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8 – 12 June, 2001

FIELD GUIDEBOOK

Bucharest, 2001

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8 – 12 June, 2001

GEOLOGICAL SURVEY OF ROMANIA



Geodynamics and Ore Deposit Evolution
of the Alpine-Balkan-Carpathian-Dinaride Province



FIELD GUIDEBOOK

Excursion A: Neogene magmatism and related metallogeny from South Apuseni Mountains
Excursion C: Mesozoic magmatic evolution of South Apuseni Mts and "banatite" related high temperature skarn occurrence

Editor: Prof. Dr. Gheorghe Udubasa, Member of the Romanian Academy

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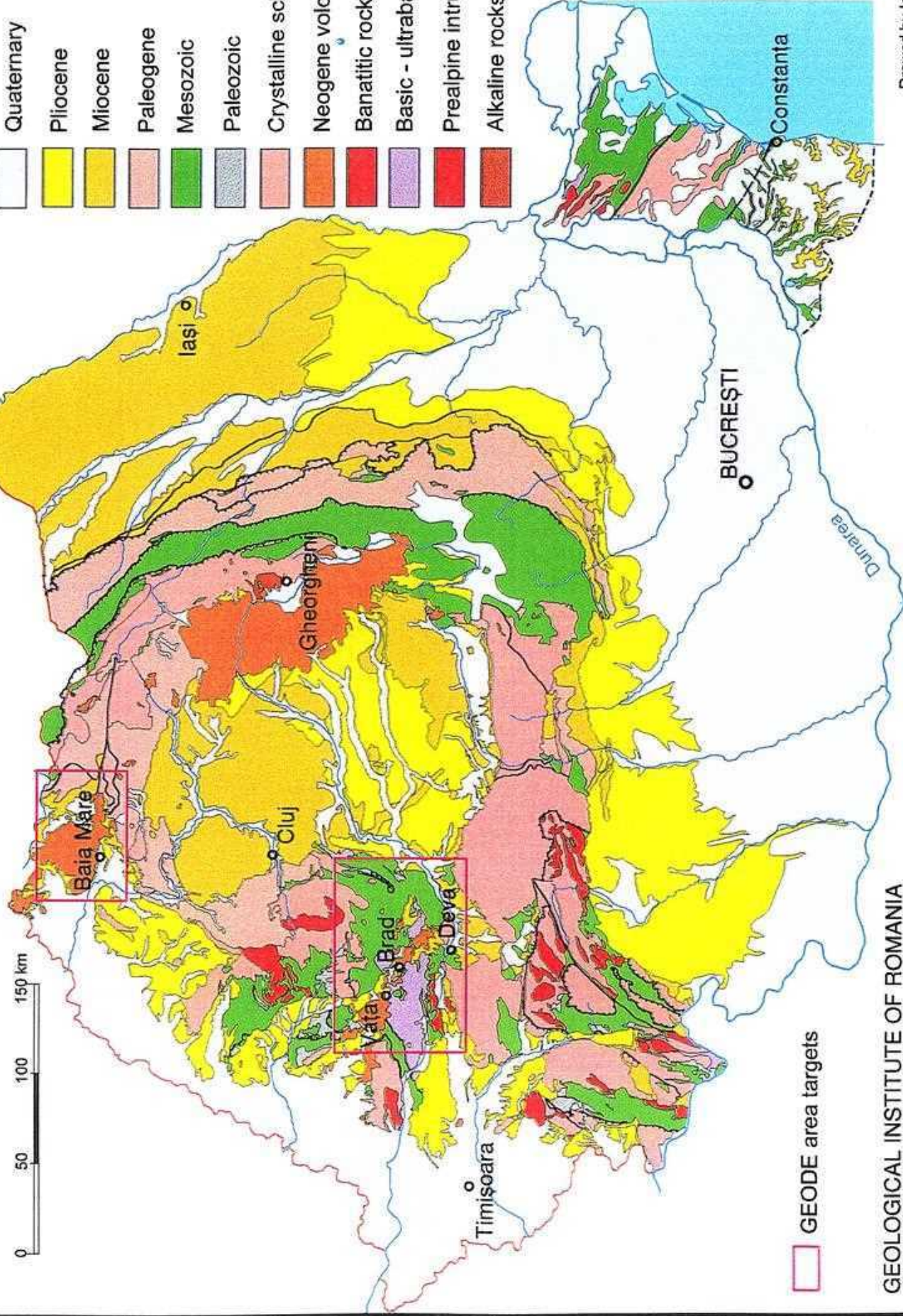
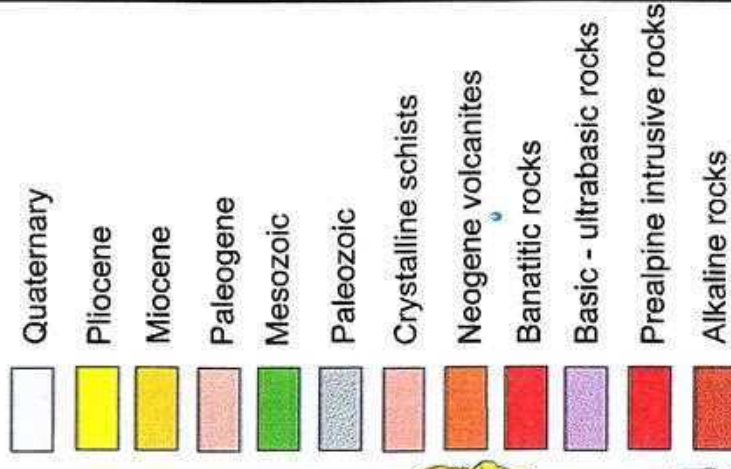
**ROSIA MONTANA GOLD
CORPORATION**

DEVA GOLD

Bucharest, 2001

GEOLOGICAL SKETCH MAP OF ROMANIA

LEGEND



[Pink box] GEODE area targets

GEOLOGICAL INSTITUTE OF ROMANIA

Drawn by Ion Gheuca

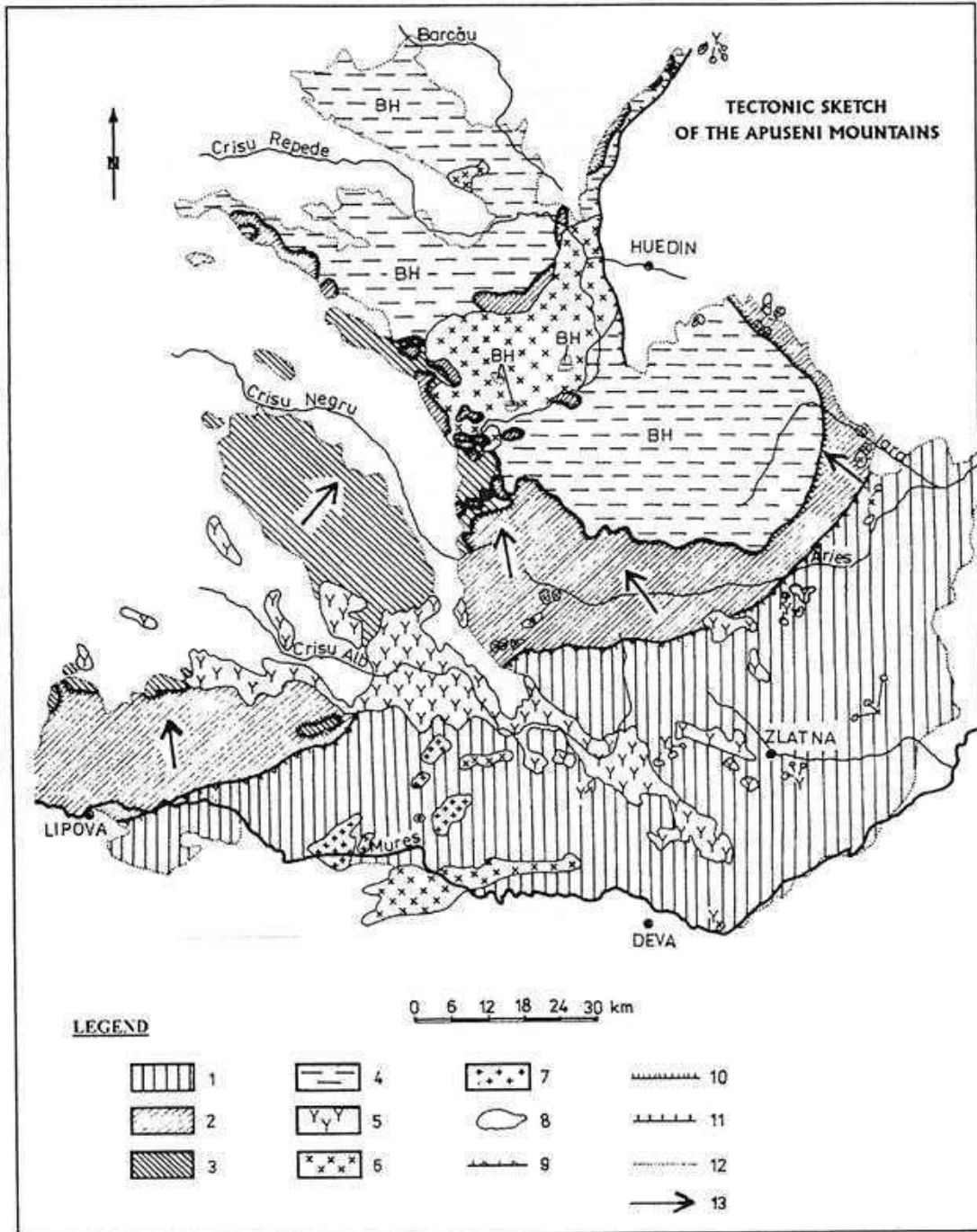
SOUTH APUSENI MOUNTAINS, GENERAL APPROACHES **CONTENT**

Geodynamics and tectonics of the Apuseni Mountains (Romania) I. Balintoni, T. Berza	3
The Mesozoic magmatites complex and the associated metallogenesis of the South Apuseni Mountains . G. Cioflica, M. Lupulescu, S. Udubasa.....	6
The Laramic ("Banatitic") magmatism in Romania. D. Russo-Sandulescu.....	14
Ore deposits related to the Laramic ("Banatitic") magmatism in Romania. G. Udubasa.....	16
Neogene magmatism in the Apuseni Mountains Romania. Evolution and geochemical features. E. Rosu	19
Neogene ore deposits from South Apuseni Mountains, Romania. Constraints and evolution. E. Rosu, L. Nedelcu, G. Udubasa, I. Pintea, M.P. Ivascanu.....	22
The estimation of the formation constraints of the main mineral deposit types E. Rosu, L. Nedelcu, I. Pintea, M.P. Ivascanu, C. Costea A. Serban, V. Alexe.....	23
Melt and fluid inclusions study in Neogene porphyry Cu-Au(Mo) from Metaliferi Mountains. I. Pintea.....	28

GEODYNAMICS AND TECTONICS OF THE APUSENI MOUNTAINS (ROMANIA)

I. Balintoni, T. Berza

The Apuseni Mountains represent an 150/150 km large outcrop of the Carpathians, separating the Pannonian Basin with large embayments, to the west, from the Transylvanian Depression, to the east; they also include a few smaler intramontane Neogene basins.



1, Laramian Transilvanides; 2, Biharia Nappe system; 3, Codu Nappe system; 4, Bihor Unit; 5, Neogene magmatism; 6, Laramian magmatites; 7, Eocretaceous Magmatites; 8, Magmatites boundary; 9, Laramian overthrust; 10, Pre-Gosau overthrust; 11, Austro overthrust; 12, Transgression; 13 Thrust direction

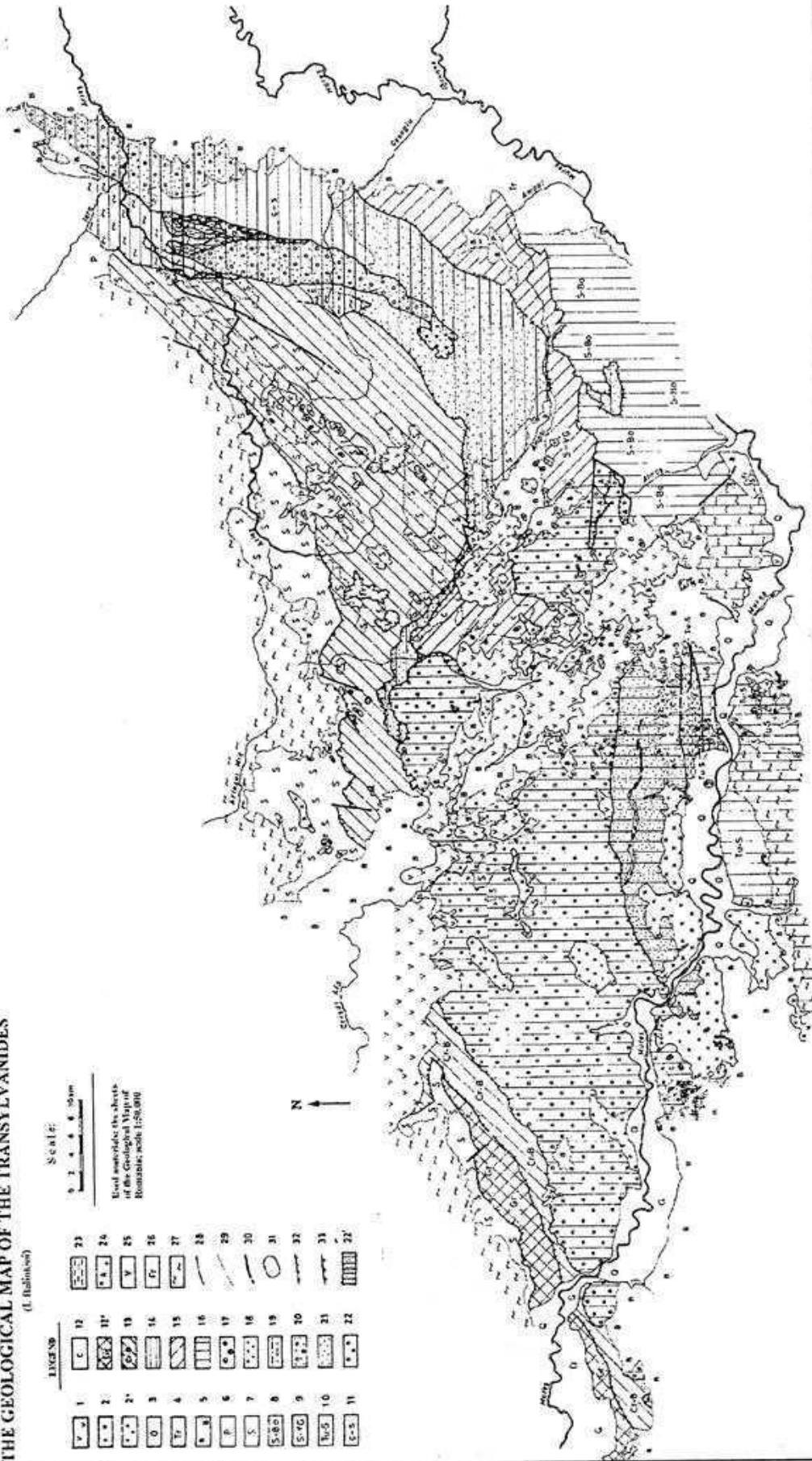
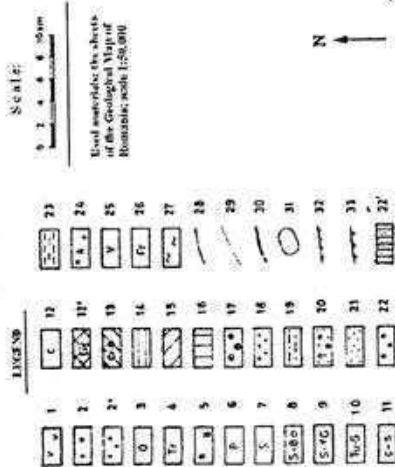
The Crisul Cald and Aries rivers divide the mostly Jurassic-Cretaceous sedimentary and igneous Southern Apuseni from the pre-Alpine metamorphic basements with Permo-Mesozoic covers of the Northern Apuseni. Southwards they are bordered against the South Carpathians by the dextral South Transylvania Fault and northwards by a Paleogene cover, hiding a complex Fault System against the East Carpathians. Northern Apuseni (or Internal Dacides – so named by Sandulescu) were correlated with Western Carpathians of Slovakia and Eastern Alps of Austria, while Southern Apuseni (or Transylvanides – following Sandulescu) were correlated southwestwards with the Vardar-Axios belt. The present-day geometry is with Transylvanides on top of Internal Dacides, and the common interpretation is of the Mid Cretaceous obduction of a (mostly) oceanic domain over a continental one, named Austro-Bihor Block or Pre-Apulian Craton.

Northern Apuseni are built of: Bihor Unit (basement and cover), Codru Nappe (predominantly cover) System and Biharia Nappe (especially basement) System; since Permian to Early Cretaceous they represented a passive margin (of the Pre-Apulian Craton), involved in shortening during Turonian, the nappe pile being sealed by Gosau-type Senonian deposits. Southern Apuseni are built up of several (up to 16, depending of author) individual nappes with Late Jurassic to Late Cretaceous sedimentary deposits, including turbidites, and Mid Jurassic to Early Cretaceous tholeiitic and calc-alkaline (basic to acid) volcanics and intrusions. Conflicting interpretation of their tectonic setting (mid-oceanic ridge, island arc, back arc) may in fact represent a time dependent evolution, from spreading to subduction in an active continental margin, up to nappe stacking during Mid Cretaceous and Late Senonian.

Both North and Southern Apuseni include Maestrichtian volcanic and plutonic calc-alkaline rocks of the Banatitic Belt province, running across tectonic borders southwards to South Carpathians and Balkans. Following a 90° Tertiary clockwise rotation of the whole Tisia-Getia block (including the Apuseni Mountains), Neogene NE-SW extension generated intramontane basins with extensive calc-alkaline volcanism.

THE GEOLOGICAL MAP OF THE TRANSYLVANIDES

(1:1,000,000)



Legend of Plate

- 1, Neogene magmatites; 2, Banatic magmatites; 3, Quaternary; 4, Tertiary deposits; 5, Badenian and younger sedimentary; 6, Palaeocene; 7, Senonian; 8, Senonian, Bozcs strata; 9, Senonian (Ramet strata); 10, Laramian tectonic units; 11, Cenomanian - Senonian; 12, Curciu-Stanija Nappe; 13, Cris-Bucium Nappe; 14, Metaliferi Mts. Nappe; 15, Curescu-Stanija Nappe; 16, Mures Nappe; 17, Vulcan Nappe; 18, Frasin Nappe; 19, Izvoarele Nappe; 20, Valca Muntelui Nappe; 21, Fenes Nappe; 22, Capalna-Techeru Nappe; 23, Cabesti Nappe; 24, Ardeu Unit; 25, Quaternary boundary; 26, Transgression; 27, Fault; 28, Magmatite boundary; 29, Laramian overthrust; 30, Austrie overthrust

THE MESOZOIC MAGMATITES COMPLEX AND THE ASSOCIATED METALOGENESIS OF THE SOUTH APUSENI MTS.

G. Cioflica, M. Lupulescu, S. Udubasa

The Mesozoic magmatites complex of the South Apuseni Mountains developed between Turda and Patars, is ca. 200 km long and ca. 40 km wide; its thickness was appreciated to ca. 3,000 m. The characteristic feature of this complex is its linear aspect (NNE-SSW) with a slight arching in the Zlatna area. The Mesozoic magmatites complex is located between the crystalline schists of the North Apuseni and of the South Carpathians.

The main piles of the Mesozoic magmatites consists of basaltic and andesitic rocks associated with acid differentiation products and with products with an alkaline tendency. The basalt flows contain small gabbro and gabbro-peridotite intrusions, in most of the cases with "schlieren" differentiates.

THE MESOZOIC MAGMATITE COMPLEX

The following subdivisions have been recognized in the Mesozoic magmatite complex: the tholeiitic series, the calc-alkaline series and the alkaline tendency series in an island arc structure; the above-mentioned subdivisions are extremely characteristic of the island arcs (Wilson, 1991). The tholeiitic rocks of the Cris Marginal Basin (Lupu, 1991) should also be added to them.

The tholeiitic series has a lower geometric position compared to the rocks of the calc-alkaline series and shows gradual transitions to the rocks of this latter series. The rocks of the tholeiitic series consist of tholeiitic basalts flows, often in pillow lava facies, with frequent transitions to anamesites and dolerites; locally variolite and tachilite appear as intercalations in the basalt flows. Ophitic, subophitic, intergranular and amigdaloid structures frequent and very characteristic.

The basalt flow pile was intruded by gabbro and subordinately gabbro-peridotite bodies, with a long axis up to 4 km. These intrusions generate hornfels in basaltic rocks, being controlled as space distribution by fault systems with a NE-SW trend. The main gabbro and gabbro-peridotite intrusions are the following:

- the Cazanesti-Ciungani layered intrusive differentiated in "schlieren" consisting of the diopside gabbro horizon in the upper part of the intrusion, the magnetite gabbro horizon, the prevalent doleritic level and the marginal microgabbro facies (Figs. 1 and 2);
- the Almas-Saliste gabbro dyke consists of an upper gabbro zone with transitions to anorthosites and a lower zone with a rhythmic layering, consisting of magnetite gabbro layers which alternate with hyperites, gabbros and dolerites (Fig. 3);
- the Julita intrusion which contains dolerites and gabbros in the lower area with rhythmic layering, as well as gabbros, hyperites, olivine gabbros and diorite gabbros in the upper zone;
- the Bunesti intrusion mostly consisting of diopside gabbros associated with magnetite gabbro layers, olivine gabbros and diorite gabbros;
- the Almasel, Cuiasi, Dumbravita and Baia intrusions have a polystadial character;
- the gabbro-peridotite intrusions are known at Rosia Noua, Corbesti and Almas-Saliste and consist of peridotites, partly serpentinitised in the lower zone, melagabbros and troctolites in the intermediate zone and olivine gabbros in the upper zone. The isotopic data indicated for the tholeiitic rock assemblages an age of 180 Ma, which might represent the Middle Jurassic (Herz et al., 1974). The radiolarite jaspers of the Gomilelor Valley in the western part of the South Apuseni Mts. would suggest a Callovian age.

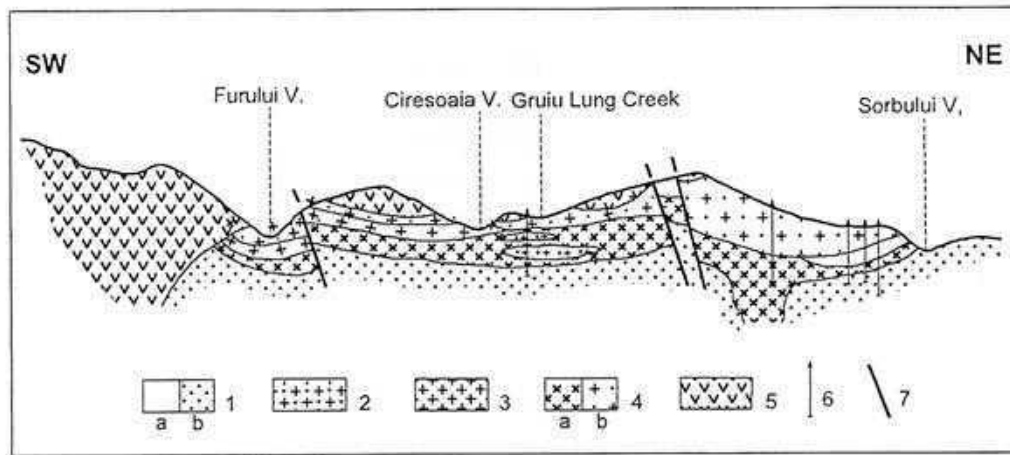


Fig. 1. Longitudinal section through the Cazanesti-Ciungani intrusion (according to Cioflica, Nicolae, 1981). 1, magnetite gabbro horizon; 4, dolerite prevailing horizon; a, dolerite, norite, olivine, gabbro, augite gabbro; b, magnetite, gabbro; 5, Eocretaceous igneous rocks; 6, drilling; 7, fault.

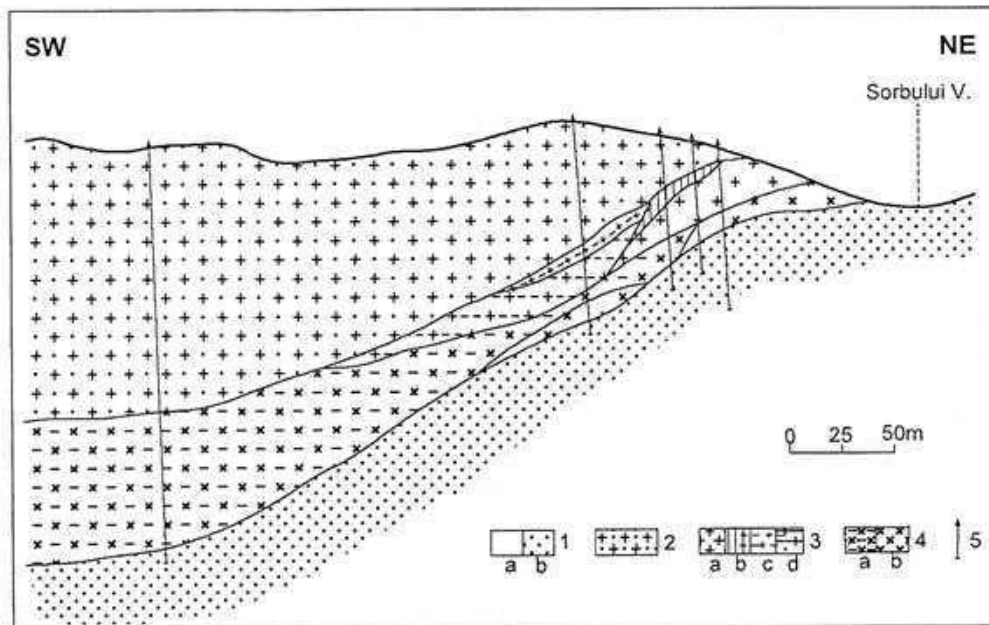


Fig. 2. Section through the north-eastern part of the Cazanesti-Ciungani intrusion (according to Cioflica, Nicolae, 1981) 1, Basalts of the tholeiitic series; a, basalts; b, hornfelsed basalts; 2, diopside gabbro horizon; 3a, magnetite hyperite; 3b, hyperite; 3c, magnetite gabbro; 3d, augite gabbro; 4, dolerite prevailing horizon; a, dolerite; b, olivine gabbro, troctolite, augite gabbro; 5, drilling.

The calc-alkaline series. The rocks of the calc-alkaline series are Upper Jurassic-Neocomian in age and represent the transition to the lower, tholeiitic unit. They are largely developed in the central part and especially in the eastern part of the South Apuseni Mts. (Cioflica et al., 1981; Nicolae, 1985); in the western part of the South Apuseni Mts., i.e. in the Troas-Parnesti region, these vulcanites have a smaller but significant extension.

Various rock differentiates do exist in the calc-alkaline series, and start from basic to acid terms, locally with intense alkaline metasomatism phenomena. Some of the various petrographic types are the following: basalts, spilites, basaltic andesites, andesites, albitized andesites, dacites, rhyodacites, rhyolites and keratophyres. The andesitic rocks and the acid differentiates build up important lava and pyroclasts piles associated with jaspers; the large abundance of rocks of the calc-alkaline series is a characteristic of island arcs (Baker, 1973, from Wilson, 1991).

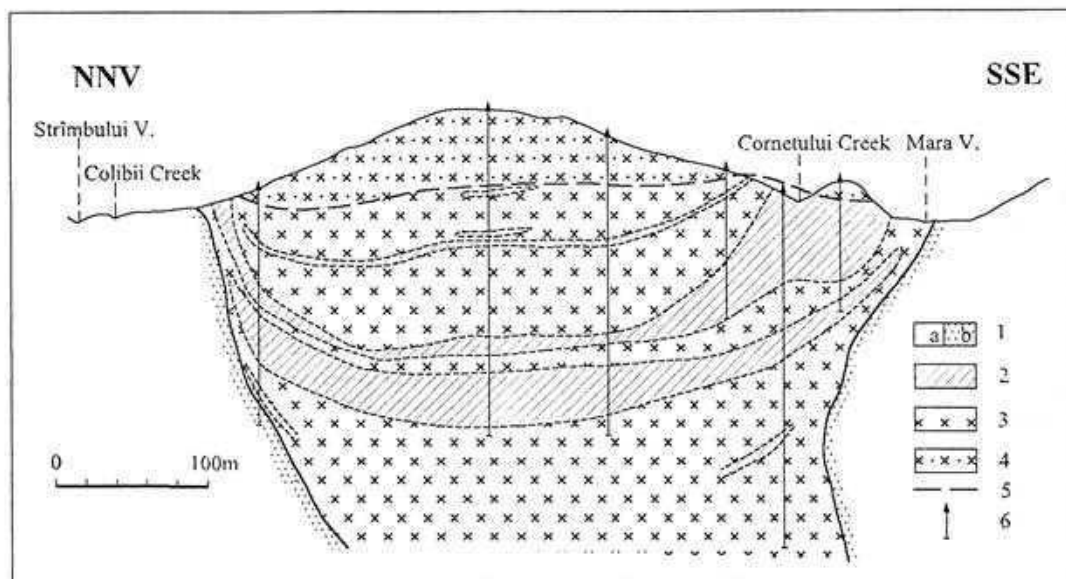


Fig. 3 Geological section through the Almas-Saliste intrusion (according to Cioflica, Savu, 1963).

1, basalts of the tholeiitic series (a) and hornfelsed basalts (b); 2, magnetite gabbro, magnetite hyperite, hyperrite, dolerite, olivine gabbro rocks from the rhythmically layered zone; 3, gabbro from the rhythmically layered zone; 4, gabbro and anorthosite rocks from the upper zone; 5, boundary between the upper zone and the rhythmically layered zone; 6, drilling.

The volcanic products can be grouped as follows (Cioflica et al., 1981): the basalt complex which covers the rock assemblages of the tholeiitic series; the lower andesites complex in which albitized andesites spatially dominate; the dacites and rhyolites complex which includes hypabyssal and subvolcanic intrusions; the upper andesites complex and the tuffs complex with Radiolaria.

In the last years some intrusions which in the past had been considered banatitic (Upper Cretaceous) are now reconsidered as regards their age. This is the case of the Cerbia and Cazanesti intrusions which at present are considered as being Eocretaceous in age (Stefan, 1986). At the same time, an age of 153.1 ± 0.6 Ma (Kimmeridgian) was determined for the Savarsin intrusion (Pana et al., 1999, in press).

The value of the $\text{Sr}^{87}/\text{Sr}^{86}$ ratio for the volcanic rocks of the calc-alkaline series varies between 0.7041 and 0.7043 (Herz et al., 1974). The porphyric structure is characteristic of the volcanic products of the calc-alkaline series, which forms a contrast with the basaltic rocks of the tholeiitic series. The porphyric basalts and some andesitic rocks can show an amigdaloid texture.

The alkaline series. Is represented by alkaline basalts (limburgites), trahyandesites (oligophyres), trachytes (orthophyres) and porphyric granosyenites. The age of these magmatites might be Neocomian. They build up stratovolcanoes and dykes, which appear in the Troas-Parnesti region in the western part of the South Apuseni Mts. The trachyandesite dykes were also identified in the Cazanesti-Ciungani and Vorta regions, in the central part of the South Apuseni Mts.; in these regions the dykes cross the Cazanesti-Ciungani gabbro intrusion and the intermediate andesites complex of Neocomian age (Cioflica, 1962; Cioflica et al., 1984).

The Cris Marginal Basin. The sedimentation process in the Cris Marginal Basin began during the Callovian. In the Callovian-Tithonian time span a volcano-sedimentary formation with two levels developed, without investigating the rocks of the basement. The lower level consisting of the gray and violaceous clays, calcarenites, violaceous and greenish jaspers, with decimetric or metric intercalations of basaltic lavas and tuffs. The upper level of this formation consists especially of an alternation of calcarenites, calcarenites with sandstones and grey-greenish clays. Violaceous silicolites, locally associated with basalt flows appear especially in the lower part of this level. Except for Tithonian formations, dated on the basis of Radiolaria, one may assume that this level might contain the Neocomian as well and probably even the Barremian (Lupu, 1991).

The characteristics of magmas. From the petrographic data various rock assemblages resulted, thus reflecting the existence of three major magma series: the tholeiitic series, the calc-alkaline series and the alkaline series (Wilson, 1991). We turned to account some published analytical data of major components, , in order to point out some characteristic features of the magma series. For the same purpose we also used the 23 analyses of trace elements (13 from the tholeiitic series and 10 of the calc-alkaline series), carried out by Lupulescu in the Laboratories of the Geology Department of Butterfield Hall, USA.

The tholeiitic character of the rock assemblages from the tholeiitic series (Middle Jurassic) and the calc-alkaline character of the rock assemblages in the calc-alkaline series (Uper Jurassic-Neocomian) result from the AFM diagram (Fig. 4).

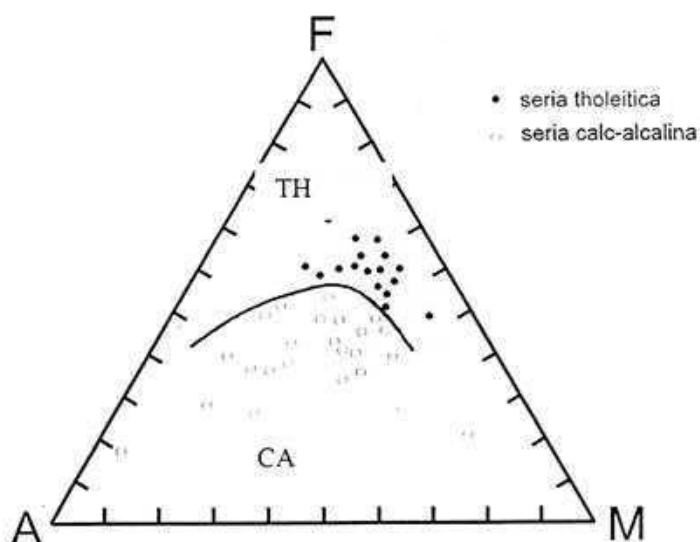


Fig. 4. AFM diagram
CA- calco-alkaline field; TH-tholeiitic field

The magmas corresponding to the rock assemblages of the tholeiitic series are characterized by various oxidation state ($w=0.3-0.8$), which strongly influenced the evolution of the gabbro magma differentiation process, with implications on the orthomagmatic metalogenesis (Cioflica & Savu, 1963). Thus the gabbro magmas, which initially were strongly oxidized, just like those which generated the Cazanesti-Ciungani intrusive with the parameter $w=0.7$, might have determined a gradual Fe-enrichment; finally from the residual magmas gabbro rocks with titanomagnetite could have been formed, rocks which have a somehow residual character (Cioflica, 1962; Cioflica & Nicolae, 1981). On the contrary, the initial gabbro magmas of a low oxidation state, just like those which generated the intrusion of Rosia Noua gabbro-peridotites, had a different evolution, finally leading to Fe-poor products and, therefore, to gabbro rocks lacking titanomagnetite.

In the Th-Hf-Ta discrimination diagram some of the projection points for tholeiitic basalts fall in the D field, characteristic of the destructive plates margins; they do not project in the A and B fields, characteristic of the N-MORB type, and for the E-MORB type and plate interior, respectively (Fig. 5).

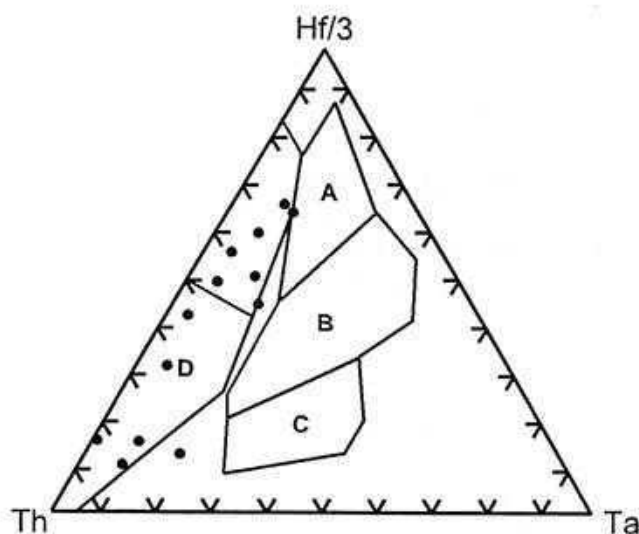
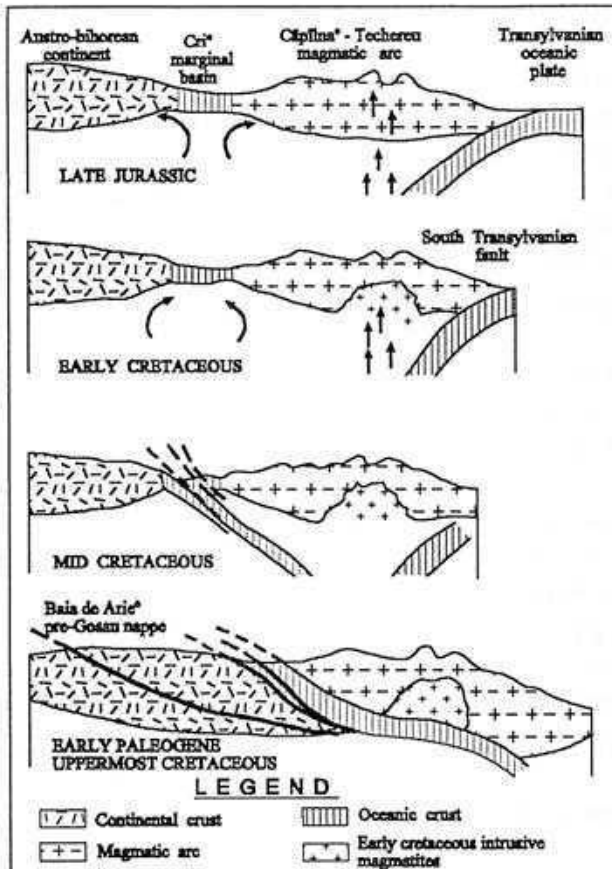


Fig. 5. Th-Hf-Ta diagram (after Wood, 1980)
A) N-type MORB; B) E-type MORB and tholeiitic within plate and differentiates; C) alkaline within plate basalts and differentiates; D) destructive plate margin basalts and differentiates

The REE have been normalized to chondrites and show a large spectrum of aspects. For instance, the tholeiitic basalts become poor in light REE in the island arcs, whereas the calc-alkaline basalts have higher contents of light REE. The slope is more obvious in case of the calc-alkaline differentiates. The small negative Eu anomaly which is present for both series, is compatible with the plagioclase fractionation; a slight positive Eu anomaly. Generally the anomalies are absent and only a positive anomaly seems to exist in the acid differentiates.



The analytic data indicate also relatively high Sr, Rb, Ba, Th and light REE contents, which is characteristic of island arcs. The $\text{Sr}^{87}/\text{Sr}^{86}$ ratio in the rocks of the tholeiitic series is of 0.7032 and varies in the calc-alkaline series between 0.7041 and 0.7043 (Herz et al.), which overlaps with the characteristic magma values of the island arcs, namely 0.703-0.704 (Gill, 1981). According to the field data and the laboratory studies, Lupu (1991) draw up a schematic model of dynamic evolution of the SW part of the South Apuseni Mts. (Fig. 6), which confirms the tectonic framework under which the Mesozoic magmatism and, of course, the associated metallogenesis occurred (Cioflica, Nicolae, 1980 a, Cioflica et al., 1980 b).

Fig. 6. Sketch model of the dynamic evolution of the south-west part of the South Apuseni Mountains (after Lupu, 1991)

THE METALLOGENESIS

Two groups of metallogenetic products are known in genetic connection with the Mesozoic magmatism: a) the metallogenesis associated to tholeiitic magmatites; b) the metallogenesis associated to calc-alkaline magmatites.

The metallogenesis associated to tholeiitic magmatites

In the genetic relations with magmatites of tholeiitic basic rocks there are also orthomagmatic Fe-Ti-V (titanomagnetite) and Ni-concentrations (Ni-pyrrhotite). The most important orthomagmatic Fe-Ti-V-concentrations are present at Cazanesti-Ciungani and Almas Saliste (Giusca, Cioflica, 1956, 1957; Cioflica, Savu, 1963, Cioflica et al., 1981).

The Cazanesti-Ciungani gabbro intrusion (Fig. 1) shows an obvious schlieren differentiation and contains titanomagnetite and illmenite disseminations and nests in the prevailing doleritic (6-10 %) and gabbro-magnetite horizons (9-16%). The exsolution structures are characteristic of metal parageneses and are represented by ulvospinel and illmenite lamelles in titanomagnetite and by hematite lamelles in illmenite (Cioflica, 1962). In the oxidation zone, the titanomagnetite was replaced by hematite and rutile. The xenomorphic character of the titanomagnetite and the illmenite, as well as their location in

interstices of earlier crystallized silicates represents information for a hysteronmagmatic metallogenesis.

The Almas Saliste intrusion (Fig. 3) contains titanomagnetite up to 12 % and illmenite up to 1.2 % in the dolerite and magnetite gabbro layers of the rhythmic stratification dyke.

The Ni-concentrations (Ni-pyrrotite) are mentioned in the tholeiitic basalts pile, in genetic connection with a mafic magmatites body; they are located in the Serboaia Valley of Ciungani and have a low significance. Extremely characteristic is the pyrrhotite, pentlandite, magnetite and chalcopyrite association; the quartz accompanies the deposition of bravoite, pyrite and hematite, partly transformed into magnetite (Petrulian, 1943, Cioflica, 1984 - unpublished data).

The Cu-pyrite concentrations have a hydrothermal character and they are vein-like. They have been investigated by Ivascanu and appear at Cazanesti, Almasel, Rosia Noua and Ciungani. The veins are located in basalt flows, especially near gabbro intrusions, with which they are in genetic relations. The veins consist of pyrite, pyrrhotite, magnetite, hematite, chalcocite, and covellite in a quartz, carbonate, chlorite and illite gangue.

Udubasa et al. (1981) also mentioned the presence of rutile, leucoxene and titanite in the Cazanesti veins. In the tholeiitic basalt flows at Almasel, some veins with polymetallic mineralizations appear and galena is abundant enough.

Beside hydrothermal veins some stockworks, such as those of Patars and Rosia Noua (Hamuleasa Valley), characterised by small veins and impregnations in the pillow-lava mass are also known. The pyrite, chalcopyrite and magnetite association are characteristic.

The metallogenesis associated to calc-alkaline magmatites*

Associated with rock intrusions of intermediate compositions are the Zn-Pb-Cu ore deposit at Vorta in the central part of the North Apuseni Mts., the Mo ores at Savarsin and Cerbia, as well as the submarine volcanogenic Mn-mineralization from Soimus-Buceava and Parnesti in the western part of the South Apuseni Mts., as well as at Godinesti in the central part of the South Apuseni Mts.

The genesis of the Vorta Zn-Pb-Cu(Au) deposit is controversial. Udubasa et al. (1978, unpublished report) defined it as a typical Kuroko-type deposit related to a bimodal (basalts and dacites) volcanism. The deposit shows two distinct ore assemblages, i.e.

(1) massive sulphides, strongly dismembered, with an elipsoidal fabric which varies in size from cm to several tens of "mugle" and are enveloped in a partly brecciated, intensively altered pile of basalts. The ore consist of intimately intergrown common sulfides with some gold (Vorta 1 ore type);

(2) stringers and veinlets with pyrite and chalcopyrite, cutting across both de Vorta-1 ore type and the silicified dacite dome (Vorta-2 ore type).

Cioflica et al. (1984) advocated the hydrothermal affiliation of the deposit, formed in relation to subvolcanic dacites of Eocretaceous age. Further on, Ciobanu et al. (this volume) agree a volcanogenic origin of the deposit, formed in relation to alkali, analcime basalts. However the alkaline overprint of the tholeiitic basalts is a secondary feature.

The volcanogenic Mn concentrations are less important and appear as lens-shaped intercalations in the Lower Cretaceous sedimentary deposits being intimately associated with jaspers; we consider that Mn was mobilized from the basalt pile. The characteristic paragenesis includes psilomelane and pyrolusite, associated with quartz, calcite, rhodochrosite and Fe-oxides; the Mn ore area contains Radiolaria and Spongia spicule remnants. (Papiu, 1956; Savu, 1972).

* Amended by the editor

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THE LARAMIC ("BANATITIC") MAGMATISM IN ROMANIA

Doina Russo-Sandulescu

The "banatitic" magmatism as defined by B.v. Cotta early in 1864, now known to include Upper Cretaceous-Lower Paleogene igneous rocks in Apuseni Mts and Banat was quite well investigated during the time. Extensive petrographic, geochemical, geochronologic and geophysics were carried out in the last time together with detailed studies on associated ore deposits. The "banatites" still represent a very attractive target, especially as regards their position in relation to the plate tectonics. Whatever the interpretation of the data would be, the existence of two distinct areas of banatite development is beyond the doubt.

I. The calc-alkaline magmatites of the Apuseni Mountains, more widespread in the northern part comprise two volcanic cycles (Stefan et al., 1992). The first volcanic cycle generated andesites, dacites and rhyolites. The last ones cover an area of about 400 km² and show a remarkable development of ignimbritic facies, especially in the Vladeasa volcano-plutonic massif, called taphrolite by Giusca (1950). Small intrusion and dykes occur in the Gilau and Mezes Mts.

The first cycle volcanics overlie the Upper-Coniacian-Lower Maastrichtian sedimentary formations and appear intruded or included in dacites and rhyolites. The K-Ar age of 61±3Ma and 61.5±5Ma confirms the stratigraphic relationships.

The second cycle consists of intrusions dioritic, quartzdiorites, quartzmonzodiorites and their porphyry counterparts, as well as of granodiorites and porphyry granites- forming veins, dykes and apophyses of a great magmatic body situated at depth. The vein-and dyke-forming rocks cut both the Lower Maastrichtian sedimentary formations and the first cycle volcanics.

In the Apuseni Mts the calc-alkaline arc magmatism forms small intrusions consisting of monzodiorites, diorite-granodiorites and granodiorite-granites.

In the western part of the South Carpathians the banatitic arc magmatism gave rise to the volcano-sedimentary formation in the Poiana Rusca Mts. However, more specific arc several intrusions which cut both the Supraetic Nappes (partly Mid-Cretaceous, reworked in the Laramian phase) and the Getic-Nappe (started in Mid-Cretaceous and finished during the Laramian phase).

In the Poiana Rusca Mts. the volcano-sedimentary formation overlies unconformably the Lower Cretaceous Flysch formation, its upper part Maastrichtian (Krautner, 1984). The intrusive event in the same area consists of microdiorites, andesites, granodiorites and granites) and they cut the lower part of the volcano-sedimentary formation. The K-Ar ages are of 70-80 Ma (Krautner, 1986; Strutinski, et al., 1986).

The intrusive banatites are best represented in the area southwards of Timis Valley. They form a plutonic and a hypabissic zone, in the West and East respectively. The isotopic ages show a large time interval (Coniacian-Paleocene) with a maximum at 75-65 Ma in the plutonic zone (zircon age is of 79 Ma, Nicolescu, 1999) and 62-52 Ma in the eastern, hypabissal zone.

The plutonic rocks in West Banat give significant magnetic anomalies (Andrei et al., 1989), delineating the following plutons: Surduc-Bocsa-Gavojdia, Ocna de Fier-Dognecea, Oravita-Ciclova and Sasca-Moldova Noua.

In the eastern zone the outcropping intrusions have small sizes but the geophysical data suggest hidden plutons to exist at the depth.

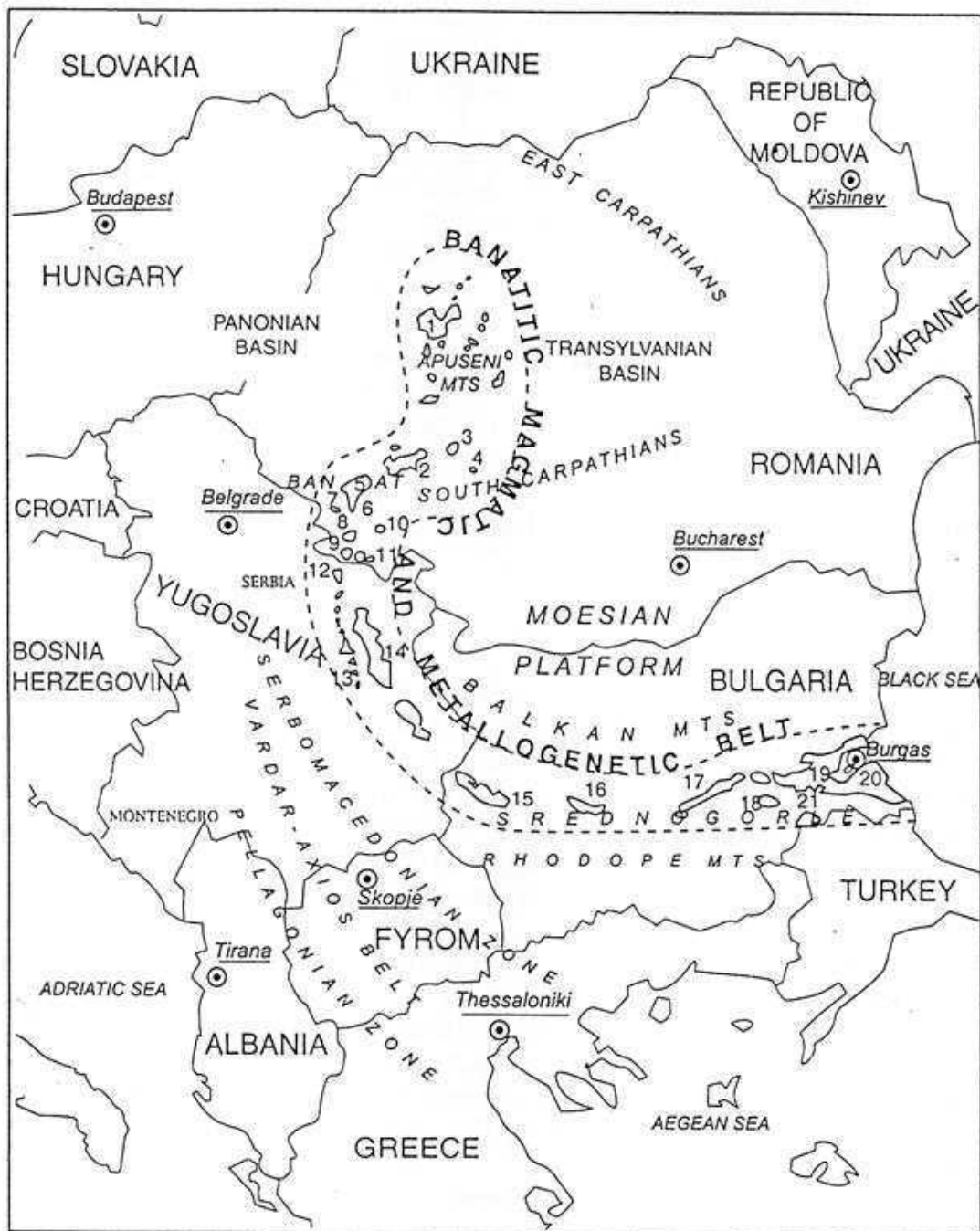


Fig. 1 Banatitic magmatic and metallogenetic belt in south east Europe.

1 Vlădeasa volcano-plutonic complex, 2 Rusca Montană volcano-sedimentary basin, 3 Demsuş volcano-sedimentary basin, 4 Baru Mare intrusions, 5 Bocşa composite pluton, 6 Ocna de Fier apophysis, 7 Surduc pluton, 8 Oraviţa intrusions, 9 Sasca-Moldova Nouă intrusions, 10 Lapuşnicel-Teregova area of dykes, 11 Lileci-Purcariu area of dykes, 12 Ridanj intrusions, 13 Krepoljin intrusions, 14 Timok volcano-plutonic complex, 15 West Srednogorie sector (Vitoshka), 16 Central Srednogorie Sector (Panagyurishte), 17 Jambol volcanics, 18 Manastir intrusions, 19 Bakadjik volcanics, 20 Burgas volcano-plutonic complex, 21 Zeljaskovo intrusive.

The polyphasic plutons at Surduc, Bocsa and Gavojdia have several specific features such as nodules of cumulates in gabbros, suggesting fractional crystallization in a mantle-derived magma, slightly modified by assimilation processes. The ^{87}Sr - ^{86}Sr ratio is of 0.7048 to 0.7061 in the rocks of the Surduc massif.

In conclusion, the two major development areas of banatites in Romania, i.e. the Apuseni Mts and the western South Carpathians (Poiana Rusca and Banat) show distinctive features as concerns geochemistry, petrography and age relations.

This is related to their derivation from two different oceanic crust consumption zones (Radulescu, Sandulescu, 1973; Sandulescu, 1984). The Apuseni Mts banatites derived subduction of the Tethysian oceanic crust under the continental crust of the North Apuseni Mts. Remnants of the oceanic crust are largely developed in the South Apuseni Mts.

The proper banatitic magmatic arc (Banat-Eastern Serbia) was generated by consumption of the oceanic-like crust from the intracontinental rift, producing the Ceahlau-Severin Units.

ORE DEPOSITS RELATED TO THE LARAMIC ("BANATITIC") MAGMATISM IN ROMANIA

Gheorghe Udubasa

The Upper Cretaceous ore-bearing magmatic belt in South East Europe extends from Romania to Yugoslavia and Bulgaria over about 700 km, with a maximum width of 70 km, called BMMB (Banatitic Magmatic and Metallogenetic Belt) by Berza et al., (1998). The tectonic setting and the origin of the dominant granodioritic-granitic trend (Apuseni, N Banat), with a subordinate monzodioritic-dioritic trend (S APuseni, S Banat) are still controversial (or evolutive), involving either a westwards subduction or magma generation in extensional regime. Corresponding to the different trends, the ore deposits show also significant differences along the belts, as reviewed by Berza et al. (1998).

The long-time lasting mining activity, partly dating back to the pre-Roman time, produced many information about the ore Deposits, especially in Banat. It was Bernhardt von Cotta who in 1867 first described the pyrometamorphic (skarn) Deposits in Banat and Serbia. Skarn and ore zoning, minerals having the type locality in Banat (ludwigite, sfalibelyite etc) or in the Apuseni Mts. (paderaitite, makovikyte, etc), coeval or spatially associated skarn and porphyry copper systems (e.g. Moldova Noua) are among the most significant features of the banatitic metallogeny in Romania.

Along with the Neogene ore province, the banatitic-related ore deposits have a nearly similar rank of contribution to the total resources estimates of Romania, i.e. about 20%. The geochemical signature of the ores is very large and includes both Fe and polymetallic ores, mostly related to skarns, as well as porphyry copper systems, exclusively confined to the southern part of the area, i.e. Banat.

Two different units have been recognized within the banatitic province of Romania.

1) The Apuseni Mts. unit, with dominant polymetallic ores, both skarn-related and vein.

An asymmetrical regional zoning has been depicted, centered on the Bihor pluton and on the proximal (and the most important) ore district, i.e. Baita Bihor (Fig. 1)

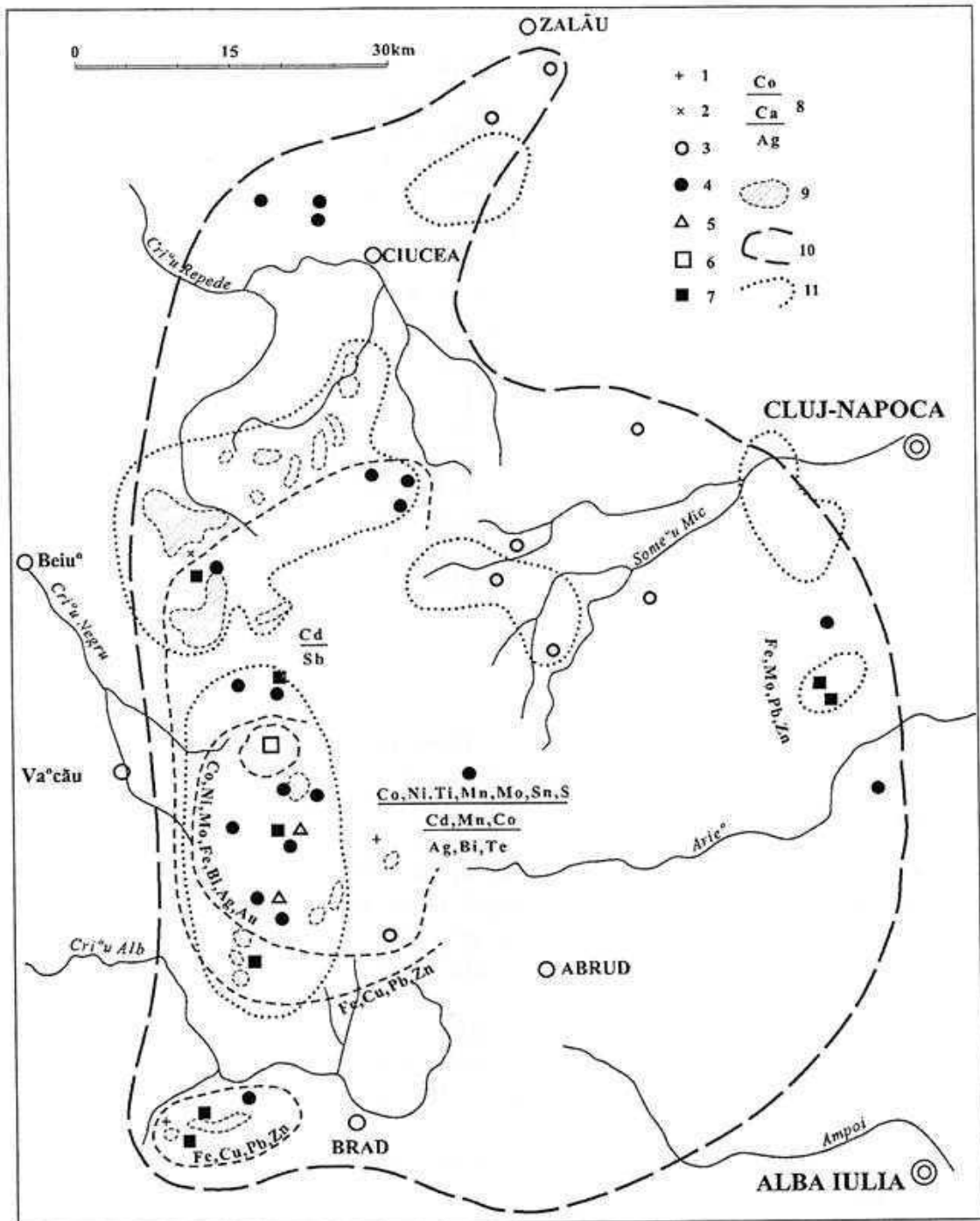


Fig. Regional distribution of the mineralization types in the Apuseni Mountains.

1, baritine occurrences; 2, brucite occurrences; 3, pyrite occurrences without gold; 4, polymetallic occurrences (Cu, Pb, Zn); 5, occurrences with Co, Ni, As, Bi, Ag, ore; 6, Bi, Mo, W, B, Cu, Pb, Zn occurrences; 7, Fe±Cu occurrences; 8, minor elements characteristic (downwards) in pyrite, sphalerite, galena; 9, outcrop areas of holocrystalline-equigranular rocks; 10, zones contours; 11, geophysical anomalies. (after Stefan et al., 1988).

2) The Banat-Poiana Rusca, with both polymetallic and copper-dominated ores, porphyry copper-molybdenum included. Here a transversal zoning and the Cu-Pb line have been assigned to an Andean subduction type metallogeny (Borcos and Vlad, 1994).

The South Apuseni area within the banatitic-related province is relatively lesser significant; the Upper Cretaceous-Lower Paleogene magmatites sparsely develop here and only minor deposits are known. However, the high temperature skarns at Magureaua Vatei are worth mentioning.

The banatitic-related ore deposition is either due to a direct magmatic affiliation, e.g. porphyry copper + molybdenum systems or to the interaction with the host rocks, mostly limestones, giving up huge amounts of skarns and hornfelses extended over hundred of meters. Nevertheless, reworking of older arc bodies or protores is obvious in some places, adding some, "alien" metals such as U (Baita Bihor, Avram Iancu) to the common metals (Cu, Fe, Bi, W, Mo, Pb, Zn, B) of the pure banatitic "line". There are also large areas with small magmatic bodies which seems to be devoid of any metallic charge, e.g. South Bihor Mts.

Of banatitic affiliation or of older or younger age, such relatively small magmatic bodies prove that the early magmatism and the associated postmagmatic processes prepared the area situated in the Metaliferi Mts. for the most (extensive (and last) magmatic event, the Neogene one.

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NEOGENE MAGMATISM IN THE APUSENI MOUNTAINS, ROMANIA. EVOLUTION AND GEOCHEMICAL FEATURES

E. Rosu

Geological settings

The Neogene-Quaternary volcanic activity in the Apuseni Mountains took place in three tectonic units: Internal Dacides (in Northern Apuseni Mountains), Transylvanides (in Southern Apuseni Mountains) and Median Dacides (in the southernmost part of the studied area).

The main tectonic structure of the actual Apuseni Mountains was established during the Laramic phase, after which a molasse formation of Maastrichtian-Paleocene age was deposited. It is composed of polymictic conglomerates, sandstones and red shales with alluvial origin, sometimes interbedded with andesites and rhyodacites. This formation was formerly considered of "Tortonian" age (Ghitulescu & Socolescu 1941) and the volcanic rocks were attributed to the first cycle of the Neogene volcanism (Radulescu & Borcos 1967; Ianovici et al. 1976). Using K - Ar dating on andesites and rhyodacites (Lemne et al. 1983) and new geological data, the age was proved to be Maastrichtian-Paleocene (Borcos et al. 1989). In the Hartagani area, the rhyolites - also thought to belong to the first cycle of Neogene volcanism, show a Lower Cretaceous age (124 Ma, Rosu et al., 1997).

Between the Maastrichtian - Paleocene molasse deposits and the Miocene ones, there is an important sedimentation gap, due the tectonic uplift of the whole area. During Eocene-Early Miocene times, the Tisia block experienced a 20° clockwise rotation at the same time as the North Pannonian Block underwent counterclockwise rotation. The Apuseni Mts. underwent a further 60° clockwise rotation after cessation of the counterclockwise rotation of the North Pannonian Block. This rotation started around 14 Ma, diminished at 13 Ma to around 28° and ceased at around 12 Ma (Panaiotu in Roşu et al., 1998, 2000; Panaiotu, 1998, Panaiotu, 1999).

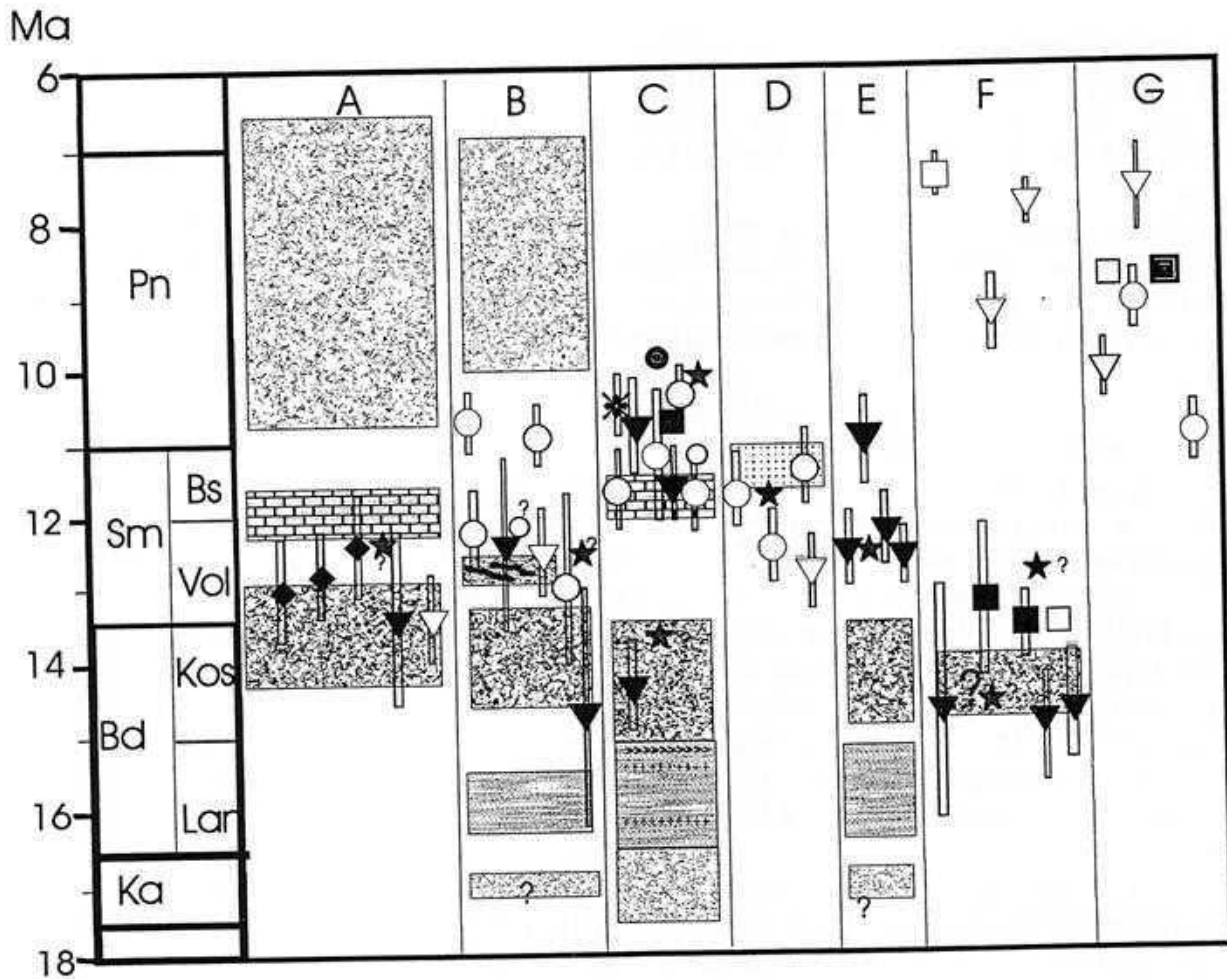
The main tectonic feature was block faulting, associated with extension and a strike-slip regime in the Carpatho-Pannonian realm. This regime has created small intramontane basins with temporally independent sedimentologic evolution. In connection with these basins and surrounding areas, a dispersed Neogene volcanic activity took place (Rosu et al 1997). The spatial occurrence of the outcrops reveals a more complicated pattern. Most are distributed along a WNW-ESE trend, roughly between Minis in the west and Zlatna in the east, in a ca. 100-km long area. Many of the igneous rocks in the eastern half of the area apparently follow a NNE-SSW trend, ca. 60 km long, between Baia de Aries in the north and Deva in the south.

Age and time-space evolution

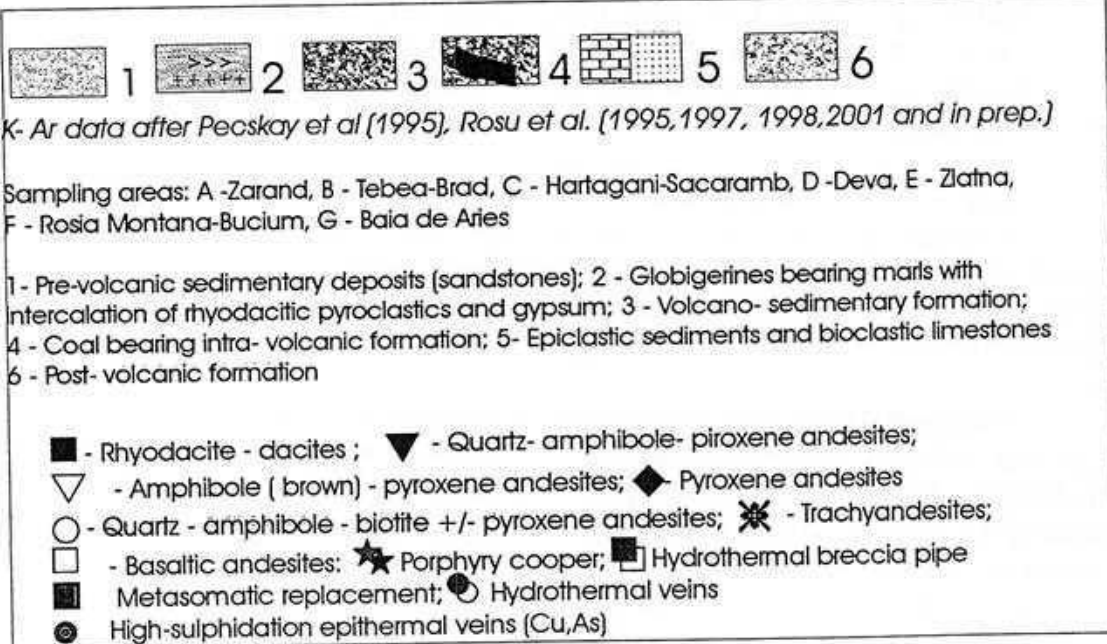
Neogene magmatic rocks in the Apuseni Mts. range in age from 14.8 to 7.4 Ma, except for the southeasternmost occurrence (Uroiş), which is 1.6 Ma old (Pecskay et al., 1995; Roşu et al., 1995, 1997, 2000, 2001). Our composition range from basalt-andesite to dacites, prevailing andesites with various mineralogical composition; some alkaline species also occur.

The general time-space evolution of volcanism is presented in Plates 1. The first volcanic products are represented by dacite tuffs, poorly developed, hosted by Globigerine bearing marls (Langhian). The main episode, represented by calc-alkaline medium to high-K quartz andesites with amphibole, pyroxene ± biotite to dacite, has beginning around 15 Ma with an explosive character giving a widespread volcano-sedimentary formation, interbedded with Spiralis bearing marls. Two intrusive activities events, forming complex volcano-plutonic structures with high-density necks and intrusive

Evolution of the Neogene volcanism in the South Apuseni M-ts based on K-Ar data and their stratigraphic confinement. Estimative age of mineralization



Legend



bodies, are distinguished by corroboration of K-Ar, paleomagnetic data and spatial distribution. First ones, calc-alkaline medium- K quartz andesites with amphibole, pyroxene $\pm$ biotite, spatially developed in Zarand-Brad-Bolcana-Zlatna-Rosia Montana-Bucium area, run between 14.7 – 11 Ma, showing a progressive clockwise rotation (60° at 14 Ma to 28° at 13 Ma, see above same data). The second one, represented by calc-alkaline medium to high- K quartz andesites with amphiboles, biotite $\pm$ pyroxene, developed between 12.6 – 7.4 Ma, without paleomagnetic rotation, display an enlarged area to Deva - Sacaramb and Baia de Aries – Rosia Montana. Small bodies (10.5 Ma) with alkaline features (trachyandesites, microdiorites) and basaltic andesites (7.4 Ma), bearing an asthenospheric geochemical signature, are the latest products for respective areas. The last episode display an alkaline character and occur only in Uroi Hill (1.6 Ma), after a gap about 6 Ma, on different geostuctural context.

Geochemistry and isotope data

Two series can be distinguished based on geochemical data: *low-Sr andesite* (oldest ones), showing a "normal calc-alkaline" features for first and second series, younger, (successive and overlap in time) *high-Sr andesite*, enrichment on Sr, Ba, light REE, alkali (which is adakite-like features rocks), exception for young products developed on first stage structures (12 to 11 Ma). Mg#, Nb increase and $^{87}\text{Sr}/^{86}\text{Sr}$ decrease with age and suggest increasing of mantle component contribution. (Roşu et al., 2000, 2001). *High-Sr andesites* occur in Deva - Sacaramb - Cetras area (in the south) and in Roşia Montana-Baia de Aries in the NNE. This specific geochemical characteristic links part of the Apuseni Mountains magmatism with a particular association, i.e. the adakite-like rocks of Defant and Drummond (1990). The term "adakite" was defined as an intermediate to acid calc-alkaline rock characterized by high Al_2O_3 and Sr, low Y and HREE, and MORB-like Sr and Nd isotopic signature. Many of the younger calc-alkaline rocks and all the alkaline rocks of the Apuseni Mts. plot at the edge of the adakite field as defined by Defant and Drummond (1990) (Fig. 7, Rosu et al 2001)

Peculiarity of magmatism, Discussions

Regarding magmatism genesis the available (major and minor elements, trace elements, Sr isotopes) data permit some discussions. Despite the calc-alkaline character and obvious trace elements subduction signature, the available isotopic data, regional geological and geotectonic frame (without any evidence for contemporaneous subduction) reclaim a non-subduction-related magmatism. A possible scenario, in accord with geotectonic, paleomagnetic and Sr isotopes ratio, involve a transtensional tectonic regime directed by contemporaneous eastward translation and clockwise rotation of Tisia-Getia terrane, in area of South Apuseni Mts., on a relatively thin lithosphere.

Expression of this are deep-seated transtensional fault systems which generate small pull-apart aligned basins, graben like, which represent structural control for magma uprising. Those activate, by adiabatic decompression, partial melting processes on a subcontinental mantle, affected by metasomatic process related to an earlier subduction events (Rosu et al., 2000, 2001) similar to these described by Hooper et al., 1995 and Hawkesworth et al., 1995.

165-048

The evolution trend from normal to adakite-like calc-alkaline magmas is largely variable in time and space. Acceleration of the extensional regime than favored asthenospheric upraise at the base of the lithosphere and as a consequence an increase in temperature, which created the necessary conditions for further adakite-like magma generation (fluid-present melting) of a fluid-rich upper lithospheric mantle or lower crust source, but also mixing with asthenosphere-derived melts. This is one way to produce adakite-like magmas, the presence of which according to Defant and Drummond (1990) and Martin (1999) suggests derivation from high-pressure partial melting of either subducted oceanic crust or underplated basic material. The rotations took place between 14 Ma and 12 Ma, facilitating the necessary pathway for emplacement of normal calc-alkaline and then adakite-like calc-alkaline and alkaline magmas after the ending of clockwise rotation. After ~12.5 Ma generation of the normal calc-alkaline magmas declined in favor of adakite-like characteristics for both calc-alkaline and alkaline character.

The most important petrogenetic process involved in magma generation in the Apuseni Mts. is probably variable degrees of partial melting of a source, which was isotopically depleted, but rather enriched in incompatible elements. The initial crustal contamination and almost lack of fractional crystallization is rather characteristic for initial slow ascent of the magmas. Further rapid ascent of magmas, was favored by the increasingly extensional regime in which the magmatic province evolved. Although dominantly calc-alkaline (normal to adakite-like), extension-related magmatism in the Apuseni Mts. is associated with minor alkaline magmas (also adakite-like), which occur late in the magmatic sequence, suggesting an asthenospheric source beneath the attenuated lithosphere or a decrease in the degree of melting at the end of extensional processes. (Rosu et al., 2001)

NEOGENE ORE-DEPOSITS FROM SOUTH APUSENI MOUNTAINS, ROMANIA. CONSTRAINS AND EVOLUTION

Rosu E., Nedelcu L., Udubasa G., Pintea I., Ivascanu P. M.

The Neogene ore- deposits of the South Apuseni Mountains are related to "normal" to "adakite-like" calc-alkaline intermediate volcano-plutonic complex structures. Volcanicity had a paroxysmal period ranging between 14.8 - 10 Ma, with a post-emplacement progressive clockwise rotation of the rock with the mean age of 14 to ca.13 Ma, being accompanied by a significant and relative continuous metallogenetic activity (plate 1).

The extensional regime facilitate "passive" emplacement of intrusions in this area offering optimal conditions for generating high density porphyry copper systems. As a consequence a strong specialization for Cu(Au) of whole district has been remarked. The tendency of enrichment in metallic components of these magmas is pointed out from Cu, Au, Ag, Pb and Zn overclark values. Relative small sized porphyry copper bodies showing primary character without or with only local subsequent convective copper enrichment processes, located in volcano-intrusive complex structures, are common. In the most cases the epithermal veins and/or breccias are spatially related to porphyry copper structures, in a peripheral position, giving rise of a complex metallogenetic structure with composite character. On this frame there are also some peculiar trends of magmatic-hydrothermal processes, which are expressed by various

types of ore deposits, as follows: porphyry copper ore deposits, base metals and/or gold breccia pipe and low/ high-sulfidation epithermal ore deposits.

Characteristic is the constant presence of gold, a positive correlation being established for the Cu-Au pair, explained by partition of copper and gold in supercritical magmatic fluids from a crystallizing magma. Sulfide stable isotope show a strong affinity of these ore deposits to magmatic-hydrothermal type, closely associated with magmatic intrusions emplaced at relatively shallow depths. The $\delta^{34}\text{S}$ data support a magmatic origin of fluids that evolved from porphyry copper to breccia pipe and base metal/gold veins suggesting a specific magmatic- hydrothermal evolution line, that involves an immiscibility process from the residual silicate melt and ending via successive boiling episodes (i. e. halite trend solutions) to a dilute aqueous solution state. This suggest the important role played by Cl and S during evolution of magmatic to hydrothermal fluids, as a transport agents of metals. The temperature data from sulfur fractionation, minor elements partition and fluid inclusion studies are in good agreement and range from 400 - >600°C for porphyry to 350-450°C for breccia pipe deposits as well as from 300- 200°C for epithermal deposits.

THE ESTIMATION OF THE FORMATION CONSTRAINTS OF THE MAIN MINERAL DEPOSIT TYPES

E. Rosu, L. Nedelcu, I. Pintea, M.P. Ivascanu, C. Costea, A. Serban, V. Alexe

Metallogenetic consideration

A detailed analysis of each zone shows that not all volcanic/subvolcanic structure simultaneously has been formed and that not all these structures are metallogene. It seems that in time some favorable moments exist for melt "specialization" in the metallogenetic way related to the early evolution of the magma chambers where crystallizing processes develop and when a fluid and metallic iron enrichment is achieve. These will constitute invisible distinct phases in the respective melts where Cl and S play an important role.

Subsequent evolution of metallogenic processes was controlled by the thermodynamic parameters of respective systems (T, P, X, f_{O_2} , f_s , Ph Eh, etc.) that generated the transition from "extraction", "accumulation", "transport" to "depositional" stage.

The porphyry system formation is closely related to favorable geostructural conditions involving a specific evolution of crystallizing processes of the shallow subvolcanic bodies. The supercritical fluids of well-defined composition (mainly K-rich) affect host rock generating potassic silicate (alkali feldspar, biotite, quartz) pervasive zone, and sericit-quartz zone or phyllic zone.

The porphyry mineralization is present as disseminations in the rock mass and especially within the centimetric wide fissures of stockwork type networks. These fissures appear as an effect of the fluid released energy, and of the repeated boiling processes and less as an effect of some tectonic processes.

In this stage, Cl represent the main complexing ligand component argued by the chloride microinclusions hosted in pyrite of the porphyry system (Nedelcu et al., 1998-2000).

The experimental thermodynamic data of mineral assemblages and fluid inclusions suggest that Cu was transported in potassic zone as a hydrochloride complex (CuCl^0). This process took

place under a high temperature range (350° - 700° C), oxidizing conditions (magnetite, hematite, anhydrite, etc) and supersaturated fluids ("hydrothermal brines"). That appear as an effect of high temperature immiscibility (Burnham, Ohmoto, 1980; Hemley al., 1992; Williams et al, 1995). Concerning Au transport in these oxidizing conditions, thermodynamics data indicate complex chlorides of (AuCl_2) type and a transition from these to a more soluble type of $[\text{Au}(\text{HS}_2)]$ disulfides complex during fluid cooling. The transition from chlorides to disulfides takes place into a 350 - 460° C range, depending on pH and $\text{H}_2\text{S}/\text{Cl}$ ratio in original fluids and if the immiscibility is present.

These all point out that transition domain from magmatic to hydrothermal stage achieves by means of porphyry systems, mentioned that no evolution standard scheme for porphyry mineralization does exist.

Despite of insufficient data, an example of an early porphyry copper stage is represented by subvolcanic body crossed by underground works at -120 Spiros level, nearby Valea Morii (Barza) structure. In this place the observation data reveal the following: a) an intense iron metasomatism characteristic for the early mineralizing porphyry type stage represented by metasomathic substitutions as nests and fissures filled up with magnetite, that prove high oxygen fugacities; dominant mineral assemblage being magnetite + plagioclase (albite) + quartz $\pm$ biotite $\pm$ chalcopyrite $\pm$ pyrite that generally corresponds to propylitic and potassic zones; b) abundant presence of magnetite unlike extremely little amounts of chalcopyrite and pyrite; c) a late assemblage represented by quartz, sericite, chlorite, carbonates-Ti oxides (rutile, leucosene) $\pm$ tourmaline, sulfides (pyrite $\pm$ sphalerite, chalcopyrite). At the eastern proximity of intrusive body are located veins 9 and 10, partial accessible at three mining levels (-60, -90, -120). Cd fractionation in sphalerite and galena reveals high temperatures over 350° C, according to that of morphologic trends of pyrite and implicitly of suprasaturation - temperature (S-T) domains of the hydrothermal fluids.

The mineral microinclusions, but especially chlorides also support the hydrothermal solution supersaturated character, and the low values of the sulphur isotopes suggest that at the lower levels of veins (between -120 and - 90 mining levels) the juvenile fluids maintained approximately initial composition.

The physic-chemical parameters for the breccia pipe and/or vein mineralizations (related to shallow- intrusive bodies) have estimated by means of pyrite morphology, compositional variations of sphalerite, isotopic composition of sulfur and fractionation of trace elements.

As regards the Bocsa – Sacaramb base metal breccia pipe mineralization the estimation of formation temperature of some synchronously deposited sulfides (sphalerite and galena) have been achieved on the basis of Cd contents that indicate a temperature ranging between 360° and 420° C (Rosu et al., 1993, unpublished data). This temperature range is in agreement with the pyrite morphology that suggests an high temperature (T) and a variable supersaturation (S): $T_{\text{H}} - S_{\text{L-H}}$.

Sphalerite, coeval with pyrite, shows structural and compositional unhomogenities expressed either by intergrowths of crystals with different morphologies, or by Fe content variation and distribution, of chalcopyrite corpuscles as an effect of the copper and iron contents variation in system.

At Coranda ore deposit the sulphur isotopic geothermometer for the sphalerite-galena pair of the breccia body intercepted at the Coranda III gallery level, a temperature of 380° C. Pyrite morphology indicates four domains S-T($S_{\text{L}} - T_{\text{H}}$, $S_{\text{M}} - T_{\text{M}}$ and $S_{\text{M}} - T_{\text{H}}$ and $S_{\text{H}} - T_{\text{H}}/S_{\text{M}} - T_{\text{L}}$) suggesting

an high thermic regime of the hydrothermal fluids and a variable supersaturation. S_{M-T_H}/S_{M-T_L} domain shows cooling zones mineralizing fluids probably due to the system opening. Also, sphalerite recorded the compositional variation of fluids that is expressed by chromatic unhomogeneities, zoning and trace element variability. These data reflect a direct linking between base metal -gold mineralization the shallow-subvolcanic body. This relation ship is nicely show by SEM-EDAX analyses on microinclusions hosted by pyrite and sphalerite (see Table 1).

At Hanes ore deposit (Zlatna zone) the Vein 11 .Towards NW, breccious vein zone becomes more extended disappearing into a mineralized breccia pipe named Metesan stock.

The mineralization is constitutes by pyrite, sphalerite, galena and chalcopyrite. Microscopically arsenopyrite and numerous mono- and multiphase microinclusions in pyrite (pyrrhotite, pyrrhotite +chalcopyrite) and mainly in sphalerite (chalcopyrite, some multiphase microinclusions in pyrite (pyrrhotite-chalcopyrrhotite-cubanite - bornite? $\pm$ mackinawite - tetrahedrite, sometimes associated with chalcopyrite and accidentally stanite ?) have also been observed. Chalcopyrite is sometimes extensively developed. Sporadically, native gold has been found as inclusions in pyrite or associated with arsenopyrite and gangue minerals. The last ones are represented mainly by quartz, sericite, illite, clay minerals, carbonates and chlorite.

Detailed microscopic observation on pyrite call attention to the fine pyrrhotite inclusions (sometimes associated with chalcopyrite) as well as that of sphalerite and galena, suggesting a relative synchronous deposition of these sulfides since the early evolution stages of the hydrothermal system. The pyrrhotite presence suggests that sulphur activity has buffered within the system and that sulfides deposition took place around the equilibrium values.

Concerning the exsolution from sphalerite, their presentation and relationships among them suggest a very complex evolution characteristic for high-temperature sphalerite in agreement with the existence of a solid solution in the $Zn-S-CuFeS_2-Fe_{1-x}$ system (Ramdohr, 1969). The results show a temperature domain ranging from $430^{\circ}-390^{\circ}$ C (estimated upon isotope geothermometer) to 225° C (formation of mackinawite exsolutions).

The Vein 37 of Larga base metal gold-mineralization (Zlatna zone) is constitutes by pyrite, arsenopyrite, sphalerite, galena, marcasite and sometimes chalcopyrite. Sphalerite frequently hosted chalcopyrite and pyrrhotite monophase microinclusions and also chalcopyrite +tetrahedrite biphas microinclusions. Gangue minerals are: quartz, sericite, clay minerals and carbonates

The sulphur isotopic fractionation shows for the sphalerite-galena pair from the central zone of ore deposits an estimated temperature of 420° C.

In the Baia de Aries structure the mineralizations are spatially and genetically related to some shallow amphibole $\pm$ biotite-bearing andesite subvolcanic bodies that intruded crystalline schists and limestones. These bodies have generated a lot of breccia pipe some of them giving an important metallogenetic role. The spatial distribution of breccia bodies show their grouping into two main structures: Afinis gold structure and Valea Lacului base metal structure. The vein systems are less developed.

Table 1 Pyrite and sphalerite-hosted mineral microinclusions recorded in EDAX spectrum

Ore deposit	Mineral microinclusions hosted in:		Alteration type *	Mineral assemblage*
	pyrite	sphalerite		
Apuseni Mountains				
A. Porphyry copper type				
Valea Morii	Na, K, Fe(Cu), Ca chlorides; anh, ap, clap+/-Th,Cu; Ca, Fe carbonates; K phyllosilicates; silicate glass; ru, py, cpy; Ca, Fe carbonates		PT PR	py, cpy, bn, mg, hem, sph, kf, cl, bi, qz, anh ep, ab, cl, act, qz, ca, py
Spiros	K chlorides, cpy		AG PT+PR	py, qz, ser, kl, ill mg, py, cpy, qz, bi, ab, cl, ep, ca, ru, ser
Voia	K, Fe, (Au) chlorides		PT, PR, AG	mg, cpy, (bn), py, hem, gn, sph, Au, ru, ti, lx, Kf, bi, qz, anh, ser, cl
Rosia Poieni	cpy, bn, mo, qz		PT PR AG	py, cpy, mo, mg, hem, po, bn, sph, gn, dig, en, lz td-tu, bi, Kf, qz, anh, zl ca, cl, ru, ab kl, ill, mt, aln
B. Gold vein type				
Valea Morii	K, Fe, (Cu) chlorides		AG	native Au, Te, tellurides, sph, gn, cpy, ser, ad, cm, qz, tu
Spiros (Veins 9, 10)	K, Fe, (Cu) chlorides Ca, Mg, Fe, Mn, (Zn) carbonates; gps, K silicates, ru, gn, sph, mc, sb, td		PR, AG	py, sph, gn, cpy, qz, ser, cl, ca, ru, tu
Musariu	K chlorides, Fe oxides; ru	K, Fe, Zn chlorides; ca	PT, PR, AG	Au, Te, tellurides, py, sph, cpy, gn, apy, td, qz, cm, ca, ba, gps
Bradisor	K, Fe chlorides			Au, Te, Au-Ag tellurides, py, gn, sph, td, jam, qz, ba
Carpen	K, Fe chlorides	K, Zn, Au, chlorides; tn	AG, AD	Au, py, mc, gn, sph, po, mk, td, bt, apy, sb, ru, hem, qz, ba, ca
Sacaramb	K chlorides; hem		AG, AD, SR, SL	Au, Te, tellurides, py, mc, apy, sph, td, bt, bl, sb, cpy, al, qz, rd, ba, ca
Baia de Aries	K, Fe chlorides; gps/anh		PR, CL, AD, SR, AG	native Au, py, apy, lol, sph, gn, cpy, al, td, bt, mg, ru, hem, mc, syl, alt, qz, ca, mnca, ank, rd, ba
C. Gold - base metal vein type				
Hanes	Fe, K chlorides		PR, CL, SR, AD, AG, SL	py(with po, po+cpy inclusions), mc, apy, sph(with cpy, cpy+po, cpo+cub, bn+/-mk, td, sn? inclusions), gn, Au, qz, ca, rd, b
Larga	K, Fe chlorides, ap, ca, zr, ad?, K silicate, hem, ru, qz, mc		PR, CL, SR, AD, AG, SL	py, sph (with cpy, po, td inclusions), gn, mc, apy, Au, qz, ca, rd, ba, ser, cm
D. Gold breccia pipe type				
Baia de Aries	K, Fe chlorides; gps/anh, ap, Ca, Mn, Fe carbonates; Al, Ca silicates; Al, K, Mg silicates; qz, py, po, sph		PR, CL, AD, SR, AG	Au, py, apy, lol, sph, gn, cpy, al, td, bt, sb, mg, ru, hem, mc, syl, alt, qz, ca, mnca, ank, rd, ba

Table 1 (continued)

Ore deposit	Mineral microinclusions hosted in:		Alteration type *	Mineral assemblage*
	pyrite	sphalerite		
Bocsa-Sacaramb	K, hem chlorides; Mn, Fe oxides; sph	K chlorides	AG, CL	sph(with cpy, mk, cpo, cub, po inclusions), gn, py, cpy, (apy, td, bt, mk, cpo, cub, po, mc under microscope), qz, ca, ba, ru, ap, ill, cm, cl
Coranda	K chlorides; ru, mc?		AG, AD, SL	sph (with Au inclusions), gn, py, sb, qz, ca, ba, (td, cpy, bt, mgt, apy, bl, po, mk under microscope) ill, ca, ad
F. Base metal replacement type				
Baia de Aries (Valea Lacului)	K, Fe chlorides; gps/anh, Ca, Fe carbonates; ti; Al, K silicates; hem, sp, py, mc		PR, CL, AD, SR, AG	sph, gn, py, al, cpy, tn, td, bt, sb, po, mg, hem, rd, mnca, ca

Minerals: ab, albite; act, actinolite; ad, adularia; al, alabandite; aln, alunite; alt, altaite; anh, anhydrite; ank, ankerite; ap, apatite; apy, arsenopyrite; ba, baryte; bi, biotite; bl, boulangerite; bn, bornite; bt, bournonite; ca, calcite; cl, chlorite; clap, chlorapatite; cm, clay minerals; cpo, chalcopyrite; cpy, chalcopyrite; cub, cubanite; dig, digenite; en, enargite; ep, epidote; gps, gypsum; gn, galena; hem, hematite; ill, illite; jam, jamesonite; Kf, K feldspar; kl, kaolinite; lol, lollingite; lx, leucoxene; lz, luzonite; mc, marcasite; mg, magnetite; mgt, meneghinite; mk, mackinawite; mo, molybdenite; mt, montmorillonite; mnca, manganocalcite; ol, oligoclase; po, pyrrhotite; py, pyrite; qz, quartz; rd, rhodochrosite; ru, rutile; sb, stibnite; ser, sericite; sn, stannite; sp, spinel; sph, sphalerite; syl, sylvanite; td, tetrahedrite; ti, titanite; tn, tennantite; tu, tourmaline; zl, zeolite; zr, zircon

Alteration type: AD, adularia; AG, argillic; CL, chloritic; PT, potassic; PR, propylitic; SR, sericitic; SL, silicic

*Compiled after unpublished data

Recent researches regarding the estimation of the physico-chemical parameters that controlled hydrothermal processes at Baia de Aries structure (Nedelcu et al., 1999.) pointed out the polistadial character of hydrothermal process evolution, as follows:

Stage I - breccia column formation, with permeable spaces, by means of supercritical fluids ($T > 600^{\circ}\text{C}$) according to Burnham's model (1985);

Stage II - formation, accumulation and ascent through these space of same high-temperature K-rich fluids that produced an intense potassic metasomatism with illite-muscovite (estimated pH values 3 – 6);

- the chloride-rich fluids of the early stage have been followed, after the sulfides precipitation, by the increasing of H_2S activity in solutions;

- temperature decreasing at about 400°C - 350°C , favoured under a lithogeochemical control (calcareous rocks) abundant deposition of zinc and lead sulfides at Valea Lacului zone, while in the gold breccia from Afinis zone, where limestones are missing, pyrite predominantly was deposited;

- geochemical spectra and correlations among trace elements of in pyrite suggest that at this moment the hydrothermal fluid composition was similar.

Stage III: - wide development of boiling processes accompanied by a gradual decreasing of temperature in the conditions of a mineralizing hiatus. Zn and Pb were eliminated from system by massive sulfide deposition in the previous stage;

- maintenance of K-rich mineral stability (sericite, illite) that involves a pH near 7, domain suggesting gold transport as complexes of As^{-2} and As^{-4} type (Seward, 1984);

- f_{O_2} strong variations that lead, according to Heinrich and Eadington (1986), to a massive deposition of arsenopyrite (and mainly of associated gold).

Stage IV: - cooling of solution up to about 100°C (suggested by high -Tl content in pyrite) led to the deposition of both, native gold and gold, silver tellurides during the final evolution phases.

MELT AND FLUIDE INCLUSIONS STUDY IN NEOGENE PORPHYRY Cu-Au (Mo) FROM METALIFERI MOUNTAINS

Ioan Pinte

Introduction

Now there are characterized 9 deposit with porphyry gold mineralizations with an average hypogene grades range usually from 0.1 to 1.0 % Cu and less than 0.1 g/t Au to 1 g/t Au and the porphyry system is spatially associated either with Au – Ag or with Pb – Zn – Au – Ag low sulphidation veins or adularia – sericite type, rarely with enargite – famatinite high sulphidation veins or acid – sulphate type (Berbeleac et al., 1995). The main mineralogical paragenesis of the inner zones which can be recognized in all porphyry copper deposits from Metaliferi Mountains (Rosia Poieni, Tarnita, Rovina, Deva, Bolcana, Valea Morii, Talagiu) include quartz – bornite, quartz – magnetite, quartz-chalcopryrite-magnetite, quartz-pyrite, anhydrite-pyrite, etc (Boştinescu, 1984). Quartz is present as small prismatic or double terminated crystals in a coarse-grained texture of the veinlets. They are the sample material used for fluid inclusion study (Pinte, 1996).

Fluid inclusion petrography

All of the investigated samples contain several types of fluid inclusions which can be classified based upon phase association at room temperature conditions in three main categories, as follows: Type I – Silicate melt inclusions; Type II – Saline melt inclusions; Type III – Vapor rich inclusions; Their characteristics are depicted in table 1.(Pinte, 2000 submitted).

Conclusions

The evidence of liquid magmatic immiscibility between silicate melt and salt melt in PCDs from Metaliferi Mountains is based upon contemporary occurrence of inclusion within the quartz crystals and they are composed by silicate melt and salt melt rich fluids in various proportion in the same cavities or in separate pairs ones. The following final conclusions are consistent with this result:

1. The temperature of vapor bubble disappearance in silicate glass inclusions and the releasing temperature of a silicate liquid film around salt melt in polyphase counterpart inclusion seem to be real trapping temperature of melt inclusions, mostly between 1000°C and 1100°C; the highest temperature have not any reasonable geological or physical meaning except for the vapor bubble disappearance in salt melt inclusion near the common boiling points of several chloride compounds;

2. Chemical composition of salt melt inclusion based on halite melting temperature ranged between 49 – 75 wt % NaCl equivalent and more realistic results by crush-leach technique was estimated (see text);

3. Usually quartz crystals are zoned because of the retreating downward crystallization process in stagnant conditions (Burnham, 1979, Shinohara and Hedenquist, 1997), and the mixture of silicate melt, salt melt + vapor were exsolved sequential in the inner part of the shallow intrusive where the protor (i.e. potassic zone) is founded. This is composed by myriads of small veins in a brittle structure filled up with quartz – pyrite, quartz – magnetite – chalcopryrite; quartz – bornite – chalcopryrite and also in surrounding rock an alteration facies with K- feldspar, biotite, magnetite is necessary present and obviously the potassic zone is obliterated by subsequent alteration product in fillic, propylitic or argillic facies;

4. The saline melt can be sometimes considered as metal solvent solution because in most microthermometric runs, depending on water content, the opaque daughter minerals were dissolved during heating and reprecipitated on cooling in the microthermometric stage;

5. In many PCDs from Metaliferi Mountains was recognized a meteoric water - dominated convective system centered on the "protore" zone and surroundings composed by veins, breccia, stocwork where the primary ore deposit (i.e. potassic zone) was altered, transported and reprecipitated as epithermal products of high sulphidation and/or low sulphidation type. The corresponding fluid inclusions in the latest hydrothermal events are low salinity aqueous inclusions also vapor – rich inclusions.

TABLE 1. Summarized characteristics of silicate melt and salt melt inclusions studied in quartz veinlets from potassic zone in several PCDs from Metaliferi Mountains. Notations: P - primary, PS - pseudosecondary, S - secondary.

Fluid inclusion Type	Shape	Size	Phase assemblage (Troom)	Solid daughter phases	Distribution	Origin	General observations
I. Silicate Melt	elongate with narrow neck, rounded, ellipsoidal "hourglass" shaped	3-30 microns	silicate glass + vapour	silicate bi - refringent grains	in quartz growth zones, clusters in the central part of quartz grains, in healed fractures as trails, tubular channels	P PS S	specific associations with salt melt inclusions in decorated growth zones in quartz grains or crystals
II. Salt melt							
A.	negative crystal, tubular, elongate	two distinct populations 3-10 30-90 microns	more than five solids + vapour bubble 40-50%	halite sylvite hydrous Fe chloride K-feldspar hematite opaque unidentified birefringents, etc	in quartz growth zones isolated random three-dimensional or in healed cracks.	Mainly P PS	liquid-free at room temperature.
B.	negative crystal, elongate, prismatic	40-80 microns	more than 3-5 solids + vapour 20-30%	halite sylvite hydrous chloride hematite opaque, etc.	zonal subsevent, mainly in healed cracks	Mainly P PS	in addition a liquid phase appear at room temperature
C.	negative crystal, prismatic, ellipsoidal	20-50 microns	more than 3-5 solids + vapour 10-20%	halite sylvite hydrous chloride hematite opaque, etc.	mainly in healed cracks trails	Mainly PS S	"halite trend" or halite homogenization fluid inclusions
III. Vapor-rich	rounded, negative crystal, ellipsoidal etc	10- 90 microns or more	low density vapor phase	small salt cubes, opaques grain, red hexagonal hematite flakes	primary clusters, healed cracks trails	P PS S	magmatic evolved fluids and released phases by successive boiling episodes.

ABCD – GEODE 2001 WORKSHOP VATA BAI, ROMANIA
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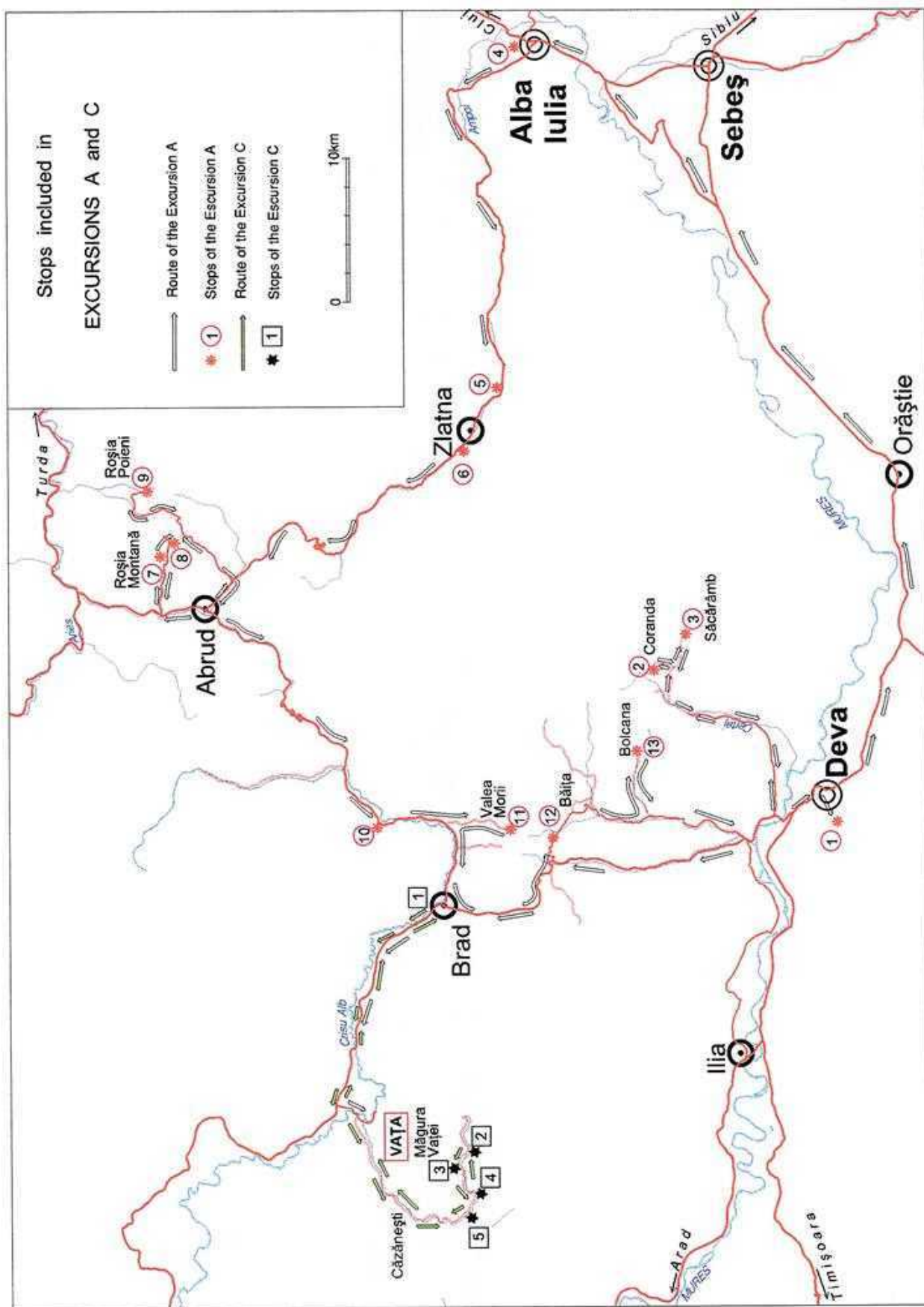
Geodynamics and Ore Deposit Evolution
of the Alpine-Balkan-Carpathian-Dinaride Province



STOPS IN EXCURSION A
(6 - 8 June)

Neogene magmatism and related metallogeny
from the South Apuseni Mts.

Bucharest, 2001



STOPS IN EXCURSION A CONTENT

Stop A1. Magmatism and porphyry copper ore deposits from Deva. M.P. Ivascanu, E. Rosu.....	1
Stop A2. Coranda base metal-gold deposit. Open pit. G. Udubasa, E. Rosu, L. Nedelcu.....	6
Stop A3. Gold-Silver Telluride Ore Deposit of Sacaramb. G. Udubasa.....	6
Stop A4. Alba Iulia.....	10
Stop A5. and A6. Upper Cretaceous-Paleocene extrusive rhyolites and andesites from the Zlatna area. E. Rosu.....	11
Stop A.7. Rosia Montana open-air Museum.....	11
Stop A.8. Rosia Montana, Cetate-Carnic. E. Rosu, L. Nedelcu, I. Pintea.....	11
Stop A. 9. Rosia Poieni porphyry copper deposit. V. Milu.....	13
Stop A. 11. Valea Morii poprhyry copper and epithermal gold vein deposit. L. Nedelcu, I. Pintea, E. Rosu, M.P. Ivascanu and S. Riemer.....	19
Stop A.12. Ormindea Belvedere.....	23
Stop A.13. Bolcana porphyry copper deposit. V. Milu.....	23

Stop. 1. Magmatism and porphyry copper ore deposit from Deva

Ivascanu M. P., Rosu. E.

The Deva structure is the southest magmatic complex of South Apuseni Mountains(SAM) Neogene magmatic belt. Is constituted mainly by subvolcanic bodies and necks of hornblende-plagioclase and hornblende – plagioclase-biotite bearing andesites in a ring like, concentric structure.

The basement is represented by epimetamorphic crystalline rocks, in greenschist facies, mainly represented by cuart, cuart-sericite and cuart-sericite-clorite(+ graphite) bearing shists, local cuart-sericite-felspatic shists. Those can be easily related to Pades epimetamorphic formation of Poana Rusca.

The crystalline basement is covered by a ~400 m sedimentary cuverture, Turonian - Coniacian age, know as Deva formation, constituted by micro-conglomerates, sandstone in cm to dm layers associated whit marls and radiolarites (Gheorghiu, 1954, Lupu and Lupu, 1966). Those are overlayed by isolated lagunar detritic deposits of Tortonian age, interlayered with cinerites and marls, correlated with volcanic activity from Brad – Sacaramb area. The Sarmatian sedimentary deposits, relatively well developed on this area, are constituted by poligenous conglomerates, sandstone's and marls (Gheorghiu, 1954). A cineritic layer and clasts of Deva type andesites attest the synchron deposition of those with magmatic activity.

Neogene magmatic rocks

The Neogene magmatites are represented by small bodies of andesites, poorly differentiated, in a subvolcanic facies, showing crossrelation with contry rocks. The contacts are intenseli reworched and the presence of poligenous breccias (tectonic breccias, contact breccias, breccia pipe) is usual.

Petrographelly tree type of andesites can be differenciaded (Bostinescu, 1983):

Amfibole bearing andesites (Nocet Hill type): Masive porphyric andesites with a microlitic matrix (up to 40%) bearing zoned plagiclase (An 35-40) and amfibol phenocrists. Biotite is accidental. Accesory minerals are apatite, magnetite and accidentally titanite.

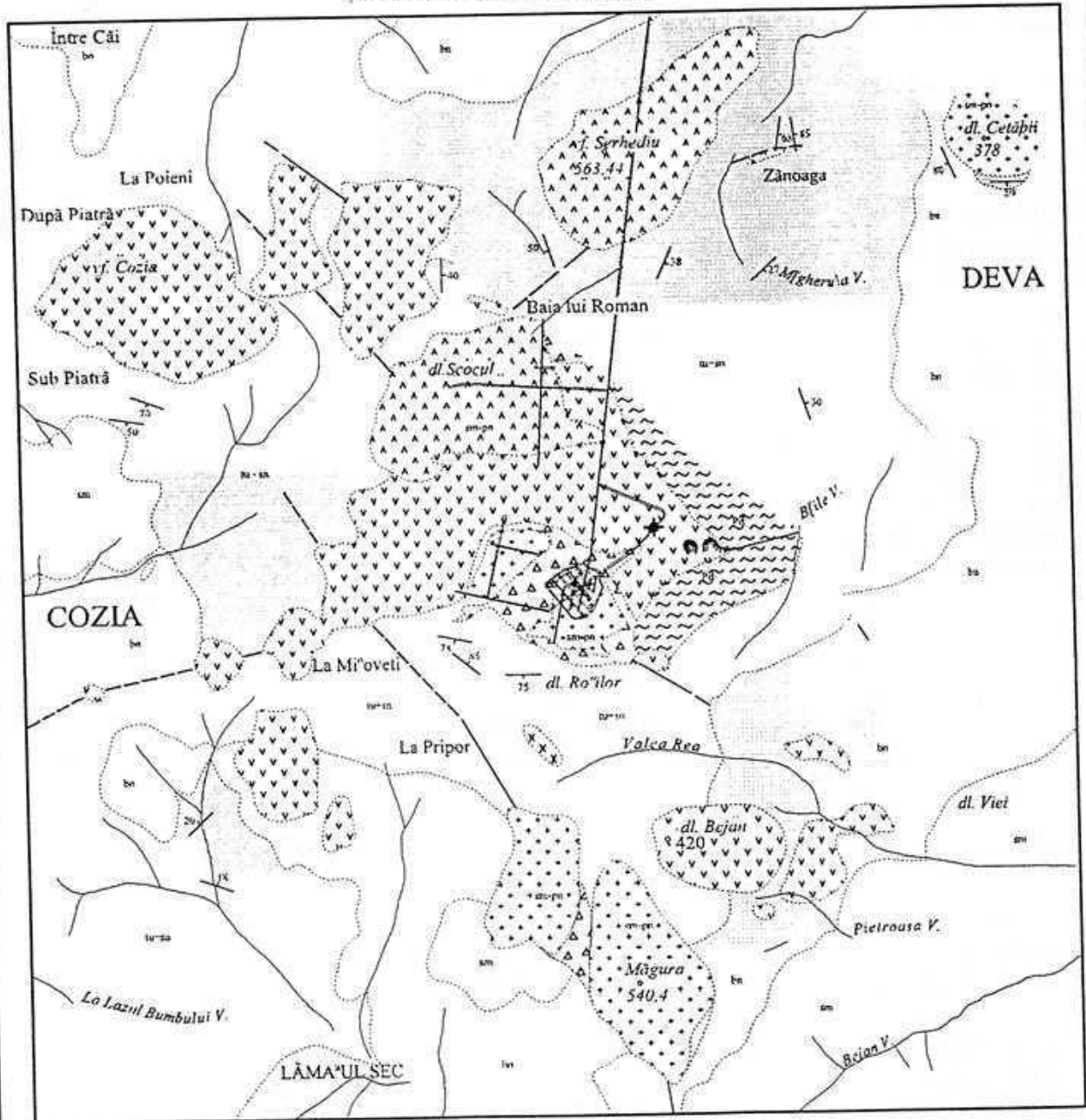
Amfibole – biotite bearing andesites (Bailor Creek type) similar texturally to Nocet type andesit can by distingushed by the constant presence of biotite phenocrists and the presence of an intermediary sized plagioclase phenochrist. The Deva porphyry copper deposit is related to a subvolcanic body of this type. Zoned and mecanic twinning plagioclase (An 20-50) and higest oxides (Magnetit- hematite) content is usual.

Amfibole bearing andesites (Serhediu Hill type) show an obvios subvolcanic caracter with giant plagioclase phenocrists (up to 5 cm), microcristalline matrix and higher phenocrist/matrix ratio. The phenocrists are plagioclase (more basic, An 55-65) and amfibole (subordonated).

Desechilibrium between phenocrists and matrix are usual (corrosion and resorbtion of amfibole and plagioclase, zoning, amfibole transformation to biotite and magnetite),

GEOLOGICAL MAP OF DEVA AREA

(after S. Bostinescu, with modifications)



MAGMATIC ROCKS

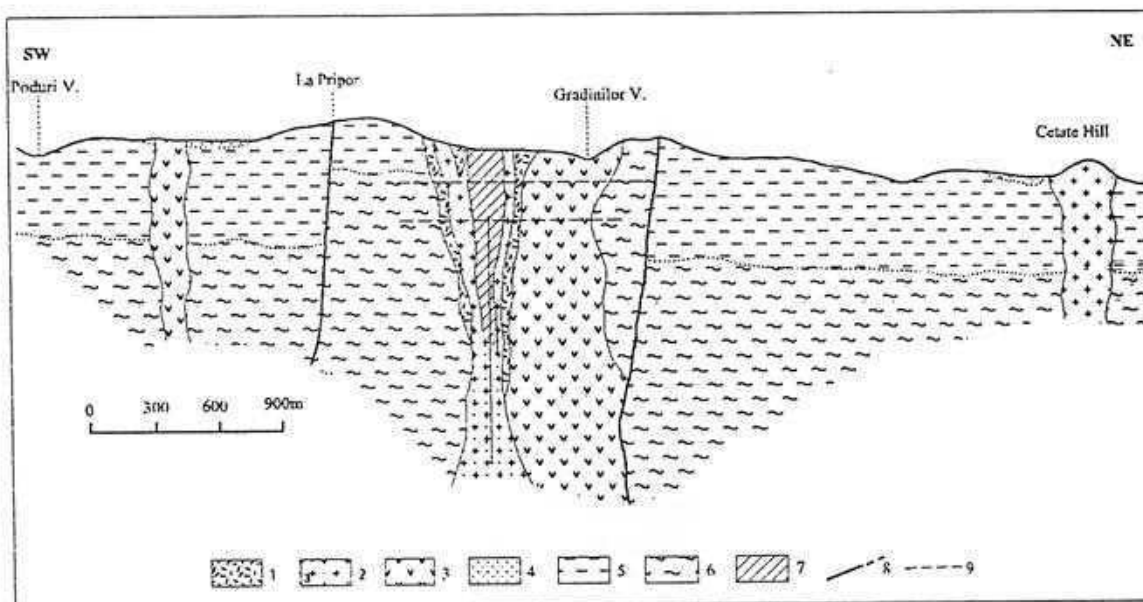
- Bailor type andesitic (amphibole + biotite bearing) a
- Serhedi type andesites (amphibole bearing) a
- Cetate type andesites (amphibole + biotite) a

METAMORPHIC ROCKS

- Carbonifer inferior
- Seria de Pades

SEDIMENTARY ROCKS

- Quaternary indivisid
- Sarmatian detritic rocks
- Badenian tufites, gravels, marls
- Turonian - Senonian "Deva strata", Microconglomerates, sandstones, radiolites



but much evident for Bailor type andesite, showing complex evolution of magmatic chamber and post magmatic transformation due by volatile exsolution.

Another feature is the presence of poligenous breccias (breccia pipes, contact and contact-tectonic breccias) related to Bailor type andesites (e.g. Bailor creek, Cetate, Magura) pointing a massive devolatilisation event of magmatic chamber. A particular attention should be pay to breccia envelope of porphyry related intrusion (Bailor Creek) wich represent an intrusion sinchrone breccia pipe.

The field relation and K-Ar data outline the evolution of magmatic activity in Deva area. First by emplacement of large volume of Nocet type andesites (12.6 ± 0.5) structurally controlled by crustal regional faults (similar to Brad Sacarimb basin). Those are follow by emplacement of biotite rich Bailor type andesites (12.1 ± 0.5 , 11.85 ± 0.5) related to porphyry mineralisation and extensive brecciation event, generating a depressurisation and volatile exsolution of magmatic chamber. The lasts are small volumes of Serhedi type andesites (12.8 ± 0.5 with more subvolcanic caracater and relatively basic chemistry. The field relation are ambiguous for time relation of Serhedi and the K - Ar data are conspiceous bue by errors Variable hydrothermal and supergene transformation affect fist two types of andesites, mainly argilisation (illite, montmorillonite, caolinit), sericitisation, cloritisation and carbonatisation.

overlapping. The relatively basic chemistry and water content, in accord whit the general trend of Neogene magmatic rocks from South Apusen Mts. claim for this time possiton of Serhedi andesites.

Deva porphyry copper deposit

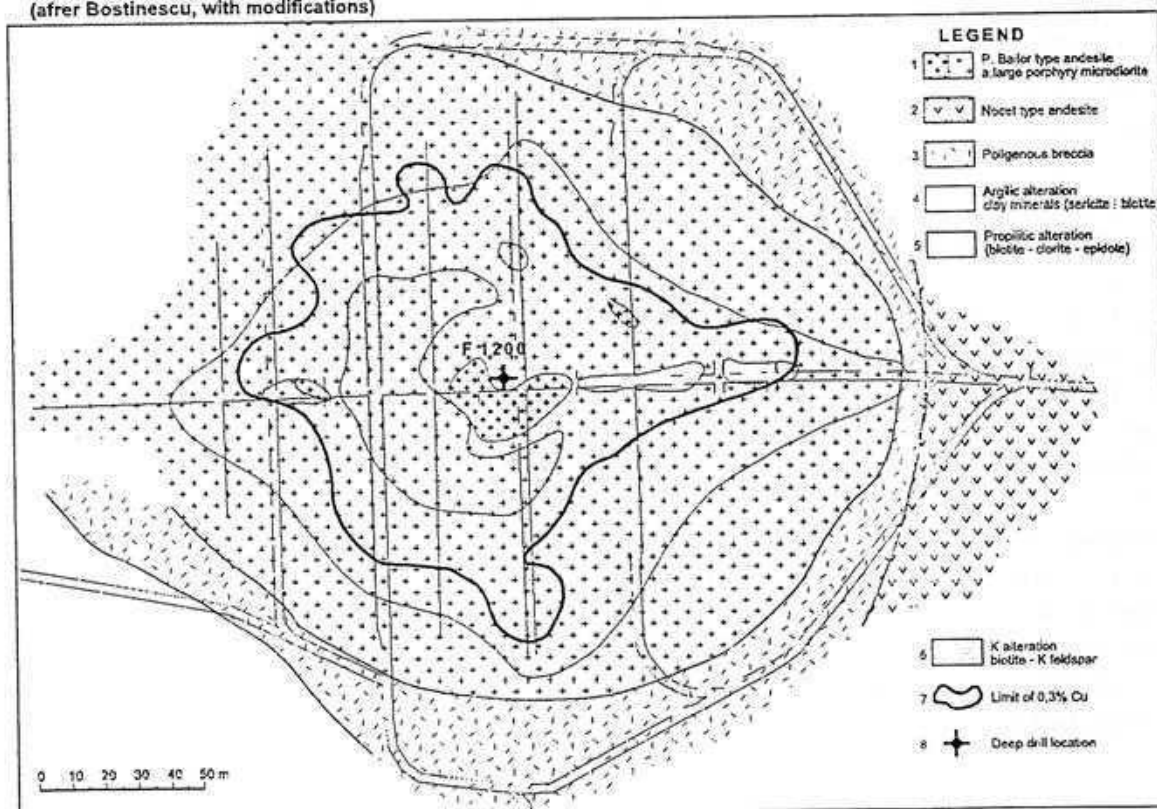
The Deva porphyry copper (Au) deposit have a central position relative to volcanoplutonic structure in the upper part of Bailor Creek, related to a subvolcanic body (Bailor Creek type) rounded by poligenous breccias. The shape of mineralisation is as a column developed porphyry stock up to several hundred meters deep.

Several processes have been claimed for the genesis of such breccia formations: tectonic crushing, repeated collapse and hydrothermal brecciation. One characteristic feature of brecciation is the spatial relation and possible genetic relation with the P. Bailor type andesite. We conclude that the hydro-brecciation by evolving magmatic fluids is the main process which acceded to widely breccia formation in area of Deva and related to porphyry stock. The collapse breccias are developed in the upper part of mineralized intrusion as an envelope. This is a matrix supported poligenous breccias with clast up to several meters sedimentary, crystalline shists and Nocet type andesite in an argillitic facies.

Alteration and mineralization

The alteration processes display a well expressed zonality mainly controlled by the distance from the intrusion axis. The subvolcanic mineralised body have a median axis where the coarsely crystallised andesite is practically unaltered. Fresh primary biotite and amphibole is characteristic. In deeper parts that evolve to a microdiorite facies. The

SKETCH OF ALTERATION PATTERN OF DEVA PORPHYRY COPPER DEPOSIT (level -240)
(after Bostinescu, with modifications)



potassic alteration, characterized by the presence of secondary biotite and K feldspar, is present in the inner zone around to fresh andesite-microdiorite core. This extend toward to rim of subvolcanic body at contact whit breccias, sligty asimetric. The outhur zone (mainly in breccias is characterized by the association of sericite-pyrite-clay minerals.

The ore assemblage is form by association of potash feldspar and biotite together whit bornite, calcopyrite, magnetite, molybdenite, sometimes rutile. In the upper parts, now mined, pyrite was another major component (Petrulian et al, 1966) whereas in deep is mising or accidental. In the deeper parts the anhydrite, zeolites and calcite become common.

A peculiarity of Deva porphyry copper deposit is the unusual abundance of high temperature bornite (more than calcopyrite) whit exolutions of cubanite, calco-pirotite, calcopyrite (or high temperature solid solution equivalent), in a bornite-magnetite assemblage. This is releated whit the high content of gold, hosted mainly by bornite (Petrulian, Bostinescu). This claim for a relatively high formation temperature of porphyry mineralization - $>500^{\circ}$ (Simon et al, 2000) and is in accord whit fluid inclusions studies showing comparable homogenization interval (Pintea, 1997). Cogenetic assemblage of melt and hypersaline fluid inclusions whit high homogenization temperatures was described.

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Stop A.2. Coranda base metal –gold deposit. Open pit.

G. Udubasa, E. Rosu, L. Nedelcu

The Coranda ore deposit is located in an uplift area of the pre- Neogene basement, which comprises Cretaceous sedimentary rocks and ophiolites (see map of area). This ore deposits is direct linking with a shallow - subvolcanic body, whose little apophysis one can see in the western part of the Coranda open pit.

The Cretaceous fine-grained sandstones alternate with black shales containing rutile /anatase, framboidal pyrite, and carbonaceous matter and/or pre -graphite (Udubasa et al., 1982). The Upper Cretaceous- Paleocene sedimentary rocks consist of microconglomerates, mica-bearing sandstone and reddish- brown shales. The volcanic rocks of this area belong to upper Sarmatian –lower Pannonian based on K-Ar data (Rosu et al., 1998, 2001). They consist of amphibole-bearing andesite which appear together with amphibole and biotite=pyroxene -bearing quartz andesite. Geochemically all andesites of this area show an adakitic-like character(Rosu et al., 2001).

As shown, this deposit is located in upper part of a shallow - andesite subvolcanic body mainly intruded in the brecciated Cretaceous sedimentary rocks locally passing to the little breccia pipe bodies. A preferred deposition of pyrite in sandstones and of galena and sphalerite in shales has been observed. This may explain the non - uniform distribution of mineralization as well as the separation of the gold –and the Pb+Zn – rich areas.

The ore minerals form impregnations (in andesites , in spilites, in Tertiary sedimentary rocks), fine veins or veinlets cutting across the bedding, ore pockets (up to 1 m in size) and short concordant thin beds in shales and sandstones. There exist also small veins within the subvolcanic body(Udubasa et al., 1982).

The main sulfide minerals are sphalerite , galena and pyrite. Microscopically were identified (Udubasa et al., 1982) fahlore (an As-rich tetrahedrite), chalcopyrite, bournonite, meneghinite, arsenopyrite, boulangerite and scarce pyrrhotite and mackinawite. Few fine gold inclusions have been observed in sulfides mainly in sphalerite. Usually pyrite grains appear to be zoned due to As and Cu anomalous contents. The sulfides are believed to have form from an unique hydrothermal supply (Udubasa et al., 1982).

The sulphur isotope geothermometer for the sphalerite-galena pair show a temperature of 380°C according to pyrite morphology that indicates an high thermic regime of the hydrothermal fluids and a variable supersaturation. In addition, sphalerite recorded the compositional variation of fluids that is expressed by chromatic unhomogeneities, zoning and trace element variability. These data reflect a direct linking between base metal –gold mineralization the shallow-subvolcanic body (Nedelcu, Rosu, 1997, unpublished data)

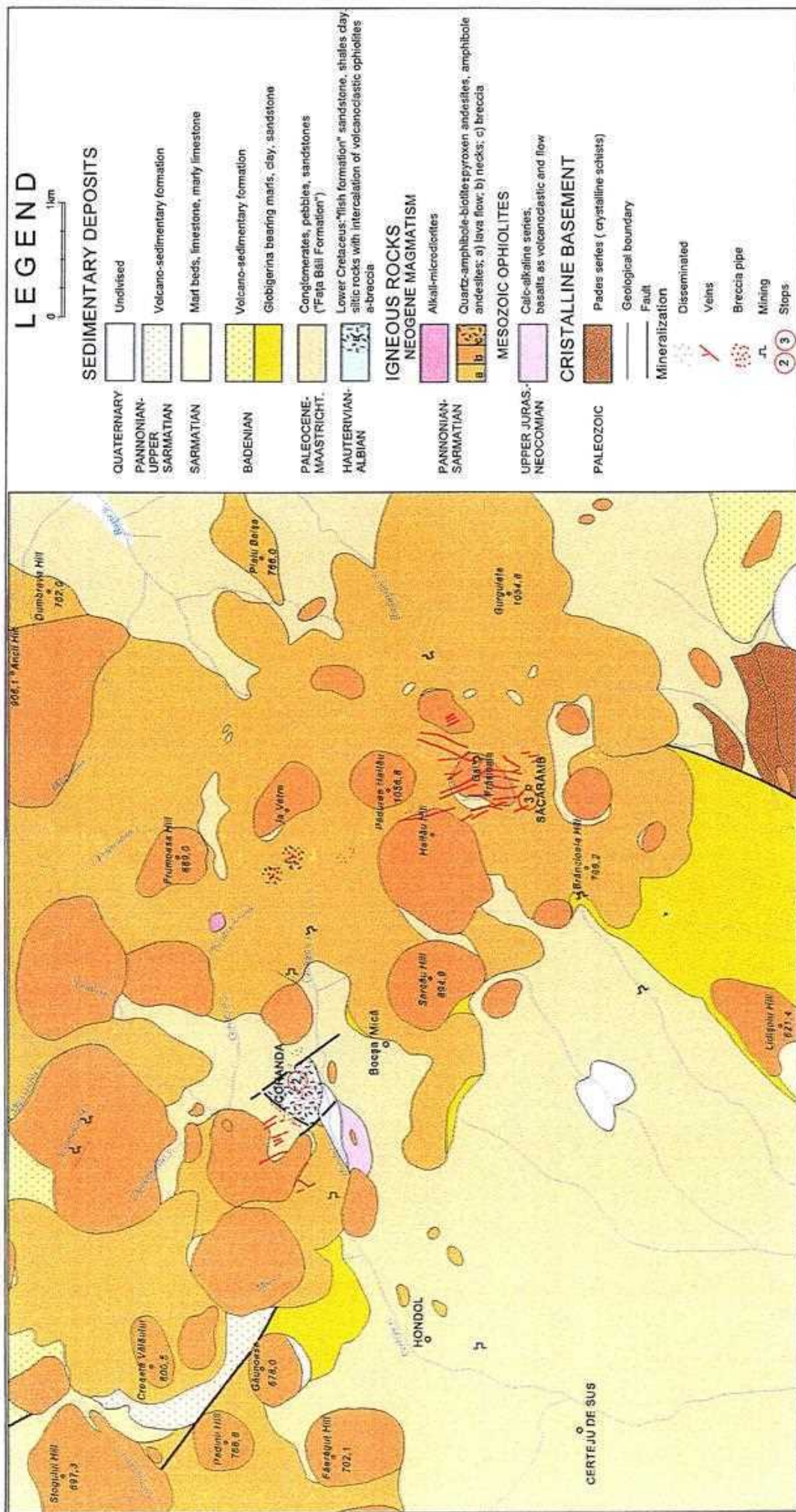
StopA 3 - Gold-Silver Telluride Ore Deposit of Sacaramb

G.Udubasa

The classical epithermal Sacaramb (formerly Nagyag) ore deposit lies in the south-eastern part of the Metaliferi Mountains (Siebenburgisches Erzgerbirge), some 20 km NE from Deva, the capital of the Hunedoara district.

The telluride-rich ore veins are located in a volcanic structure built up of hornblende- and pyroxene-bearing quartz-andesites .The volcanic rocks of this area belong to upper Sarmatian –lower Pannonian based on K-Ar data (Rosu et al., 1998, 2001). They consist mainly of amphibole and biotite=pyroxene bearing quartz andesite and subordinately of

GEOLOGICAL MAP OF HONDOL-SĂCĂRĂMB AREA (E. Rosu)



amphibole bearing andesite. Geochemically all andesites of this area show an adakitic-like character (Rosu et al., 2001).

The rocks show a pervasive propylitic alteration and argillic zones directly connected to the vein walls. Locally developed silicification zones occur especially in the Upper Cretaceous-Tertiary sedimentary deposits (sandstones and conglomerates – Fata Baii Formation)). The vein area is relatively small (some 1000 sqm). The vertical development of the vein system is about 600 m. Practically, all the major veins are contained by the central volcanic neck showing a gradual reduction of its diameter towards depth. The garland-like distribution of the veins is somewhat asymmetrical as the eastern vein groups are more largely developed.

Some 230 veins are known in the Sacaramb area. Their number drastically diminishes towards depth. An average thickness of 0.3 m, locally reaching a maximum of about 2 m, has been estimated for the whole net of veins. Their length considerably varies, the most important ones being of 500-600 m.

A typical feature of the Sacaramb ores is the development of the so-called "Glauch" veins, that is joint fillings consisting of very fine-grained, sometimes earthy material, reminiscent of fluidization products. Such veins are either gold-bearing or completely barren. The late formation of the Glauch veins by collecting material both from the country rocks and the ore veins may explain their random distribution and the contrasting precious metal contents.

Samples with gold- and silver-tellurides are now difficult to find in the slowly dying Sacaramb mine. After nearly 250 years of continuous exploitation the Sacaramb ores are ever poorer and large parts of the mine seem to be completely exhausted. However, still interesting metal contents do exist in the middle part of the mine.

Clay-, carbonate-, and quartz-rich vein filling can be seen on "Daniel" mine dump.

Outstanding samples with tellurides from the Sacaramb mine are hosted by some domestic museums, such as the Gold Museum in Brad, the mineralogical collections of the Universities of Bucharest and Cluj-Napoca and that of the Brukental Museum in Sibiu (Natural History Section) as well as the National Museum of Geology in Bucharest. Some samples do exist in the small minerals and rocks collection of the Coranda-Certej Mining Enterprise; such samples have been collected in recent years from different parts of the mine. Unfortunately, their number dramatically diminished in 1974 by the partial destroying of the host building provoked by a mud flood from the tailings ponds.

Nevertheless, samples with tellurides from the Sacaramb mine may be found in many European museums and they still furnish materials for further studies. The old samples are especially of great scientific value; in Europe (Ramdhor and Udubassa, 1973), krautite – a new mineral species (Fontan et al., 1975) as well as tellurantimony, the first occurrence in Romania (Popescu and Simon, 1992).

The Sacaramb ores are very rich in mineral species; more than 100 minerals have been described in the area, the most important being the gold-silver tellurides; some of them have their type locality at Sacaramb, e.g. nagyagite, krennerite, petzite, stuetzite, muthamannite, as well as the hydrated manganese arseniate, the kraunite. The Sacaramb mine is still the sole occurrence of some other minerals in Romania, e.g. of plumbogumite, jordanite or in the Metaliferi Mountains, e.g. semseyite, erythrite, hoernesite etc. Some features of the Sacaramb minerals are given in Table 4, which includes also some historical data of mineralogical interest.

The distribution of minerals within the Sacaramb mine was not uniform. Ghitulescu and Socolescu (1941) gave a general picture of the main mineral assemblages in the different vein groups, which typically contain the following parageneses.

- quartz, rhodochrosite, nagyagite, with abundant common sulphides: Magdalena vein group (SE part of the mine);
- quartz, barite, rhodochrosite, sylvanite, krennerite, gold, common sulphides: Longin vein (NE part of the mine);
- calcite, petzite: Nepomuc vein group (SW part of the mine); alabandite was quite abundant in the Nepomuc veins too.

By far incomplete, such an attempt is somewhat reminiscent of Hofer's (1866) "ore formations", i.e. quartz-tellurium (Quartz-Tellur Formation), rhodochrosite-tellurium (Rothspathige-Tellur Formation), and sulphides (Formation der Schwefelmetalle) for which, however, no definite spatial boundaries could be given. The failure of a generalized paragenetic succession is obviously related to a non-simultaneous opening of the vein fractures. Nevertheless the common sulphides were earlier deposited as compared to the tellurides but the sulphosalts were later. Giusca (1935) gave the most interesting example of such sequence, i.e. sphalerite-galena-nagyagite-altaite-bournonite-tetrahedrite. The same author remarked the general tendency of decreasing tellurium and of increasing silver contents of the mineral species as the deposition proceeds. Recurrences are also possible, as well as metasomatic reactions and/or decomposition processes. Such an example is given by Udubasa (1986) in the case of nagyagite; its decomposition commences with the development of the fine altaite rims around the nagyagite lamellae; further reactions result in fine intergrowths of altaite, petzite, hessite, krennerite and gold, which may completely replace the nagyagite lamellae.

Some historical data on the Sacaramb mine

The first mining working undertaken in the Sacaramb area is the Maria gallery (altitude 784 m), probably in 1746. There follows a nearly 250 years period of continuous exploitation of the mine. In the meantime more than 300 km of exploratory, extraction and stope preparation mining workings have been done in the area. The main horizons of the mine include a vertical interval about 450 m and a time interval of about 150 years, i.e.

Maria horizon (784) (1746)

Bernat horizon (723 m) (1757)

Josephi horizon (637 m) (1765) lately named Ferdinand

Franz horizon (494) (1824) lately named Carol

Franz Joseph horizon (335 m) (1898) lately named Nicolae

Numerous intermediate horizons have been also done to open the richest parts of veins, as well as another five horizons under the "Erbstollen" Nicolae, i.e. from -40 m to -200 m and the uppermost horizon, Frasinata (altitude 840 m). In 1940 the image of the horizontal workings was still an amazingly dense net (Fig. 7). At the beginning the gold tenor was of about 80-100 g/t and it gradually diminished down to 2-3 g/t in the present-day mine workings.

During the period 1784-1930 some 50,561 kg of Au+Ag were produced, giving an annual production of 276 kg of precious metals (Helke, 1934). Afterwards the productions was of about 300 kg Au and 500 kg Ag annually (Ghitulescu and Socolescu, 1941). After the World War II the production data became secret. If an average annual value of 500 kg Au+Ag would be estimated for the period 1941-1991, the total amount of gold and silver extracted from the Sacaramb veins would be of some 85,000 kg.

The precious metal contents continuously decreased towards depth. In the deepest part of the mine (under the Nicolae horizon) the veins have had a reduced thickness and have contained almost only common sulphides with some included in them. The tellurium content in galena was only of 200-400 ppm. Finally, even the base metal contents became

unsatisfactory and the lower part of the mine was closed. The mining activity continued either in exploiting the old waste fills (contained locally up to 2-3 g/t Au and more) or in searching the ending parts of the veins, the zones between the main veins or those between the main horizons.

About 150 published papers do exist on the Sacaramb area. The history of the Sacaramb gold-telluride ore deposit began in 1744 or 1745 when a Romanian countryman show to Ignaz von Born an ore sample which has proves to be very rich in gold (Schmidt, 1897). After this somewhat casual find, the Sacaramb mine furnished materials form many mineralogical studies, economic geology, mining geology and petrography. A short chronological selection is given below (Table) including especially the main "events" of the mineralogical knowledge. Sacaramb/Nagyag is the type locality of many minerals.

Table

Historical Development of the Mineralogical Knowledge of the Sacaramb ore deposit

1717	Koleseri's "Auraria Romano-Dacica" is probably one of the first assessments of the Transylvania gold.
1744-1745	- Born's chance to receive a sample of gold-rich ore which contained the "future nagyagyte".
1772	Born and Scapoli named the mineral "aurum galena"
1783	Hacquet: first crystallographic record of the Sacaramb gold ("Mineralogische Rhapsodien"). Also the first report on the gold in the area by Muller von Reichenstein.
1800	Beudant: a further name of nagyagyte: "elasmose"
1803	Stutz: systematic presentation of many minerals.
1832	Karsten gave the future nagyagyte the name "Blatererz"
1842, 1845	Haidinger gave the name nagyagyte; first description of petzite, previously described by Petz as "Tellursilber"
1857	Hingenau: new mineral data
1866	Hofer: further mineralogical data
1877	Krenner in Budapest and von Rath in Bonn simultaneously described a new mineral, named by Krenner "Bunsenin" Neatly and frankly, G. von Rath gave the mineral the name "krennerite". Previously used name: Gelberz, Weisstellur, Mullerin, Kottonerz.
1878	Schrauf: detailed crystallographic data on nagyagyte: first description of stuetzite: the latter has been discredited by Thompson in 1951, but lately redefined.
1885	Sipoecz: chemical analyses of nagyagyte
1887	Inkey: first geological monography of the area, with many data on the minerals.
1894	Vrba: crystallographic study of sylvanite (28 forms)
1897	Privoznik: chemical analyses of nagyagyte.
1911	Haidinger: first description of muthmannite. Thopmson (1949) failed to synthesize muthamannite and considered it as dubtful species. Later data showed that muthmannite is, however, a valid mineral species.
1924	Boldirew: chemical analyses of nagyagyte
1930	Tokody: description of xanththoconite and proustite
1934	Helke: first modern ore microscopy stdudy
1935	Gossner: structural data on nagyagyte (tetragonal symmetry)

1935, 1936, 1937	Giusca: many ore microscopical and chemical data on tellurides; his nagyagite formula $\text{AuPb}_7\text{Te}_3\text{Sb}_2\text{S}_9$ seems to be the most appropriate.
1941	Ghitulescu and Socolescu - first monography of the Metaliferi Mts: many data on Sacaramb.
1958	Binder: Historical data on mineralogical discoveries in Transylvania, in the Sacaramb area included.
1970	Stumpfl: microprobe analyses of nagyagite; his formula implies substitution $\text{Te}=\text{S}$ rather than $\text{Te}=\text{Sb}$, as Giusca proposed.
1973	Ramdhor and Udubasa: frobergite identification.
1975	Fontan, Orliac, Permingeat: discovery of krautite.
1986	Udubassa: step-by step decomposition of nagyagite.
1992	Popescu and Simon: record of coloradoite and tellurantimony

In addition to this, it is worth of mention that during the past century the Sacaramb mine was a practical training site for young mining engineers from many European countries. The mining school of Sacaramb was the best (at least) in Transylvania: in 1839 J. Grimm wrote a practical guide form miners, especially for the beginners ("Praktische Anleitung zur Bergbaukunde für den Siebenburgen Bergmann, insbesondere für die Zöglinge der Nagyager Bergschule" - Wien, 1839).

Stop A.4. Alba Iulia

Alba Iulia, the capital of the Alba County is situated near the Mures River. Near to Alba Iulia, in Dacian Apulum fortress the Romans had the residence of the 13th Gemina legion. The remnants of Daco-Roman city have been found at Alba Iulia and the Regional Museum has a rich collection of Roman antiquities.

At Alba Iulia, in 1600, Michael the Brave (Mihai Viteazul) proclaimed himself prince of Walachia, Transylvania, and Moldavia, achieving (for short time) the first union of these three great provinces of Romania. Three centuries later, on December 1, 1918, at Alba Iulia was pronounced the union of Transylvania with Romania and in 1922, the Romanian's King Ferdinand I and Queen Marie were crowned in the Orthodox cathedral.

The Alba Iulia fortress was built up between 1715-1738 as residence of the Austrian governor and administration of Transylvania. The sightseeing of the fortress offers the view of the 13th century Roman Catholic cathedral (the highest church in Romanesque style from Romania), the Batthyaneum Museum (founded in 1792) where about 500 Incunabula and a Codex Aureus from the 8th century are preserved, the new Orthodox cathedral, the National Museum of the Union, and the recent equestrian statue of Michael the Brave.

Stops 5 and 6. Upper Cretaceous-Paleocene extrusive rhyolites and andesites from the Zlatna area
E. Rosu

Maastrichtian-Paleogene molasse formations are developed in Zlatna-Stanija and Sacarimb-Hartagani basins. Their lithology consists of polymictic conglomerates, gravels with intercalation of sandstones and red clays (Fata Baii Formation). In the basal part of this succession are interlayered lava and volcanoclastics of rhyolitic-andesitic composition. They were named as rhyolites and andesites belonging to Fata Baii Formation.

Stop 5

Fata Baii rhyolites nicely crop out in Patringeni, being intercalated (up to 50 m thick) in conglomerates. They represent lava flows, sometime brecciated associated laterally with volcanoclastic deposits.

Their petrographic composition consists of small crystals of plagioclase (15-20% An), sanidine, quartz and rarely biotite, usually with opaque rims. The groundmass present fluidal or massive structures and is vitreous or cryptocrystalline.

Stop 6

Fata Baii andesites outcrop here. They represent lava flows sometimes autobrecciated with variable thickness (ca. 5-50m). They sometimes are associated laterally with volcanoclastic deposits of the same composition.

Their petrographic composition consist of amphibole-pyroxene andesites, showing slightly porphyritic texture (different from the Neogene andesites, which are largely porphyritic). Their compositions is represented by plagioclase, amphiboles, partially with opaque rims, augite and hyperstene (transformed usually in bastite and clorite); accidentally quartz and biotite are found. The groundmass is dominant being hyalopilitic or pilotaxitic, rarely passing to microcrystalline.

Stop A7. Rosia Montana open-air Museum

In the precincts of the Rosia Montana mine, the open-air museum will be visited. Here, old tools for mining, extraction and gold recovery, as well as objects, monuments and inscriptions since the Roman times are exhibited. The Roman galleries will be visited, too.

Stop A.8. Rosia Montana , Cetate-Carnic
Rosu E., Nedelcu L., Pintea I.

At Rosia Montana - Corna the Tertiary deposits are represented by a volcano – sedimentary formation (and lacustrine sediments ?) affected by explosive processes during the emplacement of shallow- subvolcanic bodies of dacites (Cetate, Carnic and Vaidoaia). At depth the igneous rocks come in contact with Mesozoic siliciclastic rocks and pre- Mesozoic crystalline schists.

The dacites appear a rather homogenous white mass in which only large bypyramidal quartz crystals strongly corroded and fissured stand out. Flakes of "baueritized" biotite as well as millimetric quartz and calcite fissures accompanied by diffuse pyritization are often noticeable. The fine granular groundmass is of a quartzo - feldspathic composition. The feldspar phenocrysts in fresh rocks allow us to assume a plagioclase with 30% anorthite. Femic minerals are also present; hornblende and biotite appear quantitatively subordinated. The accessory minerals are represented by apatite, zircon, and pyrite. Both the groundmass

and the phenocrysts particularly are invaded by adular, argillaceous minerals, sericite, carbonates, chlorites and quartz.

The explosive – intrusive breccias were emplaced in several episodes related to dacites from Carnic, Cetate, and Vaidoia (Stefan et al., 1998, submitted)

The first generation breccias are most widely developed and they form a funnel-shaped body (enlarged towards surface) that affected the sedimentary and volcano – sedimentary (both, Badenian age). The igneous component of this breccia has mineralogically and structurally distinct features (more euhedral and smaller phenocrysts of plagioclase and generally no quartz phenocrysts). These eruptive rock may come from peripheral parts of the volcanic dacitic body or rather from independent old Neogene bodies of dacites. Dacites with pseudobipyramidal quartz, plagioclase, hornblende, biotite and sanidine phenocrysts have proved to have lesser contribution to the first breccia generation than to the mixed breccia pipes that follow.

The new breccias (containing a lot of dacitic elements with a megaporphyric texture) were generated by further accumulation of fluids that exploded and where mineralized after solution circulation. The fluids that caused explosions and produced breccia bodies, are probably both magmatic – hydrothermal and phreato – magmatic. The breccias bodies form pipes and/or irregular shape mainly consist of Neogene dacitic rocks as well as elements of Badenian lacustrine sedimentary rocks (sandstone, conglomerates, limestones, coal) (Igre – Vaidoia zone), blocks of crystalline schists from the basement (Cetate, Carnicel) and fragments of Cretaceous sedimentary rocks also appear. This breccia pipes occur mainly in the upper part of subvolcanic dacite bodies.

Fluidization was very intense and produced the reworking of the material from older breccias producing pellets (up to 2 cm in size) and rounded centimetric to decimetric (subordinate) blocks of crystalline basement and sometime, of Cretaceous sandstones. The mixed breccia and rhyodacite rocks are penetrated by fine, black, tuffisitic material also resulted by fluidization processes. The mixed breccia from Cetate, Carnic and Carnicel generally reveal the angular outlines of blocks and fragments; the size of elements range from less than 1 cm to 2-3 dm and the rock matrix ratio is very variable.

The mineralization is a composite system of breccia pipes and veins. The features of vein is typically for a breccias structures: mainly low angle dip, low thickness and lengths. Gray mineralized breccias forming pipes and/or shapeless bodies are intruded by black breccias; the reverse situation also has been observed. Sometimes, breccias are formed exclusively by dacites often as crackle – breccias without any movement of fragments.

In the Rosia Montana area appear numerous breccia pipes (“volburi”) as well as thin black veins of mixed fine material (“chinga”), both of them are the preferred concentration loci for the rich native gold ores.

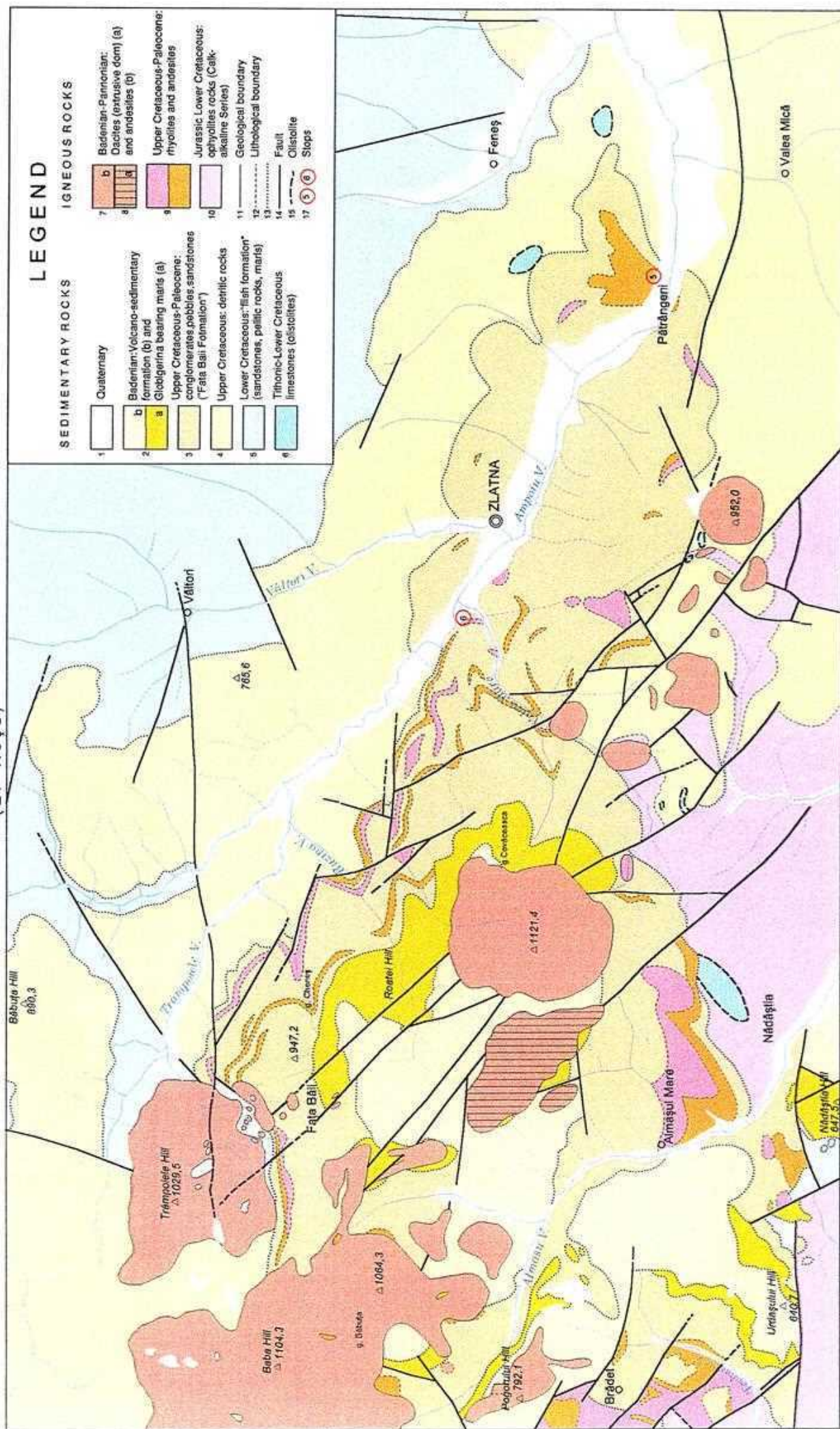
Alteration and mineralization:

Early stage : quartz, sericite, adularia ? and impregnation of euhedral pyrite crystals (about 1 mm in size).

The subsequent stages: quartz (sometimes amethyst), sericite, adularia, rhodocrosite, argillic alteration and pyrite, marcasite, arsenopyrite, gold, subordinate sphalerite, chalcopyrite, galena, alabandite, tetrahedrite; peculiar proustite, pearceite, polybasite, argentite.

Based on the pyrite morphology, the fluids of Rosia Montana structure is characterized by variations of supersaturation from low – Carnic zone to moderate values – Vaidoia – Orlea zone and from medium to high values – Cetate – Carnicel zone; the same data, show the high fluid temperatures (about 350° C). There was a moment of sudden cooling recorded by pyrite morphology (marked by abundant appearance of pentagonal dodecahedron) which is supposed to be caused by opening the system (adiabatic distension → fluid boiling → late mineralization at low temperatures).

GEOLOGICAL MAP OF ZLATNA - ALMAȘUL MARE AREA (E. Roșu)



Stop A.9. Rosia Poieni porphyry copper deposit Viorica Milu

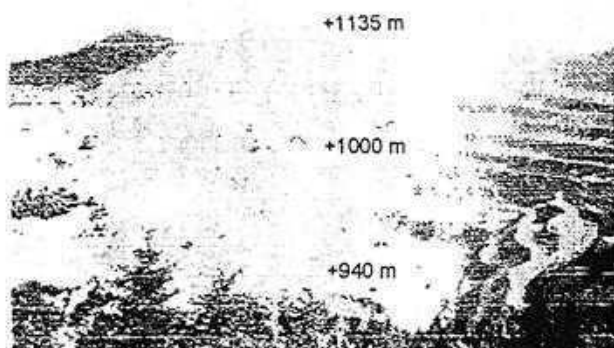


Fig. 1. Rosia Poieni open-pit mine viewed from northwest. The advanced argillic alteration occurs in the upper half part of the open pit. The numbers represent the altitude (m above sea level). The height of each bench is 15 m.

Rosia Poieni deposit is located in the Alba district, approximately 8 km southeast of the town of Abrud. Discovery resulted from local geological, geochemical and geophysical research programs carried out in the 1960's and 1970's. Later exploration by adits and drilling outlined a porphyry copper ore deposit.

Ionescu (1974) and Ionescu et al. (1975) carried out a mineralogical and petrographic study of rocks from the Rosia Poieni area. They identified the disseminated character of the copper mineralization and the zonal alteration pattern. Bostinescu (1984) presented new data regarding the geology of the deposit

and compared it to other porphyry copper deposits from the South Apuseni Mountains. Geologic information comes mainly from the open-pit mine (Fig. 1) and also from outcrops, galleries, and some exploration drilling. The present vertical extent of the open-pit mine is 300 m (between +910 m level and +1210 m level, not visible on Fig. 1).

Geological setting. The Rosia Poieni magmatic structure is located in the Rosia Montana - Bucium sedimentary basin. The basement consists of pre-Mesozoic metamorphic rocks covered by Cretaceous and Tertiary sedimentary formations (Fig. 2). The magmatic products are represented by intrusive bodies and pyroclastics of variable compositions: rhyodacites, dacites, quartz-amphibole-biotite andesites, amphibole-pyroxene andesites and basaltic andesites.

In the area of Rosia Poieni, the oldest Neogene igneous rock (intrusions and pyroclastics) is the Poieni andesite characterized by common hornblende, plagioclase, and quartz phenocrysts and a groundmass of plagioclase and amphiboles. Magnetite and apatite are accessory minerals. During the Sarmatian, the Poieni andesites were intruded by a subvolcanic body characterized by a porphyritic texture, the Fundoaia microdiorite. Hornblende, plagioclase, and minor rounded quartz phenocrysts occur together with magnetite, apatite and zircon as accessory minerals. The groundmass, microgranular in the core and in the deepest parts of the intrusive body, and progressing to a microcrystalline texture towards the periphery, consists of plagioclase, hornblende, quartz, magnetite, and apatite. The intrusion is < 1 km in diameter. The main wall rocks, the Poieni andesites, and the intrusion have similar chemical and mineralogic composition. Around the subvolcanic body, especially at its upper part, there are intrusive breccias that appear to be associated with the emplacement of the Fundoaia body.

At the periphery, amphibole-bearing andesite and quartz andesite (bodies and lava) crop out; these andesites are considered to be Sarmatian in age, too. They lack mineralization and are only propylitized (Bostinescu 1984). Pyroclastics, lavas and small bodies of brown hornblende ($\pm$ pyroxene) andesites represent the youngest volcanic products (9.3 ± 0.5 Ma, Rosu et al. 1997).

Porphyry-type ore deposit. Both the Fundoaia subvolcanic body and the Poieni host rocks show intense effects of hydrothermal alteration. The mineralization and hydrothermal alterations are spatially related to the Fundoaia intrusion. Drill and underground data define an elliptical ore body with a maximum extension of 875 m at the + 500 m level (Ionescu, 1974). The porphyry copper deposit was explored to 1200 m depth.

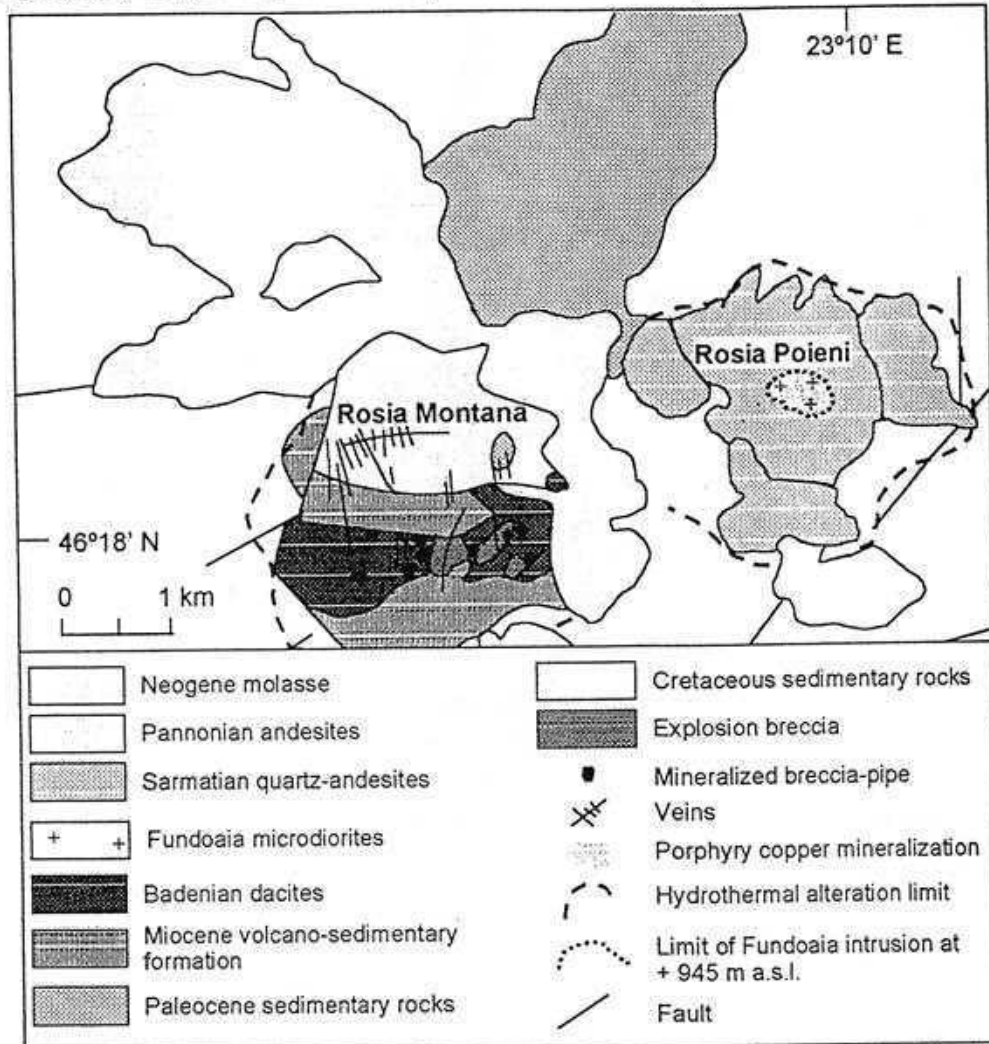


Fig. 2. Geological map of the Rosia Montana - Rosia Poieni Neogene volcanic area (Bordea et al., 1979).

The mineralization consists of pyrite, chalcopyrite, magnetite, hematite, molybdenite, and bornite with subordinate tetrahedrite-tennantite, enargite (luzonite-stibioluzonite), and digenite, and minor pyrrhotite, sphalerite, galena, covellite, and chalcocite. Chalcopyrite is the dominant hypogene copper-mineral. Mineralization occurs as disseminations through pervasively altered rocks and within veins and fractures forming a well-developed stockwork that is best developed in the potassic zone.

At least 90 percent of the disseminated porphyry copper type mineralization is located in the Fundoaia subvolcanic body, only locally extending beyond it. The Poieni andesites, that crop out in the open-pit mine show effects of intensive hydrothermal alteration and a general lack of Cu mineralization, except in the contact zone with the porphyritic intrusion. The main high-grade zone (> 0.6 % Cu) is located in the central part of the intrusion. Outside the potassic alteration limits, the copper content decreases to < 0.1 % Cu, except where phyllic alteration is superimposed on potassic alteration (Fig. 3). The upper part of the Rosia Poieni structure that is affected by advanced argillic alteration is barren (< 0.05 % Cu). Pyrite is

ubiquitous throughout the ore body and is the main sulfide in the upper part of the volcanic structure, especially in the advanced argillic zone. There is no correlation between copper and molybdenum content. Minerals from the tetrahedrite-tennantite series and enargite (luzonite) rarely occur. Gold values greater than 0.02 ppm Au (lower limit of detection) are restricted to the potassic ($\pm$ phyllic) altered rocks but on average they do not exceed 0.115 ppm (Milu, 1999). In the argillic zone, the analyzed samples generally have no detectable Au.

Alteration. Figure 3 represents a reconstruction of the Roşia Poieni volcanic structure (Milu, 1999, 2001a). This cross-section shows the relationships between the igneous rocks and alteration types and zones, and also between the porphyry copper system and more shallow environment. On the basis of different parageneses, four alteration types have been distinguished: potassic, propylitic, phyllic and advanced argillic. These alteration zones vary from a potassic core to an annular phyllic alteration through a well-developed advanced argillic zone. The propylitic zone occurs as a broad halo around the other alteration types. Vertically, the alteration products change from advanced argillic, to phyllic, and then to potassic-altered rocks at depth.

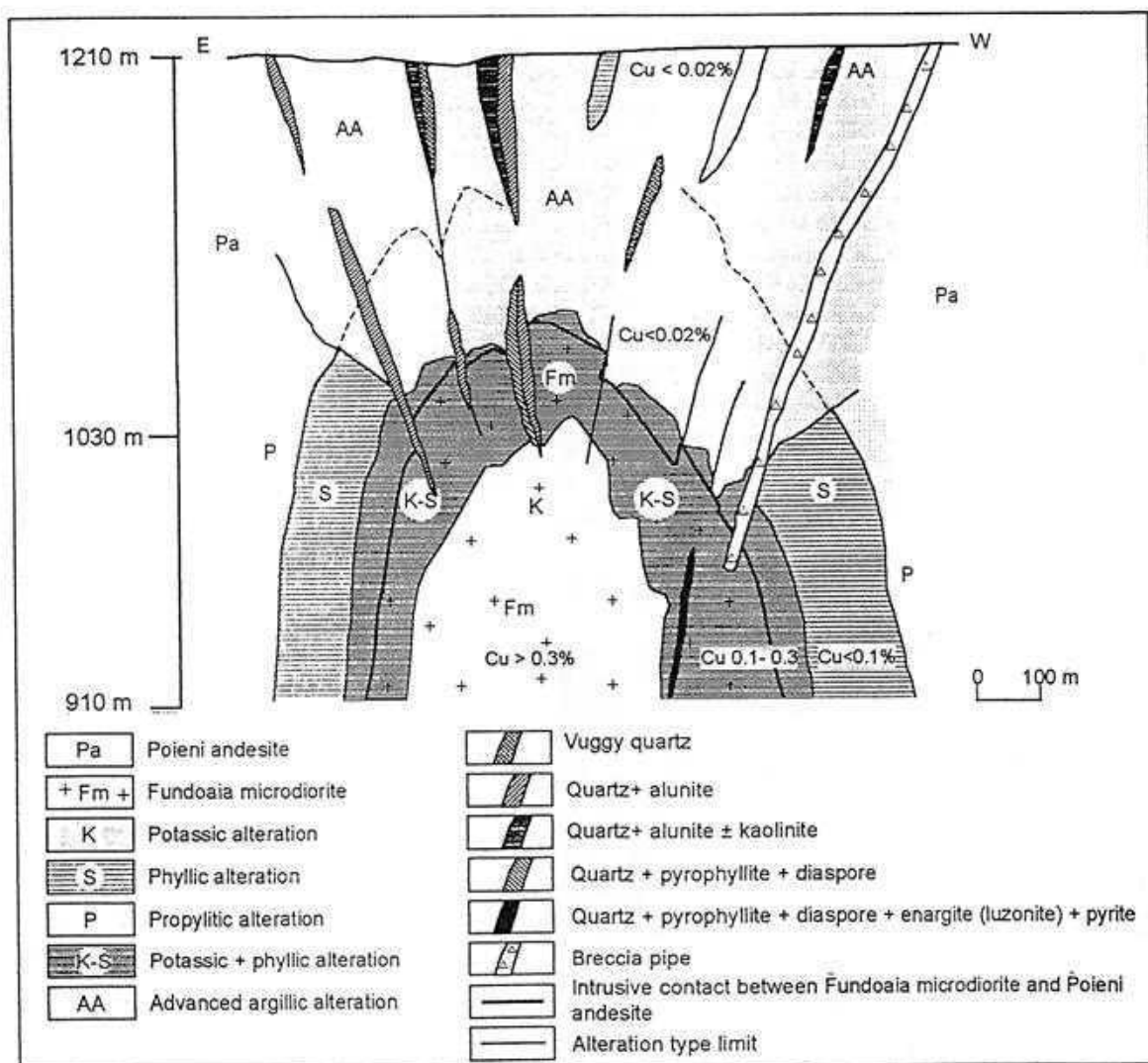


Fig. 3. Cross-section through the Roşia Poieni magmatic structure, showing the porphyritic intrusion and host rocks, the alteration types and zones, and the relationship between them (Milu, 1999, modified Milu et al., 2001a).

Potassic alteration minerals either replaced the preexisting igneous phenocrysts and groundmass or crystallized in fine veinlets. Primary mafic minerals have been partially to totally consumed. Overall, the limit of occurrences of secondary biotite generally corresponds to the limits of the Fundoia subvolcanic body. Three types of secondary biotite have been distinguished in the altered igneous rocks: replacement biotite, disseminated biotite, and veinlet biotite. *Replacement biotite* resulted from the alteration of primary hornblende and plagioclase. This biotite commonly contains rutile inclusions, occurs as anhedral to subhedral grains, both in pseudomorphous aggregates after preexisting mafic minerals and as flakes and irregular patches in the rock. *Hydrothermal disseminated biotite* crystals form fine-aggregates in the groundmass. *Veinlet biotite* occurs as well-developed flakes or fine-grained euhedral to subhedral crystals associated with quartz $\pm$ K-feldspar, chlorite, anhydrite, magnetite, chalcopyrite, and pyrite. During later phyllic alteration, alteration biotite was largely converted to chlorite and sericite. Primary plagioclase was variably altered to albite, K-feldspar, phengite, illite, interlayered illite-smectite minerals, smectites, kaolinite, and quartz. Orthoclase replaced both plagioclase phenocrysts, and together with biotite and quartz, amphiboles. The entirely rock is permeated with patches of microperthite and intergrown orthoclase and quartz.

A zone of *phyllic alteration* occurs peripheral to the potassic alteration core and overprints it. Within the Fundoia porphyritic intrusion, phyllic alteration is superimposed on marginal zones of potassic alteration products. On the Poieni andesites, this type of alteration is superimposed on the outer part of the potassic alteration zone and on the inner part of the propylitic alteration zone (Fig. 3). Phyllic alteration is characterized by the replacement of almost all rock-forming minerals and earlier alteration minerals by abundant illites (+ phengites), quartz, pyrite, variable amounts of illite-smectite mixed layers (ISII and IS), minor smectite, and kaolinite. Generally, the original rock textures are preserved. The rocks are enriched in pyrite that occurs as veins and disseminations. Feldspars are partially to completely obliterated. In rocks with early potassic alteration, phyllic alteration occurs preferentially along fissures and veinlets. They contain quartz, sericite, and pyrite $\pm$ chlorite. In the wall rocks the mineral assemblage contains secondary biotite and hydrothermal alkali feldspar (as relict minerals), albite, chlorite, and sericite. Albite replaces a more An-rich plagioclase and forms albite rims on plagioclase partially replaced by sericite, chlorite, and pyrite.

In the upper part of the Rosia Poieni volcanic structure, *advanced argillic alteration*

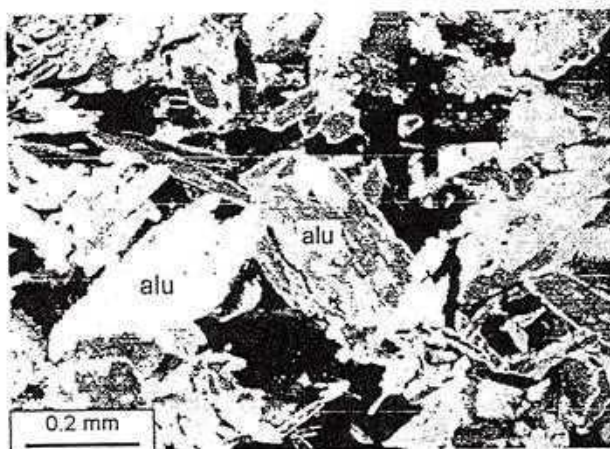


Fig. 4. Photomicrographs in transmitted light showing well-developed crystals of alunite (alu). Rosia Poieni open pit, bench + 1000 m.

overprints the earlier potassic, phyllic and propylitic alterations. The mineral assemblage consists of minerals stable in an acid, relatively low-temperature and near-surface environment: alunite, kaolinite, dickite, pyrophyllite, diaspore, zunyite, and minamiite, with sulfides including pyrite, enargite and luzonite. Vugs formed where the early rock phenocrysts were completely dissolved. Alunite (Fig. 4) crystallized in veinlets and open spaces formed by acid leaching of amphibole and feldspar phenocrysts and groundmass. Only the habit of the phenocrysts can be recognized. Alunite was detected between the + 1000 m level

(in the open pit) and + 1256 m level (the surface prior to mining). The presence of alunite in

the top of the intrusion supports a shallow-level of emplacement of the Fundoia porphyritic body. Pyrophyllite and diasporite occur in the advanced argillic assemblage, particularly at deeper levels. Zünite was found associated with quartz, pyrophyllite, alunite, and minamiite. The zünite presence is consistent with a magmatic-hydrothermal environment (Reyes 1990). Disseminated pyrite is common in the advanced argillic alteration zone. Veins with enargite (luzonite) occur both within and outside the porphyry intrusion. Within the top of the intrusion there are veins (cm to dm in width) with luzonite and pyrite associated with quartz, pyrophyllite, and diasporite. The diasporite contains a mineral of the *svanbergite-woodhouseite* series, which forms under acid conditions (Stoffregen and Alpers 1987).

The *propylitic alteration* occurs distal to all other alteration zones, extending beyond the open pit boundary. Propylitic alteration is pervasive and is represented mainly by chloritization of the primary amphibole phenocrysts (common hornblende) and groundmass material. Feldspars are fresh or are partially replaced by albite, carbonates, epidote, and sericite.

Melt and fluid inclusion data. The euhedral quartz crystals and grains from the vein system show several stages of crystal growth, corresponding to repeated pulses of fluid circulation through the rock. Detailed fluid inclusion study (Pintea, 1993, 1995, 1996, and in preparation) show that the earliest fluid phases are characterized by a double immiscibility: firstly between magmatic (glass – bearing) and brine inclusions (silicate magma/saline melt immiscibility; Pintea, 1995), and secondly between highly concentrated brine and vapor-rich inclusions (liquid/vapor immiscibility = boiling). The homogenization temperature in silicate glass and associated salt-rich inclusions ranged between 1100 and 920°C, although the brine inclusion microthermometry showed even more large intervals of homogenization temperature between 1100 and 450°C. It should be noted that the lowermost values are correspondent to halite homogenization temperatures. The salinity values estimated by halite point dissolution temperatures ranged between 60 – 90 wt. % (NaCl + KCl) for 206 determinations (Pintea, 1993). The successive episodes of incipient boiling correspond to significant differences in the overall chemical composition of the different fluid types (Damman et al., 1996). In each episode, various metals are involved: Fe and Cu in the first episode, and other elements (Pb, Zn, Br, Rb, Sr) in the second episode. Metallic elements in the vapor-rich inclusions witness to the possibility of metal transport in the gaseous phase during the boiling processes.

Evolution of hydrothermal processes. Based on the chemical compositions of the alteration minerals, the relationships between them, the mineralization parageneses, and the application of mineral geothermometry, information about the evolution of the system was obtained (Milu, 1999, Milu et al., 2001a). The alteration types appear mainly to be controlled by the chemical composition of the hydrothermal fluids and/or the temperature of the system, with a continuity from magmatic to hydrothermal conditions as indicated by fluid inclusion data (Pintea 1993, 1995, Damman et al. 1996). The alteration minerals reflect cooling of the hydrothermal system from > 400°C (biotites), to 300°-200°C (chlorites and illites in veinlets) and then to the lower temperatures of kaolinite, illite-smectite mixed layers, and smectite crystallization. Hydrothermal alteration started with an extensive potassic zone in the central part of the system that passed laterally to propylitic zone. It was followed by phyllic overprint of the early altered rocks. Nearly barren advanced argillic alteration subsequently superimposed the upper levels of the porphyry copper alteration zones.

Stop. A.11. Valea Morii porphyry copper and epithermal gold vein deposit

L. Nedelcu, I. Pinte, E. Rosu, P. Ivascanu and S. Riemer

Valea Morii ore deposit belongs to the Barza mining field of the famous "Gold Quadrilateral" of Apuseni Mountains and is located about 10 km southeast of the town of Brad. Barza mining field comprises two main porphyry copper and epithermal gold vein deposits (Valea Morii and Musariu) and also two epithermal gold vein deposits (Bradisor, Carpen). Recently, nearby the Valea Morii structure, a new porphyry copper body named Spiros was discovered.

Geology of this area is characterized by the presence of Mesozoic island arc volcanics (basalts, andesites, diorites), Miocene sedimentary and volcano-sedimentary (Badenian) deposits and volcanic and subvolcanic rocks of Sarmatian-Pannonian age. The Tertiary volcanics consist especially of pyroclastics, flows and intrusion of the Barza andesite type (Ghitulescu, Socolescu, 1941; Ianovici et al, 1969; Borcos et al., 1980; Berbeleac, 1980) (see geological sketch).

According to Borcos and Berbeleac (1983) the Valea Morii intrusion was formed during two major events followed by an minor one. The main intrusion was divided into two textural units: 1) the oldest one consists of hornblende + biotite and pyroxene andesite-quartz porphyry andesites and 2) another one, more recent, which composes dyke-like porphyry diorite- quartz porphyry diorite. The minor intrusive event, less frequent, is characterized by quartz porphyry hornblende $\pm$ pyroxene dykes (younger diorites).

The fault system of Valea Morii structure reveals a north-south strike with a 60-80° W dipping. These faults cross-cutting the porphyry copper mineralization and represent the hydrothermal solution circulating ways responsible for native gold and polymetallic ore vein formation.

The quartz sulfide veinlet stock of the porphyry copper body consists of at least three systems of veinlets (Borcos, Berbeleac, 1983). Most of the veinlets, trending NW-SE and E-W, dip steeply southwest and north or are nearly horizontal.

Porphyry copper mineralization

This type of mineralization is intimately related to a porphyry stock/body of amphibole and pyroxene andesite that intruded the volcano-sedimentary and volcano products. The best interesting aspects of this mineralization could be observed in Valea Morii open pit (see Fig.).

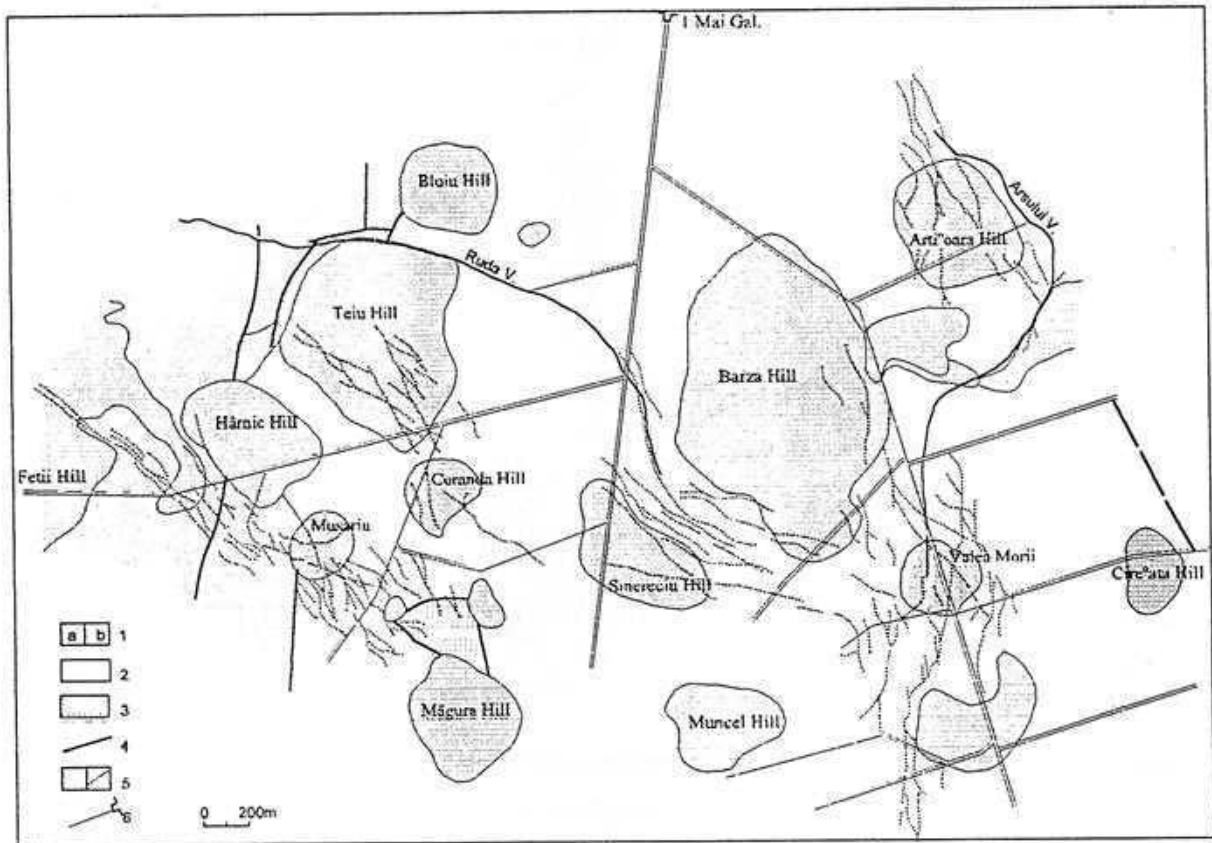
The main ore minerals of porphyry stock are chalcopyrite and pyrite hosted in the greish - violaceous coarse quartz veinlets where they are frequently associated with magnetite. Minor amounts of bornite, sphalerite and hematite have been also found (Borcos, Berbeleac, 1983).

According to mutual relationships among mineralized veinlets that cross-cutting each other the following sequences of ore mineralization deposition could be presumed:

- 1) quartz-magnetite-pyrite-chalcopyrite
- 2) quartz-pyrite $\pm$ chalcopyrite
- 3) anhydrite/gypsum-pyrite
- 4) Ca and Fe carbonates (calcite, siderite).

Concerning the type and distribution of alteration within the porphyry body one can see a general zoning with a potassic core followed lateraly by a prophylic alteration and a argillic one.

A detailed picture on this alteration zoning is depicted by Borcos et al. as follows:



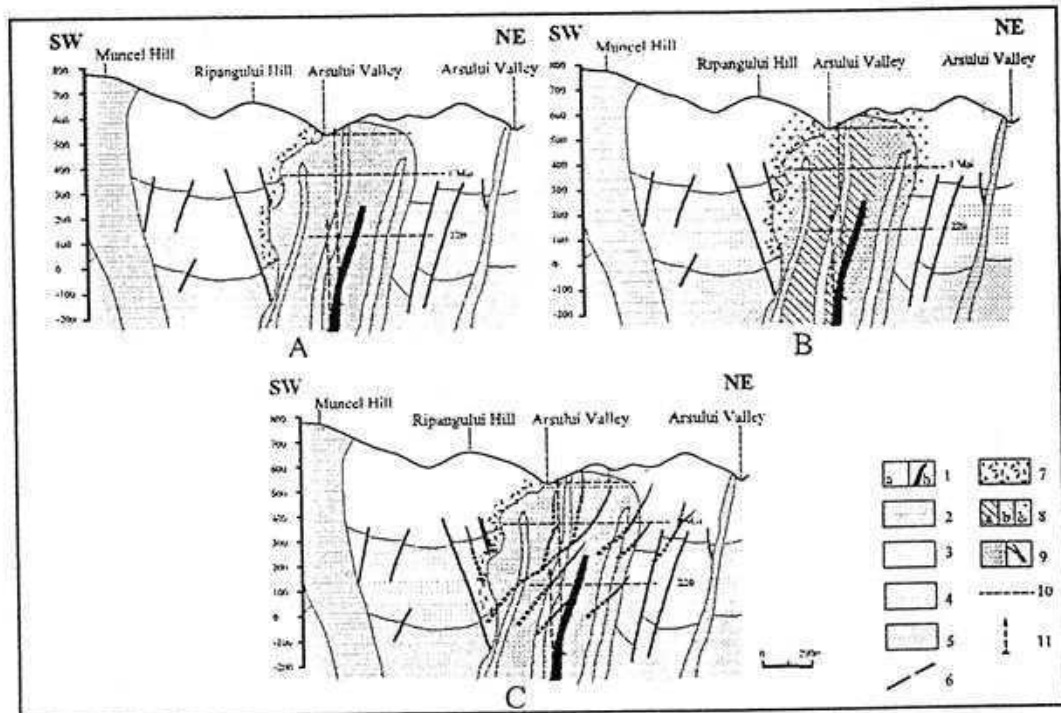
Geological sketch of the Barza -Musariu area (after Borcos and Berbeleac, 1983), 1, andesite - quartz andesite (Upper Badenian - Pannonian); a, neck and dyke; b, pyroclastics and lavas; 2, sedimentary and volcano - sedimentary deposits (Upper Badenian in age); 3, island arc volcanics (Upper Jurassic - Lower Cretaceous); 4, fault; 5, porphyry copper (a) and native gold - base metal deposits (b); 6, 1 Mai gallery.

The potassic alteration is represented by potash feldspar and biotite. In this case the main minerals generated by the potassic alteration are the orthoclase, microperthite, biotite and chalcopyrite.

The propylitic alteration affects both the central zone of the mineralized andesitic body superposing to the potassic alteration, and its outer zones. The propylitization took place in space being differentiated by the formation of three mineral assemblages: chlorite - calcite $\pm$ talc - montmorillonite - kaolinite (1) epidote-chlorite $\pm$ calcite $\pm$ albite (2) and chlorite-epidote-calcite (3).

The propylitized rocks preserve their primary structure in the fissure fillings, being accompanied by quartz, chalcopyrite, magnetite and pyrite.

The propylitic alteration that mainly marks the outer part of porphyry stock includes two-mineral assemblages as hydromicas-kaolinite-montmorillonite $\pm$ illite and sericite-chlorite-montmorillonite. These minerals/assemblages appear also in the vicinity of the veins and towards the deeper levels of the andesitic body, as well as in the central zone of the ore deposit, within the inner core, wherein most of the potassic and propylitic mineral assemblages are lacking. During this alteration stage the rock structure and texture disappear.



Reconstruction of the Valea Morii deposit formation (after Borcos and Berbeleac, 1983) A, schematic geological cross-section; B, early alteration - mineralization stage; C, late alteration - mineralization stage. 1(a), diorite - quartz porphyry diorite (older diorite); 1(b), hornblende + pyroxene porphyry diorite (younger diorite); 2, andesite quartz - porphyry andesite intrusions; 3, andesitic and quartz andesitic pyroclastics and flows; 4, sedimentary and volcano - sedimentary rocks (Upper Badenian in age); 5, island arc volcanics (Upper Jurassic - Lower Cretaceous); 6, fault; 7, breccia; 8, potassic (a), propylitic (b) and sericitic - argillic alteration (c); 9, porphyry copper (a) and native gold and base metal deposits (b); 10, mining level; 11, drilling.

The last detailed observations on alteration and mineralization of the Valea Morii porphyry copper ore deposit has been performed by Reimer and Ivascanu in open pit during 2000 fieldworks.

The dominating background alteration is chlorit-epidote-sericite-calcite ("propylitic") systematically overprinted by sericite- quartz or illite-montmorillonite-caolinite related to epithermal veins development. The K-fsp alteration is always overprinted by "propylitic alteration" at scale of outcrop or cm developed related to mt and/or quart-mt veinlets in core forming fresh porphyry diorite.

Summarising all observations on the relative chronology of porphyry style veins (+ associated alteration styles) of different mineralogy we can define a systematical time sequence as follows:

1. Fragments of porphyry veins (q>) in core porphyry andesite(-> diorite) indicate a non continuous intrusion/cooling down process
2. Either tiny pure mt-veins or pure qtz veins represent the relatively oldest PC vein generation, reversal crosscutting between them or mixed qtz-mt veins suggesting

synchronous deposition. Further, if potash alteration was observed, it would always develop as K-fsp rims along the first stage porphyry veins (pure qtz, pure mt or qtz+mt veins)

3. Sulphide-bearing veins (cpy and/or py) always crosscutting the (2) type veins and more veins with an higher amount of sulphide minerals are crosscutting veins with less sulphide minerals; e.g. pure sulphide veins are always younger than qtz-sulphide
4. Carbonates, either in new developed cracks or in reopened porphyry veins of any style described above, always represent the last event of mineral precipitation and therefore fluid flow. The fluid that precipitated the carbonates (Fe-bearing double carbonates / calcite), very often causes a sericitic vein alteration halo. The fluid that precipitated the carbonates might be the first generation of the epithermal mineralising stage.

Gypsum / anhydrite bearing or monomineral veins is ubiquitous, but can be connected with overprinted propylitic alteration. Generally the gypsum/anhydrite bearing veinlets are subsequently to main porphyry mineralization.

The observed epithermal veining occurred in a bigger scale (outcrop) than the porphyry veining (hand specimen). Therefore no real crosscutting relations were observed. The relative chronology is rather based on single vein observations, which recorded several stages of fluid flow and mineral precipitation.

1. Large-scale epithermal veins (outcrop scale) developed more or less distinct planar fabrics.
2. Small-scale epithermal veins (hand specimen scale) followed and reopened more or less pre-existing porphyry style veins.
3. Sphalerite and few galena (rarely observed) are commonly located towards the rim of the big epithermal veins.
4. This stage of mineralisation is followed by quartz +/- pyrite precipitation; especially the occurrence of pyrite doesn't seem to be very systematically.
5. Qtz+py is commonly followed by a volumetrically dominating period of pure qtz-precipitation.
6. Something like "vuggy" silica was observed in a few veins; this documents the relatively earlier precipitation of a not preserved mineral with well-developed cleavage. These minerals might have been carbonates, which were dissolved by the fluid that crystallised the euhedral qtz-xx in the open vugs of the epithermal system.
7. Barite overgrowths euhedral qtz-xx in vugs and cavities and represents therefore the latest precipitated mineral.

The propylitic intrusive rock is characterized by almost fresh mafic phenocrysts, which is consistent with a small degree of veining. Close to veins chlorite replaces mafic minerals and the fsp starts to become sericitic. Complex alteration overprinting sequence, following different stages of fluid flow. In this special case mt-veins are crosscutting the porphyry-style qtz vein (with a sequence of alterations). This mt-veins are crosscut themselves by qtz+sulphide veins. Reopened porphyry veins filled with qtz+ZnS+PbS (few) (this refill may belong to breccia 2 event).

The alteration patterns, mineralogy and crosscutting relation suggest the following sequence of mineralization:

<i>Vein mineralogy</i>	<i>Alteration pattern</i>
<i>tiny black quartz-magnetite veins</i> <i>quartz-magnetite-chalcopryrite veins</i>	<i>related to K alteration</i> <i>orthoclase-biotite-microperthite</i>
<i>quartz-pyrite-chalcopryrite+-magnetite veins</i> <i>quartz – pyrite+-chalcopirite veins</i> <i>chlacopryrite only veins</i> <i>anhydrite/gypsum-pyrite+-calcite</i>	<i>overprinted "propylitic alteration" or feldspar</i> <i>destructive alteration characterized by:</i> <i>chlorite-calcite+-kaolinite-montmorillonite</i> <i>epidote-chlorite+-calcite+-albite</i> <i>chlorite-epidote-calcite</i>
<i>quartz-pyrite-calcite</i> <i>calcite-siderite+-pyrite</i> <i>Characteristic reopening and filling of first to stage</i> <i>type veins</i>	<i>Sericitic and argillic alteration characterized by:</i> <i>Sericite-chlorite-illite-montmorillonite</i> <i>Hydromicas-kaolinite-montmorillonite+-illite</i>
<i>Epithermal base metal and gold bearing veins</i>	<i>Sericite-chlorite-clay minerals</i> <i>Clay minerals</i>

Stop A. 12. Ormindea. Bellvedere of Neogene volcanic structure towards eastern part of Baita sedimentary basin (Cetras, Stogu, etc.)

Stop A.13. Bolcana porphyry copper deposit

Viorica Milu, Ioan Pinteau

The Bolcana deposit is located in the Hunedoara district, approximately 15 Km northeast of the town of Deva. The ore deposit have been identified and studied beginning with 1970's resulting in important contributions (Andrei et al., 1973; Vasilescu and Covaci, 1977-1983; Bostinescu et., 1978, 1981, 1983, 1993; Udubasa and al., 1978, 1981 - GIR internal reports; Velciov et al., 1986, 1990 - MINEXFOR SA internal reports).

Local Geology. The Bolcana deposit belong to the Neogene Brad-Sacaramb metallogenic district. The basement of the area consists of Middle Jurassic-Lower Cretaceous ophiolitic rocks (basaltic andesites and basalts as lava flows and pyroclastics) and Lower Cretaceous rhyolites (Baita rhyolites) overlaid by a Paleocene sedimentary formation (Almasul Mare Formation) characterized by gravels, sands and silty clays (Borcos et al., 1986). Unconformably, a sedimentary formation (Middle Miocene in age) outcrops. It consists in clays, sands and gravels (Lupu et al., 1982) (Fig. 1).

In the area of Bolcana, the oldest Neogene igneous rocks are represented by andesites that occur as lava flows, intrusions and pyroclastics. They are Sarmatian in age and are known as Hondol-Faerag andesites. A subvolcanic body (Bolcana intrusion) of microdioritic composition intrudes these andesites. Bolcana body is located in the central part of the Dumbravita - Teascu - Faerag Neogene volcanic zone (Cioflica et al., 1966) and it outcrops in a small area (Fig. 1). The Bolcana intrusion was explored to 1300 m depth. Around the subvolcanic body there are intrusive polymictic breccias (with ophiolitic and Neogene andesitic elements). The youngest volcanic products are represented by quartz andesites (Fig. 2). They lack of mineralisation (Bostinescu, 1984).

Mineralisation. Bolcana is a porphyry Cu-Au ore deposit with associated epithermal veins. The distribution of copper mineralisation and hydrothermal alteration show a close spatial relationship to the Bolcana porphyry. In horizontal section, at the Grimm horizon (+ 320 m), the mineralised body has a maximum extension (750 m / 440 m).

The porphyry Cu-Au mineralization is represented by chalcopyrite, pyrite, bornite, magnetite, hematite, molybdenite, with subordinate gold (mainly as inclusions in chalcopyrite). Chalcopyrite is the dominant copper mineral (Fig. 3). Rock analyses show that Cu is positively correlated with Au, whereas there is no correlation between these elements and Mo. The Cu and Au contents increase with depth, the high-grade ore being within Bolcana intrusion affected by potassic $\pm$ phyllic alteration.

The epithermal mineralisation consists of pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, bournonite, marcasite, native gold, arsenopyrite and pyrrhotite. There are polymetallic veins in gangue of carbonates and auriferous veins in gangue of quartz (Udubasa et al., 1978, 1981 - GIR internal reports).

Alteration. On the basis of different parageneses, four alteration types were separated (Milu, 1999; Milu et al., 2001b): potassic, phyllic, argillic and propylitic. The *potassic*

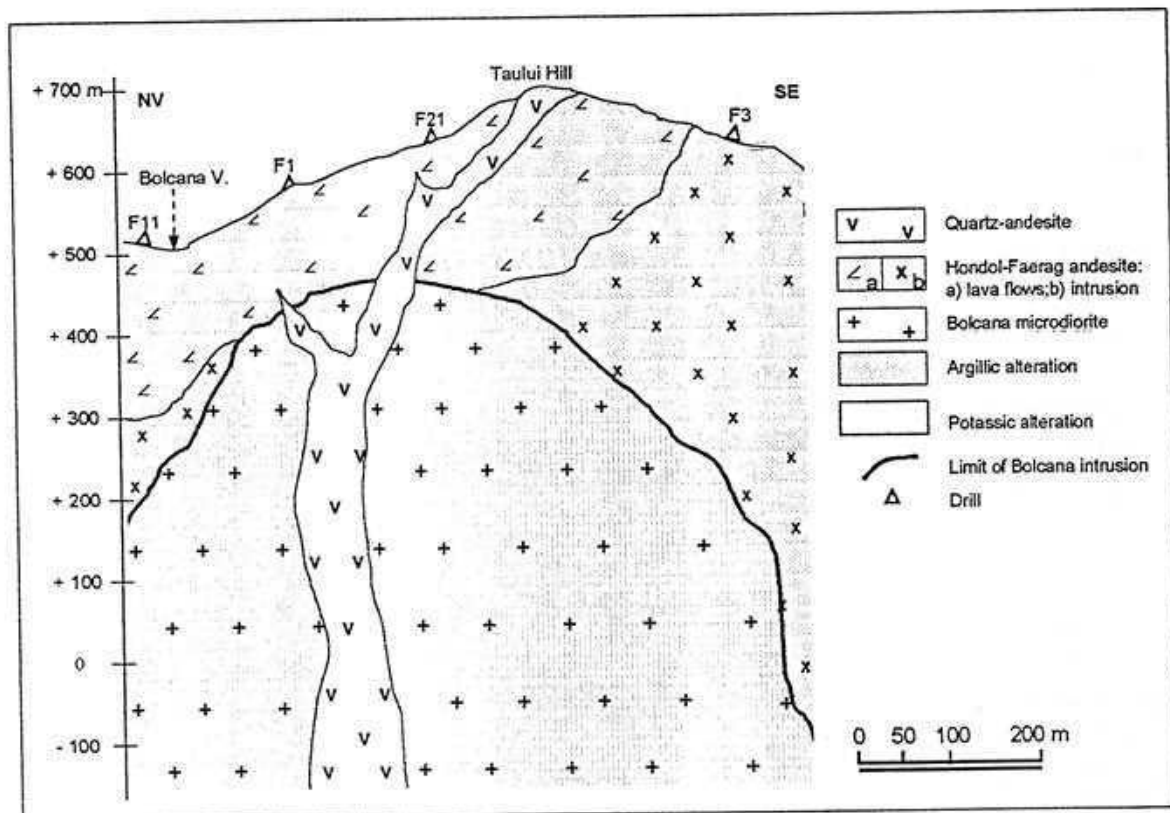


Fig. 2. Simplified cross-section through the Bolcana structure (Bostinescu, 1993 - unpublished data).

upward either to phyllic and then to argillic alteration or directly to argillic alteration. The drilling data in the core of porphyry intrusion indicated that potassic altered rocks are still present to 1000 m depth (e.g. F4 drill, Fig. 1).

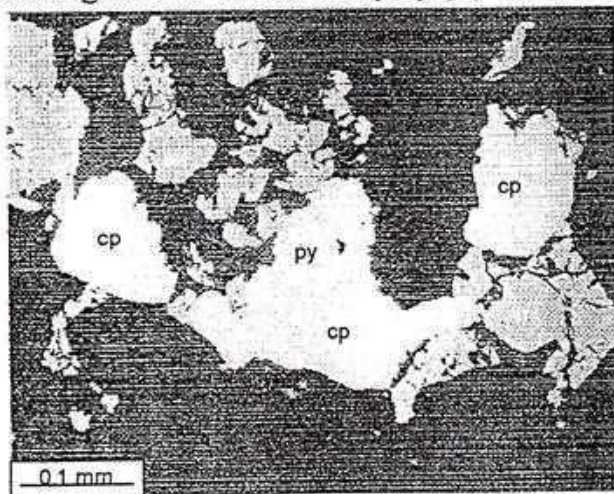


Fig. 3. Photomicrograph in reflected light showing the association chalcopyrite (cp), pyrite (py) and magnetite (mt). Drill F4, depth 736 m.

The biotite (Mg-biotite), and K-feldspar are the essential minerals in this assemblage; chlorite (clinochlore 1MIa and 1MIb), anhydrite, actinolite, albite and sericite are also present. The *phyllic alteration* is developed at a low level and the characteristic minerals both crystallized in veinlets and replaced the pre-existing minerals in wall rocks. The phyllic assemblage consists of illite, phengite, illite-smectite mixed-layer minerals (ISII and IS), quartz and pyrite, with subordinate chlorite, anhydrite and relicts of biotite and K-feldspar.

The *argillic alteration* (intermediate argillic type) affected the upper part of the Bolcana

system. This alteration type is characterized by the presence of kaolinite, smectite, mixed-layer minerals and carbonates. Fissures bearing alteration minerals characteristic of phyllic and argillic alteration crosscut even the deeper part of the porphyritic intrusion. The *propylitic alteration* affected mainly the Hondol-Faerag andesites and occurs like a broad halo of the other alteration types, and as relict islands to the margins of the argillic alteration zone. Propylitic rocks consists of chlorite, epidote, actinolite, and minor sericite and carbonates. The large development of sulphidation (Udubasa et al., 1978) and carbonatation (calcite) is a particularity of Bolcana hydrothermal system. Anhydrite often replaced by

Fig.

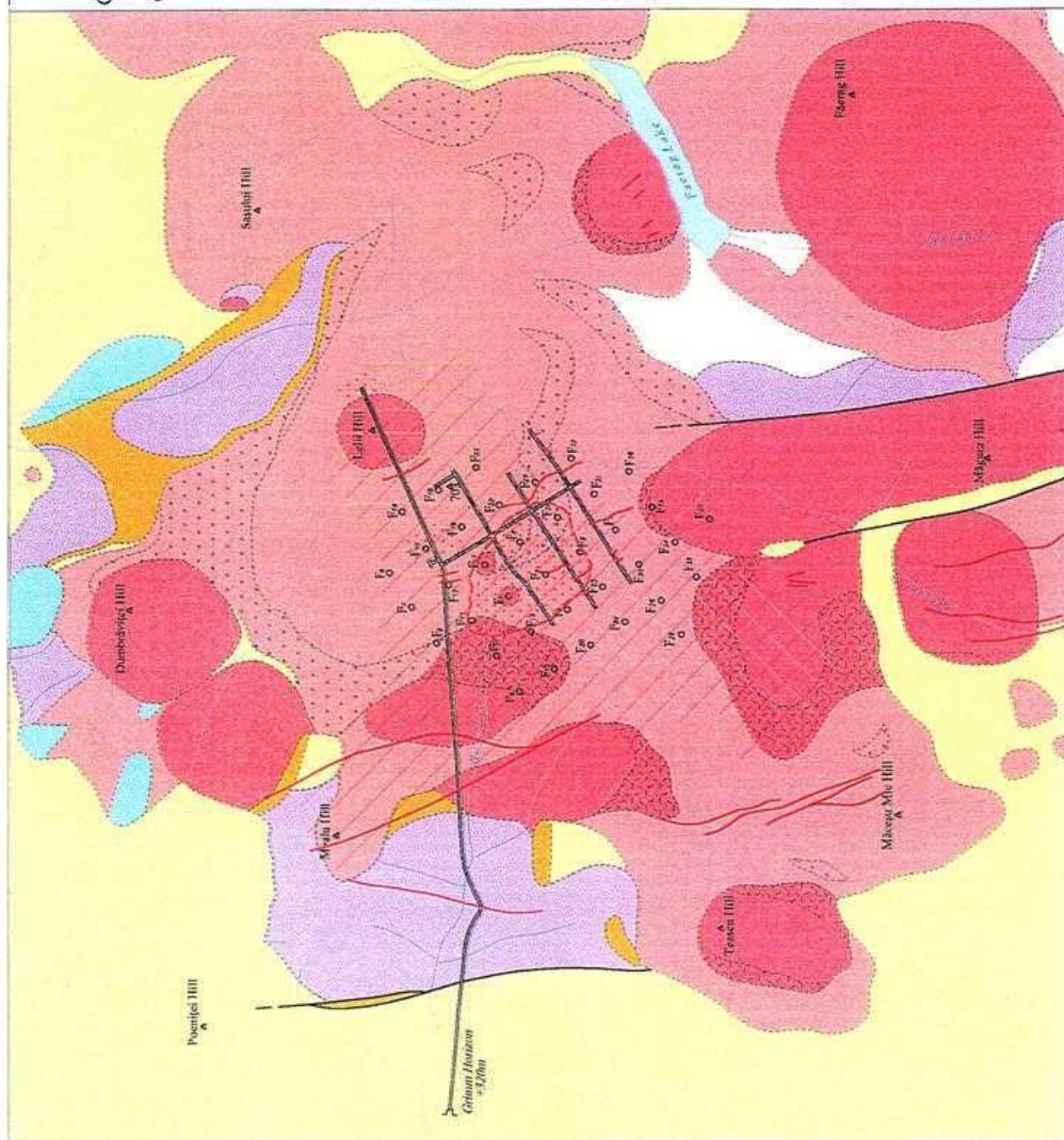
O. VASILESCU, S. COVACI (1982)
GEOLOGICAL MAP OF THE TROITA - MĂGURA
MINING AREA

Used materials: L. VASILESCU, O. VASILESCU, A. STEFAN (1959); B. JUDE (1960); G. CIOPLIKĂ,
G. UDUBAȘA, G. ISTRATE (1965); N. BERINDE, E. EGRY (1973); G. UDUBAȘA (1981)

0 100 200 300 400 500 1000 m

LEGEND (modified)

- | | |
|-------------------------------------|---|
| SARMATIAN -
LATE DARDENIAN | Andesite: a) lava flows; b) necks, dykes;
c) breccias; d) pyroclastics |
| MIDDLE MIocene | Clays, sands, gravels |
| PALEOCENE | Almasul Mare Formation
(gravels, silty clays, sands) |
| EARLY
CRETACEOUS | Baita rhyolites |
| LATE JURASSIC | Reef limestones |
| EARLY CRETACEOUS
MIDDLE JURASSIC | Ophiolites (basalts, andesitic basalts) |
| | Argillised rocks |
| | Silicified rocks |
| | Sericitised rocks |
| | a) vein
b) Mineralisation
b) dissemination |
| | Limit of Bolcana intrusion
at Grimm horizon |
| | Fault |
| | Gallery |
| | Drill |



gypsum (especially where phyllic + argillic alteration overprints the potassic alteration) occurs both in the veinlets and groundmass.

Melt and fluid inclusion data. At Bolcana fluid and melt inclusions show almost the same characteristics as the other investigated porphyry copper deposits (Pintea, 1996). Although it should be stressed that anhydrite and magnetite as daughter minerals seem to be a special feature of the polyphase saline melt inclusions in this ore deposit. High homogenization temperatures, between more than 800 to 1100°C, were obtained in salt melt inclusions. These inclusions are frequently synchronous with silicate glass inclusions in the growth zones of coarse grain quartz from the veinlet network. Salinity based on halite melting point ranged between 60 – 80 wt % NaCl equiv. ($n = 50$). The minimum trapping pressure (inferred from H₂O – NaCl system phase equilibria) that corresponds to the recorded temperatures and estimated salinity range between 0.5 and 1 kb (Chou, 1987).

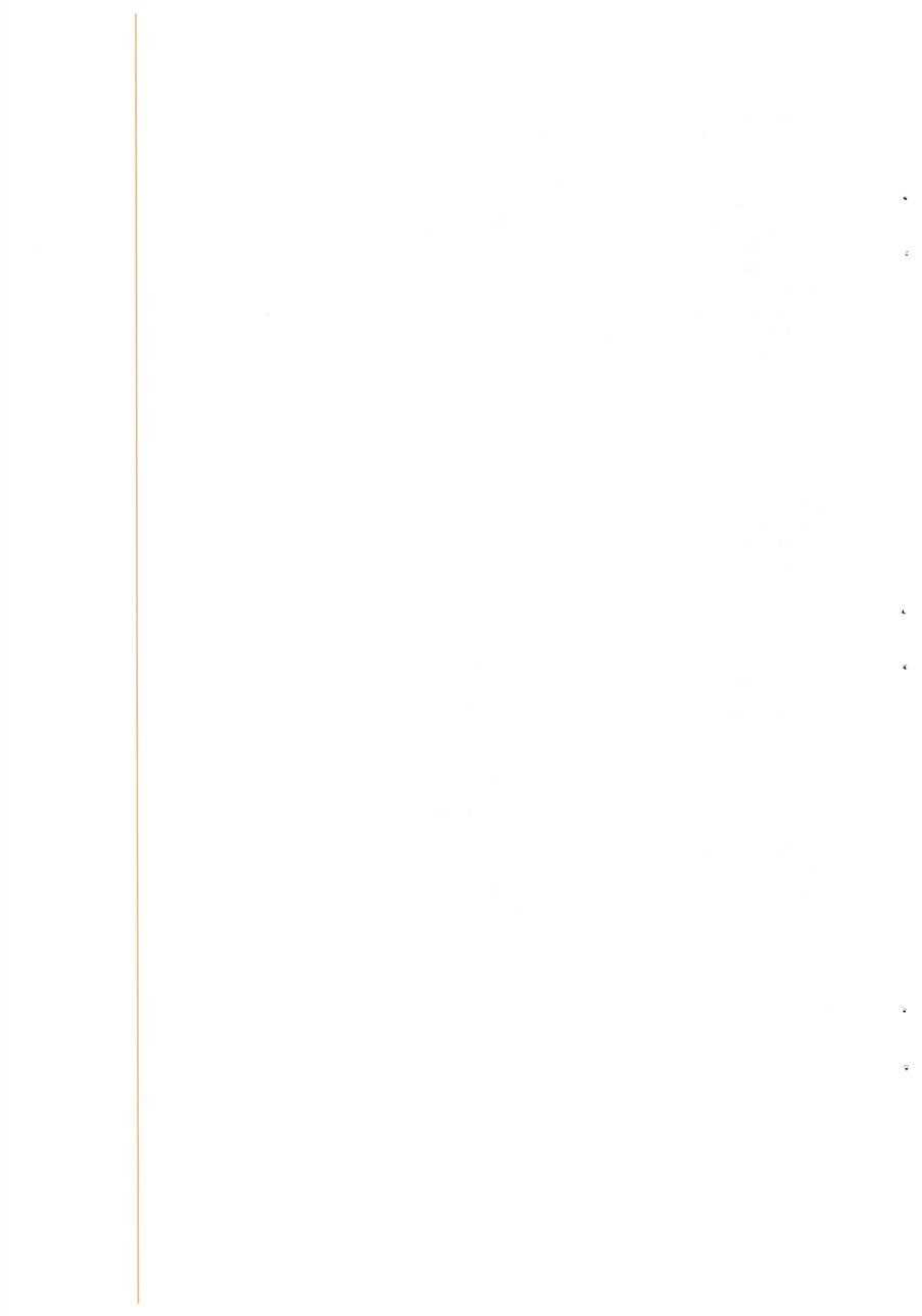
Geothermometry on the alteration minerals. Using mineral chemistry of some alteration minerals their crystallisation temperatures were estimated applying different geothermometers (Tab. 1) (Milu et al., 2001b). Taking into consideration the values obtained and also the alteration zones and the stability domains of specific minerals, the alteration pattern at Bolcana is the result of an overprinting of the alteration process. Propylitisation seems to be nearly simultaneous with, but peripheral to, potassic alteration. Phyllic alteration post-dates the potassic alteration and it is supposed would have formed a reduced halo around the Bolcana intrusion. Argillic alteration overprints the other alteration types.

Geothermometer	Crystallisation temperatures		
<i>Illite</i> (Cathelineau, 1988)	260 - 230°C (replacement illite)		
<i>Chlorite</i> (Cathelineau et Nieva, 1988)	355 - 345°C (chlorite in veinlet)	320 - 285°C (chlorite on groundmass)	275 - 265°C (chlorite on phenocrysts)
<i>Biotite</i> (Le Bel, 1979)	450 - 350°C (replacement biotite)		

Decreasing
temperature
↑

Table 1. Crystallisation temperatures of illite, chlorite and illite (Milu et al., 2001b)

Conclusions. The studies on the Bolcana deposit indicate an evolution of the system from an early period of porphyry copper mineralisation to a late period of epithermal mineralisation. The potassic alteration and porphyry copper mineralisation are spatially related and are thought to be formed almost at the same stage with the likelihood that the mineralisation process continued during later alteration process.



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ABCD – GEODE 2001 WORKSHOP VATA BAI, ROMANIA
8 – 12 June, 2001

Geodynamics and Ore Deposit Evolution
of the Alpine-Balkan-Carpathian-Dinaride Province



STOPS IN EXCURSION C
(11 June)

Stop C.1. "Gold Museum" - Brad.....	1
Stops C.2. and C.3. High temperature skarn occurrences in Magureaua Vatei area, South Apuseni Mts.....	2
Stop C.4. Vein copper ore deposit from Cazanesti Valea Caprei area.....	6

Bucharest, 2001

Stop C. 1. "Gold Museum" - Brad Verdes G.

The small Brad town has always been "the capital gold" in the Metaliferi Mountains, being situated within the area with the richest and most productive gold deposits in the Carpathians. Brad was also the headquarters of the "Mica" Mining Society acting between the World Wars I and II. Beside the gold production furnished for centuries (the Mining Enterprise Barza is still operating) the Brad town possesses one of the "most precious museums" in Romania, i.e. the museum of gold samples from all the gold mines in the Metaliferi Mountains. The recorded setting up of museum goes back to 1912 but it seems that the collecting of gold samples began as early as 1896. Not only gold samples from the Brad area - as it was at the beginning of the collecting activity - but also from other ore deposits in Romania gradually entered the museum. There are also donated samples as well as samples obtained by exchanges with domestic foreign museums. The museum still belongs to the Barza mining Enterprise.

Over 2200 samples are contained by the museum, some 1000 of which are of gold; the remaining ones represent a systematic mineralogic collection with samples from different occurrences in Romania and in the world. In addition, the museum possesses also some archaeological pieces, old mining working tools as well as photographic records dating back to the beginning of the XX century.

The museum has 8 exhibiting rooms, most of them hosting an amazing number of gold samples of different forms. There are samples with needle-like, lamellar, moss-like gold or dendrites and even crystals of gold. Nice zoomorphic gold samples (lizards, ducks, pelicans, poppies, bird wings etc.) and gold leaves and flowers, as well as nuggets are presented. In addition, most of the gold and silver tellurides are found here, among which those with nagyagite (Blattertellur) and sylvanite (Schrifterz) are outstanding samples.

The most intriguing and beautiful samples are those from the Valea Morii mine including threadlike gold with small crystal of calcite and quartz strung on its; there are also fine gold lamellae as well as gold-galena intergrowths. The famous sample with the gold crystal (about 1 cm in size) has been furnished by this marvellous mine too. Interesting are also the various associations of gold with barite, typical of the Bradisor mine.

The Musariu mine was and still is the king of gold mines in the Metaliferi Mountains. It produced the greatest amounts of gold and furnished also beautiful gold samples. The animal-looking gold forms came from here. Very typical of the Musariu mine is the association of gold with calcite crystals (scalenohedra, rhombohedra) as well as the various intergrowths of gold with arsenic. The gold plate reminiscent of Romania's outline has been found in the Musariu mine.

Beside the systematic mineralogy comprising interesting samples of diamond (South Africa), sulphur (Italy) a big pyrite cube (10 cm in size) etc, the museum contains also a collection of agates from Romania, Australia and Brazil, samples of amber from the Baltic Sea coast and a special exhibition presenting many of the minerals having the type localities in the Metaliferi Mountains or in Romania, e.g. nagyagite, sylvanite, native tellurium, pseudobrookite, etc.

Stops C.2. and C.3. High temperature skarn occurrences in Magureaua Vatei area, South Apuseni Mts. Marincea S.

The first part of this half-day excursion affords a look at two of the most spectacular occurrences of high-temperature calcic skarns in Romania: the upper Cerboaia Valley (Magureaua Vatei) and the Cornet Hill. Both occurrences are located at some 7 km south-southwest from Vata Bai and at approximately 20 km west of Brad (which is the closest town) and are accessible only partially by car. They represent two of the very rare occurrences of high-temperature calcic skarns in the world (fewer than forty records of such rocks were mentioned to date by various authors).

The occurrence of high-temperature skarns at Magureaua Vatei and Cornet Hill has been known for over two decades (Stefan *et al.*, 1978; Istrate *et al.*, 1978). A third occurrence, *i.e.* that at Oravita, has been described by Constantinescu *et al.* (1988) and a fourth, at Ciclova is under study (Katona *et al.* - in prep, Marincea *et al.* - in prep.).

The high-temperature calcic skarns from Magureaua Vatei and Cornet Hill occur at the very contact of two monzodiorite - quartz monzonite bodies which probable age is Paleocene - Ypresian age according to Stefan *et al.* (1988). These magmatic bodies were certainly emplaced during the "banatitic" event, of Late Cretaceous - Paleogene age, and may be described as "banatite" using the term coined by von Cotta (1864).

Stefan *et al.* (1982) published a comprehensive account of the intrusive rocks of the area and quotations in the text are from their paper. The intrusions from Cornet Hill and Magureaua Vatei are among the more basic of the banatitic suite in the area. They consist largely of quartz-monzodiorites and monzodiorites with subordinate granodiorites and quartz monzonites, and were emplaced at shallow crustal levels during the second cycle of the banatitic evolution in the Apuseni area (Stefan *et al.*, 1988). Marginal facies of syenite may be interpreted as metasomatic products (*i.e.*, inner endoskarns or "contaminated" rocks: Pascal *et al.*, 2001 - in press; Marincea & Dumitras, this symposium).

The protolith of the high-temperature skarns in the area consists in micritic reef limestones with clastic interlayers. No fossils have yet been recorded from this limestone, but certain lithological characteristics reinforce the correlation with similar limestone sequences from the Drocea Mountains (Lupu *et al.*, 1993) and accounts for the Tithonic age.

Stop C.2. The skarn occurrence in the upper basin of Cerboaia Valley

The object of this brief excursion is the examination of the classical outcrop of gehlenite on the upper Cerboaia Valley, described by Stefan *et al.* (1978). The visit involves 1 to 1.5 km of easy walking on a field track that follows upstream the Cerboaia Valley, from the finish of the car-practicable road (at about 6 km upstream from Cazanesti). Vehicles should be left at the end of the forest road that follows the valley.

This outcrop offers one of the largest exposures of the monzodiorite - limestone contact in the area. It was described in some detail by Stefan *et al.* (1978) and most recently by Piret (1997) and Pascal *et al.* (2001 - in press). This excellent exposure permits the examination of a gehlenite-bearing pegmatoid skarn that outcrops in the left bank of the Cerboaia Valley, which is one of the most spectacular even seen in the world.

As shown by Stefan *et al.* (1978), the succession of mineral associations from monzodiorite to the calcitic marble defines a well-expressed metasomatic zoning. The zoning described by Stefan *et al.* (1978) (*i.e.*, monzodiorite / gehlenite + garnet $\pm$ vesuvianite / garnet + gehlenite + wollastonite / wollastonite + garnet / marble) is more complex and may be

described as follows: monzodiorite / (Al-rich) diopside + gehlenite $\pm$ wollastonite / gehlenite + wollastonite + garnet + perovskite / wollastonite + vesuvianite + garnet $\pm$ perovskite / diopside + wollastonite + garnet (Pascal *et al.*, 2001 - in press). Pegmatitic development of both gehlenite (crystals of up to 15 cm in length) and wollastonite (the 2M polytype - crystals of up to 30 cm in length) is particularly spectacular. In gehlenite, the solid solution toward åkermanite vary from Ak 33.64 to Ak 38.13 (mean Ak 36.22). The rock additionally contains calcite, monticellite, rankinite (?), hydroxyllestadite, magnetite, pyrite and secondary minerals such as hibschite, thomsonite, tobermorite, mountainite (?), calcite and allophane (Pascal *et al.*, 2001 - in press, Marincea *et al.* - in prep.).

Three generations of garnet may be distinguished: (1) A first generation (Grs 75-79) is Ti-poor ($\text{TiO}_2 < 0.5$ wt.%), in equilibrium with gehlenite and occurs as skeletal star-shaped crystals. (2) A second generation (Grs 42-65) occurs as thin veinlets that crosscut the gehlenite or wollastonite mass or as clusters of crystals and is also Ti-poor ($\text{TiO}_2 < 0.9$ wt.%). (3) A third generation is a titanian andradite (TiO_2 up to 10 wt.%) which occurs as clusters of crystals enclosed by the wollastonite mass.

Textural relations among the principal minerals suggest the overprint of at least three mineral associations, as follows: (1) A high-temperature (early metasomatic) association, which includes gehlenite, monticellite, Ti-poor grossular-andradite, magnetite, perovskite, wollastonite and diopside and probably represents the overprinting of at least two mineral parageneses. (2) A late metasomatic association, which comprises vesuvianite, hydroxyllestadite and titanian andradite. (3) A subsequent hydrothermal and weathering association including thomsonite, tobermorite, calcite, mountainite (?) and allophane.

Stop C.2. The spurrite-tilleyite skarn from Cornet Hill

The starting point for this excursion is located at about 9 km upstream from Cazanesti on the forest road that follows the Ponor Valley (about 18 km on the road that follows the Vata and Ponor valleys, from Vata Bai), at the junction of Ponor with a small tributary valley. In this point the cars should be left and about 1.5 km of steep climb is needed for ascend the hill. Topographically, the Cornet Hill forms a pleasing profile bordering the south side of the Ponor Valley, then the climbing is easy. The footpath traverses mainly the forest and the hilly open pasture and the walk affords fine views to east and southeast. An excellent view of the Ponor Quarry, which exploits the high-purity coarse-grained calcite resulted from the thermal recrystallization of the Tithonic limestones, may be taken from a point located at about 100 m north from the final target.

The skarns from Cornet Hill, first described by Istrate *et al.* (1978), outcrop to the north of the intrusive body, over an area of several hundreds of square meters. A geological sketch of the area, redrawn from Istrate *et al.* (1978), is given in Figure 1. The contact between the intrusive body and the limestone is generally obscure, but the skarn area appears to vary in width between 0.5 and 30 m.

The skarns from Cornet Hill are one of the few occurrences of spurrite-tilleyite bearing skarns in the world. Excepting these species, Istrate *et al.* (1978) also revealed the presence of additional high temperature phases such as gehlenite, wollastonite, vesuvianite, Ca-garnets and spinel. Two recent studies of Piret *et al.* (1997; 1998) gave new information on the main high temperature minerals and mentioned scawtite, but bring little essentially new data on the other secondary phases that are expected to occur. The occurrence of hydroxyllestadite, monticellite, perovskite and xonotlite was recently mentioned by Pascal *et al.* (2001 - in press) in a paper that focus on the high temperature assemblages; more alteration products of these assemblages were described by Marincea *et al.* (2001 - in press). The list of secondary

minerals also includes tobermorite 11 Å, riversideite, plombièrite, hibschite, thomsonite, gismondine and probably defernite and djerfisherite.

As well as on the upper Cerboia Valley and more obviously here, periplutonic zoning may be observed. The zoning described by Istrate *et al.* (1978) is, from the outer to the inner part of the metasomatic area: calcite (marble) / tilleyite / spurrite / wollastonite + gehlenite + vesuvianite / quartz-monzonite. Pascal *et al.* (2001 - in press) described this zoning in greater detail and introduced an endoskarn wollastonite - grossular zone at the contact of the intrusive body. Given the limited present exposures, it is not possible to comment further on more details on the internal zoning of this skarn.

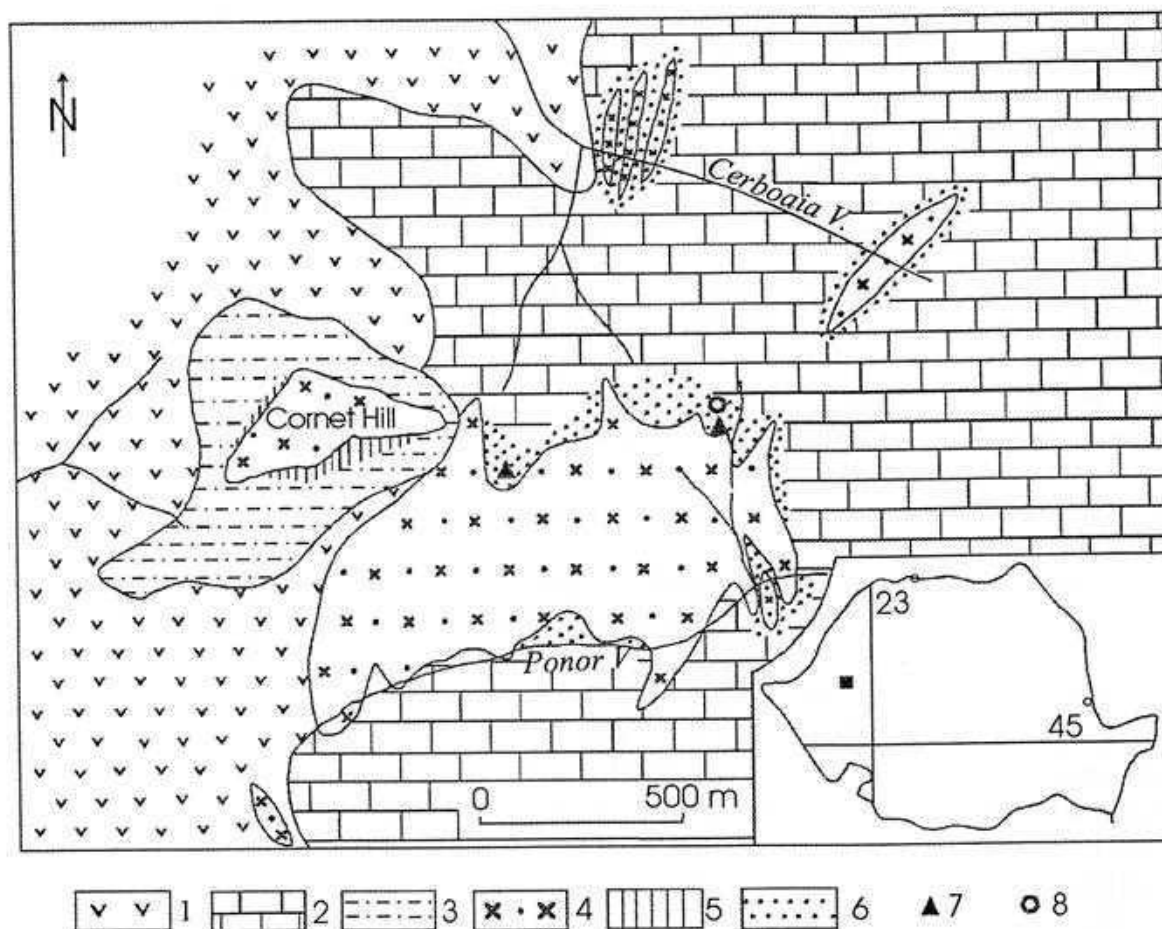


FIG. 1. Geological sketch of the Cornet Hill area. Symbols in the legend represent: 1- Mesozoic ophiolites; 2 - Tithonic limestones; 3 - Cretaceous sedimentary deposits (marls, calcareous sandstones and clays); 4 - quartz-monzodiorite; 5 - hornfels; 6 - skarns; 7 - occurrence of spurrite; 8 - occurrence of tilleyite.

The mineralogy of the high-temperature paragenesis is most complex than that at Magureaua Vatei and accounts for a higher pressure of CO₂ (Pascal *et al.* 2001 - in press). The high-temperature assemblage principally contains gehlenite, spurrite, tilleyite, wollastonite (the 2M polytype) and calcic garnet, with scarce perovskite, monticellite and hydroxyllellestadite. Gehlenite is coarse grained, without pegmatitic development. The solid solution toward åkermanite vary from Ak 22.90 to Ak 36.28 (mean Ak 29.80). As well as at Magureaua Vatei, three generations of garnet may be distinguished on the basis of textural relationships, as follows: (1) A first generation consists in Ti-poor grossular (Grs 74- 89, TiO₂

< 0.2 wt.%), in equilibrium with gehlenite, and occurs as skeletal, star-shaped crystals. (2) A second generation of garnet is also a grossular (Grs 58- 78), with low andradite (Adr 21-38) and morimotoite (Mor 1-4) and occurs as small subhedral crystals that are generally associated with gehlenite and wollastonite, rarely with spurrite or tilleyite. (3) A third generation of garnet is a Ti-rich andradite (Grs 31-39, Mor 4-12) that develops in subhedral to euhedral crystals up to 8 mm in diameter, generally enclosed by the gehlenite or tilleyite masses.

Tilleyite is particularly spectacular and occurs in massive bluish gray to dark gray aggregates ("orbicules") separated by a web-like network of very thin (up to 2 mm) white veinlets containing scawtite, calcite, plombièrite, tobermorite or riversideite.

The skarns from Cornet Hill have clearly undergone a late metasomatic event which has produced diopside veins cross-cutting tilleyite, spurrite, or gehlenite, small masses and veins of vesuvianite replacing gehlenite, etc. Subsequent hydrothermal and weathering overprinting of the primary assemblages resulted in the formation of three secondary parageneses (1) an early hydrothermal one that includes scawtite, xonotlite, hibschite, and calcite; (2) a late hydrothermal one that includes 11 Å tobermorite, riversideite, thomsonite, gismondine, aragonite, calcite and (3) a weathering paragenesis that includes plombièrite, portlandite, and allophane (Marincea *et al*, 2001 - in press).

Sampling is relatively easy and most of these mineral species can be collected on the field.

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Stop C.4. Vein copper ore deposit from Cazanesti - Valea Caprei area Ivascanu S., Ivascanu M.P.

Situated in the upper part of Ponorului Valley the Cazanesti Valea Caprei copper deposit is representative for the Mesozoic hydrothermal metallogeny in area of South Apuseni mountains. The host rocks are represented by basalts, pillow basalts lava flows, intruded by synchronous dikes of dolerites and anamesites from the tholeiitic (Jurassic inf. Callovian, ~180Ma, by Rb-Sr). Small gabbro-melagabbro differentiates as comagmatic intrusive bodies are usual. Those are normally overlaid by calco-alkaline serie (Callovian-Neocomian, 140 Ma) as basalts, basalt andesites as lava flows and autoclastic breccias. Some high Si differentiates, with an alkaline trend are considered as a separate series.

The magmatic intrusive history is continuous in Eocretaceous time by acids differentiates as granodiorites, monzogranites (107-135 Ma) (e.g. Savarsin-Cerbia and Pietroasa magmatic complexes) to Măgurea Vatei body considered as having "laramian" age, giving contact

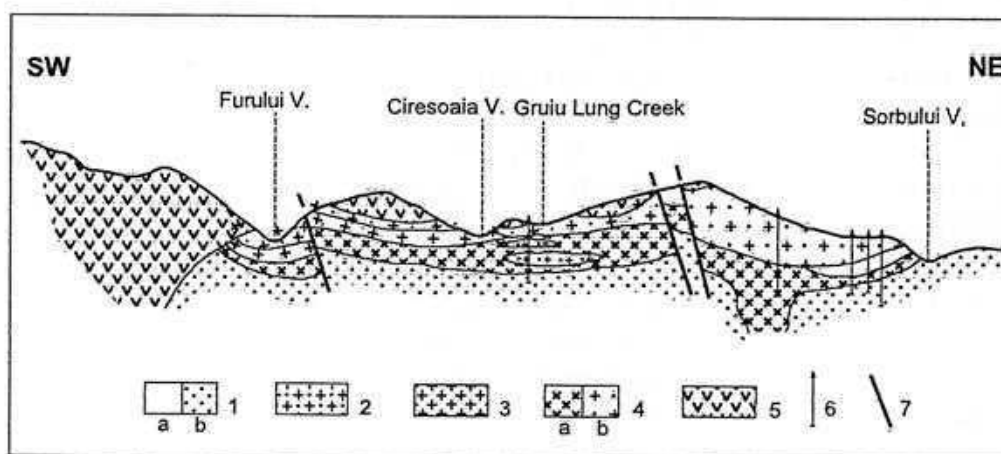
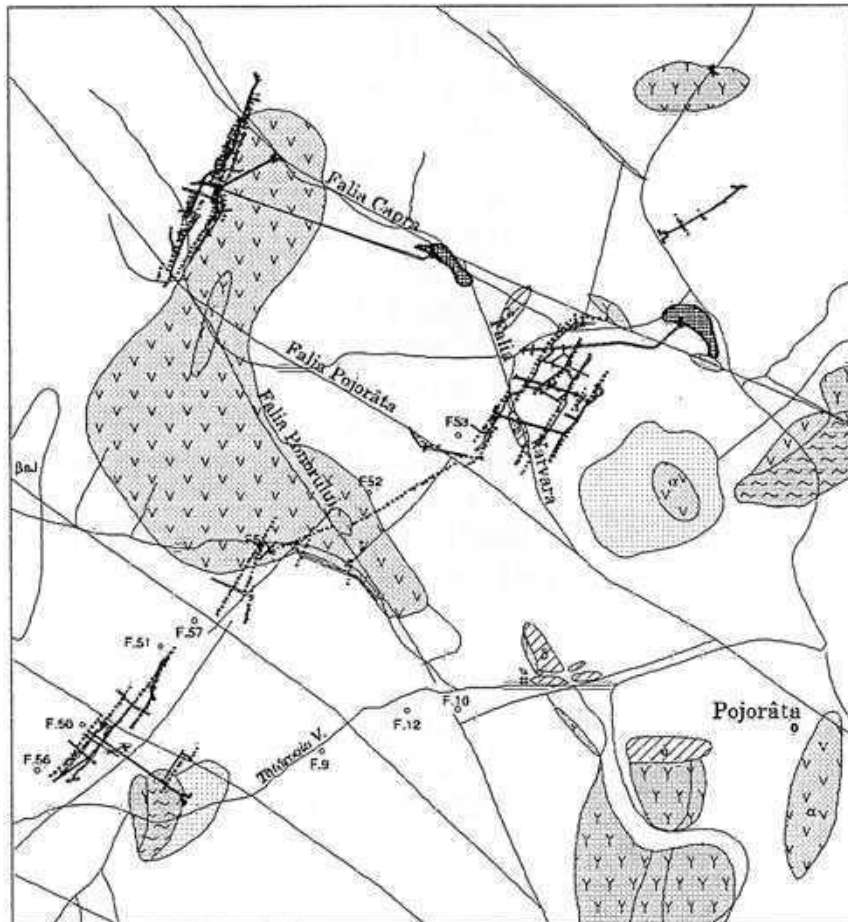


Fig. 1. Longitudinal section through the Cazanesti-Ciungani intrusion (according to Cioflica, Nicolae, 1981). 1, magnetite gabbro horizon; 4, dolerite prevailing horizon; a, dolerite, norite, olivine, gabbro, augite gabbro; b, magnetite, gabbro; 5, Eocretaceous igneous rocks; 6, drilling; 7, fault.

Geological sketch map of Cazanesti mining sector



LEGEND

SEDIMENTARY ROCKS

Jasp and marls

MAGMATIC ROCKS

Eocretaceous intrusive series

Granodiorites, diorites, andesites, riolites

Calco-alkaline series

Andesites, diorites, riolites

Tholeiitic series

Gabbrous, microgabbrous

Anamesite, dolerite

Basalts pillow lavas

Mineralization: veins

Geological boundary

Fault

Halda

Mining

Put

Foraj

Pod

metamorphism and skarn phenomena in Jurassic-Kretacic limestone sedimentary deposits (Previous stops).

The hydrothermal copper deposit from Cazanesti is structurally controlled by pre-laramian age extensional faults in two main parallel alignments oriented NW-SE, characterized by high dip angles (up to 80°). at the surface those are marked by a up to 100 m area of intense hydrothermal alteration (clay minerals, chlorite, pyrite, quartz). The veins with variable thickness (usually large than 1m) are short (100-200 m) and interconnected in a area more than 1800 m long. Is remarked the tendency to resemble in one main vein in deep.

The structures is tectonically reworked by NE-SW faults considered by laramian age which shear the mineralization sometimes more the 2 Km. The influence of Magureaua Vatei body, considered from above criteria to be younger is minimal, despite is close to two Km.

The mineralogy of the deposit is quite simple, fact characteristic for mineralization related to "ophiolites from South Apuseni Mts. Thr pyrite, calcopyrite, hematite, musketovite. The gangue is build up by quartz, calcite, epidote and chlorite, somewtimes zeolites. As minor components can be found the galena, sphalerite, tennantite alabandine, native gold and rutile, oligist. The content in copper, the main interesting metal, is more than 1%, but because of vein characteristics of mineralization the deposit is considered economically unproductive.

The genesis is considered from available data to be related to calc-alkaline intrusive series (diorites, microdiorites, andesites) and to be reworked by Eocretaceous magmatic series (influence of Pietroasa body, outlined by a peculiar paragenesis more rich in base metals, superimposed on primary one in the Capra sector).

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ABCD – GEODE 2001 WORKSHOP VATA BAI, ROMANIA
8 – 12 June, 2001

Geodynamics and Ore Deposit Evolution
of the Alpine-Balkan-Carpathian-Dinaride Province



STOPS IN EXCURSION B
(12 - 15 June)

Epithermal deposits in Baia Mare Region
(Cavnic and Baia Sprie)

Bucharest, 2001

CONTENT

1. SUBDUCTION - RELATED MAGMATISM AND ASSOCIATED METALLOGENY IN BAIA MARE REGION (ROMANIA).....	3
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Kovacs, M.

2. CAVNIC EPITHERMAL DEPOSIT	9
---	----------

Mariaş, Z., Kovacs, M., Iştván, D.

3. BAIA SPRIE EPITHERMAL DEPOSIT	13
---	-----------

Kovacs, M., Grancea, L., Iştván, D., Nedelcu, L.,
Mihalache, A., Chiuzbăian, C.

Subduction - related magmatism and associated metallogeny in Baia Mare Region (Romania)

Marinel Kovacs

IPEG Maramureş Baia Mare

Baia Mare Region (northwestern part of Romania) represents one of the most important metallogenic district in the Carpatho-Balkan area. It includes the Gutâi volcanic chain which belong to the Neogene-Quaternary volcanic chain of the Eastern Carpathians.

The magmatism of the Baia Mare Region (Gutâi volcanic chain) is related to the Miocene subduction of the European plate beneath the Alcapa and Tisza-Dacia microplates. A continental margin arc type volcanism took place during the Upper-Middle Miocene in the area generating a typical calc-alkaline magmatic series, from basalts to rhyolites (predominant pyroxene basaltic andesites and andesites).

The Pre-Neogene basement consists of metamorphic rocks belonging to the Inner and Median Dacides and Cretaceous-Paleogene sedimentary formations of Transcarpathian Flysch forming the Băbeşti-Tiacovo, Petrova/Măgura, Botiza and Lăpuş overthrust units (Săndulescu et al, 1993).

The most important tectonic structure in the area is the W-E trending major transcrustal / wrench fault Cărlibaba-Carei (Dragoş Vodă / Bogdan Vodă fault, Săndulescu, 1984) situated in the southern part of the Gutâi Mts. This major fault represents the prolongation of the Mid-Hungarian Line (Csontos, Nagymarasy, 1998).

The volcanic activity in the Baia Mare Region took place partly contemporaneously with significant sedimentary deposition processes in the marginal basins (the northeastern part of the Pannonian basin and the northwestern part of the Transilvanian basin) forming the Neogene molasse deposits (Badenian-Pannonian).

The volcanism in the Baia Mare Region started with an acidic phase (related to the Middle Miocene areal silic CA volcanism from the Carpatho-Pannonian Region) consisting of ignimbrites and ignimbrite-derived volcaniclastics associated with mostly volcanogenic sediments (Fülöp, 1998, Fülöp, Bernad, 2000).

The acidic volcanism was followed by the intermediate / andesitic arc-type volcanism developed during the Sarmatian and Pannonian (13.4-6.9 M.a., Pecskey et al, 1995, fig.1). It had an explosive and effusive character, forming complex volcanic structures and / or some isolated volcanoes (especially in Oaş Mts. where different type of extrusive domes occur, Fülöp, Kovacs, 1996, 1999). The great bulk of the volcanics represents lava flows, well developed in the upper part of the volcanic structures, sometimes forming widespread lava plateaux (e.g. the northern part of the Gutâi Mts.).

An intrusive magmatism with subvolcanic or intravolcanic shallow level intrusions is coeval especially with the paroxysm of the andesitic volcanism (11.0-9.0 M.a., Kovacs et al, 1997). The intrusive rocks include mainly andesites and microdiorites and microgranodiorites, monzodiorites and tonalites.

Recent petrogenetic studies (Kovacs, 1998, 2000) emphasized the subduction-related (arc-type) character of the Gutâi intermediate volcanism. Major and trace elements geochemistry carried out the CA (fig.2) and medium K character of the volcanism and its affinities with the high Ce / Yb arcs. The strong LILE and LREE enrichments, the HFSE depletion (fig.3) and Sr-Nd isotopes negative correlation represent typical magmatic constraints for a subduction zone-related magmagenesis.

A depleted MORB type mantle wedge ($Nb / Ta = 16.1$, $Zr / Hf = 34.6$) represents the mantle source for the parental magmas. This mantle wedge was slightly metasomatized by subducted fluids ($Ba / La = 17$). The mantle source enrichment by addition (3-7%) of subducted sediments (constrained by low Ce / Pb, high Pb / Nd and enriched Pb isotope composition) represents the main mantle source related process. The parental magmas were generated by partial melting processes with amphibol as residual phase.

The petrogenetic processes for Gutâi volcanics are related to the evolution of the magmas in the continental crust of the overriding plate. Geochemical and isotopic data ($^{87}Sr / ^{86}Sr = 0.7070 - 0.7094$, $^{143}Nd / ^{144}Nd = 0.5125 - 0.5123$) assert significant crustal assimilation both by MASH and AFC processes.

Besides the main FC and AFC processes, mixing and mingling were involved in the petrogenesis of the Gutâi volcanics (related to the evolution of the parental magmas in upper to mid, 10-25 km, crustal reservoirs).

An important metallogenic activity is associated with the calc-alkaline, subduction-related magmatism in the Baia Mare Region. The hydrothermal mineralizations consist of typical low sulfidation, predominant vein-hosted polymetallic and gold rich epithermal deposits.

The epithermal deposits are related to some tectonic and magmatic structures. The first ones correspond to the major Cârlibaba – Carei transcrustal / wrench fault with numerous associated tensional fractures and other satellites structural zones (fig.4).

A possible shallow depth batolith (Borcoş, Vlad, 1994) represents the main magmatic structure which has controlled the development of the main epithermal systems. The mineralizations are strictly associated with intrusions developed in complex volcanic structures or in sedimentary formations.

The Baia Mare Region hydrothermal systems represent typical related intrusions epithermal systems.

The hydrothermal alterations are predominant adularia-sericite types, very well developed especially in the Ilba – Nistru and Săsar – Dealul Crucii metallogenic fields.

The mineralizations consist mainly of vein-systems. Associated stockworks and breccia pipes occur much subordinated. A hidden porphyry copper system is developed only in the southern part of the Țibleş Mts. (Udubaşa et al, 1983, fig.6). The veins present a horizontal extent (length) from several hundreds of meters up to 5 km (e.g. Principal / Main Vein in Baia Sprie ore deposit), 0.3-10 m thickness and 300-1000 m vertical extent.

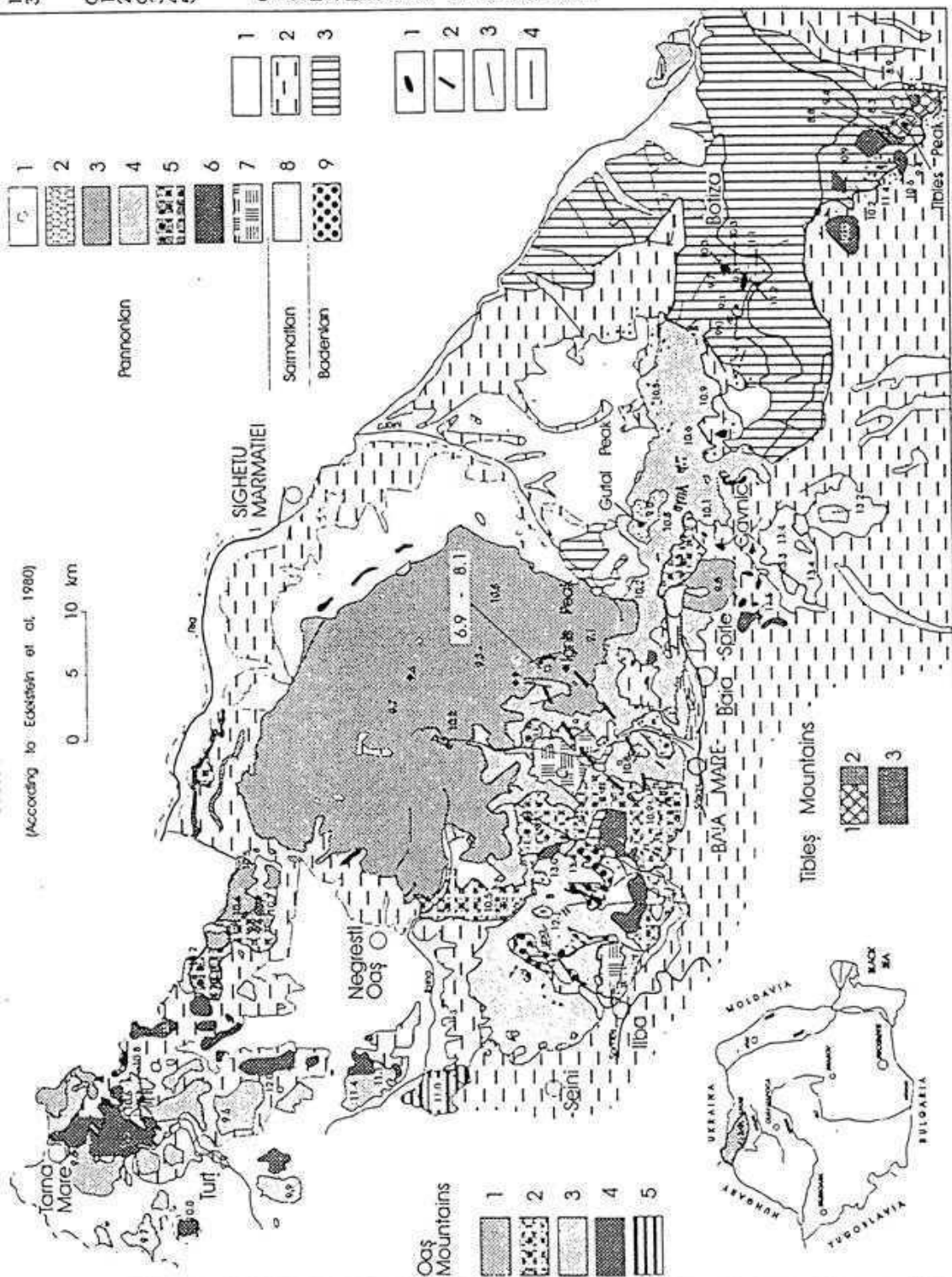
A vertical zonality, Au-Ag in the upper part, Pb-Zn in the middle part and Cu in the deeper part is well developed in the majority of the ore deposits (the most typical is Baia Sprie ore deposit). A horizontal / lateral zonation is also developed in some metallogenic fields (e.g. Pb-Zn $\rightarrow$ Cu±Pb-Zn $\rightarrow$ Cu+Au in Nistru ore deposit).

Mineralogical composition of the ores consists of very complex mineral assemblages with Fe, Sn, W, Bi minerals in the firsts mineralogenetical assemblages and Au, Ag, As, Sb minerals in the latests.

SIMPLIFIED GEOLOGICAL MAP OF THE GUȚĂI-OAȘ-TIBLEȘ MOUNTAINS WITH K-Ar DATA

(According to Eusebiu et al, 1980)

0 5 10 km



Sedimentary deposits:

1. Quaternary;
2. Neogene;
3. Paleogene.

Igneous rocks:

Oaș Mountains:

1. Upper pyroxene andesites;
2. Quartz-andesites and quartz-dolites;
3. Lower pyroxene andesites;
4. Dolites and hyalodolites;
5. Rhyolites, peilites.

Guțai Mountains:

1. Basalts; hornblende, pyroxene andesite (Guțai type);
2. Pyroxene andesite and pyroxene basaltic andesite (Ighis-Maria, Sapința and Mogasa type);
3. Pyroxene basaltic andesites, pyroxene andesites and amphibole-pyroxene andesites;
4. Quartz andesites, basaltic andesites, dolites and hyalodolites;
5. Pyroxene andesite;
6. Pyroxene basaltic andesite and pyroxene andesites, subordinated pyroxene dolites;
7. Volcaniclastic complex, mainly ignimbrites.

Tibleș Mountains:

1. Quartz-monzodolites;
2. Andesites, microdolites and dolites;
3. Microgranodolites and dolites.

1. Intrusions;
2. Veins;
3. Faults;
4. Overthrusts.

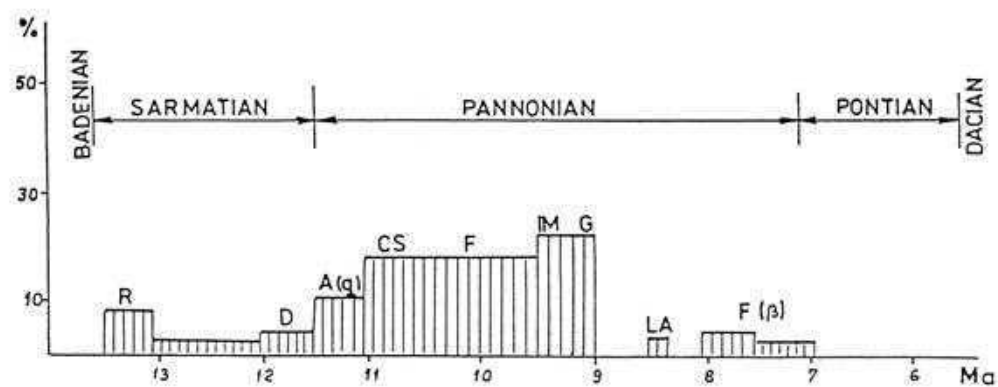
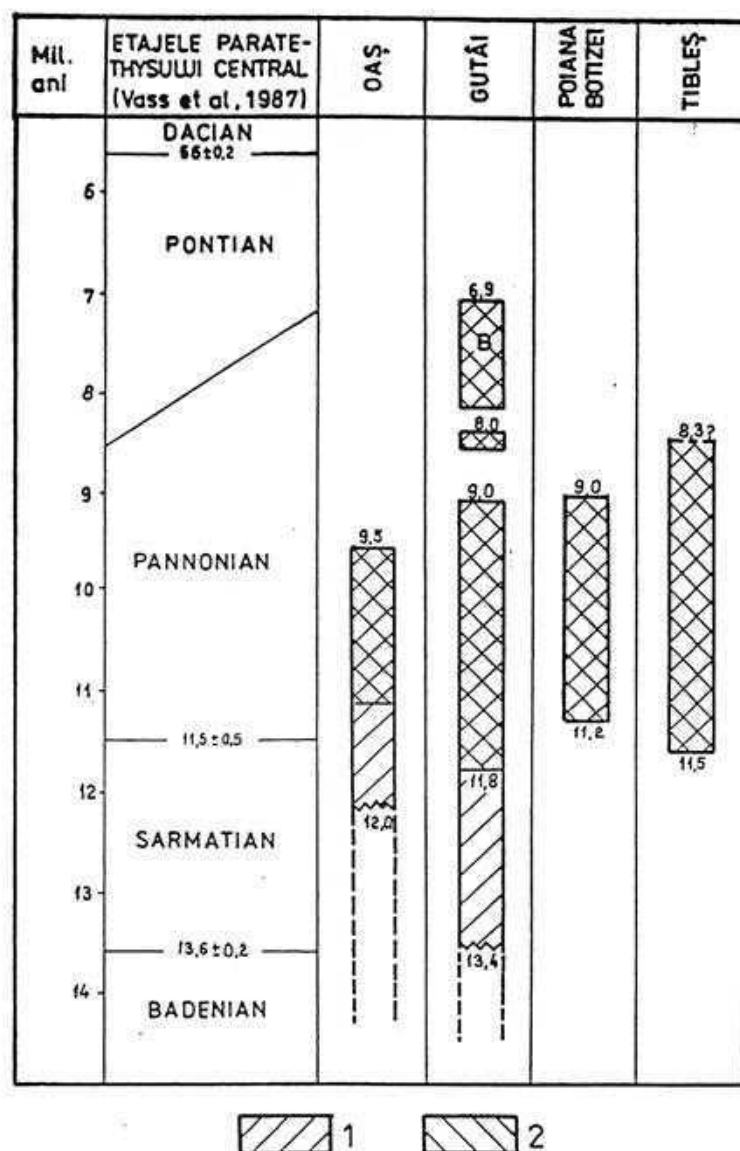


Fig.1 - The K-Ar ages of the Baia Mare Region magmatic rocks: 1 - effusive rocks; 2 - intrusive rocks (Pecskay et al, 1995, Kovacs et al, 1997)

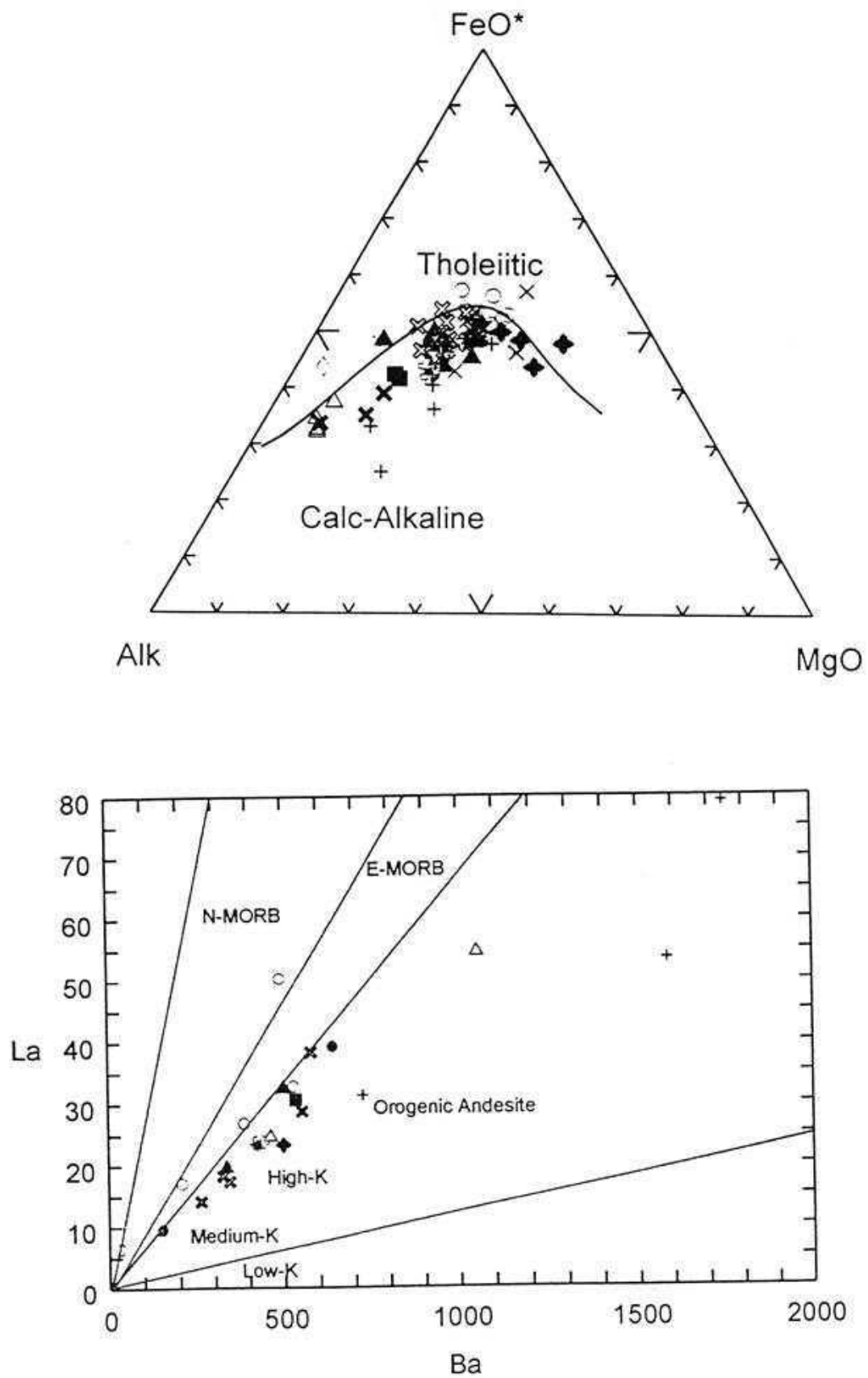
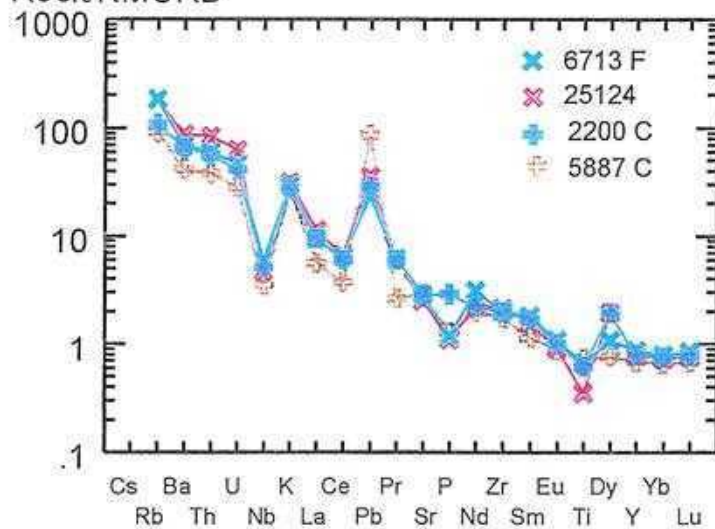
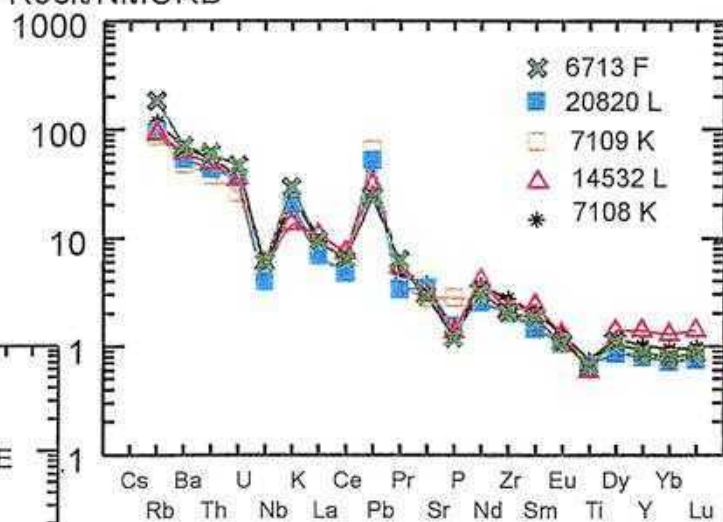


Fig.2 - The Gutai Mts. arc-type volcanics distribution in the AFM and La-Ba (Gill, 1981) diagrams (Kovacs, 1998)

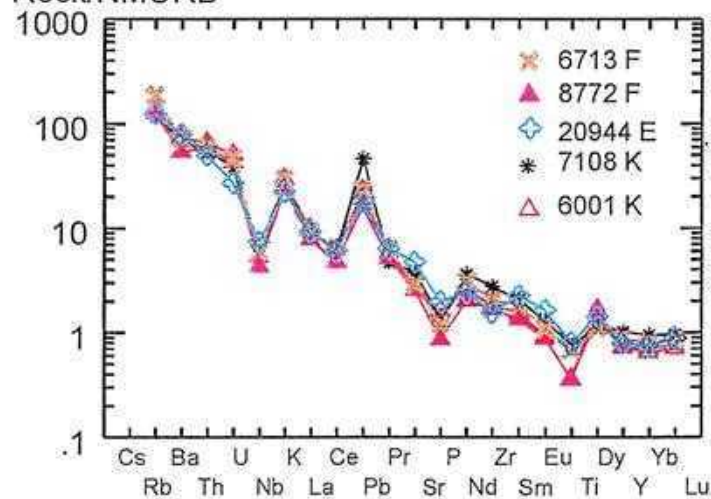
Rock/NMORB



Rock/NMORB



Rock/NMORB



Rock/NMORB

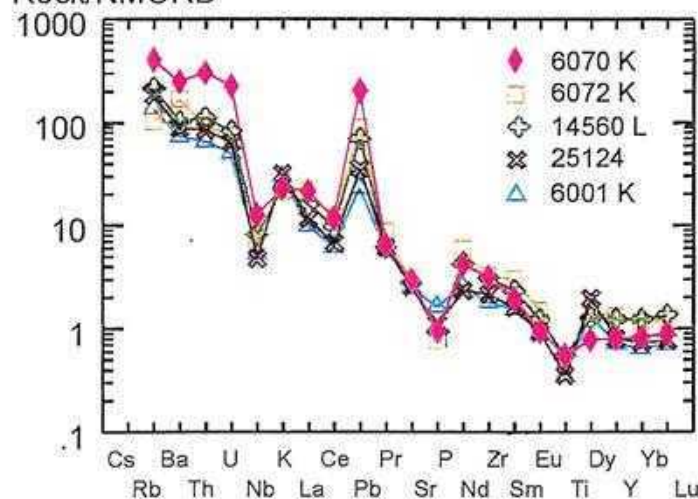


Fig.3 - NMORB normalized diagrams for different petrographic rock types of the intermediate arc-type volcanism from Gutâi Mts. (Kovacs, 1998)

The sulfides – pyrite, sphalerite, galena, chalcopyrite, stibnite and the sulfosalts – tetrahedrite, bournonite, jamesonite, pyrargyrite are the main ore minerals. The native elements (Au, Ag, Cu) and tungstates (wolframite, scheelite) are much subordinate.

The gangue mineral assemblages include quartz, adularia, sericite, clay minerals, carbonates, rhodonite/rhodochrosite, barite and gypsum. Two different gangue mineral assemblages are strictly associated with the two main types of the Baia Mare Region epithermal mineralizations: 1). Quartz-illite / sericite + adularia, for the Au-Ag $\pm$ Pb, Zn mineralizations (e.g. Săsar ore deposit) and 2). Quartz – calcite – rhodochrosite / rhodonite $\pm$ adularia for the Pb-Zn $\pm$ Au, Ag, Sb mineralizations (e.g. Cavnic ore deposit).

The hydrothermal activity and the metallogenic events in the Baia Mare Region took place in a short time interval (11.5-7.8 M.a.). In the Gutâi Mts. it developed in two main phases: the first phase took place in the Lower Pannonian (11.5-10.0 M.a.), including the Ilba-Nistru base metal + gold and Săsar gold-silver epithermal systems. The second phase took place in the Upper Pannonian (9.4-7.9 M.a.) including the Herja, Baia Sprie, Șuitor, Cavnic, Băiuț base metal + gold epithermal systems.

The metallogenic activity in the Oaș and Țibleș Mts. is contemporaneous with the second phase of the Gutâi Mts. (9.6-7.8 M.a.).

Radiometric age datings (K-Ar, Ar-Ar) have emphasized a gap (0.5-2.0 M.A.) between magmatic and metallogenic events, similar with many subduction zone – related epithermal systems.

As a whole, the Baia Mare Region epithermal systems had a complex evolution emphasized by some peculiarities: very complex mineral assemblages, many mineralizations stages (e.g. 7 stages in Cavnic ore deposit, Mariaș, 1996), high fluctuation in the salinity and temperature of the fluids (e.g. Cavnic, Baia Sprie, Mariaș, 1996, Grancea et al, 1999, in print, Piantone et al, 1999).

This complex evolution is related to some main features of the Baia Mare Region hydrothermal mineralizations:

- 1). The epithermal systems were "open" / active systems during the formation of the ores. It has been controlled by local tectonic events (reactivation of the vein hosted fracture) and by magmatic events (brecciation processes, e.g. pipe / dyke breccias involving phreatomagmatic activity);

- 2). The convective hydrothermal systems were reactivated by mixing processes with meteoric water and by new injections of magmatic fluids/brine;

- 3). The presence of the boiling processes.

The genesis of the Baia Mare Region epithermal systems is related to the evolution of the intracrustal mantle-derived magmas (subduction-related). Pb isotopes signatures of the host igneous rocks and galena from different polymetallic + Au rich vein deposits assert a common crustal contamination source (fig.8).

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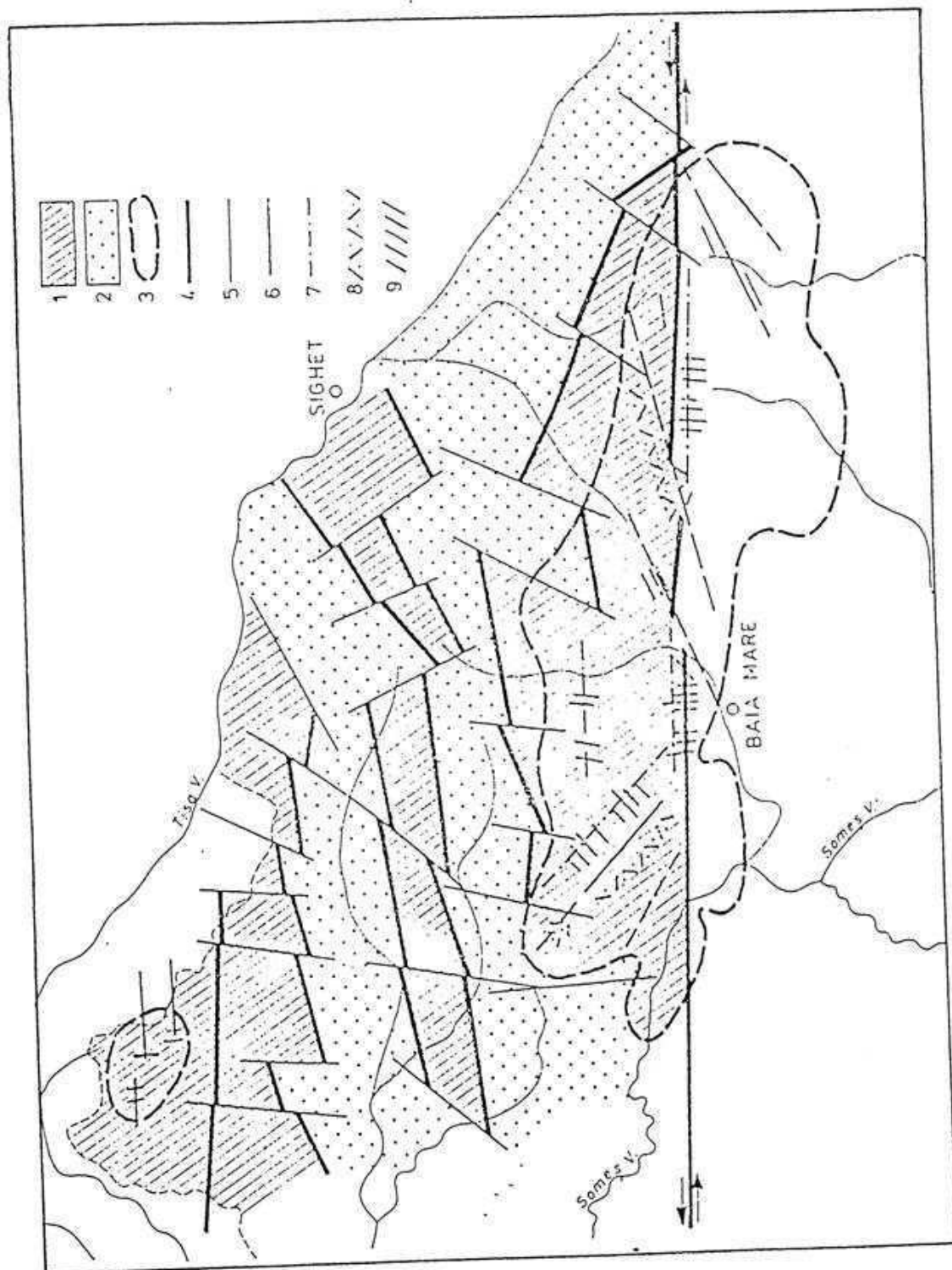


Fig. 4 - Relationship between major geotectonic and metallogenic elements in the Baia Mare area (acc. to Borcoş and Vlad, 1994)
 1. Horst; 2. Graben; 3. Inferred Neogene Pluton; 4. Transcrustal fracture; 5. Pre-Neogene reactivated fracture; 6. Fracture with metallogenic function; 7. Tectono-volcanic alignment with metallogenic function; 8. Mineralized breccias; 9. Veins.

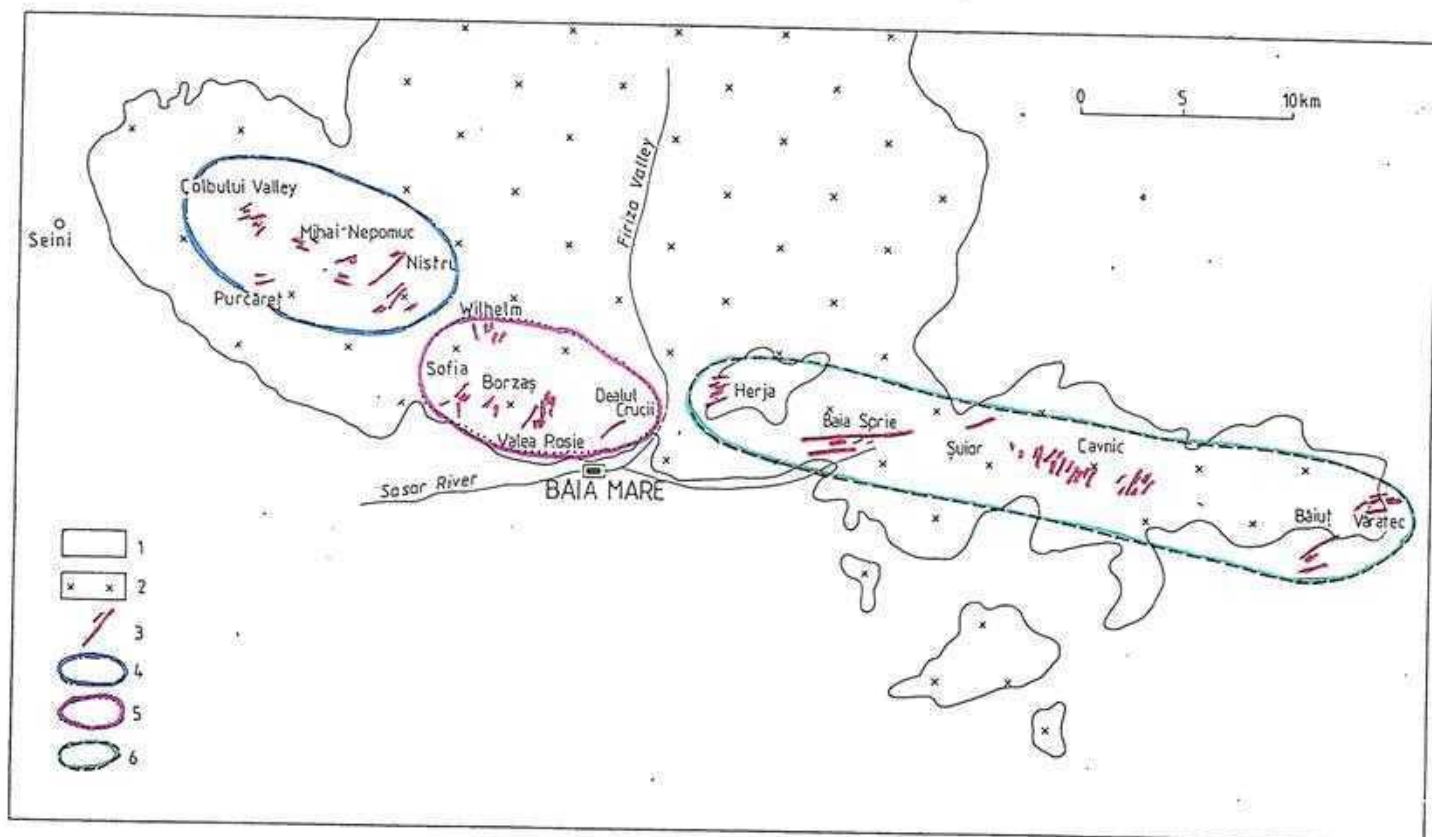


Fig. 5 - The main ore deposits from the Gutâi Mts: 1, Quaternary, Neogene and Paleogene sedimentary deposits; 2, Neogene volcanic rocks; 3, Veins; 4, Base metal metallogenetical field Ilba-Nistru; 5, Gold epithermal system Sasar-Dealul Crucii metallogenetical field; 6, Base metal ($\pm$ gold) metallogenetical field Herja-Baiut.

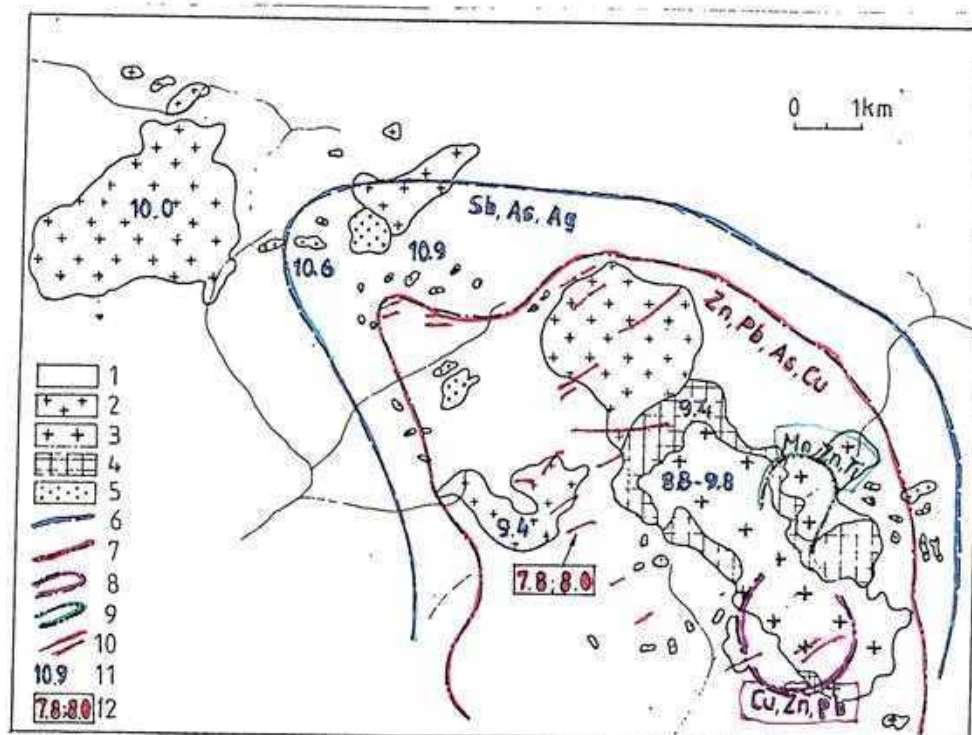


Fig. 6 - Metallogenetic map of the Tibleș Mts (according to Udubașu et al, 1983) with radiometric data. 1. Oligo-Miocene sedimentary rocks; 2. microgranodiorites and dacites; 3. quartz monzodiorites; 4. quartz microdiorites and andesites (the ring of the main intrusion); 5. diorites, quartz diorites, microdiorites and andesites; 6. external belt of lower temperature vein assemblages; 7. inner zone of high temperature vein assemblages; 8. copper enriched ores and the hidden porphyry system; 9. Mo-Cu-Zn-Ti-B disseminations; 10. veins; 11. K-Ar ages of the igneous rocks; 12. K-Ar ages on sericite

Udubaşa, Gh., Edelstein, O., Pop, N., Răduţ, M., Iştván, D., Kovacs, M., Vera Pop, Stan, D., Bernad, A., Götz, A. (1983) - The Ţibleş neogene igneous complex of North Romania: some petrologic and metallogenetic aspects. An. Inst. Geol. Geofiz., LXI, p. 285-295.

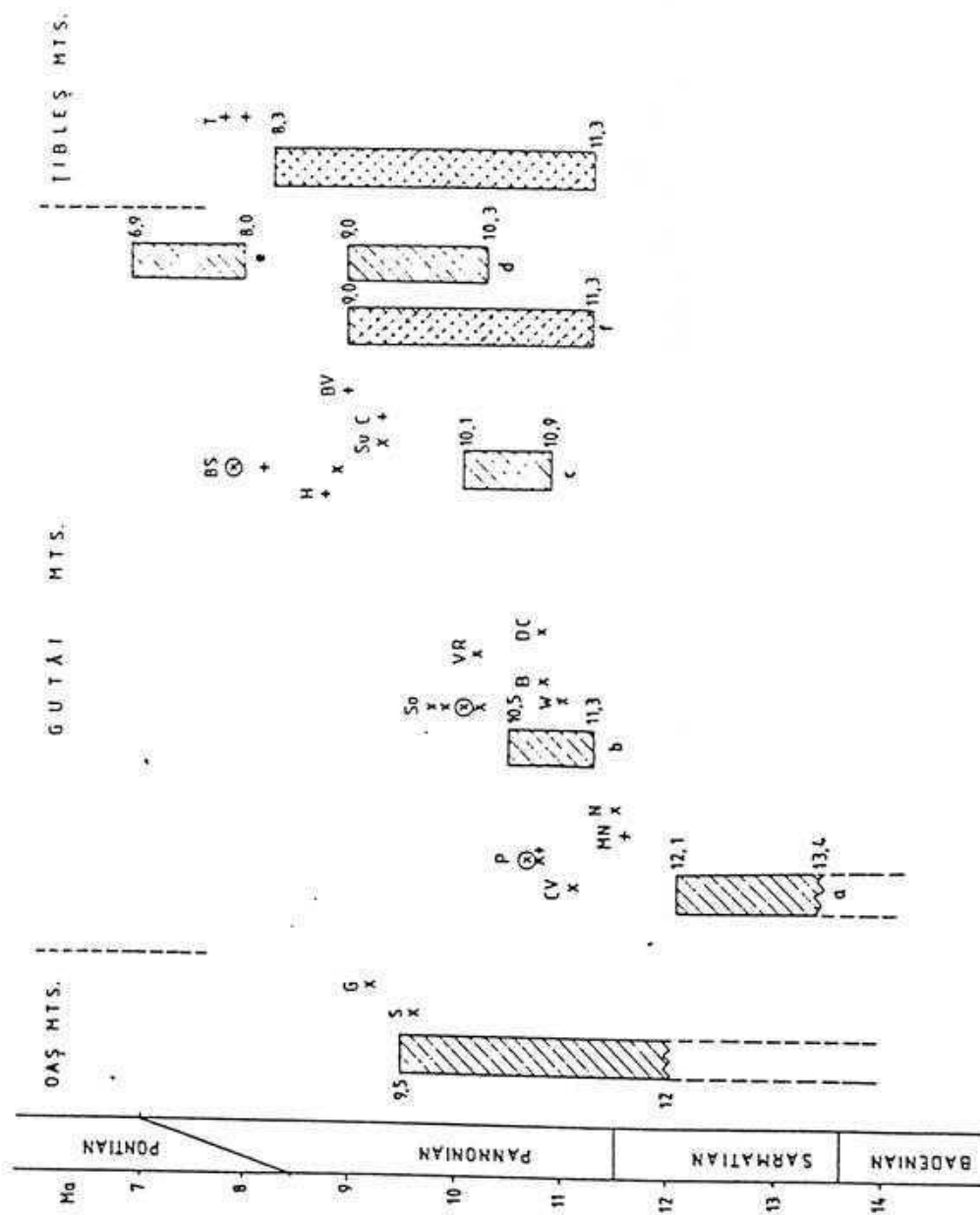


Fig. 7—Geochronological data for the magmatic rocks and the hydrothermal K-bearing minerals from the main ore deposits in the Oaș-Gutâi-Tibileș Mts.; vertical columns = time interval recorded by K-Ar dates in fresh magmatic rocks;

x = K-Ar ages on adularia; (x) = Ar-Ar ages on adularia (Lang et al., 1994);

+ = K-Ar ages on illite;

ore deposits: S = Socca; G = Ghezuri; CV = Colbul Valley (Ilba); P = Pucăreț; MN = Mihai Nepomur; N = Nistru; So = Săsar (Sofia); W = Wilhelm; B = Borzob; VR = Valea Roșie; DC = Dealul Crucii; H = Herja; BS = Baia Sprie; Su = Șuor; C = Căvrie (Rontă); BV = Băiut (Văratec); T = Tibileș.

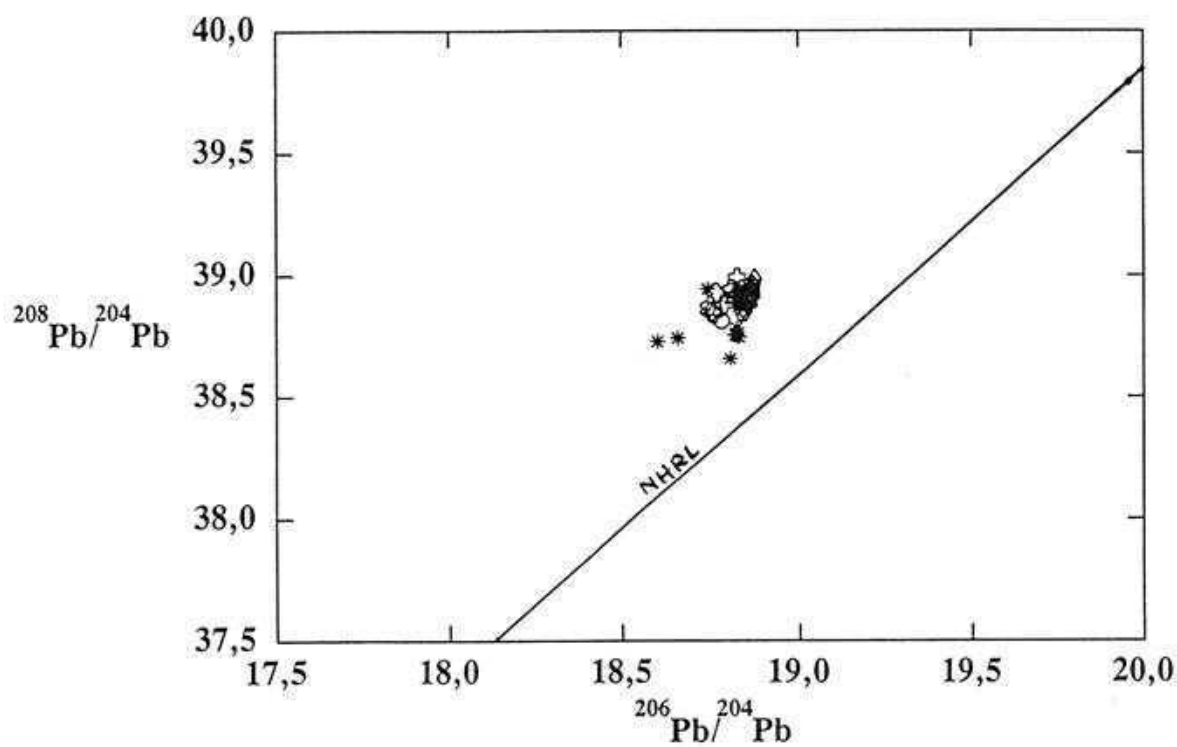
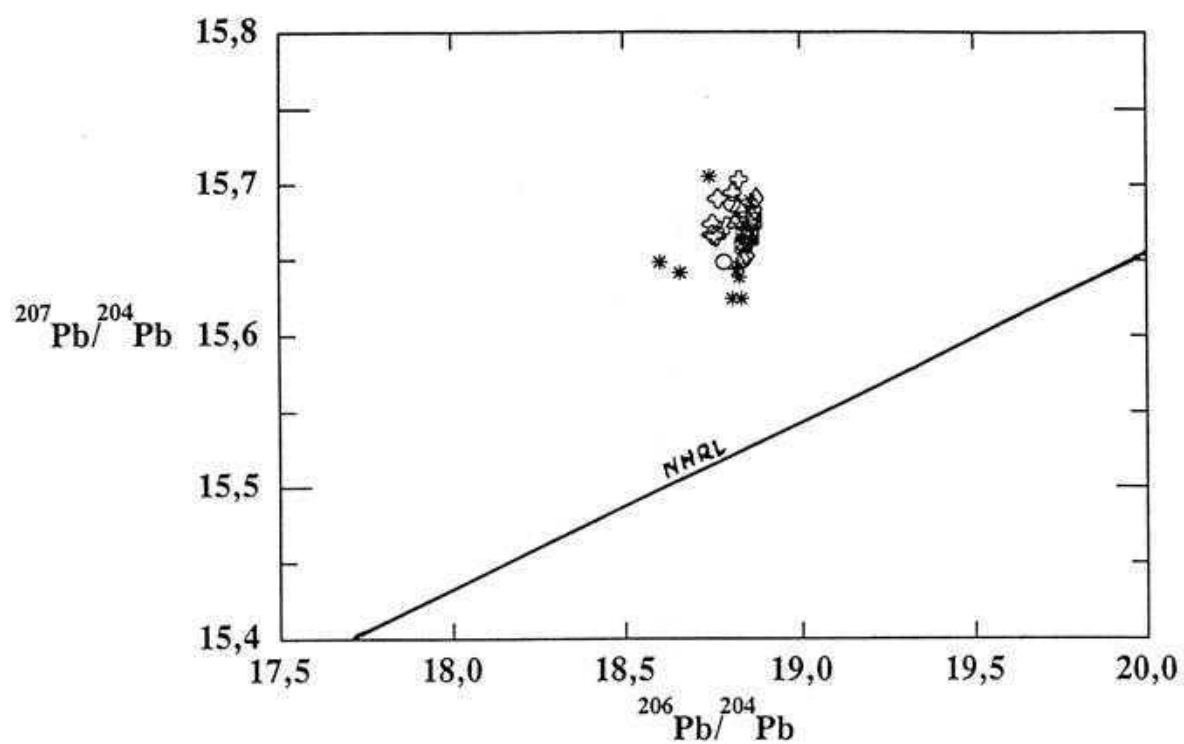


Fig.8 - Pb isotopes data of the magmatic rocks and galena (stars) from different Baia Mare Region epithermal deposits

CAVNIC EPITHERMAL DEPOSIT

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The town of Căvnic is situated at approximately 35 km East of Baia Mare. Close to the town, one of the most well-known metallogenic field of the Gutâi Mts. – the Căvnic ore deposit – is developed.

This metallogenic field is developed within an area with widespread Pannonian (11.3 – 10.1 Ma) volcanics, of stratovolcanic type. They are resting upon the Neogene (Badenian-Pannonian) molasse deposits overlying the basement, composed of overthrust units belonging to the Transcarpathian Flysch. Cretaceous-Paleogene formations form a N-S trending anticlinal and are known from drillings and some deeper mining works.

Structurally, the metallogenic field is situated in a strongly tectonical fractured area along the major transcrustal Bogdan Vodă (Cârlibaba-Carei) fault. The very complex tectonical movements within the plane of this fault carried out a main system of paralel fractures (extension faults), with a NNE-SSW trending comprising the main veins of the metallogenic field.

The Neogene volcanism displays a complex character, its explosive and effusive products alternating, especially at the basis of the succession, carrying out a volcanoclastic complex, locally with sedimentary deposits interbedded. At the upper part of the stratovolcanic structure, the lavas are predominant. They are represented by different petrographical types (pyroxene basaltic andesites, pyroxene hornblende andesites, quartz bearing andesites). An intense intrusive activity is associated to the extrusive one – many intrusions are known both at the surface and especially in mine workings and drillings. In the Bolduţ ore deposit, the intrusive bodies are well developed being very different from the petrographical point of view (quartz-diorites and gabbros, monzodiorites, microgranodiorites, andesites).

Hydrothermal alterations consist of extensive argillic alteration with local silicification. It is to note the absence of an important potassic alteration, adularia being present only locally and only as a gangue mineral.

The Căvnic epithermal system consists of two vein groups constituting two ore deposits exploited in the Bolduţ Mine – in the west and in the Roata Mine – in the east, all having cca 6 km in length and 3 km in width.

In the Bolduţ ore deposit, veins form a paralel main system trending NNE-SSW, being disposed at 120-350 m distance. This system is found also in the Roata ore deposit. A previous secondary system, trending ENE-WSW, is developed in the Bolduţ ore deposit.

The veins are hosted by both the volcanic formations and intrusions and the sedimentary deposits. In the eastern part of the Bolduţ ore deposit, breccia pipe and dyke structures are developed (Mariaş, 1993). They are poorly mineralized and are crossed by some vein fractures (Orban I and II, Ungarn veins).

The length of the veins varies between 200 and 2500 m. The vertical extent is about 800 m at Bolduţ and 600 m at Roata. The thickness of the veins ranges between 0.5 and 7 m, the majority of the veins being of 1-2 m. There are also thick zone (5-7 m) on the main veins.

The mineralization has a polymetallic character ($Pb + Zn \pm Cu, Au$) with an obvious zonality (especially on the vertical). In the upper part of the ore deposit occurs a gold-silver mineralization, with native gold and silver sulfosalts. Frequently, gold grades exceed 10 g/t.

Textures in veins include rugs, banding, breccious and colloform textures. More than 90 minerals have been described in the two ore deposits.

The vein mineralization was deposited during a single hydrothermal process in which seven stages [M1÷M7] of the fluids tectonic-metallogenic evolution were distinguished (Marias, 1996). The chemistry of a certain stage together with the active "contemporaneous" tectonics associated to that stage constitutes a mineralization moment. Each moment is sequentially related to the previous moment. The first moment [M1] is subsequent to the hydrothermal "ventilation" structures, of "breccia pipe" or "breccia dyke" type. Not all the moments are found in one and the same vein section.

The first moment [M1] is made up mainly of oxidic parageneses: hematite + red quartz, magnetite $\pm$ scheelite; the ore of this moment is red-brownish or blackish in colour.

The moment [M2] marks the preponderance of magmatic conductive systems. The paragenesis is dominated by pyrite - chalcopyrite. The ore texture is massive, frequently banded (with [M1] paragenesis), or of metasomatic substitution (of [M2] for [M1]). In [M1] absence, [M2] is placed in the vein marginal zone, adjacent to the host rock.

The moment [M3] marks the massive deposition – by boiling – of $Pb-Zn + (Au, Ag)$ mineralization). Prevailing paragenesis consists of sphalerite, galena, chalcopyrite $\pm (Au, Ag)$. Ore colour is black, spotted with yellow (chalcopyrite), in massive, banded or nested textures.

The moments [M4] and [M5] mark post-boiling stages. The fluid chemistry developed towards two geochemical directions depending on the input of meteorically induced fluids. The moment [M4] characteristic paragenesis is represented by sulfides sphalerite, galena, chalcopyrite, antimonite, argentite $\pm$ sulphosalts: tetrahedrite, bourmonite, freislebenite, berthierite, chalcostibite, ring shaped jamesonite, gold frequently native; accompanying gangue minerals include calcite, kutnahurite, dolomite. The moment [M4] marks the increase of carbonate-metal ratio at the expense of silica-metal ratio decrease (from [M3]). It represents the first moment of mixing (a mixture of magmatic fluids with the meteoric fluids induced in the hydrothermal system. The moment [M5] may be considered as a residual extension of [M3]. It is represented by massive white cryptocrystalline quartz, and as for sulfides or precious metals are concerned it is barren.

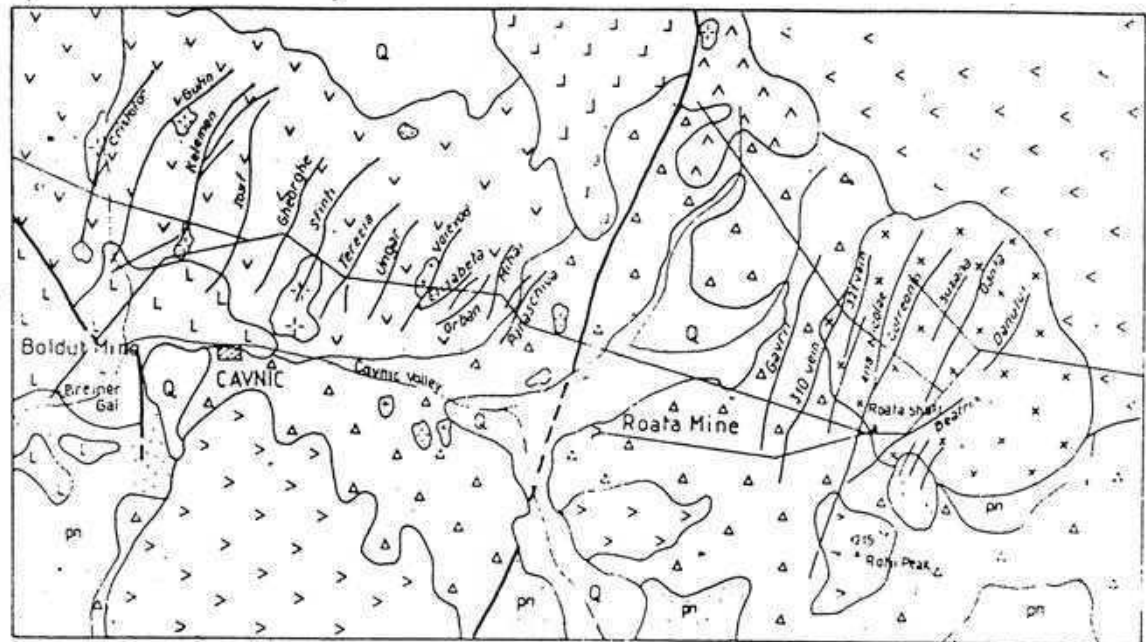
The moment [M6] is also deposited from a fluid mixture (meteoric + magmatic). The ore displays a pink colour, due to preponderance of rhodochrosite + sulfides $\pm$ sulphosalts.

The moment [M7] marks the "thermal drop down" of the hydrothermal system, with paragenesis depositing temperatures around 100 – 150°C. Paragenetic associations consist of calcite-dolomite, often stalactite like, barite, cinnabar, auripigment, realgar, stibarsenic, native gold, fluorite, clay minerals.

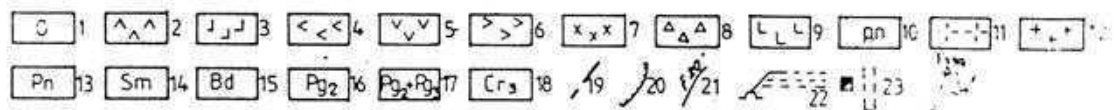
The homogenization temperature (°C) emphasized by the fluid inclusion study (on quartz, carbonates and sphalerite samples collected from different veins and levels) vary between 207°C and 324°C. The deposition temperature corresponding to each stage (moment) are presented in the next table.

Fig.1 Simplified geological map of the Căvnic zone (after Edelstein et al, 1992)

Scale 1:25,000



LEGEND



1. Quaternary; 2. Pyroxene andesites (Dealului type); 3. Py ± hb andesites (aphanitic type); 4. Py andesites (Măgura Mare type); 5. Pybasaltic andesites (Căvnic-Șuor type); 6. Py ± hb andesites (Higea-Rău type); 7. Hbpy andesites (Gottlieb type); 8. Volcaniclastic complex; 9. Qz andesites (Șuor type); 10. Volcanic-sedimentary deposits; 11. Pyroxene, diorites and monzodiorites; 12. Qz andesites and granodiorites; 13. Pannonian; 14. Sarmatian; 15. Badenian; 16. Eocene flysch; 17. Eocene-Oligocene flysch; 18. Senonian; 19. Fault; 20. Overthrust; 21. Vein; 22. Gallery; 23. Shaft; 24. Drillings

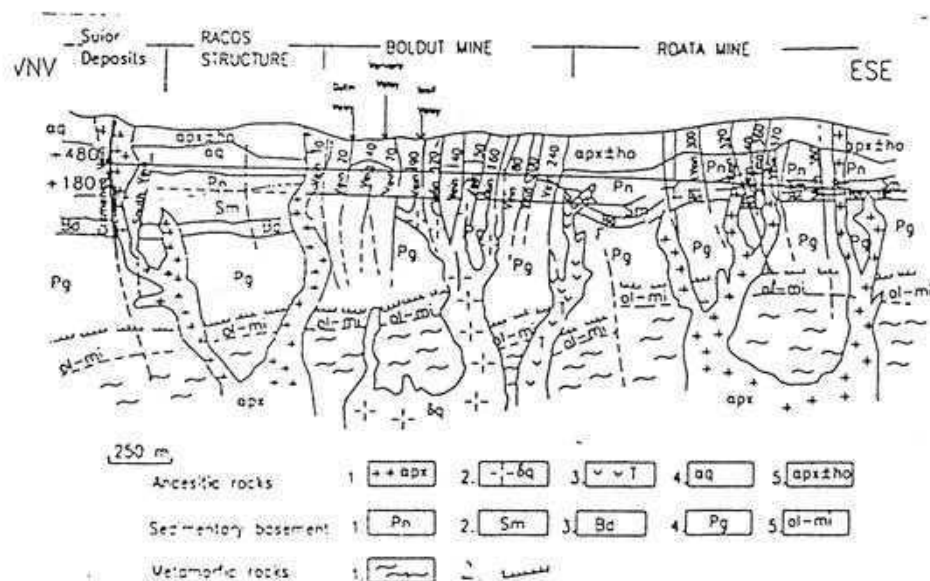


Fig. 2 – Geological cross-section through the Căvnic epithermal ore deposit (Marias 1996). Explanation: Andesitic rocks: 1. Pyroxene andesite, 2. Quartz diorite, 3. Tonalite, 4. Quartz andesite, 5. Amphibole andesite; Sedimentary basement: 1. Pannonian marls, 2. Sarmatian flysch, 3. Badenian calcareous marls, 4. Paleogene flysch, 5. Oligocene – Miocene marls and grit stones; Metamorphic rocks: 1. Micaschist and gneiss, 2. Overthrust nappe).



A

B

C

D

E

F

Mineralization moment	Freezing temp. (CO ₂) °C			Filling temperature °C		
	Min	Max	Average	Min	Max	Average
M1	-4	-1.8	-2.9	279	324	302
M2	-7.3	-1.7	-4.5	266	322	294
M3	-3.2	-1.6	-2.4	264	298	281
M4	-2.6	-0.7	-1.7	245	298	271
M5	-3.6	-1.7	-2.7	265	302	284
M6	-3.8	-1.6	-2.7	207	248	227

The global salinity of the mineralizing fluids vary between 1.2 and 14 wt% NaCl equiv. The salinity spans a considerable range, (e.g. from 5 to 14 wt% NaCl) in the same mineralization stage (Grancea et al, in print).

Analyses of oxygen isotope ($\delta^{18}\text{O}$) and (δD) were performed on samples of quartz and carbonate in order to establish the origin of the mineralizing fluids. These analyses were carried out in the laboratories of BRGM – Orléans, France.

Thus, $\delta^{18}\text{O}_{\text{quartz}}$ values from the quartz of metallogenic moments vary from +6,7‰ to +11,1‰ against SMOW, that pleads for a magmatic origin of mineralizing fluids, alike other base metal epithermal ore deposits (Field and Ficareck, 1986).

The $\delta^{18}\text{O}_{\text{quartz}}$ variation with time, as metallogenic events developed in the [M1-M5] range shows an enrichment in heavy isotopes as the boiling phenomenon evolves and is subsequently generalized (in [M3]) (Marias, 1996), afterwards $\delta^{18}\text{O}_{\text{quartz}}$ values decrease for [M4-M5].

The $\delta^{18}\text{O}_{\text{H}_2\text{O}}$ values (computed from $\delta^{18}\text{O}_{\text{quartz}}$ values, $\delta^{18}\text{O}_{\text{carbonates}}$ values and homogenization temperature of fluid inclusion consistently increase as mineralizing stages evolve from in the same time with the evolution of the mineralization stages from +1,8‰ (for [M1]) to +4,1‰ (for [M2]) and to +3,6‰ (for [M3]) afterwards these values also decrease.

The δD values obtained on quartz crystals vary from -71 and -109 ± 10 ‰. Considering the $\delta^{18}\text{O}$ - δD ratios, Carnic hydrothermal system was dominated by fluids in which the magmatic component increased on the [M1-M3] interval, while in later stages of the process [M4-M7] mixed fluids prevailed, eventually the meteoric ones became prevalent.

The $\delta^{34}\text{S}$ values obtained on sphalerite and galena from stage (moment) 3 and on pyrite crystals from stages 1 to 4, exhibit a narrow range extending from +0.3 to +5.2‰. Calculated $\delta^{34}\text{S}$ fluid values, assuming a temperature of 300°C and H_2S dominated hydrothermal system are close to +3.4‰ and are consistent with a magmatic sulfur source (Piantone et al, 1999).

No variation of Pb isotopes exist during the main ore deposition stages suggesting a single metal source (Marcoux et al, 1996).

K-Ar datings on illite from Roata mine veins emphasized a cca 1 M.a. younger age (9.3 ± 0.5 M.a.) comparative with the host volcanic rocks (Kovacs et al, 1997).

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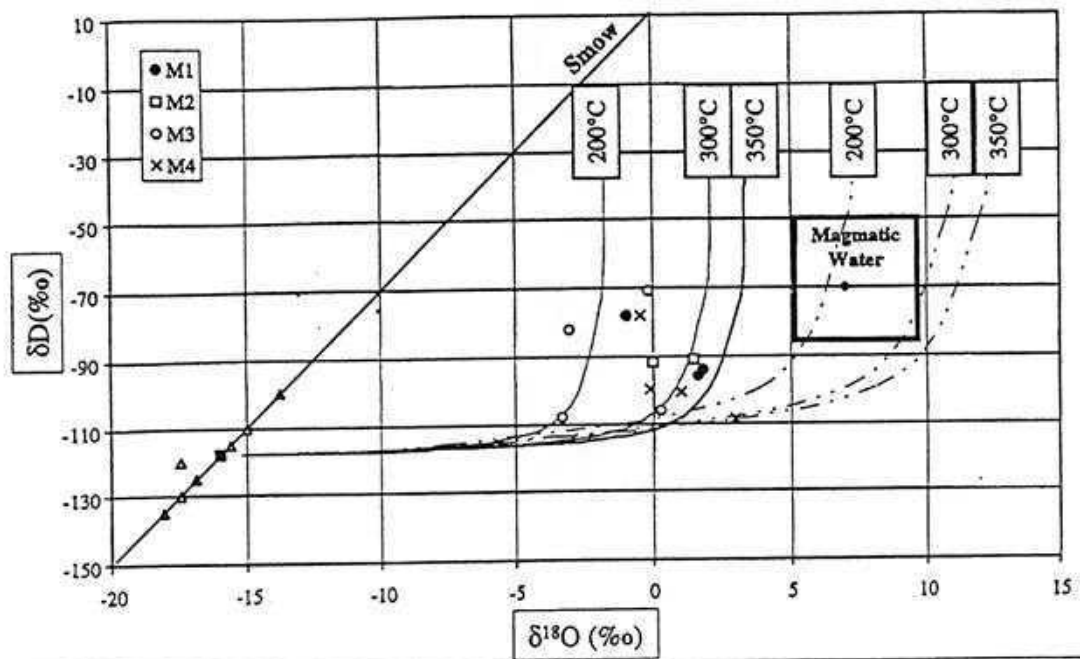


Figure 3. $\delta^{18}\text{O}$ plotted against δD of quartz from the four main ore deposition stages. The diagram shows variations in fluid isotopic composition equilibrated with propylitized volcanic rocks (full lines) and sedimentary rocks (dashed lines) as a function of the initial fluid composition, T. Various water/rock ratios are also reported (from Piantone et al., 1959)

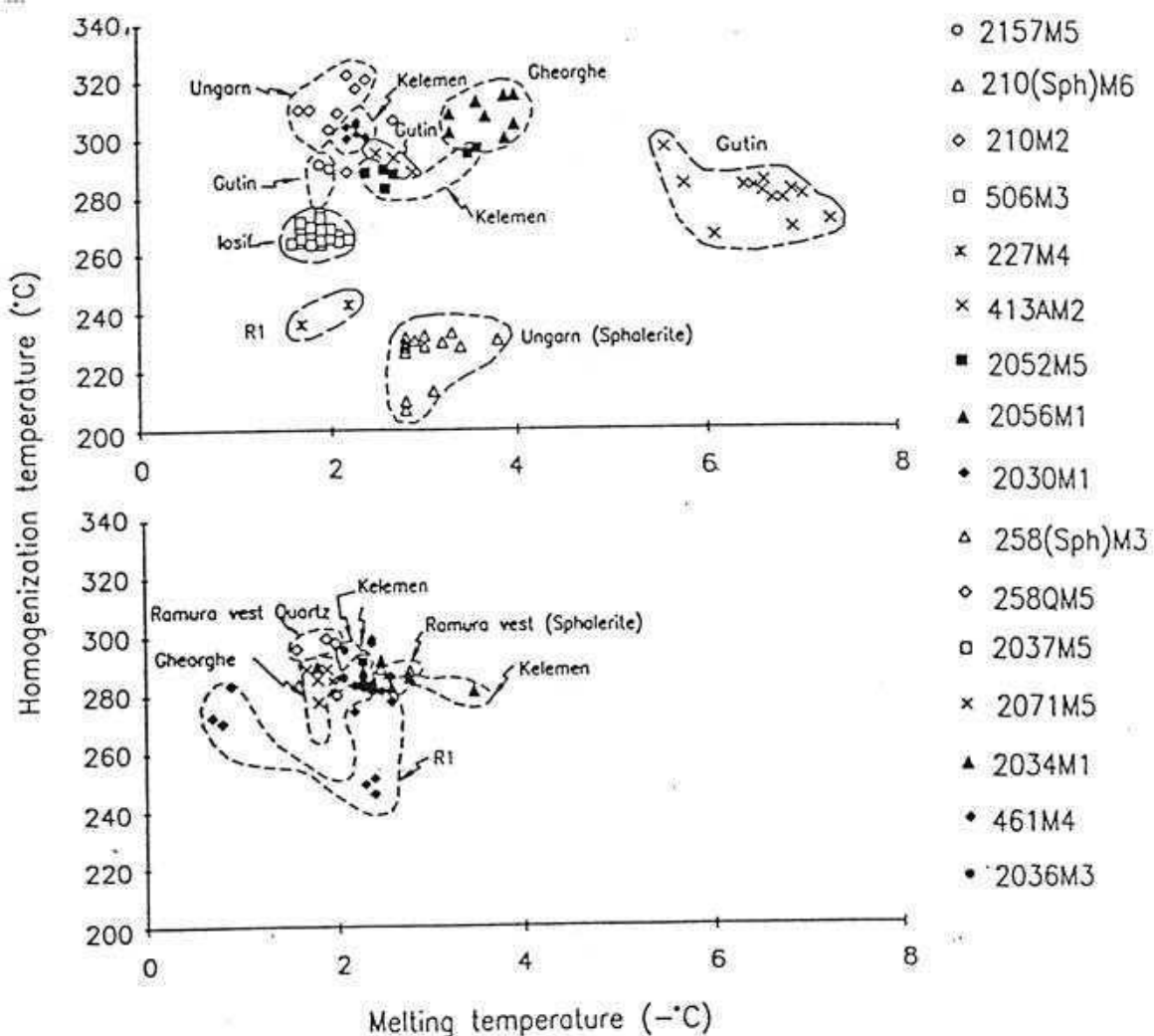


Fig 4 - The homogenization temperature reported to the melting temperature for the veins and mineralization moments in Cavnic ore deposit (Bolduț mine, Măriș, 1996)



Fig. 5. Unmineralised breccia dyke associated with Ungarn N Vein (+180 level, Bolduț Mine - Mariaș, 1996)



Fig. 6. The contact between breccia-pipe and sedimentary host rock from Ungarn vein. Căvnic deposit (Marcoux et. al., 1994)

BAIA SPRIE EPITHERMAL DEPOSIT

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4. REMIN Company, Baia Mare

The Baia Sprie ore deposits consists of veins developed in a tectonic structure - a system of two major faults, E-W trending, which delineate a compartment with very thick lavas (more than 800 m). This graben represents only a part of the volcano-tectonic alignment Tăuţi - Baia Sprie - Şuitor situated on the direction of the major transcrustal fault Bogdan Vodă (Cărlibaba-Carei). The two main veins of the Baia Sprie ore deposits are developed along the faults that outline the graben - the Main Vein in the north and the New Vein in the South. A NE-SW tectonic system also appears within the graben, containing major mineralizations such as the Diagonal Vein in the central part of the graben.

Marcoux et al (1994) emphasized the presence of the breccia pipe and breccia dyke structures in the eastern part of the Baia Sprie ore deposit involving synmineralization phreato-magmatic volcanic activity.

Recent investigation (Mihalache, A. & Chiuzbăian, C. in print) evidences the following breccia - types: 1). Polygenous mineralized breccia (Fig. 7, a) consisting of hydrothermalized adésite od dacite and most clasts with blocks coloured fine grained marl. These breccia may be assigned to the "breccia pipe" type. 2). Cupriferous breccia (Fig. 7, b,c,d) with a cupriferous matrix with cement adésite and marl and sandstones clasts, 3). Polymetallic - hydrothermal (filonian) breccia consisting of cupriferous breccia clasts cemented by a mainly polymetallic matrix, 4). Tectonic breccia (Fig. 7, e) made up by rounded and S-shaped andesite and sedimentary elements hosted into a milonitic silicified and carbonated matrix impregnated with pyrite.

The Main Vein represents the longest vein known in Romania until now (5250 m). Its thickness varies between 0.5 and 22 m and its known development is more than 750 m in height. The New Vein (Southern Vein) has a maximum length of 2100 m, being developed especially in the western part, on a thickness that does not get over 7 m. The maximum length of the Diagonal Vein is cca 600 m and its thickness varies between 0.5 and 1 m. The Main Vein has many branches: the most important is the Terezia Vein, in the central-western part, having a length of 600 m.

The general character of the mineralizations constituting the Main, the New and the Diagonal veins is polymetallic (lead and zinc). Some parts of the Main Vein display a copper character at the deeper level and a gold-silver character especially at the upper level. Its branches from the bed (in the Minei Hill zone) have also a gold-silver character.

The wall rock alteration which preceded the metallogenic activity exhibits a distinct vertical and horizontal zonality and symmetry in the vicinity of the ore veins. The chloritized zone is characteristic of the lower level of the ore deposit, meanwhile the adularized, sericitized and argillized zones occur towards the median and high levels of this one (Stanciu, 1973).

The complex character of the metallogenic activity is pointed out by a very rich mineral paragenesis, over 70 minerals being known so far, some of them being identified in this ore deposit for the first time in the world (andorite, semseyite, klebesbergite, felsöbanyite, dietrichite, monsmendite, szmikite, Udubaşa et al, 1991). From the many mineralogic studies regarding the Baia Sprie ore deposit, those of Manilici et al. (1965) in the Principal vein, of Petruian et al (1971) in the Nou vein and Borcoş et al (1975) for Baia Sprie ore deposit are the most outstanding ones.

The Principal (Main) vein, which towards the upper part has numerous branches both in the hanging wall (Boului, Rotmundy, Leppen, Emeric etc.) and in the foot wall (Levesi Elly, Lobi is the best known). In these branches high grade gold and silver ores are to be mentioned. The ores of the Principal vein and its deep-seated branches show several varieties of texture depending on the types of deposition as follows: massive, brecciated and banded. The breccious character is due to the cementing both of andesitic fragments with pyrite and chalcopyrite impregnation and of fragments of pyrite-chalcopyrite ores by a lead-zinciferous mineralization. The banded textures show asymmetrical banding of the base-metal sulphides and quartz. Very often, in the inner part of the vein, cavities filled with idiomorphic minerals formed during different stages of the metallogenic activity have been found. Generally, the Principal vein has a rich mineral paragenesis such as native elements (S, As, Au, Ag), base-metal sulphides, sulfosalts, arsenides, antimonides, oxides, carbonates, sulphates, wolframites, phosphates and silicates.

The mineralogical studies (Manilici et al, 1965, Borcoş et al, 1975) indicate the following characteristic metallic and gangue mineral assemblages: pyrite, chalcopyrite, chlorite, wolframite, scheelite; pyrite, chalcopyrite, quartz $\pm$ dolomite; pyrite, sphalerite, galena, quartz; pyrite, chalcopyrite, sphalerite, galena, quartz; sphalerite, galena, stibnite, quartz, calcite, barite; barite, galena, tetrahedrite.

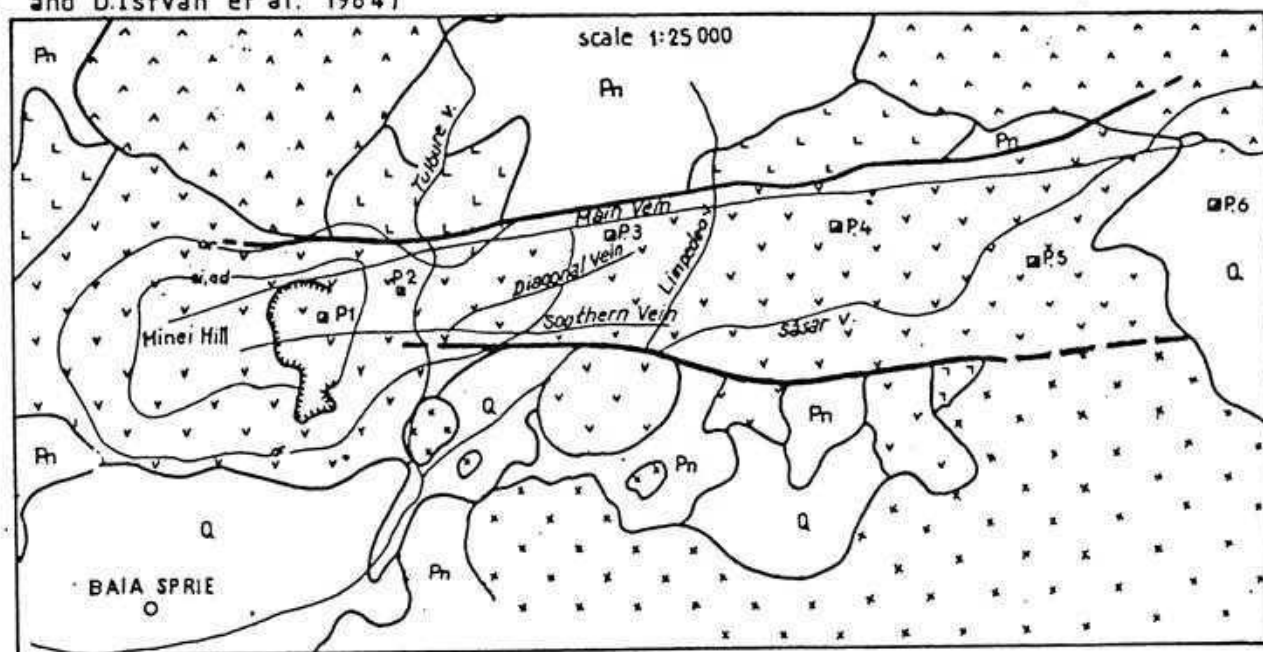
The relationships between the metallic and gangue minerals suggest their deposition during two main metallogenic stages. During the early main cupriferous stage the paragenetic sequence leads to the deposition of the pyrite, chalcopyrite, specular-hematite, scheelite, wolframite and magnetite with chlorite, quartz, ankerite and barite. The second main mineralogenetic stage shows lead-zinciferous and gold-argentiferous characters and the minerals are pyrrhotite, sphalerite, chalcopyrite, galena, tetrahedrite, antimonite, freislebenite, different sort of sulfosalts and native elements with quartz, adularia, calcite, rhodochrosite and barite.

The cupriferous mineralization appears both in the independent vein branches such as Terezia from the lower part of the ore deposit and in the Principal vein having a different distribution in comparison with the dominant lead-zinciferous mineralization.

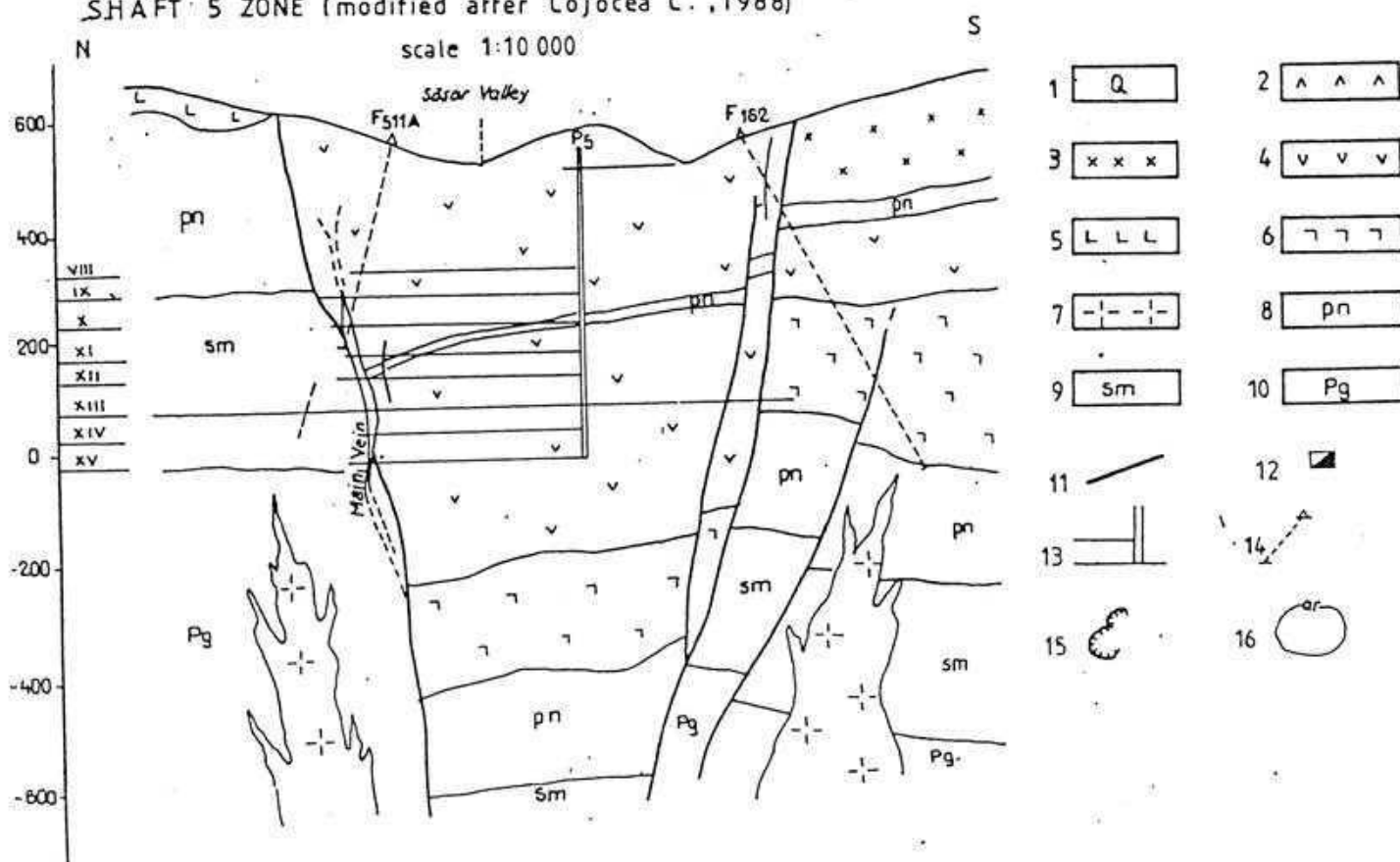
The lead-zinciferous mineralization is typical for the median portion of the Principal vein in its zone where the most intensive mineralizing process has taken place. The lead-zinciferous mineralization is grading to a gold-argentiferous one. Thus, the zonality of the mineralization during a single metallogenic phase is very obvious.

In the Nou vein, the texture of the ore is dominant by massive, locally banding and breccia zones with cavities. Generally no sharp boundaries diffusion-like branching veinlets or thin

Fig 1 SIMPLIFIED GEOLOGICAL MAP OF THE BAIJA SPRIE ZONE (after M Gabor et al., 1988 and D.Istvan et al. 1984)



GEOLOGICAL CROSS SECTION THROUGH BAIJA SPRIE EAST ORE DEPOSIT SHAFT 5 ZONE (modified after Cojocă C., 1988)



1. Quaternary; 2. Pyroxene andesites; 3. Pyroxene basaltic andesites; 4. Pyroxene ± hornblende, quartz andesites (Baia Sprie type); 5. Quartz bearing andesites; 6. Biotite dacites (Dănești type); 7. Intrusions; 8. Pannonian sedimentary rocks; 9. Sarmatian sedimentary rocks; 10. Paleogene flysch; 11. Veins and faults; 12. Shafts; 13. Gallery and shaft; 14. Drillings; 15. Quarry; 16. Hydrothermal alteration zone.

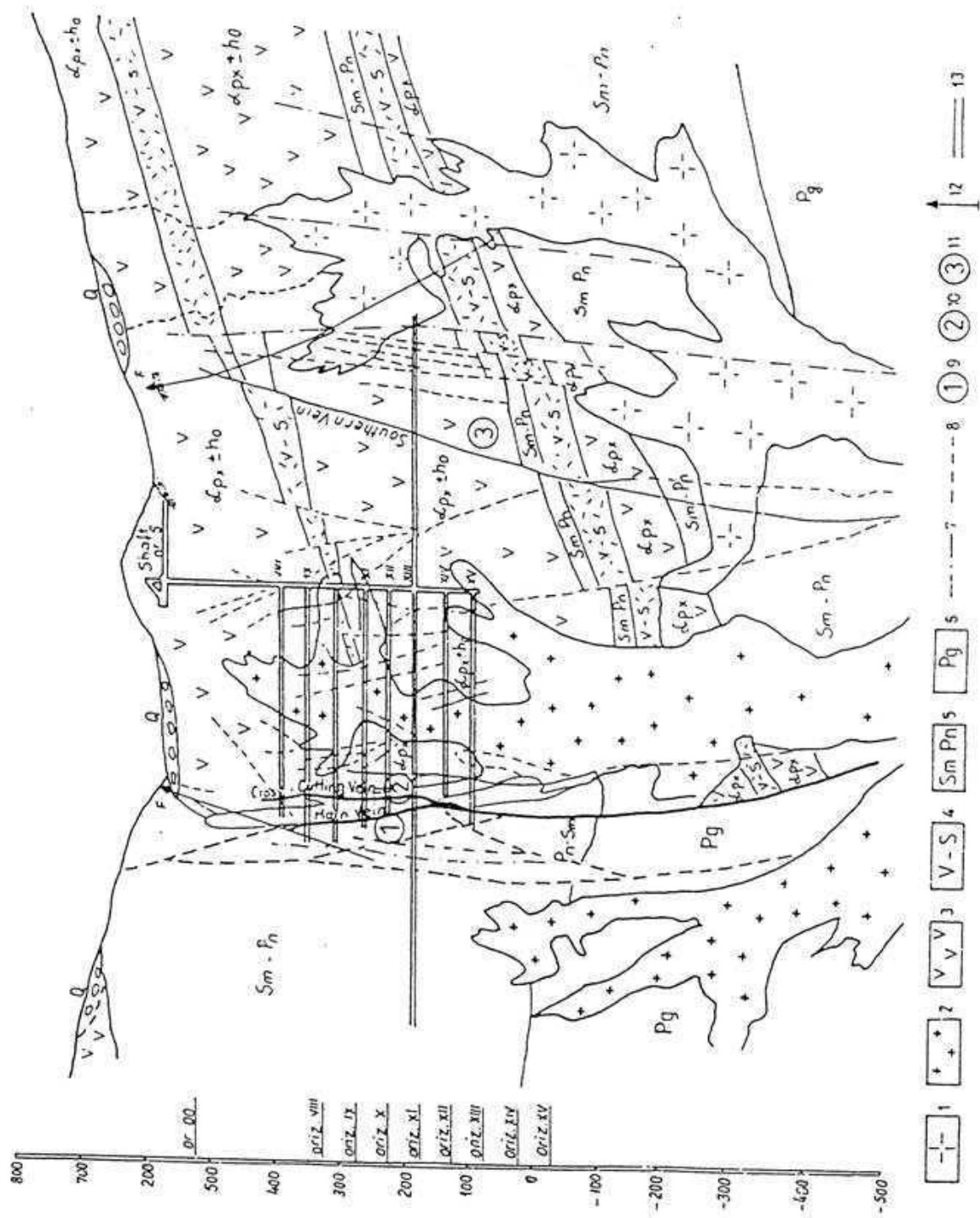


Fig. 2 - Cross section through Baia Sprie ore deposit (Eastern part) (M. Zoltan, 1993).
 1. dacite; 2. porphyry microdiorite; 3. pyroxene and amphibole andesite; 4. volcano-sedimentary formation; 5. non-differentiated Sm-Pn
 sedimentary deposits; 6. Paleogene; 7. Vein; 8. Fault; 9. Main Vein (1); 10. Diagonal Vein (2); 11. Southern Vein (3); 12. Drilling; 13.
 Galleries.

bandings of the ores in the host rocks are typical. The mineralization has a base-metal character with dominant sphalerite and galena to which chalcopyrite, marcasite, stibnite, sulfosalts, realgar, auripigment, quartz, calcite, siderite, ankerite and barite associate. The mineralogic studies (Petrulian, 1971, Borcoş et al, 1975) indicate that the metallogenic activity began with the deposition of pyrite and minor mispickel close associated with large amounts of sphalerite with exsolution blebs of chalcopyrite. Very often tetrahedrite and bournonite associate with sphalerite. Subordinate, new generations of sphalerite, chalcopyrite and galena continuously deposited. Chalcopyrite is subordinate and does not show special enrichments in the vein filling. It seems that galena was deposited more or less contemporarily with chalcopyrite and appear to be associated with the sulfosalts. The mineral paragenesis exhibits a lead-zinc character of the ore.

The Diagonal vein, 600 m in length, 200 m in height and 0.1-1 m in thickness, is opened between the XI and XIV mining levels. The ores exhibit dominant massive texture and locally banded and brecciated ones. The principal minerals are sphalerite, galena, pyrite and quartz, with subordinate chalcopyrite and scarce tetrahedrite at the upper part. The sulfosalts are sporadically found and show irregular distribution.

Recent complex study (Bailly et al, 1998, Grancea et al, in print) carried out important features of the Baia Sprie epithermal systems. Five mineralizing events have been identified: 1. Stage M1 (Fe); 2. Stage M2 (Cu-Bi-W); 3. Stage M3 (Pb-Zn); 4. Stage M4 (Sb); 5. Stage M5 (Au-Ag).

The Au-Ag level is well defined in the upper part of the ore deposit. In Minei Hill open pit, Grancea et al (in print) emphasized an Au-Ag mineralization of the M5 stage. The Ag-rich character is due to the presence of numerous microscopic Ag-bearing sulfosalts (freibergite, pyrargyrite, myargyrite) detected especially within the galena crystals.

Fluid inclusion microthermometric data were reported by many authors: Manilici et al (1965), Lang (1979), Pomârleanu et al (1985). A 2000 - 3000C range of homogenization temperatures was emphasized for the main stage of the mineralization. Nedelcu and Pintea (1993) report homogenization temperatures ranging from 1470C to 3590C and the salinities between 3.6 to 19.95 wt% NaCl equiv. They also carried out the presence of the boiling process.

Bailly et al (1998), based on the fluid inclusion from quartz and sphalerite study noted a temperature ranging from 1500C to 3000C and a salinity which vary from 0 to 21 wt% NaCl (fig.3).

Recent fluid inclusion study in the Minei Hill open-pit (Grancea et al, in print) emphasized that the majority of the homogenization temperature (T_h) of fluid inclusions in the veins ranges from 1760 to 2540C and the salinities in fluids are in the range of 5 to 15 wt% NaCl equiv. The altered country rocks with a quartz-sericite (adularia, rare sulfides) paragenesis, appear to contain more dilute fluids (with about 6wt% NaCl equiv. and $T_h = 1740C$). Most of fluid inclusions from the Minei Hill open-pit mineralization (upper part of Baia Sprie ore deposit) have moderate salinities, similar to other Ag-rich epithermal deposits (Fresnillo, Mexico or Creede, Colorado).

Radiometric data (K-Ar and Ar-Ar, Lang et al 1994, Kovacs et al, 1997) emphasized a very good correlation between the adularia and illite (from Principal/Main Vein) forming age (fig.4). The 7.9 ± 0.1 M.a. Ar-Ar age is the youngest age for the epithermal mineralizations in Baia Mare metallogenic region.

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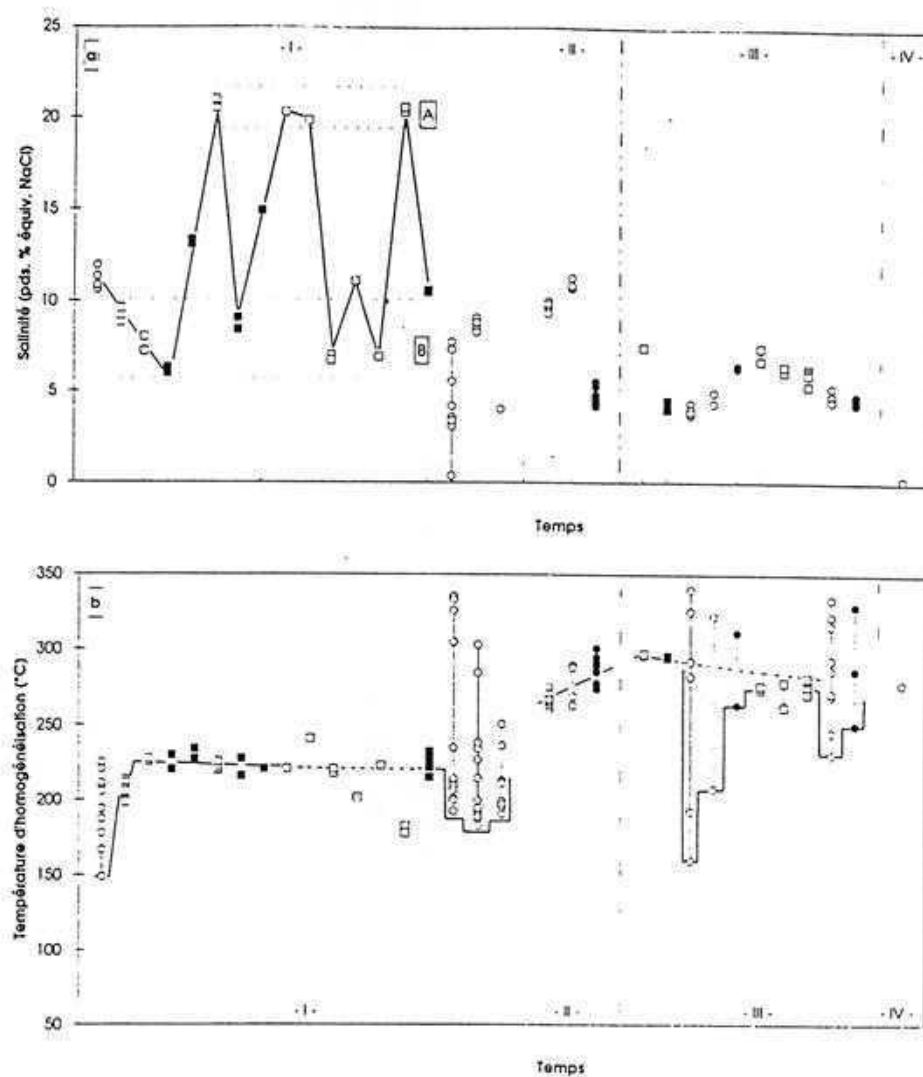


Fig.3 Salinity and fluid-homogenisation temperatures evolution with time. All the inclusions arranged along a given vertical line are contemporaneous, in quartz crystals (circle) or in sphalerite (square), of primary (open symbol) or secondary (black symbol) origin. (from Bailly et al., 1998)

Sample	Location	Age	Laboratory
Adularia			
Rom19	Baia Sprie Mine Principal Vein, XIV level	9.0 $\pm$ 0.2 7.9 $\pm$ 0.1 (Ar-Ar)	Jerusalem (Lang B.)
Rom21	Baia Sprie Mine Principal Vein, XIV level	9.3 $\pm$ 0.2	Jerusalem (Lang B.)
25.021	Baia Sprie Mine Principal Vein, XIII level	8.7 $\pm$ 0.4	Debrecen (Pécskay Z.)
92 MB-125	Dealul Minci Quarry	8.89 $\pm$ 0.2	Grenoble (Bonhomme M.)
92 MB-126	Dealul Minci Quarry	8.92 $\pm$ 0.2	Grenoble (Bonhomme M.)
Illite			
92 MB-127	Baia Sprie Mine, Shaft 5 Principal Vein, XIII level	7.65 $\pm$ 0.83	Grenoble (Bonhomme M.)
92 MB-128	Baia Sprie Mine, Shaft 5 Principal Vein, XIII level	8.95 $\pm$ 0.87	Grenoble (Bonhomme M.)
92 MB-129	Baia Sprie Mine, Shaft 5 Principal Vein, XIII level	7.94 $\pm$ 0.63	Grenoble (Bonhomme M.)

Fig.4 Radiometric data of the Baia Sprie ore deposit

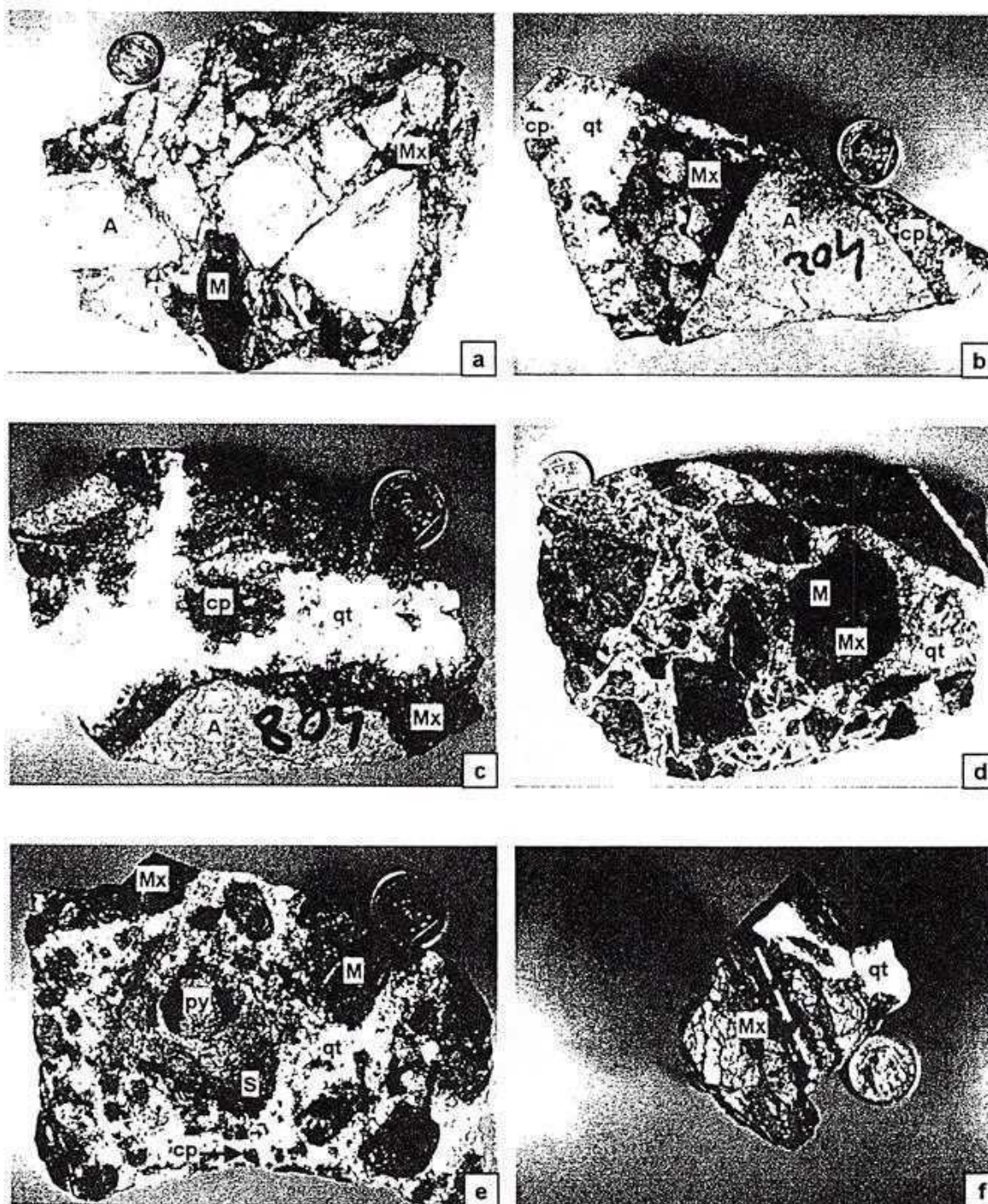


Fig.5 - Pipe breccia with andesite fragments cemented with marls in the Baia Sprie East mine, X horizon (Marcoux et al, 1994)



Fig.6 - Sarmatian volcano-sedimentary formation (marls, reworked tuffs and volcanic breccia) developed immediatly near the northern border of the Baia Sprie graben (Baia Sprie East mine XIV level, Marcoux et al, 1994)

Fig. 7. Different breccia types from Principal Vein Zone in Baia Sprie deposit (Mihalache & Chiuzbaian, in print)



Abbreviations: A - andesite; cp - chalcopyrite; M - marl; Mx - matrix; py - pyrite; qt- quartz; S - sandstone.

LEGEND

SEDIMENTARY DEPOSITS

	Quaternary
	Pannonian
	Sarmatian
	Badenian
	Lower Miocene
	Upper Cretaceous - Paleocene
	Upper Cretaceous
	Lower Cretaceous
	Upper Jurassic - Lower Cretaceous
	Upper Jurassic

IGNEOUS ROCKS

Pliocen Quaternary

Alkaline rocks; trachyandesite

Neogene magmatism (Badenian - Pannonian)

Rocks with alkaline features: trachyandesites, basaltic trachyandesites - microdiorites

Medium - to High K calc-alkaline andesites and adakite-like rocks: basalt andesites, andesites, quartz andesites, dacites; 1-volcanoclastic rocks and lava flow; 2-necks and shallow subvolcanic bodies; 3-breccia bodies

Volcano-sedimentary formation

Upper Cretaceous - Paleocene magmatism

Intrusions: diorites, quartz diorites, granodiorites and their porphyry varieties

Extrusive rocks: volcanoclastics and lava flow

Mesozoic ophiolites (Jurassic - Lower Cretaceous)

1-Spilites (in Fenes Nappe); 2-basalts (B) in Cris Nappe

Calc-alkaline series:
1-Porphyric basalts, andesites, dacites, rhyolites as piroclastics and flow
2-Eocretaceous intrusions rocks (dykes and bodies): diorites, granodiorites, tonalites, andesites, dacites and rhyolites

Tholeiitic series:
1-aphanitic intersertal basalts, anamesite, dolerite;
2-gabbros

PRE-ALPINE BASEMENT

Undifferentiated formations

Geological boundaries

Thrusts

Faults

GENETIC TYPES OF ALPINE DEPOSITS AND OCCURENCES

NEOGENE METALLOGENY

1. Porphyry Copper Systems

- porphyry copper
- porphyry copper associated with epithermal veins

2. Hydrothermal

- veins
- stockwork - breccia pipe
- impregnation
- replacement

3. Sedimentary

- placer gold

UPPER CRETACEOUS - PALEOGENE METALLOGENY

pyrometasomatic (thermal recrystallization, skarns)

porphyry copper

veins

MESOZOIC METALLOGENY

Liquid magmatic

Hydrothermal: veins and/or stockworks

volcano-sedimentary (lenses)

ORE DEPOSITS AND OCCURENCES ASSOCIATED TO ALPINE MAGMATISM

ORE DEPOSITS AND THEIR MAIN ELEMENTS

ORE DEPOSITS ASSOCIATED TO NEOGENE MAGMATISM

- 1 - Afinis: Au, Ag, Te (Pb, Zn, Cu)
- 2 - Valea Lacului: Pb, Zn, Au, Ag
- 3 - Rosia Poieni: Cu, Au, Mo
- 4 - Tarina: Au, Ag
- 5 - Vartop: Au
- 6 - Cetate: Au, Ag
- 7 - Carnic: Au, Ag
- 8 - Bucium Rodu: Au, Ag
- 9 - Contu: Au, Ag
- 10 - Vulcoi - Corabia: Au, Ag
- 11 - Bucium Tarnita: Cu, Au
- 12 - Arama: Cu, Au, Ag, Pb, Zn (Ge)
- 13 - Botes: Au, Ag
- 14 - Babuia: Hg
- 15 - Izvorul Ampoiului: Hg
- 16 - Breaza: Au, Ag
- 17 - Hanes: Au, Ag; Pb, Zn, Cu
- 18 - Larga: Au
- 19 - Fata Baii - Larga: Au, Ag, Te; Au, Ag, Pb, Zn
- 20 - Metesan: Pb, Zn (Au, Ag)
- 21 - Baba: Pb, Zn
- 22 - Almas - Dl. Negrii: Au, Ag (Pb, Zn)
- 23 - Muncaceasca E: Au, Ag; Pb, Zn, Cu
- 24 - Popa - Stanija: Au, Ag, Te, Pb, Zn, Cu
- 25 - Muncaceasca W: Cu, Au
- 26 - Borzesti: Au, Ag
- 27 - Stanija - V. Tisei: Au, Ag (Pb, Zn)
- 28 - Valea Tisei: Cu, Au
- 29 - Remetea: Cu
- 30 - Colnic: Cu, Au
- 31 - Sacaramb: Au, Ag, Te (Pb, Zn)
- 32 - Bocsa - Sacaramb: Pb, Zn
- 33 - Coranda: Pb, Zn, Au, Ag
- 34 - Hondol: Au, Ag
- 35 - Paraul lui Avram: Cu, As
- 36 - Magura: Au, Ag; Pb, Zn
- 37 - Bolcana: Cu, Au
- 38 - Troita: Pb, Zn, Au, Ag
- 39 - Trestia: Au, Ag
- 40 - Baita Craciunesti: Au, Ag, Pb, Zn
- 41 - Voia: Cu, Au
- 42 - Draica: Au, Ag
- 43 - Valisoara: Au, Ag; Pb, Zn
- 44 - Cordurea: Au, Ag, Te
- 45 - Canel: Au, Ag
- 46 - Hartagani: Au, Ag; Pb, Zn
- 47 - Valea Morii: Cu, Au
- 48 - Ruda - Barza: Au, Ag; Pb, Zn, Cu
- 49 - Bradisor: Au, Ag
- 50 - Musariu: Cu, Au, Ag
- 51 - Magura Tebei: Au, Ag
- 52 - Caraci: Au, Ag; Pb, Zn
- 53 - Bratosin: Au, Ag, Pb, Zn
- 54 - Talagiu: Cu, Au
- 55 - Rastoci: Au, Ag
- 73 - Deva: Cu, Au, Mo

ORE DEPOSITS ASSOCIATED TO UPPER CRETACEOUS MAGMATISM

- 56 - Magureaua Vatei
- 57 - Rompi - Ioneasca Cu, Au
- 58 - Bulza: Pb, Zn (Au, Ag)

ORE DEPOSITS ASSOCIATED TO MESOZOIC OPHIOLITES

- 59 - Ciungani: Ni
- 60 - Cazanesti Ciungani: Fe, Ti, V, Ni; Cu
- 61 - Almas Saliste: Fe, Ti, V; Cu
- 62 - Dl. Mare: Pb, Zn, Cu (Au, Ag)
- 63 - Cerbia: Mo
- 64 - Pietris: Cu
- 65 - Savarsin: Mo
- 66 - Almasel: Cu
- 67 - Rosia Noua: Cu
- 68 - Cazanesti: Cu
- 69 - Vorta: Pb, Zn (Au, Ag)
- 70 - Tamasesti: Mn
- 71 - Parnesti: Mn
- 72 - Soimus - Buceava: Mn

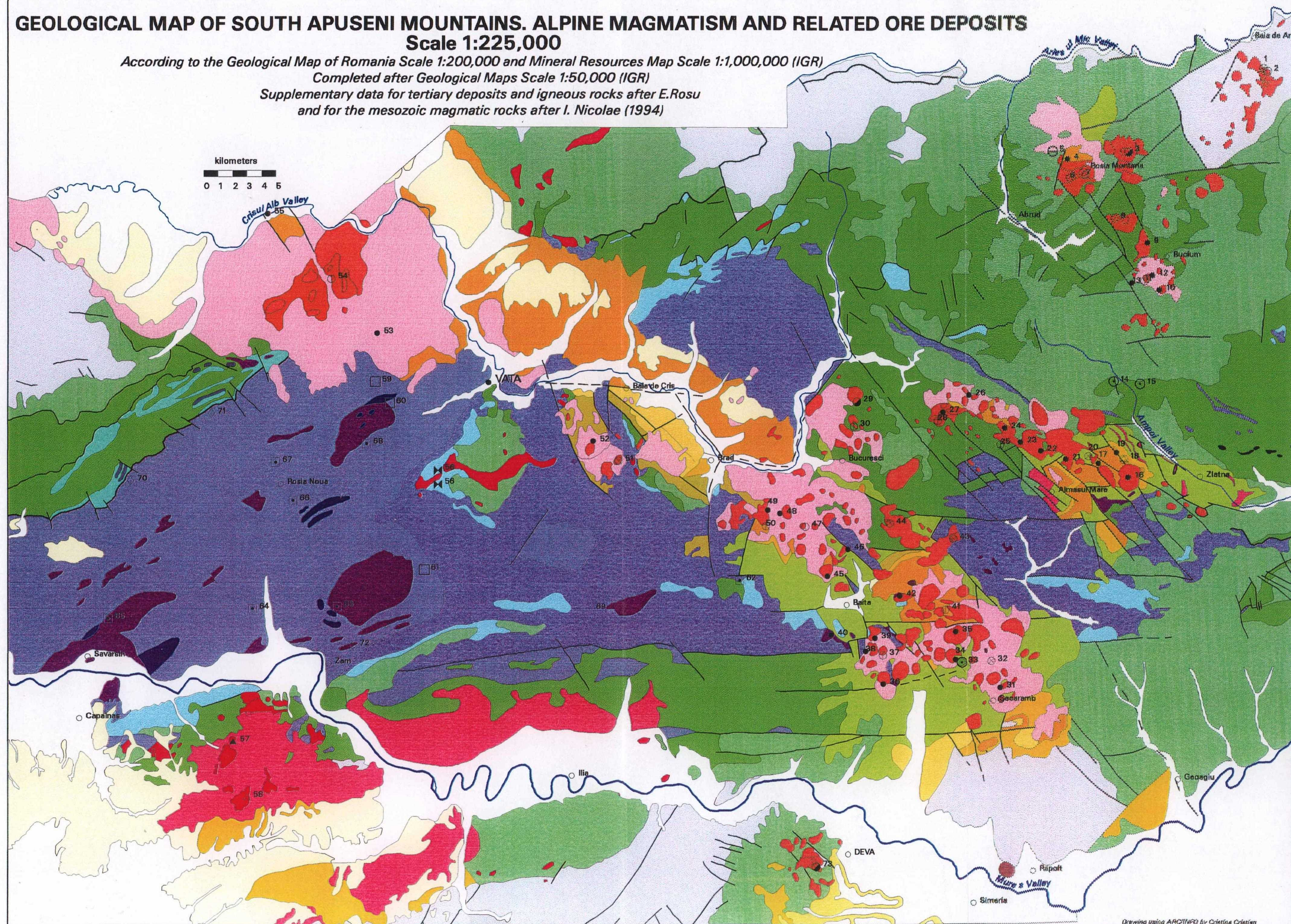
GEOLOGICAL MAP OF SOUTH APUSENI MOUNTAINS. ALPINE MAGMATISM AND RELATED ORE DEPOSITS

Scale 1:225,000

According to the Geological Map of Romania Scale 1:200,000 and Mineral Resources Map Scale 1:1,000,000 (IGR)

Completed after Geological Maps Scale 1:50,000 (IGR)

Supplementary data for tertiary deposits and igneous rocks after E. Rosu
and for the mesozoic magmatic rocks after I. Nicolae (1994)



THE NATIONAL COMPANY OF COPPER, GOLD AND IRON "MINVEST" S.A. DEVA - ROMANIA

ORGANIZATION

The National Company of Copper, Gold and Iron "MINVEST" S.A. Deva was established in accordance with the Decision of Government 808/13.11.1998 and it runs as a state owned commercial company under the rule of the Ministry of Industry and Resources - The General Department of Mine and Geology

ACTIVITY AREA AND STRUCTURE

MINVEST operations are developed within 7 counties of Romania and the organisation is based on territory criteria. MINVEST S.A. comprises 10 mining subsidiaries and 1 mining branch.

ACTIVITY

- copper, gold-silver, ferrous, polymetallic and metal slags mining and processing, the extraction and processing of quarry materials and gravels
- sale of products
- geological and technological investigations and researches
- design
- equipment repairs and maintenances
- laboratory analysis
- international cooperation relationship and import-export operations
- investments-development
- employees training
- strategies-restructuring activity
- mine closure and preservation
- environment protection



GABRIEL RESOURCES LTD.

- Gabriel is one of the first active mining development and exploration companies in Romania, where a western based mining law was introduced in June 1998.
- Through joint ventures with Romanian state mining company Minvest S.A., Gabriel has assembled a portfolio of world class gold-silver and copper-gold projects in two mineral licenses within the historically productive "Golden Quadrilateral" in west-central Romania.
- Gabriel is operator and the controlling shareholder in the joint ventures with Minvest S.A., having a 80% interest in Rosia Montana Gold Corporation S.A.
- The most advanced project, Rosia Montana, has a resource of 13 million ounces of gold and 49 million ounces of silver and has proceeded to Final Feasibility Stage.
- Other advanced exploration projects include Corabia, Bucium Tarnita, Frasin and Bucium Rodu.
- Gabriel is well financed, and run by an experienced management team.
- Gabriel is currently listed on the Toronto Stock Exchange



EUROPEAN GOLDFIELDS LTD

European Goldfields was listed on the CDNX on June 13th 2000 and its business is to explore and develop its concessions in Europe's historic and prolific precious metals region of Transylvania, Romania.

The company has four concessions; Certej, Baita, Bolcana and Zlatna. Within these areas are a number of identified gold deposits on which a significant amount of underground grid-pattern exploration was undertaken by state companies. Management believes that these concessions have excellent potential to host major mining projects. The ongoing work program is designed to test the known mineral deposits and to identify new targets using modern day exploration and development techniques.

The initial focus is to expand the Certej gold-silver deposit which has a near surface multi-million-ounce resource. The grades of Certej are similar to Gabriel Resources nearby multi million ounce world-class Rosia Montana gold project.

The management of European Goldfields are also involved in Gabriel Resources, and have generated significant shareholder value.





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