Romanian Journal of
MINERALOGY

continuation of

DĂRI DE SEAMĂ ALE ŞEDINŢELOR INSTITUTULUI DE GEOLOGIE ŞI GEOFIZICĂ
COMPTES RENDUS DES SÉANCES DE L'INSTITUT DE GÉOLOGIE ET GÉOPHYSIQUE
(1. Mineralogie–Petrologie)

Founded 1906 by the Geological Institute of Romania

ISSN 1220-5621

Vol. 77
Supplement Nr. 2

THIRD SYMPOSIUM ON MINERALOGY
25–29 AUGUST 1995
BAIA MARE

EXCURSION GUIDES

GHEORGHE UDUBAŞA (ED.) – MINERALS AND MINERAL OCCURRENCES IN THE BAIA MARE MINING DISTRICT

I.G.R. 45 N 24° E

Institutul Geologic al României
Bucureşti – 1995

GEOLOGICAL INSTITUTE OF ROMANIA

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ROMANIAN JOURNAL OF MINERALOGY supersedes "Dări de Seamă ale Şedinţelor", Series 1/Mineralogy – the last volume with this title being No. 74.

Rom. J. Mineralogy is also the Bulletin of the Mineralogical Society of Romania, a member the EMU and IMA. Thus, this journal follows the rules of the Commission on New Minerals and Mineral Names of the IMA in all the matters concerning mineral names and nomenclature.

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ISSN 1220-5621
Classification index for libraries 55(058)

Printed by the Geological Institute of Romania
Bucharest

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INTRODUCTION

G. Udubaşa, Geological Institute of Romania, **M. Kovacs,** CUARŢ S.A.

The Baia Mare mining district represents one of the first order metal producers of Romania, with a well known and documented mining history, going back to the Roman time. Both metal- and mineral-rich ores do exist here, most of them being related to the igneous activity of Neogene age. In addition, large scale stratiform ores, related to Lower Cambrian Tulgheş Group, are known and exploited for many years in the eastern part of the area. Very large and uncommon rich in mineral species are the ore deposits at Baia Sprie (Felsöbanya), perhaps the most representative vein deposit in Romania. The ore beds and lenses reaching thickness of up to 40m in the Borşa area represent the second keystone of the mining activity of the district and of the country, perhaps the largest deposits of this type (Kieslager) in Europe.

Some other less common ore deposits further contribute to the fame of the Baia Mare mining district: the Turţ deposit hosting ore veins up to 20m thick consisting mostly of galena, with an uncommon occurrence of hydrothermal ilvaite; the Răzoare Mn-Fe deposits with a highly diversified mineral composition, including two olivines (manganoan fayalite and tephroite), many species of manganese humites (sonolite, alleghanyite, etc.) not only as mineralogical curiosities but also as compact beds reaching thicknesses of up to 2m; the Ţibleş area exhibiting a well expressed horizontal zoning centred on a still hidden porphyry copper system, the Stejera deposits of high quality kaolinite, the Oraşu Nou bentonite deposits with huge amounts of reserves, etc.

The northern part of Romania covered mostly by the Baia Mare mining district displays a very complicated geologic structure, which partly explains also the diversity and richness of the mineral deposits. The dominant feature of the area is given by the abundant development of the Neogene volcanic rocks forming both volcanic structures and subvolcanic or even intrusive bodies.

The volcanic chain cuts Neogene sedimentary deposits of molasse type and Paleogene sequences belonging to the nappes of transcarpathian flysch, as well as (partly) metamorphic rocks of Lower Cambrian age. In addition, some faults of regional importance trending E-W are known or inferred, mostly in the southern part of the area, where the ore-richest occurrences are located.

In the geologic evolution of the area several events resulted in the development of at least four rocks units or sequences with corresponding main mineral forming processes:

(1) The Upper Precambrian metamorphic rock pile of the Preluca Mts., where both significant Mn-Fe deposits (Răzoare) of highly diversified mineral composition and muscovite-apatite-tourmaline bearing pegmatites are typically developed. Late (Eocene?) alteration of some aplite dykes resulted in the formation of high quality clay deposits (Răzoare).

(2) The Lower Cambrian metamorphic Tulgheş Group containing significant Cu-Zn-Pb-Ag massive sulphide deposits in the Maramures Mts. Late overprint by Neogene intrusive bodies complicated once more the mineral composition of the ores; faulting and fracturing of probably same age are also responsible for post-genetic complications regarding the structure of the ore bodies and of the ore itself.

(3) The Paleogene sedimentary rocks of flysch type occur mostly involved in overthrusting structures (eastern part) as uplifted areas within the Neogene volcanic chain (e.g. Herja-Chiuzbaia area) as well as a sedimentary cover of the crystalline basement (southern and eastern parts). Generally, such formations lack any significant mineral deposits.

(4) The most significant and economically of utmost importance are the Neogene magmatic and sedimentary rocks. Both volcanic structures followed by shallow intrusive bodies (in the Oaş-Gutâi area) and subvolcanic to intrusive massifs (Toroiaga, Ţibleş) form a well developed, E-W

trending, geologic unit more than 100 km in length. Thick volcanoclastic sequences are locally well exposed pointing out to a complex evolution of the volcanic activity. Recent K/Ar and Ar/Ar dating showed that the main magmatic activity of intermediate composition in the Oaş-Gutâi-Ţibleş area has a quite narrow time interval of emplacement (13-7 Ma), followed at relatively short interval (less than 1 Ma) by strong mineralising processes. The latter gave rise to important ore deposits (Pb-Zn and Au-Ag) mostly of vein type. Subordinately there occur either porphyry like systems (Ţibleş) or stockwork type gold mineralizations (e.g. Borzaş). The most typical alteration is the adularization, for the first time described and characterised by Giuşcă (1961) in the Baia Mare region.

From a mineralogical point of view the Baia Mare mining district is also of prime importance. About 150 mineral species are here known and several of them have their type-locality in some celebrated ore deposits such as Baia Sprie (Felsöbanya), Herja (Kisbanya) etc (see chapter 2 for details).

In addition, the Răzoare Mn-Fe deposit displays a quite uncommon alternance of contrasting mineral assemblages, i.e. Mn-fayalite-dannemorite-pyroxmangite-magnetite and tephroite-manganese humites (sonolite, alleghanyite etc) and jacobsite. The deposit is unique in that it contains uncommon rich pods and lenses of manganese humites, the grain of which may sometimes reach also uncommon size for such minerals (about 1mm).

The following presentation include details about the most significant features of the Baia Mare mining district including the history of mining activity and the creation of the museum of regional mineralogy, which is perhaps unique in Europe.

A general view on the geology of the area is given in Fig. 1. The map contains also the location of the main stops to be visited during field excursions.

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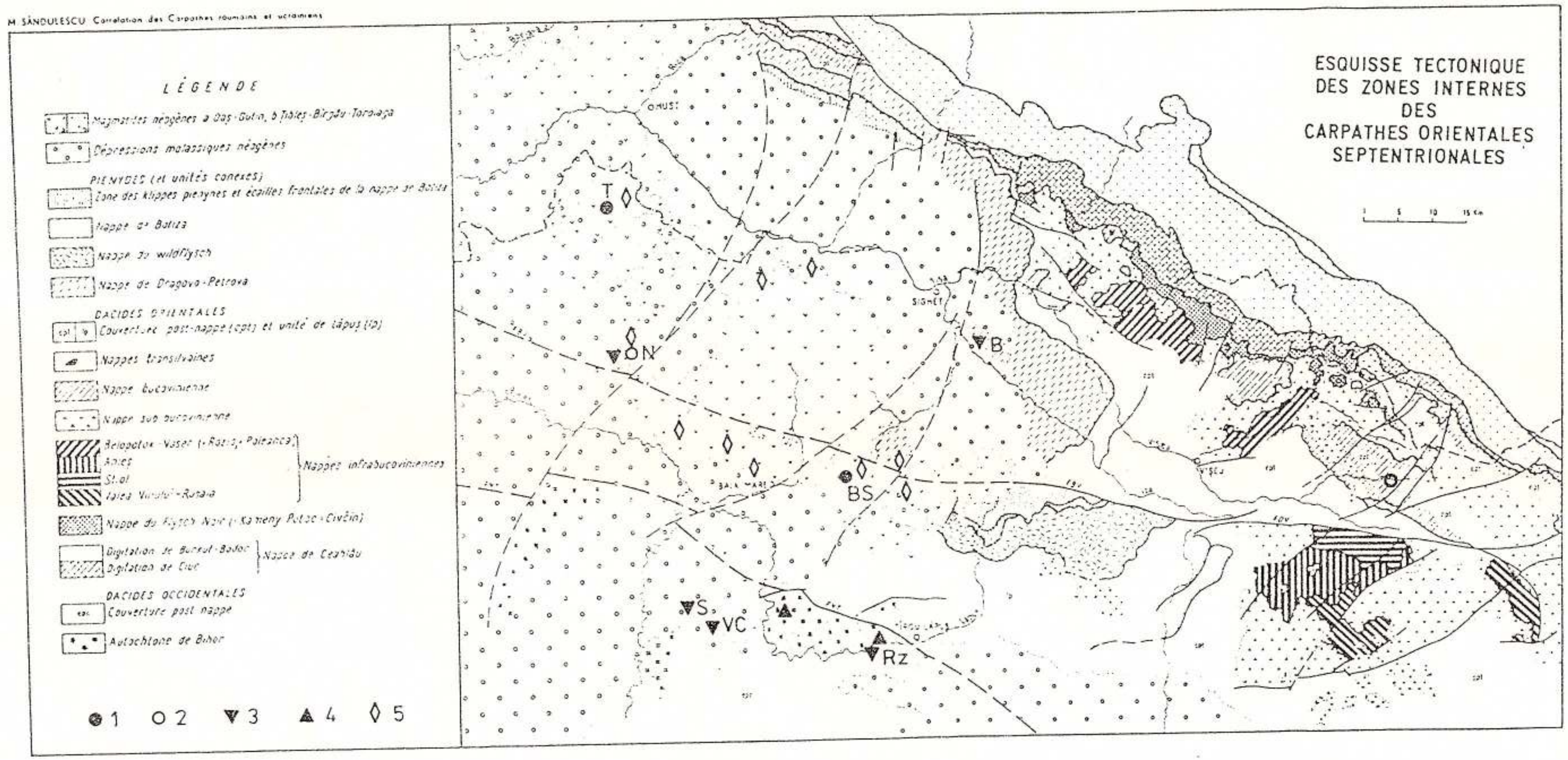

Fig. 1 - Structural sketch of the Northern part of Romania, with excursion localities.
1, Excursion A (BS - Baia Sprie; T - Turţ); 2, Excursion B (Baia Borşa); 3, Excursion C (B, Bârsana; ON, Oraşu Nou; Rz, Răzoare; S, Stejera; VC, Valea Chioarului); 4, Excursion D (Preluca Mts.); 5, Excursion F (Neogene Volcanics)

BRIEF HISTORY OF MINING IN NORTHERN ROMANIA

G. Popescu, University of Baia Mare

Mining activity in the Northern part of Romania has a long and traditional history as proved by archaeological investigations and historical records.

The mining activity started with surface mining, then passed to underground workings reaching in time deeper and deeper levels.

1. Early historical periods: The earliest mining traces date back to the Middle Palaeolithic. The archaeological studies have outlined traces of several sites where silica (opal) rich rocks have been mined, e.g. in the Oaş area (Remetea, Boineşti, Călineşti, Bicsad etc) considered to be about 35000 years old. They continued to be in operation during the Upper Palaeolithic too.

The Neolithic period (especially the Upper Neolithic) is characterised by use of the so-called "Maramureş silex" (in polished form), that according to E. Comşa covered large areas towards Bucovina and down to the Upper Someş River area.

Several bronze objects dating from the Age of Bronze were discovered in Baia Mare area. These were studied by Dr. C. Kacso. As these discoveries were situated nearby the non-ferrous deposits their mining is dating from the same age. The chemical analysis performed on several objects discovered here have revealed that the bronze compositions included other non-ferrous metals, prevailing in Baia Mare, instead of tin (specifically inexistent in Baia Mare area).

The historical development of iron ores mining in the Lăpuşului Basin may be traced by discoveries of very old objects. The earliest iron-made object found and surely dated in Romania (the 13th Century BC) is "Celtic hatchet discovered at Lăpuş.

2. Antiquity and Early Middle Age: It is well known that in 106 AD the Romans transformed kingdom of Dacia into an imperial province. The highly developed mining of Dacia came to be reorganised by the Romans extending gold mining workings already existing in the Apuseni Mts. towards other areas of Dacia. However, the Romans did not reach Baia Mare area, the "border" being established along the Someş valley.

In Baia Mare and Maramureş area the Dacians continued to be organised in their own formations, where the "free Dacians" lived.

The gold and silver mined from the Baia Mare ore deposits were likely to be the economical support for the military power of the "free Dacians". However, the Romans have a certain economic influence upon the areas exceeding the Northern border of the Roman kingdom, which was proved by several discoveries in Baia Mare and adjoining areas (e.g. Roman coins etc). No doubt, a technological influence also existed. Traditionally, there are mentioned several "Roman galleries" and one of the Săsar river tributary confluent is named Roman valley.

Later on, during the migration of the so-called "barbarian" tribes, the mining activity discontinuously developed. The gold mines of Cavnic might have been operating since the 6th-7th century, while the Slav tribes passed through the area; the toponimical evidences are a proof of these influences.

Between 600-800 AD four big salt mines operated in Maramureş, near the town Sighet.

Gold mining in Baia Mare consisted both of underground workings and by washing the alluvial materials. Like Daco-Roman tradition, when such mines were royal and then imperial monopoly, the gold washing sites continued to belong to the local voivodes. By the end of the 9th century and early 10th century, the statal formation of the Menumorut voivode, with headquarters adjacent to Oradea, extended to Satu Mare - Baia Mare. Indecisive fights with the Hungarian tribes, led Menumorut deciding to marry his daughter with the son of the Hungarian Duke, Arpad, and provided him as dowry the gold mines of Baia Mare, as well.

Since then and until the 16th century, the Baia Mare mines belonged to the princesses of the Hungarian crown and the town was named Rivulus Dominorum ("River of Princess"). The name was replaced by that of Baia Mare only in the 16th century (the word "baia" means "mine").

3. The Evolved Middle Age: The silver mining near Rodna (eastern part of the area) developed in the 13th century. During the great "Tartar Invasion" in 1241 the Tartars robbed the Rodna mine having been attracted by the fame of mining of this place.

The first documents about the gold and silver mines of Baia Mare are dating from the first half of the 14th century. These documents were prepared in Latin language. The document issued in 1347 by king Ludovic included organising and technologic details about mining in Baia Mare.

During the following century, the mines of Baia Mare were passed to the ownership of the great army leader, Iancu de Hunedoara, a voivode of Romanian origin, that became in 1446 the Governor of Hungary. Iancu de Hunedoara and his son, king Matei Corvin (1458-1490) supported the development of mining in Baia Mare. The gold resulted from the mines of the area was processed in the form of coin at the famous mint of Baia Mare. The activity of this mint lasted several centuries.

After the Turkish have destroyed the Hungarian kingdom (1526) the mines of Baia Mare area were disputed by the Habsburg Empire and by the Transylvanian Principality. By the middle of the 16th century the mining of Baia Mare area slightly declined. There were preserved records of an "expertise" prepared by two specialists delegated by the king. The inventory provided on that occasion enabled the creation of a view of the workings expansion; the historians and technologists added some comments on these documents. As a result of the control, the leader of the Baia Mare mines was dismissed in 1553. Note that he was a man of education (was mentioned as the "Man of letters") and had a serious technological background. His library included 35 books.

At the beginning of the following century (17th century) the explosives started to be applicated in Baia Mare, soon after the testing of the black mine powder from Tirol and Slovakia.

Most of the stoping works were proceeded by manual chopping and by the "fire stoping" process (heating of the face for 2-3 days, followed by instantaneous cooling, spraying the face with water). This procedure continued to be used until the 19th century.

The major operating mines of this period were those of Baia Mare, Baia Sprie and Cavnic. These mines are still operating nowadays.

4. The mining activity in the 18th and 19th centuries: Between 1526-1691 Transylvania was under the suzerainty of Turkey, later on belong to the Habsburg Kingdom, then to Hungary (1867-1918) and in 1918 entered the community of the Romanian "countries".

During the Austrian time the mining activity evolved at quite high level. In Baia Mare there was the Central Mining Office for Transylvania. In 1755 some 35 mines operated in the area. In addition, numerous small "peasant mines" started to operate too with a certain state support.

Early in the 18th century the first long distances galleries were dug and deeper parts of the veins started to be known. The hydraulic water power was used both for extraction and underground water evacuation.

New technologies were added in the 19th century. The biggest (30 H.P.) steam engine was installed in 1840 at Dealu Crucii, the second one in Transylvania (the first one was that at Zlatna, Apuseni Mts.). The hydraulic water power successfully replaced the steam power. At Dealul Crucii a long distance pressure water pipeline has been finished in 1864, that counted as a technical peak at that time. Between the two pipeline ends there was a level difference of about 100 m and the total power reached 45 H.P., used to evacuate the mining waters.

Long distance galleries became more and more frequent such as Ferdinand at Cavnic, Schweitzer at Valea Roşie etc, as well as mine shafts. Some of them, e.g. the Terezia shaft at Baia Sprie is still in operation.

In the second half of the 19th century further enhancements of mining technologies have occurred. Explosive-using facing developed firstly by applying black power and then dynamite. Stope filling started especially at Baia Sprie and Cavnic; timber supports were gradually replaced by shaped stones resulting in an increase of use duration; electric power instead of steam power was already used at Baia Sprie in 1895 both for supplying the hoisting engine and the water evacuation pump.

Ore processing plants were largely used especially since 1860. Wooden stamping/crushing mill with tens of stakes were installed at all the operating mines. In 1860 a crushing mill with 60 wooden stakes existed at Dealul Crucii. In 1897-1898 the old wooden mills were replaced with californian, steel stakes mills.

At the end of the 19th century the number of the private mining companies significantly increased. In 1878 in the Baia Mare area some 119 such companies already existed. Most of the mines produced especially gold and silver ores. For example, the annual production of the Băiuţ mine was of 17-35 kg of gold and 6-60 t of copper; the Cavnic mine produced 25 kg of gold, 1900 kg of silver and 250 t lead. The production drastically decreased (8-12 times) during the world war I.

5. The Inter-War Period: After the war-related declining of the mining activity the Romanian administration (in 1918 Transylvania became part of the Kingdom of Romania) supported the straightening and enhancement of the mining activity, especially by the Mining Law (1924, modified 1929, 1937), by encouraging the private miners or miners small companies, by permission of foreign capital (French, Belgian and Hungarian) to invest etc.

The Romanian-Hungarian Company "Petroşani" contributed much in 1936 to the opening and development of the Sofia-Săsar gold mine. The "Phönix" Chemical Society's investments at Herja allowed a significant increase of lead and silver production. Many other mines such as Dealul Crucii, Valea Roşie, Baia Sprie and Cavnic were considerably enlarged. The first flotation plant for gold ores was already operating in 1930 at Dealul Crucii and at Baia Sprie a plant for differential flotation of base metal ores was built up in 1931. In 1937-1939 the first cyanidation plant for gold ores has been installed at Săsar mine.

For all the operating mines air compressors were soon purchased and put into operation. The ore transport was mainly assured by using horses.

6. Post-War Period: Following the Nationalisation Law in 1948 the mining activity developed on the basis of the so-called "Five-Years-Plans" and the production of non-ferrous metals drastically increased. During the 1948-1989 period the mining activity of the Baia Mare area was characterised by:

(a) Intensive geological research by using new geophysical and geochemical prospecting methods, combined exploration methods (drilling and underground workings), systematic sampling and mathematical data processing. This led to substantial reserves increase, to extension of old mines and to discovery of new ore deposits such as Şuior, Burloaia, Ilba, Oaş etc.

(b) Development of mining capacities by increasing the ore production. As compared to the year 1948 the production of many old mines considerably increased: 4 times at Herja, 8 times at Baia Sprie, 12 times at Cavnic. In addition, new mines have been opened: Baia Borşa (in 1957), Ilba (1962), Săsar (1963) etc. However, some old mines were closed: Valea Borcutului (1948), Dealul Crucii and Valea Roşie (1950), Jereapăn (1956).

(c) Modernisation of mining technologies. Starting with the year 1954 new mining methods were used such as the temporary storing of ores. By 50's also the methods of roof-caving work and the descendent working with stone packing by using concrete consolidation were introduced. Later on, the dry manual stoping method drastically diminished down to only 15-20 % of the total ore production. At Şuior the open pit was in operation during 1964-1973 the escavation being started at 1060 m and stopped at 920 m. Thereafter, the extracting activity continued through underground workings.

At the same time Widia-drills for blasthole drilling and wet drilling (for avoiding silicosis) were introduced. In the 60's new timbering methods were used (anchor timbering, by injection of concrete), then also new explosive types, fan-like disposal of blastholes etc. Electric energy replaced the horse underground transport in 1955.

The flotation plant at Cavnic is operating since 1954 and that of Baia Mare since 1962. The enhancement of the cyanidation plant at Săsar was accompanied by a big flotation for the ores from the western part of the Baia Mare district. Other flotation plants were built up also, near some mines (Baia Borşa, Turţ, Rodna etc) situated far from Baia Mare town.

MINERALS AND MINERAL VARIETIES FIRST DESCRIBED IN THE BAIA MARE MINING DISTRICT

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The Baia Mare hydrothermal ore deposits furnished materials for new minerals that have the following type localities:

Baia Sprie: andorite, dietrichite, felsöbanyite, klebelsbergite, monsmedite, semseyite, szmikite
Cavnic: rhodochrosite, rhodonite ?, whewellite ?
Dealul Crucii: fülöppite
Herja: fizelyite, parajamesonite

In addition, several varieties have been described here, such as kenngottite, zinkfanserite (Baia Sprie), kapnite, kapnicite, and kapnikite (Cavnic or Capnic) as well as the erroneously described eggonite (see Udubaşa et al., 1992 a, for details). Except dietrichite all the minerals have been found again and supplemented with many new data. Unfortunately no type materials have been identified yet, all the recent data being obtained on neotypes, generally old museum samples.

A. Valid mineral species

Andorite, $PbAgSb_3S_6$, orth

The andorite was described by Krenner (1892) in ores from Baia Sprie (Felsöbanya). The name was given after Andor Semsey, a celebrated mineral collector in that time. Andorite has priority over sundtite and webnerite, found at Oruro, Bolivia by Brögger (1893) and Stelzner (1894), proved by Prior and Spencer (1897) to represent copper varieties of andorite. However, the Oruro material studied by Ungemach (1923) showed two distinct morphological types of andorite, later confirmed by Donnay and Donnay (1954) by using XRD, who distinguished andorite IV and andorite VI. The two phases were shown to exist at Baia Sprie too, forming syntaxic intergrowths (Moëlo et al., 1989). The terms proposed by Moëlo et al. (1984) for defining significant compositional and structural differences, i.e., quatrandorite and senandorite, were not submitted to the CNMMN and thus the names do not have an official status. The relationships with ramdohrite and "nakaseite" (renamed also andorite XXIV) still remain unclear. The new classification of the sulphosalts by a IMA Committee will probably solve the complex nomenclature problems of the andorite-fizelyite series.

Dietrichite, $(Zn, Fe^{2+}, Mn^{2+})Al_2(SO_4)_4.22H_2O$, mon.

The mineral was found as coatings in old mining workings at Baia Sprie and previously named "zinc-bearing" alum. It was collected in 1878 by I. Szmik, analysed by W. Dietrich and named dietrichite by J. Schröckinger (1877). Dietrichite forms needle-like crystals, radially disposed; soluble in water. Very rare! Baia Sprie is still the sole occurrence.

Felsöbanyite/Felsöbanyaite, $Al_4(SO_4\,(OH)_{10}\,.\,5H_2O$, orth (?)

Described in 1853 by Kennott, the felsöbanyite has got in 1948 a rival of same composition, i.e., the basaluminite (Bannister, Hollingworth, 1948), presumed to be hexagonal, i.e., a possible dimorphous of felsöbanyite. However, Papp and Weisszburg (1989) have shown basaluminite to be a fine grained variety of felsöbanyite. The mineral is rare, even if the occurrences of basaluminite would also be taken into consideration (England, France, Russia).

Fizelyite, $Pb_{14}Ag_5Sb_{21}S_{48}$, mon

The mineral was found by the mining engineer Sandor Fizely in samples from Herja (Kisbánya) associated with semseyite, galena, siderite and quartz. Full description was given by Krenner and Loczka (1926) but the first announcement seems to be much older: Embrey and Fuller (1980) indicate a "F. Krantz's Circular of January 1914", appeared in the Appendix to the 6^{th} edition of Dana's System of Mineralogy, 1915, p. 30. The mineral belongs to the andorite-fizelyite series (Moëlo et al., 1989) and is quite rare mineral species, being so far restricted to some Romanian (Baia Sprie, Herja/Kisbánya and Băiţa Bihor/Rezbánya) and French occurrences (La Grange, Aureuze, Largentière).

Fülöppite, $Pb_3Sb_8S_{15}$, mon.

The mineral was named after the collector Dr. Bella Fülöpp and fully described by Finaly and Koch (1929). In most of the cases the type locality is given as Baia Mare (Nagybanya). In fact, fülöppite was found in the Dealul Crucii mine (near Baia Mare) in ores from the Main Vein. A further occurrence in Romania is Săcărâmb (Nagyag), as quoted in many textbooks, but this may be a taken over error, due to similarity of Nagybanya and Nagyag. At Săcărâmb the fülöppite has never been mentioned (Udubaşa et al., 1992 b).

Klebelsbergite $Sb^{3+}{}_4O_4(OH)_2(SO_4)$, orth.

The klebelsbergite is a further mineral having Baia Sprie as type locality..It was described by Zsivny (1929) by naming it after the Hungarian teacher Kuno Klebelsberg, probably a mineral collector. The klebelsbergite usually forms yellow coatings on stibnite crystals. The formula and the structure were both established quite late by Nakai and Appleman (1980) and Menchetti and Sabelli (1980). Very rare; no other occurrences are known yet.

Monsmedite (?), $H_8K_2Tl^{3+}{}_2(SO_4)_8 \cdot 11H_2O$, (?), cub.

A mineral of quite uncommon composition, first announced as a new species in 1963 by Götz et al. (unpubl. report at a scientific session). Some data were published by Manilici et al. (1965). Full description was given by the discoverers (Götz et al., 1968). The name is related to the Latin name of Baia Sprie, i.e., Mons Medium. A similarly looking mineral was later found in the Săsar gold mine. Zemann (1993) casts doubt about the validity of the mineral, especially due to insignificant Tl contents; the monsmendite could be a Tl-bearing voltaite.

However, it is necessary to show that the material existing in Vienna and Paris originates in the veins from Săsar, not in the veins of the type locality, Baia Sprie. Unfortunately, the type material in which high Tl contents were apparently found, was probably lost (A. Götz, 1995, pers. comm. to G. Udubaşa).

Parajamesonite, $Pb_4FeSb_6S_{14}$, orth.

The orthorhombic dimorphous of jamesonite was reported by Zsivny and Náray-Szabó (1947) in material from Herja. No later confirmation does exist in spite of careful investigations of a great number of samples containing jamesonite from Herja, e.g. Udubaşa (1992).

Rhodochrosite, $MnCO_3$, trig.

The type locality of rhodochrosite, i.e. Cavnic, is given only as concerns the name, first appeared in Hausmann (1813) by using analyses of Lampadius (1800) on material from this locality (Udubaşa et al., 1992 a). Abundant in veins from Cavnic, but also present in many other mines. Type locality given as Săcărâmb (Rădulescu, Dimitrescu, 1966; Antonovici, 1969; Mureşan et al., 1990) is an error.

Semseyite, $Pb_9Sb_8S_{21}$, mon.

The quite widespread sulphosalt semseyite was discovered at Baia Sprie by Krenner in 1881 and named in honour of the mineral and meteorite collector Andor Semseyi (1833-1923). The mineral forms rosette-like aggregates, sometimes disposed on galena, representing beautiful museum samples. There are many other localities where semseyite was found, i.e., Herja, Cavnic, Toroiaga etc.

Szmikite, $MnSO_4.H_2O$, mon

The mineral was found at the upper levels of the Baia Sprie deposit (gallery Sf. Mihai) and described in 1877 by Schröckinger. The name was given in honour of Ignaz Szmik, a mining engineer at Baia Sprie. New data from other occurrences were obtained by Tatu (1989). It is a secondary mineral, forming stalactites on the walls of old mine workings.

In addition, Szakall and Gatter (1993) give also Cavnic as type locality for rhodonite (described by E. Ruprecht in 1783) and whewellite (described by H.J. Brooke in 1840). However, it is not clear if the data refer to the names only or to the compositions as well.

B. Other mineral names related to the occurrences in the Baia Mare area (varieties and old, unnecessary names)

Cubosilicite, said to be a cubic variety of silica, was described in 1899 by Bombicci at Trestia, south of Cavnic, in form of cubes entirely pseudomorphosed by the celebrated blue chalcedony. New data on the Trestia chalcedony suggest pseudomorphs of chalcedony on melanophlogite (Ilinca, 1989), the valid name for the cubic silica.

Eggonite from Baia Sprie described by Schrauf (1879) as a cadmium silicate was proved to be an aluminium phosphate hydrate (Krenner, 1929). Larsen and Montgomery (1940) have found a similar mineral in Utah and named it sterrettite; refining of its composition led to renaming the mineral as kolbeckite, initially considered as a phosphate silicate of Al, Ca, Fe, Be, then as scandium phosphate hydrate, which is the composition given by Fleischer and Mandarino (1991). According to Kostov and Breskovska (1989) eggonite = kolbeckite.

Ilbaite from Ilba (Moţiu and Suciu, 1987) was not submitted to the CNMMN as proposal for a new mineral species. The data are insufficient to characterise a new species (Am. Min., 17, 1990). It is a fine grained allophane.

Kapnicite of Kenngott (1856) is synonymous with wavellite, found at Cavnic, namely Bolduţ mine, Francisc vein.

Kapnikite of Zepharovich (1859) is a local name of rhodonite.

Kapnite from Cavnic is a ferroan smithsonite; the name was given by Breithaupt (1841).

Kenngottite is a lead-bearing miargyrite (4% Pb) found at Baia Sprie (Haidinger, 1856).

Rädelerz is a name given by Breithaupt (1832) for twinned crystals of bournonite from Cavnic. It means wheel ore or cog-wheel ore.

Zinkfauserite (Tokody, 1949) is a Zn- and Mn-bearing epsomite from Baia Sprie. The fauserite itself is a discredited mineral name too, already in 1941 given by Strunz as a Mn variety of epsomite.

The data presented above are based mainly on the papers of Bologa (1977), Udubaşa et al. (1992) as well as on the book of Rădulescu and Dimitrescu (1966). The last one includes, however, some errors such as Săcărâmb being the type locality of rhodochrosite, the occurrence of blue chalcedony, i.e. Trestia, said to be in the Metaliferi Mts. etc. The errors have been taken over in other books appeared in the last time, as well as in the paper of Antonovici (1969), Mureşan et al. (1990) etc.

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MUSEUM OF MINERALOGY BAIA MARE

V. Gorduza, Museum of Mineralogy, Baia Mare

November 6, 1989 is the birth day of this museum, one of the most representative mineralogy museums in Romania. Its history started as early as 1969 by organizing a mineralogical collection with the Maramureş County Museum (history, fine arts and ethnography). The sample number increased from 1502 in 1969 to 3272 in 1975, then to 14,274 in 1985. Now the museum has a total number of about 15,000 samples obtained either by proper collecting efforts in underground workings or by buying and donations. The museum is open also to the public and contains two distinct sections, i.e., (1) general geology of the Baia Mare mining district, with representative samples of all types of rocks and ores existing and a systematic collection for every mine in the district, and (2) an outstanding selection of minerals and mineral aggregates, some of them representing wonderful and non-repeatable combinations of forms and colours. The uniqueness of this collection consists also in that the samples are exclusively from the Baia Mare mines. The quartz, carbonates and sulfide samples are the most numerous (more than 75 percent) but other mineral classes are represented too, e.g. sulfates and wolframates (about 18 percent), etc. Such a distribution of minerals in museum largely corresponds to their distribution in the Baia Mare ore deposits. Moreover, the exposed samples were also selected by using an aesthetic point of view (Gorduza, 1977).

There are numerous samples both of scientific interest and of aesthetic values. Several big transparent gypsum crystals cover the necessity of having some items such as " the biggest in Romania". The Cavnic mine produced the most beautiful samples containing gypsum.

The stibnite is a widespread sulfide mineral in Baia Mare district, occurring in several mines, e.g., Baia Sprie, Herja, Săsar, Băiuţ etc. In spite of this the mineral displays numerous forms and associations which make the stibnite-bearing samples to be far from uniformity. Needle-like crystals from Baia Sprie build up beautiful samples, in which the length of individuals may reach 20-25 cm with thicknesses of only 1-3 mm. Sometimes fine crystals of barite or carbonates hang on stibnite needles, as if they were pierced by stibnite. Other times several generations of stibnite with different sizes can be seen together. The Herja stibnites have a more pronounced prismatic habit and form beautiful aggregates sometimes resembling hedgehogs. By continuous length shortening and probably increasing formation temperature (Udubaşa et al., 1992) the Băiuţ stibnite shows a normal prismatic habit, very often with crystals very rich in crystallographic forms. A special appearance displays the stibnite from the Săsar gold deposit: it forms rosettes up to 5-7 cm in diameter, as a rule dispersed on a contrasting white, silica-rich background.

Further worth of seeing are samples with wolframite prismatic crystals, various coloured barite crystals, reaching sometimes uncommon sizes of 15-25 cm, calcite aggregates with various forms, pyrrhotite "roses" from Herja, quartz crystals from everywhere in the district, pyrite cubes with edges of up to 10 cm, semseyite from Ţibleş aggregates, fizelyite, chalcostibite, andorite, siderite, sfalerite black and honey-yellow crystals, bournonite twinned crystals (Rädelerz, cog-wheel ore) etc. Last but not least the tetrahedrite crystals from Cavnic and the wonderful freibergite crystals from Herja represent points of attraction of high value. In addition, the calcite spheres up to 7-8 cm in size are samples of extreme rarity if not unique in their kind; moreover the half white-half black spheres form one of the keystones of the museum. The black colour of calcite is due to fine inclusions of jamesonite needles (Udubaşa & Gorduza, 1980). Many other samples cannot be described; they have to be seen, directly on display.

The value of samples is in fact invaluable. As a result of adequate relationships to other museums, several expositions have been organized with samples from the Baia Mare museum both in Romania, i.e., Piteşti (1980), Bucureşti (1980), Piteşti (1980), Galaţi (1986), Piatra Neamţ (1987), Braşov (1988) and abroad, i.e. Vienna (1982, 1984), Graz (1984), Linz (1984, 1993), Klagenfurt (1985), Innsbruck (1985), Salzburg (1986), München (1990), Lyon (1991), Orléans (1995).

Acknowledgements:

The museum staff thanks to the colleagues from CUARŢ S.A. and REMIN Baia Mare for their invaluable help in organizing the general design, for supplementing the lacking samples and for their permanent support during the realization of the museum and afterwards. Dr. G. Udubaşa (IGR, Bucharest) has given also some suggestions and contributed to the writing of this short presentation.

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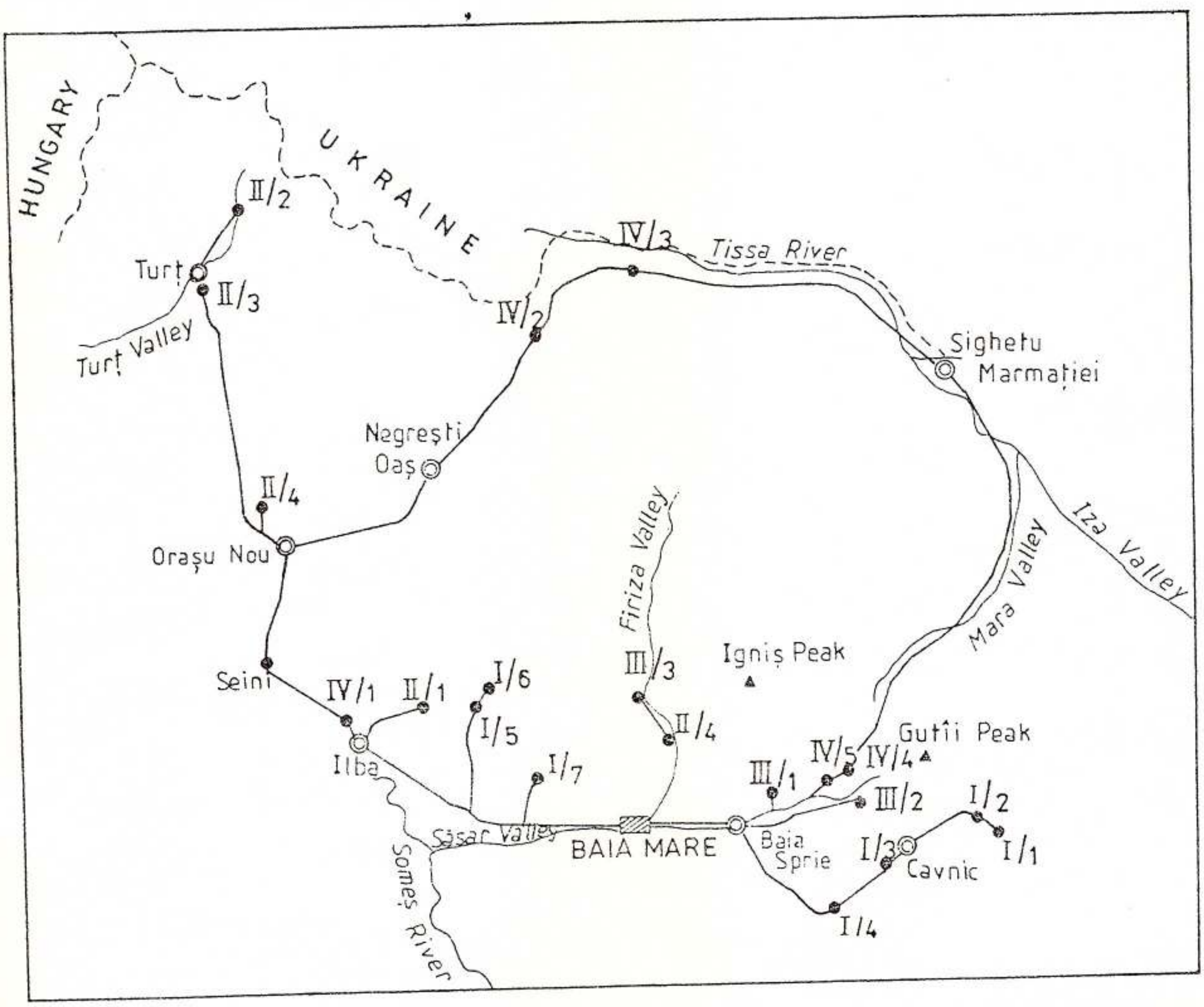
EXCURSION F

NEOGENE VOLCANISM AND ASSOCIATED METALLOGENY IN THE OAŞ-GUTÂI MTS. (EAST CARPATHIANS).

Leaders: **M. Kovacs,** CUARŢ S.A., Baia Mare,
D. Istvan, CUARŢ S.A., Baia Mare,
Alexandrina Fülöp, CUARŢ S.A., Baia Mare.



Volcanicity/Metallogeny in Oaş-Gutâi Mts. General Remarks

Kovacs M., CUARŢ S.A, Baia Mare

The Oaş-Gutâi Mts. belong to the Neogene/Quaternary volcanic chain of the Eastern Carpathians. They represent the north-western segment of the chain from Romanian territory (Fig. 2).

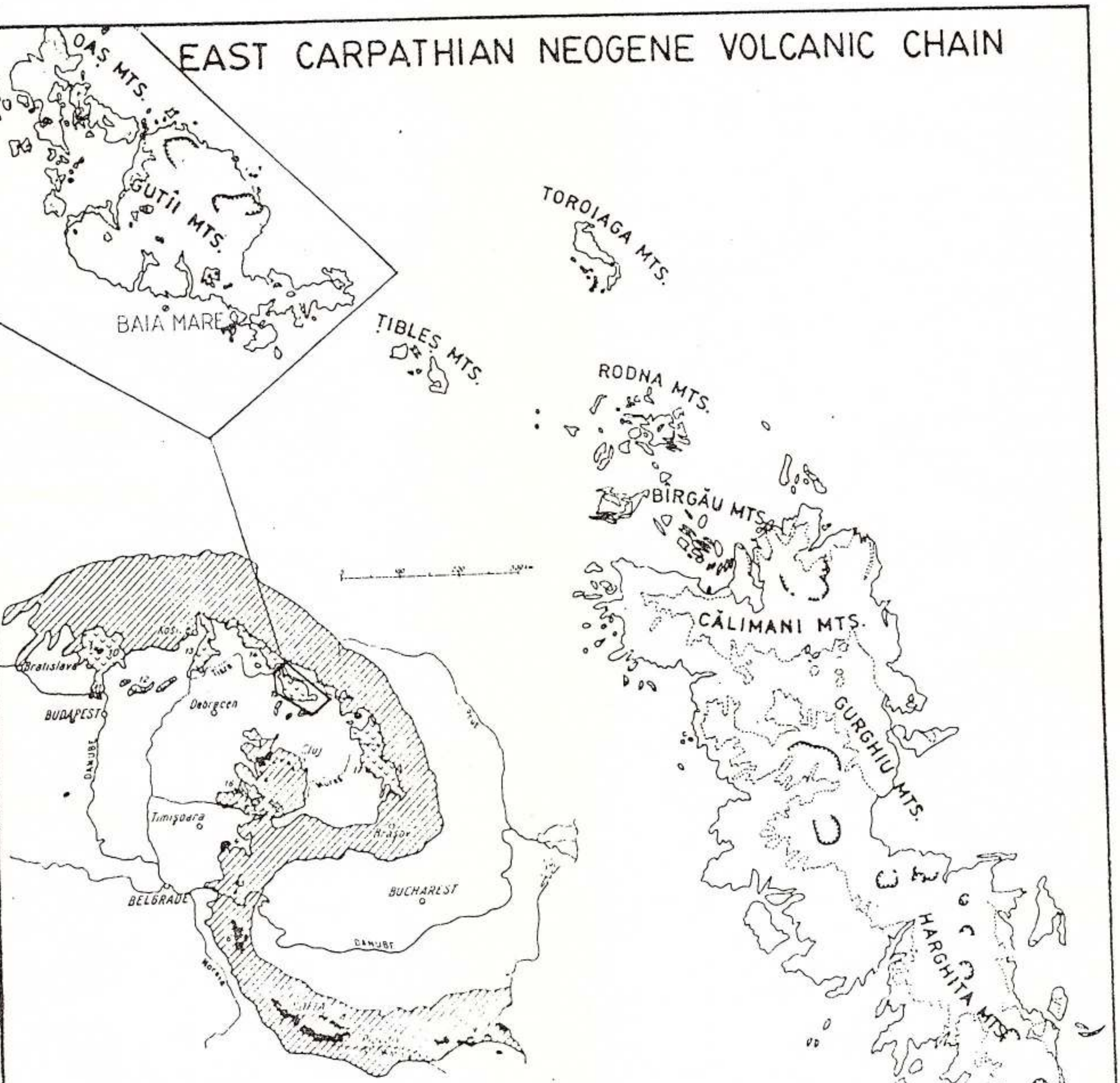


Fig. 2 - East Carpathians Neogene volcanic chain and the position of the Oaş-Gutâi Mts. within the Carpatho-Balkan orogenic area.

The Neogene calc-alkaline volcanism is related to the subduction processes from the Carpathians orogenic arc as a result of the pre Apulian - Eurasian paleoplates postcollision compressive phase (Rădulescu, Săndulescu, 1973, Rădulescu et al., 1994).

The Pre-Neogene fractured basement, with horsts and grabens, consists of crystalline rocks belonging to Mediane Dacides and Cretaceous - Paleogene sedimentary formations of Transcarpathian Flysch forming the Botiza, Lăpuş and Petrova overthrust units (Săndulescu, 1984). The most important tectonic structure in the area is the Pre-Neogene E-W trending major transcrustal fault (Cîrlibaba - Carei fault) situated on the southern border of the Gutâi Mts. (Fig. 3). Related to this tectonic system, a deep-seated Neogene pluton was recently put in evidence by geophysical studies (Borcoş et al., 1991, 1993, Andrei et al., 1994, unpubl. data, Borcoş, 1994).

The volcanic activity in the Oaş-Gutâi Mts. took place partly contemporaneous with significant sedimentary deposition processes in the marginal basins (the north-eastern part of the Pannonian basin and north-western part of the Transylvanian basin) forming the Neogene molasse deposits (Badenian-Pannonian in age). Taking into account the geochemical features of the volcanicity for the whole Carpathians arc, two main volcanic types were recognised in Oaş-Gutâi Mts.: acidic calc-alkaline and intermediate calc-alkaline respectively. The volcanic activity in Oaş-Gutâi Mts. had started with the acidic explosive phase generating pyroclastic products widespread in the south-western part of the Gutâi Mts.. The rhytmicity of the volcanism and the evolution of the sedimentary basin led to the formation of a volcano-sedimentary formation. This acidic pyroclastic rocks also occur as interbedded sequences at deep levels, in the Oaş Neogene molasse deposits. The pyroclastic deposits consist of ignimbrites and associated falls deposits. The strongly welded ignimbrites are more frequent than the slightly welded ones (Fülöp, Crihan, in print).

The age of this volcanics have been determined biostratigraphically as Badenian-Lower Sarmatian.

The intermediate calc-alkaline volcanism in Oaş-Gutâi Mts. had an explosive and effusive character, forming complex volcanic structures and/or some isolated volcanoes (especially in Oaş Mts.). The intense erosional processes complicated the recognition of the volcanic structures. The great bulk of the volcanics is effusive (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.). The explosive products consist of mainly pyroclastic falls and subordinate of pyroclastic flows. Reworked pyroclastic rocks, pyroclastic sediments and mixing products are also well represented.

Due to the spatial relations with the sedimentary basins (the above mentioned marginal basins and some small intravolcanic basins) widespread volcano-sedimentary complexes belonging to different volcanic phases are developed both in Oaş and Gutâi Mts.

An intrusive magmatism with a subvolcanic or intravolcanic shallow level character is coeval especially with paroxysm of the intermediate volcanic activity (in Pannonian).

The volcanic rocks are typical for the calc-alkaline suites consisting of basaltic andesites, andesites, dacites and subordinately of rhyolites and basalts (Fig. 4). Medium K pyroxene andesites are the most predominant rocks in Gutâi Mts. whereas the dacitic rocks are very well developed in Oaş Mts. often like extrusive domes.

The Gutâi Mts. represent the unit with the most complex volcanism. According to Giuşcă et al. (1973) and Borcoş et al. (1973), the volcanic activity developed in three cycles: the first cycle corresponds to the Badenian-Buglovian volcanism (corresponding to the CA acidic volcanism), the second cycle consists of four distinct phases between Sarmatian and Pontian and the third cycle includes the Pontian-Pliocene volcanics (corresponding to the CA intermediate volcanism). On the basis of the biostratigraphical data, Jude (1977, 1986), Edelstein et al. (1980), Borcoş et al. (1986) emphasised the Pontian-Pliocene age for the products of the CA intermediate volcanism from Oaş Mts.

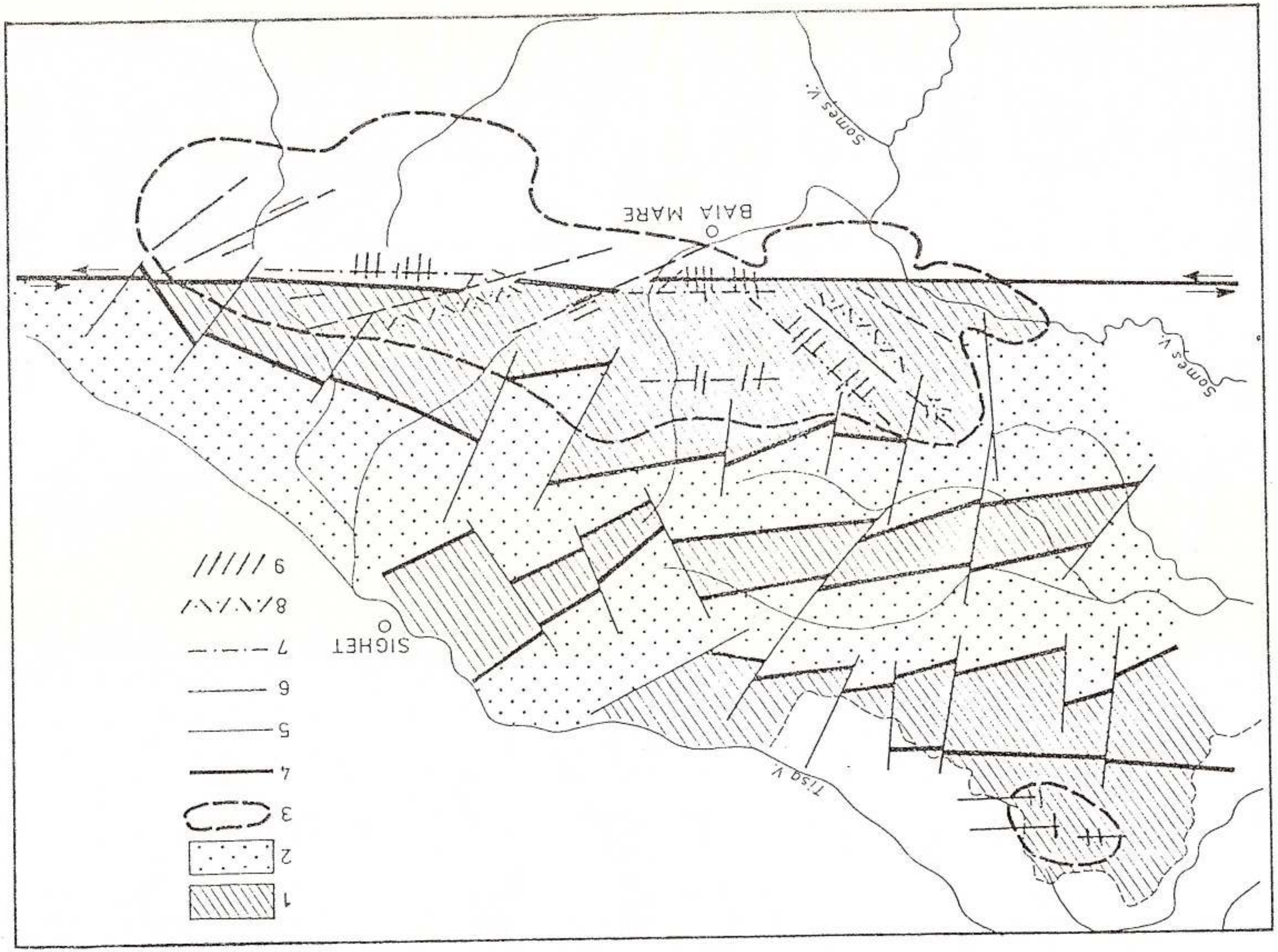


Fig. 3 - Relationship between major geotectonic and metallogenic elements in the Baia Mare area (acc. to Borcoş and Vlad, 1994) 1, Horst; 2, Graben; 3, Inferred Neogene Pluton; 4, Transcrustal fracture; 5, Pre-Neogene reactivated fracture; 6, Fracture with metallogenic function; 7, Tectono-volcanic alignment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

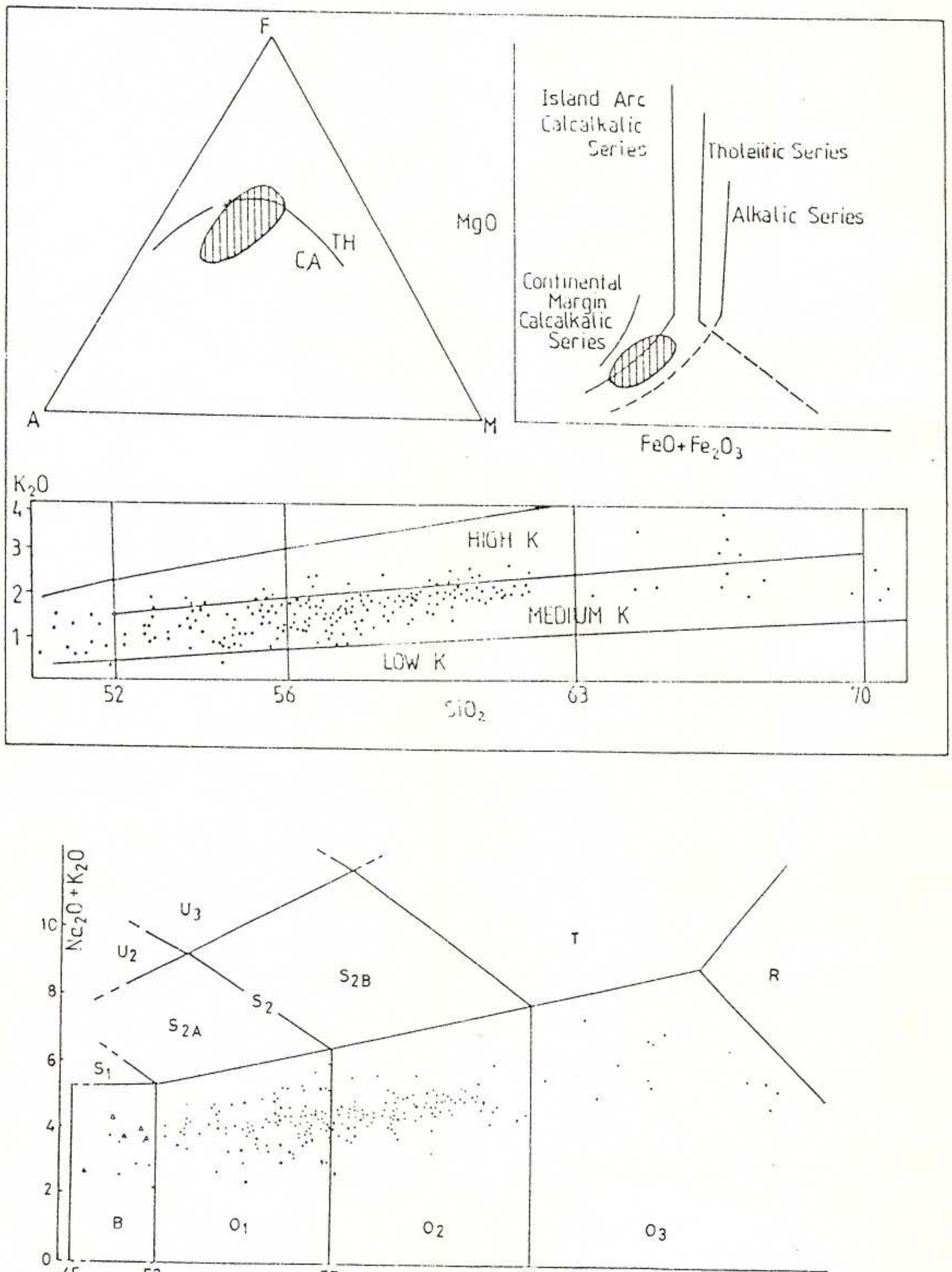


Fig. 4 - Distribution of the intermediate volcanics of the Gutâi Mts. in different classification diagrams.

Recent K-Ar datings (Edelstein et al., 1992, 1993, Pecskay et al., 1994, Pecskay et al., in print) on fresh rocks from Oaş-Gutâi Mts. led to a new image of the evolution of the CA intermediate volcanism. In Oaş Mts. the intermediate volcanism had a rapid evolution during a short time interval (12.0 - 9.5 Ma). In Gutâi Mts. the intermediate volcanism was initiated in the Lower Sarmatian and continued till Upper Pannonian (13.4 - 9.0 Ma). After a 1 Ma of quaiescence, a basic final phase, consisting of small intrusions of basalts ceased the volcanism (8.0 - 6.9 Ma) (Fig. 5).

The most important and complex activity took place during the Pannonian (see Fig. 6 and Tab. 1).

The K-Ar datings on the intrusions from Poiana Botizei area (which represents the transitional zone to the Subvolcanic Unit Ţibleş - Toroioaga - Rodna - Bîrgău) show that the subvolcanic activity was contemporaneous with the paroxysm of the volcanism from Oaş-Gutâi Mts. (11 - 9 Ma).

The intrusive bodies from the Oaş-Gutâi Mts. present very different morphological and petrographical features; dykes and irregular apophyses and subordinately sills and microlaccolites occur (from a few meters to maximum 2-3km in size) consisting of basaltic andesites and andesites, microdiorites, quartz diorites and gabbros, quartz monzodiorites, (micro)granodiorites and tonalites, in order of their frequency.

It is worth to notice the great variety of the textural features, the porphyritic aspects being predominant.

As mentioned above, the Guţâi Mts. has the most complex volcanic evolution and as a whole the CA intermediate volcanics represent the predominant products. Recent geochemical investigations (Kovacs et al., 1992, 1994) have emphasised some important features regarding to the petrogenetic aspects of the magma generation related to the subduction processes developed in this zone. The negative Eu anomaly appears as a significant pattern of the volcanics from Gutâi Mts. and as a whole, the REE patterns are comparable with those of the volcanic rocks related to the actual subduction zones. A low tholeiitic trend for the first intermediate volcanics (Sarmatian pyroxene basaltic andesites) was pointed out in the evolution of the CA parental magmas.

The low contents of Sr (196-338) are typical for the island arcs (see fig. 7A). The great values of Rb and Rb/Sr and $^{87}Sr/^{86}Sr$ ratios (tab. 2), in contrast with the smaller values of the K/Rb ratios assert a significant crustal contamination of the parental magmas. These data are in accordance with the crust thickness values (calculated on the basis of Condie relation) ranging between 25-40km. They also are in agreement with the seismic data for the Moho limit (Socolescu et al., 1973), 28-31km in the western part of the Gutâi Mts. (Negreşti-Oaş zone) and 33km in the south-eastern part of Baia Mare town (see also Fig. 7 B).

The crustal contamination of the generating magmas had taken place both during the crossing of the relative thick sialic crust and during their evolution in secondary magma chambers, where the fractional crystallisation processes were associated with assimilation.

The hydrothermal alterations consist of predominantly adularia-sericite type (typically low-sulphidation system, especially in Gutâi Mts.) and only in some areas advanced argillic type. An early propilitization, resulting from the activity of reducing H_2O - CO_2 - H_2S solutions in a partial closed system was emphasised by Stanciu (1984) for the large majority of the alteration areas.

The mineralizations consist of epithermal vein system having a base-metal and gold-silver character. The stockworks and breccia pipes are subordinate.

In most of the cases the mineralizations developed almost entirely as vertical or subvertical veins of several hundreds of meters up to 5 km in length and down to 800 m in depth. The majority of the ore deposits reveals a well developed vertical zonality: gold-silver in the upper part, lead-zinc in the middle part and copper in the deeper part (especially in Gutâi Mts.).

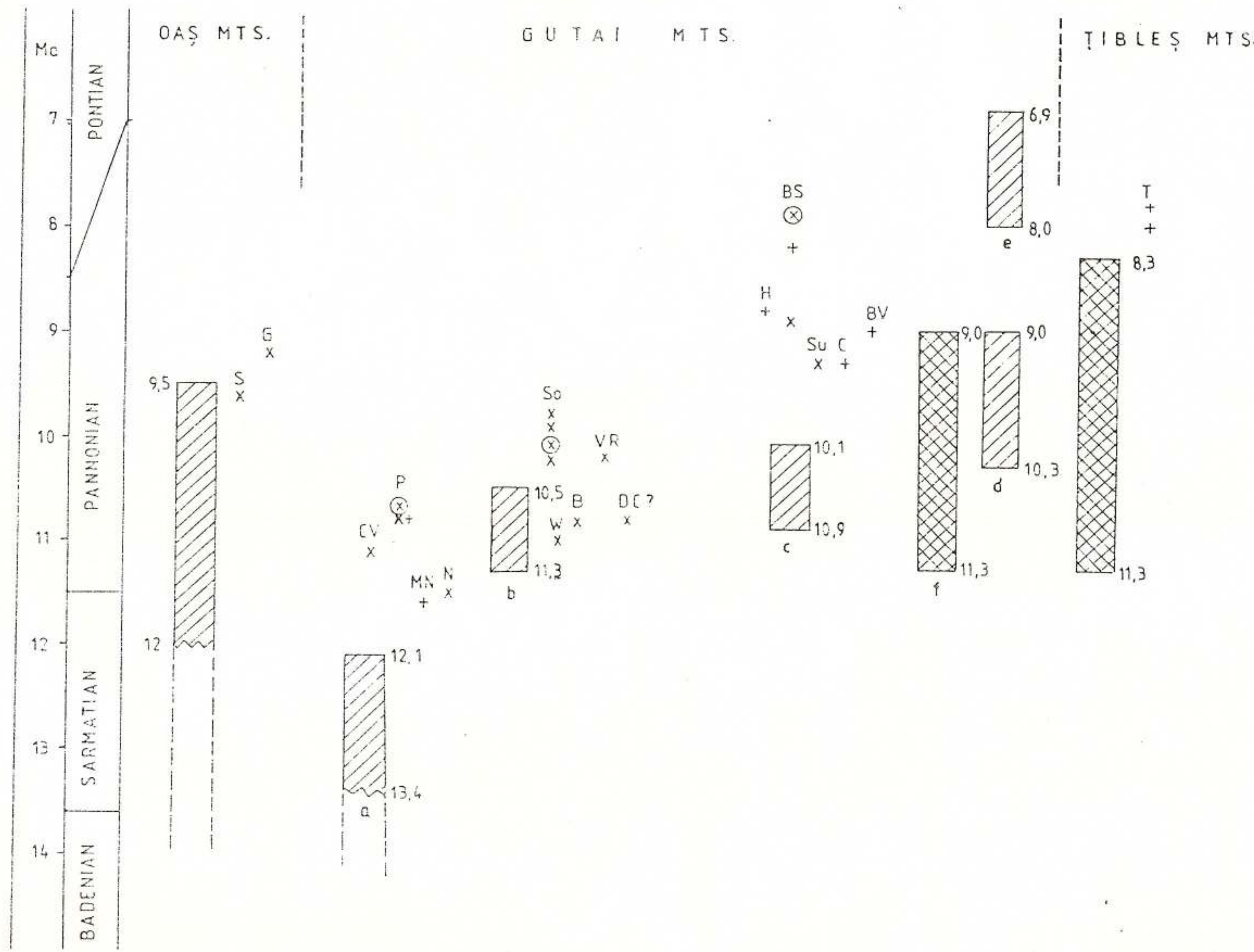


Fig. 5 - Geochronologic data for the magmatic rocks and hydrothermal K-bearing minerals in several ore deposits in the Oaş-Gutâi-Ţibleş Mts.

Vertical columns = time interval recorded by K-Ar dates in fresh magmatic rocks: a = pyroxene basaltic andesites and andesites (Seini type); b = quartz bearing andesites (Piscuiatu type); c = pyroxene basaltic andesites and pyroxene, hornblende andesites (Jereapăn type); d = pyroxene andesites and basaltic andesites (Igniş-Mara, Săpânţa and Mogoşa type); e = pyroxene basalts (Firiza zone); f = subvolcanic intrusions from Poiana Botizei area; x = K-Ar ages on adularia; ⊗ = Ar-Ar ages on adularia (Lang et al., 1994); + = K-Ar ages on illite; ore deposits: S = Socea; G = Ghezuri; CV = Corbului Valley (Ilba); P = Purcăreţ; MN = Mihai Nepomuc; N = Nistru; So = Săsar (Sofia); W = Wilhem; B = Borzaş; VR = Valea Roşie; DC = Dealul Crucii; H = Herja; BS = Baia Sprie; Su = Şuior; C = Cavnic (Roata); BV = Băiuţ (Văratec); T = Ţibleş.

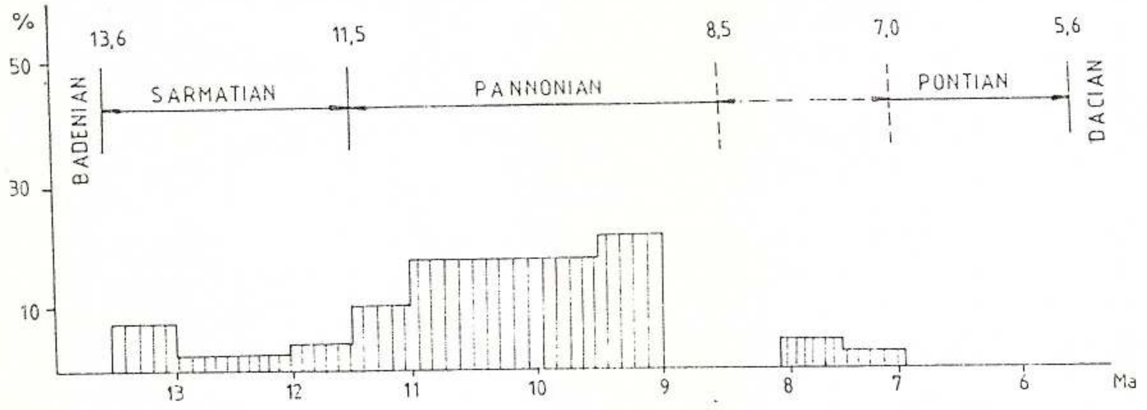


Fig. 6 - Distribution of the K-Ar ages of volcanic rocks in the Gutâi Mts.

In the Oaş Mts. the main ore deposits, Socea - Tarna Mare, Ghezuri and Penigher - Turţ have a base metal character. The mineralizations consist of vein system located both in volcanics and in intrusions and of some breccia columns (like breccia pipes).

The most well known ore deposits occur in the southern part of the Gutâi Mts. (Baia Mare area); three metallogenetical fields include more than 15 main ore deposits in exploitation.

Based on radiometric determinations (K-Ar and Ar-Ar methods) on adularia and illite carried out at geochronological laboratories in Jerusalem, Grenoble and Debrecen, recent studies pointed out a new interpretation regarding to the evolution of the metallogeny in Oaş-Gutâi Mts. (Lang et al., 1994, Kovacs et al., in print).

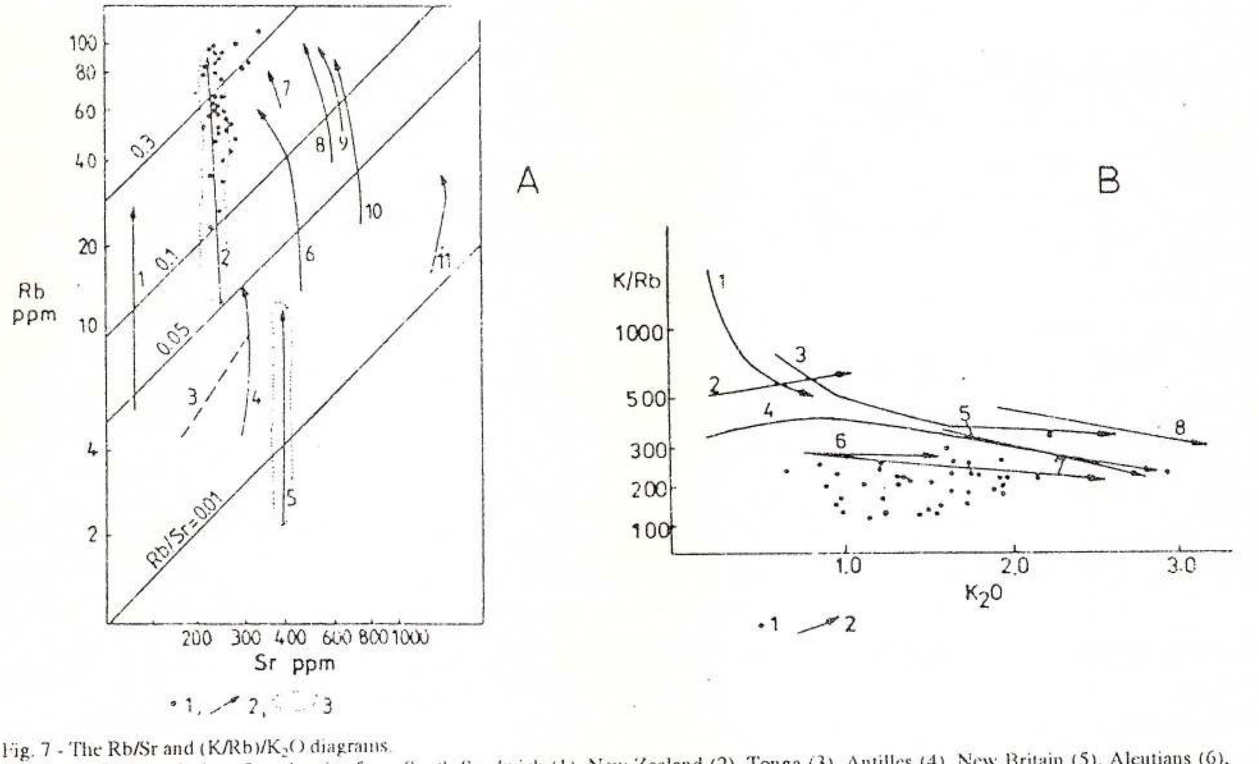


Fig. 7 - The Rb/Sr and $(K/Rb)/K_2O$ diagrams.
A. 1. Gutâi Mts. andesites; 2. volcanics from South Sandwich (1), New Zealand (2), Tonga (3), Antilles (4), New Britain (5), Aleutians (6), Sumatra (7), Chile (8), Peru (9), Eolian (10), Cascade (11); 3. Variation field of the results for two cases (fide Gill, 1981);
B. Gutâi Mts. andesites (1) and other areas, New Britain (1), Tonga (2), Aleutians (3), Jawa (4), New Guinea (5), Grenada (6), New Zealand (7), Peru (8).

The hydrothermal activity and metallogenetic events have developed during the Pannonian (11.5 - 7.9 Ma). The previously considered Sarmatian and Pontian phases (according to Giuşcă et al., 1973 and Borcoş & Lang, 1973) have not been proved.

The metallogenesis in Gutâi Mts. consists of two main phases: the first took place during Lower Pannonian substage (11.5 - 10.0 Ma), including the Ilba - Nistru and Săsar - Dealul Crucii ore districts and the second one was in Upper Pannonian (9.4 - 7.9 Ma) including those of Herja - Băiuţ district.

The metallogenetic events in Oaş Mts. are contemporaneous with the second phase of Gutâi Mts..

Figure 5 summarises the radiometric data for the magmatic and hydrothermal activity from the Oaş - Gutâi Mts. and shows the relationships between the mineralizations and the host igneous rocks. It is worth to notice the presence of a gap (0.5 - 1.5 Ma) between the ages of the mineralizations and the host magmatic rocks emphasising the lack of a direct genetic relation between mineralizations and the host rocks.

These relations pointed out in Baia Mare metallogenetical area are very similar with that of other occurrences of the subduction zones.

FIRST DAY

A. Volcanism and metallogeny in the eastern part of the Gutâi Mts.

Kovacs M., Istvan D., CUARŢ S.A., Baia Mare

The eastern part of the Gutâi Mts. represents one of the most complex volcanic area from the whole Oaş-Gutâi chain. The volcanic activity took place in an area with Neogene (Badenian-Pannonian) molasse deposits overlying the basement composed of overthrusted units belonging to the Transcarpathian Flysch (Cretaceous-Paleogene). Various volcanic products-volcaniclastic deposits, lava flows and intrusions, belonging to different volcanic structures are widespread at the surface, consisting of different rock types-basaltic andesites, andesites and dacites (Sarmatian and Pannonian in age).

A simplified succession of the main volcanic phases from the eastern part of the Gutâi Mts., on the basis of recent K-Ar datings, is as follows:

Biotite, pyroxene, hornblende, quartz andesites (Gutâi type)	9.0-9.3 Ma
Pyroxene basaltic andesites (Mogoşa type)	9.5 Ma
Pyroxene basaltic andesites, pyroxene andesites and pyroxene hornblende andesites (Jereapăn type)	10.1-10.9 Ma
Quartz-bearing andesites (Şuior type)	11.3 Ma
Biotite dacites (Dăneşti type)	11.6 Ma
Pyroxene andesites and basaltic andesites (Răchiţele type) and pyroxene dacites (Şatra type)	13.2-13.4 Ma

STOP I/1. Urzicari quarry (Rotunda). Gold mineralization in Pannonian pyroxene basaltic andesites.

In this small quarry there occur pyroxene basaltic andesites (54.6% SiO_2 and 1.4% K_2O) in which some irregular zones of hydrothermal alterations develop. Due to the alterations, the massive rocks present heterogeneous aspects, sometimes breccious.

An intense argillization zone is related to a fault zone 1.2 m thick located in the north-eastern part of the quarry. Some quartz veinlets occur within the fault zone containing gold.

Other fracture zones with a breccious character and calcite and pyrite occur in the andesites from the quarry.

STOP I/2. Bolchiş quarry. Volcaniclastic deposits and pyroxene andesites intrusion.

The Pannonian andesitic volcanism in the Cavnic-Rotunda area displays a complex character, its explosive and effusive products alternate, especially at the lower part of the succession, where a volcaniclastic complex contain locally interbedded sedimentary deposits. At the upper part of the stratovolcanic structure, the lava flows are predominant. An intense intrusive activity was associated to the extrusive one - many intrusions being known both at the surface and especially in the mining works and drillings.

On the right side of the Rotunda-Cavnic road, near the Bolchiş quarry, Pannonian volcaniclastic deposits occur. They consist of pyroclastic rocks - lapilli and coarse to fine tuffs with interbedded thin tuffites.

In the Bolchiş quarry there occur pyroxene andesites representing an intrusion which pierces the volcaniclastic deposits. One may see nice columnar joints, differently oriented as a result of two main cooling joints systems.

In the eastern part of the quarry, some joints with secondary minerals 15-20cm thick crossing the cooling joints can be also seen.

STOP I/3. Dealul Bărarului quarry. Upper Pannonian basaltic andesites (Mogoşa type) dyke.

On the right side of the Cavnic Valley there is a small quarry in which an intrusive body - a SE to NW oriented dyke which pierces the Pannonian sedimentary deposits can be seen. The contact between the igneous and sedimentary rocks is visible in the right side of the quarry.

This dyke is situated in a peripheral zone of the Mogoşa volcanic structure and consists of pyroxene basaltic andesites. The main petrographic feature of this rocks is the glomeroporphyritic texture, due to the presence of the aggregates of pyroxene phenocrysts. The groundmass has a holocrystalline structure without any oriented texture.

The age of this intrusion can be considered similar at least with the age of the lava flows from the Mogoşa Peak (9.5 Ma, Edelstein et al., 1992).

STOP I/4. Cavnic Valley. Sarmatian pyroxene andesites lava flows and Pannonian pyroxene hyalorocks.

In the southern extremity of the eastern part of the Gutâi Mts. The Sarmatian volcanic products are widespread. They overlie the Sarmatian sedimentary deposits and consist mainly of lava flows represented by pyroxene andesites (Răchiţele type) and pyroxene dacites (Şatra type).

The age of this volcanics was long time discussed due to their spatial position, i.e., in an isolated area with sedimentary deposits. Previously it was considered by different authors, as similar in age with the volcanic products from the Cavnic-Rotunda area or Mogoşa volcanic structure. Recent K-Ar datings prove their Sarmatian age: 13.3-13.4 Ma for the Răchiţele andesites and 13.2 Ma for the Şatra dacites (Edelstein et al., 1992, Pecskay et al., 1994).

In a small quarry situated on the right side of the Cavnic Valley, at about 5km south from Cavnic town, occur the Răchiţele pyroxene andesites (58.9% SiO_2, 2.0% K_2O, 2.9% Na_2O). They represent a lava flow which presents irregular zones with breccious textures and secondary minerals: opal-chalcedony, carbonates, clay minerals, Mn oxides and Fe hydroxides.

Near the quarry, across the Baia Sprie - Cavnic road, there are nice outcrops in Pannonian volcanic products - Piatra Roşie - Cetăţele type hyalorocks. These volcanics, developed in the Dăneşti - Cetăţele area, belong to the first phase of the Pannonian volcanism from the eastern part of the Gutâi Mts..

Coeval with some acidic lava flows and volcaniclastic deposits - Dăneşti biotite dacites (11.6 Ma), there occur some exclusive pyroxenic products having a transitional character between andesites and dacites. These volcanic products or a volcaniclastic complex, very well developed in Piatra Roşie Hill consisting of pyroclastic deposits with some interbedded sedimentary rocks, autoclastic breccias, hyaloclastic rocks and coherent lava flows. The latest consist of glassy rocks with porphyritic textures, with small amounts of plagioclase and pyroxene phenocrysts (hyaloandesites - hyalodacites).

B. Volcanicity/metallogeny in the southern part of the Gutâi Mts.

Istvan D., Fülöp A., CUARŢ S.A., Baia Mare

In the southern part of the Gutâi Mts., from Badenian to Pannonian, a complex volcanic activity took place. Very different volcanic rocks occur in this area: ignimbrites and associated fall deposits which, together with the interlayered sedimentary rocks, form a volcano sedimentary formation (Badenian), andesitic lava flows and pyroclastic rocks (Sarmatian) and andesitic and subordinate dacitic lava flows and pyroclastic rocks (Pannonian). Many intrusions, especially in Sarmatian, are associated with these volcanic products.

Some of the most well known ore deposits - Au-Ag and base metal - of Baia Mare metallogenic district are located in this area.

Nistru Valley represents an illustrative area of the Ilba-Nistru metallogenic field (Nistru-Băiţa ore deposit) with an interesting succession of Badenian and Sarmatian volcanics, hydrothermal aureoles and mineralizations which may be seen in some outcrops.

C. Badenian rhyodacitic formation

The Badenian rhyodacitic formation extend along the southern border of Gutâi Mts., on an area between Seini and Baia Mare, being covered by younger volcanic and sedimentary deposits. Its thickness decreases from W towards E, from Racşa area (600m) to Săsar area (50m), respectively.

The constituents of the formation are the volcaniclastic deposits and the sedimentary deposits. They occur interbedded suggesting the more appropriate term of "volcano-sedimentary formation" (Borcoş et al., 1975). The volcaniclastic deposits are represented by pyroclastic deposits and volcanogenic sediments. The pyroclastic deposits are represented by two genetic types: the ignimbrites and the fall deposits. The main part of the formation consists of ignimbrites. They are massive, without bedding and grading. The grain sizes are ranging from fine tuffs to breccias. The welding is characteristic, strongly welded ignimbrites being more frequent than the slightly welded ones.

Ignimbrites are composed of pumice clasts, crystals, lithics and an ash-sized matrix. The pumice clasts are flattened and stretched during the welding, forming fiammes. They are aligned in accordance with the flow direction. This foliation defines the eutaxitic texture assessing the hot state deposition of these pumice flows. Fiammes are usually altered into chlorites, sericites, clay minerals and carbonates. Crystals are represented by quartz, adularized plagioclase feldspar, chloritized biotite and pyroxene pseudomorphosed by chlorites, adularia and silica. Different other clasts are represented by co-magmatic unvesiculated lithics, accidental and accessory lithics of magmatic origin (pyroxene andesites), fragments of sedimentary rocks (sandstones, siltstones, clays, marls) and metamorphic rocks (quartzites, shists).

The matrix is composed of glass shards preserving their Y-like, cuspate, platy shapes (bubble wall pumice fragments) or flattened and sintered together; ash-sized clasts of quartz and plagioclase feldspar appear also within the matrix. It is devitrified into a mosaic of quartz and feldspar (granophyric texture) or it is altered into chlorites, adularia, silica, clay minerals and/or carbonates.

The fall tuffs are represented by well stratified deposits, moderately to well sorted. Their grain sizes correspond to fine and coarse tuffs, rarely to lapilli tuffs and breccias.

The fine and coarse tuffs are composed mainly of glass shards and crystals. Glass shards have the same morphologies suggesting magmatic explosions. The same crystals are present, pseudomorphosed by the same assemblages found within the ignimbrites composition. Crystals tuffs were very often recognised.

The lapilli tuffs and breccias are pumice-rich deposits composed of stratified flattened pumice clasts and small amounts of crystals and glass shards. They are strongly altered, the pumice clasts being pseudomorphosed by chlorites, clay minerals and carbonates.

The volcanogenic sediments are closely associated to the non-volcanic sedimentary deposits. They are bedded and their grain sizes are sharply different from those of the surrounding sediments. The main deposits are the pyroclastic sandstones and conglomerates associated with marls and siltstones with different amounts of reworked pyroclasts.

The volcanic clasts, mainly of pyroclastic origin are represented by crystals of quartz, plagioclase feldspar and rarely biotite and pyroxene, unvesiculated lithics, pyroxene andesites. Other lithic may be present, fragments of sedimentary and metamorphic rocks, bioclasts, all cemented by carbonates and small amounts of terrigeneous components (micas, quartz, feldspars, quartzites).

The non-volcanic sedimentary deposits are represented by marls and siltstones (which predominate) and sandstones and conglomerates. They may contain small amounts of reworked pyroclasts.

STOP I/5. Nistru Valley. "Coroana de Aur" - Badenian welded ignimbrites (Fig. 8).

"Coroana de Aur" is an occurrence of typical welded ignimbrites belonging to the Badenian rhyodacitic formation. Three flow units may be seen, with a total thickness of approximately 30m. They are completely unsorted, without grading, with a bedding suggested by the sequence of the flow units. The grain size corresponds to breccias or lapilli tuffs.

The deposits are strongly altered during the propylitic alteration with adularia.

The main components are the fiammes pseudomorphosed by chlorites and clay minerals. They include small amounts of crystals. These fiammes are aligned defining a planar foliation, subparallel to the bedding.

The crystals are represented by quartz, plagioclase pseudomorphosed by adularia and sericite, chloritized biotite and pyroxene pseudomorphosed by chlorites, adularia and silica.

The lithics are abundant, the composition of these ignimbrites being very heterogeneous. They are represented by pyroxene andesites, the microlitic groundmass of magmatic rocks, siltstone and sandstone fragments.

SIMPLIFIED GEOLOGICAL MAP OF THE NISTRU ZONE (after Bernad et al., 1988)
scale 1: 2500

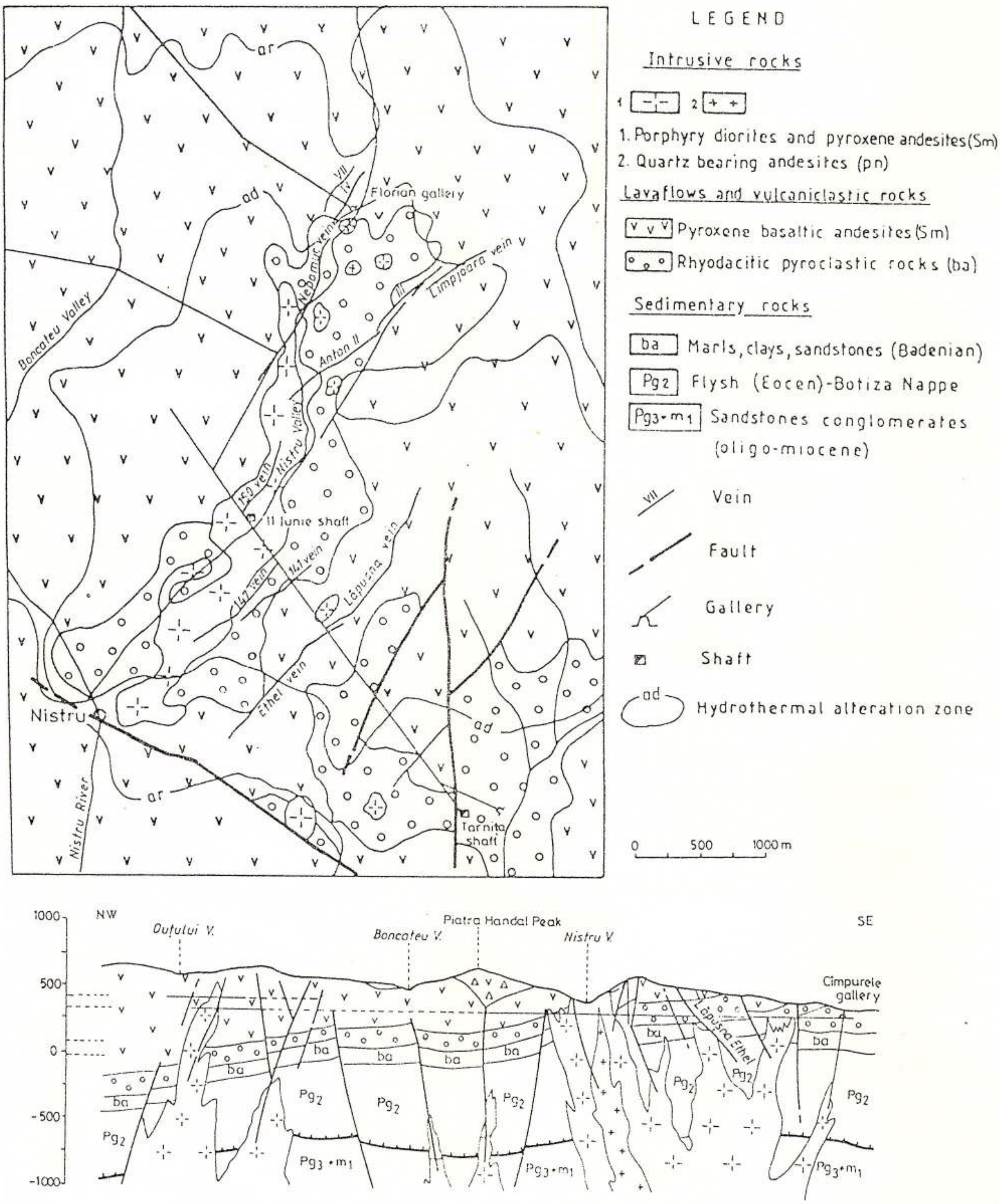


Fig. 8

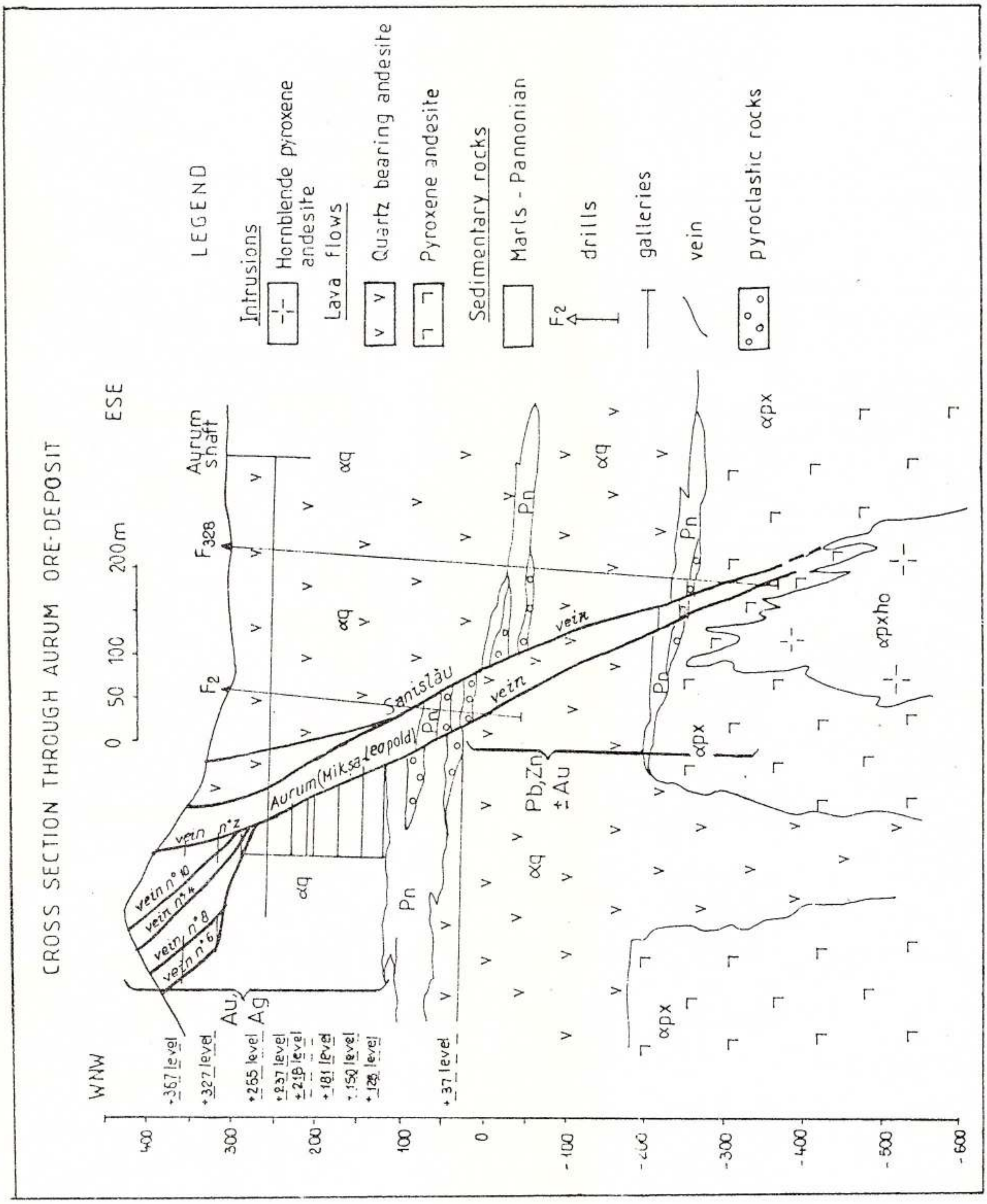

CROSS SECTION THROUGH AURUM ORE-DEPOSIT
WNW
ESE
0 50 100 200m
Aurum shaft
F2
F328
LEGEND
Intrusions
Hornblende pyroxene andesite
Lava flows
Quartz bearing andesite
Pyroxene andesite
Sedimentary rocks
Marls - Pannonian
drills
galleries
vein
pyroclastic rocks
+367 level
+327 level
+255 level
+237 level
+218 level
+181 level
+150 level
+128 level
+37 level
Au, Ag
Pb, Zn ± Au
vein n°z
vein n°10
vein n°4
vein n°8
vein n°6
Aurum (Miksa-Leopold)
Sanislău
vein
αq
αpx
αpxho
Pn
400
300
200
100
0
-100
-200
-300
-400
-500
-600

Fig. 9

The matrix is composed of recrystallised welded shards, deformed and compacted at the margins of the crystals. Due to the granophyric crystallisation of the glass, it displays a mosaic of fine quartz and feldspar. Alteration minerals also appear: chlorites, silica, clay minerals.

STOP I/6. Valea Mare-Galbena vein group (Fig. 9).

The veins represent the central-south-eastern part of the Nistru-Băiţa ore deposit and are related to a main intrusion-andesites and microdiorites at the surfaces which passes to microdiorites in the deeper part of the mining works.

a). The northern part of the Valea Mare-Galbena vein group.

There may be seen some veins located in Sarmatian pyroxene basaltic andesites (lava flows) strongly altered (argillizations and silicifications). These veins have a Pb-Zn character, consisting of sphalerite, galena, marcasite and pyrite in quartz gangue.

b). The central part of the Valea Mare-Galbena vein group.

The mineralizations have a copper character. The main vein, Nepomuc is located on a fracture between the Badenian volcano-sedimentary formation and the main intrusion of Nistru Valley.

c). Anton vein group.

There may be seen a copper mineralization enriched in gold especially in the upper part of the vein (free gold or gold included in quartz).

STOP I/7. Toncii Valley. Potassic alterations (adularia) and gold-silver mineralizations.

Toncii Valley area represents the surface zone of the Aurum gold ore deposit, situated within the Săsar-Dealul Crucii metallogenic field. The gold epithermal mineralizations are developed in an area with very thick lava flows (cca 700m) considered as a volcano-tectonic structure (graben) or a caldera. The Sarmatian-Pannonian intermediate volcanic products are predominant and at the surface, lava flows of quartz-bearing andesites are widespread.

Typical gold epithermal systems hydrothermal alterations are developed within the whole area: large potassic alterations (adularia), local silicifications and/or argillizations. The content of K_2O in the adularizated andesites varies between 7-11% (the average=9.3%).

The main vein (Aurum) is 900m length and 2m thick (average). In the lower part, the mineralization passes to a lead-zinc character (Fig. 9).

SECOND DAY

D. Volcanism and metallogeny in the western part of the Gutâi Mts. and in the Oaş Mts.

Kovacs M., Fülöp A., Istvan D., CUARŢ S.A., Baia Mare

STOP II/1. Ilba. Porcului Valley - Badenian ignimbrites and fall deposits.

Ilba, Porcului Valley quarry represents an occurrence of a sequence of ignimbrites and fall deposits. The sequence is composed of two parts:

- the lower part consists of three ignimbrite flow units 3, 1.5 and respectively 3 m thick. They are unsorted, ungradded but with a well bedding. The composition is relatively homogeneous, lithics appear rarely. The grain size corresponds to breccias and lapilli tuffs.

The three flow units are separated by pumice-rich fall tuffs, very thin, 2-5cm thick. They are sorted and stratified due to the compaction of the pumice clasts. The grain size is coarse corresponding to lapilli tuffs or breccias. Such a layer appear also at the top of the lower part.

- the upper part is composed of two fall units 0.35 and 2m thick. The first thinner layer consists of coarse tuff moderately to well sorted and homogeneous. The second thicker one represents a fine fall tuff, very well sorted and homogeneous.

The ignimbrites are composed of pumice clasts, very compacted and stretched, suggesting a strong welding. The crystals are represented by quartz, plagioclase feldspar, biotite and rarely pyroxene. They are altered as a result of propylitization with adularia. Lithics of pyroxene andesites and sedimentary (clays and siltstones) fragments are rare. The matrix is composed of welded glass shards; together with the fiammes, that define the eutaxitic texture very clear under the microscope. The glass shards recrystallized into quartz and feldspar and then altered to specific propylitic assemblage.

The fall tuff are composed of glass shards with typical Y-shape, cuspate and platy morphologies. They are often recrystallized into quartz and feldspar or are altered into clay minerals and silica. The same crystals are present and the thinner layer contains also small compacted pumice clasts. The rocks are propylitized but often the argillic process is dominant.

STOP II/2. Turţ - Ghezuri area (Oaş Mts.)(Fig. 10)

Oaş Mts represent the north-western part of the Neogene volcanic chain Oaş - Gutâi - Ţibleş. The volcanic activity in this segment had a complex character, the explosive, effusive and associated intrusive manifestations taking place especially during the Pannonian (11.0-9.5 Ma).

Different kinds of volcanic structures - monogenetic or/and complex volcanic structures and sometimes associated extrusive domes were formed in direct relation with sedimentary basins. Therefore, besides lava flows and pyroclastic rocks, volcano-sedimentary complexes are widespread.

In the north-central part of the Oaş Mts., in Turţ-Ghezuri area-different products of the intermediate volcanism occur. At the surface andesitic and dacitic lava flows are well developed.

The Ghezuri subvolcanic structure consisting of dacites, microgranodiorites with a vein system of Pb-Zn mineralization, located on the western flank of the intrusion, is developed in the northern part of the area. In the southern part, another mineralised subvolcanic structure (Penigher) base-metal ore deposits occurs. Both the two intrusive structures are located within sedimentary deposits with some associated volcano-sedimentary sequences.

Many boreholes, the majority of them deepest than 1000m, were drilled in this area emphasising the presence of different kinds of intrusions in the whole zone. These boreholes crossed the volcanic products in the upper part and the Pannonian, Sarmatian and in rare cases Badenian sedimentary deposits with some interbedded pyroclastic sequences in the lower part.

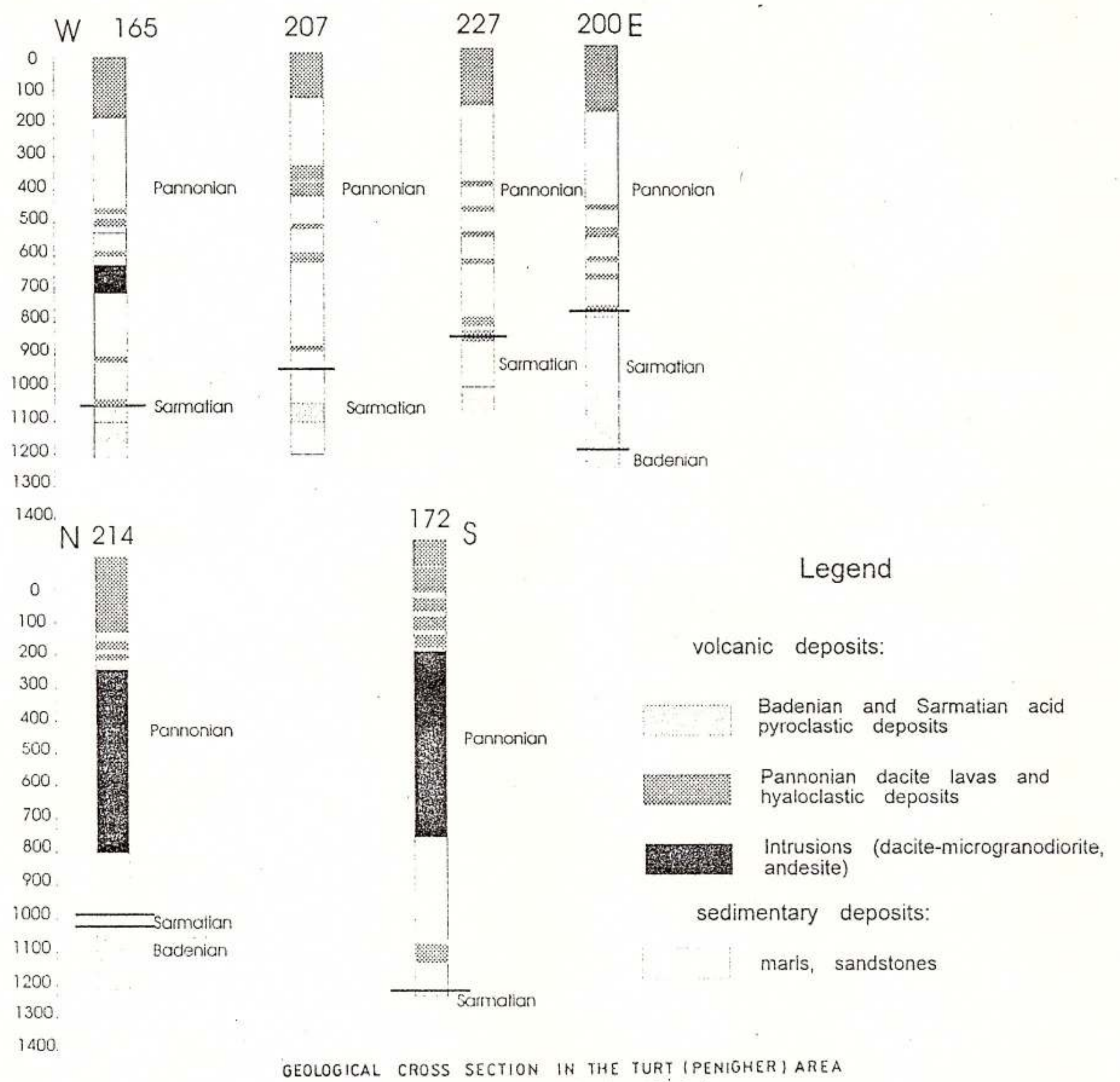
In the F 214 drilling, located in the southern part of the Ghezuri structure, one can see a very interesting succession from Pannonian dacitic volcanic products in the upper part to the Badenian acidic explosive volcanics in the lower part. The intrusive body of Ghezuri structure was also crossed on a few hundred meters.

The F 236 drilling, located on the southern part of the Penigher-Turţ ore deposit, on an area with exclusive sedimentary deposits at the surface crossed the monzodioritic intrusion which represents the main type rock of the subvolcanic structure.

Besides the volcanic and subvolcanic rocks and the sedimentary sequences, one can also see, in the two boreholes, different types of hydrothermal alterations and some base-metal mineralizations.

Lithological Columns of the Drillings from Turt-Ghezuri Area (Turtului Valley)

(according to Fülöp, Crihan, 1993)



GEOLOGICAL CROSS SECTION IN THE TURT (PENIGHER) AREA

(according to Kovacs et al, 1993)

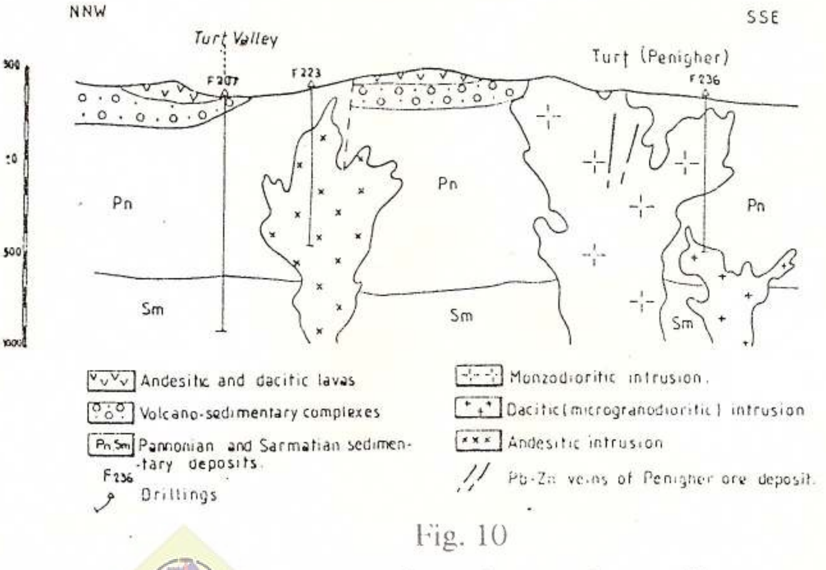


Fig. 10

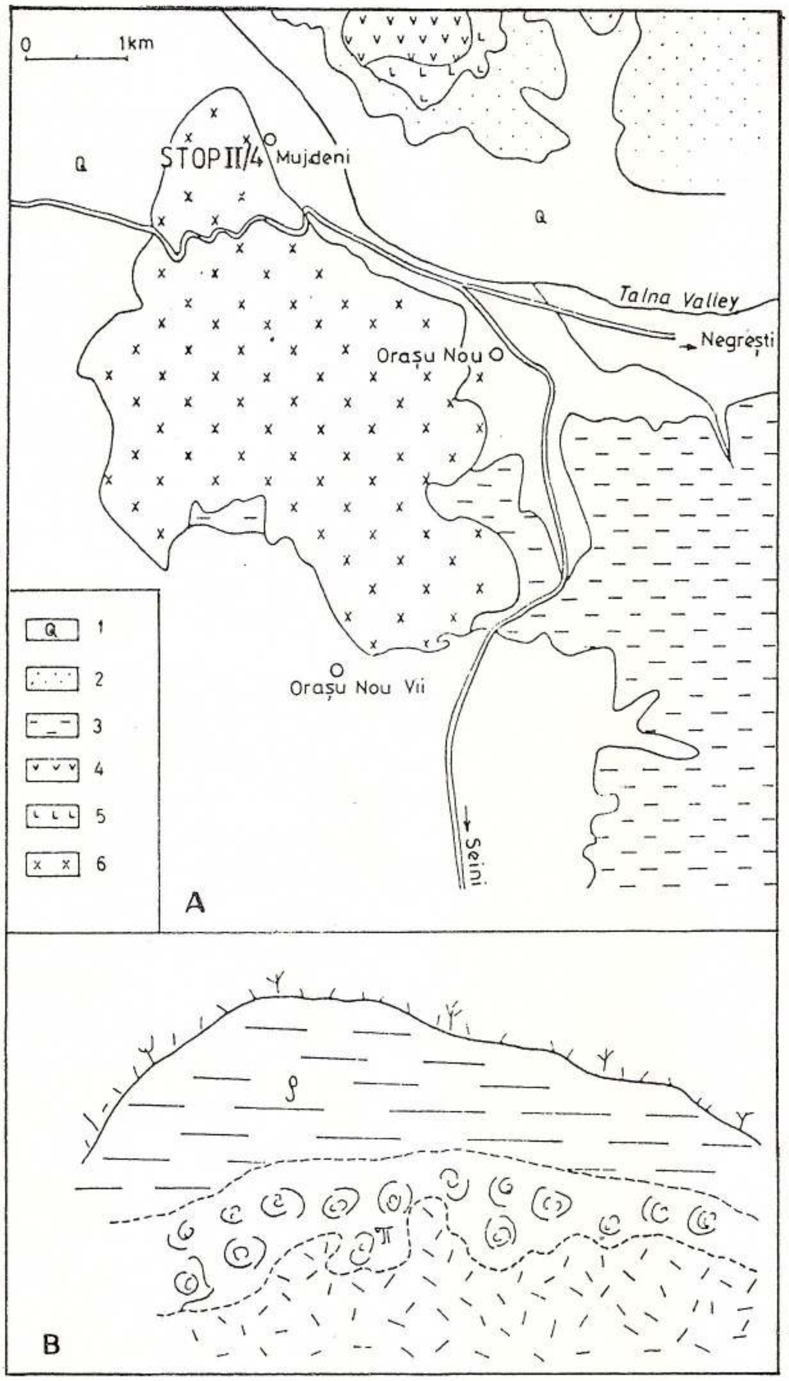


Fig. 11 - Geological sketch of the Orașu Nou-Mujdeni zone (acc. to Edelstein et al., 1980).
1, Quaternary; 2, Pontian (?) sedimentary rocks; 3, Pannonian sedimentary rocks; 4, Hyalodacites; 6, rhyolites and perlites.
A. The Mujdeni quarry. ρ, rhyolites; π, perlites;
B. Bentonitized perlites.

STOP II/3. Turţ quarry. Pannonian dacites.

The acidic rocks are well spread within the intermediate calc-alkaline volcanic rocks in Oaş Mts. They consist of pyroxene dacites or hyalodacites (Jude, 1977, 1986) and microgranodiorites (as some associated intrusive bodies).

Near the Turţ village, in an area with sedimentary deposits, dacitic volcanic products occur. They consist of coherent lava representing an isolated lava flow or an extrusive dome. At approximate 1 km toward east developed lava flows consisting of pyroxene andesites and hyaloandesites.

In the quarry one can see very interesting textural aspects: intense fissured zones with perpendicular joints on the flowage plans, nice columnar joints with perfect geometrical forms having different thickness and generally being oriented in the flowage plan and some massive and homogeneous, unfissured zones.

The rocks often present fluidal textures even some banded aspects. On the joints and within vacuoles occur secondary minerals (carbonates, clay minerals).

The Pannonian age of these dacites (9.9 Ma K-Ar age) is older than the previously considered age on the basis of the biostratigraphical data (Pontian - Pliocene ?).

STOP II/4. Mujdeni quarry (Oraşu Nou). Rhyolites and bentonitized perlites (Fig. 11).

The Mujdeni quarry is situated at about 3.5km from Oraşu Nou village, north from the Baia Mare-Satu Mare highway. In this quarry there may be observed the products of the rhyolitic massif from Oraşu Nou: lava flows and hyaloclastic rocks consisting of rhyolites and perlites.

These rocks have a special position both within the volcanic succession of Oaş-Gutâi Mts. and as spatial development. The rhyolitic massif from Oraşu Nou represents an isolated volcanic area situated in the connection zone between Oaş and Gutâi Mts.. Many researches consider that this massif belongs to the Oaş Mts. unit, being situated in the Negreşti-Oaş basin which represents the eastern most part of the Pannonian basin.

The rhyolitic volcanism from Oraşu Nou area represents a distinct phase of the volcanic activity from Oaş-Gutâi Mts. which took place in the Lower Pannonian (11.0 Ma K-Ar age).

The rhyolites occur in the upper level of the quarry and have fluidal and banded textures due to the alternating laminae differently coloured. In many cases they have a vacuolar textures, the vacuoles being filled with secondary minerals (zeolites, siderite, silica, rarely sulphides).

In the middle level of the quarry occur nice massive perlites with typical features which, in the lower part of the level pass to hyaloclastites. The perlites are bentonitizated especially in the lower level of the quarry. For more details see the Guide of Excursion C.

THIRD DAY

E. Volcanism and metallogeny in the central part of the Gutâi Mts.

Kovacs M., CUARŢ S.A., Baia Mare

STOP III/1. Baia Sprie base metal ore deposit (see the Guide of Excursion A).

STOP III/2. Şuior. Pannonian quartz andesites lava flows.

Pannonian quartz andesites represent the products of a distinct phase of the Neogene volcanism from Gutâi Mts., developed within the whole southern part of the Gutâi Mts., the most widespread in the central part, between Băiţa and Firiza Valleys.

This type of rock was named "quartz andesite" due to its mineralogical feature given by the presence of the quartz phenocrysts, sometimes with great size (5-6mm). From mineralogical point of view, these rocks are very homogeneous - the amphibole always being present together with the quartz, plagioclase and pyroxene as phenocrysts. The Pannonian quartz-bearing andesites are mainly acid andesites (59-62% SiO_2) but there are also basaltic andesites (54-57% SiO_2). The Pannonian age of these volcanic rocks have been established very precisely on the basis of the relationships with sedimentary deposits paleontologically dated. K-Ar ages are in good agreement with the biostratigraphical data. The K-Ar data correspond to the age range of 11.5-10.5 Ma.

On the road to Şuior mine, there are nice outcrops in Pannonian quartz-bearing andesites (Şuior type). Lava flows related to the Poiana Cremenea volcanic structure occur as cliffs with remarkable pseudoagglomerates aspects due to the weathering processes. The rocks are fresh and contain large sized amphiboles and sometimes autigene xenolithes.

The chemical composition of the K-Ar dated sample from Poiana Cremenea Peak is as follows:

SiO_2 = 60.79	Na_2O = 2.99	Sc = 29.23	Rb = 70.81
Al_2O_3 = 16.85	K_2O = 1.74	V = 140.54	Sr = 228.19
Fe_2O_3 = 3.58	TiO_2 = 0.46	Cr = 31.45	Ba = 336.15
FeO = 2.85	P_2O_5 = 0.10	Co = 60.51	Nb = 9.96
MnO = 0.11	CO_2 = 0.35	Ni = 12.47	Pb = 4.84
MgO = 3.10	H_2O^+ = 0.62	Zr = 124.66	Th = 7.16
Ca = 5.43	H_2O^- = 0.76	Y = 20.16	U = 2.02

La=19.58	Ce35.49	Pr=6.80	Nd=14.70	Sm=3.52
Eu=0.89	Gd=3.61	Tb=0.58	Dy=7.64	Ho=0.76
Er=2.19	Tm=0.33	Yb=2.14	Lu=0.35	

$^{87}Sr/^{86}Sr$=0.7080

STOP III/3. Firiza lake. Neogene intrusive body in Paleogene flysch.

In the Firiza lake area (15-20km north from Baia Mare) the Paleogene flysh deposits are in a tectonical position over the Neogene deposits (sedimentary and magmatic rocks). Some intrusions pearce the sedimentary rocks of the Paleogene flysh.

In the visited outcrop one can see the contact between a small intrusive body consisting of pyroxene ± amphibole andesites and the flysh deposits. The thermometamorphic aureoles in the sedimentary rocks are very slow developed but the mechanical effects at the contact are impressive.

The igneous rocks present a microporphyric texture and propylitic alterations.

STOP III/4. Limpedea quarry (Ferneziu). Vertical columns in an acidic andesite.

Limpedea quarry is situated at approximately 5km north from Baia Mare on the road to Firiza lake. It is an old quarry, where, some years ago, volcanic rocks were exploited for building rocks.

In the front of the first step of the quarry, nice vertical columns, more than 20m high, with remarkable geometric forms occur.

Due to their peculiar aspects, many years these rocks were considered as basaltic ones! Only in the last 10 years it was emphasised that they consist of acidic pyroxene andesites (SiO_2 = 60.5-62.9%, K_2O = 1.96-2.12%).

The age and their deposit have been interpreted in different ways. The isometric form emphasised by recent geological field investigations and the microtextural aspects (a holocrystalline groundmass) suggest a possible intrusion or a part of an extrusive dome and not a lava flow.

FOURTH DAY

F. Gutâi Mts. tour

Kovacs M., Fülöp A., Istvan D., CUARŢ S.A., Baia Mare

STOP IV/1. Ilba quarry. Pannonian pyroxene andesites.

In the south-western part of the Gutâi Mts. the Sarmatian intermediate volcanics are the most widespread. Pannonian volcanics, consisting of pyroxene andesites (Ilba type) cover or pierce these products in the Ilba area. Sometimes, the volcanism developed under subaqueous conditions.

The Ilba quarry is situated near the Baia Mare - Satu Mare road, in the Ilba village (20km west from Baia Mare). In this quarry one may see pyroxene andesites (56.6% SiO_2, 1.9% K_2O, 2.2% Na_2O) differently interpreted by different authors - as the front of a lava flow deposited in marine environment or as a subaqueous extrusive body respectively.

Nice radial columnar joints develop in the central part of the outcrop. In the upper part and in some marginal zones of the quarry there occur autobreccias cemented by colloidal silica containing a rich faunal association of characteristics molluscs for the Middle Pannonian (Congeria ramphophora ramphophora, Melanopsis fosils fosils, Melanopsis bonei bonei, Limnocardium, Hydrobia, Teodoxus).

STOP IV/2. "Sîmbra oilor" quarry. Upper Pannonian pyroxene andesites.

In the northern part of the Gutâi Mts. a strong volcanic activity took place in the Upper Pannonian. Some complex volcanic structures were built up having a stratovolcanic feature with mainly lava flows developing at the surface.

The volcanics consist of pyroxene basaltic andesites and pyroxene andesites. Some intrusive bodies are known especially in some boreholes or in the peripheral zones of the lava plateau at the surface.

In the "Sîmbra oilor" quarry there occur pyroxene andesites representing one of the peripheral intrusive body. It is the northern most body developed in the Huta Certeze sedimentary area, outside the volcanic field.

The rocks are black and massive with porphyritic texture and many vacuoles containing secondary minerals (chlorite, carbonates, zeolites and opal). Plagioclases (An_{48-76}), ortho and clinopyroxenes appear as phenocrysts in a microcrystalline groundmass.

The age of the volcanics from the northern part of the Gutâi Mts. was previously considered Pliocene. Recent K-Ar data show their Upper Pannonian age (9-10 Ma).

STOP IV/3. Piatra. Remeţi tuff-Sarmatian plinian fall deposits.

Remeţi tuff represents a pyroclastic deposit developed at the border of the northern slope of Gutâi Mts., at its boundary with Maramureşului Basin.

The tuff extends over some 8km with a general E-W trend. The thickness varies between 5-25m. Remeţi tuff is interbedded within lower Sarmatian sedimentary deposits, marls with explosion of Cibicides lobatulus and sandstones (Gherman E., Ichim T., 1955).

As a whole, Remeţi tuff is composed of well-stratified deposits with layers ranging in thickness from 10cm to a few meters. They are well to moderately sorted, with a relative homogeneous composition. The grain sizes correspond to lapilli, coarse and fine tuffs.

The main components are: pumice clasts, glass shards, crystals of quartz, feldspar and biotite.

Magmatic and metamorphic lithics are very rare. More often, terrigeneous components, micas and clay minerals appear in small amounts. These components are separated in well-defined layers of lapilli tuff and respectively coarse and fine tuffs.

The lapilli tuffs are composed almost entirely of larger pumice clasts (1-4cm in size) and small amounts of glass shards and crystals. The pumice clasts have fibrous tube vesicles often compacted and devitrified into spherulites of zeolites (clinoptilolite) or a mosaic of fine grained quartz and feldspars. Other secondary minerals such as clay minerals (kaolinite, montmorillonite) and carbonates (calcite) also appear. Glass shards have typical morphologies pointed-out by secondary clay minerals: Y-shaped, cuspate, platy. They represent bubble wall pumice fragments. Angular crystals of quartz, plagioclase feldspar and fine lamellae of biotite appear in small amounts. Microlitic magmatic lithics are very rare.

The coarse and fine tuffs are composed mainly of glass shards and crystals; small-sized pumice clasts also appear. The glass shards preserve their typical morphologies suggesting magmatic explosions. The crystals are angular fragmented and sometimes these clasts are abundant. The pumice clasts are devitrified into zeolites or are argillized. Clay minerals and muscovite are considered to be of terrigeneous origin. Some quartzites fragments appear very rare.

Remeţi tuff is a plinian fall deposit in proximal facies. Magmatic explosions are considered to be responsible for their genesis and the subaqueous depositional environment is admitted.

On an affluent of Şugatagului Valley from Piatra village, at 200m from the bridge, one can see some typical occurrence of Remeţi tuffs. Alternations of fine and coarse tuffs with lapilli tuffs appear on the valley, disposed on sedimentary deposits (marls). The layers have thickness ranging from 10cm to 70cm. The fine and coarse tuffs are well sorted and have white-brownish colour (due to argillization and iron-hydroxides) and the lapilli tuffs are green, green light due to the zeolites - forming process.

STOP IV/4. Laleaua Albă quarry. Upper Pannonian composed dykes.

At aprox. 10 km from Baia Sprie town, on the highway Baia Mare - Sighetu Marmaţiei, in a quarry which now represents a geological monument, a composed dyke is exposed. This dyke is the greatest body among the subvolcanic intrusions, mainly as dykes, which occur in this area crosscutting the Pannonian andesitic volcaniclastic complex.

The dykes consist of two types of rocks: quartz bearing andesites forming the ring and macroporphyritic dacites in the core of the dykes.

The mineralogical composition is quite similar: plagioclase, quartz, hornblende, clino and ortopyroxene, biotite as phenocrysts, magnetite and ilmenite as opaque accessory minerals. The large crystals of plagioclase (max. 3 - 4 cm in size) and the numerous xenolites (max. 30 cm in size) represent the main features of the dacites.

A cross section in this dyke with the dacitic core and the quartz andesites ring very well exposed can be seen in the quarry situated near the highway. The white colour of the dacite emphasises the striking shape of the core suggesting a tulip flower. In the north-western part of the quarry a very interesting contact between the two types of the rocks can also be seen.

An Ar-Ar determination (Lang, unpublished data) on a large crystal of plagioclase shows 8.5 Ma for the dacitic core of the dyke which is in accordance with the new geological data.

STOP IV/5. Gutâi winding road. Pannonian andesitic volcaniclastic complex.

In the southern part of the main ridge of the Gutâi Mts., between Igniş Peak and Gutâi Peak, a well spread andesitic volcaniclastic complex, belonging to the Middle Pannonian volcanic phase, is developed.

This complex consists mainly of coherent lava flows and autoclastic rocks (autobrecciated lavas), pyroclastic deposits and more subordinately of epiclastic volcanic rocks.

The lava flows are represented by pyroxene basaltic andesites and andesites. The K-Ar determination on a pyroxene basaltic andesite (Pécskay et al., 1994) proves their Middle Pannonian age (10.2 ± 0.4 Ma).

On the windings of the Sighetu Marmaţiei - Baia Mare highway there are some outcrops, in which the products of the volcaniclastic complex can be seen:

- pyroclastic deposits consisting of different grain size, mainly coarse fallout pyroclastic rocks (breccias and microbreccias);
- coherent lavas which pass to autoclastic lavas.

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EXCURSION A

TWO REPRESENTATIVE VEIN DEPOSITS (Au-Ag AND Pb-Zn) RELATED TO NEOGENE VOLCANIC STRUCTURES

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FIRST DAY

BAIA SPRIE ORE DEPOSIT

Underground and upper part visit of the Principal Vein

The Baia Sprie ore deposit is situated at about 10 km East of Baia Mare, on the road to Sighetu Marmației and at 2 km north-east from the centre of the Baia Sprie town. The Baia Sprie mine, together with Valea Roşie and Dealu Crucii mines from Baia Mare, are the eldest mines in Gutâi Mts.. The ore deposit was exploited with small breaks from the Middle Age till nowadays. Till 1957 approximately 5,700,000 tones of ore were exploited. The Baia Sprie ore deposit is one of the most important deposits of the districts with well developed veins it contains and as type locality of some minerals first described there: andorite, felsöbanyite, klebelsbergite, dietrichite, semseyite, szmikite, monsmedite.

The metallogenetical activity is associated to the Jereapăn pyroxene and amphibole andesite phase (Manilici et al., 1965, Borcoş et al., 1972) of Pannonian age, 10.9-10.1Ma (Kovacs and Edelstein, 1993). Recent K-Ar data indicate the age of 9.3-7.65Ma for the mineralization (Iştvan et al., 1993).

The mineralization from Baia Sprie is emplaced along the Dragoş Vodă wrench fault. The main veins are developed on the northern and southern limits of an andesitic dyke (Popescu, Ştefănoiu, 1972). This dyke is the local geological element with the greatest role in the generation of the veins. The Principal vein and the Nou vein emplaced on the northern, respectively southern limit of the dyke, are formed on shear joints and the Diagonal vein is hosted by a extension joint

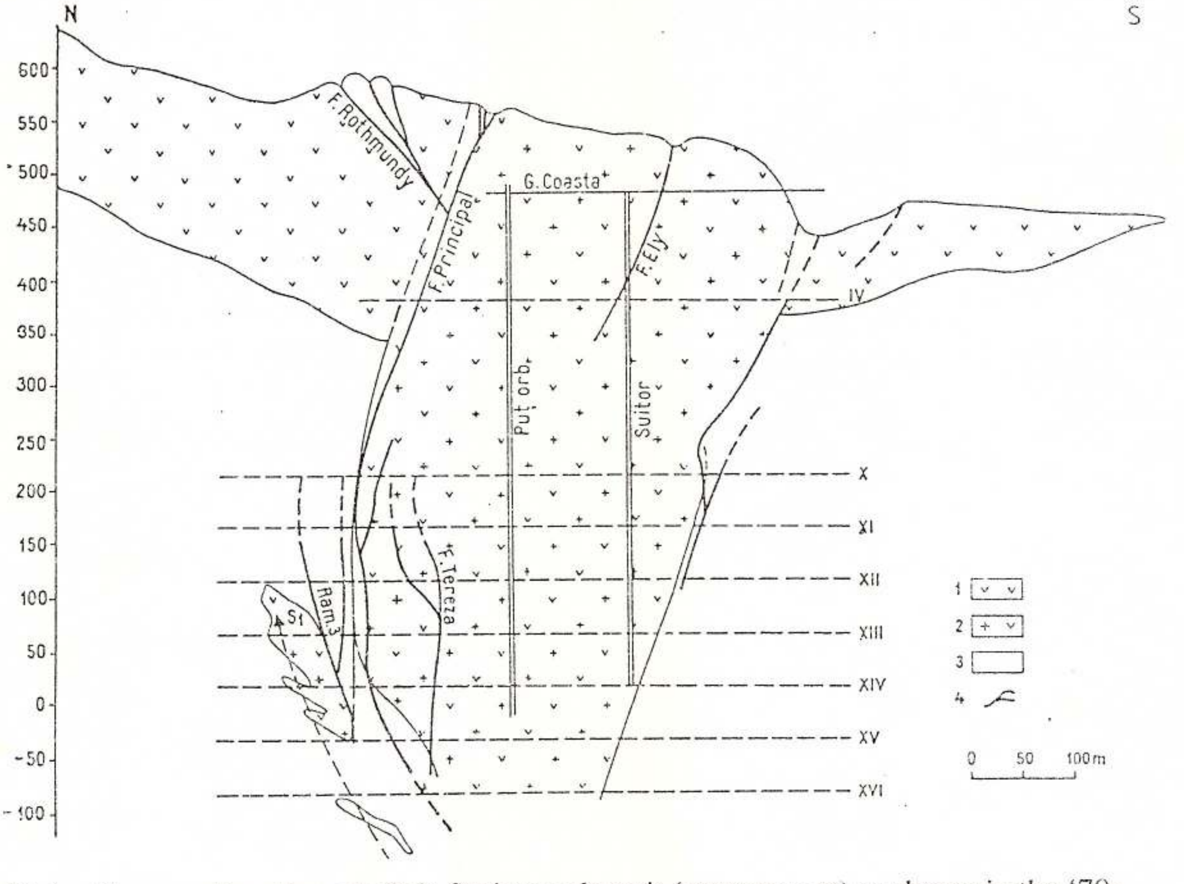

Fig. 12 A - Cross section through Baia Sprie ore deposit (western part) as shown in the '70s.
1, Andesite lava; 2, Dyke; 3, Pannonian; 4, Vein.

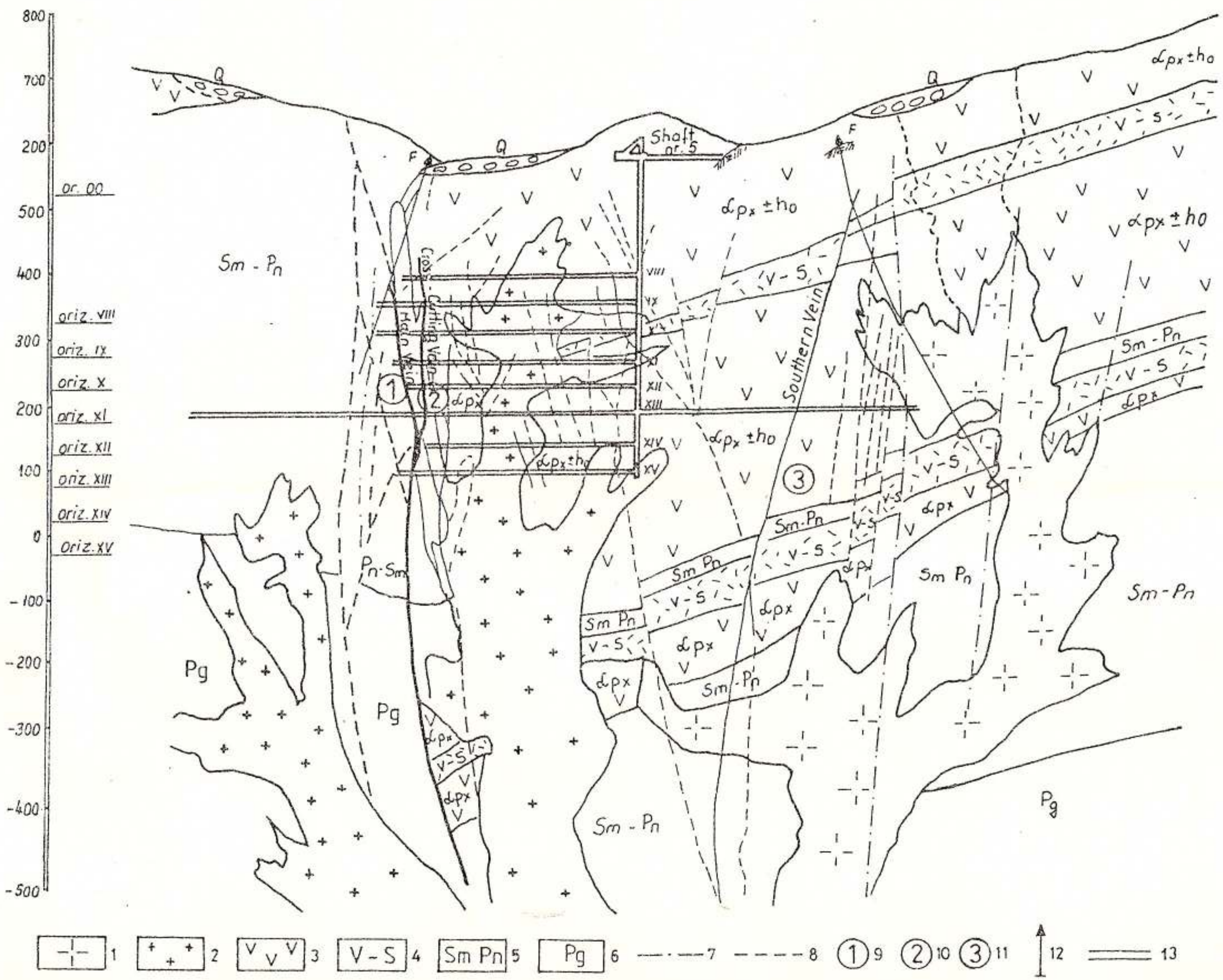

Fig. 12 B - Cross section through Baia Sprie ore deposit (Eastern part) (M. Zoltan, 1993).

1, dacite; 2, porphyry microdiorite; 3, pyroxene and amphibole andesite; 4, volcano-sedimentary formation; 5, non-differentiated Sm-Pm sedimentary deposits; 6, Paleogene; 7, Vein; 8, Fault; 9, Main Vein (1); 10, Diagonal Vein (2); 11, Southern Vein (3); 12, Drilling; 13, Galleries.

Until 1972, the Baia Sprie ore deposit was known only in its western part, between Valea Borcutului and Valea Tulbure comprising Minei Hill (Mons Medius) with veins emplaced on the accompanying joints of the Principal vein and constituting the main objective of exploitation during the centuries. On the basis of some theoretical approaches (Popescu and Ştefănoiu, 1972, Borcoş et al., 1973) and of some exploration works (Ştefănoiu, 1970-1973, unpubl.) was proved the continuity towards east of the Principal vein (Fig. 12A, 12B).

The Principal vein is emplaced on the northern part of the mineralised structure and it was traced on direction on 5250 m, being the longest vein in Romania. It is situated within andesites in the upper part of the ore deposits and in the lower part within sedimentary deposits; in the middle part the Principal vein cross-cuts the boundary between andesites and the Pannonian sedimentary deposits. In both the upper and the lower parts, it is composed of numerous branches. Along dip it is developed on more than 800 m, and the thickness varies between 0.5-22 m. The upper part including also the vein branches had high gold and silver grades; between the horizons V-X, the mineralization is mainly of lead-zinc type, and below the X horizon, it has a copper character. The special distribution of the mineralization in the Principal vein suggests its zonal character and the existence of two phases of mineralization, one with lead-zinc and gold-silver character and another one with pyrite-copper character. Some authors considered that in time the pyrite-copper mineralization is followed by the lead-zinc one (Manilici et al., 1965, Borcoş et al., 1973).

The Nou vein is 2100 m long, has a maximum thickness of 6 m and a vertical development of 200 m. It is emplaced south of the andesitic dyke, in sedimentary deposits. The mineralization has a lead-zinc character.

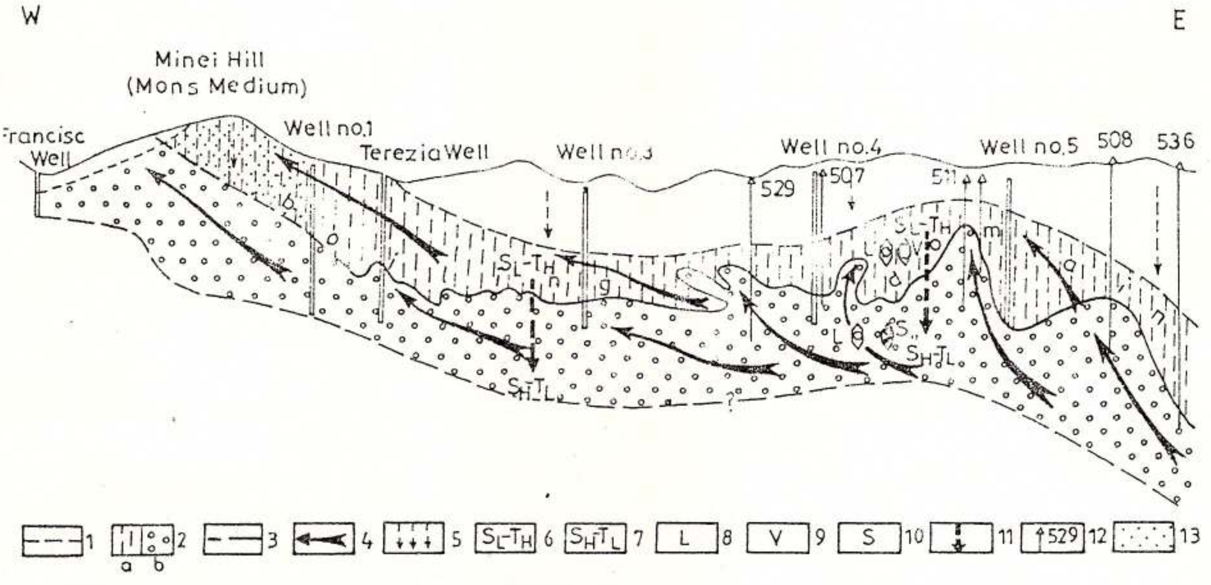

Fig. 13 - Reconstruction of the hydrothermal ore deposition at Baia Sprie.

1, boundary of the mineralized zone; 2, morphological trend zones of pyrite: cube-pentagonal dodecahedron C-P (a), cube-octahedron-pentagonal dodecahedron ± {hkl} forms C-O-P ± {hkl} (b); 3, base of the boiling domain; 4, flow direction of the endogenous fluids; 5, flow direction of the meteoric water; 6, low supersaturation-high temperature; 7, high super-saturation - low temperature; 8, liquid inclusions; 9, gas (vapour) inclusions; 10, heterogenous fluid inclusions with solid phases; 11, descendant deposition of the mineralization; 12, borehole; 13, gold zone.

The Diagonal vein has 600 m length, 200 m high and 1m thickness and it is developed between the XI and the XIV horizons. The host rock is the pyroxene and amphibole andesite, strongly hydrothermally altered. The mineralization is identical with that of the Nou vein, having a lead-zinc character.

The Terezia vein is emplaced in the lower-central-western part, between the Principal vein and the Sudic vein, with a length of 600 m and a pyrite-copper mineralization.

The base metal mineralization is characterised by some massive, banded, breccious and concentric textures. The banded texture (Fig.13) is suggested by successive alternations of sulphides and gangue minerals. The bands may present also breccious, massive or concentric textures. The breccious texture is composed of argilized and silicified rocks, crossed by veinlets of quartz and pyrite, chalcopyrite, propylitised andesites fragments, pyrite fragments, sphalerite, galena, all in a quartz gangue. Fragments of the copper mineralization are cemented by the lead-zinc one. The predominant texture is the massive one.

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

The most complex mineralogical studies on Baia Sprie ore deposit are those by Manilici et al. (1965) for the Principal vein and Petrulian et al. (1971) for the Nou vein. Many of the minerals described at Baia Sprie belong to the Principal vein and mainly to its the upper-western part. Some features of the minerals described at Baia Sprie are given in the Table 1.

Table 1. Mineral species identified at Baia Sprie

	Mineral species or varieties	Remarks
	Adularia	Crystals of 0.01mm long. Manilici et al., 1965
1	Albite	Mentioned by Manilici et al., 1965, idiomorphic crystals, 0.01-0.05mm in size.
2	Andorite	Type locality. First description and chemical analysis by Krenner (1893). Prismatic crystals of 5-10mm, associated with quartz, plumosite on sphalerite and tetrahedrite. 22 crystallographic forms
3	Anglesite	Alteration product of galena. Manilici et al. (1965)
4	Ankerite	In the gangue of the copper mineralization. (Manilici et al., 1965). Chemical analysis by Gh. Lahovary, Bucharest
5	Argentite	Mentioned by Cădere (1925)
6	Arsenopyrite	Small crystals with quartz, stibnite (Krenner, 1876). Chemical analysis by Loczka (1885)
7	Azurite	Spherical reniform aggregates. Zepharovich (1859)
8	Barite	Big crystals up to 3cm, tabular, elongated on b axis, 14 forms, coloured in white, yellow, red, brown, black, blue. Braun (1932), Giuşcă (1929), Maklari (1940), Vendl (1922), Zeller (1923)
9	Berthierite	First cited in Baia Sprie by Krenner (1928)
	"Bog manganese"	Mentioned by Zepharovich V. (1859)
10	Bornite	Veinlets crossing chalcopyrite. Manilici et al.(1965)
11	Bournonite	Short prismatic or tabular crystals star-like twins associated with sphalerite, chalcopyrite, quartz (Krenner, 1881, Tokody, 1940)

12	Calcite	
13	Cerussite	Replaces galena along cleavages (Manilici et al., 1965)
14	Cervantite	Mentioned by Manilici et al. (1965)
15	Chalcanthite	Szellemy, 1984
16	Chalcedony	In the Eastern part of Mons Medius (Dealul Minei). Manilici et al. (1965)
17	Chalcocite	Associated with bornite within copper bearing mineralization (Manilici et al., 1965)
18	Chalcopyrite	Usually massive or druses associated with pyrite and sphalerite. Tokody (1940) determined the following forms (201), (110), (111), (605) .
19	Chlorite	Fine lamellae, associated with the copper bearing mineralization. Manilici et al. (1965)
20	Cinnabar	Rare, in the upper part of the Principal vein branches. Helke (1938), Manilici et al. (1965)
21	Covellite	On the lower levels of the Principal vein. Manilici et al. (1965)
22	Diadochite	In the Principal vein. Szellemy (1894)
23	Diaphorite	Isolated crystals with isometric habit, associated with semseyite. Discovered in Baia Sprie by Krenner (1877), who describes 11 crystallographic forms. According to Hulyak (1903) it is associated with mirargyrite. Also described by Tokody (1942)
24	Dietrichite	Found in the abandoned roadways at Baia Sprie, as accicular, fibrous crystals of at most 3cm. Schroeckinger J. (1878).
25	Dolomite	Cited by Haidinger (1843). Frequent in the vein fill. Manilici et al. (1965)
	"Eggonite"	Cited by Manilici et al., 1965
26	Epidote	Idiomorph and allotriomorph crystals in the gangue. Manilici et al. (1965)
27	Felsöbanyite	Described for the first time in the world at Baia Sprie by Haidinger in 1925 (after Strunz,1982). Krenner in 1928 determined its optical properties.
28	Fizelyite	Described for the first time by Krenner I., Loczka J. (1925). It occurs in the upper part of the Principal vein. Cădere (1925)
29	Fluorite	Superceanu (1957)
30	Freieslebenite	Shorts crystals with metallic lustre, there were described 12 crystallographic forms. Elongated crystals along the „c" axis. First described by Cotta, Fellenberg (1862) then by Krenner (1877)
31	Galena	Perfect crystals, compact masses with pyrite, sphalerite, antimony, chalcopyrite, quartz (Helke, 1938). Manilici et al. (1965) identified three galena generations.
32	Gypsum	Idiomorph crystals. Tokody L. (1939) described the (010), (110), (111), (525) forms
33	Hematite	Mentioned by Giuşcă (1937)

34	Jamesonite	Fragile aggregates, needle shaped fine crystals, inclusions in calcite and barite. Helke (1938), Koch, Grasselly (1960). Chemical analysis Loczka (1908)
35	Kaolinite	Nests in the vein fill, resulted from the transformation of andesites (Manilici et al., 1965)
36	Kermesite	Pseudomorphs on stibnite
37	Klebelsbergite	Type locality
38	Laumontite	Ackner (1855)
	Limonite	In the vein fill, in the upper part of the Principal vein. (Cădere, 1925)
39	Magnetite	Manilici et al. (1965)
40	Malachite	In the upper part of the Principal vein. Manilici et al. (1965)
41	Marcasite	Tabular, columnar, reniform crystals pseudomorphs after calcite. Krenner (1928), Superceanu (1957)
42	Melanterite	Well developed crystals (010), (001), (101), (110). Maklari (1943)
43	Melnicovite	In the upper part of the Principal vein. Manilici et al. (1965)
44	Meneghinite	Superceanu (1957)
45	Metacinnabarite	Associated with barite and stibnite. Krenner (1928)
46	Miargirite	Described under the name of kenngottite and contains lead, short prismatic habit, 16 crystallographic forms are described. Krenner (1879)
47	Millerite	Manilici et al. (1965)
48	Monsmedite (?)	Described for the first time in Baia Sprie by Götz et al. (1968), being invalidated by Zemann (1993)
49	Native Arsenic	Spherical aggregates with realgar, orpiment, sphalerite. Zepharovich (1859, 1873, 1893), Szellemy (1894)
50	Native Gold	Lamellae and filiform associated to silver. Included in quartz and sulphides. Szellemy (1894)
51	Native Silver	Filiform lamellae. Szellemy (1894), Superceanu (1957)
52	Orpiment	Small crystals with realgar, barite, stibnite, sphalerite. Manilici et al., 1965
53	Pirargyrite	Compact with proustite, pyrite, galena, sphalerite. Traube (1890)
	"Pitticite"	With realgar, orpiment, pyrite, sphalerite. Peters (1861)
54	Plagioclase	Rare within the vein fill, generally sericitized. Manilici et al. (1965)
	Plumosite	Hair-shaped, feltlike crystals. Manilici et al., 1965
55	Polybasite	Black foils on the upper part of the Principal vein, frequently with pyrite, pyrargirite in drusy cavities of quartz. Szokol (1902), Takody (1942), Giuşcă et al. (1963)
56	Proustite	On the upper part of the Principal vein in vugs together with quartz, pyrite, pyrargyrite, silver. Tokody (1941)
57	Pyrite	Compact masses associated with other sulphides. Manilici et al. (1965) recognised three generations. The cube and pentagonal-dodecahedral forms are prevailing. Tokody (1911), Franzenau, Tokody (1941)

58	Pyrolusite	Earthy masses. Cotta and Fellemberg 18
59	Pyrostilpnite	With pyrite, sphalerite, pyrargyrite. Krenner (1877), Toth (1862)
60	Pyrrhotite	Rare. Superceanu (1957)
61	Quartz	Frequently in the vein fill: Tokody (1938) described the Japanese twin and the (1010), (1011), (0111), (1121), (5161) crystallographic forms. It is formed in the temperature range of 180-305°C (Savul, Pomârleanu, 1961)
62	Realgar	Occurs as short prismatic crystals of up to 1cm. There are described 18 crystallographic forms. Löw M. (1912)
63	Rhodochrosite	On the upper part of the Principal vein together with andorite, stibnite, quartz, sphalerite, barite. Szokol (1902), Takody (1942)
64	Samsonite ?	Mentioned by Superceanu (1957); according to Udubaşa et al. (1992) it is an unlikely occurrence
65	Scheelite	On lower levels of the copper bearing mineralization, mentioned by Superceanu (1957) and Giuşcă et al. (1963). Occurs as bypiramidal crystals. Manilici et al. (1965)
66	Semseyite	Type locality (Krenner, 1881). Chemical analysis performed by Sipöcz (1886). Small tabular crystals including 6 crystallographic forms; (100), (001), (111), (221), (113), (113).
	"Sericite"	Pseudomorphs after plagioclase. Manilici et al. (1965)
67	Siderite	Stalactitic, reniform, greyish-yellow to red brown (Tokody, 1942) or rhombohedral shaped crystals associated with quartz. Manilici et al. (1965)
	Specularite	Frequently occurs in the copper bearing mineralization as nests, veinlets. Manilici et al. (1965)
68	Sphalerite	Rarely well developed crystals, sometimes twinned, brown and yellow coloured. Manilici et al. (1965) distinguished three generations
69	Stephanite	Mentioned by Cădere (1925)
	"Sterrettite"	Described for the first time by Krenner (1929)
70	Stibiconite	Occurs on the stibnite. Takody (1942)
71	Stibnite	Accicular, short prismatic crystals ending with pyramids, radial aggregates. There were determined 29 crystallographic shapes. Krenner (1865), Nett (1918), Tokody (1938)
72	Sulphur	Earthy, powdery, white-yellow coloured on pyrite, realgar, orpiment. Stoicovici, Gliszczynski (1936)
73	Symplesite	Fibrous-radial green mass, mentioned by Krenner (1886)
74	Szmikite	Described for the first time in Baia Sprie by Schroeckinger (1877). Occurs as concretions, stalactites, earthy, powdery mass.
75	Tetrahedrite	Chemical analysis by Pákozdy, 1949. Tetrahedral and dodecahedral crystals of 3-5mm. Tokody et al., 1940.
76	Valentinite	Short prismatic crystals, Koch (1923) describes 7 crystallographic forms out of it.

77	Voltzite	Mentioned by Tokody (1942)
78	Wolframite	Occurs in the deepest cooper bearing areas. Thin, blade-shaped, prismatic, tabular crystals. The crystallographic constants were determined by Krenner (1875) and Koch (1925) describing 18 forms. Also described by Superceanu (1957) and Giuşcă et al. (1963)
79	Wurtzite	Mentioned for the first time by Laspeyeres (1884).
80	Xanthoconite	In Baia Sprie it was described under the name of rittingerite (Krenner, 1877)
81	Zinckenite	Mentioned by Superceanu (1957).
	"Zinkfausenite"	Stalactitic, prismatic. Described for the first time in Baia Sprie by Tokody (1949), describing 6 crystallographic forms.

The list is largely based on data from Rădulescu and Dimitrescu (1966) and Udubaşa et al. (1992).

The Dealul Minei (Mine Hill) site is situated on the upper western extremity of the Principal vein. The Principal vein situated above the Borcut gallery (level-IV, elevation +376m) has numerous hanging wall branches: Boului, Ignaţiu, Rotmundi, Amadei, Matei, Ignat, Emeric, Pokol and also footwall branches, such as: Greisi, Levesy, Eli, Omindszenti, Oculi, Baptista, Rogate, Joli.

The ore in these branches is lead-zinc bearing with high gold and silver content, having a quartz, chalcedony, barite gangue. The base metal mineralization of Lebesy branch crosses red jaspers. Between the Levesy and Leppen branches there are disperse zinc bearing mineralizations. Native gold occurs as small foils disposed on quartz or included in pyrite, especially on the Levesy and Leppen branches. A gold bearing quartz level developed on the upper part of several branches (Amadei, Eli, Pocol, Joli). The roof veins, especially Rotmundi, Amadei, Pokol had higher silver grades and the footwall veins, Levesy, Eli and the Principal vein had higher gold grades. On Levesy vein, at the contact with the Principal vein a stockwork with 80-100m in length, 25-40m in thickness, 25m in depth was exploited, resulting 5 quintals of gold (Pálfy, 1916).

We visit the disperse mineralization, placed in the footwall of the Principal vein situated between the Principal vein and the Leppen branch. The disperse mineralization associates with intense silicification and adularization areas while the Principal vein is bordered by intense argilization areas. The mineralization is developed especially along diagonal fractures towards the strike of the Principal vein. The assemblage of the Principal vein footwall is made up of sulphides and iron oxides and hydroxides. Sulphides are represented by pyrite, galena, sphalerite, sometimes marcasite and low amounts of chalcopyrite. The oxides and hydroxides are represented by blade-shaped hematite, goethite. The gangue minerals are the following: quartz, calcite, siderite, adularia, barite and clay minerals.

The upper part of the Principal vein and its branches became famous because of the numerous rare minerals and especially sulphosalts described and discovered in these areas.

The base metal and copper bearing mineralization may be examined mainly in underground workings on the Central-Eastern part of the Principal vein.

The medium part of the Principal vein includes a base metal mineralization, and its lower part is predominantly copper bearing, the Terezia Shaft Branch being a veritable copper bearing vein.

The mineralization of Principal vein is rather complex, prevailing the common sulphides and the massive texture.

Along this portion, the mineralogical composition of the Principal vein is simpler than in the upper part, the sulphosalts occurring more rarely except the bournonite and tetrahedrite. The relation between the metallic and gangue minerals suggests their deposition during two ore-forming stages.

During the first, copper bearing stage: pyrite, chalcopyrite, wolframite, scheelite, hematite, stibnite, tetrahedrite, quartz, dolomite, ankerite, barite were deposited.

The second ore-forming stage contains a base metal mineralization including: pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, stibnite, melnicovite, marcasite, realgar, native gold and some sulphosalts in addition to the gangue minerals: quartz, calcite, dolomite, siderite, adularia, barite.

The recent work of Nedelcu and Pintea (1993) on the pyrite morphology and on fluid inclusion in quartz from the Baia Sprie Main Vein led to a reconstruction of the mechanism and evolution of the hydrothermal process.

Based on the pyrite morphology trend two distinct domains have been separated in the Main Vein plane as follows (Figure 13): an upper one, with C-P trend and a lower one, with C-O-P±{ hkl} trend. The two domains correspond to the concentration and temperature conditions inferred from the topographic analysis of the faces and habit of the pyrite crystals, characterised by: low supersaturation-high temperature (SL-TH) for the upper domain (C-P) and high supersaturation-low temperature (SH-TL) for the lower domain (C-O-P±{hkl}).

According to the previous data of Nedelcu et al. (1992) the fractionation of the sulphur isotopes in the sphalerite-galena pairs indicates inequilibrium in most of the studied cases situated at the boundary (transition zone) between the two mentioned domains.

Table 2. Isotopic composition of sulphur in the sphalerite and galena from the Main Vein, Baia Sprie

Horizon	Sample no.	$\delta^{34}S$/CDT (‰)	
		sphalerite	galena
X	B8	-3.73	-3.59
X	B19	+1.29	-4.67
X	B20	+4.82	-6.28
XI	B26	+3.17	-2.28
XI	B28	-0.62	+7.69
XI	B115	+8.27	-0.84
XI	B116	-1.56	-3,66
XII	B107	+18.84	+4.83
XIII	B135	+1.90	+21.35
XIV	BS46	+6.45	+7.62
XIV	BS48	-3.64	-6.40
XV	B120	+4.87	-6.45

The study of the fluid inclusions from the quartz suggests both the conditions and the course of the hydrothermal process:

a) The coexistence of the L and V type inclusions as well as the Th corresponding values suggest that boiling was the main process undergone by the hydrothermal fluid.

b) The fluid type-depth relationship makes possible the separation of two domains:

- at the lower part (beneath horizon XIII) the S type fluid inclusions and a not too high homogenisation temperature (Th) prevail;

- at the upper part (between horizons XIII and X), the coexistence of the L and V type inclusions indicates the maximal boiling zone (important decompression determined by the opening of the fissure; obvious mixture with meteoric water).

c) The quartz crystals are zoned. The relationship between the crystal zonality and the type of the fluid inclusions shows the existence of:

- a central zone (I) in which the L+V type inclusions prevail;

- external zone (II) in which the S type inclusions prevail.

In this case the decrease of the homogenisation temperature (Th) from (I) to (II) indicates a monoascendent hydrothermal process, the parageneses deposited being a result of the physico-chemical variations undergone by fluids, mainly due to the boiling.

In accordance with the distribution mode of the fluid inclusions and of the metallic mineral parageneses (the presence of wolframite and sheelite), the boiling paroxysmal moments superpose on the zone between horizons X and XIII.

d) The Tmi/Th diagram (Figure 14) suggests that in the case of the Main Vein the fluid evolved towards a continual unmixing, from initial fluids (probably of magmatic origin) poor in vapours, with low salinity and high temperature, to fluid phases of high salinity (liquid part) and water vapours which leave the system concomitantly with the temperature decrease.

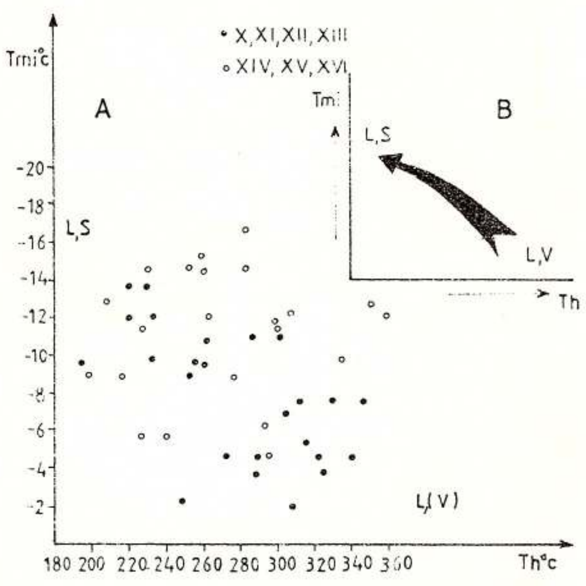

Fig. 14 - The Tm^0C/Th^0C diagram for the fluid inclusions in quartz from Baia Sprie.
X - XVI, mining levels where investigation was possible.

It follows that the fluid inclusions at Baia Sprie represent heterogeneous aqueous fluid of relatively low salinity that evolved within a generally monoascendent process, whose physico-chemical variations determined the formation of the main parageneses.

The comparison between the results of the morphologic study of pyrite and those of the study of the fluid inclusions in quartz reveals the superposition of the morphological trends on the domains of the fluid inclusions as follows:

- upper domain: the L+V type inclusions correspond to the C-P trend and to the SL-TH concentration-temperature domain;

- lower domain: the S type inclusions correspond to the C-O-P±{hkl} trend and to SH-TL domain as well as to the appearance of the negative striated pyritohedron which would underline the subsequent Cu deposition (Endo, Sunagawa, 1973).

All these suggest that the deposition of the metallic charge took place descending from the upper part towards the lower part of the vein (Figure 13). Also, the present geometry of the mineralization in the straight plane of the Main Vein, with its inflexions and eastern sinking permits the outlining of a model of the hydrothermal process with a great approximation degree, based on the following trends of the fluids, the boiling process and the metal deposition (Figure 13). This model indicates that:

a) The fluids evolved along the fracture, from the lower eastern part of the structure towards its upper, western part in the Minei Hill.

b) The opening of the fracture led to an important decompression of the fluids resulting in the starting of the boiling process and sulphide precipitation.

c) The deposition of the metals took place descending beginning with Pb and Zn at the upper part and ending with Cu at the lower part of the hydrothermal „pipe". The mixture of the meteoric water in this process seems evident, especially in the „discharge" zone of this „pipe" in the Minei Hill, a zone characterised by the gold precipitation.

Abbreviation: C-cube, O-octahedron, P-pentagonal dodecahedron, L-liquid, V-vapour, S-solid, Th-homogenisation temperature, Tmi-melting ice temperature.

SECOND DAY

THE TURŢ-GHEZURI (VIEZURI) ORE-DEPOSIT

The Oaş district is located in the north-western part of the Neogene metal sub-province of the Eastern Carpathians. This metallogenic unit includes predominantly base-metal ore deposits such as the Ghezuri, Socia, Penigher. The most representative is the Ghezuri (Viezuri)-Turţ ore deposit.

The Viezuri vein mineralization is concentrated on the western part of a subvolcanic porphyry microdiorite body crossing Pannonian and Sarmatian sedimentary rocks. The upper part of the ore body, down to the depth of 250 - 300 m is named Mihai vein. This vein is situated along the contact between the subvolcanic porphyry microdiorite body and the hypersthene bearing andesites, between which a Pannonian sedimentary wedge is enclosed. The main vein is accompanied by several branches. The Mihai vein is hosted by the sedimentary rocks on the western slope of the subvolcanic body, and the veinlets are partly hosted by the Pannonian deposits and partly by the adjacent hypersthene andesites (Fig. 15).

In the depth, the mineralization beneath the Mihai Vein occurs as vein beams located nearly entirely in the subvolcanic body close to their western contact with the Pannonian sedimentary rocks. The vein system was intercepted by mine workings between level -150 (+170 m) and - 300 (+20m), and by drillholes down to the absolute elevation of -800m. The range between -50(+270m) and surface, along Mihai vein (approx. 300m) was mined before 1900 for gold, leaving a based metal mineralization layer of 800 - 100 cm in the footwall of the vein.

A gap of 50 m within the mineralization, being made up of several quasi-parallel veins forming a vein beam system exists below -100 level. The thickness of the vein beam at level -150, located mostly in the sedimentary rocks, ranges between 4 and 6 metres.

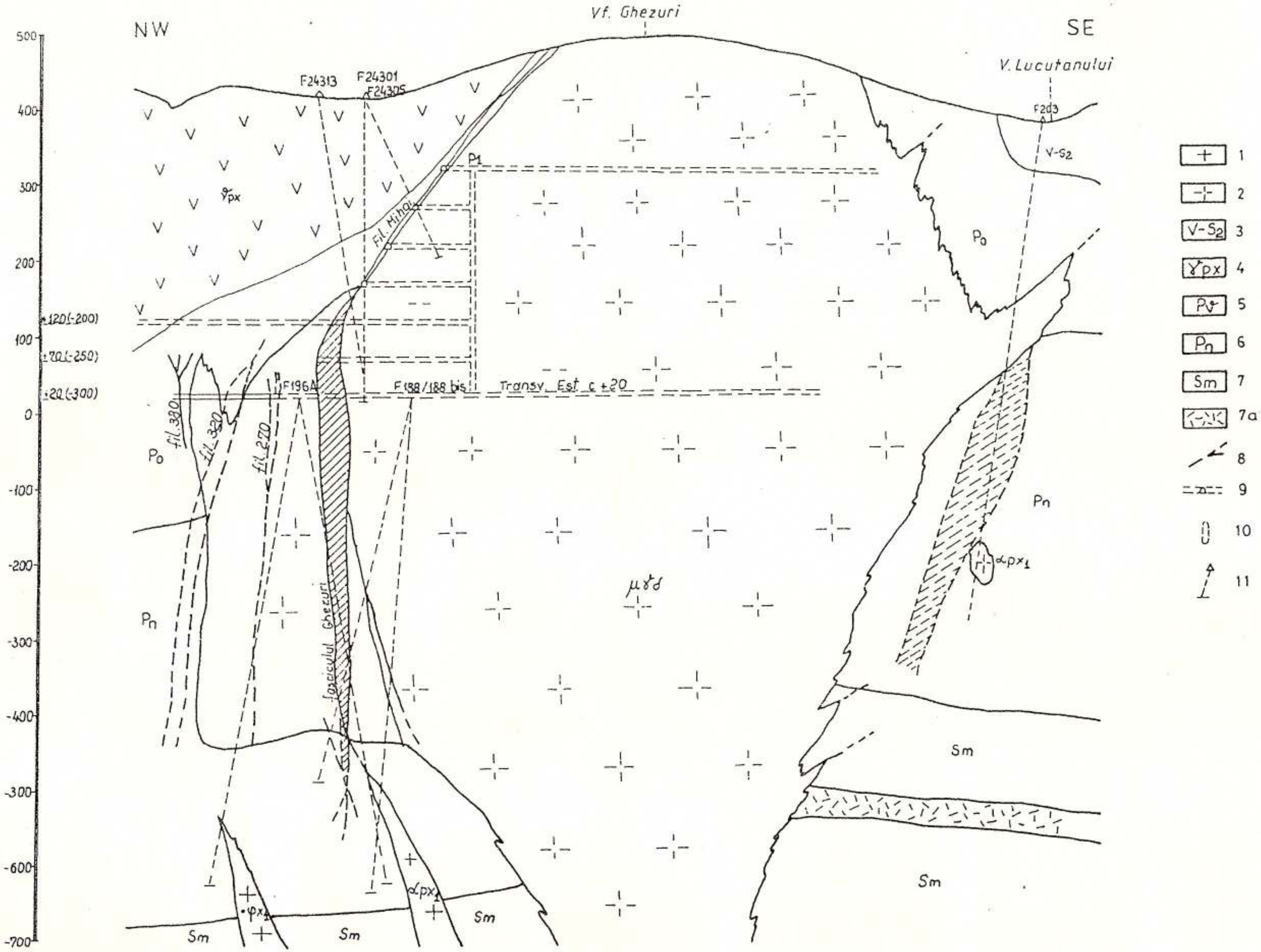

Fig. 15 - Cross section through Turţ ore deposit.

1. porphyry microdiorite; 2. porphyry microgranodiorite; 3. volcano-sedimentary formation; 4. pyroxene hyalodacites; 5. Pontian (clays, sands, marls); 6. Pannonian (marls, sandstones, clays); 7. Sarmatian (marls, sandstones, tuffs); a, pyroclastics; 8. Veins; 9. Gallery; 10, shaft; 11, drillings.

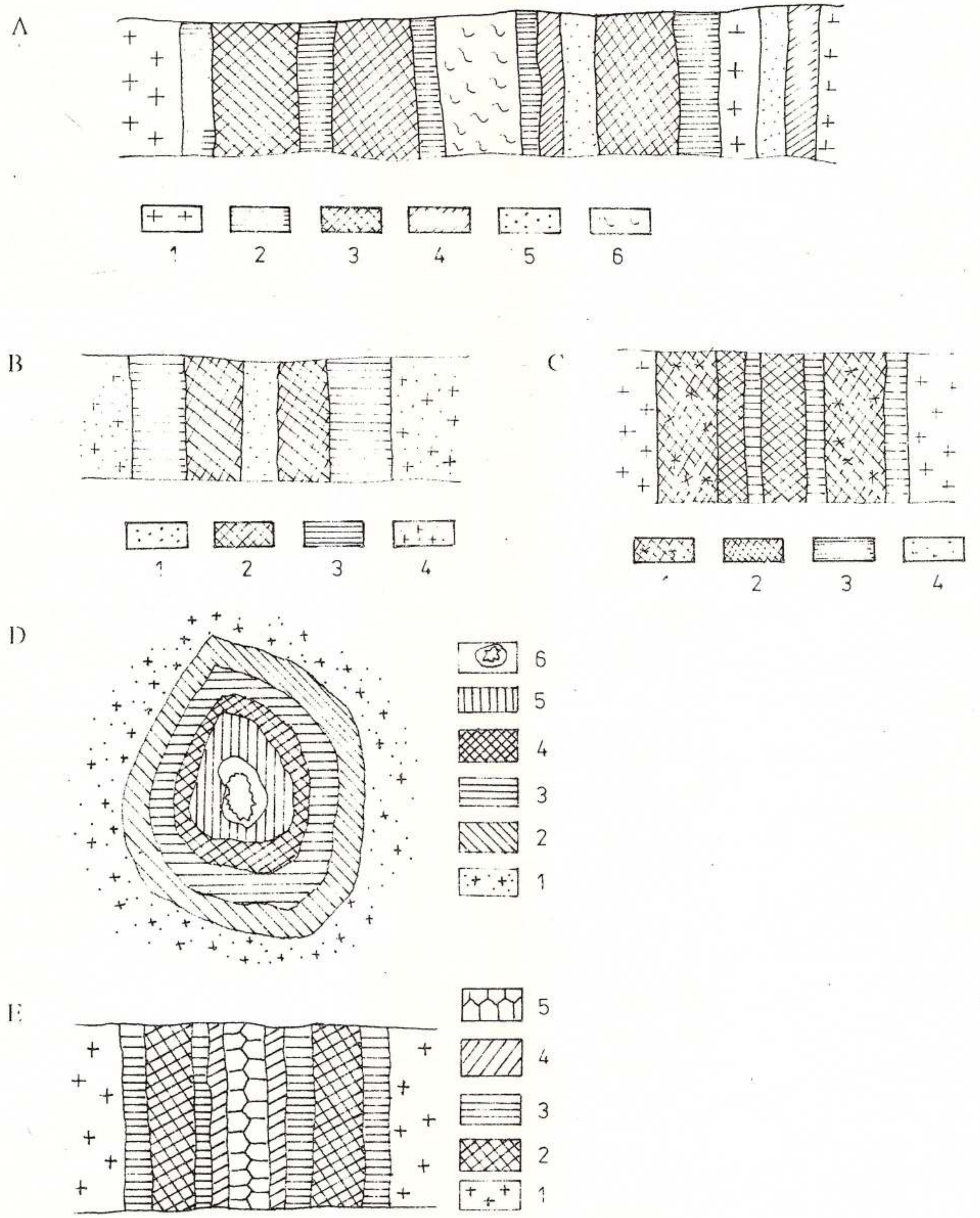

Fig. 16 - Ore structures at Turț.

A. 1, altered volcanics; 2, pyrite ± sphalerite; 3, galena; 4, shpalerite + galena + chalcopyrite + carbonates; 5, sphalerite + chalcopyrite + carbonate; 7, hornfels.

B. 1, siderite; 2, galena; 3, pyrite + chalocpyrite + quartz, 4, altered microgranodiorite.

C. 1, pyrite + chalcopyrite + galena; 2, galena; 3, pyrite; 4, altered microgranodiorite.

D. Geode 40 cm in diametre; 1, altered volcanics; 2, sphalerite; 3, pyrite + sphalerite + galena; 4, ilvaite; 5, chalcopyrite + quartz; 6, barite.

E. 1, altered volcanics; 2, galena; 3, pyrite; 4, ilvaite; 5, quartz.

Between the level -150(170 m) and -200 (+120) the Viezuri vein system crosses the western apical part of the subvolcanic body. The mineralization includes two marginal veins, between which small veins and veinlets developed, having the same composition. The Eastern vein could be related, as position, to the Mihai vein, located on the upper part. On level -250 the subvolcanic body and the vein beam system extend towards south, having an overall length of 450 m. The vein zone includes five main veins of 1 meter width; along their strike several vein branches have been detected. The area between the main veins includes centimetre sized veins and several millimetre sized veinlets; the porphyry microgranodiorite is highly adularized, sericitised, silicified and impregnated with pyrite and some sphalerite. On level -300, the main veins are not clearly confined, the faults being more dispersed, frequently pinching out. Two further vein areas were intercepted 90 meters and 160 meters west to the previous ones on level -300. The vein beam extends southwards on the strike, at level -300.

On the Eastern part of the intrusive body, on level -300, a mineralised area was intercepted, showing the same features as those of the western vein beams hosted by sedimentary rocks. The mineralized area has a width of about 40 meters.

Near the contact with the sedimentary rocks the vein system includes extended ore mineral enrichment areas (especially galena). These enrichment areas resulted from the abundant mineral deposition from solutions caused by the screening of the circulation paths by sedimentary rocks and also due to the veins dip change.

The banded (Fig. 16) and breccious textures prevail on the upper part of Mihai vein. The predominant textures in the vein beam hosted by the subvolcanic body are massive, banded, breccious; rarely voids occur also. The banded structure including bands of various composition, suggest the poliascending character of the mineralization. Colomorph textures combined with banded ores within the Mihai vein, might be the result of simultaneous nucleation and growth of sulphides in a silica gel (Jude, 1986).

The Viezuri vein system has a simple mineralogical composition, including pyrite, sphalerite, galena, quartz and carbonates. The sulphosalts, oxides and sulphates occur subordinately.

Minerals of the Turţ - Ghezuri ores (mainly according to Jude, 1980, 1986)

	Adularia	Monomineralic nests of 10 cm in the salband
1.	Alunite	Replaces plagioclase feldspar
2.	Arsenopyrite	Microscopic euhedral grains with pyrite and chalcopyrite
3.	Native gold	Microscopic inclusions in quartz, sphalerite, galena in Mihai vein, in ilvaite or pyrite
4.	Orpiment	Thin crusts along joints
5.	Barite	Lamellae in voids with marcasite
6.	Bornite	Accessory formed at the expense of chalcopyrite
7.	Bournonite	Microscopic, with sphalerite and quartz
8.	Chalcedony	In the upper part of Mihai vein
9.	Calcite	Massive and rhombohedrons bands up to 2 cm
10.	Chalcopyrite	Scalenohedral, pseudotetrahedral crystals of 1 - 5 mm, nests in compact galena
11.	Chalcocite	Formed on chalcopyrite
12.	Kaolinite	Nests and bands associated with galena, sphalerite, pyrite in the second mineralization stage
13.	Cerussite	Association of galena
14.	Cinnabar	With stibnite, marcasite, pyrite

15.	Chlorite	Associated with ilvaite and first generation pyrite
16.	Covellite	Secondary mineral on chalcopyrite
17.	Quartz	Compact bands and crystals of maximum 3 cm (1010, 1011)
18.	Cubanite	Lamellae in chalcopyrite, associated with pyrrhotite. Chemical analysis: Cu=23.8%, Fe=39.6%, Ag=0.33%, S=36.2%
19.	Dolomite	Rhombohedral crystals in geodes
20.	Fluorite	Formed after adularia in the salband
21.	Galena	Compact bands associated with pyrite, sphalerite, in geodes: cubic, cube-octahedral, octahedral, rhombohedral-dodecahedral crystals
22.	Goethite	Replaces sulphides
23.	Garnets	Grains less than 1 mm, associated with quartz and ilvaite.
24.	Halloysite	Associated with the second stage sulphides
25.	Hematite	In assemblage with ilvaite, pyrite, chalcopyrite
26.	Ilvaite	Mentioned for the first time in the hydrothermal ore deposits of Romania by Jude (1981)
27.	Jamesonite	Needle-shaped crystals in calcite, bordering galena
28.	Jarosite	On the upper part of Mihai vein
29.	Magnetite	Microscopically associated with ilvaite, garnets, pyrite, chalcopyrite
30.	Marcasite	Frequently on the upper part of Mihai vein. Fibrous, encrusting and film-like forms on siderite
31.	Montmorillonite	Associated with kaolinite
32.	Pyrite	Cubic euhedral, cubic-pentagonal, pentagonal, octahedral crystals. Compact mass associated with sphalerite and galena. Three generations identified.
33.	Pyrrhotite	Microscopic inclusions in sphalerite and chalcopyrite
34.	Realgar	Encrustings in geodes
35.	Rutile	Impregnations in rock fragments.
36.	Scheelite	With pyrite, in quartz veins, 1-2 mm thick
37.	Semseyite	Microscopic grains in galena
38.	Sphalerite	Compact masses associated with galena, pyrite. In geodes cubic, octahedral, dodecahedral, tetrahedral, cube-octahedral crystals 2.4-8.5% Fe
39.	Siderite	Compact bands of the third stage mineralization. Rhombohedral crystals
40.	Stibnite	Submillimetric crystals in quartz and calcite
41.	Tetrahedrite	Microscopic associated with chalcopyrite
42.	Wurtzite	Radial disposed prismatic crystals

There is an enrichment area down to level -250, where the galena content is higher than that of sphalerite. Beneath level - 250 the galena amount decreases, sphalerite prevails and a relative copper enrichment can be noticed.

The hydrothermal occurrence of ilvaite in the hydrothermal rocks of Romania is unique. At Turţ it forms centimetre sized bands along the contact between the veins and host rock or occurs as thin veinlets resulted during the first stage mineralization with pyrite, magnetite, chalcopyrite, cubanite, pyrrhotite. Ilvaite was formed at high temperatures of about 400^0C and at a total pressure of about 500 bars, under conditions of high CO_2 fugacity.

The ilvaite, pyrite, chalcopyrite, sphalerite, native gold assemblage is an interesting mineralogical assemblage; the native gold occurs as isometric grains of 0,056 - 0,044 mm. The gold deposited during the first mineralization stages; Jude (1986) observed native gold in microgranular quartz and pyrite in the upper part of the Mihai vein. This mineral was formed within a wide temperature range and on a large vertical extent.

The products of the Neogene metallogenesis from the Oaş district, the Viezuri one included, belong to the mineralizations formed in the subduction area of the inner Carpathian chain. The metal source was a calco-alkaline magma with high silica alkali and volatile content. The mineralization is hosted by felsic rocks such as those from Viezuri: dacites and porphyry microdiorites of subvolcanic character. The ore forming process in the Viezuri structure took place earlier than in other fields. The metallogenesis proceeded in successive stages, during a long time interval.

During the first ore forming stage the adularia was deposited in the vein salband, followed by magnetite, ilvaite, pyrite, sphalerite, hematite, scheelite, quartz and chalcopyrite with sphalerite exsolution, with chalcopyrite and pyrrhotite and cubanite inclusions. During the following ore forming stage, at a high sulphur fugacity and high temperature, the following ore minerals formed: pyrite, chalcopyrite, sphalerite, galena, quartz; sphalerite prevails over galena. The third stage mineralization contain greater amounts of galena in addition to pyrite, sphalerite, chalcopyrite, quartz, clay minerals. The final stage includes a low temperature assemblage made up of carbonates (siderite) together with pyrite, sphalerite, galena sulphosalts (tetrahedrite, bournonite, jamesonite), barite, marcasite, cinnabar. This generation formed under low sulphur fugacity conditions and high CO_2 activity.

Under hipergene conditions the following secondary minerals have formed: goethite, chalcocite, covellite, bornite.

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EXCURSION C

CLAY MINERALS AND ZEOLITE OCCURRENCES

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Introduction

The Baia Mare area is well known for the importance and the variety of the metaliferous ore deposits which contain interesting and rare mineral associations. This rarity is completed by some peculiar non-metallic deposits, ones of them constituting the objectives of our field-trip.

In this respect, Stejera kaolin deposit represent the most important primary kaolin generated by old weathering processes in Romania, the bentonite deposits of Valea Chioarului, Răzoare and Oraşu Nou show peculiar genetic features, and Bârsana zeolitites point out to a special way of volcanic ash alteration. A supplementary explanation must to be done as regards bentonite deposits. Bentonite, was first used as a rock term by Knight in 1898 for a highly colloidal, plastic clay with swelling and thixothropic properties, occurring in the Cretaceous beds of Fort Benton, Wyoming. These clays were originated in the alteration of volcanic ash in situ, as showed by Hewitt in 1917. The term was redefined by Ross and Shannon (1926) who limited it to clays formed by the alteration of volcanic ash in situ, composed essentially of smectite clay minerals and characterised generally by highly colloidal and plastic properties. Subsequently, the term was extended to any clay which is composed dominantly of a smectite clay mineral, and whose physical properties are controlled by this clay mineral (Wright, 1968), without reference to a particular mode of origin. The last definition was also accepted by Grim and Güven (1978) in their book on bentonites. The bentonite deposits which will be visited point out non-classical genetic patterns: parent rocks consisting of rhyodacites, aplites and perlites, transformed by hydrothermal and/or deuteric processes.

A general picture of the bentonite discussed is shown in Fig. 17.

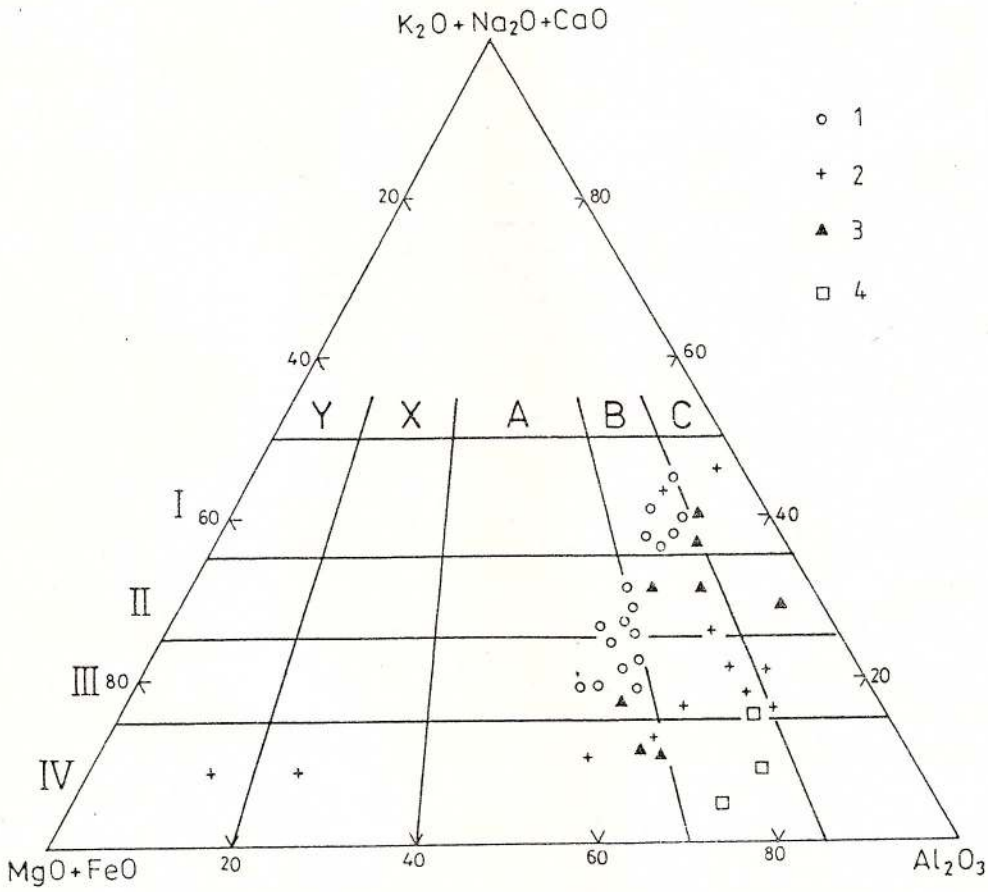

Fig. 17 - The bentonite diagram of England and Jorgensen.
1, bentonites from Valea Chioarului; 2, bentonites from Răzoare; 3, bentonites from Oraşu Nou; 4, bentonites from Racşa.

FIRST DAY

Route: Baia Mare - Şomcuta - Stejera - Valea Chioarului - Răzoare - Tg. Lăpuş - Mănăştur - Baia Mare.

1st Stop: Stejera kaolin deposit

Parent rocks: feldspathic gneisses
Origin: weathering
Characteristic minerals: kaolinite, smectite, illite, ± halloysite, chlorite, vermiculite, random I/S mixed layers.

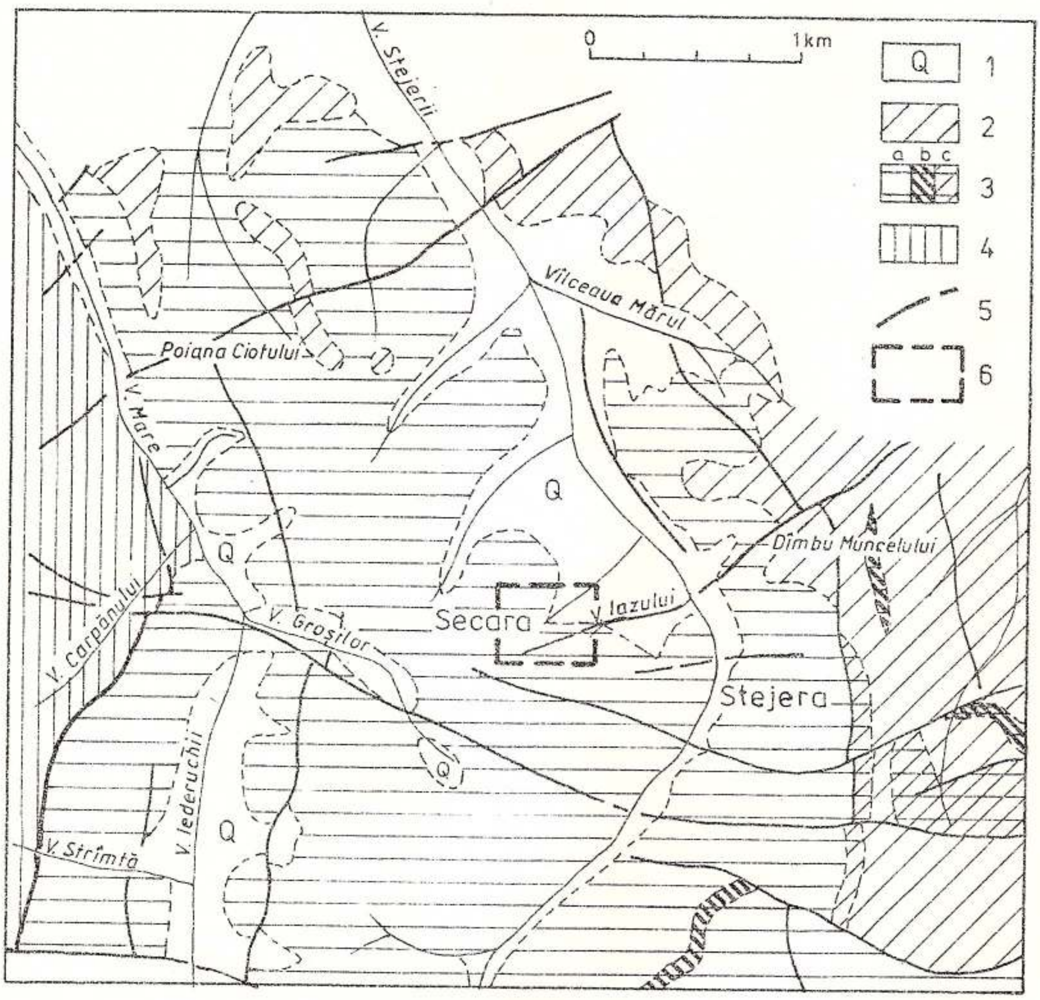

Fig. 18 - Geological sketch of the Stejera bentonite area.
1, Quaternary; 2, Miocene sedimentary deposits; 3, Paleogene sedimentary deposits; 4, Crystalline formations; 5, faults; 6, area to visit.

Geological setting

The Stejera kaolin deposits (Fig. 18) represent a weathering crust relic, formed on expense of crystalline schists of Someş series (Precambrian) made up by quartz-feldspathic and, subordinately, by micaceous rocks. In fact, the kaolin deposit consists of a weathered saprolitic horizon, covered by discontinuous beds and lenses of kaolinous sandstones and breccias, which underlies thin Lower Eocene continental deposits represented by gravels, sands and variegated clays (Jibou Formation). The kaolin deposits of Stejera show an irregular bed shape, 1.5-22m thick, dipping southwards (Kalmar et al., 1979).

Petrology and mineralogy

The parent rocks are represented by quartz-feldspathic gneisses, two mica paragneisses, quartzitic schists, micaceous quartzites, and micaschists, but only the feldspathic rocks and partially micaschists show important kaolinitisation phenomena. The incipient weathering results in kaolinite and subordinately illite developed on fine joints, cleavages and outlines of the feldspars (lower part of the weathering profile). Upwards the rock is intensively replaced especially as concerns feldspars and sometimes micas; the quartz appears corroded. However, the structure of the primary rocks can still be recognised (saprolite). The uppermost part of the profile consists of sedimentary rocks (sandstones, microbreccias, breccias) some 10m thick showing intensive argillization of matrix and of some rock fragments.

The most important clay mineral is the kaolinite (50-80%); the halloysite is also present. The smectites (Cheto dioctahedral montmorillonite) may locally be dominant (60%). Illite is common (5-25%) and sporadically occur chlorite, dioctahedral vermiculite and random illite/smectite mixed layers (Kalmar et al., 1979).

A typical lateritic weathering crust is developed with an upper, kaolinite dominated part and a lower part with prevailing smectites and illite. The non-clay minerals are more frequent in the coarser fractions (quartz, micas) and sporadically occur in the finer fractions (Fe oxides and hydroxides, calcite, dolomite, pyrite, garnet etc.).

The clay minerals were studied by XRD, IR, DTA and electron microscopy showing typical features and properties. The crystallinity degree of kaolinite is highly variable. The montmorillonite is represented by the Ca-variety, generally of low crystallinity.

The chemical composition of the Stejera kaolin varies as follows:

SiO_2	46.26-84.95 %	CaO	0.12-3.02%
TiO_2	tr.-1.14 %	Na_2O	0.21-4.20%
Al_2O_3	7.16-33.38 %	K_2O	0.42-6.64 %
Fe_2O_3	1.32-8.38 %	SO_3	tr.-0.19 %
MgO	0.14-3.37 %	L.O.I.	1.45-11.76 %

Some minor elements are also present in the kaolin: Ti = 280-3300 ppm; Mn = 30-800; Pb = 0-300; Ga = 0-230; Cu = 0-62; Sn = 0-130. The total reserve estimates are of ca 6 Mil. t.

Genesis

The Stejera kaolin is of residual nature with typical transitions from fresh rocks through a saprolite zone to completely argillized rocks. The kaolin formation implies intensive leaching of silica and alkalis at low pH values, typical of lateritic alteration (Kalmar, 1973; Angelescu, 1975; Pop, 1977).

2nd Stop: Valea Chioarului bentonites

Parent rocks: rhyodacites
Origin: hydrothermal alteration

Characteristic minerals: Na-montmorillonite, ± kaolinite, illite.

Geological setting

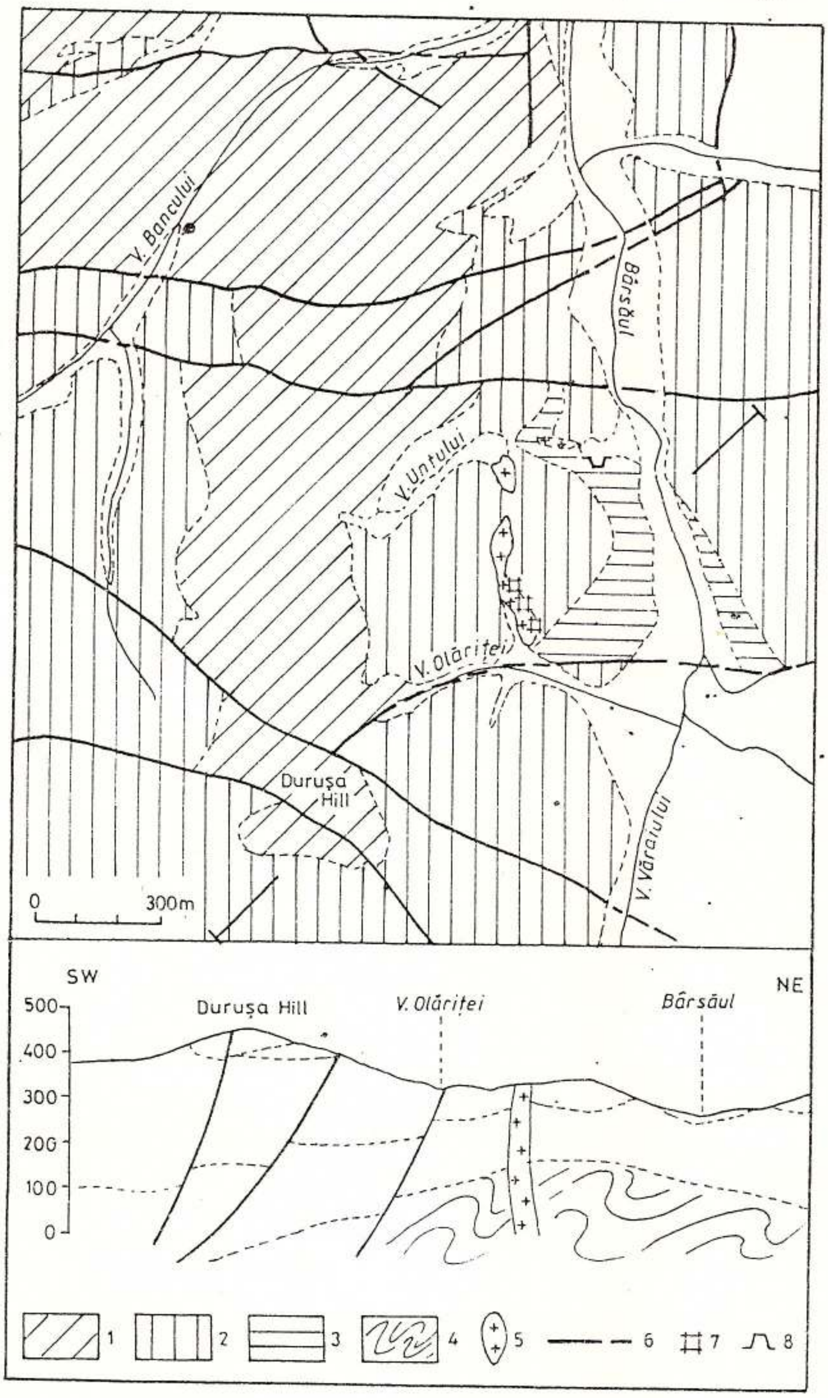

Fig. 19 - Geological sketch of the Valea Chioarului bentonite area (after Kalmar, 1975, simplified).
1, Badenian; 2, Paleogene; 3, Upper Cretaceou; 4, Crystalline schists; 5, Rhyolites; 6, Faults; 7, Shaft; 8, Galleries.

The bentonite deposit in Valea Chioarului is situated between the crystalline massifs of Preluca and Ţicău. The parent rock is represented by a rhyodacite dyke of probably Upper Cretaceous-Lower Paleogene age that cuts sedimentary rocks Senonian to Lower Paleogene in age. The Senonian rocks consist of grey marly sands with sandstone intercalations. The near-dyke Paleogene rocks are represented by so-called Jibou Strata, i.e. Lower variegated clays consisting of polygenous gravels with metamorphic rock fragments (quartzites, feldspatic gneisses etc) weakly cemented by a variegated clay matrix.

The rhyodacite dyke has a known length of about 400m (significantly reduced in the depth) and variable thickness of 16-60m. The strike is NNE-SSW and the dip towards SW (Fig. 19)

Petrology and mineralogy

The fresh rhyodacite has a grey-whitish colour and a porphiritic texture and a massive and/or fluidal structure. Phenocrysts of albite-oligoclase, sometimes zoned and twinned, of sanidine, of corroded quartz and of biotite occur in a glassy matrix (Kalmar, 1975). The dyke has a fresh nucleus enveloped by intensely altered zones.

The bentonite is usually greasy and has a grey or grey-greenish colour, locally also being whitish, yellowish or red-pinkish, especially at the boundaries with the Paleogene sedimentary rocks. Relics of primary rhyolite structures are often present, especially as concerns the phenocrysts. The glassy matrix is sometimes slightly crystallized (Ştefan et al., 1981).

The fraction less than 2 μm is mineralogical homogenous and consists practically only of montmorillonite, with sporadically occurring illite and/or kaolinite. The most frequent non-clay minerals are the zeolites (Rădan et al., 1982).

Both Na-montmorillonite and the Ca-montmorillonite are present. Thermic behaviour is intermediate between Cheto and Wyoming types. The DTA curves suggest also the presence of both montmorillonite varieties. Electron microscope images show wavy montmorillonite lamellae, sometimes with a fan-like form.

Chemical analyses of bentonites and rhyodacite are shown in the table below, from which a significant leaching of SiO_2, K_2O and Na_2O and a relative enrichment in Al_2O_3 and MgO can be seen. Among the minor elements only B (30-200 ppm), Ba (550-950 ppm), Zr (180-270 ppm) and Sr (300-515 ppm) show significant values. The reserve estimates are of about 2.5 Mil. tons.

The chemical variations are as follows:

SiO_2	54-74	76
Al_2O_3	13.3-17.2	11.8
Fe_2O_3	0.95-2.31	1.05
MgO	1.66-2.40	0.9
Na_2O	2.12-3.34	3.79
K_2O	0.82-1.25	1.55
H_2O^+	3.65-5.27	4.26

Genesis

The bentonite is of hydrothermal origin (Mârza and Ghergari, 1963; Kalmar, 1975). The excess of silica at the hanging wall of the deposit suggest per ascensum movement of solutions with an alkaline character. This favoured the formation of smectites. The kaolinite is accidentally occurring as a result of supergene alteration.

3rd Stop: Răzoare bentonites

Parent rocks: plagiaplites and pegmatites

Origin: hydrothermal alteration

Characteristic minerals: Ca-montmorillonite ± illite, kaolinite, chlorite, sepiolite, vermiculite

Geological setting

The bentonite deposit is located on the southern slope of the Preluca crystalline massif (Fig. 20). The metamorphic rocks consist of paragneisses and biotite-rich micaschists, quartzites, marbles and amphibolites. Lenses and veins of pegmatites and plagiaplites develop especially within paragneisses. On such rocks form the bentonites from Răzoare, showing irregular development of clay minerals.

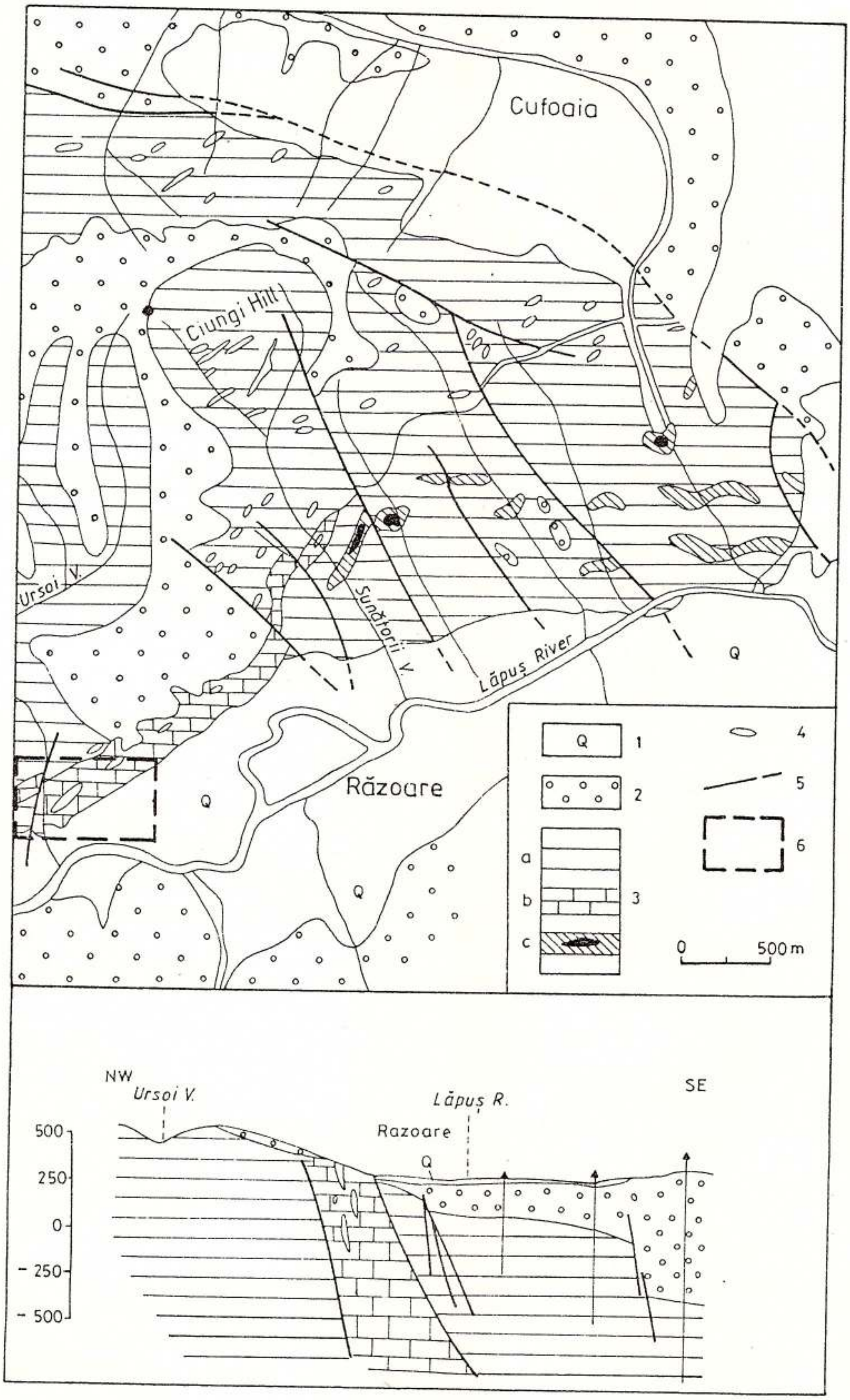

Fig. 20 - Simplified geological map of the Răzoare area (Kalmar, 1973)
1, Quaternary; 2, Sedimentary deposits; 3, Metamorphic rocks: a, micaschists, gneisses, amphibolites; b, marbles; c, black quartzites with Mn-Fe ores; 4. pegmatites; 5, Faults; 6, Area to visit.

Petrology and mineralogy

The plagiaplites parent rocks contain 80-95% plagioclases (20-35% An), 0-15% quartz and minor amounts of tourmaline, muscovite, apatite, biotite (Giuşcă and Anton, 1968). The pegmatites are composed of large muscovite lamellae, quartz and feldspars. The alteration proceeds gradually, the clay minerals entirely replacing the aplite veinlets.

The Răzoare bentonite is white, greenish of pink, sometimes resembling a soapstone. At the boundaries rims consisting of chlorite, actinolite, tremolite and diopside can be observed (Mârza et al., 1966). Vermiculite and chlorite-vermiculite mixed layers were also mentioned (Brana et al., 1986).

No differences were recorded as concerns the clay minerals formed on plagiaplites or pegmatites. The dominant mineral is Ca-montmorillonite, intermediate between Cheto and Wyoming, well crystallized, with which small amounts of illite, kaolinite and chlorite associate. Rarely there occurs also sepiolite as well as relic non-clay minerals (Rădan et al., 1982).

The chemical variations of the Răzoare bentonites are given in the table below (acc. to Grigorescu and Butucescu, 1971):

SiO_2	49-52 %	CaO	2.8-5%
TiO_2	0.12-0.14 %	Na_2O	0.5-1.5%
Al_2O_3	23-25 %	K_2O	0.3-1.0 %
Fe_2O_3	0.19-0.27 %	MnO	0.08-0.20 %
MgO	3-3.4 %	L.O.I.	10-17 %

The minor element contents are generally low, even of Ba (10-112 ppm), Sr (45-115 ppm) and B (10-200 ppm).

The reserves were estimated at about 550,000 tons.

Genesis

The bentonites are of hydrothermal origin but the parent rocks are somewhat uncommon. The genetic process is still unclear, some authors favouring the hypothesis of two phases of transformation: (1) a contact metasomatic effect of pegmatites on marbles and (2) a low temperature circulation of alkaline solutions giving rise to argillization (Mârza et al., 1966; Giuşcă and Anton, 1968).

SECOND DAY

Route: Baia Mare - Seini - Oraşu Nou - Negreşti - Săpânţa - Sighet - Bârsana - Ocna Sugatag - Baia Sprie - Baia Mare.

4th Stop: Oraşu Nou bentonites

Parent rocks: perlite

Origin: deuteric and/or hydrothermal alteration

Characteristic minerals: Ca-montmorillonite, ±illite, kaolinite, halloysite, chlorite, cristobalite

Geological setting

The Oraşu Nou bentonite deposits are situated in the SW corner of the Oaş basin and have formed on acidic volcanic rocks of Badenian age (1^{st} phase of eruption in the area; age about 11 Ma). Covering Sarmatian sedimentary rocks the acidic volcanism generated either perlites (or perlitic glassy rocks) or rhyolites and associated pyroclastics as a function of their position to the shoreline of the Pannonian lake.

The perlites form a quasi uniform level covered by rhyolites and pyroclastics some 40-50m thick (Fig. 21). The bentonites occur as lenses, 0.5-30m thick and an elongated form (100-400m x 50-250m).

Petrology and mineralogy

The parent rocks exhibit spheroidal separations, the spheroidal aggregates being 1-3mm in diameter, reaching exceptionally 5cm. Their colour is black and grey-yellow. The rocks consist of a prevailing glassy fluidal matrix with 30-35% small elongated crystals (longulites) in which skeletal feldspars phenocrysts can be observed. The plagioclase feldspars exhibit varying composition from 22-25% An (oligoclase) to 65% An (labradorite). The matrix contains also fragments of pyroxene andesites and of muscovite-bearing quartz rich sandstones (Bârlea, 1969).

The bentonites have variable colours, from yellow-white to greenish of pinkish. They are greasy rocks.

The main mineral is the Ca-montmorillonite. Sporadically occur also illite and kaolinite, the last one probably of supergene origin. Non-clay minerals such as cristobalite and zeolites are also present. The DTA study suggest montmorillonite be of Wyoming type.

The composition of bentonites is shown in the table below (acc. to Grigorescu and Butucescu, 1971):

SiO_2	55-73 %	CaO	1.1-2.0%
Al_2O_3	14.5-22.6 %	Na_2O	2.16-3.10%
Fe_2O_3	0.24-2.50 %	K_2O	+
MgO	0.35-1.80 %	L.O.I.	0.7-12.4 %

The minor element contents are low. Only Ba (77-190 ppm) and Zr (135-210 ppm) show significant values.

The reserve estimates are of about 6 Mil. tons.

Genesis

The bentonitization of Oraşu Nou perlites has been generally connected with circulation of solutions which allowed also the lava cooling, to which some hydrothermal solutions added. According to Rădan et al. (1982) the Oraşu Nou bentonite deposit may be assigned to the deuteric alteration type (Grim and Güven, 1978), described as acting in the Karoo System, South Africa and Milos Island, Greece. The most significant difference between perlites and rhyolites consists of their water content, i.e. 2-4% in perlites and 0.1-0.6% in rhyolites. The perlites underwent prevailingly a montmorillonite alteration whereas in rhyolites kaolinite ± illite preferentially form.

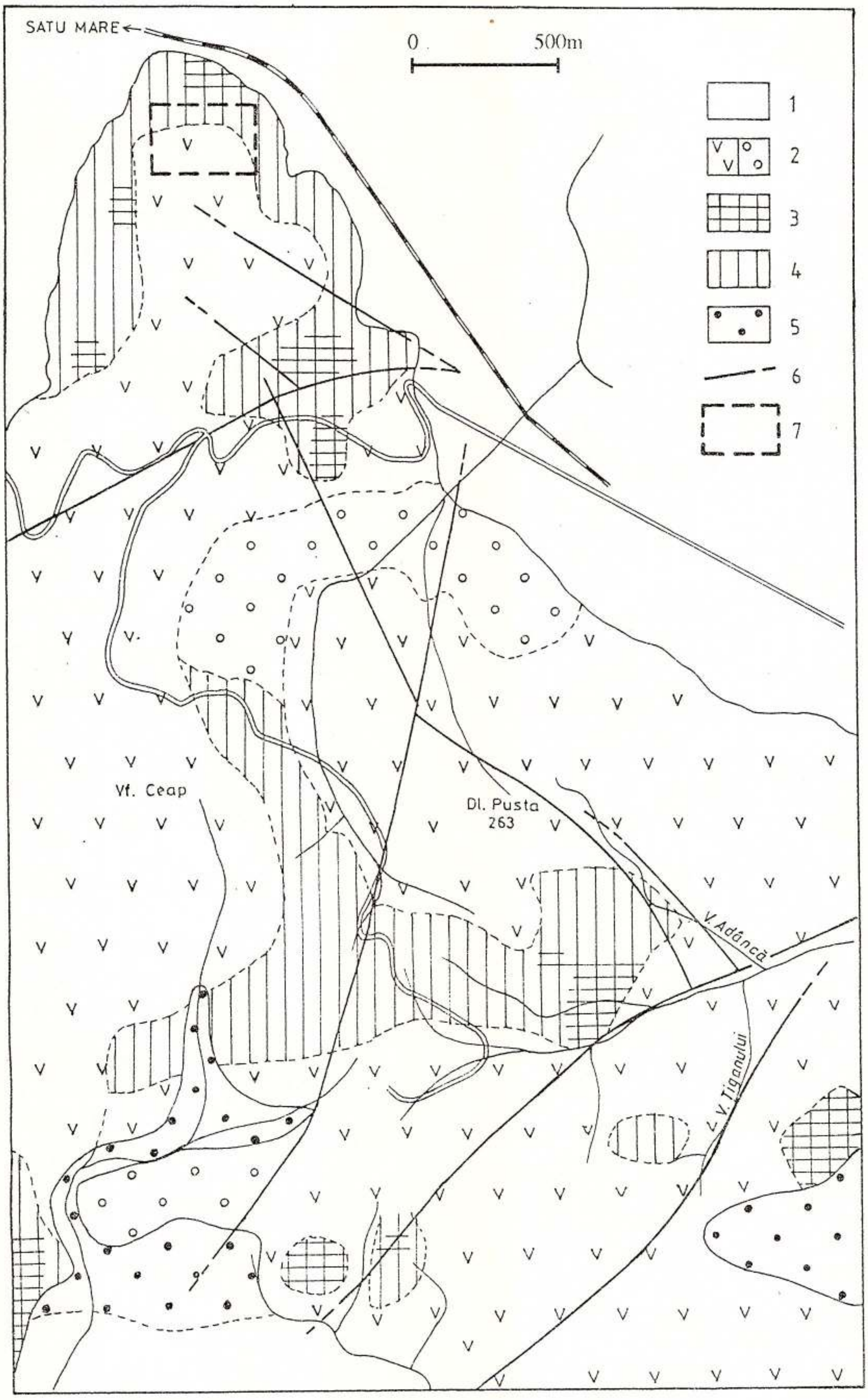

Fig. 21 - Geological sketch of the Oraşul Nou area.
1, Quaternary; 2, Rhyolites, pyroclastics; 3, Perlites; 4, Bentonites; 5, Sarmatian sedimentary rocks; 6, Fault; 7, Area to visit.

5th Stop: Bârsana zeolite bearing tuffs

Geological setting

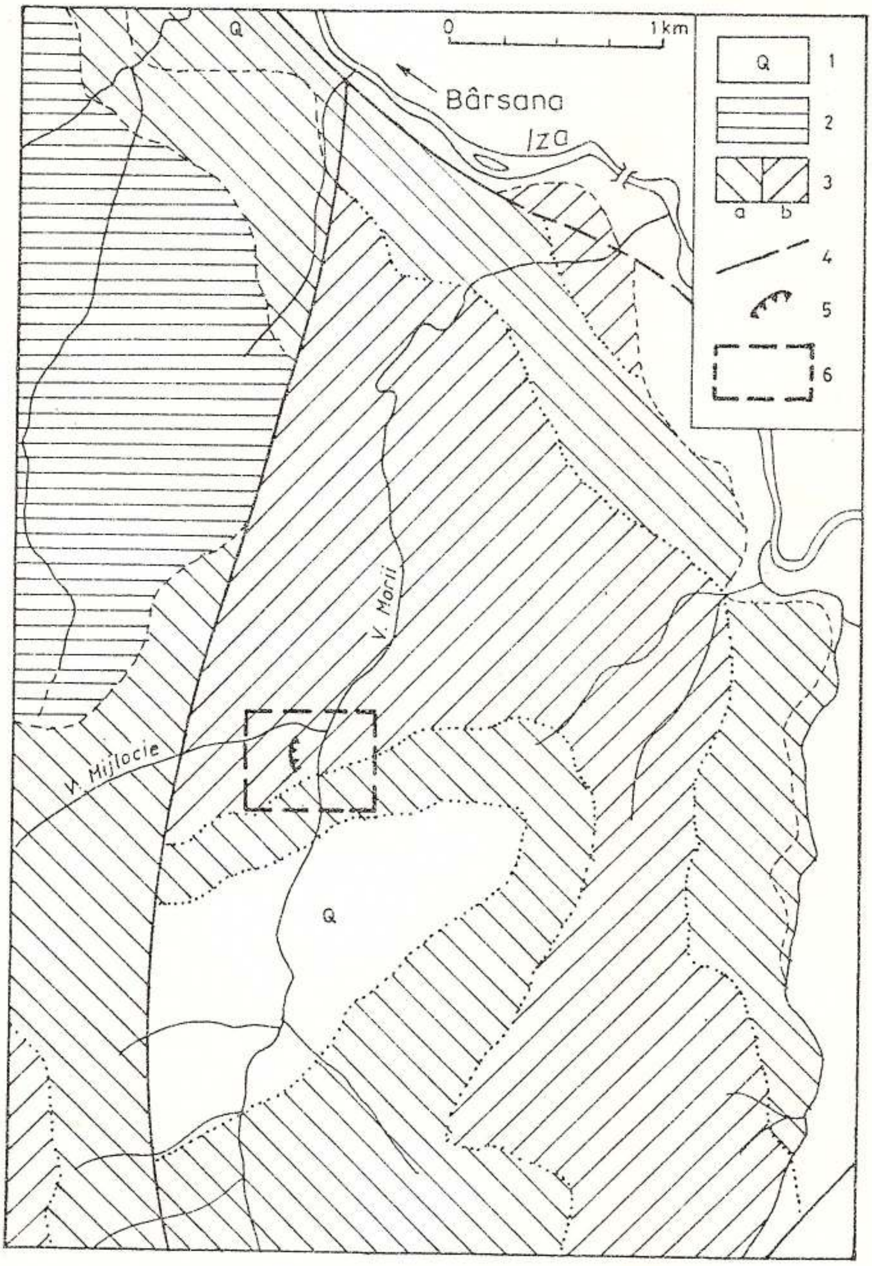

Fig. 22 - Geological sketch of the Bârsana area with zeolite tuffs.
1, Quaternary; 2, Sarmatian; 3, Badenian: a, marls, sandstones, rock salt: gypsum breccias; b, dacitic tuffs; 4, Faults; 5, Quarry in zeolite tuffs; 6, Area to visit.

The Bârsana zeolite deposits are situated on the eastern border of the Maramureş Basin. The host rocks are the Badenian sedimentary rocks transgresively overlaying the Paleogen Flysch of the Eastern Carpathians. The Badenian rock sequence some 1000-1200m thick starts with dacitic tuffs representing the parent rocks of the zeolite deposits (5-15m) covered by Globigerina marls (4m); there follow marly sediments, gypsiferous sandstones and salt deposits, the "Radiolaria shale" and Spirialis marls. The zeolite-bearing tuffs may be observed in two quarries in the vicinity of the Bârsana village (Fig. 22).

Mineralogy and petrology

The main component of the zeolite bearing tuffs is the volcanic glass, i.e., vitroclasts and matrix (90%) to which crystaloclasts (plagioclase, K-feldspar, quartz, micas) add (10%). Sporadically there occur also lithoclasts (quartzite, andesite). The glass is largely devitrified and transformed in zeolites, rarely associated with smectites, celadonite and illite. The dominant zeolite mineral is clinoptilolite. Heulandite and mordenite are present too.

The chemical composition of the zeolitic tuffs shows following variations (Barbat and Marton, 1989):

SiO_2	66.80-69.47 %	CaO	2.59-4.27%
TiO_2	0.31-0.39 %	Na_2O	1.05-2.75%
Al_2O_3	11.20-11.60 %	K_2O	1.75-2.7 %
Fe_2O_3	1.37-2.0 %	L.O.I.	5.82-14.17 %
MgO	0.77-1.65 %		

Minor element contents: As = 80-300 ppm, Mn = 3-200 ppm, Mo = 3-10 ppm, V = 10-15 ppm.

Other properties: apparent specific gravity: 1.98g/cm^3, specific surface: 15.85 m^2/g (12.3-20.4), reactive silica: 9.34 % (5.0-18.43), ionic exchange capacity: 141 mcg/100.

Genesis

The zeolites generate by devitrification and recrystallization of volcanic grass derived from volcanic ash fallen in marine waters (halmirolisis). Diagenetic changes may also have occurred.

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EXCURSION B

THE STRATIFORM PYRITE AND BASE METAL ORE DEPOSITS HOSTED WITHIN THE TULGHEŞ SERIES IN THE BAIA BORŞA AREA, MARAMUREŞ MOUNTAINS

Leaders: **RADU D.**, CUARŢ S.A., RO-4800 Baia Mare, Romania,
COOK N.J., Mineralogical Institute, University of Würzburg, D-97074 Wurzburg, Germany.

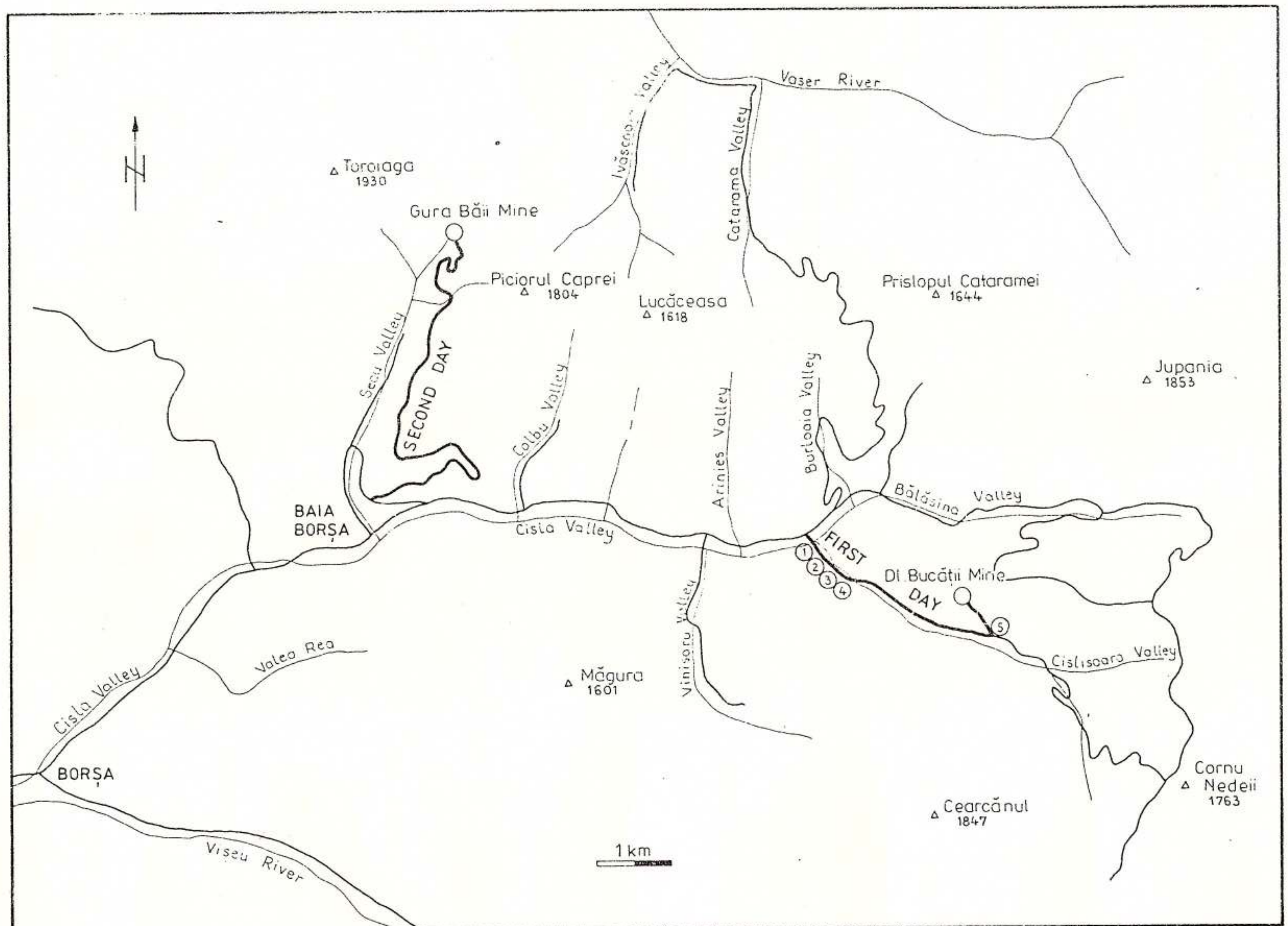


Fig. 23 - Routes of the Excursion B.

Regional setting

The Cu-Zn-Pb-Ag-(Au) massive sulphide ore deposits from the Maramureş Mts., which occur between the Vaser River to the North and the Cisla Valley to the South, represent economically important sulphide ore deposits hosted by metamorphic schists of the Tulgheş Series.

Geotectonically, the Tulgheş Series from the Maramureş Mts. constitutes a part of the Carpathian Orogen that extends along more than one third of the territory of Romania. The Carpathian Orogen includes the Dacides, which are Cretaceous tectogenetic units. In this area, the Central Dacides are developed, and they form the backbone of the Carpathian sygmoid, clearly following the double curve of this orogenic system. The Central Dacides are represented by a group of basement nappes resulting from shearing (Săndulescu, 1984). The Eastern Carpathians include the group of Central-East Carpathians nappes. These are, in descending tectonostratigraphic order the Bucovinian Nappe, the Sub-Bucovinian Nappe and the Infra-Bucovinian Nappe. The Tulgheş Series with massive sulphide ore deposits from Maramureş Mts. occurs within the Bucovinian Nappe.

The geological setting of the area is that of a basement of crystalline schists (Tulgheş Series) overlain by the sedimentary units of Upper Cretaceous, Eocene and Oligocene, age which represent post-tectonic cover rocks. Subsequently, this complex of crystalline and sedimentary rocks was penetrated by Neogene intrusions (Fig. 24).

Since the objective of this field trip is the presentation of crystalline schists and their relationships with the magmatic intrusions, the presentation of the sedimentary rocks has been omitted.

The Tulgheş Series

The Tulgheş Series extends along the entire length of the Eastern Carpathian metamorphic belt (200 km) and also north-westwards into the Northern Carpathians, where it is known as the Gelnica Series. The Tulgheş Series bears a remarkably constant lithology, including the following units (after Kräutner, 1980, 1988):

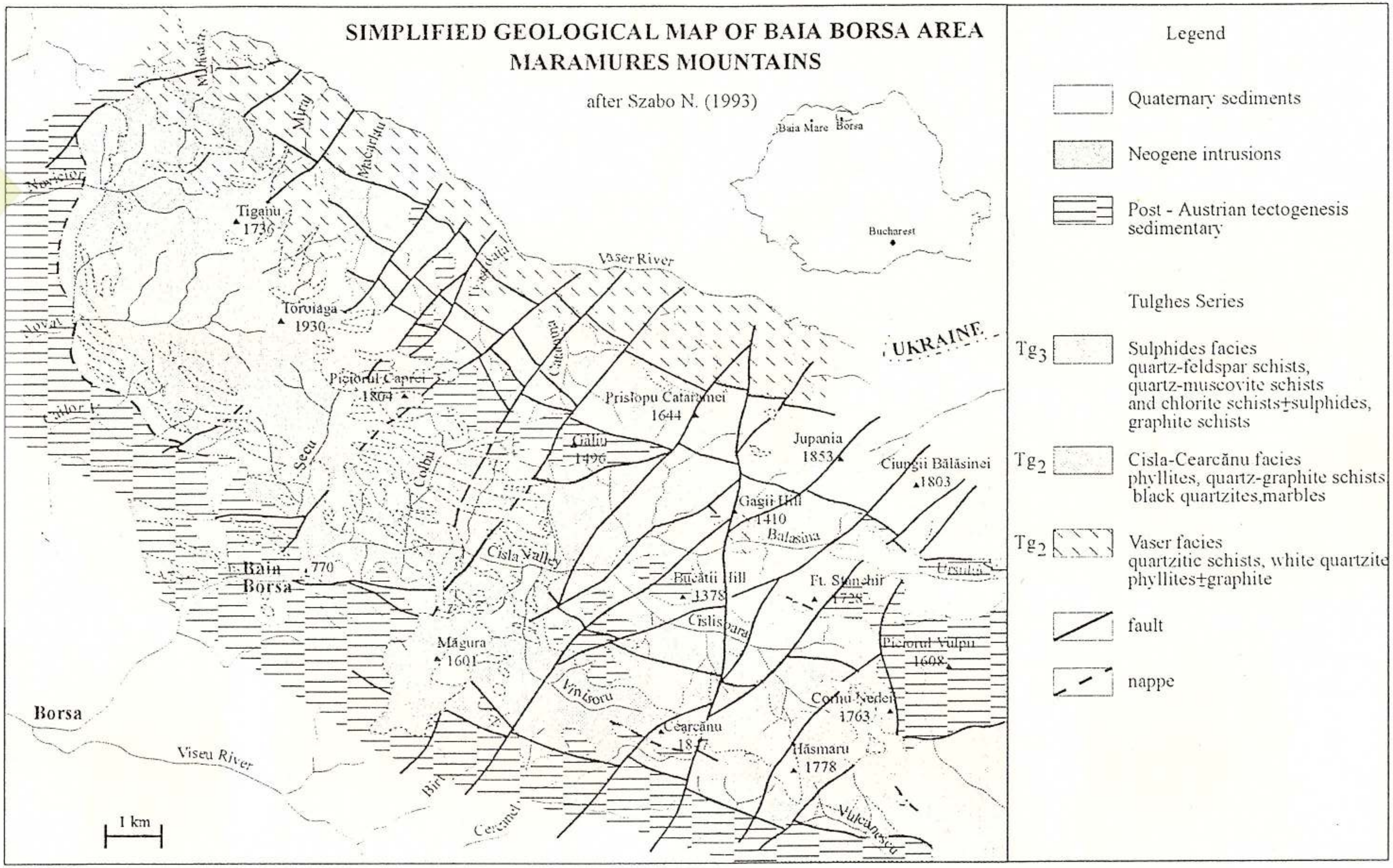
Tg 1. The Lower blastodetrital quartzitic Formation (500m). The lower part of the Bucovinic sequences includes quartz-muscovite schists with interlayered feldspar bearing quartzites.

Tg 2. The Graphite-bearing formation with metalidites (300-600m). It is represented by an alternation of sericite-graphite schists, metalidites, quartz-sericite schists, metagreywackes and limestones. The metaliditic rocks in the Mestecăniş Nappe are associated with syngenetic manganese ores.

Tg 3. The rhyolitic volcano-sedimentary Formation forms the thickest part of the series (1200-2450m). Alkaline rhyolitic metatuffs and metatuffites, corresponding to five eruption stages are associated with rhyolitic metaepiclastic rocks. Between them, detritic members including chlorite-sericite schists, sericite quartzites, graphite-sericite schists and chlorite-sericite schists with albite porphyroblasts are interbedded. In the lower part, a sequence of basic metavolcanites (the Isipoaia metabasites) is found. The base metal sulphide deposits are related to volcanic stages 1, 2 and 5.

Tg 4. The blastodetrital quartzite-phyllitic Formation (1500-2500m). After cessation of magmatic activity, sedimentation of rhyolitic and dacitic units from volcanic structures took place. An alternating sequence of acid metaepiclastites, phyllitic rocks and quartzites was deposited. The middle part of the column is made up of metapelitic rocks (phyllites). Quartzites and metagreywacke occur in the upper part of the sequence.

Fig. 24



SIMPLIFIED GEOLOGICAL MAP OF BAIA BORSA AREA
MARAMURES MOUNTAINS
after Szabo N. (1993)
Baia Mare
Borsa
Bucharest
UKRAINE
Vaser River
Viseu River
Borsa
Baia Borsa
770
Tiganu 1736
Toroiaga 1930
Piciorul Caprei 1804
Prislopu Cataramei 1644
Galiu 1496
Jupania 1853
Ciungii Bălăsinei 1803
Gagii Hill 1410
Balasina
Cisla Valley
Bucătii Hill 1378
Ft. Stanchir 1728
Cislispara
Piciorul Vulpii 1608
Corhu Nedei 1763
Măgura 1601
Vintsoru
Cearcănu 1847
Hăsmaru 1778
Vulcanescu
Secu
Colbu
Catarama
Myraj
Macarlau
Birt
Ceremel
Ursului
1 km
Legend
Quaternary sediments
Neogene intrusions
Post - Austrian tectogenesis sedimentary
Tulghes Series
Tg3 Sulphides facies quartz-feldspar schists, quartz-muscovite schists and chlorite schists±sulphides, graphite schists
Tg2 Cisla-Cearcănu facies phyllites, quartz-graphite schists, black quartzites,marbles
Tg2 Vaser facies quartzitic schists, white quartzite phyllites±graphite
fault
nappe

Tg 5. The Upper blastodetritic formation with graphitic rocks and basic metavolcanites and limestones (600m). The upper part of the known sequence includes an alternation of graphitic schists and graphite quartzites with sericite-chlorite schists, quartzites, metagreywacke, limestones, sericite-chlorite schists with albite porphyroblasts and greenschists (basic metavolcanites).

Only a part of the Tulgheş Series is observed in the Maramureş Mts. The Vaser Formation is developed in the lower part and can be correlated with the lower part of the Tulgheş Series, and partly, also with the Rebra Series. The *Tg 3* rhyolitic-volcanic formation is very well developed in the Baia Borşa area, where it is associated with base metal sulphide ore deposits. Fig. 25 presents a schematic stratigraphic profile of Tulgheş Series in Maramureş Mts.

Recent geochemical studies of *Tg 3* rocks from Baia Borşa (Cook, unpubl.) reveals a great diversity in volcanic affinities, from tholeiitic to calc-alkaline. Although such trends are by no means uncommon in other comparable terranes, the significance of these new findings remains to be more fully investigated.

Massive pyrite and base metal ore deposits within the Tulgheş Series in the Maramureş Mountains

The sulphide ores generally occur as lenses (up to some hundreds meters in length) composed of massive sulphides. Each lens is elongate, with the long axis approximately twice that of the width. Thicknesses range from as little as 1 metre to as much as 20 metres or more. In areas of pinching, these ores are interdigitated with the enclosing schists in which they are conformably interlain, and generally grade into schists impregnated with pyrite (Fig. 26). Each lens shows a distinct metal zonation, in which one extremity is more Cu-rich, and the other more Zn-Pb rich. This can best be related to primary patterns of proximal and distal exhalations on the sea floor.

The structural settings of the ore deposits has been largely determined by their metamorphic and tectonic history. The ores display evidence of having taken part in the same metamorphic history of their host rocks. Tectonic control over metal distributions is evident, especially for Cu, where that element is concentrated in zones of reduced stress.

Intensely altered rocks, representing a hydrothermal alteration zone enclose each ore lens. Although primary relationships to the ore are after disturbed by tectonism (the alteration zones having been the focus for much of the tectonic movement), continuing work is attempting to show if there are patterns of zonation within the alteration, and furthermore to identify gain and loss of elements and/or changes in rock volume.

Idioblastic pyrite is frequently rounded or elongate and displays abundant cataclastic fracturing. The pressure shadows surrounding pyrite commonly contain chalcopyrite and other more ductile sulphides and/or clots of dense Mg-rich chlorite. Chlorite, muscovite, albite, quartz and minor carbonate are the main gangue minerals. Chalcopyrite, sphalerite and galena occupy the matrix between the pyrite porphyroblasts, where they are intimately intergrown with one another, infilling fractures in fractured pyrite, or as inclusions in that mineral.

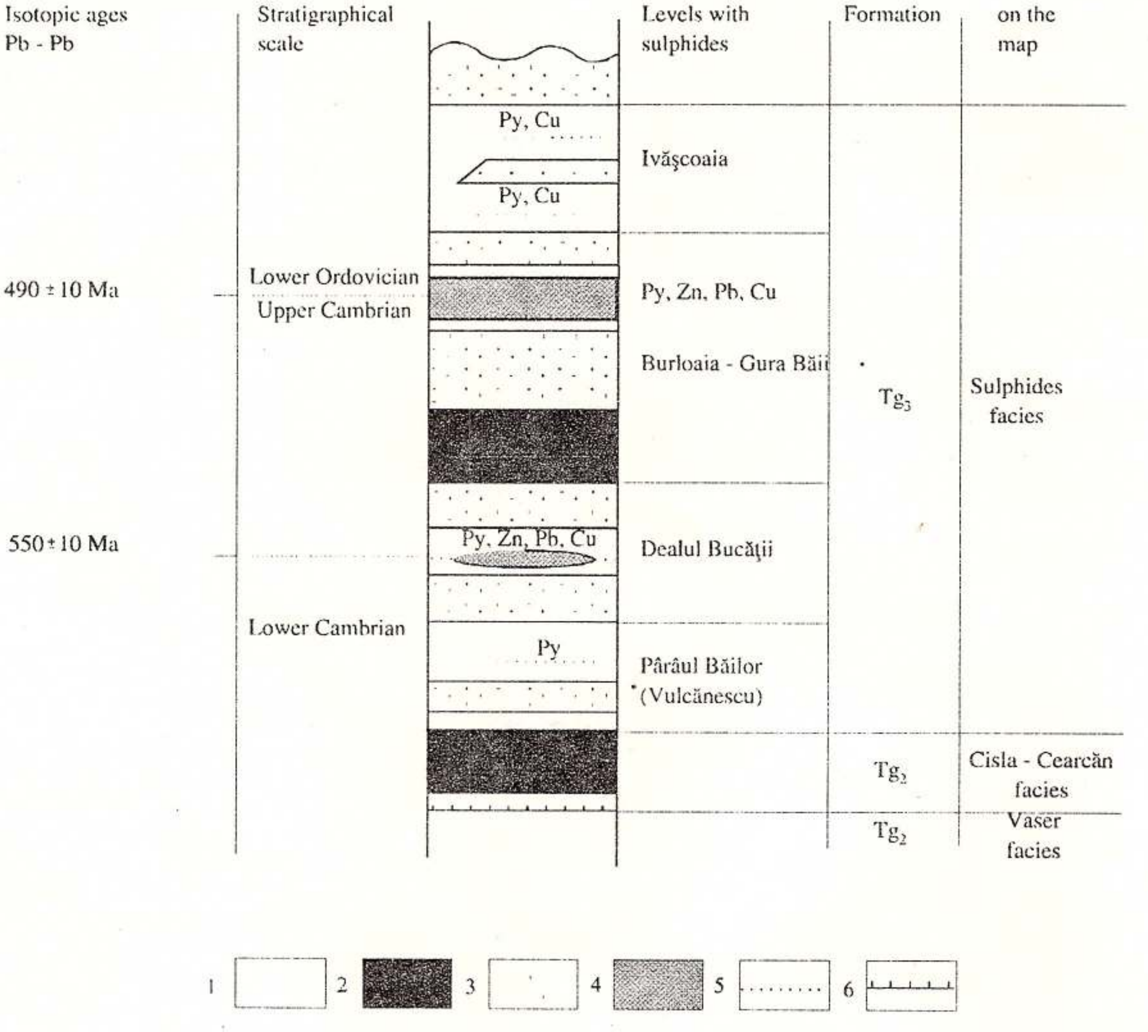
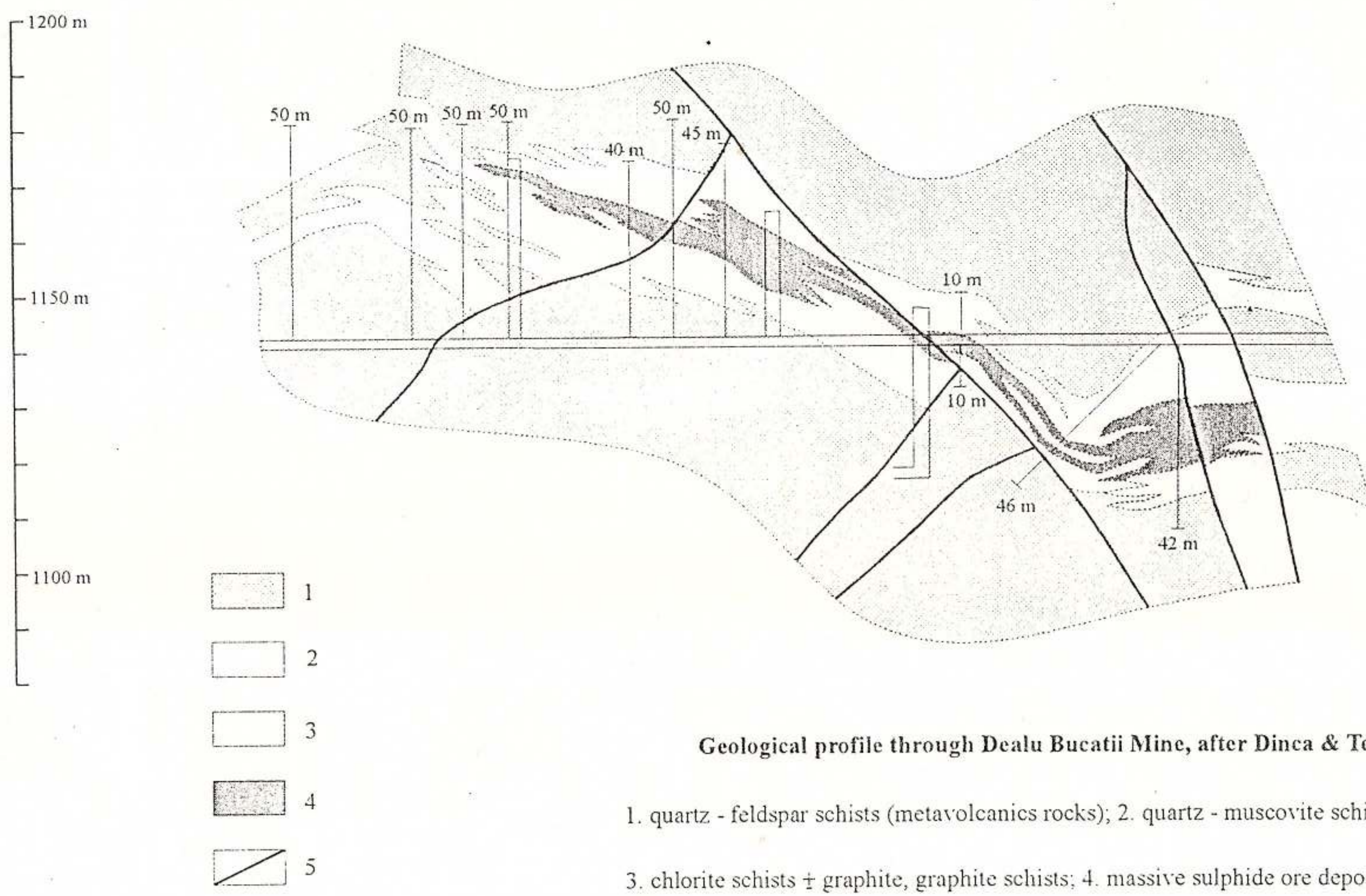


Figure 25. Schematic stratigraphic profile of Tulgheş Series in the Baia Borşa area, Maramureş Mts. 1- non - feldspathic schists; 2 - graphite quartzites, graphite bearing schists; 3 - quartz - feldspar schists; 4 - massive pyrite and base metal ore deposits; 5 - disseminated sulphide bearing horizons; 6 - nappe (?).



Geological profile through Dealu Bucatii Mine, after Dinca & Telman (1993)

1. quartz - feldspar schists (metavolcanics rocks); 2. quartz - muscovite schists ± chlorite

3. chlorite schists ∓ graphite, graphite schists; 4. massive sulphide ore deposit; 5. fault

Fig. 26

Table 4. Qualitative mineralogical composition of some individual massive sulphide ore deposits from Maramureş Mountains (after different authors)

Name of the ore deposits		Gura Băii	Măcârlău	Colbu	Burloaia	Dealul Bucăţii
sulphides	principal (10-80%)	pyrite	pyrite	pyrite	pyrite	pyrite
sulphides	subordinate (1-10%)	sphalerite galena chalcopyrite	sphalerite galena chalcopyrite	sphalerite galena chalcopyrite	sphalerite galena chalcopyrite	sphalerite galena chalcopyrite
sulphides	<1%	arsenopyrite pyrrhotite marcasite tetrahedrite galenobismuti te bournonite stannite jamesonite	arsenopyrite pyrrhotite marcasite tennantite- tetrahedrite galenobismut ite bismuthinite stannite bornite covellite chalcocite	arsenopyrite pyrrhotite marcasite tennantite- tetrahedrite galenobismut ite proustite- pyrargyrite freislebenite jamesonite stannite	arsenopyrite pyrrhotite tennantite- tetrahedrite galenobismut ite cubanite valeriite wurtzite bornite	arsenopyrite marcasite tetrahedrite bournonite galenobismut ite stannite bornite chalcocite
Native elements		gold	gold electrum	gold	gold electrum	gold
Oxides		cassiterite magnetite Ti oxides	cassiterite magnetite Ti oxides	cassiterite magnetite Ti oxides hematite	cassiterite magnetite Ti oxides	cassiterite hematite ilmenite Ti oxides
gangue	Silicates	quartz chlorite (thuringite, prochlorite, chlinochlore) muscovite albite	quartz muscovite chlorite (ripidolite) albite	quartz muscovite (phengite) chlorite (chlinochlore, ripidolite) albite	quartz muscovite chlorite	quartz muscovite (phengite) chlorite (prochlorite, pennine) feldspar sphene
gangue	Carbonates	calcite dolomite siderite	calcite dolomite	calcite dolomite ankerite	calcite dolomite ankerite	calcite siderite ankerite
Other minerals (epigenetic?)		semseyite		barite		semseyite

The sulphide ore deposits from Tulgheş Series are essentially pyrite ores. Contents of Cu, Zn, and Pb are highly variable within individual ore lenses, but are locally extremely high. Extraction of these metals, and also Ag and Au can be achieved even at low grades, making them of economic importance. Obstacles to efficient exploitation are however presented by both the finely intergrown nature of the ore, and also the extensive faulting of the ore lenses. Silver is present both within the galena (at concentrations up to as much as 1.0 wt. %) and as discrete Ag minerals of which the most important is argentian tetrahedrite (8 - 16 wt. % Ag) according to Cook (unpub. data). Gold is present as electrum, typically enclosed in chalcopyrite. Other ore minerals are observed as inclusions in pyrite, chalcopyrite, sphalerite and especially galena. The galena is also Bi-bearing, the Bi content correlating well with Ag, strongly suggesting sub-microscopic inclusions of Bi-Ag minerals. A systematic study of sulphosalt mineralogy currently in progress has failed to confirm the presence, in the massive lenses, of many minerals previously reported (freislebenite, semseyite, jamesonite). These minerals are only observed in veins superimposed on the stratiform deposits and may be an epigenetic overprint.

The qualitative mineralogical composition of some ore deposits from Maramureş Mts. is presented in the Table 4.

The age of the epimetamorphic rocks from the Tulgheş Series

The preserved palynological associations (Iliescu & Mureşan, 1972; Timofeev, 1973; Iliescu & Kräutner, 1975) indicate sedimentation of the Tulgheş sequences between the Vendian and Lower Cambrian. This is supported by radiochronologic dating on syngenetic minerals (Pb-Pb=500 ± 30 Ma) from Leşu-Ursului, Fundu Moldovei, Bălan and on the zircon from the rhyolitic metatuffs and porphyroids (600±40 Ma; Boiko et al., 1975).

Kräutner et al. (1976) provides a review of the K-Ar radiometric date for the regenerated metamorphic rocks of the Eastern Carpathians. The values obtained for the Tulgheş Series are as follows:

muscovite	257-308 Ma
biotite	218-289 Ma
whole rock	88-472 Ma

Within the Bucovinian Nappe, ages in the range 300-325 Ma prevail. These reflect an intense regeneration during the Hercynian. The profound and extensive regeneration of the Tulgheş Series is also indicated by the presence of abundant Hercynian deformations S_2 and S_3 (Kräutner & Popa, 1973; Kräutner et al., 1975) and the dephengitization of the white mica.

The estimated age of the mineralization from the Tulgheş Series in the Maramureş Mts., based on the isotopic determinations by Pb/Pb methods carried out by Popescu (1975) is as follows: 550±10 Ma (Lower Cambrian) for Dealu Bucăţii level and 490 Ma (Upper Cambrian-Lower Ordovician) for Burloaia-Gura Băii level.

Several samples analysed by K/Ar method gave the following results (Zincenco, 1978):

Sample No	Rock type	Location	Mineral	Age Ma
MM-1185	muscovite schists with chlorite, quartz, calcite, pyrite	Cişlişoara break altitude 1805	muscovite	260±5
MM-2	muscovite-chlorite schists with albite porphyroblasts	Dealu Bucăţii mine gallery 11000 m 950	muscovite	249±5
MM-3	quartz-muscovite-chlorite schists	Dealu Bucăţii mine breach 110004	muscovite	256±5
MM-4	talc-muscovite-quartz schists	Măgura mine gallery no 9	talc-muscovite	206±6

These four samples are disposed along an isochron that gives an age of 261±1 Ma, considered to be that of uplift of the terranes following Hercynian metamorphism.

Genetic concepts

During the past 150 years, the geological literature has contained an abundance of not only geological and petrographical information, but also a large amount of genetic data regarding the massive sulphide ore deposits from the Tulgheş Series. The genetic concepts put forward up to date are both various and contradictory. They have included nearly all possibilities of sulphide ore formation. The concepts and opinions can be grouped into two main categories:

1. Theories considering that the sulphide ores were not metamorphosed and represented hydrothermal ores with magmatic origin.

This point of view was put forward in 1850 by B. von Cotta for the Fluturica-Cîrlibaba ore deposits and by Pantó & Földvari (1950) for the Bălan ore. Subsequently, in 1961, Socolescu extended the idea of the hydrothermal origin of Baia Borşa ore deposits to all the massive sulphide ore deposits from Eastern Carpathians, relating them genetically to the metalogenesis associated with Neogene magmatism. The same interpretation was preferred by Gurău & Rădulescu (1967).

2. Concepts in which it was believed that the sulphide ore deposits were subjected to regional metamorphism.

According to the pre-metamorphic process, the formation of sulphide ores could have occurred in three ways, resulting from the regional metamorphism of:

a) *Hydrothermal veins.* This idea was presented in 1958 by Savu & Vasilescu referring to the exposures along the Cisla Valley (Baia Borşa), by Badea et al. (1962, 1963) for the Leşu Ursului deposit, and subsequently reconsidered by Petrulian et al. (1966), Ghiţulescu et al. (1969).

b) *Sedimentary deposits*, on the basis of their stratiform character and stratigraphic control of the deposits. This idea was supported by Kräutner (1942, 1943), while investigating the mineral deposits of Fundu Moldovei-Pojorîta-Valea Colbului. The idea was rejuvenated by Savu et al. (1952, 1953) for the area between Fundu Moldovei and Holda. The sulphides were supposed to be deposited in a reducing environment, rich in organic materials and their spatial relation with the porphyrogenic rocks (acid metavolcanics) was considered to be only stratigraphic and not genetic. Gheorghiu (1953) provided much evidence for the sedimentary conditions, pointing out the role of bacterial activity during the sedimentation process. During the last years, Popa (1982) tried to explain this assumption, suggesting detritic and bacterial accumulation before the metamorphism of sulphide ores.

c) *Volcano-sedimentary deposits*

Although Gheorghiu (1953) and Ghika-Budeşti (1954) favoured a continental source of metallic elements, they also raised the possibility of a volcanic supply. In 1958, Gheorghiu reconsidered these opinions and pointed out the possibility that the base metal sulphide deposits could have formed as a result of the weathering of volcanic products from volcanic discharges. In 1961, Dimitrescu described the origin of sulphide deposits as „exhalative" and „sedimentary-volcanic" for the first time. The volcanic-exhalative origin was supported in 1962 by Savu and Vasilescu; hydrothermal solutions reached the sedimentary basin and produced hydrosols, which subsequently formed the base metal sulphide lenses. In 1964, Kräutner supported the volcano-sedimentary origin for the Fundul Moldovei ore and of the similar ores from crystalline rocks elsewhere in the Eastern Carpathians. Kräutner (1965) reviewed the various data, concluding that the massive pyrite and base metal deposits represented volcano-sedimentary formations that were of hydrothermal origin and also regionally metamorphosed. In recent years, many authors

(Zincenco et al., 1973; Balintoni et al., 1973; Mureşan, 1977) and local geologists have chosen to accept this model. These mineral deposits were described as Kuroko type metamorphosed ores (Kräutner, 1977) in which distinct paleo-structural positions and depositional types were recognised (Kräutner, 1984). In 1989, Kräutner developed two depositional models with a transition between them, considering that the massive sulphide and disseminated sulphide deposits related to the rhyolitic volcanic-sedimentary rocks might be considered as a fundamental genetic type. The differences between each individual ore or province could be explained by different local ore forming conditions, reflecting depositional type.

Recently, Şeclăman et al. (1992, unpub.) suggested a model in which a subduction process is invoked, considering that the major dehydration metamorphic reactions have led to three water sources:

- free water (from the pores and zeolites)
- chloritic water (from chlorite and greenschists)
- serpentinic water (from the serpentinites)

The depth of the three water sources and the order of their occurrence depends on the position of isotherms in the subduction area. Four such possibilities with various subduction rates are discussed. All versions accept that the water contains volatiles that allow for formation of various metal composites (especially chlorides). When these chlorides are present, feldspar and muscovite start to precipitate after passing the 450° isotherm and could also lead to the formation of sulphide deposits in epimetamorphic rocks.

Although the syngenetic volcanic exhalative model is now widely accepted, some uncertainties remain. The extent of metamorphic remobilisation of ore components and the possibility of some contribution of metals from an epigenetic source overprinting the regionally metamorphosed deposits are central themes to ongoing research in the Baia Borşa area. Preliminary data (Cook, unpub.) has shown evidence for substantial syn-metamorphic (?) remobilisation and redistribution of ore components. However, such processes, as well as some epigenetic overprinting relating to the Neogene magmatism are of only minor significance to the ore masses in a volumetric sense. Furthermore, the contribution of organic-related sedimentary processes may yet prove to have been significant, at least for some of the deposits. Analysis of S-isotope compositions, currently in progress, may offer some new evidence in this direction.

Neogene intrusions of the Toroioaga Massif

Socolescu (1954) outlined the multistage evolution of Neogene magmatism in the area, which begins with massive andesites and diorites, continued with dacitic andesites and dacites and was completed by hornblende and pyroxene andesites.

In opposition to this interpretation, Dimitrescu (1954, 1955, 1959) and Szöke (1962, 1965, 1966) mentioned a single intrusion with local differentiations, deriving various petrographic types.

After the investigations made by Berza et al. (1978, 1979, 1980) on the Neogene magmatites, results supported the same polystage interpretation as that of Socolescu; these authors having identified five petrotypes which justify five intrusion stages based on mutual relations. According to the order of intrusion these are the following: quartz andesites of Novicior (I), Toroioaga andesites (II), quartz porphyric diorites of Secu-Novăţ (III), quartz andesites of Vertic (IV) and andesites of Piciorul Caprei (V).

The chemical characteristics provide for the following evolution of intrusions: first and fourth stages represent the most acid types, the second and third are intermediates, and the fifth stage has the most basic composition, each of them corresponding to an andesitic magma. Berza et al. (1984) described a new andesite type, the pyroxene andesite of Arşiţa (VI), situated on the west of the described area, considered to belong to the sixth stage, based on its mineralogical and geochemical features.

Concerning the time of intrusions, Lemne et al. (1980) plotted a K/Ar isochron, pointing out a radiogenetic age of 6 Ma for the emplacement of third and fourth intrusions stages. Several recent K/Ar dating performed by Pécskay et al. (1994) gives significantly older ages:

Petrographic type	Mineral	K/Ar age
microgranodiorite with biotite of Vertic	biotite	9.6±0.4
microgranodiorite with biotite of Vertic	feldspar	9.7±0.5
andesite of Toroioaga	biotite	10.2±1.3 (?)
andesite of Toroioaga	total rock	10.4±0.9

Transformations following magma consolidation are as follows: propylitization, chloritization, epidotization, adularization, biotitization, tourmalinization, argilization, silicifiation.

The sulphide accumulations and the epidote, adularia, biotite neoformations were formed after the consolidation of the fifth stage products, along NE-SW fractures, creating access for the hydrothermal solutions.

Microscopic, geothermometrical and geochemical observations have outlined the base metal character of the mineralizations which display a vertical distribution trend (Borcoş et al., 1982).

The lower level of the veins includes the following assemblages: pyrite, pyrrhotite, chalcopyrite ± arsenopyrite, sphalerite, galena, sulphosalts, quartz, calcite, dolomite.

The middle part of the veins includes the following assemblages: pyrite, sphalerite, galena, sulphosalts ± chalcopyrite, arsenopyrite, quartz, calcite, dolomite, locally one may record an increase of Au and Ag contents, especially related to the presence of chalcopyrite.

The upper part of the veins include pyrite, sphalerite, galena ± chalcopyrite, quartz, calcite, barite, dolomite, associated with Cu, Pb and Ag sulphosalts and high Au contents.

Steclaci (1962)(in Szöke & Steclaci, 1962) made an important contribution to the knowledge of sulphosalts in the Toroiaga ores, noting the presence of: bournonite, semseyte, jamesonite, plumosite, tetrahedrite, freibergite, boulangerite, geocronite, matildite and germanite. Cook (unpub. data) has also identified several Bi-sulphosalts in the Toroioaga ores. The secondary minerals present are: chalcocite, covellite, malachite, anglesite, argentite and stromeyerite.

The emplacement of intrusive bodies led to the formation of a contact halo within the surrounding country rocks of the Toroioaga magmatic massif. The Eocene and Oligocene sedimentary deposits were subject to a very weak metamorphism. The transformations of the crystalline schists are more important, starting from the simple recrystalisation to the formation of various hornfelses: hornfels with cordierite, quartz and tourmaline; hornfels with cordierite, andalusite, quartz, biotite and tourmaline; hornfels with cordierite, quartz, biotite, plagioclase and tourmaline (after Ciornei et al., 1980). In addition to these, Szöke (1962) also determined hornfels with tourmaline and corundum.

FIRST DAY

Geological profile along the Cişlişoara Valley up to Dealu Bucăţii Mine

Several outcrops including the major petrographical types of Tulgheş Series from Maramureş Mts. will be visited.

1st Stop. *Quartz-feldspar schists* (= porphyroides = metarhyolites)

The mineralogical association is essentially simple, represented by quartz+albite (oligoclase, An<20%)+muscovite chlorite microcline. The plagioclase feldspar occurs in the same thin section as porphyroblasts with variable anorthite contents considered to be relicts of the pre-metamorphic rhyolitic volcanism. The albite included in the assemblage is considered to be a product of metamorphism or of pre-metamorphic hydrothermal alteration associated with ore formation according to other workers. The extent to which the mineralogy and geochemistry of the units was influenced by this pre-metamorphic convective hydrothermal alteration is the subject of continuing research.

The assemblage of this outcrop is quartz+microcline+muscovite, apatite, zircon and epidote as accessory phases. The structure of the rock is microblastic. It was observed that the above assemblage has a distinct position compared to the bulk sulphide deposits of the area, having been observed in the lower and/or upper part of mineralisations of most ores from Maramureş Mts.. The microcline always occurs as neoformations, replacing the pre-existing minerals. It develops as microblasts of 0.01mm size, disposed parallel to the main foliation of the rock. It rarely occurs as large well developed crystals with cross-hatch twinning. The variation of optical characteristics could be observed in the same microcrystal, due to the considerable variation of triclinic character in some crystal.

For the development of microcline the following reactions have been proposed by Grama (1994):

$$\underset{\text{muscovite}}{KAl_3Si_3O_{10}(OH)_2} + \underset{\text{quartz}}{SiO_2} \quad \underset{\text{microcline}}{KAlSi_3O_8} + \underset{\text{X-andalusite}}{X\ Al_2SiO_5} + H_2O \quad (1)$$

where X-andalusite is unstable and combines with the various cations existing in the system (Fe, Mg, Ca etc.) forming chlorites.

$$\underset{\text{muscovite}}{KAl\ Si_3O_{10}(OH)_2} + KCl \quad \underset{\text{microcline}}{KAlSi_3O_8} + \underset{\text{fluid}}{H_2O + Cl_2} \quad (2)$$

Along the joints which cross the rock schistosity the reverse reaction with the development of quartz + muscovite can be observed.

2nd Stop. *Muscovite-chlorite schists* (= metatuffs metapelites)

The quartz-feldspar schists are overlain by muscovite-chlorite schists represented by the assemblage: quartz+muscovite+chlorite biotite and the accessory minerals; rutile, apatite and tourmaline. The structure of the rocks is lepidoblastic. The schists include a S_1 plane (remnant) and a S_2 plane (principal) with transposition from S_1 to S_2. In some cases, the muscovite from S_2 is replaced by small microcline blasts formed by consumption of muscovite.

This petrographic type occurs as an envelope around the ore lens (assemblage: pyrite+sphalerite+galena±chalcopyrite), most frequently the assemblage includes quartz + muscovite ± chlorite (muscovite schists, quartz-muscovite schists). Locally the designation of sericite schists has been used although it was demonstrated that the white mica is a muscovite 3T.

When it appears, the pyrite is associated with chlorite and has been deformed by cataclasis. Under the microscope, various degrees of deformation are observed.

3rd Stop. *Greenschist*

This petrographic type is not widely developed; it typically occurs interlayered between other schists. It includes the following assemblage: quartz+oligoclase+chlorite muscovite and as accessory minerals: epidote, apatite, Ti oxides, calcite which occur along the joints perpendicular to the rock schistosity. The plagioclase occurs as porphyroblasts exhibiting a crystal rotation tendency with the development of the albite deformation twins.

The carbonate is encountered as later neoformations along joints which cross the rock. The carbonate occurs in each petrographic type belonging to Tulgheş Series, resulting in the corrosion of previously formed silicates. The origin of this carbonate may be either metamorphic or magmatic. This is somewhat problematic, since there is often no direct evidence for the presence of magmatic lodes in the vicinity. It is however more realistic to consider that the emplacement of Toroioaga intrusions (because of the thermal gradients generated) allowed either remobilization of the carbonate and sulphides from the metamorphic rocks, and also because comparable assemblages exist within veins specific to the magmatism.

4th Stop. *Chlorite bearing phyllites, chlorite schists*

The greenschists are overlain by chlorite bearing phyllites, made up of quartz+chlorite muscovite and accessory minerals: apatite, tourmaline, zircon and Ti oxides. The structure is lepidoblastic, and one can observe a relict S_1 plane and a very well developed S_2 plane. This petrographic type is interlayn between other schist varieties or borders the ore lenses. An increase in the sulphide content is observed towards ore, which is correlated with the Fe/(Fe+Mg) ratio of the silicates (chlorite, muscovite) which decreases sharply towards ore, as the iron becomes preferentially bound in pyrite (Zincenco et al., 1980).

The chlorite schists are intimately associated with the sulphide assemblage pyrite+chalcopyrite+sphalerite galena.

5th Stop. *Quartz-graphite schists, graphite schists, black quartzites*

The stratigraphic succession of the Tulgheş Series from the Maramureş Mts. includes several levels of quartzitic rocks with graphite, featuring the quartz+graphite muscovite chlorite assemblage, with the following accessory minerals: tourmaline, zirconium, rutile and apatite. Graphite occurs as a fine grained powder, forming band and agglomerations disposed parallel to the rock foliation, the variable graphite content leading to the differentiation of various petrographic types. Graphite occurs as an accessory mineral throughout most petrographic types rich in phyllosilicates.

The quartz-graphite schists and graphite schists are considered to be formed by the metamorphism of an organic rich sediment. Some geologists however prefer to invoke the abyssal origin of graphite, relating it to the Neogene magmatism of the Toroioaga massif.

Dealu Bucăţii Mine

The Tulgheş Series hosting the ore deposit, is made up of alternating metavolcanics and metasedimentary rocks, metamorphosed to greenschist facies.

Two types of wall rocks can be recognised, corresponding to meta-volcanic rocks, and a group of terrigeneous rocks which probably represent either sea-floor sediments, organic precipitates, and/or mixtures of volcanic detritus and sedimentary material.

The volcanic level includes regionally metamorphosed volcanic rocks, separated into the following groups:

1. The group of porphyritic rocks (acid metavolcanic rocks) made up of two rocks type: a) quartz-feldspar schists with quartz crystaloclasts, microcline plagioclase; b) quartz-feldspar schists with plagioclase porphyroblasts, without microcline.

2. The group of muscovite schists with albite porphyroblasts

3. The group of chlorite schists with albite porphyroblasts, that typically occur in the zones of copper enrichment, interlayered with the other schists; chlorite is represented by the thuringite, pycnochlorite and chlinochlore associations.

The terrigeneous level is represented by predominantly quartz bearing rocks: black quartzites±graphite, white quartzites±feldspars, quartz-graphite bearing schists and quartz-muscovite schists.

An ore level has been outlined within the volcanic level of quartz+muscovite±chlorite schists (Dealu Bucăţii level) including a massive lens. This level appears to be continuous, being interrupted only by several delineating faults. Laterally, the lenses pinch out, passing to sphalerite, galena and/or pyrite disseminations. The central part of the lens exhibits a pronounced zoning of the metals, the pyrite being disposed in thin (centimetre scale) levels alternating with very fine crystallised sphalerite-galena levels. The mineralogical composition of the ore was given in Table 4.

The geochemical observations are supported by chemical analysis performed both on massive ore and disseminations. The unequal distribution of the major metals (Zn, Pb, Cu) required the application of several statistical methods for the purpose of examining the distribution patterns typical to the relevant ore. As the distribution of these elements in similar ore deposits of the Eastern Carpathians was lognormal, the some distribution law was also assumed for the Dealu Bucăţii ore deposit.

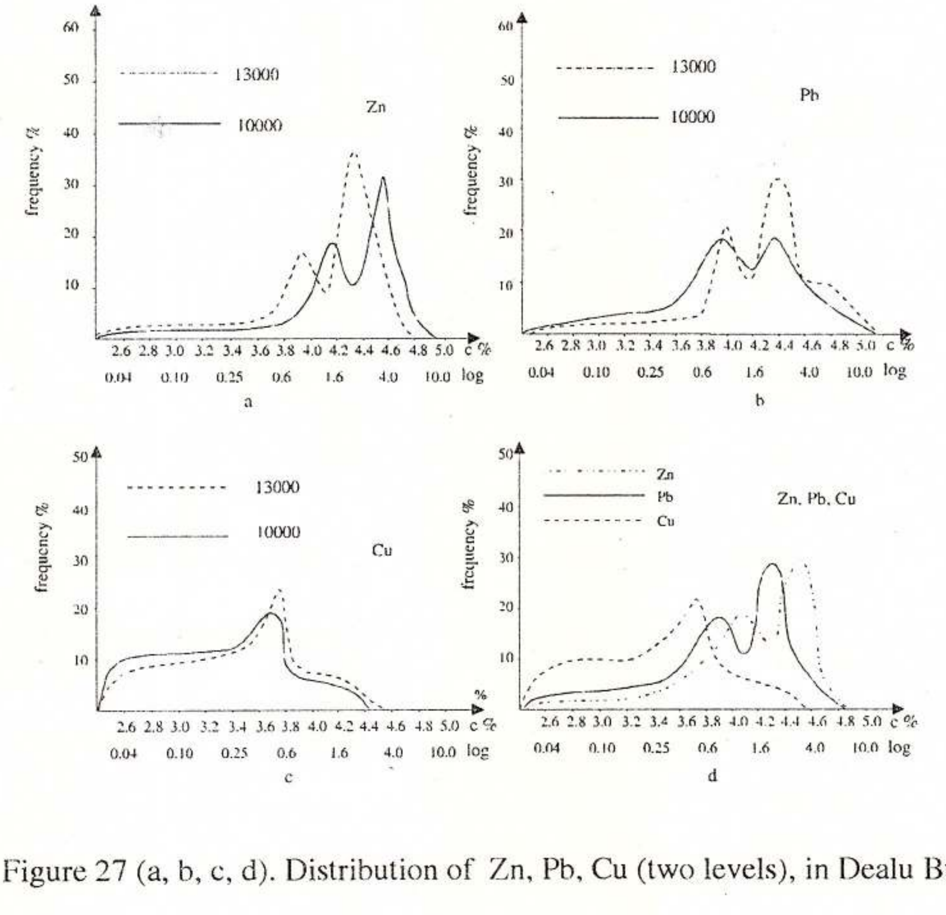


Figure 27 (a, b, c, d). Distribution of Zn, Pb, Cu (two levels), in Dealu Bucăţii mine.

Based on the interpretation of the diagrams (see fig. 27) one may conclude the following (Samoilă, 1975):

- the Zn, Pb, Cu contents decrease with the depth
- the Zn/Pb ratio is 2/1, comparable with other ore deposits of the area
- different behaviour of Cu compared to that of Zn and Pb
- Zn and Pb has a bimodal distribution, confirming the unhomogenous character of the ore, that is assumed to be deposited either in two stages or, during a single stage, and subsequently modified by metamorphism.

SECOND DAY

Geological profile from Baia Borşa to Gura Băii Mine

The profile crosses three of the six intrusive stage described in the Toroioaga massif from South to North.

The first outcrops in the southern part are represented by Toroioaga andesites with hornblende and biotite (second stage). They are made up of several 1-2mm size plagioclase, hornblende and biotite, rarely pyroxene and/or quartz phenocrysts giving a microcrystalline, cryptocrystalline, or microlitic structure.

Further on, very well developed porphyritic quartz diorites with hornblende and biotite±pyroxene of Secu Novăţ type (third stage) occur towards the North, as an elongated body with a NW-SE trend, considered to be a dyke, exposed by erosion, with a maximum width of 1.5km. It is considered to be the central and deepest facies of the Toroioaga andesites because of the similar mineralogical assemblages and chemical compositions. The porphyry quartz diorites have a fine grained groundmass than the Toroioaga andesites. The main magmatic body pinches out towards East, on Colbului Valley, as several dykes of tens of meters in length and up to several meters wide, being intruded into the crystalline schists. The grain-size of the groundmass in this area becomes much finer (these phenomena can be observed between Secu and Colbului Valley) allowing us to describe these rocks as porphyritic quartz diorites and quartz monzodiorites and only locally as andesites.

The Vertic type quartz andesites (fourth stage) occur as elongated dykes of several kilometres in length and some hundreds meters (in width) oriented NW-SE crossing the Secu Novăţ diorites and the Toroioaga andesites or crystalline schists.

The transformations following the magma consolidation reported by Socolescu (1952), Borcoş (1954) and Dimitrescu (1955) are detailed by Szöke (1962), who identified biotitization and tourmalinization besides the reported propylitization, chloritization and epidotization. These were further studied by Gurău et al. (1977), Ciornei et al. (1980), Borcoş et al. (1982) and Berza et al. (1978, 1979, 1980, 1984).

The most widespread post-magmatic alteration is considered to be the propylitization, which affected almost all products of the first four intrusion stages

Biotitization as a hydrothermal metamorphic process results in the production of small biotite plates substituting the melanocratic phenocrysts and groundmass. It occur sporadically in the Toroioaga andesites and Secu-Novăţ diorites and rarely in other petrographic types. It is supposed that the process developed in several stages, although there is no evidence confirming the migration of the hydrothermal biotite from the later intrusions into the earlier ones.

Tourmalinization occurs in two circumstances: a) as substitute of phenocrysts and (very rarely) of groundmass and b) in breccias that include crystalline schists and andesite fragments. It is considered that these neoformations belong to several intrusion stages (II, III, IV).

Epidotization is generally accompanied by sulphide disseminations and formation of adularia.

The above mentioned transformations reach their peak in the vicinity of ore veins. The outcrop of these veins features several breccias, affected by epidotization, pyritization and frequently also biotitization.

The emplacement of the magmatic intrusions from the Toroioaga massif has led to the formation of various contact types between the magmatic and crystalline rocks.

The first contact type is the „cold contact" within which the crystalline schists do not seem to be thermally affected, at least not beyond a few millimetres, with only a small „roasting" area along the contact between magmatic rocks and crystalline schists. Only a plastic deformation of the crystalline rocks is evident without significant changes in the mineralogical assemblages.

The second type includes brecciation of the crystalline schists. These tectonic breccias are made up of angular schist fragments of centimetre to decimetre size. There are two possibilities: a) the brecciation areas are subsequently crossed by hydrothermal solutions, that may result in several mineralizations depending on the metallic content; b) the solutions do not circulate and therefore the matrix is made up only of the constituent silicates of the crystalline schists (quartz, muscovite, chlorite, albite, microcline).

Further type of contact results in various hornfelses after the crystalline schists, depending on the temperature and chemical composition of the latter. The most typically encountered hornfels occur in the albite-epidote facies. As the assemblages are comparable with those of the regionally metamorphosed greenschists, they may be distinguished based on evidence of recrystallization, and also on some biotite and amphibole neoformations.

Although several assemblages typically to the hornblende hornfels facies in the Toroioaga massif were described, the quartz+microcline±albite±muscovite±biotite assemblage is frequent on the Eastern slope of Secu Valley, mainly because the most widespread crystalline schists are the quartz-feldspar schists.

The last type of relationship between the crystalline schists and igneous rocks is provided by crystalline rock enclaves (ranging in size from centimetres to some ten meters) in the magmatic rocks, that are exposed thanks to the erosion level. These enclaves may or may be not affected by the thermal effects of the magmatism, as determined by local conditions, resulting in typical assemblages of the hornblende hornfels facies.

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EXCURSION D

MEDIUM GRADE METAMORPHIC ROCKS OF THE PRELUCA MASSIF AND THE RĂZOARE Mn-Fe DEPOSIT

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Geological Setting of the Preluca Massif (Fig. 28)

The Preluca Massif is one of the crystalline horsts bordering the northern part of the Transylvanian depression.

Structurally, the crystalline rocks of the Preluca Massif belong to the Baia de Arieş series of the Internal Dacides, that are equivalent with the Rebra series of the Median Dacides (Balintoni, 1982) exhibiting very close resemblance with them. Kalmar (1994), considered the metamorphic rocks to belong to the Someş series.

The metamorphic roçks of Preluca Massif were separated in 4 formations (Balintoni, 1982):

- the Răzoare lower terrigene formation made up of plagioclase gneisses, mica-schists, quartzites and limestones on the upper part
- the Măgureni carbonate formation made up nearly entirely of carbonate rocks, especially of dolomite limestones
- the Preluca Nouă amphibolite formation includes various amphibolite rocks alternating with gneisses, mica-schists, carbonate rocks and black quartzites
- the Valea Cavnicului upper terrigene formation including mica-schists, quartzites and subordinately gneisses.

According to J. Kalmar (1994) the metamorphic rocks encountered in the Preluca Massif include:

- the Răzoare gneiss formation with biotite, garnet and kyanite paragneiss
- the Măgureni carbonate formation with crystalline limestones and dolomites
- the Preluca Nouă formation including mica-schists with two mica, quartzite schists, paragneisses, amphibolites, amphibolitic gneisses, pyroxenites, amphibole schists, orthogneisses, leptinite, black quartzites, garnet mica-schists
- the Ţicău formation: leptinite orthogneisses, garnet mica-schists, amphibolites, black quartzites.

The initial metamorphism was of Barovian type occurring of almandine amphibolites facies (staurolite and kyanite zone), followed by a metamorphism of almandine amphibolites facies (sillimanite zone) and a Hercinian retromorphism in the green schist facies (chlorite zone).

The pegmatites occur as metamorphical differentiation products. The metablastic migmatites in the south-eastern part of the massif were formed in the lower Proterozoic age.

Kalmar (1994) concluded that the metamorphism proceeded before the Upper Carboniferous age (based on the Rb-Sr data) during the Hercinian orogenesis. The Pb-Pb datings on the Răzoare gneisses gave 1.3±0.3 billion years age, thus placing the earliest metamorphic homogenisation into the Middle Algonkian. The K-Ar datings on the mica and amphibole bearing rocks of Preluca, show that the retromorphism occurred 84-110 million years ago and was correlated with the Austric movements (Middle Cretaceous).

Sedimentary deposits bordering the Preluca Massif consist of Cretaceous, Paleogene and Miocene formations, as described by Bombiţă and Rusu (1982).

FIRST DAY

THE MAGNESE-IRON DEPOSIT AT RĂZOARE
(acc. to Udubaşa et al., in press)

General data

The manganese-iron deposit at Răzoare, Preluca Mts., România, is a stratiform concentration of manganese-iron and iron minerals showing evidences of regional metamorphism

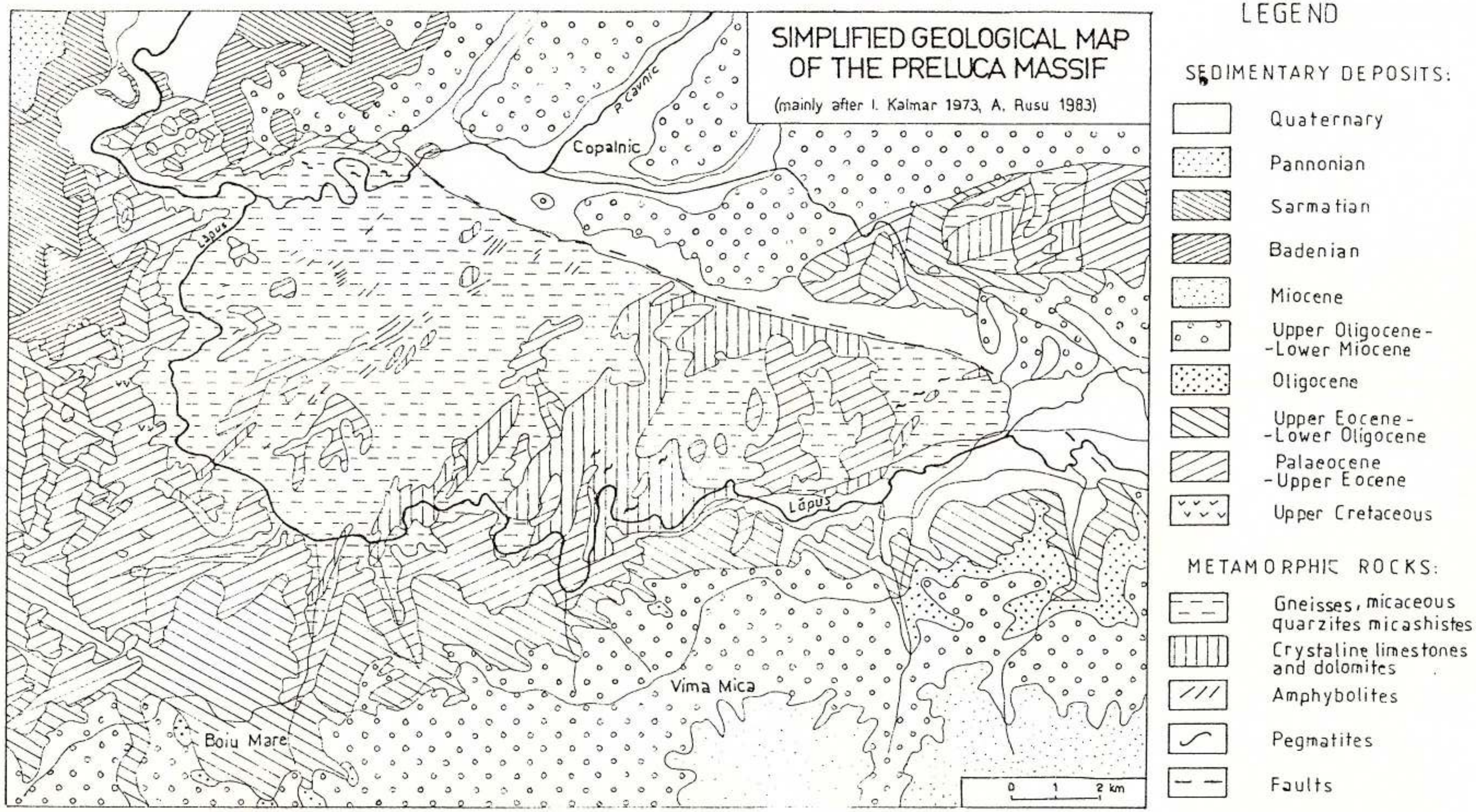
SIMPLIFIED GEOLOGICAL MAP
OF THE PRELUCA MASSIF
(mainly after I. Kalmar 1973, A. Rusu 1983)
P. Cavnic
Copalnic
Lăpuş
Lăpuş
Vima Mica
Boiu Mare
0 1 2 km
LEGEND
SEDIMENTARY DEPOSITS:
Quaternary
Pannonian
Sarmatian
Badenian
Miocene
Upper Oligocene-
-Lower Miocene
Oligocene
Upper Eocene-
-Lower Oligocene
Palaeocene
-Upper Eocene
Upper Cretaceous
METAMORPHIC ROCKS:
Gneisses, micaceous
quarzites micashistes
Crystaline limestones
and dolomites
Amphybolites
Pegmatites
Faults

Fig. 28.

in the upper amphibolite facies. The ores consist of silicates, carbonates and oxides, forming lenses up to 60 m thick, which are invariably enveloped by nearly continuous bands of blackish quartzites reaching a maximum thickness of about 2 m. The deposit is enclosed in a sequence of kyanite-bearing micaschists, paragneisses, pegmatites, carbonate rocks and amphibolites interpreted to be of Precambrian age. At least three metamorphic events have been recognised in the host metamorphic rocks and in the ores as well.

The ores contain about 60 minerals species, from which nearly the half represents primary minerals. The typical minerals of the Răzoare deposit are: manganoan fayalite, dannemorite, rhodochrosite, pyroxmangite and jacobsite. The manganese humite minerals (sonolite, alleghanyte, leucophenicite and jerrygibbsite), tephroite, carbonate fluorapatite and a scarcely developed orthopyroxene, are here for the first time described.

Three mineral assemblages have been recognised displaying different position within the ore-bearing sequence. The bottom is defined by the rhodochrosite-rich assemblage, containing also jacobsite, manganoan fayalite and apatite. It follows an assemblage composed of tephroite and manganese humite minerals, with which jacobsite associates. The upper part of the ore sequence is clearly amphibole dominated, typically containing dannemorite, spessartine, magnetite, pyrrhotite, with a definite enrichment in quartz to the hanging wall. The Fe:Mn ratio seems to characterise both the lower parts (Mn>Fe) and the upper part (Mn<Fe) of the ore-bearing sequence.

The available, but still incomplete data, suggest a polyphase metamorphism of the ores and support the pre-existence of a slightly "layered" primary protolith of sedimentary origin.

The ores contain 18-20% Mn, 17-20% Fe, 8-13 SiO_2 and 0.5% P_2O_5 showing a quite constant Mn:Fe ratio.

The Mn-Fe-bearing rock sequence is located in the south-eastern part of the crystalline "island" (see Fig. 21).

The rock sequence directly hosting the Mn-Fe ores includes kyanite-bearing micaschists, paragneisses and quartzites.

The ore beds or lenses invariably exhibit rather continuously developed envelopes of black quartzites of varying compositions (Fig. 29). They consist of biotite- and garnet-bearing quartz-carbonate schists, magnetite-bearing microblastic quartzites, plagioclase- and biotite-bearing quartzites, amphibole-bearing quartzites. The Mn contents of such rocks is generally low, acting as geochemical barriers. Two groups of minor elements show significant variation, i. e. Cu, Zn, Ni and Mo with increasing contents and Ba, Sc and Zr with decreasing ones as compared to each other and with the increasing contents of some major elements (Fe_2O_3, P_2O_5 and MnO).

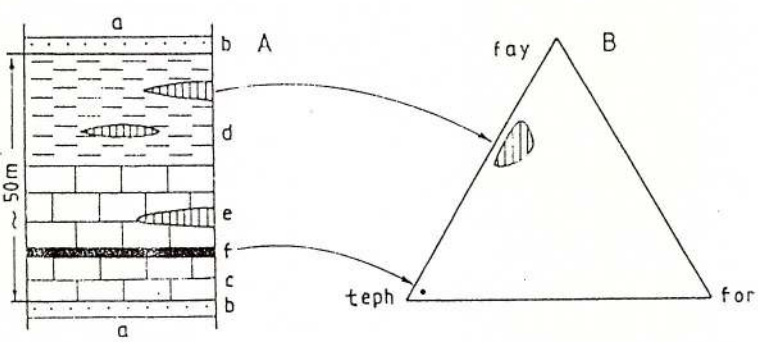

Fig. 29 - Lithologic column of the ore-bearing rock sequence at Răzoare (A) and the ternary diagram (B). a, host micaschist and gneisses; b, black quartzites; c, rhodochrosite and jacobsite; d, dannemorite + magnetite + pyrrhotite; e, manganoan fayalite; f, tephroite and manganese humites.

Mineralogy

The mineralogical composition of the Răzoare ores is quite complex. The main manganese minerals are: olivines (manganoan fayalite and tephroite), dannemorite, manganese humite minerals (MHM), pyroxmangite, rhodochrosite, jacobsite and spessartine. Special mention deserve the MHM, the calderite-rich garnet, the carbonate fluorapatite and the tephroite, minerals which have not been previously reported from this locality. The scarcely developed orthopyroxene (presumably a manganoan ferrosilite) has to be especially emphasised as it suggests a higher grade of the main metamorphic event.

The minerals are medium grained but locally pegmatoid-like aggregates especially of pyroxmangite and manganoan fayalite grains up to 5-6 cm were found. Generally, the ore is massive, sometimes with a well-expressed banding which is presumed to be mainly of metamorphic origin. It occurs at the microscopic scale and under the microscope as well.

However, in such ochres some small geodes were found which are lined with needle-like pyrolusite crystals forming also rosettes, limpid microcrystals of quartz of common habit and small barite crystals.

The primary minerals show preferential association that generally could be interpreted as reflecting primary deposition features and different stages of metamorphic evolution. In a carbonate dominated fine grained matrix there are beds or lenses of different compositions in which the leading minerals are the Mn-Fe-silicates. Jacobsite and magnetite may occur everywhere in the stratigraphic column, but the preference of jacobsite for the MHM is obvious whereas the magnetite associates mainly with the dannemorite rich aggregates; the pyrrhotite is also frequently centred on the amphibole-rich parts.

Jacobsite and magnetite are the most frequently encountered opaque minerals. They are preferentially associated with the MHM and dannemorite, respectively. Thus, they rarely occur together; if this is the case, magnetite seems to be later formed. However, some grains were observed to have an intermediate colour between magnetite and jacobsite, probably ascribable to the mineral iwakiite.

The pyrrhotite is the next frequent opaque mineral and it is at the same time the most frequent sulphide. Unlike magnetite, it prefers the dannemorite dominated assemblage. The pyrrhotite is always accompanied by chalcopyrite and accidentally it contains minute grains of gold.

Genesis

The Răzoare Mn-Fe ore deposit underwent a medium (-high) grade metamorphism (upper almandine amphibolite facies) together with the whole pile of surrounding metapelites. The retrograde metamorphic evolution during the Caledonian and the Hercynian events led to a much more complicated mineralogy.

There are numerous typical interlocking metamorphic textures in the ores at Răzoare. Triple junction points could be seen at magnetite, jacobsite, olivines and even rhodochrosite grain boundaries. No evidence inconsistent with a premetamorphic sedimentary origin of the Răzoare deposit was found.

The metamorphic evolution of the Răzoare ores is quite complicated and the geological environment could not be precisely reconstructed. However, it can be assumed that the 'layered protolith" approached a composition roughly corresponding to a mixture of manganese carbonate, iron oxide and silicate, with variable amounts of calcium phosphate, graphite and locally silica. The first metamorphic event corresponds to the formation of a paragenesis including manganoan fayalite, a calderite-rich garnet and a seldom occurring orthopyroxene.

Closely related to the second metamorphic peak there is a peculiar pegmatoid-like development of pyroxmangite, fayalite and dannemorite under conditions of increasing fluid activity in the system. This corresponds to the abundant pegmatite development (numerous bodies rich in green apatite and black tourmaline) within the host metapelites.

1st **Stop**: Răzoare open pit

The most significant mineral assemblages can be seen in the open pit, where the host rocks crop out too but show varying degree of supergene alteration.

The waste dumps offer also the possibility to find interesting samples, provided the visitor has patience, a good hammer and enough time (the last one will be allotted by the organisers). The most frequent material existing contains dannemorite, sometimes with lenses of manganoan fayalite, pyroxmangite, magnetite etc. The assemblage containing tephroite + manganese humites + jacobsite can also be found; the macroscopic recognition of such a rare assemblage would be made easier by the constant presence of black jacobsite grains, completely lacking in the similarly looking pyroxmangite samples. Secondary manganese minerals can also be found, but pyrolusite needles in geode are very rare.

The pegmatites of Răzoare area

General data

In the Răzoare area (South Eastern of Preluca Massif) there are several pegmatite occurrences. The pegmatite bodies occur within the plagioclase gneisses, along the contact of plagioclase gneisses with the crystalline limestones or within the crystalline limestones. They occur as simple, sometimes ramificated lens shaped or irregular bodies disposed quasiconcordantly or discordantly to the foliation of the host rocks. Their length ranges between 10-500 meters and the width between 10-15 meters. The structure is different i.e., isogranular and heterogranular aplitic to pegmatitic with large crystallised elements providing graphic-micrographic and perthite like textures.

The pegmatites may exhibit symmetrical and asymmetrical zoning (Ciungi Hill, Arşiţei valley and Sunătorii valley, respectively). The pegmatites include the following zones:

- the contact zone with fine grained quartz, tourmaline crystals disposed parallel to the contact, subordinately muscovite and feldspar
- the external zone with graphic textures, muscovite (abundant), tourmaline, apatite, garnet
- the intermediate zone: symmetrical development, including feldspar, quartz, muscovite
- the nucleus with block type quartz including plagioclase, muscovite, tourmaline

Mineralogical composition of the pegmatites

The minerals found in the pegmatites are: quartz, feldspar, muscovite, biotite, chlorite, tourmaline, apatite, garnet, zircon. The following minerals were also mentioned: beryl (Zsivni, 1944; Stanciu, 1951; Kalmar, 1972; Pomârleanu, 1976), danburite and baddeleyite (Stanciu, 1951), monazite, orthite, titanite (Mârza, 1986).

Quartz occurs in various forms, suggesting its genesis in several stages. The feldspar is represented by plagioclases, albite and acid oligoclase with Ab_{90-93} An_{7-10}. The plagioclase feldspar has the following normative composition (Pomârleanu, 1974) $Ab_{83.60}$ $Or_{2.74}$ $An_{13.66}$-$Ab_{92.43}$ $Or_{2.16}$ $An_{5.41}$. Based on the plagioclase feldspar occurrence two plagioclase generations may be distinguished:

- Plagioclase I (oligoclase) of millimetre-centimetre size associated with quartz muscovite, mostly deformed and altered, muscovite and quartz occurring along the twinning and cleavage planes. In the hydrothermally affected lenses the plagioclase I is generally transformed in clay minerals

- Plagioclase II (oligoclase) of submillimetre size resulted further to the fragmentation of plagioclase I and its recrystallization. The albite occurs as small blades next to the junction between two plagioclase I crystals or associated with orthoclase and/or microcline, resulting the replacement perthites.

The alkali-feldspars are represented by orthoclase and microcline. The orthoclase prevails in the Ciungi area. It is associated with acid plagioclase resulting replacement perthite structures. Orthoclase is affected by various alteration grades, starting with the presence of muscovite along the cleavage planes to the total replacement with muscovite and quartz. Microcline is rarely twinned (albite-pericline law).

Muscovite is common in pegmatites not affected by hydrothermal solutions. It is associated with feldspar, quartz, tourmaline, apatite. The later generations are replacing the other minerals along the cleavage and twinning planes (feldspars) or filling the spaces between the other minerals. The quartz-muscovite intergrowths are common. Its maximum size reached 15x20cm (Ciungi area).

Biotite occurs subordinately in the outer area of the non-argillized pegmatite bodies. It is mostly chloritized or may be replaced by muscovite. Mârza (1986) considered, based on the X ray analysis, that the green product on the biotite was a hydrobiotite.

Tourmaline is very common along the contact areas of the pegmatites, its crystals being oriented parallel to the contact plane. It forms with the quartz typical graphic texture. According to Kalmar (1973) the tourmaline from Răzoare has the following composition: 63% shörlite and 37% dravite. Microscopically one could observe a zoning within the tourmaline crystals.

Garnets occur mainly in the internal or intermediate area. They appear as millimetre to centimetre size crystals, as monocrystals in the feldspar or quartz mass or as small crystals associated with quartz, tourmaline, apatite. Pomârleanu obtained the following molecular ratios: pyrope 2.3-3.0%, almandine 56.2-57.0%, spessartine 37.3-38.6%, andradite 2.7-3%.

Apatite occurs with quartz, muscovite, plagioclase feldspar, tourmaline. It is green coloured with millimetre to centimetre size crystals (maximum 3.5x6cm). Determinations undertaken by Mârza (1986) have outlined the presence of fluorapatite including minor elements as K, Mn, Fe, Mg, Al, Cu. Mn^{2+} substitutes Ca^{2+} in the in the apatite lattice. Also La (200 ppm), Dy, Sm, Eu contents were detected. Chlorite occurs as neoformation mineral formed after biotite and garnet. When replacing biotite it also forms besides quartz and muscovite a polymineral assemblage. Zircon was identified by Pomârleanu (1974) in vugs as short prismatic millimetre and submillimetre size crystals with bipiramidal faces. Beryl, described by Pomârleanu (1974) occurs subordinately as nests, and white green friable crystals or compact masses.

Genesis

Three assumptions were submitted regarding the formation of the pegmatite bodies in the Preluca crystalline massif:

- the first hypothesis implies that the pegmatites were the product of a deep magmatism. Szadecky (1920), Stanciu (1951) considered danburite and baddeleyite to be the main evidences. Pomârleanu (1974) considered that the quartz in plagioclase gneisses, the deformation around the pegmatites and the transformation halo around the pegmatites, the contacts between the pegmatites and the country rocks, support also such an origin;

- a second hypothesis was accepted by Kalmar (1973); according to this hypothesis the pegmatites are a result of alkaline fluid circulation from low pressure zones and of a non-homogeneous tectonic deformation during late metamorphic events of the gneiss-rich rock sequence. The fluids may have either a magmatic source or an ultrametamorphic one;

- a third idea (Radu, 1990) puts forward a subsolidus reconversion of a quartz-feldspar rich material, developed within pressure shadows of more competent rocks. Subsequent fragmentation and replacements gave rise to present day picture of the pegmatite swarms.

2^{nd} **Stop**: The Ciungi pegmatite area

The area is situated some hundreds of meters far from the Răzoare open pit. Here exist numerous waste dumps of old galleries, on which beautiful samples with black tourmaline and green apatite crystals can be found, as well as large muscovite lamellae. Garnet, zircon and beryl are very rare and can be found only by chance.

SECOND DAY

Crystalline schists from the Domoşei Valley perimeter (Fig. 30)

The major petrographic types that may be encountered in the area are the following: plagioclase gneisses, amphibolites, pegmatites and quartzites, crystalline limestones.

The plagioclase gneisses are the most widespread metamorphic and include a complex mineral association made up of overlapping mineral assemblages.

The main minerals, are: acid plagioclase, quartz, biotite, muscovite. In addition, chlorite and apatite frequently occur; sporadically kyanite, staurolite and garnet may be observed in limited zones.

The plagioclase is an oligoclase, with 20% An. It forms xenoblastic, highly interlocked grains or intergrown with micas. The plagioclase has frequently undergone plastic deformations, laminations, being elongated along the main rock foliation.

Locally the plagioclase was replaced by albite or potassic feldspar, represented by microcline bordering the plagioclase blasts.

The mica species are represented by muscovite and biotite. They occur as prismatic blades (sometimes deformed) disposed on the rock displacement planes. The mineral transposition from the primary foliation (S_1) of the rock onto the actual, very well outlined foliation (S_2) is rather common. Thus, muscovite has been mechanically transformed (deformation of the cleavage plane, initial cataclasis) and biotite has been intensely chloritized.

As an uncommon situation, biotite was observed as a neoformation mineral on garnet, as very fine blades developed along its fissures.

Garnet may occur either laminated along the S_2 foliation, rupturally deformed and substituted (sometimes pseudomorphosed) by chlorite or by biotite; or in subidioblastic grains strictly associated with quartz, disposed on displacement planes (foliation). The chemical analysis indicated almandine and spessartine, respectively.

The kyanite is rare and occurs only in primary mineral association. It forms short prismatic grains, associated with staurolite and muscovite, being substituted by a very fine sericite.

Staurolite is rather rare and it belongs also to the primary mineral assemblage. Its relation with kyanite is ambiguous, however there are several features that would suggest replacement of kyanite by staurolite.

The accessory minerals are: apatite, tourmaline, zircon.

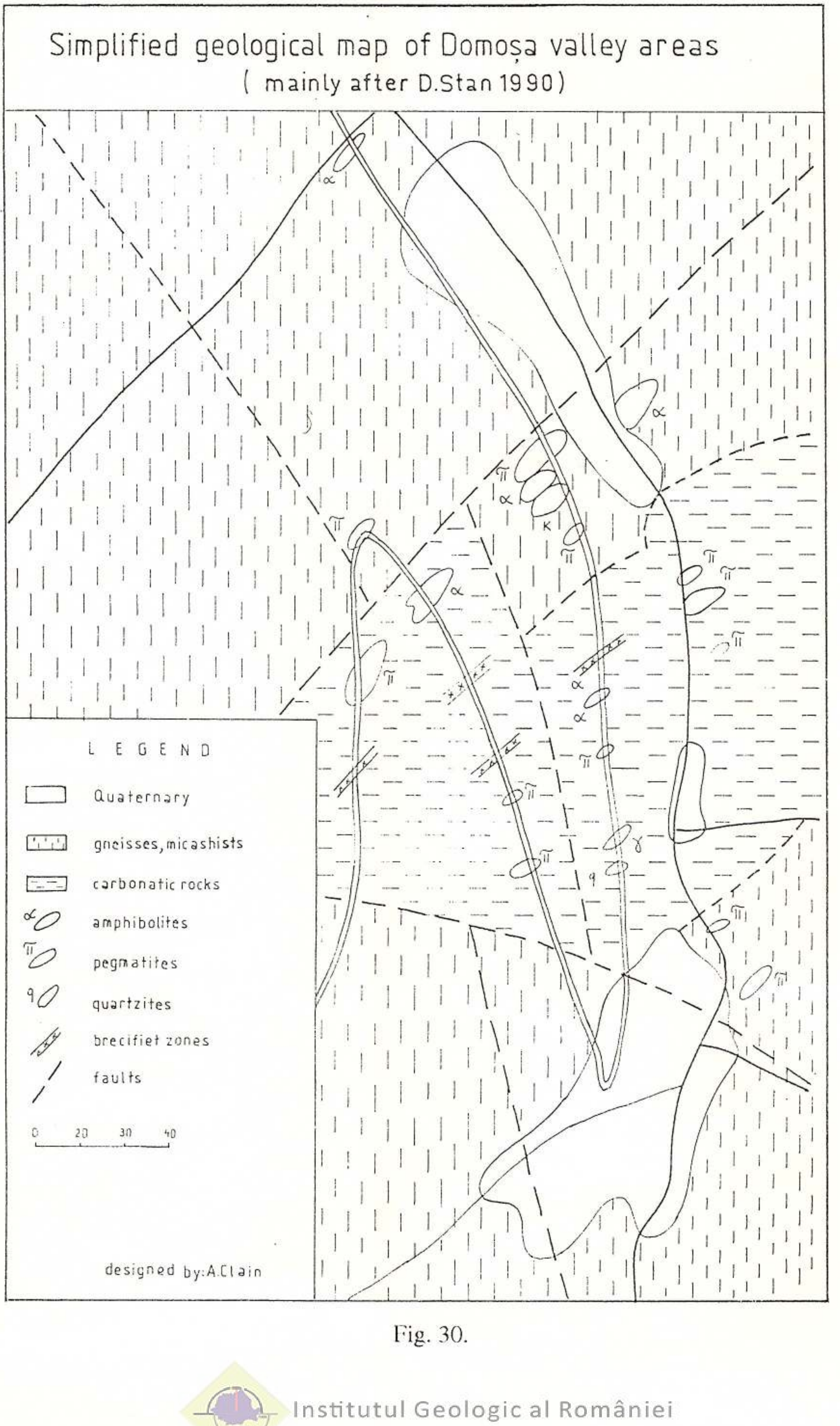
Simplified geological map of Domoșa valley areas
(mainly after D.Stan 1990)
LEGEND
Quaternary
gneisses, micashists
carbonatic rocks
amphibolites
pegmatites
quartzites
brecifiet zones
faults
0 20 30 40
designed by: A.Clain

Fig. 30.

Structurally the rocks exhibit rather various aspects. The lepidoblastic or porphyroblastic structures, however, are prevailing, resulting a S_2 with penetrating features that sometimes may erase S_1. An oblique fissure system compared to S_1 with frequent quartz and mica remobilization may also be observed.

The polydeformational character of the plagioclase gneisses is rather evident, frequently showing two S-planes and oblique fissures filled up with quartz and mica.

The amphibolites are less widespread compared to the plagioclase gneisses, developed as tabular or circular bodies "included" into the gneiss mass. The main minerals are: amphiboles, plagioclase, biotite, titanite, garnet, chlorite, epidote, opaque minerals.

The amphiboles are represented by green hornblende and actinote.

The green hornblende practically appears in all of the studied thin sections, as blastic elongated prismatic grains along the S_1 foliation commonly transposed penetratively onto the S_2 foliation of the rock. It may have poikiloblastic aspects including titanite, quartz or epidote. It is substituted by chlorite or actinote. Accidentally, in addition to the actinote, along the cleavage finely developed biotite grains may occur.

The plagioclase is an oligoclase with 17-23% An, like that of the plagioclase gneisses. It occurs as isolated grains, xenoblasts in the amphibole mass, having undergone transformations into a clay or sericitic mineral mass. It could be marginally corroded by albite (as a very fine ring around the plagioclase blasts). Besides the green hornblende, it is the primary mineral of the association.

Epidote and titanite are poikiloblasticly included into amphibole. These minerals may be both primary and reaction minerals.

The crystalline limestones have a limited distribution forming small "wedges" within the plagioclase gneisses. Its mineralogy is simple, including dolomite and calcite, developed in highly intergrown blastic grains.

Besides calcite and dolomite, tremolite, chlorite, talc (?) as reaction minerals of dolomite with quartz may be locally observed.

The pegmatite cropping out in the Domoşei Valley - Copalnic area form veinlets of 0.5 m thick, hosted by plagioclase gneisses or crystalline limestones. The mineralogy of these pegmatite bodies varies from body to body, from the very simple, (exclusively quartz and plagioclase feldspar) to the very complex one, including plagioclase feldspars, quartz, muscovite, biotite, garnet, tourmaline, microcline, apatite, chlorite and zircon.

Metamorphic rocks in the Cristurii Valley and Grajdului Valley (Fig. 31)

The metamorphic rocks between the Cristurii Valley and Grajdului Valley (Preluca Mts.) are structurally situated on the upper part of the Preluca Nouă formation (Balintoni, 1982) along the limit with the Cavnicului Valley formation. They consist of: plagioclase gneisses, amphibolites, micaschists.

The plagioclase gneisses are the most widespread rocks of the area. Their mineralogy is complex including:

- primary minerals: acid oligoclase (17-20% An), albite, quartz, muscovite, biotite, garnet, ± green hornblende, ± potassium feldspars (microcline)
- secondary minerals: chlorite, epidote, titanite, carbonate
- accessory minerals: apatite, zircon, rutile.

Commonly the rocks exhibit two S-planes.

Amphibolites form tabular or circular bodies in the plagioclase gneisses, their thickness ranging from several metres to several ten metres. The main primary minerals are: oligoclase, green hornblende and quartz. The secondary minerals: actinote, chlorite, albite, epidote, titanite, carbonates; accessory minerals: rutil (± ilmenite).

The rocks appear polydeformed with a penetrative S_2. Simultaneously one may observe fissures that are discordant with the S_2, quartz, chlorite or sometimes adularia may be observed "cutting" the entire amphibole mass.

Micaschists are less developed than the amphibolites, forming 'thin" alignments within the plagioclase gneiss mass (i. e. the alignment along Grajdului Valley). The micaschists include: quartz, muscovite, biotite, garnet, staurolite, kyanite as principal minerals, chlorite as secondary mineral and apatite, tourmaline, zircon as accessory minerals.

Based on microscopic and field observations a succession of mineralogical and structural transformations that affected the gneisses, amphibolites and micaschists as well, could be outlined.

During the first stage, the regional metamorphism (of the amphibolite subfacies with almandine) is overlain by a retromorph evolution (the green schist facies, the albite+epidot subfacies) resulting the following chemical reactions:

- in the plagioclase gneisses:

$\rightarrow$ oligoclase + almandine + biotite + H_2O + CO_2 $\rightarrow$ albite + chlorite + muscovite + calcite + quartz

$\rightarrow$ oligoclase + biotite ± H_2O ± CO_2 $\rightarrow$ albite + muscovite + zoisite ± calcite + quartz

$\rightarrow$ oligoclase + biotite + almandine + H_2O $\rightarrow$ muscovite + chlorite + epidot

- in the amphibolites:

$\rightarrow$ green hornblende + H_2O $\rightarrow$ actinot + chlorite + epidot

$\rightarrow$ green hornblende + H_2O + $CO_2$$\rightarrow$ chlorite + titanite + epidot + quartz

The thermo-baric equilibrium of these reactions suggests temperatures ranging between 410 - 500 ^{0}C and a pressure of 2-3 kb.

The second evolution stage involves an abundant K-feldspar development. The supply resulted from outside of the system generated by several migmatite bodies (Kalmar, 1973).

The third evolution stage was generated by the NW-SE trending. The studied mineral reactions were the following:

staurolite + muscovite + quartz $\rightarrow$ kyanite + biotite + H_2O

muscovite + quartz $\rightarrow$ kyanite + orthoclase + H_2O

biotite + H_2O $\rightarrow$ chlorite + K$\uparrow$

To this third stage no neoformation of minerals is connected but intense mechanical transformations (plastic and cataclastic deformations).

The fourth evolution stage is connected to the development of NE-SW trending fissures and fractures. Frequently occur cataclastic phenomena, that sometimes might be called even blastomillonites, followed by adularization.

The characteristic mineral assemblage of this stage, occurring in the micaschists and plagioclase gneisses is: adularia + chlorite + epidote + calcite ± quartz.

Therefore, we may conclude that the metamorphism that has affected the crystalline schists of the Grajdului - Custurii Valley perimeter (Preluca massif) included four evolution stages, and can be regarded as polyphasic.

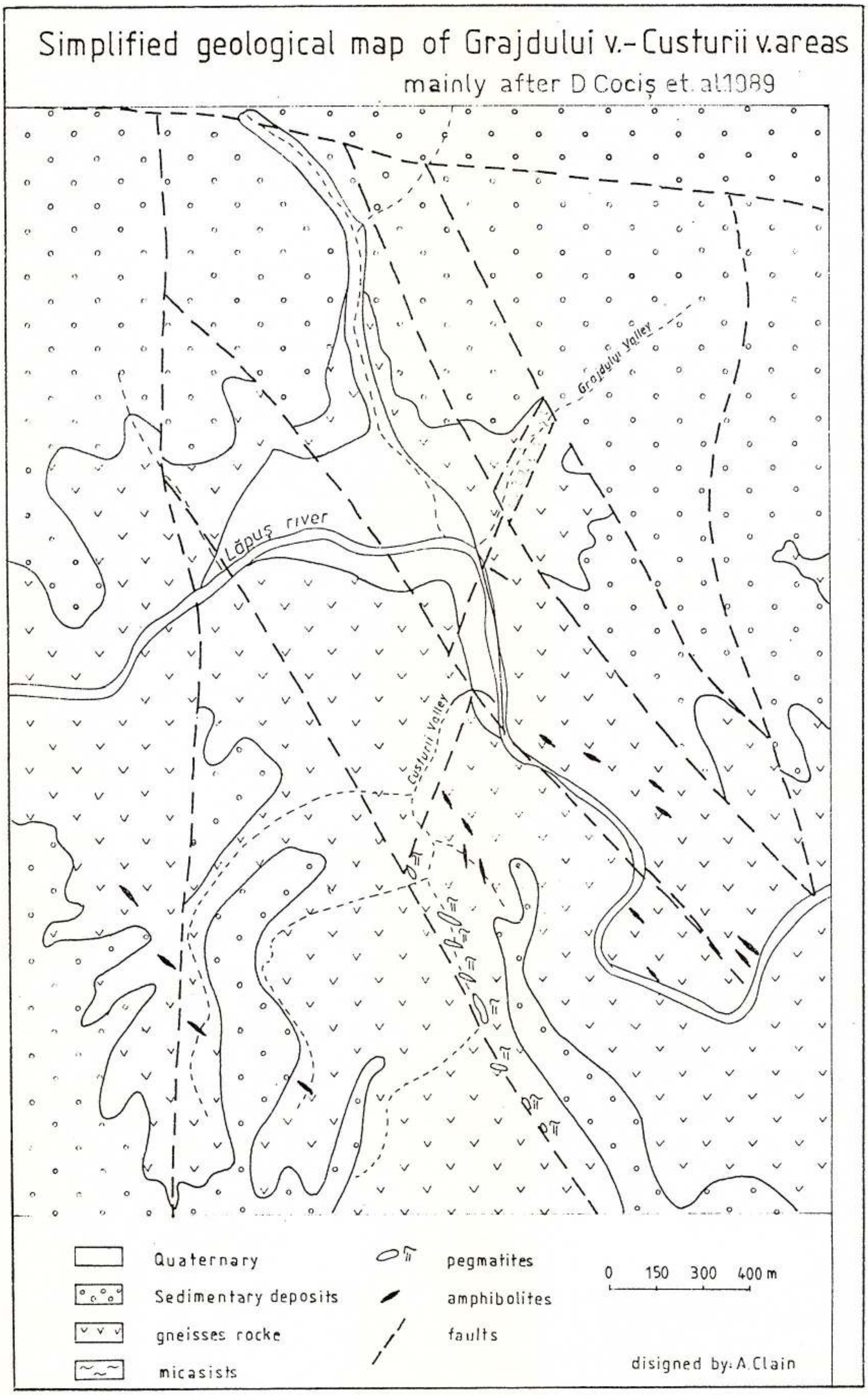
Simplified geological map of Grajdului v.- Custurii v.areas
mainly after D Cociș et. al.1989
Grajdului Valley
Lăpuș river
Custurii Valley
Quaternary
Sedimentary deposits
gneisses rocke
micasists
pegmatites
amphibolites
faults
0 150 300 400 m
disigned by: A.Clain

Fig. 31.

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