the content of strontium is constant during the process of magmatic differentiation of the calc-alkaline series.

On the other hand, while the potassium content shows a tendency of increase from more basic rocks to more acid rocks of the massif, barium, usually geochemically associated with this major element, shows a tendency of decrease in the same direction. Thus, the different geochemical behaviour of these chemical elements in the study rocks is confirmed once more.

The geochemical behaviour of strontium and barium in the magmatic differentiation process is also indicated by the variation of the $Ba \times 10^2/K$ and $Sr \times 10^2/Ca$ ratios. Whiile the values of the $Sr \times 10^2/Ca$

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ratio are in the beginning constant and then increase slightly in the granitic rocks, the values of the Ba $\times$ 10^2/K ratio decrease strongly towards the more acid terms of this rock series.

The variation of the contents of scandium, yttrium and ytterbium during the magmatic differentiation process shows a tendency of their decrease concomitantly with the transition from quartz diorites to granites and then a slight tendency of increase in the most acid terms. The contents decrease is more marked for scandium and yttrium than for ytterbium. A greater variation of the ytterbium contents in granitic rocks as compared with the other two trace elements is also obvious.

4.2.9. *Distribution of Radioelements*

The contents of the radioelements uranium, thorium and potassium were determined by gamma spectrometry using the following energetic values : 0.350 MeV for uranium, 0.238 MeV for thorium and 1.470 MeV for potassium (Tab. 9).

The parameters of the statistical distribution of the radioelements contents (Tab. 7) show some geochemical particularities of the distribution of these chemical elements in the study rocks.

The contents of uranium vary between 0.9 and 13.4 ppm in the granitic rocks (average value 3.9 ppm) and between 1.6 and 10.5 ppm in quartz diorites (average value 4.4 ppm). Both in granites and in quartz diorites the contents of uranium show a moderate variation, the values of the variation coefficients ranging from 60 to 70%.

The contents of thorium vary between 1.2 and 31.1 ppm in granites and between 3.4 and 45.1 ppm in quartz diorites pointing to a special increase in the latter rocks. Likewise, the higher contents of thorium versus the uranium ones in the granitoid rocks are emphasized by the value of the Th/U ratio which is higher in quartz diorites than in granites. The variation of the potassium contents is quite uniform (V = 22-24%) and shows a slight trend of increase towards the granitic rocks.

The average contents of the radioelements in the Vîrful Pietrii granitoids as well as the Th/U ratio do not exceed the variation limits of the average contents in other granitic massifs (Adams et al., 1959 ; Coulomb, 1959 ; Larsen, Gottfried, 1960 ; Rogers, Ragland, 1961). According to the above mentioned authors, the high contents of radioelements in different granitoid rocks would vary between 2.3 and 6.7 ppm for uranium and between 8.3 and 27.6 ppm for thorium. Therefore, the average values of the radioelements in the Vîrful Pietrii pluton occur in the lower parts of these intervals.

In comparison with the average value of 5.2 and the variation limits 2.2-14.4 of the Th/U ratio obtained for 50 granitoid massifs in the U.S.S.R. (Kazițîn, Socievanov, 1968) the granitoid rocks of the Vîrful Pietrii massif possess a more reduced conntent of thorium and are les radioactive.

Likewise, a comparison of the average contents of the radioelements in some granitoid massifs of the Danubian Autochthon (Savu et al.,

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TABLE 9

Radioactive elements contents and values of radiogene heat production in granitoid rocks of the Vf.Pietrii massif

No.	Sample no.	Location	U ppm	Th ppm	K %	Th/U	H.P. µcal/g.an
1	2	3	4	5	6	7	8
		Quartz diorites					
1	153	Brook Pecineaga	5.0	12.6	3.40	2.5	7.09
2	192	Bistra Mărului	3.0	8.5	2.70	2.8	4.62
3	196	Bistra Mărului	3.7	7.5	2.70	2.0	4.93
4	197	Bistra Mărului	3.0	18.7	2.30	6.2	6.55
5	218	Bistra Mărului	7.1	33.9	2.80	4.8	12.72
6	219	Bistra Mărului	10.5	34.2	2.90	3.2	15.29
7	220	Bistra Mărului	9.5	45.1	4.00	4.7	17.04
8	221	Bistra Mărului	1.8	3.4	2.00	1.8	2.53
9	222	Bistra Mărului	4.2	13.4	2.30	3.2	6.37
10	223	Bistra Mărului	7.7	28.5	3.60	3.7	12.29
11	225	Bistra Mărului	1.6	8.8	3.20	5.5	3.79
12	257	Brook Capra Foii	2.8	10.0	2.00	3.6	4.58
13	258	Brook Capra Foii	1.7	22.0	3.20	12.9	6.51
14	259	Brook Capra Foii	2.8	8.3	2.20	2.9	4.30
		Granites					
15	4	Brook Marga	3.8	16.0	3.80	4.2	7.00
16	6	Brook Bun	1.7	8.0	4.50	4.7	4.05
17	10	Brook Marga	2.0	10.6	3.20	5.3	4.44
18	11	Brook Strîmbu Mare	3.0	15.4	3.40	5.1	6.19
19	12	Brook Strîmbu Mare	6.3	9.4	3.30	1.4	7.37
20	13	Brook Strîmbu Mare	4.4	3.4	3.20	0.7	4.75
21	14	Brook Strîmbu Mare	9.8	11.8	3.80	1.2	10.54
22	15	Brook Strîmbu Mare	13.4	9.7	3.40	0.7	12.64
23	16	Brook Strîmbu Mare	5.0	8.1	3.50	1.6	6.16
24	17	Brook Strîmbu Mare	3.8	9.7	3.50	2.5	5.66
25	18	Brook Strîmbu Mare	3.9	9.2	4.20	2.3	5.82
26	19	Brook Strîmbu Mare	3.4	12.8	3.80	3.7	6.07
27	20	Brook Strîmbu Mare	7.1	8.1	3.10	1.1	7.64
28	21	Brook Strîmbu Mare	5.6	13.4	3.10	2.3	7.61
29	22	Brook Strîmbu Mare	3.0	5.1	3.30	1.7	4.10
30	23	Brook Strîmbu Mare	2.9	13.2	4.50	4.5	5.97
31	24	Brook Strîmbu Mare	3.2	13.3	4.00	4.1	6.08
32	25	Brook Strîmbu Mare	2.5	16.0	3.30	6.4	5.92
33	26	Brook Strîmbu Mare	2.6	8.8	3.30	3.3	4.55
34	27	Brook Strîmbu Mare	4.1	14.2	3.20	3.4	6.70
35	29	Brook Strîmbu Mare	3.6	9.9	3.00	2.7	5.42
36	30	Brook Strîmbu Mare	2.6	10.5	3.80	4.0	5.02
37	31	Brook Strîmbu Mare	4.0	11.5	3.40	2.8	6.14
38	32	Brook Strîmbu Mare	4.5	8.0	3.20	1.7	5.75
39	33	Brook Strîmbu Mare	3.1	3.5	2.10	1.1	3.53
40	34	Brook Strîmbu Mare	4.1	9.2	3.10	2.2	5.67
41	35	Brook Strîmbu Mare	3.4	11.4	3.10	3.3	5.60
42	36	Brook Primezu	4.1	8.7	3.60	2.1	5.70
43	37	Brook Popii	2.5	9.7	3.00	3.8	4.57
44	38	Brook Popii	2.0	5.6	3.20	2.8	3.44
45	39	Brook Popii	3.8	9.5	3.30	2.5	5.56

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(Table 9 - continued)

1	2	3	4	5	6	7	8
46	40	Brook Strîmbu Mic	1.3	9.4	3.20	7.2	3.69
47	42	Brook Strîmbu Mic	3.3	8.8	2.80	2.6	4.92
48	43	Brook Strîmbu Mic	4.9	8.3	3.70	1.6	6.24
49	44	Crest Strîmbu	4.5	10.4	3.10	2.3	6.20
50	45	Brook Scărişoara	1.9	9.5	3.20	5.0	4.15
51	47	Brook Scărişoara	2.8	5.5	3.60	1.9	4.12
52	48	Brook Scărişoara	1.9		3.70		
53	49	Brook Scărişoara	2.1	8.4	3.10	4.0	4.05
54	50	Brook Scărişoara	2.4	9.0	3.60	3.6	4.52
55	51	Brook Scărişoara	2.3	10.8	3.70	4.6	4.84
56	52	Brook Niermeş	6.5	7.1	3.80	1.0	7.19
57	53	Brook Niermeş	9.8	8.1	3.70	0.8	9.66
58	54	Brook Niermeş	8.0	8.1	3.70	1.0	8.46
59	55	Brook Niermeş	8.1	12.5	4.40	1.5	9.60
60	57	Brook Borlova Mică	5.5	7.3	4.60	1.3	6.72
61	58	Brook Borlova Mică	5.8	5.5	4.80	0.9	6.63
62	59	Brook Borlova Mică	8.4	8.9	3.90	1.0	8.96
63	61	Brook Ogaşul Negru	5.6	7.3	4.90	1.3	6.87
64	62	Brook Ogaşul Negru	4.4	5.7	3.60	1.2	5.32
65	63	Brook Prodana	2.6	7.3	3.30	2.9	4.25
66	64	Brook Prodana	5.9	7.1	3.50	1.2	6.67
67	65	Brook Prodana	6.6	7.6	4.30	1.1	7.50
68	66	Brook Prodana	4.6	6.6	3.40	1.4	5.60
69	67	Brook Prodana	7.8	8.2	4.10	1.0	8.44
70	68	Brook Prodana	7.5	8.1	4.20	1.0	8.23
71	72	Brook Niermeş	9.2	6.4	4.10	0.6	9.10
72	73	Brook Niermeş	3.6	7.0	3.60	1.9	5.00
73	74	Brook Borlova Mare	6.3	7.4	3.70	1.1	7.08
74	75	Brook Borlova Mare	6.2	7.6	3.60	1.2	7.02
75	76	Brook Borlova Mare	5.9	4.1	2.00	0.6	5.67
76	77	Brook Borlova Mare	10.1	4.5	1.30	0.4	8.62
77	78	Brook Borlova Mare	6.1	5.4	0.90	0.8	5.78
78	79	Brook Borlova Mare	2.5	7.3	5.00	2.9	4.64
79	81	Brook Niermeş	5.8	8.9	3.90	1.5	7.07
80	82	Brook Niermeş	4.1	21.1	3.60	5.1	8.18
81	83	Brook Niermeş	7.1	15.5	3.90	2.1	9.34
82	84	Brook Niermeş	7.3	12.5	3.90	1.7	8.81
83	86	Brook Negru	5.2	13.6	4.50	2.6	7.73
84	87	Brook Bisericuţei	4.5	8.9	4.00	1.9	6.15
85	88	Brook Stînii	4.8	11.8	3.30	2.4	6.75
86	89	Brook Stînii	3.6	11.0	4.00	3.0	5.91
87	90	Brook Stînii	3.4	6.9	3.60	2.0	4.83
88	94	Crest Marga-Niermeş	2.4	5.6	3.80	2.3	3.90
89	95	Crest Marga-Niermeş	3.1	11.3	3.80	3.6	5.55
90	97	Crest Sturu	3.9	8.5	3.40	2.1	5.46
91	99	Bistra Bucovei	3.9	10.2	3.10	2.6	5.72
92	106	Bistra Bucovei	3.0	11.6	3.20	3.8	5.37
93	107	Bistra Bucovei	3.7	11.8	3.30	3.1	5.95
94	109	Bistra Bucovei	2.9	12.6	3.00	4.3	5.45
95	110	Bistra Bucovei	3.2	11.4	3.60	3.5	5.59
96	124	Bistra Bucovei	3.1	10.0	2.60	3.2	4.96
97	127	Bistra Bucovei	1.2	5.0	3.10	4.1	2.71
98	132	Bistra Bucovei	1.5	4.5	3.10	2.9	2.83
99	136	Bistra Bucovei	2.3	4.0	3.60	1.7	3.45
100	137	Bistra Bucovei	1.9	3.9	3.40	2.0	3.08

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(Table 9 - continued)

1	2	3	4	5	6	7	8
101	100	Brook Dăncioana	2.1	13.6	3.60	6.4	5.22
102	102	Brook Dăncioana	0.9	4.8	3.70	5.3	2.62
103	111	Brook Moduşu	2.0	5.9	3.90	2.9	3.69
104	112	Brook Moduşu	3.3	12.1	3.20	3.6	5.69
105	113	Brook Moduşu	2.7	9.7	3.10	3.5	4.75
106	114	Brook Moduşu Mic	2.6	5.1	3.60	1.9	3.89
107	115	Brook Moduşu Mic	2.2	5.9	3.50	2.6	3.73
108	116	Brook Moduşu Mic	2.3	7.6	3.40	3.2	4.12
109	117	Brook Moduşu Mic	3.0	5.3	3.50	1.7	4.19
110	118	Brook Moduşu Mare	2.6	13.3	3.50	5.1	5.50
111	119	Brook Moduşu Mare	3.8	10.0	3.50	2.6	5.72
112	121	Brook Moduşu Mare	2.7	9.3	3.00	3.4	4.64
113	122	Brook Moduşu Mare	11.3	9.1	4.50	0.8	11.28
114	123	Brook Moduşu Mare	3.4	6.0	3.10	1.7	4.52
115	128	Brook Tarniţa	4.2	8.6	3.20	2.0	5.65
116	135	Brook Sciomîu Mare	1.7		3.10		
117	141	Bistra Mărului	2.1	8.2	0.40	3.9	3.28
118	143	Bistra Mărului	8.3	7.7	4.00	0.9	8.58
119	144	Bistra Mărului	5.7	11.2	3.00	1.9	7.21
120	145	Bistra Mărului	5.4	11.0	3.90	2.0	7.19
121	148	Bistra Mărului	3.7	4.1	4.10	1.1	4.63
122	149	Bistra Mărului	1.6	2.7	1.50	1.7	2.11
123	150	Bistra Mărului	4.9	5.3	3.30	1.1	5.53
124	151	Brook Pecineaga	3.8	6.6	3.60	1.7	5.07
125	152	Brook Pecineaga	4.6	17.7	3.30	3.8	7.79
126	155	Brook Pecineaga	4.9	11.4	3.80	2.3	6.88
127	156	Brook Pecineaga	3.1	11.6	3.40	3.7	5.50
128	160	Brook Pecineaga	5.2	13.8	3.30	2.6	7.45
129	161	Brook Pecineaga	5.3	14.0	2.80	2.6	7.42
130	162	Brook Pecineaga	3.0	14.7	3.10	4.9	5.97
131	163	Brook Tămăşilă	7.1	20.9	1.00	2.9	9.63
132	164	Brook Tămăşilă		31.1	2.90		
133	166	Brook Tămăşilă	5.2	6.1	4.70	1.2	6.28
134	167	Brook Tămăşilă	4.4	21.2	2.60	4.8	8.15
135	168	Brook Tămăşilă	3.3	15.3	2.60	4.6	6.17
136	169	Brook Murgana	7.5	30.9	3.00	4.1	12.46
137	170	Brook Murgana	10.3	18.2	3.00	1.7	11.97
138	171	Brook Murgana	2.2	11.3	3.70	5.1	4.86
139	172	Brook Murgana	3.0	9.2	4.70	3.1	5.30
140	173	Brook Murgana	5.7	20.4	3.30	3.6	9.13
141	175	Brook Loloaia	3.2	9.8	4.40	3.0	5.48
142	176	Brook Loloaia	4.2	17.8	2.40	4.2	7.27
143	177	Brook Peceneguţa	4.4	12.3	3.10	2.8	6.51
144	178	Brook Peceneguţa	4.0	18.3	4.10	4.5	7.69
145	180	Brook Peceneguţa	2.5	8.4	3.40	3.3	4.42
146	181	Brook Sturu	3.6	7.2	4.10	2.0	5.17
147	182	Brook Sturu	1.1	11.5	4.10	10.4	4.21
148	183	Brook Sturu	4.6	6.1	3.90	1.3	5.63
149	184	Brook Sturu	3.0	15.0	3.10	5.0	6.03
150	190	Brook Valea Rea	3.4	7.2	3.90	2.1	4.97
151	193	Bistra Mărului	1.9	9.1	1.90	4.8	3.72
152	199	Bistra Mărului	1.1	5.9	2.70	5.3	2.71
153	201	Bistra Mărului	1.1	7.3	3.90	6.5	3.32
154	202	Bistra Mărului	1.6	11.7	3.10	7.3	4.34
155	204	Bistra Mărului	7.3	9.3	4.20	1.3	8.32
156	224	Bistra Mărului	5.8	8.6	3.00	1.5	6.76

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(Table 9 - continued)

1	2	3	4	5	6	7	8
157	226	Bistra Mărului	2.5	9.5	3.70	3.8	4.72
158	227	Bistra Mărului	1.4	9.4	3.20	6.7	3.77
159	228	Bistra Mărului	2.0	4.9	1.70	2.5	2.90
160	229	Bistra Mărului	1.6	4.0	0.60	2.5	2.13
161	230	Bistra Mărului	2.6	6.0	2.80	2.3	3.85
162	232	Bistra Mărului	1.9	10.2	3.10	5.3	4.26
163	233	Bistra Mărului	2.3	7.9	1.00	3.4	3.53
164	206	Brook Bloju	2.2	12.2	3.70	5.5	5.04
165	209	Brook Bloju	1.9	7.9	2.60	4.1	3.67
166	210	Brook Bloju	2.7	6.8	3.00	2.5	4.14
167	211	Brook Jdimiru	2.6	16.2	4.00	6.2	6.22
168	214	Brook Jdimiru	9.4	14.5	1.30	1.5	10.11
169	216	Brook Jdimiru	2.6	8.5	5.90	3.3	5.19
170	261	Brook Capra Foii	4.1	8.1	3.60	1.9	5.58
171	246	Brook Dalci	2.9	9.2	3.50	3.2	4.90
172	249	Brook Dalci	2.2	6.4	3.40	2.9	3.80
173	250	Brook Dalci	1.3	7.4	3.70	5.7	3.43
174	254	Brook Izvorul Alb	1.9	6.8	3.60	3.6	3.72
175	255	Brook Izvorul Alb	1.1	4.6	3.30	4.2	2.61
176	256	Brook Izvorul Alb	3.2	7.3	3.20	2.3	4.66
177	238	Brook Michi	2.8	6.4	1.20	2.3	3.65
178	239	Brook Michi	4.5	5.2	1.20	1.1	4.64
179	234	Crest Zănoguţa-Prislop	1.1	9.1	3.00	8.3	3.43
180	235	Crest Michi-Zănoguţa	1.5	3.7	3.30	2.4	2.73
181	263	Brook Netiş	1.7	3.9	3.29	2.3	2.91
182	264	Brook Netiş	1.3	4.3	3.45	3.3	2.74
183	265	Brook Netiş	1.6	2.4	3.61	1.5	2.62
184	266	Brook Netiş	1.4	3.8	3.11	2.7	2.62
185	267	Brook Netiş	1.5	1.9	3.19	1.3	2.34

Analyst: Ioan Tiepac

1973) indicates that the Vîrful Pietrii granitic rocks have a much lower radioactivity than most of them, whereas the Vîrful Pietrii quartz diorites are the richest ones in radioelements.

The accessory minerals (zircon, allanite, sphene, monazite, apatite) have the highest contents of uranium and thorium. The abundance of these minerals in rocks can determine a high level of the radioelements concentration for the whole rock. The microscopic study of the quartz diorites indicated much higher amounts of accessory minerals (sphene, apatite and zircon) in comparison with granites, thus pointing out the relationship between the increase of the radioelements contents and the abundance of the accessory minerals in quartz diorites.

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The unimodal aspect of the frequency histograms of the contents (Fig. 11), drawn up on an arithmetical scale, reveals the homogeneous character of the study statistical population. At the same time one can

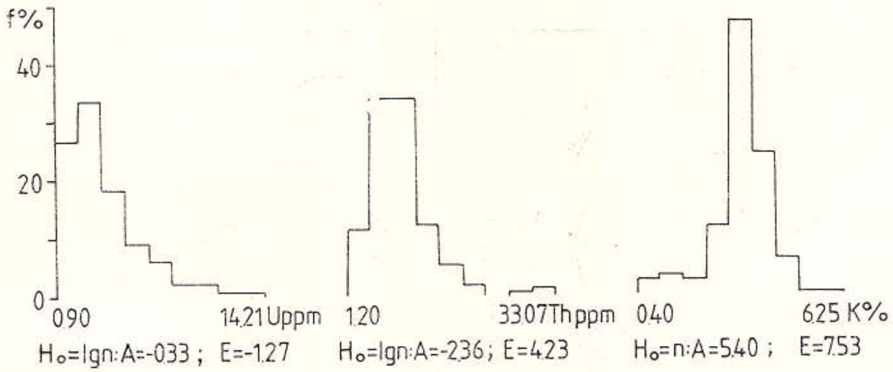

Fig. 11 — Frequency histograms of the radioactive elements in leucogranites.

observe a variation of the symmetry degree of the histograms from high left asymmetric (e.g. in case of the uranium contents) to an almost symmetrical distribution (e.g. in case of potassium). This variation is also emphasized by the quantitative verification of the statistical distribution laws. Thus, while for uranium the lognormal distribution law is checked, thorium shows only a tendency towards lognormal distribution ; on the contrary, the contents of potassium show a tendency towards normal distribution. Both the correlation diagrams and the values of the correlation coefficients indicate the lack of a significant relationship between the contents of radioelements ($r_{U-Th} = 0.37$; $r_{Th-K} = 0.15$; $r_{U-K} = 0.15$).

The study of the areal variability of the radioelements contents in the Vîrful Pietrii granites was carried out by means of the polynominal trend analysis.

The study of the computed maps (Fig. 12) indicates a trend of increase of the uranium and thorium contents from the massif edges towards its central part. This trend is more obvious particularly for thorium, which shows a maximum zone in the central part of the massif. For uranium, besides the maximum zone developed in the central part and perpendicuar to the elongation trend of the massif, there is also a slight trend of increase of the contents towards the northwest of the massif.

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Unlike uranium and thorium, potassium areal distribution is rather different. The radioactive potassium contents, generally quite uniform within the granitoid massif, show a trend of increase towards the massif edges forming two maximums, a smaller one in the north and a more

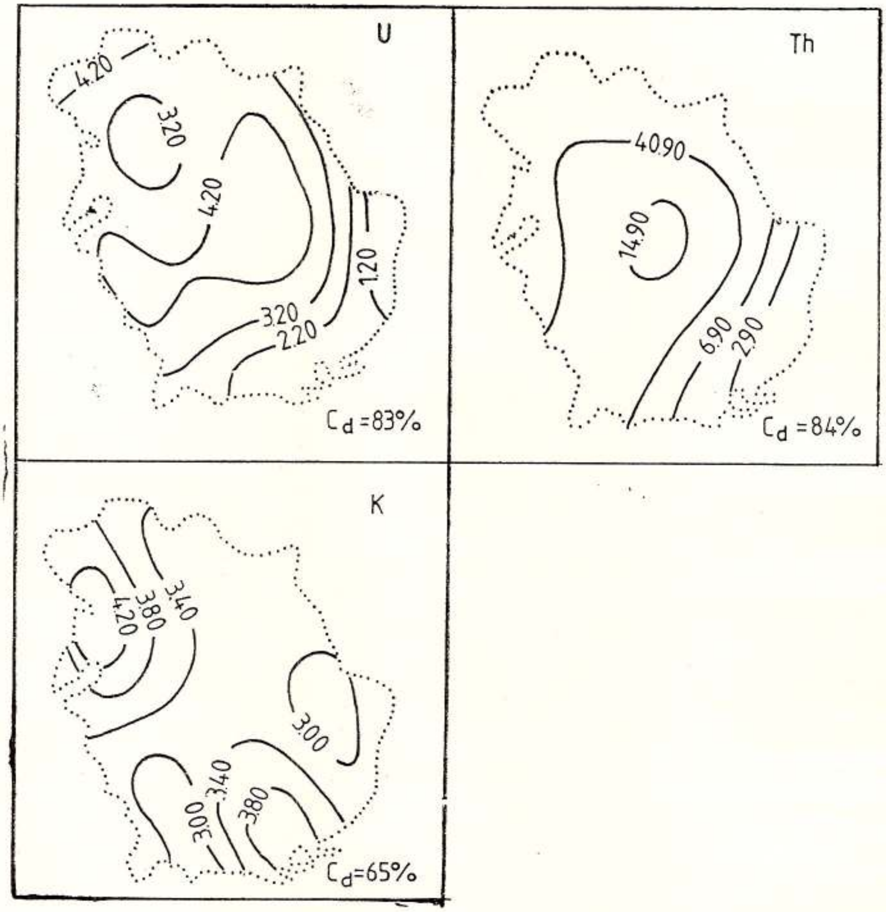

Fig. 12 — Areal distribution of radioactive elements contents.

obvious one in the north-west. However, the lower values of the determination coefficients suggest that a great part of the variability of this chemical element is proved by random variations.

4.3. Genesis of the Vîrful Pietrii Granitoids

The relationships with the surrounding rocks, structure, texture, mineralogical composition, origin of enclaves and general aspect of the pluton prove the magmatic origin of the Vîrful Pietrii granitoid. For this

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reason, the genesis problems of the granitoids of the massif refer in fact to the origin, way of differentiation, emplacement and crystallization conditions of the magma.

The sialic nature of the granitoid massifs in the Danubian Realm was mentioned by Codarcea, Pavelescu (1963), Giușcă et al. (1969) and Savu (1970) who pointed out that during orogenesis phenomena granitoid magmas can be formed by processes of crustal anatexis. These processes followed the formation laws of the natural meltings studied by von Platen (1965), Winkler (1967), Brown and Fyfe (1970), Fyfe (1970).

Under the influence of the pressures occurred during the orogenic processes and favoured by the presence of deep fractures (Savu, 1972) the primary granitoid magma begins to rise towards the upper levels of the Earth's crust where, due to the new conditions of pressure and temperature, begins to differentiate.

The presence of hornblende- and biotite-bearing diorite enclaves in the Vîrful Pietrii granites, e.g. those in the Bistra Mărului Valley, in the right side of the Pecineaga Valley and in the Bloju-Păltineț Crest, in the south of the massif, proves their consolidation previously to the granites one. The relationships between the diorite and leucogranite bodies as well as their mineralogical and geochemical features point to their formation in different stages and sources.

Petrographic evidence and the presence of more basic rocks (granodiorites), in the peripheral part of the massif (west and south), distribution of granitic facies (marginal facies and central facies), as well as geochemical arguments — e.g. areal distribution of the major and trace elements — illustrate the concentric structure of the granitoid massif pointing to a differentiation process due to the gradual consolidation of pluton from the margins towards the interior.

The position of the Vîrful Pietrii granitoids within the residual petrogenetic system is shown in Figure 13. The study granitic rocks occur either inside or in the close vicinity of the projection field of the ideal granites (Tuttle, Bowen, 1958) ; however, a slight shifting of the plotting points towards the Q peak of the diagram. Considering von Platen's observation (1965), according to which for each normative anorthite percentage increases with 1%, the distribution of the plotting points coincides even better with the zones of the compositions within maximum temperatures of melting at water pressures ranging between 0.5 and 4 kilobars.

The dispersion of the normative components of the Vîrful Pietrii granites on the QOrAb diagram is also probably due to the post-crystallization reaction between granite and vapour phase (autometamorphism;

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Savu, 1972). The proof of the activity of a vapour phase in granites is indicated also by the high frequency of the replacement structures of plagioclase by microcline.

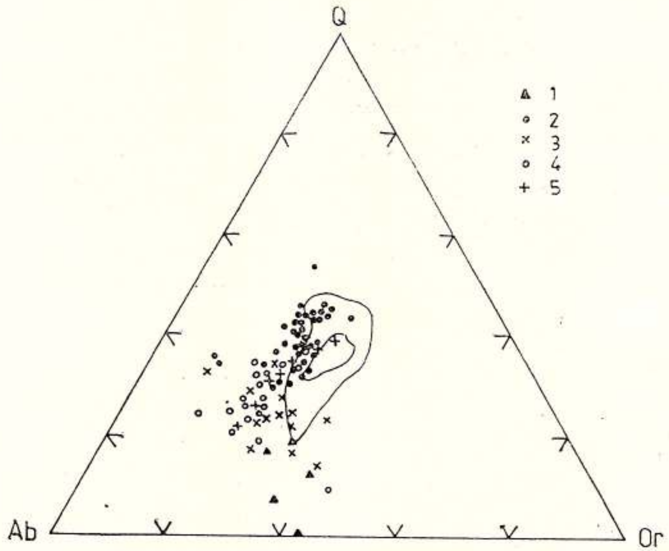

Fig. 13 — *Q Or Ab* diagram.
1, quartz diorites; 2, Vîrful Pietrii granites; 3, Furcătura granitoids; 4, Petreanu granitoids; 5, position of the eutectic minima at P_{H_2O} ranging between 0.5 and 10 kb.

As the normative anorthite content in the study rocks frequently exceeds 2 per cent it is more correctly (Kleeman, 1965) to plot the rocks in the Or-Ab-An-Q system, in which the relationship between the average granite composition and the low temperature zone is closer than in the Or-Ab-Q system, especially at water pressures higher than 2000 bars. As shown in Figure 14, almost all the projection points of the study granitic rocks occur in the distribution field of the ideal granites and they point to a close relationship with the zone of minimum melting. It constitutes a significant argument in favour of the hypothesis of the granites formation in the Vîrful Pietrii massif by crystallization from a granitic magma.

The distribution of the projection points on the diagrams of the Or-Ab-Q and Or-Ab-Q systems indicates a formation temperature of the granites between 670° and 690° at pressure up to 4-5 kilobars, according to the water content. The presence of pertites in rocks also points to a formation temperature of granite of about 660°C confirming its magmatic origin.

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Another proof of the formation of the primary granitoid magma by the melting of the Earth's crust is the hypoaluminous character of the Vîrful Pietrii granitoids. The high values of the Rb/Sr ratio (> 0.20) also reveals the lithogene origin of the primary granitoid magma.

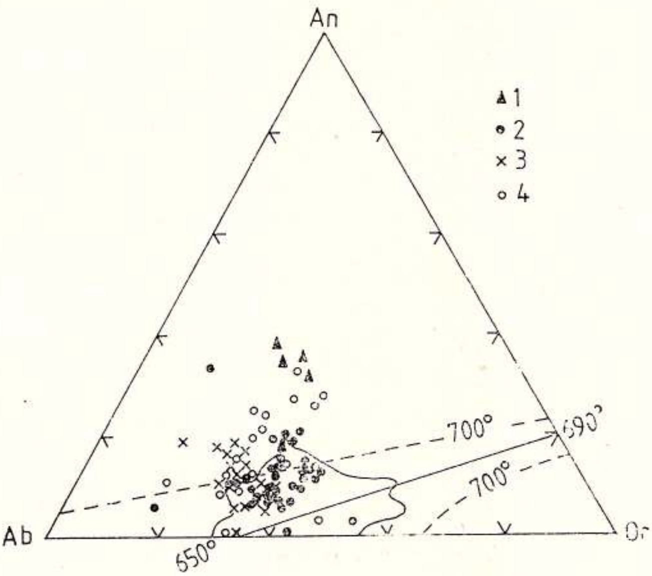

Fig. 14. — An Or Ab diagram (see legend to Fig. 13).

The variation trend only towards acid compositions (among the most acid ones from all the Danubian granitoid bodies), the relatively low Fe^{3+}/Fe^{2+} ratio, the presence of muscovite and garnet, considered by Beckinsale (1979) among the mineralogical and geochemical features of "S"-type granites (supposed to come from the melting of the continental crust) are also revealed by the Vîrful Pietrii granitoids.

The geochemical data presented both for the major elements and the trace elements show that the primary magma differentiation process which generated the Vîrful Pietrii granitoids followed the evolution trend of the calc-alkaline magmas.

The concentration variations of the trace elements are significant for the estimation of the evolution of the magmatic processes. The trace elements trend to be sensitive indicators particularly of the differentiation processes, because their partition coefficients (between the solid phase and the liquid phase) are generally lower than those of the major elements. Moreover, the concentration variations of the trace elements tend to become more regular than those of the major elements more highly affected by the real concentration of the element within the system, by the composition variations of the crystallizing phases and by the melting saturation with a certain component.

Most of the study trace elements of the Vîrful Pietrii granitoids show contents around the clark values typical of these rock types.

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A significant geochemical characteristic of the petrogenesis of the Vîrful Pietrii leucogranites is represented by the low contents of the chemical elements from the ferromagnesian group, both major and trace elements, the lowest ones from all the Danubian granitoid bodies which prove the formation of these rocks from a strongly differentiated acid magma.

Also the variation trends of certain chemical elements — K/Rb, Ba/Rb, Rb/Sr and Ba/K — in the Vîrful Pietrii granitoids are similar with those shown during the fractional crystallization of the calc-alkaline magmas, a fact mentioned by Taylor (1965), Taylor et al. (1968) and Condie (1969) in other granitoid bodies.

Another proof concerning the formation of the Vîrful Pietrii granitoids by fractional crystallization from an acid magma is the slight trend of plagioclase and potash feldspar to form zonary structures.

The magma mobility and its moving from the formation place in the present position is illustrated by the unconformable position of the granitoid body in relation to the surrounding rocks and by the thermal contact metamorphic aureole, which proves that the magma temperature was high enough.

The emplacement time of the Vîrful Pietrii granites is not well specified yet. The radiogene age of the Vîrful Pietrii granite obtained by the K/Ar method (Soroiu et al., 1970) is of 280 M.A., which would correspond to the Carboniferous. But, as shown by Gherasi et al. (1968, 1973, 1975), taking into account that in the Vidra Formation occur reworked fragments of Vîrful Pietrii granites, the granite is of ante-Devonian age. Thus, the obtained radiogene age is due to a rejuvenation.

After consolidation, the Vîrful Pietrii granitoids underwent both autometasomatic processes under the influence of residual solutions, that led to the hydrothermal alteration of plagioclases and their substitution by microcline, and to some high external pressures revealed by cataclasis phenomena of the component minerals in the mylonitic marginal facies.

5. PETREANU MASSIF

The mountainous massif lying between the Retezat Mts to the east and the Vîrful Pietrii Mts to the west is known in the relevant literature as the Petreanu massif.

The Petreanu granitoid bodies are of an elongated, irregular shape and oriented north-southwards ; their length is of ca 20 km and the widths vary from 2-3 km in the south to ca 10 km in the centre (Picui Crest-Petreanu Crest).

The opinions on the rock genesis of this massif changed concomitantly with the enrichment of the geological knowledge, in general and the profound geological survey in the study region. Thus, Schafarzik (1899) considered them orthogneisses, pointing out that Mrazec had mentioned their origin in a granitic intrusion. Gherasi (1937) who studied the southern part of the massif, called them granites supposing that the material from which they formed would be mixed. Later (Gherasi,

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1959), on the basis of the structure and mineralogical composition of the rocks, he changed the denomination into granitoid gneisses pointing out their genetic significance.

The petrostructural researches (Gherasi, Dimitrescu, 1968) showed that, in fact, the Petreanu massif consists of two complexes of migmatic rocks which differ both as regards their petrographic features and their stratigraphic position. Thus, in the north of the massif, the migmatic complex of the Furcătura gneisses displays a mostly metatectic character, whereas in the north the Petreanu migmatic complex shows a predominantly metablastic, granitoid character. The above-mentioned complexes are separated by a very narrow rock strip (Nisipoasa Formation — Dimitrescu, 1985) affected by migmatic processes.

According to Kräutner (1980) the granitoid rocks were formed by an *in situ* migmatization of an alkaline metasomatosis. Later on (Kräutner et al., 1981) he considered that only the Petreanu granitoid rocks were formed in that way, whereas the Furcătura granitoids would be of an intrusive origin.

Dimitrescu (1985) reviewed the above-mentioned hypothesis (Gherasi, Dimitrescu, 1970) and considered that the Petreanu granitoid rocks represent one or two metamorphosed intrusive bodies.

The Petreanu granitoid rocks are quite varied in structure and from the mineralogical composition point of view (Fig. 15).

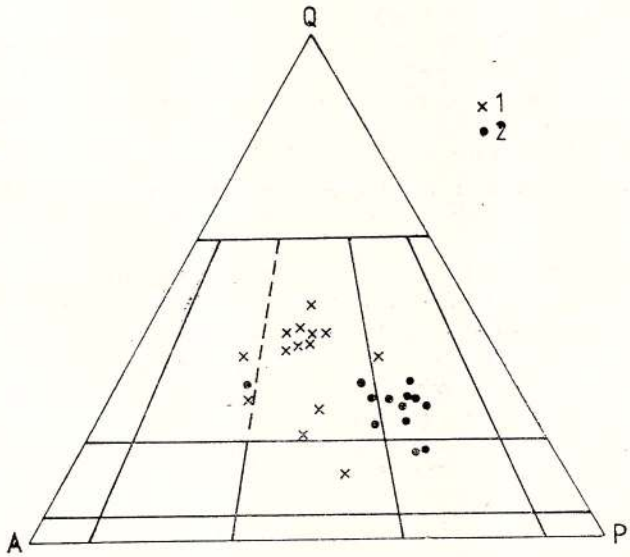

Fig. 15 — *QAP* diagram.
1, Furcătura granitoids ; 2, Petreanu granitoids.

Both the rocks of the Furcătura granitoid body and those of the Petreanu granitoid body are intruded by veins of eruptive rocks : microgranitic veins, aplites, pegmatites and quartz veins.

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5.1. **Furcătura Granitoid Body**

This granitoid body forms a zone which begins in the right side of the Rîul Mare River and continues westwards up to Furcătura Clopotivei ; then it curves southwards in the Jura Valley and extends eastwards again in the right side of the Rîul Mare River up to east of Căldării Brook. Thus, the Furcătura granitoid rocks occupy a horseshoe-shaped area, opened eastwards, surrounding from three sides the Rof antiform (Morariu, 1982) which, according to Gherasi and Dimitrescu (1970), "constitutes the leading structure of the whole northwestern flank of the Retezat granodioritic massif".

In stratigraphic respect, the Furcătura granitoid body lies between the Rof Formation consisting of micaceous schists with garnets, leptinites and amphibolic schists, in the lower part, and the Nisipoasa Formation, mainly represented by quartz-biotite schists, in the upper part.

The contact of the Furcătura granitoids with the Rof Formation is clear ; leucocrate gneiss veins which intrude this formation occur only locality. Accordinng to Codarcea and Gherasi (1945) and Berza et al. (1983) it would be a tectonic contact (thrust plane) by which the Furcătura granitoids thrust over the Rof Formation ; in Dimitrescu's opinion (1985) it is a common magmatic contact brought in the present position as a result of two superposed foldings. The upper contact, with the Nisipoasa Formation, is also trenchant but according to the above-mentioned authors it is a magmatic one, the crystalline schists being considered as the cover of the Furcătura body.

The rocks of this granitoid body are not uniform, several petrographic types being distinguished due to the variations of structure and mineralogical composition. The biotitic granitoid rocks are the most widespread, but porphyroid granitoid gneisses and leucocrate granitic gneisses occur as well. The granitoid gneisses usually display an undulatory parallel structure. When they are more quartzous they have a plan-parallel structure and when more feldspathic they become massive.

Biotitic granitoid gneisses show a parallel or granular structure ; they are intruded by concordant leucocrate veinlets giving rise to stromatic migmatites or oblique, sinuous ones forming phlebitic migmatites. In places, the rocks display an ophtalmitic structure due to the metasomatic feldspathization whereas in other cases they become granular due to the increase of the plagioclase content getting a nebulitic aspect. Such nebulitic migmatites are found in the Pîrîul Repede Brook, Pîrîul cu Pietre Brook, Căldării Brook and in the left side of Rîul Mare River nearby Bălanu.

In a quarry in the right side of the Rîul Mare River, south of the Luncii Brook, there are massive, granular, biotitic granitoids penetrated by apophyses of leucocrate granitic gneisses and aplitic veinlets, giving rise to stromatic and phlebitic migmatites.

Porphyroid granitoid gneisses form cliffs in the Rîul Mare River bed downstream "La Greblă" bridge. They contain microcline developed in metablasts and more rarely in idioblasts with biotite inclusions. Local-

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ly, leucocrate pegmatoid bands and aplitic veinlets or small enclaves of schists occur in the porphyroid granitoid gneisses. Due to the feldspar metablastesis the rocks display a nebulitic aspect ; they no longer show an oriented structure, biotite being irregularly disposed. Such nebulitic migmatites can be observed in the blocks in the Rîul Mare River bed upstream the confluence with the Luncii Brook and on the Pîrîul Repede Brook.

Muscovite-bearing leucocrate gneisses constitute a small body south-east of the Furcătura Clopotivei Crest. They also form small apophyses or veins which intrude the biotitic granitoid gneisses. Their relationships with other petrographic types point out their intrusive character.

Under the microscope the Furcătura granitoids present a hypidiomorphic texture, consisting of quartz, plagioclase, microcline, biotite and muscovite in different amounts for each rock type.

Quartz is granoblastic ; it occurs as discontinuous bands or as nests, in places lens-shaped (Pl. III, Fig. 1). In most cases the crystal edges are quite irregular frequently with interfingerings between each other and an undulatory extinction.

Plagioclase is an oligoclase with 10-25% An and is represented by two generations. Plagioclase of the first generation is anhedral, of small sizes, and does not contain biotite inclusions, whereas that of the second generation is subhedral, even euhedral, prism-like, of larger size (0.8-1.5 cm), porphyroblastic and contains biotite and quartz inclusions. This plagioclase was formed by metablastesis and imprints a porphyroid aspect to the rock.

Plagioclase is usually altered, turbid and contains sericite and zoisite microlites. Polysynthetical twins appear more rarely as shadows of altered plagioclase. The myrmekitic intergrowths are extremely rare and very poorly developed (Pl. III, Fig. 2).

Microcline is randomly spread and sometimes it is even absent from the rock. It usually occurs as large crystals with irregular contour and always fresh. Microcline frequently contains inclusions of altered plagioclase, biotite, drop-like quartz and even sphene (Pl. III, Fig. 3). It often displays a characteristic crossed twin, but the microperthitic separations are very rare. A reaction zone, formed of a fine aggregate of sericite, quartz, albite and epidote, occurs around the microcline crystals.

Biotite is a common component of the biotitic granitoid gneisses but it is almost absent in the leucocrate ones where it yields to muscovite. It appears as fine lamellas with parallel or subparallel orientation in the biotitic granitoid gneisses and unoriented in the porphyroid gneis-

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ses. It is pleochroic with brown-yellowish hues after Ng and yellow after Np. Locally, it shows a beginning of chloritization.

Muscovite is more rarely found in biotitic granitoid gneisses and occurs more frequently in the leucocrate ones. It forms small-sized lamellas usually oriented giving a gneissic structure to the rock. It forms neither intergrowths nor reaction traces like other minerals.

Epidote (granular, usually in nests), apatite (rounded, short-prismatic crystals) and sphene (euhedral crystals or slightly rounded grains) occur as accessory minerals.

5.2. **Petreanu Granitoid Body**

The rocks of the Petreanu body constitute an S-shaped zone elongated towards NNE, lying between the Tomeasa Mt and the Runcu Crest; further westwards it extends up to the Petreanu Mt where it bends towards NNE up to the Cracul Crest surrounding the Furcătura granitoid body. From the Netiș Brook to the Runcu the Rîul Mare River flows through the Petreanu granitoid body, which forms rocky walls and steep gorges displaying an almost continuous outcrop along its length.

The petrographic types constituting the Petreanu body are represented by granitoid gneisses and banded gneisses. The granitoid rocks of the Petreanu body are generally concordant with the predominant foliation of the surrounding crystalline schists belonging to the Bodu Formation.

Both at the periphery of the body and inside it occur intercalations of crystalline schists unaffected by metasomatosis (resisters), conformable with the gneiss schistosity where it can be distinguished. Such intercalations of crystalline schists of the metres order, represented by biotitic gneisses and biotitic quartzites, occur downstream Gura Zlata at about 1 km on both sides of the Rîul Mare River. Smaller intercalations of retromorphosed amphibolic or biotitic gneisses are also found nearby the northern margin of the granitoid body, in the left side of the Rîul Mare River south of the confluence with the Nisipoasa Brook and on the Căprioarei Brook. Intercalations of biotitic gnesses and amphibolites also occur on the Valea Mare Brook.

From the petrographic and structural point of view there is a large variability of the rock types, characteristic of the granitization processes. Thus, as shown by Gherasi (1937), large zones of obvious schistosity, formed of migmatic gneisses intruded by aplitic veins conformable with the schistosity („lit-par-lit" gneisses) or unconformable, giving a diadysitic aspect, occur beside nebulitic granitoid gneisses and massive granitoid gneisses with feldspar porphyroblasts. It is difficult to make a regional

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separation of the petrographic types occurring in the granitoid body because of their random spreading. However, after the structural aspect, one could observe the predomination of the banded gneisses with a stronger schistosity in the north of the granitoid body, whereas in the south prevail the granitoid gneisses with a less oriented structure or even a massive one.

A common feature of the granitoid rocks of the Petreanu body is the presence, in different amounts, of large-sized (0.5-3 cm) fresh potash feldspar porphyroblasts (Pl. IV, Figs. 1, 2).

Petreanu granitoid rocks display wide variations of the mineralogical composition which, however, do not depend too much on the rock type.

Banded gneisses are widely distributed in the north of the Petreanu granitoid. The banded aspect of these rocks is given by the alternation of more schistous, biotitic and feldspathic parts with centimetric leucocrate bands, conformable (stromatic migmatites ; Pl. V, Fig. 1) or oblique, sinuous (phlebitic migmatites ; Pl. V, Fig. 2). Ptygmatic folds are rarely found. The above characteristics clearly differentiate them from the granitoid gneisses.

Banded gneisses frequently present a lenticular, oriented structure and contain microcline grains. Usually, the microcline crystals are elongated, oval and are developed both in the melanocrate portions of the rock and in their leucocrate bands (Pl. V, Fig. 1). Other times the microcline crystals are idiomorphic, with a rectanguar outline and sizes of 1—2 cm. Due to the increase of the content of feldspar the rock schistosity decreases and the rocks become almost massive as the granitoid gneisses.

Granular biotitic banded gneisses occur too, within which the microcline crystals are elongated parallel to the foliation or microgranular with feldspar bands parallel to the foliation. These migmatites are intruded by fine metatectic aplitic bands concordant with the schistosity plane of the paleosoma.

Under the microscope the banded gneisses display a granoblastic or granolepidoblastic texture.

Quartz presents an undulatory extinction with a characteristic mortar structure pointing to recrystallization. It occurs as nests or bands of grains of variable sizes.

Plagioclase is found in large amounts ; it is strongly altered and packed with a cluster of fine crystals of sericite and zoisite. It is an acid oligoclase (An_{10-20}). Albite twin is frequently found. In places, the twin lamellas are very fine, indicating the secondary character of these crystals. Plagioclase is often corroded and substituted by microcline.

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Microcline occurs either as large ovoid crystals or as small crystals or masses which replace plagioclase. It is usually fresh and contains remains of altered plagioclase, "drop-like" quartz and biotite. Crystals are surrounded by a reaction zone formed of a very fine aggregate of quartz, sericite and muscovite (Pl. III, Fig. 4).

Biotite is slightly pleochroic, from dark brown to light brown. In places it is chloritized and slightly deferred, when pseudomorphoses of pennine after biotite with an abnormal (violaceous) pleochroism occur. In rocks with a lower content of potash feldspar the parallel biotite lamellas give an oriented structure to the rock. Concomitantly with the increase of the microcline content and especially of the large crystals the structure becomes lenticular and then almost massive.

In the marginal zones of the granitoid body common green hornblende occurs sporadically and pyroxenes very rarely.

As accessory minerals, the banded gneisses contain apatite, as small grains or short rounded laths, magnetite, as irregularly-shaped isolated crystals, and pyrite as masses. In the Zeicani Brook nearby the spring zone, in the bed of the brook, concentrations of pyrite crystals occur in a stratiform position (Pl. V, Fig. 2).

Granitoid gneisses possess a less oriented structure, lenticular or even massive. The massive granitoid gneisses occur in the Rîul Mare River in the Gorganu bend, at the confluence of the Rîul Mare River with the Bodu Brook, south of Gura Zlata and upstream the confluence of the Radeș Brook with Rîul Mare River at about 1 km.

According to the ratio between biotite and microcline, there are darker coloured biotitic granitoid gneisses, with small amounts of potash feldspar and a more oriented structure, e.g. in the Lunca de Lațuri Brook and the Valea Mare Brook, and light grey, massive granitoid gneisses with numerous microcline porphyroblasts. As a result of the gradual increase of the feldspar content there are gradual transitions between these types.

When neosoma consists of feldspar porphyroblasts (microcline) they give the rock an undulatory structural aspect (ophtalmitic structure). According to Menhert (1968) this structure is characteristic of migmatites and all the migmatic rocks display it at least as traces. The large microcline crystals, more rarely the plagioclase ones, are frequently ovoidal ; in the more advanced stages of metasomatosis there is a tendency towards the idiomorphic habitus. Such rectangular large porphyroblasts are found in the Slatina Pocinești Brook (Pl. IV, Fig. 1).

When the migmatization is more intense the paleosoma cannot be macroscopically separated from the neosoma and the rock shows a nebulitic aspect. In such rocks only weakly differentiated rocks can be observed due to a slightly different content of minerals. The rocks formed

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in the most advanced stage of metasomatosis are highly homogeneous. Restricted zones with such migmatites occur in the right side of the Rîul Mare River at its confluence with the Valea Mare Brook, downstream the confluence with Căprioarei Brook and in the Gorganu bend.

Under the microscope the texture of the Petreanu granitoids is similar with that of the plutonic rocks of the granite-syenite-diorite group.

Quartz is found as nests or bands. It is xenomorphous and shows an undulatory extinction. Quartz is characterized by the absence of inclusions, which implies their resorption during the crystallization.

Plagioclase is frequently found, usually as idiomorphous crystals. It is almost always turbid, altered and transformed into a thick mass of sericite and zoisite. Unaltered plagioclase is rarely found and in that case polysynthetic twins can be noticed. Frequently, the plagioclase crystals show corroded margins filled with quartz and microcline. It is an oligoclase with 10-25% An.

Microcline occurs as xenoblasts with irregular margins intruding the plagioclase. It is fresh and frequently contains inclusions consisting of biotite lamellas, drop-like remains of plagioclase and quartz. Usually it presents a quadrille structure and is rarely perthitic. In places occurs an albitization of the microcline which starts at the crystal edge.

Potash feldspars of the Petreanu body present a quite high triclinicity, the values of the 2V angle ranging between 70 and 85°.

Microcline distribution in the granitoid gneisses is not uniform resulting in the formation of more or less potassic rocks. Granitoid gneisses devoid of microcline are very rare. In the granitoid gneisses no orientation of the microcline porphyroblasts versus the foliation can be observed. More often than not the microcline porphyroblasts are surrounded by a fine aggregate formed of sericite, quartz, albite and epidote.

Biotite occurs in variable quantites and is the only mineral that under conditions of a less intense metasomatosis stil preserves the primary orientation. It forms irregular lamellas and shows the following pleochroism: Ng = Nm = dark brown, Np = yellowish. Inclusions of accessory minerals in biotite are rarely found. Locally, biotite is altered and transformed into chlorite and slightly deferred.

Muscovite appears especially in more leucocrate types of the granitoid gneisses.

Epidote, apatite, sphene and more rarely magnetite occur as accessory minerals.

5.3. Vein Rocks

Both the Furcătura and Petreanu granitoid bodies are penetrated by vein rocks represented by microgranitic veins, aplites, pegmatites and vein quartz.

The Petreanu granitoid rocks include veins of metric leucocrate microgranites, e.g. those in the Zeicani Brook, Bodu Brook and in two small brooks in the Tomeasa Mount. The rocks of these microgranitic

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veins are of a white-grey colour, fine- to medium-grained and display a massive structure.

Aplites are the most frequent vein rocks within the Petreanu massif, penetrating both granitoid bodies. The thickness of the aplitic veins varies from some centimetres up to several decimetres. Zones with several such occurrences of aplitic veins appear in the left side of the Rîul Mare River, nearby Bălanu, in the Pîrîul Repede Brook, in the Pîrîul cu Pietre Brook and the Căldării Brook (in the Furcătura granitoid body), and in the Lunca de Lațuri Brook, Valea Mare Brook, Tomeasa Brook and the Rîul Mare River and south of Gura Zlata, south of the confluence with the Radeș Brook (in the Petreanu granitoid body).

The aplitic rocks consist of a microgranitoid leucocrate mass formed of xenomorphic quartz with undulatory extinction, plagioclase and potash feldspar, almost devoid of melanocrate minerals. The albitic plagioclase (An_{8-10}) occurs as altered hipidiomorphic crystals with traces of polysynthetic twins. Potash feldspar is xenomorphic ; it displays a cross texture and more rarely of microcline-perthite.

Isolated quartz occurrences appear within the Furcătura and Petreanu granitoid rocks. They usually occur as subcentimetric or centimetric veinlets, e.g. in the Lunca de Lațuri Brook and Valea Mare Brook, and more seldom as random agglomerations. Larger quartz veins are found only in the Cracul Brook, in the Petreanu granitoid body, and are mined out in a small quarry. They consist of white quartz, in places with chlorite nests, and very rarely with quartz idiomorphic crystals.

Pegmatitic veins are very seldom found in the granitoid rocks of the Petreanu massif. The pegmatitic rocks never form well-outlined veins or distinct bodies. They usually occur as irregular nests near by deformation zones.

5.4. Geochemistry of the Granitoid Rocks in the Petreanu Massif

5.4.1. *Petrochemical Features*

The petrochemical study of the granitoid rocks in the Petreanu massif is based on 36 complete analyses on silicates (Tab. 10) belonging to the following rock types : 17 Furcătura granitoids and 19 Petreanu granitoids.

The statistical parameters presented in Table 11 show differences of chemistry between the Furcătura and Petreanu granitoids, which are closely connected with their mineralogical composition.

Although the variation limits of the oxides for the two granitoid bodies do not differ too much, there are significant differences between their average contents. Thus, the contents of SiO_2 and Na_2O, are much higher in the Furcătura granitoids, and the contents of Al_2O_3, Fe_2O_3, FeO, MgO, TiO_2 and P_2O_5 are much higher in the Petreanu granitoids.

These differences in the rock chemistry indicate important differences in the process of formation and evolution of the two granitoid bodies. R_1-R_2 diagram (Fig. 2) indicates a variation of the character of the granitoid rocks in the Petreanu massif from monzodiorites to granites.

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TABLE 10

Chemical composition of granitoid rocks of the Petreanu massif

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	202	56	22	197	48	11	32	90	71	19	92	65	198	62	52	204	9
	Furcătura																
	biotite granitic gneiss	granitic gneiss	granitic gneiss	granitic gneiss	granitic gneiss	granitic gneiss	granitic gneiss	granitic gneiss	porphyroid granitic gneiss	granitic gneiss	granitic gneiss	granitic gneiss	leucocrate granitic gneiss	granitic gneiss	leucocrate granitic gneiss	aplite	aplite
SiO_2	67.09	67.35	67.44	67.66	67.67	66.67	69.54	69.56	69.64	69.75	71.51	71.66	72.76	72.94	73.37	73.45	73.96
TiO_2	0.34	0.26	0.37	0.27	0.31	0.31	0.22	0.40	0.26	0.13	0.18	0.17	0.06	0.15	0.06	0.03	0.10
Al_2O_3	17.79	16.98	14.33	17.73	16.88	15.63	16.46	13.15	16.26	17.74	15.41	14.57	15.84	12.61	13.74	15.66	14.56
Fe_2O_3	0.93	0.65	1.04	0.72	1.02	0.83	1.05	0.29	0.94	0.52	0.68	2.14	0.19	0.65	0.18	0.24	0.37
FeO	1.41	1.35	1.15	1.07	1.35	1.80	0.63	200	0.95	0.29	0.60	0.36	0.20	0.21	0.18	0.13	0.26
MnO	0.17	0.12	0.06	0.16	0.08	0.09	0.14	0.07	0.08	0.07	0.12	0.11	0.12	0.04	0.07	0.07	0.08
MgO	1.29	0.91	1.50	1.00	0.79	0.74	0.27	2.10	0.33	0.16	0.80	0.14	0.60	1.80	1.08	0.53	0.14
CaO	2.46	2.93	3.64	2.57	2.97	2.56	2.19	2.66	2.28	3.21	1.57	1.50	1.36	2.38	1.07	1.25	0.94
K_2O	2.66	2.95	3.72	2.91	2.62	3.38	3.30	3.41	3.18	1.94	3.00	3.57	3.96	3.80	3.92	2.91	3.83
Na_2O	4.33	5.35	5.24	4.36	5.25	5.26	4.63	4.83	5.25	6.05	5.38	4.35	4.16	4.39	5.62	4.85	4.71
P_2O_5	0.12	0.13	0.22	0.14	0.15	0.16	0.13	0.22	0.09	0.04	0.09	0.09	0.03	0.05	0.04	0.01	0.03
H_2O	0.89	0.47	0.35	0.90	0.49	0.89	0.98	0.57	0.63	0.53	0.70	0.68	0.50	0.77	0.45	0.46	0.68
CO_2			0.10					0.20									
S			0.06					0.03						0.08			
Total	99.48	99.45	99.22	99.49	99.58	100.32	99.54	99.49	99.89	100.43	100.04	99.34	99.78	99.87	99.78	99.59	99.66
Fe_2O_3/FeO	0.66	0.48	0.90	0.67	0.76	0.46	1.67	0.15	0.99	1.79	1.13	5,94	0.95	3.10	1.00	1.85	1.42
FeO/MgO	1.09	1.48	0.77	1.07	1.71	2.43	2.33	0.95	2.88	1.81	0.75	2.57	0.33	0.12	0.17	0.25	1.86

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Table 10 - continued

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	151	183	111	141	158	112	185	220	163	193	101	134	80	125	195	34	180	140	81
	~	Petreanu																	
	biotite granitoid gneiss	biotite granitoid gneiss	porphyroid granitoid gneiss	biotite granitoid gneiss	granitoid gneiss	granitoid gneiss	granitoid gneiss	granitoid gneiss	porphyroid granitoid gneiss	granitoid gneiss	granitoid gneiss	granitoid gneiss	granitoid gneiss	porphyroid granitoid gneiss	granitoid gneiss	porphiroid granitoid gneiss	granite	granite	granite
SiO_2	55.98	56.94	59.99	60.89	61.04	62.28	62.45	63.09	63.14	64.01	64.40	66.00	66.03	66.41	68.41	68.43	68.94	73.20	73.77
TiO_2	0.75	0.79	0.71	0.42	0.58	0.59	0.15	0.37	0.65	0.55	0.49	0.60	0.55	0.32	0.31	0.27	0.16	0.14	0.18
Al_2O_3	18.95	18.46	18.33	14.29	17.71	20.49	17.48	16.21	14.91	19.05	19.07	11.40	17.23	12.55	17.38	16.42	19.51	14.08	14.02
Fe_2O_3	2.31	2.16	1.87	3.37	2.49	0.96	2.43	2.86	1.61	0.64	0.81	2.88	1.29		0.94	1.42	0.02	0.47	0.67
FeO	3.12	3.32	2.65	2.26	2.18	2.52	1.86	1.82	2.72	1.56	2.04	2.29	1.90	1.24	0.86	0.69	0.58	0.27	0.59
MnO	0.12	0.14	0.12	0.08	0.22	0.21	0.10	0.08	0.08	0.13	0.18	0.07	0.12	0.08	0.12	0.13	0.07	0.04	0.09
MgO	3.90	3.73	3.00	2.90	2.85	2.03	2.40	1.80	2.60	1.78	1.97	2.80	1.43	1.80	0.44	1.06	0.87	0.95	0.43
CaO	5.00	5.39	4.45	6.16	4.08	3.07	4.62	4.62	4.90	2.86	3.00	4.97	3.57	3.92	1.79	1.53	1.50	1.93	1.93
K_2O	4.30	3.25	3.34	4.51	3.74	2.68	3.10	3.07	3.10	3.38	2.84	3.10	2.88	5.08	2.90	3.36	1.63	3.25	3.72
Na_2O	3.28	3.24	3.50	3.69	3.04	3.76	[illegible]	4.01	4.67	3.88	3.82	4.67	4.10	3.83	5.03	5.11	5.33	4.45	3.80
P_2O_5	0.43	0.43	0.46	0.25	0.38	0.26		0.18	0.07	0.22	0.17		0.16	0.20	0.12	0.12	0.04	0.03	0.05
H_2O	1.34	1.68	1.14	0.43	1.26	1.03	0.91	1.37	0.69	1.56	0.89	0.65	1.08	0.92	1.49	1.06	0.89	0.80	0.65
CO_2				0.48			0.50	0.24	0.20			0.20		0.32					
S				0.08			0.03	0.08	0.06			0.03		0.09					
Total	99.48	99.53	99.56	99.81	99.57	99.88	99.72	99.80	99.40	99.62	99.68	99.66	100.34	99.41	99.79	99.60	99.54	99.61	99.90
Fe_2O_3/FeO	0.74	0.65	0.71	1.49	1.14	0.38	1.31	1.57	0.59	0.41	0.40	1.26	0.68	2.14	1.09	2.06	0.03	1.74	1.14
FeO/MgO	0.80	0.89	0.88	0.78	0.76	1.24	0.78	1.01	1.05	0.88	1.04	0.82	1.33	0.69	1.95	0.65	0.67	0.28	1.37

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TABLE 11
Statistical parameters of major chemical components in granitoid rocks of the Petreanu massif

	Furcătura (n = 17)					Petreanu (n = 19)				
	x_{min}	x_{max}	$\bar{x}$	s	V	x_{min}	x_{max}	$\bar{x}$	s	V
SiO_2	67.09	73.96	70.24	4.35	7	55.98	73.77	64.49	4.77	7
TiO_2	0.03	0.40	0.21	0.26	97	0.14	0.79	0.45	0.21	47
Al_2O_3	12.61	17.79	15.61	1.58	10	11.40	20.49	16.71	2.53	15
Fe_2O_3	0.18	2.14	0.73	0.79	90	0.02	3.37	1.62	0.97	60
FeO	0.13	2.00	0.82	1.36	128	0.27	3.32	1.81	0.90	50
MnO	0.04	0.17	0.09	0.04	42	0.04	0.22	0.12	0.05	44
MgO	0.04	2.10	0.83	1.33	122	0.43	3.90	2.04	1.02	50
CaO	0.94	3.64	2.21	1.23	50	1.50	6.16	3.65	1.44	39
Na_2O	4.16	6.05	4.94	0.64	13	2.55	5.33	3.93	0.71	18
K_2O	1.94	4.06	3.24	0.51	16	1.63	5.11	3.52	0.79	22
P_2O_5	0.01	0.22	0.10	0.15	113	0.03	0.46	0.23	0.23	102

The distribution of the analysed samples points to a clear differentiation between the Petreanu granitoids, with a more basic character (quartz monzodiorites, granodiorites) and the Furcătura granitoids, with a more acid character (granites, granodiorites). In comparison with the Vîrful Pietrii granites, both the Petreanu granitoids and the Furcătura ones present a more basic character.

The projection of the *Q, A, P* values computed by Rittmann's method (1973) indicates a quite important variation in the chemical-mineralogical composition of these rocks. This variation is stronger within the Petreanu granitoids, a characteristic of rocks in whose formation the metasomatic processes played a preponderent part. *QAP* diagram shows that the Furcătura granitoids differ from the Petreanu ones, the former possessing a more granitic average composition as compared with the latter ones with a more granodioritic composition. By the projection of the analysed rocks in the *FMA* diagram (Fig. 16) two distinct fields result which clearly differentiate the two granitoid bodies by the variation of the alkali content whereas the ratio between iron and magnesium remains constant.

The *CNK* diagram (Fig. 17) emphasizes the almost constant content of potassium as compared with the variations occurring along the Na—Ca line. The distribution of the analysed rocks in distinct zones illustrates the decrease of the calcium content as compared with alkalies concomitantly with the intensification of the granitization process and makes possible the discrimination of the higher—Na Furcătura granitoids from the higher—Ca Petreanu granitoids.

It is worth mentioning the lower content of potassium and the higher content of sodium of the granitoid rocks in the Petreanu massif as compared with the average of the pelitic rocks computed by Shaw (1956) and the clays average computed by Turekian and Wedepohl (1961).

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The ratios between the alkali contents in the granitoid rocks of the Petreanu massif are emphasized by the Na_2O—K_2O diagram (Fig. 18) on which the analysed rocks are plotted in the field of the acid metamorphic

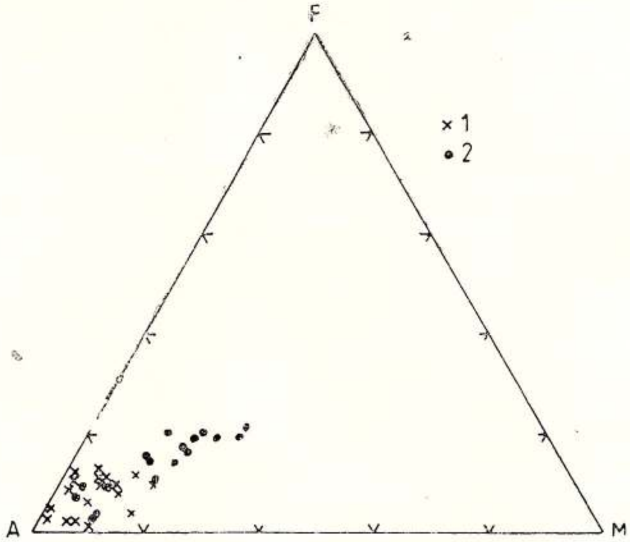

Fig. 16 — *FMA* diagram (see legend to Fig. 15).

rocks (Mehnert, 1968). In comparison with the averages of the granitoids in the Earth's crust (Baird et al., 1963), the granitoid rocks of the Petreanu massif, especially the Furcătura ones, display a more sodic ten-

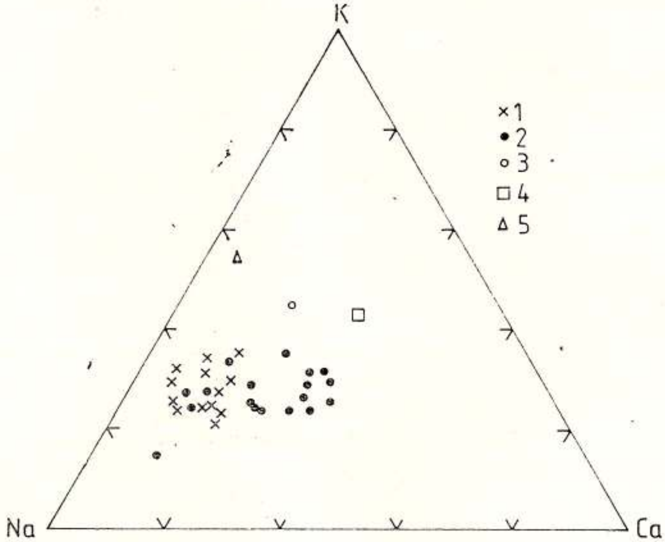

Fig. 17 — *CNK* diagram. 1, Furcătura granitoids; 2, Petreanu granitoids; 3, pelites (Shaw, 1956); 4, clays (Turekian, Wedepohl, 1951); 5, arkoses (Pettijohn, 1963).

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dency, the values of the K_2O/Na_2O ratio for the latter ranging between 0.5 and 1. At the same time the alkali amount points out clearly the more alkaline character of the Furcătura granitoids as compared with the Petreanu ones.

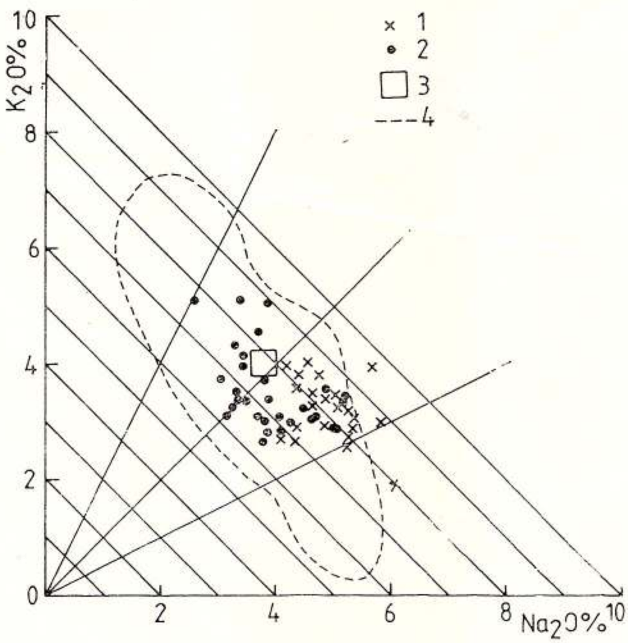

Fig. 18 — Na_2O — K_2O diagram.
1, Furcătura granitoids; 2, Petreanu granitoids; 3, average value of granitoids in the Earth's crust (Baird et al., 1963); 4, field of acid metamorphic rocks (Mehnert, 1968).

Korjinski diagram (Fig. 19) illustrates once more the differences between the Furcătura and Petreanu bodies, their granitoids being projected in different fields.

The rocks of the two granitoid bodies also occupy different fields in the *al* — *alk* — *c* + *fm* diagram (Fig. 20). The Furcătura granitoids occur in a field situated closer to the *al-alk* side, which points to a higher content of leucocrate minerals; unlike them the Petreanu granitoids fall is a field closer to the *c-fm* peak of the diagram.

The CIPW normative composition of the granitoid rocks in the Petreanu massif emphasizes some of their particularities. Thus, although the variation limits of the virtual contents of quartz are similar for the two rock bodies — between 4.39% and 32.13% for Furcătura granitoid and between 4.11% and 32.85% for Petreanu granitoid — the average content of this mineral is slightly hegher in the former body. In contrast with the variation of the normative content, the virtual content of orthose is not significantly different. The components of the normative plagioclase (Ab, An) show a weak tendency of reverse variation; the virtual

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of albite are a little higher in the Petreanu granitoid rocks
contents 'he virtual contents of anorthite are higher in the Petreanu
whereas
granitoids.

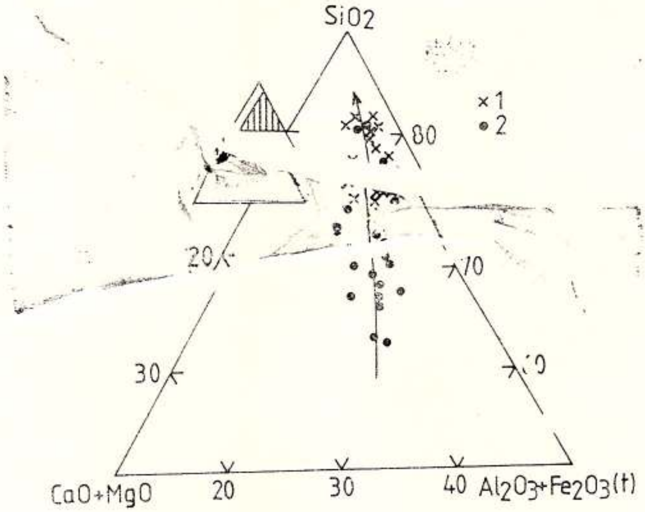

Fig. 19 — Korjinski diagram.
1, Furcătura granitoids; 2, Petreanu granitoids.

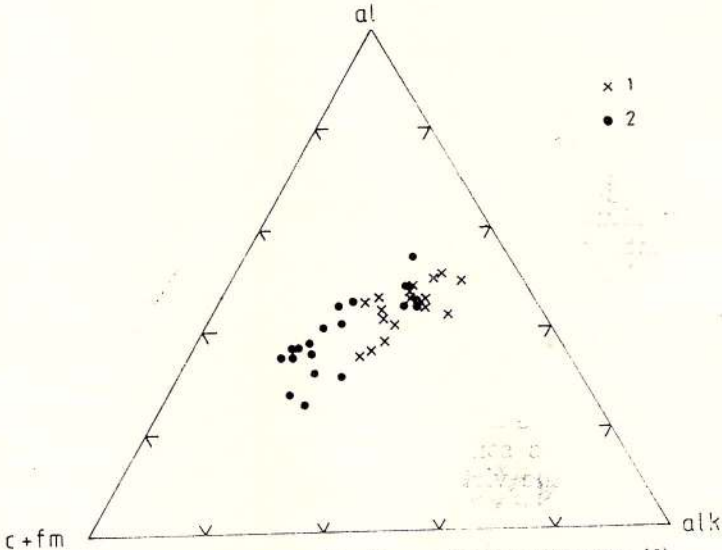

Fig. 20 — *al* — *alk* — *c* + *fm* diagram (see legend to Fig. 19).

The distribution of the normative melanocrate minerals illustrates more clearly significant variations as regards the participation of different virtual minerals in the formation of the study rocks.

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5.4.2. *Statistical Distribution of Major Elements*

The average contents of the major elements in the Furcătura and Petreanu granitoid rocks (Tab. 11) correspond to rocks with an acid chemical composition. The contents of the major elements in the granitoid rocks show a different statistical variation. Thus, for some chemical elements, generally ferromagnesian ones, one can observe a quite significant variation of the contents of MgO, P_2O_5, TiO_2 and Fe_2O_3, which is more pronounced for the Furcătura body than for the Petreanu body. The lowest variations of the contents occur at SiO_2, Na_2O and K_2O, that is at the chemical elements added to the host rocks during the granitization process which led to a certain uniformity of their contents. Both the aspect of the frequency histograms and the quantitative verification of the statistical distribution law points to differences between the two granitoid bodies. Thus, while most of the major chemical components of the Furcătura body show an obvious tendency towards the lognormal statistical distribution law, the majority of the major chemical components of the Petreanu body tend to the normal statistical distribution law. The bimodal aspect of some of the frequency histograms suggests the unhomogeneous character of the rocks.

5.4.3. *Correlation between Major Elements*

A significant geochemical aspect of the formation process of the Furcătura and Petreanu granitoids is represented by the establishing of the relationships between the major chemical components of the rocks. The presence and character of these relationships were emphasized by means of the linear correlation coefficients (Tab. 12).

TABLE 12

Correlation coefficients between major chemical components in granitoid rocks of the Furcătura Body (above diagonal) and of the Petreanu Body (below diagonal)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5
SiO_2		-0.73	-0.41	-0.64	-0.74	-0.49	-0.51	-0.79	-0.01	0.57	-0.70
TiO_2	-0.70		0.21	0.71	0.89	0.34	0.44	0.78	-0.02	-0.31	0.91
Al_2O_3	-0.39	0.20		0.30	0.32	0.65	-0.15	0.33	-0.61	-0.07	0.15
Fe_2O_3	-0.50	0.48	-0.27		0.57	0.37	0.08	0.61	-0.04	-0.40	0.65
FeO	-0.84	0.80	0.23	0.58		0.42	0.48	0.73	-0.06	-0.26	0.87
MnO	-0.45	0.51	0.62	0.23	0.50		0.06	0.18	-0.07	-0.47	0.36
MgO	-0.82	0.65	0.10	0.52	0.78	0.24		0.50	0.26	-0.37	0.47
CaO	-0.74	0.59	-0.14	0.68	0.80	0.10	0.82		-0.22	-0.27	0.72
K_2O	-0.25	0.23	-0.42	0.73	0.21	0.01	0.29	0.44		-0.38	0.08
Na_2O	0.64	-0.43	-0.23	-0.49	-0.55	-0.45	-0.57	-0.59	-0.49		-0.28
P_2O_5	-0.82	0.79	0.37	0.61	0.78	0.63	0.70	0.66	0.40	-0.71	

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The frequency of the correlation connection between the contents of the major chemical components differs in the two granitoid bodies. Thus, whereas for the Petreanu body about 70 per cent of the computed linear correlation coefficients display values lower than 0.4, for the Furcătura body they represent only 50 per cent. More than half of the correlation coefficients with significant value show a close ($0.6 < r < 0.8$) and very close connection ($0.8 < r < 1.0$) between the variation of the major chemical components contents. Among the lowest values of the correlation coefficients, which indicate in fact the absence of any correlation between the contents of the respective chemical elements, it is worth mentioning those between K_2O-MnO for the Petreanu granitoid body and between K_2O-TiO_2 and K_2O-SiO_2 for the Furcătura granitoid. The highest values of the correlation coefficients occur between the contents of FeO, TiO_2 and P_2O_5 for the Furcătura granitoid and between the contents of SiO_2 and those of FeO, MgO and P_2O_5 for the Petreanu granitoid.

Except for K_2O and Al_2O_3, which present almost no significant correlations with the other major chemical components in neither of the granitoid bodies, the other major elements display a close correlation between their contents. As regards the sense of the correlation, a study of the correlation coefficients values points out as a significant petrogenetic aspect that except for sodium and less for potassium all the other correlation coefficients between SiO_2 and the other chemical components have a negative sign indicating a reverse variation of their contents. This fact is in agreement with the two modes of formation of the granitoid rocks : by crystallization from a magmatic melting and by granitization.

5.4.4. *Areal Variability of the Major Elements Contents*

The areal distribution of the contents of major elements is important in the research of the petrogenesis of the granitoids in the Furcătura and Petreanu bodies. The trend surfaces were computed separatedly for each of the granitoid bodies for the main eight major chemical components (Figs. 21, 22). The computed trend surfaces for alkali are based on a larger number of chemical analyses as compared with the other major elements.

SiO_2. The areal distribution of silica indicates an increase of the content of this chemical element towards NNW for both granitoid bodies (Fig. 21). This variation trend is evidenced by the distribution of the zones with SiO_2 maximum and minimum contents in the two granitoid bodies.

Al_2O_3. The areal distribution of Al_2O_3 shows a reverse variation of the contents of this chemical element versus those of the silica contents. The zones with maximum contents of Al_2O_3 coincide with those with minimum contents of SiO_2 and viceversa.

Fe_2O_3 and FeO. The content of Fe_2O_3 shows a trend of increase towards the western part of the Furcătura body unlike the FeO contents which display a maximum zone in the northeastern part of the granitoid body. In the Petreanu granitoid body the areal distribution of the two chemical components is similar, the zones with maximum contents being superposed. As

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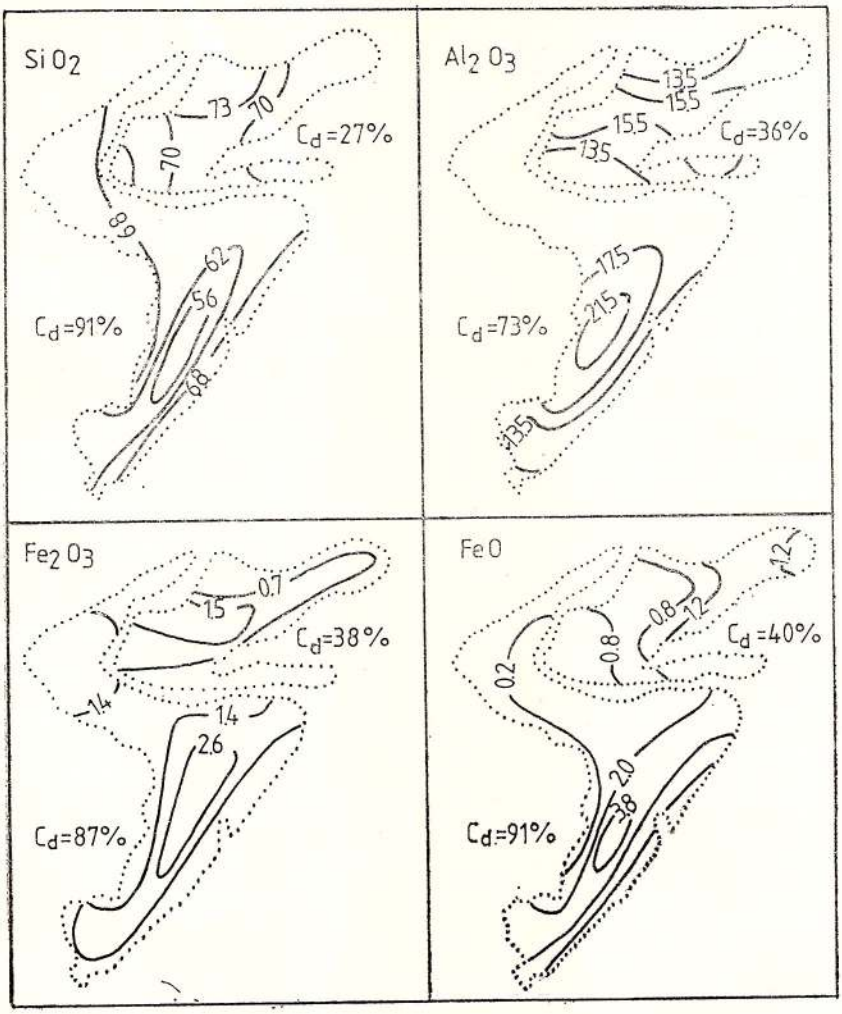

Fig. 21 — Areal distribution of SiO_2, Al_2O_3, Fe_2O_3 and FeO contents.

in case of silica, the two granitoid bodies differ by the value of the determination coefficients of the computed trend surfaces.

MgO and CaO. The areal distribution of the MgO contents indicates a trend of increase towards the northern and southern parts of the Furcătura body, whereas in the Petreanu body the zone with maximum contents occupies a central position in the south of the body. The areal distribution of the CaO contents shows a trend of increase towards NE and SW of the Furcătura body. In the Petreanu body the variation of the CaO contents is quite similar to that of the MgO contents.

Na_2O and K_2O. The areal distribution of the alkalis indicates a reverse behaviour in the two granitoid bodies, the maximum contents zones of a

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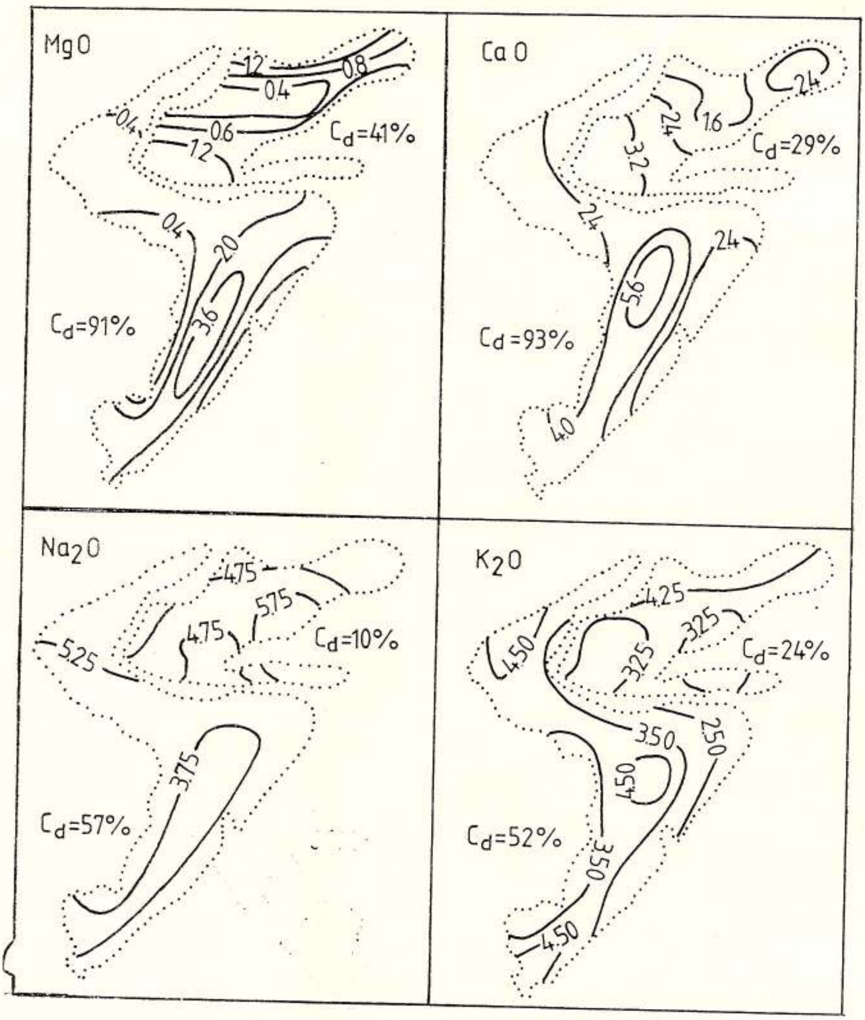

Fig. 22 — Areal distribution of MgO, CaO, Na_2O and K_2O contents.

chemical component coinciding with the minimum contents of the other component.

The areal variability study of the major chemical components points out no connection between their areal distribution in the two granitoid bodies suggesting differences in the formation mode of the granitoids.

5.4.5. *Factor Analysis*

The behaviour of the chemical elements under physico-chemical conditions proper to the petrogenetic processes is relevant for the understanding of the formation process of the granitoids in the Petreanu massif.

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The R-mode analysis emphasized the contribution of each major element in the rocks global variation.

TABLE 13

Values of R-mode factors for granitoid rocks of the Petreanu massif

	Furcătura			Petreanu		
	F 1	F 2	F 3	F 1	F 2	F 3
SiO_2	-0.9730	-0.1776	0.0963	-0.9478	0.1355	-0.1527
TiO_2	0.9795	-0.0404	-0.1517	0.8338	-0.2193	0.2098
Al_2O_3	0.3064	0.9077	0.1916	0.2345	-0.9085	0.0115
Fe_2O_3	0.8061	-0.0234	0.1962	0.6552	0.6363	0.0143
FeO	0.9364	0.0012	-0.1934	0.9335	-0.0779	0.2942
MnO	0.6062	0.4023	0.6197	0.4286	-0.6918	-0.3306
MgO	0.8301	-0.3732	0.1592	0.9390	0.1146	0.2001
CaO	0.9020	0.1013	0.3259	0.8356	0.4403	0.2570
K_2O	0.1362	-0.8892	0.2977	0.4114	0.6175	-0.6082
Na_2O	-0.6471	0.3071	-0.6169	-0.7773	0.0232	0.4668
P_2O_5	0.9478	-0.1049	-0.1928	0.8100	-0.2900	-0.3138
Sum. square	6.7324	2.0649	1.1668	6.1423	2.4543	1.0558
Var. explic.	61.2040	18.7724	10.6077	55.8394	22.3121	9.5982

Table 13 and Figure 23 show the significance of the major contribution, but in a reversed sense, of FeO, TiO_2, P_2O_5, MgO and CaO, on the one hand, and SiO_2, on the other hand, within factor 1 for both granitoid bodies.

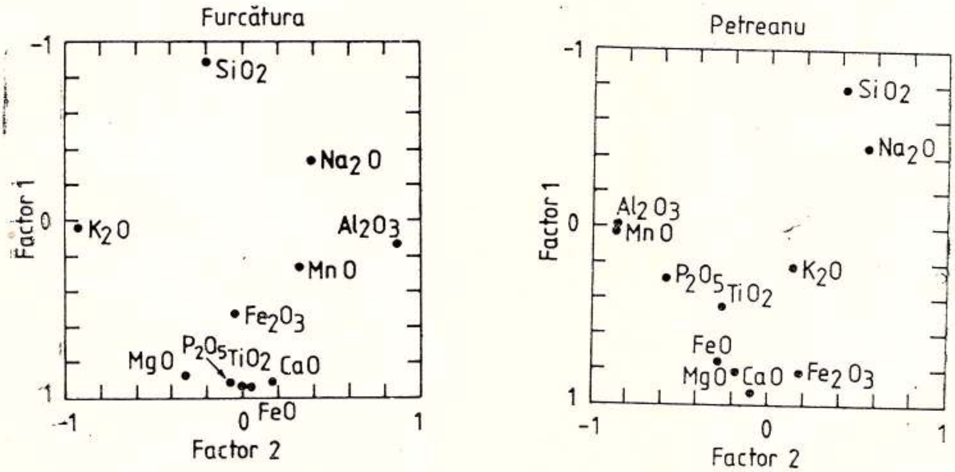

Fig. 23 — Diagram of rotated factors 1 and 2.

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This factor proves almost 61 per cent of the total variation for the Furcătura body and 56 per cent, respectively, for the Petreanu body, being the most important factor when explaining the rock variability. The other factors, each justifying less than 10—20 per cent of the total variation, contain the effect of only one major chemical component.

The fact that the alkali elements, that play a significant part in the metasomatic processes, do not represent a high percentage in the global geochemical variation (factor 1) of the granitoid rocks in the Petreanu body and in the following factors represents a further argument in favour of the hypothesis according to which as a result of these processes the variation of the alkali contents was diminished by a supply of residual fluids, somehow uniform, in the composition.

The contribution of each analysed sample in the total variation of the granitoid rocks was established in the Q-mode analysis. Almost the entire geochemical variability of the rocks is comprised by the first factor (more than 90 per cent for each granitoid body). The studied samples tend to occur on a continuous curve pointing to a gradual transition between the more basic terms and the more acid ones of the analysed rocks ; this trend is more obvious for the Furcătura body than for the Petreanu one.

The results obtained using this method of study were useful for the computing of a synthetic geochemical indicator for a more complete description of the geochemical variability of the study rocks.

As shown by the R-mode analysis, the main chemical components which characterize best the formation process of the granitoid rocks in the Petreanu massif are FeO, TiO_2, P_2O_5, MgO, CaO and SiO_2. For this reason only these chemical components were taken into account and the percentages of each sample for the first Q-mode factor were computed. The factor thus obtained justifies more than 90 per cent of the rock variation and the individual percentages of this factor can be considered as indicators of the geochemical differentiation process. As the influence of the other chemical elements has been eliminated, the sample distribution in the matrix rotated by factors becomes clearer. The drawn up diagrams (Fig. 24) evidence better

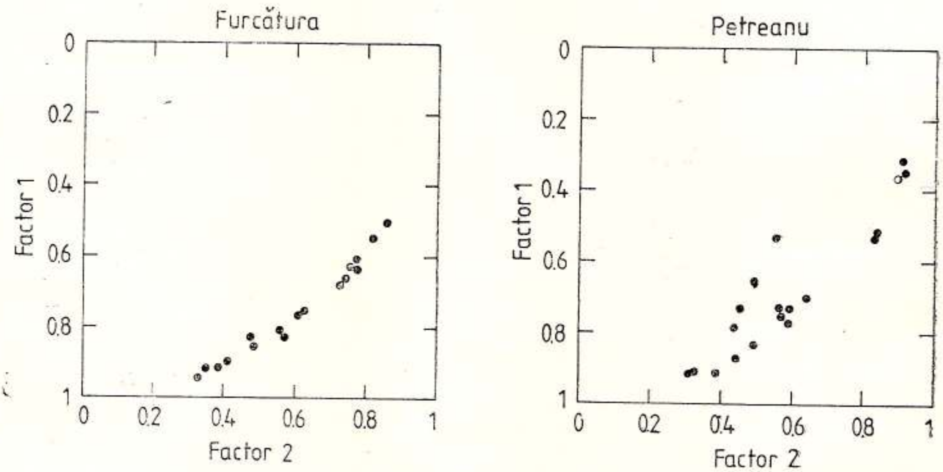

Fig. 24 — Diagram of rotated factors 1 and 2 (only 6 components).

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the petrochemical variations of these rocks by defining a larger variation domain.

In order to establish the areal variation trends of this geochemical variation the individual percentages of the first Q-mode factor were used when computing and drawing up a trend map (Fig. 25). The obtained trend

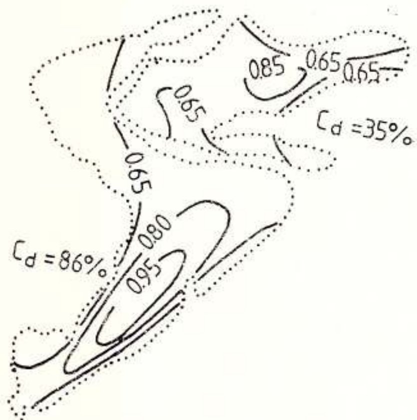

Fig. 25 — Areal variation of the petrogenetic index.

map for the Furcătura body presents a maximum value of the computed petrogenetic indicator in the central zone of the granitoid body. In the Petreanu body the maximum values of this indicator form an elongated zone in the southern part of the granitoid body. The areal distribution of the values of this indicator illustrates the existence of the geochemical and petrogenetic differences between the Furcătura and Petreanu granitoid rocks.

5.4.6. *Content and Statistical Distribution of the Trace Elements*

As shown by many researchers (Shaw, 1964; Taylor, 1965, etc.) the knowledge of the content and distribution of the trace elements plays an important part in the clearing up of the petrogenetic processes. With that end in view the granitoid rocks in the Petreanu massif were analysed by spectrographic (Tab. 14) and X-ray fluorescence method (Tab. 15) and the results of the quantitative analyses were computed, several statistical parameters being calculated (Tab. 16).

Copper. The contents of copper in the Furcătura and Petreanu granitoids vary much (V = 100 %), the variation limits ranging between 4 ppm, and 40 ppm. The average copper content in the two granitoid bodies displays quite close values.

Lead. The variation domain of the lead content differs in the two granitoid bodies, being quite limited for the Furcătura body and much larger for the Petreanu body.

Although both copper and lead are calc-alkali elements with a trend of maximum accumulation in the late magmatic stages they have a different geochemical behaviour (Szadeczky-Kardoss, 1955). This behaviour is illustrated also by the variation of their average contents in the granitoid rocks of the Petreanu massif. The average lead content is much higher in the

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TABLE 14
Trace elements contents in granitoid rocks of the Petreanu massif

No.	Sample no.	Cu	Pb	Sn	Ga	Ni	Co	Cr	V	Li	Be	Ba	Sr	Sc	Y	Yb	La
Furcătura																	
1	4	10	25		15	1	1	2	7			670	350				
2	5	8	28		13	2		1	6			350	200				
3	7	10	25	1	21	3	4	3	20			930	450	5.5	19	2.7	48
4	9	40	28	1	18	1		2	7		4.5	100	65				
5	11	9	29	1	19	3	4	3	23		6	1120	440	5.5	18	1.8	< 30
6	17	10	28	1	19	2		1	11			1200	460				
7	18	9	27	< 1	17	2		1	7		3.8	1700	290	2.5	16	1.3	< 30
8	19	9	22	2	15	2		2	8		3.5	640	580				
9	24	9	24	3	19	2	2	2	16		3.1	2100	520	4.5	22	2	42
10	25	23	25	< 1	19	4	4	3	28			1750	600				
11	42		30		26	6	6			17		1400	740				
12	48	13	28	1	23	4	4	3	32		4.4	950	730	4	16	1.5	< 30
13	52	6	26	1	17	3	1	1	5		3.5	400	310	1.5	22	1.8	< 30
14	56	11	28	1	21	3	4	3	23		5.2	1150	670				
15	60	17	20	1	20	2	3	1	16		4.7	1550	720	2.5	15	1.1	55
16	62		35		20	3	3		3	3		1100	420				
17	65	11	25	2	20	2	2	1	13		3.9	870	510	2	17	1.3	< 30
18	71	15	20	1	22	2	2	2	17		2.7	1500	860				
19	86	7	23	1	18	2	2	1	12		3.2	1220	230				
20	90	13	11	1	19	3	3	2	24		3.5	1800	390	5	15	1.3	96
21	92	9	23	< 1	18	3	2	1	11			1400	700				
22	197	5	32	1.2	19	2	4	3	19		3.8	1300	800	4	17	1.6	30
23	198	4	40		18	2	1.5	1	11		4	430	250				

Petreanu granitoids than in the Furcătura ones as a result of the isomorphous substitution of potash by lead in the crystalline network of the potash feldspar which is more abundant in the Petreanu granitoids.

Tin. The contents of tin in the granitoid rocks ranges between 1 ppm and 3 ppm, displaying very low average values. The geochemical behaviour of tin in the Furcătura and Petreanu bodies is similar to that of lead.

Gallium. The gallium contents display the lowest variation trend from all the trace elements analysed in the granitoid rocks, the variation coefficient being the lowest one.

Nickel. Unlike gallium, the nickel contents in granitoid rocks show a marked variation trend, its values varying between 1 ppm and 6 ppm in the Furcătura body and between 2 ppm and 54 ppm in the Petreanu body. The nickel contents are very different in the granitoid rocks of the massif. The Petreanu granitoid rocks display a nickel content five times higher than the Furcătura granitoid rocks. Being known the nickel geochemical affinity for the ferromagnesian minerals (Goldschmidt, 1954) in which it can substitute Fe^{2+} and Mg^{2+} the higher nickel concentrations in the Petreanu granitoids are explained by the high amount of melanocrate minerals in these rocks.

The average content of nickel in aplites is very close to that in the granitoid rocks of the massif.

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Petreanu (Table 14 – continued)

24	32	12	22	1	19	2	3	1	14		3	1850	620	4	16	1.1	30
25	34	11	16	1	18	2	3	2	14		2.7	2200	440	2.5	15	1.1	50
26	80	12	25	1	21	5	5	7	43		3.7	1370	900				
27	81	14	40		14	3	2	2	22		2.2	3600	650				
28	85	31	20	2	24	10	9	19	64		3.2	1700	1000	1.1	19	2.1	58
29	98	9	50	2	24	9	4	9	59			850	580				
30	101	8	170	2.6	26	7	4	8	38		4.1	1050	750				
31	108	9	60	1.8	27	8	5	11	57		4.5	1100	800				
32	111		75		18	4	4		15	17		1800	800				
33	112	7	80	2.2	26	9	5	8	52		2.2	1750	900	8.5	19	1.7	56
34	116	8	52	2.2	24	10	4	14	40			1100	870				
35	117	5	14	3.1	28	13	8	23	73		2.6	1800	1700	14	28	2.6	78
36	118	43	38	3.6	25	34	11	63	73		5.8	1180	930				
37	125	4	30	2.2	22	10	5	17	41		2.2	1800	1600				
38	129	33	125	3.7	26	54	14	90	97		6	1350	1000	16	32	3.2	82
39	137	7	25	2.4	20	37	14	85	110		5.3	1620	1150				
40	140	8	27		12	2	2	1	8		1	3400	820				
41	141	6	26	2.7	28	30	10	60	80			2100	1700				
42	142	9	16	2	18	19	10	50	70		3	2900	1000	12	22	2.3	76
43	143	70	27	2	17	40	19	100	95			1800	850	16	22	2.7	60
44	148	6	22	1.3	23	12	9	23	78		2.7	2000	1700				
45	151	19	32	2.3	24	34	15	70	95		5.5	1700	1600				
46	152	9	57	1.7	25	14	10	27	90		2.5	1800	1100	8	19	1.8	125
47	158	4	15	1.7	20	20	9	40	72		3	2600	1700	13	29	2.8	96
48	160		40		19		9		50	17		1500	600				
49	163	4	19	1.5	22	15	8	30	72		3.1	1750	1500	10	25	1.8	90
50	165		50		16		10		25	12		1600	870				
51	167		30		13		9		20	3		1800	900				
52	176	6	82	2	20	18	10	40	82		3.7	1950	1400	14.5	31	2.5	75
53	180	7	53		23	11	4	4	12		1.8	430	600				
54	183	10	20	2.3	22	19	14	30	118		4.2	1500	1000	18	32	3.3	80
55	185	9	42	1.6	20	16	9	36	17		2.8	1900	900	9	26	2.4	68
56	193	5	31	1.1	23	6	4	7	44		6	1350	800	7.5	19	1.9	70
57	195	8	12	1.8	19	9	4	6	12		2.9	600	570				
58	220		15						40	7		1600	750				
59	124	12	35	2.2	26	11	4	11	17		2.3	620	950				
60	135	8	75	2.1	27	12	4	8	19			500	420				
61	147	12	42	2.2	24	10	3	10	16			540	600				
62	166	5	78		19	11	3	9	17			2000	1600				

1 – 25, granitic gneisses; 28–39, 41–56, 58, granitoid gneisses; 26, 27, 40, 57, granites; 59 – 62, aplites

Analysts: Viorica Mîndroiu and Constanța Udrescu

Cobalt. Although the variation domain of the cobalt content is more reduced than in case of nickel, the high value of the variation coefficient points to a marked variation trend of the cobalt contents especially in the Furcătura granitoid rocks. Due to the atomic features the geochemical behaviour of cobalt in the studied rocks is similar to the nickel behaviour, the content differences between the granitoid bodies mentioned in case of nickel occur also for cobalt. Thus, the cobalt contents in the Furcătura granitoid rocks are, generally, less than 5 ppm, whereas the Petreanu granitoid rocks

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TABLE 15
Contents and relations of some trace elements in granitoid rocks of the Petreanu massif

No.	Sample no.	Rb	Sr	Y	Zr	Nb	K/Rb	Ba/Rb	Rb/Sr
Furcătura									
1	22	119	719	8.0	155	14.3	260		0.16
2	197	135	689	8.7	145	15.8	179	9.62	0.20
3	48	109	685	13.9	155	16.1	199	8.71	0.16
4	11	148	587	20.0	136	21.7	189	7.56	0.25
5	32	107	700	14.8	168	14.3	256	17.28	0.15
6	90	133	332	15.4	146	8.3	212	13.53	0.40
7	92	125	647	11.8	137	15.2	199	11.20	0.19
8	198	191	269	34.6	78.2	19.3	172	2.25	0.71
9	62	166	332	21.1	62.1	17.3	189	6,62	0.50
Petreanu									
10	151	151	730	22.4	188	16.3	236	11.25	0.21
11	183	127	686	23.6	179	16.8	212	11.81	0.18
12	117	100	860	24.0	216	15.6	277	18.00	0.12
13	141	128	756	16.7	186	11.8	292	16.40	0.17
14	158	110	812	24.5	195	10.7	281	23.63	0.14
15	112	93.6	634	18.9	150	12.8	237	18.69	0.15
16	163	140	767	20.9	212	13.0	183	12.50	0.18
17	193	145	706	17.9	200	14.1	196	9.44	0.20
18	101	94.4	623	22.6	141	13.3	250	11.12	0.15
19	134	128	919	8.2	188	15.8	200		0.14
20	125	106	849	11.3	165	14.7	398	16,98	0.13
21	195	120	449	9.6	209	12.4	200	5.00	0.27
22	180	73.8	587	8.0	142	12.0	183	5.82	0.12

Analyst: Gabriela Grabari

are higher than this value. Unlike nickel, the average cobalt content in aplites is, however, much lower than that in the granitoid rocks.

Chromium. The contents of this chemical element present the most marked variation from all the studied trace elements in the granitoids of the two bodies. The chromium contents in granitoids vary concomitantly with the amount of melanocrate minerals. The much higher contents of chromium in the Petreanu granitoids than in the Furcătura ones can be explained by the isomorphism between Cr^{3+} and Fe^{3+} whose ionic rays are 0.64 and 0.67 A, respectivelly. The average chromium content in aplites is much lower than that in granitoids.

Vanadium. The variation domain of the vanadium contents ranges between 3 ppm and 118 ppm, showing a quite marked variation of its concentration. As in case of other trace elements associated with melanocrate

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TABLE 16
Statistical parameters of trace elements distribution in granitoid rocks of the Petreanu massif

	Furcătura						Petreanu					
	n	$X_{min.}$	$X_{max.}$	$\bar{X}$	s	V	n	$X_{min.}$	$X_{max.}$	$\bar{X}$	s	V
Cu	21	4	40	11.8	14.5	100	34	4	70	12.6	13.3	105
Pb	23	11	40	26.2	6.8	25	39	12	170	43.3	32.2	74
Ni	23	1	6	2.7	5.3	146	35	2	54	15	12.1	81
Co	18	1	6	2.9	4.1	108	38	2	19	7.3	4.2	57
Cr	21	1	3	1.9	3.2	158	34	1	100	27.1	27.6	102
V	22	3	32	14.5	20	109	39	8	118	51.3	31.5	61
Ba	23	100	2100	111.4	523	46	39	430	3600	1642	702	43
Sr	23	65	860	491	210	43	39	420	1700	990	385	39
Sn	16	1	3	1.2	1.4	93	30	1	3.7	2	0.7	33
Be	15	2.7	6	4.0	2.9	62	27	1	6	3.4	1.4	40
Ga	23	13	26	18.9	2.7	14	38	12	28	21.6	4.1	19
Li	2	3	17				5	3	17	11.2		
Rb	9	109	191	137			13	73.8	151	115	22	19
Sc	10	1.5	5.5	3.7			15	1.1	18	10.3	5.1	50
Y	10	15	22	17.7			15	15	32	23.6	5.8	24
Yb	10	1.1	2.7	1.7			15	1.1	3.3	2.2	0.7	30
La	10	30	96	42			15	30	125	73	22	30
Nb	10	8.3	21.7	15.8			13	10.7	16.8	13.7	1.8	13
Zr	9	62.1	155	131			13	141	216	181	26	14
U	53	0.8	5.6	2.3	1.0	44	85	0.5	9.3	2.7	1.8	69
Th	53	0.4	39.4	7.4	5.7	78	86	2.5	33.9	12.1	5.9	49
K	53	1.1	6.9	3.2	0.9	29	86	1.4	6.4	3.4	0.8	25

minerals, the high vanadium contents occur in the Petreanu granitoids. The isomorphous substitution with the corresponding vanadium ions of the Ti^{4+} ions (r =0.66 A) and P^{5+} ions (r = 0.35 A) in the sphene and apatite network, accessory minerals found frequently in the analysed granitoids, explains the quite high average content of vanadium in these rocks.

Beryllium. The contents of this chemical element are, generally, reduced, ranging between 1 and 6 ppm. The average content of beryllium in the granitoid rocks of the Petreanu massif is close to the that found by Goldschmidt and Peters (1932) in the granitic rocks.

Barium. Barium contents do not show a quite high variation coefficient, most of the studied samples having values closer to the average value. Although the variation of the barium contents versus the mineralogical composition of the study rocks is not as obvious as in case of other trace elements (Ni, Cr, V), the highest contents of barium are found in rocks richer in potash feldspar and micas. The higher average contents of barium in these rocks can also be explained by the abundance of potash feldspars in the Petreanu granitoids.

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Strontium. The geochemical behaviour of strontium is very similar to that of barium, as shown by Rankama and Sahama (1950), the rocks with high contents of one of the two metals being usually rich in the other metal, too. The average content of strontium in the Petreanu granitoids is more than twice higher than in the Furcătura granitoids. The higher contents of strontium in the Petreanu granitoids can be explained by the geochemical affinity for K^+ and Ca^{2+}, ions with radiums close in size with that of Sr^{2+}, present in the crystalline network of feldspars, minerals representing more than two thirds of the rock volume.

A comparison of the average content of barium and strontium in the Petreanu granitoids with that in the Rathjen gneisses in South Australia (White, 1966), in which the average content of barium is 720 ppm and of strontium 130 ppm, indicates that in the Petreanu granitoids the average content of barium is more than twice higher and that of strontium seven times higher.

Scandium. The scandium contents in the two granitoid bodies vary between 11 ppm and 18 ppm, the variation coefficient being quite high. This variation of the scandium contents is determined by the clear trend of this chemical element to concentrate mainly in the network of the melanocrate minerals in which it can replace Mg^{2+} (r = 0.78 A) and Fe^{2+}(r = 0.83 A).

The average content of scandium in the Petreanu granitoids is almost three times higher than in the Furcătura granitoids clearly demonstrating this trend.

Rare earths. The rare earths elements contents show a medium variation, although the values of their average contents are quite different. The average contents of the rare earths are twice or three times higher in the Furcătura granitoids than in the Petreanu ones.

Niobium. The niobium contents in the analysed granitoids are quite uniform and there is no difference between the Furcătura granitoids and Petreanu granitoids. The average value of the niobium contents in the Furcătura and Petreanu granitoids is lower than that computed by Taylor (1964) for the granitic rocks in the Earth's crust (20 ppm).

Zirconium. The zirconium contents in the granitoid rocks vary from 62.1 ppm to 216 ppm. Unlike niobium, zirconium distribution displays significant differences between the two bodies, the average content of zirconium in the Furcătura granitoids being much lower than in the Petreanu granitoids and than the average value for the granitic rocks in the Earth's crust (180 ppm). The average content of zirconium in the Furcătura granitoids is closer to the average content of this chemical element in the Vîrful Pietrii granitoids (120 ppm) than that of the Petreanu granitoids.

Rubidium. The variation domain of the rubidium contents in the Furcătura and Petreanu granitoids ranges between 73.8 ppm and 267 ppm. The variation of the rubidium contents in the Furcătura and Petreanu granitoids points out the mineralogical influence on the distribution of this chemical element. Thus, the Furcătura granitoids, although with an average content of K_2O close to that of the Petreanu granitoids, present an average content higher than the Petreanu granitoids due to the greater quantity of biotite as compared with potash feldspar. The average content of rubidium in the Furcătura granitoids (137 ppm) is very close to that of Vîrful Pietrii granite and to the average value for the granitic rocks in the Earth's crust,

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while the average content of the Petreanu granitoids (115 ppm) is much lower,

This difference between the Furcătura and Petreanu granitoids is evidenced also by the values of the ratios K/Rb, Ba/Rb and Rb/Sr which have a special petrogenetic significance. Thus, in the Furcătura granitoids (198) the average values of the K/Rb ratio is almost identical with that in the Vîrful Pietrii massif (197), while the average value of this ratio in the Petreanu granitoids (242) is higher and almost equal to that computed for the granitoids in the Earth's crust (Erlank, 1968). The same variation is observed in case of the Ba/Rb ratio whose average value is lower in the Furcătura granitoids (9.26) than in the Petreanu granitoids (13.4). In exchange the value of the Rb/Sr ratio is twice higher in the Furcătura granitoids (0.34) than in the Petreanu ones (0.17).

The frequency histograms (Fig. 26) of the trace elements contents, drawn up on aritmethical scale, do not indicate significant differences bet-

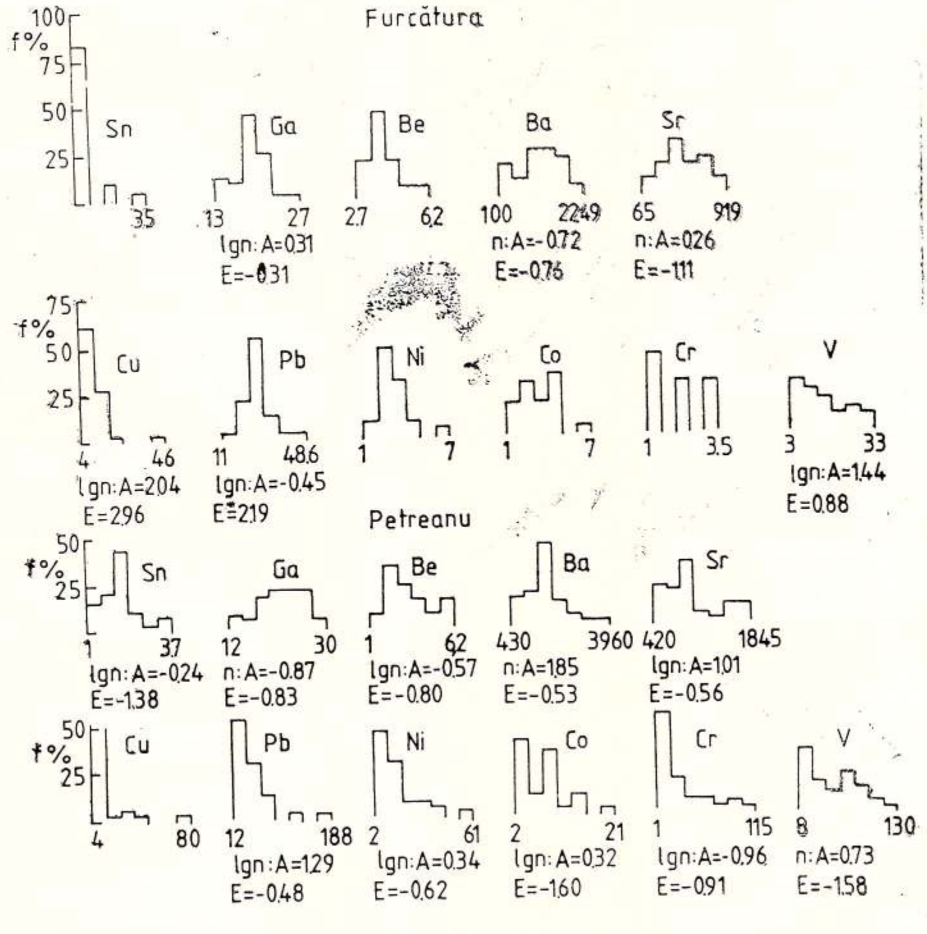

Fig. 26 — Frequency histograms of the trace elements.

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ween the two bodies. The values of the numerical test evidence the lognormal character or the tendency towards lognormal statistical distribution of the contents of most of the trace elements except for barium and strontium in the Furcătura body and for barium, gallium and vanadium in the Petreanu body.

The different behaviour of gallium, strontium and barium in comparison with the other trace elements is probably due to their presence in almost equal quantities in two or several minerals unlike the other trace elements which are concentrated especially in a single mineral.

5.4.7. *Trace Elements Correlation*

The study of the relationships between the trace elements contents in the Furcătura and Petreanu granitoids points out a moderate frequency of the correlation between the contents of these chemical elements(Tab.17).

Almost half the number of the computed linear correlation coefficients indicates a significant correlation between the study trace elements contents ($r > 0.4$). The highest values of the correlation coefficients occur between cobalt and chromium in the Furcătura granitoids and between Co, Cr and V in the Petreanu granitoids. There is a good correlation ($0.6 < r < 0.8$), especially in the Furcătura body, between some of the study trace elements (ca 30 per cent of the computed correlation coefficients). In all cases the sign of the correlation coefficient is positive indicating a direct correlation between the variation of the trace elements contents.

A particularity of the Petreanu granitoid body is the absence of any correlation between the lead and copper contents and the contents of the other study trace elements.

TABLE 17

Correlation coefficients between trace elements in granitoid rocks of the Furcătura Body (above diagonal) and of the Petreanu Body (below diagonal)

	Cu	Pb	Sn	Ga	Ni	Co	Cr	V	Be	Ba	Sr
Cu		0 07	0 42	0.17	0.46	0.68	0.62	0.50	0.61	0.02	-0.14
Pb	0.08		0 41	-0.01	0.34	0.34	0.37	0.04	0.54	-0.20	-0.14
Sn	0.25	0.35		-0.23	0.58	0.00	0.62	0.45	0.00	0.19	0.04
Ga	-0.05	0.23	0.50		0.30	0.41	0.18	0.43	-0.02	0.39	0.48
Ni	0.24	0.06	0.69	0.43		0.80	0.74	0.66	0.76	0.42	0.30
Co	0.30	-0.14	0.40	0.17	0.83		0.81	0.75	0.00	0.52	0.28
Cr	0.22	-0.01	0.58	0.37	0.92	0.89		0.77	0.77	0.23	0.14
V	0.14	-0.06	0.35	0.40	0.72	0.81	0.84		0.65	0.47	0.38
Be	0.34	0.20	0.25	0.48	0.53	0.57	0.57	0.62		0.07	-0.06
Ba	-0.06	-0.25	-0.19	-0.49	-0.11	0.18	0.09	0.27	-0.13		0.72
Sr	-0.27	-0.15	0.25	0.17	0.49	0.49	0.58	0.56	0.16	0.45	

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Several correlation diagrams have been drawn up in order to study the relationships between some trace and major elements that can be substituted isomorphically in the mineral crystalline networks.

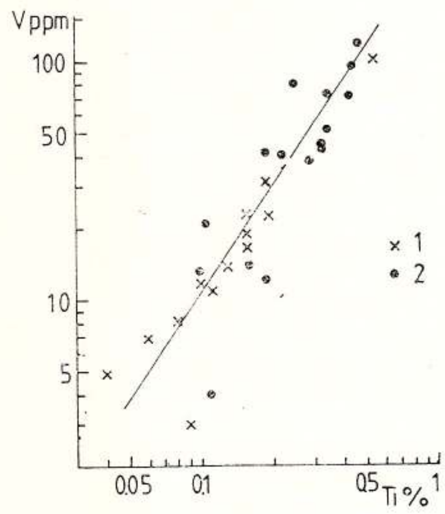

Fig. 27 — V-Ti diagram (see legend to Fig. 19).

Except for the V-Ti diagram (Fig. 27), which shows a very good correlation between the contents of these chemical elements evidencing their geochemical affinity and the possible isomorphic substitution of Ti^{4+}(r=0.68 A) by V^{3+}(r=0.74 A), the diagrams drawn up for the other pairs of chemical elements (Pb-K, Ba-K, Cu-Fe^{2+}, Cu-Mg) point to the lack of any correlation between the variation of their contents.

5.4.8. *Variation of the Trace Elements Contents*

Although not all the granitoid rocks of the Petreanu massif were formed by crystallization from a magma proper, their appearance can be connected with a magmatic phase represented either by residual solutions, that led to the granitization of the host rocks, or by the anatexis of the preexistent rocks.

The study of the variation of the trace elements contents during the granitization processes represents an important aspect of the geochemistry of the granitoid rocks in the Petreanu massif. Several ratios and diagrams point out :

— aluminium content, although shows wide variations from one sample to another, tends to decrease concomitantly with the increase of the rock acidity, that is from the Petreanu granitoids towards the Furcătura granitoids. The gallium content decreases in the same sense as the aluminium one illustrating the geochemical relationships between these chemical elements (Shaw, 1964). The $Ga \times 10^3/Al$ ratio varies between 0.15 and 0.37 with an arithmetical mean of 0.23 ;

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— the variation of the Mg and Fe_{tot} contents indicates an obvious decrease concomitantly with the transition towards more acid terms of the Furcătura granitoids. This trend also occurs in the variation of the contents of chromium, nickel, cobalt and vanadium, but it is much diminished especially for cobalt and nickel. The behaviour of the trace elements geochemically associated with iron and manganese in the granitization process is pointed out both by the variation of the ratio of these elements versus the major elements contents and by the variation of the ratios between them. Thus, the values of the ratios between the mentioned trace elements and Fe_{tot} decrease from the Petreanu granitoids towards the Furcătura granitoids. The $V \times 10^3/Fe_{tot}$ ratio shows the highest variation degree, whereas the $Co \times 10^3/Fe_{tot}$ ratio presents a very low variation ;

— the content of strontium and barium decreases concomitantly with the increase of the rock acidity. The variation of the barium and potassium contents indicates the absence of any relationship between them, suggesting that the barium presence is related with another chemical element, probably calcium. The geochemical behaviour of barium and strontium in the granitoids formation process in the Furcătura and Petreanu bodies is illustrated also by the variation of the $Ba \times 10^2/K$ and $Sr \times 10^2/Ca$ ratios. In spite of the wide dispersion of the values of the mentioned ratios a trend of decrease of the ratios towards the more acid rocks of the Furcătura body is obvious ;

— the variation of the scandium, yttrium and ytterbium contents in the study granitoids indicates a decrease of their contents simultaneously with the increase of the rock acidity, and, for yttrium and ytterbium, a slight trend of increase of the contents of these elements in the most acid terms of the Furcătura granitoids.

5.4.9. *Distribution and Correlation of the Radioelements,*

The contents of uranium, thorium and potassium have been determined in order to study the radioactivity of the granitoid rocks of the Petreanu massif (Tab. 18).

The unimodal aspect of the distribution histograms, drawn up on an aritmethical scale (Fig. 28), points out the homogenous character of the analysed rock collectivity. The degree of symmetry of the frequency histograms varies from highly left asymmetric for uranium to almost symmetric in case of potassium. The quantitative checking of the statistical distribution aw of the radioelements contents shows that they present a lognormal statistical distribution in both granitoid bodies.

The statistical distribution parameters (Tab. 16) evidence the variation of the radioelements contents in the study rocks. The uranium average contents in the two bodies are quite close, whereas the thorium average content in the Petreanu body is almost twice higher than in the Furcătura body. The highest thorium contents in comparison with the uranium contents in the granitoid rocks are also pointed out by the supraunitary value of the Th/U ratio. The variation of the radioactive potassium contents in the Furcătura and Petreanu bodies is smaller than that of uranium and thorium . The granitoid rocks of the Furcătura and Petreanu bodies display

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TABLE 18

Radioactive elements contents and values of radiogene heat production in granitoid rocks of the Petreanu massif

No.	Sample no.	Location	U ppm	Th ppm	K %	Th/U	H.P. μcal/g.an
1	2	3	4	5	6	7	8
		Furcătura					
1	2	Rîul Mare	2.5	11.4	2.40	4.6	4.75
2	3	Rîul Mare	2.0	7.9	2.70	3.9	3.77
3	4	Rîul Mare	1.3	3.7	3.60	2.8	2.66
4	5	Rîul Mare	1.0	3.1	4.10	3.1	2.46
5	6	Rîul Mare	2.4	9.0	2.60	3.7	4.25
6	7	Rîul Mare	2.9	11.9	3.10	4.1	5.33
7	9	Rîul Mare	3.0	1.5	3.60	0.5	3.46
8	10	Rîul Mare	2.4	9.9	2.90	4.1	4.52
9	11	Rîul Mare	1.9	9.1	3.00	4.8	4.02
10	36	Rîul Mare	3.0	5.7	4.27	1.9	4.48
11	37	Rîul Mare	2.8	7.3	2.70	2.6	4.23
12	43	Rîul Mare	2.9	9.9	3.20	3.4	4.96
13	54	Rîul Mare	1.3	2.3	1.10	1.7	1.71
14	56	Rîul Mare	1.4	5.1	3.30	3.6	2.93
15	15	Brook Rîuşorul Hobiţei	5.0	16.6	3.20	3.3	7.83
16	16	Brook Rîuşorul Hobiţei	1.8	10.8	2.40	6.0	4.12
17	18	Brook Rîuşorul Hobiţei	1.6	4.1	3.20	2.6	2.85
18	19	Brook Rîuşorul Hobiţei	1.1	0.6	1.60	0.5	1.35
19	22	Brook Rîuşorul Hobiţei	2.1	6.3	2.60	3.0	3.49
20	23	Brook Rîuşorul Hobiţei	1.5	4.6	3.10	3.0	2.85
21	24	Brook Rîuşorul Hobiţei	2.3	6.7	3.30	2.9	3.91
22	25	Brook Rîuşorul Hobiţei	0.8	39.4	3.75	49.2	9.48
23	38	Brook Luncii	3.1	7.5	2.60	2.4	4.46
24	39	Brook Luncii	1.8	4.5	3.50	2.5	3.16
25	40	Brook Luncii	4.9	6.1	2.20	1.2	5.39
26	41	Brook Luncii	1.7	8.2	2.20	4.8	3.48
27	42	Brook Luncii	3.3	1.8	3.40	0.5	3.69
28	46	Brook Bălanu	3.5	17.7	3.40	5.0	7.01
29	48	Brook Repede	2.2	8.2	2.40	3.7	3.89
30	49	Brook Repede	2.6	6.3	5.40	2.4	4.62
31	51	Brook Rof	2.6	9.1	3.70	3.5	4.72
32	52	Brook Rof	1.8	3.1	4.00	1.7	3.01
33	53	Brook Rof	1.2	2.4	4.00	2.0	2.44
34	57	Brook Jura	1.4	5.1	3.30	3.6	2.93
35	58	Brook Jura	1.1	5.3	3.00	4.8	2.67
36	59	Brook Jura	2.6	5.9	2.70	2.3	3.81
37	60	Brook Jura	1.5	7.1	2.70	4.7	3.24
38	62	Brook Valea cu pietre	2.0	4.3	2.90	2.1	3.10
39	63	Brook Valea cu pietre	3.1	3.6	3.58	1.2	3.93
40	64	Brook Valea cu pietre	2.3	6.3	3.10	2.7	3.78
41	65	Brook Valea cu pietre	3.3	7.7	3.50	2.3	4.89
42	66	Brook Valea cu pietre	1.3	5.9	3.30	4.5	3.02
43	86	Brook Căldării	5.6	12.9	3.40	2.3	7.59
44	87	Brook Căldării	2.7	0.4	5.30	0.1	3.48
45	88	Brook Căldării	1.8	6.1	2.10	3.4	3.10

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(Table 18 - continued)

1	2	3	4	5	6	7	8
46	89	Brook Căldării	2.4	7.7	3.30	3.2	4.18
47	90	Brook Căldării	2.8	13.4	3.00	4.8	5.53
48	91	Brook Voila	3.1	7.0	2.60	2.2	4.36
49	69	Brook Sipote	1.6	7.8	2.40	4.8	3.38
50	70	Brook Sipote	1.9	5.0	6.90	2.6	4.25
51	71	Brook Sipote	2.8	6.5	3.00	2.3	4.15
52	72	Brook Sipote	1.5	7.0	2.80	4.6	3.25
53	73	Brook Sipote	0.8	4.1	2.90	5.1	2.19
		Petreanu					
54	140	Brook Cracului	0.5	7.9	3.87	15.8	2.99
55	141	Brook Cracului	1.2	9.5	3.57	7.9	3.74
56	142	Brook Cracului	1.4	8.4	3.76	6.0	3.72
57	143	Brook Cracului	3.1	14.2	3.88	4.6	6.15
58	144	Brook Cracului	4.5	19.9	2.34	4.4	7.90
59	145	Brook Cracului	5.0	18.5	2.62	3.7	8.06
60	27	Brook Slatina	4.1	14.2	2.98	3.5	6.64
61	28	Brook Slatina	3.3	19.5	4.66	5.9	7.57
62	29	Brook Slatina	1.1	6.5	4.12	5.9	3.22
63	30	Brook Slatina	0.8	3.3	3.10	4.1	2.08
64	31	Brook Slatina	1.8	2.9	3.20	1.6	2.76
65	32	Brook Slatina	1.8	6.7	3.10	3.7	4.07
66	34	Brook Slatina	1.9	6.9	3.10	3.6	3.60
67	80	Brook Scoabele	2.0	11.4	1.40	5.7	4.12
68	81	Brook Scoabele	1.4	4.2	3.50	3.0	2.81
69	84	Brook Băldiniş	1.4	8.3	3.20	5.9	3.55
70	85	Brook Băldiniş	1.0	9.3	2.80	9.3	3.35
71	94	Rîul Mare	6.9	17.3	4.40	2.5	9.66
72	95	Rîul Mare	5.8	11.8	4.10	2.0	7.70
73	96	Rîul Mare	7.0	11.4	3.80	1.6	8.42
74	97	Rîul Mare	3.7	14.2	2.64	3.8	6.25
75	98	Rîul Mare	2.8	15.4	3.60	5.5	6.10
76	99	Rîul Mare	1.2	3.2	4.50	2.6	2.73
77	100	Rîul Mare	2.8	15.4	3.30	5.5	6.02
78	101	Rîul Mare	4.2	13.9	2.80	3.3	6.60
79	102	Rîul Mare	2.9	14.2	2.93	4.9	5.75
80	103	Rîul Mare	5.5	10.7	2.79	1.9	6.91
81	104	Rîul Mare	3.6	10.4	2.18	2.9	5.30
82	105	Rîul Mare	2.8	11.9	3.18	4.3	5.28
83	106	Rîul Mare	2.6	10.2	2.96	3.9	4.74
84	113	Rîul Mare	2.1	10.3	2.49	4.9	4.26
85	115	Rîul Mare	1.1	17.7	3.40	16.1	5.26
86	116	Rîul Mare	1.0	16.1	4.05	16.1	5.04
87	117	Rîul Mare	0.9	11.9	3.07	13.2	3.87
88	118	Rîul Mare	2.9	20.8	4.57	7.2	7.51
89	121	Rîul Mare	1.3	12.9	3.05	9.9	4.35
90	122	Rîul Mare	1.0	13.7	4.16	13.7	4.59
91	123	Rîul Mare	1.0	13.8	4.15	13.7	4.60
92	125	Rîul Mare	1.1	10.4	3.77	9.4	3.90
93	138	Rîul Mare	8.9	21.0	4.80	2.4	11.99
94	154	Rîul Mare	1.8	26.1	3.44	14.6	7.46
95	155	Rîul Mare	1.3	18.6	4.00	14.3	5.75
96	158	Rîul Mare	1.1	10.7	3.78	9.7	3.96
97	159	Rîul Mare	1.4	22.2	3.21	15.8	6.33
98	157	Rîul Mare	3.0	2.9	6.43	1.0	4.51
99	161	Rîul Mare	3.3	9.3	2.55	2.8	4.96
100	162	Rîul Mare	1.8	8.9	2.47	4.9	3.76

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(Table 18 - continued)

1	2	3	4	5	6	7	8
101	163	Rîul Mare	1.3	18.5	3.01	14.2	5.46
102	164	Rîul Mare	1.4	19.5	3.30	13.9	5.81
103	165	Rîul Mare	1.5	18.5	3.43	12.3	5.72
104	166	Rîul Mare	3.9	8.0	3.31	2.1	5.34
105	167	Rîul Mare	3.8	10.5	3.18	2.8	5.73
106	168	Rîul Mare	2.4	18.1	3.19	7.5	6.23
107	169	Rîul Mare	4.5	11.9	3.77	2.6	6.68
108	170	Rîul Mare	4.0	7.8	2.71	1.9	5.21
109	171	Rîul Mare	6.8	3.3	2.48	0.5	6.29
110	173	Rîul Mare	0.8	3.9	1.73	4.9	1.83
111	108	Brook Căprioarei	2.4	18.8	2.68	7.8	6.24
112	109	Brook Căprioarei	3.2	20.2	3.72	6.3	7.38
113	110	Brook Căprioarei	2.8	10.5	3.03	3.7	4.96
114	111	Brook Căprioarei	5.5	18.2	2.75	3.3	8.40
115	112	Brook Căprioarei	1.4	12.1	3.02	8.6	4.26
116	127	Brook Lunca de laţuri	3.8	33.9	5.36	8.9	11.00
117	128	Brook Lunca de laţuri	4.1	20.9	4.87	5.1	8.49
118	129	Brook Lunca de laţuri	3.3	14.4	4.75	4.4	6.57
119	131	Brook Lunca de laţuri		20.2	3.91		
120	132	Brook Lunca de laţuri	1.4	5.7	4.32	4.1	3.33
121	133	Brook Lunca de laţuri	1.7	6.4	4.64	3.8	3.77
122	134	Brook Lunca de laţuri	1.5	8.9	2.63	5.9	3.58
123	135	Brook Lunca de laţuri	2.5	10.6	3.10	4.2	4.78
124	136	Brook Lunca de laţuri	2.5	8.8	3.53	3.5	4.54
125	137	Brook Lunca de laţuri	2.0	4.0	4.82	2.0	3.56
126	146	Brook Valea Mare	1.4	11.7	2.46	8.4	4.03
127	147	Brook Valea Mare	3.6	12.0	2.54	3.3	5.71
128	148	Brook Valea Mare	0.9	9.7	3.17	10.8	3.45
129	149	Brook Valea Mare	2.4	4.2	4.13	1.7	3.71
130	151	Brook Valea Mare	4.9	15.2	4.08	3.1	7.72
131	152	Brook Valea Mare	1.0	16.2	2.98	16.2	4.77
132	153	Brook Valea Mare	2.9	11.1	3.09	3.8	5.17
133	176	Brook Bodu	1.2	8.0	3.13	6.7	3.32
134	177	Brook Bodu	0.9	3.4	3.11	3.8	2.18
135	179	Brook Bodu	1.8	2.5	1.51	1.4	2.22
136	182	Brook Netiş	9.3	9.5	3.03	1.0	9.51
137	183	Brook Netiş	2.3	7.3	3.14	3.2	3.99
138	184	Brook Netiş	0.9	7.2	3.01	8.0	2.91
139	185	Brook Netiş	1.2	11.3	2.99	9.4	3.94

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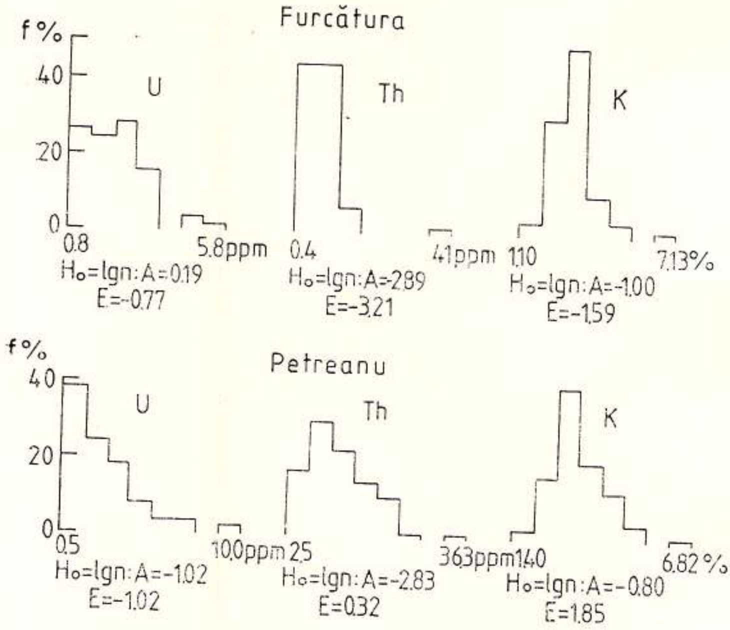

Fig. 28 — Frequency histograms of the radioactive elements.

smaller average contents of radioelements in comparison with other granitoid massifs of the Danubian Realm (Savu et al., 1973).

The correlation diagrams and the very low values of the computed linear correlation coefficients ($r_{U-Th} = 0.20$, $r_{U-K} = 0.11$, $r_{Th-K}=0.03$ for the Furcătura body and $r_{U-Th}=0.26$, $r_{U-K}=0.05$, $r_{Th-K}=0.14$ for the Petreanu body) point to the absence of such relations between the radioelements contents in the Petreanu granitoids.

The areal distribution (Fig. 29) of the uranium and thorium contents in the Furcătura body points out a trend of increase towards the margins of the body, particularly to the northern side. The contents of radioactive potassium do not show any clear trend of variation in the Furcătura body. In the Petreanu body all the three radioelements show a trend of increase of the contents towards the axial zone in the southern part of the body.

5.5. *Genesis of the Granitoid Rocks in the Petreanu Massif*

Unlike the Vîrful Pietrii granitoid, whose magmatic origin has not been contested up till now, the formation of the granitoid rocks in the Petreanu massif was and still is under discussion, evidencing the complexity of the geological processes in the study region.

The enumeration of the hypotheses based on the geological researches related to the nature and genesis of the two granitoid bodies in the Petreanu massif shows that it might represent :

— the superficial part of some intrusive bodies (Giușcă, 1974) ;

— metamorphosed intrusive bodies (Mrazec in Schafarzik, 1899 ; Dimitrescu, 1985) ;

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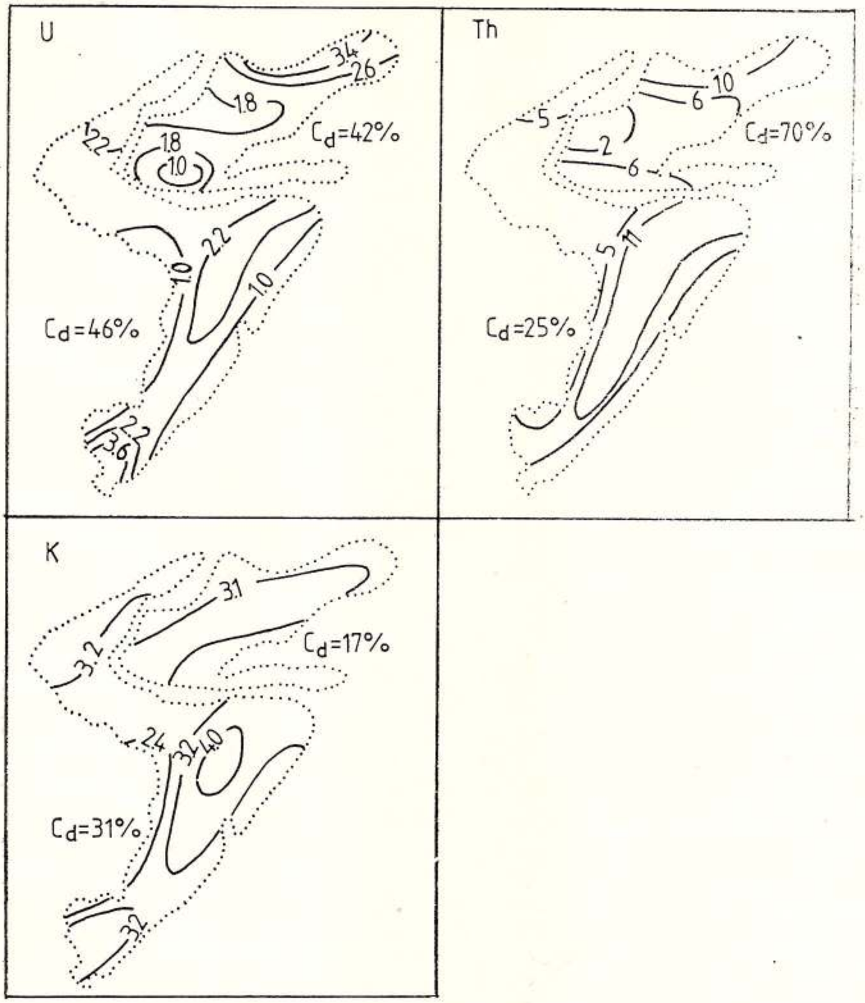

Fig. 29 — Areal distribution of the radioactive elements content.

— an intrusive body (Furcătura) and a migmatic one (Petreanu) (Kräutner et al., 1981);

— two migmatic bodies : —lateral migmatization (Gherasi, Dimitrescu, 1970);

— *in situ* migmatization (Gherasi, Dimitrescu, 1970; Kräutner, 1980).

The mineralogical, petrographical, geochemical and structural observations point out significant differences between the Furcătura and Petreanu granitoids, suggesting different petrogenetic and evolution processes.

As already mentioned at the mineralogical description of the rocks, although they consist of the same mineralogical components, their percentage differs and for this reason in the Furcătura granitoid the more acid petrographic types predominate (granites and leucocrate granites) whereas the Petreanu granitoid is composed mostly of granodioritic rocks.

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The porphyroid structure with potash feldspar megablasts is much more frequent in the Petreanu granitoids, whereas in the Furcătura granitoids they are less frequent and plagioclase metablasts occur.

The intrusive character, evidenced in the Furcătura body by the relationships between the leucocrate granitic gneisses and the biotitic granitoid gneisses, is not observed in the Petreanu granitoid.

Another difference between the two granitoid bodies is the higher frequency of the crystalline schists intercalations of different sizes and compositions in the Petreanu granitoids, unlike the Furcătura granitoids where they are almost absent.

Among the geochemical differences we mention the following :

— a more acid average chemical composition of the Furcătura granitoids corresponding to a granitic magma, as compared with a more basic average chemical composition of the Petreanu granitoids, corresponding to a granodioritic magma ;

— a higher variability of the contents of major elements in the Petreanu granitoids as compared with that in the Furcătura granitoids ;

— the greater amount of alkalis and the sodic trend of the Furcătura granitoids as compared with the smaller amount of alkalis and the potassic trend of the Petreanu granitoids ;

— the variation diagrams also illustrate significant geochemical differences between the rocks of the two mentioned bodies ;

— the average contents very different for most of the trace elements, which are twice up to five times lower in the Furcătura granitoids as compared with the Petreanu ones ;

— the relationships between the contents of trace elements are different in the rocks of the two granitoid bodies ;

— unlike the Petreanu granitoids, the Furcătura granitoids display a similarity of the contents and variation trends of some major and trace elements with the Vîrful Pietrii granitoids.

Considering all this, it is probable that the Furcătura and Petreanu granitoids might have been formed differently. The mentioned arguments point to their formation in two different stages : during the first stage the formation of the Furcătura granitoids took place as a result of a magmatic intrusion accompanied by metasomatic processes (sodic metasomatosis) ; during the second stage the formation of the Petreanu granitoids took place due to an intense alkaline metasomatosis (mostly potassic).

In the Petreanu body the metasomatic granitization of the host rocks consisted in a supply of alkalis and silicas and a release of ferromagnesian chemical elements. Recent researches show that the ionic diffusion occurs only on small distances, even in relatively long time-spans and that the ionic transport in a fluid phase seems more likely for the regional granitization. The residual fluids were much richer in water and could form pegmatitic segregations in the Petreanu granitoids giving rise to an intense local potassic metasomatosis as one can see in the Valea Mare Brook.

The projection of the study rocks in the Or-Ab-Q ternary system (Fig. 13) shows obvious differences between the rocks of the two granitoid bodies. Thus, while the Furcătura granitoids plot closely along the minimum eutectic zone and in the neighbourhood or even inside the field of the ideal granites, proving the possibility of their formation from a magmatic melt,

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the Petreanu granitoids display a very wide spreading, pointing to no relation with the maximum thermic zone.

The alkaline metasomatic process is clearly evidenced by the shifting of the plots in the field of very high pressures (more than 5—10 kilobars) towards the peaks Ab (for both bodies) or Or (only for the Petreanu granitoids) of the diagram in relation with both the field of ideal granites and with the field of the Vîrful Pietrii granitoids. The absence of a melt proper in the formation process of the Petreanu granitoids is also illustrated by the diagram of the Or-Ab-An-Q (Fig. 14) which points out that the study rocks do not show any relation with the minimum thermic zone, most of them occurring at great distances from the field of ideal granites than the Furcătura granitoids.

The similar chemical composition of the magma that generated the Furcătura granitoids and of that from which the Vîrful Pietrii granitoids crystallized is suggested also by the geochemistry of some trace elements. In this respect are of note both the average contents and the very close or identical ratios of some trace elements such as Zr, Nb, Sc, Y, Yb, Co, Rb, and K/Rb, Rb/Sr, respectively, in the Furcătura granitoids and Vîrful Pietrii granite.

At the same time, as shown by Taylor (1965), the magmatic differentiation led to a significant enrichment of rubidium as compared with potash in the last differentiates. Provided that such residual solutions invaded the host rocks and granitized them, then a low K/Rb ratio compared with the rocks formed by magma crystallization should result. The higher value of this ratio, as well as of other ratios with a similar petrogenetic significance — e.g. Ba/Rb and Rb/Sr — in the Petreanu granitoids versus the Furcătura ones — suggests that the residual fluids, which led to the formation of the Petreanu granitoids, did not resulted from the magma which generated the Furcătura granitoids.

As regards the time of formation of the Petreanu granitoids, Gherasi et al. (1974) pointed out that it took place after the metamorphosis of the formations later called Nisipoasa and Bodu formations by Dimitrescu (1985), because the metasomatic processes affected them too as evidenced by the feldspar metablastesis. The Precambrian age of the Petreanu granitoids is proved by the value 656 ($\pm$19) MA obtained by the K/Ar method for a biotitic gneiss from an enclave in the Petreanu granitoid situated downstream Runcu (Soroiu et al., 1972).

6. RADIOGENE HEAT OF THE GRANITOID ROCKS IN THE ȚARCU MOUNTAINS

The accurate estimation of the geothermic problems and of the radiogene heating ones was influenced by the lack of adequate data concerning the heat productivity by radioelements and the radioactivity distribution in the study materials especially its vertical distribution in the Earth's crust.

The evidence on the distribution of U, Th and K in magmatic rocks is fundamental when interpreting petrological and geological matters of magma generation and differentiation, of radiogenic heat production and heat flow and generally the evolution of the Earth's crust. Nowadays is widely accepted the hypothesis according to which the Earth's internal heat

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depends on the radioelements distribution in the Earth (Rankama, 1963) and that the heat flow observed on the surface of the continents can be ascribed to the heat generated by radioelements. Thus, the knowledge of the distribution of these producers of radiogenic heat elements in rocks where the heat flow is measured is essential for any significant interpretation.

Radiogenic heat production of the granitoids in the Țarcu Mts was computed from the contents of U, Th, K on the basis of Birch's estimations (1954) of heat production (1 ppm Th = 0.20 μ cal/g an ; 1 ppm U = 0.73 μ cal/g an ; 1%K = 0.27 μ cal/g an).

The values of the radiogenic heat production for the Vîrful Pietrii granitoids (Tab. 9) range between 2.11 μ cal/g an in granites and 15.29 μ cal/g an in quartz diorites, and in the granitoid rocks of the Petreanu massif (Tab. 18) they vary between 1.35 and 9.48 μ cal/g an in the Furcătura granitoids and 1.83 and 11.99μ cal/g an in the Petreanu granitoids. The average values of the radiogenic heat production in the Petreanu granitoids are higher than those in the Furcătura ones, but both are lower than the average values for the Vîrful Pietrii granitoids (Tab. 19).

TABLE 19
Average contents of radioactive elements and average values of radiogene heat generation in some granitoid bodies

	U ppm	Th ppm	K. %	C.R. μ cal/g an
Vîrful Pietrii	3.9	9.5	3.4	5.63
Furcătura	2.3	7.4	3.2	4.02
Petreanu	2.7	12.1	3.4	5.41
Muntele Mic	4.1	15.5	3.6	7.06
Cerna	2.8	12.2	2.8	5.24
Sfîrdin	4.3	17.5	3.5	7.58
Cherbelezu	7.5	18.4	3.9	10.10
Ogradena	4.3	5.7	3.8	5.31
Boulder batholith	3.9	15.4	3.3	6.80
Southern California batholith	1.7	5.5	1.7	2.70
Batholiths from west U.S.A.	2.5	11.6	2.4	4.70
Canadian shield	2.4	10.3	2.6	4.60
Continental crust	2.8	10.0	2.6	4.70

As compared with other granitoids in the Danubian Realm, the average values for the radiogenic heat production in the Vîrful Pietrii and Petreanu granitoids are situated in the lower part of the variation domain of these values. The average value of the radiogenic heat production for the Furcătura granitoids is even the lowest one of all the average values of the Danubian granitoids taken into account, whereas the average value of the radiogenic heat production for the Vîrful Pietrii granites is close to the average values of the Cerna and Ogradena granitoids.

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The average values of the radiogenic heat production of the granitoids in the Ţarcu Mts are close to those of the granitoids in North America and to the average value of the continental crust.

Studying the variation of the radiogenic heat production in relation to different petrochemical parameters, Tilling et al. (1970) showed that the radiogenic heat production varies according to the character of the magmas which yielded the rocks.

On the diagram in Figure 30, the average values of the radiogenic heat production place the granitoids in the Ţarcu Mts either exclusively in the field of calc-alkaline magmas (Petreanu granitoids) or to the common variation zone of the calc-alkaline and calcic fields (Vîrful Pietrii granites and Furcătura granitoids).

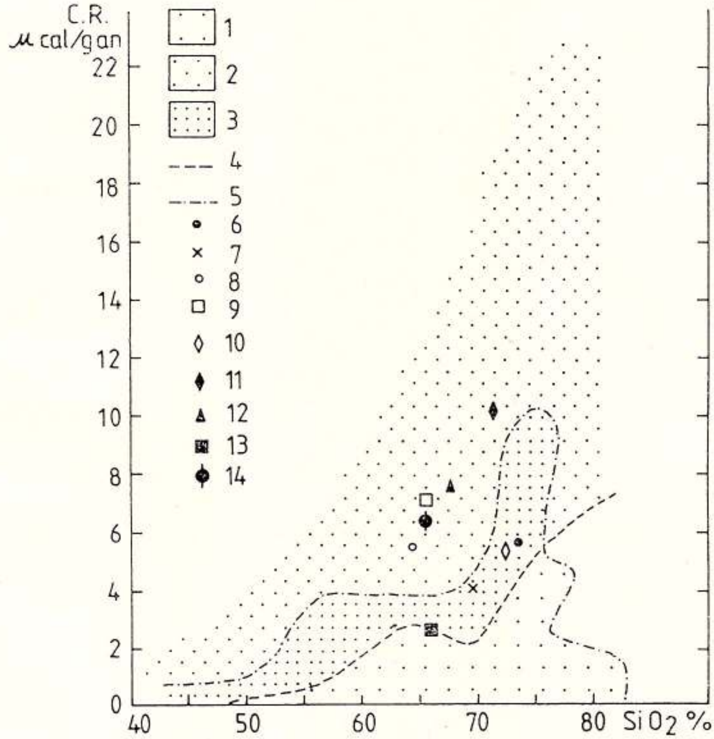

Fig. 30 — Generalized diagram of heat production versus SiO_2 content.
1, field of calcic magmas; 2, field of calc-alkali magmas; 3, superimposed zone of calc-alkali and calcic fields; 4, lower limit of the calc-alkali field; 5, upper limit of the calcic field; 6, Vîrful Pietrii granite; 7, Furcătura granitoid; 8, Petreanu granitoid; 9, Muntele Mic granite; 10, Ogradena granite; 11, Cherbelezu granite; 12, Sfîrdin granite; 13, Southern California batholith; 14, Boulder batholith.

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7. COMPARISON BETWEEN THE VÎRFUL PIETRII, FURCĂTURA AND PETREANU GRANITOIDS

The mineralogical and geochemical observations evidence notable differences between the granitoid rocks in the Vîrful Pietrii and Petreanu massifs. The petrographic differences between the rocks of the three granitoid bodies were observed by Schafarzik (1901) and Gherasi (1937) who referred them to different rock groups according to the classification of that time.

The Vîrful Pietrii granites form a circular-oval-shaped plutonic body unconformable in relation to the surrounding crystalline schists, whereas the granitoid rocks in the Petreanu massif constitute two irregular bodies — Furcătura and Petreanu — which are in different relationships with the surrounding crystalline schists.

The Vîrful Pietrii granites are light grey, medium-grained rocks with equigranular structure, massive or weekly oriented inside the massif and more strongly oriented at the margin of the massif. The porphyroid facies is poorly represented. The Furcătura and Petreanu granitoids are rocks of a light up to dark grey colour, with an equigranular structure, from strongly oriented subparallel up to massive. The porphyroid facies is frequently found.

The mineralogical composition of the rocks of the three granitoid bodies is quite similar as regards the mineral species participating in their formation. They, however, differ by the minerals percentage in the rock formation. Thus, the Vîrful Pietrii granites are richer in quartz than the Petreanu and Furcătura granitoids wihich contain a greater amount of feldspars, especially plagioclase. As regards micas the difference is more clear because the Vîrful Pietrii granites contain only muscovite while in the Furcătura and Petreanu granitoids micas are represented especially by biotite, muscovite occurring only as a product of the plagioclase hydrothermal alteration. The three bodies differ also as regards the variation of the mineral contents. Unlike the Vîrful Pietrii massif, where there is a uniformity in the variation of the mineral contents, the granitoid rocks of the Furcătura and Petreanu bodies display significant variations of the mineral contents.

These differences in the mineralogical composition, especially in quantitative respect, determine the different character of the rocks of the three granitoid bodies, as shown on the *QAP* diagrams (Figs. 1 and 15). Most of the Vîrful Pietrii granitoids plot in the granite field, while the Furcătura and Petreanu bodies fall mostly in the granodiorite field.

The mineralogical and petrographical differences of the three bodies are also reflected in their chemical composition. Tables 2 and 11 show significant differences both as regards the average content and the variation of the major chemical components contents. The major chemical components contents present a more uniform variation in the Vîrful Pietrii granites than in the Furcătura and Petreanu bodies.

Except for lithium, beryllium, ytterbium and uranium, the average contents of all the other trace elements (Tab. 7 and 16) are almost twice or four times lower in the Vîrful Pietrii granites than in the Furcătura and Petreanu granitoids, while the average contents of lithium and ytterbium are almost equal. Another difference between the rocks of the three granitoid bodies consists in the frequency and intensity of the correlation between the trace elements contents. In the Vîrful Pietrii granites only 15 per cent of the computed correlation coefficients have a significant value while in the

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Furcătura and Petreanu granitoids the correlation coefficients with higher values exceed 50 per cent.

A comparison of each of the two granitoid bodies in the Petreanu massif with the Vîrful Pietrii granitoids points out that the chemistry of the Furcătura granitoids is closer to that of the Vîrful Pietrii granite than to the chemistry of the Petreanu granitoids. This fact is evidenced, on the one hand, by the statistical distribution (average content and variation limits) of the major elements and of most of the elements and, on the other hand, by the geochemical relationships between different chemical elements illustrated by the values of their ratios (see diagrams and tables).

Besides these simple methods of comparison other multidimensional statistical methods with a high confidence degree — e.g. discriminant analysis and Wilks criterion — were also used. The values of Wilks criterion and the results of the discriminant analysis invalidate the hypothesis of the equality of the averages and variances of the three bodies — Vîrful Pietrii, Furcătura and Petreanu — and therefore of some geochemical characters identical for these rocks.

The differences evidenced between the rocks of the three granitoid bodies point to different petrogenetic and evolution processes of these rocks.

REFERENCES

Adams J. A. S., Osmond K. J., Rogers V. J. J. (1959) The geochemistry of uranium and thorium. *Physics and Chemistry of the Earth*, 3.

Ahrens L. H. (1953) A fundamental law of geochemistry. *Nature*, 172, 4390.

Andreeva E. D. et al. (1981) Clasificația i nomenclatura magmaticeskih gorhnih porod. Moskva

Baird A. K., McIntyre D. B., Welday E.E. (1965) Granitic rocks of the San Bernardino Mts. California : Chemical composition and variability within 2000 square miles. *Geol. Soc. America Special Paper*, 82.

Beckinsale R.D. (1979) Granite magmatism in the tin belt of South-East Asia. In "Origin of granite batholiths. Geochemical Evidence". Atherton M. P., Tarney J. (editors), Shiva Publ. Limited, Liverpool.

Berza T., Kräutner H., Dimitrescu R. (1983) Nappe structure in the Danubian of the Central South Carpathians. *Asoc. Geol. Carp. — Balk., Congr. XII, 1981*, București.

Birch F. (1954) Heat from radioactivity. In "Nuclear Geology", Faul H. (editor). John Wiley & Sons, Inc., New York.

Bodnarenko V. N. (1964) K voprosu o primenenii empiriceskih uravnenii regresii v gheohimiceskih isledovaniah. *Geohimia*, 7, Moskva.

Brown G. C., Fyfe W. S. (1970) The production of granitic melts during ultrametamorphism. *Contr. Mineral. Petrol.*, 28, Heidelberg-Berlin.

Chayes F. (1960) On correlation between variables of constant sum. *J. Geophys. Res.*, 65, 12, Washington.

Codarcea Al., Pavelescu L. (1963) Considérations sur la genèse des roches granitoïdes de l'autochtone danubien des Carpathes Méridionales. *Asoc. Geol. Carp.-Balc., Congr. V, 1961*, București.

Institutul Geologic al României

— Gherasi N. (1944, 1945) Report, the archives of the Geological Committee, Bucharest.
Condie K. C. (1969) Petrology and geochemistry of the Laramic Batholith and related metamorphic rocks of Precambrian age, Eastern Wyoming. *Geol.,Soc. America Bull.*, 80, Boulder.
Coulomb R. (1959) Contribution à la géochimie de l'uranium dans les granites intrussifs. Thèse, Fac. Sci. Univ. Paris.
Didier J., Lameyre J. (1969) Les granites du Massif Central français : étude comparée des leucogranites et granodiorites. *Contr. Miner. Petrol.*, 24, Heidelberg-Berlin.
Dimitrescu R. (1985) Danubianul munţilor Petreanu şi Retezat în regiunea Rîu Mare. *D. S. Inst. Geol. Geofiz.*, 70–71/1, p. 269–289, Bucureşti.
Erlank A. J. (1968) The terrestrial abundance relationship between potassium and rubidium. In "Origin and Distribution of the Elements". Ahrens H. L. (editor). Pergamon Press, Oxford.
Fairbridge W. R. (1972) The Encyclopedia of Geochemistry and Environmental Sciences. Van Nostrand Reinhold Company, New York.
Fyfe W.S. (1970) Some thoughts on granitic magmas. In "Mechanism of Igneous Intrusion", Newall G.,Rast N. (Editors).
Gherasi N. (1937) Etude pétrographique et géologique dans les monts Godeanu et Ţarcu (Carpathes Méridionales). *Ann. Inst. Geol. Rom.*, XVIII(1933), Bucureşti.
— Zimmermann V., Zimmermann P. (1968) Structura şi petrografia şisturilor cristaline din partea de nord a munţilor Ţarcu (Banatul de est). *D. S. Inst. Geol.*, LIV/1, Bucureşti.
— Medeşan Al. (1968) Consideraţii asupra prezenţei unor roci magmatogene bazice în munţii Ţarcu. *D. S. Inst. Geol.*, LIV/1. Bucureşti.
— Dimitrescu R. (1968) Contribuţii petrotectonice cu privire la structura cristalinului danubian în partea nordică a munţilor Retezat şi Petreanu. *An. şt. Univ. Iaşi, Secţ. II b*, XIV.
— Dimitrescu R. (1970) Anticlinalul Rof şi rolul lui in structura părţii nordice a munţilor Retezat şi Petreanu. *An. şt. Univ. Iaşi, Secţ. II b*, XVI.
— Visarion A., Zimmermann P. (1973) Consideraţii asupra vîrstei unor şisturi cristaline şi depozite sedimentare din autohtonul danubian, situate la marginea de nord a munţilor Godeanu (Carpaţii Meridionali). *Stud. cerc. geol. geofiz. geogr., seria geol.*, 18, 2, Bucureşti.
— Visarion A., Zimmermann P., Iordan M. (1975) Asupra vîrstei paleozoice (Devonian) a formaţiunii de Vidra din partea de nord a munţilor Ţarcu (Carpaţii Meridionali). *D. S. Inst. Geol. Geofiz.*, LXI/4, Bucureşti.
— (1959, 1967) Reports, the archives of the Institute of Geology and Geophysics, Bucharest.
Giuşcă D., Savu H., Bercia I., Kräutner H. (1969) Sequence of tectonomagmatic pre-Alpine cycles of the territory of Romania. *Acta Geologica, Acad. Scient. Hung.*, 13.
— (1974) Petrologia rocilor endogene. Ed. tehnică, Bucureşti.
Goldschmidt V. M. (1937) The principles of distribution of chemical elements in minerals and rocks. *J. Chem. Soc.*, London.
— (1954) Geochemische Verteilungsgesetze der Elemente. Oxford.
— Peters Cl. (1932) Zur Geochemie des Berylliums. *Nachr. Ges. Wiss. Göttingen, Math.-physik. Klasse*, III.
Hauer G., Stache F. (1863) Geologie Siebenbürgens. Wien.
Inkey B. von (1891) Die Transylvanischen Alpen vom Rothenturmpass bis zum Eisernen Thor. *Math. Naturwiss. Ber. aus Ungarn*, IX, I Hälfte, Budapest.
Kaziţin Yu. V., Socevanov N.N. (1968) Uran v mineralah nekotorih magmaticeskih complexov Zabaicalia. *Trudî VSEGEI*, 142, Moskva.
Kleeman A. W. (1965) The origin of granitic magmas. *J. Geol. Soc. Australia*, 12, Canberra.
Klovan J. E. (1975) R-and Q-mode factor analysis. In "Concepts in Geostatistics", McCammon R.B. (editor), Springer Verlag, New York.

Institutul Geologic al României

Kolbe P., Taylor S. R. (1966) Major and trace element relationships in granodiorites and granites from Australia and South Africa. *Contr. Mineral. Petrol.*, 12, Heidelberg-Berlin.

Korjinski D. S. (1968) Acidity-alcalinity in magmatic processes. *Rept. XXII Session Int. Geol. Congr.*, Prague, *1*.

Kräutner H. (1980) Lithostratigraphic correlation of Precambrian in the Romanian Carpathians. *An. Inst. Geol. Geofiz.*, LVII, București.

— Năstăseanu S., Berza T., Stănoiu I., Iancu V. (1981) Metamorphosed Paleozoic in the South Carpathians and its Relations with the Pre-Paleozoic Basement. *Asoc. Geol. Carp.-Balk., Congr.* XII, *Guide to Excursion* A 1, București.

Krumbein W. C., Graybill J. S. (1965) An introduction to statistical models in geology. McGraw-Hill Book Co., Inc., New York.

Larsen E. S., Gottfried D. (1960) Uranium and thorium in selected suites of igneous rocks. *Am. Jour. Sci.* (Badley volume). 258-A.

Laves F., Vishwanathan R. (1967) Relation between the axial angle and triclinicity of K-feldspars and their significance for definition of "stable" and "unstable" stages of alkali feldspars. *Schw. Miner. Petr. Mitt.*, 47, 1, Berne.

Locardi E., Mittempergher M. (1967) Relationship between some trace elements and magmatic processes. *Geol. Rundschau*, 57, 1.

Le Maître R. W. (1976) Some problems of the projection of chemical data into mineralogical classifications. *Contr. Mineral. Petrol.*, 56, Heidelberg — Berlin.

Mehnert K. R. (1968) Migmatites and the origin granitic rocks. *Elsevier Publ.*, Amsterdam.

Miller R. L., Kahn J. S. (1962) Statistical analysis in the geological sciences. New York.

Morariu D. (1982) Anticlinalul Rof sau antiforma Rof? *D. S. Inst. Geol. Geofiz.*, LXVII/5, București.

— Morariu Al. (1982) Un nou model structural al regiunii Țarcu — Riul Mare. *D. S. Inst. Geol. Geofiz.*, LXVII/5, București.

Nockolds S. R. (1954) Average chemical compositions of some igneous rocks. *Bull. Geol. Soc. America*, 65, Boulder.

— (1966) The behaviour of some elements during fractional crystallization of magma. *Geochim. Cosmochim. Acta*, 30, New York.

Oftedal I. (1967) Lead contents in microcline from some granites and pegmatites. *Norsk Geol. Tidskr.*, 47, 2.

Pettijohn F. J. (1963) Chemical composition of sandstones — excluding carbonate and volcanic sands. In : Data of geochemistry, 6th ed., Chapter 3.U.S. Geol. Prof. Paper 440-S.

Platen H. von (1965) Experimental anatexis and genesis of migmatites. In "Control of Metamorphism", Pitcher W. S., Flinn G. W. (editors), Oliver&Boyd, Edinburgh, 10.

Rankama K., Sahama Th. G. (1950) Geochemistry. Univ. Chicago Press, Chicago.

— (1963) Progress in Isotope Geology. *Interscience Publ.*, London.

Rittmann A. (1973) Stable mineral assemblage of igneous rocks. Springer-Verlag, Berlin.

Roche H. de la, Marchal M. (1978) Leucogranites et granites du massif de Valencia de Alcantara (Espagne). *Sci. de la Terre*, XXII, 2, Orleans.

— Letterrier J., Grandclaude P., Marchal M. (1980) A classification of volcanic and plutonic rocks using R_1 R_2 diagram and major analyses — its relationships with current nomenclature. *Chemical Geology*, 29, Amsterdam.

Rodionov D.A. (1961) K vopresu o funkțiah raspredelenia sederjanii elementov v izverjenîh gornîh porodah. *Doklad? AN SSSR*, 141, 3, Moskva.

Rogers J. J., Ragland P. C. (1961) Variation of thorium and uranium in selected granitic rocks. *Geochim. Cosmochim. Acta*, 25, New York.

Institutul Geologic al României

Sandell E. B., Goldich S.S. (1943) The rare metallic constituents of some American igneous rocks. *Jour. Geology*, 51, Chicago.

Savu H. (1970) Structura plutonului granitoid de Sușița și relațiile sale cu formațiunile autohtonului danubian (Carpații Meridionali). *D. S. Inst. Geol.*, LVI/5, București.

— Vasiliu C., Udrescu C. (1972) Studiul petrologic și geochimic al granitoidelor sinorogene și tardeorogene din zona plutonului de Sușița (Carpații Meridionali). *An. Inst. Geol.*, XXXIX, București.

— Vasiliu C., Udrescu C., Tiepac I. (1973) Crystalline schists and Baikalian granitoid rocks in the Muntele Mic region. *An. Inst. Geol.*, XLII, București.

— Vasiliu C., Udrescu C. (1974) Pétrologie et géochimie des migmatites artéritiques de l'autochtone danubien (Carpates Méridionales). *D. S. Inst. Geol.*, LX/1, București.

Schafarzik Fr. (1899) Die geologischen Verhältnisse des Umgebung von Borlova und Pojana Mörul. (Bericht über die im Szarko-Godjan-Gebirge im Jahre 1897 ausgefürte geologische Spezial-Aufnahme). *Jahresber. d. k. ung. geol. R.—A.*, Budapest.

— (1901) Uber die geologischen Verhältnisse der SW-lichen Umgebung von Klopotiva und Malomvitz. (Bericht über die im Jahre 1898 im westlichen Retyezat-Gebirge aufgeen geologische Spezialaufnahme). *Jahresber. d. k. ung. geol. R.—A.*, Budapest.

Shaw D. M. (1956) Geochemistry of pelitic rocks. Part III : Major elements and general geochemistry. *Geol. Soc. America Bull.* 67, Boulder.

— (1964) Interprétation géochimique des éléments en traces dans les roches cristallines. Masson, Paris.

— (1968) A review of K-Rb fractionation trends by covariance analysis. *Geochim. Cosmochim. Acta*, 32, New York.

Soroiu M., Popescu Gh., Gherasi N., Arsenescu V., Zimmermann P. (1970) K-Ar dating by neutron activation of some igneous and metamorphic rocks from the southern branch of the Romanian Carpathians. *Eclogae geol. Helv.*, 63, 1, Lausanne.

— Popescu Gh., Kasper U., Dimitrescu R. (1972) Nota preliminară asupra geocronologiei cristalinului danubian. *An. șt. Univ. Iași, Secț. II b*, XVIII.

Streckeisen A. (1967) Classification and nomenclature of igneous rocks. *N. Jb. Miner Abh.*, 107, Stuttgart.

— Le Maitre R. W. (1979) A chemical approximation to the modal QAPF classification of the igneous rocks. *N. Jb Miner. Abh.*, 136, 2, Stuttgart.

Stur D. (1862) Bericht über die Ubersichtsaufnahme des süd-westlichen Siebenbürgers im Sommer 1860. *Verh. d. k.k. geol. R.—A.*, Budapest.

Szadeczy-Kardoss E. (1955) Geokemia. Akademia Kiado, Budapest.

Tauson L. V. (1967) Geochemical behaviour of rare elements during crystallization and differentiation of granitic magmas. *Geochemistry International*, 4, Washington.

Taylor S.R. (1964) Abundance of chemical elements in the continental crust : a new table. *Geochim. Cosmochim. Acta*, 28, New York.

— (1965) The application of trace element data to problems in petrology. *Physics and Chemistry of the Earth*, 6, Amsterdam.

— Emeleus C. H., Exley C.S. (1956) Some anomalous K/Rb ratios in igneous rocks and their petrological significance. *Geochim. Cosmochim. Acta*, 10, New York.

— Heier K. (1960) The petrological significance of trace element variations in alkali feldspar. *Intern. Geol. Congr. 21-st, Copenhagen, 1960, Rep . Session Norden*, 14.

— Ewart A., Capp A.C. (1968) Leucogranites and rhyolites. Trace element evidence for fractional crystallization and partial melting. *Lithos*, 1, 2, Oslo.

Tilling R. I., Gottfried D., Dodge F. C. W. (1970) Radiogenic heat production of contrasting magma series : Bearing on interpretation of heat flow. *Geol. Soc. America Bull.*, 81, Boulder.

Institutul Geologic al României

Turekian K. K., Kulp J. L. (1956) The geochemistry of Sr. *Geochim. Cosmochim. Acta*, 10, New York.

— Wedepohl K. H. (1961) Distribution of the elements in some major units of the Earth's crust. *Geol. Soc. America Bull.*, 72, Boulder.

Tuttle O. F., Bowen N. L. (1958) Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8 - KAlSi_3O_8 - SiO_2 - H_2O$. *Geol. Soc. America Mem.*, 74.

Vinogradov A.P. (1962) Srednee soderjanie himiceskih elementov v glavnih tipah izverjenih gornih porod zemnoi kori. *Gheohimia*, 7, Moskva.

Vistelius A. B. (1960) Skew frequency distributions and fundamental law of the geochemical processes. *Jour. Geology*, 68, 1, Chicago.

— (1964) Informational characteristic of frequency distributions in geochemistry . *Nature*, 202, 4938, London.

— (1980) Principles of mathematical geology. Nauk Press, Leningrad.

— Sarmanov O. B. (1961) On the correlation between percentage values : major component correlation in ferromagnesian micas. *Jour. Geology*, 69, 2, Chicago.

Wager L. R., Mitchell R. L. (1951) The distribution of trace elements during strong fractionation of basic magma — a further study of the Skaergaard intrusion, East Greenland. *Geochim. Cosmochim. Acta*, 1, New York.

Wedepohl K. (1956) Untersuchungen zur Geochimie des Pb. *Geochim. Cosmochim. Acta* 10, New York.

White A. J. R. (1966) Genesis of migmatites from the Palmer region of South Australia. *Chemical Geology*, 1, Amsterdam.

Whitten E.H. T. (1963) Application of quantitative methods in the geochemical study of granitic massifs. *Royal Soc. Canada Sp. Publ.*, 6, Ottawa.

Winkler H. G. F. (1967) Petrogenesis of metamorphic rocks. 2nd ed., Springer-Verlag, Berlin.

Zimmermann P., Zimmermann V. (1965) Report, the archives of the Enterprise of Geological and Geophysical Prospections, Bucharest.

GEOCHIMIA ROCILOR GRANITOIDE DIN MUNȚII ȚARCU

(Rezumat)

Recent, ca urmare a reanalizării tuturor informațiilor geologice acumulate în ultimele decenii Kräutner et al. (1981) și Berza et al. (1983) au arătat că formațiunile cristaline ale autohtonului danubian aparțin la două mari unități tectonice — danubianul inferior și danubianul superior —consstituite la rîndul lor din mai multe subunități.

Corpurile granitoide din masivele Vîrful Pietrii și Petreanu sînt situate în partea de nord-vest a autohtonului danubian în metamorfitele ferestrei tectonice Petreanu -Rof aparținînd danubianului inferior.

Stratigrafia, petrografia și structura unităților litostratigrafice din partea de nord-vest a autohtonului danubian au fost descrise ca urmare a cercetărilor efectuate de numeroși cercetători (Schafarzik, 1901 ; Gherasi, 1937 ; Gherasi, Dimitrescu, 1968 ; 1970 ; Kräutner, 1980 ; Dimitrescu, 1983, etc.)

Șisturile cristaline care apar în unitatea de Petreanu-Rof, și care prezintă relații directe cu rocile granitoide, aparțin la următoarele unități litostratigrafice : formațiunea de Rof, formațiunea de Nisipoasa, formațiunea de Bodu, formațiunea de Vidra și grupul de Zeicani.

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Masivul Vîrful Pietrii

Masivul granitoid Vîrful Pietrii formează un corp plutonic cu contur elipsoidal avînd axele de dimensiuni apropiate (15 × 11 km) din care cauză pare aproape circular. Rocile granitoide ale masivului Vîrful Pietrii aflorează între rîul Bistra Bucovei la est și rîul Bistra Mărului la vest.

Din punct de vedere petrografic masivul Vîrful Pietrii este alcătuit din granite leucocrate, care ocupă suprafața cea mai mare, din granodiorite, care apar cu totul sporadic în zona marginală și diorite cuarțifere, care apar sub forma unor corpuri mici în partea de vest a masivului.

Enclave de șisturi cristaline în rocile granitoide, cît și apofize ale corpului granitic apar frecvent în șisturile cristaline înconjurătoare.

Descriere petrografică și mineralogică

Roca predominantă este un granit leucocrat de culoare cenușie deschisă, albicioasă cu textură aproape masivă în partea centrală a corpului granitoid și cu textură orientată sau slab orientată în zonele marginale. Ca extindere faciesul șistos nu depășește 500—600 m de la marginea masivului spre interior. Acestor diferențe texturale nu le corespund decît variații slabe de structură și compoziție mineralogică. O varietate de granite mai alcaline, cu microclin, apare sporadic ocupînd suprafețe mici pe pîrîul Murgana și pe pîrîul Pecineaga la confluența cu Bistra Mărului.

Din punct de vedere mineralogic rocile granitice ale masivului Vîrful Pietrii sînt alcătuite din cuarț, plagioclaz, microclin și muscovit, la care se mai adaugă foarte rar biotit în zonele marginale. O caracteristică a granitului de Vîrful Pietrii o reprezintă absența mineralelor melanocrate.

Granodioritele apar cu totul sporadic în zona periferică a masivului granitoid fără a forma zone distincte. Astfel de iviri izolate de dimensiuni metrice au fost întîlnite pe pîrîul Michi și pe pîrîul Pecineaga. Caracteristicile texturale și structurale ale rocilor granodioritice sînt asemănătoare cu cele ale rocilor granitice diferențele manifestîndu-se mai ales în proporția mineralelor componente. De remarcat participarea mai frecventă a biotitului care poate ajunge pînă la 4—5% din volumul rocii.

În partea de vest a masivului granitoid Vîrful Pietrii pe valea Bistra Mărului apar două corpuri mici de roci dioritice cunoscute sub denumirea de diorite de Bistra (Gherasi, 1937). Iviri mai mici de diorite, de ordinul metrilor sau cîtorva zeci de metri, apar în rocile granitice. Rocile dioritice sînt străbătute de apofize și filonașe granitice punînd în evidență relațiile lor cu rocile granitice, relații din care rezultă că dioritele s-au format înaintea rocilor granitice ale masivului Vîrful Pietrii.

În masa corpului granitoid Vîrful Pietrii se întîlnesc numeroase intercalații de șisturi cristaline. Dimensiunile lor variază foarte mult și de obicei depășesc ordinul metrilor. Ele sînt reprezentate mai ales prin șisturi clorito-sericitoase și șisturi cuarțitice cu muscovit și biotit.

Geochimia rocilor granitoide din masivul Vîrful Pietrii

Caractere petrochimice

Studiul petrochimic al rocilor granitoide din masivul Vîrful Pietrii se bazează pe un număr de 43 analize de silicați reprezentînd 37 granite, un granodiorit și 5 diorite cuarțifere.

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Parametrii petrochimici obținuți prin prelucrarea datelor de analiză chimică au fost folosiți pentru :

— caracterizarea rocilor granitoide prin stabilirea compoziției mineralogice normative (C.I.P.W. și Rittmann) și a tipurilor petrografice pe baza unor clasificări chimico-mineralogice (diagramele $R_1 - R_2$, *QAP* și Q'-ANOR) ;

— determinarea tipului de magmă ;

— caracterizarea procesului de diferențiere magmatică.

Diagrama $R_1 - R_2$ (fig. 2) pentru clasificarea rocilor plutonice arată că rocile granitoide din masivul Vîrful Pietrii aparțin la următoarele tipuri petrografice : granite, granodiorite, diorite cuarțifere și diorite. În comparație cu alte metode aceasta arată o corespondență foarte bună cu clasificarea mineralogică.

Cu excepția unui singur caz, toate tipurile de magmă caracteristice rocilor granitoide din masivul Vîrful Pietrii aparțin seriei calcoalcaline. Diagramele de variație arată că magma din care au cristalizat rocile granitoide a avut un caracter calcoalcalin și că procesul de diferențiere magmatică a urmat linia de evoluție a unor magme de alcalinitate normală.

Distribuția statistică a elementelor majore

Studiile efectuate de numeroși cercetători au subliniat importanța geochimică a funcțiilor de repartiție ale conținuturilor elementelor chimice arătînd că acestea reprezintă o caracteristică genetică dintre cele mai importante ale procesului de formare a rocilor, legea fenomenului.

Studiul variabilității conținuturilor elementelor evidențiază o variație mai mare a conținuturilor elementelor majore din granite în raport cu cele din dioritele cuarțifere. Aspectul unimodal al histogramelor de repartiție ale conținuturilor elementelor majore din leucogranite arată caracterul omogen al colectivității de roci. Caracterul lognormal al distribuției statistice a majorității componenților chimici majori din leucogranite pledează în favoarea unui singur proces petrogenetic, în timp ce tendința spre normalitate a K_2O indică participarea a două sau mai multor procese la formarea mineralelor ce conțin acest component chimic. Acest fapt este confirmat mineralogic de prezența microclinului și muscovitului de neoformație, rezultate în urma unui proces de autometamorfism.

Corelația dintre elementele majore

Examinarea valorilor coeficienților de corelație dintre conținuturile elementelor majore evidențiază, în general, o corelație slabă ($r < 0{,}4$), numai 35% din numărul coeficienților de corelație prezentînd valori semnificative. Dintre aceștia din urmă aproape două treimi indică o corelație satisfăcătoare ($0{,}4 < r < 0{,}6$) între variabilele cercetate și numai o treime arată o corelație bună ($0{,}6 < r < 0{,}8$). Variabilele cele mai frecvent corelate sînt SiO_2, Al_2O_3 și Fe_2O_3, în timp ce MnO și Na_2O aproape că nu prezintă legături semnificative cu ceilalți componenți.

Variabilitatea areală a conținuturilor elementelor majore

Repartiția areală a conținuturilor elementelor chimice constituie o caracteristică importantă cu profunde semnificații petrogenetice în procesul de formare a rocilor granitice.

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Pentru cercetarea variabilității areale a conținuturilor elementelor majore a fost aplicată metoda analizei suprafețelor polinomiale de tendință. Hărțile de tendință (fig. 5, 6) ilustrează ca o trăsătură generală a tuturor componenților chimici majori o tendință de variație a conținuturilor controlată de forma corpului granitoid. Astfel, în timp ce silicea și alcaliile arată o tendință de creștere a conținuturilor dinspre marginile plutonului spre zona centrală, conținuturile celorlalți componenți chimici majori manifestă o tendință de scădere în aceeași direcție.

Analiza factorilor

Pentru precizarea rolului componenților chimici majori în desfășurarea proceselor petrogenetice s-a utilizat analiza factorilor pentru stabilirea contribuției fiecărei variabile la variația totală. Rezultatele analizei R-mod evidențiază contribuția majoră, dar de sens contrar, a TiO_2, FeO, CaO, P_2O_5 și MgO pe de o parte și a SiO_2 de cealaltă parte în explicarea variabilității rocilor.

Rezultatele analizei R-mod și ale analizei Q-mod au fost folosite ca bază pentru calculul unui parametru petrogenetic sintetic care să ilustreze procesul de diferențiere magmatică. Ponderile individuale ale primului factor, care justifică peste 90% din variația geochimică a rocilor, au fost utilizate în construirea unei hărți de tendință (fig. 9). Harta obținută reflectă caracterele generale ale procesului de diferențiere și cristalizare magmatică. Valorile parametrului sintetic calculat evidențiează atît o tendință de creștere de la marginile plutonului spre partea sa centrală, cît și o legătură între forma plutonului și modul de variație al acestui parametru.

Conținutul și distribuția elementelor minore

Conținuturile elementelor minore din rocile granitoide ale masivului Vîrful Pietrii se încadrează între limitele de variație stabilite pentru tipul petrografic respectiv. Variația conținuturilor elementelor minore în leucogranite este diferită. Astfel, în timp ce pentru unele elemente minore ca La, Ga și Co conținuturile sînt aproape uniforme, pentru alte elemente minore ca Li, Cr și Cu conținuturile prezintă variații importante.

Majoritatea elementelor minore analizate prezintă o distribuție statistică lognormală, distribuție caracteristică răspîndirii elementelor minore în roci.

Valorile raportului K/Rb din rocile granitoide ale masivului Vîrful Pietrii se încadrează între limitele stabilite pentru rocile magmatice, evidențiind totodată o îmbogățire relativă a rubidiului în raport cu potasiul. O tendință de variație similară este ilustrată și de raportul Ba/Rb. Valorile raportului Rb/Sr sînt cuprinse între 0,14, în dioritele cuarțifere, și 5,10, în rocile granitice.

Corelația dintre elementele minore

Cercetarea corelației dintre elementele minore din leucogranite a arătat că numai 15% din coeficienții de corelație calculați au valori semnificative. Dintre aceștia o legătură foarte strînsă a fost identificată numai între Y-Yb

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și Co-La. Cele mai frecvente legături de corelație sînt prezentate de Sr, Ba, La, Co și Ni, în timp ce alte elemente nu prezintă aproape nici un fel de corelație, așa cum sînt Cu, Be și Ga.

Variația conținuturilor elementelor minore

Pentru a evidénția comportarea geochimică a elementelor minore în timpul diferențierii magmatice a fost cercetată variația atît a conținuturilor elementelor minore, cît și a unor rapoarte dintre acestea și elementele majore cu care se asociază geochimic, în raport cu indicele de diferențiere magmatică. Din diagramele construite rezultă :

— conținuturile de galiu sînt destul de uniforme ;

— conținuturile de Ni, Co, Cr și mai puțin V scad treptat odată cu diferențierea ;

— conținuturile de Sr, Ba, Sc, Y și Yb arată o tendință de scădere odată cu trecerea de la dioritele cuarțifere la leucogranite.

Distribuția elementelor radioactive

Conținuturile de uraniu variază între 0,9—13,4 ppm în leucogranite și între 1,6—10,5 ppm în dioritele cuarțifere, iar cele de thoriu sînt cuprinse între 1,2—31,1 ppm în leucogranite și între 3,4 —45,1 ppm în dioritele cuarțifere.

În comparație cu alte masive granitoide din autohtonul danubian rocile granitice din masivul Vîrful Pietrii au o radioactivitate mult mai scăzută decît majoritatea acestora, în timp ce dioritele cuarțifere sînt cele mai bogate în elemente radioactive.

Repartiția areală a conținuturilor elementelor radioactive în leucogranitele din masivul Vîrful Pietrii arată o tendință de creștere a conținuturilor de U și Th dinspre marginile masivului spre partea centrală a acestuia. Această tendință este mai evidentă pentru thoriu care prezintă o zonă de maxim exact în partea centrală a masivului.

Geneza rocilor granitoide din masivul Vîrful Pietrii

Relațiile cu rocile înconjurătoare, structura, textura, compoziția mineralogică, natura enclavelor și aspectul general al plutonului au făcut ca originea magmatică a corpului granitoid Vîrful Pietrii să nu fie pusă la îndoială. Din acest motiv, problemele de geneză ale rocilor granitoide ale masivului se referă de fapt la originea, modul de diferențiere, punerea în loc și condițiile de cristalizare a magmei.

Originea litogenă a magmei granitice este evidențiată de o serie de caracteristici cum sînt proiecția rocilor granitice în cîmpul de distribuție al rocilor metamorfice acide din diagrama propusă de Mehnert (1968), caracterul hiperaluminos al rocilor și valorile ridicate ale raportului Rb/Sr. Tendința de variație numai spre compoziții acide, raportul Fe^{3+}/Fe^{2+} relativ scăzut, prezența muscovitului și granatului, considerate printre caracteristicile mineralogice și geochimice ale granitelor de tip „S" sînt evidențiate și de rocile granitoide din masivul Vîrful Pietrii.

Poziția rocilor granitice din masivul Vîrful Pietrii în sistemul petrogenetic rezidual indică formarea lor prin cristalizare dintr-o magmă de com-

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poziție granitică la o temperatură de 670—690°C și la presiuni de pînă la 4—5 kilobari în funcție de conținutul de apă. Prezența în rocă a unor pertite arată, de asemenea, o temperatură de formare a granitului în jur de 660°C confirmînd originea lui magmatică.

Punerea în loc a corpului granitoid s-a efectuat într-un cîmp slab de forțe tectonice care au afectat în special zonele marginale ale plutonului. Timpul de punere în loc a granitului de Vîrful Pietrii nu este bine precizat.

Masivul Petreanu

Pe măsura acumulării de noi cunoștințe, ca urmare a aprofundării cercetărilor geologice din regiune, ipotezele asupra genezei rocilor acestui masiv s-au modificat. În prezent se consideră că rocile granitoide din masivul Petreanu formează două corpuri distincte; corpul granitoid Furcătura, situat în partea de nord a masivului și corpul granitoid Petreanu, situat la vest și sud de primul corp.

Granitoidul de Furcătura

Corpul granitoid Furcătura ocupă o suprafață sub forma unei potcoave deschisă spre est înconjurînd din trei părți anticlinalul Rof. Stratigrafic corpul granitoid Furcătura este cuprins între formațiunea de Rof în partea inferioară și formațiunea de Nisipoasa în partea superioară.

Corpul granitoid Furcătura este alcătuit în principal din gnaise granitoide biotitice, pe lîngă care mai apar gnaise granitoide porfirice și gnaise granitice leucocrate. Relațiile gnaiselor granitice leucocrate cu celelalte tipuri petrografice evidențiază caracterul lor intrusiv.

Granitoidul de Petreanu

Rocile granitoide de Petreanu alcătuiesc un corp neregulat în formă de S alungit în direcția NNE, fiind cuprinse între formațiunea de Nisipoasa în partea inferioară și formațiunea de Bodu în partea superioară. Rocile predominante ale corpului granitoid Petreanu sînt gnaisele granitoide și gnaisele migmatice. Din punct de vedere petrografic și textural apare o mare variabilitate a tipurilor de roci. O separare regională a tipurilor de roci întîlnite este foarte greu de realizat deoarece răspîndirea lor este cu totul întîmplătoare. Alături de zone largi cu șistozitate evidentă, alcătuite din gnaise migmatice străbătute de filoane aplitice, se găsesc gnaise granitoide nebulitice și gnaise granitoide masive cu porfiroblaste de feldspați.

Geochimia rocilor granitoide din masivul Petreanu

Caractere petrochimice

Studiul petrochimic al rocilor granitoide din masivul Petreanu se bazează pe un număr de 36 analize de silicați.

Parametrii statistici calculați arată că între cele două corpuri granitoide există deosebiri evidente de chimism, care sînt în strînsă legătură cu compoziția mineralogică a rocilor. Deși limitele de variație ale oxizilor pentru cele două corpuri granitoide nu diferă prea mult, totuși conținuturile lor medii se deosebesc semnificativ. Prelucrarea analizelor chimice prin

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diferite metode evidenţiază următoarele caracteristici petrochimice ale rocilor granitoide :

— rocile granitoide din masivul Petreanu corespund în general unor roci de compoziţie granitică şi granodioritică ;

— rocile granitoide din corpul Furcătura au un caracter mai acid în raport cu cele din corpul Petreanu.

Distribuţia elementelor majore

Conţinuturile elementelor majore arată o distribuţie statistică diferită în rocile granitoide din masivul Petreanu. Astfel, unele elemente majore, în general cele feromagneziene, prezintă o variaţie destul de importantă a conţinuturilor, care este mai pronunţată în corpul granitoid Furcătura decît în corpul granitoid Petreanu. Variaţiile cele mai mici ale conţinuturilor apar la SiO_2, Na_2O şi K_2O, adică la elementele chimice adăugate la rocile gazdă în timpul procesului de granitizare care a condus la o anumită uniformizare a conţinuturilor lor.

Corelaţia între elementele majore

Frecvenţa corelaţiei între conţinuturile componenţilor chimici majori diferă ın cele două corpuri granitoide. Astfel, în timp ce pentru corpul Furcătura 70% din coeficienţii de corelaţie lineară au valori mai mici de 0,4, pentru corpul Petreanu ei reprezintă numai 50%. Peste jumătate din coeficienţii de corelaţie cu valoare semnificativă arată o corelaţie bună sau foarte bună între conţinuturile elementelor majore. Valorile cele mai ridicate ale coeficienţilor de corelaţie apar între FeO, TiO_2 şi P_2O_5 pentru corpul granitoid Furcătura şi între SiO_2 şi FeO, MgO şi P_2O_5 pentru granitoidul de Petreanu.

Variabilitatea areală a conţinuturilor elementelor majore

Studiul repartiţiei areale a conţinuturilor componenţilor chimici majori efectuat separat pentru rocile celor două corpuri granitoide din masivul Petreanu evidenţiază următoarele caracteristici :

— conţinuturile de SiO_2 manifestă o tendinţă de creştere spre partea de NNV a masivului Petreanu ;

— conţinuturile de Al_2O_3 prezintă o tendinţă de variaţie inversă faţă de cea a SiO_2 în ambele corpuri granitoide ;

— conţinuturile elementelor feromagneziene arată o tendinţă de variaţie diferită în cele două corpuri granitoide ;

— variaţia areală a conţinuturilor de alcalii indică o comportare inversă în cele două corpuri granitoide, zonele cu conţinuturi maxime ale unui component chimic coincizînd cu conţinuturi minime pentru celălalt component.

Analiza fa ctorilor

Rolul componenţilor chimici majori în procesele petrogenetice ale rocilor granitoide din masivul Petreanu a fost evidenţiat cu ajutorul analizei R-mod prin stabilirea contribuţiei la variaţia globală a rocilor. Contribuţia cea mai

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importantă, dar de sens contrar, o au pe de o parte FeO, TiO_2, P_2O_5, MgO și CaO, iar de cealaltă parte SiO_2 în ambele corpuri granitoide.

Indicatorul petrogenetic calculat separat pentru corpul Furcătura și pentru corpul Petreanu evidențiază existența unor deosebiri geochimice și petrogenetice între rocile granitoide din cele două corpuri ale masivului.

Conținutul și distribuția elementelor minore

Datele de analiză, ca și parametrii statistici calculați, evidențiază următoarele caracteristici :

— conținuturile elementelor minore din rocile granitoide ale masivului Petreanu se încadrează între limitele de variație stabilite pentru rocile granitoide din scoarța terestră ;

— elementele minore se deosebesc între ele prin conținuturile și gradul lor de variație manifestat în rocile celor două corpuri granitoide. În timp ce Cu, Sn, Be, Ga, Ba, Sr, La, Y și Nb prezintă variații reduse și conținuturi, în general, apropiate în cele două corpuri granitoide, Pb, Ni, Co, V, Sc și Zr prezintă variații mult mai mari și au conținuturi mult mai ridicate în rocile corpului granitoid Petreanu decît în cele ale corpului granitoid Furcătura ;

— deosebirea dintre rocile granitoide de Furcătura și cele de Petreanu este subliniată și de valorile unor rapoarte ale unor elemente chimice care au o semnificație petrogenetică deosebită cum sînt K/Rb, Ba/Rb și Rb/Sr ;

— apariția frecventă a corelației, valorile cele mai ridicate ale coeficienților de corelație fiind între conținuturile de Co, Cr și V ;

— cu excepția thoriului, conținuturile medii ale elementelor radioactive în cele două corpuri granitoide sînt destul de apropiate.

Geneza rocilor granitoide din masivul Petreanu

Spre deosebire de masivul Vîrful Pietrii, formarea rocilor granitoide din masivul Petreanu a fost și este încă discutată, evidențiind complexitatea proceselor geologice care au avut loc în această regiune.

Observațiile mineralogice, petrografice, structurale și geochimice arată deosebiri importante între cele două corpuri granitoide sugerînd procese petrogenetice și de evoluție diferite. Astfel, deși rocile sînt formate din aceiași componenți mineralogici proporția dintre aceștia diferă, motiv pentru care în corpul Furcătura predomină tipurile petrografice de compoziție mai acidă decît în corpul granitoid Petreanu.

Structura porfiroidă este mult mai frecventă în rocile granitoide ale corpului Petreanu decît în cele ale corpului Furcătura. Caracterul intrusiv evidențiat în corpul Furcătura de relațiile dintre gnaisele granitice leucocrate și gnaisele granitoide biotitice nu este observat în corpul granitoid Petreanu.

Dintre diferențele geochimice menționăm :

— compoziția chimică medie mai acidă a rocilor granitoide de Furcătura față de cea a rocilor granitoide de Petreanu ;

— variabilitatea mai ridicată a conținuturilor elementelor majore în rocile granitoide de Petreanu în raport cu cele de Furcătura ;

— tendința sodică a rocilor granitoide de Furcătura față de tendința potasică a celor din corpul Petreanu ;

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— conținuturi medii foarte deosebite pentru majoritatea elementelor minore.

Argumentele menționate sugerează formarea acestor corpuri în două etape diferite și anume : într-o primă etapă a avut loc formarea rocilor granitoide de Furcătura, ca urmare a unei intruziuni magmatice însoțită de procese metasomatice (metasomatoză sodică), iar într-o a doua etapă s-au format rocile granitoide de Petreanu datorită unei intense metasomatoze alcaline (preponderent potasică).

Această ipoteză este sprijinită și de dovezi termodinamice rezultate din proiecția rocilor granitoide în sistemele petrogenetice. Se constată că, în timp ce rocile granitoide de Furcătura manifestă relații strînse cu zona de minim termic, demonstrînd posibilitatea formării lor dintr-o topitură magmatică, în cazul rocilor granitoide de Petreanu aceste relații lipsesc.

Căldura radiogenă a rocilor granitoide din munții Țarcu

Producerea căldurii radiogene a rocilor granitoide din munții Țarcului a fost calculată pe baza conținuturilor de U, Th și K.

Valorile medii ale producerii căldurii radiogene în rocile granitoide de Petreanu sînt mai ridicate decît în cele de Furcătura, dar ambele sînt mai scăzute decît valorile medii pentru rocile granitoide din masivul Vîrful Pietrii.

În comparație cu alte masive granitoide din autohtonul danubian al Carpaților Meridionali corpurile granitoide din munții Țarcului au valorile medii ale producerii căldurii radiogene dintre cele mai scăzute.

EXPLANATION OF PLATES

Plate I

Fig. 1 — Quartz diorite, Bistra Mărului River (1 : 1).

Fig. 2 — Granite in marginal facies, Bloju Brook (1 : 1).

Plate II

Fig. 1 — Vîrful Pietrii granite ; twinned and fissured plagioclase. N+, × 30, Marga Brook.

Fig. 2 — Vîrful Pietrii granite ; microcline with inclusions of altered plagioclase and „drop-like" quartz. N +, × 15, Marga Brook.

Fig. 3 — Vîrful Pietrii granite ; potash feldspar with a zonary structure. N+, × 15, Vîrful Pietrii Summit.

Fig. 4 — Vîrful Pietrii granite ; deformed muscovite with undulatory extinction and marginal reaction rim. N+, × 15, Marga Brook.

Plate III

Fig. 1 — Furcătura granitoid gneiss ; quartz grains disposed as bands and lenses. N+, ×20, Riușorul Hobiței Brook.

Fig. 2 — Furcătura granitoid gneiss ; marginal myrmekites. N + × 35, Rîul Mare River.

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Fig. 3 — Furcătura granitoid gneiss; microcline megablast with inclusions of plagioclase, „drop-like" quartz and sphene. N +, × 25, Rîul Mare River.

Fig. 4 — Petreanu granitoid gneiss; ameoboidal-shaped microcline metablast with reaction zone. N +, × 10, Căprioara Brook.

Plate IV

Fig. 1 — Migmatic gneiss with ophtalmitic texture, 1 : 1, Slatina Pocinești Brook.

Fig. 2 — Granitoid gneiss with a massive texture and potash feldspar porphyroblasts, 1 : 1, Rîul Mare River.

Plate V

Fig. 1 — Banded gneiss with stromatic texture, 1 : 1, Rîul Mare River.

Fig. 2 — Banded gneiss with flebitic texture, 1 : 1, Zeicani Brook.

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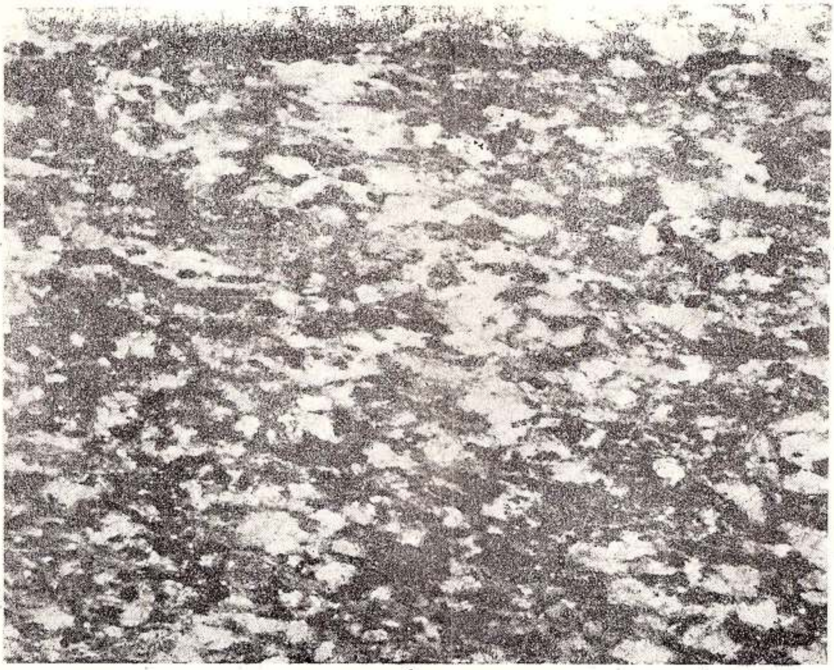

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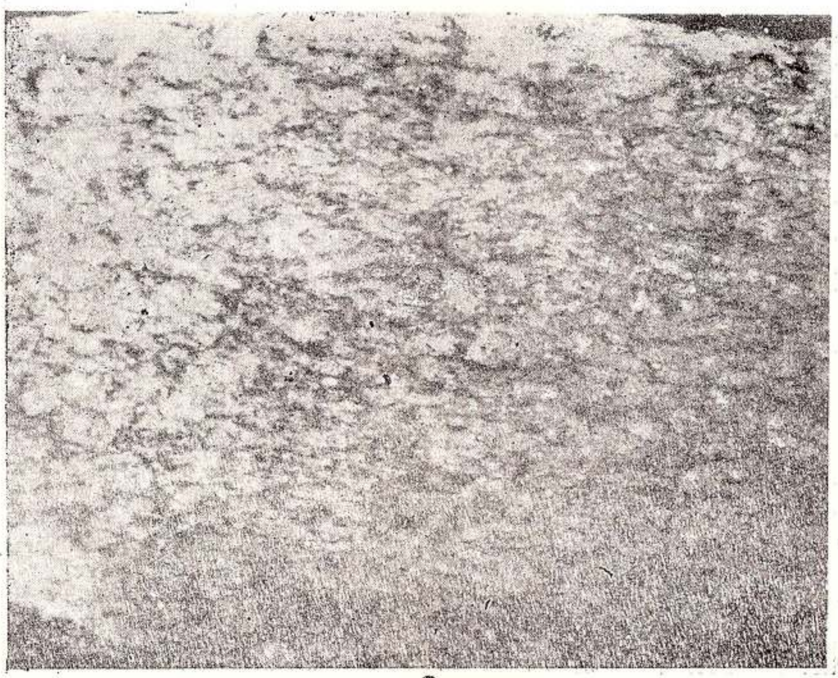

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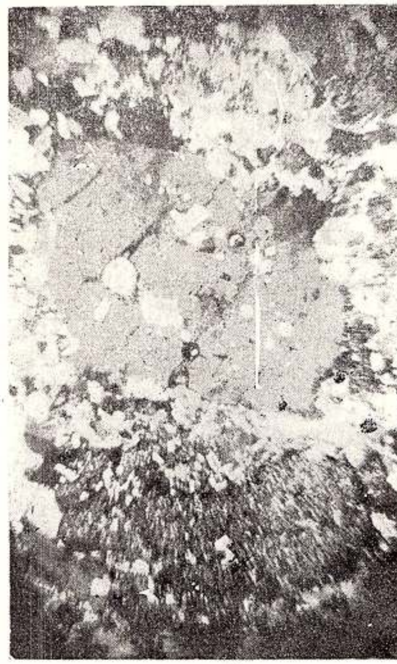

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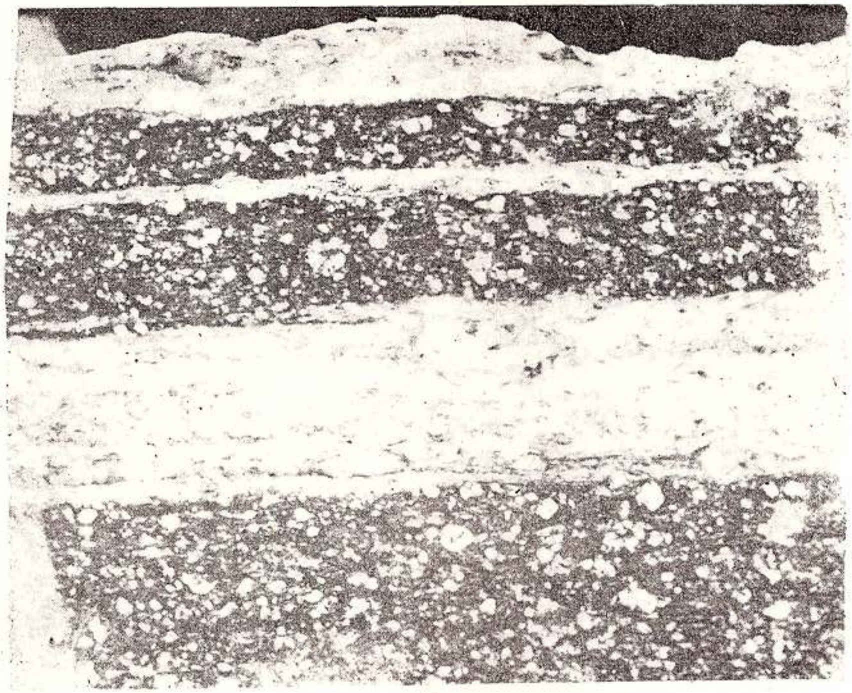

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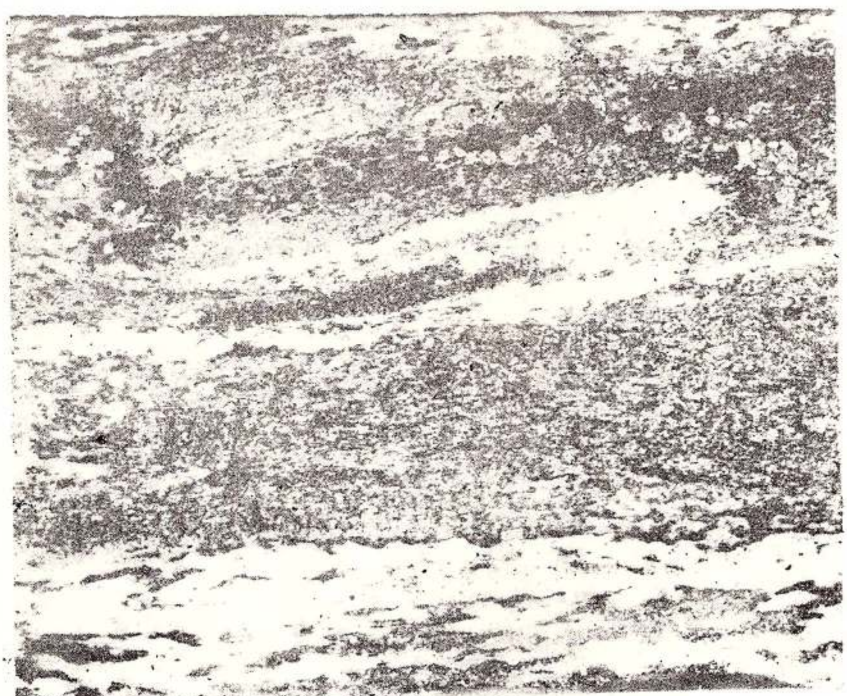

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GEOLOGICAL AND PETROGRAPHICAL STUDY OF NORTH RETEZAT MOUNTAINS[1]

by

VIOREL MACALEŢ[2]

Danubian Units. Getic Nappe. Polymetamorphism. Prograde metamorphism. Retrograde metamorphism. Metamorphic rocks. Granodiorite. Major elements. Minor elements. Structural Analysis. South Carpathians — Crystalline Danubian Domain — Retezat Mts; Crystalline Getic Domain.

Abstract

Component geological formations in the northern part of Retezat Mts belong both to the Getic Domain and to the Danubian Domain, which are now in tectonic relations. At the same time, within the Danubian, two important tectonic units — Lower and Upper Danubian Units — have been outlined. The Getic Nappe is constituted of meso-catametamorphic, Dalslandian formations of the Sebeş-Lotru series. Here the polyphasic character of metamorphism was pointed out. Formations of Lower Danubian Unit have been distributed to Rîuşorul, Drăgşan and Nucşoara Valley crystalline series, to Retezat granitoids (granodiorites and tonalites) and to Oslea anchimetamorphic formations. Formations of Upper Danubian Unit are all included in Zeicani crystalline series bearing two complexes. Drăgşan series and lower complex of Zeicani series, probably Rîuşorul series too, are considered to be synchronous and older in age (Cadomian); in an upper position, they follow Nucşoara Valley formation and upper complex of Zeicani series (Upper Cadomian, eventually Old Caledonian); the succession is finished with the deposits of Oslea formation which are distributed to Silurian-Lower Cretaceous interval. Within the Danubian metamorphics, there have been also noticed several stages of metamorphism; thus, an initial progressive metamorphism corresponding to the conditions of quartz-albite-epidote-almandine subfacies of greenschists facies $\simeq$ almandine zone was followed by a static retromorphism at regional scale (probably during Caledonian movements mainly epirogenetic) and by a new metamorphic recrystallization under conditions of quartz-albite-epidote-biotite subfacies, probably during Hercynian orogenesis. Granodioritic intrusions (in a little colder rocks) caused a weak metamorphism of thermal contact in Drăgşan series schists; thus, an aureola was born, in which schistous hornfelses bearing biotite and epidote are very widely developed.

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[2] Institutul Politehnic. Splaiul Independenţei nr. 313, Bucureşti.

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Résumé

Etude géologique et pétrographique de la partie nord des monts Retezat. Les formations géologiques qui forment la partie nord des monts Retezat — l'objet de la présente étude — appartiennent au domaine gétique et à celui danubien, qui à présent ont des liaisons tectoniques. On a séparé pour le Danubien deux unités tectoniques importantes : unité danubienne inférieure et unité danubienne supérieure. La nappe gétique comporte les formations méso-cata-métamorphiques, dalslandiennes de la série de Sebeș-Lotru, où on a mis en évidence le caractère polyphasique du métamorphisme. Les formations de l'unité danubienne inférieure ont été distribuées aux séries cristallophylliennes de Riușorul, Drăgșan et vallée Nucșoara, aux granitoïdes (granodiorites et tonalites) de Retezat et à la formation anchimétamorphique d'Oslea. Les formations de l'unité danubienne supérieure ont été attribuées en totalité à la série cristallophyllienne de Zeicani, avec deux complexes. La série de Drăgșan et le complexe inférieur de la série de Zeicani, probablement la série de Riușorul aussi sont considérées synchrones et plus anciennes (cadomiennes), en position supérieure, en continuité de la formation de vallée Nucșoara et le complexe supérieur de la série de Zeicani (cadomien-supérieures, même calédoniennes anciennes) ; la succession achève par les dépôts de la formation d'Oslea attribués à l'intervalle Silurien-Crétacé inférieur. Pour les métamorphites du Danubien on a déterminé aussi plusieurs phases de métamorphisme ; un métamorphisme progressif de début correspondant aux conditions de subfaciès quartz-albite-épidote-almandin du faciès des schistes verts — la zone de l'almandin — a été suivi d'un rétromorphisme statique à l'échelle régionale (possiblement pendant les mouvements calédoniens, épirogénétiques avec prépondérence) et par une nouvelle recristallisation métamorphique dans les conditions du subfaciès quartz-albite-épidote-biotite, pendant l'orogenèse hercynienne. L'intrusion des granodiorites (dans des roches un peu plus fraîches que celles-ci) a déterminé un faible métamorphisme de contact thermique dans les schistes de la série de Drăgșan, avec la formation d'une auréole où les cornéennes schisteuses à biotite et épidote enregistrent un grand développement.

INTRODUCTION

This study deals with the zone between the basin of Nucșoara Valley, westwards and the basin of Rîul Bărbat Valley, eastwards. It covers the crystalline in the northern slope of Retezat Mts (South Carpathians). Northwards and southwards, its limits have geological origin, namely the contact with Hațeg sedimentary basin and with Retezat granitoid massif, respectively.

From geomorphological point of view, it belongs to the alpine domain, having level differences up to 800 m and a complicated morphology. The highest peaks are in the south, having about 1400 m, west of Rîul Alb — the summit being Prislop (1393.5 m) and Colțu Mare (1443.5 m) peaks — and only 1100—1200 m eastwards. Southern summits go northwards on parallel ridges of slow slopes, following Ascuțitul (1244.7 m), Știrbina (1239 m), Măgura Măceștilor (1050.5 m), Vîrful Muchii (about 900 m) and Dîlma (808 m) peaks, then the slopes suddenly become evident and finish at the contact with sedimentary deposits (with heights between about 600 and 700 m). Owing to these heights, this crystalline zone corresponds to one of the lower steps of Rîul Șes erosion level. Actual aspect of the relief is dued to petrographical composition, the crystalline zone (especially Danubian crystalline) forming a "landing" between the granitoid massif and Hațeg basin ; at the same time, sudden evident slope at the contact with the sedi-

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mentary of the Haţeg tectonic basin is caused by the fault system, owing to which the basin sank, so that ridges are transversally cut off, forming characteristic triangular areas, which are about plane.

Hydrographical network is tributary to Strei river, main valleys of Nucşoara, Mălăieşti, Paroşului, Rîul Alb, Apa Lazului and Rîul Bărbat, flow about from south to north ; generally their profile is deep and has a big slope in the mountains, then suddenly lessens when comes out in Haţeg basin. Excepting Paroşului and Rîul Alb, on these valleys, there are forrest roads, which deeply enter the mountains ; at the same time, lately, there have been built several roads which facilitate the way to Rîul Mare — Retezat hydro-energetic headquarters.

This paper represents the result of seven years investigations (1977—1984). During the first two years, we covered the whole zone through a mapping at scale 1 : 25000 and so we created a first whole image ; later on, we retook and profoundly studied most of the profiles at the same time with a systhematical test of all rock types ; we also noticed mesoscopic elements for each lithological unit and each tectonic sector ; in order to find some possibilities of correlation, we added some profiles in adjacent zones. Field observations have been completed, studying almost 1000 microscopic sections, and using the results of more than 40 complete analyses of silicates and informative spectrals, 15 diffractometric X-ray analyses, more than 20 thermal analyses (ATD and dilatometric ones) all of them being done on the author's samples ; at the same time, in order to complete the tectonic image, we built 43 sector tectonograms, including more than 7000 measurements of schistosity and fissure planes.

When I wrote this paper, I was helped by prof. dr. doc. R. Dimitrescu, who also suggested me to chose the Retezat Mts zone as subject for my theses of doctor's degree ; I am very grateful to him for everything he has done to me. Secondly, I thank the Geology Department of Iaşi University "Al. I. Cuza" and especially prof. dr. V. Erhan, whose support and kindness constituted an impulse and an obligation too for my activity as geologist. I am also grateful to dr. N. Gherasi, who in 1976 introduced me the secrets of the Retezat Mts and to prof. dr. doc. V. Manilici who helped me during the whole period, when I elaborated this paper. At the same time, I am grateful to dr. A. Gurău and dr. T. Berza for my fruitful discussions with them and for their suggestions regarding various aspects of metamorphics. I also thank all those who contributed to this paper, concluding it by means of discussions, suggestions, bibliography or analyses.

I. GEOLOGICAL INVESTIGATIONS HISTORY

Regarding Retezat Mts zone, we have the first summary geological informations in the papers of some Hungarian and Austrian investigators at the end of the last century — Stur (1866) ; Hauer, Stache (1863, 1869) ; Inkey (1889) ; Schafarzik (1898) ; Nopcsa (1905). This first stage has a general character and is crowned by Murgoci papers (1904, 1905, 1912). The second investigation stage begins after 1927 when the Institute of Geology retakes the investigation of South Carpathians ; thus, Streckeisen, Gherasi (1931) ; Streckeisen (1932, 1934) ; Codarcea (1933, 1940) ; Gherasi (1937) ; Manolescu (1937) ; Ghika-Budeşti (1938) achieved real monographical studies,

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references and now they inquire important zones which also imply Retezat Mts.

After an intermission, to the end of '50 year, detailed investigations on South Carpathians geology amplify and continue up to now, when at a superior level of knowledge, there is an obvious tendency to write some general papers. The following papers have direct or indirect implications on Retezat Mts : Pavelescu (1953 a, b ; 1963) ; Pavelescu, Răileanu (1963) ; Pavelescu, Pavelescu (1964, 1969) ; Gherasi, Dimitrescu (1968, 1970) ; Micu, Paraschivescu (1970) ; Schuster (1972) ; Savu (1973) ; Solomon, Pop (1973) ; Năstăseanu (1973, 1976) ; Stănoiu (1973, 1976, 1982) ; Gherasi et al. (1974) ; Visarion, Solomon (1974) ; Bercia (1975) ; Berza (1975, 1978) ; Solomon et al. (1976) ; Hîrtopanu (1978) ; Kräutner (1980) ; Kräutner et al. (1981) ; Macaleţ (1983) ; Berza, Seghedi (1983) ; Berza et al. (1983) ; Dimitrescu (1986).

Besides the studies of fundamental character, numerous data of observation which often constituted some synthesis studies, now brought the papers of geological prospecting in order to point out the economic potential of Retezat Mts. So, Gherasi, Pîrvu (1956) inquire the basin of Nucşoara brook for talc, Micu (1965, 1966) prospects NE of Retezat Mts zone for iron and manganese ores and together with Paraschivescu (1967) inquire the zone between Nucşoara and Rîul Alb for talc ; during 1969—1972, Solomon, Pop and Tomescu did geological and geochemical investigations for non-ferrous ores in the zone of Rîul Bărbat. In 1973, Pop synthetized the mineralization premises and indications. At the same time, Macaleţ (1977—1980) did geological, petrographical and structural studies in order to determine the concentration conditions of useful minerals within the crystalline formations between Rîuşorul and Rîul Bărbat.

II. GEOLOGY OF THE REGION

During 1904—1905, for the first time, Murgoci noticed the existence of tectonic relations between mesometamorphic and „epimetamorphic" crystalline (I group and II group respectively — Mrazec, Murgoci) in the central and western part of South Carpathians. Posterior investigations confirmed and brought numerous new data regarding the existence of a huge overthrust nappe — Getic Nappe. Under it, Danubian formations occur as a tectonic halfwindow in Parîng , Vîlcan, Retezat, Petreanu, Ţarcu and Mehedinţi Mts.

Geological formations which constitute the northern part of the Retezat Mts between Nucşoara and Rîul Bărbat valleys belong both to the Getic Nappe and to the Danubian.

1. Getic Nappe

It occupies the northern part of the zone, lying on a small width (300—1000 m) from the left slope of Nucşoara to the left slope of Rîul Alb, then it becomes wider (max. 4000 m) eastwards up to the basin of Rîul Bărbat. Northwards, it is covered by the sedimentary deposits of Haţeg basin and southwards it thrusts over the Danubian crystalline formations. It is constituted of crystalline formations of an advanced degree of metamorphism, which bear Mesozoic sedimentary deposits on a small area (Fig. 1).

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1.1. Crystalline Formations belong to the Sebeș-Lotru series (Savu, Pavelescu, 1968) = Sebeș-Lotru group of Karpian supergroup (Kräutner, 1980) and almost completely they are constituted of an alternance of various types of gneisses and subordinately of micaschists, in which there are rare

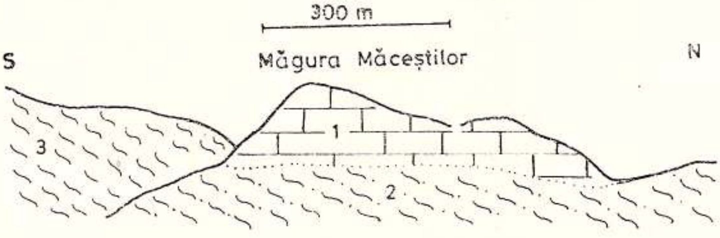

Fig. 1 — Getic Nappe and Danubian ; according to the photo — left slope of Riul Alb. Getic Nappe. 1, sedimentary limestones ; 2, micaschists with garnets ; 3, Danubian.

and weak intercalations of amphibolitic rocks ; isolatedly, there can be met veinlets or small decimetric lenses of quartz-feldspathic pegmatites bearing muscovite. From structural point of view, two types of metamorphics obviously can be distinguished — one type of a coarse structure , in which can be separated microcline gneisses, muscovite-biotitic paragneisses, micaschists, feldspathic quartzites, according to mineralogical composition and quantitative relation among component minerals ; another type of a fine-grained structure, which is mostly constituted of biotitic paragneisses bearing garnet. Usually, typical amphibolites associate in the first group, while amphibolitic gneisses in the second one ; a special type is represented by eclogitic amphibolites which crop out on the Piscurilor brook (left tributary of Șerel brook). Excepting the amphibolites and some microcline gneisses which have obvious contacts with the surrounding rocks, in all the other cases the contacts are gradually, passing from one rock type to another one, being done on a certain distance. At the same time, most of the relations are harmonious, excepting some microcline gneisses ; such a situation is met on the left slope of Mălăiești brook, where, inside the microcline gneisses, there are decimetric intercalations of chloritized amphibolites, after which gneisses have been intensely tectonized ; another case was noticed on Piscurilor brook, where bigger bodies of microcline gneisses have apophyses, intersecting the schistosity of the other gneisses.

The metamorphics of the Getic crystalline have been partly retromorphosed in the same time with an accentuated cataclasis (breccification and mylonitization), especially near the overthrust plane on the Danubian formations.

The metamorphic parageneses, chemical composition and crystallinity degree show that all types of described rocks within the Getic crystalline were born through the metamorphosis under conditions of almandine amphibolitic facies, kyanite-almandine-muscovite subfacies, sillimanite-almandine-muscovite subfacies and seldom sillimanite-almandine-orthoclase subfacies (Turner, Verhoogen, 1960) of some initial eruptive formations —

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amphibolites and at least some of microcline gneisses or sedimentary ones — the other gneisses and micaschists.

Small stratigraphic thickness of Sebeș-Lotru series does not permit the separation of some distinct lithostratigraphical units. This is also the reason for difficult correlation with the surrounding regions. However, multitude of microgranular biotitic paragneisses between Rîul Bărbat and Paroșului Valley and microcline gneisses between Mălăiești and Nucșoara represent arguments to draw a parallel between the crystalline of Sebeș-Lotru series in these two zones with the upper part of lower complex (G_1) and respectively, the middle complex (G_2) which Bercia (1972, 1975) separated in the Godeanu massif. So, they could be included in the lower gneissic formation, respectively leptino-amphibolitic formation (Kräutner, 1980; Kräutner et al., 1981).

Lately, most authors recognize that the formations of Sebeș-Lotru series (group) were born during the Upper Precambrian A = Middle Preterozoic = Karpian.

1.2. **Sedimentary Formations** on the crystalline of the Getic Nappe develop starting with the left slope of Mălăiești Valley up to Apa Lazului, being interrupted in the basin of Rîul Alb. The basis has a thin strip between Paroșului Valley and Apa Lazului (being widely developed in Măgura Măceștilor); it is mostly constituted of massive reef strongly-fissured limestones, which belong to Barremian-Lower Aptian interval (Maciu, Ionescu, 1977), or to Middle Oxfordian-Lower Aptian (Stilla, 1985). In upper position, to limestones, there is a detrital complex, which is developed only between Mălăiești and Rîul Alb, and contains conglomerates, gritstones, clays and marls belonging to the Cenomanian-Turonian interval (Maciu, Ionescu, 1977) or to Vraconian-Cenomanian-Middle Turonian (Stilla, 1985).

2. Danubian

The Danubian in North Retezat Mts is constituted of crystalline formations, granitoid rocks and weakly metamorphosed sedimentary formations. Micu, Paraschivescu (1970) and Gherasi et al. (1974) point out an overthrust line within the formations of autochthon, so prolonging eastwards the division line at regional scale of Danubian formations, which was recognized by Stănoiu (1973) in SW of South Carpathians; Macaleț (1983) separates between Nucșoara and Rîul Bărbat, an unit of a paraautochthon part. Synthetizing previous structural opinions for the whole Danubian, Berza et al. (1983) outlines here two Alpine tectonic units — Lower Danubian Unit and Upper Danubian Unit. We use this division in this paper.

2.1. **Lower Danubian Unit.** Component geological formations of this unit can be distributed to Drăgșan series, in which took place the intrusion of Retezat granitoids, to Rîușorul series, to Nucșoara Valley formation and to Oslea formation.

2.1.1. *Rîușorul Series.* Using this name, Pavelescu (1953) distinguished in the basin of Rîușorul Valley a prevailing quartzitic series which he distributed to the crystalline schists and renounced the name of Rîul Mare

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series (Gherasi, Streckeisen, 1933). Gherasi & Dimitrescu (1964) use this name but only for the formations between Nucșoara Valley and Rîușorul Valley origin ; later on, Gherasi (1974) uses it up to Radeș ridge. Gherasi et al. (1974) shows that Rîușorul series is well developed between Rîușorul and Nucșoara valleys, lying in the axial zone of Rof-Ascuțitul anticline fold ; reading seven palynological samples determined by A. Visarion, the authors conclude that the age of the deposits is Upper Precambrian.

In our zone, the rocks of this series constitute the whole ridge at left of Nucșoara Valley between Ascuțitul peak and the saddle south of Capul Dealului and continues eastwards in the basin of Nucșoara **V**alley ; here in the north, they are opened only in the left slope, plunging under the rocks of Nucșoara Valley formation and in the south, they reach the basin of Mălăiești Valley.

If in the Rîușorul basin, the petrographical unit is remarkable, the series being almost totally constituted of quartzitic schists bearing biotite, in the Nucșoara and Mălăiești basins, the rocks of this series are a little different, being represented by quartz-biotitic schists ± sericite ± chlorite and quartzitic sericito-chloritous schists ± calcite ; subordinately, there are met retromorphosed amphibolitic schists and quartz-sericito-graphitous schists.

2.1.2. *Nucșoara Valley Formation.* In the basin of Nucșoara Valley, lying on the Rîușorul series and bearing the formations of the Upper Danubian Unit in tectonic position, there are rocks which Pavelescu (1953) and Micu, Paraschivescu (1970) attributed to the Tulișa series and Gherasi et al. (1974) to the Rîușorul series. Because it has differences in comparison with both series, Macaleț (1983) suggests for these rocks the name "Nucșoara Valley formation".

An opened contact between Nucșoara Valley formation and Rîușorul series is on the left tributary of Nucșoara, which has the origin in the saddle, south of Ascuțitul peak. About 870 m height on both banks of the tributary, with divergent falls, there are opened quartz-sericitous ± graphitous schists, belonging to Nucșoara Valley formation and on the brook direction there are finely-grained, coarser quartz-biotitic schists of Rîușorul series (Fig. 2).

They are different from the schists of Rîușorul series through the low-grade metamorphism, a lot of graphitous schists as well as crystalline limestones ; from the rocks of Oslea formation, they are different through the

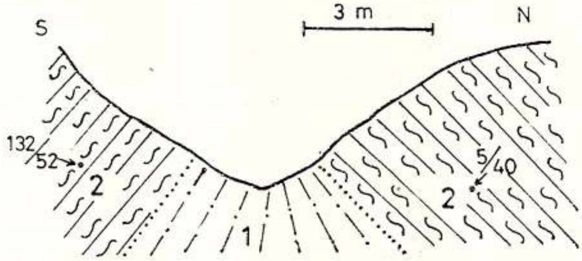

Fig. 2 – Contact between Rîușorul series (1) and Nucșoara Valley formation (2) ; outcrop sketch – left slope of Nucșoara river.

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higher grade of metamorphism and mineralogical and petrographical composition. The formation has a detritogenous character, a small thickness, being strongly folded, sometimes even at the outcrop scale (Fig. 3).

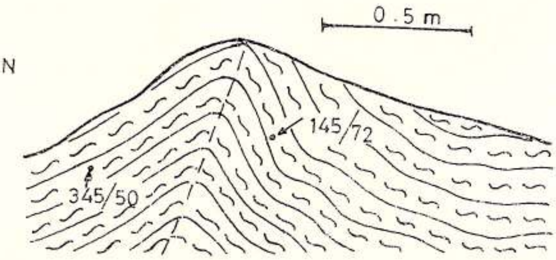

Fig. 3 — Microfold in the schists of Nucșoara Valley formation ; outcrop sketch — right bank of Nucșoara river.

2.1.3. *Drăgșan Series (Sericito-Chloritous Complex)*. We kept this name (sensu Pavelescu, 1953) only for the crystalline with which contact the Retezat granitoid rocks and bear the rocks of Oslea formation or of Rîușorul series. Westwards from Prislop peak, the schists attributed to Drăgșan series mostly correspond to the complex of lower basic metatuffs (Gherasi et al., 1974). In our zone, this series rocks are not so developed, the best opened being those west of the perimeter, as a continuous strip of 400—700 m width and being generally WSW-ENE directed in the basins of Nucșoara and Mălăiești valleys ; eastwards they are opened only in the other end of the perimeter between the upper basin of Șerel and Rîul Bărbat valleys, forming a narrow strip of maximum 200—250 m width. Drăgșan series is widely developed east and south of Retezat granitoid massif. From petrographical point of view, all the rocks of Drăgșan series between Nucșoara and Rîul Bărbat, are mostly quartzous, having various types of quartz-sericite-chloritous schists and subordinately quartz-amphibolitic schists, which were born through metamorphism under conditions of green schists facies of some pelitic sediments bearing rare intercalations of basic tuffs and tuffites ; although it is isolated, the presence of garnet makes us appreciate that locally, regional metamorphism reached the almandine isograde being followed by a retromorphism.

Everywhere, when the contact of granitoid rocks bearing Drăgșan series schists is not masked by Oslea formation, very close to the contact, biotitization and sometimes feldspathization are very obvious. When we farther the contact, biotite quantity reduces, then after 200—300 m, we notice normal rocks of the series, so that we can admit that cover rocks suffered a metamorphism of thermal contact which lie over regional metamorphism of Drăgșan series, changing into schistous hornfelses bearing biotite.

2.1.4. *Retezat Granitoids* are here represented by marginal facies of NE end of Retezat massif, coming into contact with crystalline formations of Drăgșan series eastwards and with Drăgșan series formations or with the deposits of Oslea formation northwards. Pavelescu (1953) describes gneissic and laminated granodiorites, stating that the lamination of marginal zones is

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caused by the consolidation of granodioritic body under conditions of stress, the contact with crystalline cover being tectonic, which in fact would explain the lack of thermal contact too ; however, the absence of a contact zone could be also explained through later changes of some contact biotitic schists. Micu, Paraschivescu (1970) distinguish a zone of quartzitic schists bearing biotite at the contact with granitoid rocks between Mălăiești brook and Cîrnic, showing that biotite presence is caused by the influence of granitoid rocks.

On the whole area, granitoid rocks are represented by granodiorites (maybe tonalites — trondhjemites too) bearing muscovite ± biotite.

Contacts with the schists in the cover which are very opened in the Nucșoara basin as well as in Rîul Bărbat, point out an interpenetration of the two rock types. In most cases, within granitoid rocks from the contact are caught lamellae of biotitized schists as well as decimetric enclaves of quartzito-chloritous schists ; at the same time, biotitized (and feldspathized) schists near the contact can be crossed by phanerocrystalline quartzitic veinlets or by granitoid rocks. On the left slope of Rîul Bărbat, in a deserted quarry situated inside the granitoid rocks, immediately under the ridge line towards Sohodol brook, there are opened at the lower part gneissic granodiorites and at the upper part there are schistous rocks ; these last ones could be considered, as well as those along the whole contact in this zone, migmatized schists so that the passage from granodiorites to schists is gradually done through a reduction of granitization. The same situation is noticed on the right slope of Rîul Bărbat both in the case of northern contact (Corbului brook) and southern one (Știrbului brook). At the same time, on the left slope of Rîul Bărbat, at about 100 m from the contact with Oslea formation. inside the granitoid rocks, there are some portions of quartz-muscovitic schists bearing epidote and biotite, which are but enclaves out of the preexisting schists. In comparison with the aspects described in the Rîul Bărbat basin, in Nucșoara Valley the contact is more sudden so that it can be partly tectonic, uplifting of granitoid massif leading to vertical movement of crystalline schists in the cover. On the other side, the development on much bigger thickness of schistous hornfelses bearing biotite in the basins of Nucșoara and Mălăiești valleys than in the basin of Rîul Bărbat, makes us think that in the west, a more profound level is opened than in the east, where granitoid rocks deepen under the strongly dislocated crystalline cover.

Along the Mălăiești brook, at about 500 m downstream the contact with granitoid rocks, on about 8 m thickness, within the schists of Drăgșan series, there are strongly laminated granitoid rocks which correspond to "the lens" figured on Pavelescu map (1953).

Regarding the age, most authors consider synkinematic granitoids in central Danubian of South Carpathians to be probably emplaced at the end of Precambrian and in any case, Pre-Silurian.

2.1.5. *Oslea Formation.* We use this name (sensu Năstăseanu, 1973) for weakly metamorphosed (anchimetamorphic) Paleozoic deposits at the upper part of Lower Danubian unit, because it is a general tendency to use this name, although because of priority reason or proximity with the zone of Tulișa Mt where they have been separated and described for the first time, it could be used the name of "Tulișa series" (sensu Pavelescu, 1953).

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The deposits of this formation continuously develop starting from Nucșoara right slope (about 250 m under ridge line) up to Rîul Bărbat Valley with an interruption on its left slope. From west to east, they transgressively display on Rîușorul series up to SW of Colțu Mare peak, on Drăgșan series in the saddle south of Colțu Mare, directly on granitoid rocks up to Șerel Valley, then, after the above mentioned interruption, they reappear on Drăgșan series ; even on the banks of Rîul Bărbat, the situation is different ; on the left bank (Fig. 4) white-yellowish limestones lean directly on

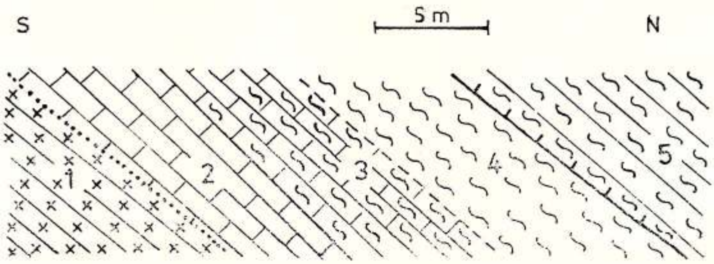

Fig. 4 — Outcrop sketch — left bank of Rîul Bărbat. 1, laminated granodiorites ; Oslea formation ; 2, limestones ; 3, limy schists ; 4, sericite-graphitous phyllites ; Zeicani series : 5, sericite-chloritous schists.

or by means of a thin level of phyllitic metapsammites on laminated granitoid rocks and on the right bank between limestones and granitoid rocks on about 10 m thickness there are quartz-sericite-chloritous schists thermally affected.

The highest thickness, up to 90—100 m, is met on Știrbina-Prislop ridge, Colțu Mare peak, the ridge right of Paroșului Valley and in the zone of Riul Alb-Poienii brook. Excepting Sălășel and Poienii brooks, where under metagritstones there is thin phyllitous level and on the right ridge of Paroșului Valley, where under metagritstones there are still phyllites and limestones, between Știrbina-Prislop ridge and Lazului Valley, the succession begins with metagritstones ± microconglomerates and continues with quartz-sericite ± graphitous phyllites, limestones and limy gritstones and again phyllites ; in some cases, the succession ends at the level of limestones (Fig. 5). A different situation is met between Preotesei brook (right branch of Valea Lazului) and Șerel Valley where the above described succession, which is here constituted only of limestones and upper phyllite level, rests on laminated metaconglomerates "Valea Beușii metaconglomerates" (Macaleț, 1983) — Figure 6. At the same time, in Rîul Bărbat slopes, the succession contains only limestones and upper phyllites, without metaconglomerates.

Concerning the thickness, generally metagritstones have 5—20 m, middle phyllites have 5—10 m, limestones and limy gritstones have 3—20 m and upper phyllites when occur have 5—50 m. Within metagritstons banks sometimes there are lenses of white quartz, as under Știrbina-Prislop ridge, where there is a lens of more than 3 m thickness and more than 25 m length.

Considering that in this zone, laminated conglomerates have a higher degree of metamorphism that the other deposits of Oslea formation and

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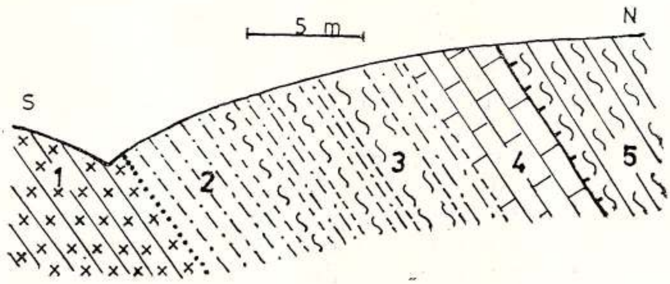

Fig. 5 — Outcrop sketch-right slope of Rîul Alb. 1, laminated granodiorites; Oslea formation: 2, metagritstones; 3, phyllites; 4, limestones; Zeicani series: 5, quartz-sericitous schists.

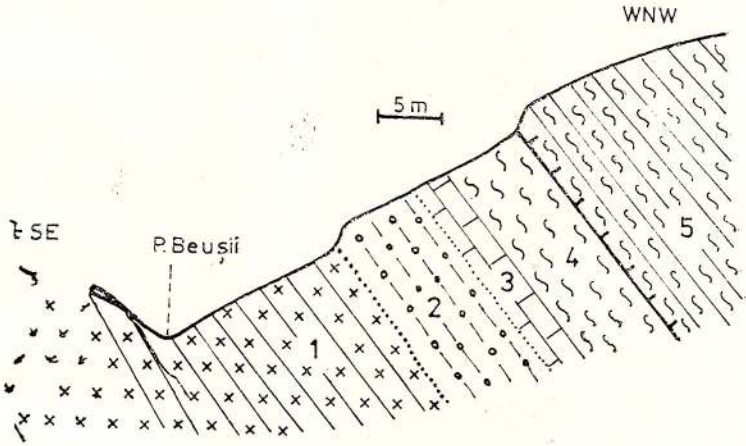

Fig. 6 — Outcrop sketch-right slope of Beușii brook. 1, laminated granodiorites; Oslea formation: 2, metaconglomerates; 3, limestones; 4, phyllites; Zeicani series: 5, quartz-sericite-chloritous schists.

directly bear the limestones level, there can be stated that between the two types of rocks, there are relations of stratigraphic (and metamorphic) discordance. So, laminated conglomerates can be equated to the conglomerates of the lower complex of Tulișa series (Solomon et al., 1976), to Retezat conglomerates (Năstăseanu, 1976) or to Capu Plaiului conglomerates (Stănoiu, 1976); main difference among them is the petrographic nature of elements and matrix. The other formations in the succession would correspond to the upper part of the lower complex and middle one in Tulișa series (Solomon, 1976), Oslea formation (Năstăseanu, 1973) or Gîrbovu formation (Stănoiu, 1976).

2.2. **Upper Danubian Unit.** Geological formations which constitute the Upper Danubian Unit between Nucșoara and Rîul Bărbat belong to its background which is entirely composed of Zeicani series (Gherasi et al., 1967, 1974; Macaleț, 1983) or Zeicani group (Kräutner et al., 1981; Berza, Seghedi, 1983; Berza et al., 1983).

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Using this name, Zeicani series, Gherasi et al. (1967) described the formations which occur at the upper side of Danubian in Petreanu Mts; they are generally covered by the Getic Crystalline and include three complexes: metatuffs and leptinites complex, metagreywackes complex and metavolcanics complex. Later, the lower complex was passed to Măgura series, Zeicani series containing only metagreywackes complex and volcano-sedimentary complex (Gherasi et al., 1974). Berza, Seghedi (1983) show that the lithological succession of Zeicani group mainly is represented by amphibolites, ocular gneisses and micaceous gneisses, which are metamorphosed under conditions of staurolite-almandine subfacies of almandine-amphibolitic facies; here we bring as argument Solomon, Pop (1973) quotation of staurolite in the schists from Valea de Munte zone (Uric). Between Rîul Bărbat and Nucșoara we included in this series all the crystalline which thrusts over the Lower Danubian Unit and is covered by the Getic Nappe, forming a EW oriented strip, having a small and relatively constant width (300—600 m) between Rîul Bărbat and Paroșului Valley and much wider westwards up to almost 3000 m on Știrbina-Prislop ridge.

From lithological point of view, we can distinguish a lower complex mostly volcanic and an upper complex mostly detrital.

2.2.1. *Lower Complex* contains most of the Zeicani series and corresponds to the complex of upper basic metatuffs of Măgura series (Gherasi et al., 1974). At the same time, on the southern part it overlies most part ot which Micu, Paraschivescu (1970) said to belong to the Tulișa series. From petrographical point of view , there can be separated chlorite-albitic schists bearing epidote and calcite, quartz-feldspathic sericito-chloritous schists quartzitic schists bearing sericite and chlorite, chlorite-albite-actinolitic schists, epidote-actinolitic schists and hornblendites. Between Paroșului and Mălăiești valleys, within this complex, metaconglomerates are very widely developed; on Sălășelului Valley and on northern ridge of Colțu Mare, they have 600—700 m width. On Nucșoara left slope, zone of Știrbina peak and on the left slope of Mălăiești brook, at about 500 m south of the contact with the Getic Crystalline, there are similar rocks but having small thickness (at most tens of meters). In this last case, on the metaconglomerates (height in outcrop of 15 m), there is a level of green chloritous schists, then quartzitic schists bearing chlorite and sericite; for this reason, we can suppose that metaconglomerates sink under the green schists, without noticing a discordance among them (they are intraformational conglomerates). But on Sălășelului Valley, sudden passage from metaconglomerates to sericito-chloritous schists can be caused by a stratigraphic discontinuity; in this case, it is about basal conglomerates.

Associated especially to metaconglomerates, there are met a few lenses of white quartz, of which that one on the left slope of Paroșului Valley crops out on about 50 m length and 3—4 m width.

A special situation have ultrabasites between Nucșoara and Mălăiești. South of Știrbina peak, immediately under the ridge line towards Nucșoara Valley on about 60 m length and about 40 m width, crops out a body of coarse hornblendites (uralitized pyroxenites) which has some parts of decimetric order constituted of epidote-actinolitic schists. West of this body,

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on a right tributary of Nucşoara brook, in the right bank, at about 150 m from the confluence, there are opened strong talcitized hornblendites which lay under quartzo-sericite-chloritous schists of phyllitic aspect of Nucşoara Valley formation; under them there are microgranular chlorite-albite-actinolitic schists bearing biotite; on the tributary direction, there are also thin levels which almost contain only biotite. Otherwise, chlorite-albite-actinolitic schists bearing biotite are widely developed on the whole right slope of Nucşoara. Also on the right slope but especially on the left one, there are several occurrences of talc schists bearing actinolite and tremolite; there is often met antigorite and crisotile. Considering also the serpentinites which occur westwards, on the left slope of Rîuşorul Valley, all these rocks have been attributed to Tulişa series (Micu, Paraschivescu, 1970) or in Măgura, Rîuşorul and Zeicani series (Gherasi et al., 1974). Some rocks described above especially hornblendites have similarities, sometimes are identical, with ultrabasites which occur westwards in the basin of Rîul Mare Valley — those on Şipote Valley and on Bodu ridge.

Because, indeed, in this zone ultrabasic rocks are hosted in various units, it seems reasonable to state that they have been emplaced on a fault system which are about ENE-WSW oriented and are reactivated at various time intervals. However, in Nucşoara basin, it seems that ultrabasic rocks and probably talc occurrences are limited only to Zeicani series which near the river crops out here and there under the schists of Nucşoara Valley formation because of its small thickness.

2.2.2. *Upper Complex* forms a continuous strip between Nucşoara Valley and Rîul Bărbat Valley having a few tens of meters in width. This complex, which is everywhere thrusted over by the formations of the Getic Nappe, mostly corresponds to the complex bearing metagreywackes of Zeicani series (Gherasi et al., 1974); Micu, Paraschivescu (1970) described these rocks at upper part of Drăgşan series as a level of chloritous schists bearing muscovite.

A characteristic profile for upper part of Zeicani series is placed on Paroşului Valley along which under chlorite-calcite-albitic schists (retromorphosed amphibolites) follow quartzitic schists bearing albite$\pm$muscovite; between muscovite schists and feldspathic sericito-chloritous schists below (of lower complex) there is a level of about 1 m thickness bearing limy metaconglomerates (Fig. 7). Similar calcite schists as those on Paroşului Valley are also met under muscovite schists on the Valea Beuşii brook.

On the left slope of Rîul Bărbat, under amphibolites lay on a same position muscovite schists and above there are quartz-sericite-chloritous schists which are crossed by numerous quartz-feldspathic separations. Contact between amphibolites and above schists is obvious; some fissures in the schists go on in the amphibolites below too.

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However, the upper part of Zeicani series is the best opened but without amphibolitic level in Nucşoara Valley. On the left slope on about 50 m stratigraphical thickness, finely-grained schists bearing muscovite from upper part gradually pass to lower part bearing coarse sericitous rocks (microconglomerates) with muscovite lamellae. Passage between them and chloritous schists below is done on a few decimetric thickness through chloritous feldspathic schists bearing rare muscovite lamellae ; this aspect would deny

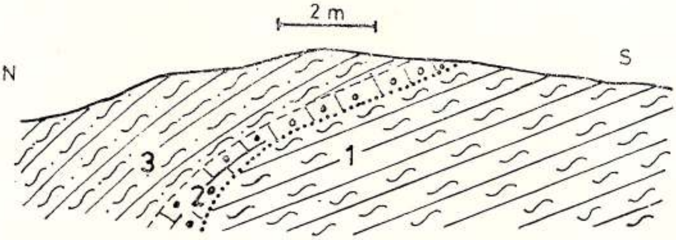

Fig. 7 — Contact between lower complex and upper complex of Zeicani series ; outcrop sketch-right bank of Paroş river. 1, quartz-feldspathic sericitous schists ; 2, limy metaconglomerates ; 3, quartzitic schists with albite and muscovite.

the fact that the apparition of muscovite schists shows a stratigraphic discontinuity. On the right slope, about 35 m under the quartzitic schists bearing albite and muscovite, there are limestones which are strongly schistous, weakly mineralized with pyrite. Between limestones and muscovite schists are chloritous feldspathic schists which however have a small quantity of muscovite lamellae. Limestones are well represented especially on the left slope where they form thin levels (generally not more than 1 m) in alternance with strongly tectonized sericitous yellow schists.

We conclude that succession of upper part of Zeicani series follows lower part in this way : limestones (limy schists) — chloritous feldspathic schists ± muscovite — quartzitic schists bearing albite and muscovite — chlorite-calcite-albitic schists (amphibolites) — quartzitic-sericito-chloritous schists (the last ones are opened only in Rîul Bărbat Valley).

If we admit that upper part of Zeicani series in this zone constitutes a separate stratigraphical unit, then the succession of the new unit would begin at the level of carbonatic rocks, the above part including chloritous feldspathic schists ± muscovite and quartzitic schists bearing albite and muscovite is of terrigene origin, differences being caused by initial detrital material, but chlorite-calcite-albitic schists (amphibolites) are metamorphic correspondents of some basic rocks.

The rocks of Zeicani series were born through the metamorphosis of a volcano-sedimentary pile under conditions of lower part of green schists

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facies ; later, they adapt to moderate conditions of the same facies, first taking place a degradation of component minerals. It is possible the last metamorphic recrystallization took place during Hercynian orogenesis, when Oslea formation was also metamorphosed and regional retromorphism took place before.

3. Hațeg Basin

Sedimentary formations of Hațeg basin close to the contact with Retezat Mts crystalline belong to Paleogene, within Nucșoara basin and to Sarmatian or Pleistocene between Rîul Alb and Rîul Bărbat (in Stilla, 1985).

Paleogene is represented by a gritty-conglomeratic complex bearing characteristic red cement and elements of crystalline schists (gneisses, micaschists, muscovite schists) and granitoid rocks.

Sarmatian is well opened between Rîul Alb and Apa Lazului, eastwards to Rîul Bărbat cropping out from under Quaternary formations only along some brooks ; it is represented by gravels, sands and clays, here and there with thin lignite intercalations.

Pleistocene is represented by terrace and piedmont deposits composed of polygenous gravels and stones, which are gathered in a sandy clay matrix of grey or yellow colour.

III. MINERALOGY AND PETROGRAPHY

1. Getic Nappe — Sebeș-Lotru Series (Group)

This unit basement is constituted of an alternance of various types of gneisses and subordinately micaschists, in which there are thin intercalations of amphibolitic rocks as follows : biotite-muscovitic paragneisses and micaschists, biotitic paragneisses, microcline gneisses, feldspathic quartzites, amphibolites, amphibolitic gneisses, breccias and mylonites, all being included in Sebeș-Lotru series. The sedimentary cover is exclusively represented by Mesozoic deposits.

Main mineralogical and petrographical aspects regarding the Getic Nappe have been discussed in a previous paper (Macaleț, 1987) that is why we add only a few figures which describe variation of anorthite content in plagioclase feldspars of biotite-muscovitic paragneisses (Fig. 8 a), biotitic paragneisses (Fig. 8 b), microcline gneisses (Fig. 8 c) and amphibolites (Fig. 8 d) ; at the same time, Figure 9 has the values of 2V angle for the microcline in microcline gneisses and Figure 10 describes the diffractogram of a microcline sample ($\Delta = 0,88$) in the same gneisses.

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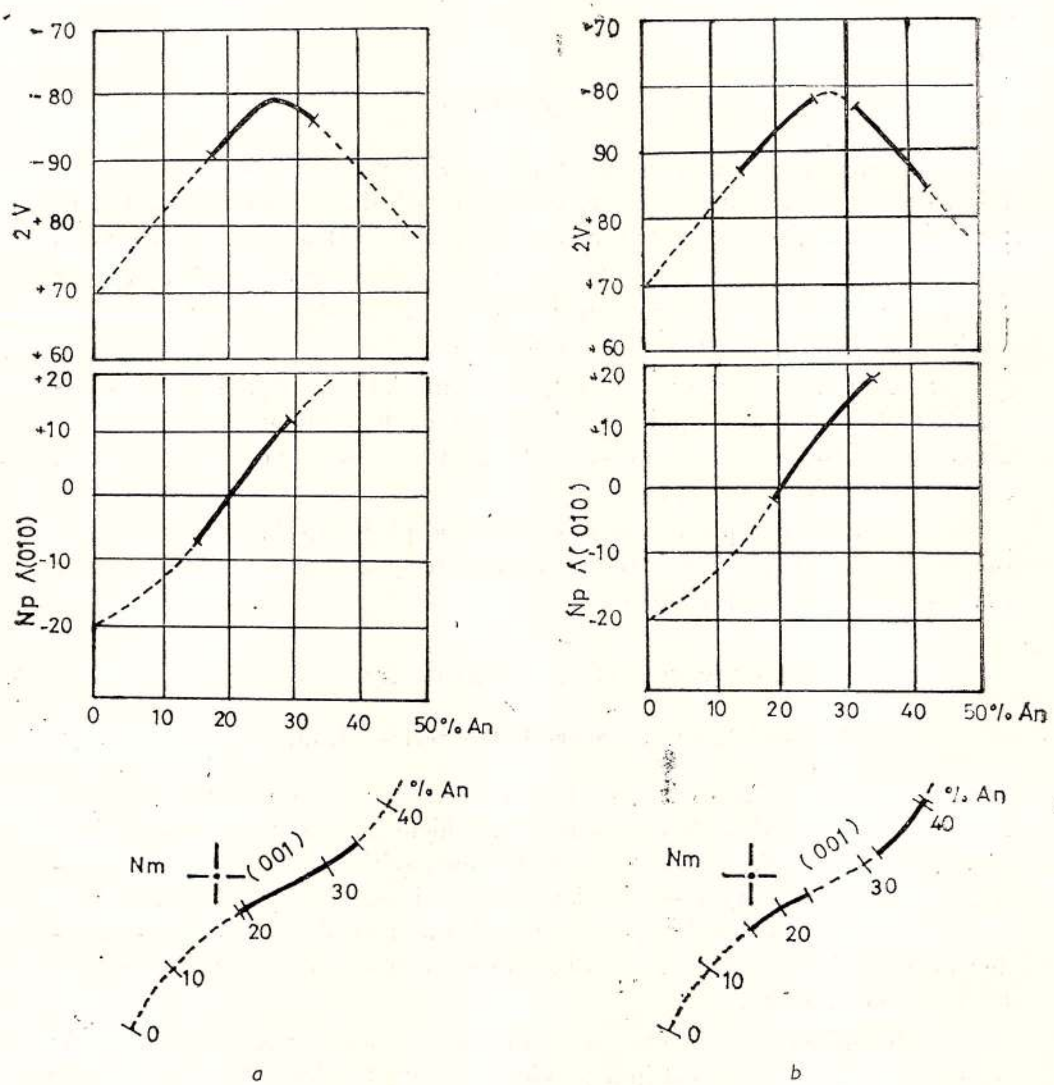

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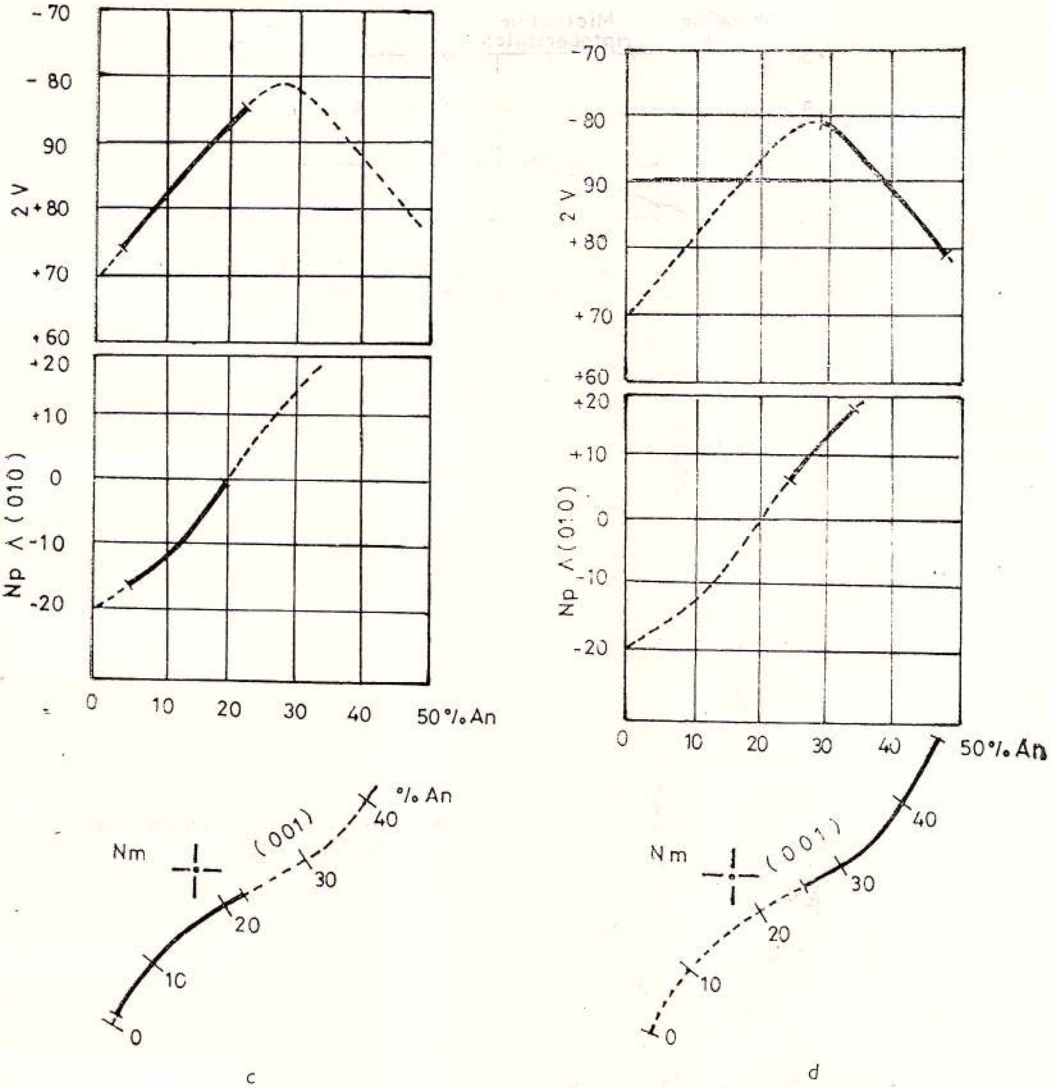

Fig. 8—2 V,Np∧ (010) and Nm∧ ⊥ (001) values for plagioclase feldspars: a, of biotite-muscovitic paragneisses; b, of biotitic paragneisses; c, of microcline gneisses; d, of amphibolites.

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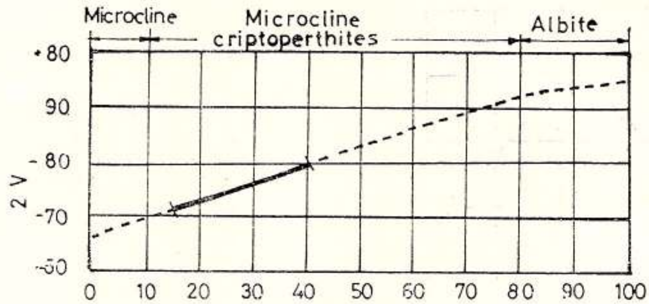

Fig. 9—2 V values for microcline in microcline gneisses.

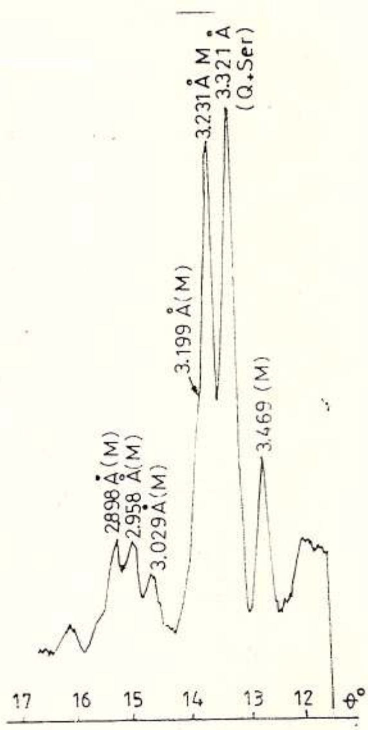

Fig. 10 — Diffractogram of a microcline sample in microcline gneisses.

2. Lower Danubian Uuit

2.1. **Rîuşorul Series.** Within this series, between Nucşoara and Mălăieşti, relative variety of described rocks is given not by quartz quantity which prevails, but the relation between lamellar minerals — chlorite, sericite, biotite; biotite in comparison with quartzitic schists bearing biotite in the basin of Rîuşorul Valley occurs in smaller quantities or even disappears in some samples, because of the retromorphism which took place in

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this zone with biotite schists. So, there are quartz-biotitic sericito-chloritous schists and quartz-sericite-chloritous±calcite schists ; subordinately there are quartz-sericite-graphitous schists and retromorphosed amphibolitic schists.

2.1.1. *Quartz-Biotitic Sericito-Chloritous Schists.* They are finely-grained, uniform or weakly-banded rocks of dark grey colour, sometimes brown in tint, silver on the schistosity surfaces and almost mat in the breach ; the schistosity is weak to middle. Under microscope, they have a granolepidoblastic structure and a weakly-stratified oriented texture, usually alternating narrow strips (up to 1 mm) which are almost entirely constituted of widely crystallized quartz, other minerals occurring in small quantities with other wider and finely-grained strips in which quartz occurs in association with biotite, sericite and chlorite in various quantities. Macroscopic dark grey colour is caused by a fine graphitous pigment which is more abundant in the zones rich in platy minerals. In some samples, besides these minerals, there are also met albite and epidote-clinozoisite (tab. 1). Sphene, tourmaline and pyrite occur as accessory minerals.

TABLE 1

	%	mm
Quartz	55-7o	o.1-o.5
Biotite	1o-15	o.1-o.3
Sericite	8-2o	o.3
Chlorite	5-12	o.3
Epidote-clinozoisite	o-5	o.o1-o.o5
Albite	o-8	o.1-o.7

2.1.2. *Quartz-Sericite-Chloritous±Calcite Schists.* They are relatively granular rocks of a weak to middle schistosity, of a general uniform grey-green colour. But there are situations when in the cutcrop or in the same sample alternate plane-parallel or irregular zones of light grey-green colour with zones of dark grey colour ; as a whole, the rock remains finely-grained, weakly schistous. Under microscope, the structure is mostly granoblastic

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or granolepidoblastic and the texture is oriented, uniform or stratified. When structure and texture are uniform, the rock occurs as a quartz grained mass, sometimes bearing a little albite, among its grains displaying small chlorite and sericite lamellae; in some zones, quartz grains are cemented with calcite — table 2.

TABLE 2

	%	mm
Quartz	60-75	0.1-0.4
Sericite	10-25	0.3
Chlorite	8-25	0.3
Biotite	0-2	0.3
Calcite	3-8	0.05-0.5
Albite	2-3	0.05-0.2

When macroscopically alternate zones of various colours, und er microscope, structure and texture of these zones are different. Zones of dark grey colour have a microgranolepidoblastic, ununiform structure; so, within a very finely-grained mass, there are irregular parts where grains are widely developed, this general aspect suggesting a probable initially uniform rock, which was later influenced by an obvious mylonitization; from mineralogical point of view, these zones are constituted of quartz, albite, sericite and chlorite. Passage to zones of light colour is suddenly done, because these last zones are very different from the structural point of view, being constituted by a much more coarse granular mass, which is relatively uniform, of quartz; among quartz grains, there are small grains of calcite as cement; chlorite also occurs in small quantities. Considering that in finely-grained zones are also present irregular parts of prevailing quartz and calcite, we can conclude that light colour zones, which are uniform granular, represent some parts resistant to mylonitization. Tourmaline, apatite, sphene, garnet, zoisite and pyrite are met as accesory minerals.

Comparing mineralogical compositions of the two types of schists, which have been described up to now, in Rîușorul series, we can notice that the only important difference is the biotite presence or absence; at the same time, the presence of finely-grained dark grey zones inside quartz-sericite-chloritous schists relates these rocks to quartz-biotitic schists, which

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have similar structure, texture and colour. However, because of mineralogical difference between the two types of schists from the point of view of clorite, biotite, calcite and albite, they could have been different in the beginning; so, biotitic schists have no calcite, albite is a lot, while sericite-chloritous schists have a lot of calcite, albite is seldom. Considering these facts, only grey, finely-grained zones within quartz-sericite-chloritous schists could be the retromorphosed equivalents of quartz-biotitic schists. Graphitous pigment causes the grey colour in all cases.

2.1.3. *Quartz-Sericite-Graphitous Schists*. They occur as small isolated lenses being finely-grained, strongly schistous, black rocks. Under microscope, they have a microgranolepidoblastic structure and oriented texture, being exclusively constituted of quartz, sericite and graphite in various quantities; graphite can be up to 20%.

2.1.4. *Zoisite Schists Bearing Chlorite and Albite*. We met these rocks only inside an outcrop of Nucşoara river. They are light grey, macroscopically the rock being constituted of a grey microgranular mass, of a weakly green tint where there are grains, which are sometimes lensy (up to 6—7 mm) and have white-yellow colour. The schistosity is very weak. Under microscope, grains of plagioclase feldspar prove to be widely developed and are almost replaced by clinozoisite as developed, long prismatic, colourless crystals and of blue birefringence colours. Clinozoisite is also present in finely-grained mass together with albite, chlorite, quartz and sericite (tab. 3); apatite occurs as an accessory mineral.

TABLE 3

	%	mm
Clinozoisite	63	o.1-1.o
Chlorite	17	o.1-o.2
Albite	13	o.o5-o.5
Quartz	5	o.o2-o.2
Sericite	2	o.1

2.2. **Nucşoara Valley Formation**. Petrographical background is represented mainly by quartz-sericite-chloritous schists or chlorite-sericitous ones and quartzitic schists bearing sericite±chlorite in which we often find intercalations of meters thickness, of quartzitic schists bearing muscovite, quartz-sericite-graphitous±chlorite±calcite schists and crystalline limestones.

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2.2.1. *Quartz-Sericite-Chloritous and Chlorite-Sericitous Schists*. They are finely-grained rocks of a well developed schistosity, which are often microfolded, grey-silver, sometimes green in tint, of a rough, satin-like aspect on schistosity planes. We seldom met a weak banding or a weak porphyric structure. At the same time, there are often small pyrite crystals, which are partly limonitized. Under microscope, their structure is grano-lepidoblastic and the texture is oriented, uniform or finely-stratified, alternating submillimetric layers of quartz with others of quartz associated with sericite and chlorite in various quantities. Sometimes, quartzitic zones are lentiliform, lenses being displayed in continuous strips which during microfolding have been broken up forming microboudines. Besides mentioned minerals in small quantities there are albite, muscovite, epidote, clinozoisite, biotite (tab. 4) and as accessory minerals there are pyrite, apatite, sphene, tourmaline and zircon.

TABLE 4

	%	mm
Quartz	52-7o	o.o5-o.4
Sericite	7-25	o.1-1.o
Chlorite	5-2o	o.1-o.6
Albite	2-8	o.2-4.o
Muscovite	2-5	1
Biotite	1	o.5

Quartz prevails as oblong grains, widely developed and has a polygonal contour in strongly quartzitic zones and smaller irregular contour in the rest of the rock. In most cases, extinction is weakly undulatory.

Sericite occurs as thin, oblong lamellae, which are displayed isolatedly and nonorientedly among quartz grains or in plane-parallel or sinuous strips in association with chlorite and quartz.

Chlorite can be abundant in some samples, being presented and distributed as sericite. It forms oblong lamellae, which often intergrow with sericite ; it has a pleochroism in tints from light green to colourless and a general low birefringence of usually dark brown, copper brown or blue colours ; there are also seldom chlorite lamellae of birefringence colours from light grey to green. Within the chloritic mass sometimes there are traces of brown-yellow or brown-green biotite ; in these cases, most of the times,

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chlorite and biotite aggregates suggest bigger lamellar forms which intergrow with muscovite lamellae; therefore, we conclude that inside initial sedimentary rock, lamellar minerals were represented by muscovite and biotite, then biotite was almost completely changed into chlorite. When chlorite has the birefringence colours from light grey to grey-green tints, it has clear blastic aspect, forming for the first time; when colours are brown or blue an indefinite aspect appears showing that it is a secondary mineral which is formed, in this case, through biotite chloritization.

Muscovite occurs only in some samples as widely developed lamellae sometimes intergrown with chlorite or biotite; in most cases, muscovite lamellae are almost completely sericitized (these are relict lamellae).

Feldspar is represented by albitized plagioclase as grains of various sizes, generally clear and fractured; it often has especially in the center of the grains traces of polysynthetical twins; only bigger grains can contain numerous inclusions of sericite and quartz. In sericite-chloritous zones can also occur blastic, clear and untwinned albite.

2.2.2. *Quartzitic Schists Bearing Sericite±Chlorite*. They are finely-grained rocks of weak to middle schistosity, of grey to dark grey colour, weak green in tint when they also have chlorite; their aspect is nacre on schistosity planes and glassy perpendicularly on these; generally, they are weakly limonitized. Under microscope, structure is granoblastic to grano-lepidoblastic, relatively uniform and texture is oriented; from mineralogical point of view, the rock is constituted of a mass of quartz which is sometimes weakly stratified; among quartz grains, there is sericite and sometimes chlorite (tab. 5) as isolated lamellae or small agglomerations; seldom

TABLE 5

	%	mm
Quartz	92-94	o.1-o.4
Sericite	2-7	o.1-o.5
Chlorite	o-5	o.1-o.3
Calcite	o-1	o.o2-o.2

lamellar minerals tend to lie on thin strips (less than 0.2 mm). Dark grey macroscopic colour is caused by the presence of graphitic pigment but in small quantities. Calcite and albite occur in small quantities (less than 1%); epidote, apatite, zircon and opaque minerals appear as accessory minerals.

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2.2.3. *Quartzitic Schists Bearing Muscovite.* They form metric layers within the other schists. They are microgranular weakly schistous rocks of a banded texture, alternating wider strips (2—8 mm) of prevailing quartz and strips of especially micaceous minerals. General colour is light grey. Under microscope, structure is not uniform, granolepidoblastic and texture is oriented, stratified ; they contain almost exclusively quartz, muscovite and sericite ; seldom we meet grains of albitized plagioclase (tab. 6). Opaque minerals, apatite and sphene can occur as accesory minerals.

TABLE 6

	%	mm
Quartz	78-82	o.o5-o.1
Muscovite	1o-15	o.1-o.3
Sericite	2-5	< o.1
Albite	1-5	o.2-1.o

2.2.4. *Quartz-Sericite-Graphitous ± Chlorite±Calcite Schists.* All are finely-grained rocks, dark grey or black in colour, nacre, satinated on schistosity planes. Generally, graphite occurs only up to 20%. Sometimes we notice macroscopically a fine stratification of white glassy strips (about 0.5—1.0 mm) which alternate with about the same thickness strips, dark grey in colour. Most samples are intensely limonitized. Under microscope, structure is not uniform, granolepidoblastic and texture is oriented, usually finely-stratified and often microfolded, alternating strips or oblong lenses of quartz, then calcite, albite, sericite, chlorite and graphite with strips of sericite, sometimes chlorite, a little quartz ; the last strips contain more graphite in quartzitic zones. In association with sericite and chlorite, there is seldom biotite partly chloritized.

Owing to mineralogical composition, that is to say some samples have calcite and chlorite in big quantities and others have not such minerals or have them in very small quantities, we could describe two types of schists : quartz-sericite-chlorite-graphitous schists bearing calcite and quartz-sericite graphitous schists. Tables 7 and 8 show mineralogical compositions for the two types of schists. Everywhere, tourmaline, apatite, sphene, rutile and pyrite occur as accesory minerals.

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TABLE 7

	%	mm
Quartz	45-55	o.o3-o.15
		o.1-o.7
Sericite	12-32	< o.8
Chlorite	5-1o	< o.8
Graphite	5-1o	fine pigment
Calcite	3-12	o.1-1.o
Albite	1-2	o.1-o.3
Biotite	o-5	< o.5
Sphene	o.5-2	o.2-o.7

TABLE 8

	%	mm
Quartz	45-6o	o.o3-o.1
		o.1-o.4
Sericite	3o-43	< 1.o
Graphite	7-2o	fine pigment
Chlorite	o-5	< o.5
Biotite	1	< o.5
Albite	1	o.o5-o.2

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2.2.5. *Crystalline Limestones*. They are often met especially on the left slope of Nucşoara Valley as some concordant intercalations of some meters thickness. They are relatively coarse rocks, about uniformly grained of a saccharoidal aspect ; sometimes they appear weakly stratified, friable of a weak schistosity. Thermal differential and dilatometric analyses on two samples indicated calcite to be the only carbonate (Figs. 11 and 12). Moreo-

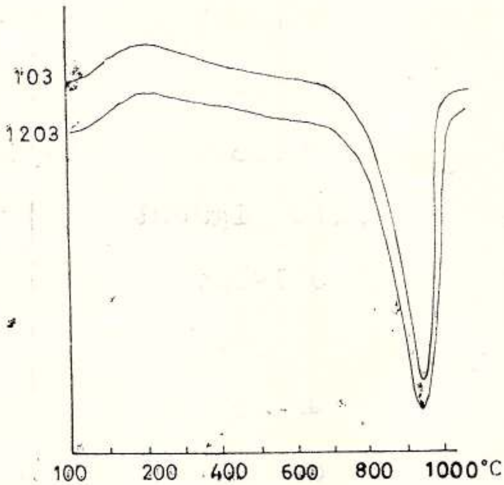

Fig. 11 — ATD curves of limestones in Nucşoara Valley formation.

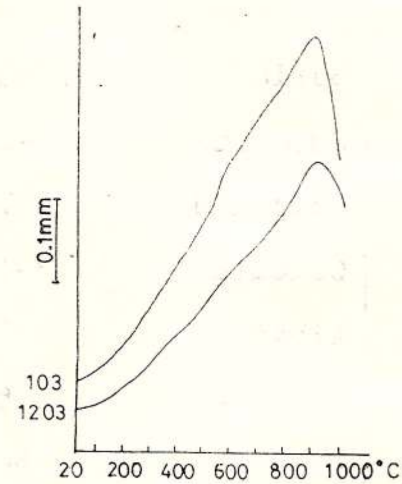

Fig. 12 — Dillatometric curves of limestones in Nucşoara Valley formation.

ver, presence of quartz is pointed out on dilatometric curves too, outlining the slope round the temperature of its polymorphic change (575°C). Under microscope, structure is granoblastic, relatively uniform, in mosaic and texture is oriented, the rock being almost constituted totally of calcite. Quartz, albite, sericite, chlorite and muscovite can occur but in very small quantities (tab. 9). Sometimes, when passage from limestone to surrounding schists is not sudden, limestone can contain a bigger quantity of quartz (up to 10%) ; this fact makes the colour darker to grey and lessens calcite granulation, its blastesis being hindered by quartz presence. Only pyrite apears as accesory minerals.

On Nucşoara right slope, within an outcrop are opened limy muscovite-chloritous schists and on the left slope, among quartz-sericite-chloritous± graphitous schists in Fîntînele, Lespezi and Zăpozii brooks, there is a concordant level of 0.5-5 m thickness, bearing white quartz-sericitous schists with calcite.

2.3. **Drăgşan Series**. Within this series , we can describe quartz-sericite-chloritous schists (petrographical background), quartz-amphibolic schists and schistous hornfelses, the last ones are to be discussed after granitoid rocks (paragraph 2.5.).

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TABLE 9

	%	mm
Calcite	97-99	o.5-1.5
Quartz	o.5-2	o.o5-o.3
Albite	< 1	o.o5-o.3
Sericite	< 1	< o.8

2.3.1. *Quartz-Sericite-Chloritous Schists*. They are grey-green rocks of a light or dark tint in function of sericite and chlorite relation, fine to middle grained of a plane-parallel schistous texture or weakly microfolded ; schistosity planes are often satinated because of sericite and chlorite flakes . With naked eye, sometimes we notice epidote and feldspar grains and rare biotite lamellae. Under microscope, structure is granolepidoblastic and texture is oriented. Main minerals are quartz, sericite, chlorite, epidote-clinozoisite, feldspar, biotite and calcite (tab. 10) ; sphene, apatite, tourmaline, rare zircon and opaque minerals occur as accessory minerals.

Quartz forms both microcrystalline agglomerations (0.02—0.1 mm) where it prevails and better developed granoblasts (0.1—0.5 mm), usually displayed in strips of 1—2 mm width. In all cases, quartz grains have irregular contours, weakly oblong forming a mosaic structure ; extinction is not uniform.

Sericite can occur in small quantities in some samples, others have up to 20—25%. When it occurs in big quantities, it displays in general sinuous strips or fills spaces among other minerals ; it also occurs as fine, weakly oriented flakes, which are especially formed on account of grains of plagioclase feldspar.

Chlorite as well as sericite quantitatively varies among large limits up to 30—35% . Pleochroism is strong from intense green to light yellow-green ; birefringence colours vary from brown to green tints. It occurs both as fine oblong flakes as well as short, well developed lamellae (up to 0.5 mm), which are sometimes overgrown with biotite and muscovite. When it appears with sericite in bigger quantity, they form a lamellar network in which other minerals are to be found.

Biotite, when it appears, it is in small quantity (less than 1%) especially as oblong lamellae which are oriented in the schistosity plane ;

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sometimes it is overgrown with chlorite. Pleochroism varies from brown-green to yellow-green.

Epidote-clinozoisite especially form small grains (0.01-0.1 mm) which are displayed in irregular agglomerations or strings but they also form bigger

TABLE 10

	%	mm
Quartz	40-70	0.02-0.1
Quartz	5-10	0.1-0.
Sericite	2-25	< 0.1
Chlorite	5-35	< 0.1
Epidote-clinozoisite	2-15	0.01-0. 0.2-1.1
Albite	1-5	0.02-0.1
Albitized plagioclase	1-3	0.2-1.5
Biotite	< 1	0.2-1.0

grains (0.2—1.0 mm), which are hypidiomorphic, sometimes twinned, strongly broken or spread within the rock; they also occur within albitized plagioclase grains. They quantitatively vary from less than 1% to about 15%.

Feldspar is represented both by clear albite grains (generally less than 0.1 mm) associated with quartz; they are not twinned or are constituted of two-three individuals associated according to (010) as well as of usually bigger grains (up to 1—1.5 mm) bearing numerous inclusions of sericite, calcite, and epidote-clinozoisite and have traces of polysynthetical twins; these last grains correspond to a more basic, relict albitized feldspar. Some sample have rare small microcline lenses (of 1—3 m thickness) bearing inclusions of quartz and albitized plagioclase.

Calcite can appear in high quantity (up to 5%) when it forms strips of grained structure (0.2—0.6 mm); but, usually, it occurs in small quantity as irregular microgranular aggregates or as isolated grains within the rock.

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2.3.2. *Quartz-Amphibolic Schists*. They form small lenses within quartz-sericite-chloritous schists being green rocks of grained aspect, weakly schistous. Under microscope, structure is granonematoblastic and texture is oriented. They are constituted of a finely-grained mass prevailing quartzitic in which develop hornblende nematoblasts orientedly displayed and feldspar grains of various sizes; epidote is also present (tab. 11).

TABLE 11

	%	mm
Quartz	45-55	o.o1-o.1
Hornblende	25-3o	o.5-1.5
Microcline	2-3	o.5-4.o
Albite+Albitized plagioclase	3-5	o.o2-o.1
Actinolite	2-5	o.o5-o.2
Epidote	1-3	o.o2-o.o5
Calcite	1-2	o.o5-o.1

Quartz forms small grains (less than 0.1 mm) which are generally oblong, of undulatory extinction and teeth structure; it constitutes about half of the rock.

Hornblende is a common variety of a pleochroism from intense green to yellow-green and with c : Ng = 14—20°; it forms weakly oblong crystals (up to 1.5 mm) often twinned having strongly broken margins. Within the prevailing quartzitic mass, there also develop small long-prismatic crystals of actinolite.

Feldspar is represented by albite as small, clear grains in association with quartz and by microcline, which forms weakly oblong grains of big sizes (up to 3—4 mm) bearing numerous microgranular inclusions of quartz, albite, calcite and even actinolite.

Epidote forms small grains (0.02—0.05 mm) and seldom big fractures grains; it is present in small quantity.

2.4. **Retezat Granodiorites.** Granitoid rocks pierce crystalline schists of Drăgşan series, being mostly represented by granodiorites. Because of a

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remarkable petrographical and mineralogical constancy, small differences occurring in structure and texture, we shall describe them together.

They are phaneritic rocks of light grey colour, of green or yellow tint, equigranular or weakly porphyritic, of a gneissic or schistous texture; this last one is more obvious because of abundant micaceous minerals. Macroscopically there are feldspars, quartz, muscovite, sometimes biotite and epidote. Under microscope, they show a holocrystalline hypidiomorphic grained structure and a texture which is more or less oriented. Strongly laminated facies show a passage to crystalloblastic structure. Main minerals are plagioclase feldspars, albite, microcline, quartz, epidote and clinozoisite, muscovite and seldom biotite. Apatite, sphene and pyrite occur as accessory minerals.

Feldspars belong to three generations. The first generation is represented by more or less idiomorphic plagioclase phenocrystals, which are generally polysyntethically twinned according to albite laws and rarely according to Karlsbad and Albite-Karlsbad law, in various saussuritization stages when form albite, sericite, kaolinite, epidote, zoisite and quartz. There is a 50—80% quantity of 0.5—3.0 mm sizes. It can be noticed a structure of schahbrettalbite within some crystals which are less changed. Sometimes, on account of this feldspar, there developed short lamellae of muscovite, which are generally displayed according to the main directions of cleavage — (001) and (010); microscopic aspects suggest that muscovite replaced the feldspar which was previously formed, even during magma's crystallization. In most cases, plagioclase crystals are surrounded by a clear zone of albite, having the characteristics of a margin of magmatic corrosion. In some cases, it is interesting to notice the apparition of plagioclase microclinization starting with the central part of crystals, later on replacing the whole crystal. We consider that initial more basic plagioclase feldspar continuously reacted with magma on the way of crystallization, more and more acide, getting a primary zonal structure. Tendency to plagioclase recrystallization was caused by later regional metamorphic processes which influenced the whole region. Generalized albitization of plagioclase makes almost impossible to appreciate its initial composition. The most frequent values of 2 V angle vary from +74° and — 85°, which would correspond to An_2—An_{20} interval. Only in a few cases, we obtained bigger values, but only An_{30}. 2 V . Np$\wedge$(010) and Nm $\wedge$ (001) values are given in Figure 13 a. An argument for a low content in anorthite of initial plagioclase can also be the small quantity of calcium minerals (clinozoisite, epidote, calcite) among its transformation products.

Second generation of feldspar is represented by microcline, microcline-perthite and albite which mix among older minerals — plagioclase, quartz, muscovite — including them and creating some lenticular forms — „ocelli" — up to 1.5—2 cm. We can remark that plagioclase feldspar included in ocellis of microcline and albite are generally as crystals of a more accentuated idiomorphism than plagioclase in the rest of the rock, usually being fresher and, having a weakly tendency to orientation; however, there are also grains of strongly corroded plagioclase. In most cases, ocellis are surrounded by a thin zone of muscovite. Microcline occurs both not twinned and polysynthetically twinned in grills; these situations can be met even inside the same grain. Optical. sign is (—) in most cases, rarely (+). Determinations

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at universal stage gave values between $-72°$ and $90°$ (Fig. 14 a), most of them varying from $-2V = 75 - 82°$ and showing a cryptoperthitic microcline. A X-ray diffractometric analysis (Fig. 15) pointed out an intermediary microcline with $\Delta = 0.80$ triclinicity index. Albite exsolutions in microcline are very often met, forming with (001) cleavage an ongle varying about from 10 and 20° ; general aspects is a perthite film. There is also microcline as small, allotriomorphic grains (0.1—1.0 mm), which are distributed at random in the rock together with quartz and albite. If in some cases,

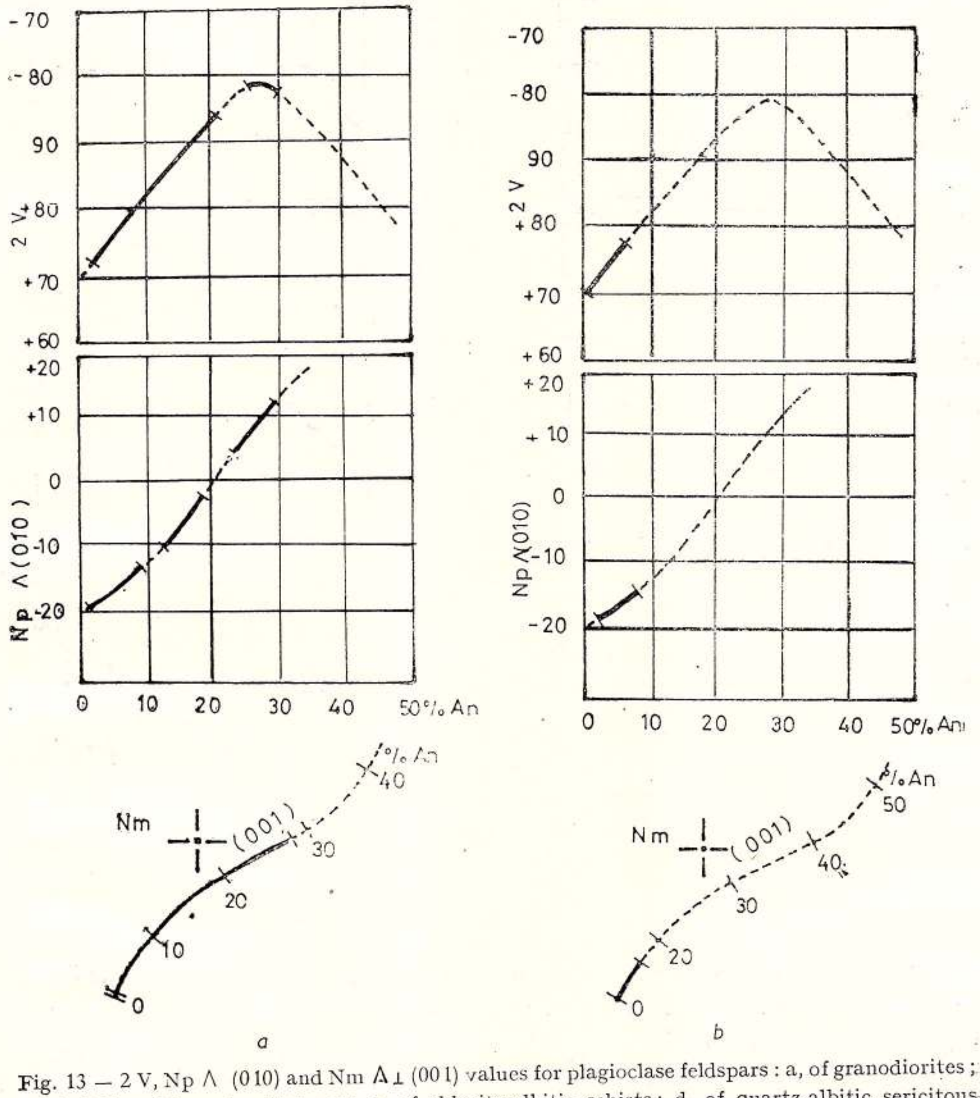

Fig. 13 — 2 V, Np Λ (010) and Nm Λ ⊥ (001) values for plagioclase feldspars : a, of granodiorites ; b, of feldspathic metagritstones ; c, of chlorite-albitic schists ; d, of quartz-albitic sericitous schists with microcline.

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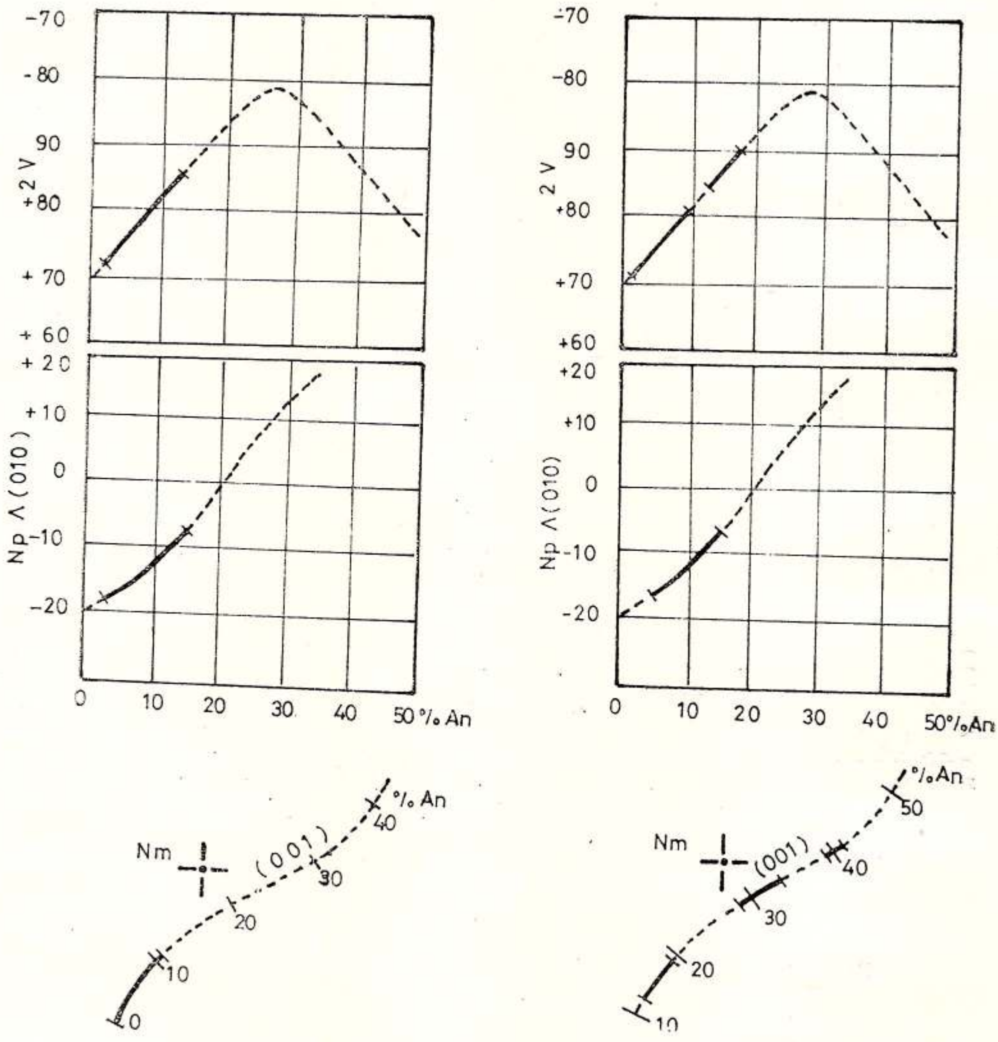
microcline is the only feldspar which includes preexisting plagioclase, constituting ocellar formations, in other cases, microcline is present in small quantity or is lacking, in its place forming fresh and untwinned albite.



c d

A X-ray diffractometric analysis, on such an ocell (Fig. 16) indicated 80—85% albite, which is associated with a plagioclase of oligoclase-andesine type, totally corresponding to microscopic observations. In some samples, microcline with albite of this second generation are varying from 15 to 20%.

The last generation of feldspar is represented by an albite as small clear crystals (0.1—0.5 mm) of about constant composition — An_4. Twins

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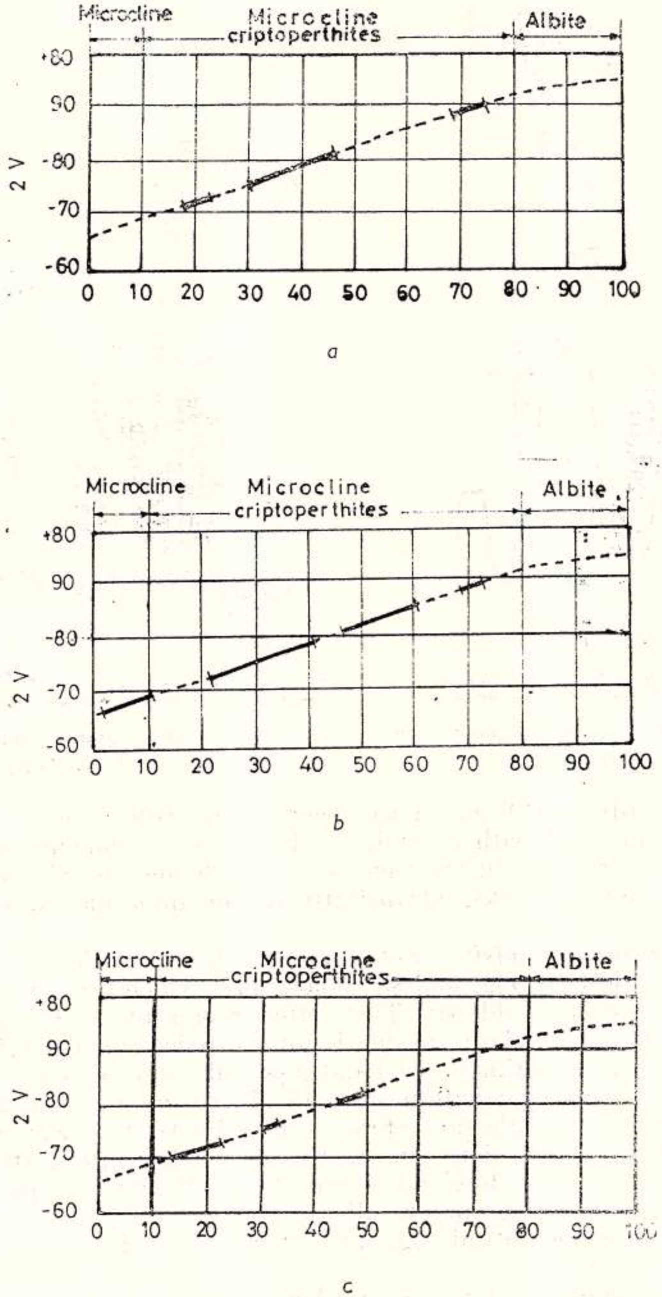

Fig. 14 — 2 V values for microcline : a, of granodiorites ; b, of feldspathic metagritstones ; c, of guartz-albitic sericitous schists with microcline.

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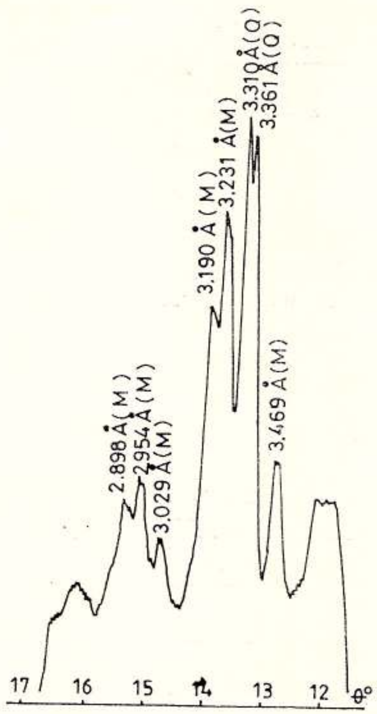

Fig. 15 — Diffractogram of a microcline sample in granodiorites.

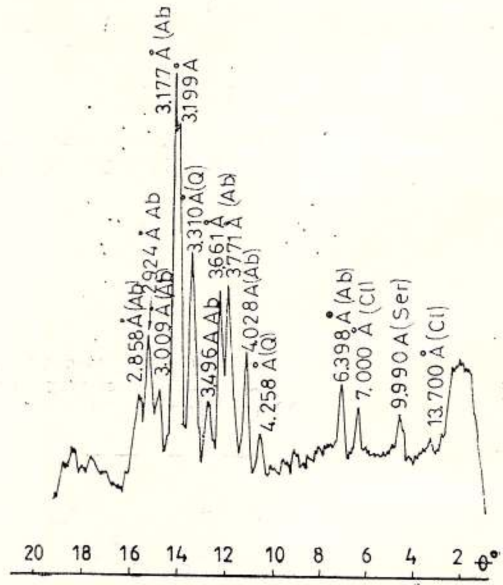

Fig. 16 — Diffractogram of an albite sample constituting ocellar formations in granodiorites.

presence according (010) which are generally constituted only of 2—3 individuals, corroborated with crystals freshness, are arguments which stress the fact they were born during regional low grade metamorphism which also influenced granitoid rocks. Quantitatively, metamorphic albite is at the most 1—2%.

Epidote and clinozoisite are often present in these rocks both as primary minerals (Pavelescu, 1953) and secondary ones which are born on account of initial plagioclase feldspar. They often represent 1—3%, rarely 8%. Primary epidote forms both prismatic idiomorphic crystals (0.5—1.5 mm), usually twinned , sometimes zoned and especially grained aggregates which are irregularly displayed within the rock. In some cases grained epidote, especially associated with quartz forms thin veinlets (2—4 mm) which cross the rock in various directions ; in other cases, in the samples strongly laminated, microgranular epidote and muscovite are displayed in parallel strips. On the margins of some epidote idiomorphic crystals, there can be often noticed a narrow zone of microgranular, recrystallized and varied oriented epidote.

Primary muscovite forms short lamellae up to 0.5 mm length, being spread all over the rock, rarely forming small agglomerations together with epidote and clinozoisite ; within strongly laminated facies, they are oriented in the plane of schistosity. In some samples, we remarked a great quantity of muscovite which moulded ocellis of microcline and albite. In some cases,

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muscovite, as short well-developed lamellae, partly replaced plagioclase feldspar. Even in the richest samples in muscovite, it is 6—7%. The second generation is represented by secondary sericite formed on account of plagioclase feldspar during the processes of metamorphic recrystallization.

Biotite , when it occurs, there is in very smal quantity, excepting some samples downstream of Lolaia waterfall on Nucşoara Valley, where it is up to 5%, as short isolated lamellae or intergrown with muscovite, which it quantitatively surpasses. Generally, there is however a tendency to increase biotite quantity near the contact with cover schists.

Chlorite is seldom met, especially on the borders of the massif and is formed on biotite account.

2.5. Contact Rocks ; Schistous Hornfelses Bearing Biotite and Epidote. They are fine to middle grained rocks of ununiform colour, generally greygreen, often mottled in colour, because of a lenticular or nodular texture ; there is seldom a plane-parallel banding. Schistosity is similar to the schists outside the aureola ; in some cases, we notice a better schistosity when coming close to the contact. On the field, increase of biotite quantity and accentuated mottled aspect are certain reasons for closing the contact, both in the north of granitoid massif and in the south on Rîul Bărbat Valley.

Under microscope, we notice an oriented microgranolepidoblastic mass which is mainly constituted of quartz, epidote-clinozoisite±albite±sericite±chlorite±muscovite, in which there are found well-developed lamellae of biotite±chlorite and bigger grains of quartz, epidote-clinozoisite and albitized plagioclase. When they occur, lentiliform (0.5—2/3—5 mm) or nodular aggregates, which are macroscopically light in colour, prove to be constituted of a microgranular mass (less than 0.05 mm) ; it is almost exclusively constituted of quartz (75%), epidote-clinozoisite (20%) and sericite and those dark in colour are formed of biotite, quartz, epidote, clinozoisite, apatite and sphene. At the same time, there can occur microcline ocellis, bearing inclusions of quartz and albitized plagioclase, being similar to ocellis in granitoid rocks. In some samples, we can add hornblende too. As accessory minerals, there are met sphene, apatite, rarez ircon and opaque minerals. Table 12 show variation limits of mineralogical composition and mineral dimensions.

Quartz prevails in all samples (50—70%) as small grains (0.02—0.1 mm) and big ones (0.1—0.5 mm), equidimensional and a little oblong, strongly caught in teeth among them and with other minerals forming agglomerations or being displayed in strips ; extinction of grains is always ununifom.

Biotite is the characteristic mineral of these rocks being able to follow all the passages from an incipient development on account of lamellar minerals — sericite and chlorite — in original quartz—sericite-chloritous schist, occurring as spots or oblong lamellae which are parallely displayed with the schistosity, associated with sericite and chlorite, up to short well-developed lamellae of porphyroblastic aspect, which are often intergrown among them or with chlorite, sometimes with muscovite too. Even when they form agglomerations or are displayed in strips, individual lamellae are weakly oriented or are not oriented at all, being irregularly displayed. In samples bearing hornblende, we have to mention how porphyroblastic biotite deve-

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lops on hornblende account; biotite lamellae cross it in various directions or grow perpendicularly to the grains'margin. At the same time, in some cases, newly formed biotite can replace grains of epidote-clinozoisite. Pleochroism of porphyroblastic lamellae has lighter tints than in the case of biotite as oblong lamellae or outside the aureola, from light brown-green to pale yellow, almost colourless and refringence colour are very light close to mus-

TABLE 12

	%	mm
Quartz	45-7o	o.o15-o.5
Biotite	2-2o	o.1-1.5
Sericite	2-15	< o.1
Chlorite	o-15	o.o5-o.7
Muscovite	o-12	o.1-o.5
Epidote-clinozoisite	4-15	o.o2-1.o
Albitized plagioclase	o-5	o.5-4
Albite	1-4	o.o2-o.1
Microcline	o-5	o.1-4.o
Hornblende	o-7	o.5-1.5
Calcite	o-3	o.1-1.o

covite. — 2 V ongle is very small, interference figure being practically uniaxial.

Biotite quantity in the samples, which was born on account of chlorite and sericite, is generally a function of coming close to the contact, however also depending on chlorite and sericite quantity from initial schist; thus at the contact there can be found muscovite lamellae, which was forme,p

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through sericite recrystallization, if chlorite quantity was not enough to form biotite, or well-developed chlorite lamellae, if initial rock had not enough sericite. Two X-ray diffractometric analyses on samples of coloured lamellar minerals from schistous hornfelses in Nucşoara Valley gave the following results. The first sample at about 150 m distance from the contact pointed out the presence in equal quantities of biotite and chlorite (Fig. 17 a) and the second sample, at the contact, shows only the biotite (Fig. 17 b).

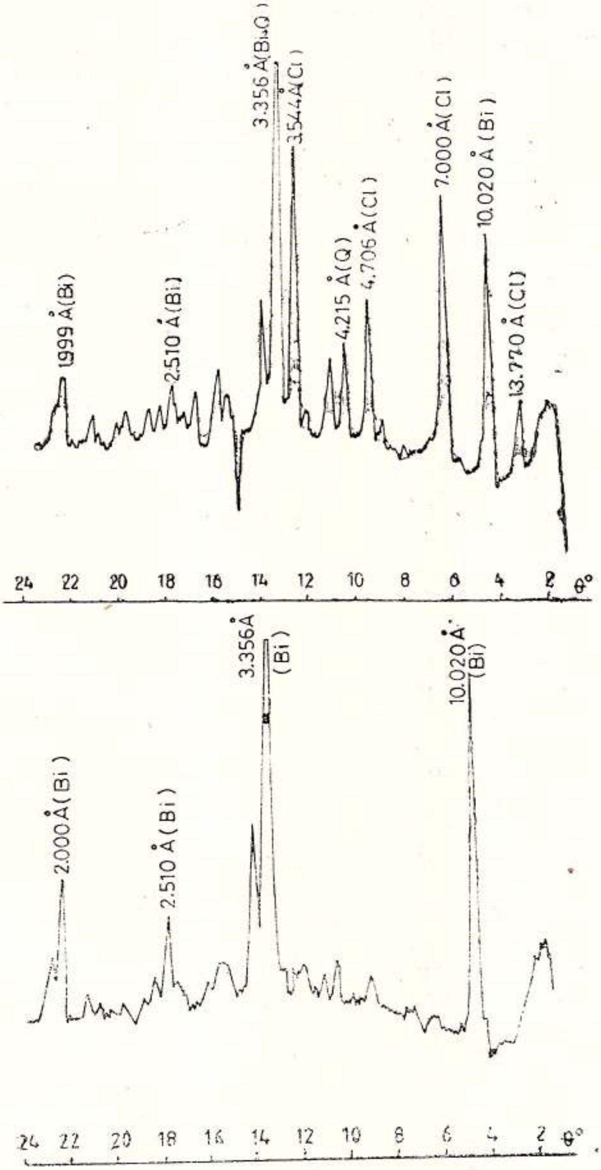

Fig. 17 a, b — Diffractograms of two samples of chlorite + biotite and biotite in schistous horfelses with biotite and epidote.

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Chlorite near the contact forms short, well-developed lamellae (up to 0.5—0.8 mm) weakly oriented, often intergrown with biotite; it has a pleochroism from light green to light yellow-green or pale yellow and light birefringence colours in grey-green tints; we have to remark some differences from chlorite in the schists far from the contact, with a pleochroism in darker green tints and darker birefringence colours, in brown-green tints. Relations between biotite and prophyroblastic chlorite rather show a simultaneous formation than a replacement of one by the other one.

Sericite is found in big quantity in samples far from the contact (up to 15—20%), then it gradually reduces generally coming close to the contact, where it is usually lacking or is present in small quantity because it reacts with chlorite to form biotite, or because of recrystallization when muscovite porphyroblasts are formed. However, at least a little of these rocks'sericite could form later on within plagioclase feldspar. It occurs as small flakes (less than 0.1 mm) which are not uniformly spread, rarely being displayed as strips parallel to the schistosity.

Muscovite, when it occurs, forms both oblong, well-oriented lamellae, displayed in strips mixed with the other minerals and short unoriented lamellae, which are similar as form and distribution to biotite lamellae near the contact; we have to remark that generally well developed lamellae of muscovite in samples exclud chlorite presence. It is quantitatively up to 5—10%.

Epidote and clinozoisite are also characteristic minerals to schistous hornfelses, sometimes they occur in big quantity (up to 12—15%). They form both small grains, which are almost uniformly distributed and bigger grains which are isolated or displayed in irregular agglomerations and strings. Sometimes, bigger grains can have an obvious, short-prismatic, twinned idiomorphism, in other times, they are strongly cataclased, fragments being spread in the rock.

Hornblende rarelly occurs in schistous hornfelses corresponding to quartz-sericite-chloritous schists. It is found a lot in those hornfelses coming from quartz-amphibolitic schists. It is a common variety with $c : Ng = 16—20°$, occuring as grains, which are generally short and spread, being replaced more or less by biotite association with chlorite and calcite; grains have 1.5—2 mm. At the same time with the replacement of common hornblende were born small, long-prismatic crystals of actinolitic hornblende which are included together with remains of original hornblende in lamellar agglomerations of biotite or being ununiformly distributed.

Feldspars are represented by plagioclase, albite and microcline, all of them being generally present in small quantities.

Plagioclase occurs as round grains, sometimes of 3—5 mm, having all passages from albitized plagioclase, sometimes with a schahbrettalbite structure and traces of polysynthetical twins, being replaced by sericite especially on the margins, up to a compact sericitic mass, which is partly recrystallized by muscovite in which there are almost no remains of feldspar; within the sericitic mass, there can be found epidote-clinozoisite, quartz, calcite and rarely biotite. In some samples, epidote-clinozoisite quantity, which is formed by plagioclase replacement, is big enough, noticing situations when one prismatic crystal of epidote completely replaced a plagioclase grain.

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Albite forms small grains especially within the microgranular quartz mass of clear aspect, being untwinned or constituted of 2—3 individuals associated according to (010) ; its quantity is only 2—3%.

Microcline is especially found in the samples near the contact, forming both isolated grains of 0.2—0.5 mm and bigger ocellis (1—4 mm) with numerous inclusions of quartz, albitized feldspar and calcite. There are also cases when albitized plagioclase of a schahbrettalbite structure is partly replaced by untwinned microcline or with grilled structure. Its quantity can be 4—5%.

Sphene is present in almost all samples, being widely developed near the contact, forming microgranular aggregates, isolated grains of irregular forms and idiomorphic crystals as pens up to 1.2 mm ; small grains of sphene are often included in biotite lamellae.

In comparison with the schists in the aureola at northern contact of granitoids, those at eastern contact can have a bigger quantity of albitized plagioclase feldspar, according to its abundance in regionally metamorphosed schists, the other features being similar.

Synthetizing the transformations of quartz-sericite-chloritous schists and of quartz-amplibolitic schists in Drăgșan series, inside the contact aureola, we can show the following :

— From outside to inside, sericite and green chlorite quantity progressively reduces, at the same time with the porphyroblastic development of light brown-green biotite and eventually of a light green-yellow chlorite. Even within the aureola, we can remark a lighter colour of biotite and chlorite when coming close to the contact. When chlorite quantity is smaller than sericite quantity, sericite could recrystallize forming muscovite lamellae ; newly formed chlorite also depends on the insufficient sericite in the initial schist.

— High quantity of sericite in some samples, which replaces plagioclase feldspar and mirocline presence near the contact indicates a potassium addition from magmatic body. This fact also caused the hornblende replacement by biotite.

— Lack of some typical minerals for contact metamorphism — cordierite and andalusite for example — was especially determined by quartzitic nature of schists, but also by a probable high stress during the contact metamorphism which at least partly overlied temporally over the regional metamorphism of surrounding rocks ; at the same time, contact temperature which was a little higher than cover rocks, caused no substantial desequilibra which lead to the apparition of some more different mineralogical associations.

However, mineralogical composition in table 12 suggests albite-epidotic facies of contact metamorphism.

2.6. **Oslea Formation.** Within this formation, we describe weakly metamorphosed Paleozoic deposits from upper part of Lover Danubian Unit.

2.6.1. *Metagritstones and Metaconglomerates*. Metagritstones are widely spread among the rocks of Oslea formation between Nucșoara Valley and Rîul Bărbat Valley, forming an almost continuous level usually at the base of the succession. But metaconglomerates are not so developed, being met

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only in the basin of Şerel Valley. The two types of rocks resemble because the conglomerates'matrix has a similar petrographical constitution with the metagritstones'(subarkosian ones).

a) *Metagritstones*. According to feldspar content, we can describe quartzitic metagritstones, which generally have no feldspar and feldspathic metagritstones — subarkosis (5—25% feldspar) and arkosis (more than 25% feldspar). Besides quartz or quartz and feldspar, in most samples sericite is present from 4 to 8%, rarely 15% or 1—2 %. Dark or light colour in the handspecimen is determined by the presence or absence of graphitous pigment which is finely spread in the rock.

Quartzitic metagritstones are not so developed, being best represented in the openings on Ştirbina-Prislop ridge and left slope of Paroşului Valley. They are hard, microgranular, massive or weakly schistous rocks of dark grey colour and glassy aspect in the breach. Massive varieties are strongly fissured ; on fissures'planes, there is oriented sericite, which creates a satinated aspect. Under microscope, the structure is mostly grained and texture is oriented ; the rock has more than 90% quartz, then sericite (tab. 13) ; graphite occurs in small quantities and seldom feldspar. They formed through the weak metamorphosis of some quartzitic gritstones bearing a little clay cement mixing with organic material.

TABLE 13

	%	mm
Quartz	9o-95	o.1-o.5
Sericite	4-8	o.1-o.4
Albite	o-1	< o.5
Graphite	1-2	fine pigment

Feldspathic metagritstones are widely spread, subarkosian ones being the best represented. Because feldspar quantity is the only difference among them, we shall describe them together. A general feature of feldspathic metagritstones is given by microcline which prevails over plagioclase.

They are relatively middle-grained, of oriented, uniform or weakly stratified texture, generally weakly-schistous. Their colour is grey, has various tints from light grey to dark grey, glassy aspect in the breach and pearly on the schistosity planes. Most samples occur weakly limonitized giving a weakly yellow or brown tint. With naked eye, especially perpendicularly on the schistosity planes, there are quartz and feldspar grains, which are generally fresh and on the schistosity planes there can be seen fine sericite lamellae. Sometimes, can occur bigger glassy lenses (up to 1 cm) of grey

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colour ; at the same time, several times we can notice numerous small levigation voids (generally less than 1.5 mm) of yellow-brown colour. Most of feldspathic metagritstones are strongly laminated, macroscopically some of them being similar with granitoid rocks. Under microscope, the structure occurs especially grained, ununiform and texture is oriented being constituted of a prevailing microgranular quartz mass together with sericite and sometimes albite ; in which there are ununiformly distributed bigger grains of various sizes, generally strongly cataclased, of microcline, plagioclase feldspar, sometimes quartz. Stratified macroscopic texture met in some cases, results alternating strips richer and poorer in sericite ; usually, strips rich in sericite are narrower, generally have less than 1 mm and those poor in sericite can have 4—5 mm thickness. Bigger lenses met in some cases are constituted of quartz and plagioclase feldspar which is strongly alterated and opacized or they are constituted only of microgranular quartz and are dressed in a thin sericite cover. These lentiliform zones are but initial pebbles. There are also limonite, sphene, epidote and tourmaline as accesory minerals. Mineralogical composition and middle sizes are given in table 14.

TABLE 14

	%	mm
Quartz	73-86	0.05-1.5
Microcline	4-20	0.3-2.5
Plagioclase and Albite	1-5	0.2-1.5
Sericite	2-15	<0.5

Quartz prevails in all samples (more than 70%), being mostly microgranular ; it occurs as oblong grains with sinuous tooth borders and accentuated undulatory extinction. When it forms bigger grains, they also have irregular contour, with broken margins and a strong undulatory extinction, sectoring completely the grains. These last grains represent an argument for the fact that microgranular quartz also resulted through a complete breaking and recrystallization of some bigger grains.

Microcline is present in all samples, several times it prevails as quantity over plagioclase feldspar, varying from 4 to 25% and often between 4 and 10%. It generally occurs as clear widely developed grains of various sizes with irregular or round margins, which are strongly fractures and recemented with microgranular quartz. We often notice microperthitic exsolutions as thin veinlets which are parallely displayed and polysynthetical twins in the grill. Refringence of fine lamellae in microperthitic exsolutions is always higher than the mass where they are found ; this means that exsolutions can

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be more basic than Ab. Conoscopically, optical sign occurs both (—) and (+), determinations at the universal stage really showing a big variation of 2V angle (form —67°to 90°) — Figure 14b, without (+) values. The figure shows that most grains are constituted of microcline — criptoperthites, their composition varying from Or_{80} Ab_{20} to Or_{30} Ab_{70} ; we have to remark that grains' mass bearing microperthitic exsolutions would have a similar composition as microcline. In some samples, microcline grains are found in various stages of argillization (kaolinization) so becoming turbid. If its kaolinization advanced with a nicols, on colourless rock background, we can notice numerous brown-yellow spots ; with two nicols, these spots are almost completely isotropic or have fine, short flakes of sericite ; in some cases, remains of microcline are kept within these isotropic zones. This means that most microcline was replaced by kaolinite and a little sericite. In some samples, there are also found small, fresh, twinned in grill microcline grains, which are displayed among quartz grains. Besides isolated grains, microcline can also be found in some polycrystalline pebbles, which are constituted of microcline, plagioclase and quartz, probably coming from the gneisses of Getic Crystalline ; a better argument for this origin is also the presence of twinning in the drill, which makes these microcline grains different from the microcline in the granitoid rocks. However, in some cases, microcline grains have inclusions of albitized and sericitized plagioclase as well as in granitoid rocks. Presence in the same sample of both microcline grains bearing albitized inclusions of plagioclase, typical to granitoid rocks and grains without inclusions, twinned in grill, typical to Getic Crystalline, makes us conclude that potassic feldspar comes from both types of rocks.

Albitized plagioclase is met in almost all samples, in most cases being subordinated to microcline, generally being 2—5%. Grain sizes are also smaller than microcline's, however being bigger than the grains of quartzitic microgranular mass. It forms grains of various sizes which are irregular or round and strongly fractured ; smaller grains can be clear and untwinned and bigger grains have often sericite inclusions, being often polysynthetically twinned, sometimes of a schahbrettalbite structure ; in some samples, plagioclase grains can be intensely impregnated with limonite and others have graphitous pigments, thus, determine macroscopically a dark grey colour. As in the case microcline besides isolated grains, plagioclase also occurs in some bigger lenses in association with quartz ; in these cases, it is completely albitized, probably coming from the gneisses of Getic Crystalline. At the same time, there are also lenses (pebbles) which are constituted only of microcline and albitized plagioclase ; microcline forms a mass of unitary optical orientation, representing a single crystal and plagioclase can be represented by several crystals included in microcline ; these lenses are pebbles of granitoid rocks.

Albite occurs as small, clear untwinned grains or constituted of 2—3 individuals twinned according to (010), associated with quartz in microgranular mass in small quantity (at most 1—2%) of blastic character. In some samples, it is interesting albite formation besides quartz on account of broken grains of microcline too. 2V, Np $\wedge$ (010) and Nm $\wedge \perp$ (001) values (Fig. 13b) show that in all cases, it is about an albite of a composition between An_0 and An_6.

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Sericite occurs in all samples, generally in small quantity sometimes more than 10%. It occurs as small, thin and oblong lamellae isolated or forming irregular agglomerations among grains of microgranular quartz or around bigger lenses of quartz and feldspar. In the case of stratified samples, well oriented lamellae of sericite are displayed in narrow strips which alternate with wider strips of quartz. When it occurs in the vicinity of grains of albitized plagioclase, it always has the tendency to form wider developed lamellae of muscovite. At the same time, sometimes there are rare muscovite lamellae which are bent or broken and partly sericitized.

Only in some samples, in small quantity occurs *chlorite*, which is represented by pennine, probably formed through chloritization of some detrital lamellae of biotite.

b) *Metaconglomerates* (Valea Beușii metaconglomerates — Macaleț, 1983) are constituted of a similar matrix, concerning their composition and structure, with coarser feldspathic metagritstones; in which are caught wider developed elements of various sizes and with different petrographical composition. As a whole, main structural characteristic is the prevailing matrix in comparison with included elements; also considering different nature of elements, we can include these rocks in the group of extraformational (basal) polymictic, weakly metamorphosed paraconglomerates. They are rocks of light grey colour of weakly yellow tints, which are constituted of a relatively coarse, hard matrix of middle schistosity in which with naked eye we can notice quartz, usually without distinguishing individual grains and feldspar as relatively fresh grains of nacre lustre and generally with sizes up to 3—3.5 mm; however, there are cases when these grains have 5—6 mm. In comparison with most of described metagritstones, in these rocks, white mica in quartz-feldspathic matrix is more widely-developed. At the level of the outcrop, we see numerous lenticular elements strongly flattened of 1—10 cm length, being dressed in a quartzitic sericitic mass. Most of these elements are exclusively represented by quartz, in small quantity there are elements constituted of quartz and feldspar, to which sometimes associates muscovite. Generally quartz elements are more widely developed than the others.

Concerning the matrix, which has constitution and structure similar with previously described feldspathic metagritstones, we show in table 15 only the composition and approximative sizes of grains in a few samples, our considerations on occasion of description of feldspathic metagritstones both regarding microgranular prevailingly quartzitic mass and bigger grains of quartz and feldspar remaining the same.

Further on we shall describe in turn the two types of elements (pebbles) of metaconglomerates — elements which are constituted of quartz and quartz-feldspathic elements.

Quartzitic elements are strongly flattened; for instance, one of the biggest elements is like a lens of 10 cm length, 8 cm width and 3.5 cm maximum thickness. Macroscopically they are constituted of a microgranular mass of light grey-white colour of a glassy aspect. Under microscope, all these pebbles are almost exclusively constituted of quartz, most of them having a relatively uniform microgranular structure and an oriented texture. Essential difference between quartzitic elements and quartzitic host mass

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is sericite content in the latter; it also contains bigger grains of feldspar. However, some elements can have a coarser, ununiform structure being constituted of widely developed grains of quartz with strong undulatory extinction and broken margins, among which there are as cement, small,

TABLE 15

	%	mm
Quartz	80-85	0.05-0.4 0.6-1.8
Microcline	8-12	0.5-3.5
Plagioclase	2-5	0.2-2.0
Sericite	4-5	0.2-1.2

oblong grains of irregular margins obviously coming from broking bigger grains; in these cases, general aspect looks like a microbreccia. Having these structural features quartzitic pebbles have all stages from a coarse, ununiform, partly cataclased quartzitic rock (microbreccia) to a microgranular rock (mylonite).

When sericite occurs, it is in very small quantity as fine isolated, a little oriented lamellae.

Rarely in the elements of a coarser structure, there are also cataclased albite grains (schahbrettalbite).

Approximative sizes of quartz are the following:

— in elements of relatively uniform microgranular structure: 0.05—0.3 mm;

— in elements of ununiform coarse structure:

0.05 — 0.2 mm . . . . .50 — 80%
0.5 — 1.8 mm . . . . .20 — 50%

Coarse quartzitic elements probably come from a quartzitic rock similar to those from Zeicani series (on the left slope of Paroşului Valley, for instance).

Quartz-feldspathic elements are found in smaller quantity than quartzitic ones and have usually smaller sizes. Their colour is grey, of yellow to brown tint, sometimes being strongly limonitized. Under microscope, they occur constituted almost totally of quartz and plagioclase feldspar, a little muscovite; they form a relatively coarse structure.

Quartz is mostly found as widely developed grains of irregular margins and undulatory extinction, strongly toothed among them or with plagio-

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clase grains. As small grains there is also quartz among fragments of plagioclase in feldspathic zones.

Feldspar is represented by strongly altered and opacized plagioclase, because of limonites penetration on cleavages and fissures. Besides limonite, as inclusions, it contains fine sericite flakes. In all grains, is kept polysynthetical twinning, lamellae being bent and interrupted ; in fact, as a whole, plagioclase grains are strongly divided.

Muscovite is the only lamellar mineral ; it occurs as short lamellae and is more abundant in some zones. Averages of planimetric analyses of some pebbles are the following :

quartz	45—50%	0.1—0.3 mm
		0.5—2.5 mm
plagioclase	48—52%	0.3—2.5 mm
muscovite	1—2%	1 mm

Having these features, these elements are fragments of Getic Crystallilne gneisses.

At least in our samples , we have to remark that there are no big elements coming from granitoid rocks. However, such elements are found in the matrix of metaconglomerates as polycrystalline grains which are constituted of quartz and microcline bearing plagioclase inclusions but whose sizes have less than a few mm.

2.6.2. *Carbonatic Rocks*. Carbonatic rocks belonging to Oslea formation are widely developed similarly with feldspathic metagritstones, being noticed almost continuously from right slope of Nucşoara towards east of Rîul Bărbat. They correspond to some limy lithic arenites (lithocalcarenites), according to calcite quantity, there can be described limestones (more than 98% calcite) and limy gritstones (about 70—90% calcite).

a) *Limestones* are quantitatively subordinated to limy gritstones, most of them being relatively middle grained ; they have a saccharoidal aspect, are weakly oriented and generally lack of schistosity. Their colour can be white, but is often light grey, generally glassy. Sometimes, they keep a banded texture, alternating grey bands with lighter ones, almost white. In the case of strongly cataclased limestones, prevails finely-grained structure. They occur strongly fissured, undoing in plates at the level of the outcrop. Thermal differential and dilatometric analyses indicated only the presence of calcite — Figures 18 and 19. Under microscope, they occur constituted of more than 98% calcite, having a relatively uniform or ununiform grained structure, according to cataclasis degree ; their texture is weakly oriented, sometimes a little stratified. There are small grains of quartz and rare sericite lamellae, but in small quantity (tab. 16).

In weakly stratified (banded) samples alternate calcite bands with bands bearing besides calcite, quartz and sericite ; the latter ones can contain albite too but in small quantity. In fact, these stratified zones are but passage rocks from limestones to limy gritstones.

b) *Limy gritstones* are widerly developed than limestones and represent passage formations from limestones to feldspathic gritstones ; they are equi-

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valent to detrital sediment which was mainly constituted of calcite mixed with quartz, feldspar and white mica. Most rocks are relatively middle-grained, oriented, weak to middle schistous ; sometimes weakly stratified, of a saccharoidal aspect, generally glassy. Their colour is grey, generally dark grey; sometimes because of weak limonitization, it occurs a brown tint. As well as limestones, limy gritstones are found in various stages of cataclasis. Under microscope, there occurs an ununiform grained structure

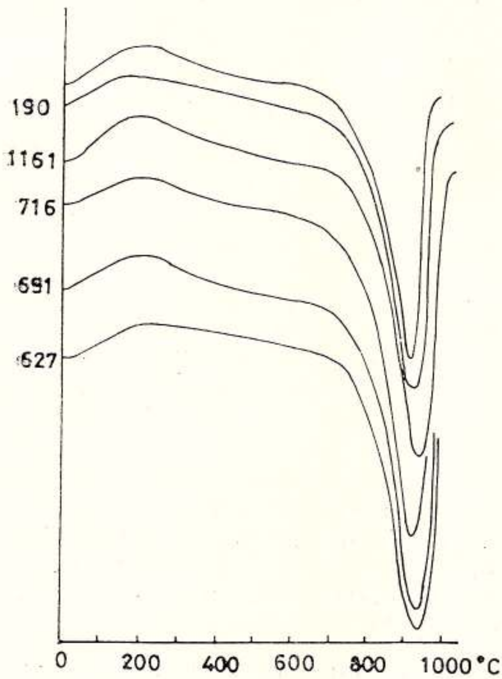

Fig. 18 — ATD curves of limestones in Oslea formation.

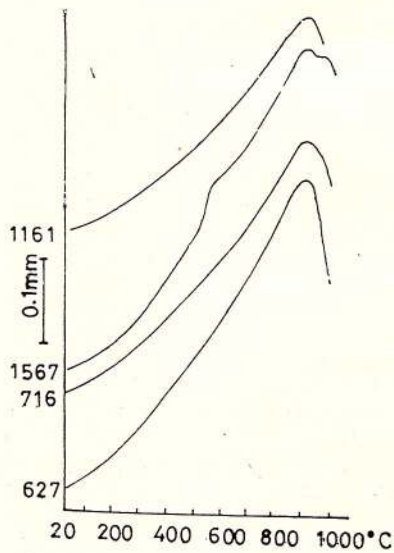

Fig. 19 — Dillatometric curves of limestones in Oslea formation.

TABLE 16

	%	mm
Calcite	98-99	o.5-1.8 o.o3-o.1
Quartz	< 1	o.o5-o.15
Sericite	< 1	o.2
Albite	< 1	o.1-o.2

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and a weakly oriented texture, often stratified. They are constituted of a calcite coarser-grained mass in which are caught feldspar grains of about the same sizes and smaller quartz grains with which albite can associate in some samples. In small quantity there is sericite, in some samples occurs graphite too (tab. 17). When the structure is stratified, macroscopically lighter bands

TABLE 17

	%	mm
Calcite	67-87	o.2-1.2 o.o3-o.4
Quartz	2-18	o.o5-o.3
Plagioclase	2-8	o.2-1.3
Microcline	o-5	o.3-1.5
Sericite	1-5	o.2-1.5
Graphite	< 2	fine pigment

have a coarser structure, prevailing calcite, quartz and feldspar being in small quantity, while darker bands are finer-grained and richer in quartz, feldspar and sericite. As cataclasis degree increases, the structure becomes finer and finer, moreover occurring numerous calcite veins (1—1.5 mm thickness) crossing the rock. As accesory minerals, there are met pyrite and partly opacized sphene, rarely zircon.

Considering carbonatic rocks in general, the fact that when they are constituted almost of calcite, granulation is coarser and grains contour tends to be polygonal, it means initial sedimentary calcarenitic rock, suffered a weak metamorphic recrystallization ; this phenomenon affected only calcite. Plagioclase feldspar was only albitized, however some smaller fragments recrystallizing to blastic albite and quartz suffered no transformation, excepting corrosion by calcite. A product of metamorphism can be also considered sericite which occurs as fine lamellae ; muscovite detrital lamellae which are widerly developed, have been bent and partly sericitized. Accentuated breccifiation and mylonitization in some samples are caused by lamination which took place after metamorphic recrystallization , during thrusting Zeicani series over Oslea formation.

2.6.3. *Sericite-Graphitous Phyllites*. Phyllites are well represented among rocks of Oslea formation as intercalations of meters and rarely tens of meters in thickness at various levels. They are rocks of dark grey colour, finely-grained and strongly schistous, schistosity planes succeeding at submillimetric distances. In most cases, perpendicularly on the schistosity, it can be

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noticed a fine stratification and on the schistosity planes of a nacre aspect, occurs graphite which can be taken on our hands. Under microscope, they are mainly constituted of quartz, sericite and subordinately graphite to which in some samples add chlorite and albite (tab. 18). Accesorily, they have pyrite, sphene, rutile, tourmaline and zircon. Their structure is micro-granolepidoblastic relatively uniform and texture is oriented, finely-stratified, sometimes microfolded, alternating strips richer in quartz with strips richer in sericite. In most cases, they are intensely limonitized.

TABLE 18

	%	mm
Quartz	40-67	0.03-0.15
Sericite	30-50	<0.8
Chlorite	0-7	<0.2
Graphite	2-20	fine pigment
Albite	0-5	0.05-0.2

16 samples of sericite-graphitous phyllites and limy rocks of Oslea formation (covering almost their whole area) which Sofia Luță analysed within IPGG labs, have no palynological content, so that we have no certain data to establish their age; the only discussions concerning the age are those in the chapter about the region geology in which we tried to correlate it with similar formations in the neighbouring zones.

3. Upper Danubian Unit

All component geological formations have been grouped in the Zeicani series (group) with a lower prevailing volcanogen complex (member) and an upper prevailing detritogen complex (member).

3.1. **Lower Complex (Member).** Component formations occupy almost 80% of the outcrop area of Zeicani series between Rîul Bărbat and Paroșului Valley and more than 90% between Paroșului Valley and Nucșoara Valley. Towards the lower part the most spread schists are chlorite-albitic schists and towards the upper part become more abundant quartz-feldspathic sericite-chloritous schists. Locally or not so spread, are met quartzitic schists bearing sericite and chlorite, chlorite-albite-actinolitic schists bearing biotite and hornblendites.

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3.1.1. *Chlorite-Albitic Schists Bearing Calcite and Epidote.* They are dark grey-green rocks, generally middle-grained and have a weakly banded aspect. In most cases, schistosity is weak, usually plane-parallel at the level of the handspecimen and rarely microfolded. Under microscope, structure is granolepidoblastic, sometimes of a prevailing clastic character and texture is oriented. The weakly banded aspect which is also noticed macroscopically, is given by an alternance of oblong lenticular zones whose width is 4—5 mm, in which prevail chlorite and albite, with those narrower zones (0.5—2 mm) in which chlorite occurs in small quantity, its place being taken by calcite besides albite; at other times, calcite occurs in small quantity or is lacking; in this situation, the rock can become rich in epidote-clinozoisite so that we could establish a reversed relation between calcite quantity on one side and epidote-clinozoisite on the other side. Quantitative relations among these four minerals can vary a lot, so that in some samples, they can prevail over the other minerals, each in turn, both albite, epidote-clinozoisite and calcite, resulting albitic schists, epidotic schists or calcitic schists. Sericite can also become a major component in some samples. Other minerals which are often met but without becoming major components, are quartz, plagioclase feldspar (relict) and biotite. Accesorily occur apatite, sphene, tourmaline and opaque minerals. Mineralogical composition and average sizes are given in table 19

TABLE 19

	%	mm
Chlorite	7-43	o.o5-o.4
Albite	17-6o	o.o4-o.5
Sericitized plagioclase	o-5	o.2-1.5
Calcite	8-62	o.o5-1.5
Epidote-clinozoisite	1-2o	o.o2-1.o
Quartz	2-11	o.o1-o.6
Sericite	o-13	o.o5-o.5
Biotite	o-5	o.o7-o.5

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Chlorite is a main mineral of these rocks, although in quantity it can vary about between 5 and 50% , very often between 25 and 40% ; at the same time, in carbonatic or albitic separations, chlorite quantity can lower under 1%. When it occurs in bigger quantity, it forms a continuous lamellar network, sometimes with numerous inclusions of sphene and rutile, in whose eyes there are albite granoblasts ; in carbonatic zones, chlorite occurs as isolated lamellae which are not uniformly distributed. It has a pleochroism from generally intensely green to green-yellow and birefringence colours in grey-green tints to brown-green ; rarely, especially in the eastern part of the perimeter, chlorite pleochroism has a lighter tint and birefringence colours can have dark brown or grey-blue tints. Especially in Nucşoara and Mălăieşti valleys, on the background of green chlorite lamellae, there can be noticed narrow and strongly oblong lamellae or only spots of dark brown-green biotite, sometimes having the tendency to develop also obliquely in connection with the orientation of the most part of chlorite ; at the same time, the two minerals occur intergrown several times. These two last aspects can be arguments for the fact that biotite developed on account of chlorite not inversely.

Albite occurs in big quantity in most samples constituting about 30—45% ; rarely, it can be 75—80% in albitic schists or it can disappear in epidote schists. It occurs as hypidiomorphic granoblasts, equidimensional or weakly oblong, generally clear and untwinned being seldom constituted of 2—4 individuals associated according to (010). In the same samples, there are zones in which albite granoblasts are included in a lamellar chloritic mass and zones in which spaces among albite granoblasts are occupied by calcite ; in this last case, there is a tendency of albite corrosion by calcite, starting from grains margins to calcite advance on albite cleavages. 2V, $Np \wedge (010)$ and $Nm \wedge \perp (001)$ values (Fig. 13c) show a variation of composition about between $Ab_{98}An_{2}$ and $Ab_{86}An_{14}$. In some samples, usually in those taken from a bigger distance of the overthrust plane on Oslea formation, besides albite granoblasts of above mentioned features, there are met unoriented, strongly cataclased grains of various sizes up to 1.5—2 mm of albitized plagioclase with generally clear margins, sometimes with a schahbrettalbite structure, its center containing numerous inclusions ; we can often notice traces of polysynthetical twins. They are 4—5% in quantity.

Calcite (Fig. 20) is present in almost all samples, usually representing 5—25% ; it can be 55—60% in calcitic schists bearing albite or under 1% in epidotic schists. In small quantities in zones with much calcite there are also quartz, chlorite and sphene ; generally, epidote-clinozoisite is lacking. In zones mostly chloritic or epidotic, calcite occurs in small quantity, forming small microgranular agglomerations ununiformly distributed.

Epidote-clinozoisite is constantly met in these rocks generally to 5—6%, excepting only some small, local separations, where it occurs 85—90%, the other minerals being represented by chlorite±actinolite, sphene and pyrite. It forms both big grains (to 1 mm) strongly broken and spread in the rock and especially small round grains or small crystals long-prismatic oriented, spread in the zones rich in chlorite.

Quartz is in small quantity in all samples (2—5%) sometimes it is lacking ; it is present in higher quantity only in some samples near the over-

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thrust plane, where chlorite-albitic schists suffered an accentuated mylonitization.

Sericite can occur in bigger quantity in the schists east of Paroşului Valley, between 2 and 10% rarely up to 20%, being present in small quan-

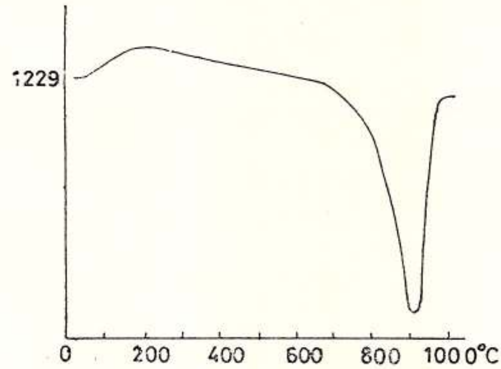

Fig. 20 — ATD curve for a carbonate sample in chlorite-albitic schists.

tity or lacking west of Paroşului Valley, where usually associated with chlorite, biotite also occurs. At the same time, sericite is more abundant in mylonitized schists above the overthrust plane than in those placed further.

Near the overthrust plane on Oslea formation, chlorite-albitic schists suffered a strong cataclasis, looking like some microbreccias or mylonites. In the most advanced stage of mylonitization, the rock occurs constituted of an alternance of beds, mainly formed of microgranular calcite, with others where prevail sericite and chlorite; among these three minerals which form a kind of matrix, there are microcrystalline agglomerations of albite and quartz; the only bigger grains inside the rock remain apatite ones, however more fissured and of a more irregular contour than in nonmylonitized schists.

— Inside chlorite-albitic schists already described, there are lenticular zones, which still keep some primary characters of the rocks on account of which they formed. They are constituted usually of dark grey-green rocks relatively uniformly-grained and of a generally weak schistosity. Under microscope, main difference from typical chlorite-albitic schists is the fact that in the eyes of chlorite-biotite network there are no clear albite granoblasts, but broken grains of albitized plagioclase with numerous inclusions and with traces of polysynthetical twins; at the same time, especially in the chloritic mass, but also in the rest of the rock, there are kept numerous hornblende remains. Other minerals are calcite, epidote-clinozoisite, sphene, actinolite and opaque minerals (tab. 20).

Chlorite forms a finely-scaled felt of light green colour and birefringence colours is dark brown and grey-blue tints, in weakly recrystallized samples or it occurs recrystallized as small lamellae, generally short, weakly oriented of an intense pleochroism from green to pale yellow and grey-green birefringence colours. It occurs often intergrown with biotite.

Biotite occurs both as light brown-green spots on the background of finely-scaled mass of chlorite and as small, short, weakly oriented lamellae

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of a pleochroism from brown-reddish to yellow and birefringence colours only a little brighter than associated chlorite. Presence of brown-green biotite associated to chlorite of brown or grey-blue birefringence colours could be a reason to change hornblende first into biotite and then into chlorite. At the same time, apparition of widely-developed brown-reddish biotite

TABLE 2o

	%	mm
Chlorite	4o-5o	o.o5-o.2
Biotite	1-5	o.o5-o.4
Albitized plagioclase	25-45	o.1-1.5
Amphibole	5-7	o.o5-1.5
Epidote-clinozoisite	1-15	o.o2-o.7
Calcite	1-1o	o.o1-o.o5

associated to chlorite with strong pleochroism and grey-green birefringence colours, this situation being met only between Nucşoara and Mălăieşti, could be caused, as in the case of other schists right of Nucşoara, by coming closer to the contact with ultrabasic rocks (hornblendites). This is because at least in our samples dark-brown or grey-blue birefringence colours seem to indicate a chlorite which was born following a retromorphism process on account of some mafic minerals—hornblende, biotite, while chlorites of birefringence colours in grey-green tints seem to have formed following a process of progressive metamorphism, tints becoming lighter and lighter as metamorphism advances.

Hornblende occurs as fragments of various sizes and forms spread inside the rock, representing remains of some well-developed primary crystals. It presents a pleochroism in light tints from light green to pale green almost colourless and strong birefringence colours ; $c : Ng = 18-20°$. Both on the background of hornblende fragments and as acicular inclusions inside some feldspar fragments, actinolite can occur.

Feldspar is exclusively represented by isolated grains or forming agglomerations of albitized plagioclase strongly cataclased. Albitization of plagioclase fragments is complete, keeping traces of polysynthetical twins ;

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sometimes, occurs schahbrettalbite structure. In most samples, plagioclase fragments are recemented with calcite, noticing only in a few samples how on their background are forming generally widely developed crystals of epidote-clinozoisite. As in the case of chlorite-albitic schists, it can be noticed a reversed relation between calcite and epidote-clinozoisite quantity. As inclusions, it can also contain sericite, chlorite, actinolite and sphene.

Calcite, when occurs, is uniformly distributed especially in zones rich in feldspar, cementing its grains as fine mortar.

Epidote-clinozoisite is abundant in some samples, especially in those with a more advantaced degree of recrystallisation. Within the chloritic mass, it usually forms microgranular agglomerations or small, isolated, round grains and in zones rich in feldspar, they can be found as round grains or idiomorphic widely-developed crystals, usually twinned.

Presence of such rocks is the best argument that all kinds of chlorite-albitic schists from Zeicani series were born through the retromorphism of some preexisting amphibolites, first taking place a degradation of component minerals, later on taking place another metamorphic recrystallization. Prevailing calcite or epidote-albitic portions were born through cataclasis and albitization of plagioclase feldspar, these processes being followed by blastesis of albite, calcite and epidote. Prevailing chloritic portions are also the result of recrystallization to chlorite of chlorite and eventually biotite, resulting from a process of hornblende degradation from original amphibolitic rock ; at the same time with chlorite, recrystallized sericite and biotite.

3.1.2. *Albite-Chlorite-Actinolitic Schists Bearing Biotite*. In spreading area of chlorite-albitic schists from right slope of Nucşoara Valley, on a small area, on both sides of hornblendite bodies which crop out south of Ştirbina peak and in Nucşoara Valley, there develop rocks which clearly individualize from surrounding rocks, both through structure and texture, as well as through the presence in their mass of some widely-developed biotite lepidoblasts. As a whole, they are especially finely-grained rocks of grey-green colour, oriented, weakly-schistous. Rarely, it occurs a weakly banded texture too. Generally they look like some green tuffs. Within aphanitic finely-grained mass, there can be seen with naked eye too numerous biotite leaflets forming thin pellicle agglomerations, which are displayed on schistosity planes as oblongspots of various sizes. There are met all stages of passage from these finely-grained rocks with a lot of biotite, through more and more coarse rocks to normal chlorite-albitic schists of the series. Under microscope, it is pointed out a microgranonematolepidoblastic mass, well-oriented, constituted of albite, chlorite, and actinolite (tab. 21), in which are displayed biotite porphyroblastic lamellae forming bands mixing with other minerals at 1—3 mm distance among them ; in the plane of oriented bands, biotite lamellae can also occur weakly oriented or even transversaly displayed. Other minerals are calcite, epidote-clinozoisite and quartz.

Actual aspects of these rocks suggest their formation on account of some chlorite-albitic schists bearing calcite and epidote through an accentuated recrystallization ; but it is not clear how potassium in biotite composition comes from.

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TABLE 21

	%	mm
Albite	40–60	0.05–0.15
Chlorite	10–25	0.05–0.2
Actinolite	4–12	0.005/0.05–0.02/0.3
Calcite	8–15	0.2–1.5
Biotite	3–10	0.05/0.2–0.3/2.5
Epidote-clinozoisite	3–8	0.03–0.3

Albite is found as small, clear grains, weakly oblong on the direction of the rock orientation, when it is associated with chlorite, actinolite and epidote and as widerly-developed grains, when it is associated especially with calcite. Grains are generally untwinned and contain numerous small acicular inclusions of actinolite. It generally resembles to albite in typical chlorite-albitic schists.

Chlorite forms small, short or weakly oblong lamellae, which are displayed in the network in strongly chloritous zones or as isolated lamellae among albite grains in rich zones in this mineral; it intergrows with actinolite and rarely with biotite. Generally, pleochroism is in light tints from light green-yellow to pale yellow, almost colourless and birefringence colours are in grey-green tints.

Actinolite is abundant in some samples, occurring as long-prismatic or acicular oriented crystals, especially associated with chlorite as well as small inclusions in albite grains. It has pleochroism from pale green to colourless and birefringence colours resemble it to tremolite; $c : Ng = 15-20°$.

Biotite forms exclusively well-developed lamellae, generally oblong and oriented, but also short lamellae transversally displayed. Most of the lamellae contain numerous inclusions of calcite, actinolite, quartz, epidote-clinozoisite, giving them a poikilitic aspect; lamellae margins are irregular as well. A X-ray diffractometric analysis on these lamellae indicated about 90% biotite and 10% chlorite- Figure 21, chlorite nature being difficult to clarify, its characteristic reflexes having a low intensity. It is characteristic carbonate and chlorite replacement by biotite, on their account forming lamellar agglomerations of biotite, unorientedly displayed; sometimes, albite grains corrode too. Biotite pleochroism is from light brown-reddish

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to pale yellow and bright birefringence colours are close to muscovite; −2V is very small, practically equal to zero. Lamellae length is up to 2—2.5 mm, thickness varying between 1/8 and 1/1 from length; there are often intergrowths among oblong lamellae and short ones, sometimes even at right angle.

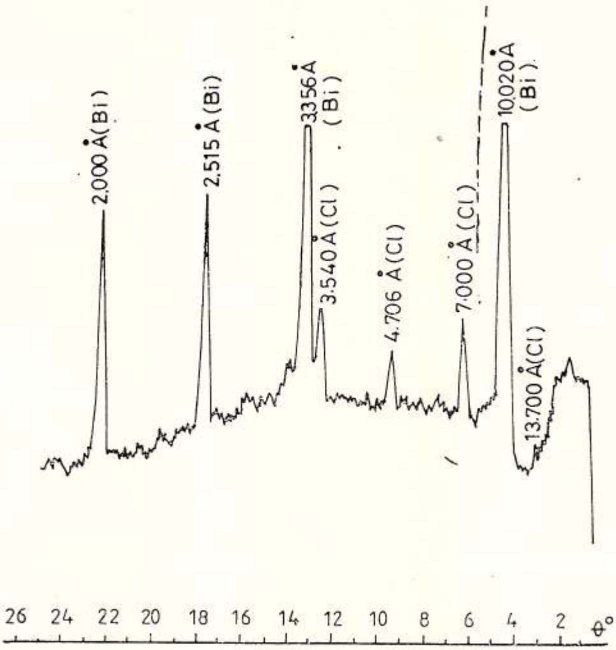

Fig. 21 — Diffractogram of a biotite sample in albite-chlorite-actinolitic schists.

Calcite is ununiformly distributed but also displays in bands or widely crystallized agglomerations (up to 1—1.5 mm) catching in their mass, well developed, round, albite grains. It is strongly corroded by biotite.

Epidote-clinozoisite is found especially as small, round grains ununiformly distributed in chlorite-actinolite-albitic mass.

Quartz is microcrystalline, being present in small quantity.

Accesorly, there can be met apatite.

Trying a few considerations on these rocks, it can be shown that their actual aspects are caused by partial recrystallization of some chlorite-albitic schists bearing calcite and epidote with formation of actinolite, biotite and new chlorite and with growth of calcite grains. Complete lack of sericite shows that it was consummed for biotite formation; at the same time, samples have no independent titanium minerals—sphene, rutile, which makes us conclude that titanium was included in newly formed biotite, calcium in sphene being set free and included in calcite. High content of titanium in biotite is confirmed by its brown-reddish colour too.

— Similar macroscopic schists with those above described but without biotite are also found as decimetrical intercalations in hornblendites which crop out south of Știrbina peak. Under microscope, they prove to be consti-

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tuted more than 85% of actinolite and epidote, minerals which also have almost Ca, Fe^{2+}, Fe^{3+}, Al, Mg from the rock ; in small quantities occur quartz and albite. Lack of micaceous minerals — sericite, biotite — rather show that aphanitic portions formed through profound transformation of amphibolic rocks in which they occur as intercalations on dislocation areas. This means that widely developed biotites on right slope of Nucșoara Valley are

TABLE 22

	%	mm
Quartz	25–4o	o.o3–o.4
Albite	1o–25	o.o5–o.4
Albitized plagioclase	12–35	o.2–5.o
Sericite	o–12	o.o1–1.o
Chlorite	5–15	o.1–o.3
Epidote-clinozoisite	1–8	o.o3–1.o
Calcite	2–5	o.o1–o.5
Biotite	o–2	o.1–1.2

not caused by some potassium from ultrabasic rocks but more probably because of the flow of some solutions rich in potassium on fracture planes in the zone of Nucșoara fault.

3.1.3. *Quartz-Feldspathic Sericito-Chloritous Schists*. At upper part of chlorite-albitic schists occur more and more frequent levels till they become prevailing, being constituted of relatively coarse-grained rocks, weakly banded and schistous of grey-silver colour on schistosity planes and dark grey-green perpendicularly on them. Schistosity planes are rugose because of numerous millimetrical feldspar grains dressed in sericite and chlorite which come out into relief. Under microscope, it is pointed out a microgranular mass of granolepidoblastic structure and oriented texture mainly formed of quartz mixed with albite, chlorite, sericite, calcite, epidote-clinozoisite in which are caught bigger grains of albitized plagioclase (tab.

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22) strongly fractured and recemented; in some samples, there can be also found epidote-clinozoisite as widely developed grains. At the same time, in the west of the perimetre, between Nucşoara and Mălăieşti, biotite associated with chlorite can occur, its quantity generally increasing from north to south.

Quartz-feldspathic schists above described are probably retromorphosed correspondents of some gneisses with similar composition, having rather a cataclastic structure not a blastic one; quartz, more fragile, was completely broken and partly recrystallized and plagioclase feldspar was mostly only fractured and albitized.

3.1.4. *Quartzitic-Schists Bearing Sericite and Chlorite.* These rocks occur as metrical intercalations in chlorite-albitic or quartz-feldspathic schists, especially west of Ríul Alb Valley. At the same time, they form an almost continuous level of a few tens of meters thickness at the base of the abrupt given by chlorite-albitic schists in front of the overthrust on the rocks of Oslea formation between Lazului Valley and Ştirbina — Prislop ridge. Because structural and textural aspects of quartzitic schists at the base of the overthrust and those which occur as intercalations at various levels, differ a lot, we shall discuss them in turn.

a) Quartzitic schists as intercalations are hard rocks, generally weakly schistous of nacre aspect on schistosity planes and glassy in the breach. Perpendicularly the schistosity, the structure occurs coarsely, relatively uniform. Within quartzitic schists on Nucşoara right slope on the schistosity planes with naked eye, biotite lamellae can be sometimes noticed; at the same time, some samples contain small lenticular agglomerations light grey in colour, glassy, ununiformly distributed. Under microscope, it is pointed out a granoblastic structure, sometimes of a weak tendency to granolepidoblastic and an oriented texture. They mostly contain quartz with which in subordinated quantities, calcite and albite from granoblastic mass can associate; as lamellar minerals, they have sericite and chlorite and on Nucşoara right slope, there is biotite (tab. 23). Accesorily, occur tourmaline, sphene, epidote-clinozoisite and pyrite.

b) Quartzitic schists which form the level above Oslea formation rocks are different from those already described, mainly through structure and texture, being similar from mineralogical point of view. They are grey-silver rocks on schistosity planes with a dense well-developed schistosity, sometimes weakly microfolded; granulation is fine. They are constituted of quartz, sericite and chlorite; in small quantities can occur albite, calcite and garnet and accesorily tourmaline, apatite and opaque minerals.

3.1.5. *Quartz-Albitic Sericitous Schists Bearing Microcline.* These rocks are the most developed between Mălăieşti and Paroşului Valley lying on chlorite-albitic schists and supporting quartz-feldspathic sericito-chloritous schists. In the rest of the perimeter, they are not so spread. Macroscopically, as a whole, they have a structure similar to ocular gneisses and generally weakly developed schistosity, with irregular rugose areas. Their colour is grey, uniform or weakly banded, alternating light grey bands of 0.5—2.0 mm thickness with thinner ones (0.5 mm) of dark grey colour. „Porphyric" aspect is given by the presence of numerous grains, which are about isometrical or

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weakly oblong on the schistosity direction, having sizes up to 8—10 mm and light grey colour, sometimes a yellow or pink tint. Under microscope, it is pointed out an oriented microgranolepidoblastic mass which is constituted of quartz, albite, sericite in which are caught widely developed grains of albitized plagioclase feldspar and microcline. In small quantities, can occur

TABLE 23

	%	mm
Quartz	75-90	0.2-0.5
Sericite	4-15	<1.5
Chlorite	1-7	<1.0
Biotite	0-1.5	<2.5
Calcite	1-8	0.1-1.5
Albite	0.5-2	0.1-0.3

chlorite and biotite (tab. 24). Accesorily occur sphene, apatite and rutile. Because of these features, they differ from quartz-feldspathic sericite-chloritous schists especially through the presence, together with albitized plagioclase, of microcline and through the very small quantity of chlorite; at the same time, epidote-clinozoisite and calcite occur in small quantities.

Quartz is prevailing mineral, forming together with albite and sericite microgranular mass, in which are caught big grains of albitized plagioclase and microcline; if these last ones did not exist, the rock would be a typical quartzitic schist bearing albite and sericite. It occurs as oblong grains of irregular margins and undulatory extinction.

Albite in microgranular mass is always subordinately to quartz forming about the same sized-grains, clear, untwinned or formed of 2—3 individuals associated according to (010); their aspect rather seems to show they are small fragments of albitized plagioclase than grains of blastic albite.

Sericite is found as isolated lamellae, diversely oriented among quartz grains or forms agglomerations or sinuous scattering bands, surrounding big grains of feldspar. In most samples, sericite has a tendency of recrystallization to muscovite as widerly developed lamellae, which sometimes have more than 1 mm thickness; at the same time, it is possible that a part of muscovite to be relict.

Albitized plagioclase is found as grains of various sizes, both isolated and included in microcline grains. Plagioclase feldspar as isolated grains resembles to that in quartz-feldspathic sericite-chloritous schists, generally

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having round or irregular contour; some grains completely keep polysynthetical twinning, others have marginal zones clear, untwinned, twin traces keeping only in the central part, where grains usually have numerous inclu-

TABLE 24

	%	mm
Quartz	40–60	0.03–0.3
Albite	5–20	0.05–0.3
Albitized plagioclase	5–25	0.2–3.5
Microcline	3–15	0.3–1.2
Sericite	7–18	0.2–1.0
Biotite	0–3	
Chlorite	0–1	

sions, almost exclusively of sericite. 2V, Np ∧ (010) and Nm ∧ ⊥(001) values (Fig. 13 d) indicated for most of grains a content between Ab_{98} An_2 and $Ab_{90}An_{10}$ interval, however also meeting more basic plagioclase with 20, 25 and even 30% An, the last one coming close to the composition of initial plagioclase which is now relict. Plagioclase feldspar included in microcline can be found as idiomorphic crystals, but it is often noticed plagioclase corrosion by microcline, being able to be completely replaced, on the background of microcline image noticing only some spots of a little higher birefringence.

Microcline occurs both as smaller grains (generally less than 1 mm) without plagioclase inclusions, with or without perthitic exsolutions as well as bigger grains with inclusions of albitized plagioclase similar to those not included in microcline. All the microcline mass in the same grain has an unitary optical orientation. It is generally untwinned, sometimes some zones keeping not enough clear the grilled twinning; rarely Karlsbad twin occurs too, the whole grain being constituted of 2 individuals. In convergent light, optical sign is (—) or (+), while at universal stage is exclusively (—), —2V angle being between 72 and 85° — Fig. 14 c, values which correspond to a cryptoperthitic microcline, as in other cases. A X-ray diffractometric analysis indicated a microcline close to maximal microcline, with triclinicity index $\Delta = 0.93$ — Fig. 22. Owing to identical optical features, both of smaller grains, without plagioclase inclusions and of bigger ones with inclusions, we can conclude that fragments without inclusions are but homogeneous

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fragments of some grains initially bigger and later fractured. Related to granitoid rocks, in which ,,ocellis'' of microcline gradually disappear in the rock mass, having numerous branches, in these rocks microcline grains are generally round, have clear limits, being usually dressed in sericite, which moulds their contour even in round portions.

Biotite, when occurs, is in small quantity as thin lamellae, isolated or associated with sericite, with pleochroism from brown-green to pale yellow; sometimes it intergrows with chlorite.

Chlorite is only met in some samples in small quantity as isolated lamellae or intergrown with biotite; pleochroism is in tints of green, usually bright ones and birefringence colours in tints of brown-copper or grey-blue.

Because microcline (partly plagioclase feldspar too) in these has similarities, several times to identity, inclusively optical aspects, with the microcline which forms ocellis in granitoid rocks, we can conclude that quartz-albitic sericitous schists bearing microcline are metamorphosed correspondents of some feldspathic conglomerates, derivatives, if not from the same granitoids, certainly from similar rocks. In fact, considering total mineralogical composition, difference between granitoid rocks and meta-conglomerates described above is given only by lack of epidote-clinozoisite and by bigger quantity of quartz in the latter.

3.1.6. *Hornblendites* . These rocks crop out on right slope of Nucşoara Valley, on Ştirbina-Prislop ridge, as blocks being also found on left slope of Mălăieşti Valley. They are phaneritic, macrogranular rocks of massive texture, green as grass up to dark green in colour. An X-ray diffractometric analysis-Figure 23 indicated the presence of more than 90% hornblende and in small quantities calcite and chlorite. Under microscope, it is pointed out a holocrystalline , panidiomorphic granular structure, weakly-oriented, constituted of hornblende crystals as prisms of 10/5 mm in size. Hornblende crystals contain grains of carbonates, epidote, sphene, oblong prisms of actinolite and tremolite and lamellar agglomerations of antigorite and chlorite. There are some portions in the rock constituted almost of carbonates (which prevail), epidote, zoisite tremolite and actinolite. As opaque minerals there are iron oxides.

Within the schists which constitute the cover of hornblendites south of Ştirbina peak but especially in those on the right bank of Nucşoara, there are noticed strong processes of biotitization, these aspects being already discussed, when we described albite-chlorite-actinolitic schists bearing biotite.

3.1.7. *Talc Schists Bearing Actinolite and Tremolite*. These rocks develop in the basin of Nucşoara brook, in numerous points being met; they are light grey-green in colour, of a silkly aspect, soft in touch and generally friable. Macroscopically, there can be often noticed oblong crystals of actinolite and tremolite displayed in a talc mass. Under microscope, it is pointed out a nematolepidoblastic structure constituted of a talc fibre-lamellar aggregate, in which there are actinolite, tremolite, a little carbonate, quartz and antigorite.

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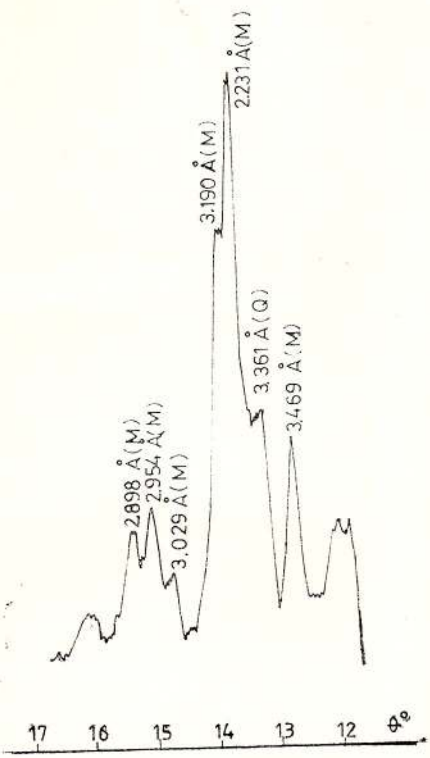

Fig. 22 — Diffractogram of a microcline sample in quartz-albitic sericitous schists with microcline.

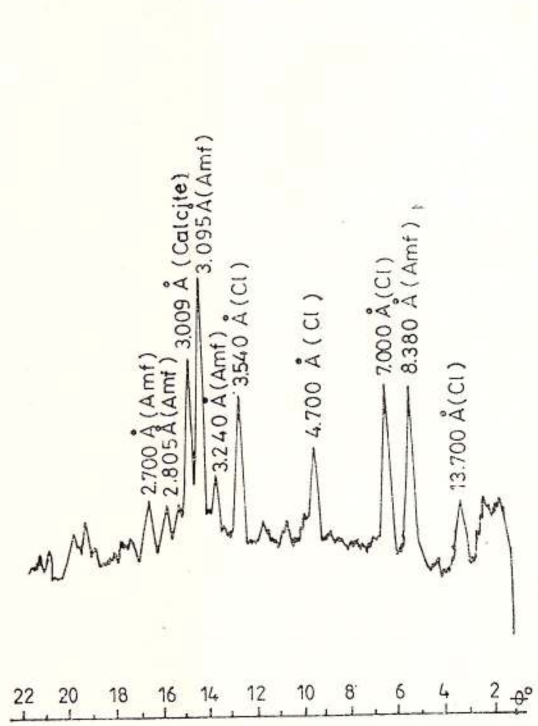

Fig. 23 — Diffractogram of amphibole sample in hornblendites.

Talc occurs as felty aggregates, colourless of high birefringence. Angle of optical axis (—2V) is very big, showing a certain content of nickel. Figure 24 shows the X-ray diffractogram of a talc sample on Nucşoara right slope.

Actinolite occurs as oblong prismatic or acicular crystals (up to 10/0.5 mm). In basal sections, it has characteristic rhombic contours. Pleochroism is weak in green-light yellow tints and birefringence is high. Extinction angle (c : Ng) is 15—18°.

Tremolite is quantitatively subordinated to actinolite, forming oblong prismatic, colourless crystals of a high birefringence.

Antigorite forms lamellar microcrystalline aggregates, lamellae being colourless of low birefringence and right extinction.

Carbonate (calcite and magnesite) can form irregular microgranular agglomerations or oblong crystals. Quantitatively, all these minerals can vary very much. Quartz and opaque minerals occur in subordinated quantities; rarely occurs chrysotilic asbestos.

Considering that initial rock, through whose transformation formed talc, antigorite and chrysotile (eventually considering also antigoritic serpentinites bearing asbestos which occurs in Riuşorul Valley), is constituted

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of hornblendites, apparition of various mineralogical paragenesis can be explained by the following chemical reactions :

2 hornblende + $2SiO_2$ + 2 $CaCO_3 \rightarrow$ actinolite + 2 epidote + + 2 $MgCO_3$;

2(actinolite, tremolite) + $5CO_2 + H_2O \rightarrow$ talc + $4CaCO_3 + MgCO_3 + SiO_2$;
2(actinolite, tremolite) + $5CO_2 + 4H_2O \rightarrow$ antigorite + 4 $CaCO_3$ + + $MgCO_3$ + $10SiO_2$.

Iron in actinolite combines with oxygen, giving oxides which occur under microscope as opaque minerals.

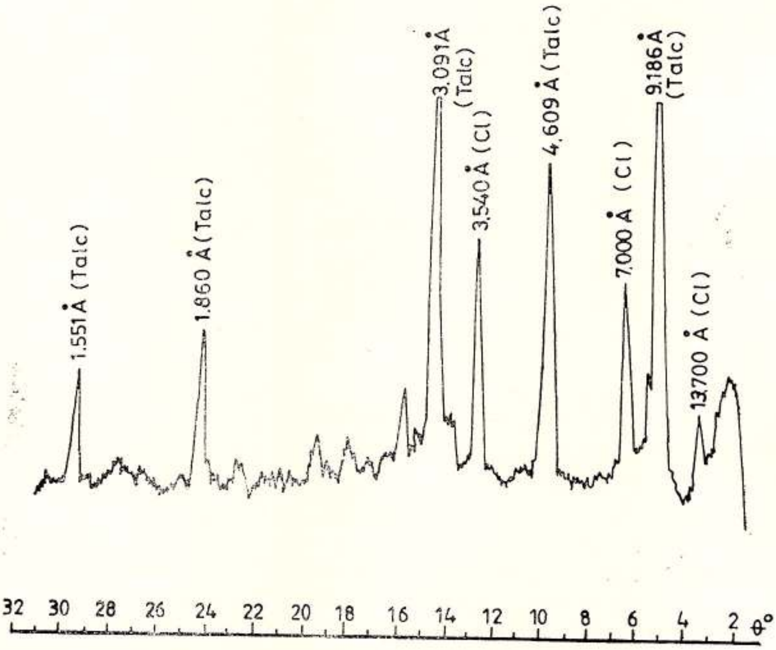

Fig. 24 — Diffractogram of a talc sample.

If in final stages talc or antigorite form, it is in function of SiO_2 quantity which comes out after the reactions. It is less probable that first antigorite forms, then it reacts with silica and changes into talc. Chrysotile can form on account of antigorite, probably by pressure increase, accompanied by an accentuated fissuring of the rock. Regarding these reactions, we notice that for their achievement H_2O, CO_2 and less SiO_2 contributed, which in this case, can be probably connected with the ascent on fracture zones of some corresponding solutions.

3.2. Upper Complex (Member). At upper part of Zeicani series, there is a complex of rocks which has at base limestones or limy schists and continues with feldspathic and quartz feldspathic schists in whose mass almost everywhere there is intercalated an horizon of quartzitic sericitous

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schists bearing muscovite; several times, the succession ends with amphibolitic rocks relatively fresh between Rîul Bărbat Valley and Valea Beuşii brook and with prevailing chlorite-calcite-albitic schists, westwards up to Rîul Mare Valley; rarely, over amphibolitic schists or over chlorite-calcite-albitic schists are still opened quartz-feldspathic schists too.

3.2.1. *Carbonatic rocks* are found almost always at the base of the complex, being represented by limestones, especially in the western part of the perimeter and by limy schists eastwards.

a) Limestones are the best represented starting from left slope of Nucşoara up to left slope of Mălăieşti brook; eastwards, they are met sporadically in the basins of Rîul Mic and Rîul Bărbat. They are microgranular rocks, weakly schistous of dark grey colour. In all samples, it is characteristic the presence of numerous small cubic crystals (usually submillimetrical ones) of pyrite in various stages of limonitization. Because of intense pyrite limonitization in some samples limestones colour can become brown-yellow. Under microscope, structure is microgranoblastic, relatively uniform and texture is weakly oriented. They are constituted of calcite grains, which are about equidimensional of irregular margins in direct contact, when form a tooth structure or among them displaying small grains of quartz and albite or muscovite lamellae; rarely are met bigger fragments of quartz. Thermo-differential and dilatometric analyses on two samples, one on Nucşoara left slope and another on Mălăieşti brook left slope pointed out calcite, as the only carbonate, quartz and pyrite, this last one through exothermal effect round 400°C value (Fig. 25, 26). In some samples, tourmaline occurs accesorily.

Mineralogical constitution and average sizes are given in table 25.

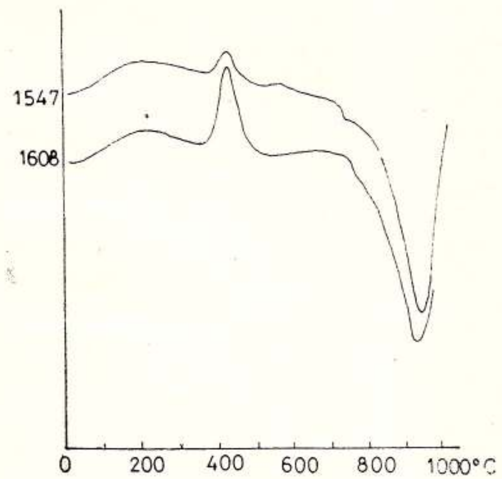

Fig. 25 — ATD curves of limestones in upper complex of Zeicani series.

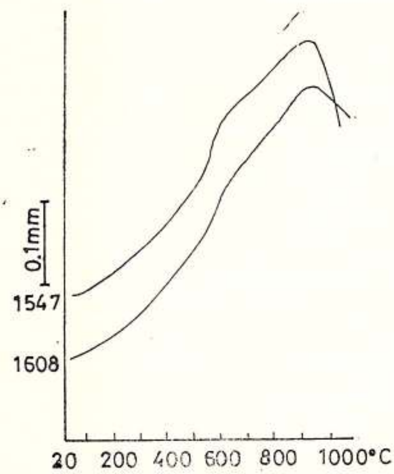

Fig. 26 — Dillatometric curves of limestones in upper complex of Zeicani series.

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Presence of muscovite lamellae relates these limestones with muscovite schists from above, from genetical point of view.

b) *Limy schists* are ununiformly grained rocks, weakly schistous of grey colour, sometimes of weak green tint. In most cases, perpendicularly

TABLE 25

	%	mm
Calcite	90–92	0.05–0.2
Quartz	5–7	0.02–0.2
Albite	2–3	0.1–0.3
Muscovite+ Sericite	1–2	0.2–0.4
Pyrite	1–3	0.1–0.5

the schistosity are noticed lenticular zones which are white and have 8—10 mm ; at the same time, they can contain widely developed lamellae of muscovite. Under microscope, they occur constituted of a finely-grained mass of calcite in which are ununiformly distributed quartz and albite grains of various sizes and wider zones mainly constituted of albite, quartz, sericite±chlorite, calcite being in small quantity or lacking.

Quartz occurs as generally widely developed grains, strongly cataclased — from grains of accentuated undulatory extinction, strongly sectorized up to fractured or fragmented grains, fragments being recemented with calcite. Quartz presence with these features in carbonatic schists cannot be related at all to chlorite-albitic schists on which they lie, so that carbonatic schists did not form on account of below schists but it was discordantly displayed, quartz representing pebbles from a microconglomeratic sediment.

Albite is found both as isolated grains in the carbonatic mass and as a main mineral in some prevailing sericite-albitic zones. Grains are generally clear, fissured usually untwinned or formed of 2—3 individuals associated according to (010).

Muscovite occurs in various stages of replacement by calcite, in the most advanced stage calcite pseudomorphosing lamellar muscovite paquets and so forming big grains on the background of fine calcitic mass. Presence of muscovite lamellae, similar to muscovite in muscovite quartzitic schists from above also individualize these rocks from below schists. This means that in this case, it is not about a replacement of initial rock — for instance

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amphibolite or chlorite-albitic schist — by calcite, but calcite represents initial cement of a microconglomerate.

Sericite is usually in smalll quantity being more abundant in zones rich in calcite and albite.

Chlorite seldom occurs, it is almost colourless and has grey-green birefringence colours.

3.2.2. *Feldspathic chloritous schists* are usually met under muscovite quartzitic schists, being relatively finely-grained rocks of oriented texture weakly schistous. Their colour is grey-green generally uniform. Schistosity planes can occur weakly wavy because of some scale-like agglomerations of chlorite ± sericite. In all samples, prevailing minerals are feldspar and chlorite, quantitative relations between them however varying from one sample to another one. Under microscope, structure is ununiform granolepidoblastic and texture is weakly oriented, constituted of a microgranular mass mainly composed of albite and chlorite mixed with sericite, calcite, quartz, epidote-clinozoisite, in which are found bigger grains of albitized plagioclase (tab. 26). Accesorily are met sphene, apatite and pyrite.

TABLE 26

	%	mm
Albite	25-60	0.05-0.2
Albitized plagioclase	15-25	0.2-2.5
Chlorite	15-45	< 0.2
Sericite	2-5	< 0.2
Calcite	3-5	0.02-0.2
Quartz	2-8	0.05-0.8
Epidote-clinozoisite	0-4	0.1-0.6
Sphene	1-4	0.2-0.8
Apatite	< 0.5	0.1-0.4
Pyrite	< 1	0.1-0.5

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Because different plagioclase grains in the same sample are replaced by different minerals — some by albite and sericite, others by albite and calcite and finally others by epidote-clinozoisite — we can conclude that respective plagioclase grains had various initial compositions, this fact being explained by detrital sedimentary nature of initial rock.

TABLE 27

	%	mm
Quartz	65-80	0.03-0.2
Sericite	7-15	< 0.2
Chlorite	0-8	< 0.2
Biotite	0-5	< 0.2
Albite	4-20	0.1-1.8
Muscovite	2-7	0.2-2.0
Calcite	1-3	< 0.2

At the same time, sphene can be considered a characteristic mineral of these schists, being formed as widely-developed grains, generally round sometimes strongly fractured. It has various stages of opacization from grains containing only a few ilmenite oriented lamellae, parallel with cleavages up to grains almost completely replaced by a continuous opaque mass.

3.2.3. *Quartzitic Schists Bearing Albite and Muscovite.* These rocks form a continuous horizon on the whole northern margin of Upper Danubian Unit, several times bearing the overthrust of crystalline schists of Getic Nappe. They can be easily recognized because of constant presence in their mass of some widely-developed lamellae of white mica, so constituting a very clear guiding mark horizon. They are grey in colour sometimes of green tint; several times, in the outcrop, their colour has brown-yellow tints, because of a small quantity of limonite spread in the rock. These schists are the best opened on Nucșoara left slope, where granulation increases from upper part to lower part of the horizon. In some cases, schistosity can be weak, but usually it is well developed; banding and microfolding are met enough rarely. They are formed of a microgranular mass, relatively uniform, mainly constituted of quartz, associated with sericite$\pm$chlorite$\pm$albite, in which are ununiformly distributed muscovite lamellae and in most cases, bigger grains

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of albitized plagioclase. In some samples, biotite is found in association with chlorite (tab. 27). Accesorily occur calcite, pyrite, limonite, apatite and rarely sphene.

Quartz prevails in all samples, occurring almost exclusively as small grains (most of them have less than 0.1 mm) which are about equidimensional or weakly oblong. Grains margins are irregular and extinction is undulatory. Sometimes, quartz forms irregular, finely-grained agglomerations in whose mass are found widely-developed quartz grains with completely broken margins which gradually disappear in the finely-grained mass. These aspects show very clearly that quartz microgranular mass formed through strong break of some bigger initial grains. But there are also met lenticular microcrystalline agglomerations of quartz of 1.5—2 mm length, surrounded by a sericitic mass, showing that these lentiliform agglomerations are but detrital quartz completely broken grains.

Sericite is present in all samples up to 15% both as small flakes isolated or associated with chlorite among quartz grains and as irregular agglomerations or strips, especially in zones rich in muscovite. It can be said that most sericite formed on account of detrital lamellae of muscovite, this fact being also stated by association in strips of sericite and muscovite.

Chlorite is found only in some samples, usually associated with sericite and rarely forming separated agglomerations. Pleochroism is in light green tints and birefringence colours in grey-blue or brown copper tints. Sometimes, when it is associated with biotite, birefringence colours are similar to biotite's, being only a little lighter.

Biotite when occurs is usually associated with chlorite with which it can intergrow. It occurs as small, short lamellae, displayed among quartz grains, forming agglomerations together with sericite and chlorite. Pleochroism is from brown-green to yellow-green.

Albite (albitized plagioclase) occurs as oblong grains or of irregular margins, often having traces of polysynthetical twins both according to (010) and (001)/[010]; twin lamellae are often bent or interrupted. Bigger grains have sericite inclusions at central part, smaller ones being generally clear. However, in some samples, big grains of albitized plagioclase are lacking, feldspar being represented only by albite as small grains (less than 0.2—0.3 mm), clear, untwinned or constituted of 2—4 individuals associated according to (010), these aspects giving them a blastic character.

Muscovite occurs as widely-developed lamellae, about equidimensional in plane, on background of quartzitic finely-grained mass . Lamellae are often bent having undulatory extinction or even broken, their ends disappearing in a fine sericitic mass. Sometimes, it forms almost monomineral agglomerations in which are kept only fragments of widely developed lamellae, most of them being changed into sericite. Most of muscovite lamellae have an advanced degree of losing aluminium, changing into phengite, 2 V angle being very small (5—10°).

Calcite is found only in some samples in small quantity, cementing quartz grains in certain zones or penetrating on fissures of feldspars and muscovite ; at the same time, it can replace pyrite in marginal zones.

These schists formed through the metamorphosis, especially dynamic, of some arkosian gritstones (graywackes) bearing muscovite.

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3.2.4. *Quartz-Feldpsathic Sericito-Chloritous Schists*. They are generally found between muscovite quartzitic schists and amphibolitic rocks or chlorite-calcite-albitic schists rarely above them too. Main difference from feldspathic chloritous schists under muscovite schists is given by prevailing quartz and bigger quantity of sericite. From the schists described with the same name, developing in alternance with chlorite-albitic schists of lower complex, differ because of lack of epidote-clinozoisite and advanced degree of cataclasis. They are hard rocks, fine to middle grained of a generally weak schistosity, of grey colour, usually uniform and rarely of a weakly banded aspect. Schistosity planes often have friction mirrors being weakly limonitized. Under microscope, structure is granolepidoblastic ununiform and texture is oriented, being constituted of a microgranular mass, ununiform too, composed of quartz mixed with albite in various quantities, to which in some zones add sericite, chlorite, sometimes calcite in which are spread bigger grains of albitized plagioclase of various sizes and subordinately quartz weakly oblong or lenticular fragments (tab. 28). Accesorily are met epidote-clinozoisite, sphene, apatite and pyrite.

Actual aspects of these schists can be caused by strong tectonization of some coarse rocks, initially constituted of plagioclase fedspar, quartz,

TABLE 28

	%	mm
Quartz	35–5o	o.o1–o.1
Albite	5–2o	o.o2–o.3
Albitized plagioclase	1o–35	o.2–3.5
Sericite	8–2o	< o.2
Chlorite	2–2o	< o.2
Calcite	1–5	< o.1
Epidote-clinozoisite	o–2	o.o5–1.5
Sphene	1–2	o.1–o.5

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muscovite and biotite. Quartz, which is more breakable, was completely broken and plagioclase was only fragmented and decalcified; at the same time, muscovite and biotite suffered a process of degradation being changed into sericite and chlorite respectively.

3.2.5. *Amphibolites*. They form a thin level of a few meters thickness, near the upper part of Zeicani series in this zone, between Șerel Valley and Rîul Bărbat Valley; the best are opened in both slopes of Rîul Bărbat. They are massive rocks or weakly schistous, of angular break, dark grey-green in colour. With naked eye, we notice numerous crystals of about 1–2 mm black-green in colour, constituting about half of the rock; these crystals are caught into an aphanitic mass of epidote colour. Under microscope, main structural characteristic of these rocks is advanced degree of cataclasis and transformation of original minerals — hornblende and plagioclase, without suffering later a substantial recrystallization. As a whole, they are 50–60% constituted of well-developed crystals of hornblende (up to 1.5–2 mm) in various stages of transformation, among which there is a fine, ununiformly grained mass, which is mainly constituted of albite, with which associate epidote-clinozoisite, chlorite, sphene and calcite in various quantites (tab. 29). We have to remark the fact that if hornblende can be more or less changed, plagioclase feldspar was completely changed. Accesorily we meet apatite and pyrite.

Hornblende prevails, occurring especially as crystal fragments, generally oblong, of irregular chipy margins; some of them have sphene and apatite inclusions. It is a common variety of a pleochroism from green with a weak tint of brown, up to light yellow-green and with $c : Ng = 17-20°$. Degree of hornblende transformation as well as newly formed minerals differ from one sample to another, both aspects being conditioned in a certain way by cataclasis degree of the rock too. In less transformed samples, hornblende is partly replaced by chlorite, especially on the margins, cleavages or fissures, calcite being in small quantity. At the same time, in some cases, chlorite and calcite are lacking, hornblende having an accentuated tendency to lose colour, becoming almost colourless, because it changes into tremolite which partly pseudomorphoses initial hornblende, without forming separate crystals ; in the tremolite mass in certain zones, we notice actinolite acicular crystals. Concomitantly with tremolite and actinolite formation was also born a mass of epidote-clinozoisite of vermicular structure. In the most advanced stages of transformation, hornblende can be eventually recognized after contour or cleavages, being totally replaced by chlorite and calcite, sometimes associated with actinolite, generally having the orientation of the two cleavage directions. In this case, ends of pseudomorphosed hornblende fragments are completely broken, passing to finely-granular zones, which in the rest of the rock include albite small grains.

Plagioclase can be recognized only in some cases as fractured, completely albitized grains of irregular margins, containing inclusions of sericite, epidote-clinozoisite and calcite and having traces of polysynthetical twins. But in most samples, plagioclase was completely replaced, on its background developing a finely-granular mass of albite, epidote-clinozoisite, sometimes calcite or sericite, in which are caught bigger fragments of hornblende. Rarely epidote-clinozoisite and sericite are to develop porphyroblastically. Small grains of albite are generally untwinned and have ununiform extinction.

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TABLE 29[x]

	%	mm
Hornblende	5o-6o	o.2-2.5
Albite	25-35	o.o1-1.o
Chlorite	1-7	< o.1
Calcite	1-5	< o.1
Epidote-clinozoisite	5-15	o.o2-o.3
Sphene	o.5-6	o.1-o.7

x Given mineralogical composition corresponds to the amphibolites in which initial hornblende was only partly replaced by chlorite and calcite.

Chlorite usually is found in association with calcite, replacing hornblende ; rarely in some samples together with chlorite there is a small quantity of biotite with which it can intergrow. Chlorite often forms beaches of finely-scaled structure, containing inclusions of sphene and epidote. Pleochroism is of light green tints and birefringence is low, colours are brown-copper and blue tints.

Calcite is more abundant only in samples in which hornblende is found in advanced stages of transformation, as fine grains mixed with chlorite and epidote-clinozoisite.

Epidote-clinozoisite especially forms microgranular agglomerations mixed with albite, calcite, chlorite, but also bigger isolated grains, ununiformly distributed.

Sphene is a characteristic mineral of these rocks, being found in big quantity in most samples. It occurs as crystals generally idiomorphic, widely-developed, ununiformly distributed or as inclusions in hornblende ; usually it has simple twins according to (100) or multiple twins. In less transformed amphibolites, opacization is weak, especially on the margins and on some

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fissures and in those strongly transformed, sphene crystals are almost completely opacized.

3.2.6. *Chlorite-Calcite-Albitic Schists*. They are often met over quartzitic schists bearing muscovite (Paroșului Valley, Valea Beușii brook, Rîul Mare), being finely-granular weakly schistous rocks of dark grey-green colour. Usually they have planes of friction mirrors. In the rock mass, we can notice with naked eye numerous calcite veinlets and pyrite crystals. Under microscope, structure is microgranolepidoblastic and texture is only weakly oriented, alternating zones of irregular forms in which prevails calcite with zones where chlorite prevails. Both in calcitic mass and in chloritic one, are caught numerous small grains of albite, maybe a little quartz, generally having less than 0.05 mm in chloritic mass and less than 0.1 mm in calcitic one. In most samples, the only bigger grains are represented by sphene, only in a few samples also finding grains of completely albitized plagioclase. In small quantities, can also occur sericite and muscovite. Accesorily are met pyrite and apatite.

Mineralogical composition and average sizes are given in table 30.

Microgranular structure and actual mineralogical composition of

TABLE 3o

	%	mm
Chlorite	37-4o	< o.1
Sericite	2-1o	< o.1
Calcite	25-35	o.2
Albite	18-2o	o.o1-o.1
Albitized plagioclase	o-2	o.5-7.o
Sphene	2-3	o.o5-o.4

chlorite-calcite -albitic schists are caused by strong cataclasis of preexisting rocks (amphibolites already described) under the overthrust plane of the Getic Crystalline, without suffering a substantial recrystallization ; only calcite was partly redistributed.

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IV. CHEMICAL AND PETROGENETICAL CONSIDERATIONS

1. Granitoids

In order to discuss the chemistry of granitoid rocks in the investigated area, we have 15 complete analyses of silicates and 15 spectral informative analyses on our samples, especially near the contact with cover schists ; only on Rîul Bărbat Valley, sampling was done on the whole opened thickness of magmatic body.

Results of chemical analyses and Niggli parameters are given in tables 31 and 32, samples being written in order of SiO_2 increase.

Table of chemical composition points out a remarkable uniformity of these rocks'chemistry, unable to find a significant correlation among major elements ; even on Rîul Bărbat Valley, when sampling was transversally done on the whole thickness of granitoid body (in order, from north to south, samples being 5, 3, 14, 7, 1 and 4) we notice no systhematical change.

Because modal mineralogical composition , which was appreciated under microscope, would give errors when we petrographically framed granitoids, because of intense transformation of most initial minerals, starting from chemical composition, we calculated normal composition — Rittmann norm (tab. 33) and CIPW norm (tab. 34). In the first case, excepting sample 15 which would be a monzogranite, all the other samples are included in the family of granodiorites and tonalites (trondhjemites) ; but plotting *QAP* values, calculated starting from CIPW norm, all samples are plotted in granodiorites field — Figure 27.

On $Q'(Q' = Q/Q+Or+Ab+An)$: ANOR $(ANOR = 100\ An/(Or+An)$ normative diagram — Streckeisen, Le Maître, 1979 — excepting two samples, all samples are plotted in granodiorites field (Fig. 28) but authors mention that in this field, can be also included some tonalites.

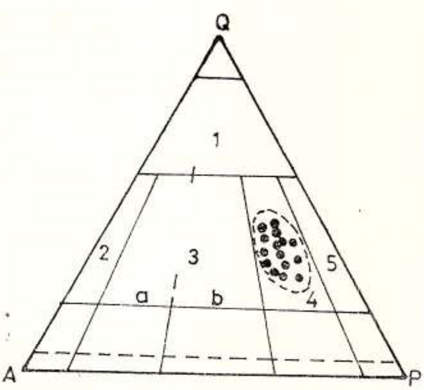

Fig. 27 — *QAP* normative diagram (CIPW) (Streckeisen, 1976). 1, xylexites ; 2, alcaline granites ; 3, granites ; 4, granodiorites ; 5, tonalites.

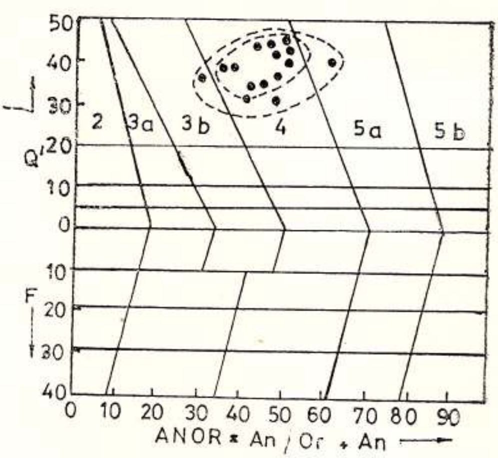

Fig. 28 — *Q'—ANOR* diagram (Streckeisen, Le Maître, 1979). 1, xylexites ; 2, alcaline granites ; 3, granites ; 4, granodiorites ; 5, tonalites.

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TABLE 31

Chemical composition of granitoid rocks

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	Fe(S)	H_2O
1	64.74	20.35	2.18	0.85	0.08	1.00	2.80	3.72	1.92	0.40	0.09	1.01	0.04	0.03	0.54
2	66.78	16.00	4.48	0.72	0.05	1.14	2.45	4.52	2.00	0.20	0.09	0.10	0.08	0.07	0.78
3	67.44	18.44	2.11	0.85	0.14	0.40	2.80	3.37	1.95	0.45	0.09	0.13	0.10	0.09	0.42
4	68.20	18.98	1.43	0.43	0.06	0.10	2.94	3.34	1.92	0.32	0.08	0.83	0.08	0.07	0.60
5	68.35	14.85	2.39	0.81	0.24	0.60	3.92	3.26	2.62	0.35	0.13	0.63	0.09	0.08	1.39
6	68.38	18.80	2.34	0.71	0.08	0.30	2.80	3.37	1.87	0.40	0.07	0.44	0.05	0.04	0.35
7	68.50	19.10	2.10	0.57	0.08	0.60	2.60	3.20	1.50	0.45	0.08	0.48	0.04	0.03	0.36
8	68.65	18.14	2.17	0.85	0.04	0.30	3.36	3.77	1.37	0.42	0.07	0.44	0.05	0.04	0.43
9	69.00	17.60	2.45	0.57	0.14	0.60	2.50	3.17	1.85	0.40	0.08	0.35	0.04	0.03	0.80
10	69.04	14.96	2.31	0.50	0.06	2.05	1.82	4.60	2.45	0.10	0.04	0.40	0.00	0.00	1.34
11	69.32	12.70	4.54	0.79	0.05	1.16	2.80	4.41	2.04	0.20	0.04	0.20	0.12	0.10	0.84
12	69.50	18.00	1.78	0.85	0.10	0.50	2.70	3.26	1.75	0.42	0.08	0.22	0.04	0.03	0.24
13	70.16	15.20	1.42	0.64	0.05	1.45	2.38	4.25	2.65	0.10	0.04	0.10	0.10	0.09	0.72
14	70.19	14.28	2.95	0.40	0.06	1.10	2.66	4.58	1.87	0.60	0.09	0.51	0.00	0.00	0.38
15	70.93	14.22	1.44	0.81	0.08	0.90	2.66	3.77	2.60	0.20	0.08	0.59	9.24	0.21	0.61

1, Rîul Bărbat, about 400 m upstream the confluence with Sohodol brook; 2, Paroșului brook, about 500 m from the northern contact; 3, Rîul Bărbat about 200 m upstream the confluence with Corbului brook; 4, Rîul Bărbat, vis-à-vis the confluence with Știrbului brook; 5, Rîul Bărbat, about 50 m from the northern contact; 6, Nucșoara brook, on left slope at about 100 m upstream the confluence (Lolaia waterfall); 7, Rîul Bărbat, the confluence with Sohodol brook; 8, Nucșoara brook, on left slope at about 200 m downstream the confluence; 9, Nucșoara brook, on branch slope, at about 300 m upstream the confluence; 10, Strugari peak; 11, Ridge between Mălăiești and Sălășel Valley, about 500 m from the contact; 12, Same as 9, in the head race (W), m 100; 13, Nucșoara brook, the confluence of the two branches; 14, Rîul Bărbat, about 500 m downstream the confluence with Sohodol brook; 15, Lazului Valley, about 400 m from the contact.

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TABLE 32

Niggli values for granitoid rocks

Sample	si	al	fm	c	alk	k	mg	ti	p	qz	c/fm
1	272.88	50.54	16.47	12.64	20.35	0.25	0.38	1.27	0.16	91.47	0.767
2	285.17	40.25	24.39	11.20	24.15	0.23	0.30	0.64	0.16	88.58	0.459
3	315.43	50.81	14.07	14.03	21.09	0.28	0.20	1.58	0.18	131.08	0.997
4	333.88	54.74	8.01	15.41	21.84	0.27	0.09	1.18	0.17	146.54	1.925
5	320.19	40.99	16.73	19.67	22.62	0.35	0.25	1.23	0.26	129.70	1.176
6	319.54	51.76	13.40	14.01	20.83	0.27	0.16	1.41	0.14	136.22	1.046
7	324.45	53.30	14.29	13.19	19.22	0.24	0.30	1.60	0.16	147.59	0.923
8	317.32	49.40	13.04	16.63	20.92	0.19	0.16	1.46	0.14	133.64	1.275
9	334.47	50.26	16.15	12.98	20.61	0.28	0.27	1.46	0.16	152.04	0.804
10	313.22	39.99	23.86	8.84	27.31	0.26	0.58	0.34	0.08	103.99	0.371
11	316.51	34.16	26.69	13.69	25.45	0.23	0.30	0.69	0.08	114.72	0.513
12	336.56	51.36	13.94	14.00	20.70	0.26	0.26	1.53	0.15	153.76	1.004
13	3[illegible].29	42.41	18.01	12.07	27.51	0.29	0.57	6.36	0.08	122.27	0.670
14	332.11	39.81	20.08	13.48	26.64	0.21	0.39	2.13	0.18	125.56	0.671
15	359.92	42.51	16.08	14.46	26.95	0.31	0.42	0.76	0.17	152.13	0.899

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TABLE 33

Rittmann norm for granitoid rocks

No.of sample / Normative minerals	1	2	3	4	5	6	7	8	9	1o	11	12	13	14	15
Quartz	26.72	26.52	31.35	37.63	32.83	36.18	35.94	34.81	34.83	28.27	29.24	35.o9	29.97	31.93	33.39
Orthose	-	9.o7	3.52	-	16.36	-	-	-	2.25	14.26	16.57	-	16.44	8.86	19.44
Oligoclase	36.42	48.59	-	34.65	-	37.57	34.16	44.74	36.53	41.55	42.36	39.72	43.11	47.45	35.68
Andesine	-	-	41.o3	-	39.77	-	-	-	-	-	-	-	-	-	-
Muscovite	18.74	-	12.o8	23.o6	-	2o.66	16.91	14.93	12.35	-	-	13.44	-	-	-
Biotite	-	9.5o	-	-	6.3o	-	-	-	-	9.43	1.o1	-	7.67	8.14	4.3o
Hornblende	-	-	-	-	-	-	-	-	-	-	8.58	-	-	-	-
Garnet	-	-	-	1.88	-	3.55	-	3.46	-	-	-	-	-	-	-
Sphene	-	-	-	-	-	-	-	-	-	-	o.15	-	-	-	-
Cordierite	14.76	4.97	1o.51	-	2.41	-	1o.9o	-	12.22	5.o5	-	1o.26	1.99	1.86	4.9o
Magnetite	o.38	o.77	o.36	o.21	o.44	o.36	o.29	o.36	o.36	o.44	1.28	o.3o	o.31	o.42	o.32
Apatite	o.17	o.18	o.18	o.16	o.25	o.14	o.15	o.14	o.16	o.o8	o.o8	o.16	o.o8	o.17	o.15
Ilmenite	o.42	-	o.48	o.34	-	o.43	o.47	o.45	o.42	-	-	o.44	-	-	-
Calcite	2.3o	o.23	o.3o	1.91	1.45	1.o2	1.o9	1.o1	o.8o	o.91	o.47	o.5o	o.23	1.16	1.34
Pyrite	o.o8	o.16	o.2o	o.16	o.18	o.1o	o.o8	o.1o	o.o8	-	o.25	o.o8	o.2o	-	o.48
Name of the rock	to-na-lite	grano-diorite	trond-hjemite	trond-hjemite	grano-diorite	trond-hjemite	trond-hjemite	trond-hjemite	trond-hjemite	grano-diorite	grano-diorite with hornblende and biotite	trond-hjemite	grano-diorite	grano-diorite	monzo-granite

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TABLE 34

CIPW norm for granitoid rocks

No. of sample / Normative minerals	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Quartz	31.49	26.67	34.58	37.74	32.67	36.74	39.40	35.42	38.76	27.54	29.82	38.27	28.66	30.92	34.11
Orthose	11.41	11.91	11.58	11.42	15.70	11.09	8.90	8.13	11.02	14.68	12.16	10.37	15.78	11.09	15.47
Albite	31.65	38.56	28.64	28.44	27.98	28.62	27.18	35.05	27.04	39.45	37.65	27.65	36.32	38.90	32.12
Anorthite	6.87	10.93	12.44	8.80	14.69	10.62	9.30	13.42	9.66	6.29	8.91	11.43	10.95	9.02	8.93
Diopside	-	-	-	-	-	-	-	-	-	-	2.74	-	-	-	-
Corindone	9.70	2.45	6.27	8.26	1.36	7.38	8.85	5.58	6.93	2.50	-	6.58	1.37	1.43	1.97
Enstatite	2.50	2.86	1.00	0.25	1.52	0.75	1.50	0.75	1.51	5.18	1.64	1.25	3.64	2.75	2.26
Ilmenite	0.76	0.38	0.86	0.61	0.67	0.76	0.86	0.80	0.76	0.19	0.38	0.80	0.19	0.98	0.38
Sphene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.22	-
Magnetite	1.71	1.63	1.54	0.37	2.08	1.21	0.65	1.48	1.00	1.54	1.71	1.71	1.59	-	1.44
Hematite	1.06	3.49	1.18	1.29	1.10	1.57	1.71	1.22	1.83	1.28	3.55	0.65	0.46	2.96	0.76
Calcite	2.31	0.23	0.30	1.90	1.45	1.00	1.09	1.00	0.80	0.92	0.46	0.50	0.23	1.16	1.35
Apatite	0.23	0.23	0.23	0.20	0.33	0.18	0.20	0.18	0.20	0.10	0.10	0.20	0.10	0.23	0.20
Pyrite	0.08	0.15	0.19	0.15	0.17	0.09	0.08	0.09	0.08	-	0.23	0.07	0.19	-	0.45
Q	38.7	30.3	39.6	43.7	35.9	42.2	46.5	39.8	44.8	31.3	33.7	43.6	31.3	34.4	37.6
A	14.0	13.5	13.3	13.2	17.2	12.7	10.5	9.1	12.7	16.7	13.7	11.8	17.2	12.3	17.1
P	47.3	56.2	47.1	43.1	46.9	45.1	43.0	51.1	42.4	52.0	52.6	44.6	51.5	53.3	45.3
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Both *QML* diagram (Fig. 29) and SiO_2 : alkalinity index diagram (Wright, 1969) — Figure 30 indicate without exception, chalcoalkaline character of analysed granodiorites ; at the same time, on SiO_2 : total alkalis diagram (Rittmann, 1967) all samples are plotted in strong and middle Pacific subprovinces (Fig. 31).

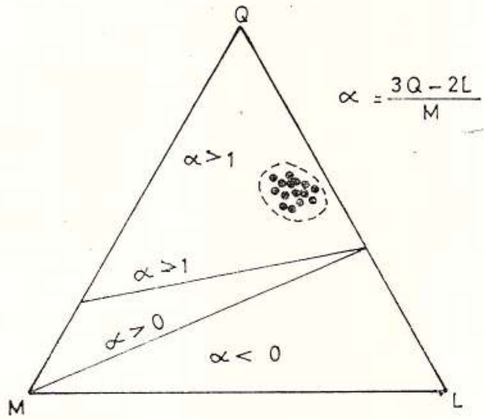

Fig. 29 — *QML* diagram (in Giușcă, 1974).

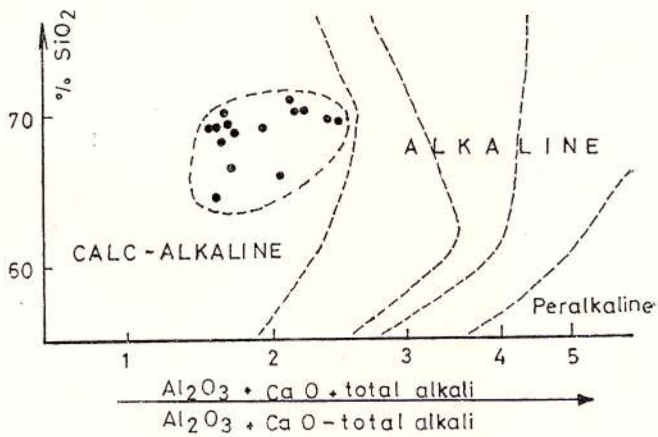

Fig. 30 — SiO_2 : index of alkalinity diagram (Wright, 1969).

On *al* : *alk* diagram, samples are plotted in fields poor in alkalis and alkaline intermediary fields — Figure 32, and on *al* : *fm* diagram (Fig. 33) only with two exceptions, in salic field, points out a negative correlation between *al* and *alk*, on one side and *fm.* on the other side.

Regarding minor elements, analyses having an informative character, we can underline only their small number and extremely small quantities.

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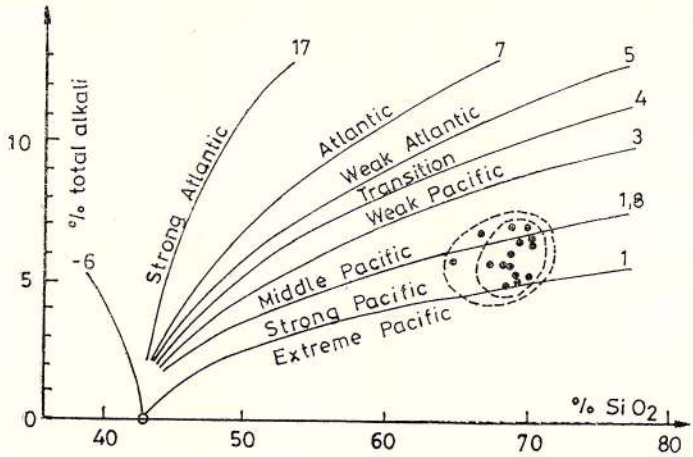

Fig. 31 — SiO_2 : total alkalis diagram (Rittmann, 1967).

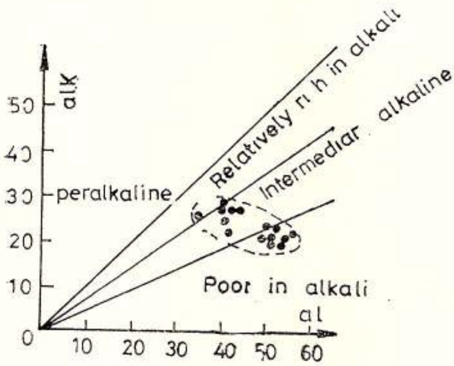

Fig. 32 — *al* : *alk* diagram .

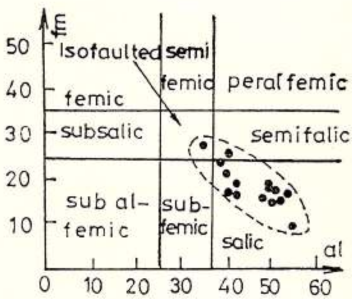

Fig. 33 — *al* : *fm* diagram.

2. Crystalline Schists

Excepting biotitic microgranular gneisses, we did silicate complete analyses only on samples of rocks with debatable premetamorphic — sedimentary or magmatic — genesis, leaving those clearly sedimentogene. For Danubian crystalline we have 13 analyses from Zeicani series — 8 chlorite-albitic schists, 4 amphibolites and a hornblendite analysis and for Getic Crystalline, we have 10 analyses : 4 microcline gneisses, 2 biotitic microgranular gneisses and 4 amphibolites.

Petrographical nature, sample location and chemical composition are given in tables 35 and 36 and Niggli parameters in tables 37 and 38.

Within some general discussions which want to show that there is no chemical convergence among magmatic rocks and certain types of sedimentary rocks during a isochemical metamorphism, Moine (1969) and La Roche (1972) propose some diagrams, which are very interesting for compo-

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TABLE 35

Chemical composition of Zeicani series rocks

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	Fe(S)	H_2O
1	43.13	13.06	2.66	6.82	0.21	9.40	9.05	3.01	0.63	2.10	0.37	4.27	0.00	0.00	4.99
2	50.15	20.12	0.67	5.87	0.20	5.50	7.19	3.28	0.36	2.10	0.30	2.07	0.00	0.00	1.94
3	43.87	14.74	3.19	7.37	0.26	6.60	7.79	3.54	0.27	1.40	0.18	4.63	0.00	0.00	4.86
4	43.68	12.84	6.71	3.55	0.19	4.40	10.65	2.64	2.52	2.00	0.65	6.95	0.00	0.00	2.84
5	56.78	15.18	1.55	5.05	0.11	5.20	4.26	4.50	1.08	1.00	0.18	2.56	0.03	0.03	2.07
6	46.19	19.48	2.80	10.10	0.25	6.20	3.86	2.67	1.44	2.20	0.23	2.31	0.00	0.00	3.91
7	43.14	14.71	2.20	7.92	0.16	9.00	7.66	2.79	0.81	1.45	0.13	4.88	0.00	0.00	4.70
8	46.48	19.04	4.16	5.45	0.16	4.50	7.56	3.45	1.20	2.50	0.35	3.22	0.00	0.00	3.66
9	44.11	15.50	6.34	8.03	0.21	4.70	11.06	2.23	0.60	3.35	0.47	0.40	0.19	0.17	1.98
10	45.49	17.45	3.18	7.42	0.27	8.55	10.50	2.63	0.90	1.08	0.07	1.23	0.00	0.00	0.67
11	43.34	15.47	3.60	8.64	0.29	6.70	7.42	3.14	0.63	2.50	0.29	4.85	0.00	0.00	3.16
12	42.58	14.34	6.16	8.86	0.27	5.90	12.52	1.76	0.45	3.35	1.54	1.54	0.00	0.00	1.43
13	39.42	18.10	2.63	5.26	0.22	11.10	10.22	1.21	0.16	0.32	0.09	2.00	0.00	0.00	7.26

1—8 : chlorite-albitic schists : 1 Nucșoara brook, left slope, about 50 m downstream the overthrust plane on Nucșoara Valley formation ; 2, Nucșoara brook, end of left slope of the viaduct ; 3, Paroșului brook, left slope, zone in which the valley direction changes eastwards ; 4, Rîul Alb, right slope, about 200 m from the valley direction and 200 m downstream the overthrust plane on Tulișa series ; 5, Poienii brook, left slope, about 20 m the valley direction and 300 m upstream the contact with the Getic Crystalline ; 6, right branch of Șerelului Valley at about 250 m upstream the confluence with Apa Beușii ; 7, Lazului Valley, left slope, at about 100 m the valley direction and 300 m downstream the overthrust plane on Tulișa series ; 8, Ridge left of Poienii brook, about 150 m north of the overthrust plane on Tulișa series ; 9—12, amphibolites : 9, Rîul Bărbat, right slope, at about 70 m the valley direction and 100 m south of the limit with the Getic Crystalline ; 10, Main ridge in left of Rîul Bărbat ; 11, Rîul Bărbat, left slope vis-à-vis 9 point ; 12, Rîul Bărbat, same as 9 ; 13, hornblendite, Știrbina- Prislop ridge.

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TABLE 36

Chemical composition of the rocks in Sebeş-Lotru series

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	CO_2	S	Fe(S)	H_2O
1	75.12	10.70	3.20	0.36	0.03	0.50	0.91	3.06	3.61	0.20	0.00	0.36	0.06	0.05	1.24
2	75.57	9.28	3.37	0.43	0.04	0.72	0.91	4.17	3.60	0.32	0.00	0.10	0.16	0.14	0.68
3	76.77	8.00	1.99	0.54	0.05	2.70	1.46	3.29	3.69	0.23	0.00	0.48	0.05	0.04	0.14
4	73.22	14.36	0.12	0.27	0.06	1.50	1.33	2.64	5.40	0.00	0.05	0.40	0.06	0.05	0.00
5	67.88	12.34	1.95	4.37	0.11	3.80	2.39	2.92	1.98	0.75	0.17	0.36	0.02	0.02	0.36
6	67.62	13.70	1.98	3.00	0.18	3.30	3.33	2.96	1.98	0.85	0.21	0.37	0.00	0.00	0.22
7	45.67	22.85	2.80	5.04	0.14	4.80	10.80	3.23	0.90	1.23	0.07	1.10	0.00	0.00	1.10
8	49.63	18.59	3.26	9.67	0.21	5.90	6.16	1.94	0.36	2.80	0.26	0.12	0.00	0.00	0.53
9	52.66	14.78	4.40	9.67	0.24	3.90	6.16	2.02	0.72	2.95	0.49	0.59	0.00	0.00	0.69
10	41.00	15.20	6.51	7.41	0.18	6.92	7.56	1.96	1.44	1.50	0.35	1.96	0.07	0.06	3.76

1—4: gneisses with microline: 1, Nucşoara brook, left slope; 2, Mălăieşti brook, left slope; 3, left tributary of Mălăieşti brook; 4, Piscurilor brook, left tributary of Şerel brook; 5—6; biotitic paragneisses: 5, Piscurilor brook, at the confluence with Şerel brook; 6, Interriver betwee Pîrîul Mic and right tributary at about 200 m the confluence; 7—10: amphibolites: 7, right tributary of Şerel brook, with the confluence in Şerel village; 8, Şerel brook, right slope, at about 300 m downstream the confluence with Pîrîul Spurcat; 9, Rîul Bărbat left slope; 10, Mălăieşti brook, left slope, as intercalations in microcline gneisses.

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TABLE 37

Niggli values for the rocks in Zeicani series

Sample	si	al	fm	c	alk	k	mg	ti	p	qz	c/fm
1	1o1.27	18.o7	51.38	22.76	7.79	o.12	o.64	3.71	o.37	-29.89	o.443
2	136.48	32.26	37.48	2o.96	9.3o	o.o7	o.59	4.3o	o.35	- o.72	o.559
3	1o8.82	21.54	46.16	23.35	8.94	o.o5	o.53	2.61	o.19	-26.92	o.5o6
4	115.35	19.98	38.9o	3o.12	11.oo	o.39	o.44	3.97	o.72	-28.64	o.774
5	178.65	28.14	41.62	14.35	15.88	o.14	o.59	2.37	o.24	15.11	o.345
6	118.o9	29.34	51.13	1o.57	8.96	o.26	o.46	4.23	o.25	-17.75	o.2o7
7	1o2.94	2o.68	52.o6	19.58	7.68	o.16	o.61	2.6o	o.13	-27.79	o.376
8	122.49	29.56	38.28	21.34	1o.83	o.19	o.46	4.95	o.39	-2o.81	o.557
9	1o4.57	21.65	44.24	28.o8	6.o3	o.15	o.38	5.97	o.47	-19.55	o.635
1o	98.45	22.25	46.66	24.34	6.76	o.18	o.59	1.76	o.o6	-28.58	o.522
11	1o6.59	22.42	49.57	19.54	8.47	o.12	o.5o	4.62	o.3o	-27.29	o.394
12	94.82	18.81	46.89	29.86	4.44	o.14	o.42	5.61	o.33	-22.93	o.637
13	85.73	23.19	5o.23	23.8o	2.77	o.o8	o.72	o.52	o.o8	-25.35	o.474

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TABLE 38

Niggli values for the rocks in Sebeş-Lotru series

Sample	si	al	fm	c	alk	k	mg	ti	p	qz	c/fm
1	468.91	39.35	21.69	6.08	32.88	0.44	0.21	0.92	0.00	237.41	0.280
2	450.44	32.58	23.85	5.81	37.76	0.36	0.27	1.43	0.00	214.92	0.244
3	430.60	26.44	33.72	8.77	31.08	0.42	0.67	0.97	0.00	220.22	0.260
4	396.14	45.77	14.05	7.71	32.47	0.57	0.86	0.00	0.11	166.27	0.548
5	273.80	29.33	43.85	10.32	16.50	0.31	0.52	2.27	0.29	107.78	0.235
6	272.92	32.58	36.59	14.39	16.44	0.30	0.54	2.58	0.36	107.16	0.393
7	107.91	31.81	32.11	27.33	8.75	0.15	0.53	2.18	0.07	-27.09	0.851
8	126.73	27.97	49.88	16.85	5.39	0.11	0.45	5.37	0.28	5.19	0.338
9	149.91	24.79	49.55	18.78	6.88	0.19	0.33	6.31	0.59	22.39	0.379
10	98.98	21.62	52.03	19.55	6.80	0.33	0.48	2.72	0.36	-28.23	0.376

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sitional fields of various types of rocks. In Figure 34, diagram (according to Moine, 1969) is given Al, Na, K differential behaviour in volcanic and sedimentary rocks; moreover, to assure a good separation of basic magmatic rocks of sediments, particularly of graywackes, they also considered the siderophile character of the first ones. In this diagram results that metamor-

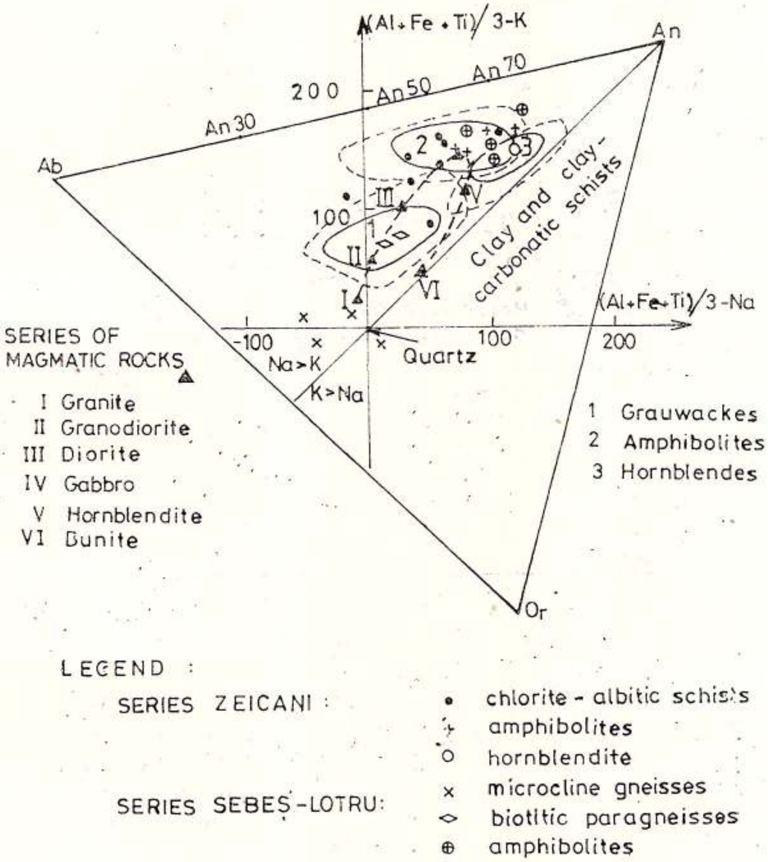

Fig. 34 — (Al + Fe + Ti)/3-K : (Al + Fe + Ti) / 3-Na diagram (Moine, 1969).

phic hornblendes are situated in the domain in which Na > K and their associations with plagioclases create an obvious differentiation from the associations of clay-carbonated rocks, as marls and carbonatic arkosis. The problem is less clear in sodic domain where occurs a light overplapping between the fields of graywackes and amphibolites. So, for the separation of amphibolites from graywackes they offer a second diagram (Fig. 35, according to Moine, 1969) in which graywackes are well delimited from basic magmatic rocks through smaller values of the two parameters; metamorphosed dolomitic graywackes have values of (Ca + Mg) parameter comparable to those of basalts, while (Al + Fe + Ti) parameter maintains at the

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level of basalts. On these two diagrams, amphibolites from Zeicani series and Getic Crystalline and most of chlorite-albitic schists plot in the field of magmatogene amphibolites and hornblendite sample plots in the field of metamorphic hornblendes ; biotitic microgranular gneisses in the field of graywackes and microcline gneisses get close the arkoses.

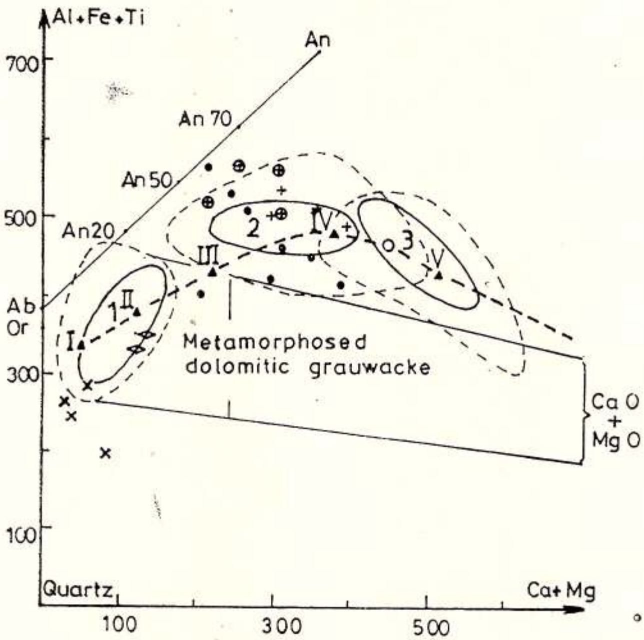

Fig. 35 — (Al + Fe + Ti) : (Ca + Mg) diagram — Moine, 1969.

In SiO_2 : 100 MgO/MgO+ Na_2O + K_2O : 100 Na_2O/MgO + Na_2O+ + K_2O diagram — Figure 36 (according to La Roche, 1972), magmatic series outline a kind of dorsal from basalts near the triangle center up to rhyolites, tendencies of sedimentary differentiation being oblique in comparison with magmatic tendencies, partly covering magmatic line. If all our amphibolites and most of chlorite-albitic schists plot in the zone of basic magmatic rocks — from quartziferous basalt to basalt, biotitic gneisses plot in the field of graywackes (near diorite), microcline gneisses having an irregular distribution but as well as preceding diagrams, near arkoses (from granodiorite to rhyolite).

On Simonen diagram, 1953 (in Holdus, 1971) in which it is represented *si* : (*al* + *fm*) — (*c* + *alk*) correlation — Figure 37, amphibolites from Zeicani series and most of chlorite- albitic schists have clear magmatic tendencies, being plotted near the basic zone of magmatic field ; a similar tendency have the amphibolites from Getic Crystalline. Among chlorite-albitic schists, sample 4, which has an isolated position on other diagrams too, plots in the field of limy sediments, this fact being explained maybe through its sampling out of a more carbonatic separation and not through the belonging to another type of rock. In the case of sample 5, it is possible that magmatic

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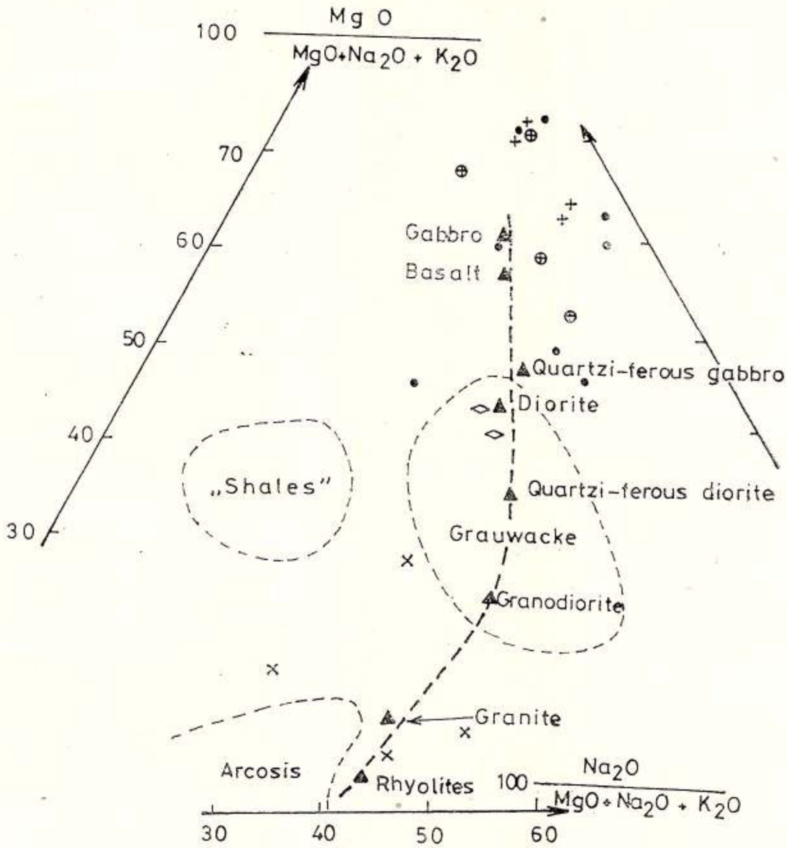

Fig. 36 — SiO_2 : 100 MgO/MgO + Na_2O + K_2O : 100 Na_2O/MgO + Na_2O + K_2O diagram (La Roche, 1972). Legend as in Figure 34.

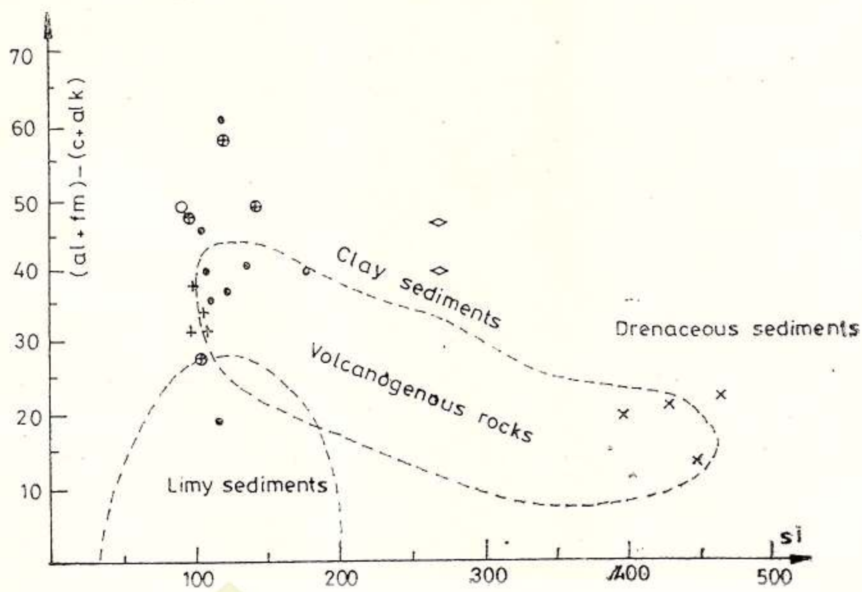

Fig. 37 — *si* : (*al* + *fm*) — (*c* + *alk*) diagram — Holdus, 1971. Legend as in Figure 34.

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material should be mixed terrigenous material in a certain quantity. Biotitic gneisses plot in the field of clay sediments and microcline gneisses in that of arenaceous sediments, partly in acid magmatic field too.

Discussing variations in Ti distribution in metabasites and its genetic implications, Misra (1971) proposed two diagrams. In the first diagram which shows variation of SiO_2 content in function of F ($F = (FeO + Fe_2O_3)/(FeO + Fe_2O_3 + MgO)$) — Figure 38, can be drawn a line which separates the fields of ortho-and paraamphibolites, TiO_2 variations in magmatic rocks and their metamorphic derivatives, showing systhematical changes with F, while this relation is almost absent in the rocks with primary sedimentary parageneses. Excepting sample 5 in chlorite- albitic schists and samples 7 and 10 of amphi-

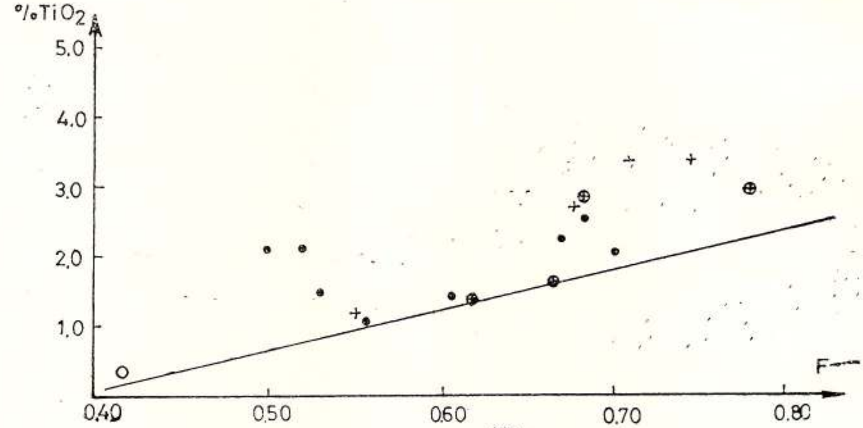

Fig. 38 — TiO_2 : F diagram (Misra, 1971). Legend as in Figure 34.

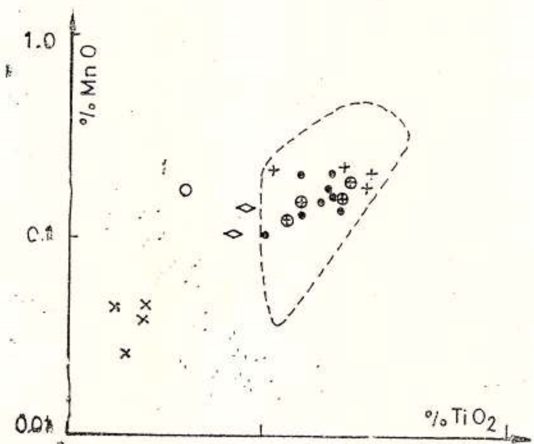

Fig. 39 — TiO_2 : MnO diagram (Misra, 1971). Legend as in Figure 34.

bolites in Getic Crystalline, all the other samples of chlorite-albitic schists and amphibolites plot in the field of orthoamphibolites. In the second diagram — on which it is shown MnO variation in function of TiO_2 — Figure 39,

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all samples of chlorite-albitic schists and amphibolites exclusively plot in the field of orthometabasites.

On *si* : (*c* + *alk*) — diagram Figure 40 , in which the field of eruptive rocks is delimited according to Burri (1959) — all samples of chlorite-albitic schists and amphibolites are focused in the center of eruptive field and the two samples of biotitic gneisses out of it.

On *ti* : *mg* diagram — Figure 41, in which we plotted samples of chlorite-albitic schists ; amphibolites and hornblendite sample, it is very wel

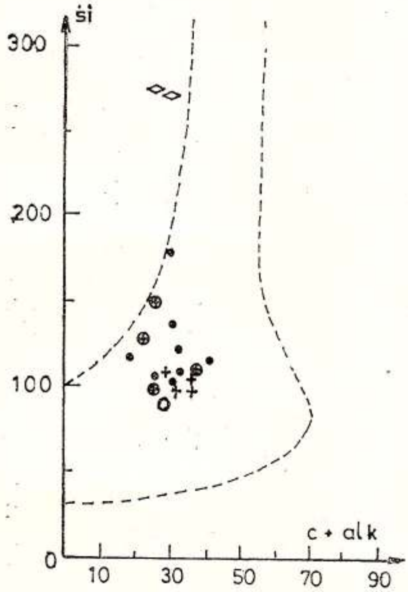

Fig. 40 — *si* : (*c* + *alk*) diagram — according to Burry, 1959. Legend as in Figure 34.

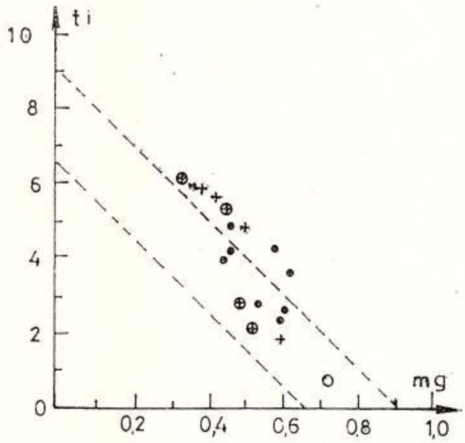

Fig. 41 — *ti* : *mg* diagram. Legend as in Figure 34.

pointed out the increase of „*ti*" parameter at the same time with „*mg*"² decrease, this relation being characteristic to the differentiation of basaltic magma, but all samples plot in the field of magmatogene amphibolites, which satisfy the relation $ti + 10\ mg = 6.5 - 9$ or very close to it. Concerning hornblendite sample, we have to remark that on diagrams in which is Mg implied, it is clearly pointed out its stronger magnezian character in comparison with chlorite- albitic schists and amphibolites.

On account of the presented diagrams, we can conclude enough certainly that both chlorite-albitic schists, maybe excepting samples 4 and 5, and discussed amphibolites come from basic magmatic rocks partly intermediary too, microgranular biotitic gneisses from graywackes and microcline gneisses were born on account of some arkosian gritstones or locally some rhyolitic tuffs. Therefore, we are to present normative mineralogical composition (Rittmann norm) with corresponding names — tables 39 and 40, for chlorite-albitic schists, amphibolites and gneisses and about hornblen-

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TABLE 39

Rittmann norm for the rocks in Zeicani series

No.of sample / Normative minerals	1	2	3	4	5	6	7	8	9	1o	11	12
Quartz	-	4.55	-	15.o8	1o.18	-	-	-	-	o.35	-	-
Sanidine	-	-	-	-	-	8.32	-	5.21	-	-	-	-
Anorthoclase	-	-	-	-	52.o4	-	-	-	-	-	-	-
Oligoclase	-	-	51.44	28.84	-	27.87	39.32	-	-	-	38.14	-
Andesine	52.41	53.o6	-	-	-	-	-	49.78	-	-	-	-
Labrador	-	-	-	-	-	-	-	-	6o.46	66.24	-	53.74
Nepheline	-	-	-	-	-	-	-	-	-	o.1o	-	-
Augite	-	-	-	-	-	-	-	-	18.oo	-	-	19.41
Hypersthene	26.4o	1o.94	22.8o	-	12.o7	13.36	24.97	11.o9	9.51	-	18.7o	11.o2
Diopside	-	-	-	-	-	-	-	-	-	9.93	-	-
Olivine	2.99	-	-	-	-	-	-	-	4.27	17.94	-	5.82
Biotite	-	-	-	32.49	-	-	-	-	-	-	-	-
Cordierite	-	22.87	8.21	4.75	17.27	38.37	16.52	2o.62	-	-	24.18	-
Sillimanite	-	-	-	o.o4	-	-	-	-	-	-	-	-
Spinel	2.54	-	2.17	-	-	1.86	3.36	o.81	-	-	1.75	-
Magnetite	1.o5	o.62	1.32	1.19	o.9o	1.47	1.18	1.o4	1.63	1.51	1.36	1.57
Apatite	o.83	o.62	o.4o	1.37	o.36	o.49	o.29	o.73	1.o7	o.15	o.63	o.8o
Ilmenite	2.55	2.34	1.67	o.98	1.o9	2.52	1.73	2.83	3.54	1.18	2.93	3.49
Calcite	11.23	5.oo	11.98	17.25	6.o4	5.74	12.63	7.9o	1.o7	3.14	12.32	4.15
Pyrite	-	-	-	-	o.o6	-	-	-	o.45	-	-	-
Name of the rock	tholeitic basalt	tholeitic quartzi-ferous basalt	tholeitic basalt	plagio-dacite	alkaline quartzi-ferous trachyte	latibasalt	tholeitic basalt	tholeitic basalt	tholeitic basalt	havaiite with quartz	tholeitic basalt	tholeitic basalt with olivine

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TABLE 4o

Rittmann norm for the rocks in Sebeş-Lotru series

Samples Normative minerals	1	2	3	4	5	6	7	8	9	1o
Quartz	42.56	38.1o	41.8o	31.32	4o.64	29.72	-	5.98	14.77	16.17
Sanidine	44.25	5o.91	43.o4	53.97	-	14.12	-	-	o.53	-
Oligoclase	-	-	-	-	31.8o	-	-	-	-	-
Andesite	-	-	-	-	-	37.o1	-	-	-	-
Labrador	4.14	-	-	-	-	-	79.25	5o.81	49.68	38.63
Anorthite	-	-	-	3.35	-	-	-	-	-	-
Nepheline	-	-	-	-	-	-	2.83	-	-	-
Biotite	6.56	-	-	1.95	25.57	-	-	-	-	37.58
Hypersthene	-	-	-	-	-	9.56	-	21.34	2o.48	-
Diopside	-	-	-	-	-	-	o.84	-	-	-
Egirine-augite	-	1o.o4	13.91	-	-	-	-	-	-	-
Olivine	-	-	-	-	-	-	11.75	-	-	-
Cordierite	1.o6	-	-	8.o4	-	6.82	-	16.64	7.21	-
Sillimanite	o.o1	-	-	o.o1	-	-	-	-	-	-
Magnetite	o.48	o.2o	-	o.o7	o.77	o.58	1.o9	1.11	1.3o	1.54
Apatite	-	-	-	o.o9	o.34	o.42	o.15	o.56	1.o6	o.78
Calcite	o.82	o.23	1.o9	o.88	o.84	o.86	2.71	o.3o	1.51	5.14
Ilmenite	-	o.21	o.o7	-	-	o.91	1.39	3.26	3.47	-
Pyrite	o.12	o.32	o.1o	o.12	o.o4	-	-	-	-	o.16
Name of the rock	alkaline rhyolite	alkaline rhyolite	alkaline rhyolite	alkaline rhyolite	plagio-dacite	dacite	hawaiite (with quartz)	tholeitic quartziferous basalt	plagiodacite	plagiodacite

dites we can only say that probably represent initial gravitational accumulations of phenocrysts, which were metamorphosed afterwards.

V. TECTONIC CONSIDERATIONS

Major elements which control the structure of northern Retezat Mts lare the overthrust of Getic Nappe, the overthrust of Upper Danubian Unit on Lower Danubian Unit and Haţeg intermountaneous tectonic basin.

As a whole, the crystalline between Rîul Bărbat Valley and Nucşoara Valley can be looked as a monoclinal structure, almost flat, with northern inclinations ; only in the western part of the perimeter, where crystallofilian formations have a big width, there develop some small anticlinal and synclinal folds, especially in the schists of Nucşoara Valley formation and less characteristic in those of Rîuşorul series, as a result of Rof anticlinal structure.

Abnormal tectonic relations between the formations of Getic domain and Danubian one have been noticed by Gh. Munteanu Murgoci in 1905 for the first time. In our region, the overthrust of Getic Nappe on the Autochthon was accepted and confirmed by all later investigators (Pavelescu, 1953 ; Micu, Paraschivescu, 1970 ; Gherasi et al., 1974 ; Macaleţ, 1983), being well pointed out both by mapping and by strong cataclasis (breccification and mylonitization), especially of the rocks above, on more than 100 m thickness. On the whole length of the overthrust line, the Getic Crystalline lies on the formations of Zeicani series upper complex and although there are no clear outcrops, we appreciate the average bent of overthrust plane of 30—40°. Murgoci (1912) considered that the overthrust of the Getic Crystalline was the result of the underpush action of Dobrogea and Prebalkans, this action beginning still during Paleozoic and continuing up to now, stating that the paroxysm of movements took place during Middle Cretaceous— between Barremian and Cenomanian. Codarcea (1940) distinguished two paroxysmal moments in the evolution of Getic Nappe : Ante-Vraconian and Ante-Campanian. From orogenetical point of view, we can say that the overthrust of the Getic Nappe ended during the Austrian and Laramian stages.

A second important overthrust line is very clear pointed out within the Danubian, lying in tectonic position the Zeicani series formations from west to east on Rîuşorul series, Nucşoara Valley formation, Oslea formation or directly on Drăgşan series. This overthrust line is mentioned by Micu, Paraschivescu (1970), but on the map which is added to the paper, it is drawn much more to the north ; Gherasi et al. (1974) drew it about at the same level as we did. The most typical contact is that with Oslea formation rocks, which can be noticed as an almost continuous, abrupt, which sometimes comes to several tens of meters, from Rîul Bărbat basin to Nucşoara right slope, because of different rocks competence which come into contact — usually quartzitic schists or chlorite-albitic schists above and phyllites below ; however, when the succession of Oslea formation ends at the level of limestones, the abrupt can be under limestones (between limestones and metagritstones below there is often a phyllitic level). Inclination of the overthrust plane is bigger than in the case of Getic Nappe coming sometimes to 60—70° (Figs. 4, 5, 6). Because of this situation, between Nucşoara Valley and Rîul Bărbat Valley, we separated within the Danubian (Macaleţ, 1983) an upper

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subunit, which is totally constituted of Zeicani series formations and a lower subunit, constituted of granitoid rocks, Drăgșan series , Riușorul series, Nucșoara Valley formation and Oslea formation. We appreciate that this dislocation took place during alpine movements, maybe at the same time with the end of Getic overthrust, although the fact that under the overthrust plane are caught weakly-metamorphosed deposits of Oslea Paleozoic formation, is no proof about a more recent age than Hercynian one.

At the same time, longitudinal dislocations which are not so big are pointed out both within the Upper Danubian Unit — the fault west of Paroșului Valley, because of which in this zone Zeicani series has the biggest width as well as within the Lower Danubian Unit in the basin of Nucșoara and Mălăiești valleys — the fault between Nucșoara Valley formation and Rîușorul series and the fault between Rîușorul series and Drăgșan series.

Contact of Hațeg basin sedimentary deposits with crystalline schists is done according to major longitudinal faults, which existed since the moment of subsidence zone formation and permanently acted on up to now, today constituting mobile limits along which takes place the uplift of surrounding mountaneous masses ; now these major fractures occur fragmented and slipped by numerous younger transversal faults (in Maciu, Ionescu, 1977).

Microtectonic Data

Structure as monocline of the whole crystalline between Nucșoara and Rîul Bărbat as well as rarity of secondary microfolds whose axes would be used as lineation (b $\simeq$ B) make almost impossible to establish directions and axial sinkings of structures in different sectors, without detailed study of planar elements — schistosity and fissures.

Schistosity (and foliation of granitoid rocks) measured in the outcrop has predominantly east-west direction with variations between 30° northwards or southwards and the most common inclination between 30° and 50°, constantly northwards, excepting the zone west of Nucșoara Valley, constituted of Rîușorul series and Nucșoara Valley formation, where can be outlined some small anticlines and synclines.

Fissures. Because in the region, it is not possible to define the position of *B* tectonic axis through direct measurements, we shall name and analyse fissures according to direction and inclination of schistosity. So, the most developed systems are those of transversal fissures (*ac*) and longitudinal ones (*h0l*), subordinately being diagonal fissures (*hkl*), too.

Starting from the tautozonality of schistosity and longitudinal fissures (in Gurău, 1982), we drew graphically the β axis ($\simeq$ *B*) and deformation ellipsoid. Several times, *AC* plane overlies or finds itself close to the maximum of *ac* fissure systems ; at the same time, there where we could measure axis of microfolds, their poles always plotted in the zone of maximum of *ac* fissure poles ($\simeq$ β axis), this fact showing that our interpretation is correct.

On account of analysing fissure systems, related to schistosity and to deformation ellipsoid, we could outline some homogeneous sectors from struc-

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tural point of view delimited by transversal faults — Plate III, which we shall discuss on units from south to north and within the unit, when it is necessary, from west to east, referring to direction and inclination of main axis of structure in each sector.

Granitoid rocks, maybe excepting the part from west of the faults in Nucşoara-Mălăieşti zone, for which our data are not conclusive, occur as a homogeneous sector, the most developed being *ac* and (*h0l*) fissure systems, prevailing the first ones ; (*h0l*) fissures occur conjugated with foliation. β axis constantly sink ENE, between N62—77°E/2—20°NE, so pointing out only weak waves both horizontaly and verticaly (Pl. III, 2—7).

Drăgşan series in Nucşoara basin has a tectonogram similar with those from granitoid rocks (with *ac* fissures strongly developed) different being only big inclination almost up to vertical of S_1. β axis has the position N 72° E/4° NE (Pl. III, 8).

In *Rîuşorul series* in comparison with the situation in granitoid rocks and Drăgşan series, tectonograms are a little more complicated (Pl. III, 9, 10, 11), maxima of fissure poles having the tendency to be displayed on longer arcs of cercle, because of the apparition of some systems of diagonal fissures (*hkl*). West of the fault in Nucşoara right slope, β axis has the position N 57° E/26°NE and eastwards N 71°E/10°E in the zone of Prislop peak and N 62°E/24° E in the left slope of Mălăieşti brook, so that between these two sectors there is no significant difference.

In *Nucşoara Valley formation*, on Nucşoara right slope fissures focus again in two clear maxima (prevailing *ac* and (*h0l*) conjugated with schistosity), β axis plunging 10° towards N 47° E (Pl. III, 12).

In *Oslea formation*, where measurements have been taken in rocks of very different competences (metagritstones, limestones, phyllites) only S_1 poles focus in well outlined maxima, fissure poles displaying on arcs of cercle, being more difficult to delimit maximum of *ac* fissures and especially (*h0l*) ; however, we have to remark that when measurements were taken only in competent rocks, these maxima can be well outlined — usually (*h0l*) poles in limestones (for instance, Colţu Mare peak) and *ac* poles in metagritstones (for instance, Poienii brook) and metaconglomerates (for instance, Valea Beuşii brook). Excepting the sectors west of Colţu Mare, where β axes sink to NE with values between N 44°E/25°NE and N 60°/32° NE (Pl. III, 13, 14), Colţu Mare (Pl. III, 15) and left slope of Rîul Bărbat (Pl. III, 16) where they are oriented E—W and are almost horizontal, in the most part of the zone, β axes constantly sink W—NW with values between N 62° W and N 90°W/ 10—32° NW (Pl. III, 17, 18, 19, 20, 21).

Within *Zeicani series*, the situation is somehow different in its two complexes.

Lower complex is fragmented in several sectors, relatively homogeneous from structural point of view :

— sector between Nucşoara right slope and Mălăieşti Valley in which β axes bent eastwards, having the position N 80°E/10°NE in Ştirbina peak

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(Pl. III, 22) and N 66°—90°/18°—20°NE between the saddle south of Ştirbina peak and the thrust over the Oslea formation (Pl. III, 23, 24).

— sector between Mălăieşti Valley and left slope of Paroşului Valley where β axes have the direction N 75°—88° E and are close to the horizontal in southern half (Pl. III, 25, 26, 27) or bending about 24° NE in northern half (Pl. III, 28).

Different situations in northern and southern halfes of the two sectors discussed up to now can be explained through the existence of a longitudinal fault, along which compartments were moved in vertical plane.

— Paroşului Valley-Lazului Valley sector, although it has a much more oblong form, it has a remarkable unitary structure, structural axes gradually curving only very little from west to east both in horizontal and vertical plane from N 57° E/27—28° NE to N 64° E/12°NE (Pl. III, 29, 30, 31, 32).

About with the same position, the structure goes on in Şerelului basin (Pl. III, 33).

— Sector in the left slope of Rîul Bărbat in which the axis bends westwards having the position N86°W/18°NW (Pl. III, 34).

In upper complex, on which overthrusts formations of Getic Nappe, can be separated from west to east about the same sectors, but it is important to remark the fact that in some sectors β axes bend to the same sense with those in lower complex (Paroşului and Rîul Bărbat valleys) — Pl. III, 35, 36 and in others in a contrary direction (Nucşoara and Şerelului valleys) — Pl. III, 37, 38.

In comparison with Lower Danubian Unit, in which the only fissure systems well-developed are *ac* and (*h0l*), excepting somehow Rîuşorul series, in the rocks of Upper Danubian Unit, especially east of Rîul Alb Valley, a third system of fissures, diagonal — (*hkl*), occurs well individualized.

In *Sebeş-Lotru series*, diagrams of fissures point out groups of their poles in numerous maxima displayed in belts, so that building ellipsoids of deformation would be riskily. However, on account of approximative axes of major structure, correlated with the geological limits, between Rîul Alb and Rîul Bărbat, where the series has a wider development, we could delimit three sectors relatively homogeneous separated by transversal faults,because of which compartments have been moved more in vertical plane (Pl. III, 39, 40, 41, 42, 43).

If in granitoid rocks, Zeicani series (lower complex), Rîuşorul series and even Nucşoara Valley formation, structural directions are similar, sometimes being identical, Oslea formation and upper complex of Zeicani series have a different situation. For instance, between the basin of Şerelului Valley and Colţu Mare peak, Oslea formation, resting on granitoid rocks and supporting the overthrust of Zeicani series, plunges WNW, strongly contrasting with the plunging of granitoid rocks and Zeicani series towards ENE; west of Colţu Mare peak up to Ştirbina-Prislop ridge, although plungings are towards north-east and are similar to above and below units, their direction is different. Somehow similar is also the situation in the case of the upper complex of Zeicani series, where as we saw, in the same compartment delimited by transversal faults the inclination of the structure can be different from the lower complex.

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Different situations, especially in the case of Oslea formation but also of Zeicani series upper complex, can be explained by the fact that their actual structure (inclusively foliation and fissure systems) is the result of advance movements of Upper Danubian Unit on Lower Danubian Unit, respectively of the Getic Nappe on the Danubian. Accepting this hypothesis, it is not difficult to reconstitute general direction of main transport; from NNE to SSW in the case of Upper Danubian Unit and from NNW to SSE in the case of the Getic Nappe; certainly, locally some exceptions can occur but caused by transversal disjunctive tectonics.

Concerning the upper complex of Zeicani series, the above discussions can be arguments for its consideration as a separate lithostratigraphical unit, newer than the lower complex and older than Oslea formation (probably synchronous with Nucșoara Valley and Rîul Mare formations).

Admitting that the two main planes of the overthrust are the result of Alpine tectonic movements, it means that during them, both the basement of the Lower Danubian Unit (Drăgșan and Rîușorul series and granitoid rocks) and of the Upper Danubian Unit (lower complex of Zeicani series) behave as some rigid blocks, without getting a new important foliation and fissuring. However, at least east of Rîul Alb Valley, in the rocks of the Upper Danubian Unit occurs a new system of shearing fissures, parallel to the direction of its advance, in diagonal (*hkl*) position on the direction of the structure; similar situation met in Rîușorul series too determined us to consider that it thrusts over the Drăgșan series. Therefore, the only important effects of Alpine tectonics are compartments according to (*AC*) faults and a little (*HOL*) longitudinal faults west of Paroșului Valley or diagonal (*HKL*) faults in the east of the zone.

All tectonic interpretations, as well as dicussions on the mineralogy, petrography and metamorphism of Drăgșan series and lower complex of Zeicani series, show that they are synchronous both concerning the age of component deposits and the metamorphism, representing one and the same lithostratigraphical unit, which is distributed to two different tectonic units as a result of a double division at regional scale.

VI. MINERAL RESOURCES

Economic potential known in our crystalline zone is reduced, although would have a certain importance talc occurrences in the basin of Nucșoara Valley as well as magnetite and sulphide mineralizations inside metabasites of Zeicani series.

Talc schists are placed exclusively in Nucșoara basin as lenses of 1—2.5 m thickness and 50—200 m length placed in the axis of some anticlinal and synclinal folds (Micu, Paraschivescu, 1970). Gherasi et al. (1974) considered that talc rocks represent concentrations associated to basic metamorphic differentiated, our point of view being expressed on the occasion of description of talc schists bearing actinolite and tremolite.

Constant presence of *magnetite* and *sphene* in Zeicani series metabasites—amphibolites and chlorite-albitic schists—implies the possibility of some accumulations of magnetite, titano-magnetite and sphene in these rocks.

Sulphide impregnations are met almost constantly in chlorite-albitic and amphibolic schists. More important occurrences are on Nucșoara right

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slope, close to the contact with hornblendite bodies, where pyrite can be 10% ; pyrite crystals are generally idiomorphic and uniformly spread. Under microscope, in some sections, besides pyrite is pointed out a light impregnation of bornite, calcosine and coveline whose occurrence can lead to the conclusion of copper presence in the pyrite network.

In Rîul Bărbat alluvia, upstream Hobița village, it was met *native gold*, probably related to veins of quartz with pyrite in crystalline schists (in Pop, 1973).

To granitoid rocks could be related some accumulations of mineral resources, presently unopened by erosion — polymetallic sulphides, rare and dispersed metals and others.

At the same time, high purity and wide development of some lenses of white quartz as those on Paroșului Valley left slope, for instance, can make profitable their investigation.

VII. CONCLUSIONS

Geological formations in northern part of Retezat Mts between Nucșoara and Rîul Bărbat have been distributed both to the Getic Nappe and to the Danubian which are presently in tectonic relations. At the same time, within the Danubian we outlined two important tectonic units — Lower Danubian Unit and Upper Danubian Unit. The overthrust lines between the Getic Nappe and the Danubian and respectively, between the two units of the Danubian are oriented approximatively E—W as well as most of the geological limits between the formations within each unit.

The Getic Nappe is mostly constituted of meso-catametamorphic crystallophylian formations totally belonging to Sebeș-Lotru series (group) attributed to Dalslandian cycle (Schuster, 1972 ; Gherasi et al., 1974) or to Lower and Middle Carpian — $Cp_1 - Cp_4$ (Kräutner, 1980) and subordinately of sedimentary formations represented by Lower Cretaceous limestones (Barremian-Aptian).

Crystallophylian formations are constituted of paragneisses and biotite-muscovitic micaschists, biotitic paragneisses bearing garnet, microcline gneisses and amphibolic rocks.

Metamorphism of Sebeș-Lotru series in our zone corresponds to Barrovian type of metamorphism (of middle pressure), taking place under conditions of amphibolitic facies (Eskola, 1939) ≈ amphibolitic almandine facies (Turner, Verhoogen, 1960), kyanite-almandine-muscovite, sillimanite-almandine-muscovite and here and there sillimanite-almandine-orthoclase subfacies. As in the case of other zones (Hîrtopanu, 1978), within the Getic Crystalline between Nucșoara and Rîul Bărbat was pointed out the polyphase character of metamorphism ; this fact is the best illustrated in biotitic paragneisses bearing garnet, finely-grained and in actinolitic gneisses. So, minerals corresponding to older phase in paragenetic equilibrium are quartz, plagioclase, biotite, almandine, kyanite (and the amphibole in actinolitic gneisses) and those corresponding to newer phase are muscovite (and biotite in actinolitic gneisses), sillimanite (fibrolite), garnet, plagioclase and quartz, the last two forming overgrowths on older feldspar and quartz. In the other types of rocks, neoformation minerals can be considered : orthoclase (in

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biotite-muscovitic paragneisses) and microcline (in microcline gneisses), both of them being related to sillimanite formation. Considering morpho-structural aspects and spacial display of neoformation minerals, we appreciate that they were born about under the same conditions of depth and temperature with older minerals but after the main episode of deformation, the metamorphism especially continuing only under the effect of lithostatic pressure (= static metamorphysm). It means that at least in our zone, the only minerals really newly-formed in this last phase of the same tectomagmatic cycle were sillimanite, orthoclase, and microcline, the other minerals suffering only a remobilization and reorganization of network.

During the Alpine overthrust, gneisses above the overthrust plane have been strongly breccified and mylonitized on about 50—150 m thickness.

The Danubian. Formations of Lower Danubian Unit have been distributed to Drăgșan, Rîușorul and Nucșoara Valley crystallophylian series, to Retezat granitoids (granodiorites) and to Oslea Paleozoic anchimetamorphic formation and those of Upper Danubian Unit wholey to Zeicani crystallophylian series with two complexes.

Regarding the deposits and the metamorphism age, we appreciate that Drăgșan series and the lower complex of Zeicani series, maybe Rîușorul series too, are synchronous and older (Cadomian), in an upper position following Nucșoara Valley formation and the upper complex of Zeicani series (Upper Cadomian, eventually Old Caledonian), then the succession ends with Paleozoic deposits of Oslea formation attributed to Silurian (eventually Lower Devonian) -- Valea Beușii laminated conglomerates and to Upper Devonian-Lower Carboniferous interval — the above side which is constituted of metagritstones, limestones and phylites.

Retezat granitoids, represented by granodiorites in our zone pierce crystalline schists of Drăgșan series framing in the granitoid group in "disharmony" (Walton, 1955) magmatic intrusive (Reed, 1956), in circumscribed massifs (Raguin, 1956), magmatic (Mehnert, 1971), or in the group of plutons in the mesozone (Buddington, 1959) ; they are synkinematic in comparison with the main episode of cover rocks metamorphism. Accepting Cadomian age of Drăgșan series metamorphism, it means that granitoids also have the same age (argued by K/Ar isochrone too of at least 540 m.y. — in Berza, 1978).

Presence of amphibolites in various stages of retromorphism among formations of Drăgșan, Rîușorul and Zeicani series as well as garnet sometimes apparition seem to complicate in a certain way the establishment of the highest degree of metamorphism in these formations ; on the other side, but excepting hornblende, plagioclase and garnet, lack of some index minerals , as relics, for an advanced metamorphism limit our discussion possibilities. Referring to mentioned minerals, we can consider the following. Almandine garnet and hornblende, although they are characteristic especially to almandine-amphibolitic facies, can also occur in quartz-albitic-epidote-almandine subfacies of green schists facies (Turner, Verhoogen, 1960) ≈ epidote-amphibolitic facies (Eskola, 1939), almandine instead of ferric chlorite, in pelitic rocks and hornblende instead of nonaluminous actinolite in basic rocks (in Turner, Verhoogen, 1960). At the same time, in basic magmatic rocks metamorphic hornblende can occur for the first time

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even in chlorite zone (Gjelsvik, 1952; Harker, 1974,) because in originally magmatic rocks, aluminium necessary to hornblende formation is found in augite itself on whose account it forms; from PT conditions variations point of view, the process being regressive, while in sedimentary calc-silicatic rocks hornblende generally forms just after conditions entering into reaction of chlorite with calcite have been attained (the earlier in garnet zone). Regarding plagioclase, presently mostly changed into albite and epidote-clinozoisite, it can reach to oligoclase with 15—17% An composition in almandine zone (in Giuşcă, 1974). Taking in view that chemical data indicated the origin both of amphibolites and most of chlorite-albitic schists analysed in basic magmatic rocks, it results certainly enough that initial progressive metamorphism did not surpass conditions of quartz-albite-epidote-almandine subfacies of green schists facies ≈ almandine zone.

Progressive metamorphism under conditions of lower part of green schists facies, was followed by a static retromorphism at regional scale (maybe during Caledonian movements, prevailingly epirogenetic — Schuster, 1972) and by a new metamorphic recrystallization under average conditions of green schists facies ≃ quartz-albite-epidote-biotite subfacies, maybe during Hercynian orogenesis.

Granodiorites intrusion (in rocks that were only a little colder than granitoids) caused a weak metamorphism of thermal contact in Drăgşan series schists, forming an aureola of 250—300 m thickness, in which schistous hornfelses bearing biotite and epidote are widely developed.

Regarding the metamorphism of Oslea formation, it took place under conditions of upper part of green schists facies — quartz-albite-muscovite-chlorite subfacies ≃ chlorite zone, maybe in Sudete stage of Hercynian cycle. Accepting also the existence of a Caledonian metamorphism, it is not excluded that in the metamorphism of Valea Beuşii conglomerates, Ardenic stage (End of Silurian) of this cycle should have played a certain part.

The effect of Alpine movements is refound in the accentuated brecciification and mylonitization, especially of Zeicani series schists close to the overthrust plane on Oslea formation.

[REFERENCES

Barron B. J. (1976) Recognition of the original volcanic suite in altered mafic volcanic rocks at Sofala, New South Walles. *Amer. Journ. Sci.*, 276, p. 604—636.

Bercia I. (1975) Metamorfitele din partea centrală şi de nord a masivului Godeanu. *St. tehn. econ. Inst. Geol. Geofiz., seria I*, 12, p. 3—159, Bucureşti.

Berza T. (1975) ,,Seria clastică'' şi cîteva probleme de stratigrafie şi metamorfism ale formaţiunilor cristalofiliene din partea externă a Autohtonului danubian (Carpaţii Meridionali). *Acad. R.S.R., Stud. cerc. geol. gefiz., geogr., seria geologie*, 20, 2, Bucureşti.

— (1978 a) Consideraţii privind vîrsta formaţiunilor cristalofiliene şi a masivelor granitoide din intrastructura părţii externe a Autohtonului danubian (Carpaţii Meridionali). *Acad. R.S.R., Stud. cerc. geol., geogr., seria geologie*, 23, 2, Bucureşti.

Institutul Geologic al României

— (1978 b) Studiul mineralogic şi petrografic al masivului granitoid de Tismana. *An. Inst. Geol. Geofiz.*, LIII, Bucureşti.

— Kräutner H., Dimitrescu R. (1983) Nappe Structure in the Danubian Window of the Central South Carpathians. *An. Inst. Geol. Geofiz.*, LX, Bucureşti.

— Seghedi A. (1983) The Crystalline Basement of the Danubian Units in the Central South Carpathians: Constitution and Metamorphic History. *An. Inst. Geol. Geofiz.*, LXII, Bucureşti.

Buddington P. A. (1959) Granite emplacement with special reference to North America. *Bull. Geol. Soc. Am.*, 70, 6, p. 671—747.

Didier J. (1973) Granites and their enclaves. Elsevier, Amsterdam.

Dimitrescu R. (1966 a) Muntele Mare. Studiul geologic şi petrografic. *An. Com. Stat Geol.*, XXXV, p. 165—258, Bucureşti.

— (1986) Le Danubien des Monts de Petreanu et de Retezat dans la région de Rîu Mare. *D.S. Inst. Geol. Geofiz.*, 70—71/1, Bucureşti.

Durrel C. (1940) Metamorphism in the Southern Sierra Nevada Northeast of Visalia, California, *Univ. California, Bul. Dept. Geol. Sci.*, 25, p. 1—118.

Engel A.E.J., Engel C.G. (1951) Origin and evolution of hornblende-andesine amphibolites and kindred facies. *Bull. Geol. Soc. Amer.*, 62, 12, p. 1435—1436.

Eskola P. (1914) On the petrology of the Orijärvi Region in South-western Finland. *Bull. Comm. Geol. Finl.*

Gherasi N. (1937) Étude géologique et pétrographique dans les Monts Godeanu et Ţarcu. *An. Inst. Geol. Rom.*, XVIII, Bucureşti.

— Manilici V., Dimitrescu R. (1967) Studiul petrografic şi geologic al masivului Ezer-Păpuşa. *An. Com. Stat Geol.*, XXXV, p. 48—104, Bucureşti.

— Dimitrescu R. (1968) Contribuţiuni petrotectonice la structura cristalinului danubian din partea nordică a munţilor Retezat şi Petreanu. *Anal. şt. Univ. Al. I. Cuza — Iaşi*, Secţ. II, b, XIV.

— Dimitrescu R. (1970) Anticlinalul Rof şi rolul lui în structura părţii nordice a munţilor Retezat şi Petreanu. *Anal. şt. Univ. Al. I. Cuza — Iaşi*, Secţ. II, b, XVI. Iaşi.

— Zimmermann P., Zimmermann V. (1974) Report, the archives of the Enterprise of Geological and Geophysical Prospections, Bucharest.

Giuşcă D., Savu H., Bercia I., Kräutner H. (1969) Sequence of tectonomagmatic pre-alpine cycles on the territory of Romania. *Acta Geol. Acad Sci. Hung.*, 13, Budapest.

— (1974) Petrologia rocilor endogene. Ed. tehnică, Bucureşti.

Gurău A. (1982) Microtectonica. Ed. tehnică, Bucureşti.

Harker A. (1974) Metamorphism. Chapman and Hall, Londra.

Hîrtopanu I. (1978) Cristalinul getic: metamorfism polifazic sau polimetamorfism? *Acad. R.S.R. Stud. cerc. geol. geofiz., geogr., seria geologie*, 32, 2, p. 180—193, Bucureşti.

— (1984) Report, the archives of the Institute of Geology and Geophysics, Bucharest.

Holdus S. (1971) Para-amphibolites from Gurskøy and Sandsøy, Su nnmøre, West Norway. *Norsk. Geol. Tidsskr.*, 51, p. 231—246.

Hurst V. J., Jones L. M. (1973) Origin of amphibolites in the Carsterville — Ville Rica Area, Georgia. *Geol. Soc. Amer. Bull.*, 84, p. 905—912.

Leake B.E. (1964) The chemical distinction between ortho-and paraamphibolites. *Journ. Petrol.*, 5, 2, p. 234—254.

Kräutner H. (1980) Litostratigraphic correlation of Precambrian in the Romanian Carpathians. *An. Inst. Geol. Geofiz.*, LVII, p. 229—296, Bucureşti.

— Năstăseanu S., Berza T., Stănoiu I., Iancu V. (1981) Metamorphosed Paleozoic in the South Carpathians and Its Relations with the Pre-Paleozoic Basement. *Ghidul excursiei A_1, Asoc. Geol. Carp.-Balk. Congr. XII, 1981*, Bucureşti.

Institutul Geologic al României

Macaleț V. (1978) Report, the archives of the Enterprise of Geological and Geophysical Prospectipons, Bucharest.

— (1980) Report, the archives of the Enterprise of Geological and Geophysical Prospections, Bucharest.

— (1983) Considerations regarding the geological structure of the Northern Part of the Retezat Mountains (South Carpathians). *Carp. Balk. Asoc. Geol. Congr., XII, 1981. An. Inst. Geol. Geofiz.*, LXI, București.

— (1987) Cristalinul getic dintre Nucșoara și Hobița (munții Retezat). *D. S. Inst. Geol. Geofiz.*, 72–73/1, p. 253–267, București.

Maciu S., Ionescu M. (1978) Report, the archives of the Enterprise of Geological and Geophysical Prospections, Bucharest.

Maier O., Solomon I., Zimmermann P., Zimmermann V. (1975) Studiul geologic și petrografic al cristalinului din partea sudică a munților Poiana Ruscă. *An. Inst. Geol. Geofiz.*, XLIII, București.

Manolescu Gh. (1937) Étude géologique et pétrographique dans les monts Vulcan (Carpates Méridionales, Roumanie). *An. Inst. Geol.*, XVIII, București.

Mehnert R. K. (1971) Migmatites and the Origin of Granitic Rocks. Elsevier, Amsterdam.

Micu C. (1966) Report, the archives of the Enterprise of Geological and Geophysical Prospections, Bucharest.

— Paraschivescu C. (1970) Contribuții la cunoașterea geologiei părții de nord a munților Retezat, între Riul Alb și rîul Nucșoara, cu privire specială asupra ivirilor de talc. *D. S. Inst. Geol.*, LVI, București.

Misra S.N. (1971) Chemical distriction of high-grade ortho-and parametabazites. *Norsk. Geol. Tidsskr.*, LI, p. 311–316, Oslo.

Miyashiro A. (1961) Evolution of Metamorphic Belts. *Journ. Petrol.*, 2, 3, p. 277–311.

Moine B. (1969) Orthoamphibolites et formations métasédimentaires calco-magnésiennes de la région d'Ambatofinandrahana (Madagascar). *Sci. de la Terre*, XIV, 2, p. 109–138.

Năstăseanu S. (1973) Notă preliminară privind paleozoicul anchimetamorfic (formațiunea de Oslea) din Carpații Meridionali. *D. S. Inst. Geol.*, LIX/4, București.

— (1976) Conglomeratele de Retezat, un reper stratigrafic în coloana formațiunilor paleozoice din estul Carpaților Meridionali. *D. S. Inst. Geol. Geofiz.*, LXII/5, București.

Nelson A.E. (1969) Origin of some amphibolites in Western North Carolina. *U.S. Geol. Survey Prof. Paper*, 650–B, p. B_1 – B_7.

Pavelescu L. (1953 a) Studiul geologic și petrografic al regiunii centrale și de sud-est a munților Retezatului. *An. Com. Geol.*, XXV, București.

— (1953 b) Cercetări geologice în munții Retezat. *D. S. Com. Geol.*, XXXVII, București.

— (1963) Contributions à l'étude du soubassement cristallin et l'aire de distribution des différentes formations cristallophilliennes dans la partie centrale et orientale de l'Autochtone Danubien. *Asoc. Geol. Carp.–Balk., Congr. V*, 1961, București.

— Răileanu Gr. (1963) Considérations générales sur l'âge des schistes cristallins de l'Autochtone des Carpates Méridionales. *Asoc. Geol. Carp. – Balk., Congr. V, 1961*, București.

— (1967) Contribution to the Study of Isortoses in the Southern Carpathians. *Rev. Roum. Géol. Géophys., Géogr., Géologie*, București.

— Pavelescu M. (1970) Cercetări geologice și petrografice în zona mediană a Carpaților Meridionali. *An. Inst. Geol. Geofiz.*, XXXVIII, București.

Phillips W.R., Griffen D.T. (1981) Optical Mineralogy — The Nonopaque Minerals. Freeman and Comp., San Francisco.

Pitcher E. W., Read H. H. (1960) Aureole of the Main Donegal Granite. *Quart., Journ. Geol. Soc. London*, 116, p. 1–37.

Institutul Geologic al României

Pop Al. (1973) Report, the archives of the Enterprise of Geological and Geophysical Prospections, Bucharest.

Raguin E. (1957) Géologie du granite. Masson, Paris.

Read H. H. (1956) The Granite Controversy. Murby, London.

Reverdato V. V., Sharapov N. V. (1970) The Controls and Selected Peculiarities of the Origin of Contact Metamorphic Zonation. *Contr. Mineral. and Petrol.*, 29, p. 310—337.

Rittmann A. (1967) Vulcanii și activitatea lor. Traducere din limba germană. Ed. tehnică, București.

Roche (La) H. (1972) Revue sommaire de quelques diagrammes chimico-minéralogiques, l'étude des associations ignees ou sédimentaires et de leurs dérivés métamorphiques. *Sci. de la Terre*, XVII, 1—2, p. 33—46.

Satynarayana K. (1974) Geochemistry of Archaean amphibolites from Karnataka State, Peninsular India. *Chem. Geol.*, 14, p. 305—315, Amsterdam.

Savu H. (1970) Structura plutonului granitoid de Sușița și relațiile sale cu formațiunile Autohtonului danubian (Carpații Maridionali). *D.S. Inst. Geol.*, LVI/5, București.

— (1978) Pre-Hercynian Granitoides in the Southern Carpathians. *Acad. R.S.R., Rev. Roum. Géol. Géophys. Géogr., série Géologie*, 22, București.

Schuster C. A. (1972) Considerații asupra evoluției Domeniului danubian (Carpații Meridionali). *D.S. Inst. Geol.*, LVIII, București.

Solomon I., Pop Al. (1973) Asupra prezenței unor minerale relicte în formațiunile epiclastice ale seriei de Tulișa din partea de nord-est a munților Retezat. *D. S. Inst. Geol.*, LIX, București.

— Visarion A., Iordan M. (1976) Considerații asupra formațiunilor cristalofiliene și anchimetamorfice din munții Vîlcan și munții Retezat (Carpații Meridionali). *D. S. Inst. Geol. Geofiz.*, LXII, București.

Stănoiu I. (1973) Zona Mehedinți — Retezat: o unitate paleogeografică și tectonică distinctă a Carpaților Meridionali. *D. S. Inst. Geol.*, LIX/5, București.

— (1976) Contribuții la stratigrafia formațiunilor paleozoice din versantul nordic al munților (Carpații Meridionali) cu implicații asupra părții externe a Autohtonului danubian. *D.S. Inst. Geol. Geofiz.*, LXII, București.

— Vîlcean (1982) Prezența fosilelor mezozoice și meta-antracitului în cadrul șisturilor cristaline ale „grupului Tulișa" din versantul nordic al munților Vîlcan și Parîng. *D. S. Inst. Geol. Geofiz.*, LXVII/3, București.

Stilla A. (1985) Géologie de la région de Hațeg-Cioclovina-Pui-Bănița (Carpathes Méridionales). *An. Inst. Geol. Geofiz.*, 66, p. 91—179, București.

Streckeisen A. (1976) To each plutonic rock its proper name. *Earth Sci. Rev.*, 12, p. 1—33, Amsterdam.

— Maître (le) W. R. (1979) A Chemical Approximation to the Modal QAPF Classification of the Igneous Rocks. *N. Jb. Miner. Abh.*, 136, 2, p. 169—206, Stuttgart.

Șeclăman M. (1972) Studiul rocilor cuarțo-feldspatice din bazinul superior al Streiului. Teză de doctorat, Universitatea București.

Turner J. F., Verhoogen J. (1960) Igneous and Metamorphic Petrology. Mc. Graw — Hill Book Comp., New York.

— (1968) Metamorphic Petrology (Mineralogical and Field Aspects). Mc. Graw — Hill Book Comp., New York.

Walton M. (1955) The emplecement of granite. *Amer. Jour. Sci.*, 253, p. 1—18.

Winchell A.N. (1933) Elements of Optical Mineralogy. Chapman and Hall, London.

Winkler J. G. H. (1976) Petrogenesis of metamorphic rocks. Springer-Verlag, New York.

Institutul Geologic al României

Wright B. J. (1969) A simple alkalinity ratio and its application to questions of non-orogenic granite genesis. *Geol. Mag.*, 106, 4, p. 370–384.

Zwart H. J. (1962) On the determination of polymetamorphic mineral associations and its application to the Bosost Area (Central Pyrenees). *Geol. Rundschau*, 52, 1, p. 38–65.

STUDIUL GEOLOGIC ȘI PETROGRAFIC AL PĂRȚII DE NORD A MUNȚILOR RETEZAT

(Rezumat)

Cercetările noastre acoperă zona cristalinului din versantul nordic al munților Retezat (Carpații Meridionali), zonă cuprinsă între bazinul văii Nucșoarei, la vest, și bazinul Rîului Bărbat, la est; spre nord și sud limitele sînt de natură geologică, reprezentate prin contactul cu bazinul sedimentar al Hațegului și, respectiv, cu masivul granitoid de Retezat.

I. GEOLOGIA REGIUNII

Formațiunile geologice care intră în constituția părții de nord a munților Retezat dintre Nucșoara și Rîul Bărbat sînt repartizate atît Pînzei getice cît și Danubianului; de asemenea, în cadrul Danubianului am conturat două unități tectonice importante — Unitatea danubiană inferioară și Unitatea (pînza) danubiană superioară.

1. **Pînza getică** este constituită în cea mai mare parte din formațiuni cristalofiliene mezocatametamorfice, aparținînd în întregime seriei (grupului) de Sebeș-Lotru, repartizată ciclului Dalslandian (Schuster, 1972; Gherasi et al., 1974), sau Carpianului inferior și mediu — Cp_1—Cp_4 (Kräutner, 1980) și, subordonat, din formațiuni sedimentare mezozoice.

Formațiunile cristalofiliene sînt constituite aproape în întregime dintr-o alternanță de diferite tipuri de gnaise și, subordonat, micașisturi, în care se găsesc rare intercalații de roci amfibolice; cu totul izolat pot fi întîlnite filonașe sau lentile mici, decimetrice, de pegmatite cuarțo-feldspatice cu muscovit. Din punct de vedere structural se diferențiază clar două tipuri de metamorfite — unul cu structură mai grosieră, în care pot fi separate gnaise cu microclin, paragnaise biotito-muscovitice, micașisturi și cuarțite feldspatice și unul cu structură fin granulară, constituit predominant din paragnaise biotititce cu granat. Cu primul grup se asociază, de obicei, amfibolite tipice, iar cu cel de-al doilea, gnaise amfibolice (actinolitice). Mai ales în apropierea planului de încălecare peste formațiunile Danubianului metamorfitele cristalinului getic au fost parțial retromorfozate, concomitent cu o brecifiere și milonitizare accentuate.

Deși grosimea stratigrafică redusă pe care este deschisă seria de Sebeș-Lotru nu permite separarea unor unități litostratigrafice distincte, totuși dezvoltarea mare a paragnaiselor biotitice cu granat, microgranulare, între Rîul Bărbat și valea Paroșului și a gnaiselor cu microclin între Mălăiești și

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Nucşoara sînt argumente pentru paralelizarea cristalinului getic din cele două zone cu partea superioară a complexului inferior (G_1) şi, respectiv, cu complexul median (G_2) separate de Bercia (1975) în masivul Godeanu. În acest mod, ar mai putea fi încadrate în formaţiunea gnaisică inferioară, respectiv formaţiunea leptino-amfibolitică (Kräutner, 1980).

Metamorfismul seriei de Sebeş-Lotru din zona cercetată corespunde tipului de metamorfism barrowian (de presiune medie), avînd loc în condiţiile faciesului amfibolitic, subfaciesurile disten-almandin-muscovit, sillimanit-almandin-muscovit şi, pe alocuri, sillimanit-almandin-ortoclaz.

Ca şi în cazul altor zone din Carpaţii Meridionali, în cristalinul getic dintre Nucşoara şi Rîul Bărbat a fost evidenţiat caracterul polifazic al metamorfismului, cel mai bine fiind ilustrat acest fapt în paragnaisele biotitice cu granat şi în gnaisele actinolitice. Astfel, mineralele corespunzătoare fazei mai vechi, în echilibru paragenetic, sînt cuarţul, plagioclazul, biotitul, almandinul (şi amfibolul în gnaisele actinolitice), iar acelea corespunzătoare fazei mai noi sînt muscovitul (şi biotitul în gnaisele actinolitice), sillimanitul (fibrolit), granatul, plagioclazul şi cuarţul. În celelalte tipuri de roci pot fi considerate minerale de neoformaţie ortoclazul (în paragnaisele biotito-muscovitice) şi microclinul (în gnaisele cu microclin), ambele fiind strîns legate de formarea sillimanitului. Ţinînd cont de aspectele morfostructurale şi de dispoziţia în spaţiu a mineralelor de neoformaţie, apreciem că acestea au luat naştere în condiţii aproximativ egale de adîncime şi temperatură cu mineralele mai vechi, dar ulterior episodului principal de deformare, metamorfismul continuînd mai ales doar sub efectul presiunii litostatice (= metamorfism static). Dacă lucrurile stau aşa, înseamnă că, cel puţin în zona noastră, singurele minerale într-adevăr nou formate în această ultimă fază a aceluiaşi ciclu tectonomagmatic au fost sillimanitul, ortoclazul şi microclinul, celelalte minerale suferind doar o remobilizare şi reorganizare a reţelei.

2. **Danubianul** din partea nordică a munţilor Retezat este constituit din formaţiuni cristalofiliene, roci granitoide şi formaţiuni sedimentare slab metamorfozate, repartizate la două unităţi.

2.1. *Unitatea danubiană inferioară*

Formaţiunile geologice care alcătuiesc această unitate pot fi repartizate seriei de Drăgşan, în care a avut loc intruziunea granitoidelor de Retezat, seriei de Rîuşorul, formaţiunii din valea Nucşoarei şi formaţiunii de Oslea.

2.1.1. *Seria de Rîuşorul* constituie în întregime creasta din stînga văii Nucşoarei dintre vîrful Ascuţitul şi şaua de la sud de Capul Dealului şi se continuă înspre est în bazinul văii Nucşoarei, unde, în partea de nord, este deschisă doar în versantul stîng, afundîndu-se sub rocile formaţiunii de valea Nucşoarei, iar în partea de sud ajunge pînă în bazinul văii Mălăieşti. Petrografic, este reprezentată mai ales prin şisturi cuarţo-biotitice şi şisturi cuarţitice sericito-cloritoase.

2.1.2. *Formaţiunea de valea Nucşoarei* (Macaleţ, 1983) se dezvoltă în bazinul Nucşoarei, stînd peste seria de Rîuşorul şi suportînd în poziţie tectonică formaţiunile Unităţii danubiene superioare. Se deosebeşte de şisturile

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seriei de Rîuşorul prin gradul mai scăzut de metamorfism, prin marea participare a şisturilor grafitoase, ca şi prin prezenţa calcarelor cristaline; de rocile formaţiunii de Oslea se deosebeşte prin gradul mai avansat de metamorfism şi prin constituţia mineralogică şi petrografică.

2.1.3. *Seria de Drăgşan.* Am păstrat această denumire (sensu Pavelescu, 1953) numai pentru cristalinul cu care vin în contact rocile granitoide de Retezat şi suportă rocile formaţiunii de Oslea sau ale seriei de Rîuşorul. Pot fi descrise diferite varietăţi de şisturi cuarţo-sericito-cloritoase şi, subordonat, şisturi cuarţo-amfibolitice.

Peste tot acolo unde contactul rocilor granitoide cu şisturile seriei de Drăgşan nu este mascat de depozitele formaţiunii de Oslea, în imediata vecinătate a contactului, biotitizarea şi, uneori, feldspatizarea sînt foarte accentuate. Pe măsura depărtării de contact, cantitatea de biotit scade pentru ca după 200—300 m să se treacă la rocile normale ale seriei, aşa încît se poate admite că rocile din învelişul granitoidelor au suferit un metamorfism de contact termic, care s-a suprapus peste metamorfismul regional al seriei de Drăgşan, transformîndu-se în corneene şistoase cu biotit.

2.1.4. *Granitoidele de Retezat* din zona studiată sînt bine reprezentate prin granodiorite (probabil şi tonalite-trondjemite) cu muscovit ± biotit, încadrîndu-se în grupa granitoidelor în „dizarmonie" (Walton, 1955), magmatice intrusive (Read, 1956), în masive circumscrise (Raguin, 1956), magmatice (Mehnert, 1971), sau în grupa plutonilor din mezozonă (Buddington, 1959); faţă de episodul principal al metamorfismului rocilor din înveliş, sînt sincinematice.

2.1.5. *Formaţiunea de Oslea* se dezvoltă continuu începînd din versantul drept al Nucşoarei pînă în valea Rîului Bărbat, cu o întrerupere în versantul stîng al acesteia, grosimea maximă nedepăşind 90—100 m. Cu puţine excepţii, succesiunea începe cu metagresii ± microconglomerate şi se continuă cu filite cuarţo-sericitoase±grafitoase, calcare şi gresii calcaroase şi, din nou, filite. O situaţie deosebită se întîlneşte între Pîrîul Preotesei (ram drept al Apei Lazului) şi valea Şerelului unde succesiunea descrisă, care aici este formată numai din calcare şi nivelul filitos superior, repauzează pe metaconglomerate laminate — metaconglomerate de Valea Beuşii (Macaleţ, 1983).

2.2. *Unitatea danubiană superioară*

Este constituită în întregime din seria (= grupul) de Zeicani, în care am separat un complex (membru) inferior, predominant vulcanogen şi un complex (membru) superior, predominant detritogen.

2.2.1. *Complexul (membrul) inferior* cuprinde cea mai mare parte a seriei de Zeicani din această zonă, petrografic putînd fi separate şisturi clorit-albitice cu epidot şi calcit, şisturi cuarţo-feldspatice sericito-cloritoase, şisturi cuarţitice cu sericit şi clorit, şisturi clorit-albit-actinolitice, şisturi epidot-actinolitice şi ultrabazite (hornblendite); între valea Paroşului şi Mălăieşti sînt bine reprezentate şi metaconglomeratele.

2.2.2. *Complexul (membrul) superior* formează o bandă îngustă la partea superioară a seriei de Zeicani, peste şisturile acestuia încălecînd pre-

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tutindeni formaţiunile Pînzei getice. Succesiunea stratigrafică începe cu un nivel de calcare (şisturi calcaroase) şi se continuă cu şisturi feldspatice cloritoase±muscovit, şisturi cuarţitice cu albit şi muscovit, şisturi clorit-calcit-albitice (amfibolite retromorfozate).

Privind vîrsta depozitelor şi a metamorfismului, apreciem că seria de Drăgşan şi complexul inferior al seriei de Zeicani, poate şi seria de Rîuşorul, sînt sincrone şi mai vechi (cadomiene), în poziţie superioară urmînd formaţiunea de valea Nucşoarei şi complexul superior al seriei de Zeicani (cadomian-superioare, eventual caledoniene vechi), pentru ca succesiunea să se încheie cu depozitele anchimetamorfice ale formaţiunii de Oslea, repartizate Silurianului (eventual Devonianului inferior) — conglomeratele laminate de Valea Beuşii şi intervalului Devonian superior - Carbonifer inferior — partea de deasupra formată din metagresii, calcare şi filite.

Acceptînd vîrsta cadomiană a metamorfismului seriei de Drăgşan, înseamnă că şi granodioritelor de Retezat trebuie să li se atribuie aceeaşi vîrstă, deşi prezenţa unor corpuri de granodiorite la vest de zona noastră, în şisturile formaţiunii de Rîul Mare, considerată siluriană, ar putea fi un argument pentru vîrsta caledoniană a intruziunii (faza ardenică).

Prezenţa amfibolitelor în diferite stadii de retromorfozare printre formaţiunile seriilor de Drăgşan, Rîuşorul şi Zeicani, ca şi apariţia uneori a granatului par a complica într-o oarecare măsură stabilirea gradului cel mai ridicat al metamorfismului atins de aceste formaţiuni ; pe de altă parte, însă, lipsa, în afară de hornblendă, plagioclaz şi granat, a unor minerale indicatoare, sub formă de relicte, pentru un metamorfism avansat limitează posibilităţile de discuţie. Se poate afirma, cu un grad destul de mare de certitudine, că metamorfismul progresiv iniţial nu a depăşit condiţiile subfaciesului cuarţ-albit-epidot-almandin al faciesului şisturilor verzi ≈ zona almandinului. Metamorfismul progresiv, în condiţiile părţii inferioare a faciesului şisturilor verzi, a fost urmat de un retromorfism static la scară regională (probabil în timpul mişcărilor caledoniene, predominant epirogenetice) şi de o nouă recristalizare metamorfică în condiţiile medii ale faciesului şisturilor verzi — subfaciesul cuarţ-albit-epidot-biotit, probabil în timpul orogenezei hercinice.

Intruziunea granodioritelor (în roci doar cu puţin mai reci decît ele) a produs un slab metamorfism de contact termic în şisturile seriei de Drăgşan, luînd naştere o aureolă, cu grosimea de pînă la 250—300 m, în care o mare dezvoltare o au corneenele şistoase cu biotit şi epidot.

Metamorfismul formaţiunii de Oslea a avut loc în condiţiile părţii superioare a faciesului şisturilor verzi — subfaciesul cuarţ-albit-muscovit-clorit ≈ zona cloritului, probabil în faza sudetă a ciclului hercinic. Acceptînd existenţa şi a unui metamorfism claledonian, nu este exclus ca în metamorfozarea conglomeratelor de Valea Beuşii să fi avut un oarecare rol şi faza ardenică (de la sfîrşitul Silurianului) a acestui ciclu. Efectul mişcărilor alpine se regăseşte în brecifierea şi milonitizarea accentuată mai ales a şisturilor seriei de Zeicani din apropierea planului de încălecare peste formaţiunea de Oslea.

3. **Bazinul Haţeg**. Formaţiunile sedimentare ale bazinului Haţegului din imediata apropiere a contactului cu cristalinul munţilor Retezat sînt

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reprezentate prin Paleogen, în bazinul Nucșoarei și Sarmațian sau Pleistocen, între Rîul Alb și Rîul Bărbat.

II. CONSIDERAȚII CHIMICE ȘI PETROGENETICE

Granitoidele. În vederea discutării chimismului rocilor granitoide am folosit rezultatele analizelor chimice complete de silicați efectuate pe 15 probe, prelevate mai ales din apropierea contactului cu șisturile din acoperiș; numai pe valea Rîului Bărbat probarea a fost făcută pe toată grosimea deschisă a corpului magmatic.

Este evidențiată o uniformitate remarcabilă a chimismului acestor roci, neputîndu-se găsi vreo corelație semnificativă între elementele majore. Plecînd de la compoziția chimică, am calculat parametrii Niggli, compoziția normală — norma Rittmann, pe baza căreia, cu excepția unei probe care ar fi un monzogranit, toate celelalte probe se încadrează în familia granodioritelor și tonalitelor (trondhjemite) și norma C.I.P.W. după care (calculînd valorile *QAP*) toate probele se proiectează în cîmpul granodioritelor; un rezultat asemănător se obține prin proiectarea probelor pe diagrama *Q'—ANOR*.

Atît diagrama *QML*, cît și diagrama SiO_2 — indice de alcalinitate indică, fără nici o excepție, caracterul calcoalcalin al granitoidelor analizate; de asemenea, pe diagrama SiO_2 : total alcalii toate probele se proiectează în subprovinciile pacifice, puternică și medie. Pe diagrama *al* : *alk* probele se proiectează în cîmpurile sărac în alcalii și alcalin intermediar, iar pe diagrama *al* : *fm*, doar cu două excepții, în cîmpul salic, evidențiindu-se o corelație negativă între *al* și *alk* pe de o parte și *fm*, pe de altă parte.

Șisturile cristaline. Cu o singură excepție (gnaisele biotitice cu granat) am efectuat analize de silicați numai pe probe prelevate din roci pentru care geneza premetamorfică — sedimentară sau magmatică — este discutabilă, lăsînd la o parte pe acelea clar sedimentogene. Pentru cristalinul danubian am folosit 13 analize din seria de Zeicani — 8 șisturi clorit-albitice, 4 amfibolite și o analiză de hornblendit, iar pentru cristalinul getic 10 analize — 4 gnaise cu microclin, 2 gnaise biotitice și 4 amfibolite.

Utilizînd o serie de diagrame, se poate trage concluzia că atît șisturile clorit-albitice cît și amfibolitele analizate provin din roci magmatice bazice, parțial și intermediare, gnaisele biotitice cu granat din grauwacke, iar gnaisele cu microclin s-au format pe seama unor gresii arcoziene sau, local, a unor tufuri riolitice. Pe baza acestei concluzii, în lucrare este prezentată compoziția mineralogică normativă (norma Rittmann), cu denumirile corespunzătoare, pentru probele analizate.

III. CONSIDERAȚII TECTONICE

Elementele majore care controlează structura părții nord-estice a munților Retezat sînt șariajul Pînzei getice, încălecarea Unității danubiene superioare peste Unitatea danubiană inferioară și bazinul tectonic al Hațegului. În ansamblul său, cristalinul dintre valea Rîului Bărbat și valea Nucșoarei poate fi privit ca o structură monoclinală, aproximativ plată, cu înclinări

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nordice; doar în partea de vest a perimetrului unde formaţiunile cristalofiliene au o lăţime mai mare, se dezvoltă o serie de cute anticlinale şi sinclinale mici, în special în şisturile formaţiunii de valea Nucşoarei, şi, mai puţin caracteristic, în acelea ale seriei de Rîuşorul, ca efect al structurii anticlinale Rof.

Raporturile tectonice anormale dintre formaţiunile domeniului getic şi ale domeniului danubian sînt bine evidenţiate atît cartografic, cît şi de cataclazarea puternică mai ales a rocilor de deasupra, pe o grosime care poate depăşi 100. Pe toată lungimea liniei de şariaj, cristalinul getic stă peste formaţiunile complexului superior al seriei de Zeicani, înclinarea medie a planului de şariaj fiind de 30—40°.

O a doua linie de încălecare importantă se evidenţiază foarte clar în cadrul Danubianului, punînd în poziţie tectonică formaţiunile seriei de Zeicani, de la vest către est, peste seria de Rîuşorul, formaţiunea de valea Nucşoarei, formaţiunea de Oslea sau direct peste seria de Drăgşan. Cel mai tipic este contactul cu rocile formaţiunii de Oslea, care se poate urmări ca un abrupt aproape continuu, ce ajunge uneori la mai multe zeci de metri, din bazinul Rîului Bărbat pînă în versantul drept al Nucşoarei, datorită în principal competenţei diferite a rocilor care vin în contact — de obicei şisturi cuarţitice sau şisturi clorit-albitice deasupra şi filite dedesubt. Înclinarea planului de încălecare este mai mare decît în cazul Pînzei getice, ajungînd uneori la 60—70°. Apreciem că această dislocaţie s-a produs în timpul mişcărilor alpine, probabil concomitent cu desăvîrşirea şariajului getic, deşi faptul că sub planul de încălecare sînt prinse depozitele slab metamorfozate ale formaţiunii de Oslea, paleozoice, nu aduce o dovadă asupra unei vîrste mai recente decît cea hercinică.

De asemenea, dislocaţii longitudinale de amploare mai redusă se evidenţiază atît în cadrul Unităţii danubiene superioare — falia de la vest de valea Paroşului, cît şi în cadrul Unităţii danubiene inferioare din bazinul văilor Nucşoara şi Mălăieşti.

Contactul depozitelor sedimentare ale bazinului Haţegului cu şisturile cristaline se face după falii majore longitudinale, fragmentate şi decroşate de numeroase falii transversale.

Pe baza anlizării sistemelor de fisuri, raportate la şistozitate şi a elipsoidului de deformaţie construit au putut fi conturate o serie de sectoare omogene din punct de vedere structural, delimitate de falii transversale.

Dacă în rocile granitoide, seria de Drăgşan, seria de Zeicani (complexul inferior), seria de Rîuşorul şi chiar formaţiunea de valea Nucşoarei direcţiile structurale sînt asemănătoare, uneori pînă la identitate, formaţiunea de Oslea şi complexul superior al seriei de Zeicani prezintă o situaţie diferită, care poate fi explicată prin faptul că structura lor actuală (inclusiv foliaţia şi sistemele de fisuri) este efectul mişcărilor de înaintare a Unităţii danubiene superioare peste Unitatea danubiană inferioară, respectiv a Pînzei getice peste Danubian. Acceptînd această ipoteză, a putut fi reconstituită direcţia generală a transportului principal; dinspre nord-nord-est către sud-sud-vest în cazul Unităţii danubiene superioare şi dinspre nord-nord-vest către sud-sud-est în cazul Pînzei getice; local pot apărea şi unele excepţii, datorate însă tectonicii disjunctive transversale.

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Admițînd că cele două plane principale de încălecare sînt efectul mișcărilor tectonice alpine, înseamnă că în timpul acestora atît fundamentul Unității danubiene inferioare (seriile de Drăgșan și Rîușorul și rocile granitoide), cît și al Unității danubiene superioare (complexul inferior al seriei de Zeicani) s-au comportat ca niște blocuri rigide, fără a căpăta o nouă foliație și fisurație importante. Totuși, cel puțin la est de valea Rîului Alb, în rocile Unității danubiene superioare apare un sistem nou de fisuri, de forfecare, paralel cu direcția de înaintare a acestora, în poziție diagonală (*hkl*) față de direcția structurii ; situația asemănătoare întîlnită și în seria de Rîușorul ne-a determinat să considerăm că aceasta încalecă peste seria de Drăgșan. Așa stînd lucrurile, singurele efecte importante ale tectonicii alpine sînt compartimentările după falii transversale (*AC*) și în mai mică măsură longitudinale (*HOL*) la vest de valea Paroșului sau diagonale (*HKL*) în estul zonei.

Toate interpretările tectonice, ca de altfel și discuțiile privind mineralogia, petrografia și metamorfismul seriei de Drăgșan și complexului inferior al seriei de Zeicani, arată că acestea sînt sincrone, atît în ceea ce privește vîrsta depozitelor care le alcătuiesc, cît și a metamorfismului, reprezentînd probabil una și aceeași unitate litostratigrafică, repartizată însă la două unități tectonice diferite ca urmare a unei dedublări la scară regională.

EXPLANATION OF PLATES

Plate IV

Fig. 1 — Plagioclase poikiloblast bearing quartz inclusions in biotite-muscovite paragneiss ; N+, × 120.

Fig. 2 — Muscovite partly changed into fibrolite, in micaschist ; N+, × 120.

Fig. 3 — Sillimanite in biotite-muscovitic paragneiss ; N+, × 120.

Fig. 4 — Biotite lamellae partly replaced by sillimanite (fibrolite), in biotitic paragneiss ; N+, × 300.

Plate V

Fig. 1 — Lamella of porphyroblastic muscovite transversally placed, in biotitic paragneiss ; N+, × 300.

Fig. 2. — Kyanite included in transversal porphyroblastic muscovite, in biotitic paragneiss ; N+, × 300.

Fig. 3 — Garnets of „atoll" structure, in biotitic paragneiss ; N+, × 300.

Fig. 4 — Sillimanite (fibrolite) at the margin and on the fissures of a kyanite grains, in biotitic paragneiss ; N+, × 300.

Plate VI

Fig. 1 — Garnet grains included in tremolite porphyroclasts, in eclogitic amphibolite ; N+, × 120.

Fig. 2 — Actinolitic gneiss bearing biotite ; N+, × 300.

Fig. 3 — Cataclasite ; N+, × 120.

Fig. 4 — Plagioclase of zonary structure pointed out by alteration, in brecciated biotite-muscovite paragneiss ; N+, × 300.

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Plate VII

Fig. 1 — Quartz-biotitic schist, Rîuşorul series ; N+, × 300.
Fig. 2 — Quartz-sericite-chloritous schist, Nucşoara Valley formation ; N+, × 120.
Fig. 3 — Quartz-sericite-graphitous schist, Nucşoara Valley formation ; N+, × 120.
Fig. 4 — Crystaline limestones, Nucşoara Valley formation ; N+, × 120.

Plate VIII

Fig. 1 — Granodiorite ; N+, × 120.
Fig. 2 — Idiomorphic crystals of albitized plagioclase included in newer albite, in granodiorite ; N+, × 120.
Fig. 3 — Albitized plagioclase, which contains muscovite inclusions, gathered into a microcline mass, in granodiorite ; N+, ×300.
Fig. 4 — Microperthitic microline, in granodiorite ; N+, × 120.

Plate IX

Fig. 1 — Schistous hornfels bearing biotite and epidote ; N+, × 120.
Fig. 2 — Quartz metagritstone bearing sericite and graphite, in Oslea formation ; N+, × 120.
Fig. 3 — Feldspathic metagritstone ; N+, × 120.
Fig. 4 — Fragment of granitoid rock , in metaconglomerate ; N+, × 120.

Plate X

Fig. 1 — Crystalline limestone, Oslea formation ; N+, × 120.
Fig. 2 — Crystalline limestone having an accentuated cataclasis ; N+, × 120.
Fig. 3 — Chlorite-albitic schist, Zeicani series ; N+, × 300.
Fig. 4 — Hornblende remains, in retromorphosed amphibolite ; N+, × 300.

Plate XI

Fig. 1 — Albite-chlorite-actinolitic schist ; N+, × 300.
Fig. 2 — Quartz-feldspathic sericite-chlorite schist bearing epidote ; N+, × 120.
Fig. 3 — Quartz-albite-sericitic schist bearing microcline ; N+, × 120.
Fig. 4 — Element surrounded by sericite, which is constituted of albite bearing plagioclase inclusions ; N+, 120.

Plate XII

Fig. 1 — Crystalline limestone, Zeicani series ; N+, × 120.
Fig. 2 — Muscovite in quartzitic schist bearing albite and muscovite ; N+, × 120.
Fig. 3 — Amphibolite partly cataclased in which hornblende mostly resists ; N+, × 120.
Fig. 4 — Amphibolite cataclased and completely changed in which we recognize only the contour of exhornblende crystals ; N+, × 120.

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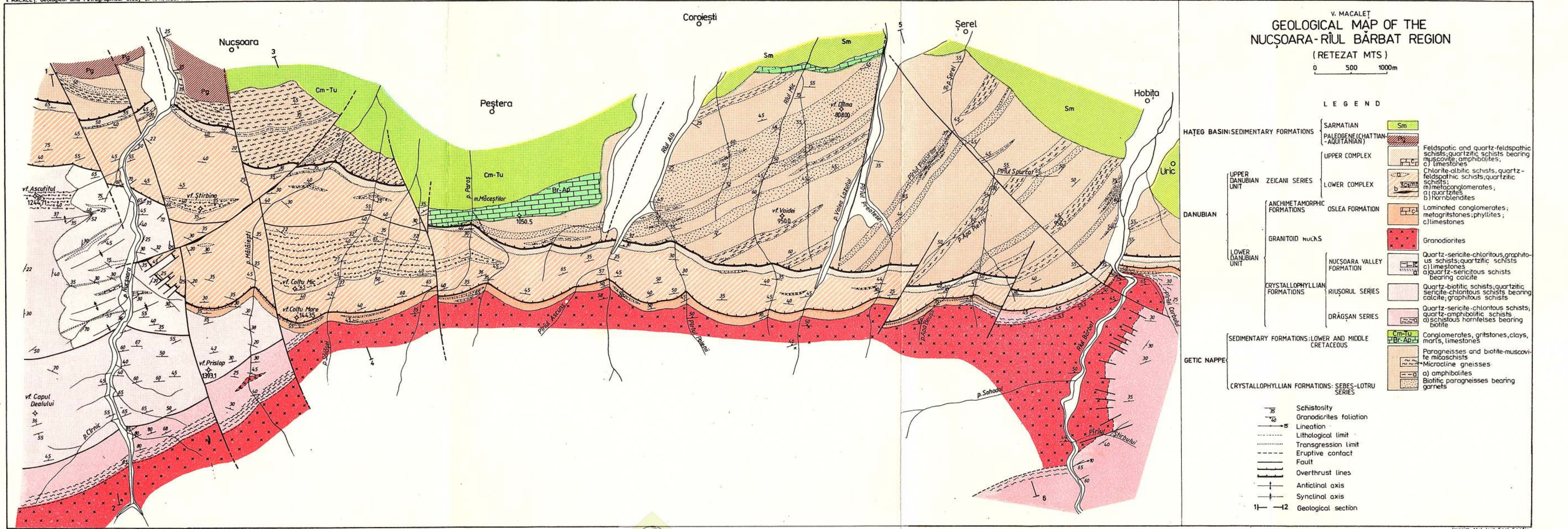

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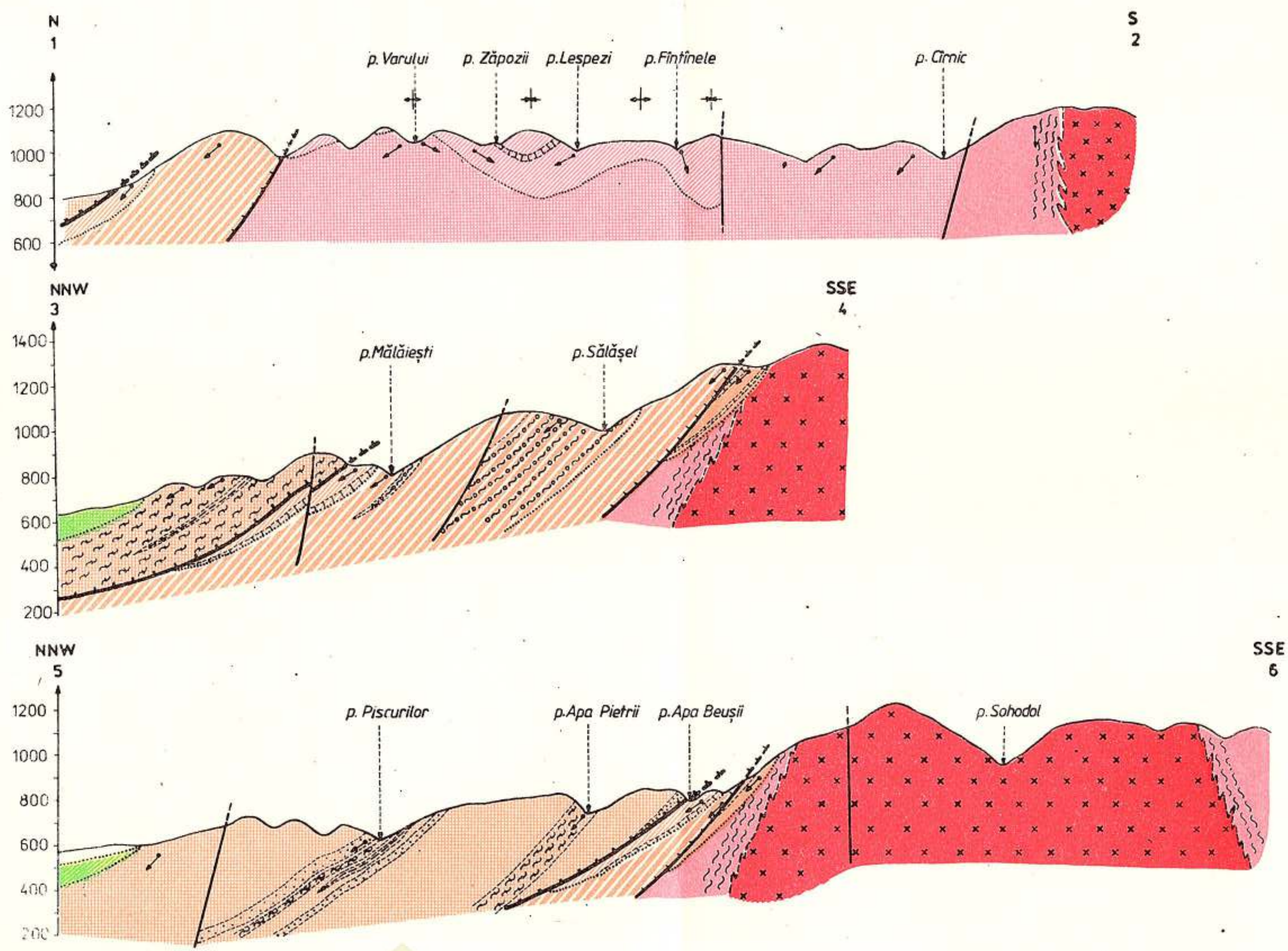

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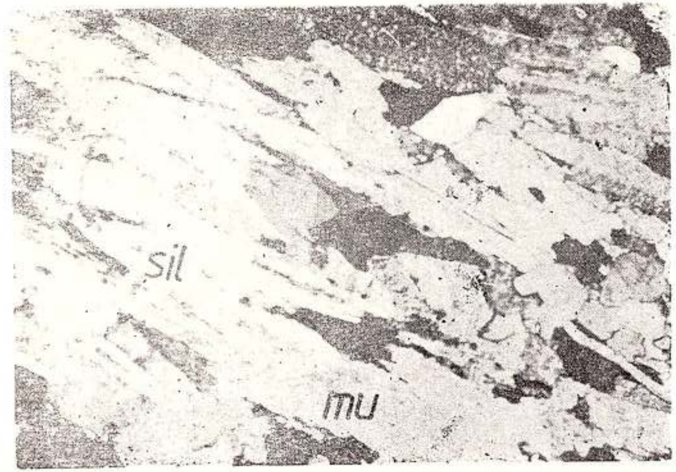

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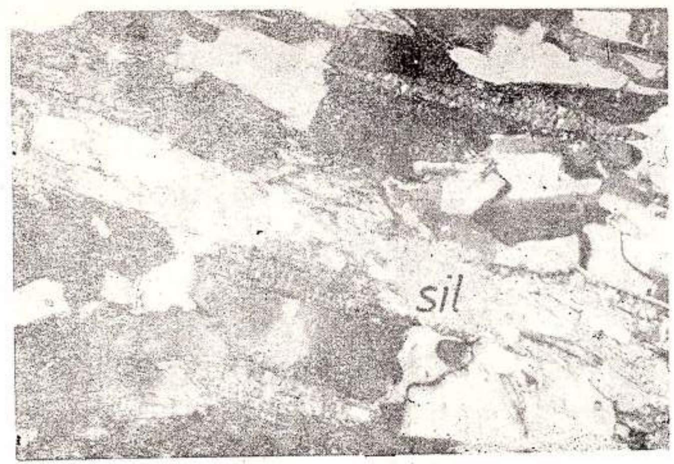

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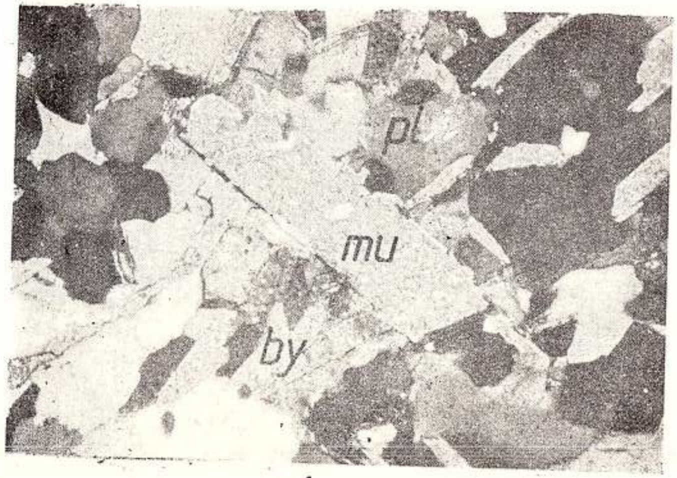

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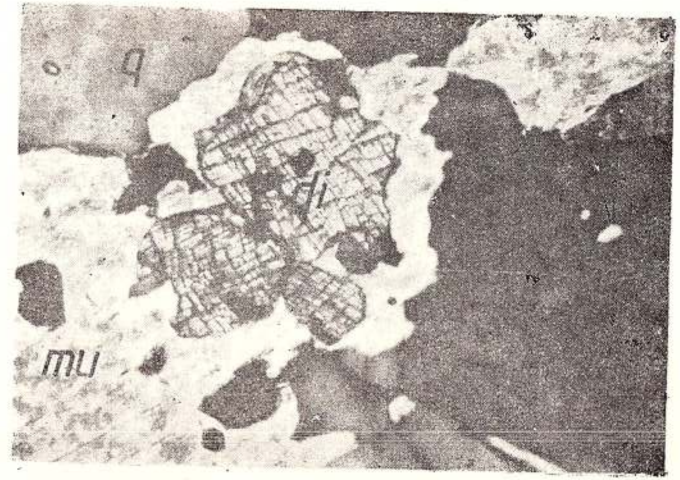

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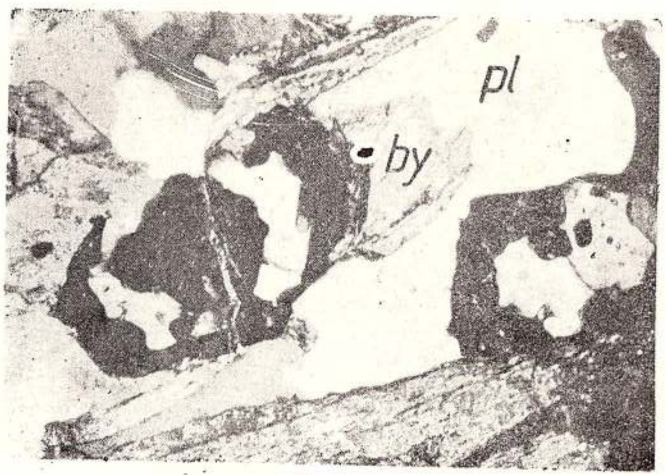

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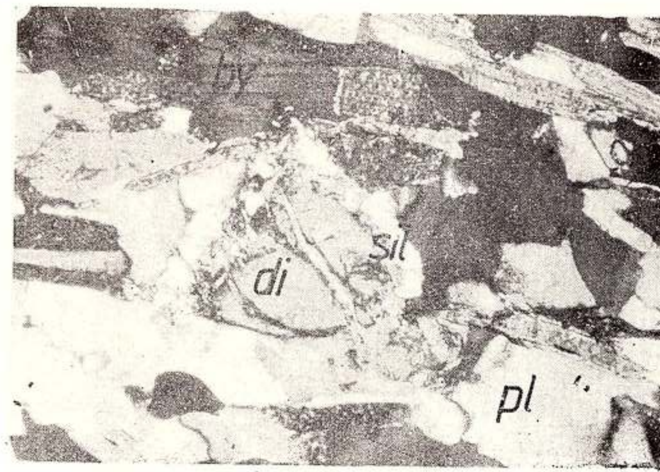

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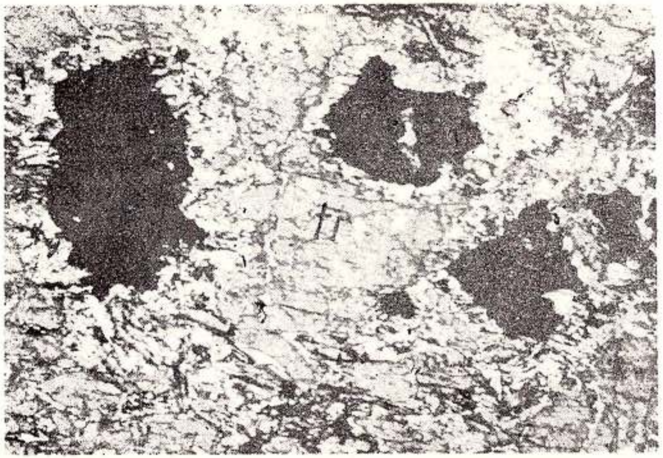
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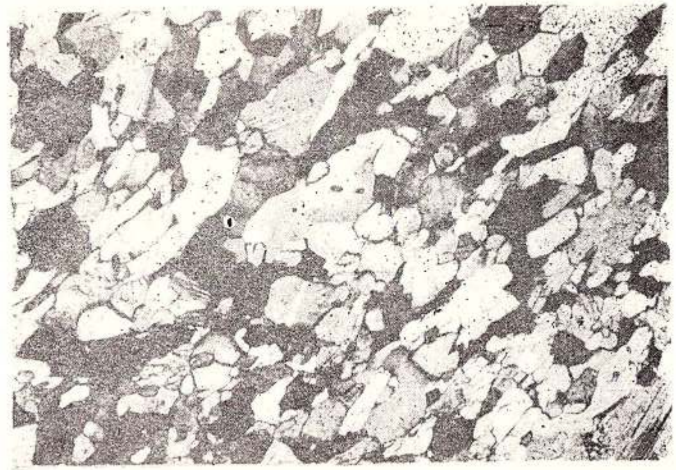
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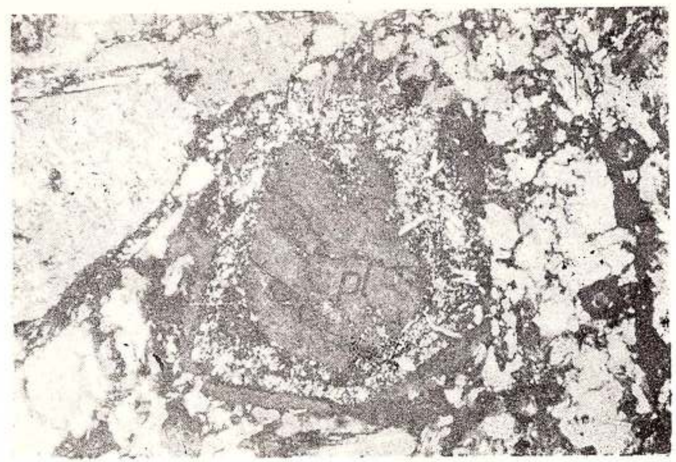
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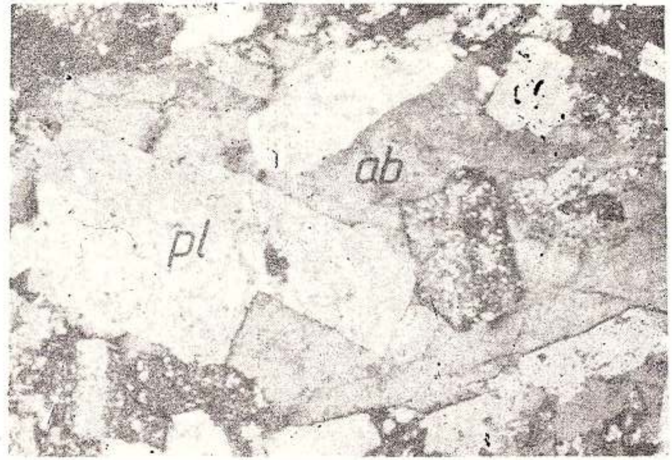

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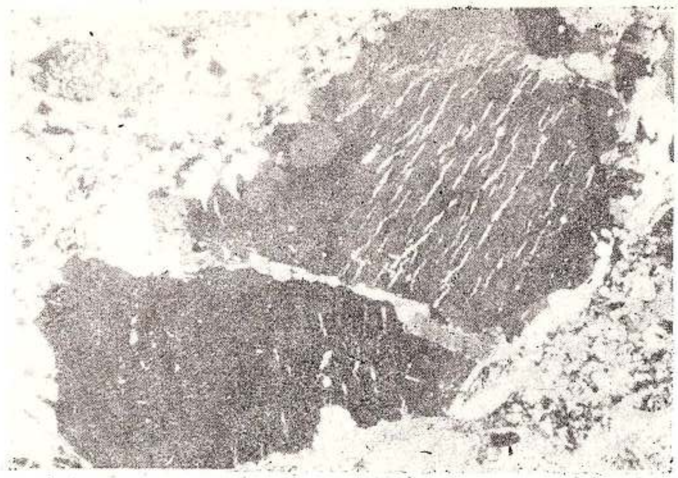

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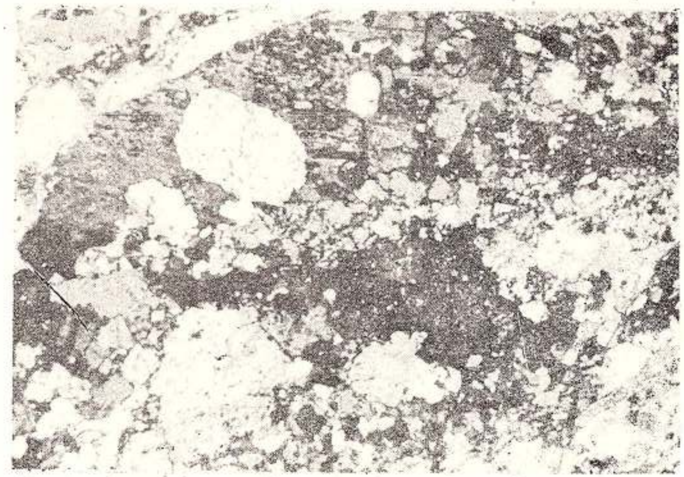

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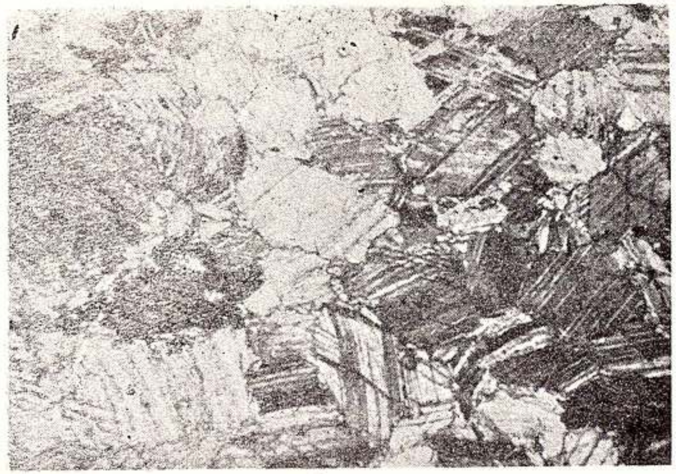

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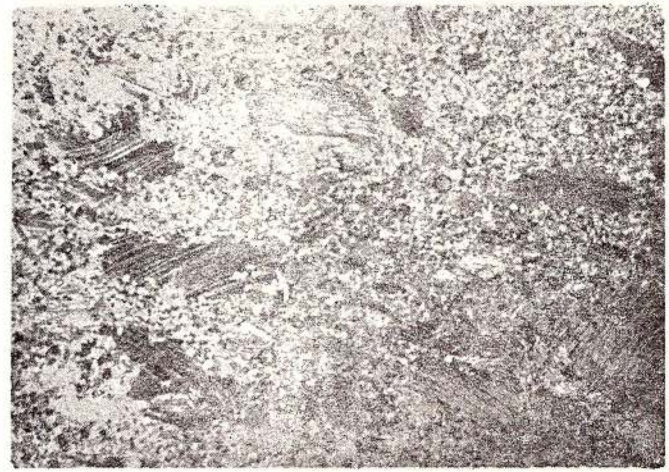

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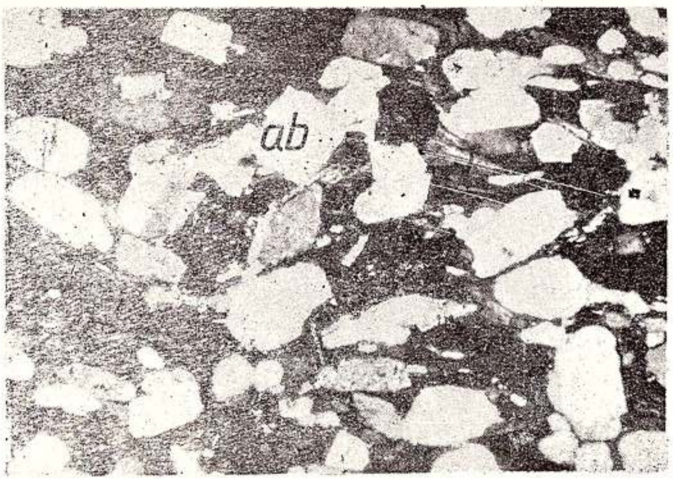

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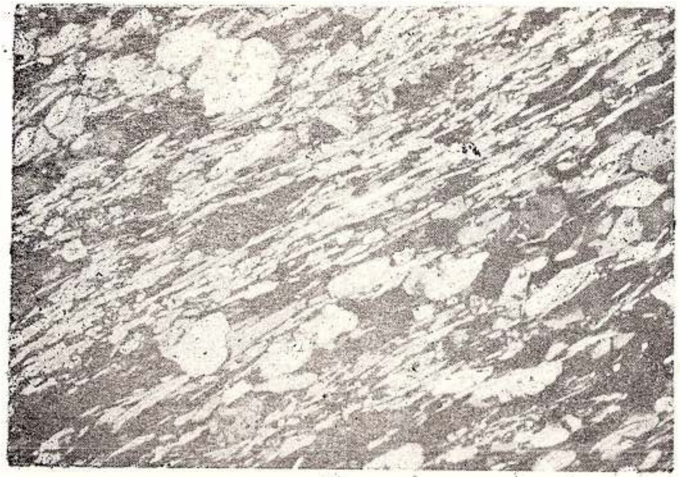

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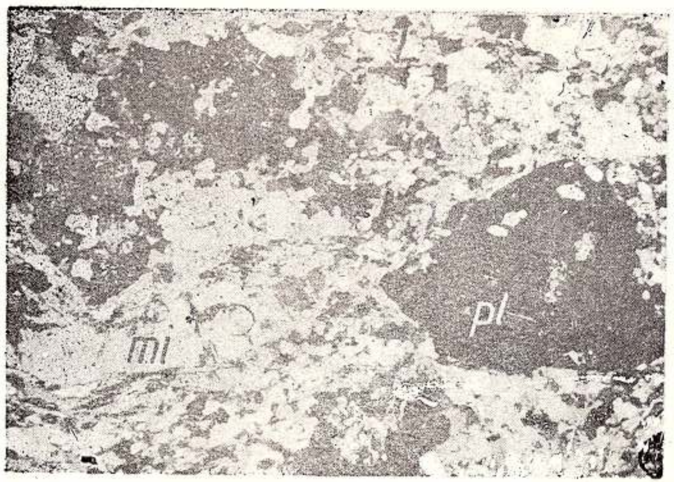

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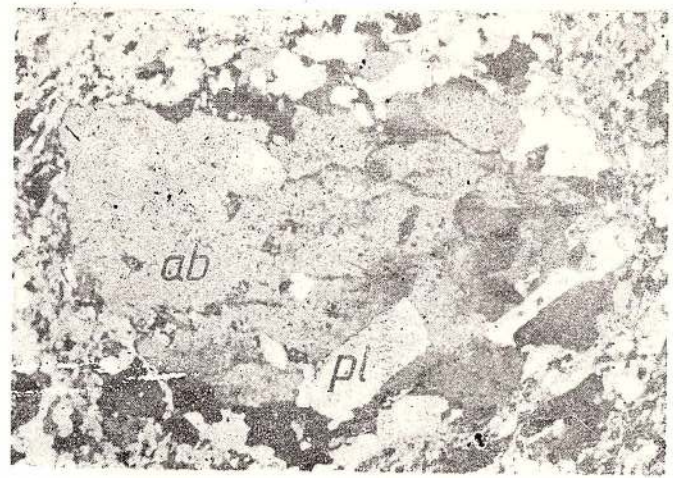

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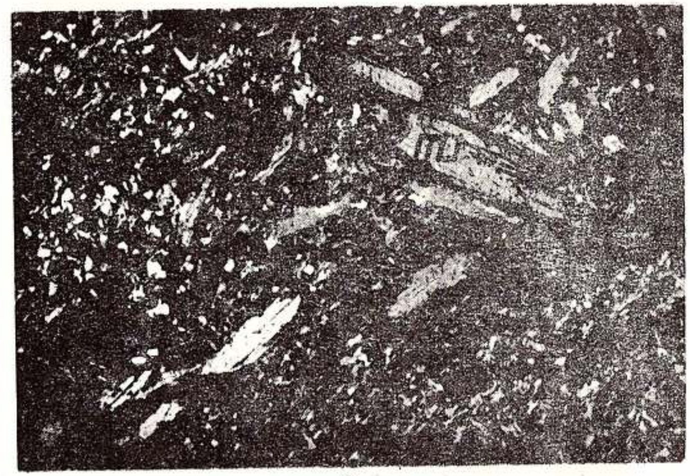

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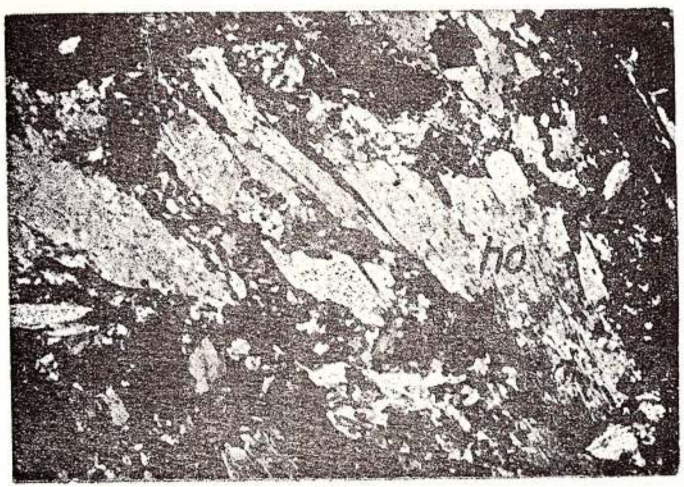

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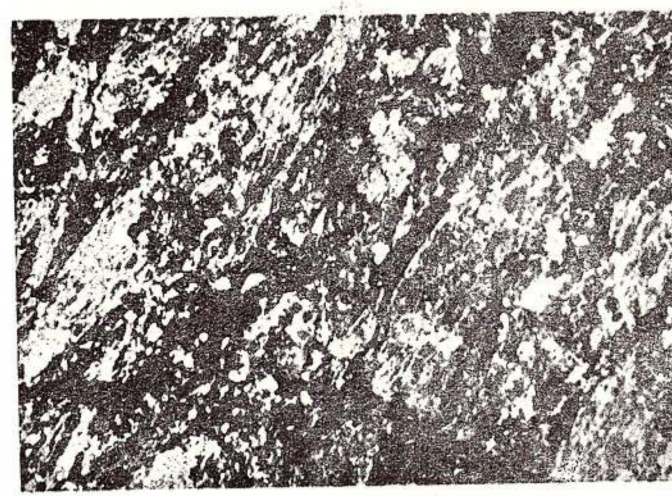

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