MINISTERUL GEOLOGIEI
INSTITUTUL DE GEOLOGIE ŞI GEOFIZICĂ

# DĂRI DE SEAMĂ ALE ŞEDINŢELOR

VOL. LXIX
1982

## 2. ZĂCĂMINTE



BUCUREŞTI
1985

Responsabilitatea asupra conținutului articolelor
revine în exclusivitate autorilor

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INSTITUTUL DE GEOLOGIE ŞI GEOFIZICĂ

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A L E

Ş E D I N Ţ E L O R

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B U C U R E Ş T I
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## CONTENU

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## 2. ZĂCĂMINTE

# THE PORPHYRY COPPER DEPOSIT AT VOIA, METALIFERI MOUNTAINS [1]

BY

ION BERBELEAC [2], ALLA ZĂMÎRCĂ [2], MARGARETA DAVID [2], ION TĂNĂSESCU [3], NICOLAE BERINDE [3]

*Porphyry copper; Cu, Au. Tertiary. Calco-alkaline volcanism. Thermic and pyrometasomatic metamorphism. Hydrothermal alteration. Hydrothermal mineralization. Biotitization. Apuseni Mountains. — Neogene igneous rocks. Brad-Săcărîmb area.*

## Sommaire

*Le dépôt de cuivre disséminé de Voia, Monts Metaliferi.*

Le dépôt de cuivre porphyrique de Voia se trouve dans la partie centrale des Monts Metaliferi. La minéralisation est en corrélation avec les roches néogènes calco-alcalines intermédiaires intrusives (andésite quartzifère, diorite porphyrique quartzifère) qui constituent une structure sous-volcanique. Le dépôt se trouve à la limite ouest du sous-volcan, pénètre partiellement les cornéennes et présente une zonalité verticale : altération argileuse et minéralisations de pyrite $\pm$ or, sulfosels d'argent, sulfures polymetaliques (filons) à la partie supérieure, altération et minéralisation propylitiques (minéralisation des oxydes de fer disséminé $\pm$ Cu) et l'altération et minéralisation potassiques (minéralisation de cuivre porphyrique) en profondeur. Le modèle génétique démontre une grande affinité pour le modèle dioritique et des traits polyascendants des processus métallogénétique. Le gisement est long de 350 m et large de 250 m, étant constitué surtout de chalcopyrite, pyrite, magnétite et hématite et de quantités mineures de bornite, cubanite, chalcocite, sphalérite, galène, molybdénite et or ; le quartz, le feldspath potassique, l'anhydrite (gypse) et la chlorite sont les minéraux de gangue les plus importants.

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[1] Received on May, 5, 1982, accepted for communication and publication in revised form on August, 9, 1982, presented in the meeting of May, 21, 1982.

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## Introduction

In the last years a significant amount of man-power and money has been invested for researches meant to establish the detailed anatomy and economical evaluation of the Voia Tertiary volcanic structure. As a result, three types of mineralizations have been recognized : 1) volcano-sedimentary disseminated pyrite ; 2) quartz-clay mineral-pyrite ± Au veins and anhydrite (gypsum) ± base metal-sulphosalt-Au veins and 3) a porphyry copper deposit (Berbeleac, 1981).

The present paper is focussed on what is considered to be the main scientific results at Voia, namely the description and interpretation of the space-time relation of volcanism and porphyry intrusion with the concurrently evolving mineralization and alteration in the porphyry copper ore body.

## Regional Geology

The geological evolution of the Voia area is closely related to that of the Metaliferi Mts in general, and to the Brad-Săcărîmb volcanic unit in particular, where molasse sedimentation and volcanism were active between the Upper Helvetian and the Pannonian time. Hercynian metamorphosed and Upper Jurassic-Lower Cretaceous unmetamorphosed (limestone, sandstone, shales, island arc volcanics) basement rocks were unconformably overlain by Tertiary sediments and volcanics (Ghițulescu, Socolescu, 1941 ; Ianovici et al., 1969 ; Berbeleac, 1975). The volcanics represent the acid and intermediate calc-alkaline products of the multi-impulse volcanic activity.

In the Brad-Săcărîmb Unit, this activity developed during two cycles (Upper Badenian-Sarmatian and Sarmatian-Pannonian) with many phases (Ianovici et al., 1969). It is known that the maximum volcanic, subvolcanic and metallogenetic activity took place in the second phase of the second cycle. Hornblende and biotite quartz andesite (Săcărîmb type), hornblende ± biotite quartz andesite (Barza type) and minor intrusions of quartz porphyry diorite are the most common rocks generated in this phase. Also most of the native gold, gold tellurides and base metal sulphide ± gold and silver veins of the Metaliferi Mts are associated with the metallogenetic activity of this phase.

The Brad-Săcărîmb Tertiary volcanic unit, as well as other ones of the Metaliferi Mts, which contain all the Metaliferi porphyry copper deposits, is an element of the Tethyan Eurasian Metallogenetic Belt (Jancovič, 1979), the Alpine Intercarpathic Province (Superceanu, 1979) or of the Carpatho-Balkan Belt (Sillitoe, 1979). The northwest trending of the volcanic units of the Metaliferi Mts is accompanied by a series of subparallel regional faults which culminate in the Metaliferi rift zones. Many intermediate intrusions tend to parallel the rift zones and their emplacement appears to have been influenced by regional faults. The copper mineralization is associated with some of these intrusive bodies. The geotectonic setting, composition of the intrusives and volcanics, alteration types and metal content of ore bodies are typical of island arc.

## Local Geology

The Voia porphyry copper deposit is located in the central part of the Metaliferi Mts, about 10 km south-east of the Brad town, or 4 km east of the Hondol mining centre (Fig. 1). It occurs in a dissected and eroded Lower Tertiary volcanic field, which contains Tertiary sedimentary, volcano-sedimentary and volcanic rocks (Fig. 2). These formations overlie unconformably the eroded Upper Jurassic-Lower Cretaceous basalt-andesitic rocks of the island arc pile. The Upper Helvetian (?)-Badenian sediments (conglomerates, tuffs, sandstones, clay, marls) occur especially at depth. A volcano-sedimentary complex (Upper Badenian-Pannonian) including abundant andesite-quartz andesite flows and pyroclastics overlies them. These rocks have in turn been cut by a subvolcanic body and irregular northwest trending dykes. The subvolcano appears very little to the surface ; its outline (Fig. 2) is demonstrated by geophysical and drilling data (Berbeleac et al., 1979, 1981). Close to the subvolcano the effects of heat and metasomatism are worth mentioning. The surrounding area has been strongly tectonized and pierced by numerous necks with circular distribution (Buha, Cetraş, Momeasa, Paua, Geamăna and Măcriş). All of them belong exclusively to the Sarmatian-Pannonian (?) eruption phases of the Barza, Săcărîmb and Cetraş quartz andesite and Cetraş dacite types (Berbeleac, 1970, 1975, 1981). The volcanics, excepting the Cetraş quartz andesite and dacite, are intruded by the Săcărîmb and Barza quartz andesite (?) and quartz porphyry diorite of the subvolcanic body. This body contains copper mineralization. Round the subvolcano the formation is of pyritic nature and consists of andesite volcanic flows, banded tuffs and tuffites, bedded volcanic breccia and sediments. Most of the Voia porphyry copper ore occurs within the subvolcano body. The northsouth trending part of the body is about 1 000 m long and up to 500 m wide, with the Voia ore body occupying its narrow central southwestern edge. The body consists mostly of porphyric hornblende, biotite quartz andesite but for some minor dykes of hornblende $\pm$ biotite quartz andesite or the hornblende biotite quartz porphyry diorite occurring at depth. The porphyric hornblende, biotite quartz andesite (Săcărîmb type) is characterized by large euhedral feldspar hornblende, biotite "books" and quartz "eyes" phenocrysts and porphyric structure. The porphyric groundmass is built up mainly of feldspar, and quartz. The hornblende $\pm$ biotite quartz andesite (Barza type ?) is petrographically similar to the Săcărîmb andesite, but the porphyric structure and the quartz and biotite amounts are less representative. The quartz porphyry diorite does not occur at surface ; It is the major intrusive rock at depth. The structure and composition are very marked. However, all structural variants are characterized by abundant phenocrysts of plagioclase, hornblende, biotite and local quartz. They are enclosed in a matrix of quartz, plagioclase, hornblende and/or biotite with accessory zircon, apatite, sphene, magnetite and ilmenite. The size of plagioclase phenocrysts and the ratio of hornblende to biotite phenocrysts show no systematic variations. That is why the "serial" type of structure is very typical of quartz por-

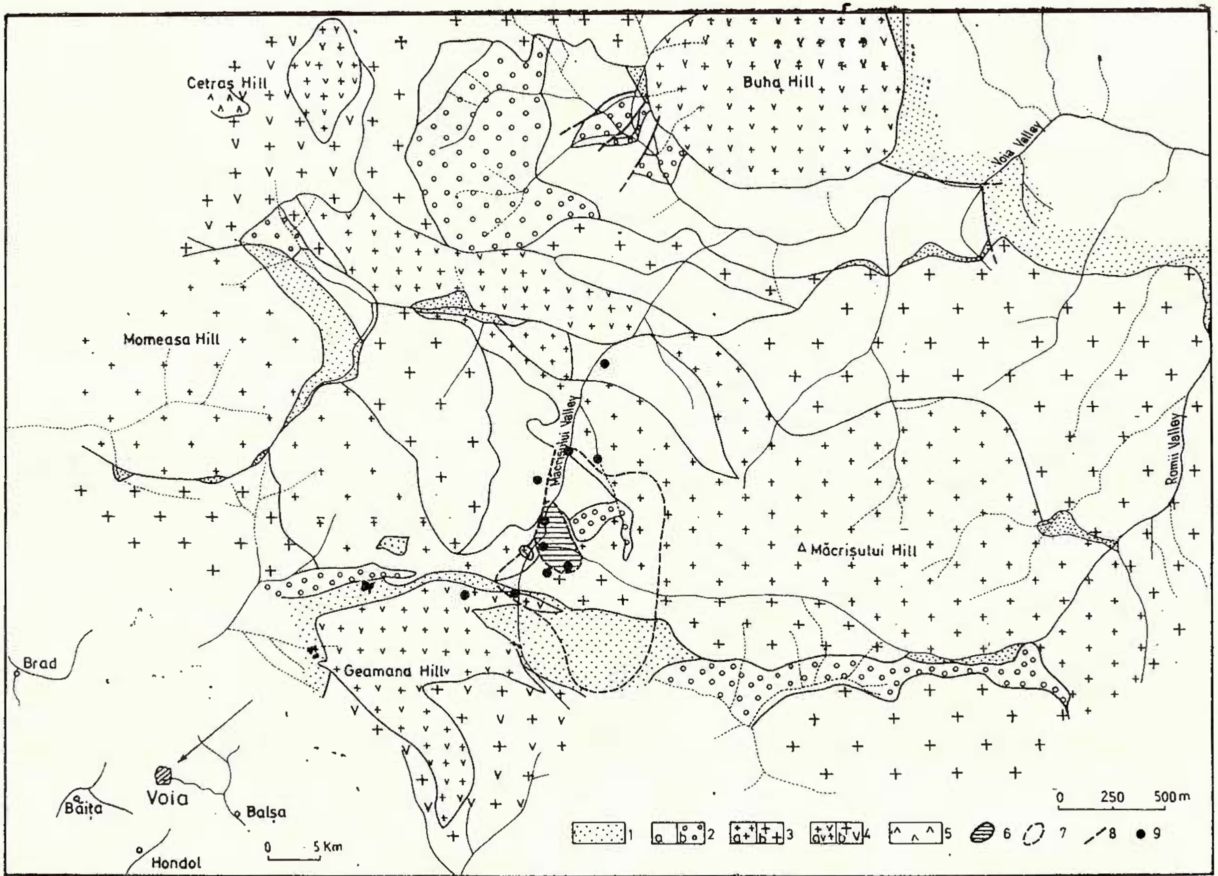


Fig. 1. — Simplified geological map of the Voia region. Upper Helvetian (?)-Pannonian (?) sedimentary-volcano-sedimentary deposits; Neogene volcanics; 2, hornblende ± biotite quartz andesite; a, flow; b, pyroclastic; 3, Săcărîmb hornblende + biotite quartz andesite: a, neck, dyke; b, flow; 4, Cetraş hornblende + biotite quartz andesite (Cetraş type); a, neck, dyke; b, flow; 5, Cetraş dacite; 5, porphyry copper body; 7, subvolcano boundary 8, fault; 9, borehole.

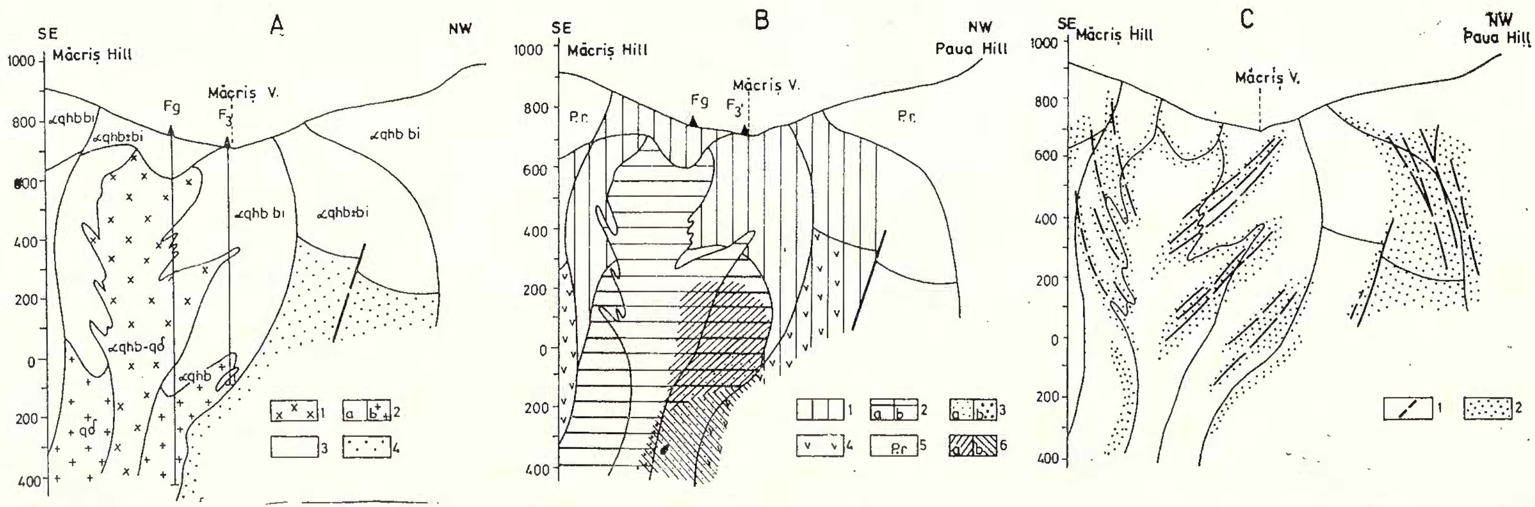


Fig. 2. — Genetic model of the Voia porphyry copper deposit. A. Schematic geologic cross section : 1, Hornblende quartz andesite (αqhb-Barza type ?)-quartz porphyry diorite (qδ) ; 2, (a) Hornblende-biotite quartz andesite (αqhbi-Săcărîmb-type) ; (b) Quartz porphyry diorite (qδ) ; 3, Lavas and pyroclastics of hornblende-bearing quartz andesite (αqhb ± bi) ; 4, Helvetian-Sarmatian sedimentary and volcanic-sedimentary deposits. B. Early alteration and mineralization : 1, Argillic alteration ; 2, Propylitic alteration : a, early ; b, late ; 3, Silicate alteration : a, early ; b, late ; 4, Hornfels ; 5, Regional propylitization ; 6, Mineralization : a, Fe-oxides ± Cu ; b, porphyry cooper. C. Late alteration and mineralization : 1, Ore veins ; 2, Argillic alteration and pyrite impregnation.

phyry diorite. As regards the relationship between the intrusive rocks of the ore body we remark that the quartz porphyry diorite cuts the Săcărîmb quartz andesite and they have been intruded by the Barza quartz andesite type. The last type of rocks shows at depth graded transition to the dioritic type.

It is likely that the copper mineralization is closely associated with a locus of multiple intrusions. Drilling mapping has recently shown that there are several different intrusives with cross-cutting age relationships. Some of them, such as the Săcărîmb quartz andesite and hornblende biotite quartz porphyry diorite are highly fractured, veined and mineralized, while younger cross-cutting Barza (?) hornblende $\pm$ biotite quartz andesites are sparsely fractured, veined and mineralized. These relationships indicate that mineralization occurred during a multiple intrusive event that may represent late-stage differentiates of the subvolcano body. Progressive mapping of drillings has indicated the presence of hornfels and quartz porphyry diorite (older diorite) xenoliths. The hornfels xenoliths increase in the horizontal plane as the Badenian rock contact is reached. This contact, controlled in the western part of the subvolcano body by four drillings, shows dips of 75°SE.

Northwest regional alignments of volcanic centres, as well as similarly trending post-mineralization dykes, indicate that the direction of structural weakness was dominant both before and after mineralization. Two major fault sets are known: 1) the most prominent and probably recent one strikes 45—65°W and dips 65—80°SW, parallel to the regional trend and 2) an older, maybe Laramian one, that is removed, strikes N50—75°E and dips 60—80°SE (Berbeleac, 1975). We note the fact that the dyke attitudes correspond to these major fault directions. Also, the majority of the vein sets of the Voia porphyry copper body generally show two prominent directions similar to the two mentioned fault directions. A third set striking N-S and dipping 70°E is also present. In the inner part of the ore body all these sets are present and they occur as stockwork veining.

### *Postmagmatic metamorphism and mineralization*

Detailed mapping of cores from the contacts between rocks has provided strong evidence of an extremely close time and space relationship between the processes of intrusion, alteration and mineralization (Fig. 2, 3, 4). The intrusive feature and relative age of the rocks are clearly demonstrated by the truncation of many early quartz veins at this contact. Here there is a strong contrast between the nearly fresh, weakly, mineralized hornlende $\pm$ biotite quartz andesite (Barza type ?) and the older hornblende and biotite quartz andesite (Săcărîmb type) and quartz porphyry diorite, which has been intensely altered to argillic and potassic assemblages; the last one is characterized by alkali-feldspar, biotite, chalcopyrite and magnetite. At the upper part, especially, the change in mineral assemblage is obvious at the intrusive contact. It is also very clear that most of the primary alteration and mineralization was accomplished before the intrusion of the hornblende $\pm$ biotite quartz andesite.

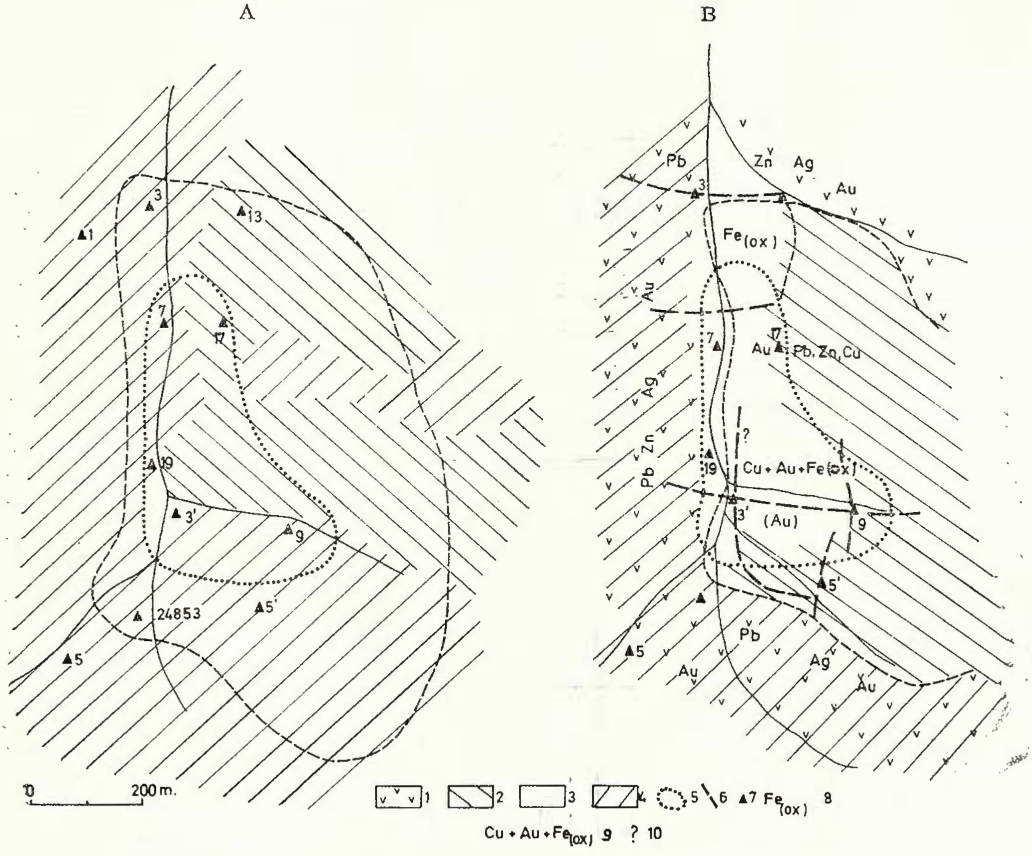


Fig. 3. — Hydrothermal alteration and porphyry copper boundary (> 0.2% Cu) ; at surface (a) and 800 m deep (b) ; 1, hornfels : hydrothermal alteration ; 2, propylitic ; 3, potassic ; 4, argillic ; 5, porphyry copper body ; 6, vein ; 7, borehole ; 8, Fe-oxides ± sulphide assemblage ; 9, porphyry copper mineralization ; 10, uncertain trend.

The postmagmatic alteration consists of thermal and hydrothermal metamorphism.

*Thermal metamorphism*

The thermal metamorphism is characterized by successive mineral associations in response to progressively rising temperature and degree of recrystallization towards the subvolcano contact. As a result, sequences specific of very low grade metamorphism (spotted slates) and low grades of metamorphism (albite-epidote hornfels, Fig. 2, 3) assemblage within aureole, do occur. The aureole appears in Badenian pelitic and aleuritic sediments, some 600—700 m below the surface ; with the help of boreholes, it has been recognized on some 100 m width in the western part of the subvolcano body (Fig. 3 b). There the albite-epidote-hornfels

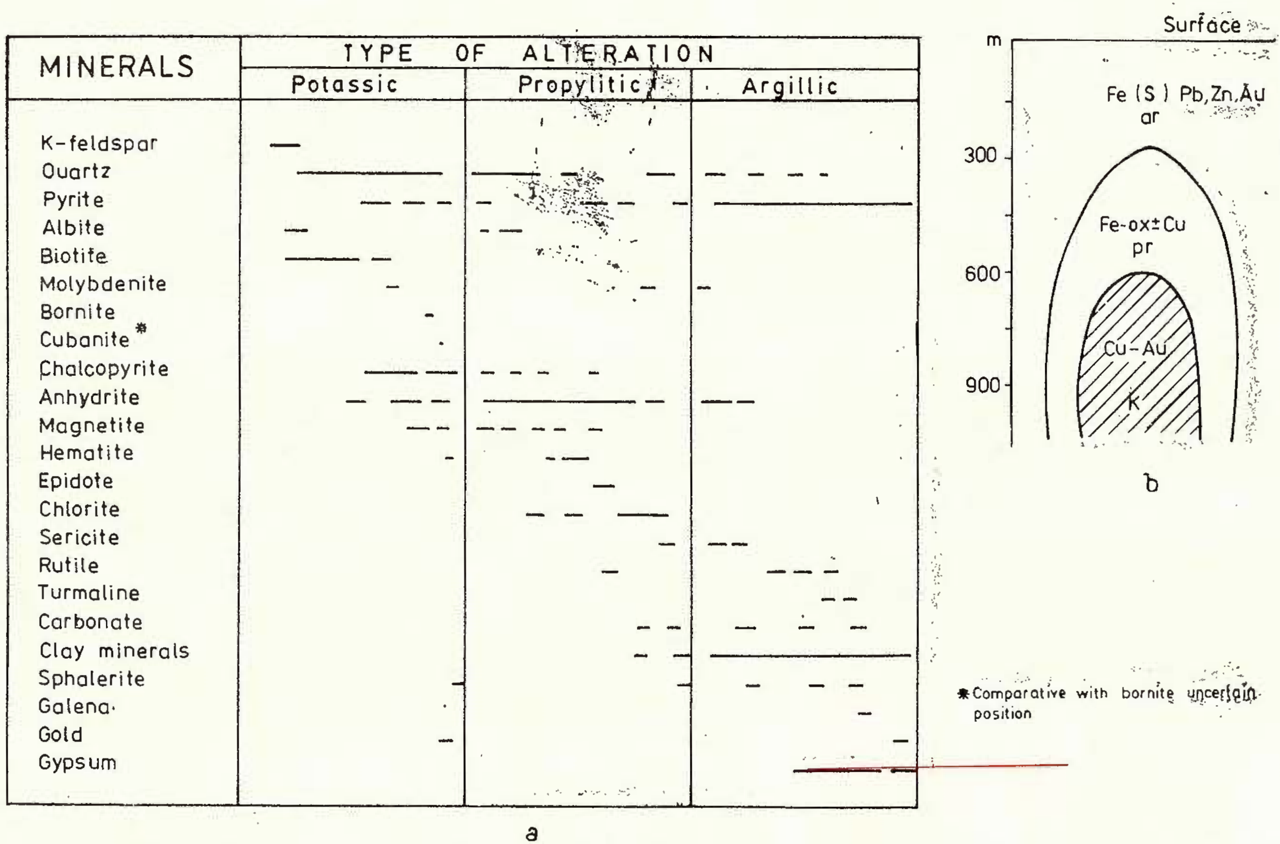


Fig. 4. — a) Diagram of the primary paragenesis of the Voia porphyry copper deposit; b) relationship between the major metallic elements and alteration zone in the Voia porphyry copper deposit : pyrite — base metal — Au in argillic zone (ar) (Fe(S), Pb, Zn, Au) ; Fe-oxides ± Cu in propylitic zone (pr) and porphyry copper body in the potassic zone (K) (Cu-Au).

assemblage (Pl.I, Fig. 1 b, c) represents the maximum extent within the aureole, wich goes probably round to the intrusion (Fig. 2 b, 4 b) ; in places this peripheral hornfels grades into spotted slates.

## Hydrothermal alteration and mineralization

Mapping and relative age relations have demonstrated that the processes of alteration and mineralization were imposed upon each successive surge of intrusion and its wall rock, before and after the emplacement of the next surge. The above mentioned processes took place during two main stages : 1) early alteration and mineralization, largely accomplished especially before the intrusion of the hornblende ± biotite quartz andesite, are characterized by a distinctive type of mineral assemblages, proper porphyry copper mineralization and 2) late alteration and mineralization manifested post hornblende ± biotite quartz andesite intrusions, represented by propylitic and especially argillic assemblages, are typical of abundant pyrite mineralization, quartz-clay mineral-pyrite ± Au veins and anhydrite (gypsum)-base metal-sulphosalt-Au veins (Fig. 2 c).

The distribution of the hydrothermal alteration and mineralization generally follows with some peculiarities the trends of the dioritic model described by Hollister (1975). The terms „potassic", „propylitic" and "argillic" are those used by Lowell and Guilbert (1970).

### *The early alteration and mineralization*

At Voia, perhaps as much as 80 percent of the copper was emplaced during this early time ol alteration and mineralization. Alteration assemblages with stable alkali feldspar and biotite and chalcopyrite-pyrite-magnetite are characteristic of both quartz veins and background mineralization. The copper is associated mainly with K-silicate alteration and low-sulphur sulphide mineralization.

The early alteration and mineralization are characterized by the zonal distribution of the products of metasomatism and of space-filling minerals. The horizontal zoning is irregular, while the vertical zoning pattern has a mushroom shape with low, distinct, deeper roots (Fig. 2). Zoning of copper mineralization shows a similar trend.

An irregular envelope of argillic alteration (caolinite, illite, calcite, gypsum ± anhydrite) with pyrite mineralization underlies the propylitic and potassic alteration with copper mineralization (Fig. 2, 4 b).

The potassic mineralization assemblages are characteristic of early alteration and mineralization at Voia. K-feldspar, albite, biotite and anhydrite are the essential minerals of this asemblage with ubiquitous and very abundant quartz. Other minerals, such as magnetite, Na-feldspar, chlorite and minor sericite are common associates ; kaolinite, zeolites and montmorillonites are absent. The maximum intensity of K-silicate alteration is marked by the increasing degree of replacement of plagioclase. The plagioclase replacement around its rims and along cross-cutting cracks and veinlets is commonly zoned. The groundmass and the haloes of some quartz veins and veinlets from the quartz andesite, quartz diorite and hornfels are accompanied by this replacement Pl. I, Fig. 2 c). K-feldspar and albite are largely restricted to the core of the ore zone wich has an elongated form and is about 350 m long and 50—250 m wide. It lies mainly within the andesites of the Săcărîmb type and in the younger quartz porphyry diorite (Fig. 2 b).

The biotitization in potassic alteration takes the form of a broad halo in hornblende ± biotite quartz andesite and quartz porphyry diorite intrusion. The principal mineral assemblage, such as at El Salvador porphyry copper deposit, Chile (Gustafson, Hunt, 1975), is biotite-sodic plagioclase-anhydrite-quartz. Accessory minerals are Fe-Ti oxides, pyrite, chalcopyrite, bornite, minor chlorite, apatite and zircon. Sometimes biotite is recognized megascopically, but, as a rule, it is present as very fine grained flakes in the rock matrix. The intense biotitization is close to intrusive contacts, where the rock is usually entirely recrystallized. In this case the plagioclase is partly preserved, but K-feldspar is generally absent or restricted to the immediate vicinity of some quartz veinlets (Pl. I, Fig. 2 c).

Within the K-potassic alteration the hornblende and ilmenite are preserved only in some cases. As a rule the hornblende phenocrysts are replaced by biotite-anhydrite-rutile assemblages ; these minerals appear as "shreddy" in original sites of hornblende phenocrysts and reveal probably the earliest and deepest manifestations of K-silicate alteration.

As regards the quartz in the potassic alteration and mineralization assemblage, we point out its abundance within the "mosaic" groundmass of the quartz andesite and/or quartz porphyry diorite as well as in veins. The veins increase in number and size towards the center of the potassic alteration and mineralization zone, (Fig. 3, Pl. I, Fig. 2 c, d), where the highest copper values do appear. Sulphide and iron oxide minerais where frequently introduced with the quartz and occasionally K-feldspar and biotite envelope the veins.

The propylitic alteration and mineralization are situated in the surroundings of the potassic zone and appear both in hornblende + biotite quartz andesite, quartz porphyry diorite and hornblende ± biotite quartz andesite ; the subsequent stage of propylitisation belongs to the Barza type andesite (?) and is very respresentative (Fig. 2 b). The characteristic constituents of the propylitic assemblages are chlorite, calcite, quartz, albite and anhydrite. Minor amounts of epidote, biotite, sericite, clay minerals are also present. Chlorite is abundant as an alteration product disseminated in rocks and veinlets. The iron oxide and sulphide replaced the mafic minerals and the first are common in chloritized hornblende. It is important to underline that the anhydrite amount in propylitic rocks is also significant.

Beyond the outer limits of biotitization and sulphide mineralization, the propylitic alteration is generally marked by the magnetite-hematite and hematite-rutile assemblage within veinlets of anhydrite ±

chlorite-quartz-calcite-pyrite and chalcopyrite (Fig. 3, Pl. I, Fig. 2 a, b). These veinlets have a chlorite and anhydrite halo (Pl. I, Fig. 1 b). The pyrite ± chalcopyrite veins with chlorite-sericite ± clay minerals are later than the Fe-Ti oxides ± chalcopyrite veins.

The copper mineralization passes from the potoassic zone to the propylitic one, but only at the lower part where the copper content is significant (Fig. 2, 4 b).

The argillic alteration and mineralization form a broad halo around the propylitic zone (Fig. 2 b) and enclose the intermediate and advanced argillic asemblages containing koalinite, illite, sericite, amorphous material, chlorite, calcite, quartz (Berbeleac et al,. 1978). The disseminated and veinlet pyrite mineralizations are very characteristic; minor amounts of sphalerite and galena are also present. Rutile is the only iron-titanium oxide in the area of high clay alteration. Clay minerals have partly or wholly replaced the feldspar and mafic minerals and their distribution is irregular. The clay is often associated with gypsum, subordinate anhydrite. There is a good general correlation between the abundance of pyrite and intesity of argillic alteration. Generally, pyrite represents 5—25 percent and appears as dissemination, veinlet fillings and millimetric or centimetric aggregates, commonly associated with anhydrite (Pl. I, Fig. 1 a). The most representative metasomatic pyrite concentrations (10—30 percent) are present within the hornfels (Pl. I, Fig. 1 b, c). The quartz veinlets appear accidentally in contrast with gypsum ± anhydrite ± sulphides, which are frequent (Pl. I, Fig. 2).

The absence of the phyllic zone and the occurrence of copper mineralization within both the potassic and the surrounding propylitic zones allow us to include the Voia porphyry copper deposit as a whole ; in the dioritic model (Hollister, 1975).

As regards the early postmagmatic alteration and mineralization manifested after the intrusion of hornblende ± biotite quartz andesite (Barza type), it is important to note that it consists of the same type of alteration and mineralization, but the assemblages of potassic alteration and mineralization as well as argillic alteration and mineralization associated with porphyry copper deposition are qantitatively insignificant the propylitic assemblage is large and follows the limits of the Barza type intrusives (Fig. 2 b).

It is also worth emphasizing that an important sulphate zone has been formed in connection with the early alteration and mineralization (Berbeleac, 1981).

The anhydrite is the principal mineral of this zone. It is one of both the earliest and the latest products of mineralization and, in fact, spans the entire history of mineralization at Voia. The bulk of the early anhydrite is impregnated and is the characteristic component of many sets of veinlets from the postassic and propylitic alteration and mineralization zones. The later anhydrite associated with late alteration and mineralization is dominantly fracture controlled and is a characteristic product of all younger veins. Thus, anhydrite is an associate of a great variety of mineral assemblages. With one exception, the set of veinlets of the first stage is present within all the veinlets that have been formed between the second and the fourth stage. The abundance in anhydrite is the greatest in hornfels, Badenian hydrometasomatized sediments, the Săcărîmb quartz andesite and quartz porphyry diorite (5—15 percent, by volume) and decreases in younger andesite (3—5 percent). There exists, just like in the case of El Salvador porphyry deposit in Chile (Gustafson, Hunt, 1975), a rough reversed correlation between the abundance in anhydrite and the abun-

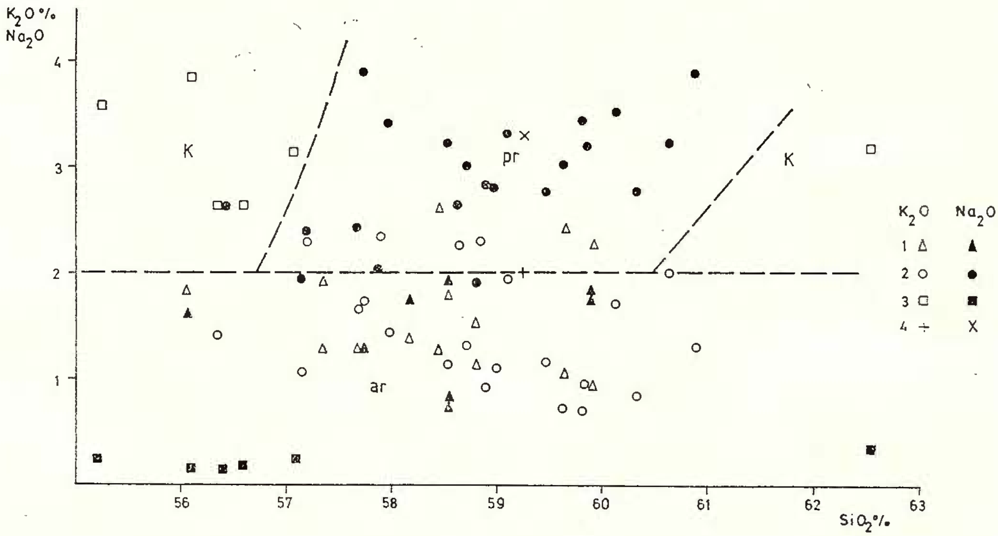


Fig. 5. — $K_2O$ and $Na_2O$ versus $SiO_2$ ratio of the Voia Neogene intrusive rocks. Alteration : 1, argillic (ar) ; 2, propylitic (pr) ; 3, potassic (K) ; 4, mean of unaltered rocks (Berbeleac, 1975).

dance in primary calcic plagioclase and hornblende. This means that the replacement of plagioclase by K-Na feldspar and the replacement of hornblende by biotite are probably the principal anhydrite-fixing reactions.

The chemical analyses of early hydrothermal products show that these are characterized by great diversity in composition. Composition underwent a change from potassic alteration and mineralization where $K_2O$, $Na_2O$, $SiO_2$ and $SO_4^{+2}$ have been concentrated ; in the argillic alteration and mineralization zone, in general, $K_2O$, $Na_2O$ and $SiO_2$ (Fig. 5) have been depleted.

*Description of the deposit*

The ore body of the Voia deposit lies on the N-S direction, on the western part of the subvolcano limit. It is about 350 m long and maximum about 250 m wide. The ore body is dipping by 70—75°E. The boundaries of the ore body are mainly the gradual transition of the ore body to poor mineralized quartz andesite, quartz porphyry diorite, hornfels and Badenian hydrometasomatized sediments. The ore does not crop out; it has been encountered by drillings, at 550 m and 950 m below the surface. Within the ore body dykes of poor mineralized hornblende ± biotite quartz andesite are encountered. The ore is closely associated especially with the potassic zone (> 0.3% Cu) of quartz andesite (Săcărîmb type) and quartz porphyry diorite; it also reaches the lower part of the propylitic alteration zone (Fig. 2 b). A small amount of the ore occurs in the Barza quartz andesite. The deposit was investigated at the depth of about 300 m, but the deepest drilling was executed at 1192 m (Berbeleac et al., 1982) and the mineralization continues at depth.

The ore minerals magnetite, hematite (specularite), rutile, pyrite, chalcopyrite, bornite, cubanite, molybdenite chalcocite and gold occur in two ways: 1) they are sprayed in the rock itself, in the chloritized and biotitized hornblende and 2) in the groundmass, in the shape of very irregular, discontinuous and segmented veinlets. These aspects of the veinlets are due not to the fact that they have been subjected to multiple shearing and segmentation, but to the fact that apparently many of them did never form with parallel walls. The gangue minerals in the veinlets are: quartz, chlorite, K-feldspar, albite, anhydrite, gypsum, clay minerals and accidental calcite. The mutual relation between the ore and gangue minerals is shown in Figures 6 and 7.

The megascopic and microscopic examination of the diversity of the ore body veinlets revealed the fact that they have been formed during two main stages with many successive moments. The first stage comprises all the sets of veinlets in which quartz, sulphide and magnetite are the principal minerals. The sequence of veins is roughly as follows: the first stage with K-feldspar, quartz ± py → quartz + K-feldspar ± pyrite — chalcopyrite — magnetite (hematite) — anhydrite — molybdenite → quartz + K-feldspar + anhydrite + magnetite (hematite). The second stage is characterized by the abundance of chlorite and sulphide in the veins. This is marked by the following successive sets of veinlets: chlorite + magnetite (hematite) ± anhydrite — albite — pyrite — chalcopyrite → chlorite + anhydrite + pyrite + chalcopyrite → chlorite — magnetite (hematite) ± pyrite — chalcopyrite. The third set represents a return to the first stage assemblage. The following veins are to be encountered: quartz + pyrite + chalcopyrite ± K and Na-feldspar → quartz — pyrite ± biotite + K-feldspar → quartz — anhydrite + pyrite + chalcopyrite. The fourth stage consists of veins abundant in anhydrite and sulphide: anhydrite + chlorite + pyrite → anhydrite + magnetite (hematite) ± chlorite + pyrite ± chalcopyrite → anhydrite + pyrite ± chalcopyrite — molybdenite → anhydrite ± chalcopyrite → anhydrite (gypsum) + clay minerals ± base metals-Au.

The microscopic study of the ore shows some peculiarities of the ore minerals, which reveal the evolution of the metallogenetic processes.

The ore has a typical disseminated structure; there are also reticulated and brecciated structures. The texture embraces a great diversity: fine to medium grained and xenomorphic to hypidiomorphic.

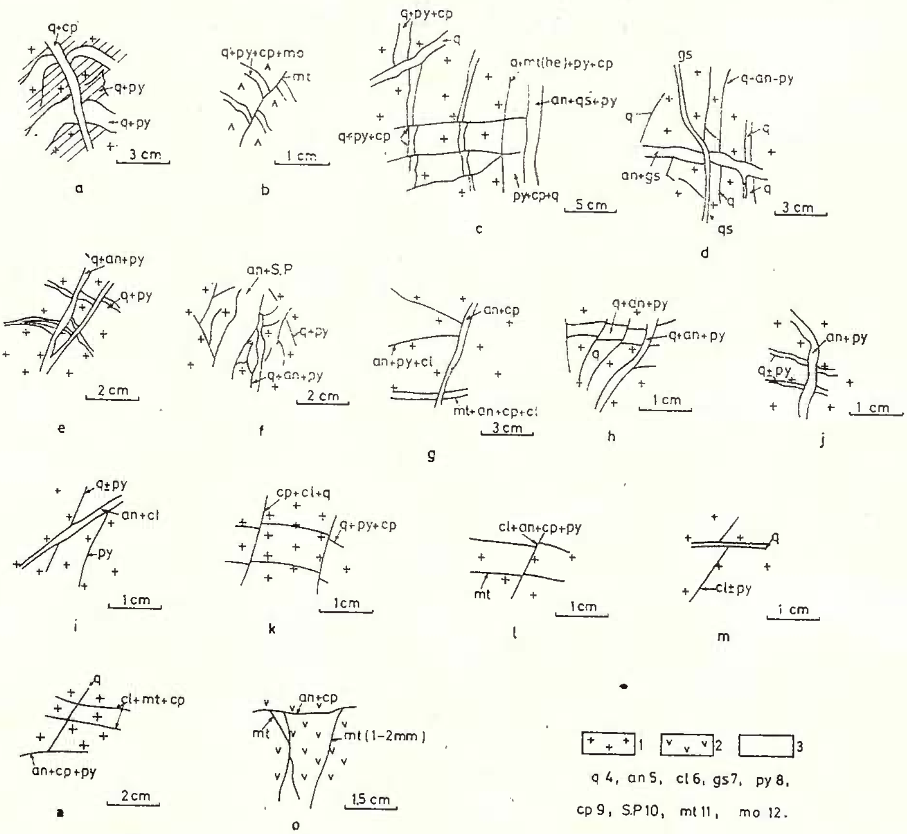


Fig. 6. — Sets of veinlets and main mineral assemblages of the Voia porphyry copper deposit.

1, quartz andesite and quartz porphyry diorite ; 2, hornfels ; 3, veinlets > 2 mm ; 4, quartz ; 5, anhydrite ; 6, chlorite ; 7, gypsum ; 8, pyrite ; 9, chalcopyrite ; 10, base metal ore ; 11, magnetite ; 12, molybdenite.

Pyrite is the most common ore mineral. It appears as anhedral and subhedral, more rarely euhedral fine and medium grains, in the groundmass and veinlets. In some quartz veins or anhydrite veins, pyrite is the unique ore mineral. But, as a rule it is closely associated with magnetite, chalcopyrite, bornite, sphalerite and cubanite (Fig. 7 i-k, m ; Pl. I, Fig. 4 ; Pl. II, Fig. 1, 2, 4). The pyrite grains are usually anhedral with rounded edges and are replaced with other ore minerals. Some pyrite aggregates are included and appear frequently broken in a chalcopyrite matrix (Fig. 7 j, m). The pyrite represents several generations, more visible in the sets of the quartz veins, quartz and anhydrite veins, chlorite and anhydrite veins and anhydrite veins (Fig. 6). We note within Badenian sediments, hornfels and in the rocks from the argillic zone the abundance of millimetric, rarely centimetric, compact aggregates of pyrite (Pl. I, Fig. 1 a, c).

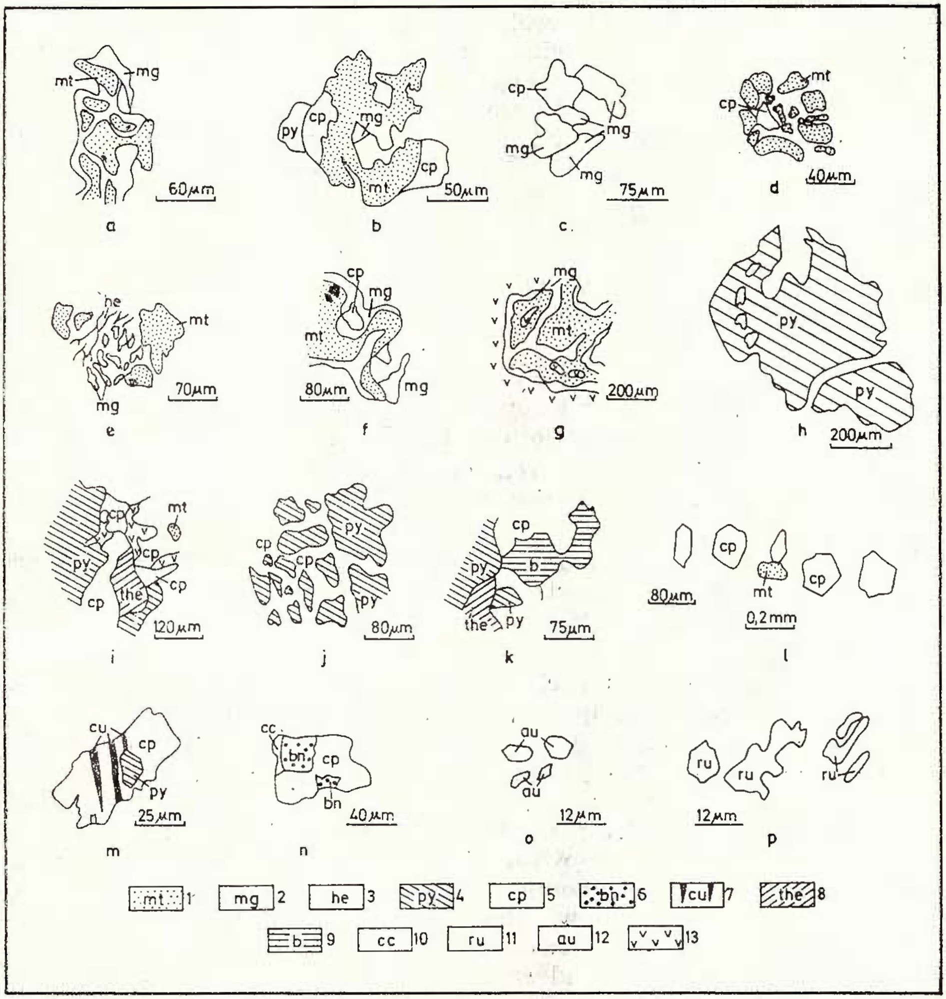


Fig. 7. — The mutual relation between some metallic minerals and gangue minerals in the copper ore.

1, magnetite 2, maghemite ; 3, hematite ; 4, pyrite ; 5, chalcopyrite ; 6, bornite ; 7, cubanite ; 8, tetrahedrite ; 9, sphalerite ; 10, chalcocite ; 11, rutile ; 12, gold ; 13, quartz.

Chalcopyrite appears mainly as fine-grained aggregates in the potassic zone. Towards the propylitic and argillic zone, the chalcopyrite decreases gradually so that at the upper part of the latter it occurs only accidentally. Chalcopyrite is a common mineral of many types of veins of the groundmass too. It occurs as isolated anhedral grains or small aggregates with irregular distribution. In the potassic zone the chalcopyrite : pyrite ratio ranges from 3 : 1 to 1 : 1. Here the chalcopyrite forms fine grains disseminated in the groundmass and fine-medium grained aggregates locally concentrated in nests, veins, fragments intimately associated with quartz, anhydrite, chlorite, Fe-oxides, pyrite, bornite and sphalerite (Fig. 6 b-d, i-k ; Pl. I, Fig. 4 ; Pl. II, 1). Isolated grains of chalcopyrite are irregular and subhedral (Fig. 7 b) and the aggregates replace and cement the pyrite (Fig. 7 i, j), quartz (Pl. II, Fig. 4), tetrahedrite (Fig. 7 i), sphalerite (Fig. 7 k) and Fe-oxides (Fig. 7 b, c ; Pl. II, Fig. 1). The association between chalcopyrite and cubanite shows intergrowth relations (Fig. 7 m).

Bornite is a minor constituent of the ore. It appears in quartz and/or chlorite, anhydrite veins as fine grains closely associated with chalcopyrite. The chalcopyrite grains are frequently replaced (Fig. 7 n) by it and chalcocite.

Cubanite occurs accidentally and shows intergrowth relations with the chalcopyrite. Within chalcopyrite two or three fine lamellae with parallel disposition have been noticed (Fig. 7 m).

Gold has been encountered only as four fine grains (Fig. 7) (0.01 mm) in quartz with pyrite and chalcopyrite veins from the potassic alteration zone.

Sphalerite and galena are minor constituents of the ore and are mainly associated with quartz anhydrite and anhydrite veins. They are common minerals in the anhydrite veinlets of the argillic zone (Pl. I, Fig. 7 e).

Molybdenite appears accidentally as fine films and veins. It is frequently associated with quartz, chlorite, chalcopyrite and pyrite.

Fe-Ti oxides consist of magnetite partly converted into hematite and maghemite ; specular hematite does also occur. Magnetite occurs as disseminations and vein fillings (Pl. II) (1—20 mm) in all rock types, hornfelses included ; most of the magnetite bulk appears in the potassic zone, the propylitic zone and generally in those parts lacking in sulphide and abounding in chlorite, albite and anhydrite. The microscopic study shows that magnetite appears 1) as isolated grains or fine aggregates resulted from altered hornblende, when accompanied by hematite and rutile and 2) as fine, compact and frequently monomineral aggregates in vein fillings ; rarely it is associated with a minor amount of pyrite and/or chalcopyrite (Pl. II, Fig. 1). The magnetite grains show anhedral and rarely subhedral boundaries. Rather frequently magnetite is partly replaced by maghemite and hematite. This replacement is progressive from the margins to the center of grains. (Fig. 7 a, b, e-g ; Pl. II, Fig. 2, 3) ; rarely this replacement was total (Fig. 7 c). Specularite was remarked as medium to large tablets in the anhydrite chalcopyrite veins at the lower part of the propylitic veins.

Rutile is a common mineral in the Voia region ; it has been encountered in all assemblages obtained by the replacement of hornblende phenocrysts and also in some quartz and pyrite veins from all alteration zones. The rutile grains show anhedral and subhedral boundaries (Fig. 7 p).

Common secondary minerals are bornite, chalcocite and goethite.

*Late alteration and mineralization*

The late alteration and mineralization are characterized by abundant pyrite and strong argillic alteration. Pyrite quartz veins, pyrite clay minerals ± Au and pyrite base metal sulphosalt-anhydrite (gypsum)-Au veins with argillic haloes, in the peripheral zones of the copper ore, pyrite mineralizations and subvolcanoes (Fig. 2, 3) are the major products of this late environment.

There is a good general correlation between the abundance of pyrite and the intensity of the argillic alteration. The late alteration and mineralization seem to follow the contact between the dyke of hornblende ± biotite quartz andesite and the rocks of the subvolcano (Fig. 2) ; it also appears outside the subvolcano.

The base metal-sulphosalt-anhydrite veins at Voia represent a peculiar case of the Tertiary structure in our country. This type of mineralization shows a vertical zonality : pyrite-gypsum ± base metals-sulphosalt-clay minerals ± Au at the upper part 100 m below the surface and base metal-sulphosalt anhydrite-Au veins at depth (Berbeleac, 1981).

## Final remarks

The Voia porphyry copper deposit is related to calc-alkaline differentiated Tertiary intermediate intrusions (quartz andesite, quartz porphyry diorite) in a subvolcano structure. The deposit occurs on the central western margin of the subvolcano body where multi-impulsive intrusions took place. It is up to 350 m long and 250 m wide and has been drilled over a vertical extent of 250—300 m. The primary mineralization is largely vein and fracture filling with some dissemination of chalcopyrite, pyrite, magnetite, which are ubiquitous together with minor amounts of bornite, chalcocite, molybdenite, hematite, maghemite, rutile, sphalerite, galena, cubanite, gold and sulphosalts. A regular alteration/mineralization zoning accompanies the primary body : potassic alteration in central core with highest grade copper mineralization and abundance of quartz sulphide and Fe-oxides veinlets ; the propylitic alteration in upper position with heavy Fe-oxides mineralizations and poor in sulphide (chlorite, anhydrite, magnetite-hematite ± pyrite-chalcopyrite veins), followed by argillic alteration, reaches the pyrite dissemination and anhydrite (gypsum), pyrite (marcasite) veinlets. All these alteration/mineralization types belong to the early stage. In contrast with it, the late alteration/mineralization stage is characterized by the same type of alteration with the remark that the potassic and argillic zones are less representative and the mineralization consists, mainly, of base metal-sulphosalt-anhydrite-Au veins. This type of mineralization occurs in marginal position as compared to the copper deposits and the subvolcano body (Fig. 3 b).

The irregular discontinuous structure of the very early quartz veins suggests fracturing as possible in the case of a plastic rather than a brittle rock. The early stage assemblages (silicates, sulphides and anhydrite) of veins and their haloes must have formed very shortly after the consolidation of porphyry intrusions. According to Gustafson and Hunt (1975) the temperature and pressure of metallogenetic processes were initially very close to those of final consolidation of intrusives (500—700°C and 600—1000 bars; 2 km deep), then this goes down to 300°C.

The late mineralization is much more obviously controlled by fractures than the early one. Late patterns of alteration and mineralization were strongly influenced by the hornblende $\pm$ quartz andesite dykes, which were the main source of heat during late mineralization. According to the above mentioned authors, the late assemblages must be formed in the conditions of low temperature (200—300°C) and pressure (100—200 bars).

The genetic model of the Voia porphyry copper deposit displays some features similar to other Tertiary deposits in Romania (Roșia Poieni, Olga Ionescu et al., 1975; Ianovici et al., 1977; Musariu and Valea Morii, Borcoș and Berbeleac, 1984), and other countries (El Salvador — Chile, Gustafson and Hunt, 1975; Marcopper — Philippines, Loudon, 1976; Papua — New Guinea; Sabah and Puerto Rico, Sillitoe, 1979). The common features consist in the mineral assemblages of the potassic and propylitic alteration and mineralization zones and the position of potassic zone within the central core of the deposit. The presence of the propylitic zone adjacent to the potassic zone and the fact that the copper mineralization occurs within the potassic and partly in the propylitic assemblages allow us to remark that the Voia porphyry copper deposit has some affinities with the dioritic model (Hollister, 1975; Vlad, 1981). Other features such as: albite, magnetite and pyrite in veinlets, insignificant amount of bornite, important dissemination of chalcopyrite, the presence of the gold stockwork structure and the island arc volcanic rocks (andesite, diorite) are also very common for the dioritic model. However it is important to note that the envelope of argillic alteration which underlies the propylitic alteration and the existence of an important sulphate zone, partly in connection with the early alteration and mineralization stage, are the most important peculiarities of the Voia porphyry copper deposit. The mineral assemblages from the propylitic hornblende, biotite, quartz andesite (Săcărîmb type) and hornblende quartz andesite (Barza type?) show no significant qualitative difference. But, in comparison with the regional autometamorphic propylisation of some andesitic veins of the Voia area, where albite and epidote are absent, while feldspar and biotite are generally fresh, the hydrothermal propylitic rocks show a great diversity of feldspar and mafic minerals alteration and albite and in some cases epidote are very characteristic. The peripheral position of the argillic zone is difficult to explain; it is possible to have formed partly synchronous with the potassic assemblages, as a result of profound changes in composition and thermodynamic conditions in the frontal part of the fluid flow. Except for the sulphate zone, which is absent, only the two known Tertiary Valea Morii and Musariu porphyry copper deposits (Borcoș, Berbeleac, 1984) are similar with this. That is why we propose to assign the model of the Voia porphyry copper deposits to the Barza porphyry copper type of the Metaliferi Mts (Borcoş, Berbeleac, 1984).

As regards the sulphate zone it is worth emphasizing that it appears starting with 150—200 m below the surface (Berbeleac, 1981) and the anhydrite, like in the case of the El Salvador porphyry deposit (Gustafson, Hunt, 1975), is one of the most common minerals of the entire history of the Voia mineralization ; it appears in both early and late products of the alteration and mineralization stage. The supergene removal of anhydrite (gypsum) increases the porosity of rocks and the sulphate zone lies below the supergene enrichment blanket. According to Norton (1972) the principal causes of anhydrite precipitation are : "1) interaction of calcium-poor acid-sulphate hydrothermal solutions with igneous rocks ; 2) reaction of hydrothermal fluids to increasing temperature ; 3) decreasing the temperature from 450°C to 200°C of a solution of a certain composition and 4) evaporation of $H_2O$ from solution by boiling the hydrothermal fluid". The condition of the multi-impulse volcanic and metallogenetic activity in the Voia region suggests a possible action of one or more of these factors. It shold be also noted that the anhydrite is a result of the deposition from the solution containing a low $Ca^{++}$ concentration and a high $SO_4^{2+}$ and hydrogen ion concentration, which reacts with calcium-bearing rocks (andesite, sandstone, marl etc.). The existence of sulphate in potassic, propylitic and argillic zone allows us to remark a low interval in the history of solutions favourable for their deposition.

The Voia genetic model, like other Tertiary porphyry copper deposits in Romania (Vlad, 1981) shows a polyascending feature of alteration and mineralization processes. That can be seen after the rock textures, types of veining and mineral assemblages as well as the general evolutionary trend of the volcanic and metallogenetic activity.

The presence of gold as by-product within the Voia porphyry copper body is in agreement with the ideas of Titley (1978) and Sillitoe (1979) about the porphyry copper of island arc belts. According to these authors it is generally true that the deposits generated in island arcs tend to be richer in gold and poorer in molybdenum than those of continental margin orogens. It is also true that much gold is native, fine-grained (10 to 30 $\mu$) and only very little is intergrown with sulphides. Gold grades increasingly in potassic alteration and seems to be directly proportional with the copper content. All these features have been described by Borcoş and Berbeleac (1984) for the Valea Morii and Musariu copper bodies and presumably other Tertiary deposits of the Metaliferi Mts are similar.

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## QUESTIONS

I. Seghedi : How do you explain the potassic type alteration in the lower part of the Voia structure (see the model) of the Barza type andesite which you consider of a later age in the intrusion succession ?

*Answer :* The alteration/mineralization process is polyascending in character, therefore they continued after the emplacement of the quartziferous andesite with hornblende (Barza).

S. Boştinescu : The propylitic alteration facies is presented as a term of the zonality of transformations associated with the Voia subvolcanic body, situated between the potassic silicate facies and the argillic one.

I am interested to know what structural or paragenetic differences have been noticed between the propylitization proper to the subvolcano and the one that regionally affects the Tertiary volcanites of the Metaliferi Mts ?

*Answer :* The propylitization noticed in the subvolcano belongs to the hydrothermal alteration type specific of the mineralization process. As far as the regional propylitization is concerned, we mention its anterior character and its development under other structural and physico-chemical conditions.

C. Chivu : 1. In the last few years a series of subvolcanic intrusions of porphyry copper structures have been identified in the Metaliferi Mts. Do they not lead to the existence of a batholite at depth — as Ghiţulescu says ? What do you think ?

2. Can we speak of an optimum level of mineralization-covering the structures known in the Metaliferi Mts ?

*Answer :* 1. The presented structure belongs to a subvolcano and it is not associated with a batholite.

2. The copper mineralization is at a level lower than the cover of the subvolcano and of other situations known in the Metaliferi Mts.

R. Jude : 1. What relations are there between the Săcărîmb andesite and the intrusion appreciated as "Barza andesite" ?

2. Couldn't the paragenesis with oxides be separated from the sulphides generations for the explanation of the geochemical evolution of the mineralizing sulphides ?

*Answer :* 1. The andesite associated with the Barza type divides the andesite assigned to the Săcărîmb type.

2. In this paper the geochemistry of the solutions is only mentioned. Function of its type, it will be dealt with in another paper.

G. Udubaşa : Do you think the mineral deposited in a long span of time, longer than several breccification moments, form several "generations" of the same mineral ?

*Answer :* The polyascending character of the mineralization/alteration makes us think we are in the presence of several generations of the same mineral.

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## EXPLANATION OF PLATES

### Plate I

Fig. 1. — Thermic and hydrometasomatic products. a) metasomatic pyrite (py) and anhydrite (an) in quartz andesite (α). Core no. 9, borehole m 693 ; b) albite (ab)-epidote (ep) hornfels. Core no. 1, borehole m 594 ; c) hydrometasomatic pyrite (py), anhydrite (an) and clay minerals (c.m) depositions in hornfels. Core no. 1 borehole m 614 ; d) Fe-Ti oxides veinlets in propylitic quartz andesite // Nic. 40×, core no. 3, borehole m 753.

Fig. 2. — Sets of veinlets. a) magnetite-hematite veinlet ± pyrite-chalcopyrite in quartz andesite (α). Core borehole no. 9, m 1150 ; b) plane of chlorite, anhydrite, quartz and chalcopyrite veinlet. Core borehole no. 9, m 1029 ; c) hornfels enclave with quartz (q), K-feldspar (k-fds), anhydrite (an) and magnetite (ml) in quartz andesite. Core borehole no. 9, m 977 ; d) generations of quartz-pyrite ± chalcopyrite veinlets in argillic quartz porphyry diorite. Core borehole no. 9, m 1074 ; e) anhydrite (gypsum)-pyrite veinlet cutting the anhydrite-base metal sulphide (an.b.s). Core borehole no. 7, m 408.

Fig. 3. a, b — quartz andesite with quartz-pyrite ± molybdenite vein brecciated and intersected by anhydrite pyrite veins ; a) core borehole no. 9, m 756 ; b) borehole no. 1, m 594 ; c) anhydrite-base metal sulphide (b.s)-tetrahedrite-Au vein. Core borehole no. 9, m 645 ; d) anhydrite (gypsum) vein within quartz andesite (α). Core borehole no. 9, m 668.

Fig. 4. — Pyrite-chalcopyrite aggregates in quartz, // Nic. 40× ; borehole no. 9, m 995.

## Plate II

Fig. 1. — Quartz vein with magnetite, pyrite and chalcopyrite aggregates, // Nic, 40× ; borehole 9, m 910.

Fig. 2. — Substitution of magnetite by hematite and maghemite, // Nic, 40× ; borehole 9, m 954.

Fig. 3. — Substitution of magnetite by maghemite, // Nic, 40× ; borehole 9, m 1120.

Fig. 4. — Cementation texture — quartz grains in chalcopyrite, // Nic, 60× ; borehole 9, m 1175.

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2. ZĂCĂMINTE

# DATE NOI PRIVIND LITOSTRATIGRAFIA ȘI METALOGENEZA PĂRȚII DE NORD A MUNȚILOR FĂGĂRAȘ [1]

DE

CRISTUDOR CHIVU [2]

*Syngenetic mineralizations. Volcano-sedimentary mineralization. Lithostratigraphy. Palynology. Metamorphites. Poiana Neamțului Series. Cumpăna Series. Green schists facies. Amphibolic facies. South Carpathians — Supragetic domains — Făgăraș Mountains.*

## Abstract

*New Data on the Lithostratigraphy and Metallogenesis of the Northern Part of the Făgăraș Mountains.* On the basis of palynological determinations correlated with lithological, structural-tectonic and metallogenetic elements, the metamorphites of the northern and north-western part of the Făgăraș Mountains have been separated in the Poiana Neamțului series, in green schist facies and the Cumpăna series, in amphibolic facies respectively. Between these units there are overthrust tectonic relations. The mineralizations with syngenetic (sedimentary and volcano-sedimentary) character are also described.

Datele pe care le prezentăm se referă la metamorfitele din partea de nord și nord-vest a munților Făgăraș, între valea Moașei (valea Avrigului la vest și valea Laita la est), cu trimiteri și mai la est, în bazinele Cîrțișoara, Arpășel și Arpașu Mare.

Prezenta lucrare cuprinde o parte din rezultatele obținute prin lucrările de prospecțiuni și de sinteză geologică, efectuate în perioadele 1965—1970 și respectiv 1980—1981.

[1] Depusă la 5 iunie 1982, acceptată pentru comunicare și publicare la 14 decembrie 1982, comunicată în sesiunea științifică a Întreprinderii de Prospecțiuni Geologice și Geofizice din 27 aprilie 1982.

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

## Cercetări geologice anterioare

În munții Făgăraș, s-au executat numeroase cercetări geologice din care amintim : Reinhard (1911), Cantuniari (1926) ; Streckeisen (1934) și Ghica-Budești (1940) care au separat trei serii : Poiana Neamțului, Făgăraș și Cumpăna.

După anul 1950 s-au intensificat cercetările geologice în diverse perimetre ale unității, avind mai ales caracter de prospecțiune. Arion et al. (1969, 1970), Pitulea (1969, 1979) au efectuat lucrări de cercetare la vest de valea Avrigului și respectiv la est de valea Viștea Mare. Diverse studii mineralogice, petrologice și structurale au fost realizate de Dimitrescu (1958, 1967, 1978) ca și unele considerații genetice asupra mineralizațiilor din zonele Arpașu și Porumbacu, Giușcă et al. (1973) au prezentat o succesiune petrografică a rocilor cristalofiliene din partea centrală a masivului. Considerații geochimice asupra rocilor amfibolitice din partea de nord-vest a masivului au fost efectuate de Mareș, Mareș (1979) și Dimofte (1969).

Savu et al. (1976) și Kräutner et al. (1980) au elaborat lucrări de sinteză asupra Carpaților Meridionali și respectiv a întregului edificiu cristalin din România — care a fost divizat în Carpian și Marisian. Șisturile cristaline din munții Făgăraș au fost incluse în Carpian (Proterozoic mediu).

## Litostratigrafia și petrografia

Stabilirea succesiunii litostratigrafice din masivul Făgăraș a fost abordată de mai toți cercetătorii care au efectuat lucrări în această unitate, formulînd diverse scheme — argumentate fie pe baza unor criterii structural-tectonice și petrografice, fie de metamorfism.

Este cunoscut faptul că în acest masiv au fost separate în general două sau trei serii metamorfice și anume : seria de Poiana Neamțului, seria de Făgăraș și seria de Cumpăna (Ghica-Budești, 1940). În ultimul timp s-a renunțat la seria de Poiana Neamțului, fiind inclusă în cea de Făgăraș (Dimitrescu, 1978 ; Savu et al., 1976 ; Kräutner et al., 1980).

Observațiile geologice pe care le-am efectuat în această parte a masivului, au condus la obținerea unor elemente de ordin geologic, structural-tectonic și palinologic, care aduc date noi la imaginea succesiunii litostratigrafice și referitor la componența seriilor metamorfice cunoscute.

### *Seria de Poiana Neamțului-Bîlea*

Metamorfitele de temperatură scăzută care aflorează în linii mari pe versantul nordic al masivului pînă la contactul cu depozitele sedimentare neogene ale bazinului Transilvaniei, prin elemente de litologie, tectonică și de metalogeneză se individualizează ca o unitate care a avut o evoluție independentă în raport cu seria de Cumpăna.

*Formaţiunea de Tunsul.* Petrografic, în arealul luat în discuţie, în imediata apropiere a cristalinului cu depozitele sedimentare, se poate separa o formaţiune slab metamorfică cu caracter predominant sericito-cloritos, filitos, în compoziţia căreia se mai recunosc şisturi cuarţito-cloritoase ± muscovit, şisturi cuarţitice cu grafit, roci cuarţo-feldspatice, adesea cu un caracter magmatogen (metatufuri acide) cu dezvoltare mare spre est (valea Cîrţişoara-valea Arpăşel) şi roci carbonatice. Ca mici intercalaţii în diverse puncte (valea Tunsului, valea Mare, valea Ursoiţa) apar şisturi cuarţito-sericitoase cu biotit fin lamelar, ce presupune existenţa unor condiţii locale PT mai ridicate, ce au dus la apariţia sporadică a biotitului, în rocile pelitice-argiloase mai ales, prin transformarea cloritului sau a muscovitului. Rocile acestei formaţiuni se caracterizează printr-un evident caracter elastic ca şi un grad ridicat de faliere. Seria de Poiana Neamţului-Bîlea are extensiune mare spre est (valea Cîrţişoara-valea Arpaşu Mare), iar în partea vestică aria se îngustează mult pînă în valea Munteanului, unde dispare după o linie orientată nord est-sud vest, suportînd tectonic partea inferioară a formaţiunii de Bîlea reprezentată prin şisturi clorito-micacee ± almandin şi nivele de roci bazice, între pîrîul Fîntînele şi valea Munteanului, la est de valea Avrigului-Poiana Neamţului. Minerale stabile în această zonă sînt : cloritul, sericitul (muscovitul) şi grafitul.

*Formaţiunea de Bîlea.* În continuitate de sedimentare şi de metamorfism se dezvoltă pe spaţii largi o alternanţă de roci terigene, vulcanogen-bazice şi roci carbonatice. Aceste roci au extindere mare în bazinele văilor Avrigului, Sărata, Porumbacu Mare, Tunsul, Laita. La est de valea Laita se dezvoltă şi mai puternic, depăşind creasta principală, între vîrful Paltinul şi vîrful Capra.

Constituţia petrografică este deosebit de complexă, se remarcă participarea unui material vulcanogen-bazic, reprezentat prin nivele de şisturi clorito-epidoto-amfibolice, şisturi cloritoase cu porfiroblaste de albit, şisturi amfibolice ± biotit, adesea cu evidente structuri şi texturi relicte eruptive (curgeri de lave şi piroclastite), cu grosimi uneori destul de mari, între valea Lişcovului-valea Munteanului şi în cursul superior al bazinelor Cîrţişoara, Arpăşel şi Arpaşu Mare. Participarea materialului vulcanogen-bazic, uneori dominantă, sugerează caracterul de eugeosinclinal al bazinului în care au evoluat sedimentele din care au rezultat aceste metamorfite. Activitatea magmatică s-a dezvoltat probabil pe un sistem fisural, concomitent cu subsidenţa bazinului.

Faciesul carbonatic este bine reprezentat atît în sectorul dintre valea Avrigului-valea Laita, cît şi mai la est, între valea Cîrţişoara şi valea Arpaşu Mare, unde apar nivele sau lentile de calcare şi calcare dolomitce. Cele care apar în valea Mare (Porumbacul) sînt fragmentate sau dispar, după importante fracturi orientate nord-nord vest — sud-sud est, în valea Porumbacului, la vest şi respectiv valea Tunsului, la est.

La vest de valea Porumbacul, nivelul de roci carbonatice este deplasat mult spre nord-nord vest, corelîndu-se cu cele din Poiana Neamţului-Faţa Varului, unde se înscriu în axul unei structuri perianticlinale, cu căderi vestice, fiind acoperite de şisturi cuarţito-clorito-muscovitice. Acestea la rîndul lor, suportă tectonic metamorfite cu staurolit și disten (complexul de Șerbota — seria de Cumpăna).

În zona centrală calcarele cristaline îmbracă un caracter marmorean, aspect ce se menține doar în Rîul Mare. Lateral se trece la faciesuri mai fin granulare, vinetii-negricioase, de calcare dolomitice și șisturi calcaroase ± grafit (pîrîul Bonții). Frecvent calcarele cuprind intercalații subțiri de șisturi clorito-muscovitice, șisturi cuarțito-cloritomicacee, șisturi biotitice piritizate, șisturi muscovito-talcoase, șisturi grafitoase și șisturi clorito-amfibolice.

Aceeași imagine geologică o întîlnim și în bazinul Avrigului, cu specificarea că rocile carbonatice din această zonă au un grad mai accentuat de fisurare-tectonizare.

În afară de calcare albe marmoreene cu muscovit, din rîul Mare, se recunosc și varietăți echigranoblastice cu caracter dolomitic.

Paragenezele care definesc stadiul metamorfic atins de aceste roci, sînt : calcit-dolomit-cuarț-muscovit, calcit-muscovit-biotit-cuarț și dolomit-talc-muscovit-almandin.

În concluzie, șisturile cristalofiliene din această formațiune (a rocilor carbonatice și a celor magmatogene bazice de Bîlea), au caracter microblastic, uneori filitic și s-au metamorfozat în faciesul de șisturi verzi, cuprinzînd și subfaciesul cu almandin.

În opinia noastră, relațiile dintre această serie, mai nouă, pe care am denumit-o de Poiana Neamțului-Bîlea (cu cele două formațiuni — la partea superioară formațiunea de Tunsul și, respectiv, la partea inferioară formațiunea de Bîlea), și seria de Cumpăna reprezentată prin formațiunea de Șerbota, sînt de natură tectonică (Chivu, 1970).

*Seria de Cumpăna*

În clasificarea pe care o propunem, seria de Cumpăna cuprinde numai metamorfite în faciesul amfibolitelor, caracterizate prin asociații cu staurolit și disten (partea superioară), iar gnaisele de Cozia și de Cumpăna ar reprezenta partea inferioară a acesteia.

În zona Șerbota-Porumbăcel, seria de Cumpăna este reprezentată doar prin formațiunea de micașisturi și paragnaise cu staurolit și disten (de Șerbota) fiind în raporturi tectonice cu seria de Poina Neamțului-Bîlea, uneori de încălecare (valea Avrigului-valea Moașei-valea Sebeșului) de la sud către nord. Ca elemente mineralogice caracteristice pentru acest complex sînt staurolitul și distenul, uneori cu participare ridicată, alături de care, mai notăm : biotit, muscovit, cuarț, almandin, plagioclaz. Accesoriu menționăm apatitul, ilmenitul, zirconul și turmalina. Biotitul are frecvente incluziuni de ortit, cu aureole paleocroice radioactive. pleocroice

De regulă, aceste metamorfite sînt puternic tectonizate, diaftorizate. Procesele retromorfe sînt mai accentuate în această zonă (valea Șerbota-vîrful Scărița-valea Avrigului) ce se corelează și cu linia tectonică majoră trasată în raport cu cele slab metamorfozate ale seriei de Poiana Neamțului. Stadiul metamorfic atins de aceste roci este relevat de prezența distenului, adesea larg dezvoltat și neorientat. Compoziția complexului este întregită de amfibolite ca nivele și intercalații, semnalate mai ales, în vîrful Scărița, uneori cu mult almandin. Cadrul geologic în care se dezvoltă, exprimă în majoritatea cazurilor o natură „para“, întrucît se pot urmări pe distanțe apreciabile, în alternanță cu micaşisturi şi paragnaise, cît şi prin lipsa în compoziția lor, a unor elemente relicte magmatice.

*Procese retromorfe*

Procese de retromorfism se recunosc în ambele serii metamorfice, dar cu o distribuție şi intensitate destul de inegală. În şisturile cristaline ale seriei de Poiana Neamţului-Bîlea, în sensul definit de noi, au o dezvoltare relativ redusă, biotitul şi granatul sînt parțial cloritizate. Mai ales la partea superioară predomină fenomenele mecanice rupturale, reprezentate prin milonitizări. Lamelele de sericit sînt torsionate, dispuse adesea după 2 plane *S* mai noi în raport cu cel inițial. Dezvoltarea porfiroblastică a muscovitului, pe care o întîlnim în unele tipuri de roci din formațiunea inferioară — de roci carbonatice şi magmatogene bazice de Bîlea —, este consecința aceloraşi procese retromorfe în care au fost implicate şi soluții cu caracter metamorfic.

Rocile slab metamorfozate sint slab afectate de modificări mineralogice prin procesele diaftoritice, care nu justifică interpretarea după care, principala masă cloritoasă din compoziția acestora este de neoformație. Studiul efectuat pe un număr mare de secțiuni arată în mod evident caracterul primar al cloritului, din care adesea se formează lamele de biotit. În zonele cu un grad de metamorfism mai avansat, modificările mineralogice sînt mai accentuate, fiind remarcate de transformarea puternică a biotitului, almandinului şi periferic a silicaților de aluminiu (staurolit, disten) în clorit şi sericit. Pe contactul dintre cele două serii, în valea Şerbota, a fost recunoscut şi cloritoidul care ia naştere pe seama distenului, fără a fi orientat, invocînd deci un moment de relaxare tectonică în timpul evoluției acestor procese retromorfe. Acest aspect este susținut şi de recristalizarea frecventă a rocilor milonitizate, însoțite deci şi de fenomene de blasteză (blasto-milonite). Se poate aprecia că intensitatea proceselor diaftoritice scade treptat spre nord şi sud, pe măsură ce ne îndepărtăm de contactul tectonic major semnalat. Datele prezentate mai sus vin în sprijinul ipotezei potrivit căreia aceste metamorfite, considerate anterior ca epizonale datorită unui retromorfism, constituie o unitate litologică cu evoluție independentă, metamorfozată regional la nivelul faciesului de şisturi verzi de tip barrovian şi ulterior a fost supusă unor procese retromorfe.

*Vîrsta metamorfitelor*

În lucrările anterioare, cristalinul Făgăraşului a fost considerat în linii mari ca fiind de vîrstă precambriană (Dessila-Codarcea, 1968; Savu et al., 1976; Kräutner, 1980). Subliniem totuşi că Dimitrescu (1978), pe baza unor determinări palinologice efectuate de Sofia Lută pe probe colectate din valea Albotei, citează următoarele forme: *Kildinella hyperboreica, Stictosphaeridium tortulosum, Synsphaeridium sa-*

*rediforme* şi *Trachysphaeridium* sp., forme care indică Precambrianul terminal cu posibilitatea de a trece în Cambrianul inferior. Cum elemente microfloristice specifice Cambrianului nu au fost identificate, autorul atribuie Precambrianului o mare parte din cristalinul Făgăraşului, mai puţin seria de Cumpăna şi apreciază că prima fază de metamorfism ar fi cadomiană.

Lucrările recente pe care le-am efectuat în partea de nord-vest şi nord ale masivului, aduc precizări privind vîrsta acestor metamorfite. Din rocile slab metamorfozate (filite, şisturi sericito-cloritoase, şisturi grafitoase etc.), din bazinele văilor Porumbacu şi Porumbăcel au fost studiate palinologic în cadrul laboratorului IPGG (Maria Mărgărit), un număr de 30 probe. S-a realizat astfel, un profil pe valea Mare (Porumbacul), de la contactul cu depozitele sedimentare pînă în valea Sărătii, nu departe de limita cu formaţiunea de Şerbota (micaşisturi şi paragnaise cu staurolit şi disten). Exemplarele determinate sînt reprezentanţi ai grupei *Acritarcha* Evitt, în majoritate de tip Sferomorphit — *Trachisphaeridium myalinum* Sin şi Liu, *Protosphaeridium* sp., *Kildinella* sp., *Stictosphaeridium* sp., *Protoleiosphaeridium* cf. *infriatum* Andon, *Microsphaera faveolata* sp., *Microconcentricum induplicata* Lin şi Sin, *Asperatasphosphaera* sp., cf. *Acanthodiacrodium* şi altele, cărora li se adaugă şi exemplare mai evoluate de tipul cf. *Polyedrixium* sp., *Veryhachium* sp., *Veryhachium* cf. *crossum* Iankansas şi *Vartiekumiene*. Din repartiţia stratigrafică a acestor elemente se desprinde concluzia clară că formaţiunile seriei de Poiana Neamţului se plasează la nivelul Proterozoicului terminal (Riphean superior-Paleozoic inferior — Cambrian inferior şi mediu). Pentru vîrsta cambriană pledează îndeosebi genurile *Polyedrixium* şi *Veryhachium*, care îşi încep evoluţia la acest timp. Investigaţiile palinologice au fost continuate şi mai la est, în bazinele văilor : Cîrţişoara, Albota şi Arpaşu Mare, care au pus în evidenţă, de asemenea, elemente microfloristice din grupa *Acritarcha* Evitt, dar unele ceva mai evoluate, din care cităm : *Stictosphaeridium sinapticuliferum* Tim., *Protosphaeridium* sp., *Cymatosphaera* sp., *Poriporretina* sp., cf. *Latoporata* sp., *Polyedrixium* sp., *Acanthodiacrodium* sp., *Archaeohystrichosphaeridium* cf. *minimum* Tim., *Lophosphaeridium* sp., *Veryhachium* sp., *Leiofusa* sp., *Baltisphaeridium primigenium* Tim., (emend.), *Baltisphaeridium* sp. Aceste elemente fitoplanctonice se regăsesc frecvent în asociaţiile ce caracterizează Cambrianul, dar cuprind şi genuri, respectiv specii, care trec în Ordovicianul inferior cum sînt : *Poriporrectina* sp., cf. *Latoporata* sp., *Leiofusa* sp. şi *Baltisphaeridium primigenium* Tim. (emend.). Privind distribuţia acestor elemente palinologice în cadrul seriei slab metamorfozate se poate remarca că de la vest spre est apar termeni din ce în ce mai noi, de la Proterozoic superior (Riphean terminal) la Cambrian-Ordovician inferior, la est de acest sector (valea Cîrţişoara-valea Arpaşu Mare).

## Elemente structurale

În cercetările anterioare cristalinul Făgăraşului a fost interpretat structural în diverse moduri : ca un anticlinal în zona de creastă a masivului, flancat de două sinclinale deversate (Dimitrescu, 1973) ; o structură monoclinală, deversată parţial spre nord (Schuster, 1977) şi ca structură antiformă (Dimitrescu, 1978).

Toate încercările de corelare a diverselor subdiviziuni litostratigrafice separate în acest masiv au devenit nesatisfăcătoare, deoarece nu au luat în considerare evoluţia celor două serii metamorfice (Poiana Neamţului şi Cumpăna) în cicluri orogenice diferite şi deci, cu structuri diferite. După datele palinologice, şisturile cristaline ce aparţin seriei de Poiana Neamţului-Bîlea, s-au cutat şi metamorfozat în orogeneza caledoniană veche (faza sardă), iar cele ale seriei de Cumpăna într-o orogeneză precambriană (preassyntică). În aceste condiţii procesele retromorfe s-au produs probabil mai tîrziu, în ciclul varistic.

Relaţiile dintre cele două serii sînt tectonice, cum deja am menţionat, aspect ce se poate constata mai ales în sectorul vîrful Negoiu-valea Şerbotei-valea Avrigului-valea Moaşei. Avansarea puternică spre nord, începînd de la est spre vest a termenilor seriei de Cumpăna peste seria de Poiana Neamţului-Bîlea, indică raporturi de încălecare. În sprijinul acestei interpretări sînt şi apariţiile de gnaise oculare, conturate în punctul „La Custuri", în aria în care se dezvoltă formaţiunea inferioară de Bîlea, încadrate de şisturi grafitoase.

Ca elemente structurale în seria de Poiana Neamţului se recunosc două plane *S*: un plan $S_1$ care reprezintă şistozitatea de stratificaţie şi un plan $S_2$ — clivajul axial, ce migrează permanent în raport cu $S_1$ de la 0° la 60—70°. Metamorfitele acestei serii se caracterizează de regulă prin forme plicative, cu flancurile strîns microcutate şi vergenţe sud-estice sau nord-estice, cu valori de la 0° la 55°. Spre deosebire de seria de Poiana Neamţului, seria de Cumpăna, care are la partea superioară formaţiunea de Şerbota cu staurolit şi disten, se caracterizează prin forme plicative mai largi şi cu dezvoltare regională.

Pe baza elementelor enunţate se poate stabili următoarea succesiune litostratigrafică (fig. 1): seria de Cumpăna cu formaţiunile de gnaise leucocrate şi oculare, formaţiunea cu micaşisturi de Măgura Cîinenilor şi la partea superioară formaţiunea de Şerbota, cu calcare şi roci amfibolice, metamorfozată în faciesul amfibolitic. În relaţii tectonice, urmează seria de Poiana Neamţului-Bîlea, în care am separat două formaţiuni: la partea inferioară formaţiunea de roci carbonatice şi magmatogene bazice, de Bîlea şi formaţiunea şisturilor sericito-cloritoase de Tunsul la partea superioară, ambele metamorfozate în faciesul de şisturi verzi. Termenul de „Vemeşoaia" folosit anterior de diverşi autori pentru a caracteriza rocile retromorfe este impropriu, întrucît este situat în afara arealului în care se dezvoltă metamorfitele în faciesuri de şisturi verzi, undeva în versantul stîng al văii Oltului. Partea bazală a seriei de Poiana Neamţului este constituită din şisturi cuarţito-cloritomicacee ± almandin, cuarţite cu biotit, şisturi cuarţito-muscovitice şi din unele secvenţe de roci bazice tufogene.

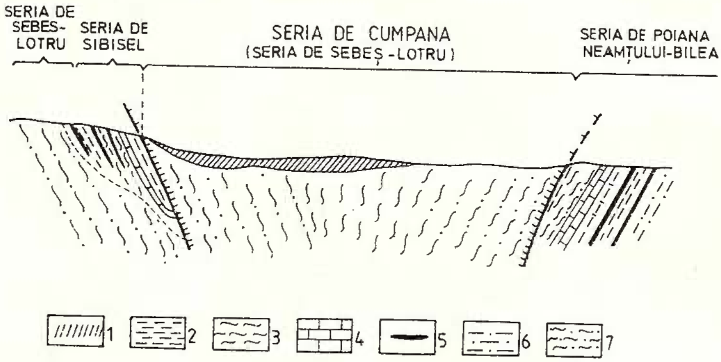


Fig. 1. — Secțiune geologică interpretativă între valea Avrigului și versantul drept al văii Oltului (Boița). 1, Eocen ; 2, șisturi cuarțitice clorito-sericitoase ± muscovitice ; 3, șisturi grafitoase ; 4, calcare, calcare dolomitice ; 5, metabazice ; 6, șisturi clorito-micacee ; 7, micașisturi paragnaise ± almandin ± staurolit ± disten.

Coupe géologique interprétative entre Valea Avrigului et le versant droit de la vallée de l'Olt (Boița). 1, Éocène ; 2, schistes quartzitiques chlorito-sériciteux ± muscovitiques ; 3, schistes graphiteux ; 4, calcaires, calcaires dolomitiques ; 5, métabosites ; 6, schistes chlorito-micacés ; 7, micaschistes, paragneisses ± almandin ± staurolite ± disthène.

## Corelarea seriei de Poiana Neamțului cu seriile din munții Cibin și Sebeș

Așa cum am menționat, relațiile dintre cele două serii, de Poiana Neamțului și respectiv Cumpăna, sînt tectonice, de încălecare, ce se pot urmări mai ales în valea Avrigului-valea Moașa Sebeșului. Asemenea relații de încălecare se cunosc și între seria de Cumpăna și seria de Sibișel, în versantul drept al văii Oltului. În această situație se poate vorbi de o încălecare bilaterală, spre est și vest, cristalinul seriei de Cumpăna încălecînd atît grupul Sibișel (Vendian-Cambrian) spre est, cît și seria de Poiana Neamțului spre est (fig. 2). Seria de Căpîlna-Cărpiniș a fost încadrată în același interval de timp (Chivu, 1974) ca și seria de Poiana Neamțului. Seria de Cumpăna se poate paraleliza cu seria de Sebeș-Lotru, care are la partea superioară o formațiune pelitică cu staurolit și disten asemănătoare cu formațiunea de Șerbota din Făgăraș. Aria orogenezei caledoniene în care s-a cutat și metamorfozat seria de Poiana Neamțului-Bîlea avea o extindere mult mai mare și la est de rîul Olt și a cărei configurație a suferit modificări importante datorită unor procese tectonice ulterioare.

## Metalogeneza

Pînă în anul 1960, erau cunoscute în această regiune, doar mineralizațiile de sulfuri metalice (galenă, blendă, pirotină) din văile Arpașu Mare și Porumbacu (Cantuniari, 1926). După această dată s-au efectuat

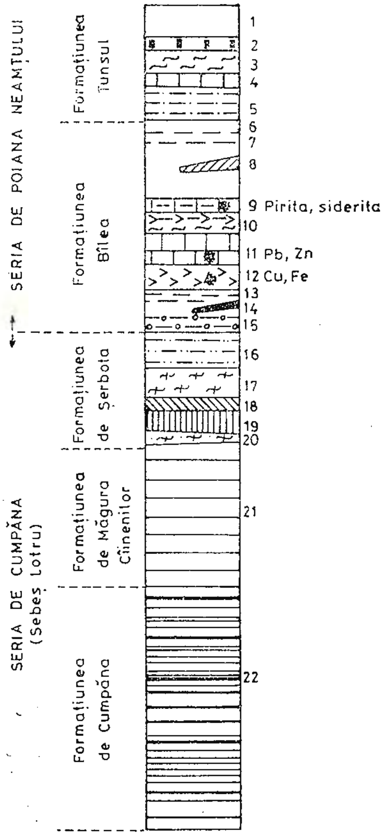


Fig. 2. — Litostratigrafia metamorfitelor din partea de nord și nord-vest a munților Făgăraș : 1 — șisturi sericito-cloritoase ; 2 — metagrauwacke, metatufuri acide ; 3 — șisturi cu grafit ; 4 — calcare ; 5 — șisturi sericitoase ± biotit, fin lowdove ; 6 — șisturi cuarțito-clorito-muscovitice ; 7 — șisturi cuarțito-muscovitice, limonitice ; 8 — cuarțite ± feldspatice ± sulfuri ; 9 — calcare cu siderit ; 10 — șisturi cloritoase tufitogene bazice ; 11 — calcare dolomitice cu galenă și blendă ; 12 — metabazite cu magnetit, pirotină ; 13 — șisturi clorito-micacee ; 14 — cuarțite cu biotit ; 15 — șisturi micacee cu almandin ± clorit ; 16 — micașisturi cu staurolit ; 17 — paragnaise cu staurolit ; 18 — cuarțite negre ; 19 — amfibolite ± biotit ± almandin ; 20 — paragnaise cu disten ± staurolit ; 21 — micașisturi, paragnaise ; 22 — gnaise oculare, gnaise leucocrate.

Lithostratigraphie des métamorphites de la partie nord et nord-ouest des monts Făgăraș : 1, schistes séricito-chloriteux ; 2, métagrauwackes, métatuffs acides ; 3, schistes à graphite ; 4, calcaires ; 5, schiste séricitеux ± biotite, finement lowdove ; 6, schistes quartzito-muscovitiques, limonitiques ; 8, quartzites ± feldspathiques ± sulfures ; 9, calcaires à sidérite ; 10, schistes chloriteux, tuffitogènes basiques ; 11, calcaires dolomitiques à galène et blende ; 12, métabasites à magnétite, phyrrhotite ; 13, schistes chlorito-micacés ; 14, quartzites à biotite ; 15, schistes micacés à almandin ± chlorite ; 16, micaschistes à staurolite ; 17, paragneisses à staurolite ; 18, quartzites noires ; 19, amphibolites ± biotite ± almandin ; 20, paragneisses à disthène ± staurolite ; 21, micaschiste, paragneisses ; 22, gneisses oculaires, gneisses leucocrates.

lucrări de prospecțiuni de detaliu care au pus în evidență o serie de ocurențe cu sulfuri în bazinele văilor : Porumbacu, Cîrțișoara, Arpășel, Arpașu Mare și Viștea Mare (Chivu, 1965, 1970), cantonate aproape în totalitate în seria de Poiana Neamțului-Bîlea, atît în rocile terigene, carbonatice, cît și în cele vulcanogen-bazice.

După gradul de participare al elementelor care alcătuiesc asociațiile metalice, fenomenele de mineralizare se pot grupa în : plumbo-zincifere, cuprifere și acumulări de fier.

*Mineralizații plumbo-zincifere.* Apar în bazinele văilor : Porumbacul, Doamnei, Cîrțișoara și Arpașu Mare. Cele din valea Porumbacu sînt localizate în parte inferioară a nivelului de calcare și calcare dolomitice cristaline, sub formă de cuiburi de galenă și blendă. Deasupra acestora apar șisturi cuarțito-cloritoase cu biotit, impregnate cu pirită și slab calcopirită, adesea limonitizate. Grosimea totală a zonei variază în general de la 0,30 m la 3 m, cu conținuturi de Pb = 0,30—0,65% și Zn = 0,50—1,5% și numai accidental valori mai ridicate de pînă la 9%. Mineralizații similare apar în valea Doamnei și Arpașu Mare, care spre deosebire de cele din Porumbacu cantonate numai în calcare dolomitice, în acest sector se regăsesc la diverse nivele litostratigrafice asociate și rocilor terigene, cum sînt cele din Piatra Dracului și Arpașu Mare (cursul median) (impregnații în șisturi cuarțitice și cuarțite cu clorit și muscovit). Grosimea zonelor cu sulfuri variază de la 0,20 m la 4,00 m conținuturile în Pb, de la 0,3—1% și cele de Zn de la 0,65—2%. În zona Arpașu Mare-sud, mineralizația se prezintă și ca șlire milimetrice sau filonașe ce străbat masa calcarelor, fără a depăși cadrul acestora. Depunerile sînt concordante cu rubanarea acestora, controlul litologic-stratigrafic este evident.

*Mineralizații cuprifere.* Asemenea mineralizații au fost identificate în bazinele văilor Porumbacu, Cîrțișoara și Arpașu Mare. În valea Mare (Porumbacu), în versantul stîng, la cca 100 m în aval de pîrîul Bonții, apar impregnații de calcopirită și pirită în șisturi cuarțito-muscovitice, pe cca 2 m grosime. Direcțional zona a fost urmărită pe cca 300 m cu lucrări miniere și de foraj. Conținuturile obținute sînt relativ mici, între 0,3 și 0,9% Cu. Zona se recunoaște după fenomenele de alterație supergenă remarcate prin : limonitizări, malachitizări și circulații carbonatice localizate strict în acest nivel.

Mineralizații cuprifere au fost întîlnite și în partea inferioară a formațiunii de roci carbonatice și magmatogene bazice, în pîrîul Puha și sub vîrful Negoiu, în roci amfibolice ca impregnații de calcopirită pe grosimi de 1—2 m. Cele mai interesante ocurențe cuprifere sînt cele cunoscute din bazinul superior al văii Arpașu Mare. Aici apar diseminări, filonașe și depuneri compacte de calcopirită și pîronită ± galenă, în gangă de cuarț și carbonați concordante cu șistozitatea. Sînt localizate în șisturi cuarțito-muscovitice, intercalate în nivele de roci bazice tufogene și de șisturi cu grafit. Grosimea zonei variază de la 0,30 la 3,50 m. Urmărirea pe direcție este extrem de dificilă din cauza afundării structurii cristalinului spre est-nord est, cu valori de la 35° la 55°.

*Geneza mineralizației.* Urmărind distribuția spațială a mineralizațiilor descrise în seria de Poiana Neamțului se constată că acestea se plasează la anumite nivele litostratigrafice, ca impregnații și ca depuneri compacte — lenticular concordante ,cu un control litologic evident. Astfel, se pot corela diverse ocurențe de galenă și blendă sau de calcopirită și pirită, care apar în bazinele Porumbacu, Cîrțișoara și Arpașu Mare, situate într-un anume nivel litologic, fie de calcare dolomitice (Arpașu Mare, Cîrțișoara și Porumbacu) sau de roci terigene. Există o corelare suficient de bună între asociațiile petrografice și cele de minerale metalice. Calcopirită și pirotina apar cu precădere asociate rocilor bazice, iar sulfurile de Pb și Zn, atît în rocile carbonatice cît și în cele terigene. Mineralizațiile au deci un caracter singenetic, cu specificarea că la unele dintre acestea apare mai pregnant caracterul strict sedimentogen, iar la altele — influențele activității vulcanogen-bazice. În funcție de aceste trăsături, mineureurile pot fi grupate în mineralizații sedimentare și vulcanogen-sedimentare, metamorfozate.

## Concluzii

Din datele prezentate se desprind următoarele concluzii : metamorfitele de presiunea medie (de tip barrovian), din partea de nord a masivului Făgăraş, pe baza elementelor de litologie, petrografie, tectonice, palinologice, ca şi cele metalogenetice aproape în totalitate ocurenţele de sulfuri metalice din Făgăraş, exceptînd cele hidrotermale din vestul acestuia, sînt cantonate în seria de Poiana Neamţului şi au un caracter sinegetic, au luat naştere într-un bazin cu caracter de eugeosinclinal care a evoluat în intervalul Riphean superior-Combrian (posibil pînă în Ordovician inferior).

Ţinînd cont de elemntele de vîrstă, cutarea şi metamorfozarea rocilor s-a realizat în orogeneza caledoniană (faza sardă), iar retromorfismul în cea hericinică. Seria de Poiana Neamţului se dezvoltă în marea majoritate în partea de nord a masivului, depăşind creasta principală doar în zona vîrful Paltinul-vîrful Capra, după care spre est se retrage treptat, odată cu avansarea spre nord a seriei de Cumpăna. În aceste condiţii metamorfitele seriei de Poiana Neamţului, sînt larg dezvoltate în partea centrală, (Bîlea, Doamnei, Arpăşel). Lateral se înregistrează avansarea seriei de Cumpăna, uneori cu carcter de şariere evident, aspect susţinut şi de identificarea unor gnaise oculare în plin areal de metamorfite în facies de şisturi verzi. Procesele de încălecare pot fi raportate orogenezei alpine. Minereurile singenetice sînt localizate preponderent în seria de Poiana Neamţului, la diverse nivele litostratigrafice.

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# DONNÉES NOUVELLES CONCERNANT LA LITHOSTRATIGRAPHIE ET LA MÉTALLOGENÈSE DE LA PARTIE NORD DES MONTS FĂGĂRAŞ

## (Résumé)

Les formations métamorphiques qui constituent en majorité les parties nord et nord-ouest des Monts Făgăraş ont été reparties à deux séries : la série de Cumpăna, dans le faciès amphibolique et la série de Poïana Neamţului dans un faciès de schistes verts. La série de Poïana Neamţului contient deux formations : la formation de Tunsul, à la partie supérieure, formée de schistes séricito-chloriteux et la formation de Bîlea, à la patrie inférieure, caractérisée par la large participation des roches basiques et carbonatiques.

À la suite des analyses palynologiques l'âge de la série de Poïana Neamţului a été établi entre le Riphéen et le Cambrien (possiblement jusqu'à l'Ordovicien inférieur) par les formes de *Baltispaerides primigenium* et *Pareparectina* etc. La série de Poïana Neamţului est microblastique par rapport aux roches de la série de Cumpăna (série de Sebeş-Lotru) qui sont largement cristallisés (la zone à distène + staurolite ± almandine la formation de Şerbota). La série de Cumpăna est constituée, selon l'auteur, par la formation de Şerbota, la formation de Măgura Cîinenilor et celle des gneisses léucocrates et oculaires (formation de Cumpăna).

Les relations entre les deux séries sont tectoniques, de chevauchement surtout, par l'avansement marqué, de sud au nord de la série de Cumpăna au dessus de la série de Poïana Neamţului (Vallée d'Avrig-Vallée de Moaşa Sebeşului).

La série de Poïana Neamţului peut être parallélisée avec la série de Căpîlna-Cărpiniş des Monts Sebeş et avec la série de Sibişel des Monts Cibin, datées comme ayant le même âge.

La plupart des minérallisations de la région ont un caractère syngénétique, soit sédimentaire, soit volcanogène-sédimentaire. Les minérais peuvent être groupés en plombo-zincifères (Porumbacu, Arpaşu, Piatra Dracului-Cîrtişoara), cuprifères (Arpaşu Sud, Porumbacu-Pîrîul Bonţii) et de fer (accumulations sidéritiques). Dans la succession lithostratigraphique présentée, la signification de la série de Poïana Neamţului est tout-à-fait différente des opinions antérieures qui considéraient que cette série ne se développe qu'à la limite avec les sédiments néogènes et représenterait des schistes cristallophiliens formés au compte de certaines roches mésométamorphiques par rétromorphisme. On argumente que cette série s'est développée dans le faciès de schistes verts et qu'ultérieurement elle a été diaphtorisée à un autre moment tectonique.

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## EXPLICATION DE LA PLANCHE

Carte géologique de la région de Valea Moaşei (Valea Avrigului-Valea Doamnei) monts Făgăraş du nord et nord-ouest, échelle 1 : 50 000. Légende — Formations sédimentaires : Quaternaire : 1, alluvions ; 2, terrasses ; 3, cônes de déjection ; 4, dépôts glaciaires ; Néogène ; 5, Tortonien ; Formations métamorphiques ; série de Poïana Neamţului (Riphéen supérieur — Ordovicien) — formations des schistes séricito-chloriteux — Tunsul ; 6, schistes séricito-chloriteux, schistes quartzitiques chloriteux ± muscovite ; 7, schistes quartzitiques séricito-graphiteux ; 8, métagrauwackes, métatuffs acides ; 9, schistes quartzitiques blancs, quartzites rubanées ; 10, calcaires, calcaires dolomitiques ; 11, schistes séricito-chloriteux ± biotite, finement granulaires ; formation des roches carbonatiques magmatogènes basiques Bîlea ; zone à chlorite ; 12, schistes quartzito-muscovitiques, phyllites séricito-quartzeuses ; 13, schistes quartzitiques à muscovite, limonitiques ; 14, quartzites blanches violacées, biotitiques ; 15, métabasites ; 16, calcaires et dolomies crystallines ; 17, schistes chlorito-micacés ± almandin ; 18, schistes micacés à almandin — zone à biotite et almandin. Série de Cumpăna (série de Sebeş-Lotru) — Anté-Protérozoïque supérieur) — formations de micaschistes et paragneisses Şerbota ; 19, micaschistes et paragneisses à almandin et staurolite ; 20, micaschistes micacés ; 21, micaschistes à almandin ; 22, amphibolites ± biotite ± almandin ; 23, quartzites amphiboliques ± almandin, quartzites noires ; 24, paragneisses à disthène ; 25, gneisses oculaires — zone à staurolite et disthène ; 26, faille ; 27, ligne de chevauchement ; 28, synclinal ; 29, anticlinal ; 30, foliation ; 31, linéation ; 32, zones minéralisées à sulfures métalliques (Cu, Pb, Zn) ; 33, ligne de profil.

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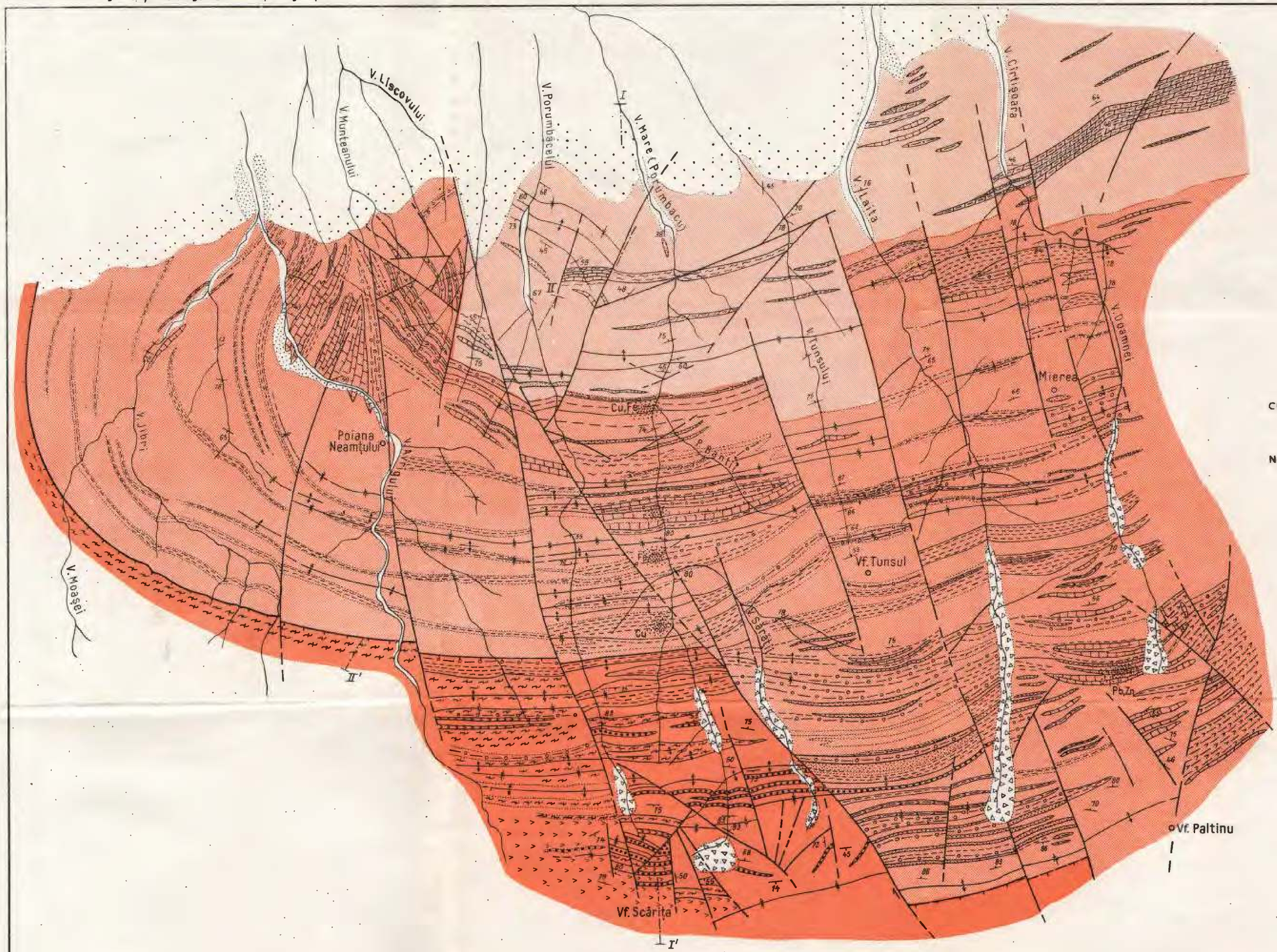



# C. CHIVU
# HARTA GEOLOGICĂ A REGIUNII VALEA MOAŞEI (VALEA AVRIGULUI - VALEA DOAMNEI) MUNŢII FĂGĂRAŞ DE NORD ŞI NORD VEST

0 1 2 Km.

## LEGENDA

### FORMAŢIUNI SEDIMENTARE

CUATERNAR
- 1 — a. Aluviuni, b. Terase
- 2 — c. Con de dejecţie, d. Depozite glaciare

NEOGEN
- 3 — Tortonian

### FORMAŢIUNI METAMORFICE

**Seria de Poiana Neamţului**

RIPHEAN SUPERIOR - ORDOVICIAN INFERIOR

Formaţiunea şisturilor sericito-cloritoase Tunşul (Zona cu clorit)
- 4 — Şisturi sericito-cloritoase; şisturi cuarţitice cloritoase ± muscovit
- 5 — Şisturi cuarţitice sericito - grafitoase
- 6 — Metagrauwacke, metatufuri acide
- 7 — Şisturi cuarţitice albe, cuarţite rubanate
- 8 — Calcare, calcare dolomitice
- 9 — Şisturi sericito - cloritoase ± biotit fin lamelare

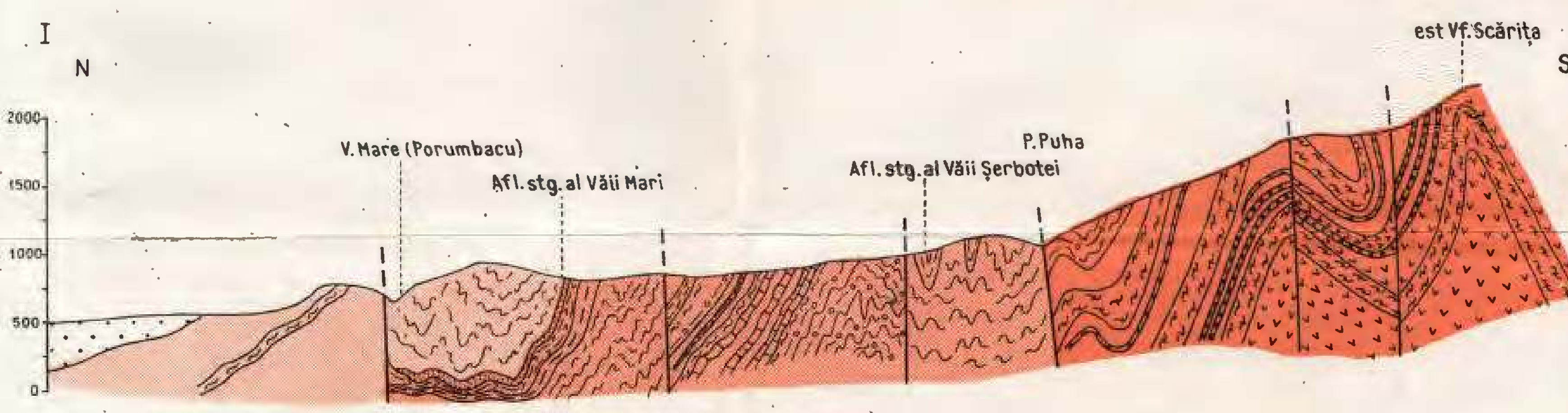
Formaţiunea rocilor carbonatice şi magmatogene bazice Bilea (Zona cu biotit şi almandin)
- 10 — Şisturi cuarţito - muscovitice, filite sericito - cuarţoase
- 11 — Şisturi cuarţitice cu muscovit limonitice
- 12 — Cuarţite albe, vineţii - biotitice
- 13 — Metabazite
- 14 — Calcare şi dolomite cristaline
- 15 — Şisturi clorito - micacee ± almandin
- 16 — Şisturi micacee cu almandin

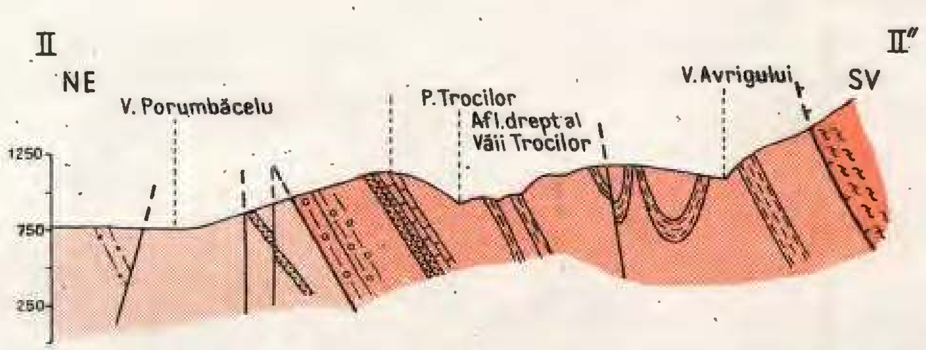
**Seria de Cumpăna (Seria de Sebeş - Lotru)**

ANTEPROTEROZOIC SUPERIOR

Formaţiunea de micaşisturi şi paragnaise Şerbota (Zona cu staurolit şi disten)
- 17 — Micaşisturi şi paragnaise cu almandin şi staurolit
- 18 — Micaşisturi micacee
- 19 — Micaşisturi cu almandin
- 20 — Amfibolite ± biotit ± almandin
- 21 — Cuarţite amfibolice ± almandin, cuarţite negre
- 22 — Paragnaise cu disten
- 23 — Gnaise oculare

- 24 — Falie
- 25 — Linie de încălecare
- 26 — a. Sinclinal; b. Anticlinal
- 27 — Foliaţie
- 28 — Liniaţie
- 29 — Zone mineralizate cu sulfuri polimetalice (Cu, Pb, Zn)
- 30 — Linie de profil








Imprim. Atel. Inst. Geol. Geof.

*D.S. Inst. geol. geofiz.* vol. LXIX (1982). Pag. 41—59

**2. ZĂCĂMINTE**

# CONTRIBUTIONS À LA CONNAISSANCE DE LA MINÉRALISATION AURIFÈRE DE SLĂTINIC-BOZOVICI (BANAT) [1]

PAR

ION ÎNTORSUREANU [2], VASILE POMÂRLEANU [2], GHEORGHE NEGUȚ [3], VASILE SERAFIMOVICI [4], VASILE ȘTREANGĂ [3], ȘERBAN ANASTASE [2], ANA ȘERBĂNESCU [2], MARIN VOICU [4]

*Au. Quartz. Vein mineralization. Miocene. Pegmatites. Aplites. Fluid inclusions. South Carpathians. Crystalline Getic and Supragetic domains — Semenic Mountains.*

## Abstract

*Contributions to the Knowledge of the Gold Mineralization at Slătinic-Bozovici (Banat).* The gold mineralization at Slătinic-Bozovici is to be found on the south-eastern border of the Semenic Massif, under the form of a lenticular vein oriented NE-SW/25—65° SE, in the metamorphites of the Sebeș-Lotru series, represented, at the upper part, by a leptyno-amphibolitic formation. The vein is made up of quartz-native gold ± pyrite, and the host rocks were subject to epidotization, chloritization, sericitization, silicification and carbonation.

Neutron activation analyses have indicated the presence of a primary halo of gold dispersion in the host rocks and a secondary halo in the transgressive sedimentary formations, Badenian in age. The study of fluid inclusions shows a tendancy of agglomerating the gold particles in the zones richer in fluid inclusions of carbon dioxide. The temperature at which auriferous quartz forms, obtained by decrepitation, has two maxima (380—400°C and 400—420°C), which suggests the presence of two pulsations with metalliferous fluids. The mineralization is Pre-Alpine in age, as both the deformation of the

[1] Reçue le 28 Avril 1982, acceptée pour être communiquée et publiée le 10 Mai 1982, présentée à la séance de 14 Mai 1982.

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auriferous quartz crystalline network (undulatory extinctions, deformation bands) and the fluid inclusion study show. Till now the origin of metalliferous fluids is not known with certainty, but the data obtained plead for the hydrothermal origin, being probably produced by the Pre-Alpine granitoids existing in the region.

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La minéralisation aurifère de Slătinic est située dans la partie sud-est des Monts Semenic, à la zone de contact morpho-structural entre le soubassement cristallin et les dépôts tertiaires du Bassin de Bozovici.

Quoique cette minéralisation ait été exploitée jusqu'en 1950, on ne possède que peu d'informations sur elle. C'est pour cela qu'on se propose de présenter, dans cette note, quelques données obtenues dans une étude préliminaire, favorisée par les travaux miniers et les forages exécutés récemment dans le chantier IFLGS — Bozovici.

## 1. Historique

À la différence de l'or détritique de la zone de Bozovici qui était connu et mis en valeur à partir du XVIII-e siècle (Griselini, 1780), la minéralisation primaire d'or a été découverte beaucoup plus tard.

C'est Cădere (1925 — fide Rădulescu, Dimitrescu, 1966) qui a mentionné l'or natif dans les lentilles de quartz des schistes cristallins.

Nous avons identifié dans l'archive de I.M. Barza de Brad des données historiques sous forme de manuscrits. Ainsi d'un „livret technique" redigé par Centrala aurului-Direcția regională Brad (1949) on apprend que la découverte du gisement aurifère de Slătinic a été déterminée par l'identification en 1922 d'un bloc de quartz aurifère insédimenté dans des conglomérats et grès stériles. Les recherches ultérieures ont montré que le bloc respectif provenait d'une lentille de quartz aurifère, intercalée dans les schistes primaires, formant un gisement primaire. Entre 1924—1948 le gisement a été donné en concession, exploré et puis exploité par des particuliers (Hanicska, Pistrilă et Popoviciu) qui ont excavé des puits, des directionnelles et des plans inclinés mais qui à présent sont complètement écroulés.

En 1948 la mine a été nationalisée et l'exploitation a été continuée par Întreprinderea minieră Orşova, jusqu'en 1950.

Lucca (1949) présente une courte description du gisement „auro-argentifère" de Bozovici, qui apparaît sous forme de „lentille à contour très irrégulier" et est encaissée dans des schistes cristallins. Quant à la minéralisation on montre qu'elle est formée d'or natif sous forme de grains au paillettes, inclus dans la masse du quartz. Le rapport géologique est accompagné par un plan de travaux miniers et quelques esquisses géologiques faites dans le sousterrain.

Il y a également un autre manuscrit, dressé par Lucca et al. (1950). Il s'agit d'un „Procès verbal" sur la cessation de l'exploitation aurifère de Bozovici, déterminée par le manque de productivité, due au contenu réduit en métaux précieux et à la discontinuité du gisement.

Petrulian (1973) attribue la minéralisation aurifère de Bozovici, tout comme celle de Valea lui Stan et Văliug, au type hypothermal métamorphosé. De même, Superceanu (1976) inclut les gisements d'or de Văliug et Bozovici dans le type catathermal-métamorphosé et les associe au cristallin gétique.

Les formations cristallines et les granitoïdes anciens de la région ont été étudiés, plus récemment, par Savu (1966 ; 1973) est les dépôts sédimentaires par Iliescu et al. (1961). C'est Hanomolo et al. (1961), Întorsureanu et al. (1981) qui ont effectué des prospections et des études géologiques.

## 2. Cadre géologique

La minéralisation aurifère de Slătinic se trouve en bordure sud-est du Massif de Semenic, dans la zone de contact transgressif entre les formations miocènes du Bassin de Bozovici et le cristallin gétique.

Le cadre géologique local est constitué par une formation leptyno-amphibolitique, des pegmatites, des aplites et des dépôts sédimentaires (pl. II).

### 2.1. Formation leptyno-amphibolitique

La formation leptyno-amphibolitique représente le soubassement de la région et est constituée d'une association d'amphibolites, schistes amphibolitiques, leptynites et schistes quartzofeldspathiques. On doit mentionner que dans le secteur étudié par nous, Savu (en Năstăseanu, Savu, 1970) sépare des leptynites et des amphibolites qu'ultérieurement il encadre dans la série de Sebeş-Lotru (Savu, 1973).

Les amphibolites sont très fréquentes, formant plusieurs niveaux à épaisseurs de l'ordre de dizaines de mètres. Sur la Vallée de Miniş et sur certains de ses affluents, les affleurements son bien ouverts ; on les rencontre également dans les fórages récemment exécutés dans la zone de Slătinic où ils sont couverts transgressivement par des dépôts sédimentaires. Il s'agit des roches vertes-noirâtres, en divers tons, quelquefois à impregnations fines de pyrite, ou faiblement épidotisées. Au microscope on observe la texture orientée et la structure nématogranoblastique, et dans la composition minéralogique entrent des amphiboles accompagnés par des plagioclases, quartz, actinote, épidote et minéraux opaques. Les amphiboles occupent jusqu'à 85—90% du volume de la roche, formant des cristaux bien développés de couleur verte, parfois à teintes bleuâtres et angles d'extinction entre 19—25°, ce qui correspond à une hornblende commune. Les plagioclases sont substitués, à différents degrées, par des agrégats de séricite, plus rarement d'épidote. Les minéraux opaques sont représentés par l'ilménite, fréquemment à aspect relict ou à exsolutions d'hématite, plus rarement magnétite $\pm$ pyrite sous forme de faibles impregnations. La composition chimique d'une amphibolite de la Vallée de Miniş est représentée dans le tableau 1.

TABLEAU 1

*Composition chimique des amphibolites*
*(E. 1693, Vallee de Miniş)*

| Oxydes | % | Eléments mineurs | p.p.m. |
|---|---|---|---|
| $SiO_2$ | 44,24 | Pb | 4,5 |
| $TiO_2$ | 2,36 | Cu | 100 |
| $Fe_2O_3$ | 15,30 | Zn | 77 |
| $Fe_2O_3$ | 4,82 | Sn | 3,5 |
| FeO | 6,85 | Ga | 16 |
| MnO | 0,18 | Mo | 2 |
| CaO | 11,82 | Ni | 61 |
| MgO | 6,79 | Co | 44 |
| $Na_2O$ | 3,31 | Cr | 95 |
| $K_2O$ | 1,00 | V | 7,5 |
| $P_2O_5$ | 0,407 | Sc | 31 |
| $H_2O^+$ | 0,42 | Y | 34 |
| $CO_2$ | 1,93 | Yb | 2,3 |
| S | 0,266 | Zr | 135 |
| | | Nb | 10 |
| | | Be | 1 |
| Total | 99,693 | Ba | 300 |
| Analyste : | A Movileanu | Sr | 300 |

La présence de l'ilménite à habitus squelétique, ou à exsolutions d'hématite (Edwards, 1954), la teneur élevée de $TiO_2$ (= 2,36%) ainsi que la valeur positive des paramètres $X_1$, $X_2$, $X_3$, calculés à partir des données analytiques (Shaw, Kudo, 1965), sont des arguments pour l'origine magmatique de ces amphibolites.

Les schistes amphiboliques sont étroitement associés à les amphibolites, formant des intercalations à épaisseurs variées. Entre les deux types de roches il y a des passages graduels, différant macroscopiquement par le degrée de schistosité. En lames minces on remarque la structure nématogranoblastique, formée de hornblende, plagioclases, quartz et de rares grains de sphène, apatite et minéraux opaques, auxquels s'ajoutent en quantité variable, de la séricite, de la chlorite, des carbonates, de l'épidote, de la biotite, des hydroxydes de fer — comme minéraux secondaires. Ces transformations, qui peuvent affecter également les amphibolites, sont plus avancées dans les échantillons de la zone du ruisseau de Slătinic et du versant droit de la Vallée de Miniş, immédiatement en amont de Bozovici.

Les leptynites sont des roches dures, de couleur gris clair, à teintes rougeâtres, formant quelques niveaux, les plus épais atteignant quelques centaines de mètres. On a trouvé des affleurements bien ouverts, résistants à l'érosion, dans la Vallée de Miniș, la Vallée de Bozovici et la crête du versant droit du ruisseau de Slătinic. Les observations microscopiques montrent des textures faiblement orientées et des structures porphyroblastiques. Elles sont constituées presque en exclusivité par des minéraux leucocrates : quartz, ortose, microcline et plagioclase, auxquels peuvent s'ajouter dans des quantités subordonnées, de la biotite, du sphène, des minéraux opaques, de l'épidote, du grenat (pl. II, fig. 2). Le quartz apparaît sous forme de hétéroblastes, un peu allongées, à des extinctions ondulatoires, intimement associées à des feldspaths potassiques, en bandes faiblement délimitées. L'ortose occupe des volumes importants de la roche (35—40%), où on observe des structures perthitiques et des inclusions corrodées de quartz. Le microcline est moins fréquent et se distingue dans des macles en grilles. Le plagioclase présente des macles albite, à 10—14% An, dépourvu de structures zonaires. La biotite participe en quantité réduite comme paillettes rares, orientées selon la texture de la roche. Les minéraux opaques sont représentés par la magnétite et la pyrite, la seconde apparaissant également sur des fissures sous-millimétriques.

Savu (1973) considère que ces roches ont résulté du métamorphisme régional des éruptions sous-marines du type des kératophyres quartzifères ou des tuffs ignimbritiques associés.

Les schistes quartzo-feldspathiques sont associés aux leptynites et aux schistes amphiboliques, entre lesquels il y a des passages graduels. Ils sont gris, à teintes verdâtres, et ont une schistosité tout-à-fait claire. C'est le quartz, le feldspath potassique, le plagioclase, la biotite, la muscovite et parfois la hornblende qui participent à la composition minéralogique, accompagnés éventuellement par des grains isolés de magnétite, sphène, épidote, ou agrégats séricitiques (pl. II, fig. 3). Le feldspath potassique est représenté par l'ortose sous forme de porphyroblastes allongés selon la schistosité et des contours dentelés au contact avec le quartz. Le plagioclase apparaît en proportions plus réduites, à des macles albite et à 4—6% An. La biotite et la muscovite forment parfois des lamelles bien développées, disposées en bandes qui déterminent la schistosité de la roche. La hornblende verte apparaît dans les roches par lesquelles se fait le passage vers les schistes amphibolitiques.

L'association intime entre les roches décrites en haut représente en ensemble une formation leptyno-amphibolitique, résultée des produits métamorphosés d'un volcanisme bimodal, à apports terrigènes, comme on a déjà montré pour d'autre régions (Dimitrescu, 1981). Comme position stratigraphique, la formation leptyno-amphibolitique est située à la partie supérieure du complexe des micaschistes ($C_4$) de la série de Sebeș-Lotru (Savu, 1973), qui a été métamorphosée dans le cycle dalslandien pendant le Précambrien supérieur A (Savu et al., 1977).

## 2.2. Pegmatites et aplites

Dans le secteur étudié la formation leptyno-amphibolitique est percée, par endroit, par des pegmatites et des aplites.

On a trouvé des pegmatites dans le versant droit du ruisseau de Slătinic, comme des petits corps filoniens, à petites épaisseurs (1—2 m), discordantes, dans des amphibolites ou des schistes amphibolitiques. Certains corps de pegmatites apparaissent également le long de la Vallée de Miniș, immédiatement en amont de la confluence avec le ruisseau de Slătinic, sous forme de lentilles à épaisseurs jusqu'à 8—10 m. Leurs rapports avec la roche qui les entourne n'ont pu être observés à cause des alluvions, mais semblent être également discordants.

Les pegmatites du ruisseau de Slătinic sont plus largement cristallisées et sont constituées d'ortose, quartz, plagioclases et muscovite à teintes verdâtres. L'ortose présente des structures pertithiques et les plagioclases sont maclés polysynthétiquement. La paragenèse primaire a été par endroit modifiée par la séricite qui substitue les feldspaths, formant quelques fois de petites veines. Les pegmatites de la Vallée de Miniș sont rougeâtres, plus finement cristallisées et ont une texture massive. La composition minéralogique est représentée par : l'ortose, le quartz, le microcline, le plagioclase, la muscovite, l'apatite (pl. II, fig. 4).

Les aplites apparaissent sporadiquement, étant rencontrées uniquement dans le versant droit de la Vallée de Miniș, sous forme de petites veines à épaisseurs centimétriques, encaissées dans des amphibolites faiblement épidotisées et avec lesquelles elles présentent le plus fréquemment des rapports discordants. Elles sont des roches grises clair, à teintes rougeâtres, texture massive, cristallisées. Sous le microscope on observe la structure microgranulaire, formée de quartz, ortose, plagioclase, de rares paillettes de biotite et minéraux opaques. Le quartz occupe 45—50% de la roche, à des contours xénomorphes et des extinctions ondulatoires d'intensité moyenne. L'ortose est, elle-aussi un composant essentiel, présentant des limites suturées au contact avec le quartz et est fréquemment impurifiée par des minéraux argileux. Le plagioclase est subordonné, étant caractérisé par des macles albite et une teneur de 5—6% An.

La position discordante et les caractères pétrographiques des pegmatites et des aplites, ainsi que leur emplacement sur une aire restreinte, suggèrent une affiliation magmatique avec un éventuel corps situé en profondeur.

### 2.3. Dépôts sédimentaires

Les formations sédimentaires de la zone investiguée sont d'âge badénien et quaternaire.

Les dépôts badéniens sont disposés transgressivement sur le soubassement cristallin et ont une large distribution, formant le remplissage du Bassin de Bozovici. Ces dépôts ont été investigués par Iliescu et al. (1967), qui ont établi la succession stratigraphique. Les rapports transgressifs entre les formations badéniennes et le soubassement cristallin sont évidents dans le secteur étudié. Ainsi, le long de la Vallée de Miniș, immédiatement en amont de la confluence avec le ruisseau de Slătinic, les conglomérats de la base ont la position N 30°E/24°SE et reposent discordamment sur les amphibolites. Le long du ruisseau de Slătinic, à environ 700 m en amont de la confluence avec la Vallée de Miniș, Serafimovici et al. (1981) mentionnent la présence du soubassement cristallin qui apparaît dans une petite fenêtre d'érosion sous les dépôts badéniens. De même, la présence de ces dépôts sur certaines crêtes, ainsi que leur configuration d'ensemble, démontrent clairement, comme on a montré antérieurement (Serafimovici et al., 1981) que leur position est transgressive discordante par rapport au soubassement cristallin.

Dans la zone de Slătinic, ces dépôts appartiennent à l'horizon basal (Iliescu et al., 1967), ayant à la partie inférieure, un niveau de conglomérats à éléments hétérogènes, bien roulés, contenus dans une matrice argilo-gréseuse rouge-brique ou verdâtre, sur lesquels repose un niveau sableux-argileux, à intercalations de microconglomérats, marnes, calcaires, tuffs volcaniques, graviers. Ces formations ont été percées également par des forages exécutés dans le versant gauche du ruisseau de Slătinic, où leurs éppaisseurs atteignent 108 m.

Les dépôts quaternaires forment des terasses, des cônes de déjection et des alluvions, les dernières étant prospectées récemment pour l'or détritique et les minéraux lourds (Serafimovici et al., 1981) et explorées par IFLGS — Bozovici pour les même minéraux.

## 2.4. Considérations tectoniques

La tectonique de la zone investiguée est directement liée à l'évolution d'ensemble de l'extrémité sud-ouest des Carpathes Méridionales. Les hypotheses récentes montrent que l'évolution géotectonique de cette région a été contrôlée par la subduction d'une microplaque (Plateforme moesique) sous la zone mobile des Carpathes Méridionales (Savu et al., 1977). Comme dans la zone de courbure entre les Carpathes et les Balcans apparaissent de nombreux corps de magmatites calcoalcalines, considérés comme produits caractéristiques pour les zones de convergence des plaques lithosphériques (Rădulescu, 1979) et sont des âges différents (antéprotérozoïque supérieur, paléogène) on suppose que les moments de convergence des plaques lithosphériques se sont manifestés à partir du Précambrien, comme on a mentionné antérieurement (Savu et al., 1977) et se sont continués probablement jusqu'au Paléogène (Airinei, 1981).

Le soubassement de la région est constitué par le cristallin gétique, engendré pendant le cycle dalslandien, dans les conditions d'un métamorphisme prépondéremment de type barrovien (Savu et al., 1977) les trois séries du cristallin gétique (Sebeș-Lotru, Miniș et Buceava) étant en rapports de concordance (Savu, 1973). Un aspect majeur du cristallin gétique du Massif de Semenic est donné par la structure en virgation (Savu, 1965) avec les linéations majeures parallèles aux plans de subduction (Savu et al., 1977).

La tectonique disjunctive a produit des modifications importantes dans le soubassement cristallin, à compartiments en horsts et grabens

(R. Botezatu, cité par Andrei et al., 1977), quelques uns d'eux devenant des bassins de sédimentation, dans le Mésozoïque et le Tertiaire.

Le secteur étudié fait partie de cette tectonique régionale et est caractérisé par une structure monoclinale, à pendages sud-est qui représentent probablement le flanc sud-est d'un synclinorium, orienté NE-SW. Cette structure a été affectée par des failles longitudinales et transversales, au long desquelles des déplacements ou des écroulements se sont produits, les seconds dans le Tertiaire, quand elle a été couverte transgressivement par les formations badéniennes du Bassin de Bozovici.

## 3. Minéralisation

Comme les vieux travaux miniers sont totalement écroulés et inaccessibles, pour l'étude de la minéralisation et des altérations nous avons échantionné les affleurements, travaux miniers de surface, forages et l'ancienne halde.

### 3.1. Forme de gisement

La forme de gisement de la minéralisation aurifère n'est pas connue en détail. Des données bibliographiques (Lucca, 1949 ; Brana, 1958) il ressort, comme on a mentionné, qu'elle se présente sous forme de „lentille à aspect très irrégulier".

En corroborant les résultats préliminaires obtenus par les travaux miners de surface et de forage, avec la description présentée par Lucca (1949), pour les trois horizons accessibles à cette époque-là, il résulte que le gisement a la forme de filon lenticulaire, dans le sens défini par Petrulian (1973), les corps de minérai se succédant à direction par effilement (fig. 1). L'effilement peut également apparaître à pendage, mais les données à notre disposition ne nous permettent pas d'apprecier les distances auxquelles disparaissent ou apparaissent les lentilles de quartz aurifère en profondeur (fig. 2).

### 3.2. Localisation

Le filon lenticulaire est encaissé dans le soubassement cristallin, représenté par des amphibolites et des schistes amphibolitiques et a la position NE-SW, à pendage moyen d'environ 40° vers le sud-est (fig. 3). Les données de cartage tant que celles du déroctage nr. 1 du versant gauche du ruisseau de Slătinic et l'esquisse (fig. 2) faite par Lucca (1949) suggèrent la position discordante de la minéralisation par rapport aux roches environnantes.

À la partie supérieure le filon a été partiellement erodé, car il vient en contact avec les dépôts sédimentaires badéniens qui moulent le quartz aurifère et même remanient des fragments de celui-ci (fig. 4).

D'ailleurs nous avons déjà mentionné que la découverte de ce gisement a été possible grâce à l'identification d'un bloc de quartz aurifère, englobé dans les conglomérats et les grès stériles.

Les structures bréchiques de quartz aurifère et la présence des zones de flexures, blocs de minérai et milonitisations dans les anciens

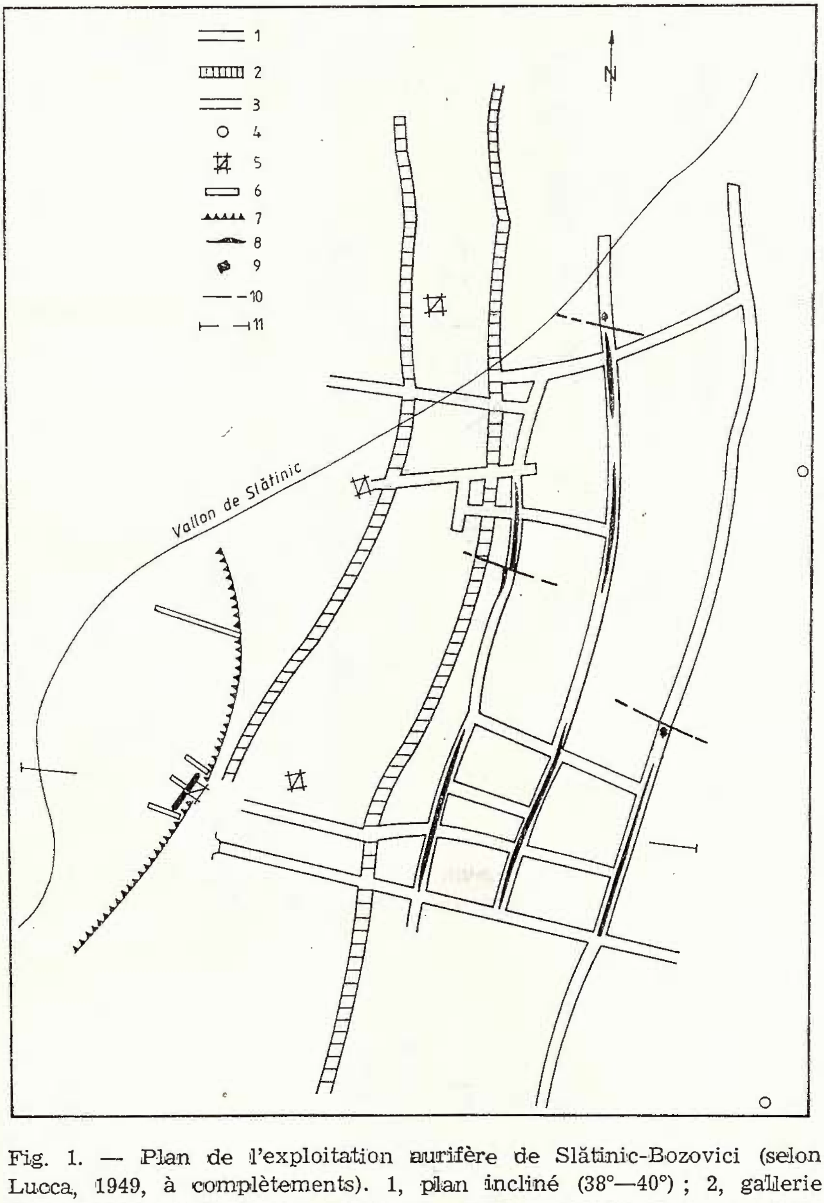



Fig. 1. — Plan de l'exploitation aurifère de Slătinic-Bozovici (selon Lucca, 1949, à complètements). 1, plan incliné (38°—40°) ; 2, gallerie écroulée ; 3, gallerie accessible ; 4, forage d'exploration ; 5, puits d'exploration ; 6, fossé d'exploration ; 7, déroctage ; 8, filon aurifère ; 9, blocs de minérai ; 10, fracture ; 11, direction de la section.

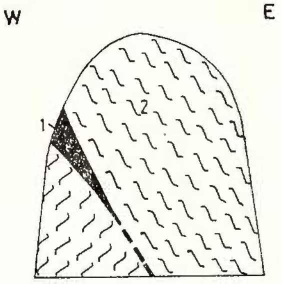



Fig. 2. — Section transversale (selon Lucca, 1949). 1, schistes cristallins ; 2, effilement du filon aurifère.

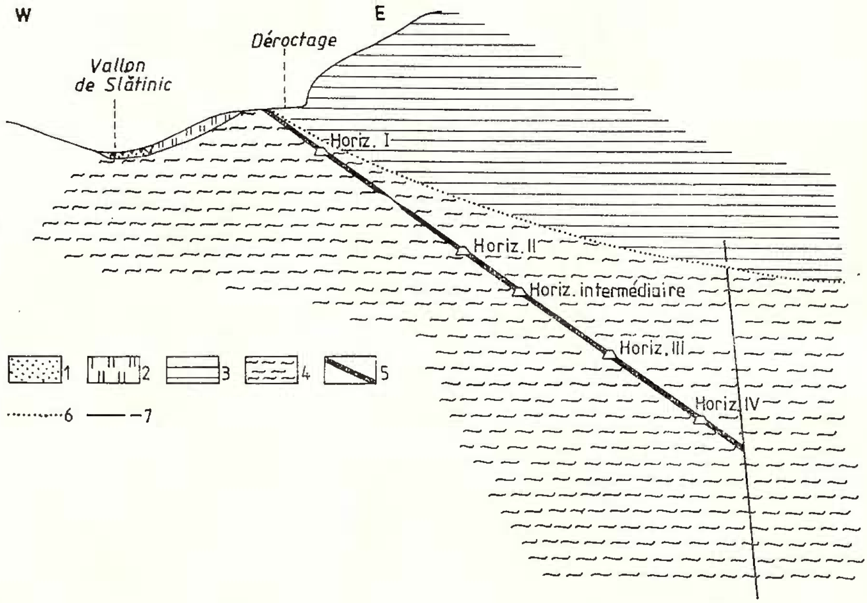



Fig. 3. — Section dans le gisement. 1, schistes cristallins ; 2, filon aurifère ; 3, dépôts badéniens ; 4, faille supposée ; 5, diluvium ; 6, alluvions ; 7, déroctage.

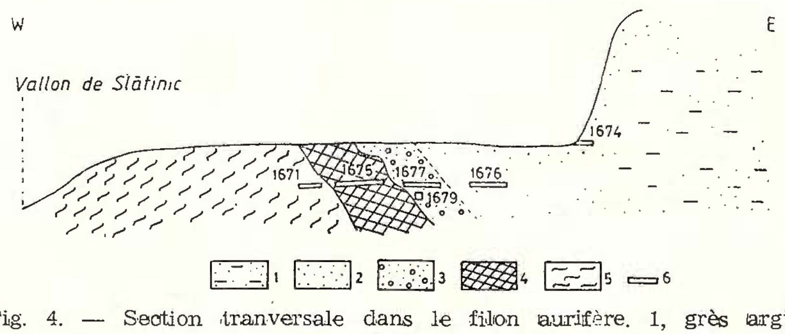



Fig. 4. — Section tranversale dans le filon aurifère. 1, grès argileux gris-verdâtres ; 2, grès argileux rouges briques ; 3, conglomérats bréchiques, limonitiques ; 4, filon aurifère ; 5, amphibolites, schistes amphibolitiques ; 6, échantillons.

travaux sousterrains (Lucca, 1949) représentent un aspect important. Ces observations montrent que le filon lenticulaire a été affecté par des fractures ou des failles, mais dans le stade actuel, les éventuels déplacements de la minéralisation, provoqués par la tectonique disjunctive ne peuvent être précisés. C'est tout-à-fait possible qu'en profondeur le filon soit écroulé au long de failles longitudinales qui ont conduit également à l'effondrement du soubassement cristallin, dans le Tertiaire, quand s'est formé le Bassin de Bozovici.

### 3.3. Composition minéralogique

Les observations préliminaires montrent que la minéralisation est constituée d'or libre et pyrite sous forme de grains fins, disposés non-uniformement dans la masse du filon lenticulaire de quartz. L'or apparaît en état natif, sous forme de grains ou paillettes, visibles quelquefois à l'oeil nu ou à la loupe, avec une distribution non-uniforme. On remarque parfois une tendance d'enrichissement vers la partie basale du filon, où le minérai est plus chloritisé. Au microscope les grains d'or présentent des contours xénomorphes, isométriques ou un peu allongés, avec des dimensions qui atteignent 0,120/0,072 mm. Les grains d'or peuvent avoir des petites apophyses dans la gangue, probablement à la limite entre les cristaux de quartz (pl. III, fig. 3, 4). Ces relations suggèrent que le dépôt de l'or a eu lieu en même temps avec ou immédiatement après le dépôt du quartz de la première génération qui constitue le remplissage principal du filon. Il est jaune doré et avec les nicoles en croissant présente une faible luminosité. De même, dans les grains d'or on a remarqué des petites inclusions de minéraux non-métalliques, à dimensions microniques. Les analyses docimasiques et par absorption atomique, effectuées sur le quartz aurifère, dépourvu d'autres minéraux métallifères, ont indiqué une finesse (pureté) élevée de l'or, entre 840 et 860.

La pyrite apparaît tout-à-fait subordonnément, dans les grains fins et rares, à dimensions microniques, dispersés dans la masse du quartz aurifère. C'est probable qu'une partie des grains de pyrite ont été affectés par les processus d'altération, à la suite desquels se sont formés des petits nids ou pellicules limonitiques. On doit mentionner que dans le matériel examiné on n'a pas recontré de cristaux de pyrite associés à l'or natif.

Le quartz représente la gangue du filon et macroscopiquement il y en a trois types :

— quartz blanc-jaunâtre, à teintes verdâtres, texture orientée et pellicules de carbonates, chlorites, hydroxydes de fer, disposées sur des fissures à épaisseurs sous-millimétriques. Les fissures forment trois systèmes à position perpendiculaire, longitudinale ou parallèle par rapport à la texture du filon. Il contient de l'or natif sous forme de petits grains ou paillettes, visibles parfois à l'oeil nu ou sous la loupe ;

— quartz gris-verdâtre, fortement bréchifié, à minéraux secondaires (chlorites, carbonates, quartz) déposés sur des fissures à épaisseurs sous-millimétriques, rarement jusqu'à 5 mm. De même, il contient des grains d'or libre observables macroscopiquement ;

— quartz blanc laiteux à fines pellicules de carbonates ou hydroxydes de fer, très faiblement fissuré ; il semble être dépourvu d'or libre.

Le premier type de quartz a été rencontré dans le déroctage exécuté dans le versant gauche du ruisseau de Slătinic, sous forme de lentille (ou pilier de sûreté ?) à position N 30°E/52°SE, et les deux derniers ont été observés dans les échantillons provenus de l'ancienne halde.

Au microscope, tous les trois types de quartz ont des textures orientées et des structures hétérogranoblastiques ou porphyroclastiques (pl. III, fig. 2). La dimension des grains varie dans des limites très larges (0,006/0,008—0,3,2/1,1 mm) et leurs bords ont des limites suturées.

Les extinctions ondulatoires sont très accentuées, à angles qui atteignent 42—44°. De même, dans beaucoup de phénoblastes de quartz on observe des bandes de déformation qui sont presque parallèles et qui présentent des extinctions à angles differents (pl. III, fig. 1, 2) et les sections perpendiculaires à la direction optique présentent fréquemment un fiable caractère biaxe. Tous ces éléments montrent que le réseau cristallin du quartz du filon aurifère a subi des intenses déformations permanentes, sous l'influence des pressions tectoniques (Spry, 1976, p. 62).

Les déformations provoquées par les pressions tectoniques ont été suivies également dans d'autres types de quartz de la région et comparées aux déformations du quartz aurifère de la zone de Slătinic. Les caracteres texturaux, l'intensité des extinctions ondulatoires et la présence des bandes de déformation montrent que le filon de quartz aurifère a subi des déformations tout-à-fait similaires à celles subies par le quartz des schistes cristallins (série de Sebeş-Lotru, Miniş et Buceava) ou par les filons associés aux granitoïdes anciens (Poniasca, Lăpuşnicu Mare). Bien au contraire, le quartz provenu de petits filons associés à des intrusions banatitiques (Lăpuşnic, Liubcova etc.) présente des déformations très réduites, matérialisées seulement par des extinctions ondulatoires et le manque complet des bandes de déformation. Ces données indiquent que le filon de quartz aurifère a subi des pressions tectoniques ressemblant beaucoup à celles subies par les métamorphites ou les granitoïdes anciens de la région. Ainsi la forme de filon lenticulaire peut être primaire, mais plutôt secondaire, à la suite de la plasticité élevée du quartz sous l'action de l'eau et des mouvements tectoniques (effect „hydrolitic weakening“ — Paterson, Kekulawala, 1979).

Au microscop on a également observé, en espèce au quartz bréchifié, de petits filons à épaisseurs sous-millimétriques, remplis par des carbonates, quartz II, hydroxydes de fer. De même, le quartz grisverdâtre se caractérise par la présence d'une chlorite pâle, en agrégats microniques, disposés non-uniformement dans sa masse ou sur des fissures, à épaisseurs sous-millimétriques.

### 3.4. Les altérations de roches environnantes

Pour examiner les altérations des roches environnantes on a récolté des échantillons de la couche du filon (déroctage), des affleurements et de l'ancienne halde. On a analysé également les roches sédimentaires qui présentent de contact transgressif avec la partie supérieure du filon aurifère.

La roche de la couche du filon (fig. 4) est tectonisée, relativement friable, de couleur verdâtre-gris, à infiltrations limonitiques. Au microscope elle est formée surtout des agrégats chlorito-sériciteux $\pm$ épidote $\pm$ carbonates $\pm$ relictes de minéraux opaques + hydroxydes de fer. Les relictes de minéraux opaques (magnétite) et l'aspect général de la roche montrent qu'à l'origine il s'agissait d'une amphibolite ou d'un schiste amphibolitique.

Les schistes cristallins trouvés le long du ruisseau de Slătinic (fenêtre d'érosion) sont probablement situés dans le toit du filon. Dans des lames minces, ils présentent des fissures à épaisseurs millimétriques remplies de carbonates $\pm$ chlorites $\pm$ hydroxydes de fer et dans des stades plus avancés arrivent jusqu'à la substitution totale par épidote + carbonates $\pm$ hydroxydes de fer. De même, les échantillons de la halde (amphibolites et/ou schistes amphibolitiques) ont été affectés par des processus d'épidotisation intenses, superposés par des chloritisations, suivies, à leur tour, par des carbonatisations, à la suite desquels les caractères initiaux de la roche ont été plus ou moins modifiés.

Les roches sédimentaires (badéniennes) sont en contact transgressif avec la partie supérieure du filon (fig. 3). Elles sont représentées par des grès limonitiques rouges-briques, friables qui englobent des éléments de roches métamorphiques (gneisses, amphibolites, quartz) roulées à différents degrées. Elles moulent le filon aurifère et même remanient certains éléments de celui-ci et sont dépourvues de silicifications, ce qui indique clairement leur position transgressive et l'âge plus récent, en comparaison avec celui du filon aurifère.

Pour établir les éléments mineurs impliqués dans les processus d'altération on a effectué des analyses spectrales et par activation à neutrons pour l'or (tab. II). De ces données informatives il résulte une dispersion primaire de l'or dans les roches de la couche (0,2690 g/t) et une forte lévigation du strontium, tandis que le reste des éléments dosés n'ont pas subi des modifications significatives. De même, dans la roche transgressive on constate un enrichissement en or (0,2394 g/t), ce qui s'explique par la dispersion secondaire (mécanique) sous l'action des processus exogènes.

### 3.5. Étude des inclusions fluides

Pour clarifier certains aspects génétiques de la minéralisation aurifère de Slătinic on a effectué des observations aussi sur les inclusions fluides.

TABLEAU 2

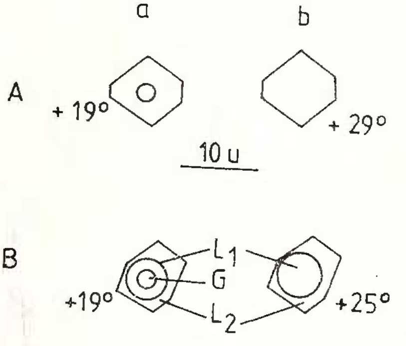
*Teneurs d'éléments mineurs des roches environnantes*

| Analyses spectrales (p.p.m.) | Activation a neutrons (g/t) | E. 1689 Pegmatite fraiche V. Miniş | E. 1693 Amphibolite fraiche V. Miniş | E. 1683 Schistes amphiboliques altérés de la couche du filon | Filon aurifère du ruisseau de Slătinic teneur moyenne (3 échantillons) | E. 1677 Conglomérats bréchiques rougeâtres du toit du filon | E. 1674 Grès argileux verdâtres, ruisseau de Slătinic, versant gauche |
|---|---|---|---|---|---|---|---|
| Pb | | 75 | 4,5 | 75 | < 2 | 55 | 11 |
| Cu | | 15 | 100 | 85 | 10 | 46 | 39 |
| Zn | | 40 | 77 | 67 | < 30 | < 30 | < 30 |
| Sn | | 6,5 | 3,5 | 3,5 | < 2 | 3 | 3 |
| Ga | | 21 | 16 | 23 | < 2 | 8 | 13 |
| Mo | | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 |
| Ni | | 5,5 | 61 | 44 | 10 | 10 | 10 |
| Co | | < 2 | 44 | 16 | < 2 | 5 | 3,5 |
| Cr | | < 10 | 95 | 130 | 10 | 42 | 26 |
| V | | 5,5 | 7,5 | 110 | 7 | 65 | 33 |
| Sc | | < 2 | 31 | 21 | < 2 | 7,5 | 7 |
| Y | | 22 | 34 | 10 | 2 | 17 | 14 |
| Yb | | 2,1 | 2,3 | 1,1 | < 1 | 1,5 | 1,3 |
| Zr | | 73 | 135 | 130 | 14 | 100 | 216 |
| Nb | | 17 | < 10 | < 10 | < 10 | < 10 | 10 |
| Be | | 7,5 | < 1 | 2,1 | < 1 | 1,3 | 1,2 |
| Ba | | 240 | 300 | 300 | 45 | 262 | 432 |
| Sr | | 56 | 300 | 10 | < 10 | 105 | 89 |
| La | | < 30 | < 30 | < 36 | < 30 | < 30 | < 30 |
| B | | < 30 | < 30 | < 30 | < 30 | < 30 | 39 |
| Ag | | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| As | | <300 | <300 | <300 | <300 | <300 | <300 |
| | Au | 0,0026 | 0,0007 | 0,2690 | | 0,2394 | 0,0009 |

*Description des inclusions fluides*

Les observations microscopiques ont mis en évidence la présence, dans le quartz aurifère, des inclusions fluides riches en $CO_2$, qui, selon le nombre de leurs phases fluides sont monophasiques, biphasiques et triphasiques. De ces inclusions les biphasiques et les triphasiques ont une fréquence plus grande. Celles biphasiques, à leur tour, sont grou-

Fig. 5. — A, inclusion fluide biphasique (gaz + liquide) de bioxyde de carbon : a, à +19°C et b, à +29°C ; B, inclusion fluide triphasique de bioxyde de carbon (gaz G et liquide $L_1$) et de solution aqueuse $L_2$ : a, à +19°C et b, à +25°C.




pées en inclusions de bioxyde de carbon (liquide + gaz) et inclusions de solutions aqueuses.

Les inclusions de bioxyde de carbon biphasiques s'homogénéisent en phase liquide entre 26° et 30°C (fig. 5 A) et celles triphasiques de bioxyde de carbon et de solutions aqueuses indiquent deux points d'homogénéisation : l'un entre 22° et 28°C, par contraction et la disparition graduelle de $CO_2$ gazeux (fig. 5 B), et le deuxième point indique des températures supérieures, de 300°C.

Les études de détail montrent que les particules d'or ont la tendance de se concentrer dans les zones où abondent les inclusions de bioxyde de carbon (fig. 5).

*Régime thermique des solutions*

Comme le diamètre des inclusions fluides est sous 5 microns il n'a pas été possible de faire des observations sur la température d'homogénéisation. En échange, on a fait recours à la méthode de la décrépitation (Pomârleanu, 1975), qui a permis d'inscrire deux décrépitogrammes représentés dans la figure 6.

Si on compare les décrépitogrammes on constate que la décrépitation du quartz gris-verdâtre commence plus tôt (320°C) que celle du quartz blanc-jaunâtre (350°C). Le maximum de fréquence de la décrépitation se trouve entre 400° et 420°C pour le quartz gris-verdâtre et 380°—400°C pour celui blanc-jaunâtre. Ce petit décalage de températures suggère la présence de deux pulsations ascendantes des fluides métallifères.

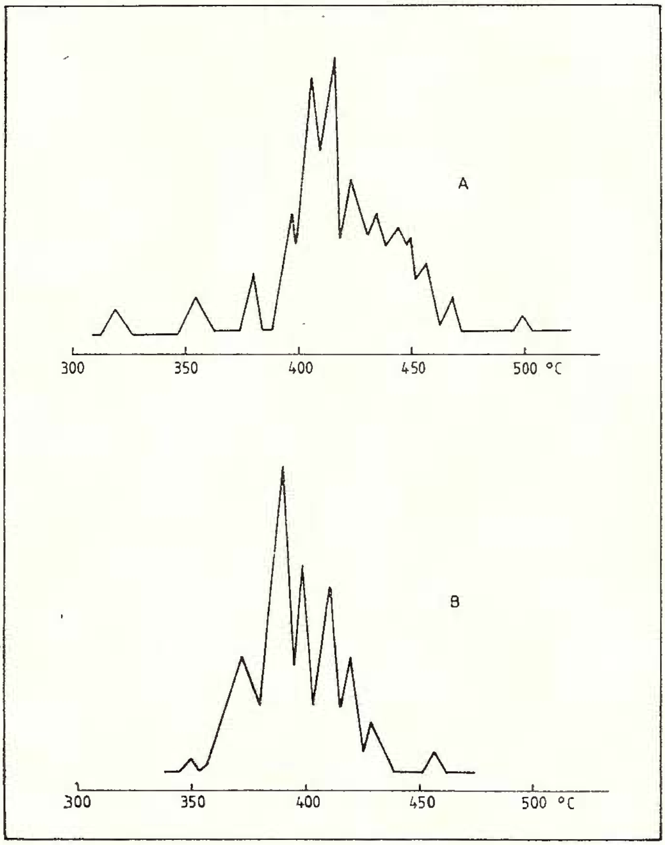



Fig. 6. — Décrépitogrammes du quartz aurifère de Slătinic de l'échantillon. A, quartz gris-verdâtre (de la halde) ; B, quartz blanc-jaunâtre (du filon).

## 4. Conclusions

La minéralisation aurifère de Slătinic-Bozovici est située en bordure sud-est des Monts Semenic, dans la zone de contact morphostructural entre le soubassement cristallin et les dépôts du Bassin de Bozovici. Elle se présente sous forme de filon lenticulaire, à effilements à direction et pendage, ayant la position NE-SW/25—65 SE. Le filon est localisé dans les métamorphites de la série de Sebeş-Lotru, qui, à la partie supérieure, sont représentées par une formation leptyno-amphibolitique, et il est partiellement erodé et couvert transgressivement par les formations sédimentaires miocènes.

Le filon lenticulaire est constitué de quartz + aur natif ± pyrite, ce qui dénote que les fluides minéralisantes ont été très riches en silice et pauvres en/ou dépourvus d'autres éléments métalliques. Les fluides ont produit dans les roches environnantes des épidotisations, chloritisations, séricitisations, silicifications et carbonatations qui se superposent et ont des intensités variables, arrivant jusqu'à substituer complètement les paragenèses primaires. Les analyses par activation à neutrons ont indiqué la présence d'une auréole primaire de la dispersion de l'or dans les roches environnantes et une auréole secondaire dans les formations sédimentaires transgressives.

L'étude des inclusions fluides montre une tendance d'agglomération des particules d'or dans les zones plus abondantes en inclusions fluides de bioxyde de carbon. La température de formation déterminée par la méthode de la décrépitation, indique un maximum compris entre 380° et 400°C et l'autre entre 400° et 420°C, ce qui suggère la présence de deux pulsations à fluides métallifères, confirmant en même temps la supposition de certaines recherches antérieures (Petrulian, 1973 ; Superceanu, 1976), selon lesquelles la minéralisation aurifère de Slătinic s'est formée dans des conditions hypothermales ou catathermales.

La minéralisation est d'âge pré-alpine, comme indiquent tant l'intensité des déformations (extinctions ondulatoires, bandes de déformation) subies par le réseau cristallin du quartz aurifère, sous l'influence des pressions tectoniques, que l'étude des inclusions fluides.

Dans le stade actuel on ne connaît pas avec certitude l'origine des fluides métallifères. Les données obtenues jusqu'à présent (les altérations des roches-hôtes, auréole primaire de la dispersion de l'or, l'étude des inclusions fluides, la paragenèse quartz + or) plaident pour l'origine hydrothermale postmagmatique, ce que suggère également la présence des massifs de granitoïdes préalpins de la région (le granitoïde de Sichevița, de Poniasca etc.), formés, probablement dans des zones anciennes de subduction. Ce qui est important c'est que certains de ces granitoïdes se caractérisent par une activité métallogénique. Ainsi, Gridan (1981) apporte des arguments pour la liaison génétique de certaines minéralisations auro-argentifères et polymétalliques de sulfures, avec le granitoïde synorogène de Buchin-Poiana, situé à la partie nord-est du Massif de Semenic. De même, Jankovič (1974) considère que les minéralisations aurifères ± schéelite, ou celles de plomb, molybdène et uranium de la zone de Neresnica-Beljanica (est de Serbie) sont associées aux granitoïdes herciniens que représentent le prolongement au sud du Danube, sur le territoire de la Jougoslavie, du pluton granitoïde de Sichevița.

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## EXPLICATIONS DES PLANCHES

### Planche II

Fig. 1. — Amphibolite à minéraux opaques (ilménite + magnétite). Vallée de Miniş, NII, × 42.
Fig. 2. — Leptynite. Vallée de Miniş. N+, × 42.
Fig. 3. — Schiste quartz-feldspathique. Vallée de Miniş. N+, × 42.
Fig. 4. — Pegmatite à structure cataclastique. Ruisseau de Slătinic, N+, × 26.

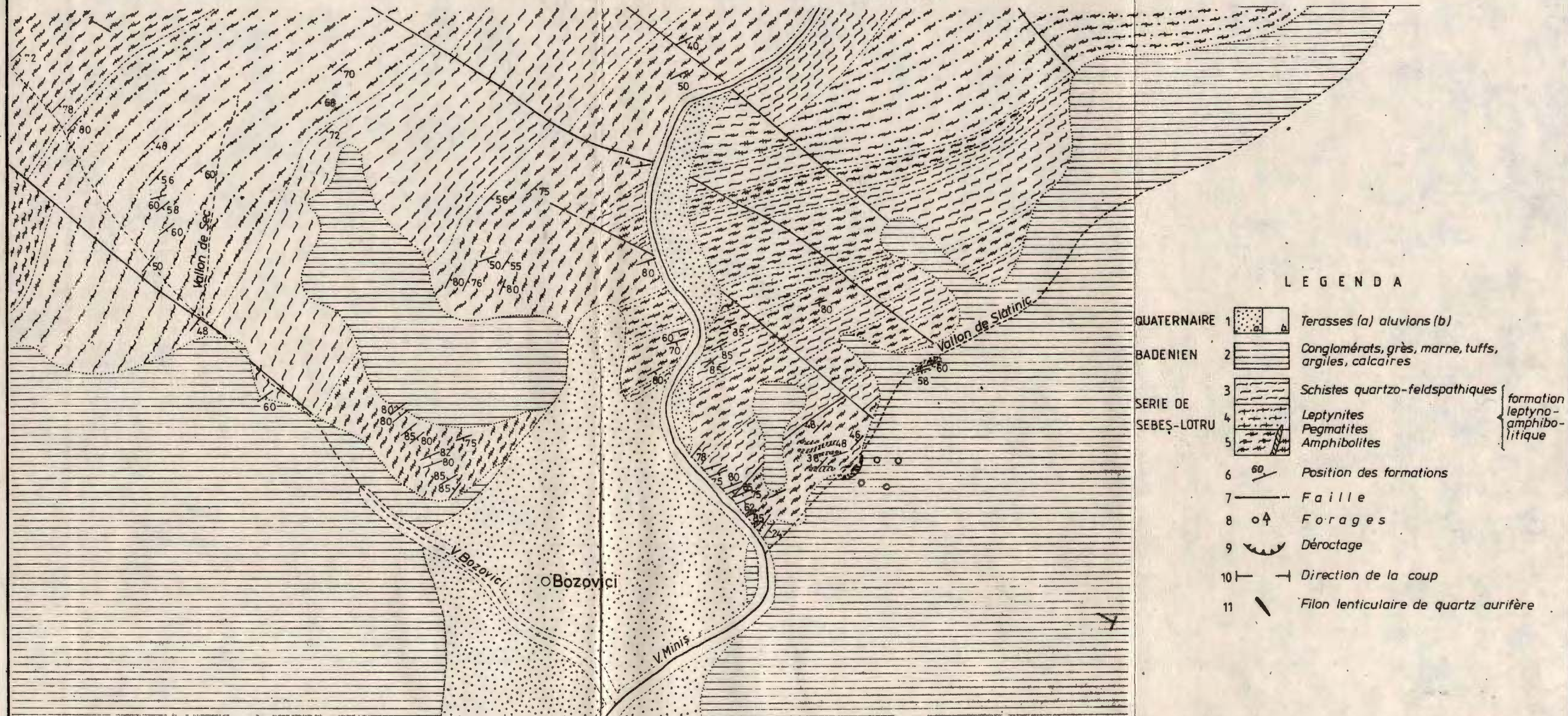
### Planche III

Fig. 1. — Quartz à bandes de déformation. Filon aurifère (déroctage), N+, × 26.
Fig. 2. — Quartz à bandes de déformation et structure porphyroclastique. Ancienne halde, N+, × 42.
Fig. 3. — Grain d'or libre, en gangue de quartz. Ancienne halde, NII, × 90.
Fig. 4. — Grain d'or libre, en gangue de quartz. Filon aurifère (déroctage), NII, × 180.

I. INTORSUREANU

# CARTE GÉOLOGIQUE DE LA ZONE DE SLĂTINIC-BOZOVICI (BANAT)

0 200 400 m




## COUP HYPOTHETIQUE DE LA ZONE DE SLATINIC-BOZOVICI (BANAT)

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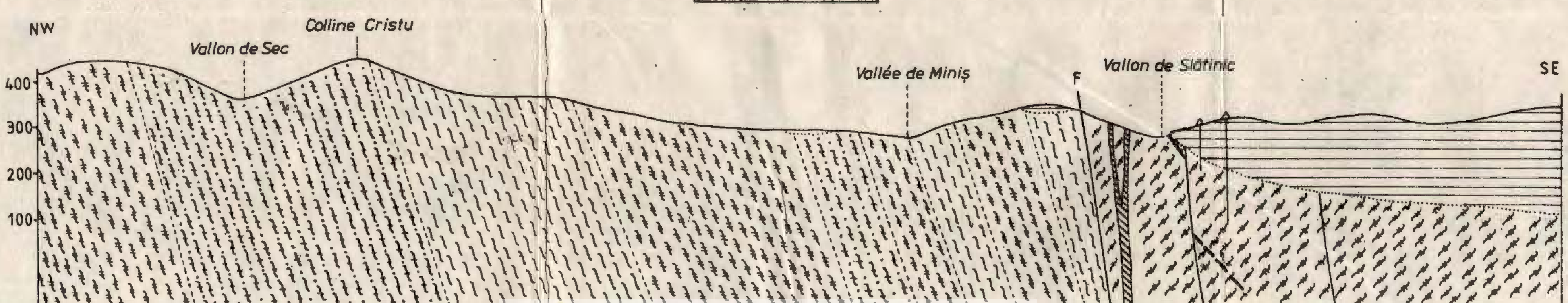





Imprim. Atel. Inst. Geol. Geof.

*D.S. Inst. geol. geofiz.* vol. LXIX (1982). Pag. 61—69

## 2. ZĂCĂMINTE

# NOTĂ PRIVIND MINERALIZAȚIILE POLIMETALICE DIN REGIUNEA LUNCAVIȚA (MUNȚII SEMENICULUI)[1]

DE

VASILE SERAFIMOVICI[2]

*Base metal mineralizations. Pyrite. Marcasite. Hydrothermal alterations. Badenian. Impregnations. South Carpathians-Crystalline Getic and Supragetic Domains. Semenic Mountains and West Țarcu Mountains.*

**Abstract**

*Note on the Polymetallic Mineralizations of the Luncavița Region (Semenic Mountains).* The study puts forth the mineralogical and structural aspects of a vein and impregnation mineralization made up of pyrite and marcasite, subordinately chalcopyrite, sphalerite and sporadically mispickel ± gold, associated in space with the Badenian formations of the Luncavița region.

Prospecțiunile geologice efectuate în anii 1980—1981, în regiunea Verendin-Luncavița, din munții Semenicului de est, au condus la obținerea unor rezultate care constituie obiectul acestei comunicări.

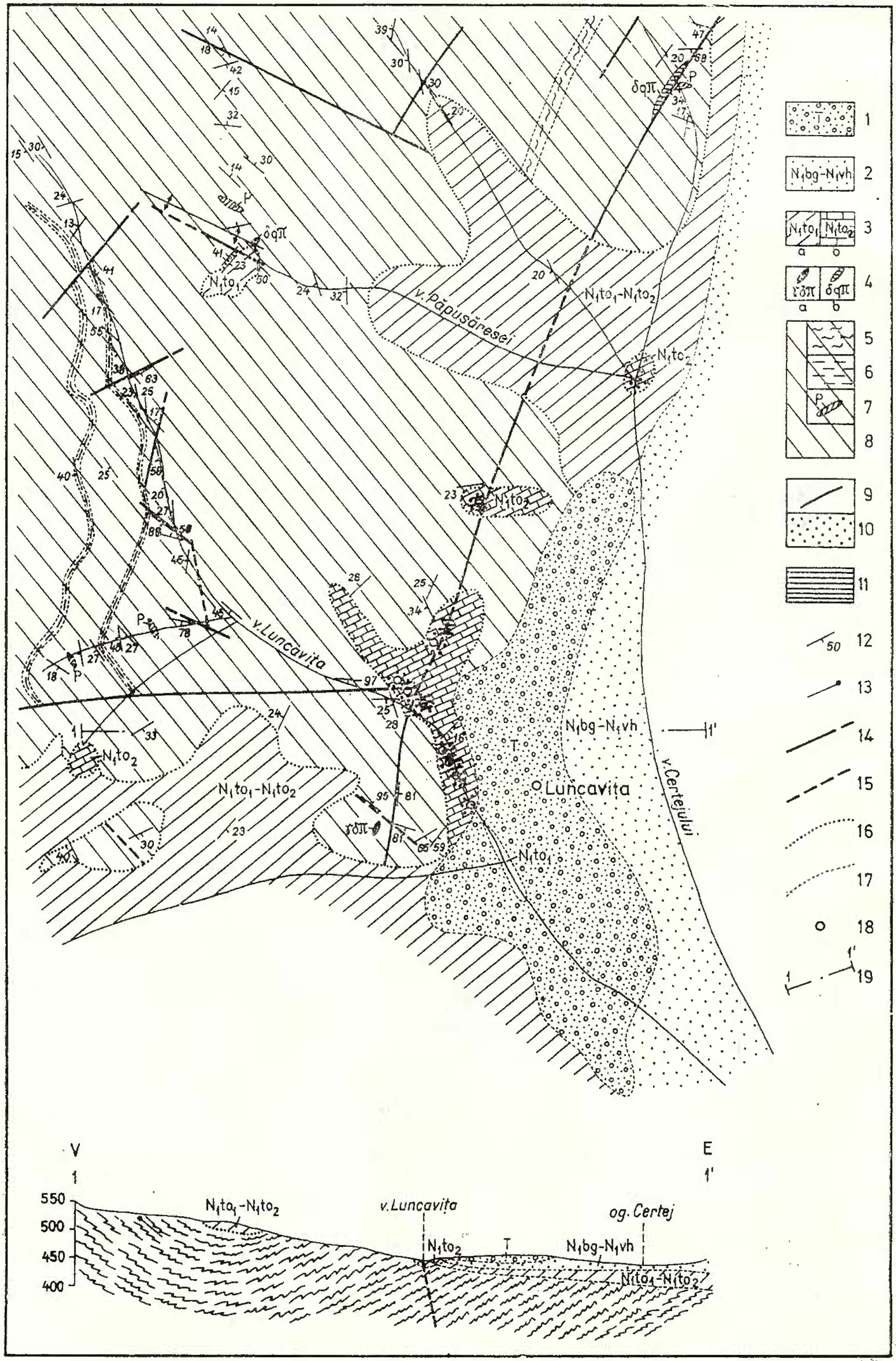
Studiul microscopic al mineralizațiilor a fost efectuat cu sprijinul geologului I. Samoilă, din cadrul laboratorului de analize microscopice, analizele chimice și spectrale au fost efectuate în laboratoarele IPGG de către chimiștii Marina Demetrescu și Elena Popa iar analizele Rx de către geolog T. Urcan.

## Geologia regiunii

La alcătuirea geologică a regiunii participă metamorfite, magmatite și depozite sedimentare. Substanțele minerale utile sînt reprezen-

[1] Depusă la 5 iunie 1982, acceptată pentru comunicare și publicare la 4 decembrie 1982, comunicată în sesiunea științifică a Întreprinderii de Prospecțiuni Geologice și Geofizice din 28 aprilie 1982.

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



v. Păpușăresei
v. Luncavița
v. Certejului
Luncavița
N1to1-N1to2
N1to1
N1to2
N1bg-N1vh
T
δqπ
γδπ
P
1
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E
1
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550
500
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v. Luncavița
og. Certej

tate de sulfuri, în care predomină pirita iar aurul apare subordonat (Serafimovici et al., 1980, 1981).

Metamorfitele aparțin Seriei de Sebeș-Lotru (zonele cu staurolit și disten și staurolit, Savu, 1974) și sînt reprezentate prin micașisturi, gnaise, cuarțite, paragnaise, amfibolite, migmatite, pegmatite și cuarț metamorfic (Hurduzeu, 1962 ; Paraschivescu, Serghie, 1963).

Cristalinul prezintă o închidere periclinală în această parte a regiunii și înclinări de 18—40° spre nord vest. Tot în cristalin, s-a remarcat o falie nord est-sud vest, cu fracturi și fisuri de sprijin nord vest-sud est, ele afectînd și calcarele badeniene.

Magmatitele apar sub formă de dykuri și filoane de dimensiuni reduse, dar cele mai multe rămîn în profunzime sau aproape de suprafața de eroziune a scoarței. Aceste magmatite sînt considerate laramice (Cretacic superior-Paleogen, Giușcă et al., 1966) și sînt reprezentate prin diorite cuarțifere, diorite și microdiorite cuarțifere porfirice și sporadic andezite cuarțifere și aplite. Pe lîngă aceste roci, Popescu (1981) menționează și prezența granodioritelor.

Formațiunile sedimentare badeniene și sarmațiene au fost observate pe toată rama de est a cristalinului din acești munți. Ne vom ocupa numai de depozitele badeniene în care a fost observată mineralizația.

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Harta geologică a regiunii Luncavița, Munții Semenicului de est. Formațiuni sedimentare ; Holocen : 1, terasă, bolovăniș, pietriș, nisip. Sarmațian : 2, Volhinian, marne, argile, gresii, nisipuri, pietrișuri ; Buglovian, argile. Badenian : 3 a, marne, tufuri, argile, nisipuri, pietrișuri, cărbuni ; b, marne, gresii, calcar de Leytha. Formațiuni magmatice ; Cretacic superior-Paleogen : 4 a, granodiorit porfiric ; b, diorit cuarțifer porfiric. Formațiuni metamorfice (Seria de Sebeș-Lotru, zona cu staurolit și disten) Precambrian sup. A ; 5, micașisturi cu almandin ; 6, paragnaise cu biotit ± muscovit ± almandin ; 7, pegmatite micacee și feldspatice ; 8, micașisturi muscovito-biotitice. Mineralizații : 9, filonașe cu sulfuri (pirită, marcasită) ; 10, impregnații sulfuri. Transformări hidrotermale : 11, carbonatări, silicifieri, feldspatizări ; 12, foliație ; 13, înclinarea foliației ; 14, falie ; 15, falie presupusă ; 16, limită de transgresiune ; 17, limită normală ; 18, analize chimice și spectrale ; 19, capete de secțiuni geologice.

Carte géologique de la région de Luncavița, Monts Semenic de l'Est. Formations sédimentaires ; Holocène : 1, terrasse, blocaux, graviers, sables. Sarmatien ; 2, Volhinien : marnes, argiles, grès, sables, graviers ; Buglovien : argiles. Badénien : 3 a, marnes, tuffs, argiles. sables, graviers, charbons ; b, marnes, grès, calcaire de Leytha. Formations magmatiques ; Crétacé supérieur — Pléogène ; 4 a, granodiorite porphyrique ; b, diorite quartzifère porphyrique. Formations métamorphiques (Série de Sebeș-Lotru, zone à staurolite et disthène). Précambrien supérieur A ; 5, micaschistes à almandin ; 6, paragneisses à biotite ± muscovite ± almandin ; 7, pegmatites micacées et feldsphatiques ; 8, micaschistes muscovito-biotitiques. Minéralisations ; 9, petits filons à sulfures (pyrite, marcasite) ; 10, impregnations sulfures. Transformations hydrothermales ; 11, carbonatations, silicifications, feldspathisations. 12, foliation ; 13, angle de la foliation ; 14, faille ; 15, faille supposée ; 16, limite de transgression ; 17, limite normale ; 18, analyses chimiques et spectrales ; 19, extrémités des sections géologiques.

Iliescu et al. (1968, 1971) împarte Badenianul în două complexe şi anume : complexul detritic inferior şi complexul detritic superior.

În complexul inferior, autorii sus menţionaţi au deosebit un orizont grezos-conglomeratic şi un orizont marnos-nisipos cu nivele de cărbuni şi tufuri. În baza acestui orizont marnos cu cărbuni, a fost observat un nivel de nisipuri cu concreţiuni de pirită şi marcasită (Iliescu et al., 1971).

Complexul detritic superior este constituit mai ales din calcare de Leytha, în aceste calcare fiind întîlnită mai pregnant mineralizaţia cu sulfuri. Acest complex detritic a fost observat stînd transgresiv pe cristalin sau pe complexul detritic inferior.

În valea Luncaviţa, s-au remarcat în bază, stînd direct pe cristalinul de Sebeş-Lotru, o brecie calcaroasă cu elemente de şisturi cristaline, variate ca mărime, peste care urmează primele bancuri masive de calcare detritice fosilifere. La anumite nivele, aceste calcare sînt mai detritice, sau mai compacte, dure, fosilifere, prezentînd intercalaţii de marne şi accidental de nisipuri.

Calcarele de Leytha au poziţii diferite, ele fiind întîlnite ca petice pe cristalin sau pe complexul marnos-nisipos inferior. Ele au direcţia nord vest-sud est şi înclinări de 5—36° nord est, în valea Luncaviţa şi nord est-sud vest cu căderi de 25° nord vest pe dealul Păpuşele.

Calcarele sînt fisurate şi pe aceste fisuri se vede o mineralizaţie polimetalică. S-au remarcat două direcţii de fisuri şi anume : o direcţie este N12V-N60V iar alta N28E-N56E. Ambele sisteme de fisuri sînt circulate de soluţii hidrotermale.

*Mineralizaţia* este preponderent piritoasă şi localizată pe fisuri, fracturi şi foliaţii în calcare sedimentare şi cristalin. Aceasta are o formă filoniană sau de impregnaţie. Apare în firul văii Luncaviţa şi pe culmea din versantul stîng al acestei văi. Mineralizaţia a mai fost întîlnită şi în bazinul miocen de la nord de Verendin, pe ogaşul Vîrtopul Mic şi afluenţii săi.

S-a observat pirită foarte fină şi marcasită care apar în roca calcaroasă fosiliferă. Această rocă este cenuşie, poroasă pe alocuri, cu geode în care este depus calcitul şi cuarţul, sau prezintă filonaşe şi acumulări de formă neregulată de pirită. S-au remarcat depuneri colomorfe şi cruste subţiri de marcasită însoţită de o gangă calcitică, uneori verzuie, probabil cu unele adaosuri mici de carbonat bazic de cupru, aşa cum reiese şi din analiza cu raze X. Asociat proceselor de carbonatare şi silicifiere s-au observat şi feldspatizări, mai ales marcate de ortoză şi subordonat albit-oligoclaz.

Analiza microscopică s-a efectuat atît pe roca gazdă prin secţiuni cît şi pe şlifuri executate din calcarele mineralizate şi concentrate de pirită, rezultate din spălarea la şaitroc şi înglobate în poliacrilat sau balsam.

S-au analizat astfel 5 probe de calcare mineralizate şi o probă de concentrat de pirită. Aceleaşi probe au fost analizate chimic pentru Au, Ag, Fe, S ; docimazic spectral pentru Au, Ag, Pt, Pd, Rh şi spectral pentru o serie de elemente chimice.

Studiul calcografic pe şlifuri, a indicat parageneza pirită + mispichel + blendă + calcopirită în probele $L_1$, $L_2$, $L_4$, $L_5$, L iar în proba $L_3$ a mai fost observată şi marcasită.

Prin analiza microscopică a secţiunilor şi şlifurilor au fost identificate minerale metalice ca :

*Pirita* apare în concentratul piritos în proporţie de 80%. Se prezintă în cristale idiomorfe, hipidiomorfe, rar rotunjite, fisurate şi parţial marcasitizate. Uneori este asociată cu cristale de mispichel, alteori cu marcasită. Ea formează masa de bază a mineralizaţiei.

*Marcasita* se prezintă sub formă de depuneri concentrice cu aspect zonar, asociată cu cristale de pirită. Nu apare asociată cu mispichelul. În proba $L_3$ este în proporţie de 25%.

*Mispichelul* în proporţie de 0,2—1% se observă sub forma unor cristale idiomorfe sau hipidiomorfe, fisurat şi asociat cu pirita. În concentrat s-au putut vedea cristale rombice formînd mici agregate.

*Calcopirita* apare în proporţie de 0,1—0,2%, în plaje neregulate şi dispersate în marcasită. S-au remarcat cristale rotunjite uneori neregulate, alteori asociate cu pirita în care apare şi ca incluziuni.

*Blenda* în proporţie de 0,1% s-a observat în granule uneori rotunjite (în concentrat) sau alteori de formă neregulată în rocă şi asociată cu calcopirita ca în proba $L_5$.

*Aurul* poate apare liber în cuarţ în zona Verendin dar şi asociat cu sulfurile. În perimetrul localităţii Luncaviţa, aurul a fost văzut într-un şlif preparat din concentratul de pirită din calcarele de pe valea Luncaviţa. Şi în acest caz, el este asociat cu cuarţ şi sulfuri.

*Ganga* mineralizaţiei polimetalice postbadeniene de la Luncaviţa este constituită din carbonaţi, cuarţ, feldspaţi, mice, silice criptocristalină, într-o rocă calcaroasă fosiliferă.

*Calcarul* mineralizat are o structură granulară, uneori micritică iar structura masivă.

**Transformări hidrotermale.** Mineralizaţia polimetalică de la Luncaviţa nu prezintă procese de alterare hidrotermală de mare intensitate.

Remarcăm faptul că, datorită intruziunilor eruptive ce străbat cristalinul în această parte a regiunii, a fost semnalat un aport de potasiu care a generat ortoza, urmată apoi de venirea feldspaţilor plagioclazi (Popescu, 1981). Acest lucru s-a observat în apropierea unora din filoanele şi dykurile eruptive, cît şi în calcarele badeniene mineralizate cu sulfuri şi aur sau în argilele verzui de aceeaşi vîrstă.

Procesele de carbonatare sînt marcate de calcit şi depuneri secundare de malachit iar silicifierea însoţeşte procesul de carbonatare, dar pe zone restrînse, cu un aport probabil şi de silice criptocristalină.

Probele prelevate din mineralizaţia badeniană, atît din zona Luncaviţa cît şi de la Verendin, au fost analizate spectral, aşa cum reiese din tabelul anexat.

Din analiza rezultatelor analizelor chimice şi spectrale, rezultă că aurul şi argintul sînt prezente pe fisuri şi falii în calcarele de Leytha, cît şi în argilele şi rocile complexului cu cărbuni din apropierea Verendinului, cu conţinuturi mici, între 0,01 şi 0,30 g/t Au şi 1,40—7,05 g/t Ag. Numai concentratul piritos L, a indicat un conţinut mai ridicat în aur şi argint. Sulful prezintă conţinuturi între 1,40% şi 3,50%.

TABEL

| Nr. crt. | nt. probei | Cu | Pb | Zn | As | Bi | Ni | Co | Cr | Mn | Mo | V | Ba | Sr | Ga | Rb | Sn | Sc | Ti | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —ppm— | | | | | | | | | | | | | | | | | | |
| 1 | II | sld | sld | 225 | 1 500 | sld | 5 | sld | sld | 400 | 15 | 3 | 1 300 | 50 | sld | 50 | — | — | — | sld |
| 2 | III | sld | 3 | 130 | 400 | sld | 30 | 300 | 30 | 300 | 30 | 3 | 15 | 100 | sld | 30 | — | — | — | 7 |
| 3 | IV | sld | sld | sld | sld | sld | sld | 3 | 3 | 1 000 | 30 | sld | 10 | 500 | sld | 200 | — | — | — | 7 |
| 4 | V | sld | sld | 115 | 1 000 | sld | 10 | sld | 3 | 1 400 | 5 | sld | 50 | 30 | sld | 30 | — | — | — | 12 |
| 5 | VI | 100 | 10 | 3 000 | sld | sld | 11,5 | 9 | 10 | p | — | 30 | 15 | 550 | sld | 150 | — | — | — | 15 |
| 6 | H | sld | — | — | sld | — | — | 3 | — | — | 3 | — | — | 3 000 | sld | 275 | 22 | 22 | — | sld |
| 7 | K | sld | sld | sld | sld | sld | sld | sld | sld | 900 | 3 | sld | 85 | 300 | sld | sld | — | — | — | sld |
| 8 | L | sld | sld | sld | sld | sld | 5 | sld | sld | 1 000 | 3 | sld | 40 | 200 | sld | sld | — | — | — | sld |
| 9 | M | sld | sld | sld | sld | sld | 5 | sld | sld | 1 000 | | sld | 15 | 650 | sld | sld | — | — | — | sld |
| 10 | N | sld | sld | sld | sld | sld | 3 | sld | sld | 1 000 | sld | sld | 450 | 600 | sld | sld | — | — | — | sld |
| 11 | A | sld | — | — | — | — | — | 9 | — | — 32 | — | — | — | 300 | sld | sld | — | — | — | 3 |
| 12 | 068 | sld | 30 | 200 | sld | sld | 35 | 11 | 45 | — | 3 | sld | — | 300 | 10 | 350 | 12 | 12 | — | sld |
| 13 | 0412 | sld | — | — | — | — | — | 7 | — | — | — | — | — | 100 | 9 | 275 | 5 | 5 | — | sld |
| 14 | OT | 8 | sld | sld | sld | 100 | 100 | — | — | — | 10 | 60 | — | — | sld | — | — | — | — | — |
| 15 | $OT_1$ | 8 | sld | sld | sld | 30 | 30 | — | — | — | sld | 22 | — | — | sld | — | — | — | — | — |
| 16 | 72B | 5 | sld | sld | sld | sld | sld | — | sld | 100 | sld | 40 | — | — | 3 | — | 3 | 3 | 1 500 | 250 |
| 17 | L | sld | sld | sld | sld | sld | sld | 3 | — | 35 | sld | 20 | — | 4 | — | — | — | — | — | — |

Analizele spectrale pentru Sb, Sc, Te, Ge, Tl, La, Y, Yb, Be, In, Nb, Li, Zr, W nu au indicat decît conţinuturi sub limita de detecţie.

— Probele II, III, IV, V, VO, J, K, L, M, N, au fost prelevate din calcare de Leytha de pe valea Luncaviţa;

— Probele 068 şi 0412 au fost prelevate din fracturi în şisturi cristaline de pe valea Luncaviţa;

— Probele OT, $OT_1$, O72 B au fost prelevate din calcare de Leytha şi argile de pe ogaşul Vîrtopul Mic;

— Proba L este un concentrat piritos din calcare de Leytha pe valea Luncaviţa.

Mineralizaţia piritoasă cupriferă ± aur întîlnită în Badenianul din jurul localităţilor Verendin şi Luncaviţa, a fost observată şi pe o serie de fracturi, orientate nord vest-sud est, în cristalinul de Sebeş-Lotru, de la vest şi nord de localitatea Verendin. În această zonă, mineralizaţia de sulfuri are pe lîngă mineralele metalice menţionate şi tetraedrit, ca şi un conţinut mai ridicat de calcopirită şi aur (Serafimovici et al., 1980, 1981). Uneori s-au observat piritizări şi mai puţin calcopirită, în rocile andezitice sau dioritice ce aflorează în regiune, făcînd posibile acumulările de tip porphyry copper (Gunnesch et al., 1978).

Considerăm că mineralizaţiile polimetalice, au ca sursă magmatismul neogen, deoarece întreaga stivă de sedimente badeniene este străbătută de soluţii hidrotermale, mai ales în zonele de intensă fracturare a fundamentului şi a acoperişului cu depozite badeniene.

Forajul 16 de la Mehadica executat pentru cărbuni, a interceptat probabil o falie neogenă, care a înlesnit circulaţia unor ape termale cu debit puternic. Analiza apei indică în prezent 24°, este clorosodică, bromurată, cu o concentraţie foarte mică şi cu 17,6 $CO_2$%, aşa cum reiese din buletinul de analiză întocmit de chimista Sanda Hera din cadrul secţiei prospecţiuni hidrogeologice a IPGG (Simion, Popa, 1974).

Prezenţa apei termale în această regiune, vine să confirme o activitate post-magmatică neogenă, probabil pînă în Cuaternar.

Cercetările ulterioare în regiune vor fi completate de date noi, ce vor fi obţinute din lucrările de prospecţiune geologică, geochimică şi geofizică însoţite de lucrări miniere şi foraje ce se vor executa în viitor.

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## NOTE CONCERNANT LES MINÉRALISATIONS POLYMÉTALLIQUES DE LA RÉGION DE LUNCAVIŢA (MONTS DE SEMENIC)

### (Résumé)

La minéralisation polymétallique de Luncaviţa des Monts Semenic d'Est, a été observée dans les dépôts badéniens des environs des localités de Luncaviţa et Verendin, dans le district de Caraş-Severin.

La région est constituée de métamorphites appartenant à la série de Sebeş-Lotru, de magmatites banatitiques sous-volcanique et de roches sédimentaires badéniennes, sarmatiennes et quaternaires.

La minéralisation a été rencontrée dans le complexe détritique supérieur prédominemment calcaire (Calcaires de Leytha). Dans ce complexe, la minéralisation polymétallique apparait sur des fractures et fissures ou plans de foliation, se continuant dans les roches métamorphiques sur lesquelles ceux-ci reposent transgressivement et discordamment.

Les calcaires de Leytha apparaissent comme des lambeaux sur les roches métamorphiques ou sur le complexe inférieur marno-sableux à charbons. Ils sont orientés nord-est-sud-ouest à valeurs de pendage de 5—35°.

La minéralisation est surtout pyriteuse, de forme filonienne ou d'imprégnation. Elle apparaît au long de la Vallée de Luncaviţa et la colline de Păpuşariţa ainsi que dans le bassin miocène du vallon de Vîrtopul Mic-Verendin.

L'étude chalcographique a mis en évidence la paragenèse : pyrite + chalcopyrite + blende + mispickel ± or, parfois également marcasite.

Dans une lame exécutée d'un concentré pyriteux on a remarqué de la pyrite (80%), de la marcasite (25%) (qui se dépose concentriquement dans des zones), de la chalcopyrite (0,1—0,2%), du mispickel (0,2—1%) et de la blende (0,1%).

L'or apparaît libre dans le quartz, dans la zone de Verendin, mais aussi associé à des sulfures, tant dans les schistes cristallins que dans les calcaires badéniens minéralisés de Luncaviţa.

La gangue de la minéralisation polymétallique postbadénienne est constituée de carbonates, quartz, silice cryptocristalline et feldspaths, dans une masse calcaire bréchique.

Les processus d'altération hydrothermale sont faibles et marqués par des carbonatations, silicifications et feldspathisations.

L'analyse spectrale docimasique a mis en évidence dans certains échantillons des teneurs de zinc qui dépassent 300 ppm et des teneurs de cuivre très réduites dans les calcaires badéniens minéralisés mais beaucoup plus élevées sur les fractures du nord-ouest de la localité de Verendin.

Nous considérons que les minéralisations polymétalliques des calcaires badéniens de Luncaviţa ont comme source le magmatisme néogène. Aux données présentées on ajoute aussi le fait que dans la région, le forage 16 exécuté par IFLGS pour les charbons de Mehadica (environ 5 km sud de Luncaviţa) a intercepté une source d'eau thermale (31°), chlorosodique, bromurée, faiblement minéralisée et à 17,6% $CO_2$. Ceci suggère de possibles manifestations postmagmatiques néogènes.

*D.S. Inst. geol. geofiz.* vol. LXIX (1982). Pag. 71—87

## 2. ZĂCĂMINTE

IUGS UNESCO

Projet 25 : Stratigraphic correlation of the Tethys-Paratethys Neog

# CONSIDÉRATIONS PALÉOFLORISTIQUES ET PÉTROGRAPHIQUES SUR LA GENÈSE DES LIGNITES DE L'OUEST D'OLTÉNIE [1]

PAR

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*Paleoflora. Lignite. Dacian. Romanian. Macroflora assemblage. Coal petrography. Palynoflora. Getic Depression.*

**Abstract**

*Paleofloristic and Petrographic Considerations on the West Oltenia Lignite Genesis.* The paleobotanic and palynologic study of the coal deposits and the coal petrographic analysis has allowed the authors to reconstruct the vegetal assemblages that participated in the genesis of the coals in the Dacian-Romanian interval in W. Oltenia. Autochthonous phytocenoses are described : *Sequoia* assemblage, moor with bushes ; swamp with *Glyptostrobus* and *Braunia ;* reed marsh *(Phragmites)* and open water assemblage. Two allochthonous vegetal assemblages are also presented in short ; mixed conifer and hardwood forest and mesophyle hardwood forest. In the end the main factors are analysed in broad lines, that conditioned the development and accumulation of vegetal biomass : water depth, salinity and basin subsidence.

## 1. Considérations générales

C'est à la fin du siècle passé, dans les ouvrages de Drăghiceanu et Sabba Ştefănescu que les charbons pliocènes d'Olténie sont mentionnés pour la première fois. Plus tard ces formations à charbons ont fait l'objet de certaines études stratigraphiques, pétrographiques ou éco-

[1] Reçue le 5 mai 1982, acceptée pour être communiquée et publiée le 10 mai 1982, présentée à la séance de 21 octobre 1982.

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nomiques, parmi lesquelles celles de Grozescu (1925), Filipescu (1942), Oncescu (1952), Cârâc (1959), Popovici (1959 a, b), Ilie, Bițoianu (1967) et Marinescu (1978).

Quoique relativement riche, la littérature géologique citée ne se refère que très rarement et seulement en passant à la genèse des charbons, les premières observations plus importantes étant les résultats des études pétrographiques d'Ilie et Bițoianu (1967). Récemment, Marinescu (1978) fait des remarques interessantes sur la migration de l'est à l'ouest des faciès limniques à charbons dans le bassin dacique.

Du point de vue litho-stratigraphique, dans l'aire investiguée les charbons sont englobés dans les dépôts attribués au Dacien et au Romanien, formés en premier lieu par des argiles silteuses, argiles charbonneuses, charbons, sables et plus rarement sables grossiers et graviers, les derniers plus fréquents dans les dépôts romaniens. Quant à l'étage Dacien nous mentionnons que selon certains auteurs, comme par example Marinescu (1978) il n'est représenté que par sa partie inférieure (Getien) selon d'autres (Pauliuc et al., 1981) il est complet, contenant le Parscovien aussi. Comme cet ouvrage ne s'occupe pas de l'étude stratigraphique de la formation à charbons on n'insiste plus sur ce problème controversé pour le moment.

Tenant compte de la complexité des problèmes concernant la genèse des charbons pliocènes d'Olténie, dans cet ouvrage nous nous proposons d'aborder leur étude en utilisant les résultats de la recherche paléobotanique, palynologique et pétrographique des complexes à charbons effectuée par les auteurs en 1979—1981, entre les Vallées d'Amaradia et de Motru (in Motaş et al., 1980 et Papaianopol et al., 1981).

## 2. Flore du Dacien et Romanien

Pour l'étude de la flore de l'intervalle Dacien-Romanien on a employé les résultats obtenus par nous, ainsi que les données connues jusqu'à présent dans la littérature de spécialité : Laurent et Marion (1898), Barbu (1933, 1954), Barbu et Givulescu (1965), Givulescu (1960), Ţicleanu et al. (1982).

Les recherches palynologiques et macrofloristiques que nous avons effectuées ont montré qu'en ce qui concerne la composition floristique le Dacien et le Romanien sont tout ressemblants, les différences entre eux visant surtout la quantité, ce qui nous a déterminé a traîter les deux paléoflores ensemble.

Les restes végétaux qui ont permis l'identification de 39 taxons (tab. 1) proviennent des intervalles stériles (empreintes foliaires et fruits) et des couches à charbons où on a trouvé des rameaux, troncs et même fruits qui, parfois, sont peu carbonifiés.

Du tableau synthétique de la macroflore il résulte qui les taxons hygro- et hydrophiles, les principaux éléments constituants autochtones de marais silvestres générateurs de lignite sont bien représentés. Le caractère autochtone de ces taxons est déduit de la présence, dans la plupart des gisements fossilifères d'un nombre impressionnant d'exemplaires de *G. europaeus*, *B. tiliaefolia* (parfois de milliers d'empreintes

TABLEAU 1

*Macroflore du Dacien-Romanien de la partie ouest d'Oltenie*

| Taxons | Formations végétales: Forêt mésophile | Formations végétales: Forêt au bord d'une rivière | Formations végétales: Forêt de marais | Formations végétales: Plantes palustres | Formations végétales: Aquatiques | TIMIȘANI | POIANA | GÎRLA | TISMANA | LUPOAIA | DEDOVIȚA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Osmunda regalis*, L. | | | + | | | + | + | | | + | |
| *Salvinia* sp. * | | | | | + | + | | | | | |
| *Pinus* sp. | + | | | | | | | | | + | |
| *Glyptostrobus europaeus* (Brngt.) Heer | | | + | | | + | + | + | + | + | |
| *Sequoia abietina* (Brngt.) Knobl ** | + | | | | | + | | | | | + |
| *Typha latissima* Al. Br. | | | | + | | | + | + | + | + | |
| *Potamogeton div.* sp. | | | | | + | | + | + | + | + | |
| *Stratiotes div.* sp. | | | | | + | | + | + | + | + | |
| *Hydrocharis* sp. | | | | | + | | + | | | | |
| *Spirematospermum wetzleri* (Heer) Chandl. | | | | | + | | + | | | | |
| *Phragmites oeningensis* Al. Br. | | | | + | | | + | + | + | + | |
| *Populus attenuata* Al. Br. | + | + | | | | + | | | | | |
| *P. grosedentata* | | + | | | | | + | | | + | |
| *Salix varians* Goepp. | | + | | | | + | + | + | + | + | + |
| *S. macrophylla* Heer | | + | | | | | + | | | + | |
| *S. pliocenica* Barbu | | + | | | | + | | | | | |
| *S. fragilis* L. | | + | | | | + | | | | | |
| *S. Ștefănescui* Laur. et Mar. | | + | | | | + | | | | | |
| *S. integra* Goepp. | | + | | | | | | | | | + |
| *Betula* cf. *macrophylla* (Goepp.) Heer | | + | + | | | | | | | | + |
| *Carpinus grandis* Ung. | + | | | | | | | | | | + |
| *C. pyramidalis* Goepp. | + | | | | | | | | | | + |
| *Alnus gaudinii* Heer | + | | | | | | | | | | + |
| *Alnus* sp. | | + | | | | | + | | | | + |
| *Juglans acuminata* Al. Br. | + | | | | | | | | | | + |
| *J. cinerea* L. | + | | | | | | + | | | | |
| *Carya sereaefolia* (Goepp.) Kräusel | + | | | | | | | | | | + |
| *Carya* sp. | + | | + | | | | + | + | | | |
| *Pterocarya denticulata* Heer | + | | | | | + | | | | | |
| *Fagus attenuata* Goepp. | + | | | | | | | | | | + |
| *Quercus roburoides* Brngt. | + | | | | | | | | | | + |
| *Castanea atavia* Heer | + | | | | | | | | | | + |
| *Acer tricuspidatum* Al. Br. | | | + | | | + | + | | + | | |
| *Liquidambar europaea* Al. Br. | | | + | | | | + | | + | + | + |
| *Parrotia* aff. *fagifolia* Heer | + | | | | | + | | | | | |
| *Buxus sempervirens* | + *** | | | | | | | | | | |
| *Sapindus* sp. | + *** | | | | | + | | | | | |
| *Braunia tiliaefolia* (Al. Br). Giv. | | | + | | | + | + | + | + | + | |
| *Trapa* sp. | | | | | + | | + | | | + | |

* Déterminé par I. Z. Barbu comme *S. reussi* et révisé par Givulescu (1968).
** Déterminé par Barbu (1933) comme *Taxodium dubium* révisé par Ţicleann et al. (1982).
*** *Sapindus* et *Buxus* sont plus fréquents dans la végétation à charactère xérophite.

foliaires), *T. latissima, Ph. aeningensis, Stratiotes* div. sp., *Salix varians* et d'autres. Une preuve évidente pour le caractère autochtone est offerte par la présence dans le même endroit et en grand nombre des rameaux de dimensions variées avec feuilles et cônes de *G. europaeus;* un exemple dans ce sens-là est le toit de la couche VI de la carrière de Poïana, ainsi que la forêt fossile à nombreux arbres restés en position verticale de la carrière de Lupoaia, au dessus de la couche X. De même, dans la plupart des carrières, mais surtout à Poïana, Gîrla, Tismana et Lupoaïa, dans le stérile de la couche on remarque souvent des rameux orientées en bas. D'autres taxons qui, pour le moment n'ont été identifiés que dans 1—2 affleurements, présentent parfois une fréquence spectaculaire, comme par exemple, les dépôts de feuilles fossiles de *A. tricuspidatum* du toit de la couche VIII, carrière de Poïana, les dizaines de fruits de Trapa de la même couche ainsi que les nombreuses empreintes de l'espèce *O. regalis* de Timişani [4].

Les éléments allochtones *(F. attenuata, Q. roburoides, C. atavia* et d'autres) ont leur origine dans les forêts mésophiles aux environs du bassin de sédimentation ; ils apparaissent sporadiquement dans les carrières de lignite, mais en représentent 70% à Dedoviţa (Ţicleanu et al., 1982), ce qu'on explique par le fait que cette localité se trouve tout près des confins du bassin. La plupart des taxons allochtones présentent seulement 1—3 exemplaires d'empreintes foliaires qui portent souvent des traces de transport (érosions ou l'absence des parties de lobe).

L'image de la flore du Dacien-Romanien est complétée par les données obtenues par des études palynologiques, qui apportent des formations nombreuses et importantes. Dans ce but on a prélevé des échantillons du lit et du toit des couches V—XII des carrières de Poïana, Roşia, Gîrla, Beterega et Lupoaia. Les analyses palynologiques ont mis en évidence la présence de nombreuses unités systématiques.

*Sporites: Hepaticae,* cf. *Riccia, Sphagnum, Lycopodium, Ophioglosaceae, Lygodium, Pteris, Polypodiaceae, Verrucarotporites, Osmundaceae, Salviniaceae.*

*Polénites: Ginkgo, Podocarpus, Keteleeria, Abies, Pinus haploxylon, Pinus silvestris, Tsuga, Cedrus, Picea, Taxodiaceae, Sequoia, Sciadopitys, Ephedra, Sparganium, Typha, Butomus, Gramineae, Cyperaceae, Lemna, Salix, Juglans, Carya, Pterocarya, Betula, Carpinus, Ostrya, Alnus, Corylus, Cannabinaceae, Fagus, Quercus, Castanea, Celtis, Zelkova, Ulmus, Loranthus, Polygonum persicaria, Chenopodiaceae, Caryophyllaceae, Nymphaea, Nuphar, Thalichtrum, Magnoliaceae, Brassicaeae, Platanus, Eucommia, Liquidambar, Rosaceae, Fabaceae, Anacardiaceae, Rutaceae, Acer, Vitis, Parthenocissus, Tilia, Nyssa, Onagraceae, Apiaceae, Myriophyllum, Araliaceae, Butomus, Ericaceae, Cornus, Symploccos, Lamiaceae, Caprifoliaceae, Dispacaceae, Compositae* and *Artemisia.*

Les éléments floristiques les plus repandus dans les spectres polyniques sont les arbres caducifoliaires, les représentants des genres: *Quercus, Ulmus, Zelkova, Celtis, Pterocarya, Alnus, Carya, Carpinus, Ostrya, Liquidambar, Fagus, Corylus, Salix* et *Tilia.* Les genres *Cas-*

*tanea, Acer, Eucommia, Juglans, Platanus* et *Aesculus* sont une présence discontinuelle.

Les Gymnospermes avec les pourcentages les plus élevés sont les Taxodiacés, suivis par *Pinus*, avec les types sylvestre et haploxylon, *Picea, Cedrus, Abies* et *Sciadopitys* et d'une manière discontinuelle apparaissent : *Ginkgo, Keteleeria, Podocarpus* et *Sequoia*.

Les arbustes étaient présents par des espèces de *Myrica* à constance remarquable quant à la fréquence (on a aussi trouvé des glandes peltées fixées sur les feuilles), *Cyrillaceae, Sapotaceae, Cornus, Ericaceae, Anacardiaceae* et parfois *Staphylea, Magnoliaceae, Rhamnaceae* et *Symploccos*.

Il y avait également une séries de lianes liées directement des arbres et arbustes : *Araliaceae, Vitaceae (Vitis, Parthenocissus)* ainsi que *Sterculiaceae*, dont la présence, dans tous les niveaux stratigraphiques et dans toutes les carrières est indiquée également par la présence fréquente des empreintes foliaires de *B. tiliaefolia* [5]. À Timişani apparaissent aussi les fruits de ce Stérculiacé (syn. *Banisteriaecarpum giganteum* (Goepp.) Kräusel, et en dehors de l'aire investiguée, à Bălteni sur la Vallée de Cerna on a découvert des exemplaires très clairs (Ţicleanu, 1982).

Les fougères sont représentées par *Salviniaceae, Polypodiaceae, Ophioglossaceae* et *Schizeaceae (Lugodium)*, et les mousses par *Sphagnum* et *Riccia*.

Les éléments palustres et aquatiques sont présents surtout par *Poaceae, Cyperaceae, Typha, Butomus, Lemna, Polygonum persicaria, Nuphar* et *Myryophyllum*.

Quoique composées d'éléments similaires, les flores du Dacien et Romanien présentent certaines différences d'ordre quantitatif. Ainsi, dans le Romanien le rôle des arbres caducifoliaires et de plus en plus grand et *Podocarpus, Tsuga, Keteleeria, Myrica, Cyrillaceae, Ericaceae, Ilex, Liquidambar europaeum* sont en déclin continuel. D'ailleurs *L. europaeum* présente un développement maximum dans d'autres zones de Roumanie, dans l'intervalle Pontien supérieur-Dacien à Cărbuneşti-Prahova (Ţicleanu in Pauliuc et al., 1970).

Du point de vue paléoclimatique on constate certaines oscillations des facteurs de température et humidité atmosphérique. Les variations de température sont reflétées par la courbe des thermophiles (fig. 2) qui présente deux minima importants, le premier au niveau du lit de la couche VI et le second, plus marqué au niveau de la couche XI. Les variations de l'humidité atmosphérique peuvent être observées sur la courbe des hygrophiles (fig. 2) où on remarque trois maxima, au niveaux des couches VI, VIII et XI ; le minimum le plus prononcé est placé au niveau de la couche X.

De l'analyse des éléments floristiques existents dans le Dacien-Romanien et de la comparaison avec les correspondants actuels il résulte pour cet intervalle de temps l'existence d'un climat de type C.f.a. (système Köppen), c'est-à-dire tempéré-chaud, humide avec des étés chauds et des hivers à température minimum au dessus de 5°C.


Fig. 1. — Esquisse avec l'emplacement des points où on a fait des recherches : a, macrofloristiques ; b, palynologiques ; c, pétrographiques.

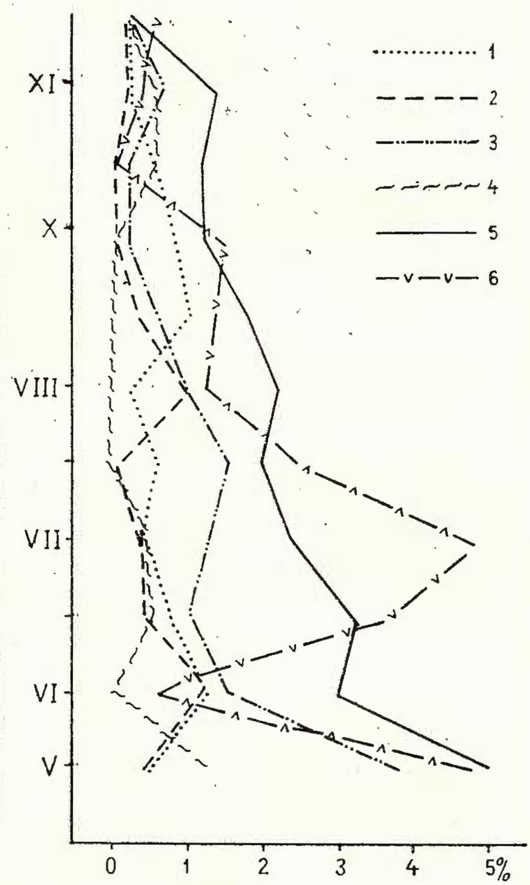


Fig. 2. — Diagramme polynique de l'association d'arbustes.
1, Myrica ; 2, Cyrillaceae ; 3, Ericaceae ; 4, Ilex ; 5, Association My+Cy+Ea+Ilx ; 6, Liquidambar.
V—XI — couche de charbon

La quantité de précipitations présentaient des variations assez grandes mais restait en tout cas au dessus de 1 200 mm/an. Le moment où l'humidité et la température arrivaient à des valeurs d'optimum écologique pour les associations génératrices de charbon s'accumulait une importante biomasse végétale.

Dans l'intervalle stratigraphique compris entre les couches de charbon V et XII, à côté des oscillations thermiques, on observe une tendance générale de refroidissement, clairement exprimée par la courbe de la phytocénose à *Myrica*, qui au dessus de la couche VIII présente une baisse constante.

### 3. Composition pétrographique des charbons

L'étude pétrographique des charbons a été effectuée sur des échantillons prélevés dans les carrières de Poiana, Gîrla, Betereaga, Lupoaïa, Roșiuța, Jilț Sud, Roșia de Jiu et Peșteana ; de même, on a étudié les charbons des affleurements sur Valea Mare et Valea Plopilor, ainsi que dans les forages des aires de Rovinari Est et Fărcășești.

L'aspect macroscopique des charbons est presque identique pour toutes les couches (IV—XIV), parce qu'elles sont constituées des même lithotypes, dont la variation quantitative s'inscrit dans des limites très restreintes, à l'exception des charbons de la région de Fărcășești, où les limites sont plus larges.

Le lithotype principal est représenté par le charbon mat brun-noirâtre, très fissuré, à stratification claire et cassure irrégulière ; souvent apparaît également, sous forme de bandes à épaisseurs variables, un charbon ligneux (xylite) constitué presque exclusivement de rameaux et troncs de *G. europaeus*, parfois faiblement carbonifiés. Secondairement apparaît également un charbon fibreux (fusaine) et un autre sémibrillant.

En comparaison avec les charbons du reste de la Dépression gétique, surtout avec ceux du secteur à l'est d'Olt, les charbons du secteur étudié sont charactérisés par un plus grand pourcentage de xylite qui présente des variations quantitatives horizontalement tout comme verticalement. On remarque ainsi un grand contenu de xylite dans les couches V, VII, VIII et X.

Le charbon fibreux (fusaine) qui peut manquer d'une couche, ou arriver qusqu'à 2—3% est non-stratifié et apparaît plus fréquemment dans les couches IV, VII-Poïana, VII-Lupoaïa et Roșiuța, VIII-Poïana et IX-Lupoaïa.

Le charbon sémibrillant, (quoi qu'il soit le lithotype le moins représenté, peut quant même atteindre, dans certaines situations, des pourcents élevés (couche IV-Valea Florilor — 17%).

Dans les couches de charbon on a identifié parfois des intercalations argileuses à épaisseurs centimétriques ; un exemple dans ce sens est constitué par la couche VI de la carrière de Gîrla, où apparaissent six intercalations d'argiles.

Les analyses microscopiques effectuées sur les lignites des carrières mentionnées ont indiqué la présence des macéraux des groupes huminite, liptinite et intertinite (tab. 2).

Les macéraux les plus fréquents sont ceux qui appartiennent au groupe de l'huminite, ce qui selon Stach et al. (1975) est dû à la carbonification des associations végétales des marais sylvestres générateurs de lignite du type : *„Sequoia moor"*, *„Myricaceae-Cyrillaceae moor"* et *„Nyssa-Taxodium moor"* qui ont engendré l'humotélinite (textinite, ulminite) et *„Reed marsch"* et la végétation d'„open water" de laquelle s'est formée l'humodétrinite (atrinite et densinite).

La quantité réduite de gélinite plaide pour un milieu sousaquatique, où le matériel végétal a subi un processus de diagenèse peu intense, manifesté par la gelification réduite des macéraux.

L'intertite, à participation réduite, confirme l'existence des parties du marais desquelles l'eau pouvait se retirer dans certaines périodes de l'année, comme dans les marais à *Myricaceae* et *Cyrillaceae*.

La présence de la fusinite peut être liée à des moments de stagnation de la subsidence, ce qui a conduit à une dégradation sous aérienne des marais sylvestres générateurs de charbons.

À côté des macéraux, dans la composition des charbons entrent également des substances minérales (0—20%) représentées par argile épigénique, pyrite épigénique et syngénique, oxydes de fer et carbonate de calcium, les derniers déposés sur des fissures. Un contenu plus grand en composants minéraux, donc un degré plus élevé d'impurité on remarque dans les couches de charbon VI, VIII, XI—XIII.

La variation des contenus en différentes macéraux d'une couche à l'autre, ainsi que dans la même couche est un indice de la diversité des associations végétales où se sont formés les charbons, et de la variation de la profondeur des eaux, de leur salinité et de leur pH.

TABLEAU 2

*Composition pétrographique des lignites*

| Groupes de maceraux | Sousgroupes de macéraux | Macéraux | % | Observations |
|---|---|---|---|---|
| Huminite | Humotélinite | Textinite | 3–34 | Concentrations maximums couche IV V. Perilor. IX Fărcășești |
| | | Ulminite | 0–17,4 | Texto-ulminite, couche IX Roșiuța |
| | Humodétrinite | Attrinite | 35–63 | Toutes les couches |
| | | Densinite | 6–22 | Couche X. Roșia de Jiu couche XI Lupoaia et VII Roșiuța |
| | Humocolinite | Gelinite | 0–3 | Conc. maximum couches XII Lupoaia et VII Roșiuța |
| Liptinite | | Corpohuminite | rare | |
| | | Cutinite | 0,08–1,33 | Grandes conc. couches XI–XII Peșteana Sud et X Lupoaia |
| | | Sporinite | 0,07–1,36 | Grandes conc. couche X Peșteana |
| | | Liptodetrinite | 0,54–2 % | VII Roșiuța, VIII Rogojelu, X Urdari |
| Inertinite | | Sclérotinite | 0,06–0,69 | Couches VI–VIII Poiana |
| | | Fusinite | 0,04–5,27 | La plupart des couches |
| | | Inertodétrinite | 0,24–1,11 | Couches X, XI Roșiuța, XII Lupoaia |

## 4. Tentative de reconstruire les associations végétales

Les éléments paléofloristiques présentés dans le chapitre antérieur indique la présence au moins de deux éléments morphologiques majeurs : une zone collinaire plus lointaine et une zone dépressionaire marécageuse très étendue. Les associations mésophiles qui végétaient dans la zone collinaire sont bien reflétées dans les spectres polyniques premièrement grâce à leur développement régional. Les associations végétales du biotype de marais présentaient des différences importantes en composition en fonction de leur position dans le marais et implicitement de la profondeur de l'eau dans le substrat. Leur distribution était contrôlée également par d'autres facteurs qui se conditionnaient réciproquement comme, par exemple : la forme du fond du marais, les conditions édaphiques, la salinité de l'eau, le pH, leur minéralisation et par des facteurs biotiques également.

L'image de la végétation dans son ensemble peut être reconstruite en utilisant les éléments paléofloristiques et les exigences écologiques des correspondants actuels.

### 4.1. *Forêts mixtes de conifères et d'arbres caducifoliaires*

Ce type de forêt, quoique située loin des marais sylvestres générateurs de charbons, grâce à l'anémophilie et au développement régional, occupe la premèire place dans les spectres polyniques. Dans leur composition entrent des conifères, des arbres caducifoliaires, les plus importants étant : *Cedrus, Picea, Abies, Tsuga, Pinus, Keteleeria, Fagus, Carpinus* et d'autres. La rareté des restes macrofossiles de *Pinus* (cônes et feuilles) des carrières investiguées constitue un argument de l'appartenance de ce genre à deux associations mésophiles qui sont loin du marais.

### 4.2. *Forêt d'arbres caducifoliaires mésophiles*

Elle représente la phytocénose la plus fréquente dans la région, étant composée de Quercineae, Ulmaceae, Julandaceae, ainsi que des espèces de *Tilia, Carpinus, Betula, Acer, Eucommia* et *Corylus*. On y ajoute des conifères comme *Tsuga, Picea,* et *Pinus*. Les lianes provenaient des Vitaceae et Araliaceae. Dans les zones de lisière et les clairières se développaient des arbustes comme : *Staphylea, Cornus, Viburnum* et *Sambucus*.

Le matériel végétal provenu de ces associations mésophiles (feuilles, pollen et plus rarement rameaux et troncs, transportés par l'eau) n'arrivait que rarement dans les marais.

Quant au biotype de marais sylvestre générateur de charbons les associations végétales y existentes ressemblent généralement au modèle présenté par Teichmüller (1958) pour les charbons du Miocène inférieur de la Vallée du Rhin ainsi que celui décrit par Givulescu (1974) pour les charbons chattiens de la Vallée de Jiu. Bien sûr, comme nous aurons l'occasion de constater de ce qui suit, il y a une série de caractéristiques des marais où se sont formés des charbons du Pliocène d'Olténie.

### 4.3. *Association à Séquoïa*

Quoique dans les spectres polyniques Séquoïa apparaisse rarement et d'une manière discontinuelle, son existence dans le Dacien est indiscutable, tenant compte des empreintes des rameaux à feuilles de Dedoviţa et Timişani. Peut-être dans les zones plus sèches des aires non-inondables des bords des marais cet arbre occupait des surfaces réduites, formant les ,,tourbières sèches". À côté de Séquoïa végétaient des especes de *Pinus* (dans la mine de Lupoaia on a trouvé des cônes de *Pinus* sp.), *Sciadopitys,* Rhus et d'autres. Sur leurs rameaux se développaient des fougères epiphites (ex. g. *Lygodium).*

En comparaison avec la grande extension de ces types de marais dans le Miocène, dans le Pliocène les surfaces occupées par le marais à Séquoïa sont peu étendues et implicitement leur rôle dans la carbogenèse est réduit.

### 4.4. *Marais à arbustes*

Dans les zones périodiquement inondées, vers le bord des marais, végétait une association d'arbustes dominée par *Myrica* et dans une mesure plus réduite par *Cyrillaceae, Sapotaceae, Ilex,* ainsi que par certaines espèces de *Magnoliaceae, Symploccos* et *Ericaceae*. Protégées par les arbustes, dans la couche inférieure il y avait des fougères comme *Osmunda regalis,* taxon fréquemment rencontré dans le Dacien de Timişani. (Barbu, 1933, 1954).

Quoique jusqu'à présent *Myrica* n'ait été identifié que par des analyses de pollen, nous considérons que la présence des glandes peltées appartenant au genre *Myrica* annule tout doute concernant la participation de ce taxon à la végétation dacienne-romanienne d'Olténie. En même temps l'existence de l'association à *Myrica, Cyrillaceae, Ericaceae* et *Ilex* est reflétée dans les diagrammes polyniques (voir fig. 3) qui présentent pour chaque composant des courbes de fréquences similaires, en remarquant une baisse graduelle de celui-ci dans le Romanien. Un parallélisme pregnant de la courbe polynique de l'association à *Myrica* est également remarquée à la courbe du pollen de Liquidambar, ce que nous fait considàrer que *L. europaeum* végétait et/ou surtout dans ce type de marais.

L'association à *Myrica* était similaire, en grand, avec les marais à arbustes de la partie SE d'Amérique du Nord, où, à côté de *Myrica cerifera* et *Cyrilla racemifolia,* qui sont dominants, un rôle secondaire revient à *Ilex cassine, Magnolia virginiana, Kalamia latifolia, Juniperus silesiacum, Liquidambar stryaciflua* et *Osmunda regalis.*

En comparaison avec le modèle donné par Teichmüller (1958) pour l'association à *Myrica* et *Cyrillaceae* du Miocène d'Almagne, l'association similaire d'Olténie est caractérisée par une plus grande participation de diverses espèces de *Salix*. De même, la quantité réduite de pollen de *Myrica* et *Cyrillaceae* comparativement au pollen provenu des autres associations de marais nous fait supposer le rôle relativement peu important de cette association dans les marais sylvestres générateurs de charbons de cette aire. Dans le même sens plaide aussi le pourcent réduit d'inerto-détrinite des couches de charbons.

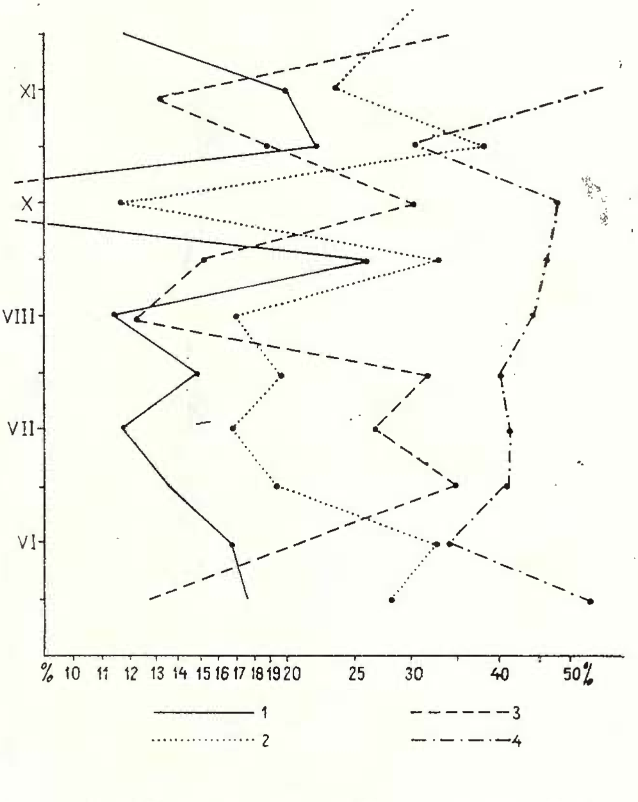


Fig. 3. — Diagramme des composants principaux des spectres sporopolyniques.
1, Termophiles ; 2, Hydrophiles ; 3, Gimnospermae ; 4, Association à Glyptostrobus.
V—XI — couche de charbon

Dans les même secteurs périodiquement inondés se développait, probablement, localement, une association de forêt à *A. tricuspidatum, Betula macrophylla, A. gaudinii* et, éventuellement, *Salicaceae*. Cette association se superpose partiellement à la zone à *Myrica*, ou, dans une mesure plus réduite à celle à *Glyptostrobus*. L'association à *G. europaeus, B. macrophylla, Alnus cecropiaefolia* et *B. tiliaefolia* représente, d'après Givulescu (1960) un composant principal des marais carbogénérateurs du Pliocène de Roumanie.

6—c. 859

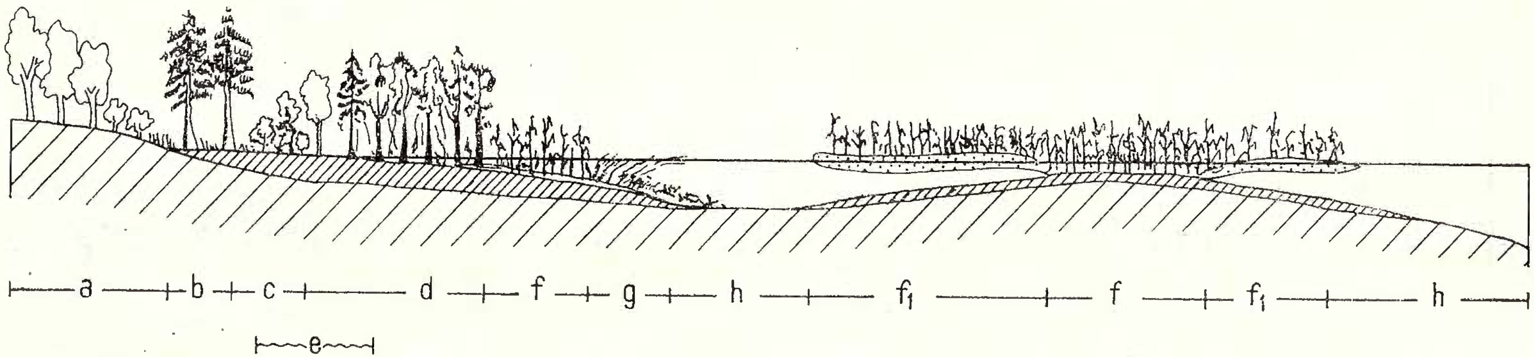


Fig. 4. — Reconstitution de l'aspect du marécage carbogénérateur pour le Dacien-Romanien de l'ouest d'Olténie.
a, forêts mésophytes (Mesophytische Wald) ; b, association à Sequoïa (Sequoia Moor) ; c, association à arbustes : Myrica ± Cyrilla, Salix, Liquidambar (Myricaceen — Cyrillaceen Moor) ; d. forêt à Glyptostrobus, Braunia ± Nyssa (Glyptostrobus, Braunia ± Nyssa Sumpfwald) ; e, forêt de marais à : A. tricuspidatum, B. macrophylla, Salix, Alnus ; (Sumpfwald) ; f, association à Phragmites (Riedmoor) ; $f_1$, île flottante (Schwimmendes Schlif) ; g, association à plantes aquatiques (Waservegetation) ; h, petite mare (Moorsee).

### 4.5. *Marais à Glyptostrobus et Braunia*

Dans le biotype de marais, l'association à *G. europaeus* et *B. tiliaefolia* représente la phytocénose avec la plus grande extension de l'intervalle Dacien-Romanien d'Olténie. Dans ce sens plaide la fréquence impressionnante des restes végétaux de *G. europaeus* (petits rameaux, à feuilles et cônes, rameaux, troncs). Les empreintes foliaires de *B. tiliaefolia* ont presque la même fréquence. Dans les dépôts à charbons du Mio-Pliocène de la Roumanie et d'autres parts d'Europe (Tchécoslovakie, Hongrie, etc.) ces deux taxons sont toujours présents, comme ont remarqué Givulescu (1960, 1970) et Ţicleanu (1982).

*Nyssa*, dont la présence a été démontrée jusqu'à présent seulement par le pollen, a un rôle secondaire dans l'association.

Sauf les espèces caractéristiques, à cette association participait aussi *Parthenocisus* (liane) et dans les espaces entre les arbres végétaient : *Phragmites, Cyperaceae, Polygonum persicaria, Typha* et *Stratiotes*, dont les feuilles sont très fréquentes dans les couches de lignite. Dans la collection de Timişani nous avons rencontré de fréquents échantillons qui contiennent à côté de *Glyptostrobus* aussi des empreintes d'*Osmunda regalis*, qui se trouvait probablement dans le substrat de l'association.

La phytocénose à *Glyptostrobus* et *Braunia* peut être comparée à l'association de type „*Nyssa, Taxodium-Sumpfwald*", décrite par Teichmüller pour le Miocène inférieur de la Vallée du Rhin. Selon Givulescu (1974) un rôle important dans la genèse des charbons du Chattien de la Vallée de Jiu était joué par l'association de type „*swamp à Taxodium*". Dans le Miocène supérieur *Taxodium* entre en extinction, étant remplacé dans l'association par *Glyptostrobus*. D'ailleurs, *G. europaeus* avait une place importante à partir du Miocène inférieur (selon Teichmüller).

Le rôle important de l'association à *Glyptostrobus* et *Braunia* résulte également de la grande quantité d'humotélinite identifiée dans la plupart des couches de charbon.

### 4.6. *Marais à Phragmites*

Généralement cette phytocénose se développe dans les marais où l'eau ne dépassait pas 2 m, profondeur jusqu'à laquelle les rhizomes de *Phragmites* sont capables de nourrir les tiges aériennes.

À des profondeurs plus grandes, les rhizomes de *Phragmites* s'entrelaçaient, forment l'île flottante „*Schwimmends Schilf*", dont l'épaisseur maximum pouvait atteindre 1,5—2 m, et qui se développait sur des surfaces qui dépassaient de dizaines et même de centaines de kilomètres carrés.

À côté de *Phragmites*, dans la phytocénose participent : *Cyperaceae, Carex, Stratiotes, Butomus, Sparganium*, différentes espèces palustres et *Typha latissima*. Dans l'île flottante pouvait apparaître *Salix* aussi.

De la fréquence des couches de lignite où on ne distingue que de restes végétaux de *Phragmites* et d'autres monocotylédones palustres (ceux de *Glyptostrobus* étant absents) on déduit le grand développement et importance de l'association à *Phragmites* dans les marais générateurs de charbons du Pliocène d'Olténie. Un autre argument dans ce sens-là est représenté par la fréquence des couches petites de charbon de 0,1—0,25 m, ayant généralement, un charbon d'une couleur plus claire, séparé par des intercalations peu épaisses, centimétriques ou décimétriques d'argiles. Dans le même sens plaide la grande quantité de humodétrinite, en espèce atrinite, le macéral avec la plus grande participation qui provient de ce type de marais.

### 4.7. *Association à plantes aquatiques*

Dans le secteur où l'eau dépassait 2 m de profondeur et il n'y avait pas d'île flottante, en „open water" s'installaient des plantes aquatiques fixées du substrat *(Trapa, Nuphar, Nymphaea, Potamogeton, Stratiotes)* ou natantes *(Lemna, Salvinia, Azolla)*. Parfois leur biomasse végétale était importante aussi par accumulation saisonnière ; si elles étaient immédiatement couvertes par des boues, des couches peu épaisses de lignite pouvaient se former. La grande quantité d'humodétrinite pouvait résulter, partiellement, également de la carbonification de ces plantes.

## Conclusions

De ce qu'on a présenté il résulte que dans la genèse des lignites de l'ouest d'Olténie, et, en extrapolant, de tout le bassin gétique, ont participé, en proportions variables, des associations végétales autochtones de marais générateur de charbons, en espèce l'association à *Glyptostrobus europaeus* et *Braunia tiliaefolia* (marais sylvestre), ensuite l'association à *Phragmites* et celle à plantes aquatiques. Dans une mesure plus réduite ont participé : l'association à arbustes *(Myrica)* et celle à arbres hygrophiles du type *A. tricuspidatum*, *B. macrophylla* et d'autres. Le rôle de l'association à *Séquoïa* était peu important.

Quant à l'aspect de la zone marécageuse, du développement spatial des couches de charbons il résulte que pendant le Dacien-Romanien les conditions paléogéographiques de cette partie du bassin dacique étaient favorables à l'existence d'un marais à grande surface et profondeurs variables. En général ce sont des profondeurs réduites, parfois il y a avait même des secteurs emerses (zones insulaires) mais aussi des secteurs où la profondeur de l'eau dépassait quelques mètres.

Le premier facteur qui a conditionné le développement et la distribution de différentes associations végétales, à l'exception du facteur climatique qui s'est maintenu favorable pendant tout l'intervalle, a été la profondeur de l'eau. Les modifications en temps de la profondeur de l'eau, suggérées par la présence de l'inertinite et causées en premier lieu par la valeur du taux de la subsidence, mais aussi par des facteurs sédimentologiques (apports quantitativement et qualitativement variables de matériel terrigène) ou hydrologiques, ont produit des changements dans le type d'association végétale, ce qui s'est reflété dans la variation des contenus de macéraux dans la même couche de charbon.

La fréquence des couches de lignite à contenu élevé d'humotélinite, provenu en principal des marais de forêt à *G. europaeus* et *B. tiliaefolia*, et d'humodétrinite qui a son origine, en espèce dans les marais à *Phragmites*, indique une profondeur des eaux qui ne dépassait que rarement 2 m. Les diverses phytocénoses du marais générateur de charbons ont eu des extensions variables en temps et en espace. Il y a eu des moments de grand développement spatial, couvrant, eventuellement tout le bassin dacique, lorsque se sont formées les principales couches de charbons.

Un autre facteur important de contrôle dans le développement de l'association végétale a été représenté par la salinité des eaux, car les plantes des associations décrites ne se sont développées que dans l'eau douce. Pană et al. [6] ont montré qu'il y a un rapport inversement proportionnel entre l'épaisseur et la fréquence des couches de lignite, d'une part, et la salinité, d'autre part.

L'accumulation de la biomasse végétale était favorisée par l'existence d'une subsidence continuelle. Tenant compte que pendant le processus de carbogenèse, à cause des pressions lithostatiques du toit de la formation de charbon, selon Ruhin (1966) l'épaisseur de la biomasse végétale accumulée doit avoir été approximativement 20 m, ce qui suppose une subsidence constante pendant une longue période de temps, ce n'est seulement la grande épaisseur des couches de lignite, mais aussi le fait que très fréquemment la testulminite a gardé sa structure cellulaire qui démontre une submersion lente. Bien sûr, dans tout le bassin la subsidence s'est manifestée d'une manière différenciée ; il y avait également des moments de stagnation, déduits de la présence de la fusinite dans le lignite.

Donc, le développement des associations végétales et l'accumulation de la biomasse qui en résulte dépendait des variations climatiques dans une mesure plus réduite car leurs variations s'inscrivent dans des limites acceptables), de la vitesse d'emersion du bassin, des phénomènes sédimentologiques (quantité et type d'alluvions), des conditions édaphiques de la salinité et d'une série de facteurs biotiques. La multitude des facteurs de contrôle a déterminé des variations horizontales et verticales des associations génératrices de biomasse végétale qui, finnalement sont reflétés dans la quantité et qualité des charbons, dans la manière dont ceux-ci se présentent en espace, en expliquant les fréquentes concentrations, effilements ou disparitions de couches.

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[4] *Osmunda regalis* a été trouvé par nous dans la plupart des échantillons provenus de la collection de I. Z. Barbu, de la Faculté de Géologie de l'Université de Bucarest. Nous remercions à cette occasion au Prof. I. Z. Barbu et au Conf. univ. Ovidiu Dragastan pour l'amabilité de nous permettre et faciliter l'étude de cette collection.

[5] Des recherches récentes montrent que *B. tiliaefolia* représente un arbre ressemblant à ceux du genre *Tarietia* des forêts marécageuses tropicales.

[6] I. Pană, I. Andreescu, G. Enache, C. Enache : Répères stratigraphiques dans les dépôts pliocènes porteux de lignite d'Olténie. Communication dans la session scientifique de la Faculté de Géologie-Géographie, Université de Bucarest, 23—24 avril, 1981.

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*D.S. Inst. geol. geofiz.* vol. LXIX (1982). Pag. 89—114

**2. ZĂCĂMINTE**

# TYPOMORPH FEATURES OF CERTAIN MINERALIZATIONS ASSOCIATED WITH SUBVOLCANIC STRUCTURES OF ROMANIA [1]

BY

GHEORGHE UDUBAŞA [2], ALLA ZĂMÎRCĂ [2], PETRE ANDĂR [2], ANCA ANDĂR [2]

*Subvolcanic structures. Typomorphism. Minor elements. Sulphides. Galena. Sphalerite. Pyrite. East Carpathians — Neogene igneous rocks; South Carpathians — Neocretaceous-Paleogene magmatites — Poiana Ruscă; Apuseni Mountains — Neocretaceous-Paleogene magmatites; Neogene igneous rocks. Brad-Săcărîmb area, Baia de Arieş area.*

## Sommaire

*Caractères typomorphiques des minéralisations associées à des structures sous-volcaniques de Roumanie.* On fait une présentation concise des données principales de certains gisements associés à des structures sous-volcaniques d'âge paléogène (Ruşchiţa, Juleşti-Valea Fagului) et néogène (Ţibleş, Toroiaga, Rodna, Bocşa-Săcărîmb, Coranda-Hondol, Baia de Arieş). Prenant en considération certaines transformation rhéologiques subies, surtout par la sphalérite et la pyrrhotite ainsi que les données expérimentales on a distingué trois types PT de gisements sous-volcaniques : (1) à des associations de basse pression et température élevée (Ţibleş, Toroiaga, Rodna) constituées de sphalérite (sph) à un contenu éléve de fer + chalcopyrite (cp) + pyrrhotite (po) + pyrite (py) ; dans la sphalérite apparaissent des inclusions multiphasiques composées de chalcopyrrhotite (cpo, ou la solution intérmédiaire du système Cu-Fe-S), cubanite (cub) et mackinawite (mck), (2) à des associations de P et T intermédiaires (Bocşa-Săcărîmb, Baia de Arieş), formées de sphalérite avec 5—7%Fe + cp + po + cpo et (3) à des associations de haute pression et basse température (Juleşti-Valea Fagului, Ruşchiţa, Coranda-Hondol) constituées de sphalérite à bas contenu de fer (moins de 5% Fe) + cp + py + bornite. Dans la sphalérite de Juleşti apparaissent des inclusions biphasiques de cp + bn. Ainsi l'abondance des brèches des derniers types peut être expliquée par la pression totale grande des volatiles pendant les processus magmatiques et postmagmatiques.

[1] Received on March, 26, 1982, accepted for communication and publication on May, 10, 1982, presented in the meeting of May, 11, 1982.

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Les sphalérites de ces minérais contiennent „des concentrations d'équilibre" de Cd et Mn, se distinguant ainsi des sphalérites des minérais des gisements volcaniques. Les galènes semblent être plus dépendantes de la position régionale des gisements, celles des minérais banatitiques (paléogènes) étant concentrées sur le côté Ag-Bi du diagramme ternaire Ag-Bi-Sb, tandis que celles de minérais néogènes sont situées sur le côté Ag-Sb.

À la fin de l'ouvrage on fait certaines considérations sur les processus de remobilisation des métaux du sous-bassement (Cu dans le cas des gisements de Juleşti et Toroiaga) et on tente une explication de l'apparition constante du triplet Mn-Te-Au dans les Monts Metaliferi.

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## Introduction

The Alpine metallogenesis (Laramian or Banatitic and Neogene) in Romania includes various types of deposits. The Laramian magmatites are generally associated with iron, lead-zinc, molybdenum-bismuth etc. pyrometasomatic ores, while Neogene metallogenesis is, as a rule, represented by gold and silver-bearing and polymetallic veins; both metallogenetic epochs are characterized by mineralizations of porphyry copper type [3]. It is certain typomorphic features such as the ore composition, postmagmatic alteration types, sulphide micromineralogy, minor elements distribution in the main sulphides and especially the relations among these elements that can define and differentiate the metallogenetic processes accompanying the ore genesis in subvolcanic or hypoabyssal environment. In order to point out certain typomorphic features of the mineralizations associated with subvolcanic structures, observation and analytical data have been taken into account, concerning the Ruşchiţa and Juleşti-Valea Fagului ores belonging to the Laramian metallogenesis — as well as the Rodna-Valea Vinului, Ţibleş, Bocşa-Săcărîmb, Coranda-Hondol ones and partially those of Toroiaga and Baia de Arieş — belonging to the metallogenesis related to the Miocene magmatism.

## General remarks

Excepting the Juleşti-Valea Fagului (Bihor Mts.) mineralizations and the Toroiaga (Maramureş Mts.) ones, all the other ores have a lead-zinc character, copper minerals being found in small amounts. The associated subvolcanic or hypoabyssal rocks generally have intermediate, andesitic-dioritic chemistry, forming laccolitic bodies, sills dykes etc., and are intruded in crystalline schists (Rodna, Toroiaga, Baia de Arieş, Ruşchiţa), in Permian and Triassic sedimentary rocks (Juleşti-Valea Fagului) in Cretaceous and Miocene (Coranda-Hondol), Paleogene (Ţibleş) ones or in sedimentary Miocene rocks and in older andesitic volcanics (Bocşa-Săcărîmb).

The mineralizations mainly appear as veins (Toroiaga-Ţibleş, Juleşti-Valea Fagului, subordinately Ruşchiţa and Bocşa-Săcărîmb); metasomatic bodies also appear in crystalline limestones (Rodna, Baia de

Arieş) or stockwork accumulations (Cornada-Hondol, partially Ţibleş, Juleşti-Valea Fagului, Bocşa, Rodna).

The mineralizing processes are, as a rule, monoascendent. In some cases some skarns formed previously, of magnesian character at Ţibleş, and of calcic character at Ruşchiţa, Baia de Arieş and Rodna.

The hydrothermal alteration of the associated eruptive rocks is variable, the extremes being represented by Toroiaga, with intensive alterations only in the very proximity of veins and Coranda-Hondol, where the whole subvolcanic body is altered (argillized-adularized).

## General characterization of the ore deposits

*Ruşchiţa*. The metamorphic rocks of the Padeş Series (Kräutner et al., 1981), represented in the ore zone especially by biotite-chlorite schists $\pm$ epidote and subordinately limestones, are pierced by Laramian subvolcanic bodies (granodioritic and dioritic porphiries, quartziferous andesites with hornblende and biotite, andesites with pyroxenes and olivine). Both the metamorphic and the eruptive rocks are regionally epidotized. In some places scattered skarn minerals do appear (garnets, pyroxenes, vesuvianite, wollastonite), locally magnetite bearing. The postmagmatic process was polyascendent in character : 1) magnetite bearing skarns, 2) sulphides (galena, sphalerite with a low content of iron — 1—3% —, sporadically pyrite, chalcopyrite, hematite, bornite) ; 3) quartz and carbonates. The skarns are mainly formed at the expense of biotite-chlorite schists, intensely fragmented, brecciified and cemented especially with quartz. The mineralizations are lead-zinc in character and make up impregnations, vein bodies and irregular lens. The last are always associated with skarn bodies formed at the expense of the biotite schists (Udubaşa, 1969, 1970 a). The pseudoconcordant shape of certain lenses has led to the hypothesis of superposed mineralizations (Pomîrleanu et al., 1973), but the microstructural elements (Fig. 1) and the ore fabric difficultly tune with such a hypothesis.

*Juleşti-Valea Fagului (Bihor Mts)*. On E-W oriented fractures banatitic eruptive bodies are intruded ; they are represented by rhyodacites and quartz bearing basalts ; the passive element of the mineralized structure is represented by Triassic sandstones and Permian dolomites, in which small bodies of magnesian skarns (forsterite, spinel, phlogopite etc.) developed ; they are, however, not directly related to the mineralizations. The rhyodacitic rocks are epidotized, adularized and argillized. The ore forms veins or impregnations in the breccias, disposed in rhyodacites and sometimes in basalts. The major minerals are galena, chalcopyrite, sphalerite (3—5% Fe) and bornite. Subordinately pyrite, boulangerite, tetrahedrite, tennantite, hematite, chalcosine, proustite and native copper have also been mentioned. The mirmekitoid intergrowths of the minerals and the biphasic inclusions of chalcopyrite and bornite in sphalerite are very characteristic (Udubaşa et al., 1980). Such inclusions are only seldom described in literature ; in Romania they have also been noticed in the Vorţa (Metaliferi Mts.) ore (Udubaşa et al., 1978).

*Rodna*. At Valea Vinului the metamorphites of the carbonate (middle) Formation of the Rebra series are pierced by Miocene eruptive bodies (sills, dykes, irregular bodies), andesitic in composition (quartz andesites with biotite and hornblende, andesites and microdiorites with hornblende + pyroxene). In the ore area these rocks are

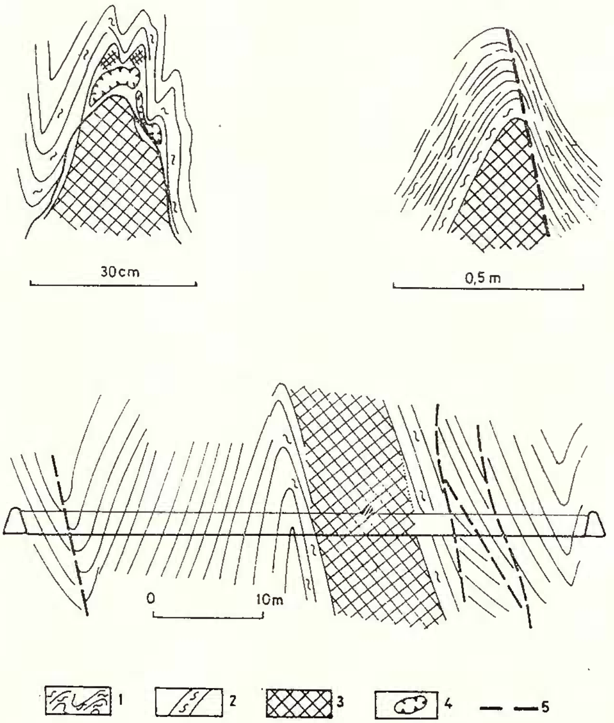


Fig. 1. — Skarnized biotite-chlorite schists ; in the axial zone epigenetic ore appears and in the bend zone there are vugs. Ruşchiţa 782 m horizon.
1, biotite-chlorite schists with skarn mineral nests (S) ; 2, massive skarn ; 3, massive ore (sphalerite + galena) ; 4, vugs with galena and calcite ; 5, faults.

intensely altered (especially argillized) and relatively large aureoles of transformations equally appear in the surrounding metamorphites ("hydrothermal diaphtoresis"). The mineralizations have pyrite lead-zinc character and are partially superposed on several types of syngenetic mineralizations (Fig. 2, Udubaşa, 1974). The epigenetic ore builds up metasomatic bodies in crystalline limestones or impregnations in andesite breccias, interpreted as explosion ones (Udubaşa, 1970 b) or as pipe structures (Socolescu et al., 1977). The main components of the ore are pyrite, sphalerite, galena, phyrrhotite, arsenopyrite, bournonite ; other minerals identified are : chalcopyrite, boulangerite (plumosite), stephanite, gold (included in pyrite and sphalerite).

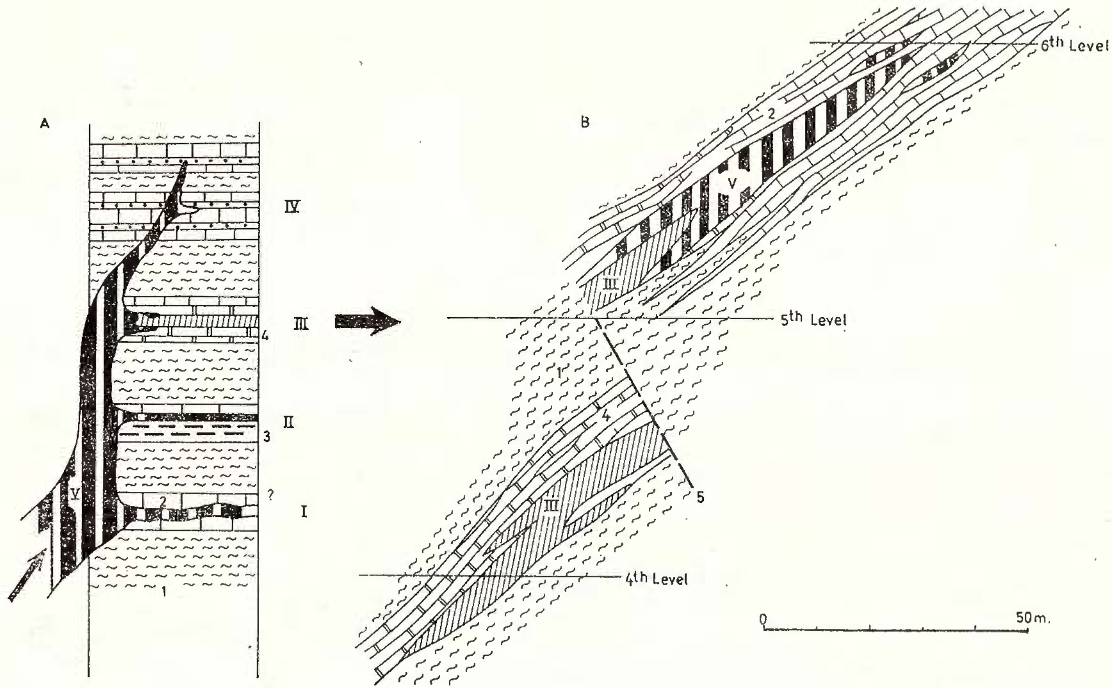


Fig. 2. — A, Stratigraphic position of the four types of syngenetic stratiform ores of the Rebra Series Carbonate Formation, on which hydrometasomatic epigenetic ores are superposed. Rodna-Valea Vinului. I, pyrite and pyrrhotite-bearing ore, completely reorganized mineralogically and structo-texturally. The only relict is the pseudoconcordant shape of the ore body, with numerous limestone lens remnants ; II, magnetite and pyrrhotite-bearing ore, accompanied by thin bands of cleiophanic sphalerite similar to the IV type one ; the superposition of the epigenetic ore is here rendered by recrystallization and the parageneses juxtaposition ; III, massive pyrrhotite associated with a level of dolomitic limestone ; the ore is partially recrystallized, sometimes being wrapped in a lead-zinc ore ; IV, the lead-zinc pyritous ore of Blazna-Gașet type, locally cut by the epigenetic ore. The degree of hydrothermal "processing" of the syngenetic ores decreases from I to IV. B, Section through the VIIth lens, Rodna-Valea Vinului, with the position of the two genetic types of ore ; III (massive pyrrhotite) and V (hydrometasomatic lead-zinc ore). 1, micaschists ; 2, crystalline limestones ; 3, amphibolic rocks ± quartz ; 4, grey dolomites ; 5, faults.

The sphalerite is iron rich (6—15% Fe) and contains abundant chalcopyrite inclusions associated with chalcopyrrhotite (or "the intermediate solid solution" of the Cu-Fe-S system ; Cabri, 1973 ; Lihacev, 1973) and mackinawite (Udubaşa, 1976). In the upper parts of the mineralized structure small calcic skarn bodies have been identified (garnets, wollastonite, pyroxene) accompanied by small magnetite amounts (Diaconu, Mihăilă, 1962). Subsequently the presence of vesuvianite has also been noticed.

*Ţibleş*. The eruptive complex consists of monzodiorites, quartz diorites, granodiorites and andesites hosted by Paleogene sedimentary rocks (Edelstein et al., 1981). Magnesian skarns containing foresterite, spinel and phlogopite have been described in the central part of the massif (Udubaşa et al., 1982 b). The base metal mineralizations form prevailingly veins, zonally developed around a possible porphyry copper-molybdenum system related to the monzodioritic and granodioritic instrusions. The main vein zone contains ores of high temperature, where the following metalliferous minerals have been identified : pyrrhotite, pyrite, arsenopyrite, sphalerite (4—12% Fe), galena, chalcopyrite, tetrahedrite and bournonite ; in the central-eastern part of the massif (V. Mesteacănul) there are sphalerite, rutile, molybdenite (Pl. 1, Fig. 1, 2) and tourmaline-bearing mineralizations forming veinlets and impregnations in altered monzodiorites. The outer area or belt contains low temperature mineralizations characterized by the presence of berthierite, iron-poor sphalerite, jamesonite (Udubaşa et al., 1984) and of silver sulphosalts (Pop et al., 1984).

*Bocşa-Săcărîmb*. The lead-zinc mineralizations build up stocks and veins, emplaced in the brecciated lavas of quartz andesites with hornblende and biotite (Săcărîmb type), partially also in the Burdigalian sandy-conglomeratic rocks. The eruptive rocks are intensely altered, and the mineralizations are found in the argillization zone, illite 2M1 being dominant. The ore is made up of pyrite, sphalerite (5—7% Fe), galena and chalcopyrite ; microscopically, arsenopyrite, tetrahedrite and bournonite (both as regular inclusions in galena), pyrrhotite and chalcopyrrhotite (associated with chalcopyrite inclusions in sphalerite). The inception and evolution of the metallogenetic process was controlled by a subvolcanic body (porphyry microdiorite with quartz, biotite and hornblende), situated at about 300 m under the mineralized area (Udubaşa et al., 1976).

*Coranda-Hondol*. The mineralizations are of lead-zinc-auriferous type and appear as stockwork developed in Cretaceous sedimentary rocks (sandstones and blackish siltstones), partially also in the Burdigalian ones, uplifted together and brecciated in the cupola of an andesitic body, completely argillized and adularized. Sphalerite (1—3% Fe) and galena are the main minerals ; pyrite has largely resulted from recrystallization of the framboidal pyrite contained in the blackish siltstones, in which pre-graphite and anastase are present too. Microscopically chalcopyrite, bournonite, meneghinite and arsenopyrite have also been identified.

There are relatively few chalcopyrite inclusions in the sphalerite with which mackinawite is sometimes associated. In an area with laminated ophiolitic rocks of the —150 horizon tellurides have been identified in ores rich in sphalerite and tennanite associated with fuchsite; the presence of kostovite, $AuCuTe_4$ is also worth mentioning, accompanying other gold and silver tellurides (Udubaşa et al., (1981) that were already known (Haiduc, Bonea, 1965; Ghergariu et al., 1980). The stockwork mineralization is believed to be monoascendent (Udubaşa et al., 1982 a) but the mineralizing process of the whole zone took place at least in two phases (Fig. 3): (1) base metal

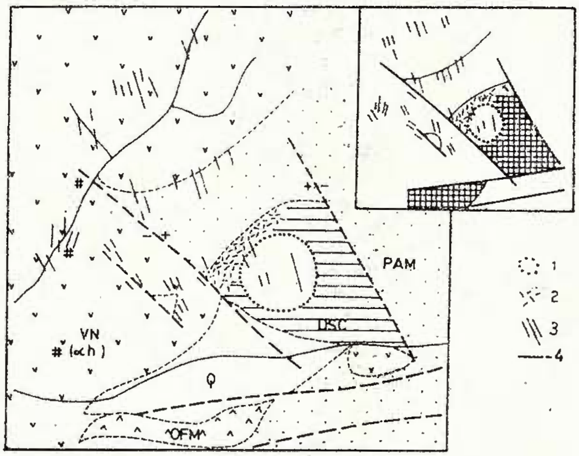


Fig. 3. — Structural map of the Coranda-Hondol area (acc. Udubaşa et al., 1981), OFM, Mesozoic basic rocks; DSC, Cretaceous sedimentary deposits; PAM, Almaşu Mare Gravels Complex (Burdigalian); VN, Neogene volcanics of the Coasta Mare volcanic structure — hornblende-bearing andesites; Q, Quaternary deposits.
1, subvolcanic body outline, checked up by mining works; 2, breccia zones; 3, gold or base-metal — gold ore; 4, fractures.

mineralization in the brecciated sedimentary rocks (Coranda-Hondol ore deposit) in relation to the Băiaga subvolcanic body and (2) gold-bearing veins (native gold with native arsenic), cutting the base metal bearing stockwork, associated with the Coasta Mare volcanic apparatus.

*Baia de Arieş*. The Baia de Arieş mineralization group includes stockwork mineralizations and hydrometasomatic base metal bodies in crystalline limestones, as well as impregnations in explosion breccias (Lazăr, 1966; Ghiţulescu et al., 1979). The Neogene eruptive rocks of the area are subvolcanic hornblende andesites ($\pm$ biotite bearing) exhibiting various stages of argillitic, chloritic and silicic alterations (Lazăr, 1966). The base metal ore is made up of pyrite, sphalerite (5—7% Fe, 1—2% Mn), galena, subordinately alabandine, hematite, stibnite, chalcopyrite, tetrahedrite and tennantite. The sphalerite and the albandine contain globular inclusions of chalcopyrite. There exist some locally developed calcic skarn occurrences (Lazăr, 1966). The similarity of the Baia de Arieş and Rodna ore deposits has been underlined by Ghiţulescu (1937) and Lazăr, Udubaşa (1965).

*Toroiaga*. The Neogene subvolcanic rocks are intruded in the metamorphites of the Tulgheş series and in Paleogene sedimentary rocks. The polyphasic character of the intrusion was underlined by Socolescu (1952) being subsequently evidenced by Berza et al. (1980), who distinguish 5 phases : (1) Novicior quartz andesites, (2) Toroiaga andesites, (3) Secu-Novăţ quartz diorites ; (4) Vertic quartz andesites and (5) Piciorul Caprei andesites. The mineralizations build up NE-trending veins, most of them being localized in the eruptive body. The character of the ore is polymetallic and cupriferous. The vertical extension of the mineralized fracture veins reaches 1 000 m (Borcoş, 1967). The dominant metalliferous minerals are pyrite, chalcopyrite, sphalerite (10—12% Fe), galena, arsenopyrite and pyrrhotite ; microscopically also bournonite, semseyite, tetrahedrite, jamesonite etc. have been identified (Steclaci, 1962). In the sphalerite there are multiphasic inclusions of chalcopyrite associated with chalcopyrrhotite, pyrrhotite, cubanite and mackinawite, similar with those of the Rodna and Ţibleş ores. As a whole the mineralizations are monoascendent. In the eastern part of the structure the eruptive rocks pierce the stratiform mineralizations of the Tulgheş Series, pyritic-cupriferous-polymetallic in character (Zincenco et al., 1973). At the very contact the fabric of the metamorphosed stratiform ores changes drastically, leading to the obvious epigenetic aspect of the ore (Pl. I, Fig. 3, 4).

## Ore mineral assemblages. Typomorph features

Excepting the Juleşti, Coranda and Ruşchiţa deposits, the ores of the presented deposits have pyrite "in excess". Pyrrhotite is present — more abundant at Rodna, Ţibleş and Toroiaga, and arsenopyrite is constantly encountered. With the same exception as above, the sphalerite is, as a rule, rich in iron (4—15%) and contains multiphasic exsolutions, of chalcopyrite (cp), chalcopyrrotite (cpo), cubanite (cub), mackinawite (mck), exhibiting a very complex evolution. These minerals appear differentiatedly — cp + cpo (Bocşa), cp + mck (Coranda), cp + cpo + mck + cub (Rodna, Ţibleş, Toroiaga, where pyrrhotite (po) is relatively frequent (Pl. II, Fig. 1—4).

Sphalerite is more abundant than galena in the Rodna, Ţibleş, Toroiaga, Baia de Arieş and Bocşa ores, while at Ruşchiţa the ratio is reversed. The lead-zinc character of the ores is dominant, cupriferous tendencies being noticed at the Toroiaga, Juleşti and Ţibleş ores ; in the last ones chalcopyrite also appears as an independent phase, in the others being present especially as exsolution inclusions whose abundance increases in the following order : Ruşchiţa-Coranda-Juleşti-Baia de Arieş-Bocşa-Toroiaga-Rodna-Ţibleş.

Sulphosalts, although in small amounts, are rather frequently observed ; the most frequent appears to be the bournonite as well as the fahlores. Bornite appears at Julești as an important component of the ore, subordinately at Rușchița, in both cases hematite being also present as primary mineral ; sporadically it has been noticed in the cupriferous veins of the Măgura Neagră, South Țibleș zones.

The monoascendent ore deposition is a general feature of these deposits ; it was preceded by short phases with skarn mineral assemblages and followed by sterile phases generally with quartz and carbonates. Many of the main ore minerals are formed quasisimultaneously, advanced intergrowths being generated. There are frequent proceses of textural reequilibration, which often lead to changes in the ore initial aspects. The commonest intra- and postgenetic phenomena are represented by exsolutions, especially in the sphalerite. The solid state diffusion often plays an important part in the reequilibration of ore minerals, leading to false successions and apparent multistadial formation of the same mineral. A conclusive example is represented by "chalcopyrite II" of certain sphalerites ; it appears on limited areas as discontinuous veinlets, in whose proximity the exsolution bodies have disappeared due to the diffusion towards lower pressure zones (the limits between grains, microfissures of the sphalerite mass) (Pl. II, Fig. 5 ; Pl. III, Fig. 1, 2).

Sphalerite is one of the ore minerals with a great "informational entropy", being stable on a large thermo-baric domain ; it has a variable chemistry and accepts numerous elements in its lattice ; besides, the natural zinc sulphide possesses many polytypes which are stable under various conditions. Therefore this mineral can provide many data on the PTX structure of the deposition environment. T°C/mol.-%FeS geothermometer in sphalerite, established by Kullerud (1953) in the first period of experimental studies could not be totally validated, although there were often acceptable concordances between the temperature values indicated by the sphalerite geothermometer and by other methods. In spite of the subsequent corrections of the T°C/mol.-%FeS geothermometric curve the temperature indications are far from acceptable. The subsequent experimental studies using various techniques (hydrothermal recrystallization, experiments in salt fluxes etc.) have shown that the respective curve can be vertical in contour or with inclination quite the reverse of the Kullerud curve (Barton, Toulmin, 1966 ; Boorman, 1967 ; Cernîsev et al., 1968 ; Godovikov, Ptitîn, 1966 ; Scott, Barnes, 1971 ; Craig, Scott, 1974 etc.). This time the experimental data are somehow in contradiction with the data concerning the natural assemblages of minerals. It is well known from numerous observations that in high temperature ores the iron content in sphalerite is high and decreases with the temperature, the mineral assemblage in which sphalerite appears being particularly important. For the Cu-Fe-Zn-S natural system, Mukaiyama & Izawa (1971) show a systematic decrease of the iron content in sphalerite ($C_{Fe}$ Sph) with the temperature, from 23 mol.%-FeS in sphalerite associated with hexagonal pyrrhotite, chalcopyrite and cubanite up to less than 1 mol%-FeS in sphalerite associated with chalcopyrite, bornite and pyrite. For the last assemblage Czamanske (1974) considers that the sphalerite geothermometer may still be applied. That is, even if the geothermometric data given by $C_{Fe}$ sph cannot be read directly on the curve, they provide important information, if correctly decoded by refined analyses and when the whole mineral assemblage with which sphalerite is formed or reequilibrated is taken into account. An example is given by pyrrhotite, that can be transformed, even in hypogenous conditions, in pyrite and magnetite aggragates (Pl. III, Fig. 3—4), like in the case of the Herja and Ţibleş ores. The present-day py + sph association is not compatible with the high iron content in sphalerite (6—13%). Under such conditions sphalerite itself can show retrograde transformations that lead to the $C_{Fe}$ modification during the post-genetic processes of textural reequilibration through solid state diffusion. There are indications that in natural sphalerite there is no simple replacement of zinc by iron, but a coupled one, of the type Zn ⇄ FeCu. Only rarely sphalerite is rich in iron that does not contain chalcopyrite exsolutions. Electron microprobe analyses prove the presence of copper in the lattice (ex. Panto, Panto, 1972 ; Udubaşa et al., 1974) occupying the octahedral ($Cu^{+2}$) or tetrahedral ($Cu^{+1}$) positions (Manning, 1966, 1968). In the mineral assemblages with iron-poor sphalerite, almost always chalcopyrite appears as an independent phase, most times following sphalerite. There is therefore a critical value of the copper concentrations in solutions — probably correlatable with the iron concentration and the sulphur fugacity — under which copper is included in the sphalerite lattice and above which chalcopyrite is separated as an independent mineral. The processes of solid state diffusion play an important part also in the extraction of copper from the ZnS lattice at low temperatures ; an example in this sense is the $Cu_3ZnS_4$ compound described by Clark, Sillitoe (1971) and observed by us in several ores of Romania : Ţibleş, Vorţa, Juleşti-Valea Fagului, Cornada-Hondol (Pl. IV, Fig. 1—4).

In the last time it has appeared possible to use sphalerite as a geobarometer (Scott, 1973, 1974) for the whole $C_{Fe}$ sph variation interval. The increasing pressure reduces the field of the solid solutions stability decreasing the solubility of the dissolved component. The stability of the solid solution increases only when the added ions have higher coordination (Kirkinski, 1966). In what the zinc sulphide is concerned, the decrease in sulphur concentration in solutions leads to the appearance of polytypes with more and more marked hexagonality (Scott, 1074). At low pressure and high iron contents it is but natural that the first to appear should be non-cubic ZnS polytypes, in whose structure it is not difficult for iron to enter, due to its 6 coordination, easily acceptable in the wurtzite type hexagonal lattice.

The highest iron contents are reported at the Rodna, Ţibleţ, and Toroiaga sphalerites (Tab. 1) where the associated subvolcanic rocks show deeper facies. The iron contents decrease progressively in the Bocşa and Baia de Arieş sphalerites, then in the Coranda ones, where the subvolcanic body was formed at relatively small depth. The situation is different at the Laramian ores ; at Juleşti and Ruşchiţa the sphalerite does not contain much iron and the mineral assemblage

TABLE 1

*The iron content in sphalerite* (%)

| Ore deposit | Fe* | Remarks |
|---|---|---|
| Rodna—Valea Vinului | 6—15 | In the Măgura Neagră zone cp also appears as independent |
| Ţibleş | 10—12 | phase, associated with iron-poor sphalerite (about 4—5 %); there is also bornite in the assemblage |
| Toroiaga | 9—11 | Chalcopyrite is „in excess", reciprocal phenomena of cp exsolution in sph and sph exsolution in cp appear. |
| Bocşa-Săcărimb | 5—7 | Extremely rarely geodes with cp crystals have been noticed. |
| Baia de Arieş | 5—7 | Excess of Mn in sphalerite (1,93 %)-Udubaşa et al., 1974; alabandine is present in the assemblage (Lazăr, 1966). |
| Coranda-Hondol | 2—4 | The frequence of the cp inclusions in sph increases with the depth. |
| Juleşti-Valea Fagului | 3—5 | Abundant copper minerals (bn, cp, ten, ttr) |
| Ruşchiţa | 1—2 | The sphalerite is generally very poor in cp inclusions |

Abbreviations: cp, chalcopyrite; sph, sphalerite; bn, bornite; ten, tennantite; ttr, tetrahedrite.

* Microprobe analyses (Rodna, Baia de Arieş; analyst — Dr. *J. Ottemann*, Heidelberg), wet chemical analyses (Rodna, Baia de Arieş; analyst: *A. Medeşan*, IPGG Bucureşti) and X-ray fluorescence analyses (the other samples; analyst; *J. Vanghelie*, IGG Bucureşti)

also contains bornite. The presence of copper in solution, probably above the mentioned critical value, led to an indirect decrease in the iron content in sphalerite. The Ruşchiţa mineralization, subsequent to the skarn phase, was formed at great (total) pressure of volatiles, but at low temperature. At Juleşti, the high concentration of copper in solution made it possible for much of the iron to be fixed in mixed compounds of copper and iron (bornite and chalcopyrite) sphalerite, formed afterwards, remaining relatively poor in iron. The Coranda mineralization was formed from solutions with moderate iron and copper concentration, iron-poor sphalerite being formed. The presence of As and Te probably compensated for the sulphur fugacity decrease, especially in the period of the auriferous vein deposition, post-dating the lead-zinc veins of the proper subvolcanic structure. The general regime in which the parageneses with sphalerite of the examined mineralizations were formed is given in Table 2 and Figure 4.

On the diagram of Figure 4 (according to Scott, 1973; Craig, Scott, 1974) the sphalerite associated with hexagonal pyrrhotite and pyrite (of Rodna, Ţibleş, Toroiaga and Bocşa), for which the geobarometer is applicable, can be clearly distinguished from the sphalerite associated only with pyrite (Baia de Arieş, Juleşti, Coranda, Ruşchiţa). In the first case it is useless to extend the diagram for the estimation

TABLE 2

*Some features of the ore deposition*

| Ore deposit | PT conditions | Inclusions hosted by sphalerite | Remarks |
|---|---|---|---|
| Ţibleş | low P | cp, cpo, po, cub, mck | Quick sulphide |
| Rodna | | | |
| Toroiaga | high T | cp, cpo, po, mck | crystallization |
| | | cp, cpo, po, mck | |
| Baia de Arieş | intermediate P | cp | |
| Bocşa-Săcărîmb | and T | cp, cpo, po | |
| Ţibleş-S | | cp, po | |
| Coranda-Hondol | | cp, mck | Slow |
| Juleşti-V-Fagului | high P | cp, bn | sulphide |
| Ruşchiţa | | cp, (bn) | crystallization |
| Ţibleş -E* | low T | cp, (jamesonité) | |

Abbreviations : cpo, chalcopyrrhotite (intermediate solid solution of the Cu-Fe-S system) ; po-pyrrhotite ; cub, cubanite ; mck, mackinawite.

* External, low T mineralization belt rich in As, Sb and Hg (U d u b a ş a et al., 1984).

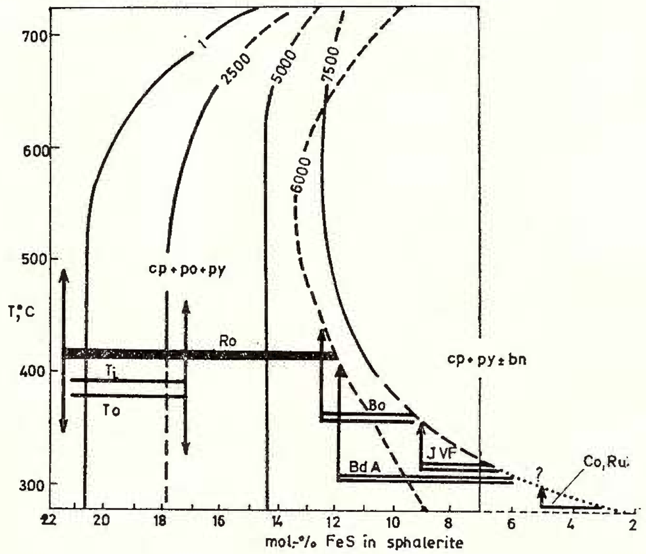


Fig. 4. — T-X projection of the isobars for the sphalerite + pyrite + hexagonal pyrrhotite solvus. The pressure is given in bars (acc. Scott, 1973), with the position of the sphalerites of the subvolcanic ores : Ro, Rodna ; Ti, Ţibleş ; To, Toroiaga ; Bo, Bocşa ; BdA, Baia de Arieş ; JVF, Juleşti-Valea Fagului ; Co, Coranda-Hondol ; Ru, Ruşchiţa. The double arrows indicate the geothermometric indetermination for contents of more than 12 mols-%FeS in ZnS, and the simple ones suggest the possible extension of the temperature interval for the pyrrhotite-free assemblages. See the text for the discussion on the two major mineral assemblages.

of temperature, the isobars being vertical up to almost 550°C ; therefore other geothermometric methods are necessary. When sphalerite is associated only with pyrite, the geobarometric indications coexist with the geothermometric ones for the 7.5 kb isobar. Extrapolating it to contents smaller than 7 moles$^0/_0$ FeS in sphalerite — although empirically — we obtain geothermometric data comparable with those offered by other methods.

### *Assemblages of minor elements in sulphides*

*Pyrite* seems to be a less sensitive mineral — in comparison with sphalerite and galena — to the geochemical variations. It is generally admitted that syngenetic-stratiform ores can be differentiated from epigenetic ones by means of the Co : Ni ratio. In the Figure 5 diagram the first are concentrated on the Mn-Ni line, and the latter towards the Co edge, but the genetic types are not very clearly separated. Recent attempts have been made to use the quantitative ratios between Co and Ni (Schrön et al., 1978 ; Bralia et al., 1979), but the genetic differentiation of the ore types exclusively on this basis is far from being enough. On the Co-Ni-Mn diagram in Figure 5 one can notice the small distances between representative points for the clark of these elements and those for a sedimentary pyrite (of Vultureni). The Mn selective adsorbition during the marcasitization process of hydrothermal pyrite probably falsifies the real ratios among elements. For this apparent reason there is no differentiation among the pyrites of the subvolcanic and volcanic ores, other types of diagrams being necessary for reaching univocal conclusions, implying also other elements, that are not currently analyzed.

*Natural sphalerite* contains numerous minor elements, whose behaviour is controlled by many factors. For discussing the typomorphism, the Cd-Mn-Cu triplet (Fig. 6) has been first of all selected. On such a ternary diagram a field — possibly a statistic population — can be outlined for the sphalerite of subvolcanic ores, a field in which the Cd and Mn contents have comparable values. For the sphalerite rich in iron it is obvious that a relative enrichment in copper takes also place, while the sphalerite poor in iron appears enriched in Cd, at aproximately constant values of Mn. Therefore on such a diagram the mineralization character is more pregnantly registered, the geochemical configuration of sphalerite being relatively independent from the age and metallogenetic appurtenance of the ore deposit.

The In-Co-Ca diagram is typochemically less expressive, but the number of analyses is much more reduced. In Figure 7 the sphalerites are grouped especially according to the iron content : in the In edge it is the sphalerites rich in iron that are concentrated (Toroiaga, Rodna, Moldova Nouă, Borod), in the Co edge, those with moderate contents of iron (Vorța, Rușchița, Nimaia), and in the Ga edge those with very poor contents of iron (Coranda, South Țibleș). No differentiation of the subvolcanic ore deposits can be noticed, the sphalerites rich in iron at Bocșa and Țibleș being projected în the central part of the

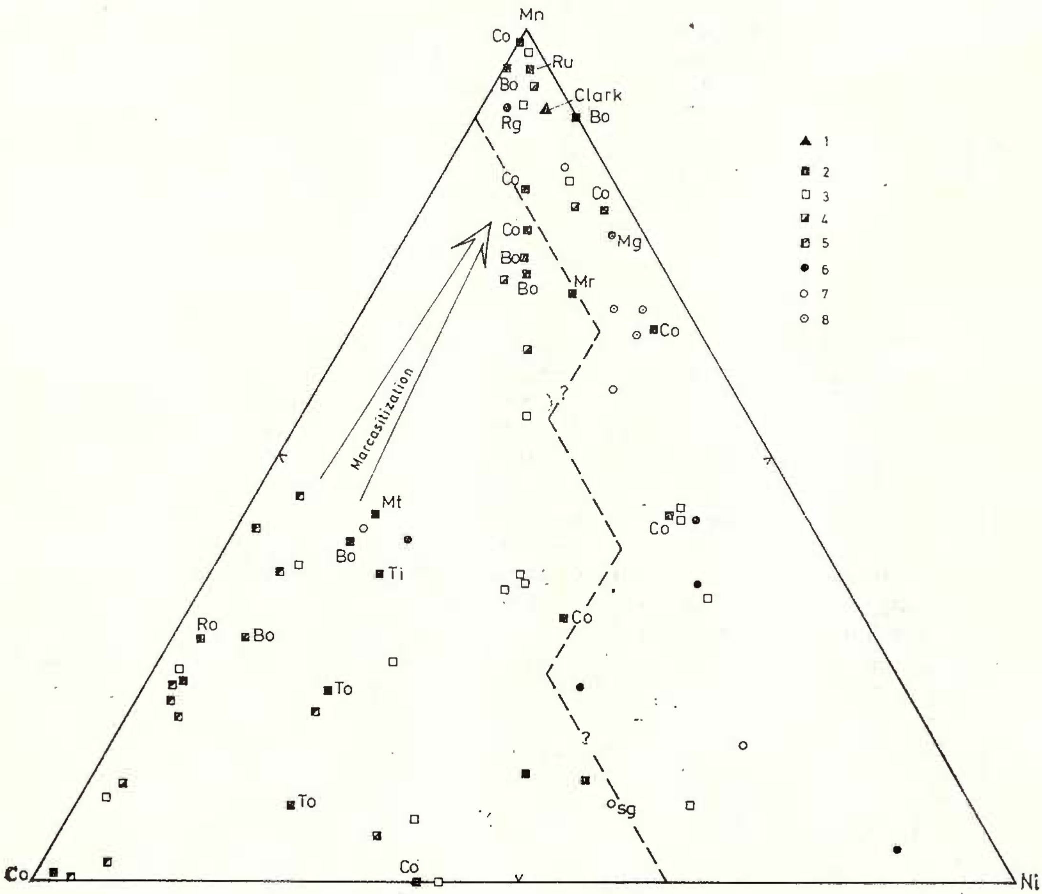


Fig. 5. — Co-Ni-Mn diagram for pyrite (analytical data from Petreuş, 1978; Cambel, Jarkowsky, 1967 and the authors' data).

1, Elements' clark in magmatic rocks (acc. Rankama, Sahama, 1970); 2, pyrite from subvolcanic ores; 3, other epigenetic ores; 4, pyrite from the Vorţa ore (possibly of the Kuroko type, Udubaşa et al., 1978); 5, pyrite from the occurrences at Pătîrş, Roşia Nouă, Almăşel, Căzăneşti etc.); 6, pyrite from syngenetic ore deposits (Rg, Rammelsberg; Mg, Meggen); 7, sedimentary pyrite; 8, pyrite (± marcasitized) from the Măgura Bretei Quarry. Abbreviations: MT, Măgura Tebei; sg, pyrite from graphitous schists (cf. Cambel, Jarkowsky, 1967); for the other abbreviations see Fig. 4. The arrow indicates the marcasitization general effect on the pyrite geochemical spectrum.

diagram. This fact could lead to the conclusion that In, Co and Ga are probably more sensitive to local geochemical factors than to a certain PT regime of the environment.

Comparing the projection points characteristic of the clark values of Mn, Cd and Cu and the average values for these elements in spha-

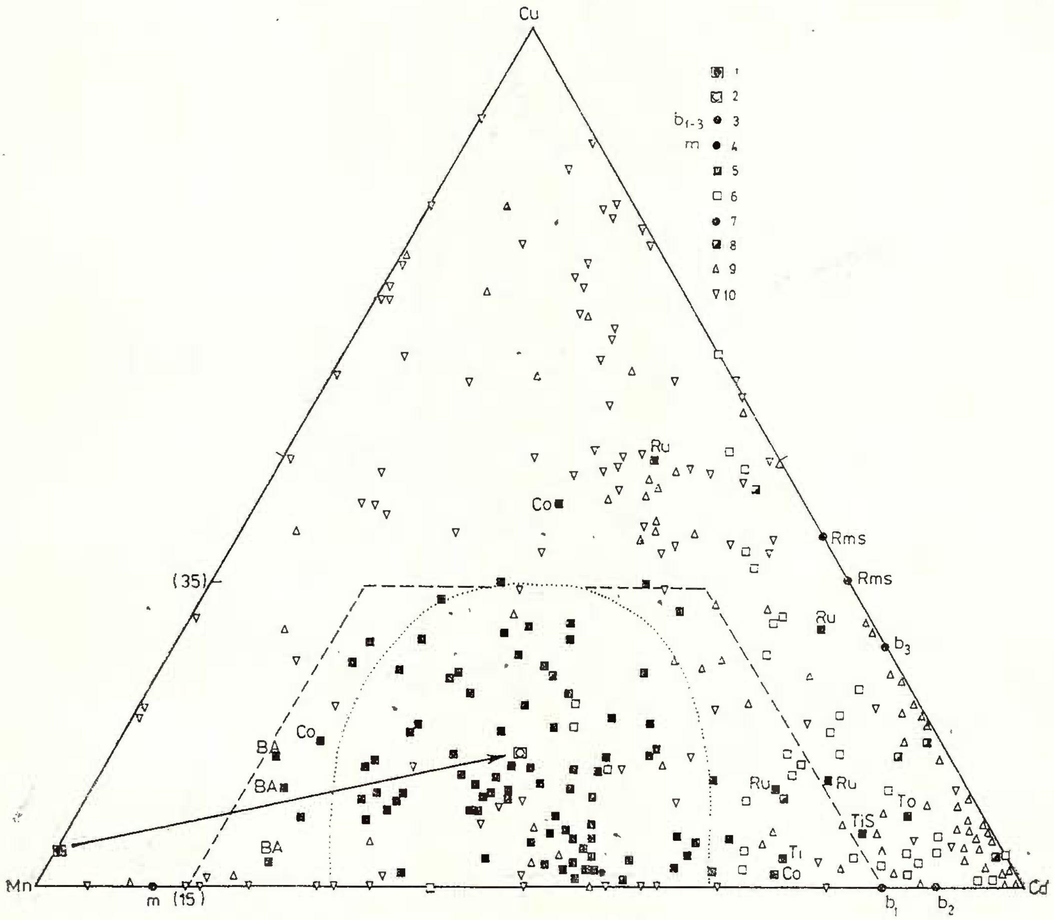


Fig. 6. — Cd-Mn-Cu diagram for sphalerite (about 300 analyses; analytical data from: Boyle, Jambor (1961); Ciuhrov (1960); Doelter, Leitmeier (1926); Giuşcă, Volanschi (1971); Graeser (1971); Nesterova (1961); Panto, Panto (1972); Sims, Barton (1961); Şadlun et al. (1968).

1, Elements' clark in the Earth crust (acc. Badalov, Povarennîh, 1968); 2, average content of the 3 elements in natural sphalerite (acc. Udubaşa et al., 1974); 3, $b_{1-3}$, brunkite (iron-free sphalerite or sphalerite with 0.2—0.6% Fe; from Ciuhrov (1960); 4, marmatite with 20,5% Fe, from Ciuhrov (1960); 5, sphalerite from subvolcanic ore deposits (for abbreviations see Fig. 4, only those projected out of the central field are marked); 6, sphalerite from other epigenetic ore deposits; 7, sphalerite from syngenetic ore deposits (Rms — Ramsbeck, West Germany); 8, sphalerite from the Vorţa ore; 9, sphalerite with less than 6% Fe; 10, sphalerite with more than 6% Fe. The average content of Fe in natural sphalerites — 6.16% (Udubaşa et al., 1974) — was calculated from 1 657 analyses.

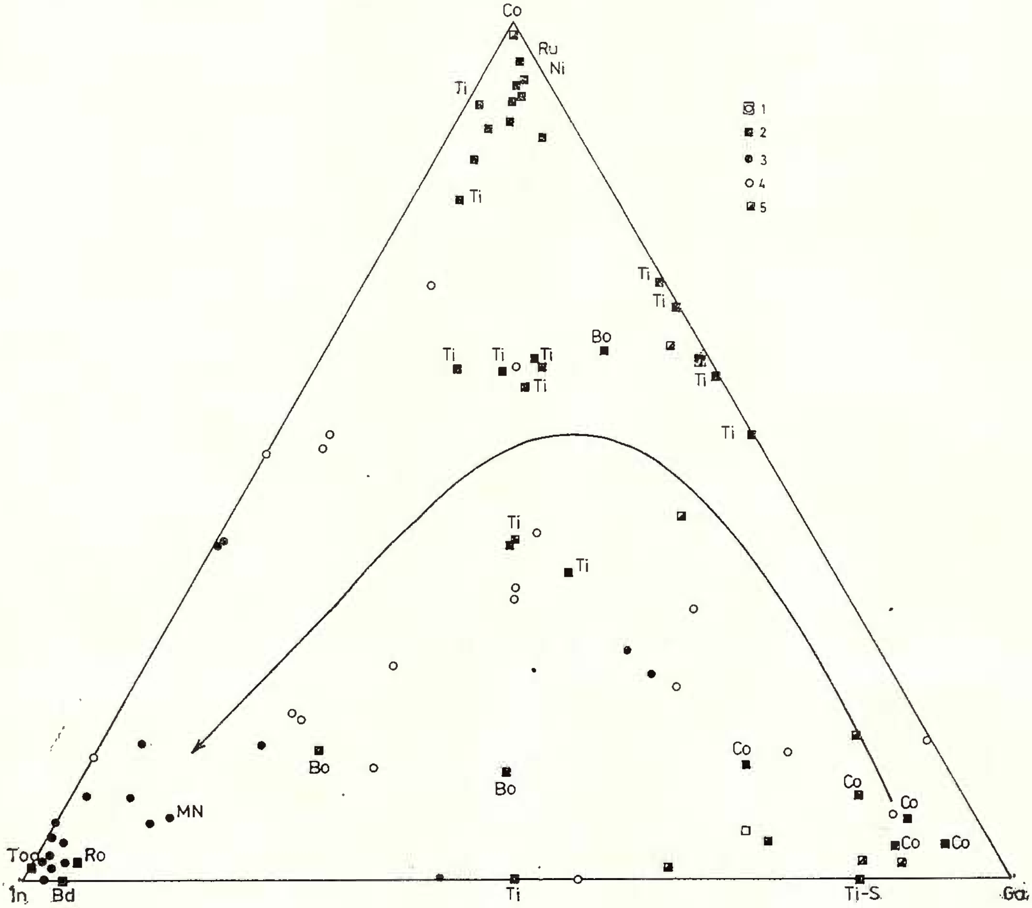


Fig. 7. — In-Ga-Co diagram for sphalerite.
1, Elements' clark (Rankama, Sahama, 1970 ; 2, sphalerite from subvolcanic ore deposits ; 3, sphalerite with more than 6% Fe ; 4, sphalerite with less than 6% Fe ; 5, sphalerite from the Vorţa ore 6% Fe. The arrow indicates the iron enrichment sense. Other abbreviations besides those in Fig. 4 : Ni, Nimaia (Făgăraş) ; Bd, Borod-Cornitel ; MN, Moldova Nouă ; Ti-S, Ţibleş-Sud (Măgura Neagră veins).

lerite (according to Badalov, Povarennîh, 1968, Udubaşa et al., 1974, respectively) there is an obvious change of the ratios among these elements in sphalerite, clearly in favour of Cd and in the detriment of Mn. In what the other triplet (Co-In-Ga) is concerned, a significant concentration of In and Co in sphalerite takes place, as compared with Ga.

In *galena* Sb, Ag and Bi are currently analyzed. On the diagram in Figure 8 the first to be noticed is the maximum concentration of the projection points near the Ag-Sb and Ag-Bi lines, corresponding

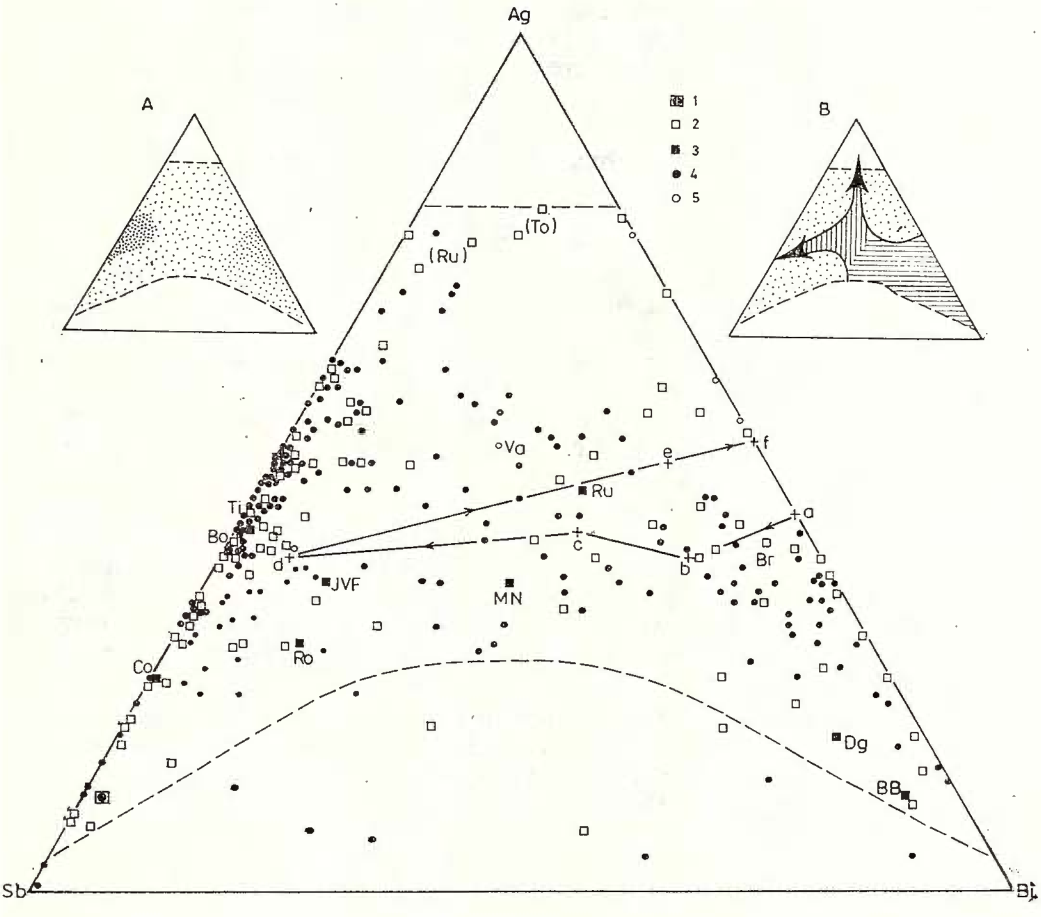


Fig. 8. — Ag-Sb-Bi diagram for galena (more than 300 analyses; analytical data from Borcoş et al., 1977, Eskenazi et al., 1971, Giuşcă, Volanschi, 1971 etc.). Other abbreviations basides those in Fig. 4 : BB, Băiţa Bihorului ; Dg, Dognecea ; Br, Brusturi ; Va, Văratec.

1, Elements' clark (after Badalov, Povarennîh, 1969) ; 2, galena from volcanic (and plutonic !) ore deposits ; 3, average values for 2 ; 4, other ore deposits ; 5, average values for 4 ; a-f, average values for the galena from magnetite-bearing skarns (a), quartz + molybdenite + chalcopyrite ore (b), base-metal skarns (c), base-metal veins (d), quart + barytine + fluorine-bearing veins (e), gold quartz-bearing veins (f). Small diagrams : A, field with the possible ratios among the 3 elements, marking the maximum concentration (in dots ; see the text for details) ; B, the possible evolution of the ratios among elements form the galena associated with laramic ores (horizontal lines) towards the galena from Neogene ones (vertical lines ; towards the "West" — most Neogene galenas ; towards the "North" — the galenas from the Văratec, Toroiaga ores).

therefore with the ratios in the $AgSbS_2$ and $AgBiS_2$ compounds. Therefore the experimental data obtained by Amcoff (1976) are confirmed also analytically for the preferential acceptance in the galena lattice of the Pb ⇄ AgSb and Pb ⇄ AgBi coupled substitutions and not so much so or even not at all for the Pb ⇄ SbBi type.

The galenas of the subvolcanic ore deposits are projected in the two maxima, representing here as well — just like in the case of Cd and Mn in sphalerite — equilibrium concentrations of these elements. The ore deposits are quite well differentiated on the basis of this diagram, as function of their metallogenetic province : the Laramian ones on the AgBi line (a few ore deposits of Bulgaria included, Eskenazi et al., 1971), and the Neogene ones on the AgSb line. The plots of galenas from Ruşchiţa, Moldova Nouă and Juleşti form a "bridge" between the two maxima. It is worth noticing that on this diagram the Văratec and Băiuţ galenas (Borcoş et al., 1977) are closer to the Laramian ones than to the Neogene ones, and the Toroiaga galena occupies a solitary position.

The geochemical affinity between Te and Bi is expressed here as well by the projection of the Băiţa Bihor galena in the Bi [4] angle, and by the migration of the projection points towards the Bi edge in direct relation with the increase in the Te content in the Spoulka ore deposit, Bulgaria. An interesting aspect has the "curve" drawn by the projection points for the galenas of certain major mineralization types (Badalov, Povarennîh, 1969).

The distribution of the projection points for galena against the point representative for the clark of the 3 elements in the Earth crust indicates an important modification of the ratios of these elements in favour of Ag and Bi and the detriment of Sb.

## Conclusions

A group of 8 ore deposits associated with Laramian (Ruşchiţa and Juleşti-Valea Fagului) and Neogene (Ţibleş, Toroiaga, Rodna, Baia de Arieş, Bocşa-Săcărîmb and Coranda-Hondol) subvolcanic structures of Romania are presented in short, emphasizing first of all the characteristics of the ore mineral assemblages, especially those of sphalerite. From observation and experimental data it can be inferred that sphalerite is a mineral with great "information entropy" that can provide a lot of information on the PTX structure of the deposition environment, provided the they are correctly decoded. Certain aspects of the ores are discussed (exsolutions, diffusion in solid state, compositional re-equilibrations due to the sulphur and oxigen fugacity variation etc., that affects sphalerite rather strongly and in a relatively easily discernible way) that cause important modifications in the mineral assemblages. If such aspects are neglected, false primary assemblages could be taken into account and thermodynamically unjustifiable or even erroneous conclusions be drawn.

On the basis of microscopic observations, the existing analytical data and experimental studies, the 8 ore deposits can be grouped in the following way :

(1) low pressure and high temperature mineral assemblages : Toroiaga, Țibleș, Rodna, in which the main assemblage is made up of marmatitic sphalerite + pyrrhotite + chalcopyrite + pyrite, to which chalcopyrrhotite, cubanite, mackinawite are added ;

(2) high pressure and low temperature mineral assemblages : Julești-Valea Fagului, Ruschița, Coranda-Hondol, in which the main assemblages contains iron poor sphalerite + chalcopyrite + pyrite + bornite ;

(3) intermediate pressure and temperature assemblages : Bocșa-Săcărîmb and Baia de Arieș, with the main assemblage represented by semi-marmatitic sphalerite + chalcopyrite + pyrrhotite + chalcopyrrhotite.

We must point out that the geobarometric estimates do not refer to lithostatic pressure, therefore no direct appreciations can be made concerning the depth at which the mineralizations were formed, but the total pressure of the volatile compounds of postmagmatic systems. Such an interpretation of data brings convincing explanations on the causes of the abundant occurrence of breccias in the Coranda, Ruschița and Julești-Valea Fagului structures as well as in those at Bocșa and Baia de Arieș, formed at intermediary pressures. In the Toroiaga and Țibleș structures the breccias have a limited development, in accordance with the lower pressure of volatiles. An exception can be considered the Rodna structure, where the hypothetical "isotherm" (Fig. 4) intersects the 1,250 and 5,000 bars, probably corresponding to a decompression in steps of the postmagmatic system. A similar situation is to be found in the Țibleș structures as a whole, where the mineralizations in the southern zone (Măgura Neagră) show a higher baric level, concording with the supposition of the existence of a porphyry copper type system (Udubașa et al., 1984).

Three of the main sulphides — pyrite, sphalerite and galena — have been geochemically analyzed for underlining certain typomorphic characters of the ore deposits associated with subvolcanic structures. The sphalerite and galena of these ore deposits are characterized by "equilibrium concentrations" of minor elements : Cd and Mn in sphalerite, Ag-Sb and Ag-Bi in galena, that forms relatively well delimited fields on the ternary Cd-Mn-Cu, respectively Sb-Ag-Bi diagrams.

In the eruptive structures with subvolcanic magmatites (chalco-alkaline, generally with andesitic-dioritic character) the metallogenetic activity seems controlled to the greatest extent by the existence of metals in the magmatic systems activated first of all by a corresponding fugacity of sulphur and a clear evolution of the differentiation processes. The surrounding rocks have in most cases a passive role of host-collector rocks, without a strong metallogenous reply, anyhow with a role difficult to define. But in certain structures there existed an active or activated "pre-metallogenic background" (or "metallic area", cf. Routhier, 1977), that sometimes brings a "supply" of metals difficult to explain by a normal evolution of the magmatic-metallogenetic systems. That is probably the case of the enrichment in copper of the Toroiaga and Juleşti-Valea Fagului structures, of the relative abundance of manganese at Baia de Arieş[5] etc. In this sense one can notice — especially for the Metaliferi Mts. — the persistence of the Mn-Te-Au triplet, that suggests a certain geochemical affinity among them and the possibility of a partial remobilization of manganese (maybe of tellurium as well ?) from pre-existing accumulations. Thus it is significant that Au and Cu tellurides occur in the Coranda-Hondol structure, in a zone of lamination of the Mesozoic ophiolitic rocks, with which in the western part of the Metaliferi Mts. manganese volcano-sedimentary accumulations are associated.

The appearance of "monzo" tendencies at the subvolcanic rocks can indicate a "deviation" of the magmatic-metallogenetic systems with dominantly polymetallic specialization (Pb + Zn + Cu) towards porphyry copper type systems, as in the case, it seems, of the eruptive Ţibleş complex.

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[3] The porphyry copper deposits are not discussed here.

[4] In the Băiţa Bihor ore deposits Bi tellurides are known (Giuşcă, 1941 ; Cioflica et al., 1977).

[5] At Baia de Arieş, C. Lazăr (personal communication, 1968) accepted the remobilization of Mn from pre-existing ores in the metamorphic rocks of the Baia de Arieş Series.

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QUESTIONS

C. Lazăr : 1. To what extent do you think the baric conditions of consolidation of eruptive subvolcanic rocks can be correlated with those under which associated metallogenesis developed in the sense presented in the paper ?

2. Do you consider that in order to establish the baric conditions in which mineralizing processes occur one must take into account the ratio between the inner pressure of the system under discussion and the outer one ?

*Answers :* 1. Generally they can and must be correlated but the problem of the depth of the consolidation of subvolcanic eruptive rocks has not been approached in this paper. For a very clear answer to this question, observations and analyses would be necessary, similar with those concerning the mineralizations, which we do not possess (so far).

2. It is obvious that the lithostatic pressure (PL) influences the way in which the mineralizing processes develop, PL largely controlling the system decompression, therefore the release and distribution of the volatile components in the associated magmatic rocks or in the surrounding formations. If PL > PV (total pressure of volatiles) it is natural for the mineralizing process to take place, most of it, within the former (superficial) magmatic system, as it seems to have been the case of the Ţibleş structure. When PL ⩽ PV, the mineralizing process can migrate out of the magmatic system ; that is the case, probably, of the structure of the type Bocşa-Săcărîmb and Ruşchiţa, where almost all the mineralizations are situated out of the subvolcanic bodies with which they are related.

DISCUSSIONS

C. Lazăr : I should like to mention that the particular importance of the communication lies, both in the presentation of a new approach in our country of the metallogenetic problems, by synthesizing many inedited and known data, as well as in the envisagement of certain directions for future researches.

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## EXPLANATION OF PLATES

### Plate I

Fig. 1. — Molybdenite lamellae (white) in quartz (black). Ţibleş-Izvorul Mesteacănului. Reflected light (RL), oil immersion, N //, ×350.

Fig. 2. — Molybdenite (white) associated with sphalerite (grey). Ţibleş-Izvorul Mesteacănului. RL, oil immersion, N //, ×350.

Fig. 3. — Pyrrhotite (po) and chalcopyrite (cp) with sphalerite stars (dark grey) ; black-quartz ; py — pyrite. Gura Băii (east of the Toroiaga structure),

horizon 1380. The sample (U-618) has been taken from a drill-hole that has intercepted the contact between the metamorphosed syngenetic ore and a Miocene eruptive body of the Toroiaga complex. RL, oil immersion, N //, ×400.

Fig. 4. — Chalcopyrite (cp) with sphalerite stars (grey-blackish) containing irregular sphalerite inclusions that, in their turn, comprise chalcopyrite blebs. Localization : see Fig. 3. RL, oil immersion, N //, ×400.

## Plate II

Fig. 1. — Complex macroinclusion in sphalerite (black) made up of chalcopyrite (white), chalcopyrrhotite or "intermediate solid solution" (light grey) and mackinawite (dark grey). Ţibleş, vein 18, RL, oil immersion, N //, ×400.

Fig. 2. — Same image, turned round ; mackinawite (white, irregular spots) is readily discernible due to the particularly strong reflection pleochroism.

Fig. 3. — Chalcopyrrhotite ("iss") (light grey) and chalcopyrite (white) intergrowth in sphalerite (black). Rodna-Izvorul Roşu. RL, oil immersion, N //, × 800.

Fig. 4. — Chalcopyrite (white) and mackinawite (black-dark grey) intergrowths in sphalerite (black). Rodna-Izvorul Roşu, oil immersion, N //, ×3000.

Fig. 5. — Chalcopyrite intergrowths (white) in sphalerite. In the lower part of the photo a succession of rather big chalcopyrite blebs is to be noticed in the middle of a sphalerite „veinlet" with no intergrowths, formed by solid state diffusion of chalcopyrite that migrated towards the fissures. Coranda-Hondol. RL, oil immersion, N //, ×400.

## Plate III

Fig. 1. — Discontinuous chalcopyrite veinlets (white) in sphalerite (grey), formed by solid state diffusion. The chalcopyrite blebs migrated towards the fissures turned into veinlets, that's why they are no longer to be found around the veinlets. Bocşa-Săcărîmb, RL, N //, ×250.

Fig. 2. — Aspects similar to those in Fig. 1, with false "chalcopyrite II" in sphalerite. Ţibleş, vein 18, RL, oil immersion, N //, ×1000.

Fig. 3. — Pyrite (white) intergrowth with magnetite (grey), formed by the (here complete) hypogene transformation of pyrrhotite. Ţibleş, Izvorul Băilor vein, RL, oil immersion, N //, ×1000.

Fig. 4. — Lamellar intergrowths of marcasite (white) and siderite (grey) formed by the supergene transformation of pyrrhotite. Ţibleş Tomnatec vein, RL, N //, ×150.

## Plate IV

Fig. 1. — Sparse chalcopyrite inclusions (white) in sphalerite ; there also appear very fine (maximum breadth 1—2 microns) veinlets with $Cu_3ZnS_4$ (for details see Udubaşa et al., 1980) that has lower reflectivity than chalco-

pyrite and relatively strong reflection pleochroism. Ţibleş, vein 15, Rosinanta. RL, oil immersion, N //, ×1000.

Fig. 2. — Same image, turned round ; The $Cu_3ZnS_4$ compound reflection pleochroism is to be noticed.

Fig. 3. — Slightly deformed sphalerite starlets (black) in chalcopyrite. Ţibleş, Preluci vein. RL, oil immersion, N //, ×3000.

Fig. 4. — Seriated sphalerite starlets (grey) in chalcopyrite formed by the amplification of primary exsolution through solid state diffusion. Bocşa-Săcărîmb. RL, oil immersion, N //, ×250.

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## 2. ZĂCĂMINTE

*RECENZII*

W. SALOMONS, U. FÖRSTNER: *Metals in the Hydrocycle. Springer Verlag, Berlin, Heidelberg, New York, Tokyo*, 394 p.

It is a very dense, information-rich book giving a comprehensive overview on the fate of metals from rocks to continental waters, from air to water and from water and air to oceans. Both the problem of pollution and of the renewable metal (concentration) can be derived, understood and properly interpreted after this book has been read.

After the introduction (Chapter 1), "Mode of Occurrence" and "Behaviour of Trace Metals During Transport" (Chapters 2 and 3) there is a systematic pursuit of metals in all the segments of the hydrogeological cycle (Chapters 4—7). "Interactions with Ligands, Particulate Matter and Organisms" (Chapter 2) gives the main processes of metal fixation in aquatic systems, emphasizing the importance of various metal-binding forms in increasing or decreasing their stability, toxicity etc. The methods for extraction of metals are minutely described too (underlining the lability of metal species which causes changes in the speciation after sampling) as well as metal uptake and transformation of metals by organisms. Chapter 3, entitled "Sediments and the Transport of Metals" contains basic data on distribution and deposition, grain size effects, anthropogenic influences on metal concentration in sediments, early diagenesis of trace metals in sediments (with special emphasis on the role of pore waters in the geochemical cycling of metals). "Metals in the Atmosphere" (Chapter 4) — their influence in all parts of the hydrogeological cycle has been recognized over the last 10 years — includes many data regarding size distribution and its influence on metal deposition as well as the possible source of atmospheric metals in different areas of the world. The problem of "Metals in Continental Water" (Chapter 5) is also well documented, accurate data being given on metal distribution and migration during weathering, pollution of soils (cadmium is preferentially taken up by plants and it may become toxic to animals), metal content of river waters, in river sediments and factors affecting them, metals in lakes and their cycling etc. Passing to "Metals in Estuaries and Coastal Environments" (Chapter 6), there are a lot of very useful data concerning such complex and dynamic systems with an extensive discussion on the Rhine Estuary; both field and laboratory investigations are presented for other estuarine systems as well, with a look at the environmental impact of metals. Chapter 7 "Metals in the Ocean" ends the systematic presentation; the oceans are treated here as loci of final fixation (i.e. for several hundred million of years) of metals in sediments at the end of a hydrological cycle. Trace metals in the oceans come from (1) rivers, (2) the atmosphere and (3) hydrothermal inputs from active ridges. Of special interest is the part concerning metal concentration in deep-sea sediments (including the manganese nodules). The last chapter (8), "Summary and Outlook" emphasizes what future research needs are to be solved in order to obtain reliable data (without much extrapolation) of the complex environmental impact problem.

A very extensive reference list (over 40 pages) and a useful subject index supplement this well written book of special value and interest for many scientists and especially for all the geoscientists.

*G. Udubaşa*

H. J. SCHNEIDER : *Mineral Deposits of the Alps and of the Alpine Epoch in Europe.* 1983, 402 pages, 184 figs.

The volume represents the third special edition of the Society of geology applied to the study of ore deposits (S.G.A.), published by Springer Verlag. The book, edited by H. J. Schneider, consists of 39 articles selected from the communications presented at the 4th international symposium on Alps ore deposits (ISMIDA), held at Brechtesgaden, West Germany, in October 1981. The contributions are grouped on : general themes ; Alps ore deposits ; geochemistry of the Alps ore deposits ; Alpine ore deposits in Europe, and sums up the main results obtained in these fields of research in the last 3—4 years. By including in the volume 13 papers on Alpine metallogenesis outside the Alps, both in Europe and in North Africa, the sphere of interest of the volume was considerably enlarged and a basis of comparison was offered, concerning both field data and the manner of interpreting them.

In the same respect, we should also mention the two articles on general problems regarding Alpine metallogenesis the first one, an outlook from „outside" the Alpine orogen, the second signed by a representative of the Alpine domain. We should also point out the special concern given to the interpretation of geochemical data in metallogenesis.

As a whole, the volume gives an adequate picture of the problems that torment specialists in the Alps metallogenesis, underlining both the progress made of late and the uncertainties which are still persisting.

*H. G. Kräutner*

W. E. GALLOAY, D. K. HODBAY : *Terrigenous Clastic Depositional Systems Applications to Petroleum, Coal, and Uranium Exploration. Springer-Verlag, New York-Heidelberg-Berlin,* 1983, 432 pages, 237 figs.

Practical necessities, especially those regarding the sources of energy have led to an explosion of researches concerning the genesis and accumulation environments of the main energetic substances. The great number of published scientific results called for the drawing up of a series of synthesis works that try to systematize disparate data, in view of identifying models with as extended an areal validity as possible. The book we are reviewing is one of these syntheses. It has a special character, that is it has related theoretic aspects of geological research with practical ones. In this respect it could represent and example worth following.

For analyzing terrigenous depositional systems, the authors use information from various fields, such as : sedimentology, sedimentary rocks petrography, hydrogeology, geochemistry, stratigraphy and tectonics. Eight chapters deal with the analysis of depositional systems, as follows : alluvial dejection cones systems, fluviatile systems, shelf terrigenous systems, slope and terrigenous basins systems, lacustrine systems and eolian systems. The authors devoted a special chapter to the hydrogeology of depositional systems. The last part of the book deals with practical applications of the depositional systems analyzed only theoretically so far. Thus, coal, uranium and petroleum are, each of them, treated in a separate chapter.

Unfortunately, the three energetic substances are unequally approached and the examples are sometimes (especially in what petroleum is concerned) rather poor, maybe also because of the insufficient degree of theoretical research of certain accumulations zones in the world.

As a whole, the volume is a valuable work and an useful tool for sedimentologists, hydrogeologists, geologists specialized in petroleum, coal and uranium studies. Besides the great amount of processed and systematized data it offers the reader, the book is both an example and an incentive concerning the manner in which should be investigated the zones from which coal, uranium and petroleum are already exploited, in view of establishing and appreciating the economic potential of prospects areas.

*M. Ştefănescu*

HELMUT KRATZCH : *Mining Subsidence Engineering, Springer-Verlag, New York-Heidelberg-Berlin,* 1983, 580 pages, 387 figs.

The book was printed in German, in 1974, under the title "Bergschadenkunde" and published in USSR, in 1978. In 1983, a new edition, in English, came out under the title "Mining Subsidence Engineering", revised and completed with 100 new figures.

The work deals with underground and surface displacements of rocks, their influence on underground mining works, on land surfaces and on civil or industrial buildings situated in the areas of influence.

In part I, "Strata Movement", the following problems are analyzed in 6 chapters :

— the way in which rocks pressure acts (displacement of strata-rocks) in exploitation works ; the situation is presented of exploitation methods with or without pillars, of total or partial exploitation ; the cover behaviour, when coal seams are exploited by frontal breaking-down or with chambers, mentioning the factors that influence convergence ;

— horizontal and vertical deformation of rocks and the chronologic evolution of strata displacement, surface piercing included ;

— the calculation of the deformation of rocks, the calculation of convergence, function of the cover type respectively, as well as the method of precalculating the rocks movement ;

— displacement of strata in wells, presenting the bases of calculation, the establishment of horizontal and vertical pressures ;

— measures for protecting wells and keeping them in operation ;

— reciprocal influences of mining works and mining practice on the rocks displacements.

In part II, "The Study of Ground Movement", the following problems are treated :

— components of rocks displacements and the precalculation of the sinking of strata (sinking throughs), with the presentation of several calculation methods ;

— preliminary calculation of land (beds-rocks) displacement ;

— the way time influences rocks deformation processes ;

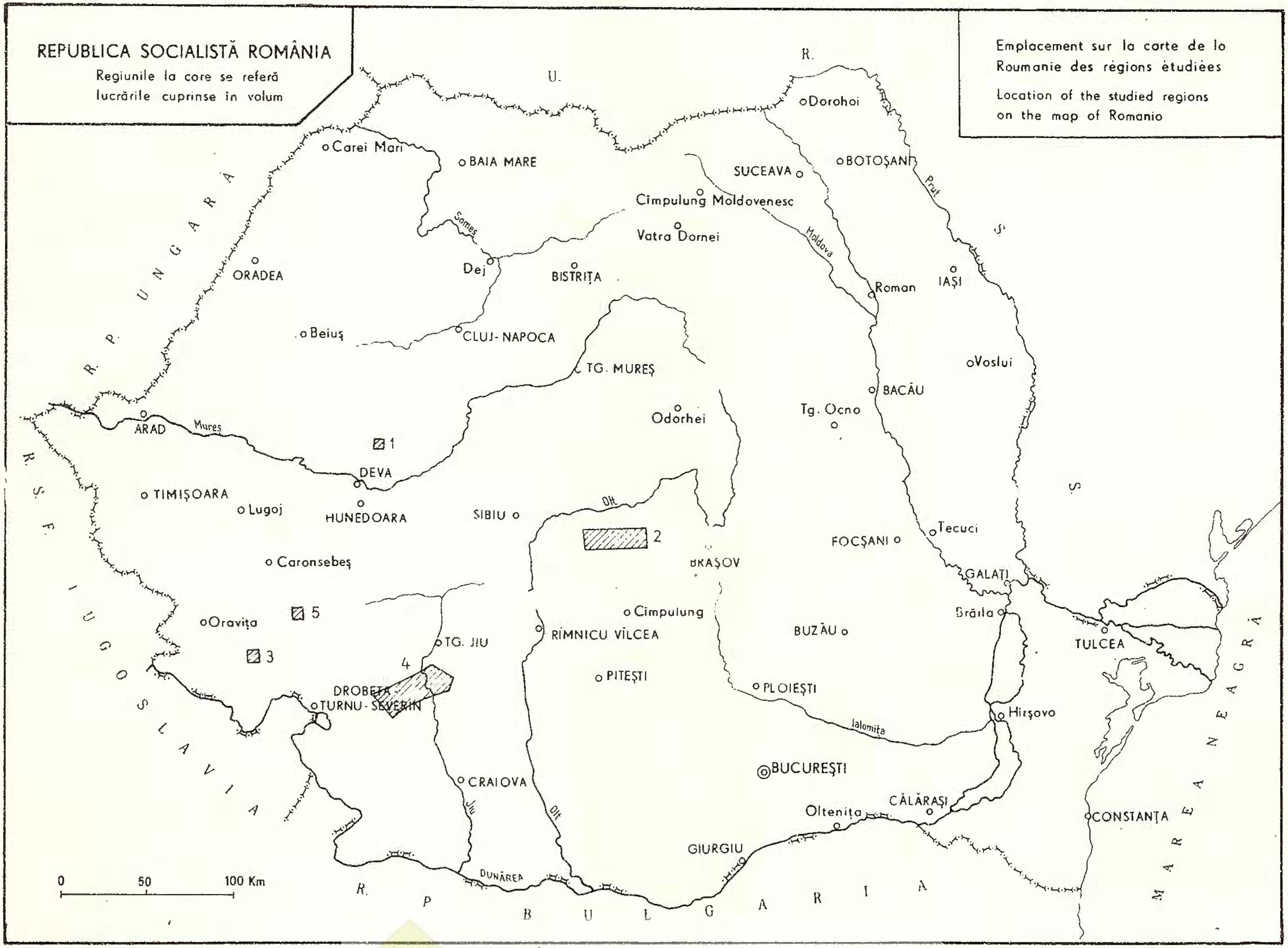
— the influence of rocks deformations on buildings and land damages caused by mining works ;

— measures necessary for reducing land and mining sites deteriorations.

The book is concieved at a high technical level. It presents phenomena, their causes and effects as well as the method of calculationg the pillars and chambers sizes and the parameters of sinking throughs.

The book is addressed to specialists and is of utmost importance for mining works designing and supervision, as well as for determining their zones of influence on the surface.

*Iulian Bădescu*


REPUBLICA SOCIALISTĂ ROMÂNIA
Regiunile la care se referă lucrările cuprinse în volum
Emplacement sur la carte de la Roumanie des régions étudiées
Location of the studied regions on the map of Romania
R. P. UNGARĂ
U. R. S. S.
R. S. F. IUGOSLAVIA
R. P. BULGARIA
MAREA NEAGRĂ
Carei Mari
BAIA MARE
Dorohoi
BOTOȘANI
SUCEAVA
Cîmpulung Moldovenesc
Vatra Dornei
Someș
Dej
BISTRIȚA
Moldova
Prut
ORADEA
Roman
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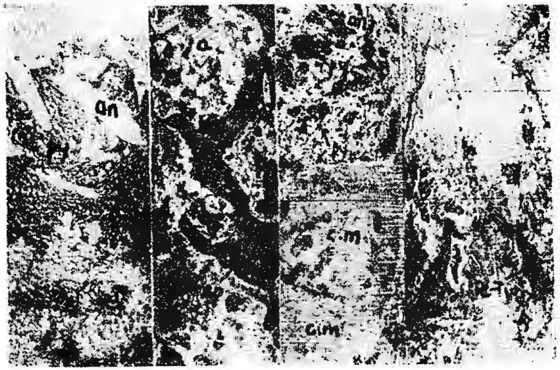
Tehnoredactor : D. ROBU
Traducător : A. BRATU
Ilustrația : V. NIȚU

*Dat la cules : noiembrie 1984. Bun de tipar : ianuarie 1985 Tiraj : 700 ex. Hîrtie scris IA. Format 70×100/56 g. Coli de tipar : 7,5. Comanda 859. Pentru biblioteci indicele de clasificare : 55(058).*

Întreprinderea poligrafică „Informația"
Str. Brezoianu nr. 23—25
București, România

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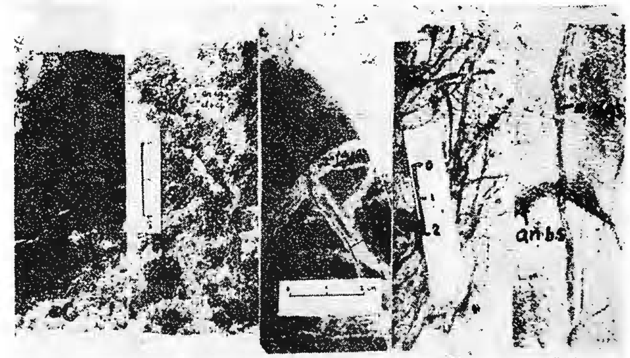


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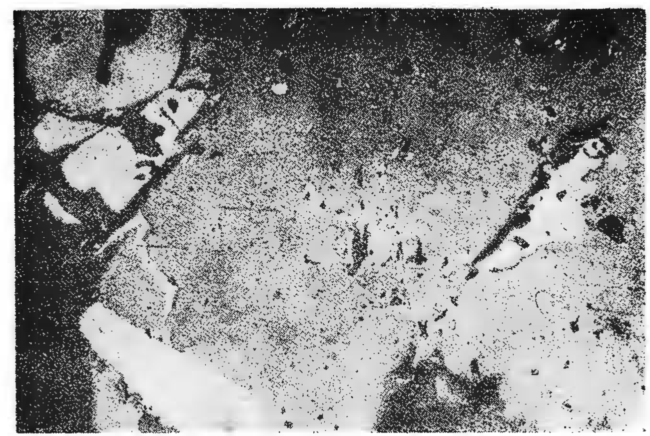

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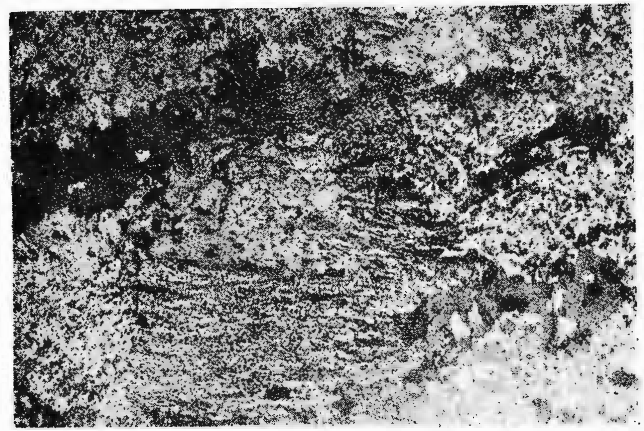

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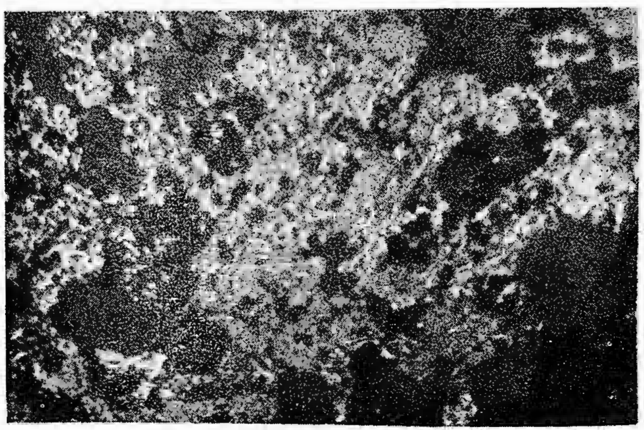

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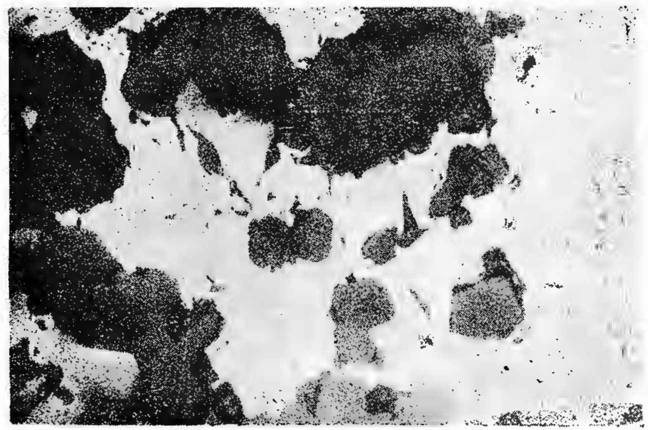

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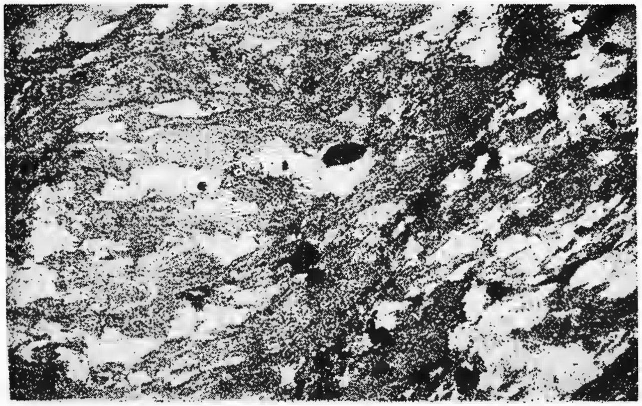

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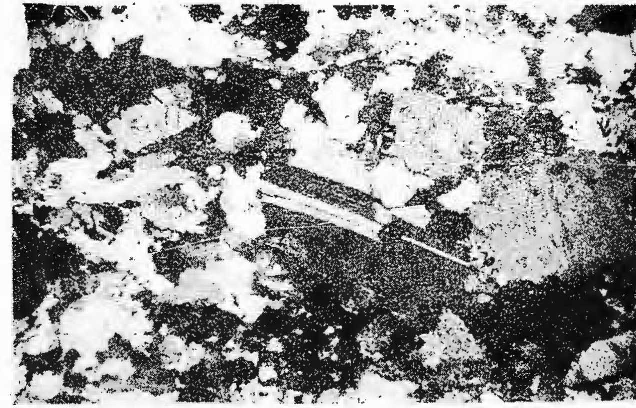

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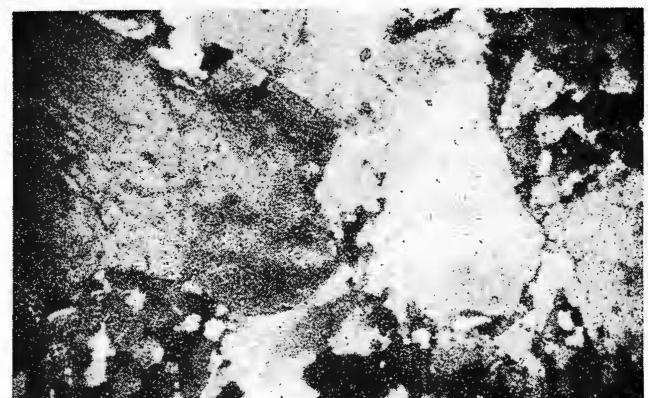

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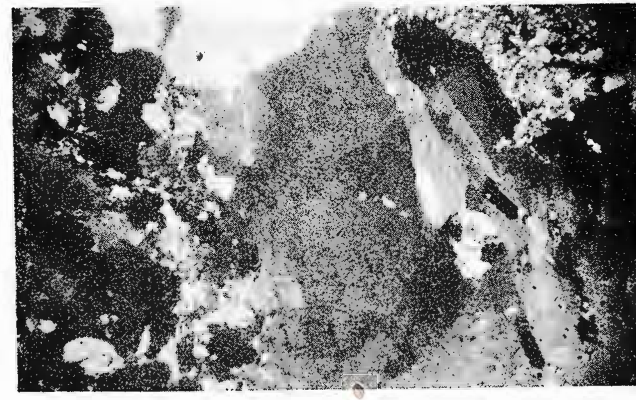

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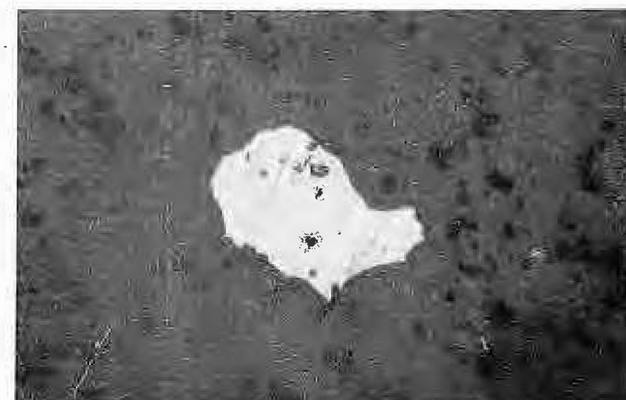

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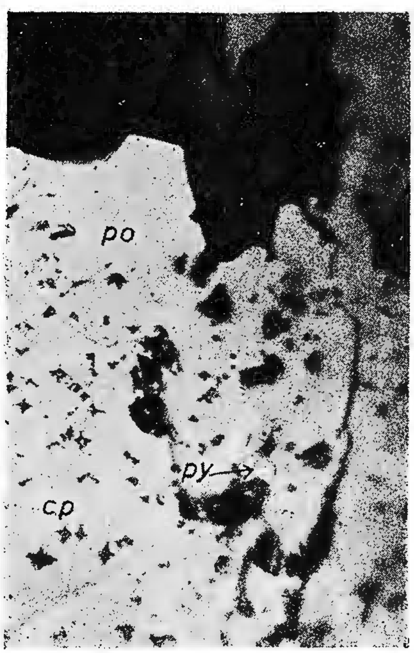


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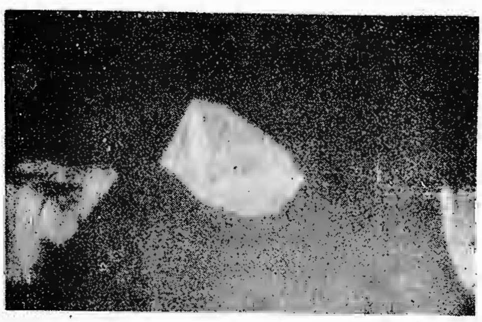

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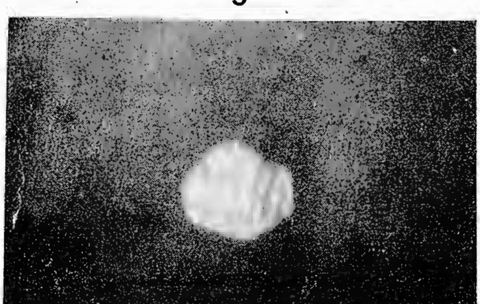

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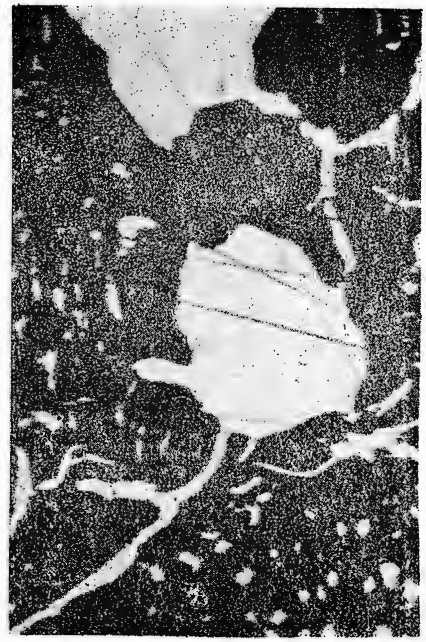

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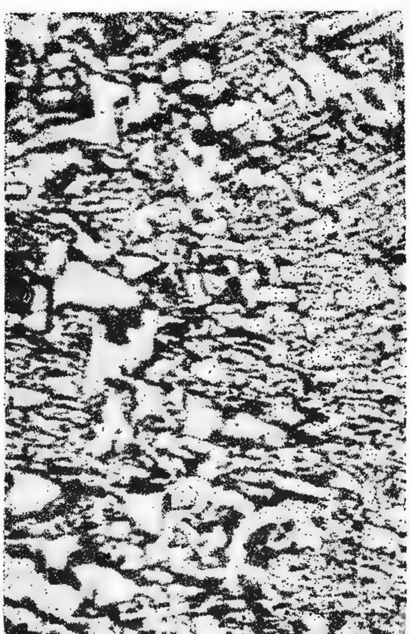

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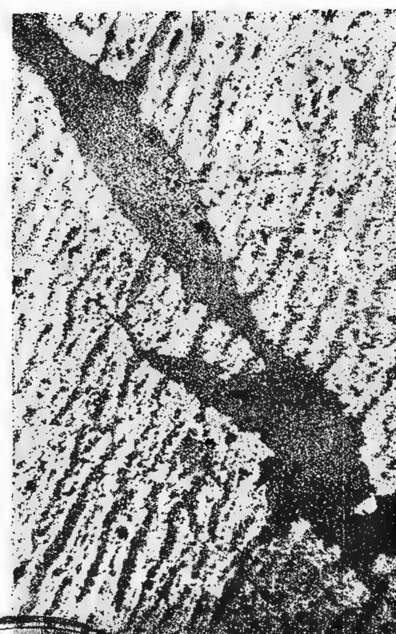

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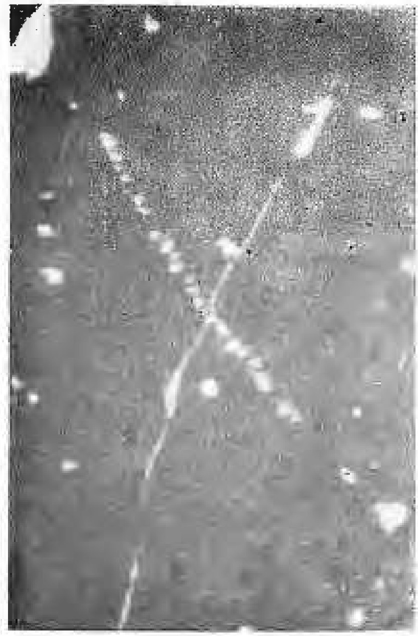

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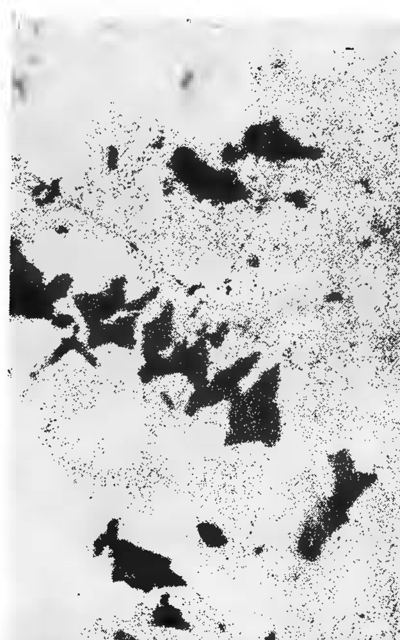

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# COMPTES RENDUS DES SÉANCES

TOME LXIX
1982

## 2. GISEMENTS