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QUALITATIVE AND QUANTITATIVE METALLOGENETIC ANALYSIS OF THE ORE GENETIC UNITS IN ROMANIA



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Executive Secretary: Georgeta Borlea

Editorial Office:
Geological Institute of Romania
Str. Caransebeș Nr. 1
RO - 79678 București - 32
Tel. (+40) 1 224 13 30, 224 20 91
Fax (+40) 1 224 04 04
e-mail: geol@igr.sfos.ro

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INSTITUTUL GEOLOGIC AL ROMÂNIEI
GEOLOGICAL SURVEY OF ROMANIA

QUALITATIVE AND QUANTITATIVE
METALLOGENETIC ANALYSIS OF
THE ORE GENETIC UNITS
IN ROMANIA

Compiled by

M. Borcoş, Ş. Vlad, G. Udubaşa, B. Găbudeanu

Bucureşti, 1998



PREFACE

Since its foundation in 1906, the Geological Institute of Romania (GIR) played the role of a Geological Survey with the main aim to realize and to print geological maps on different scales. The GIR was also the birth place of (1) soil science in the country (1907), later on evolved as a specialized institute in the frame of Ministry of Agriculture, (2) of marine geology (1975) recently (1995) transformed into the National Institute of Marine Geology and Geoecology, (3) of Geophysics (1925), partly moved (geophysical prospecting) to the Prospecting Enterprise, (4) of geochemistry (1950), evolved as a laboratory for preparing and editing the geochemical map of Romania, and (5) remote sensing (1973), which became and is now the best endowed laboratory of this kind in Romania.

The country coverage with various geological maps is relatively good, the 1:500,000, 1:200,000 and 1:1,000,000 maps being already printed, as well as the basic geological map on the scale 1:50,000 which covers now about 80 % of the mountainous areas of Romania. By using all the available data (geological and geophysical) cross sections on the scale 1:200,000 were also printed; they radially cross all the country's significant geological entities and/or units. In addition, different specialized maps, e.g. geophysical, hydrogeological, ecological etc. are also existing.

The geochemical atlas of Romania on the scale 1:3,000,000 is now being printed and that on the scale 1:1,000,000 is being prepared. The genetic map of mineral deposits on the scale 1:1,000,000 and the map of mineral resources on the scale 1:500,000 will be soon finished and printed.

The GIR with a coordinating and workable role has elaborated thorough studies and documentation for all mineral resources from Romania. After 1990 the estimated potential of reserves and resources has been reassessed according to the classification systems recommended by European Economic Commission.

The publications of the GIR also cover all the active geoscience fields in the institute, from mineralogy, through petrology, mineral deposits and environmental geology to regional geology and tectonics.

In the activity of the GIR both basic geoscience development and applied research are assured by a staff of about 160, from which more than 42 individuals have already the Ph.D. and about 20 are "on the route" to obtain it.

This is why the GIR can provide any type of geological information and the present book is a presentation on a national scale of the results of the qualitative and quantitative metallogenetic studies inferred from the geotectonic evolution of the territory. The book should be a first help to any foreign company interested to invest in the Romanian mining industry. The related maps, available for sale, could be anytime supplemented by more detailed maps of zones of special interest. The ore deposits classified here do not always discriminate the mined resources and the targets as the latter might provide supplementary information about the extension and development of the ore fields and zones.

The data presented below are based on a compilation from the most representative published and unpublished reports of the GIR, mostly totally taken over, partly adapted and/or completed (Giușcă et al., 1969; Ianovici, Borcoș, 1983; Rădulescu, Kräutner, Borcoș, 1984; Borcoș et al., 1983-1984; Udubașa, 1984, 1987, 1993, 1996; Udubașa et al., 1998; Vlad, Borcoș, 1994, 1997; Borcoș, Vlad, 1994; Borcoș et al., 1994-1998; Borcoș, Găbudeanu, Rădulescu, 1994; Găbudeanu, Borcoș, Vlad, 1997-1998), thus ensuring a homogeneous form of presentation, at the same time offering alternatives to recent theories.

For a more detailed information, the references also include other published and unpublished geological reports not cited in this paper.

Prof. Dr. G. UDUBAȘA
Director General of GIR

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I. INTRODUCTION

Geographically, Romania is located in Central Europe, at nearly the same distances far from Ireland, North Cap and Sverdlovsk (Fig. 1).

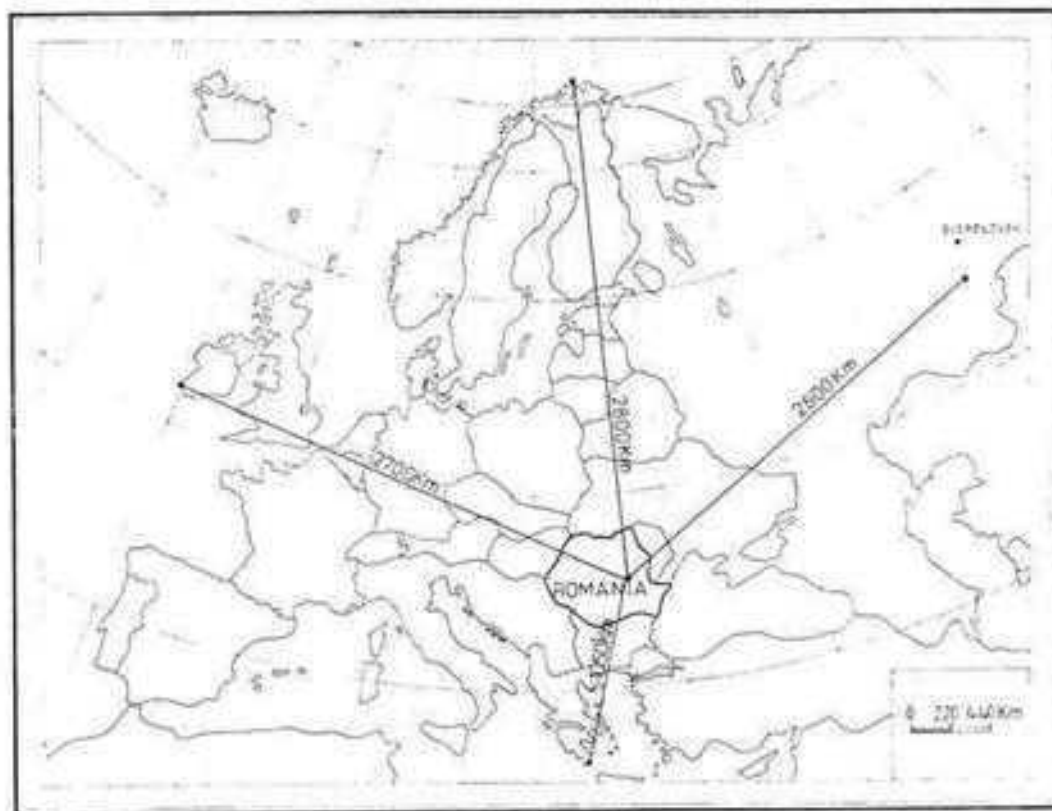


Fig. 1 - Romania. Location

In European terms, Romania is rich in mineral potential, especially oil, gas, salt, gold and silver ores and non-ferrous metals. Historically, the Romanian mining industry has frequently been at the forefront of European development, often leading the way to the identification and evaluation of deposit types that have subsequently proved to be of major importance elsewhere.

In Romania varied ore deposits have been exploited from the earliest times, gold, copper, lead, zinc, manganese, iron and salt having been worked extensively.

Archaeological evidence suggests that there has been mining in Romania for thousands of years, with artifacts from various ages having been shown to have been made from locally produced metals and minerals. Ore production became better organised during the Roman period, while simultaneously processing techniques became more diversified (Borcoş et al., 1994).

The earliest mineral working for which evidence exists was Palaeolithic flint and stone production: the sites of several "workshops" having been identified (Fig. 2). Gold production commenced at Cireşata in the Brad district of the Apuseni Mountains during the Neolithic period (10,000-1,900 BC) both from hard-rock and alluvial deposits; salt was also produced at this time from the Moldova region, and possibly copper. Artifacts indicate that copper smelting and casting were practised and coloured ceramics from this period show

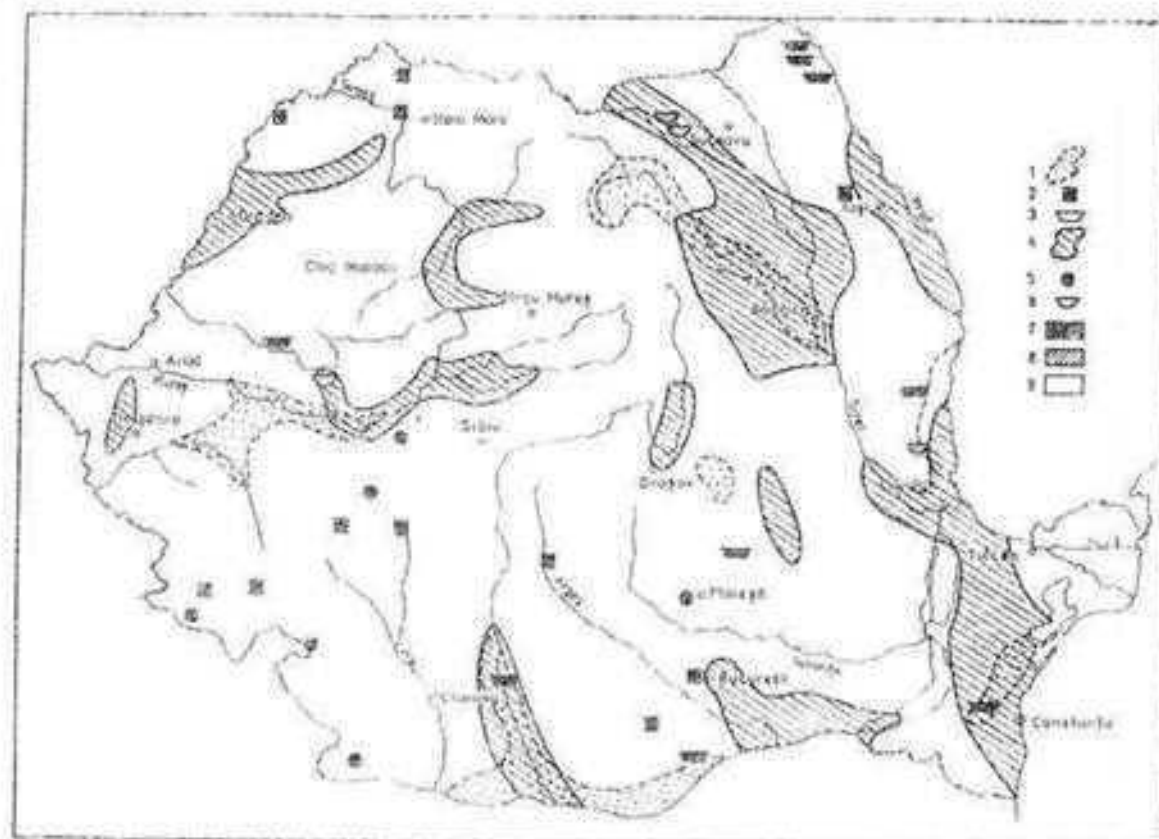


Fig. 2. Mining activity in the Palaeolithic-Neolithic period (see to Boroş et al., 1994)

Key: Palaeolithic: 1 - areas of abundant archaeological discoveries; 2 - unconnected archaeological sites; 3 - extraction sites; Neolithic: 4 - areas of abundant archaeological discoveries; 5 - unconnected archaeological sites; 6 - extraction sites; 7 - stone flint; 8 - salt; 9 - gold.

that manganese was used as a pigment.

During the Bronze and early Iron Ages, gold and copper were produced in Transylvania, and in the Banat, Oltenia and Dobrogea districts (Fig. 3). Gold production was also centred on the Metaliferi Mountains, in the Brad district and probably at Roşia Montană. Salt was produced through evaporation, and bronze, gold and iron production was widespread.

Between 450 BC and 106 AD in the Geto-Dacian period, underground mining commenced for gold, other metals and for salt (Fig. 4). Large-scale quarries were opened for building stone and metallurgical technology progressed, with the introduction of reducing furnaces for iron ore. Bronze, gold and silver metallurgy and manufacture also developed, the scale of gold production being indicated by the 165,000 kg of gold that were taken to Rome as spoils of war by the emperor Trajan.

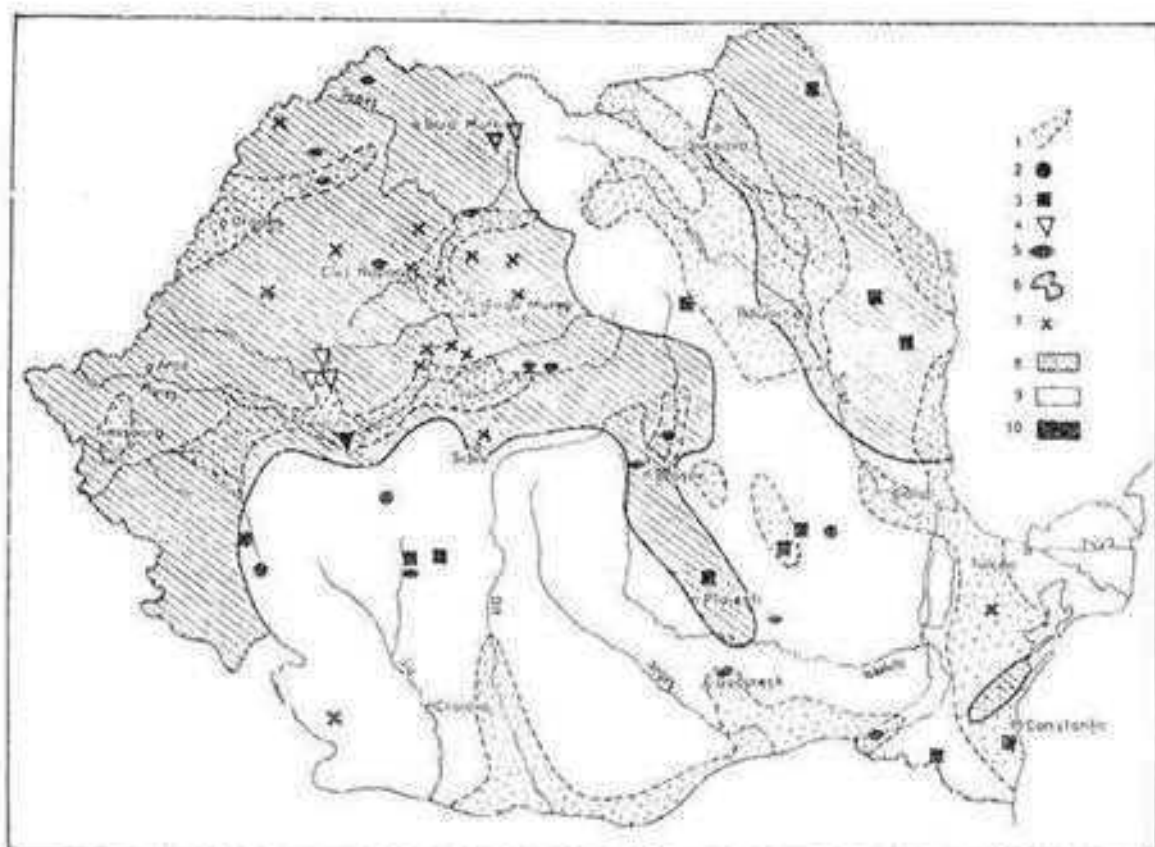


Fig. 1 - Mining activity in the Bronze and First Iron Ages (acc. to Borcos et al., 1984)

Key: 1 - areas of abundant Palaeolithic and Neolithic archaeological discoveries; 2 - unconnected archaeological sites in the bronze age; 3 - unconnected archaeological sites in the first Iron Age; 4 - extraction sites; 5 - bronze processing centres; 6 - areas of abundant Bronze and First Iron Age archaeological discoveries; 7 - iron processing centres; 8 - salt; 9 - gold; 10 - copper.

Mining activity increased during the Roman period with intensive working of deeper deposits as well. Lead production increased from iron and copper smelting, silver output was derived from non-ferrous ores and cinnabar was produced for use as a dye. Existing centres of gold, silver and salt production included the Metaliferi and Polna Ruscă Mountains and the Banat district, and new centres appeared in the Rodna and Baia Mare district.

Metal and salt mining continued after the Roman period, new deposits being identified and worked and cast iron being produced for the first time (Fig. 5). Between the 13th and 17th Centuries, new mining technologies were introduced, and water-powered stamps came into use for ore crushing. New deposits of copper, lead, zinc, iron and manganese were also found in the East Carpathians during this time, and towards the end of the period the first records of the country's mining heritage were produced. The second half of the 17th Century marked the appearance of the first institutions whose main goals were to organise, supervise (local offices, masters' offices, commissariats and mining inspectorates) and settle (mining tribunals and courts of law) mining activity. The first mining law came into force in 1854, being replaced in 1924 by a new law on the constitution of the unitary Romanian state.

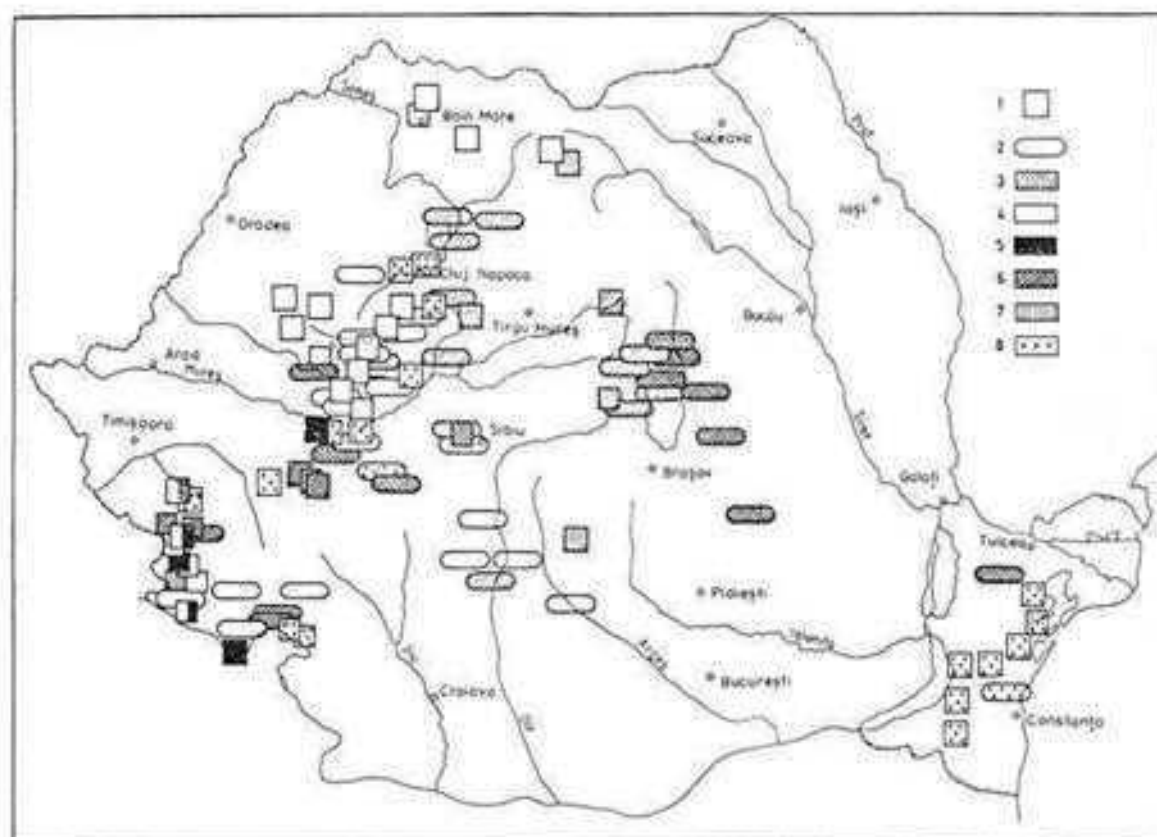


Fig. 4 - Mining activity in the Second Iron Age and Roman periods (acc. to Borcoş et al., 1994)

Key: 1 - active mining sites in the Roman period; 2 - active mining sites in the Geto-Dacian period; 3 - salt; 4 - gold; 5 - copper; 6 - iron; 7 - lead; 8 - building stone.

The industrialisation of the mining industry since the mid-19th Century included the introduction of modern explosives, mechanised drilling, and the use of electrical power underground. Between 1890 and 1896 California stamps, roll mills and ball mills were introduced for ore reduction, copper calcining commenced in 1876 and in 1917 Romania's first cyanidation gold plant opened.

The last 150 years have seen the compilation of a huge amount of data about Romania's mineral deposits and potential. All major areas of interest have been covered, including those of potential hydrocarbon interest. Reference must also be made to the large number of minerals that were first identified in Romanian deposits, including the element tellurium, which was discovered in gold ore at the Faţa Băii ore deposit (Zlatna district) in the Metaliferi Mountains.

In the past, numerous deposits have been evaluated and have been either exhausted or abandoned on the basis of criteria that do not apply in today's economic environment. As yet, there has been little opportunity to re-evaluate such occurrences, although the country's agencies responsible for exploration and development retain a huge amount of information on all aspects of deposit geology and resource estimations, obtained from past drilling programmes and thorough geological investigation. Even in recent years, exploration by the state agencies has hampered by lack of resources, and there is thus excellent potential for

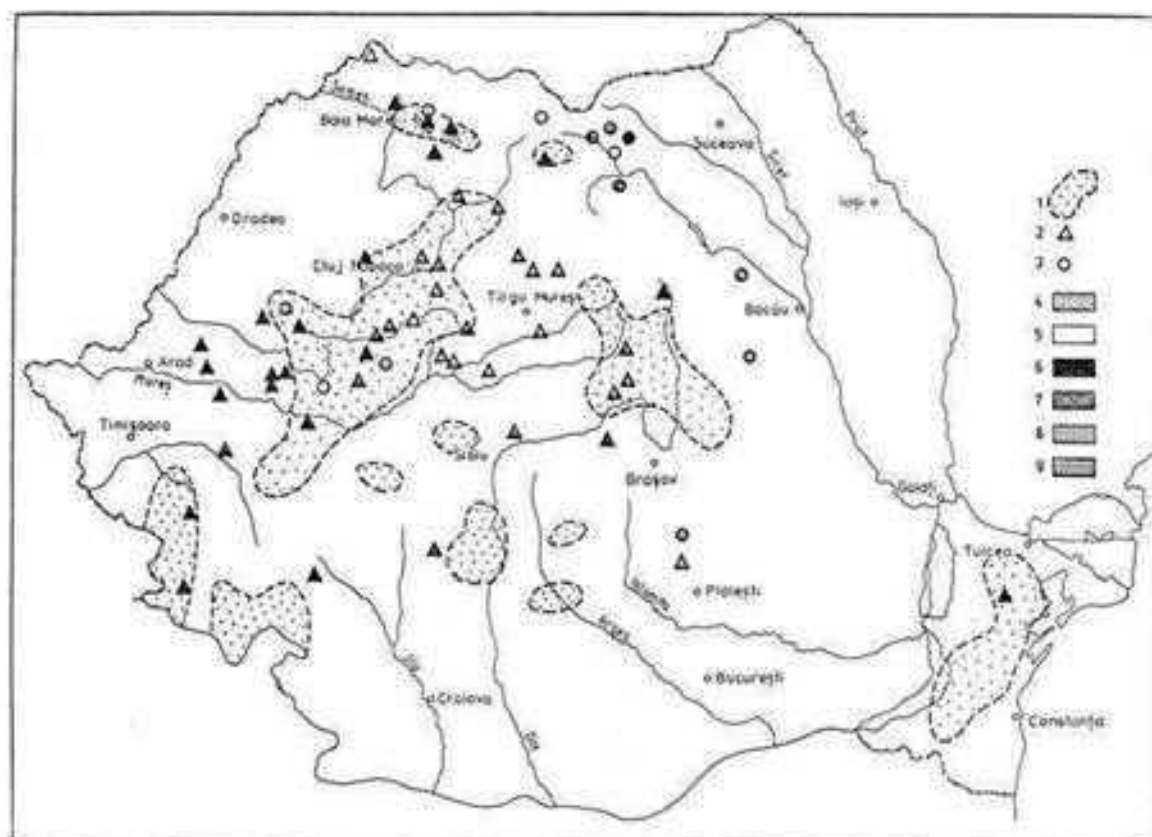


Fig. 5 - Mining activity in the pre-feudal and feudal periods (acc.to Borcoș et al., 1994)

Key: 1 - active mining areas in the Geto-Dacian and Roman periods; 2 - active mining areas in the pre-feudal period; 3 - active mining areas in the feudal period; 4 - salt; 5 - gold; 6 - copper; 7 - iron; 8 - lead and zinc; 9 - mercury.

overseas investment in both grassroots exploration and the re-appraisal of properties about which substantial amounts of data already exist.

Recent geological and geophysical work has shown that there are, in fact, many mineral prospects both near-surface and at depth that have considerable potential for further investigation, and that offer interesting opportunities for overseas investors interested in the country's mineral resources:

The most productive mining centres with classical metalliferous ore deposits (containing gold, silver, lead, zinc, copper, iron and manganese) are located in Neogene volcanic zones in the Metaliferi and Oaș-Gutâi Mountains (referred to as types a1 and a2 respectively in Table 1), and in the Banat region (b1) and in the Bihor massif (b2) related to Upper Cretaceous-Paleocene intrusive structures, as well as in the East (c1) and South Carpathians in the Poiana Ruscă massif (c2), or in Dobrogea (c3), the latter related to Palaeozoic or older metamorphic rocks. The significance of these zones, worked intensively since ancient times, is shown by the amount of metals (extracted and existing potential) estimated for some of the representative ore deposits.

II. MAJOR GEOTECTONIC UNITS OF ROMANIA

MOBILE ZONES

From both structural and metallogenetic points of view the Romanian territory belongs to the Alpine realm and represents a part of the subglobal Mediterranean (Tethyan)-Himalayan belt.

Geomorphological units of the Central and South-Eastern Alpine orogen are as follows: Eastern Alps, West Carpathians, East Carpathians, Apuseni Mountains, Transylvanian Basin, South Carpathians, Balkans-Srednagora, Pannonian Basin, Serbo-Macedonian Massif, Rodopi Massif, Dinarides, Albano-Hellenides (Fig. 6).

Romania comprises the Carpathian Mountains chain, namely the East and South Carpathians, Apuseni Mountains, with intramontaneous Transylvanian and Pannonian Basins, surrounded by the foreland (mainly plains in Moldova and Muntenia, eroded mountains in Dobrogea). The major geotectonic units are represented by two mobile Alpine regions, the Carpathian and Northern Dobrogea, and pre-Alpine cratons (Moesian, Scythian and Moldavian platforms).

The Carpathian chain is a long-lived (pre-Alpine and Alpine) orogen bound westwards by the Alps and south-eastwards by the Balkans. It has a peri-cratonic position, south of the Eurasian Plate. This structure is built up in Romania of inner units (North Apuseni Mts.), moulded by the external Carpathian arc (the East Carpathians), as well as the South Carpathians which consist of basement and cover nappes, magmatic belts and massifs, sedimentary post-tectonic structures.

The basement nappes are built up of pre-Mesozoic crystalline schists and Upper Paleozoic-Mesozoic sedimentary rocks (Inner Dacides, Median Dacides and Marginal Dacides). The Inner Dacides occur in the North Apuseni Mts., as a prolongation of the Austroalpine structure of the Eastern Alps; the main tectogenetic event is pre-Gosau. The Median Dacides develop from the East to the South Carpathians. The innermost part of the East Carpathians ("Crystalline-Mesozoic zone") contains Bucovinian, Subbucovinian and Infrabucovinian nappes formed during Hercynian and Austrian deformations. The Bucovinian Unit proceeds to the West Carpathians, whereas the Subbucovinian and Infrabucovinian nappes correlate with Supragetic and Getic Nappes of the South Carpathians, which were involved in Laramian deformations too. The Supragetic and Getic units proceed to the Serbo-Macedonian massif and farther to the Inner Balkanides, Rhodopi and Strandja, the Marginal Dacides occur in the South Carpathians and were considered earlier as Autochthon ("Danubian realm"). Modern interpretations divide them into the Lower Danubian Unit and Upper Danubian Unit, both involved in pre-Alpine and Alpine/Austrian and Laramian thrustings. Recent drilling data provide evidence of Danubian thrusting over the Moesian Platform during intra-Sarmatian deformations.

Cover nappes built up of Mesozoic flysch sediments and ophiolites are represented by Transylvanides in the South Apuseni Mts and East Carpathians and External Dacides in the East and South Carpathians (black flysch nappes proceeding to Ukraine and Ceahlău-Severin nappe to Eastern Serbia and Srednagora). The main tectogenetic events are Austrian and Laramian.

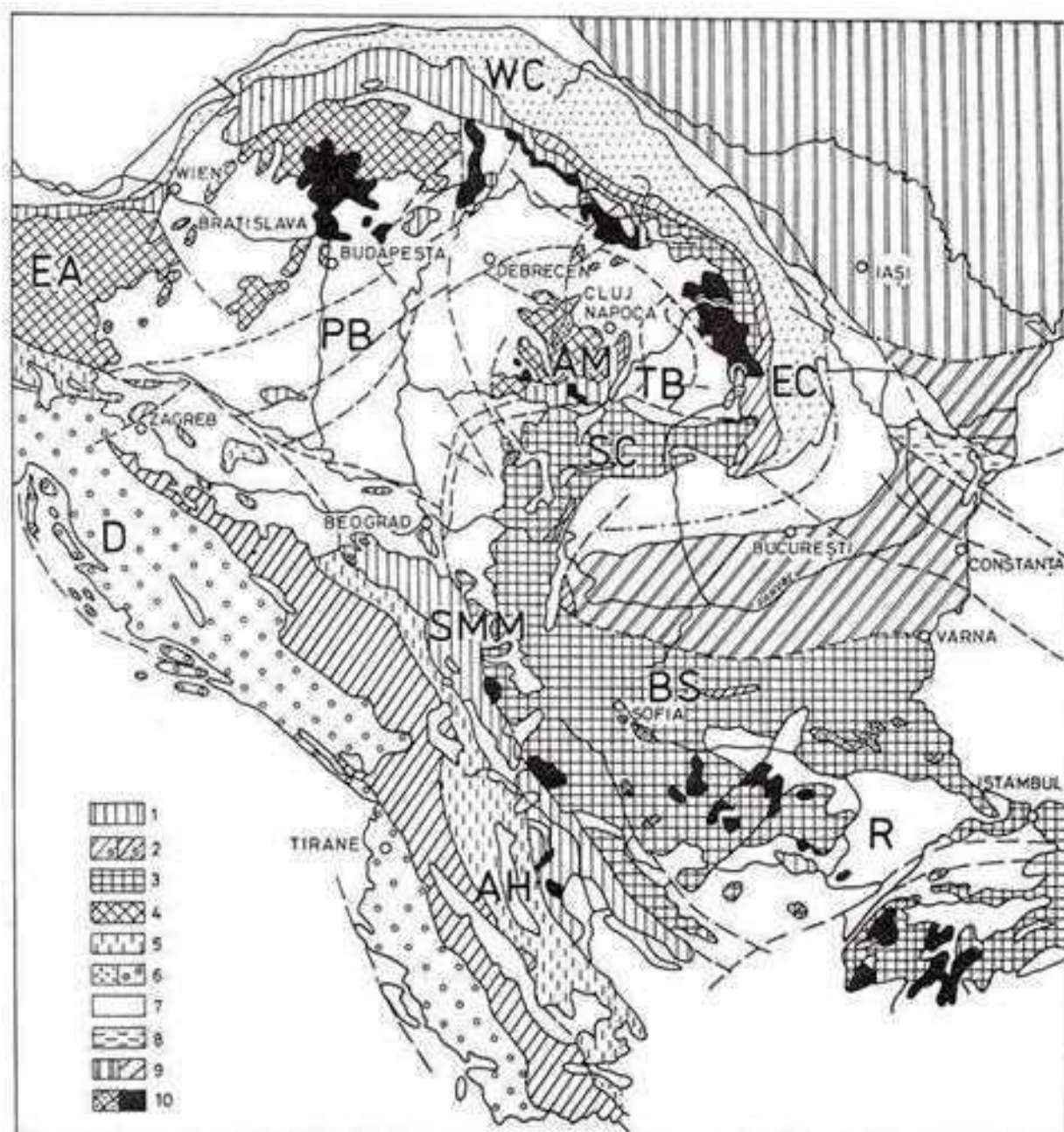


Fig. 6 - Carpatho-Balkan orogen and adjacent areas (geotectonic setting according to Săndulescu, 1984; geomorphological parts according to various authors).

Key: EA - Eastern Alps; WC - West Carpathians; PB - Pannonian Basin; AM - Apuseni Mountains; TB - Transylvanian Basin; EC - East Carpathians; SC - South Carpathians; D - Dinarides; SMM - Serbo-Macedonian Massif; BS - Balkan-Srednogora; AH - Albanides-Hellenides; R - Rodopi. 1, Neotethysian suture; 2, adjacent sutures: a) Ceahlau Severin-Strandja zone; b) Pindus-Serbian zone; 3, European basement units; 4, pre-Apulian basement units; 5, Apulian/Pelagonian basement units; 6, cover units: a) Moldavides; b) outer Dinarides and Hellenides; 7, Post-tectonic cover; 8, North-Dobrogea; 9, platforms: a) Moldavian (East European) platform; b) Moesian and Scythian platforms; 10, Alpine magmatic rocks: a) Banatites; b) Neogene igneous rocks.

Cover nappes built up of Upper Cretaceous-Paleogene flysch sediments and Miocene molasse in the East Carpathians that consist of Pienides (a relay of the Transylvanides, proceeding to Ukraine; the main tectogenetic events are Laramian and Lower Miocene) and Moldavides (a group of six nappes proceeding to the Ukraine; the tectogenesis was multistage during the Neogene times).

Magmatic belts and massifs of various ages are incorporated in, or penetrate, parts of the above-mentioned groups of nappes. Worth mentioning are Danubian pre-Alpine granitoids and, especially, two major petrogenetic assemblages of calc-alkaline character: the Laramian magmatic belt ("Banatites") in the Apuseni Mts. - South Carpathians and in the Tertiary volcanic arc in the East Carpathians with related South Apuseni occurrences.

Sedimentary post-tectonic structures consist of the foredeep around the East and South Carpathians, molasse depressions, that is Pannonian and Transylvanian Depressions, post-tectonic covers throughout the whole Carpathian range.

The North Dobrogea area has no connection with the Carpathians and is a shorter-lived structure when compared to them. This region is the western part of a chain proceeding from the South Crimea and Greater Caucasus. It contains tectonic units built up of pre-Mesozoic crystalline schists, anchimetamorphic rocks and granitoids in the west, and prevailing carbonatic-clastic and bimodal basaltic-rhyolitic rocks in the east. The main compression took place during the Kimmerian tectogenesis.

PRE-ALPINE PLATFORMS

The Moesian Platform represents the Carpathian foreland in the southern part of the country. It is separated into two sectors by the Intramoesian fault (Dobrogea sector and Wallachian-Prebalkan sector). The basement is Precambrian and the cover ranges from the Paleozoic to the Cenozoic.

The Scythian Platform correlates with the Central European Platform and corresponds to "Meso-Europa" (Stille, 1924) of Epihercynian timing.

The Moldavian Platform corresponds to the termination of the East European Platform, south of the Ukrainian Shield. The basement is Precambrian and the cover Precambrian to post-Precambrian.

GEODYNAMIC EVOLUTION OF THE ROMANIAN TERRITORY

The geodynamic evolution of the Romanian territory followed successive cycles of ocean opening and closing (Wilson orogenic cycles). Geologic, structural and metallogenetic data provide evidence for reconstitution of more recent and post-tectonic settings. The only complete sequence of spreading/compression events belongs to the Alpine cycle whereas pre-Alpine cycles are represented by parts of their sequences incorporated in Alpine structures.

The present-day architecture of the Romanian territory is associated with the development of the Tethyan trench system (Palaeo- and Neo-Tethys). Both short-lived and more evolved rifts are characteristic of this setting and yielded various types of magmatic and metallogenetic products. Interpretation of ocean floor spreading, subduction, collision and

post-collision events is sometimes difficult because of contradictory assessments about the use of plate/microplate/sialic block, subduction or subfluence, ophiolite meaning/significance (island arc and/or ocean floor spreading products), calc-alkaline volcanicity (subduction-related or rift-related magmatism), position to and correlation with the major Tethyan suture, accept or refusal of back-arc settings in the Carpathians etc.

Pre-Alpine geodynamic models-paleotectonic reconstructions in the Carpathians are difficult to ascertain. The Alpine evolution, according to recent interpretations (especially Săndulescu, 1983, IGCP Project no.198 etc.), is related to the main Tethyan suture, that is the Vardar zone and its prolongation crossing the Carpathian orogen. During the spreading period the Transylvanian oceanic area and the intracontinental rift of the External Dacides occurred. Compressions gave rise to the actual curved Carpathian configuration and the complex nappe structures, whereas the calc-alkaline magmatism is considered of subduction type and assigned to the external Dacitic trough. An alternative hypothesis postulates the inheritance of the Carpathian curvature (e.g. Vlad, 1980, 1986, IGCP Project no.169).

The linear distribution of the magmatic arcs suggests a restricted transversal arc migration; their pinning is aquiescent to compression of the above-mentioned narrow elongated troughs and arc range behind the elaborate curvature of the East Carpathians. Different portions of the magmatic arcs exhibit changes in evolution, ages and petro-metallogenetic characteristics along strike and/or width; association with back-arc extensional products is not uncommon.

The North Dobrogea geodynamic model is based on a complete orogenic evolution in Paleozoic (spreading compression with subduction and collision products), followed by rifting, formation of oceanic crust, deformation with nappe thrusting during Kimmerian times (Săndulescu, 1984). The alternative interpretation put forward the role played by the Triassic intracontinental rifting with bimodal magmatism yielding an aulacogen-like failed arm linked with the Tethys through the Crimea and Greater Caucasus (Vlad, 1978).

III. QUALITATIVE METALLOGENESIS OF THE ROMANIAN TERRITORY

The metallogenic map of Romania (scale 1:2,500,000), prepared by Ianovici, Rădulescu, Dimitrescu, Kräutner and Mirăuță in 1966, was the first attempt to present the metallogenetic elements of Romania in a systematic form. Subsequently the same method of presenting processes in terms of both time and space was used by Rădulescu, Borcoș, Kräutner, Savu, Vasilescu in 1969 to produce a metallogenetic map of Romania on the scale of 1:1,000,000. This shows the structural, stratigraphical, geochemical and geodynamic control on the conditions of formation of the accumulations of metallic and non-metallic useful mineral resources, and also the position and particular characteristics of the 24 metallogenetic provinces defined.

According to the idea adopted, which is also used in the maps on a scale of 1:200,000 produced for the main mining regions of the country, a metallogenetic map, regardless of scale, represents the "genetic units" of mineral concentration with their typical areas of development. Each genetic unit is identified in geographical and temporal terms as part of the process of geological evolution by its particular conditions of accumulation,

typically reflected in the relationships between its genetic and geochemical characters and the processes of magmatism, sedimentation and metamorphism. It was decided that the basic unit may reasonably be considered to be the metallogenic province which, with rare exceptions, coincides with the corresponding petrological units. Detailed work carried out having regard to the geographical distribution of ore deposits, as also to their age and paragenetic and geochemical nature, led to the defining of subordinate metallogenic units - sub-provinces, zones, districts, fields - or even to the individual identification of a number of isolated deposits. This mode of presentation may be considered as classic and is able to provide the maximum amount of information needed for an understanding of the combination of circumstances which led to the formation of useful mineral resources. This information was subsequently used as a basis for the preparation of the scale 1:1,000,000 maps of useful mineral resources in Romania and of numerous prognostic maps and documents (Borcoş, Kräutner, Udubaşa, Săndulescu, Năstăseanu, Biţoianu, 1984).

The concept of plate tectonics concerning the Romanian territory was introduced in the geological literature in the early 70's (e.g. Rădulescu, Săndulescu, 1973; Bleahu, 1974; Hertz, Savu, 1974 etc.).

First metallogenetic interpretation in terms of plate tectonics is due to Ianovici, Vlad, Borcoş and Boştinescu (1977) taking into account Romanian porphyry copper occurrences. Subsequent significant contributions on plate tectonics and metallogenesis belong to Vlad, concerning North Dobrogea (1978) and Banat metallogenesis (1979), Cioflica and Vlad (1980, 1984), Vlad (1986) about Alpine metallogenesis, Folea, Vlad and Berbeleac (1987) referring to Cu-Pb-Zn metallogeny during Alpine and pre-Alpine Wilson cycles, Berbeleac (1988), Rădulescu, Borcoş and Săndulescu (1994) who correlated the main relations between geotectonics and metallogenesis during the Alpine time taking into account metallogenetic specialisation too, and Vlad, Borcoş (1994, 1997) on Alpine metallogenesis of the Romanian Carpathians.



Numerous ore deposits known and mined since Roman and even pre-Roman times (Au, Ag, Pb, Zn, Cu, Mn, Fe, etc.) have intensively been extracted, mainly the high-grade ores. Various metallic minerals were described as *locus typicus* occurrences the world over from very well-known ore regions as Baia Mare, South Apuşeni Mts and Banat. Baia Mare vein sets and the Gold Quadrangle are famous in the geological literature for their classical gold-silver deposits whereas skarns from Banat are reference deposits of this kind.

The occurrence/distribution of metalliferous deposits within the above-mentioned geotectonic framework is various from both quantitative and qualitative view-points. Platforms contain restricted deposits (iron and copper ores) only in the Dobrogean realm. The mobile regions are characterized by minor Ba, Cu, Pb, Zn, Fe mineralization in the North Dobrogea region and widespread mineralization throughout almost all stratigraphical levels of the Carpathian orogen. The complex geological structure of the Carpathians explains the great variety of the genetic/paragenetic metalliferous types resulted during a long evolution, from Precambrian to Quaternary. In some cases, the remobilization played an important role in the diversification of primary ore forming processes. Metallogenetic heredity and metallogenetic

evolution in association with events of several Wilson orogen cycles are basic concepts that permit a correlation attempt between geological features controlling pulsative ore deposition during several cycles with the inherent geochemical behaviour of major metals, obvious especially for the Upper Paleozoic and the Alpine cycle. Consequently, Precambrian, Paleozoic and Alpine metallogenetic events are taken into account and reviewed below (Fig. 7, Plate I).

PRECAMBRIAN METALLOGENESIS

Basement nappes of the Carpathians and a restricted area of Dobrogea expose in places were well preserved Fe, Pb-Zn and Cu-pyrite deposits assigned to undeveloped sequences of Wilson orogenic cycle/cycles. The Precambrian metallogeny represents only 5 % of the total resources estimates of the country. Iron ore predominates and builds 70% of the national iron potential. An overview on Precambrian metallogeny in the South Carpathians is given by Udubaşa (1987).

Metallogenesis associated with carbonate rocks (possible equivalent to metallogenesis related to intracontinental rifting, Vlad, Borcoş, 1997)

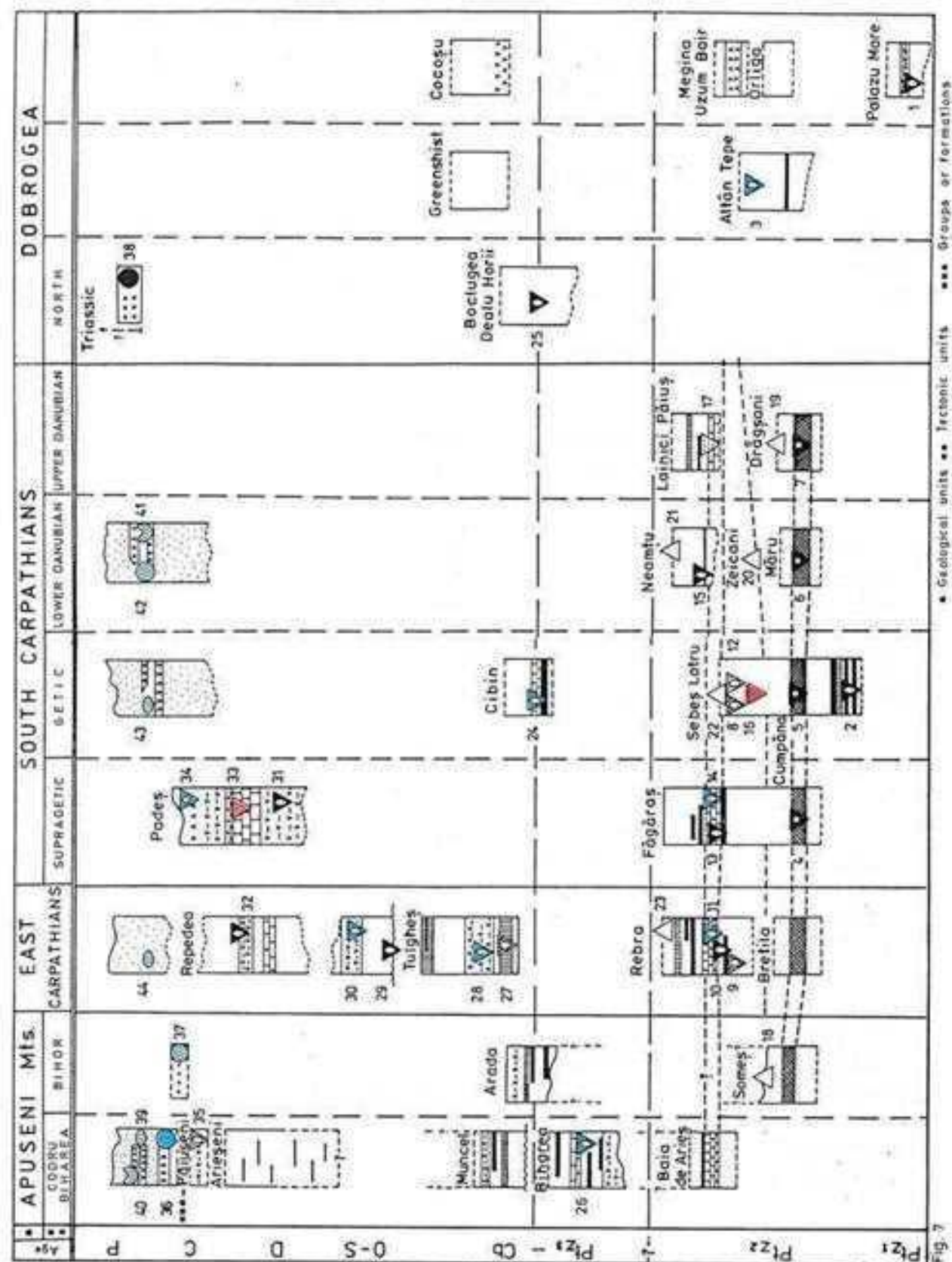
This activity is represented by Pb-Zn carbonate hosted occurrences found in the East and South Carpathians. The most significant deposits (e.g. Blazna Valley) are found in the medium-grade metamorphosed Rebra Group of Upper Proterozoic age (East Carpathians). Its middle part ("the carbonate formation") contains stratabound ores lenses (mainly pyrite, sphalerite, galena, chalcopryrite) related to silicate, graphite and quartz intercalations in carbonate rocks (Udubaşa, 1972/1996; Udubaşa et al., 1983). Minor occurrences of the same genetic type are located in the polymetamorphic Făgăraş Group (South Carpathians).

Massive sulphide deposits (possible equivalent to metallogenesis related to ocean-floor spreading, Vlad, Borcoş, 1997)

The metallogeny is provided by mineralization of Cyprus-like type. Massive Cu-pyrite ores are found in the Precambrian polymetamorphic Altân Tepe (AT) series of the Dobrogean craton (Fig. 8). The upper part of the Altân Tepe series (AT 2) exhibits a conspicuous volcano-sedimentary character and encloses several "en echelon" subvertical lenses of massive sulphides (pyrite, chalcopryrite, magnetite, sphalerite, galena, pyrrhotite) surrounded by impregnation pyrite halo (Mureşan, 1972; Berbeleac, 1986).

Restricted occurrences of this kind are found in the metabasitic middle part of the Biharia series of Upper Proterozoic age (Bihor massif of the North Apuseni Mts). They are found in the Brusturi-Luncsoara-Poiana district and a recognizable mobilization of metals during the Laramian metallogenesis is to be mentioned (Lazăr et al., 1980).

The Getic Nappe of the South Carpathians contains minor metagabbro bodies with disseminated Ni-Cu-Co ores (especially pyrrhotite, chalcopryrite, pentlandite) in the vicinity of the Vâlsan Valley (Udubaşa et al., 1988).



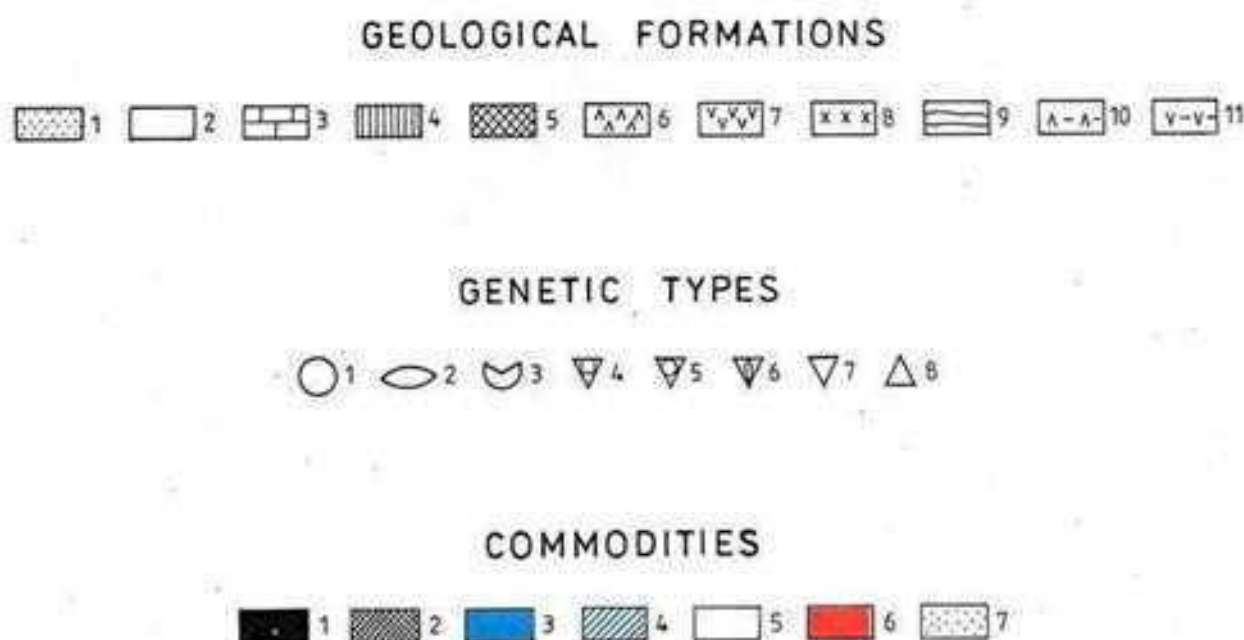


Fig. 7 - Suggested time distribution of representative accumulations of metalliferous and nonmetalliferous mineral resources using lithostratigraphic correlation markers of the Proterozoic and Paleozoic formations (acc. to Kräutner in Zoubek, 1988, with completions)

Key: **GEOLOGICAL FORMATIONS:** 1, molasse formations; 2, metadetrital rocks; 3, limestones and/or dolomites formations; 4, graphite schist formations; 5, leptino-amphibolitic formations; 6, acid volcanic rocks; 7, basic volcanic rocks; 8, granite-granitoide; 9, amphibolites; 10, rhyolitic metavolcanics; 11, basic volcano-sedimentary formations.

GENETIC TYPES: 1, hydrothermal; 2, marine; 3, volcano-sedimentary; 4, metamorphosed magmatic liquid; 5, metamorphosed hydrothermal; 6, metamorphosed volcano-sedimentary; 7, metamorphic; 8, metamorphic differentiation.

COMMODITIES: 1) Fe, Ni±Cu, Cr; 2) Mn±Fe, barite; 3) Cu, Pb, Zn, Py, Au, Ag, barite; 4) U-Th, TR, Zr, Nb, Ta, -Cu, Pb, Zn, Py, Mo, Bi; 5) Muscovite, quartz, feldspar; 6) Li, Be, Kyanite, talc; 7) Graphite.

REPRESENTATIVE ACCUMULATIONS: 1. Palazu Mare (Fe); 2. Armeniş, Valea Fierului-Boufari (Fe); 3. Altân Tepe (Fe, Cu); 4. Poiana Mărului (Ni); 5. Titianu (Ni); 6. Puskarschi (Cr); 7. Vălsan (Ni, Cu); 8. Delineşti (Mn); 9. Răzoare (Mn); 10. Băzdăga (Fe, Cu); 11. Valea Blaznei (Py, Zn, Pb±barite); 12. Grădiştea de Munte (U, Th, Tr, Nb, To); 13. Arpaş (Fe); 14. Porumbacu (Py, Zn, Pb); 15. Topleţ (Fe); 16. Negovanu (Kyanite); 17. Ungurelaş (Graphite); 18. Muntele Rece (Feldspar, U); 19-23. Uricani (Quartz), Teregova (Feldspar), Voineasa (Muscovite), Conţu (Li), Pietrele Albe (Be); 24. Boişa Haţeg (Py, Zn, Pb); 25. Bocluş (Fe); 26. Şipot-Dibart (Cu, Pb, Zn, Fe, barite); 27. Iacobi (Mn); 28. Burloaia-Fundu Moldovei-Leşu Ursului-Bălan (Py, Cu, Pb, Zn); 29. Rusaia (Fe); 30. Izvorul Cepii (Py); 31. Teliuc, Ghelâr (Fe); 32. Izvorul Bistriţei (Fe); 33. Leleş (talc); 34. Muncel (Pb, Zn), Veţel (Cu, Zn, Pb); 35. Păuşeni (U, Cu); 36. Highiş (Cu, Py); 37. Muntele Mare (U); 38. Balabancea, Măcin (Fe); 39. Zimbru, Padiş (U)±Cu, Pb, Zn; 40. Rămuşa (U, Mo); 41. Ilişova-Gabretina (U, Cu, Pb, Zn); 42. Sviniţa-Streniac (U±Cu, Pb, Zn); 43. Budimic, Ciudanoviţa (U); 44. Repedeu (U).

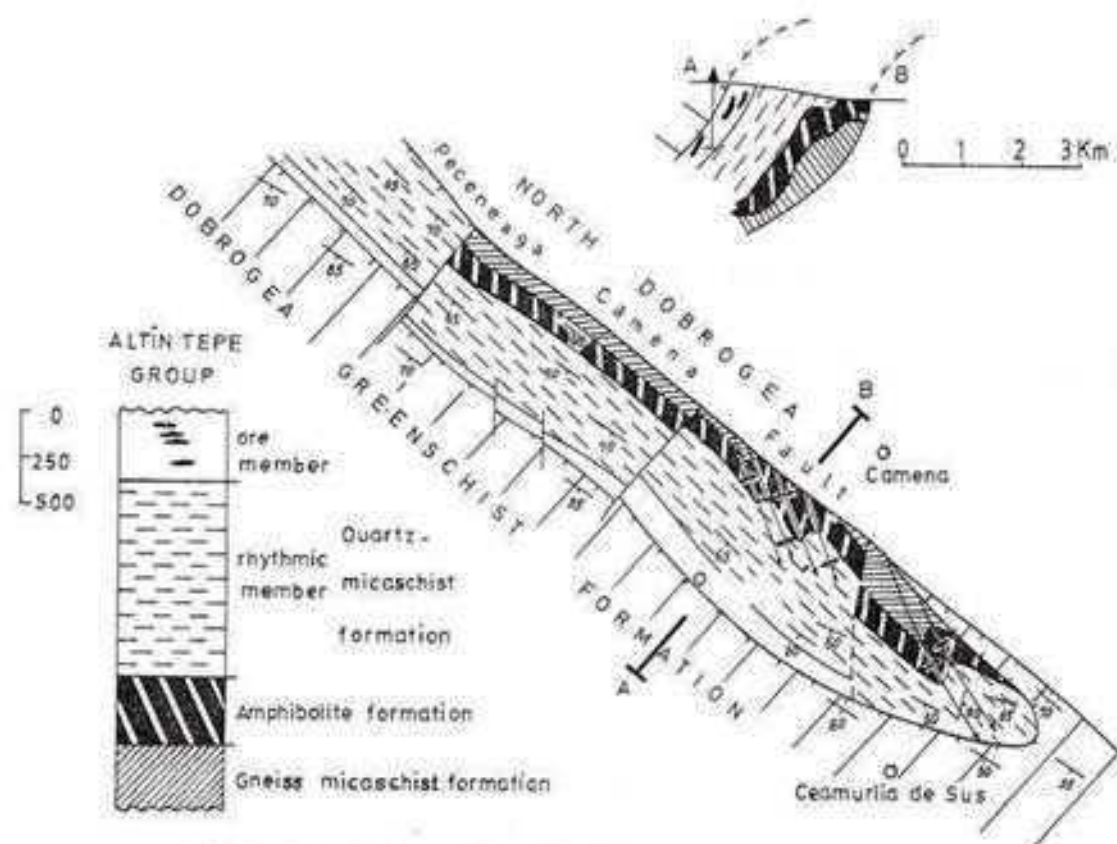


Fig. 8 - Geological map of the Altân Tepe area (acc. to Mureșan, 1972)

Banded iron formation (possible equivalent to metallogenesis related to passive plate margin, Vlad, Borcoș, 1997)

Fe ores (hematite, magnetite) in cummingtonite, quartzite, amphibole-almandine-Fe-diopside-rocks, associated with the lower formation of the Palazu Mare Group (Lower-Middle Proterozoic), occur at Palazu Mare, in the cratonic part of Dobrogea (Fig. 9). They are similar to deposits of Krivoy Rog type belonging to the Karelian cycle that are hosted by the Ukrainian shield (Giușcă et al., 1976).

Significant Mn-Fe ores related to Precambrian metamorphics are known in the Preluca Mts. There are several ore lenses consisting of manganoan fayalite, mangangonnerite, pyroximangite, jacobsonite, rhodochrosite etc., with an obvious vertical zoning (Udubașă et al., 1996).

Metallogenesis in subduction-related setting

Minor base-metal ores (lens-like) bodies and impregnations of pyrite, pyrrhotite, sphalerite, galena, arsenopyrite similar to the Kuroko type are hosted by acidic metavolcanics at Răchițele-Gingineasa (Arada formation of Someș Group-Vlădeasa massif, North Apuseni Mts). Laramian epigenetic ores found in the same area suggest that Alpine remobilization played an important role in the metallogenetic achievement of the North Apuseni Mts. (Panaite et al., 1973; Gheorghiescu et al., 1980).

Last but not least, some comments about the Precambrian pegmatites: minor Be and Li-bearing pegmatites are found in the South Carpathians. Spodumene bearing pegmatites found at Conțu, in the Middle Proterozoic Sebeș-Lotru Group of the Getic Nappe, are the most characteristic. Alternative to the magmatic formation, Hann (1987) estimates that pegmatite genesis is a metamorphic process resulting in differential matter mobilization and anatexis through metasomatism.

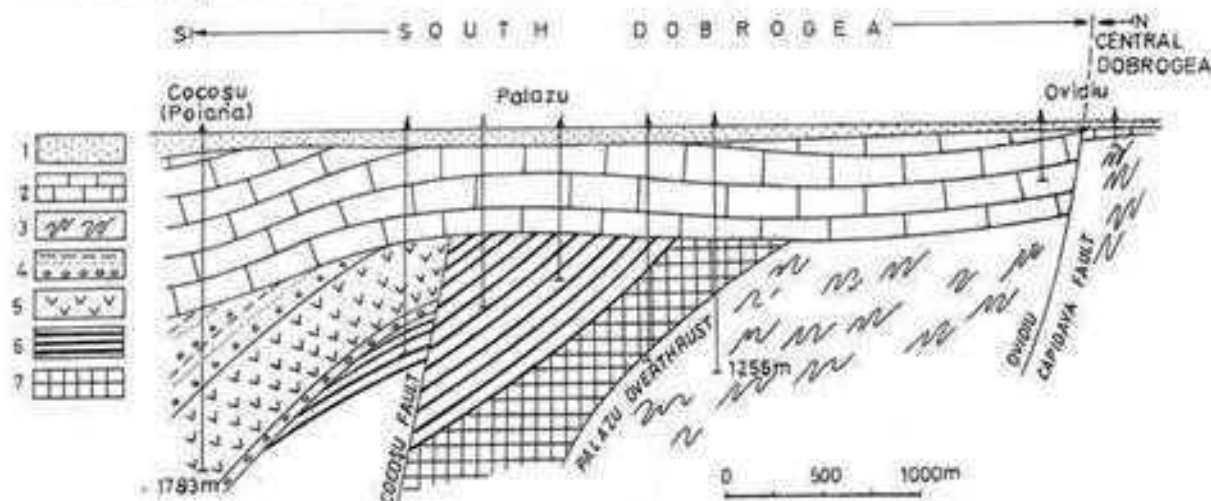


Fig. 9 - Cross-section through the northern part of South Dobrogea in the Ovidiu-Palazu-Cocoșu region (acc. to Majer, in Zoubek, 1988).

Key: 1 - Upper Cretaceous and Cenozoic cover; 2 - Jurassic carbonate cover; 3 - Dobrogea "Greenschist Formation" (Baltăgești Member) (Upper Brioverian); 4-5 - Cocoșu Group (Brioverian): 4 - upper detrital formation; 5 - lower spilitic formation; 6 - Palazu Mare banded iron ore formation (Lower Proterozoic); 7 - Gneisses (Archean?)

LOWER PALAEOZOIC METALLOGENESIS

The metallogenesis is characterised by Fe-Mn, Cu, Ba and U deposits related to intracontinental rifting which promoted the Caledonian cycle. Except the Izvoru Cepii Cu-pyrite stratiform ores located in the Ordovician-Silurian Repedea Series (East Carpathians), metallogenetic products, that might be ascribed to the Caledonian orogeny in the broad sense, are not exposed. The most representative occurrences of the Lower Palaeozoic metallogenesis are linked to the Tulgheș Group (East Carpathians). According to age, setting and petro-metallogenetic characteristics the interpretation of rift related metallogeny (Folea et al., 1987) is therefore adopted.

The East Carpathian metalliferous occurrences represent around 20 % of the total resource estimates of Romania. A 180 km long belt located in the Bucovinian-Subbucovinian nappes runs NW-SE from Baia Bôrșă to Bălan. Mineralizations of Pb-Zn, Cu-pyrite, Fe-Mn and Ba character are related to volcanogenic sequences of the Cambrian-Lower Ordovician Tulgheș Group. The metalydite (metajaspilite)-graphite assemblage with specific black quartzites exposes lenses of Fe-Mn ores (rhodocrosite, rhodonite, tephroite, spessartite, mangangrunerite, Fe and Mn oxides and hydroxides etc) at Cârlibaba, Iacobeni, Broșteni and of Ba ores at Holdița-Broșteni (Bistrița Mts) (Hârtoapanu, 1996). The volcano-sedimentary

formation with characteristic bimodal basic-acid volcanics contains folded and boudined massive sulphides and stratiform disseminated sulphides deposits (pyrite, chalcopryrite, sphalerite, galena and arsenopyrite, locally also cassiterite, bismuthinite, bournonite, tetrahedrite) (Kräutner, 1966, 1984, 1988, 1989). The ores are found in four metallogenetic districts, Borşa-Vişeu (Maramureş) (Figs. 10, 11), Fundu Moldovei-Leşu Ursului, Harlagia-Şumuleu and Bălan-Fagu Cetăţii.

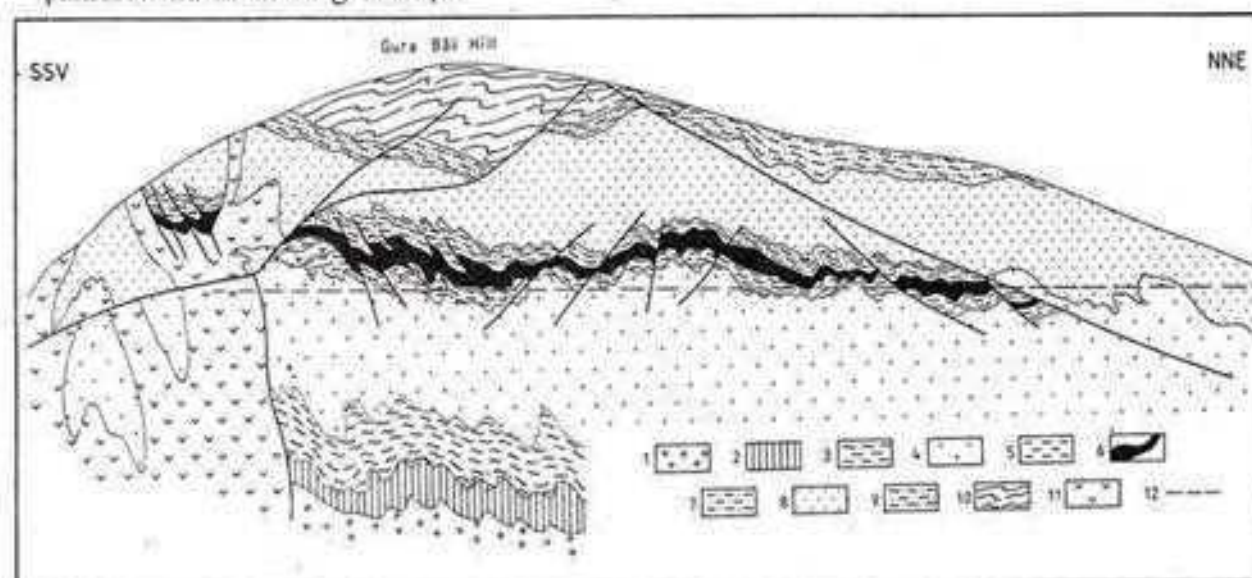


Fig. 10 - Geological cross-section through the Gura Băii ore deposit (acc. to Zincenco et al., 1975).

Key: 1 - Deaful Bucăţii rhyodacitic metavolcanics; 2 - Deaful Bucăţii base-metal level; 3 - lower phyllitic graphitic schists; 4 - Burloaia-Gura Băii lower rhyodacitic metavolcanics; 5 - lower phyllitic muscovitic schists; 6 - impregnation and massive-looking base-metal ore from Burloaia-Gura Băii level; 7 - upper phyllitic schists; 8 - Burloaia-Gura Băii Upper rhyodacitic metavolcanics; 9 - upper phyllitic graphitic schists; 10 - muscovitic-quartzitic schists (Ivăşcoia horizon); 11 - neogene andesites; 12 - faults.

Kräutner (1984) divided the ores into three morphologic-depositional types:

- Isipoaia type: massive sulphide lenses with inner Cu-base metal character and outer Cu-pyrite mineralization and peripheral pyrite halo (e.g. Burloaia, Gura Băii, Colbu, Leşu Ursului zone II, Fundu Moldovei zone I);
- Fundu Moldovei type: stratiform disseminated Cu-pyrite as ore-bearing beds (e.g. Fundu Moldovei zones II and III, Leşu Ursului zone III);
- Leşu Ursului type: base metal massive ore grading to Pb-Zn (e.g. Leşu Ursului zone I) or Cu (e.g. Bălan) disseminations. Ore veins are found in places as a result of metamorphic mobilisation (e.g. Bălan).

Less extended similar Cambrian occurrences are found elsewhere, namely in the South Carpathians (stratabound pyrite, sphalerite, galena, chalcopryrite, bornite ores at Boiţa Haţeg, Cibin Group of the Getic Nappe) and in the North Apuseni Mts. (small-sized concordant lenses and impregnations of Cu-pyrite ores at Lupşa, Muncel Nappe of the Gilău-Muntele Mare Massif).

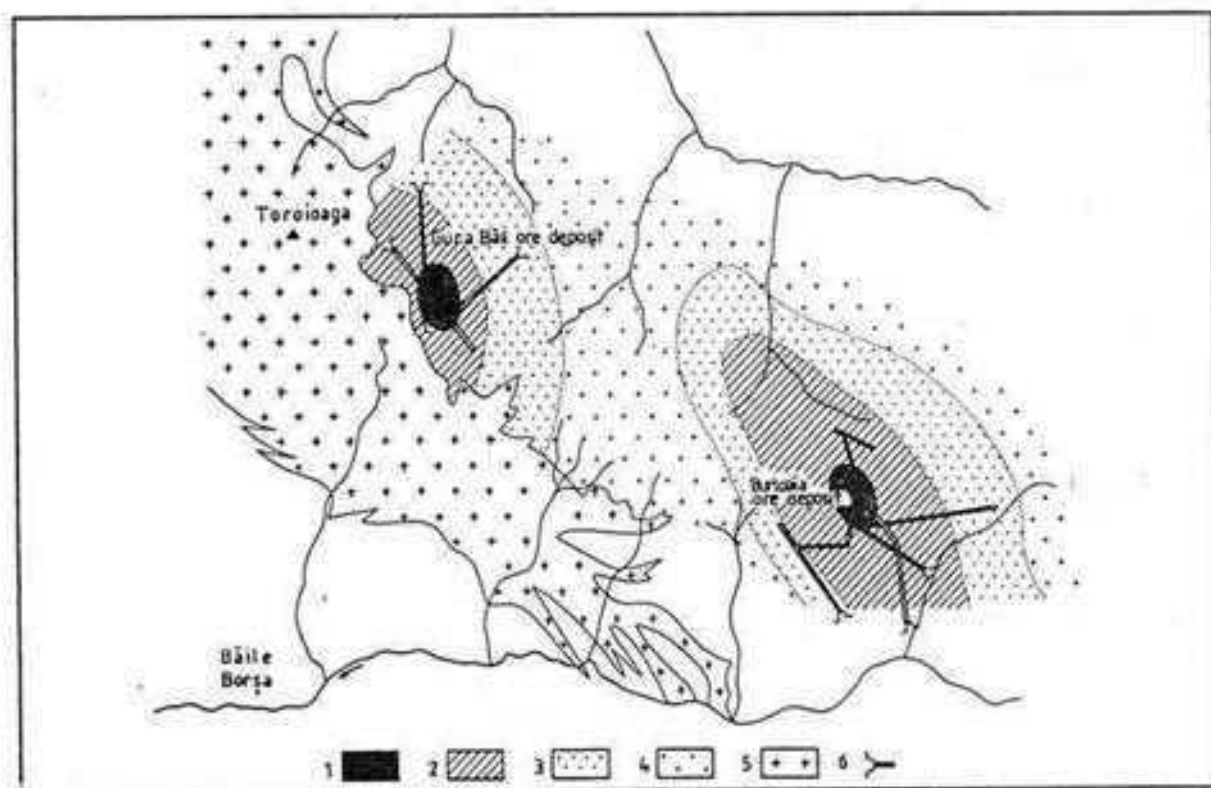


Fig. 11 - Facies distribution in the Burloaia-Gura Băii district (acc. to Zincenko, 1975).

Key: 1 - central facies with Pb-Zn bearing massive pyritic ore; 2 - intermediate facies with Cu-Pb-Zn bearing massive and/or disseminated pyritic ore; 3 - marginal facies with Zn-Cu bearing disseminated pyritic ore; 4 - Cu-bearing disseminated pyritic ore; 5 - Neogene volcanic rocks; 6 - underground development.

UPPER PALAEOZOIC METALLOGENESIS

The basement nappes and the Permian molasse of the South Carpathians and Apuseni Mts. are preferential sites of Fe, Cu, Mo, Pb-Zn and U ores related to incipient and advanced stages of a Variscan Wilson orogenic cycle. Such occurrences represent only 2 % of the total resources estimates of the country.

Metallogenesis related to intracontinental rifting

The products are represented by Fe-Ba, Pb-Zn lenses (siderite, ankerite, dolomite, calcite, magnetite, hematite, barite, galena, sphalerite) found in the Devonian calcareous chlorite-albite and sericite-chlorite schists of the Rușchița-Alunu greenschists formation, Ghelar Series, Supragetic Nappes (Poiana Ruscă massif of the South Carpathians). The ores are of Lahn Dill type and cluster in the Ghelar-Teliuc district (Kräutner, 1977) (Figs. 12, 13).

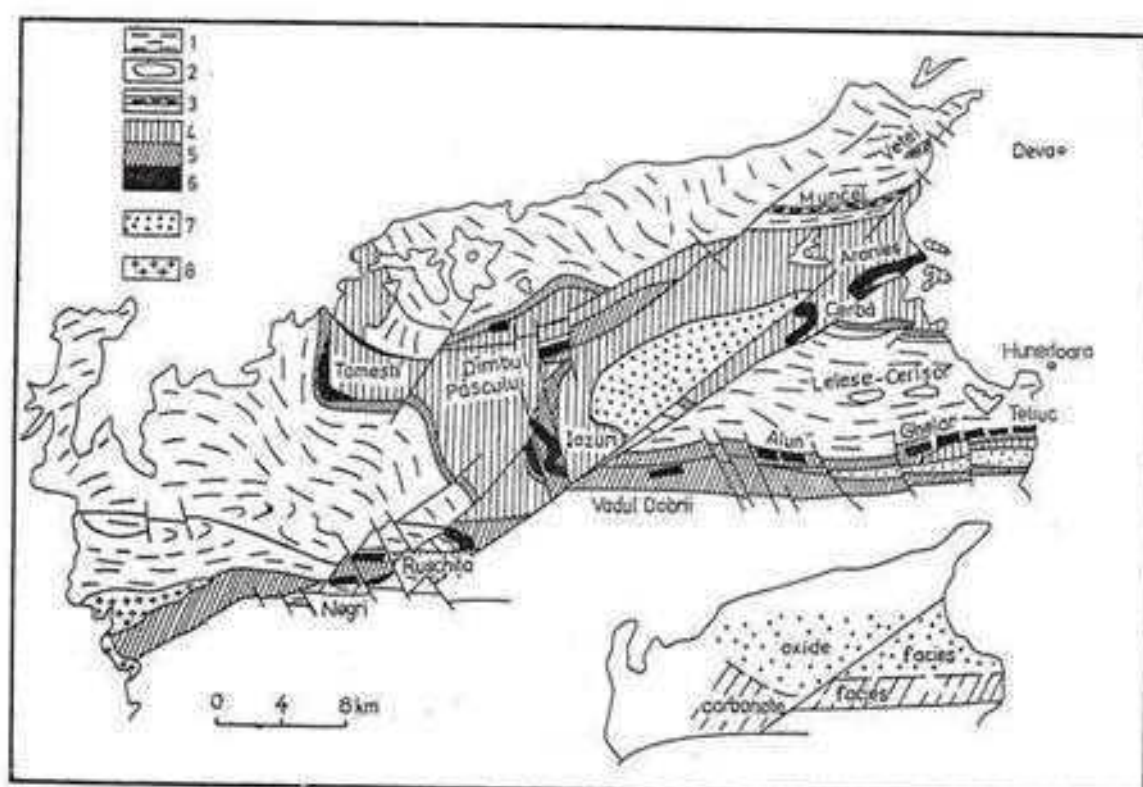


Fig. 12 - Poiana Ruscă Hercynian crystalline massif - South Carpathians (acc. to Krätner, 1970).

Key: 1 - Padeș Series (Upper Devonian - Lower Carboniferous); 2 - Lelese-Cerșor - type talc accumulations; 3 - Muncel-Veșel type base-metal accumulations; 4 - basic volcano-sedimentary formation (Middle Devonian); 5 - metatuff deposits; 6 - iron ore in carbonate and oxidic facies; 7 - pre-Devonian Paleozoic crystalline schists (Bătrâna Series); 8 - Paleocene granitoids.

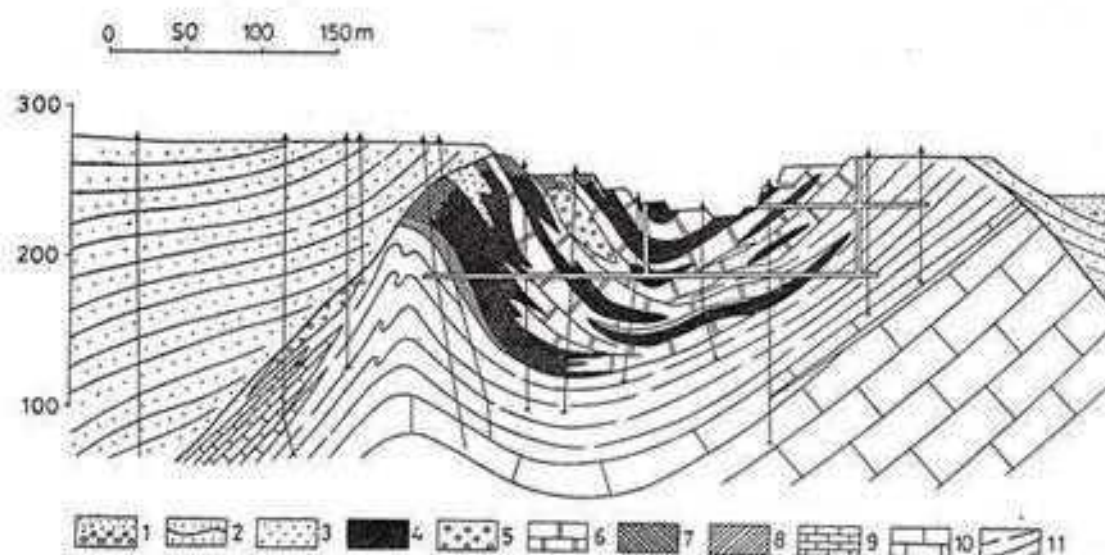


Fig. 13 - Geological section through the Teliuc ore deposit (acc. to Krätner, 1970).

Key: 1 - alluvia; 2 - gypsum marks; 3 - quartzites; 4 - chalybite; 5 - iron dolomite; 6 - dolomites within the ore deposit; 7 - limonite; 8 - itabirite, magnetite; 9 - limestones; 10 - dolomites; 11 - chlorite-sericite and chlorite - calcareous schists bearing tuffite.

Metallogenesis in subduction-related settings

The Carboniferous Pades series with related ores occurs in the north-eastern part of the Poiana Ruscă massif (South Carpathians) and the Rapolt massif (Apuseni Mts) (Kräutner, 1964). The Muncelu Mic-Rapolt district contains Pb-Zn-Cu stratiform banded and disseminated ores partly mobilised along schistosity; the host rock is acidic metavolcanic part of the Leșnic formation (upper part of the Padeș series) (Gurău, 1967, 1980). Muncelu Mic deposit is of Pb-Zn character ($Pb/Zn = 1/2$) and Veșel deposit of Zn-Cu character ($Zn/Cu = 2/1$).

Metallogenesis in post-collision related settings

In Permian molasse environments stratiform Cu-U and discordant Cu-Mo mobilisates occur in sandstone-microconglomerate levels at Zimbru and Cu stockworks and U vein-like ores in rhyolites at Rănușă, in the Moma massif (North Apuseni Mts) (Vlad, 1980). The ores consist of pitchblende, chalcopyrite, umohoite, bornite, calcite, covellite, tetrahedrite, molybdenite and pyrite in quartzose gangue and belong to an ensialic aborted rift. Similar Cu-U ores are found at Ciudanovița, South Banat region (South Carpathians).

ALPINE METALLOGENESIS

The Alpine metallogenesis characterised especially by Au, Ag, Pb, Zn, Cu, Mo, Mn, Fe ($\pm$ Ti, V, W, Sb, Bi, Cd, Hg, Co, Cr, Ni, U, Th, Tr) is significantly developed throughout the mobile zones of the Romanian territory (Carpathians and North Dobrogea).

Metallogenesis related to all stages of a Wilson orogenic cycle has been recognized, i.e. from intracontinental rifting to spreading-, subduction-, collision- and post-collision-related settings. The geological features that controlled the episodic ore deposition during this cycle are correlated with the geochemical behaviour of the major metals (Plate I). The main stages are connected with the Laramian (Banatitic) magmatic products (especially skarn deposits and porphyry deposits) and Late Tertiary volcanic product (especially vein deposits and porphyry deposits).

Most important metallogenetic areas are moreover coincidental with plutonic spatial disposition, especially with the subvolcanic structures, much more obvious in case of Tertiary magmatism (Fig. 14). Highly significant is the fracture set connected to the pluton, its evolution controlling the metallogenetic events.

Such genetic relationships, at present well specified by adequate means of geological and geophysical studies, have been promoted in the Metaliferi Mountains (Ghițulescu, 1935) and to a large extent geophysically proved in the volcanic zones of the East Carpathians and in the western part of the South Carpathians, in the banatitic province (Socolescu et al., 1964; Socolescu, 1972, respectively).

Metallogenesis related to intracontinental rifting

The products of this metallogenetic activity are found both in the Carpathian and the North Dobrogean realms.

The Dobrogea well expressed NW-SE trending alignments of bimodal (basaltic) rhyolitic igneous rocks are especially associated with stratabound Ba-Pb-Zn and Fe ores within Spathian calcareous-terrigenous turbidites of the Tulcea tectonic unit (Vlad, 1978).

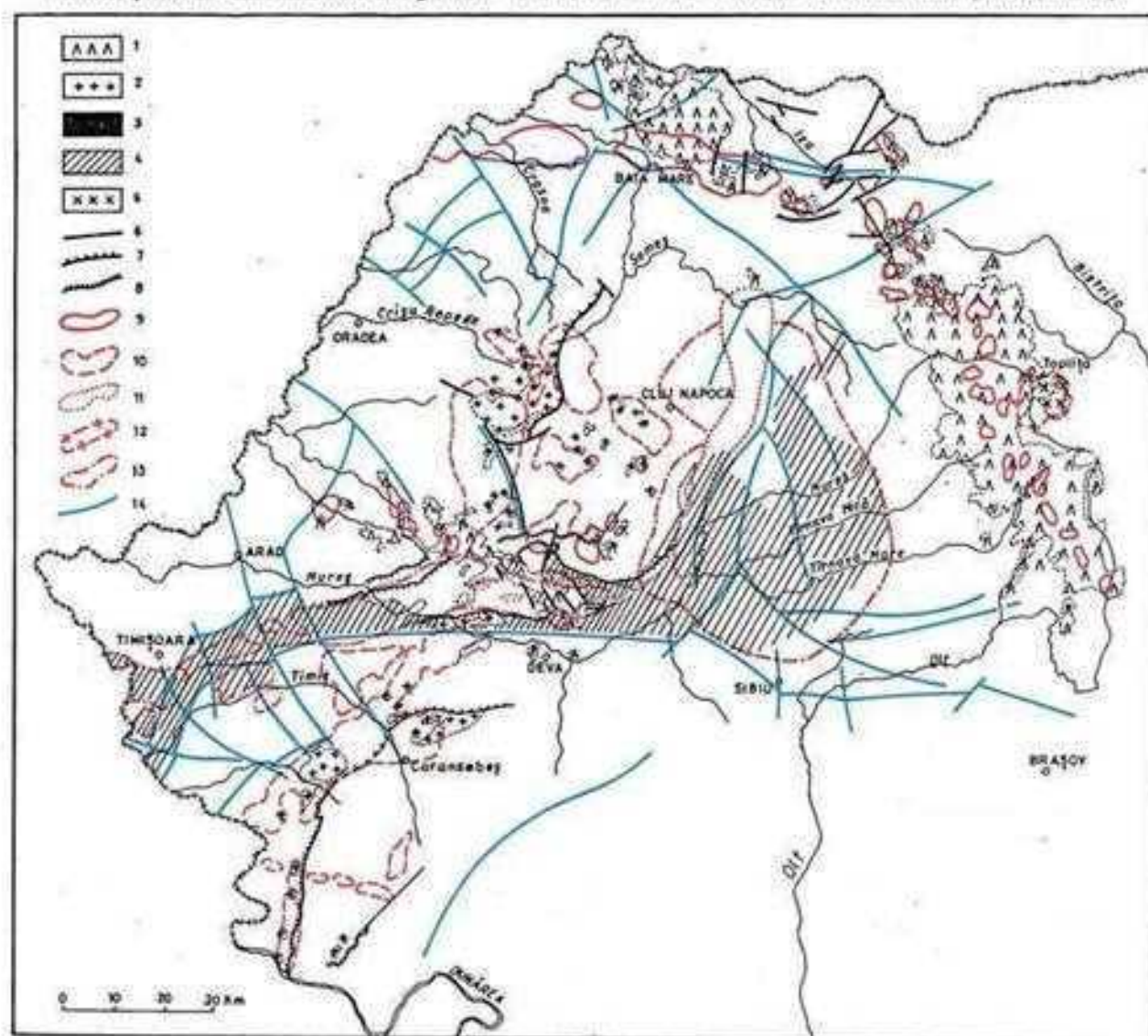


Fig. 14 - Alpine magmatic concealed structures, deduced from geophysical data (acc. to Andrei et al., in: Vlad, Borcoş, 1994).

Key: 1- Neogene volcanics; 2 - Upper Cretaceous-Paleogene magmatites; 3 - island arc products – andesites and basalts, Upper Jurassic-Lower Cretaceous in age; 4 - Jurassic ophiolites; 5 - Jurassic alkaline intrusions; 6 - fault; 7 - inverse fault; 8 - nappes; 9 x - plutons and Neogene intrusive bodies; 10 x - plutons and intrusive bodies, Upper Cretaceous-Paleocene in age; 11 x - plutons and intrusive bodies, Upper Jurassic-Lower Cretaceous in age; 12 x - Jurassic alkaline intrusions; 13 x - deep-seated extend of the ophiolitic complex; 14 x - major fractures (x = Geophysical elements)

In the Somova-Cortelu area stratiform sedimentary barite with subjacent massive Pb-Zn ores formed inside minor submarine depressions; subsequent small-sized Ba-Pb-Zn veins occurred in steep-dipping fractures along anticline crests and Pb-Zn-Ba-F stockworks in K-altered rhyolites. The margin of the North Dobrogea Triassic rift contains infiltration skarns of Rio Marina type within some Spathian turbidites at Iulia. The skarn deposits contain hematite-magnetite as a result of Fe mobilisation from the basement. Other details concerning the geology and the mineralogy of these types of ore deposits in Ianovici et al. (1957, 1977), Vlad (1978).

The Danubian units of the South Carpathians contain Mo-W mineralization in the Mraconia region. The environment consists of bimodal magmatic products represented by north-south striking monzogranite-granodiorite dykes and lamprophyre dykes that penetrated mylonitised metamorphic rocks of the Neamtu series (Metallogenetic unit 1A in Plate I). A major monzogranite dyke underwent potassic and phyllic alteration; molybdenite and common sulphides veinlets and impregnations occur in the phyllic zone. Carbonate intercalations of the surrounding crystalline schists were converted into skarns with scheelite, pyrite, chalcopyrite, magnetite and hematite. Radiometric age data (209-145 m.y., K-Ar) and bimodal magmatic products with associated porphyry Mo mineralization are characteristic of an aborted ensialic rift. It is, however, difficult to ascertain if this rifting represents back-arc extension of Late Paleozoic collisional Ogradena granitoids or incipient intracontinental rupturing during the Early Mesozoic (Vlad et al., 1984).

The basement nappes of the South and East Carpathians contain small Pb-Zn-Ba ore deposits. The Făgăraș Group (South Carpathians) is cut by Jurassic bimodal (alkali-rhyolite and lamprophyre) dykes and Pb-Zn ore veins controlled by regional ENE-WSW lineation. Common sulphides occur in carbonate, quartz or barite gangue (Bârsa and Șinca-Holbav metallogenetic districts) (Manilici, 1956; Nedelcu, Anton, 1964). Aborted rifts found in the Bucovinian Nappe (East Carpathians) contain Ba-Pb-Zn, Fe and Mo occurrences related to Mesozoic sedimentary and igneous rocks, as explained below (Ianovici, Borcoș, 1983).

Triassic dolomitic limestones at Delnița contain stratabound Fe (siderite) ores associated with minor barite and Pb-Zn ores. The lens-like bodies are mainly sideritic-ankeritic in the east and hematitic in the west (Tănăsescu, Pitulea, 1962; Ianovici et al., 1963).

Along the Ostra-Gemenea-Slătioara alignment barite and witherite accumulations are associated with base-metal ores. At Ostra north-south striking veins cut the metamorphic basement and the Mesozoic sedimentary cover. At least two barite generations have been recognized as well as witherite, pyrite, sphalerite, galena, tetrahedrite; at depth the penetrated gneisses are impregnated with barite. It seems likely that early barite occurrences were remobilised during post-Jurassic rifting, before major Middle Cretaceous deformation. The mineralization is found discontinuously as far as Gemenea and Slătioara where base-metal and barite veins cut the crystalline schists (Metallogenetic Unit 1B in Plate I).

The Jurassic-Lower Cretaceous (196-121 m.y.) ring-like alkaline intrusion that occurs at Ditrău exhibits a conspicuous zonal structure; inner foidites are surrounded by syenite and monzonite. Hornblendite, diorite, granite and alkali-granite occurrences are peripheral. Numerous lamprophyre, microsyenite, alkali-granite and aplite dykes cut the massif. Albitite segregations and carbonate veins occur locally. Porphyry Mo-like mineralization occurs along east-west alignments, especially in the east at Aurora. The vein

ores are at Jolotca hosted by diorite and hornblendite and contain common sulphides and subordinate ilmeno-rutile, ilmenite, monazite, tapiolite, columbite. The veins cutting the syenite contain xenotime, common sulphides and niobo-tantalates (Ianovici, 1938; Codarcea et al., 1958; Ianovici, Ionescu, 1964; Constantinescu et al., 1983; Jakab, 1998) (Metallogenetic Unit 1C in Plate I).

Metallogenesis related to ocean floor spreading

The Severin Nappe of the South Carpathians contains ophiolites and related pyritic Cu ores. During Mesozoic times an elongated basin with oceanic crust formed between the Getic and the Danubian realms (first named "Eastern basin" by Rădulescu and Săndulescu, 1973); it corresponds to the above-mentioned rift of the East and South Carpathians. The resulting basaltic flows and pyroclastic rocks associated with Lower Cretaceous flysch sediments of the Severin Nappe were obducted eastward during Laramian compression when the Getic and the Danubian realms collided. Cioflica et al. (1981) provided geological and geochemical evidence that the ophiolite association formed as tholeiitic ocean-floor basalts in a small ocean basin; the related ore deposits at Baia de Aramă, were ascribed to the Joma type *sensu* Pearce and Gale (1977). They occur in basalts as small stratiform pods of massive chalcopryrite, with subordinate pyrite and sphalerite in quartz gangue (Savu et al., 1986). The massive ore is commonly underlain by pyrite + chalcopryrite + sphalerite stockworks (Metallogenetic Unit 2 in Plate I).

Metallogenesis in subduction-related settings

Three successive Alpine subduction events in the Romanian Carpathians gave rise to the vast majority of metallic ore deposits in Romania.

Jurassic-Lower Cretaceous, Upper Cretaceous-Paleocene and Late Tertiary events in turn yielded ore deposits of island arc or Andean types (Plate I).

The Jurassic-Lower Cretaceous subduction yielded three stages of magmatism in the South Apuseni Mts (Fig. 15). These are a tholeiitic series and subsequent calc-alkaline series, both of island arc type, and a final spilitic complex associated with an active marginal basin (Nicolae et al., 1992).

The metallogenesis related to the tholeiitic series consists of Fe-Ti-V and Ni late-magmatic segregations in gabbroic intrusions and pyritic Cu veins and stockworks in basaltic lavas (Socolescu, 1940; Savu, 1972; Cioflica, Vlad, 1984). The Fe-Ti-V segregations are found as titanomagnetite + ilmenite nests, lenses and grains within layered gabbroic bodies at Căzănești-Ciungani. The Ni ores are confined to the Ciungani gabbroic body wherein pyrrhotite and pentlandite with associated chalcopryrite and magnetite occur as a small pod. The pyritic Cu volcanogenic ores are considered of Gjersik type *sensu* Pearce and Gale (1977). Various veins and stockworks are controlled by brecciated basalts at Căzănești-Ciungani, Almășel, and Roșia Nouă (Socolescu, 1940; Savu, 1972). The mineralization at Pătârș is located in the upper part of a basaltic unit and contains an inner zone with pyrite + chalcopryrite veinlets and a massive pod, surrounded by a disseminated pyrite aureole (Vlad et al., 1998).

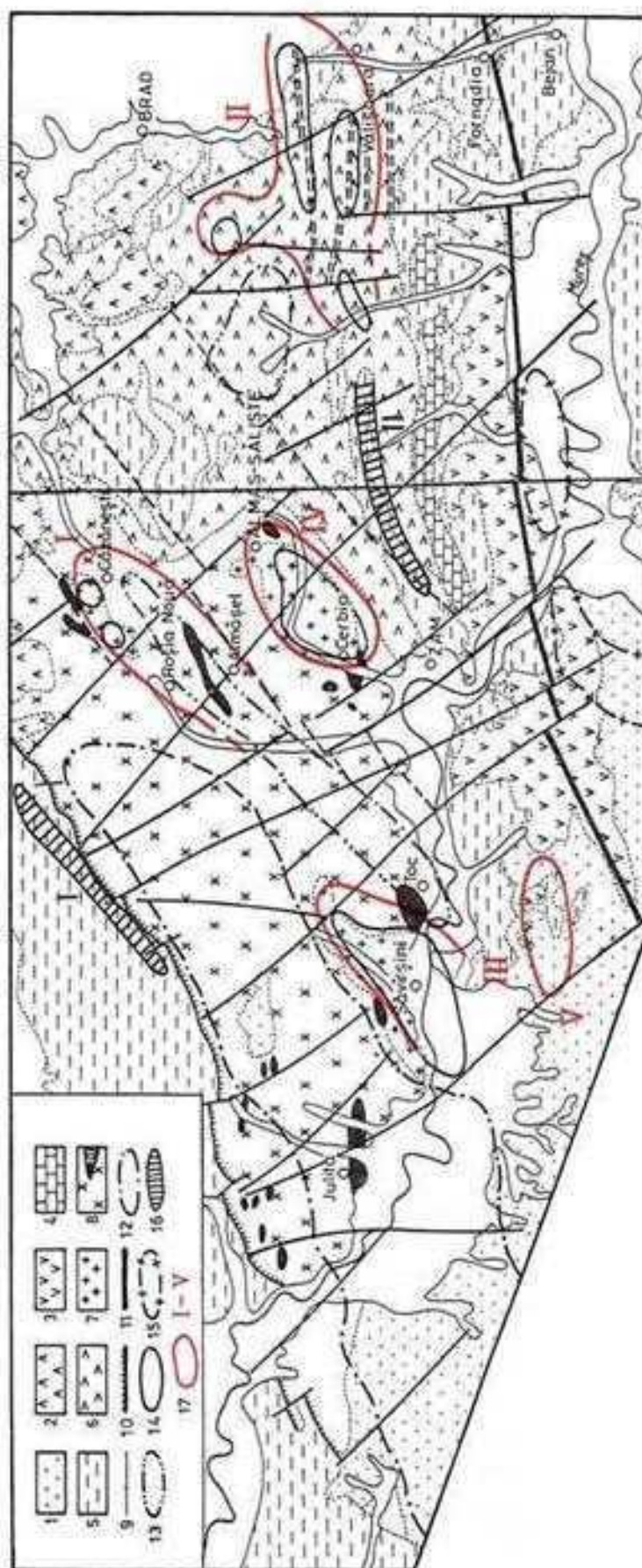


Fig. 15 - Ophiolites and island arc products in the alpine structural setting of the central-western part of the Southern Apuseni Mountains (acc. to Andrei et al., 1986). Key: 1 - Neogene molasse; 2 - Neogene volcanics; 3 - Upper Cretaceous-Paleocene volcanics; 4 - Jurassic sedimentary formations; 5 - Cretaceous sedimentary formation; 6 - Upper Jurassic-Lower Cretaceous island arc products - andesite, basalt; 7 - diorite-granodiorite; 8 - Jurassic ophiolites, gabbros with Fe, Ti, V b); 9 - Fault; 10 - Nappe; 11 - Valea Muresului transcrustal fracture; 12 x - Sheeted-dyke complex; 13 x - Gabbro-diorite intrusions Jurassic in age; 14 x - Granodiorite intrusions Lower Cretaceous in age; 15 x - Quartz-diorite intrusions Paleocene in age; 16 x - Fe-Mn prospective area (I. Soimut-buceava, II. Parnesti); 17 x - Base-metal prospective area (II. Vorta-Dealul Marc, III. Savarsin, IV. Cerbia, I. Cazanesti-Rosta).

The calc-alkaline series contain base-metal ores at Vorta. The dacitic-andesitic rocks and related pyroclastics underwent strong silicification and argillization. The altered bimodal volcanics contain E-W striking lenses and impregnations of pyrite, sphalerite, galena and chalcopryrite and it was thought that the ores are of Kuroko type (Udubasa et al., 1970, unpubl. data). Vlad (1984), Vlad et al. (1998) took over that such an island arc suite of rocks may incorporate Kuroko-porphyry copper systems.

Minor volcano-sedimentary Mn ores associated with jaspers occur in Lower Cretaceous sediments at Șoimuș-Buceava, Pârnești and Godinești (Socolescu, 1940; Savu, 1972).

This island arc-related metallogenesis is represented in Plate I, Metallogenetic Unit 3.

The Upper Cretaceous-Paleocene widespread westward subduction gave rise to polyphase calc-alkaline magmatism (Laramian magmatism, also known as "Banatitic"). This magmatic belt is 280 km long in Romania, and runs from the Apuseni Mts. in the North, to the South Carpathians. It extends further southwards in Eastern Serbia (Yugoslavia) and still further to Srednagora (Bulgaria) (Cioflica, Vlad, 1980). The major intrusive event, commonly with a monzodiorite or diorite-granodiorite evolutionary trend or a granodiorite-granite evolutionary trend or both, is metallogenetically the most important. The magmatism of the monzodiorite or diorite-granodiorite type was generally related to copper mineralization in porphyry environment. The magmatism of granodiorite-granite type generally yielded base-metal ores in non-porphyry environment: skarn deposits predominate, whereas vein deposits are rare.

In Romania, the Laramian or Banatitic belt is comprised between the North Apuseni, South Apuseni and South Carpathian subbelts. These subdivisions result from different subduction-related settings; they are at present distributed along a major N-S lineation.

North Apuseni subbelt

This metallogenetic unit is characterized by granodiorite-granite magmatism and widespread base-metal metallogenesis (Metallogenetic Unit 4a in Plate I, Fig. 16). Two metallogenetic zones have been recognized (Cioflica, Vlad, 1984):

1) the inner zone corresponding to a northwestward direction of subduction exhibits a complex metallogenesis in the Bihor-Gilău Mts. It contains Fe, Mo, Bi, W, Cu, U, Co, Ni, Pb, Zn, B, Au and Ag ores in skarns, stratiform-impregnation bodies, and veins in the Băișoara (Lazăr, Intorsureanu, 1982), Băița Bihorului (Giușcă, 1941; Stoici, 1974, 1983) and Lunșoara-Brusturi-Poiana districts (Berbeleac, Ionescu, 1969; Giușcă et al., 1976; Lazăr et al., 1978). Băița Bihorului is the most important deposit. The ore zoning around the pluton is Mo-Bi-W-Cu-U-Pb-Zn/Mo-Bi-W-Cu-U-Pb-Zn-B and is expressed in a vertical column extending up to 1.5 km away from the granite pluton. Calcic and magnesian skarns contain molybdenite, bismuthinite, Bi sulfosalts and tellurides, scheelite (three generations), Cu minerals, galena, sphalerite, szabolyite + ludwigite, fluoborite and kotoite. Metasomatised detrital hornfels (epidote + chlorite + actinolite, albite + quartz and sericite + quartz associations) contain U and Cu in stratabound lenses and molybdenite in impregnations and veinlets, whereas Paleozoic detrital rocks and crystalline schists situated far from the pluton enclose bands and veins of common sulphides ores. The same granitic intrusion yielded

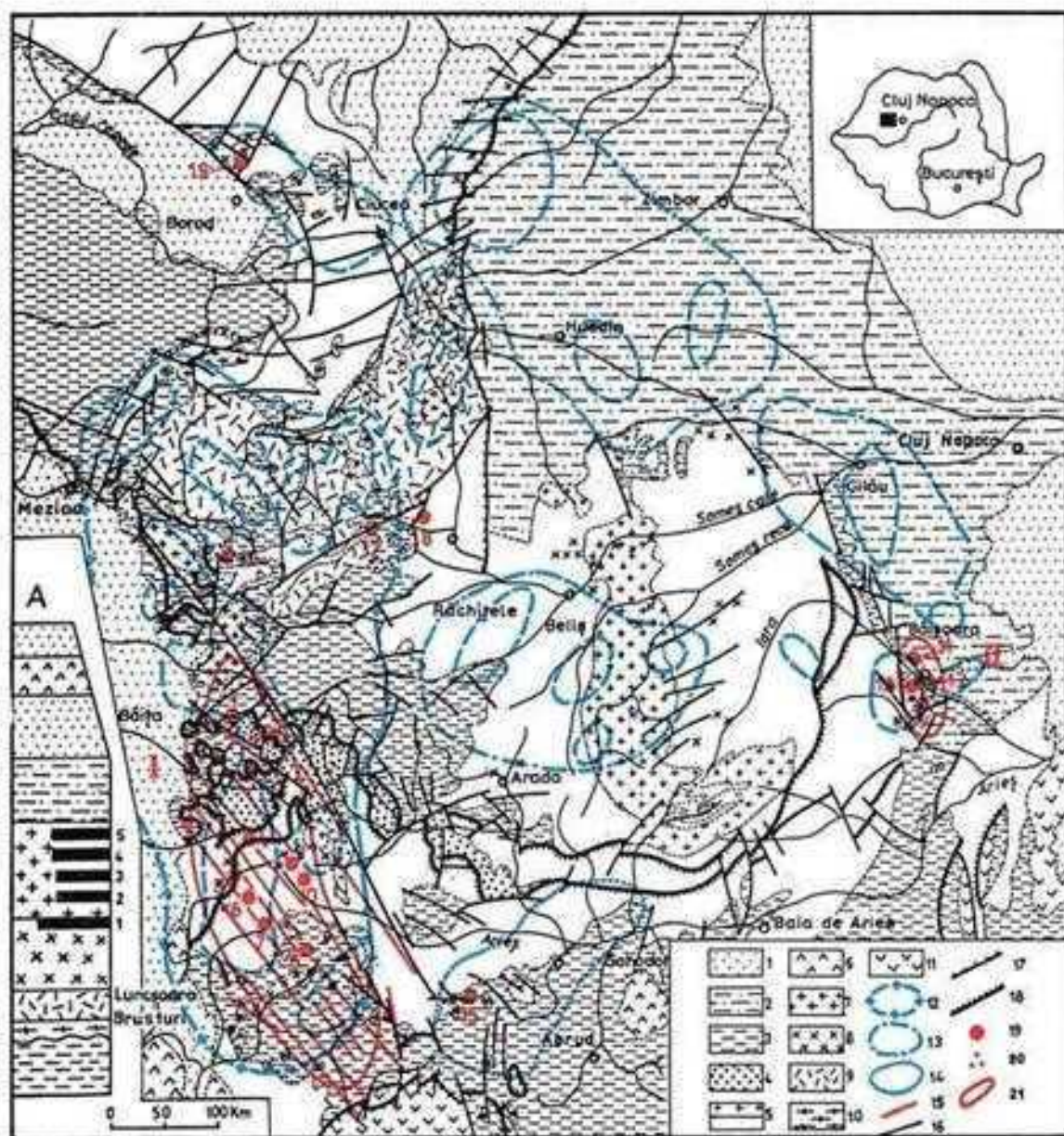


Fig. 16 - Upper Cretaceous-Paleocene magmatism and metallogensis in the Alpine structural setting of the Apuseni Mts region (acc. to Borcoș, Andrei et al., 1994; Borcoș et al., 1994).

Key: 1 - Tertiary molasse; 2 - Paleogene epicontinental formations; 3 - Mesozoic sedimentary cover; 4 - Permian molasse; 5 - Metamorphic formations: a - granitoids; 6 - Neogene volcanics; 7* - granite-granodiorite complex; dacites, andesites; 8* - quartz-diorites; 9* - andesite-quartz andesites; 10 - rhyodacitic volcano-sedimentary formation, Upper Cretaceous in age; 11 - Mesozoic ophiolites; 12 x - pluton; 13 x - intrusive major structures with their culminations; 14 x - intrusive structures of intermediary composition; 15 - tectonomagmatic and metallogenic alignments; 16 - fault; 17 - inverse fault; 18 - nappes; 19 - main accumulations (1-19 denominations); 20 - occurrences; 21 - districts.

Denominations of the accumulations:

1 - Julești-Valea Fagului; 2 - Valea Seacă; 3 - Băia Bihor; 4 - Izvorul Bihorului; 5 - Valea Titșor; 6 - Valea Vacii; 7 - Brusturi-Luncșoara; 8 - Râul Mic; 9 - Izvorul Anieșului; 10 - Gruiul Dumii; 11 - Lița; 12 - Masea; 13 - Nyerghes; 14 - Căcova; 15 - Sohodol; 16 - Budureasa; 17 - Valea Boia, Valea Stanciului; 18 - Răchitea; 19 - Borod-Cornișel.

* 7-9 Intrusions Paleocene in age

x Geophysical elements

"pentametallic" (U, Ag, Ni, Co, Bi) ores in veins and Cu-U ores as stratiform impregnations at Avram Iancu and replacement base-metal ores at Brusturi and Luncșoara (Lazăr et al., 1980).

2) the outer zone (for the same subduction sense) is noted for base metals and is located in the Vlădeasa Massif. Hydrothermal Pb-Zn ores occur in the Scind-Răchițele (Panaite et al., 1973; Gheorghiescu et al., 1980) and Borod-Cornișel districts (Berbeleac et al., 1982).

Some further details concerning the regional zoning in the area are given by Ștefan et al. (1988).

South Apuseni subbelt

In a restricted area the products are represented by monzodiorite or diorite-granodiorite magmatism with calcic Fe-skarn deposits (Vața) and granodiorite-granite magmatism with Mo-Cu-pyrite vein deposits (Săvârșin, Cerbia). Recent radiometric age data suggest that this magmatism may be of Lower Cretaceous age (Ștefan, 1986). The plutonism would represent the completion of the above-mentioned island-arc subduction event.

South Carpathian (Banat-Poiana Ruscă Mts) subbelt

This unit consists of two zones that are parallel to a suture-like contact between two crustal blocks that collided during the Laramian deformation (Vlad, 1979). The suture is the remnant of the above-mentioned rift of the East and South Carpathians (Metallogenetic Unit 4b in Plate I, Fig. 17. The magmatic intrusive bodies related to the metallogenetic activity are well illustrated in the outlined geophysical images (Andrei et al., 1994) (Fig. 14):

1) the inner zone (for a westward direction of subduction) in the South Banat Mts exhibits a monzodiorite or diorite-granodiorite magmatism and related Cu-Mo porphyries that occur at Moldova Nouă (e.g. Suvorov orebody, Gheorghită, 1975) and Sasca (Constantinescu, 1980);

2) the outer zone in the North Banat-Poiana Ruscă Mts exposes granodiorite-granite magmatism with Fe, Cu, Pb-Zn skarn deposits (Dognecea and Ocna de Fier) and Mo-W-Cu skarn deposits (Oravița) (Codarcea, 1930, 1931; Vlad, 1974; Gheorghiescu, 1975).

Conceptual ore forming models related to Banatitic metallogeny. Regional occurrences, tectonic characteristics, alteration and zoning, ore mineralogy and other related elements form the outline of the metallogenetic models in porphyry and non-porphyry environments (Vlad, Borcoș, 1996) (Plate I).

Fig. 17 - Upper Cretaceous-Paleocene magmatism and metallogenesis in the Alpine structural setting of the West Meridional Carpathians (acc. to Andrei et al., 1989).

Key: 1 - Neogene molasse; 2 - Mesozoic sedimentary cover; 3 - Permian molasse; 4 - metamorphic formations, a) granitoids, b) basic and ultrabasic rocks; 5 - Upper Cretaceous-volcano-sedimentary formation a), Upper Cretaceous volcanics b); 6 - diorites, granodiorites, andesites; 7 - granites-granodiorites; 8 - monzodiorites-monzogranites; 9 - gabbros-monzogabbros; 10 - fault; 11 - inverse fault; 12 - nappe; 13 - overthrust plane; 14 - pluton; 15 - pluton culminations of acid composition; 16 - pluton culminations of intermediary and basic composition; 17 - main ore deposits (1. Rușchița, 2. Ascuțita, 3. Vlășoara, 4. Tâncova, 5. Ocna de Fier, 6. Dognecea, 7. Surduc, 8. Oravița, 9. Ciclova, 10. Sasca Montană, 11. Moldova Nouă-Suvorov; 12. Moldova Nouă; 13. Vărad; 14. Lăpușnicul Mare; 15. Teregova-Lăpușnicel); 18 - metallogenic districts: I. Rușchița, II. Tâncova, III. Ocna de Fier-Dognecea, IV. Oravița, V. Moldova Nouă-Sasca, VI. Liliaci-Nasovăț, VII. Teregova-Lăpușnicel.

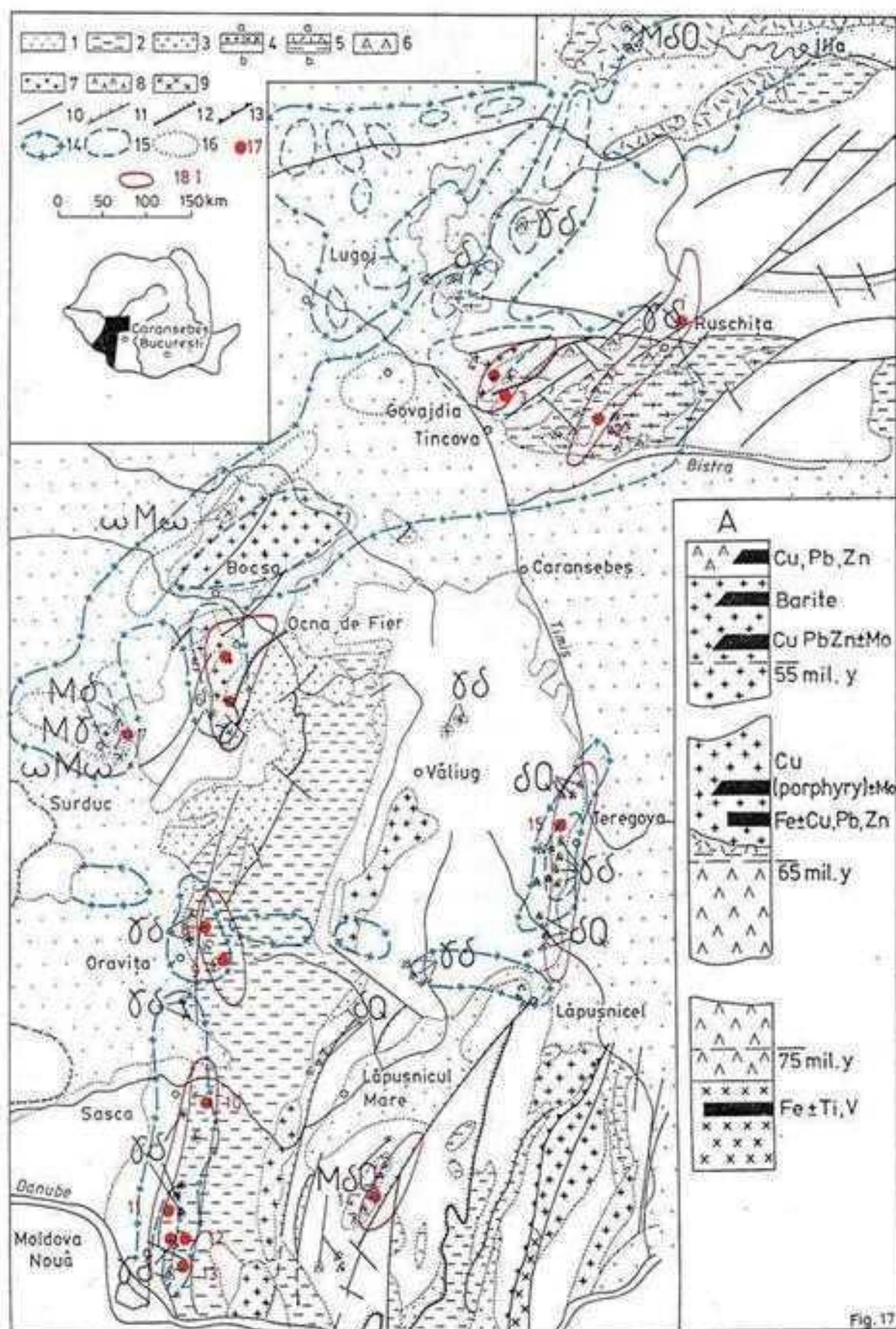


TABLE 1 - Model Suvorov-Granodiorite Type, Cu-Mo Monoascendent Evolution, Skarn Halo (M IV in Fig. 18A, Plate I)

DESCRIPTION. Chalcopyrite + pyrite in stockwork in hydrothermally altered hypabyssal-subvolcanic intrusives and in related skarn with retrograde alteration.

GEOLOGICAL ENVIRONMENT

Rock types. Monzodiorite and diorite to granodiorite plutons with hypabyssal-subvolcanic apophyses intruding carbonate rocks or calcareous siliciclastic sequences of Mesozoic age. The sedimentary rocks belong to the Getic Nappe and the igneous rocks to the Banatic belt developed in the Apuseni Mts., Banat-Poiana Rusca Mts., Eastern Serbia and Srednagora.

Age 72-67 m.y.

Structural type. The porphyry copper system is centered on subvolcanic apophyses of deep-seated plutons.

Depositional environment. Deep-seated intrusion of N-S striking and westward dipping tongue-like pluton in mainly carbonate milieu. Intense fracturing: first order strikes N-S and second order strikes E-W (orthogonal system). Permeable volcano-plutonic complex with volcanic part eroded and subvolcanic hypabyssal apophyses exposed.

Major tectonic setting. Andean-type magmatic arc.

Large scale zonality/associated deposit types. Cu-Mo stockwork in hydrothermally altered igneous host — skarn Cu ± Mo, W — replacement Pb-Zn — telethermal As-Sb — presumable Carlin gold.

DEPOSIT DESCRIPTION

Mineralogy. Magnetite ± chalcopyrite, pyrite impregnations in potassic zone, pyrite + chalcopyrite ± sphalerite, molybdenite, tetrahedrite veinlets and pyrite + chalcopyrite impregnations in phyllic zone (restricted areas of intensive silicification contain molybdenite ± pyrite, chalcopyrite veinlets and impregnations). Magnetite that replaced andraditic garnet and pyrite + chalcopyrite veinlets and impregnations in skarn with extensive fracturing and propylitization.

Alteration. Pervasive potassic alteration (biotite + K feldspar + anhydrite) in the lower part of the subvolcanic apophyses is associated with andraditic garnet in carbonate rocks. Phyllic alteration (sericite + quartz + chlorite) in the upper part of the subvolcanic apophyses is associated with argillic (montmorillonite ± kaolinite) and propylitic (epidote + chlorite + calcite) alteration in skarn. The alteration pattern is concentric of Lowell and Guilbert type.

Ore controls. Intense stockwork veining in igneous and skarn rocks contains most of the copper.

Weathering. Argillization and "limonitization".

Geochemical signature. Cu, Mo, Pb, Zn, As (Sb, Au, W)

Deposits/Prospects Moldova Nouă, Vărad, Garana, Valea Mare, Suvorov, Corcana-Baies, Greci-Apele Albe), Sasca, Șopot (Lilieci, Purcariu, Nasovat)

TABLE 2 - Model Bozovici-Granodiorite Type, Cu-Mo Monoascendent Evolution, Pyrite Halo (M V in Fig. 18B, Plate I)

DESCRIPTION. Stockwork veinlets of quartz, chalcopyrite, pyrite and molybdenite in porphyritic minor intrusion.

GEOLOGICAL ENVIRONMENT

Rock types. Minor quartz diorite to quartz monzodiorite apophyses of deep-seated plutons intruding crystalline schists of Pre-Mesozoic age. The metamorphic rocks belong to the Getic Nappe and the igneous rocks to the Banatitic belt developed in the Apuseni Mts., Banat - Poiana Rusca Mts., Eastern Serbia and Srednagora

Age. "Laramian"

Structural type. High-level porphyry subvolcanic-hypabissal apophyses and dikes. The porphyry copper system not well expressed.

Depositional environment. Deep-seated intrusion of N-S striking plutons in crystalline schists and shallow (subvolcanic-hypabyssal) apophyses.

Major tectonic setting. Andean-type magmatic arc.

Large scale zonality/ associated deposit types. Not expressed.

DEPOSIT DESCRIPTION

Mineralogy. Quartz veinlets with chalcopyrite, pyrite, magnetite and molybdenite in the upper part of the potassic zone and sporadic molybdenite, chalcopyrite and magnetite impregnation in the lower part of the potassic zone (Bozovici). Pyrite $\pm$ chalcopyrite, magnetite impregnations in phyllic and argillic zone (Teregova-Lapusnicel). Disseminated pyrite halo.

Alteration. Pervasive potassic alteration (biotitization) at Bozovici, restricted potassic, phyllic and argillic alterations at Teregova-Lapusnicel. The alteration pattern is not well expressed.

Ore controls. Veinlets and mineralized fissures in the upper part. The stockwork pattern is replaced at depth by impregnations (Bozovici).

Weathering. Not well expressed.

Geochemical signature. Cu, Mo, Pb, Zn

Deposit/Prospects. Bozovici, Teregova-Lăpușnicel

Metallogenetic models in porphyry environment. The South Carpathian subbelt contains porphyry deposits and prospects that have in common the occurrence of porphyritic tongue-like apophyses of deeply buried plutons of monzodiorite or diorite to granodiorite composition. Such apical setting represents centres of zoned hydrothermally developed sulphide mineralization and rock alteration controlled by intensively fractured host rocks. Two models are outlined, that is the Suvorov model with skarn halo and the Bozovici model (Vlad and Borcos, 1996). Their relevant characteristics are presented in Tables 1, 2 and Figure 18.

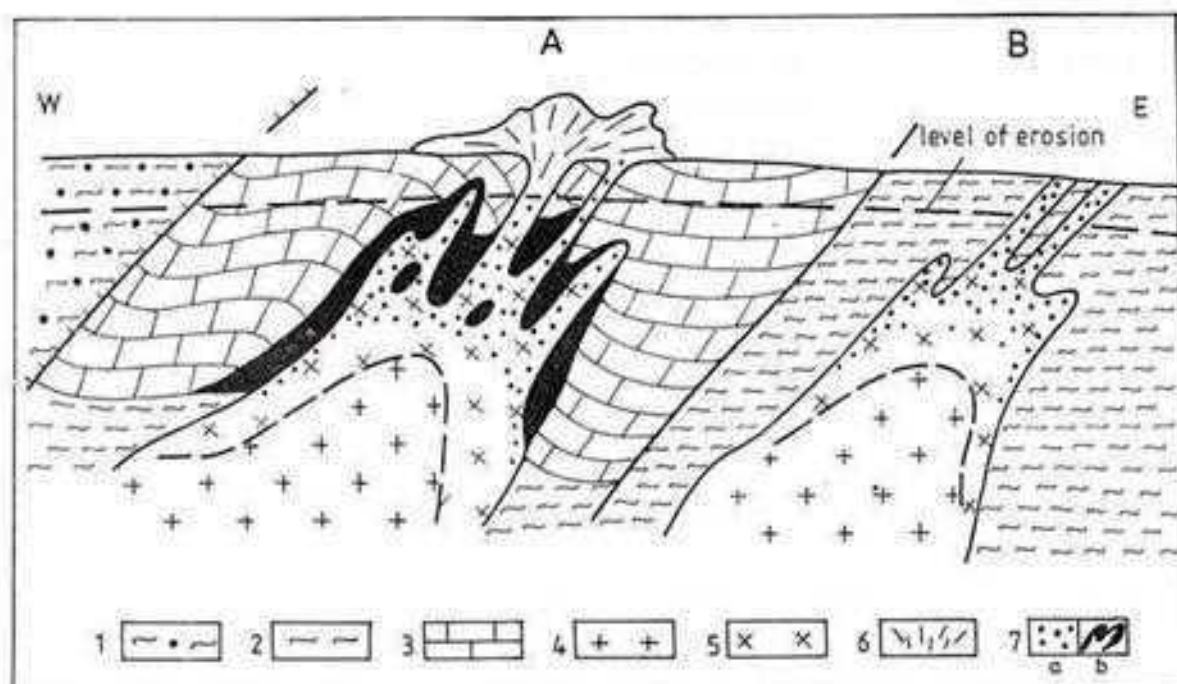


Fig. 18 - Banatitic porphyry copper models (acc. to Vlad, Borcoş, 1996).

Key: A. Model Suvorov; B. Model Bozovici. 1 - Supragetic crystalline schists; 2 - Getic crystalline schists; 3 - carbonate rocks; 4 - monzodiorite and diorite to granodiorite plutons; 5 - subvolcanic and hypabissal apophyses of dioritic to granodioritic composition; 6 - volcanic edifices of andesitic composition; 7 - mineralization: a) porphyry copper; b) Cu skarn.

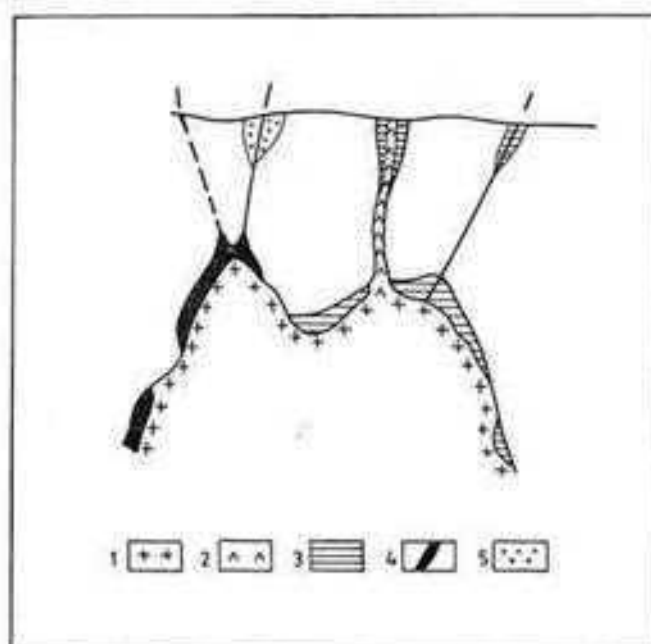


Fig. 19 - Banatitic skarn models (acc. to Vlad, 1990).

Key: 1 - granitoid pluton; 2 - dyke; 3 - Model Băița Bihorului; 4 - Model Ocna de Fier; 5 - Model Dognecea.

**TABLE 3 - Model Ocna de Fier: Fe-Cu Skarn Deposits
(M II in Fig. 19, Plate I)**

DESCRIPTION. Magnetite + hematite, chalcopyrite + pyrite in calcic dark skarns and in magnesian skarns.

GEOLOGICAL ENVIRONMENT

Rock types. Granodiorite pluton intruding carbonate rocks. The carbonate rocks belong to the Supragetic nappe and to the Transylvanide and Apusenide Groups of Nappes. The plutons belong to the Banatitic belt developed in the Apuseni Mts., Banat-Poiana Rusca Mts., Eastern Serbia and Srednagora.

Age. "Laramian"

Structural type. The skarn association occurs near the igneous contact by diffusion/infiltration metasomatism (proximal skarns).

Depositional environment. Crystalline schists and sedimentary carbonate rocks intruded by felsic plutons.

Major tectonic setting. Andean-type or island arc subduction-related magmatism.

Large scale zonality/associated deposit types. Contact aureole around the pluton: Fe-Cu skarn -- Pb/Zn skarn -- polymetallic replacement or pyrite veins.

DEPOSIT DESCRIPTION

Mineralogy. Magnetite + hematite $\pm$ ludwigite, pyrite, chalcopyrite, sphalerite, galena. Bi minerals may be present.

Alteration. Dolomitic environment: grossularite + vesuvianite inner zone; diopside + phlogopite center; forsterite $\pm$ phlogopite, clinohumite outer zone, calciphyre peripheral zone. Retrograde alteration to tremolite, epidote, serpentine, talc. In places high temperature fassaite, spinel.

Calcareous environment: andradite in zone; pyroxene restricted outer zone; marble peripheral zone. Epidote, chlorite, tremolite-actinolite as post-skarn minerals. In places high temperature spurrite and melilite (Măgurea Vătei).

Igneous rocks may be altered to diopside + grossularite (endoskarn).

Ore controls. Irregular or tabular iron oxides bodies in andradite skarn or fractures zones in marble. Magnetite + ludwigite in magnesian skarns. Associated igneous rocks are barren.

Weathering. Fe-rich gossan.

Geochemical signature. Fe, Cu, Pb, Zn, Co, Bi. Strong magnetic anomalies.

Deposits: Ocna de Fier, Băișoara, Măgurea Vătei, Tincova.

Metallogenetic models in non-porphyry environment. The Apuseni Mts and South Carpathian subbelts contain skarn deposits and prospects related to granodiorite - granite plutons. When wall-rocks are mainly calcareous, Fe-Cu skarn deposits occur near the contact and Pb-Zn skarn deposits occur far from the contact. When wall-rocks are various sedimentary rocks and coeval or older igneous rocks, magnesian and calcic skarns with Mo, W, Bi, Cu, Pb, Zn and B mineralization are found near and away from the pluton.

Three models are defined that is the Ocna de Fier model and the Dognecea model of commonly calcareous host rock with proximal and distal skarn formation, respectively, and the Băița Bihorului model with extended skarn formation through the whole contact aureole of the pluton. These contrasts are the result of processes that proceed to different extent in response to similar felsic magmatism and wall-rocks of various origin. Tables 3, 4, 5 and Figure 19 show their main characteristics.

TABLE 4 - Model Dognecea: Pb-Zn Skarn Deposits
(M III in Fig. 19, Plate I)

DESCRIPTION. Sphalerite + galena in dark calcic skarns.

GEOLOGICAL ENVIRONMENT

Rock types. Granodiorite pluton intruding carbonate rocks. The carbonate rocks belong to the Supragetic Nappe and to the Transylvanide and North Apusenide Groups of Nappes. The plutons belong to the Banatitic belt developed in the Apuseni Mts., Banat-Poiana Rusca Mts., Eastern Serbia and Srednagora.

Age: "Laramian"

Structural type. The skarn system occurs hundreds of meters from intrusive by infiltration metasomatism (distal skarns).

Depositional environment. Crystalline schists and sedimentary carbonate rocks intruded by felsic plutons.

Major tectonic setting. Andean-type or island arc subduction-related magmatism.

Large scale zonality/associated deposit types. Contact aureole around the pluton: Fe-Cu skarn -- Pb/Zn skarn -- polymetallic replacement or pyrite veins.

DEPOSIT DESCRIPTION

Mineralogy. Sphalerite + galena + pyrite $\pm$ magnetite, chalcopryrite, arsenopyrite, pyrrhotite.

Alteration. Andradite restricted inner zone; Mn-salite to Mn-ferrosalite (Fe-diopside) center, Mn-hedenbergite outer zone; marble peripheral zone. Retrograde alteration to tremolite-actinolite, chlorite, epidote, ilvaite.

Ore controls. Mn-hedenbergite $\pm$ ilvite skarn contains pipe-like or tabular Pb-Zn orebodies.

Weathering. Gossan with strong Mn oxide stains.

Geochemical signature. Zn, Pb, Mn, Cu, Co, As.

Deposits: Dognecea, Ruschița, Tincova, Brusturi.

These ore deposits have been mined since pre-Roman times and described in the last century by such well-known geologists (from the Freiberg school) as B. von Cotta and F. Pošepny. Accordingly, the deposits at Dognecea, Ocna de Fier, Băița Bihorului became famous all over the world. They have a rich and complex paragenesis, with up to 200 ore and gangue minerals. Several minerals were described from these deposits for the first time, e.g. ludwigite, szaibelyite, veszelyite, etc., cf. Udubașa et al. (1992).

**TABLE 5 - Model Baita Bihorului: Mo-Bi-W-Cu Skarn Deposits
(M I in Fig. 19, Plate I)**

DESCRIPTION. Molybdenite, scheelite, chalcopyrite, Bi-minerals in calcic light skarns and magnesian skarns.

GEOLOGICAL ENVIRONMENT

Rock type. Granite (granodiorite) pluton (batholith) intruding carbonate rocks and carbonate-siliciclastic sequences. The carbonate rocks belong to the Getic Nappe and the Apusenide Group of Nappes. The plutons belong to the Banatitic belt developed in the Apuseni Mts., Banat-Poiana Rusca Mts., Eastern Serbia and Srednagora.

Age: "Laramian"

Structural type. The skarn system occurs near igneous contacts by diffusion/infiltration metasomatism (proximal skarns at Oravita and Baita Bihorului) and hundreds of meters from the contact by infiltration metasomatism (distal skarns at Ciclova and Baita Bihorului).

Depositional environment. Contacts and roof pendants of pluton and thermal aureoles of pluton and apical zones of stock that intrude carbonate rocks and carbonate siliciclastic sequences.

Major tectonic setting. Andean-type or island arc subduction-related magmatism.

Large scale zonality/associated deposit types. Contact aureole around the pluton: Mo-W skarn -- Bi-W-Cu skarn -- Pb-Zn skarn -- B marble. "Pentametallic" veins, U-Cu polygenetic, Pb-Zn replacement.

DEPOSIT DESCRIPTION

Mineralogy. Scheelite + molybdenite + chalcopyrite + bismuthinite + Bi minerals $\pm$ sphalerite, galena, arsenopyrite, lollingite, glaucodote, gold, bornite, tetrahedrite, cubanite. Fluoborite, ludwigite, szaybellite and kotoite may be present.

Alteration. Dolomitic environment: grossularite + vesuvianite inner zones, diopside $\pm$ phlogopite center, clinohumite + chondrodite $\pm$ phlogopite outer zone; calciphyre, kotoite marble and brucite marble peripheral zones. Retrograde alteration to talc, serpentine, chlorite, tremolite. In places high temperature fassaite, forsterite, spinel.

Calcareous and calcareous-siliciclastic environment: ribbon rock of wollastonite and grossularite + vesuvianite alternating layers, metasomatised (skarnified) hornfels is diopside + wollastonite + grandite. Retrograde alteration to epidote, actinolite, chlorite.

The pluton may be altered to periskarn and grossularite + vesuvianite endoskarn.

Igneous rocks found as dikes throughout the contact aureole are converted into grossularite + vesuvianite skarn.

Ore controls. Tabular Mo-W and pipe-like (Cu-Bi-W; Pb-Zn) ore bodies in magnesian skarns. Mo-W impregnations, pods and veins in ribbon rock. Associated igneous rocks occurring as dikes may be mineralized (Mo $\pm$ W stockwork in grossularite $\pm$ vesuvianite skarn).

Weathering. In places enrichment zone with secondary Cu-sulfides, native copper and cuprite.

Geochemical signature. W, Mo, Zn, Cu, Bi, Au, Ag, B

Deposits. Băița Bihorului, Oravița, Ciclova.

Late Tertiary westward subduction during Neogene times (*sensu* Rădulescu and Săndulescu, 1973) gave rise to volcanics mainly of andesitic type and their deep-seated correspondents, that occurred rhythmically from Badenian to Lower Pliocene time, very well expressed in the East Carpathians (Oaş-Gutâi region, Călimani-Gurghiu-Harghita volcanic chain and Toroiaga-Bărgău-Țibleș subvolcanic zone) and in the South Apuseni Mts (Metaliferi Mountains).

Ore deposits related to volcanics were considered during years as epithermal (*sensu stricto*) mineralizations (Au-Ag-Te character prevailing in the South Apuseni Mts and Au-Ag and base-metal in the Oaş-Gutâi region) formed during several stages in Badenian-Pontian times. Genetical models based on Neogene magmatism evolution and related metallogenesis and significance of geological-geophysical evidence were provided by the South Apuseni Mts and Baia Mare geotectonic settings (Ghițulescu, 1935; Ghițulescu, Borcoș, 1968; Borcoș, Andrei, 1984; Borcoș et al., 1994 a,b, 1997) and point to the intimate relation between deep-seated intrusions and associated subvolcanic characters which, in turn, represent the infrastructure of superficial/surface volcanic piles.

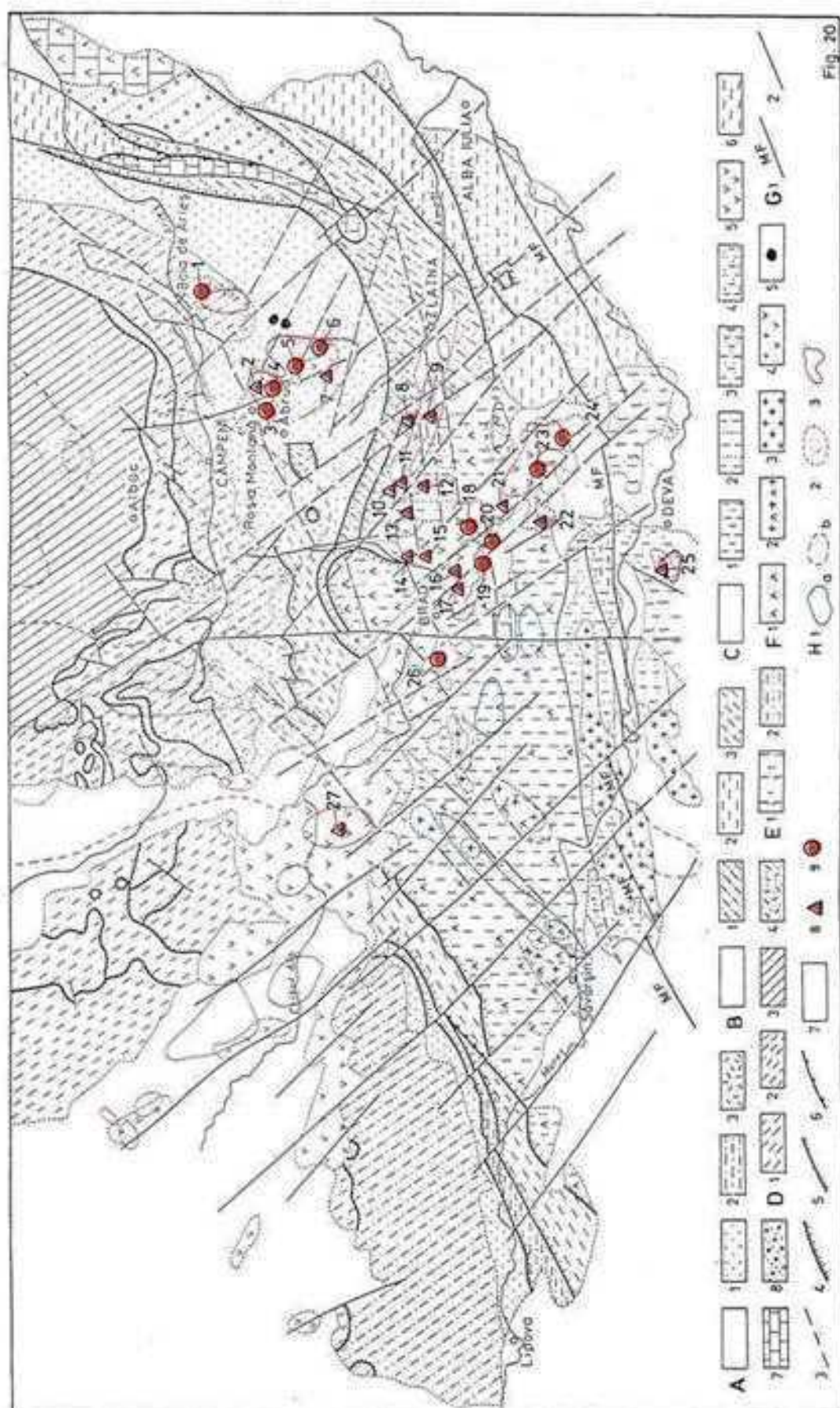
More than 50 % of the total resources estimates of Romania is given by Neogene metallogenesis of breccia pipe, veins and porphyry type found in two major units, the East Carpathians volcanic arc and the South Apuseni Mts volcanics. The most important metals related to this event are gold, copper, lead and zinc.

The petrogenetic and metallogenetic characteristics of these Tertiary volcanic rocks have been described by numerous authors, beginning in the last century. Comprehensive reference works of more recent decades include those by Ghițulescu, Socolescu (1941), Giușcă et al. (1968 a,b, 1973), Rădulescu et al. (1973, 1981), Ianovici et al. (1969, 1976), Ianovici, Borcoș (1983), Borcoș (1976, 1994 a,b, 1997), Peltz et al. (1973), Seghedi et al. (1994), Udubașă (1970), Udubașă et al. (1984).

Fig. 20 - Location of porphyry and epithermal accumulations in the schematic structural metallogenetic map of the Metaliferi Mts. (acc. to Borcoș et al., 1998).

Key: A. Units coming from southern continental margin of the North Apuseni Mts: 1 - Bucium Unit; 2 - Groși Nappe; 3 - Frasin Nappe; B. Units coming from marginal basins: 1 - Feneș Nappe; 2 - Valea Mică-Gâlda Nappe; 3 - Criș Nappe; C. Units coming from island arc realms: 1 - Căpâlnaș-Techereu Nappe; 2 - Cărechiu-Stănița Unit; 3 - Căbești Unit; 4 - Bejan Unit; 5 - Hospea Unit; 6 - Colții Trascăului Nappe; 7 - Bedeleu Nappe; 8 - Rameți Beds - Mesocretaceous-post-tectonic cover; D. North Apuseni Mts: 1 - Bihor Autochthon; 2 - Codru Nappes system; 3 - Biharia Nappes system; 4 - Gosău Formation - post-tectonic cover; E. Units situated on the Supracrustal and Getic crystalline basement: 1 - Rapolt Crystalline; 2 - Bozeș Nappe; F. Magmatic rocks: 1 - Jurassic (ophiolites s.l.); 2 - Eocretaceous (granite-granodiorites); 3 - Upper Cretaceous-Paleocene (banatites); 4 - Neogene (mostly andesitic associations); 5 - Pliocene-Quaternary (basalts); G. Conventional signs: 1 - Mureș fault (South Transylvanian Fault); 2 - fractures system geologically determined; 3 - fractures system geophysically deduced; 4 - Laramian nappes; 5 - Pre-Gosău Nappes; 6 - Meso-Cretaceous Nappes; 7 - Tertiary molasse; 8 - porphyry copper accumulations; 9 - epithermal accumulation; H. Alpine plutonic bodies: 1 - Eocretaceous magmatites: a) tholeiitic, b) calc-alkaline; 2 - Upper Cretaceous-Paleocene magmatites; 3 - Neogene magmatites.

Neogene representative accumulations: 1. Baia de Arieș; 2. Roșia Poieni; 3. Roșia Montană; 4. Rodu-Frasin; 5. Conțu; 6. Corabia; 7. Târnița; 8. Trâmboie; 9. Haneș-Larga; 10. Stănița; 11. Muncăceasca Vest; 12. Măgura; 13. V. Tisei; 14. Rovina; 15. Colnic; 16. V. Morii; 17. Musariu; 18. Vălișoara; 19. Băița; 20. Căinel-Draica; 21. Voia; 22. Boleana; 23. Hondol; 24. Săcărâmb; 25. Deva; 26. Caraci-Tebea; 27. Talagiu-Bratosin.



*Neogene volcanicity/metallogenesis in the
South Apuseni Mountains (Metaliferi Mts)*

The Tertiary volcanic activity of this unit evolved from the Paleocene to the Pontian within intramontane basins which began their activity in the Paleocene and are superposed on NW-SE trending regional fractures of the Laramian system (Borcoş et al., 1986, Fig. 20). During the Neogene segments of this fracture system were intensely reactivated and they determined a new involvement of the basins in new subsidence movements, with the thickening of the molasse deposits concomitantly with the formation of numerous volcanic edifices and related subvolcanic structures and metallogenic processes. The intersection points of the major pre-Neogene tectono-magmatic (pre-Laramian) alignments, trending E-W and NE-SW, and Laramian alignments, trending NW-SE, constitute zones of maximum volcanic and metallogenetic mobility (Ghiţulescu, Borcoş, 1968; Borcoş, 1976; Vlad, 1980; Borcoş, Andrei, 1984). A general image stresses out that within the same post-tectonic basins first developed a Paleocene mostly extrusive volcanism with alternations of andesites and rhyolites included within a volcano-sedimentary formation (Borcoş et al., 1986). South of the Mureş Valley, andesites, basalts, basanites are to be found, which correspond to products formed at

the expense of hot spots (Rădulescu et al., 1994); the radiometric data point to ages ranging between 38 and 46 m.y. (Kräutner, Kräutner, 1985). Subsequently to the phases of the Neogene volcanism Upper Pliocene-quaternary basalt occur locally, i.e. the two Detunata peaks in the eastern vicinity of the Bucium-Roşia Montana volcanic zone and the westernmost part of the Mureş passage, at Lucareţ. They are considered as intraplate magmatic activity.

The Neogene volcanism extended northwards and on the border of the Bihor massif, but especially towards the west in the Zarand basin, prolonging towards the Pannonian Depression, a direction in which most of the volcanic products are buried in the Neogene molasse (Ivanovici et al., 1969). The evolution of the Neogene volcanic activity generally proved by radiometric data (Lemne et al., 1981; Roşu et al., 1997, 1998) from the Badenian to the Pliocene was marked by several sequences that can be grouped depending on the tectonic regime, the petrochemical character, the age of the products and the presence of the metallogenetic processes. The most important volcanic activity took place during the Badenian, Sarmatian and Pannonian (Borcoş, 1976), the generated extrusive and intrusive products being preceded by volcano-sedimentary formations that provide good regional correlation markers.

It has thus been demonstrated that at the end of the Badenian and Sarmatian metallogenetic processes took place, the most quantitatively and qualitatively important ones being the Brad-Săcărâmb andesitic phase (Ghiţulescu, Socolescu, 1941; Borcoş, 1976).

The first metallogenetic phase of Badenian age manifests locally and it is associated with dacites, rhyodacites and quartz andesites. The mineralizations correspond to the epithermal, mainly of auriferous type, without tendencies of primary variation, the composition consisting of native gold, gold-silver sulphosalts and only subordinately of gold-base metal surrounded by characteristic hydrothermal transformation products (adularization - silicification - argillisation). The representative deposits of this phase belong to two districts, Roşia Montană - Conţu and Băiţa and Căinel-Draica.

The second Sarmatian metallogenetic phase of the greatest importance is associated with the andesitic, dioritic and quartz-dioritic subvolcanic structures. At present it is considered that the essential element in the evolution of the magmatic processes and in the position of the mineralizations is represented by the Neogene plutons lying at depths ranging between ± 0 and $-1,500$ m; taking into consideration these depths as well as the geotectonic peculiarities specific to each zone, the succession of the vents with the location of the centres of maximum volcanic activity and metallogenetic intensity can be established. In such cases the existing geological and geophysical data make possible the drawing out of a pattern of geological evolution and formation of the metalliferous (porphyry and hydrothermal) accumulations that may be applied to all the Neogene volcanic zones in the Apuseni Mts. A genetic model in the Zlatna district can be generalized in all the Apuseni Mts Subprovince, that is most of the deposits can be related to the subvolcanic bodies situated on the protuberances of the plutons vertically representing the transition to the volcanic structures and edifices, formed as a rule within the same phases of activity. Thus, special conditions appeared (large zones with high values of the geothermal gradients and great tectonic permeability) in which the metallogenetic processes led to the accumulation of the metalliferous concentrations of porphyry $\pm$ hydrothermal type in the interval of some columns up to $1,500 - 2,000$ high. The porphyry copper systems display the tendencies of primary variation of the mineralizations. In general, the gold and gold-silver base metal hydrothermal systems cross the zones with copper disseminated mineralizations; the superposition of the hydrothermal transformation products specific to the two types of mineralization is also quite obvious. Locally there occur also tendencies of horizontal variation of the mineralizations, with transitions from the cupriferous to the auriferous base-metal mineralizations and even to the cinnabar ones (Zlatna volcanic zone). Such relationships enable the location of the accumulations with respect to the erosion level, the position of the accumulations differing from one zone to another and even within the same zone. There are cases in which the upper part of the porphyry copper type deposits has entirely been eroded along with the whole supposed succession of associated hydrothermal accumulations (Roşia Poieni); in some other cases the apical part of the porphyry copper structures reaches the surface level or undercrops ($50-100$ m), the structures being thus crossed or bordered by base-metal and gold vein systems (Valea Morii, Tarniţa, Bolcana); sometimes, the porphyry structures lie at depths ranging between 400 and 800 m (Musariu, West Muncăceasca, Tălagiu, Voia). The latter case provides representative examples in which the zonality of the mineralization and the supposed genetic relationship existing between the porphyry and hydrothermal type accumulations can be followed (Borcoş et al., 1978; Udubaşa et al., 1981; Borcoş et al., 1983, 1994; Vlad, Borcoş, 1996). The cogenetic relationships between the two porphyry and epithermal mineralisation types formed in distinct sequences, but within the same process (phase), are also pointed out by the results of the sulphur isotopic study (Borcoş et al., 1982; Borcoş, Gaftoi, 1985).

The hydrothermal accumulations belonging to this Sarmatian phase show on the whole a prevalingly gold-silver character. They include native gold, gold tellurides and gold base-metal sulphosalts, gold base-metal sulphides in various parageneses and metallic mineral associations indicating a mineralogical succession in four geochemically distinct phases, often delimited also by tectonic discontinuities (superposed systems of mineralized fissures, brecciations) (Borcoş, 1976; Ianovici et al., 1969, 1976). Depending on the local

conditions, the metallogenic succession appears totally or partially, some stages showing a greater development or lacking altogether. Vertically, the deposits show large intervals of superposition with associations of the various paragenesis formed, constituting as a rule the median part of the deposits where, within the same or in different ore bodies, there occur various lead-zinc, copper or auriferous-pyrite ore type.

Since 1960 special attention has been paid to the next depth level, in which the auriferous base-metal mineralizations with significant gold contents (2-5 g/t) have intensely been turned to account, especially native gold is still being identified. The metallic mineral association for this interval is formed mainly of pyrite sphalerite, chalcopryite, galena, mispickel (the deposition succession that may be generalized in 70 % of the cases) that vary quantitatively; the enrichments in chalcopryite are known more rarely. Towards the final base-metal sequence and the beginning of the gold sequence, an association of tellurides (krennerite, sylvanite, nagyagite, altaite, hessite, petzite) occurs only in some deposits especially in Săcărâmb, Fața Băii, present also subordinately in Stănița, Baia de Arieș ore deposits, preceded or intergrown with tetrahedrite; in other deposits there occurs an association of sulphosalts. Germanium minerals also associate with such ores in the Bucium-Arama deposit (Ivanovici et al., 1969, 1976).

Due to exploration works which have been carried out (galleries, drillings) it could be established that in the lower part of the deposits the hydrothermal accumulations consist prevalingly of pyrite (between 5-15 mass percent of the ore bodies) pyrrhotite, variably chalcopryite; sphalerite and galena are subordinately omnipresent; hematite occurs only locally, sporadically also arsenopyrite and marcasite.

Although the copper dissemination mineralizations were recorded a long time ago, during exploitation (Deva, Valea Morii, Coranda, Trâmpoiele) and exploration works (Roșia Poieni, Musariu-Barza, Muncăceasca-Zlatna), the identification of the corresponding genetic type as well as of the possible economic prospect were achieved much later - since 1970 (Ivanovici et al., 1969, 1976, 1977; Ionescu, 1974; Andrei, Andrei, 1974; Andrei, Calotă, 1974; Borcoș et al., 1973, 1976, 1977, 1978, 1983, 1989, 1994, 1998; Berbeleac et al., 1976, 1977, 1981, 1982, 1989, 1995; Vlad, 1983; Boștinescu, 1980, 1983, 1984).

The Deva deposit is almost mined out; the Roșia Poieni deposits are now being exploited; similar accumulations at Târnița, Bolcana and Rovina are prepared for exploitation; other accumulations (Trâmpoiele, Haneș-Larga, Muncăceasca, Musariu, Voia, Talagiu as the most important ones) are only partly explored. The most favourable forming conditions of these mineralizations are due to final intrusive (andesitic-dioritic) sequences from the major structures and/or volcanic edifices which are usually located at the intersection of the main ophiolitic Laramian and Tertiary tectonomagmatic lineaments trending EW, NE and NW, respectively. The apical part of these mineralized bodies is frequently located in Sarmatian andesitic extrusive products; at depth these come into contact with sedimentary and/or metamorphic formations (most of the situations) or even with metamorphic formations (locally at Deva and Roșia Poieni).

The zonal character of the copper mineralization is well expressed in most of the bodies. In the succession and distribution of the products two zones - a central potassic and a marginal argillic ore - can be distinguished; in a few cases a phyllic zone could also be noticed (Borcoș et al., 1978, 1983; Boștinescu, 1984). The values and spatial distribution of the copper contents are nearly directly related to the potassic alteration; therefore one can

delimit relatively homogeneous, quasi-concentric zones with contents varying between 0.3 and 0.6 % Cu in the central potassic halo; which can be locally characterized by higher gold-values, i.e. of 0.7 g/t and more.

The presence of gold in the copper mineralization is constant; a positive correlation between copper and gold can be established; the global Cu/Au ratio varies from one district to another (Borcoş et al., 1983). Especially in the Deva and Roşia Poieni deposits, where the basement is predominantly crystalline, one can notice a concentration tendency towards the periphery and depth of the molybdenite ~ 30-150 ppm compared to a decrease of the copper and gold contents. Molybdenite appears with lower values 40-90 ppm (Boştinescu, unpubl. data).

Conceptual ore forming models. In terms of tectono-magmatic features, porphyry-epithermal relation, composition and intensity of mineralization and alteration the following models have been identified (Vlad, Borcoş, 1996; Borcoş, Vlad, 1997):

- two models of porphyry copper system, that is Valea Morii porphyry epithermal model and Roşia Poieni porphyry with pyrite halo model;
- the non-porphyry environment is also represented by two models, i.e. Roşia Montană composite system of breccia pipe and Săcărâmb vein set.

Their main characteristics are presented in Tables 6, 7, 8, 9 and Figures 21, 22.

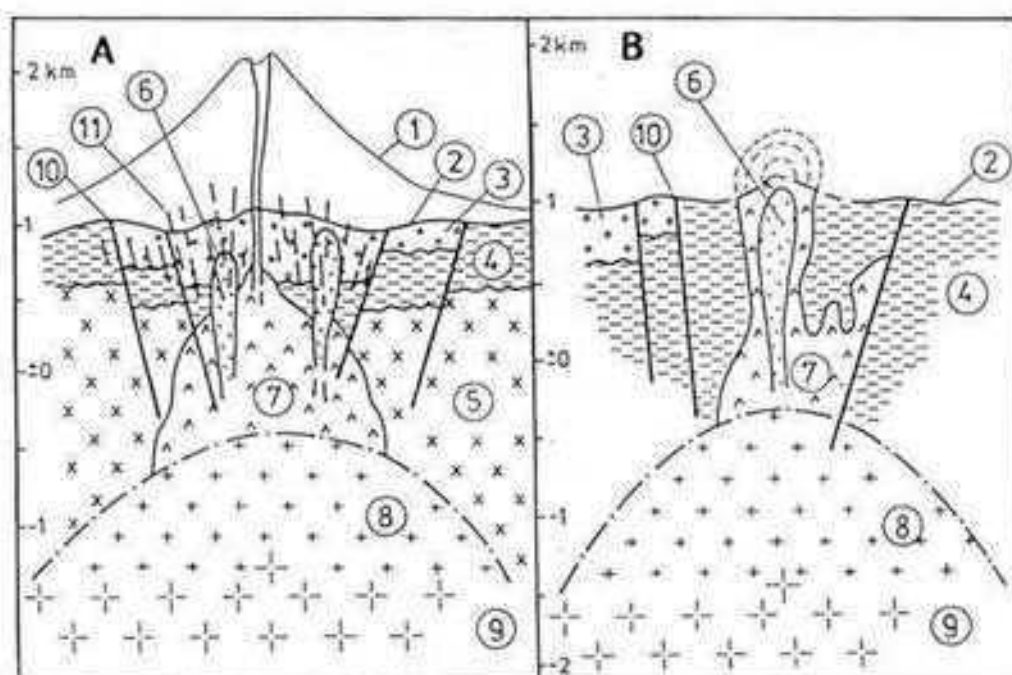


Fig. 21 - Tertiary porphyry models in the South Apuseni Mts (acc. to Vlad, Borcoş, 1996).

Key: A. Model Valea Morii; B. Model Roşia Poieni: 1 - syn-ore palaeosurface; 2 - level of erosion; 3 - siliciclastic rocks of the Tertiary molasse; 4 - Mesozoic sedimentary rocks; 5 - ophiolites; 6 - porphyry copper intrusion; 7 - composite subvolcanic structure; 8 - culmination of pluton; 9 - pluton; 10 - fracture; 11 - Au-Ag and Au-Ag-Pb-Zn sets of veins.

**TABLE 6 - Model Valea Morii-Diorite Type, Cu-Au Polyascendent Evolution
Epithermal Veins Halo (M IX in Fig. 21A, Plate I)**

DESCRIPTION. Stockwork veinlets of chalcopyrite $\pm$ magnetite, bornite in porphyritic intrusions of subvolcanic type and volcanic rocks.

GEOLOGICAL ENVIRONMENT

Rock types. Quartz andesite to quartz diorite and andesite flows.

Age: Sarmatian.

Structural type. The porphyry copper system is centered on subvolcanic apophyses corresponding to culminations of deep-seated plutons.

Depositional environment. Volcano-plutonic complexes situated at the intersection of the main ophiolitic, Laramian and Tertiary tectono-magmatic lineaments trending E-W, NE-SW and NW-SE, respectively. The apical part of the mineralized system is commonly located within Tertiary volcanic rocks, sandstones, conglomerates and pyroclastics. At depth the igneous rocks come in contact with Mesozoic sedimentary and ophiolitic rocks and pre-Mesozoic metamorphic rocks. The Tertiary igneous assemblages occur in molasse basins controlled by reactivation of early fracture systems.

Major tectonic setting. Back arc reactivation along extensional fault systems.

Large scale zonality- associated deposit types. Cu-Au stockwork in hydrothermally altered subvolcanic body -- Au-Ag $\pm$ Te and Pb-Zn $\pm$ Cu veins in hydrothermally altered volcanic rocks -- pyrite halo in some intruded rocks (e.g. Mesozoic ophiolites).

DEPOSIT DESCRIPTION

Mineralogy. Chalcopyrite $\pm$ magnetite with ilmenite or rutile inclusions + pyrite with rutile inclusions $\pm$ bornite, sphalerite, tetrahedrite, galena, gold, molybdenite veinlets and chalcopyrite + magnetite + pyrite impregnations in potassic zone.

Alteration. Potassic alteration (K feldspar + biotite with superposed anhydrite, adularia, albite, sericite, chlorite, actinolite, calcite) in subvolcanic bodies. Peripheral early and pervasive propylitic alteration (chlorite + actinolite + epidote + calcite).

The alteration pattern is similar to the diorite type.

Ore controls. Veinlets and fractures of quartz, chlorite, epidote and sulphide are closely spaced.

Weathering. Bleached country rock, "limonitization"

Geochemical signature: Cu, Au, As, Ti, Mn, Pb, Zn, Ag, Mo, Sb, Bi, Co, Ni

Deposits / Prospects: Valea Morii, Musariu, Bolcana, Voia, Colnic, Tălagiu, Haneş-Larga, Trampoiele, Muncăceasca W, Valea Tisei, Târnița.

**TABLE 7 - Model Roşia-Poieni-Diorite Type, Cu-Mo Polyascendent Evolution
Pyrite Halo (M VIII in Fig. 21B, Plate I)**

DESCRIPTION. Chalcopyrite + pyrite $\pm$ molybdenite in stockwork in hydrothermally altered porphyritic intrusion.

GEOLOGICAL ENVIRONMENT

Rock types. Quartz andesite to quartz diorite porphyry stocks and related breccia intruding crystalline basement, Cretaceous and Tertiary sedimentary rocks.

Age. Sarmatian.

Structural type. High-level intrusive porphyry contemporaneous with faults and breccia pipes.

Depositional environment. Plutonic cupola and related subvolcanic intrusion along tectonic alignments striking E-W or NW-SE in the Tertiary molasse basin. The igneous assemblage penetrated in the crystalline pre-Mesozoic basement and Cretaceous flysch and Badenian-Sarmatian molasse.

Major tectonic setting. Back arc reactivation along extensional fault systems.

Large scale zonality associated deposit types. Not expressed.

DEPOSIT DESCRIPTION

Mineralogy. Pyrite + chalcopyrite + molybdenite $\pm$ magnetite, hematite veinlets with subordinate pyrrhotite, bornite, sphalerite, galena, digenite, enargite-famatinite, lusonite-stibiolumonite, tetrahedrite-tennantite in potassic zone.

Alteration. Potassic alteration (biotite + quartz $\pm$ Q-feldspar and anhydrite) in the porphyritic intrusion, partly replaced by albite $\pm$ actinolite. Argillic alteration (kaolinite + illite + montmorillonite $\pm$ alunite) at the margin of the subvolcanic body. Early propylitization (calcite + chlorite + rutile + albite) in surrounding volcanic rocks. The alteration pattern is similar to the diorite type.

Weathering. Restricted chalcocite blanket and gossan.

Geochemical signature. Cu, As, Mo, Ti, Mn, Au, Pb, Zn, As, Bi, Se, Ta.

Deposits Prospects. Roşia Poieni, Bucureşti-Rovina, Deva, Măgura.

**TABLE 8 - Model Roşia Montană-Precious Metal Breccia Pipe and Veins
(M X in Fig. 22A, Plate I)**

DESCRIPTION. Epithermal gold in volcanic rocks and associated sedimentary rocks.

GEOLOGICAL ENVIRONMENT.

Rock type. Dacite to rhyodacite and quartz andesite and associated volcano-sedimentary and sedimentary siliciclastic rocks.

Age. Badenian

Structural type. Fracture and breccia mineralization in dacite flow above subvolcanic plugs

Depositional environment. Volcano-plutonic complexes situated at the intersection of the main ophiolitic, Laramian and Tertiary tectonomagmatic alignments in molasse basins. The regional lineation is NW-SE and exhibits local phreatomagmatic explosions with associated ore formation. Breccia pipes as apex of the mineralized system occur in the volcanic edifices or toward their margins. At depth the igneous rocks come in contact with Mesozoic siliciclastic and ophiolitic rocks and pre-Mesozoic crystalline schists.

Major tectonic setting. Back arc reactivation along extensional fracture systems.

Large scale zonality - associated deposit types. Epithermal gold (quartz-adularia), polymetallic veins and replacement.

DEPOSIT DESCRIPTION

Mineralogy. Pyrite + arsenopyrite + gold, subordinate sphalerite, chalcopyrite, galena, alabandite, tetrahedrite. Peculiar proustite, pearceite, polybasite, argentite.

Alteration. Regional propylitization, quartz + sericite + adularia, argillic alteration.

Ore controls. Intimate association of quartz-adularia alteration with gold shoots.

Weathering. Bleached country rock, "limonitization"

Geochemical signature: Au, Ag, As, Sb, Bi, Ti, Se, Tl.

Deposits: Roşia Montană, Radu-Frasin, Cănel, Draica, partly Baia de Arieş.

**TABLE 9 - Model Săcărâmb-Precious Metal Veins
(M XI in Fig. 22B, Plate I)**

DESCRIPTION. Epithermal Au-Ag-Te in volcanic rocks and associated siliciclastic sequences, local polymetallic veins.

GEOLOGICAL ENVIRONMENT

Rock types. Quartz andesite and andesite and associated siliciclastic sedimentary and volcano-sedimentary rocks.

Age. Sarmatian.

Structural type. Vein and stockwork sets in apical part of subvolcanic plugs.

Depositional environment. Volcano-plutonic complexes situated at the intersection of the main ophiolitic, Laramian and Tertiary tectonomagmatic alignments in molasse basins. The apex of the mineralized system is commonly located within Tertiary volcanic and subvolcanic rocks and siliciclastic rocks. The basement consists of Mesozoic siliciclastic rocks and ophiolites.

Major tectonic setting. Back arc reactivation along extensional fracture systems.

Large scale zonality - associated deposit types. Polymetallic veins or stockworks and replacement, distal gold metasomatic disseminated.

DEPOSIT DESCRIPTION

Mineralogy. Stage 1 is pyrite + pyrrhotite + arsenopyrite + sphalerite + galena + chalcopyrite + alabandite. Stage 2 is represented by common sulphides and nagyagite, krennerite, silvanite, altaite, hessite, petzite, tellurium, tetrahedrite, boulangerite, jamesonite, antimonite, arsen, gold in quartz + carbonate (mainly rhodocrosite) + clay minerals gangue.

Alteration. Regional propylitization; chloritization, quartz + adularia, sericitization, argillic alteration.

Ore controls. Tendency of horizontal and vertical zonality. Quartz + adularia alteration is intimately associated with Te-Au-Ag mineralization, sericite and argillic alteration is associated with Pb-Zn-Au-Ag mineralization and chloritization with pyrite-Pb-Zn mineralization.

Weathering. Bleached country rock, "limonitization"

Deposits: Săcărâmb, Stănija, Fața Băii, partly Baia de Arieș.

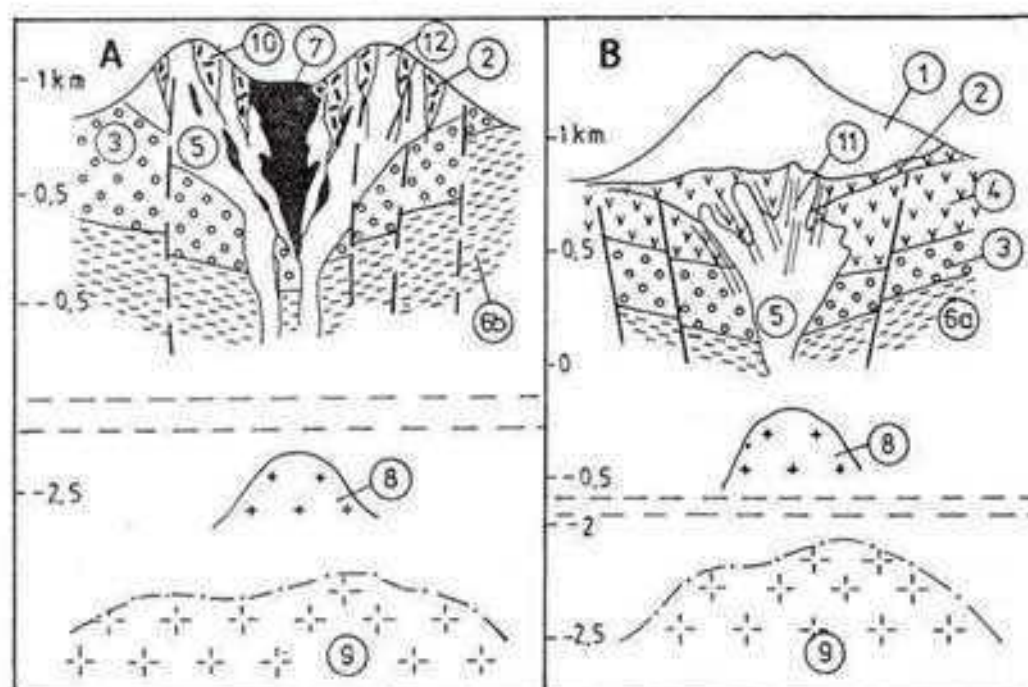


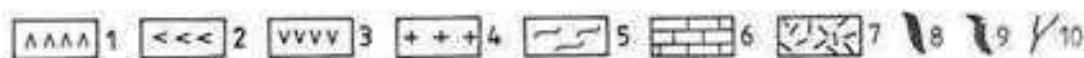
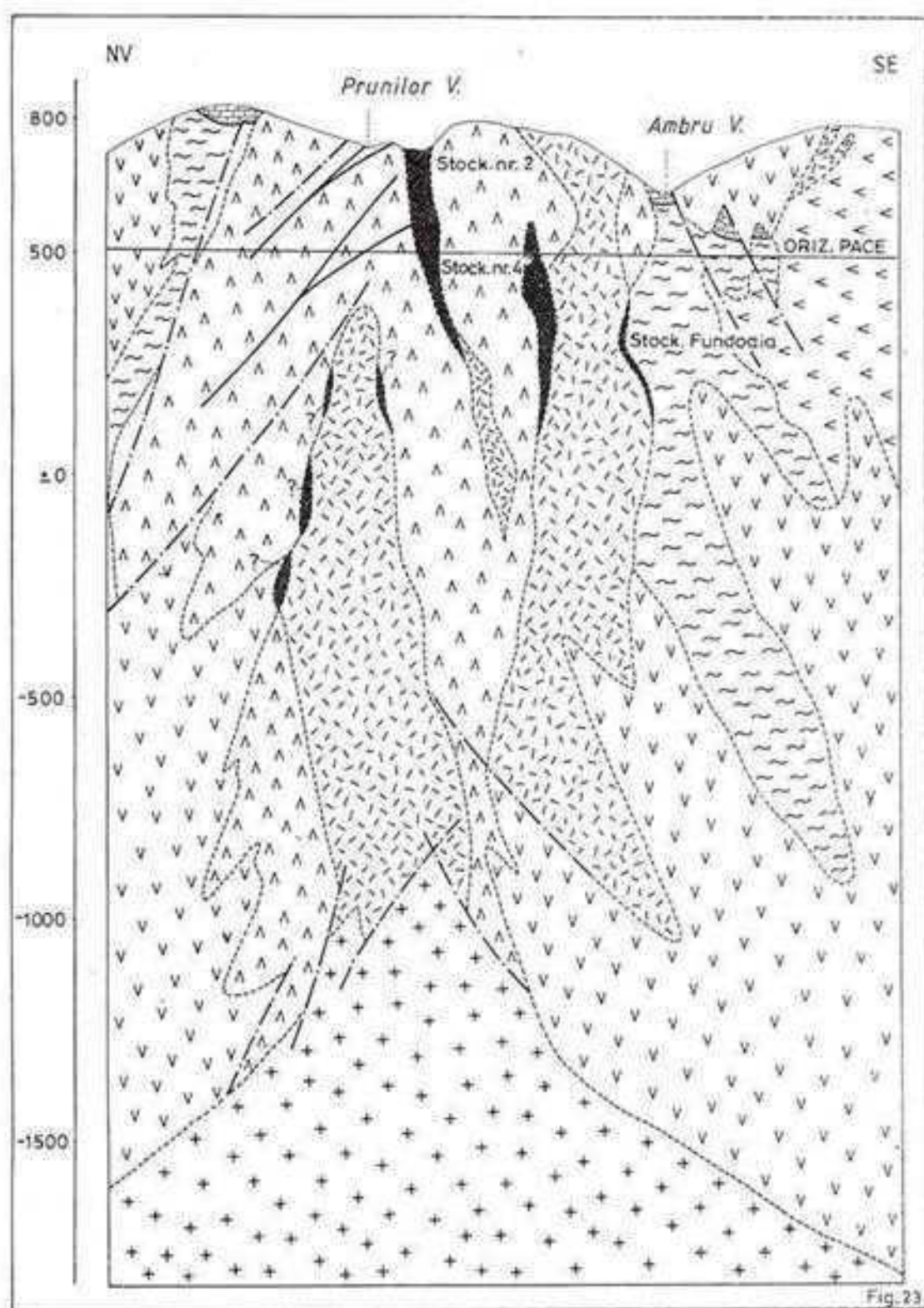
Fig. 22 - Tertiary epithermal models in the South Apuseni Mts. (acc. to Borcoş, Vlad, 1997).

Key: A. Model Roşia Montană; B. Model Săcărâmb: 1 - syn-ore palaeosurface; 2 - level of erosion; 3 - siliciclastic rocks of the Tertiary molasse; 4 - volcanic products; 5 - subvolcanic body; 6 - underlying rocks (a - Mesozoic ophiolitic and associated sedimentary rocks; b - crystalline schists and Mesozoic sedimentary rocks); 7 - phreatomagmatic explosion breccia; 8 - culmination of pluton; 9 - plutons; 10 - breccia pipe; 11 - vein; 12 - stockwork mineralization.

At Baia de Arieş, a special type of breccia pipe was identified by Ghiţulescu in 1958 (unpublished data). This was generated by the percussive blast of some punctiform volcanic eruptions, ejecting gases with volcanic ash without lavas or any other form of liquid magma. In most of the cases, the breccia pipe usually with pipe-like formes represents ideal structural traps of richest gold concentrations (Ghiţulescu, Pitulea, Ghiţulescu, 1979) (Figs. 23, 24).

Fig. 23 - Schematic section through Afişiş andesitic body (acc. to Ghiţulescu, Sprânceană, 1983, with completions)

Key: 1, 2, 3 - successive andesitic intrusions; 4 - pluton culmination; 5 - crystalline schists; 6 - crystalline limestones; 7 - breccia pipes; 8 - gold stockworks; 9 - gold veins; 10 - fractures.



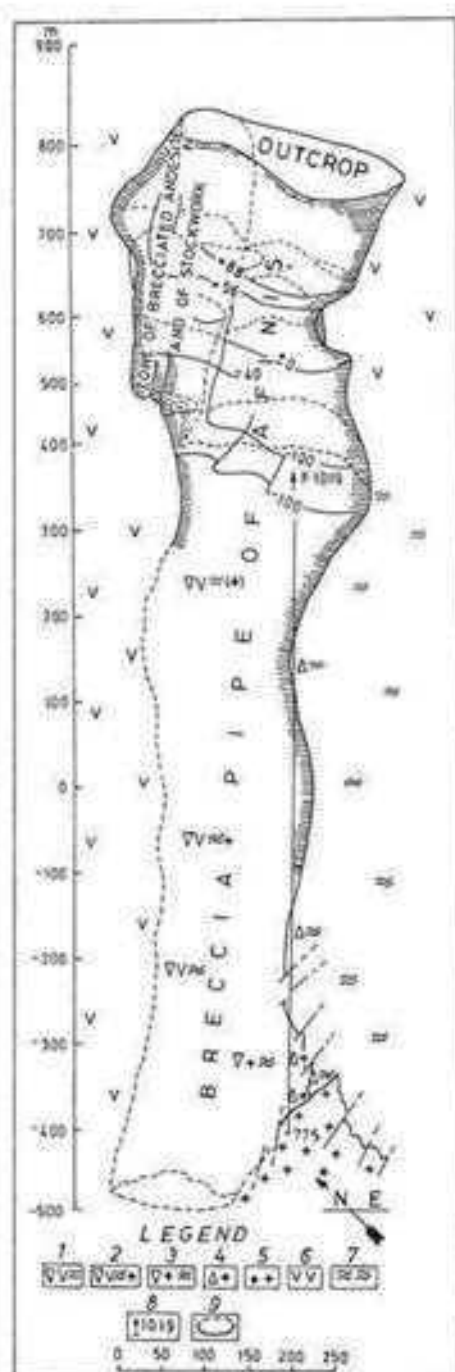


Fig. 24 - Perspective representation of the Afanîş breccia pipe (acc. to Ghiţulescu et al., 1979).

1 - pipe-like polygenous brecciform formation with fragments of macroporphry andesite and crystalline schists; 2 - pipe-like polygenous brecciform formation with two andesite types (macro- and microporphry); 3 - pipe-like polygenous brecciform formation with microporphry andesite and crystalline schists; 4 - brecciated microporphry andesite; 5 - apex of diffused mineralized microporphry subvolcanic body; 6 - Afanîş andesite; 7 - crystalline schists; 8 - drilling; 9 - mining level.

The mineralising solutions penetrated inside the andesite blocks, already affected by hydrothermal alteration, yielding an impregnation of gold-bearing metalliferous sulphides. The process developed as a metasomatism, whose intensity decreased from the periphery to the core of the block, so that, in certain cases, it became sterile. The richest mineralisation was formed by the deposition of gangue and metalliferous minerals in empty space. The composition of this mineralisation is relatively simple, including approximately 6% pyrite, 3% arsenopyrite, 1% marcasite, 0.2% hematite and magnetite, 0.1% sfalerite, 0.05% alabandine, 0.05% chalcopryite, 0.01% galena and 0.01% gold and silver stibio-telluride ($(\text{Ag,Au})\text{Fe}_2$) (Niţulescu et al., 1957).

The most characteristic product of this type of mineralisation is represented by a deposit of microcrystalline silica intergrown with microscopic crystals of pyrite, marcasite and gold bearing arsenopyrite. As crystallisation forms it is worth mentioning the filiform marcasite ornated by rhombic crystals of gold bearing arsenopyrite. The mineralisation occurs as compact siliceous crusts of a dark grey colour (black crusts covering the andesite blocks). The empty space between blocks is filled, more or less completely, by short and thin crystals of white quartz in association with small crystals of metal sulphides. The presence of carbonates (calcite, siderite, rhodochrosite) and fluorine is noticed in the gangue. The free silica is the prevailing element, exceeding usually 60%; if this is better represented (up to 90%), it is rich in gold. A positive quantitative relationship between gold, arsenic and silica is also observed (Ghițulescu, Sprânceană, 1983).

Neogene volcanicity/metallogenesis in the Oaş-Gutâi Mountains

The Oaş-Gutâi Neogene volcanic area represents a distinct sector of the volcanic arc proceeding almost continuously from the West Carpathians to the East Carpathians. They were formed in the same major geotectonic setting; differences are marked only by their volcanic and metallogenetic evolution (Fig. 25). Volcanicity of the Oaş Mts shows affinities towards the Transcarpathian region; their igneous products built up the southern portion of the Viskovo-Beregovo sector, whereas the Pannonian-Pliocene volcanic suites prevail with related base-metal and Au-Ag mineralization. In the Gutâi Mts the volcanicity acted intensively and almost continuously from Badenian to Pliocene, giving rise to numerous igneous suites and several metallogenetic sequences of base-metal and Au-Ag character of significant economic interest (Borcoş et al., 1973; Giuşcă et al., 1973; Borcoş et al., 1975, 1996; Lang, 1979).

The recent geotectonic setting inferred from geological-geophysical data promoted in the Oaş-Gutâi region an infrastructure composed of Neogene plutons in genetical relations with several fracture systems that controlled the development/emplacement of the volcanicity/metallogenesis (Socolescu, 1964, 1965; Andrei et al., 1994; Borcoş et al., 1973, 1994, 1996; Crahmaliuc, 1999). The pre-Neogene basement consists of metamorphic rocks and Cretaceous-Paleogene sedimentary rocks, dislocated along a pre-Neogene latitudinal fracture system. The major ruptural line - Dragoş Vodă fault is situated on the southern margin of the Gutâi Mts and extends, significantly, along the strike (100 km toward East up to Cărlibaba and 120 km toward West beyond Carei). This pluton as well as the pluton delineated in the Oaş area occur in an uplifted compartment of the basement. It is likely that similar fractures striking E-W are to be found north of the Dragoş Vodă fault with extension in the Oaş region and further to adjacent volcanic areas, from Hungary and Ukraine wherein geophysical anomalies indicate deep-seated plutons, too. Additional regional fracture sets strike especially E-W and NW-SE (Borcoş et al., 1980). They cut the plutons promoting significant tectonic reactivation, mainly of levogyre displacement. Such reactivation acted periodically during the plutonic/volcanic events, yielding dense fracturation with important role in metallogenetic initiation and distribution (Borcoş et al., 1996).

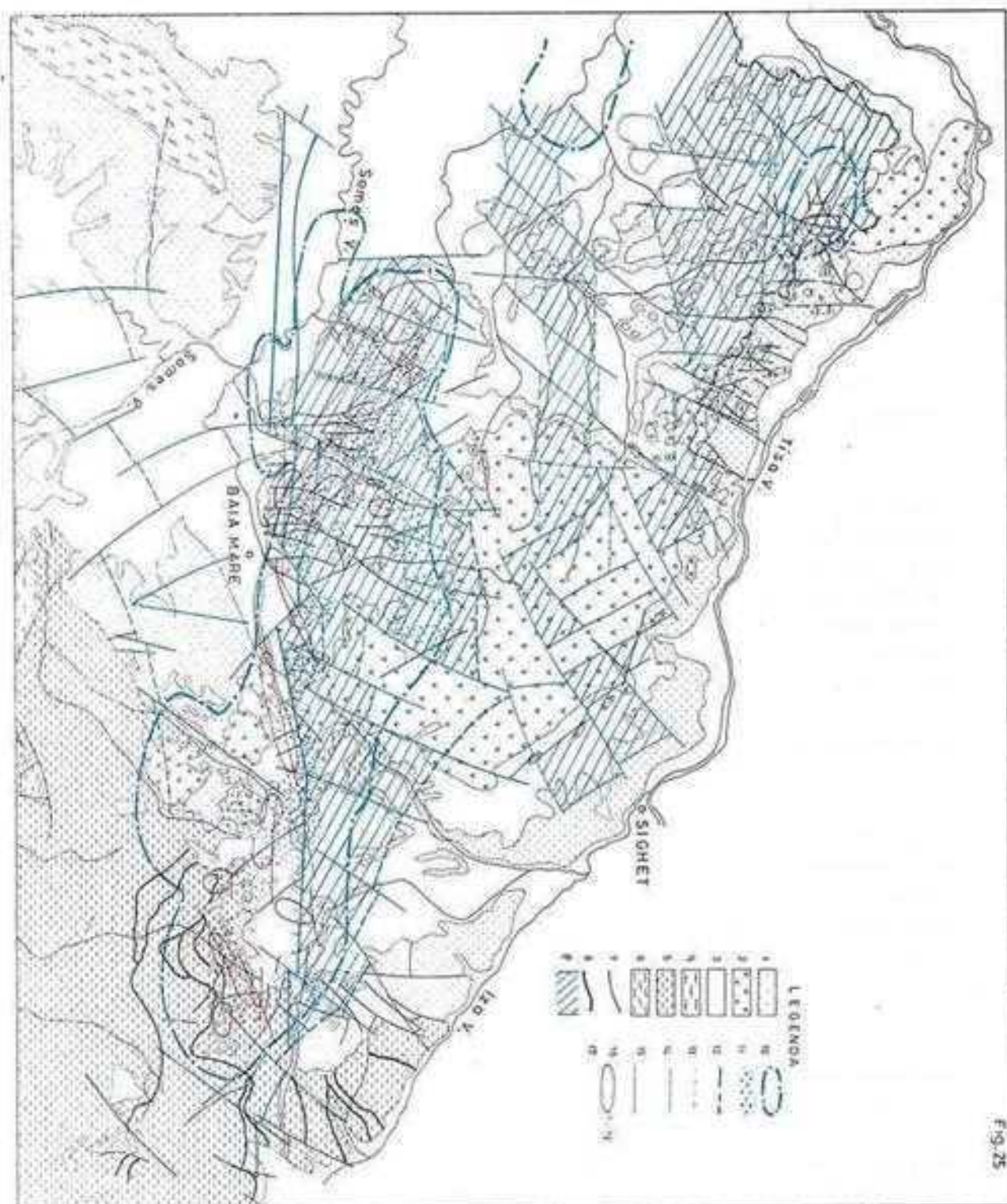


Fig. 25

Alternation of sedimentary with igneous sequences and related volcano-sedimentary formations delineate three successive volcanic phases during Badenian-Pliocene periods of time (Borcoş et al., 1973, 1994, 1996).

The first event is Badenian-Sarmatian and exhibits a prevailing acidic character (rhyolite, rhyodacite); ignimbrite and volcano-sedimentary formations are common. They are located on the south-eastern part of the Gutâi Mts and north-eastern part of the Oaş Mts and proceed in the Transcarpathian region and in the southern Hungary where they develop widely.

The second event is mainly andesitic and polystadial. From Volhynian to Lower Bosphorinan times the igneous products are widespread in both Oaş and Gutâi Mts and comprise three ore forming sequences related to Sarmatian pyroxene andesites, Pannonian quartz andesites and Pontian andesites. The most representative occurrences are found in the southern-central part of the Gutâi Mts and all over the Oaş Mts.

The third event started at the end of Pontian times and continued in the Pliocene. The character is mainly andesitic, with frequent extrusive character. These igneous rocks are commonly found in the northern part of the Oaş-Gutâi Mts; they correlate with similar occurrences found in the Transcarpathian region as well as in the Călimani-Gurghiu-Harghita chain.

In the Oaş-Gutâi region, numerous investigations have been undertaken, yielding significant data concerning the structure, igneous and metallogenetic activities. The Neogene pluton of the Gutâi area, especially the contact metamorphism in surrounding rocks and its homogeneous quartz-dioritic character, suggest that its emplacement preceded or acted simultaneously with the early Sarmatian volcanic phase. Information of this kind is going to be provided by investigation of ruptural tectonic kinematics, geochemical and radiometric behaviour displayed by a co-operation team of the GIR, B.R.G.M. and "Cuarţ" S.A. Baia Mare.

Ore deposition is related to three phases with specific metallogenetic character corresponding to ore forming events (Borcoş et al., 1974 a, 1975, 1976, 1994, 1996; Stanciu, 1972, 1973). These districts relay in a rather continuous metallogenetic zone along the southern border of the Gutâi massif, following the eastward migration of the volcanic activity.

Early metallogenetic phase consists of mainly base-metal and gold mineralization, confined to Sarmatian pyroxene andesites of the Ilba-Nistru district. It delineates two NW-SE metallogenetic alignments. The northern lineament is a tectono-volcanic sensu stricto structure; vein sets are commonly normal on its axis. The southern lineament is a fracture

Fig. 25 - Neogene volcanics in the Alpine structural setting of the Oaş-Gutâi region
(acc. to Borcoş et al., 1994).

Key: 1 - Neogene molasse; 2 - Post-ore Upper Pontian-Pliocene andesites; 3, Sarmatian-Pontian andesites (metallogenetic phase); 4 - Badenian volcano-sedimentary formations; 5 - Paleogene flysch; 6 - metamorphic formations; 7 - fault; 8 - nappes; 9 x - tectonic compartments; 10 x - Neogene pluton; 11 x - pluton culminations; 12 x - Dragoş Vodă transcrustal fracture; 13 x - pre-Paleogene fractures partly reactivated; 14 x - pre-Neogene fractures partly reactivated; 15 - main metallogenetic alignments; 16 - mining fields (1. Racşa, 2. Ilba, 3. Nistru, 4. Săsar, 5. Valea Roşie, 6. Wilhelm, 7. Tyuzosa, 8. Ludovica, 9. Valea Negrii, 10. Dealul Crucii, 11. Herja, 12. Baia Sprie-Şuitor, 13. Căvnic, 14. Roata, 15. Brainer, 16. Băiut, 17. Văratec, 18. North Băiut, 19. Jereapăn)

x Geophysical elements

sensu stricto with metallogenetic role; it contains breccia and impregnations bodies of local Cu character.

The subsequent metallogenetic phase is of prevailing Au-Ag character and was formed in relation to Pannonian quartz andesites. The ore occurrences are distributed in the central part of the southern portion of the massif that is the Săsar-Valea Roşie district. The most important alignment is found in the South, in connection with a reactivated sector of the important Dragoş Vodă fault. The Săsar and Valea Roşie deposits represent vein groups with numerous branches usually disposed normal to the axes of the lineament.

The last metallogenetic phase is in association with Pontian pyroxene andesites, found especially in the central-eastern part of the massif. This phase is more complex, showing an gold/base-metal even Cu character, specific to almost all deposits and with a remarkable vertical zoning. Major deposits are controlled by NE-SW fractures crossing the significant Dragoş Vodă fault. The following metallogenetic fractures are recognized from west toward east: Dealul Crucii - Herja - Baia Sprie - Şuor - Băiuţ - Văratec and the tectono-volcanic alignment named Căvnic-Roata with veins disposed normal to the axis. They show a polystadial formation, with specific recurrences of Au and base-metal mineralization; complex breccia pipes with irregular shape and large sizes are common. Along the same SW-NE fracture system Dl. Crucii - Herja, Băiuţ - Văratec Au and base-metal deposits consist of vein groups related to subvolcanic bodies. The Căvnic-Roata tectono-volcanic alignment comprises vein groups of similar polyascendant character, controlled by simultaneous ore forming and tectonic brecciation.

The above-mentioned districts contain sequences of metallic/gangue associations that can be used as geochemical markers or discriminative elements of those three metallogenetic events.

According to recent results (Lang et al., 1994; Kovacs et al., 1998) in the Gutâi Mts the metallogenetic activity developed in two main phases: the first phase took place in the Lower Pannonian (11.5 - 10 m.y.), including the metallogenetic events from Ilba - Nistru and Săsar - Dl. Crucii districts, and the second one is in the Upper Pannonian (9.4 - 7.9 m.y.), including those from Herja - Băiuţ district. The metallogenetic activity in the Oaş and Tibleş Mts is contemporaneous with the second phase of the Gutâi Mts (9.6 - 7.8 m.y.). The presence of a gap (0.5 - 1.5 m.y.) between the ages of the epithermal mineralisations (adularia-sericite type) and the host magmatic rocks in this region is very similar as compared to other subduction-related occurrences worldwide.

Conceptual ore forming conditions. Tectono-magmatic setting, alteration, zoning and ore mineralogy correspond to two models, that is Baia Sprie breccia (phreato-magmatic explosion type) - vein deposit with base-metals and precious metals, and Căvnic vein deposit, with base-metal and precious metals (Vlad, Borcoş, 1997) (Tables 10, 11, Fig. 26).

Neogene metallogeny in the Toroiaga-Bărgău-Tibleş subvolcanic zone

The so-called subvolcanic zone of the Neogene volcanic chain of the East Carpathians contain base metal ores mostly of vein type, with subordinate disseminated and breccia-pipe ores. The host rocks are andesitic in composition (Toroiaga, Rodna, Bărgău) and

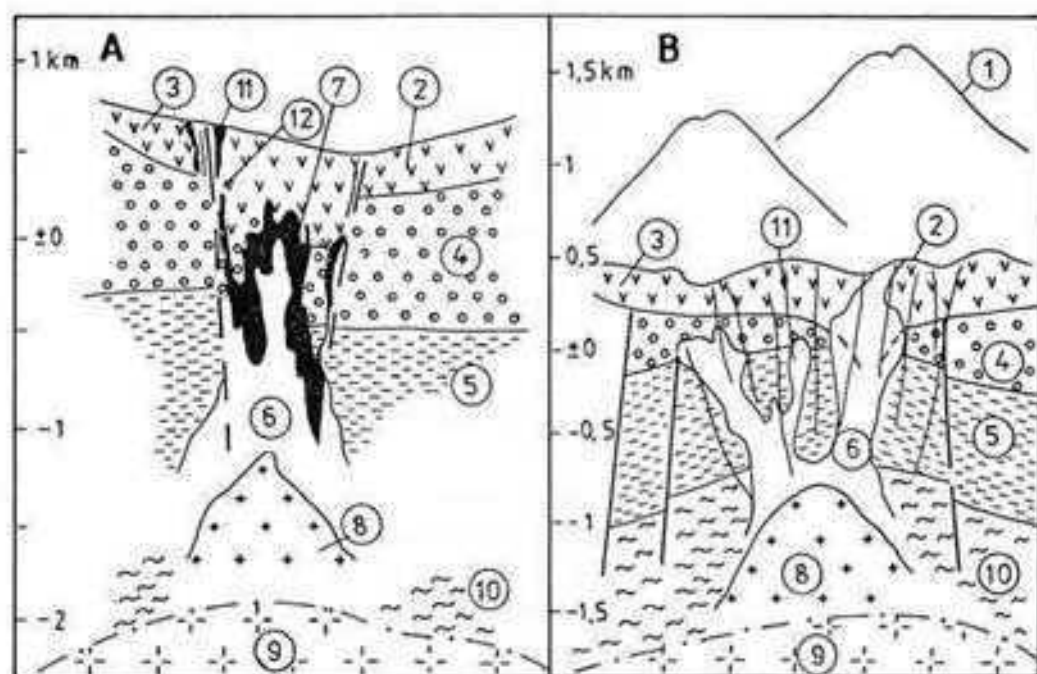


Fig. 26 - Tertiary epithermal models in the Oaş-Gutâi Mts. (acc. to Borcoş, Vlad, 1997).

Key: A. Model Baia Sprie; B. Model Căvnic: 1 - syn-ore palaeosurface; 2 - level of erosion; 3 - volcanic products; 4 - siliciclastic rocks of the Tertiary molasse; 5 - hornfels in Paleogene sedimentary host rocks; 6 - subvolcanic body; 7 - phreato-magmatic explosion breccia; 8 - culmination of pluton; 9 - pluton; 10 - crystalline schists; 11 - vein; 12 - stockwork mineralization.

display a much more complex structure and composition in the Țibleș Mts. Here intrusive rocks of monzodiorite and granodiorite composition form the central part of the massif. The peripheral zones consist of rocks of andesitic composition and form either a nearly continuous belt around the intrusive nucleus or small to very small bodies intruded into surrounding Paleogene sedimentary rocks. The metallogeny of the Țibleș massif is also a very complex one, displaying a well-developed regional zoning, with high temperature associations (pyrrhotite, arsenopyrite, pyrite, iron-rich sphalerite etc.) in the central part, being nearly completely surrounded by a belt of lower temperature associations (stibnite, kermesite, cinnabar, berthierite, owyheeite etc.) (Fig. 27). In addition, in the southern part of the intrusive nucleus the veins are slightly enriched in copper, a fact which parallel both alteration types (K-feldspar, biotite etc.) and mineral parageneses (veinlets of magnetite and chalcopyrite) suggesting the presence of a hidden porphyry copper system (Udubaşa et al., 1983, 1994; Pintea, 1998).

The Toroiaga veins contain Cu-Pb-Zn ores with local gold enrichment zones. In addition to the major common sulphides, numerous sulphosalts were described here, both Sb-dominated (Steclaci, 1968) and Bi-dominated (Cook, 1997). General features of the petrography and geochemistry of the whole ore field are given by Borcoş (1967), Borcoş et al. (1982), Berza et al. (1981).

The Rodna ore field is related to subvolcanic rocks of andesitic composition intruding metamorphic rocks that host stratiform Pb-Zn ores in carbonate rocks. The hydrothermal ores form both replacement bodies in carbonate rocks and dissemination within

TABLE 10 - Model Baia Sprie-Polymetallic and Precious Metal Breccia Pipe and Veins (M VI in Fig. 26A, Plate I)

DESCRIPTION. Epithermal gold and polymetallic veins and breccias.

GEOLOGICAL ENVIRONMENT

Rock types. Quartz andesite and andesite and associated sedimentary rocks. The igneous rocks belong to the Later Tertiary volcanic arc of the East Carpathians.

Age. Sarmatian-Pannonian, Pontian

Structural type. Epithermal system controlled by subadjacent pluton situated in major crustal fault.

Depositional environment. Volcano-plutonic complexes. Deposits related to subvolcanic level undergoing phreatomagmatic explosion along reactivated NW-SE and SW-NE regional fracture sets. The Late Tertiary pluton of quartz diorite composition is situated at 2 to 4 km depth. The metalliferous systems extend 1.5 km away from the apical part of the plutonic culmination.

Major tectonic setting. Island-arc volcanic setting.

Large scale zonality/associated deposit types. Epithermal gold (quartz-adularia), polymetallic veins.

DEPOSIT DESCRIPTION

Mineralogy. Early stage with pyrite + chalcopyrite + hematite, scheelite, magnetite, wolframite in chlorite + quartz + ankerite + barite gangue. Subsequent stage with pyrrhotite + sphalerite + chalcopyrite + galena.

Alteration. Regional propylitization, chloritization, quartz + adularia, sericitization, argillic alteration.

Ore controls. Tectonic fractures and anastomosing fissural systems. Vertical zoning: top to bottom Au-Ag -- Pb-Zn-Au-Ag -- Cu-Pb-Zn -- Cu +- W. Selective association of gold with quartz-adularia alteration, polymetallic ores with sericite-argillization and copper with chloritization.

Weathering. Bleached country rock. "Limonitization".

Geochemical signature. Cu, Pb, Zn, Au, Ag, As, Sb, Bi, Se, Cd, Ga, Te, Ti, W, Co, Ni.

Deposits: Baia Sprie, Suior, partly Baiut-Varatic, Vf.Tapului-Mihai-Nepomuc.

the breccia-pipes (as described by Socolescu et al., 1977). The ores contain iron-rich sphalerites, pyrrhotite, pyrite, arsenopyrite, galena as well as native gold (mostly in the breccia ores), Ag tellurides and some sulphosalts (Udubaşa, 1970, 1976, 1984).

Small ore occurrences exist also in the Bărgău Mts, forming either veins (Pb-Zn-As and some gold, e.g. Colibiţa) and impregnations in brecciated andesites and Paleogene sedimentary rocks. They are quite similar to the ore occurrences found in the southwards situated Călimani Mts (e.g. Stănceni) (Peltz et al., 1981).

**TABLE 11 - Model Cavnic-Base Metal and Precious Metal Veins
(M VII in Fig. 26B, Plate I)**

DESCRIPTION. Epithermal gold and polymetallic veins.

GEOLOGICAL ENVIRONMENT

Rock types. Quartz andesite and andesite and associated sedimentary rocks. The igneous rocks belong to the Late Tertiary volcanic arc of the East Carpathians.

Age. Sarmatian-Pannonian, Pontian

Structural type. Epithermal system controlled by subjacent pluton situated in major crustal fault.

Depositional environment. Volcano-plutonic complexes. The mineralized system is commonly located within volcanic rocks. It is centered on subvolcanic apophyses corresponding to culmination of the quartz diorite pluton. The mineralized column is 1.5-2 km high. At depth the igneous rocks come in contact with Early Tertiary siliciclastic rocks converted into hornfels. The sedimentary rocks are displaced along distensional N-S fractures.

Major tectonic setting. Island-arc volcanic setting.

Large scale zonality associated deposit types. Epithermal gold (quartz-adularia), polymetallic veins.

DEPOSIT DESCRIPTION

Mineralogy. Early stage with pyrite + chalcopyrite + hematite + magnetite in quartz $\pm$ chlorite, epidote gangue. Stage 2 is pyrite + sphalerite + galena + chalcopyrite + arsenopyrite in quartz, adularia, carbonate, clay minerals and barite gangue. Stage 3 contains pyrite + galena + sphalerite + chalcopyrite + tetrahedrite in quartz and carbonate (especially rhodochrosite) gangue. Last stage with pyrite + tetrahedrite + bournonite + jamesonite + gold + realgar + orpiment in quartz, gypsum and carbonate gangue.

Alteration. Regional propylitization, chloritization, quartz + adularia, sericitization, argillic alteration.

Ore controls. Tectonic: major fracture and related fault systems. A tendency of vertical zoning from Cu-Pb-Zn bottom zone to Pb-Zn-Au-Ag toward top.

Weathering. Bleached country rock, "limonitization"

Geochemical signature. Pb, Zn, Cu, Au, Ag, As, Cd, Ga, In, Se, Te, Bi, Sb, Mn.

Deposits. Cavnic, Roata, Herja, Ilba, Nistru, Dealul Crucii.

The Toroiaga and Rodna ore fields were exploited for many years (the Rodna mine is dated 1241, when a significant silver production was yielded) and the ore bodies are mostly exhausted. The Tibleş area was intensively explored. The resulted ore reserves of quite good quality are partly oxidized, a fact hampering further mining activity. However, the exploration of the southern part, showing features of a porphyry copper system remained largely unexplored.

*Neogene volcanicity/metallogenesis in the
Călimani-Gurghiu-Harghita Mountains*

The Călimani-Gurghiu-Harghita volcanic chain represents the largest occurrence area of Neogene volcanics not only in Romania but also in the whole Carpathians. It consists of a 160 km long continuous volcanic range with decreasing width, height and volume from North to South.

The chain displays a roughly median position between the East Carpathian structural units (Upper Cretaceous to Paleogene "Transcarpathian Flysch" unit in the north, the "Crystalline-Mesozoic zone" unit in the east, the Cretaceous Flysch unit in southeast) and the Neozoic Transylvanian basin molasse. Contrasting crustal structure of these two major tectonic units is reflected by their crustal thickness as pointed out by magnetotelluric investigations: about 40 km beneath the East Carpathians and about 30 km beneath the Transylvanian Basin (Stănică et al., 1986, 1990). The volcanic chain thus appears to be spatially related to the structural boundaries between them, excepting the South Harghita segment that crosscuts the East Carpathian tectonic units.

The tectonic image of the Călimani-Gurghiu-Harghita chain based on complex geophysical data interpretations suggest the presence of major NW-SE trending tectono-magmatic alignments (controlled probably by collision and subduction geometry), strike-slip fractures (trending generally E-W) and distensional fractures (generally N-S trending) (Fig. 28). Postcollisional compressive tectonism was still active in the outer East Carpathians during volcanism in the Călimani, Gurghiu and North Harghita segments of the chain, while volcanic activity along the South Harghita chain, i.e. the terminus segment, was coeval with Late Pliocene to Pleistocene extensional tectonism. This resulted in intramountain basin formation in the nearby areas and in within-plate alkali basaltic volcanism in the neighboring Perșani Mts. (Rădulescu et al., 1973, 1981; Seghedi et al., 1994; Balintoni et al., 1996).

Increasing amount of geological data suggests that the volcanic structures belonging to the Călimani-Gurghiu-Harghita chain consist of a central volcanic zone with subvolcanic intrusive bodies in its infrastructure, an intermediate zone corresponding to volcanic cone (mainly consisting of lava flows) and a peripheral, mainly volcanoclastic zone. Explosive-effusive volcanic activity prevailed in all the stratovolcanic edifices building up a chain of adjoining and partially overlapping composite edifices with well-developed peripheral volcanoclastic aprons.

Typical calc-alkaline rocks ranging from basaltic andesites to dacites form the great bulk of the chain (Rădulescu, 1973; Peltz et al., 1973). Small volume of tholeiitic volcanic products and high-alumina basalts occurs in the Călimani Mts. An along-chain short distance variation from typically calc-alkaline to shoshonitic composition was pointed out in the southernmost segment (Seghedi et al., 1986, 1987).

The whole Călimani-Gurghiu-Harghita chain was the site of a typical along-arc migration of the volcanism during Neogene and Quaternary times (Rădulescu et al., 1973, Peltz et al., 1987). Volcanism began in the Călimani Mts at 9.5 m.y. over an area already hosting earlier subvolcanic intrusions (10.5 - 9.8 m.y.). Volcanism ceased at about 0.2 m.y. in South Harghita at the end of a spectacular short-distance age progression along this chain terminus (Szakacs et al., unpubl.data).

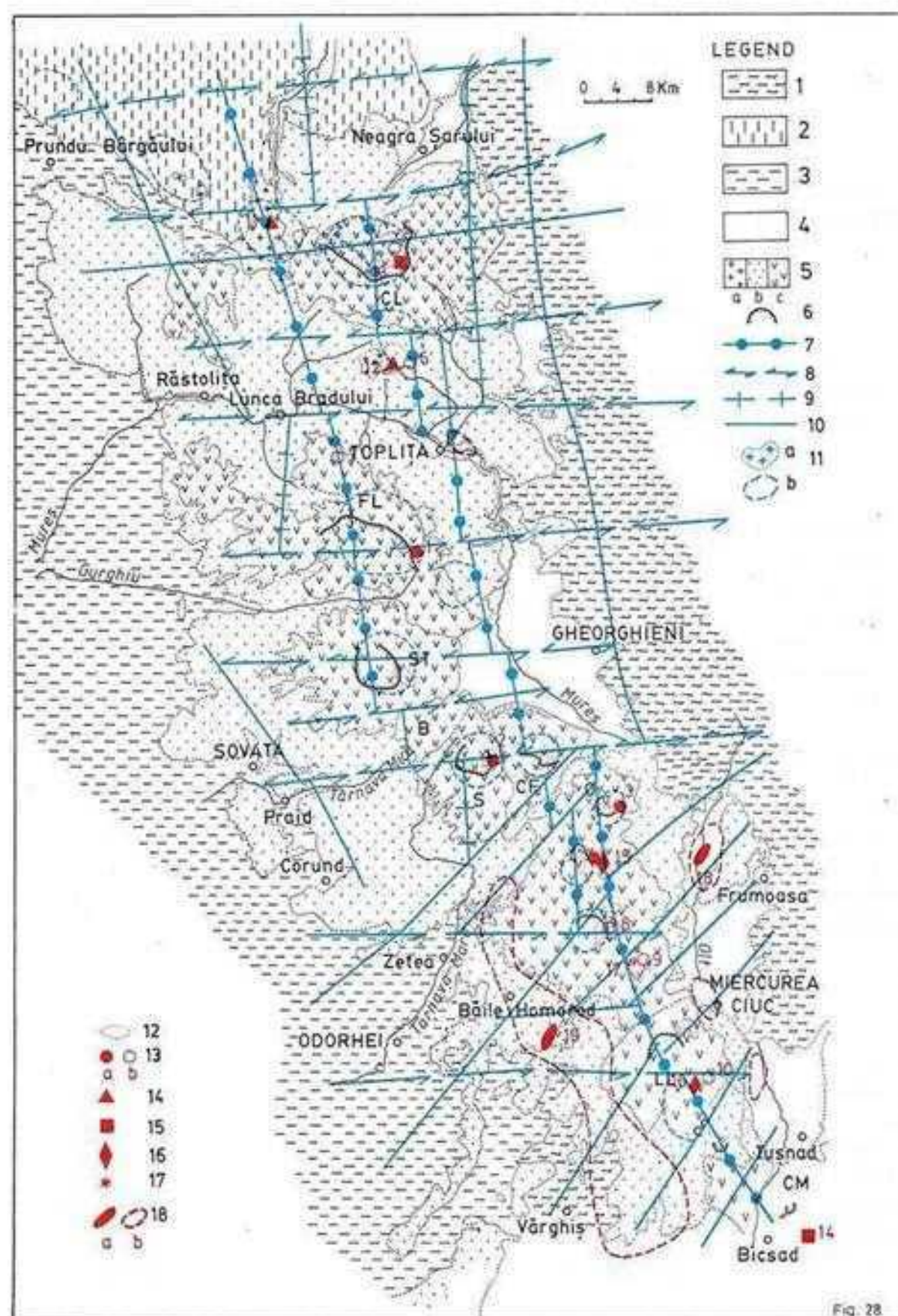


Fig. 28

Fig. 28 - Geological sketch of the Călimani-Gurghiu-Harghita volcanic chain with structural and metallogenetic features (acc. to Seghedi et al., 1994).

Key: **A. Geological features:** 1 - East Carpathian structural units (Crystalline-Mesozoic Zone and Flysch Zone); 2 - Transcarpathian Flysch (Upper Cretaceous-Paleogene); 3 - Transylvanian Basin molasse (Miocene); 4 - Intramountain depression (Upper Pliocene to Quaternary); 5 - Neogene/Quaternary Călimani-Gurghiu-Harghita volcanic chain: a) prevolcanic intrusions; b) volcanoclastic formations; c) stratovolcanic edifices (CL = Călimani, FL = Fâncel-Lăpușna, ST = Seaca - Tâtarca, S = Șumuleu, CF = Ciurani-Fierăstraie, O = Ostoros, IC = Ivo-Cocoizaș, V = Vârghiș, LL = Luci-Lazu, C = Cucu, P = Pilisca, CM = Ciomadul); 6 - Calderas and craters (topographic rim).

B. Tectonic and structural features based on geophysical data interpretation: 7 - Major tectono-magmatic alignments; 8 - Major strike-slip faults; 9 - Major distensional fractures; 10 - other major fractures; 11 - volcanism-related intrusions: a) outcropping; b) partially or totally inferred from geophysical data.

C. Metallogenetic features: 12 - outlines of major areas of hydrothermal alteration; 13 - porphyry copper occurrences (1. Lepeș, 2. Șumuleu, 3. Ostoros, 4. Ivo-Cocoizaș) (a); Porphyry-like alteration = mineralization (5. Călimani, 6. Mermezeu, 7. Jirca, 8. Vârghiș, 9. Harghita-Băi, 10. Sântimbru) (b); 14 - gold-base metal occurrences (11. Dornșoara, 12. Zebrac); 15 - sulphur occurrences: a) major (13. Negoiu Românesc), b) minor (14. Turia); 16 - cinnabar occurrences (15. Ivo-Cocoizaș, 16. Băile Sântimbru); 17 - clay minerals deposit (17. Harghita-Băi); 18 - iron ore (siderite) occurrences: a) major occurrences (18. Mădăraș, 19. Lueta-Vlăhița); b) occurrence area.

There is a strong evidence proving the existence of several different types of hydrothermal processes (Stanciu, 1984): 1) porphyry copper systems related to intrusive magmatic processes, 2) hydrothermal processes related to fractures, 3) postvolcanic activity, and 4) geothermal anomalies related to weak areal meteoric-hydrothermal mineralization. Information on the Călimani-Gurghiu-Harghita chain is quite recent and, in places, incomplete due to the fact that the surface observation is strongly limited by the scarcity of outcrops; mining works and especially drillings, that only at several locations reached 1,200 m deep. Postmagmatic hydrothermal processes were focused in the infrastructure of volcanic edifices and they induced transformations within the prevolcanic basement (intercepted in boreholes at Zebrac and Șumuleu structures), the volcanoclastics (Ciurani-Fierăstraie) and, mostly, the stratovolcanic assemblage (Peltz et al., 19981, 1982).

The alteration and mineralization were controlled by subvolcanic intrusions (andesite and/or microdiorite, occasionally monzodiorite or granodiorite/dacite) located at different levels of the stratovolcanic edifices. They are especially located inside the craterial and caldera areas where the intrusive processes took part in the building up of the volcanic edifices towards the end of the regional eruptive activity.

The most representative process developed in the Fâncel-Lăpușna (Lepeș zone), Șumuleu, Ostoros and Ivo-Cocoizaș edifices are located along the major tectono-magmatic alignment (Peltz et al., 1976; Stanciu, 1976, 1977) (Fig. 29). Considering all the paragenetic aspects (very complicated due to the metasomatic interferences in the multi-intrusive spaces and the superposition of the alteration and metallogenetic products), a zonal development of hydrothermal products centered on the generating intrusions can be observed. The succession is: biotite - amphibole - chlorites - argillic - tourmaline alteration. The biotite alteration, and subordinately the amphibolic one, both with innermost position, formed during the late magmatic phase on an initial propylitic (autometamorphic type) background that in places preserves small relics of fresh rock. The subsequent alterations are the result of hydrothermal fluid activity that gave rise to transitional chloritic rocks and then, by contamination with

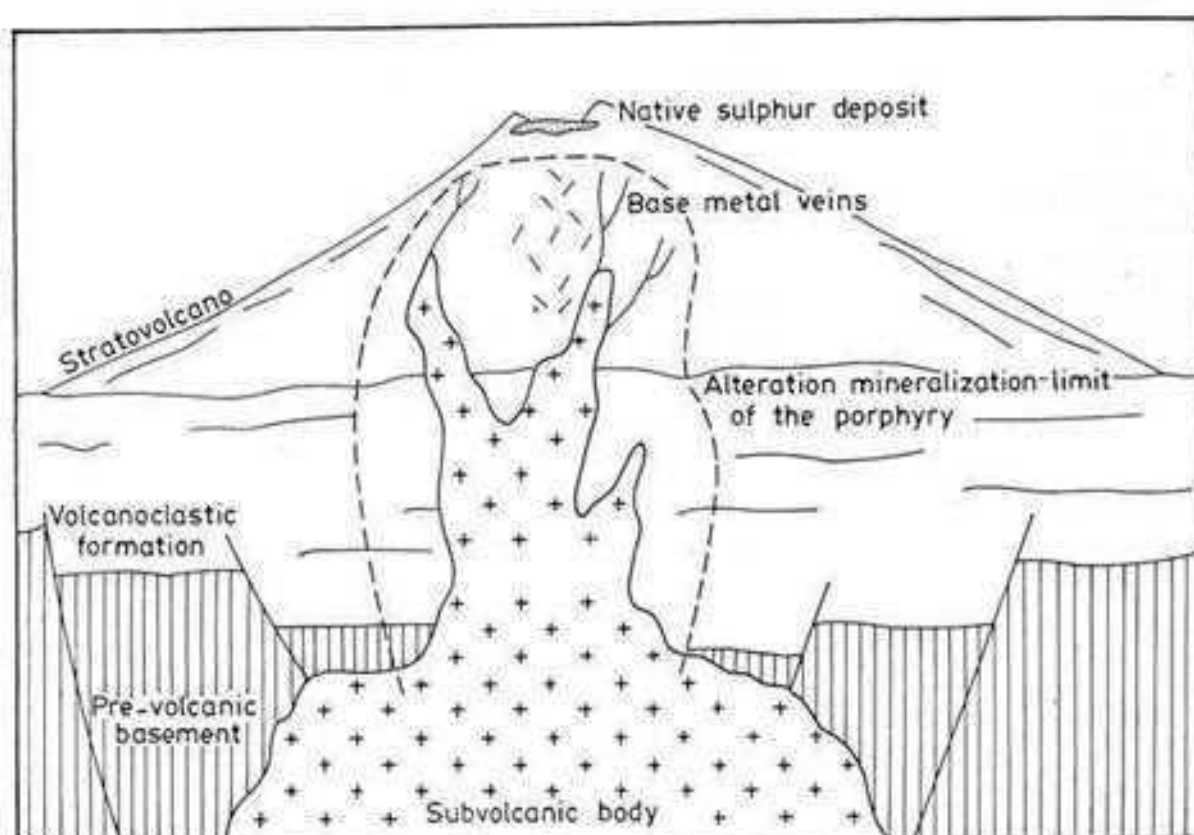


Fig. 29 - Hypothetic sketch showing the succession of the hypogene products of the Calimani-Gurghiu-Harghita chain (acc. to Stanciu, 1976).

meteoric waters, generate a pervasive argillic alteration mostly occurring within the host stratovolcanic formation. At this stage the porphyry system-related alteration is completed in the Gurghiu Mts while in the Harghita Mts the hydrothermal process continued with an intense tourmaline metasomatism accompanied by the formation of tourmaline-quartz veins (Peltz et al., 1982a; Stanciu, 1984). There is not sufficient evidence but it is possible that such formations may represent the final moments of the breccia pipe structures that are commonly associated to copper mineralization located within stratovolcanic edifices, i.e. in the Andine Cordillera in Chile and Argentina (Sillitoe, Sawkins, 1971).

The metallic minerals occur as disseminations, fissures and blurred veinlets being deposited concomitantly with the alteration process. However, a slight metallization was observed in the propylitic zones, too. Pyrite is found in all alteration zones and the magnetite-pyrrhotite-chalcopyrite assemblage is associated with the internal alteration. As the copper content is low, no zones of economic interest have been outlined yet. In the external argillic zone the metallic paragenesis is much simpler with pyrite as the characteristic mineral. The tourmalinic rocks contain pyrite with or without marcasite, sporadically molybdenite or chalcopyrite.

Late-stage intrusive breccias formed along certain fracture planes at Șumuleu and Ivo-Cocoiaș.

In the upper part of the porphyry-copper system small quartz vugs and base-metal sulphide veins are frequently found. Lateral passage towards fissural deposition and cinnabar stibnite impregnations are observed at Ivo-Cocoizaş.

Partial aspects of the porphyry-type alteration are recognized in the Călimani caldera, at Mermezeu, Jirca, Seaca-Tâtarca, Harghita-Băi (with near-surface accumulations of argillic rocks) and Sântimbru-Băi areas (Peltz et al., 1982).

The hydrothermal processes related to the postvolcanic tectonic activity appear generally at the exterior and upper part of the porphyry system. At Zebrac a common alteration (propylitic-chloritic-argillic) took place around the endogenous veins and breccias with base-metal and gold tellurides. A somewhat similar situation has been encountered at Dornişoara (NW of Călimani Mts.). In the Sântimbru-Băi and Ivo-Cocoizaş cinnabar zones the alteration is weak and argillization accompanied by superposed carbonation and silicification $\pm$ tourmalinization are prevailing (Vasilescu, 1964; Peltz et al., 1974).

Numerous minor areas with poor indications of mineralization are controlled by non-mineralized fractures and zones of brecciation surrounded by argillic halos passing to silicic halos following circulation pathways. Such areas represent the terminal part of hydrothermal processes with still unknown continuity at depth. They are most frequent in the Harghita Mts. This process type is specific to the volcanism in the Călimani and Harghita Mts. In Negoiu Românesc area inside the Călimani caldera solfatara-type exhalations interacted with local aquifers giving rise to native sulphur and limonite deposition conformable with the stratification in the volcanic pile. The sulphur concentrations occur as lenses and beds in a silicification aureole formed in andesitic pyroclastics. Massive sulphur is associated with pyrite, melnikovite and marcasite; subsequently, a less widespread association consisting of limonite, goethite and hydrogoethite overlapped the sulphur/sulphide association (Mureşan, Peltz, 1969; Stanciu, 1984).

The western and the eastern parts of the Călimani-Gurghiu-Harghita Mts contain numerous small iron (siderite) deposits closely related to the volcanoclastic formations (Mureşan, Tănăsescu, 1981; Peltz et al., 1982; Ianovici et al., 1983). Among them two major accumulations are located at Mădăraş and Vlăhiţa. The mineral paragenesis displays low temperature assemblages such as monomineral siderite $\pm$ opal, marcasite. Such types of iron deposits, considered to be generated under volcano-sedimentary or hydrothermal metasomatic conditions, according to Szakacs (1992), represent a peculiar type of "meteoric hydrothermal" accumulations. Silica-saturated aquifers provided suitable chemical traps for siderite-opal coprecipitation.

At Vlăhiţa-Lueta iron ore has been mined more than 200 years long and it is now practically exhausted.

Metallogenesis in passive margin-related settings

Restricted Fe occurrences of Paleogene age are found at Căpuş (Gilău Massif, North Apuseni Mts) within epicontinental sediments. The ores are represented by limonitic oolites found in carbonatic, chloritic and glauconitic cement (Vinogradov et al., 1963; Stoicovici, Mureşan, 1964). Such sedimentary Fe ores were considered to be formed on the north-western passive continental margin of the Transylvanian small ocean after unification of the South Apuseni Mts island arc with the North Apuseni Mts sialic block.

Shear zone related ores

In the metamorphic rocks of the South Carpathians and to a lesser extent in the Apuseni Mts there are several ore occurrences of varied composition, but always gold-bearing or even gold-dominated, which can be ascribed to the shear zone related ore type. The first genetical approach was made by Udubaşa (1978, unpubl. data) in ascribing the gold ores at Valea lui Stan, Căpătâna Mts to this ore types, at that time named "tectogenic". Later on, the data were published (Udubaşa, Hann, 1988) and similar gold ores, i.e. Someşul Rece (Apuseni Mts), Jidoştiţa and Văliug (South Carpathians), have been considered to belong to the shear zone related ores.

Productive shear zones, as described by Udubaşa et al. (1998), needing a protore to act as such, contain not only gold ores, but also polymetallic ones (partly "pentametallic") (Figs. 30, 31). Typically, shear zone related are the complex ores of the

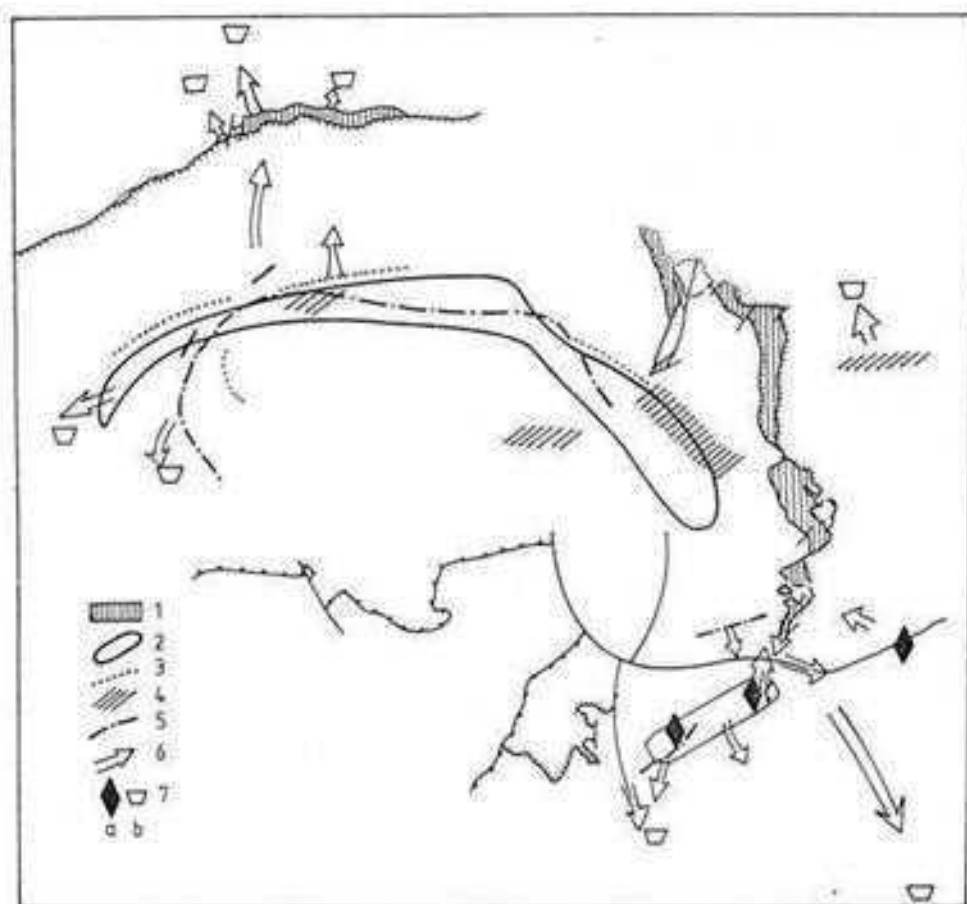


Fig. 30 - Schematic representation of the gold protors from the central part of the South Carpathians, with the gold migration directions in the alluvial formations (acc. Udubaşa et al., 1992).

Key: 1 - Sebişel Series; 2 - manganiferous belt; 3 - nests of titaniferous hematite in quartz lenses; 4 - rocks rich in kyanite; 5 - blastomylonite belt; 6 - migration directions of gold from protors; 7 - gold concentrations (a - primary, especially associated to the shearing zones: I. Costeşti-Horezu; II. Valea lui Stan; III. Perişani; b - secondary-alluvial); 8 - research areal.

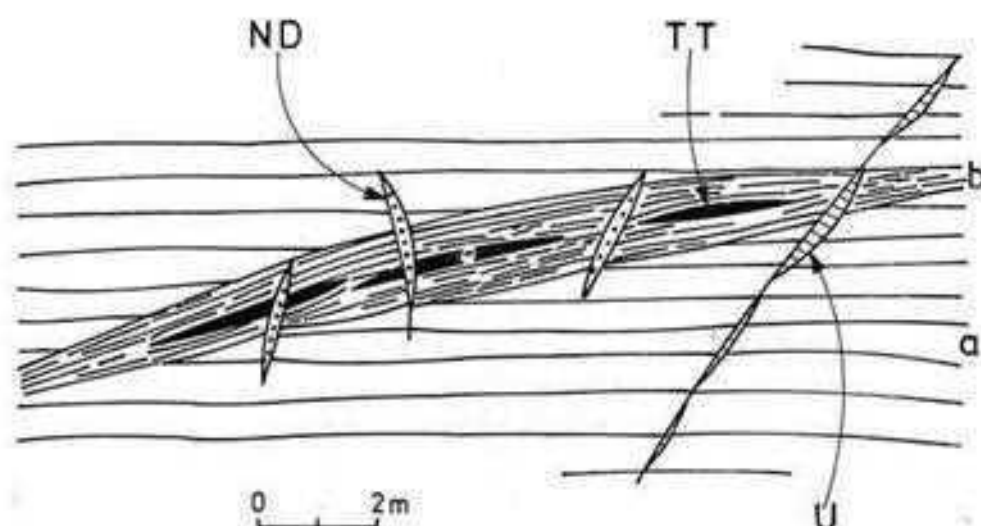


Fig. 31 -- Relationships between the fahlband-like ores (TT-Tibra-Tâncava) + ND (Neguleț-Dăniș) and the late (Alpine?) uranium mineralization (U - pitchblende-thucholite) in the Leaota Mts. (acc. Udubașa et al., 1992) Country Rocks are (a) micaschists and paragneisses with (b) sheared counter parts.

Leaota Mts (considered to represent veins related to collision granitoids by Vlăd, Dinică (1984), where both gold ores and base-metal ores exist and sometimes coexist in the same space. The setting is quite similar to that of Skandinavian fahlbands. Further data on the Leaota and East Făgăraș ore occurrences are given by Udubașa (1987, 1993), Lupulescu (1984) etc. It is to note that the shearing in the above-mentioned zones is of different ages, i.e. from Hercynian to Alpine, and some ores seem to be reworked by later events, including magmatic ones (e.g. at Văliug) and Alpine, sometimes brittle shearing. The small-sized shear zones (SSSZ, acc. to Udubașa et al., 1998) lack epigenetic overprints, show always protorees (mostly amphibolites) and display highly discontinuous development of ore bodies or of gold-rich zones. However, the gold content might locally be as high as 100 g/t (e.g. Valea lui Stan).

Metallogenesis in the post collisional-related settings

Burdigalian sandstones belonging to Miocene molasse of the East Carpathians comprise minor stratabound base-metal ores (sphalerite, galena, subordinate amounts of pyrite, chalcopryite) at Jitia (Săndulescu et al., 1988).

Miocene-Pleistocene heavy minerals accumulations (fossil placers)

By prospecting and exploration works and by technologic studies, carried out in the most favourable situations, three representative areas with numerous accumulations and occurrences of sands with heavy minerals have been outlined: Getic Depression, apparently the most important, Banat and Moldavian Platform (Panin, Panin, 1969; Panin et al., 1988; Jipa et al., 1985) (Fig. 32).

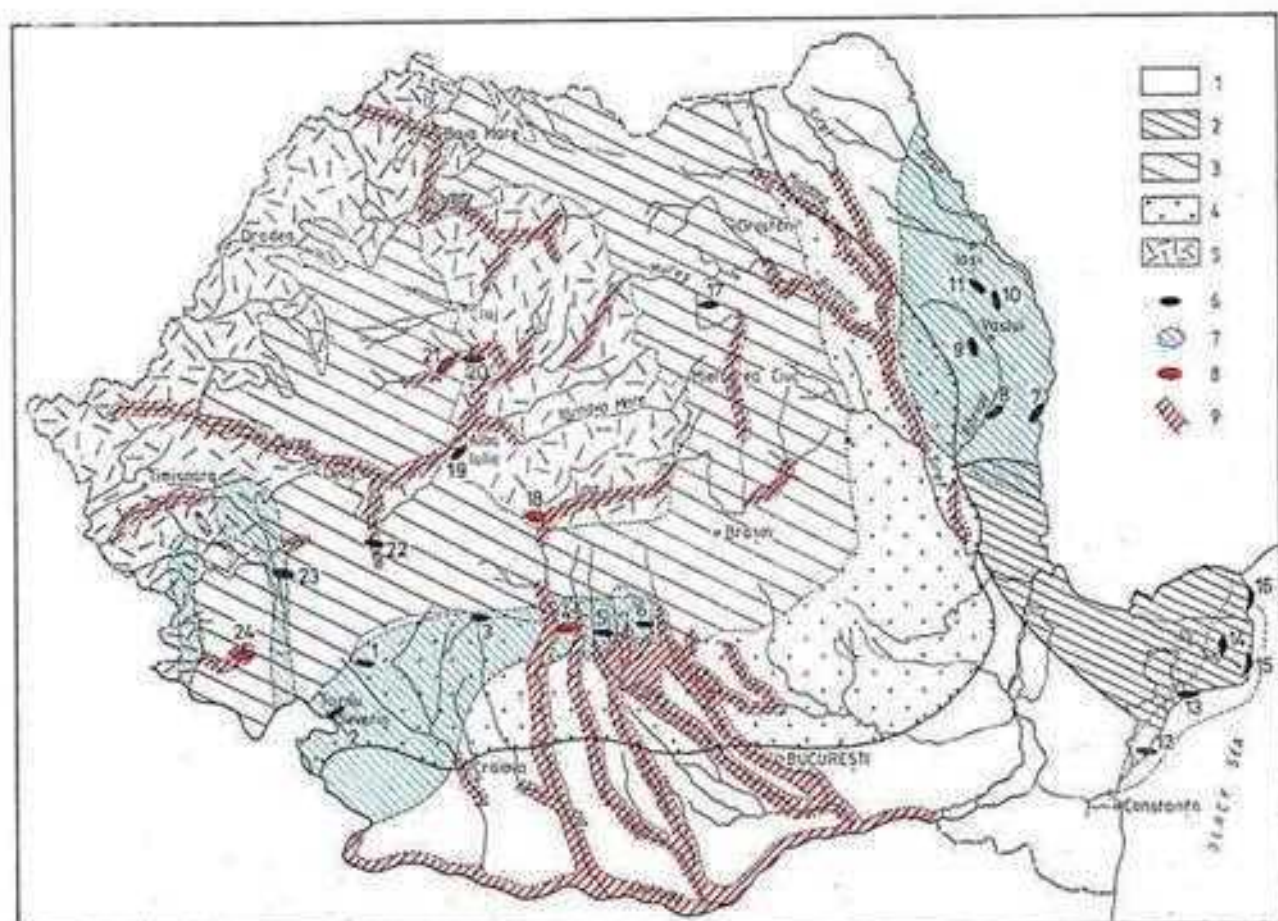


Fig. 32 – Schematic distribution of the heavy minerals and alluvial gold accumulations in Romania.

Key: 1 - Sedimentary cover of the Moesian, Scythian and East-European platforms; 2 - Carpathian orogen; 3 - North Dobrogean orogen; 4 - Carpathian foredeep; 5 - Intramontane depression; 6 - Areal with occurrences and (a) accumulations of heavy minerals (Ti-Zr-Au); 7 - Areal with occurrences and (a) accumulations of alluvial gold. Representative accumulations: 1, Glogova-Baboiesti-Ohaba-Sisești; 2, Malovai-Hinova; 3, Mateesti-Alunu; 4, Raureni; 5, Gemenea-Tigveni; 6, Măzgana-Oncești; 7, Mugești-Igești; 8, Bursucani-Zorilești-Pogana; 9, Iana-Corodești; 10, Codăiești-Michești; 11, Scheia-Tăcuța; 12, Chituc; 13, Perisor; 14, Ivancea-Lumina-Rusu; 15, Sf. Gheorghe-Buhuz; 16, Cardou Sfistofca; 17, Ditrău; 18, Cibin Olt; 19, Pianu; 20, Cornești-Mihai Viteazu; 21, Arieș Valley; 22, Hațeg; 23, Caransebeș; 24, Bozovici.

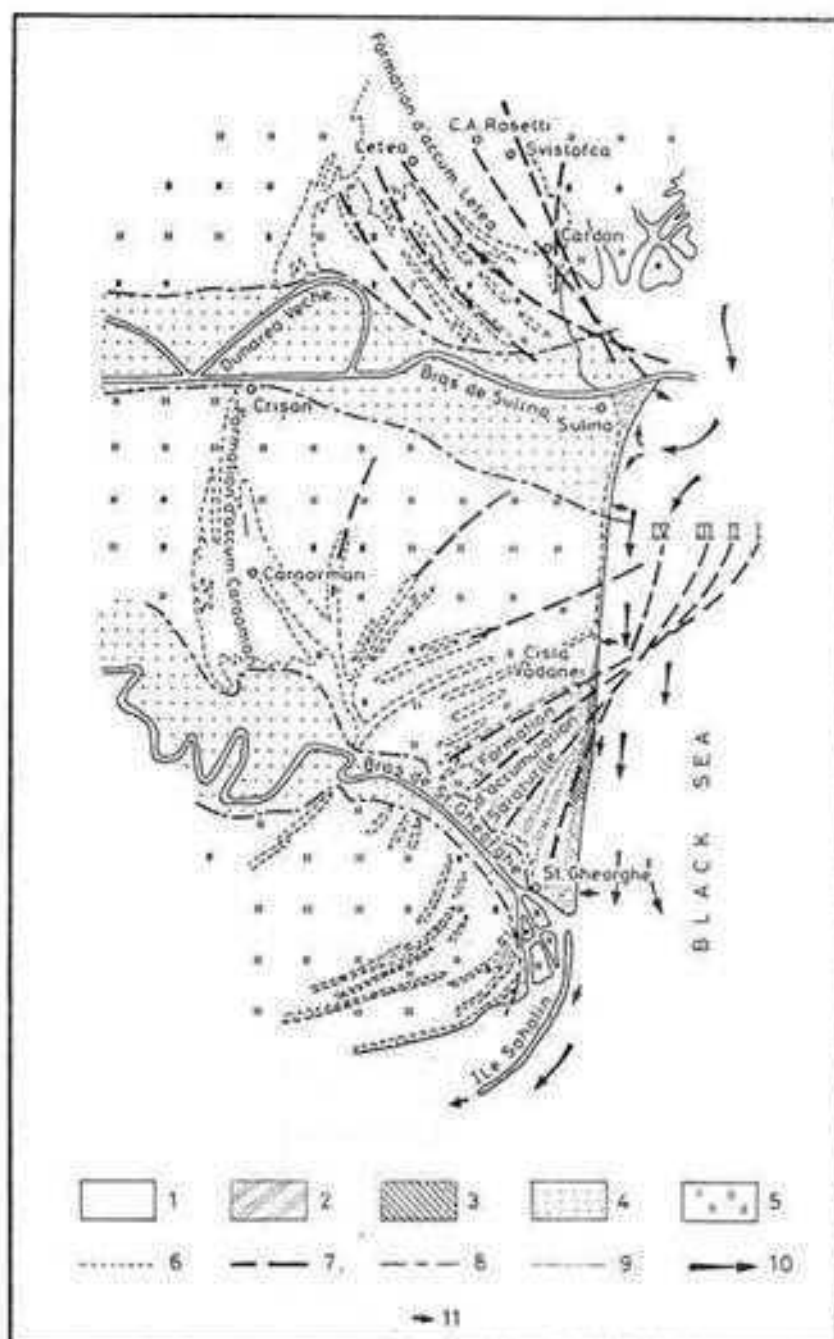


Fig. 33 – Sketch-map showing the Sulina paleo-delta evolution and the formation of Sărăturile as well as the genesis of the heavy mineral concentrations in the latter (acc. to Panin, Panin, 1969). The figures I, II, III, IV underline the Sulina paleo-delta retreat and the simultaneous progression of the Sărăturile formation.

Key: 1 - Accumulation formations (Letea-Caraorman) and older isolated littoral bars; 2 - Sărăturile accumulation formations and their juxtaposed littoral bars; 3 - heavy minerals concentration; 4 - meandering zones of Sulina and St. Gheorghe arms; 5 - marshes and lakes; 6 - limits of the formation to accumulation and isolated fossil bars; 7 - lines showing the shore evolution; 8 - limits of meandering zones of the Danube arms; 9 - present-day shore; 10 - offshore currents; 11 - movement of the shore-line (erosion, accumulation or equilibrium, transient sedimentation).

In the Getic Depression, in the Jiu, Olt, Argeş and Dâmboviţa basins, there is an important potential of heavy mineral concentrations, identified or outlined by exploration works and technologic studies. Such concentrations are disposed at several levels at the upper part of the Pontian and the base of the Dacian and they occur as lenses in the Dacian upper horizon. The mineralogical composition is, in general, similar; the common paragenesis consists of: pyroxenes, amphiboles, ilmenite, garnets, magnetite, hematite, rutile, brookite, titanite, anatase, zircon, staurolite, apatite, kyanite, epidote, tourmaline, xenotime, monazite, titanomagnetite. Among the heavy minerals, ilmenite represents between 60 and 90%; zircon is represented mainly by metamict varieties. The Pliocene accumulations also contain monazite, quantitatively better represented. In most cases gold is found as well. Among the most important accumulations one may mention: Glogova, Boboieşti, Ohaba-Şişeşti, Mateeşti-Alunu, Malovăţ-Hinova and Tigveni (Fig. 32).

In Banat, several occurrences have been identified, mostly similar with those in the Timiş Valley basin, between Orşova, Caransebeş and Lugoj. The association of the heavy minerals determined in concentrates is, as follows: magnetite, ilmenite, garnets, zircon, staurolite, apatite, rutile, titanite, tourmaline, epidote, hornblende (Fig. 32).

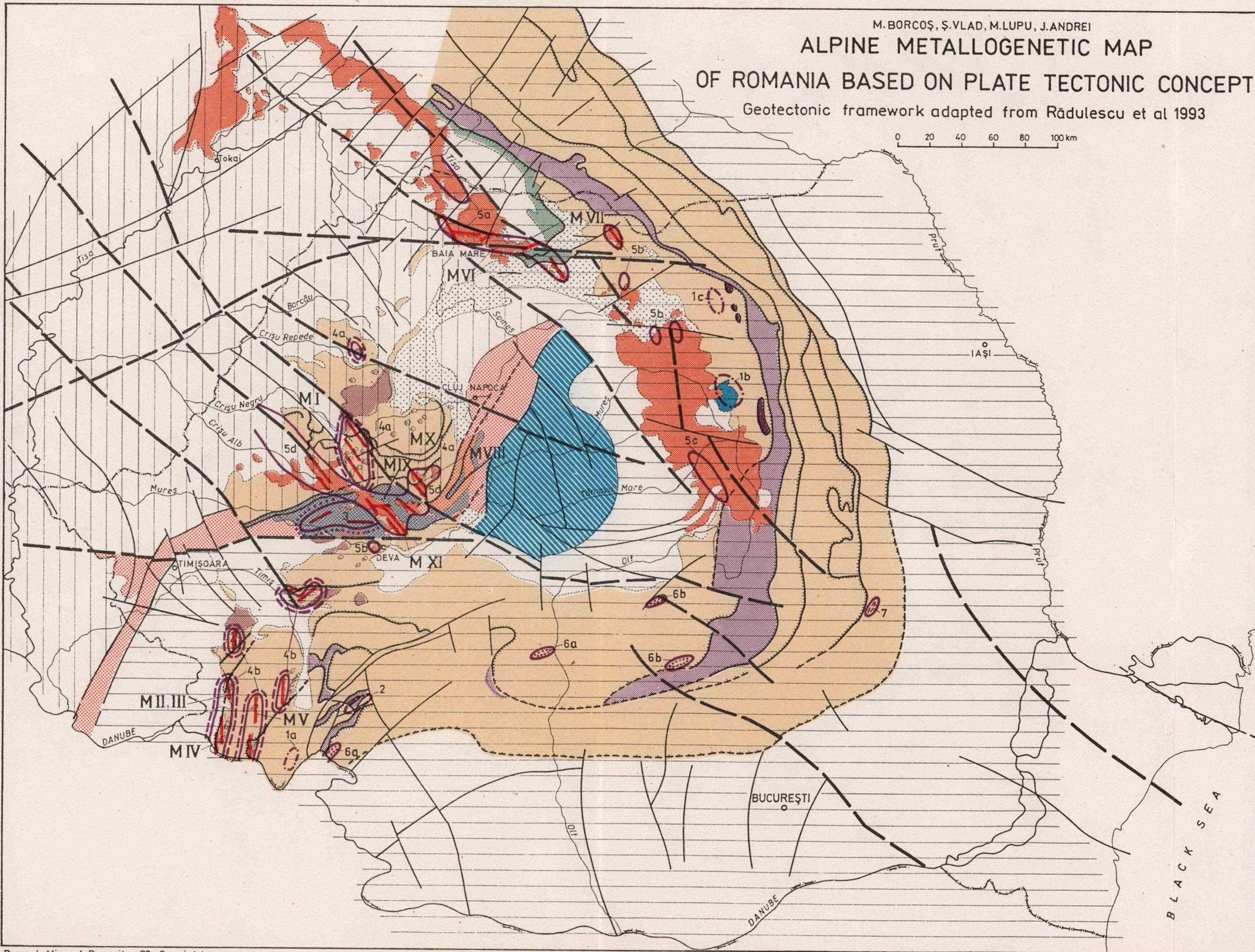
Similar accumulations of heavy minerals, with a significant geological potential, are known in the Moldavian Platform, in the zone between the Prut and Siret rivers. The most representative accumulations are: Mugeşti-Igeşti-Bursucani, Pogana, Iana-Corodeşti, Codăeşti-Micleşti, Scheia-Tăcuţa. The presence of zircon concentrates has been pointed out at several sandy levels, of Kersonian, Meotian and Pontian-Dacian age. In most cases higher contents of ZrO_2 (up to 0.2%), in comparison with other accumulations, have been identified (Fig. 32).

Recent deltaic and littoral accumulations

The Danube Delta is located between the Moldavian Platform in the North and the Dobrogean orogen in the South. The heavy mineral concentrations resulted by successive removal of older deposits and the formation of younger sand (Panin, Panin, 1969) (Fig. 33). It is noteworthy that heavy mineral enrichment occurs in the important erosion areas, whereas the light fraction predominates where sands have accumulated. The oldest erosion levels in the south-eastern Caraorman formation correspond to the Phanagorian regression (3000-4000 years ago); they were formed by the erosion of the Sf. Gheorghe I delta and the promotion of the Sulina delta. The erosion level related to the Letea formation is younger (1000 years ago); it affected the Sulina Phanagorean delta while the Chilia delta progressed towards the sea. Heavy minerals zones are exposed in the southern Caraorman formation, in the Letea formation and in the Sărăturile and Chituc sandbanks. The heavy mineral fraction consists of garnet, ilmenite, magnetite, zircon, rutile, titanite, monazite, epidote, staurolite, kyanite, tourmaline, apatite, amphiboles, sillimanite, pyroxenes and chromite. The ilmenite, zircon, magnetite and rutile contents are of commercial interest. The distribution is fairly sporadic; in the Caraorman formation it ranges between 2 and 150 kg/t, and in the Letea formation between 20 and 50 kg/t. The Sărăturile and Chituc sandbanks contain major concentrations, 3-4 km long north of Sfântu Gheorghe; they occur along the Chituc zone. Heavy mineral accumulations (29-36 kg) fringe the inland margin. The external sides of the Caraorman and Sărăturile

M. BORCOȘ, S. VLAD, M. LUPU, J. ANDREI
ALPINE METALLOGENETIC MAP
OF ROMANIA BASED ON PLATE TECTONIC CONCEPT
 Geotectonic framework adapted from Rădulescu et al 1993

0 20 40 60 80 100 km



Geotectonic setting

- East and Central European segment of the Eurasian Plate
- Ceahlău Severin and Black Flysch oceanic paraoceanic domain ($J_{2+3}-K_1$)
- Carpathian orogen including foredeep

Major Tethyan suture and related domains

- a. Active continental margin related units (J_2+K_1); 1, exposed; 2, covered
- b. Transylvanian Tethys ocean area ($T_2-J_3, K_1?$), covered
- c. East carpathian obducted nappes (T_2-K_1)
- d. Pienides (J_3-Pg_3)
- Apulian segment of the African Plate
- Intramontane depressions and platform cover ($Pg-m$)
- Post-tectogenetic cover (K_2-m_1)
- Rift related igneous rocks: alkali intrusions (K_1)
- Subduction related igneous rocks: mafic to felsic volcano-plutonic complexes, felsic intrusions and associated sedimentary rocks ($J_2?-K_1$)
- Subduction related igneous rocks: andesite volcanics, felsic volcano-plutonic complexes, intermediate to felsic intrusions (K_2-Pg_1)
- Subduction related igneous rocks: intermediate volcano-plutonic complexes (M-Q)

Geological boundary

- Fault
- Deep Fracture
- Nappes, a. concealed

Genetic ore types

- Hydrothermal vein
- Hydrothermal breccia
- Hydrothermal replacement
- Skarn
- Porphyry
- a) epithermal-porphyry
- b) skarn-porphyry
- Mafic-ultramafic related
- Volcanogenic
- Volcano-sedimentary
- Sandstone-hosted
- Shear zone related
- Polygenetic/Remobilised

Commodities

Hg
 Au-Ag
 Au-Ag-Te
 Au-Ag-Pb-Zn
 Au-Ag-Pb-Zn-Cu
 Pb-Zn
 Pb-Zn-Cu
 Cu
 Cu-Au
 Cu-Mo
 Mo
 Mo-Bi-W
 Co-Ni-U-Ag-Bi
 U
 Ba
 Fe
 S

Size of ore deposits

- Large deposits
- Medium deposits
- Small/very small deposits

LEGEND

Metallogenic units in terms of plate tectonics

- 1. Rift related
 - 1a. Mo
 - 1b. Mo
 - 1c. Ba
- 2. Spreading related
 - Cu
- 3-5. Subduction related
- 3. Upper Jurassic-Lower Cretaceous event
 - Pb-Zn; Fe; Cu; Mo
- 4. Upper Cretaceous-Paleocene event
 - 4a. U; Co-Ni-U-Ag-Bi; Mo-Bi-W, Cu, Fe, Pb-Zn-Cu; Pb-Zn
 - 4b. Pb-Zn, Pb-Zn-Cu, Fe, Cu, Cu-Mo; Cu-Mo; Cu-Mo
- 5. Late Tertiary
 - 5a. Pb-Zn, Pb-Zn-Cu, Au-Ag; Au-Ag-Pb-Zn-Cu
 - 5b. Pb-Zn-Cu; Pb-Zn
 - 5c. S; Fe; Pb-Zn
 - 5d. Cu-Au; Cu, Cu-Mo; Au-Ag; Au-Ag-Te; Au-Ag-Pb-Zn; Au-Ag; Pb-Zn; Hg
- 6. Collision related
 - 6a. Au-Ag
 - 6b. Pb-Zn, Pb-Zn-Cu, Co-Ni-U-Ag-Bi
- 7. Post-collision related
 - Pb-Zn

Metallogenic alignments

Metallogenic models related to Upper Cretaceous-Paleocene (A) and Late Tertiary (B) subduction events

A. MI - Băița Bihorului
 MII - Ocna de Fier
 MIII - Dagnecea
 MIV - Suvorov
 MV - Bozovici

B. MVI - Baia Sprie
 MVII - Căvnic
 MVIII - Roșia Poieni
 MIX - Valea Morii
 MX - Roșia Montană
 MXI - Săcărâmb

The following maps were used for completion of the geotectonic framework:

J. Andrei (1994) - Alpine deep seated magmatic bodies based on geophysical data related to plate tectonic elements. 1:1M (unpubl. data).

K. Brezysanszky (1989) - Magyarország és Környekének Hegységsszerkezete, 1:2M.

M. Borcoș et al. (1994) - Schema structurală a spațiului Carpat-Pannonic, 1:2M (unpubl. data).

I. Gavăț et al. (1983) - Harta structurii profunde a R.S.R., 1:0.5M.

Z. M. Lyashkevitch et al. (1983) - Tectonomagmaticheskaya karta Ukrayinskih Karpat, 1:1M.

M. Lupu (1983) - Tectonic sketch of the Apuseni Mts., 1:1M, In: An. Inst. Geol. Geofiz., 50.

D. Rădulescu et al. (1993) - Harta magmatogenetică alpină a României, 1:1M.

I. Rumpel and F. Horvath (1989) - Tectonic map of the Pannonian basin and surrounding regions, 1:2M. In: Am. Asoc. Petr. Geol. Mem., 45.

M. Săndulescu (1984) - Harta geneto-tectonică a Europei alpine centrale și de sud-est, 1:2.5M. In: "Tectonica României".

sandbanks contain 90% quartz. The bottom alluvium and the suspended sediments of the Danube Delta contain 2-12 kg/t of heavy minerals.

Subactual and actual alluvial heavy mineral and gold accumulations

The results of the researches pointed out that numerous hydrographic basins of the main rivers in Romania contain heavy minerals accumulations (Ti, Zr, Au bearing) and gold with a variable distribution, whose economic significance is to be determined (Jipa et al., 1985; Panin et al., 1988). It is to note the actual alluvia and alluvial terraces with interesting contents of heavy minerals, identified in the Bozovici-Caransebeş-Orşova, Haţeg basins, Pianu zone - Transylvania Basin, Olt, Jiu-Argeş rivers area and Gemenea-Târgovişte in the Getic Depression, Corneşti-Mihai Viteazu zone (Turda), Drăganului Valley-Poieni-Morlacă zone in the Apuseni Mountains and Ditrău massif (Fig. 33).

Heavy minerals accumulations are also included in the sediments of storage lakes at Porţile de Fier, for which a quantitative prognosis has been determined, and at Bicaz.

IV. QUANTITATIVE METALLOGENESIS OF THE ROMANIAN TERRITORY

The quantified metallogenetic analysis is focused on the assemblage of the metalliferous mineral resources with the total mineral potential (TMP) evaluated in metal metric tons and/or per cent, on types of substances, which cumulates, according to the systematics adopted by IGR, the reserves (exploited + actual) and resources (Borcoş et al., 1997), that corresponds to the recommendations made by the European Economic Committee (1997) concerning the classification of the reserves of mineral resources. The potential is also rendered evident by the size of ore deposit, in agreement with the norms used by the Commission on the Geological Map of the World - Sub-commission on Metallogenetic Map, thus establishing their share within the metallogenetic units representative for the Romanian territory (Table 12).

TABLE 12

SIZE OF THE BODIES (DEPOSITS/PROSPECTS)

SUBSTANCE	LIMIT BETWEEN THE SIZES (metric tons metal)		
	2 and 1	3 and 2	4 and 3
Pb or Pb+Zn	50.000	1.000.000	4.000.000
Cu	50.000	1.000.000	10.000.000
Au +/- Ag	10	50	500
Mo	5.000	50.000	200.000
Mn	500.000	5.000.000	100.000.000
Fe(+Mn); Fe-Ti-V	10.000.000	100.000.000	1.000.000.000

1 - small ore deposits; 2 - medium ore deposits; 3 - large deposits; 4 - very large deposits

The quantitative metallogenetic analysis was also based on: (1) the assessment of mineral potential including non-ferrous ores (Pb+Zn, Cu < 0.4 %), gold-silver ores and ferrous-ores (Fe, Mn, Fe < 15 %, Ti-V), (2) the relation of ore deposits to plate-tectonics settings (Cioflica, Vlad, 1984; Vlad, 1986; Rădulescu et al., 1994; Vlad, Boroș, 1994, 1997) and the modelling studies of the representative genetic types.

The quantified metallogenetic study refers only to the global aspects of the accumulations (regardless of their mineability or non-mineability) estimated in TMP¹ (metal metric tons and/or per cent), which includes reserves (exploited and/or existent) and resources.

Besides the analysed metalliferous ores which, as a matter of fact, are best represented on the whole territory, several metalliferous substances that can also be mentioned (especially uranium, molybdenum, tungsten, mercury, chrome, and nickel) due to the limited volumes have not been used in the analysis as they cannot change substantially the value of the estimated TMP.

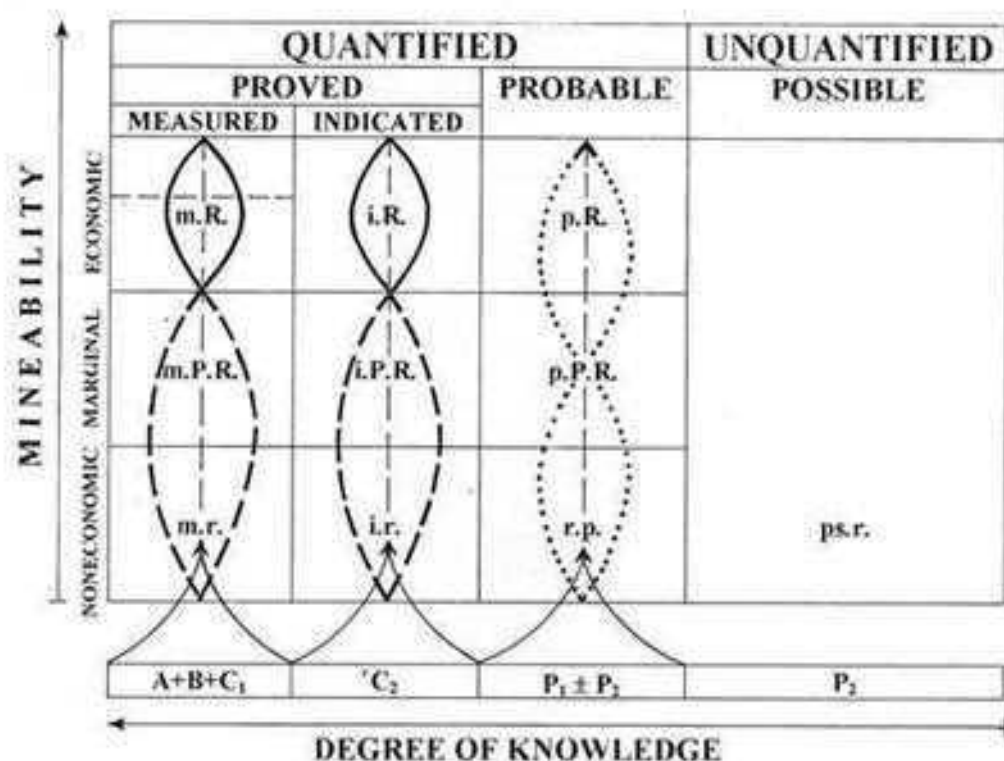
The main preliminary conclusions give information about the preferential location of the accumulations in metallogenetic districts according to the metallogenetic space-time evolution, about the metallogenetic specification, on the geotectonic units, about the genetic and geologic processes and about the geographic units; the assessment of the productivity of the ore genetic types on geologic processes and units; the share of the main composition types of mineralizations within the yielding sources and processes.

The proposed classification system and analysis methodology make possible the reintegration of the existing reserves and resources according to the tridimensional scheme of representation of the geological, technological and economic features, recently adopted by the Economic Commission for Europe (United Nations) (Figs. 34, 35). The aspects determined for the representative types of metalliferous ores permit a clear differentiation of the economic reserves from the non-economic ones and take into consideration the position of the perspective reserves whose integration and economic significance are to be better specified. The results obtained for the base-metal, cupriferous, gold-silver and ferrous ores confirm, for the main ores deposits, ore deposit groups and genetic-mining units (districts, mining fields), the high geo-economic confidence degree of the system and, at the same time, they can contribute to the establishing of the policies and strategies of development in the fields of fundamental and applicative surveys (geologic and technologic) and of the capitalization of the mineral resources.

Space-time distribution and global estimation on metallogenetic districts (Plate II, Table 13)

The metallogenetic evolution of Romania's territory is associated with major time-stratigraphic intervals, each one with a distinct share and metallogenetic specialization which corresponds to: non-differentiated Proterozoic cycles 49.54 %, Caledonian cycle 4.34 %, Hercynian cycle 9.89 % and Alpine cycle 36.0 %; the uncertain pre-Alpine accumulation represents only 0.89 %.

¹ The values mentioned in the text for the various units, types and genetic processes are referred to TMP, corresponding to the whole territory of Romania.



TRANSPPOSITION OF THE ACTUAL STRUCTURE OF THE MINERAL POTENTIAL IN THE PROPOSED CLASSIFICATION SYSTEM

- Reserve from group audit partially inadequately placed
- Reserve from group out of audit and unclassified, partially cumulated
- Prognosis reserve ($P_1 \pm P_2$), partially cumulated and/or inadequately placed

CORRESPONDENCES

i.R. + i.r. - Reserves and resources of immediate interest

- m.R. = $A + B + C_1$ - reserves from group of audit
- i.R. = C - reserves in extension of the audit reserve
- $p.R. + p.r. = P_1 \pm P_2$ - prognosis reserves

P.R. + p.r. - Reserves and resources of perspective

- m.P.R. = $B + C_1$ - reserves from out of audit
- = C_1 - unclassified reserves
- i.P.R. = reserves in extension of reserves out of audit
- = C_2 - unclassified reserves
- $p.P.R. + p.P. = P_1 \pm P_2$ - prognosis reserves

r - Resources

- m.r. = $B + C_1$ - reserves from out of audit
- = C_1 - unclassified reserves
- i.r. = reserves out of audit
- = C_2 - unclassified reserves
- $p.r. + ps.r. = P_1 \pm P_2$ - prognosis reserves

Fig. 34 - System of reserves and resources classification and reconversion of the mineral potential from the alpha-numeric system in the system adopted by CE-ONU.

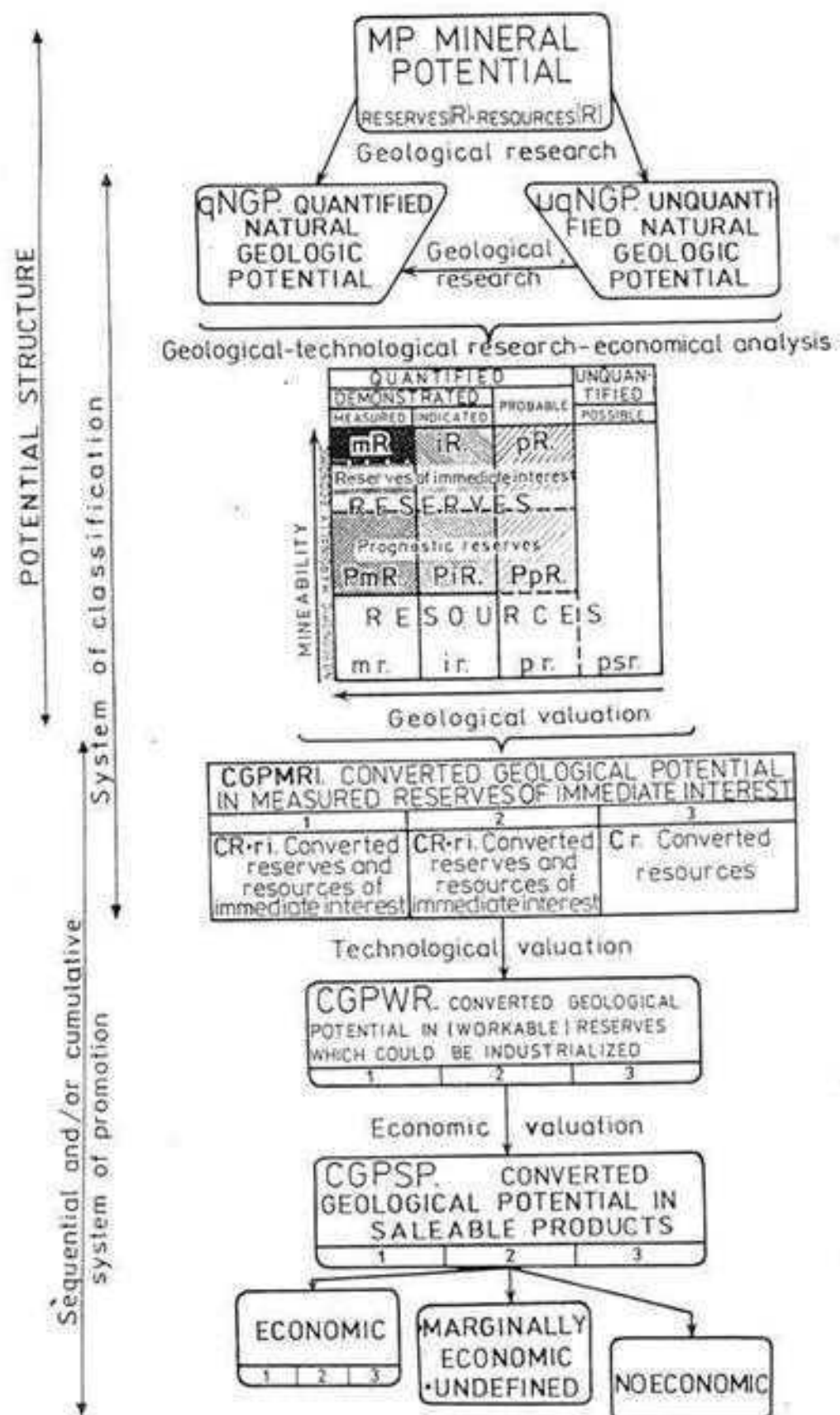


Fig. 35 - Scheme of analysis and promotion of the geologic potential

Table 13

Systematics of the geological potential distributed on geotectonics cycles, geological processes and metallogenetic districts/zones

GEOTECTONIC CYCLES (% total potential)	GEOLOGIC PROCESS - ORE BEARING FORMATIONS (% referred to cycle; % referred to total potential)	DISTRICT (D) ZONE (Z)	No.	Geo- graphic units ¹	Genetic types ²	COMMODITIES	Potential D or Z referred to:			Size of accumula- tions ³	Classi- fication D or Z	
							Genetic process-%	Geo-tect cycles-%	Total potential-%			
CYCLES PROTEROZOIC NON-DIFFERENTIATED 49.54%	Metamorphic formations (Pt ₁)	D. Palazu	1	S.D.	11(8)	100 Fe.	100.00	77.08	38.18	a2	1	
	Carbonatic, amphibolic and micaceous formations (Pt _{2,3}) 22.92% 11.35%	D. Valea Blaznei-Guset	2	E.C.	11(9)	96.48 Pb+Zn; 0.07 Cu; 3.44 Fe.	2.83	0.65	0.32	c1-2	24	
		D. Bazdaga	3	E.C.	11(9)	87.38 Pb+Zn; 12.62 Cu.	0.01	0.003	0.002	c1	75	
		D. Razoare	4	E.C.	11(9)	50.46 Mn; 49.54 Fe.	43.06	9.87	4.89	b2	5	
		Z. East Carpathians	5	E.C.	11(9)	90.59 Pb+Zn; 9.41 Cu.	0.23	0.05	0.03	c1	55	
		D. Porumbacu-Arpaș	6	S.C.	11(9)	91.36 Pb+Zn; 8.64 Cu.	0.10	0.02	0.01	c1	62	
		Z. Banat-Muntii Sebes	7	S.C.	11(10)	31.46 Fe; 68.54 Mn.	46.48	10.65	5.28	b2	4	
		D. Delinesti-Tamova	8	S.C.	11(10)	67.80 Fe; 32.20 Mn.	5.88	1.35	0.67	a1	20	
		D. Toplet	9	S.C.	11(6)	52.20 Fe; 47.80 Mn.	0.65	0.15	0.07	a1	41	
		D. Valea Fierului-Boutari	10	S.C.	11(6)	100 Fe.	0.16	0.04	0.02	a1	60	
		D. Armenis	11	S.C.	11(6)	100 Fe.	0.27	0.06	0.03	a1	51	
		D. Altan-Tepe	12	C.D.	11(5)	100 Cu.	0.32	0.07	0.04	d1	48	
CALEDONIAN 4.34%	Extensional submarine basic volcanism (Pt ₃ -Cb ₁) 1.44%; 0.06%	D. Silvas-Boita-Lingina	13	S.C.	11(5)	100 Pb+Zn.	68.11	0.98	0.04	c1	45	
		D. Boclughea-Camena	14	N.D.	11(5)	1.23 Cu; 98.77 Fe.	31.89	0.46	0.02	a1	59	
	Rhyolitic volcanism (Cb) 29.93% 1.3%	D. Baia Borsa	15	E.C.	11(5)	84.61 Pb+Zn; 15.30 Cu; 0.09 Au+Ag.	65.15	19.50	0.85	c1-2; d1	17	
		D. Fundu Moldovei-Lesu Ursului	16	E.C.	11(5)	45.33 Pb+Zn; 54.64 Cu; 0.03 Au+Ag.	14.37	4.30	0.19	c1; d1	31	
		D. Caribaba-Doma-Anni	17	E.C.	11(5)	88.67 Pb+Zn; 11.33 Cu.	3.27	0.98	0.04	c1	46	
		D. Balan-Tulghes	18	E.C.	11(5)	17.04 Pb+Zn; 82.96 Cu.	16.74	5.01	0.22	c1; d1	29	
		D. Comana-Venetia	19	S.C.	11(5)	100 Pb+Zn.	0.47	0.14	0.01	c1	66	
	Graphitous formation with lydites (Cb)	D. Vatra Dornei	20	E.C.	11(9)	30.22 Fe; 69.78 Mn.	100.00	68.63	2.98	b1	7	
	HERCYNIAN 9.89%	Volcano-sedimentary formations of extensional type (S) 0.49%; 0.05%	D. Anies	21	E.C.	11(6)	100 Cu.	0.22	0.001	0.0001	d1	78
			D. Rusaia	22	E.C.	11(5)	100 Fe.	99.78	0.49	0.05	a1	42
Submarine basic volcanism (D) 97.78%; 9.68%		D. Teluoc-Ruschita	23	S.C.	11(5)	93.89 Fe; 6.11 Mn.	87.21	85.29	8.44	a1	3	
		D. Iazuri-Cerbal	24	S.C.	11(5)	100 Fe.	12.79	12.51	1.24	a1	15	
Rhyolitic volcanism (Lower Carboniferous) Granitic magmatism (P)		D. Muncel-Rapolt	25	S.C.	11(5)	95.74 Pb+Zn; 4.21 Cu; 0.05 Au+Ag.	100.00	1.71	0.17	c1-2; d1	33	
		D. Soimus-Dud	26	A.M.	11(5)	100 Cu.	100.00	0.001	0.0001	d1	79	
UNCERTAIN PRE-ALPINE	Accumulations with uncertain source and position	Z. W. Zone of South Carpathians	27	S.C.	11(5)	87.36 Fe; 13.64 Mn.	100.00	100.00	0.22	b2	29	
ALPINE 36.00% of which: Exogenous 12.43% of total Alpine Endogenous 31.53% of total potential	Mesozoic carbonatic formations	D. Moneasa	28	A.M.	11(5)	73.42 Fe; 26.58 Mn.	100.00	3.56	1.29	b1	14	
	Detrital formations (J1)	D. Valea Mare-Suncuius	29	A.M.	7	100 Fe.	100.00	0.13	0.05	a1	44	
	Marine formations (Cr)	D. Campulung Moldovenesc	30	E.C.	8	100 Fe.	100.00	0.26	0.10	a1	37	
	Epicontinental formations (Pg)	D. Capus-Savadiș	31	T.B.	8	100 Fe.	100.00	8.40	3.04	a1	6	
	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₃ - E.C.) 45.02%; 16.21%	D. Ditrau	32	E.C.	4	100 Fe.	95.45	42.70	15.47	a1	2	
		D. Somova-Marca	33	N.C.	13	95.16 Pb+Zn; 4.80 Cu; 0.04 Au+Ag.	0.29	0.13	0.05	c1	43	
		D. Iulia-Eschibaiac	34	N.D.	2	99.45 Fe; 0.37 Cu; 0.18 Mn.	4.26	1.91	0.89	a1	19	
		D. Baia de Arama	35	S.C.	5	100 Cu.	100.00	0.02	0.01	d1	64	
	Island arc magmatism - tholeiitic assoc. (J ₃ -Cr ₁) 5.63% 2.03%	D. Drocea	36	A.M.	5	18.44 Pb+Zn; 81.56 Cu.	0.21	0.012	0.004	d1	9	
		D. Drocea	36	A.M.	4	82.99 Fe; 16.64 Ti; 0.37 V.	91.43	5.11	1.85	a1		
		D. Techereu	37	A.M.	4	90.91 Fe; 9.09 Ti.	4.00	0.22	0.08	a1	39	
		D. Pamesti	38	A.M.	6	100 Mn.	0.10	0.01	0.002	b1	72	
	Banatitic magmatism - calc-alkaline assoc. (Cr ₂ -Pg ₁) 15.2% 5.47%	D. Vorta-Dealul Mare	39	A.M.	5	94.77 Pb+Zn; 5.23 Cu.	4.21	0.24	0.09	c1	38	
		D. Moldova Noua-Sasca	40	S.C.	2	7.13 Pb+Zn; 46.69 Cu; 0.002 Au+Ag; 46.03 Fe; 0.15 Mo.	14.59	2.20	0.80	c1; d1	16	
		D. Oravita	41	S.C.	3	98.33 Cu; 1.67 Mo.	5.07	0.77	0.28	d2		
		D. Oravita	41	S.C.	2	83.10 Pb+Zn; 16.74 Cu; 0.01 Au+Ag; 0.15 Mo.	0.50	0.08	0.03	c1; d1	50	
		D. Oravita	41	S.C.	3	100 Cu.	0.13	0.02	0.01	d1		
		D. Ocna de Fier-Dognecea	42	S.C.	2	1.61 Pb+Zn; 0.49 Cu; 0.001 Au+Ag; 96.68 Fe; 1.22 Mn.	32.26	4.87	1.77	a1; c1	10	
		D. Tincova	43	S.C.	2	11.64 Pb+Zn; 88.36 Cu; 0.001 Au.	0.09	0.01	0.01	c1; d1	68	
		D. Ruschita	44	S.C.	2	100 Pb+Zn.	0.12	0.02	0.01	c1	36	
		D. Ruschita	44	S.C.	1	99.41 Pb+Zn; 0.57 Cu; 0.02 Au.	1.82	0.27	0.10	c1		
		D. Bocsa-Hauzești	45	S.C.	1	72.22 Pb+Zn; 27.78 Cu.	0.02	0.004	0.001	c1	77	
		D. Liliaci-Lapusnicul Mare	46	S.C.	3	97.20 Cu; 0.01 Au+Ag; 2.79 Mo.	0.26	0.04	0.01	d1	81	
		D. Poiana Rusca	47	S.C.	1	99.99 Cu; 0.01 Au.	0.06	0.01	0.003	d1	69	
		D. Baisoara	48	A.M.	1	96.57 Pb+Zn; 3.39 Cu; 0.04 Ag.	4.13	0.82	0.23	c1	8	
		D. Baisoara	48	A.M.	2	99.42 Fe; 0.58 Mn.	34.50	5.23	1.89	a1		
		D. Gilau	49	A.M.	1	99.99 Pb; 0.01 Ag.	0.04	0.01	0.002	c1	70	
		D. Baita-Hamagiu	50	A.M.	1	92.29 Pb+Zn; 7.48 Cu; 0.23 Au+Ag.	0.14	0.02	0.01	c1	34	
		D. Baita-Hamagiu	50	A.M.	2	84.68 Pb+Zn; 15.30 Cu; 0.02 Au+Ag.	2.14	0.32	0.12	c1		
		D. Budureasa-Valea Fagului	51	A.M.	1	11.09 Pb+Zn; 0.41 Cu; 0.001 Au+Ag; 88.54 Fe.	2.27	0.34	0.12	a1; c1	35	
		D. Vlădeasa	52	A.M.	1	86.44 Pb+Zn; 13.50 Cu; 0.06 Au+Ag.	0.14	0.02	0.01	c1	65	
		D. Borod-Cornitel	53	A.M.	1	95.21 Pb+Zn; 4.74 Cu; 0.05 Au+Ag.	0.17	0.03	0.01	c1	63	
	D. Magureaua Vatei-Birtin	54	A.M.	1	99.72 Pb+Zn; 0.25 Cu; 0.03 Au+Ag.	0.11	0.02	0.01	c1	40		
	D. Magureaua Vatei-Birtin	54	A.M.	2	95.21 Fe; 4.79 Mn.	1.32	0.20	0.07	a1			
	Neogene volcanism - calc-alkaline assoc. (m-pl) 22.48% 7.37%	D. Tarna Mare	55	E.C.	1	95.03 Pb+Zn; 4.86 Cu; 0.11 Au+Ag.	3.95	0.80	0.29	c1	26	
		D. Ilba-Nistru	56	E.C.	1	80.55 Pb+Zn; 19.35 Cu; 0.10 Au+Ag.	3.19	0.65	0.23	c1-2; e1	27	
		D. Sasar-Valea Rosie	57	E.C.	1	96.42 Pb+Zn; 2.67 Cu; 0.91 Au+Ag.	0.41	0.08	0.03	c1	52	
		D. Dealu Crucii-Bairut	58	E.C.	1	90.14 Pb+Zn; 9.72 Cu; 0.14 Au+Ag.	18.76	3.92	1.38	c1; e1	12	
		D. Huta-Certeze	59	E.C.	6	100 Fe.	0.29	0.06	0.02	c1-2	58	
		D. Torioga	60	E.C.	1	59.78 Pb+Zn; 39.98 Cu; 0.24 Au+Ag.	0.38	0.08	0.03	a1	54	
		D. Tibles	61	E.C.	1	92.14 Pb+Zn; 7.74 Cu; 0.12 Au+Ag.	0.29	0.06	0.02	c1; d1	57	
		D. Rodna	62	E.C.	1	77.97 Pb+Zn; 1.37 Cu; 0.07 Au+Ag; 0.16 Mn; 20.43 Fe.	2.50	0.51	0.18	c1	32	
		D. Calimani	63	E.C.	1	97.66 Pb+Zn; 2.27 Cu; 0.07 Au+Ag.	0.11	0.02	0.01	c1	18	
		D. Calimani	63	E.C.	5	100 Fe.	10.35	2.11	0.76	c1		
		D. Madaras	64	E.C.	6	99.83 Fe; 0.17 Mn.	19.03	3.87	1.40	a1	11	
		D. Lueta-Vlahita	65	E.C.	6	98.09 Fe; 1.91 Mn.	6.82	1.39	0.50	a1	22	
		D. Toplita-Ciuc	66	E.C.	6	96.77 Fe; 3.23 Mn.	7.44	1.51	0.55	a1	21	
		D. Rosia Montana-Contu	67	A.M.	1	100 Au+Ag.	0.02	0.005	0.002	e1-2	74	
		D. Baita-Cainei-Draica	68	A.M.	1	100 Au+Ag.	0.0004	0.0001	0.00003	e1-2	80	
		D. Baia de Anes	69	A.M.	1	97.29 Pb+Zn; 2.52 Cu; 0.19 Au+Ag.	0.47	0.10	0.03	c1; e1	49	
		D. Bucium-Rosia Poni	70	A.M.	1	81.31 Pb+Zn; 17.12 Cu; 1.57 Au+Ag.	0.06	0.01	0.004	c1	13	
		D. Bucium-Rosia Poni	70	A.M.	3	99.50 Cu; 0.07 Au+Ag; 0.43 Mo.	18.15	3.69	1.34	d2		
		D. Zlatna-Stanija	71	A.M.	1	99.82 Pb+Zn; 0.18 Au+Ag.	0.53	0.11	0.04	c1; e1	30	
		D. Zlatna-Stanija	71	A.M.	3	99.78 Cu; 0.22 Au+Ag.	2.31	0.47	0.17	d1		
		D. Brad-Sacaramb	72	A.M.	1	98.32 Pb+Zn; 0.70 Cu; 0.98 Au+Ag.	2.01	0.41	0.15	c1; e2	25	

The non-differentiated Proterozoic cycles include mainly iron and manganese accumulations, and subordinately lead-zinc ones occurring in two formations: the former, Karelian metamorphic formations (Ptz_1) (38.18 %) and the latter, carbonate, amphibolic and micaceous formations ($Ptz_{2,3}$) (11.35 %). Most of the potential distributed in the Palazu district is represented by iron mineralizations. The accumulations related to the carbonate, amphibolic and micaceous formations ($Ptz_{2,3}$) are spread over 11 districts or metallogenetic zones in the South and East Carpathians and Central Dobrogea, of which, from the TMP point of view, the most important are: Banat zone – Sebeş Mts, as well as Răzoare, Blazna Valley and Delineşti - Târnova districts. Most of the potential can be referred to the iron and manganese accumulations, and only to a lesser extent to the lead-zinc accumulations. The size of ore deposit, except those at Palazu, Sebeş Mts, Răzoare and Blazna Valley which are of a medium size, ranges within the limits accepted for small-sized accumulations.

As regards the mineability of the ores, regardless of the composition types, it is to note that the majority of the accumulations within these cycles are hard to be mined (situated at shallow depths, low contents, high degree of accumulations spreading) or unmineable.

The Caledonian cycle includes accumulations (mainly lead-zinc, copper and manganese) which occur at three geological levels: the order of the TMP these are, as follows: graphite formation with Cambrian lydites (2.98 %), Cambrian rhyolitic volcanism (1.30 %) and extensional submarine basic volcanism ($Ptz_3 - Cb_1$) (0.06 %), respectively. In general, the accumulations have a simple composition, which includes either manganese ores ($\pm Fe$) (graphite formation with Cambrian lydites) or lead-zinc ores ($\pm$ copper, $\pm$ gold) (Cambrian rhyolitic volcanism and basic submarine one $Ptz_3 - Cb_1$), or copper ($\pm$ lead $\pm$ zinc) (Cambrian rhyolitic volcanism). The major districts are in the East Carpathians at Vatra Dornei (manganese ore), Baia Borşa and Fundu Moldovei – Leşu Ursului (lead and zinc ore, beside copper and subordinately gold). As regards the size of the ore deposit, most of the accumulations are small-sized, except the ore deposits from the Baia Borşa district (Dealul Bucăţii – Cornul Nedei and Gura Băii – Măcăriu – Ivascoia – Novicior) which are medium-sized.

The mineability of the manganese ores is reduced due to the low contents and to the high degree of spreading of the mineralizations, while the lead-zinc ores raise several problems particularly as regards the technology of recovery of the metals and the obtaining saleable concentrates (e.g. in the districts Baia Borşa and Fundu Moldovei – Leşu Ursului).

The Hercynian cycle contains various ore deposits (iron, lead – zinc in copper) located in several geological levels, as follows: Devonian sub-marine basic volcanism (9.68 %), Lower Carboniferous rhyolitic volcanism (0.17 %), Silurian extensional - type basic formations (0.0001 %) and Permian granitic magmatism (0.0001 %). The most important genetic units – districts – are related to the Devonian basic volcanism with iron mineralisations (to which manganese is also associated in small amounts) (Teliuc – Ruşchita district, the third one as regards the value of the potential), as well as to the Lower Carboniferous rhyolitic volcanism with lead-zinc mineralisations (to which copper and in places gold are associated) (Muncel – Rapolt district). With one exception

(the Muncel lead-zinc ore deposit of medium size), all the other accumulations are of small size.

As regards the mineability, the majority of the accumulations have small contents of metals.

Several small-sized iron (+manganese) accumulations occur in the western part of the South Carpathians, which represent only 0.22 % of the potential, whose **pre-Alpine** source and position are unknown.

The Alpine cycle contains accumulations with the largest ore composition types (lead-zinc, copper, gold, iron and manganese) related to several processes, both exogenous and particularly endogenous ones.

Among the exogenous mineralisations (4.48 %), mention should be made of the accumulations related to the Paleogene epicontinental formations (3.04 %), with higher values of the TMP, and the Cretaceous marine formations (0.10 %), and the Jurassic detrital formations (0.05 %) with lower values of the TMP. Generally, the exogenous processes are characterised by small-sized iron accumulations ($\pm$ manganese).

The endogenous mineralisations represent 31.53 % which could be put in relation with rifting, spreading, island arc, subduction and collision geotectonic and magmatic processes.

The major metallogenetic processes are, as follows: bimodal and alkaline rifting magmatism ($T_1 - J_3$; $J_1 - J_3$) (16.21 %), subduction related to the Neogene volcanism ($m - pl$) (7.37 %) and to Banatitic magmatism ($Cr_2 - Pg_1$) (5.47 %), related to collision (?) (0.42 %) or to spreading processes ($T_2 - J_3$) (0.01 %); some of the accumulations have an uncertain source and position (0.04 %). Within the above-mentioned processes, in most cases, complex lead-zinc ($\pm Cu \pm Au, Ag$), copper ($\pm Pb, Zn \pm Au, Ag; \pm Au \pm Mo$), gold (gold-silver) ($\pm Pb, Zn, Cu$), iron ($\pm Ti, U$) and manganese accumulations formed.

As regards the size of the ore deposit, the accumulations are generally small-sized. Medium-sized ore deposits are rarely found, e.g. gold accumulations at Barza and Roşia Montană, or lead-zinc accumulations at Ghezuri - Penigher, Baia Sprie, Băiuţ, Căvnic and Şuor. From the point of view of the mineability, most of the accumulations related to the Alpine cycle are recoverable. There are, however, exceptions such as those related to a part of the iron accumulations (particularly the exogenous ones which are difficult to be mined or are worked out; among the endogenous accumulations, the orthomagmatic ones are difficult to be mined or have low contents, and the volcano-sedimentary ones are worked out or with low contents), lead-zinc accumulations (especially those related to the collision processes or to uncertain source and position), and gold accumulations (related to shear zones with uncertain source and position).

Small Au-Ag accumulations and Pb-Zn and Fe-Mn occurrences from the South Carpathians and the Apuseni Mts represent only 0.10 % of the TMP, their Alpine source and position being uncertain.

Taking into account the age of the main accumulations and occurrences in Romania, a general picture of different mineral associations or parageneses was established as shown in Figure 36 (Udubaşa, 1992). Some minerals (expressed by their main elements) have formed practically during the whole time interval since the Precambrian till Recent, i.e. iron-, copper, lead-zinc- and calcium (mostly calcite) minerals. Some other show a clear enrichment during certain time periods, such as the minerals of Mo, Mn, Cr etc. Finally, there are time-bound mineral assemblages, i.e. minerals of Au, Ag, Sb, Bi, Hg. Regarding the species number, the richest mineral-forming processes are those related to the Neogene igneous activity, producing locally clear and intense remobilization of some elements from the pre-Neogene basement. Very conspicuous are such processes in Northern Romania (Baia Mare zone), where abundant rhodochrosite appears associated with important vein sulphide assemblages (e.g. Căvnic ore deposit, Popescu, 1978). Much more complex seem to be the remobilization processes in the Metaliferi Mts., where a typical geochemical triad, i.e. Au-Te-Mn, has been depicted in connection with the active role of the basement (mostly ophiolitic) in furnishing at least Mn, if not Au and Te, too (Udubaşa et al., 1985). In the same region, a "metallic area" (in the sense of Routhier, 1977) rich in Mo has been found, which was repeatedly activated during the Lower Cretaceous-Miocene time yielding some molybdenite occurrences located mostly along the Mureş mobile zone.

Productivity of the ore genesis and geologic processes (Tables 14 and 15)

The most productive genetic ore types in terms of TMP are the volcanogenic - sedimentary type with 66.36 % (of them Palazu Mare deposit is 38.17 %), followed by orthomagmatic ores (represented by Fe < 15 %) with 17.39 %. The metasomatic ores (skarn and distal replacement) types are 4.48 %, hydrothermal veins - breccia pipe type is 3.71 %, porphyry copper types are 2.02 % and the exogenous ores are 4.48 %.

An integrated metallogenetic approach of commodities Pb-Zn, Au-Ag, Cu, Fe and Cu < 0.4 %, Fe < 15 % is reviewed below.

Pb - Zn. The ore formation is widely distributed across the stratigraphic-time scale. Alpine and Upper Paleozoic occurrences prevail with 65 % and 22.47 % of the TMP. The Banatitic and Tertiary subduction events yielded 15.26 % and 80.70 % of the total Pb+Zn potential of the Alpine cycle. The most important genetic type is hydrothermal vein - breccia pipe, computed as 53.56 % TMP, followed by volcanogenic metamorphosed deposits with 30.87 % TMP. The deposits taken into consideration are commonly of small and medium size. Large deposits are represented by Căvnic-Roata and Baia Sprie vein deposits and Baia Borşa volcanogenic deposit.

Cu. The ore formation shows a similar pattern compared to Pb-Zn occurrences. Alpine ores represent 58.12 % TMP and Upper Paleozoic ores 37.18 % TMP. The Banatitic and Tertiary subduction events yielded 66.36 % and 32.63 % of the total Cu potential of the Alpine cycle. The most productive genetic type is the volcanogenic metamorphosed with 40.8 % TMP. Metasomatic types enclose 36.61 % TMP. Copper deposits in Romania are of small and medium size.

Table 14

Productivity of compositional types of ores and of yielding geological processes

ORE TYPES	GEOLOGIC PROCESS / ORE BEARING FORMATIONS	GENETIC TYPES ¹	Metals - %		SIZE OF ACCUM ²
			Genetic type	Total potent.	
LEAD - ZINC 4.36%	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	51.05	4.86	c1-2
	Rhyolitic volcanism (Cb)	11,5	20.86	1.96	c1
	Banatic magmatism - calc-alkaline assoc. (Cr-Pg)	1,2,3	13.67	1.30	c1
	Carbonatic, amphibolitic and micaceous formations (Plz _{2,3})	11(5,6,9,10)	8.17	0.78	c1-2
	Rhyolitic volcanism (Lower Carboniferous)	11,5	3.84	0.37	a1,b1,c1,d1
	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₂ - E.C.)	2,4,13	1.07	0.19	c1
	Extensional basic submarine volcanism (Plz ₂ -Cb ₁)	11,5	1.01	0.10	c1
	Collision (?)	12,13	0.18	0.10	c1
	Alpine accumulations with uncertain source and position	13	0.13	0.02	c1
	TOTAL Pb+Zn		100.00	9.70	
COPPER 1.16%	Banatic magmatism - calc-alkaline assoc. (Cr-Pg)	1,2,3	38.49	0.98	d1-2
	Rhyolitic volcanism (Cb)	11,5	36.76	0.94	d1
	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	18.79	0.48	d1-2
	Carbonatic, amphibolitic and micaceous formations (Plz _{2,3})	11(5,6,9,10)	3.57	0.09	d1
	Spreading - tholeiitic assoc. (T ₁ -J ₁)	5	0.78	0.02	d1
	Rhyolitic volcanism (Lower Carboniferous)	11,5	0.63	0.01	d1
	Collision (?)	12,13	0.52	0.01	d1
	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₂ - E.C.)	2,4,13	0.43	0.02	a1,b1,c,d1
	Extensional basic submarine volcanism (Plz ₂ -Cb ₁)	11,5	0.02	0.00	d1
	Volcano-sedimentary formations of extensional type (S)	11(5,6)	0.01	0.00	d1
	Granitic magmatism (P)	1	0.01	0.00	d1
	TOTAL Cu		100.00	2.55	
GOLD - SILVER 0.01%	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	67.30	0.03	e1-2
	Rhyolitic volcanism (Cb)	11,5	9.02	0.003	e1
	Banatic magmatism - calc-alkaline assoc. (Cr-Pg)	1,2,3	2.23	0.0003	e1
	Rhyolitic volcanism (Lower Carboniferous)	11,5	0.94	0.0001	e1
	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₂ - E.C.)	2,4,13	0.21	0.0001	e1
	Collision (?)	12,13	0.20	0.0001	e1
	Alpine accumulations with uncertain source and position	13	0.11	0.00003	e1
	TOTAL Au+Ag		100.00	0.03	
IRON 44.67%	Metamorphic formations (Plz ₁)	11,6	58.17	39.61	a2
	Submarine basic volcanism (D)	11,8	13.95	9.50	a1
	Carbonatic, amphibolitic and micaceous formations (Plz _{2,3})	11(5,6,9,10)	7.06	4.81	a1
	Banatic magmatism - calc-alkaline assoc. (Cr-Pg)	1,2,3	6.30	4.29	a1
	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	4.92	3.35	a1
	Epicontinental formations (Pg)	8	4.63	3.16	a1
	Mesozoic carbonatic formations	7	1.44	0.98	a1
	Graphitous formation with lydites (Cb)	11,9	1.37	0.93	a1
	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₂ - E.C.)	2,4,13	1.08	0.71	a1
	Collision (?)	12,13	0.61	0.41	a1
	Pre-Alpine accumulations with uncertain source and position	13	0.29	0.20	a1
	Marine formations (Cr)	8	0.15	0.10	a1
	Alpine accumulations with uncertain source and position	13	0.04	0.03	a1
	Extensional basic submarine volcanism (Plz ₂ -Cb ₁)	11,5	0.03	0.02	a1
	TOTAL Fe		100.00	66.10	
MANGANESE 9.53%	Carbonatic, amphibolitic and micaceous formations (Plz _{2,3})	11(5,6,9,10)	67.56	11.10	b1-2
	Graphitous formation with lydites (Cb)	11,9	22.17	3.64	b1
	Submarine basic volcanism (D)	11,8	5.50	0.90	b1
	Mesozoic carbonatic formations	7	3.56	0.60	b1
	Banatic magmatism - calc-alkaline assoc. (Cr-Pg)	1,2,3	0.38	0.06	b1
	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	0.32	0.05	b1
	Pre-Alpine accumulations with uncertain source and position	13	0.32	0.05	b1
	Collision (?)	12,13	0.05	0.01	b1
	Alpine accumulations with uncertain source and position	13	0.02	0.00	b1
	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₂ - E.C.)	2,4,13	0.01	0.00	a1,b1,c,d1
	TOTAL Mn		100.00	16.41	
COPPER (Cu<0.4%) 2.02%	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	85.94	13.13	d1-2
	Banatic magmatism - calc-alkaline assoc. (Cr-Pg)	1,2,3	14.06	2.18	d1-2
	TOTAL Cu<0.4%		100.00	15.31	
IRON (Fe<15%) 17.42%	Rifting (bimodal T ₁ -J ₁ - N.D.; alkaline J ₁ -J ₂ - E.C.)	2,4,13	99.25	60.18	a1,b1,c1,d1
	Volcano-sedimentary formations of extensional type (S)	11(5,6)	0.31	6.27	a1
	Detrital formations (J ₁)	7	0.30	0.19	a1
	Neogene volcanism - calc-alkaline assoc. (m-pl)	1,3,5,6	0.14	0.18	a1
	TOTAL Fe<15%		100.00	66.82	

¹ - 1. Hydrothermal; 2. Skarn; 3. Porphyry; 4. Orthomagmatic; 5. Volcanogenic; 6. Volcano-sedimentary; 7. Residual;
8. Chemical precipitation; 9. Associated to carbonate rocks; 10. Associated to siliciclastic rocks; 11. Metamorphosed;
12. Tectogenous; 13. Polygenetic - remobilised.

² a - iron, b - mangan, c - lead + zinc, d - copper, e - gold + argent (size of accumulation according to Table 13)

Table 15
Productivity of genetic types of ores and of yielding geological processes

GENETIC TYPES (% of total potential)	GEOTECTONIC CYCLES ¹ (% of genetic type potential)	GEOLOGIC PROCESS - ORE BEARING FORMATIONS	%GP(OBF) of genetic type potential	SIZE OF ACCUMULATIONS ²
HYDROTHERMAL 2.90%	HERCYNIAN - 0.003%	Granite magmatism (G ¹)	0.003	d1
	ALPINE 99.997%	Baritic magmatism - calc-alkaline assoc. (Cr ₁ -Pg ₁)	16.80	a1:c1:d1
SKARN 5.34%	ALPINE 100%	Neogenic volcanism - calc-alkaline assoc. (m-p)	83.20	a1:c1:2:d1:e1:2
	ALPINE 100%	Rifting (remodal T ₁ -J ₁ - D.N. alkaline J ₁ -J ₂ - C.O.)	12.84	a1
PORPHYRY 2.02%	ALPINE 100%	Baritic magmatism - calc-alkaline assoc. (Cr ₁ -Pg ₁)	07.16	a1:c1:d1
	ALPINE 100%	Baritic magmatism - calc-alkaline assoc. (Cr ₁ -Pg ₁)	14.80	d1:2
ORTHOMAGMATIC 17.46%	ALPINE 100%	Neogenic volcanism - calc-alkaline assoc. (m-p)	85.20	d1:2
	ALPINE 100%	Rifting (remodal T ₁ -J ₁ - D.N. alkaline J ₁ -J ₂ - C.O.)	08.09	a1
VOLCANOGENE 0.86%	ALPINE 100%	Island arc magmatism - tholeiitic assoc. (J ₁ -Cr ₁)	11.11	a1:d1
	ALPINE 100%	Spreading - tholeiitic assoc. (T ₁ -J ₁)	1.02	d1
VOLCANO-SEDIMENTARY 2.43%	ALPINE 100%	Island arc magmatism - tholeiitic assoc. (J ₁ -Cr ₁)	10.38	a1:d1
	ALPINE 100%	Neogenic volcanism - calc-alkaline assoc. (m-p)	88.59	a1:c1:d1
RESIDUAL 1.34%	ALPINE 100%	Island arc magmatism - tholeiitic assoc. (J ₁ -Cr ₁)	0.06	b1
	ALPINE 100%	Neogenic volcanism - calc-alkaline assoc. (m-p)	99.92	a1
CHEMICAL PRECIPITATION 3.14%	ALPINE 100%	Mesozoic carbonatic formations	96.47	b1
	ALPINE 100%	Detrital formations (J ₁)	3.53	a1
VOLCANOGENE METAMORPHOSED 1.62%	ALPINE 100%	Marine formations (Cr ₁)	3.03	a1
	ALPINE 100%	Epicontinental formations (Pg ₁)	96.95	a1
VOLCANO-SEDIMENTARY METAMORPHOSED 0.12%	PROTEROZOIC NON-DIFFERENTIATED-2.27%	Carbonatic, amphibolic and micaceous formations (Pt ₂ -J ₁)	2.27	d1
	CALEDONIAN 84.24%	Extensional basic submarine volcanism (Pt ₂ -Cb ₁)	3.87	c1:d1
CHEMICAL PRECIPITATION METAMORPHOSED 47.85%	HERCYNIAN - 0.007%	Rhyolitic volcanism (Cb ₁)	80.37	c1:2:d1
	HERCYNIAN - 0.007%	Volcano-sedimentary formations of extensional type (S)	3.00	a1
VOLCANO-SEDIMENTARY METAMORPHOSED 0.12%	PROTEROZOIC NON-DIFFERENTIATED-99.92%	Rhyolitic volcanism (lower Carboniferous)	10.50	c1:2:d1
	HERCYNIAN - 0.08%	Carbonatic, amphibolic and micaceous formations (Pt ₂ -J ₁)	99.92	a1:b1
ASSOC. TO CARBONATIC ROCKS METAMORPHOSED 8.23%	PROTEROZOIC NON-DIFFERENTIATED-79.78%	Volcano-sedimentary formations of extensional type (S)	0.08	d1
	HERCYNIAN - 20.22%	Metamorphic formations (Pt ₂ -J ₁)	79.78	a2
ASSOC. TO SILICICLASTIC ROCKS METAMORPHOSED 5.94%	PROTEROZOIC NON-DIFFERENTIATED-63.69%	Submarine basic volcanism (O)	20.22	a1
	CALEDONIAN - 36.31%	Carbonatic, amphibolic and micaceous formations (Pt ₂ -J ₁)	63.79	a1:2:c1:2
TECTOGENOUS - 0.0002%	ALPINE - 100%	Graphitic formation with lodes (Cb)	36.31	b1
	PRE-ALPINE UNCERTAIN - 30.53%	Carbonatic, amphibolic and micaceous formations (Pt ₂ -J ₁)	100.00	a1:b1
POLYGENETIC AND OF REMOBILISATION 0.71%	ALPINE 69.47%	Collision (T)	100.00	c1:a1
	ALPINE 69.47%	Accumulations with uncertain source and position	30.53	a1:b1
POLYGENETIC AND OF REMOBILISATION 0.71%	ALPINE 69.47%	Rifting (remodal T ₁ -J ₁ - D.N. alkaline J ₁ -J ₂ - C.O.)	6.65	c1
	ALPINE 69.47%	Collision (T)	57.89	a1:b1:c1
	ALPINE 69.47%	Alpine accumulations with uncertain source and position	4.93	a1:c1:e1

¹ - EC - East Carpathians; SC - South Carpathians; AM - Apurimac Mountains; TD - Transilvanian Depression; SD - South Dobrogea; CD - Central Dobrogea; ND - North Dobrogea
² - a - iron, b - mangan, c - lead - zinc, d - copper, e - gold + argent (size of accumulation according to Table 13)

Au - Ag. Gold mineralization is intimately associated with the Alpine cycle that provided 87.41 % TMP. The Tertiary subduction event yielded 85.38 % TMP in epithermal systems and subordinately porphyry coppers. Barza and Roşia Montana are world class deposits and the rest are of small and medium size.

Fe. Iron metallogeny is characteristic of Precambrian to Alpine cycles, with special regard to the Lower Proterozoic that yielded 59.34 % TMP. Iron in Paleozoic is 12.63 % TMP and increases during Alpine time to 19.67 % TMP and decreases during Middle and Upper Proterozoic to 6.81 % TMP. The chemical sediments related genetic type is the most important, promoting 80.18 % TMP. The Palazu Mare deposit is of large size but its mineability is still problematic, due to hydrogeologic conditions and deep location. The remaining deposits are of small and medium size.

Cu < 0.4 %. This is in fact the class of porphyry copper assessed separately from other copper ore types due to low-grade and difficulties in mineability. They are associated with Banatitic and Tertiary magmatic subduction events and have small to medium size. They may be reinterpreted in economic terms due to the common presence of Au and/or Mo byproducts and genetic association with epithermal systems.

Fe < 15 %. This type of lower contents ore is of no economic importance for the time being. Iron occurs in orthomagmatic ores associated with the Ditrău alkaline massif yielding 92.43 % TMP. This is an intracontinental rifting related setting during incipient evolution of the Alpine cycle in the Carpathian realm.

Besides the major elements taken into account in the potential assessment, the metalliferous accumulations also contain several minor elements, among which at present Sn, W, Cd, Se, Te, Be, Sb are recovered directly in the processing activity or indirectly in the metallurgic process, in low amounts, whereas As, Co, In, Ti, Ga, Cu, Ge can be recovered (especially in metallurgy), with values compatible worldwide (Niţulescu, 1962; Borcoş et al., 1983; Pandeleşcu et al., 1986).

One should also take into account the share of the metallic elements possible to be recovered from the tailings or old dumps, which generally cumulate considerable volumes, important particularly for Au, Ag, Pb, Zn and for the typical minor elements (Borcoş et al., 1978).

Metallogenetic specialisation of the main stages of geotectonic cycles/units and major geographic units (Table 16)

The quantitative metallogenetic specialisation can be inferred from the variable association of the main mineralisation types (ferrous, non-ferrous and precious metals), from the value of the ratio between the potentials (in terms of TMP) corresponding to the ferrous (iron + manganese) and non-ferrous ores (lead + zinc + copper), as well from the particular occurrence of some elements that determine the specific qualitative feature like Mo, W, Ti, V, Au, Te.

Taking into account the geotectonic settings of the Alpine cycle, one can observe an increase of the complexity of the metallogenetic process, also noticed in the variety of the compositional types of ore. This evolution line also includes the decrease of the value of the ratio Fe+Mn/Pb+Zn+Cu from 65.78 in the rifting zone to 2.02 in the

Table 16

Quantitative metallogenetic specialization of the main stages of geotectonic evolution

GEOTECTONIC CYCLES	COMMODITIES	M			E			T			A			L			S		
		Pb+Zn		Cu	Au+Ag		Fe	Mn		Cu<0.4%	Fe<15%								
		%	%	%	%	%	%	%	%	%	%	%							
PROTEROZOIC	Fe, Mn, Pb+Zn, Cu	0.70	0.08	0.02	86.44	12.79	0.00	0.00	0.00	0.00	0.00	0.00							
CALEDONIAN	Mn, Pb+Zn, Fe, Cu	21.29	9.60	0.02	21.19	47.89	0.00	0.00	0.00	0.00	0.00	0.00							
HERCYNIAN	Fe, Mn, Pb+Zn, Fe<15%, Cu	1.64	0.07	0.001	92.58	5.21	0.00	0.00	0.00	0.00	0.00	0.49							
UNCERTAIN PRE-ALPINE	Fe, Mn	0.00	0.00	0.00	87.36	13.64	0.00	0.00	0.00	0.00	0.00	0.00							
ALPINE	Fe<15%, Fe, Pb+Zn, Cu<0.4%, Cu, Mn, Au+Ag ± Ti, V, Mo	7.98	1.88	0.02	35.40	1.25	5.53	47.62											
- EXOGENOUS	Fe, Mn, Fe<15%	0.00	0.00	0.00	91.27	7.63	0.00	1.05											
- ENDOGENOUS	Fe<15%, Fe, Pb+Zn, Cu<0.4%, Cu, Mn, Au+Ag ± Ti, V, Mo	9.11	2.15	0.03	26.87	0.24	6.32	54.23											
- Rifting	Fe<15%, Fe, Pb+Zn, Cu, Mn	0.28	0.03	0.0001	4.24	0.01	0.00	95.45											
- Spreading	Cu	0.00	100.00	0.00	0.00	0.00	0.00	0.00											
- Island arc	Pb+Zn, Cu, Mn	4.03	0.39	0.00	0.00	0.10	0.00	79.56											
- Subduction	Fe, Pb+Zn, Cu<0.4%, Cu, Mn, Fe<15%, Au+Ag	21.29	5.05	0.06	57.31	0.51	15.51	0.17											
- Banatites	Fe, Pb+Zn, Cu, Cu<0.4%, Mn	10.56	7.97	0.004	75.58	0.66	5.12	0.00											
- Neogene	Fe, Pb+Zn, Cu<0.4%, Cu, Mn, Fe<15%, Au+Ag	29.25	2.89	0.11	43.76	0.41	23.22	0.29											
- Collision	Fe, Pb+Zn, Cu, Mn	1.84	1.41	0.004	95.71	1.02	0.00	0.00											
Uncertain source and position	Fe, Au+Ag, Mn	15.91	0.00	0.03	77.43	6.63	0.00	0.00											

collision zones (excepting the island arc processes – 6.59). The metallogenetic complexity of the subduction stages is rendered evident by the increase of the contents of Au-Ag, and subordinately of Mo-W-B, Sb-Bi-Te-Ge and Hg.

The ore composition of the Alpine cycles is relatively homogeneous, the differences consisting only in the variation of the ratios between the associations of ferrous and non-ferrous ores; the highest values of this ratio were recorded in the Proterozoic cycles (190.61), and the lowest ones in the Caledonian cycle (5.29).

The geographic units that cumulate most of the potential are, as follows: South Dobrogea (155.36 mil. tons, exclusively iron), East Carpathians (125.95 mil. tons - iron, manganese, lead-zinc, copper, the ferrous ores occurring in significant amounts), South Carpathians (78.17 mil. tons - iron, manganese, copper and lead-zinc, the ferrous ores prevailing), and Apuseni Mts (31.79 mil. tons - lead-zinc, copper, iron, gold-silver, manganese, with diversified mineralisations and locally with significant concentrations of gold-silver, copper and lead-zinc).

The economic aspects that include the intense mining activity (since ancient times) and the value of the potential of mineable reserves and resources point out the importance of the geographic and/or geologic units. From this point of view it is to mention the East Carpathians mainly due to their lead-zinc and copper ores potential associated to the Neogene volcanism and to the Cambrian rhyolitic one. The importance of the Apuseni Mts consists especially in the volumes and quality of the gold-silver, lead-zinc $\pm$ Au and copper ores associated to the Neogene volcanism and the ferrous, copper, lead-zinc $\pm$ Au ores related to the Banatitic magmatism. The western part of the South Carpathians (Banat and Poiana Ruscă) proved also to be important if one considers the iron accumulations associated to the Devonian sub-marine basic volcanism and to the Banatitic magmatism, through the porphyry type copper and lead - zinc $\pm$ Au and copper mineralisations related to the Banatitic magmatism.

V. CONCLUSIONS

The present attempt to correlate qualitative metallogenetic interpretations of time-space ore formation with quantitative data for the Romanian territory provides valuable information about metallogenetic specialisation, intensity of metallization and size of mineral deposits.

The time-stratigraphic depositional sequences suggest the following metallogenetic specialization of various geotectonic cycles that is better expressed as TMP:

Lower Proterozoic cycle - Fe;

Middle and Upper Proterozoic cycles - Mn, Fe, Cu, Pb, Zn;

Lower Paleozoic cycle - Mn, Fe, Cu, Pb, Zn ($\pm$ Au, Cr, Ni, Th, U, REE);

Upper Paleozoic cycle - Fe, Cu, Pb, Zn (Mo, W, U, Th, REE);

Alpine cycle - Cu, Pb, Zn, Au, Ag, Fe, Mn, Mo ($\pm$ Ti, V, W, Sb, Bi, Cd, Hg, Co, Cr, Ni, U, Th, TR).

The paragenetic features of the mineralisations point out the obvious tendency of metallogenetic specialisation that is also rendered evident by the ratio

Fe+Mn/Pb+Zn+Cu, which varies from 190.62 for the Proterozoic non-differentiated cycles to 5.29 for the Caledonian cycle.

The intensity of metallisation is preferentially related to major magmatic events: i.e. acidic and bimodal volcanicity in Lower Paleozoic, granitoids during Upper Cretaceous-Paleocene and volcano-plutonic complexes of intermediate character in Miocene-Pliocene. Ore formation of this kind yielded important deposits of skarn, porphyry and epithermal types and volcanogenic (metamorphosed) type that cluster in the East Carpathians, South Carpathians and Apuseni Mts. Their economic importance is better expressed in terms of TMP.

Regarding the size of the ore deposit most of the accumulations are small-sized (very many being found at the lower limit); the medium-sized ore deposits are: Palazu (Fe), Răzoare (Mn-Fe), Sebes Mts (Mn), Blazna Valley (Pb+Zn), Bucății Hill - Cornu Nedeli (Pb+Zn+Cu), Gura Băii - Măcărâu - Ivășcoia - Novicior (Pb+Zn+Cu), Muncel (Pb+Zn+Cu), Ghezuri-Penigher (Pb+Zn±Au-Ag), Baia Sprie (Pb+Zn±Cu-Au-Ag), Băiut (Pb+Zn±Cu-Au-Ag), Căvnic (Pb+Zn±Cu-Au-Ag), Suior (Pb+Zn±Au-Ag), Rosia Poieni (Cu), Moldova Nouă (Cu±Mo), Bucium-Tarnita (Cu±Au), Barza (Au), and Rosia Montană (Au). World class Au-Ag deposits at Barza and Rosia Montană or large Pb-Zn ± Cu, Au, Ag deposits at Căvnic and Baia Sprie point to the predominant non-ferrous character of the metallogenesis in Romania.

The classification of the districts according to the size of the TMP stresses out that the ferrous accumulations are situated on the first places: Palazu (Fe), Ditrău (Fe), Teliuc - Ghelar (Fe), Banat - Sebes Mts (Mn-Fe), Răzoare (Mn-Fe), Căpus - Savadislă (Fe), Vatra Dornei (Mn), Băisoara (Fe, Pb+Zn), Drocea (Fe), Ocna de Fier (Fe, Pb+Zn); one should consider that most of TMP is either non-mineable or worked out.

Quantitative and qualitative characterisation of the genetic types of mineralisations renders evident the most productive genetic types which generated, in most cases, accumulations of no economic significance (or hard to be mined), of chemical precipitation, metamorphosed, associated to the Karelian metamorphic formation (Ptz₁) (47.86 %), orthomagmatic associated to the Alpine rifting processes (J₁-J₃) (17.40 %), accumulations associated to metamorphosed carbonate rocks, corresponding to the non-differentiated Proterozoic cycles (carbonate, amphibolic and micaceous formations - Ptz_{2,3}) and to the Cambrian graphite formations (8.23 %), as well as accumulations associated to metamorphosed siliciclastic rocks, corresponding to the carbonate, amphibolic and micaceous formations (Ptz_{2,3}) (5.94 %). Among the genetic types that generated accumulations with a high degree of mineability mention should be made of the hydrothermal, skarn, porphyry and metamorphosed volcanogenic types that yielded significant accumulations of lead-zinc, copper, gold (silver) in the Alpine cycle, and the last one in the Caledonian cycle.

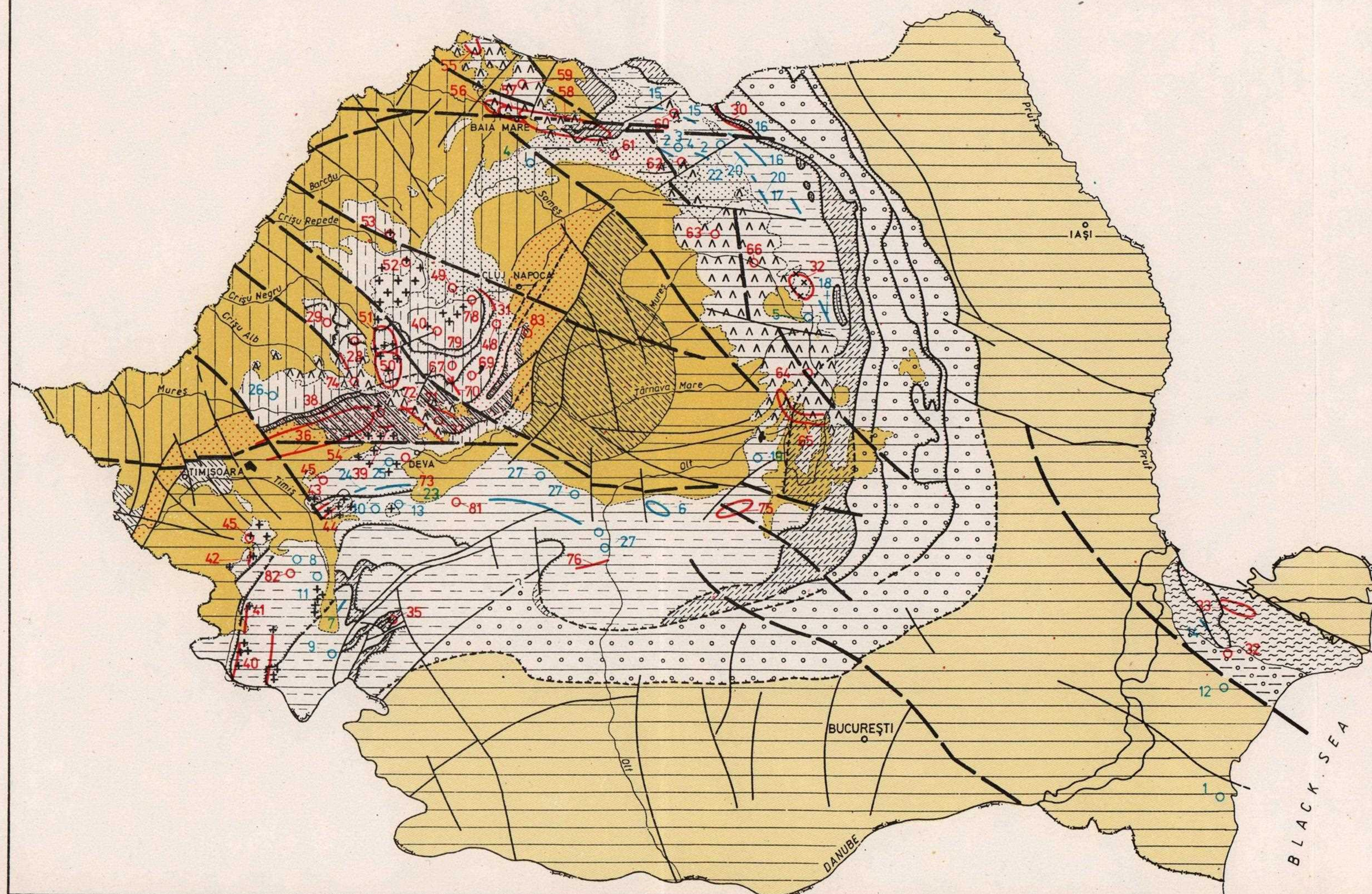
Quantitative distribution of the ore types: regardless of the economic significance, the iron (84.09 %) and manganese (9.53 %) ores are associated usually to the Proterozoic and Lower Paleozoic geologic processes, these representing 70 %. The lead-zinc (4.36 %) and copper (3.18 %) ores, although subordinated, are spread within a larger interval, starting with Ptz_{2,3} up to the Neogene, the most productive geologic processes being the Alpine ones at the level of the Miocene-Pliocene volcanism. The gold-silver ores (0.01 %) are mostly associated to the Neogene volcanism (87.30 %), constituting, however, accumulations with high concentration and metallisation, especially in the Metaliferi Mts.

M. Borcoş, B. Găbudeanu, Ş. Vlad

SCHEMATIC REPRESENTATION OF THE METALLOGENETIC DISTRICTS OF ROMANIA

(Geotectonic setting acc. to D. Rădulescu, M. Săndulescu, M. Borcoş 1993; M. Borcoş, Ş. Vlad, M. Lupu, J. Andrei 1997)

0 20 40 60 80 100 km



Legend

- South-western and eastern margin of the European Plate and the associated units
 Eastern and central segment of the Eurasian Plate
- Oceanic and para-oceanic realms of the Ceahlău-Severin and Black Flysch units ($J_{2-3}-Cr_1$)
- Eastern and southern Carpathian orogen, the foredeep (a) inclusive
- Tertiary cover of the platforms (Moesian, Scythian and East-European)
- North-Dobrogean Orogen associated to the Late Paleotethys
 Post-tectonic cover (Cr_2)
- Kimmerian units including the Paleozoic basement and pre-Paleozoic formations ($T-J_{3+}Pt_{2+3}+Pz_1$)
- Tethyan major suture and the associated realms
 Units related to the active continental margin (J_2-Cr_1) a – at surface, b – covered
- Covered Transylvanian oceanic realm (T_2-Cr_1)
- Obducted nappes from the East Carpathians (T_2-Cr_1)
- Pienides (J_2-Pg_3)
- Apulian segment of the African Plate
- Intramontane depressions ($Pg-N$)
- Post-tectogenetic covers (Cr_1-m_1)
- Major associations of Alpine magmatic rocks
 Magmatic rocks generated by the Jurassic-Neocomian rifting: alkaline intrusions ($J_2?-Cr_1$)
- Magmatic rocks generated by the Jurassic-Neocomian subduction: mafic-felsic volcano-plutonic complexes ($J_2?-Cr_1$) and associated sedimentary formations
- Magmatic rocks generated by the Upper Cretaceous-Paleogene subduction: andesitic extrusions, felsic volcano-plutonic complexes and felsic-intermediary intrusions (Cr_2-Pg_1)
- Magmatic rocks associated to the Neogene subduction – intermediary volcano-plutonic complexes (m-pl)
- Intrusive rocks associated to the Quaternary post-collision processes: alkaline basalts (Q)
- Fault
- Deep fracture
- Nappes, a. covered
- Metallogenic units (districts* represented by isolated accumulations – a, preferentially disposed lineary – b, and areally – c)
- Pre-Alpine districts 1-27
 a b c
- Alpine districts 28-83
 a b c

* under special conditions, the districts correspond either to the metallogenic zones, or to some isolated accumulations, according to Table I

The data obtained can contribute to the delimitation of the major areals and targets which, by the geo-economic characteristic and genetic models of the mineralization accumulations, raise for discussion future research programmes.

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MAY 4, 1998

GOVERNMENT OF ROMANIA

THE MINING LAW

**THE PARLIAMENT OF ROMANIA
ASSEMBLY OF REPRESENTATIVES**

SENATE

THE MINING LAW

The Parliament of Romania adopts the present law.

The present Mining Law regulates the mining activities in Romania, stimulating the capitalization of the mineral resources, which are public property. The Law assures maximum transparency of the mining activities and a fair competition, without discrimination between the property forms, the origin of capital and the nationality of the operators.

The investments in the mining domain are encouraged by fiscal and administrative facilities, being free of any constraint concerning the return of the investments and the utilization of the obtained profit.

CHAPTER I

GENERAL PROVISIONS

ARTICLE 1

The mineral resources located on the territory and in the subsoil of the country and of the continental shelf in the Romanian economic area of the Black Sea, delimited in accordance with the principles of international law and of international regulations to which Romania is a party, are the exclusive object of public property and they belong to the Romanian State.

ARTICLE 2

(1) The mineral resources which are the subject of the present law are: coal, ferrous and non ferrous minerals, aluminum rocks and minerals, noble, radioactive, rare and disperse metals, non metallic useful substances, useful rocks, precious and semiprecious stones, peat, mud and therapeutically peat, non combustible gas, bituminous rocks, heating from hydrogeothermal systems, mineral and flat waters, mineral-thermal waters, as well as mining metallurgic residues from barren dumps, decantation ponds and other technological facilities.

(2) For underground waters, the provisions of this law are applied only for the exploration, evaluation and registration of the reserves.

ARTICLE 3

For the purpose of this law the terms and the expressions herein are defined as follows:

1. *Mining activity* means all the work related to the prospecting, exploration, development, exploitation, processing, concentration, metallurgic extraction and commercialization of mining products;
2. *Administration - given info* - is the right granted by the State, through the Competent Authority, to public institution to conduct mining activities under a license;
3. *Competent Authority* is the National Agency for Mineral Resources, an agency that represents the interests of the state in the sector of mineral resources;
4. *Mining Cadastre* means the specialized document which contains technical, economic, legal and other important information about instituted perimeters;
5. *Mining Book* is the recording document through which all the mining and geological works, mining lands and other assets within a instituted exploitation perimeter are identified, registered and represented on maps and cadastral plans. It contains all legal documents of any nature concerning a prospecting, exploration and exploitation perimeter or in connection with such a perimeter, and all data concerning the owners of the land, the topography of the perimeter, all mining works and facilities existing thereon, and also the situation of the reserves and the production for each substance;
6. *Concedent* is the Competent Authority empowered by the law to grant the concession;
7. *Mining Concession* is the right granted by the State, through the Competent Authority, to a concessionaire to conduct mining activities under a license;
8. *Concessionaire* is the TitleHolder to which the Mining Concession is granted;
9. *Development* means all operations related to the construction of mines, open pits and quarries, building and assembling of specific equipment, installations and other facilities necessary for the extraction, processing transportation and temporary storage of mining products and residues;
10. *Exploitation* means all activities performed in the underground and/or at the surface in order to extract mineral resources, process and deliver them in specific forms;
11. *Exploration* means all studies and activities for the identification of the deposits, their quantitative and qualitative evaluation, as well as the determination of the technical and economic conditions for their use;
12. *National Geologic Fund* means all the data related to the mineral resources of the country, obtained from petroleum and mining activities, no matter the nature of the storage support;
13. *National Reserves Fund* means all the reserves recorded and registered by the Competent Authority, for each type of mineral resource of the country, determined according to the specific regulations;
14. *Force majeure* means unpredictable, unavoidable and non removable event, which generates a temporary or definitive impossibility to partially or totally carry out the Title Holder's obligations;
15. *License* means the legal document entered into, in accordance with the provisions of this law, between the concedent and the concessionaire, for the purpose of conducting mining activities;
16. *Environment* means all the natural elements and conditions, defined according to the Environmental Law, No. 137/1995, which might be affected through mining activities;

17. *Radioactive ore* – accumulation of uranium, thorium, as natural chemical compounds;
18. *Ministry* is a specialized body of the public central administration, with responsibilities in the mineral resources domain;
19. *Prospecting, Exploration and Exploitation Perimeter* means the area corresponding to the projection on the land surface of the contour of the portion of earth's crust where, for a determined interval of depth, prospecting, exploration and, respectively exploitation activities are conducted, and also the areas of land needed for production purposes located beyond the limits of the said area;
20. *Exploitation permit* means the juridical act issued by the Competent Authority, granting the exploitation right for a determined quantity of ordinary rocks, peat and alluvial gold;
21. *Prospecting permit* means the juridical act issued by the Competent Authority, granting the right to carry out prospecting works;
22. *Protection pillar* means parts of the mineral reserve or of the surrounding rocks, which are not extracted in a defined period or permanently and in which are not carried out mining works, in view to protect the underground or surface mining works within the exploitation perimeter, the rivers' borders or other surface objectives;
23. *Close Activity Plan* means all the technical, economical, social and environment documentation, which motivates the closure of the exploitation and includes the necessary actions to ensure the funding and the effective achievement of the closure measures;
24. *Environmental Rehabilitation Plan* means a plan for the environmental restoration of the exploitation perimeter, according to the Environmental Law;
25. *Mining production* means the mining product commercialized by the Title Holder;
26. *Mining Metallurgic Residues* means the material resulted from the mining extraction, preparation and metallurgic processing of the mineral resources, which is evacuated in barren dumps, decantation ponds and other technological facilities;
27. *Prospecting* means all studies and surface operations conducted in order to identify the possibility of the existence of the mineral resources accumulation;
28. *Royalty* represents a payment to the state, based on a percentage of the value of mining production obtained by the title holder, as compensation for the decrease of the reserves of mineral resources;
29. *Mineral Resource* means natural substance from the crust formed as a result of geological processes, which can be used as it is or after preparation in economic or social activities;
30. *Reserve* means a part of a deposit, with established quality and quantity through exploration and exploitation works, for which technical and economic conditions for capitalization were determined;
31. *Title Holder* means any Romanian or foreign legal person authorized to conduct mining activities by virtue of a license;
32. *Deposit* means a natural accumulation of mineral resources that can technically and economically be capitalized.

ARTICLE 4

(1) The mining activities are carried out by legal persons, who are registered according to the law and are specialized in conducting such activities or will be organized for this purpose.

(2) The mining activities can be also carried out by physical persons, according to Art. 18,19 and 20 of the present law.

(3) The mining activities are carried out only within the perimeters authorized for this purpose by the Competent Authority, except the activities mentioned in para.(2).

ARTICLE 5

(1) All data and information, irrespective of their manner of storage, concerning the Romanian mineral resources, as determined under Art. 1 herein, shall be submitted to the Competent Authority and belong to the Romanian State.

(2) The data and information obtained by the legal persons through their mining activities, shall be used by them for their interest, without any payment or constraint, during the entire period of their mining activity.

(3) The disposition to the third party of the data and information regarding the Romanian mineral resources shall be made with the Competent Authority's agreement.

(4) The data and information on special mineral resources that are subject to a special law can only be used according to the provisions of that law.

ARTICLE 6

(1) Access to the lands required to conduct mining activities shall be granted in accordance with the law, through:

- a) sale - purchase of the lands and, if the case may be, of the buildings located on them, through legal acts, at the prices agreed by the parties;
- b) lands exchange, together with moving the affected owner and the reconstruction of the buildings on the new granted land, on the expenditure of the Title Holder, which benefits on the vacated land;
- c) land rental on determined period, establishing the usufruct based on contracts concluded between the parties;
- d) expropriation for public interest cause, in accordance with the law;
- e) the concession of the lands declared public property;
- f) an association between the owner of the land and the titleholder of the license, through social capital contribution equivalent to the value of the land.
- g) others procedures provided by the law;

(2) A legal lien, if the case may be, is instituted in favor of the title holder of the operations over the lands required by the mining activities which have to be conducted outside the exploitation perimeter, as well as over those required by exploration operations and by any other operations involved;

(3) The exercise of the legal lien right provided for in para. (2) shall be made against payment of an annual rental to the landowners affected by such right.

(4) The duration of the legal lien provided for in para. (2) shall be for the term of mining activities, and the lands which are to be affected shall be determined, with respect to their surfaces and owners, following the principle of causing as little harm as possible to the ownership right.

(5) Access to the lands affected by the legal lien provided by para (2) should be determined through negotiations between the titleholder of the mining operation and the landowners, with observance of the principle of equal treatment and equity.

(6) Any dispute between the title holders of mining activities and the land owners shall be settled by the competent courts of jurisdiction in accordance with the legal provisions.

(7) If the state sells the assets which were expropriated under para. (1), d) here above, the former owners or their inheritors, as the case may be, shall have a preemption right, under equal conditions, for which purpose they shall be notified by the state administration or through publicity about the conditions of the sale.

(8) Access to the lands on which are located historical, cultural and religious monuments, archeological sites of important interest and natural reservation, shall be made with the approval of the legal authorities involved.

CHAPTER II

TURNING MINERAL RESOURCES INTO VALUE

ARTICLE 7

The mineral resources shall be turned into value through mining activities for which purpose these activities shall be concessioned to national mining companies and societies and also to Romanian or foreign legal persons or given into administration to public institutions by the Competent Authority, according to the present law.

ARTICLE 8

(1) Prospecting phase shall be conducted on the basis of a non exclusive permit, issued at the request, within a perimeter of a geometrical shape, with the sides oriented North-South and East-West, defined by topogeodezical coordinates.

(2) The size of the block shall be multiple of the minimum area of 45 km².

(3) The prospecting permit shall be issued for a period of maximum 3 years, with an advance payment of an annual fee.

(4) The prospecting permit does not assure any exploration and/or exploitation rights.

(5) The titleholder of the prospecting permit presents to the Competent Authority annual documentation regarding the work conducted and the results obtained and a final report, comprising the investigation method used and the results obtained.

ARTICLE 9

(1) Exploration shall be conducted on the basis of an exclusive license, issued at the request, to the interested Romanian or foreign legal persons selected through a semestrial public offering by the Competent Authority, based on a work program and an adequate bank guaranty to be applied for environmental restoration purpose.

(2) The exploration license shall be issued, according to the law, for all the mineral resources existent in the perimeter, within maximum 180 days from the announcement date of the public offering, but no later than 30 days from the date of the public offering results.

(3) The exploration license shall be granted for a maximum period of 5 years, with a renewal right of no more than 3 years, paying in advance an annual fee.

(4) The size of the exploration perimeter shall be multiple of the minimum area of 10 km² and will be reduced by 50% after the first 2 years and by 25% more (from the initial size) after 4 years.

(5) Usually, the exploration perimeter will be rectangular, with the sides oriented North-South and East-West, defined by topogeodezical coordinates.

(6) The titleholder of the exploration license will present to the Competent Authority annual documentation regarding the work conducted and the results obtained and a final report, comprising the exploration method applied, the works performed and the results obtained.

(7) The TitleHolder of an exploration license has the right to obtain, upon request, the exploitation license for any mineral resources discovered, according to the present law.

ARTICLE 10

(1) Mining shall be conducted on the basis of an exclusive license, granted for all the mineral resources within an exploitation perimeter.

(2) The exploitation license shall be granted to:

- a) the title holder of the exploration license, on its request;
- b) the winner of a public offering, organized by the Competent Authority, according to the present law.

(3) The exploitation license shall be granted, through negotiation, based on an application, accompanied by:

- a) feasibility study which ensures the capitalization of the mineral resources and the deposit protection;
- b) development plan of the exploitation;
- c) the environmental impact study, approved according to the law;
- d) environmental rehabilitation plan accompanied by a bank guaranty, based on the value of the development plan and the environmental impact study, and calculated according to norms for applying the present law.

(4) The exploitation license shall be granted for maximum 20 years, with the right of continuation for successive periods of 5 years each.

(5) The titleholder of the exploitation license will pay an annual tax on surface and a mining royalty, according to the present law.

ARTICLE 11

(1) The license is concluded in written form; for exploitation, the license comes into force after its approval by the Government.

(2) The provisions of the license shall remain valid for the entire duration thereof, under the terms existing on the date the agreement was made.

ARTICLE 12

The Competent Authority shall authorize in writing the commencement of the mining activities provided in the license, within 60 days from granting the license.

ARTICLE 13

(1) Within ninety days from the coming into effect of the license the foreign legal persons which obtained the right to conduct mining activities must set up and maintain a branch or a subsidiary in Romania for the whole duration of the concession.

(2) In the event two or more foreign parties acquire together mining rights with respect to the same perimeter, the obligation of setting up and maintaining a branch or subsidiary in Romania shall be incumbent solely on the company which was designated to represent the interests of such parties.

ARTICLE 14

(1) The titleholder of a license can transfer its rights thus obtained and its obligations thus undertaken to another legal person only subject to the written agreement issued by the Competent Authority. Any transfer made in the absence of such agreement shall be null and void.

(2) The license for giving into administration is not transferable.

ARTICLE 15

Within the limits of an exploitation perimeter, the Competent Authority, in accordance with the legal provisions, can grant exploration and/or exploitation rights for some mineral resources to legal persons other than the titleholder of the license, with his permission.

ARTICLE 16

The right conferred by administration or concession is a right distinct from the ownership over lands and can in no way be affected by the title holder for the benefit of any third party, except the case mentioned in Art. 14.

ARTICLE 17

The right of operating granted by the license can constitute a guaranty for bank loans, in order to conduct the mining activities provided by the license, with the written approval of the Competent Authority.

ARTICLE 18

(1) For the useful construction rocks and peat accumulations, established and limited quantities may be extracted by economic agents for a limited period of time based only on the exploitation permit issued by the Competent Authority. The exploitation permit shall be released to the first applicant, legal or physical person.

(2) For the exploitation of sands and gravel from the bed rivers, the permit for exploitation is issued after the approvals required by the water legislation.

(3) The areas for which exploitation rights are granted through permits are annually established and renewable by the Competent Authority.

(4) For obtaining the exploitation permit, the applicants are obliged to pay the fee for the exploitation activity and mining royalty, in accordance with the law.

The fee shall be paid at the issued date of the exploitation permit, and the mining royalty periodically during the period of validity of the permit.

ARTICLE 19

The useful construction rocks, such as: clay, sands, gravel, andesit, basalt, calcareous, sinter and others, or peat accumulations and mineral water springs located on private lands, can be used by the landowner only for its own needs, without paying the taxes and the mining royalty.

ARTICLE 20

(1) Physical persons, based on an exploitation permit issued by the Competent Authority can carry out the recovery works of gold from the alluvial, not included in a mining concession.

(2) The physical persons in charged with the gold recovery activity from alluvial are obliged to pay the taxes and mining royalties provided by the law.

ARTICLE 21

The mining concession or the mining administration shall terminate:

- a) Upon expiration of the duration for which it was granted;
- b) Upon relinquishment by the titleholder of the license, as provided in Art. 22;
- c) Upon revocation of mining concession or mining administration rights by the Competent Authority, as provided in Arts. 23, 24, 25;
- d) In case of occurrence of events which represent causes of force majeure, as defined in the license.

ARTICLE 22

(1) The titleholder of a license may relinquish the agreement if upon the date the Competent Authority is notified about such relinquishment the titleholder cumulatively meets the following conditions:

- a) provides the Competent Authority with all the documents regarding the operations conducted until the date of notification of relinquishment, and with all the results thereof;
- b) provides the Competent Authority with the amount representing the value of any works provided in the environment rehabilitation plan which have not been completed.

(2) Within 60 days from the date of notification of relinquishment the Competent Authority shall verify the fulfillment of the conditions set forth in para. 1.

(3) If the Competent Authority did not notify its refusal, upon the expiration of the 60 days time provided in the para. 2 the license is canceled and the Competent Authority will have the obligation to issue its decision to terminate the administration or concession, which shall be effective as of the date of expiration of the aforementioned time.

(4) In the event of a refusal from the Competent Authority, the TitleHolder may ask the competent court of jurisdiction or of arbitration, as the case may be, to determine that requirements are met for the unilateral cancellation of the license.

(5) In the event the court of jurisdiction or of arbitration determines that requirements are met for the unilateral termination of the license, the Competent Authority shall issue the decision of termination of the administration or concession, which shall be effective from the date the decision (i.e. of the court) becomes final and irrevocable.

ARTICLE 23

The Competent Authority may withdraw the administration or the concession if, despite the contravention sanction applied, the title holder of the license, within 30 days from receipt of the notification:

- a) does not fulfill its obligations regarding the date of commencement of mining activities;
- b) continues to interrupt the operations for a period of more than 30 days, without the agreement of the Competent Authority;
- c) makes use of exploitation methods or technologies other than those provided in the development plan;
- d) conducts mining activities without having been authorized to do so.

ARTICLE 24

The Competent Authority shall suspend or withdraw the concession or administration if it finds that the title holder of a license:

- a) does not abide by a decision of judicial court or arbitration with respect to the mining activities;

- b) becomes subject to reorganization or a legal process of liquidation for insolvency;
- c) intentionally provides the Competent Authority with false data and information as to its mining activities or violates the confidentiality requirements set forth in the license;
- d) jeopardizes by the manner of conducting mining activities the possibility of the future exploitation of the deposit, or grossly violates the norms regarding the protection and the reasonable exploitation of the deposits, or the authorization regarding the protection of environment or the safety of the workers has been withdrawn;
- e) does not pay within the terms established by the license the fees, taxes and royalties owed to the State.

ARTICLE 25

(1) Withdrawal of administration/concession for any of the reasons provided in Arts. 23 and 24 shall be effective with regard to the titleholder of the license after 30 days from the date the titleholder was notified (about such decision) by the Competent Authority.

(2) Within the time provided in para. 1, the titleholder of the license may ask the court of law or arbitration, as the case may be, to annul the act of withdrawal concession or administration.

(3) At the request of the titleholder of the license and upon hearing the Competent Authority, the court may decide to suspend the act of withdrawal until the decision becomes final.

ARTICLE 26

(1) In case of occurrence of one of the events provided in Art. 21 (d), the title holder of the license shall notify the Competent Authority within 15 days from the occurrence of such event, submitting the documents which certify the force majeure issued by the legally authorized organization for this purpose. The termination of concession or administration shall be effective after 30 days from the date of notification of the force majeure.

(2) If, within the time of 30 days provided in para. (1), the Competent Authority notifies the title holder of the license its refusal to accept the event invoked by the title holder as being a circumstance of force majeure which definitely makes impossible the initiation or the continuation of mining activities, for reasons which are not attributable to the title holder, then the title holder may ask the competent judicial or arbitration court, as the case may be, to rule the unilateral cancellation of the license for cause of force majeure, without the title holder being obliged to pay damages.

(3) In the event a cancellation decision of the license is issued, the Competent Authority shall, after the judicial or arbitration decision becomes final, issue the decision of termination of the concession or administration, which shall be effective as of the date provided in para. (1).

ARTICLE 27

(1) The decision concerning the termination of the mining concession or mining administration shall be published in the Official Monitor of Romania which shall mention the date it becomes effective, and shall be recorded in the Mining Book by the Competent Authority.

(2) Upon termination of the mining concession or mining administration for any of the reasons provided for in Art. 21, (a), (b) and (c), the exploitation, with all its annexes, existent at that

date, shall be transferred to the ownership of the State without any compensation and free of any encumbrances or liens whatsoever.

(3) The TitleHolders, legal persons shall be liable for the improvement of all environment factors, affected by the mining activity, according to the environmental rehabilitation plan as approved by the Competent Authority.

(4) Within maximum of three months from the termination of the administration or concession, the Competent Authority shall determine the measures to be taken in connection with the exploration and/or exploitation perimeter and related installations, upon consultation with the Ministry.

(5) The title holder of a license shall be further liable, in accordance with the rules which determine the civil extracontractual responsibility, for the damages caused to the third parties by its fault as a result of mining activities conducted prior to the date of termination or relinquishment, even if such damages are evidenced after the termination of concession or administration.

CHAPTER III

RIGHTS AND OBLIGATIONS OF THE TITLE HOLDER

ARTICLE 28

The titleholder of the license has the following rights:

- a) To have access, in the conditions provided for by the law, to the lands or the areas needed for the conduct of mining activities within the boundaries of the perimeter provided for by the license;
- b) To conduct within the boundaries of the perimeter all the mining activities provided for by the license;
- c) To dispose of the quantities of mineral resources produced;
- d) To use, according to the law, sources of surface and underground waters as necessary to conduct the mining activities;
- e) To associate with other legal persons, with the agreement of the Competent Authority, for the purpose of carrying out the mining activities provided in the license. The national companies, which capitalize the mineral substances under this regime through license, shall also obtain the approval of the Ministry to join with other legal persons;
- f) To obtain from the Competent Authority, in accordance with the law, the data and information required for the conduct of mining activities, to keep and use such data and information, as well as those obtained from its own operations, for the entire duration of the license.
- g) To interrupt the operations more than 30 days, if it can prove to the Competent Authority that will improve the development plan by introducing new technologies and equipment, superior to that agreed initially, obtaining the agreement of the Competent Authority.

h) To build roads, bridges, railways, electricity networks and other infrastructure utilities necessary for the conduct of mining activities, according to the law;

ARTICLE 29

The titleHolder of the license has the following obligations:

a) To comply with the norms, regulations, and instructions issued for the application of this law, and with the provisions of the license;

b) To prepare, in accordance with the provisions of the license, technical and economic documentation for carrying out the mining activities and to submit the documentation to the Competent Authority for agreement, according to the articles 8, 9 and 10. For the National companies and societies the agreement of the Ministry will be also needed.

c) To obtain, prepare, keep up to date and to submit to the Competent Authority, on the scheduled dates, all data, information, and documentation established in the license, concerning the mining activities carried out and the results obtained. In the case of radioactive deposits the data will be also transmitted to the competent authorities in the domain, according to the law;

d) To keep confidential the data obtained from the Competent Authority and the Ministry and the data acquired through its own operations, and not disseminate such data without the agreement of the Competent Authority and the Ministry;

e) To retrieve and protect the natural associations of crystals of esthetic value named "mine's flowers" from the mining works carried out and to inform the Competent Authority.

f) To utilize with priority, competitive local labor of appropriate qualification;

g) To grant the Romanian State the preemption right for the purchase, under the terms provided in the license, of the mineral resources obtained on commercial terms and, at international prices;

h) Within 60 days from the termination of the administration or concession by any of the ways provided under Article 21 to return to the Competent Authority the granted perimeter, in accordance with the provisions of Article 27, para. 5;

i) To fulfill on the scheduled dates the measures indicated in writing by the Competent Authority in the carrying out of its functions, according to the law.

j) To assure the environmental reconstruction and restoration of the perimeters affected by the mining works performed, in accordance with the law.

k) To update the necessary topographical measures and to complete the plans of all the works carried out during the mining activities according with the regulations issued by the Competent Authority.

l) To store toxic, radioactive, or any other polluting and hazardous substances, during the mining works, in accordance with the legal provisions

m) To obtain the agreement of the harbor authorities and the Ministry of Transportation, in case of carrying out mining activities in the internal water way area..

n) To organize by the entrances of the mine which constitute the employees access and also in the underground, emergency medical centers equipped with personnel, medical apparatus, specific instruments and materials, according to the norms issued by the Ministry of Health.

(2) If the titleholder of the license is a National Company or society, it has the following responsibilities to the Ministry:

- a) To develop and submit annually, within the established terms, the financing plan necessary to carry out the works provided by the license.
- b) To submit the required information concerning the production and the achieved investments, as well as the way of using the granted funds from the State budget.
- c) To accomplish in due time, the notified measures, according to the law.
- d) To provide the Competent Authority with the data and documents from the above para. a), b) and c), approved by the Ministry, for updating the Mining Cadastre and Mining Book.

CHAPTER IV

MINING FEES, TAXES AND ROYALTIES

ARTICLE 30

(1) The titleholders of the licenses shall pay to the State budget a fee for the activity of prospecting, exploration and exploitation of mineral resources and a mining royalty.

(2) The annual fee for the prospecting activity shall be established at Lei 5,000/ km².

(3) The annual fee for the exploration activity shall be established at Lei 20,000/ km². It is doubled after two years and becomes five times greater after four years.

(4) The annual fee for the exploitation activity shall be established at Lei 5,000,000/ km².

(5) The value of the fees provided for in para. (2), (3) and (4), at the request of the Competent Authority will be up-dated through a Government Decision according to the inflation rate.

ARTICLE 31

(1) The mining royalty, owed to the State budget, shall be equivalent to a quota of 2% of the value of the mining production obtained by the titleholder annually.

(2) The mining royalty is due beginning with the day of commencement of production and is payable quarterly until the 20th day of the first month of the following quarter.

ARTICLE 32

The titleholder has the obligation to submit to the Competent Authority, all the data about the production obtained in the license area, in order to calculate the mining royalty.

ARTICLE 33

(1) The verification of the accuracy of the data that provides the basis for the calculation of the fee for the activity of exploitation of mineral resources and of the mining royalties shall be carried out by the Competent Authority, and by the state bodies having financial control functions.

(2) Failure to pay in time the fees for the exploitation activity of mineral resources shall entail the application of penalties for delay, in accordance with the fiscal law, and compensatory damages shall be provided in the license in the event of failure to timely pay the mining royalty.

ARTICLE 34

(1) For the documents issued during the fulfillment of its functions: approvals, prospecting, exploration and exploitation permits, documents for the confirmation of the reserves, authorizations, and other papers and for accessing and using documents and information concerning mineral resources and the Mining Book, the Competent Authority shall charge fees, which shall be determined with the approval of the Competition Office.

(2) The income obtained by the Competent Authority pursuant to para. (1) above will be used for the preparation of the data packages, launching of the public offerings, organization of presentation rounds, purchase of material, organization of bidding rounds, endowments and preparation of studies. The income left non-spent at the end of the budget year shall be transferred to the following year as income at the disposal of the Competent Authority.

ARTICLE 35

The payment of fees, taxes and royalties provided for by the present law does not exempt the title holder from the payment of all the legal fiscal obligations, to the extent that such obligations are applicable and subject also to the provisions of Art. 11 para (2).

ARTICLE 36

(1) The titleholders of the licenses shall benefit from the following incentives:

- a) payment of the profit tax at the tax rates provided by the law in effect on the date of conclusion of the license, unless the tax law is changed to the benefit of the title holder;
- b) exemption from payment of duties for imports of the assets required for the conduct of mining activities, made by the title holders or their contractors;
- c) exemption from payment of duties for imported household and personal goods required by the expatriate personnel of the title holder, its affiliated companies and foreign subcontractors; the goods thus exempted shall be designated in the annexes to the license;
- d) exemption from payment of duties for new imported equipment and installations, which are not produced in the country and are needed for the environment rehabilitation.

(2) In addition, the titleholders that are foreign legal persons shall benefit from and be governed by the Romanian Law for foreign investments

(3) The incentives, which are granted to the titleholders of licenses under this law shall remain unchanged for the entire duration of the license.

CHAPTER V

CLOSURE OF MINES

ARTICLE 37

(1) A mine or quarry that is in exploitation can cease completely its activity when:

- a) the exploitable reserves of mineral substances were exhausted;
- b) the exploitation became unprofitable from an economic point of view;
- c) the activity must cease because of force majeure reasons that have as origin natural or field causes such as: flood, tumbling down, glide of the ground, mine fire, gas explosion, etc., in spite of all the technical interventions of the license owner.

(2) When one of the above causes occurs and has been legally ascertained, the Competent Authority should be advised by the titleholder to agree to the closure of the exploitation.

(3) The Competent Authority agrees on the temporary or final closure of the exploitation activity, based on the closure plan. For the areas licensed to national mining companies and societies, the Ministry shall also agree such closures.

ARTICLE 38

(1) The initiative of a mine or quarry closure, belongs to the title holder who will submit to the Competent Authority an application for mine closure, as well as the closure plan, which must include:

- a) the reason of closure, based on the technical economic documentation;
- b) the technical closure or conservation program of the exploitation; in case of national companies and societies, the program will be agreed also by the Ministry and the environment rehabilitation program by the Ministry of Environment;
- c) social protection program, through reemployment and/or professional reconversion; financial compensation and/or regional development measures by creating new work places;
- d) program to rehabilitate the environment and/or to prevent its deterioration following the termination of activity;
- e) the land vacating procedure.

(2) The mining activity ceases upon the analysis and acceptance, by the Competent Authority and the Ministry, of the closure plan and its implementation. The decision to close a mine will be approved by the Government.

(3) The mining perimeters approved to be temporary closed can be granted in concession to another titleholder after the closure date. The Competent Authority can organize a public offering of the perimeter, based on the technical economic documentation.

ARTICLE 39

(1) The responsibility to monitor the obligations resulted from the closure plan of a mine or quarry belongs to the Competent Authority. For the national companies and societies, such monitoring will be done in conjunction with the Ministry.

(2) During the implementation of a mine or quarry closure plan, the titleholder must satisfy the conditions and requirements of all the legal authorities that approved the closure plan.

CHAPTER VI

THE COMPETENT AUTHORITY

ARTICLE 40

The Competent Authority responsible for the application of the provisions of this law is the National Agency for Mineral Resources, acting under the Government of Romania and is authorized:

a) To administrate the mineral resources and the national geological fund, public property of the State, including the granting and issuing of all licenses and permits under this law;

b) To establish the clauses and the terms of the permits and licenses, to regulate the mining activities by means of norms, regulations and technical instructions issued for the application of the law;

c) To receive, verify and register the information and data concerning the mineral resources reserves and to organize the geological and production data base, to set up the national database of mineral resources; the official data regarding the mineral resources reserves shall be those registered with the national database;

d) To establish, together with the Office of Competition, the tariffs, provided by Art. 34 para (1), in accordance with the legal provisions;

e) To supervise and verify the production of mineral resources with a view to determining the royalties;

f) To follow up the application of the measures established with regard to the protection of the soil and subsoil during and after the mining activities, according to the legal provisions;

g) To verify the compliance by the titleholder with the provisions of the license, as well as with the relevant norms, regulations, and instructions, and to dispose measures to ensure the observance of them;

h) To agree on the documentation regarding geological and exploitation works to be carried out, as well as the documentation for mine closure, only with the provision and approval, according to the law, of the environmental protection and ecological reconstruction measures.

i) To institute hydrogeological protection perimeters, for the underground water (mineral and thermomineral), mud and therapeutic peat, and agree on the sanitary protection perimeters.

j) To cease the exploration or exploitation operations carried out outside the granted perimeter, those without approved technical documentation, as well as those, which by the manner of their being conducted may cause irrational exploitation or degradation of the deposits, until the elimination of the causes which generated them;

k) To elaborate the regulations, and technical instructions concerning the application of the present law, with the assistance of the relevant ministries;

l) To prepare and keep the Mining Book up to date; the legal acts and documents that are not entered into the Mining Book cannot be opposed by third parties;

m) To investigate and notify the failure to fulfil the provisions of the present law.

(2) The establishment, organization and the mandate of the National Agency for Mineral Resources shall be determined by Government decision.

CHAPTER VII

RESPONSIBILITY OF THE MINISTRY

ARTICLE 41

To accomplish the provisions of the present law, the Ministry has the following responsibilities:

a) To prepare the strategies and policies for the development of the mineral resources domain, which are submitted to the Government for approval; to monitor their accomplishment according to its competencies; the strategies and policies are applied to the economic agents only in their favor.

b) To evaluate and approve the budget for the achievement of the mineral resources production of the national mining companies and societies in accordance with Article 29, para. (2);

c) In order to apply the strategy and the policies provided in para. a) and the budget provided in para. b) above, the Ministry will prepare programs, including prospecting and exploration programs, which are to be realized under the State budget;

d) Is the main manager of the credits from the budget granted for new technologies and development, prospecting and geological exploration, technical research, environmental protection, restructuring and other activities in the mineral resources domain.

e) To assure the preparation of studies, based on which, together with the Ministry of Finance, selects the mining products, which are temporarily exploited under the State budget, and establish their prices, in accordance with the law.

f) To agree together with the Ministry of Labor and Social Protection, norms concerning the work safety in the mining industry.

g) To prepare, together with the Ministry of Labor and Social Protection, owners organizations and trade unions medical assistance programs, risk and accidents

insurance, to recover and compensate those affected by work accidents and professional diseases, in the mining activity.

h) To agree on the feasibility studies and the development plan of the national companies and societies, as well as the permanent or temporary closure of the mining activities.

i) To establish national policies in the social problem domain, for the areas with mining activity, together with the Ministry of Labor and Social Protection and the local public administration.

j) To elaborate drafts of laws and Governmental decisions for the mining activities.

CHAPTER VIII

SANCTIONS

ARTICLE 42

The non-compliance by the titleholders of the permits and licenses with the obligations provided by the present law shall be considered a contravention, if according to the law is not a crime, and shall be punished with a contravention fine as follows:

a) from no less than Lei 10 mil. to no more than Lei 20 mil. for the violation of the obligations provided in Art. 13 and Art. 29 para. 1, (b) and (i)

b) from no less than Lei 20 mil. to no more than Lei 50 mil. for committing the acts provided in Art. 23, as well as for the violation of the obligations provided for in Art. 29 para. 1, (a), (e), (f), (k) and (l);

c) from no less than Lei 50 mil. to no more than Lei 100 mil. for the violation of the obligations provided in Art. 4 (2) and in Art. 29 para. 1, (d), (g) and (j).

ARTICLE 43

(1) The commitment for the second time of any of the contraventions punished according to Art. 42, for which the law stipulates the revocation of the administration or concession, is sanctioned with the double of maximum fine provided in Art. 42.

(2) The further violation of the clauses for which sanctions are provided under Art. 42 shall entail the application of the provisions of Art. 40 para. 1, (j).

(3) To the extent that the present law does not provide otherwise, the contravention provided in Art. 42 shall be subject to the provisions of Law No. 32 of 1968 regarding the investigation and sanctioning of contravention, with its further amendments, but except Art. 25, 26 and 27.

(4) The value of the fines provided in Art. 42 and 43 para. (1), will be regularly updated following the procedures established in Art. 30 (5) of the present law.

ARTICLE 44

The fines shall be disbursed to the state budget.

ARTICLE 45

The investigation of the failure to comply with the obligations and of the contravention, as well as the application of the fines shall be made on the basis of a written report which shall be prepared by the authorized staff of the Competent Authority and also by the state institutions with responsibilities in the financial control domain.

CHAPTER IX**TRANSITORY AND FINAL PROVISIONS****ARTICLE 46**

(1) The public institutions, the national mining companies and other economic agents shall continue their activities at those locations, under administration, where on the date of publication of the present law they conduct exploration, development and exploitation operations.

(2) Within 90 days from the coming into effect of the present law, the public institutions, the national mining companies and other mining companies shall finalize the determination of the perimeters for exploration, development and exploitation for the locations provided by para.(1) and shall apply to the Competent Authority for their concession or administration, according to the present law.

ARTICLE 47

The disputes caused by the interpretation and application of the licenses shall be resolved by the courts of jurisdiction from Romania and also the international courts, unless the parties agreed for a settlement by arbitration.

ARTICLE 48

Within 90 days from the publication of this law in the Official Monitor of Romania, the Competent Authority shall issue the norms necessary for its application, which shall be approved by a Government Decision.

ARTICLE 49

Within 90 days from the publication of this law in the Official Monitor of Romania, the Ministry together with the Ministry of Labor and Social Protection and the Unions and Patronage involved in mining domains, shall issue the Statute of the Personnel from the Mining Industry, which shall be approved by a Government Decision.

ARTICLE 50

For the purpose of quick mitigation response in case of work accidents and other damages, a mining emergency stations shall be established by the titleholder.

Mining emergency stations shall be organized at each mine or quarry, or in centralized units by mining basin or regions. The decision belongs to the titleholder, which is obliged beforehand to obtain the approval of the Territorial Inspectorate of Labor Protection and Environmental Local Agency.

The organization and functioning of the mining emergency stations will be made, in accordance with Romanian legislation regarding the environment protection and labor protection.

ARTICLE 51

(1) In order to prevent the accidents, in the mining activity, as well as for labor recovery and/or for providing death compensation and aid to legal successors, professional non-profit associations can be organized as legal persons, according to the law.

(2) These associations are organized and carry out their work according to their own statute.

(3) The obligativity of the Title Holder of the license to contribute to the intervention fund of the association will be mentioned in the association statute and the quantum of the contribution will be established through an agreement between the parties.

ARTICLE 52

For the radioactive raw materials, the National Commission for Nuclear Control applies the control of nuclear security, informs the National Agency for Atomic energy and this informs the specialized international bodies, according to the agreements and conventions to which Romania is a party.

ARTICLE 53

The present law shall come into effect after 90 days from its publication in the Official Monitor of Romania.

ARTICLE 54

Upon the coming into effect of the present law, any other provisions which are contrary to this law are abrogated.

The Assembly of Representatives and the Senate adopted this law in the meeting of February 19, 1998, in accordance with the provisions of art.74 para (1) and art.76 para (2) from the Constitution of Romania.

Bucharest, March 5, 1998

No. 61

NORMS FOR APPLYING THE MINING LAW

Governmental Decision no. 639/September 25, 1998

GENERAL PROVISIONS

Art. 1 National Agency for Mineral Resources (NAMR) organizes, administrates and capitalizes the national geological fond (National Geologic Database) and the national reserves fond, parts of general geological knowledge of Romanian territory.

Art. 2 NAMR will issue technical instructions regarding the modalities and the terms for transmitting the data, information and documentation resulted from mining activities and petroleum operations and also regarding the exploitation and capitalization of the national geological fond, under the provision of Mining Law (art. 5, 29 c), 34 and 40, c).

NAMR will also establish, according to the Mining Law and with the approval of the Ministry of Finance, the methodology and instruction regarding the registration, calculation, payment and reporting of the annual taxes related to the prospecting, exploration and exploitation activities and mining royalty.

Art. 3 In order to analyze and utilize the data, information and documentation from the national geological fond, regarding the mineral resources, NAMR charges tariffs established according to the provision of the art. 34 of the Mining Law.

The Romanian or foreign legal person may obtain from NAMR, according to the Law, the data and information necessary to prepare their offers, with the obligation to keep the confidentiality of the data and information and to use them only for the purpose for which they were obtained.

The Title Holders of the concession or administration acts have the obligation to keep the confidentiality of the data and information obtained from NAMR, as well as from their own activity and do not spread them without the NAMR's approval, during the entire period of their license.

Failure of these provisions will be penalized in accordance with the provisions of the art. 42, c), from the Mining Law.

Art. 4 The access of administration or concession titleholders at the mining activities fields is granted according to the provision of the Mining Law, Art. 6

Prospecting, exploration or exploitation perimeters are defined through topogeodezical coordinates and are established through giving under administration or concession contracts (prospecting permit, exploration license, and exploitation permit).

The delimitation and the description of prospecting, exploration and exploitation perimeters are realized through documentation. The content of this documentation will be established in technical instructions issued by NAMR.

Art. 5 If the access to the land situated within the limits of an exploitation perimeter can be realized only by expropriation for public utility, the commencement of this procedure will be done by the titleholder according to the provisions of the Law.

DEVELOPMENT OF MINERAL RESOURCES

Art. 6 The contracts of giving under administration or concession provided by the Mining Law, depending on the operations carried out are as follows:

- a. prospecting permit
- b. license of giving under administration for exploration
- c. concession license for exploration
- d. license for giving under administration for exploitation
- e. concession license for exploitation
- f. exploration permit
- g. NAMR agreement for the joint between the license's titleholder with other legal persons to carry out the mining activities established by the giving under administration or concession license
- h. NAMR approval to transfer a concession license for exploration or exploitation to another legal person

NAMR will establish the clauses and the preparation conditions for mining agreements, in order to be negotiated with the potential concessionaire.

Art. 7 Based on the prospecting permit, studies of the existing data and geological mapping, geochemistry, magnetometry, radiometry, electrometry, gravimetry, seismometry, teledetection, tests in halls and surface excavation, laboratory analyses, technological researches of preparation in laboratory stage, and other kinds of works can be carried out, in order to establish the general conditions favorable for mineral resources accumulation.

Art. 8 Prospecting works are carried out within a perimeter defined through topogeodezical coordinates, based on a nonexclusive prospecting permit, issued by NAMR upon the request of Romanian or foreign interested legal persons, during 30 days from the application registration.

Art. 9 The titleholder of a prospecting permit will submit to the NAMR, annual documentation and the final report stipulated by the Mining Law, within maximum 60 days upon the expiration of the mentioned period.

Art. 10 The titleholder of a prospecting permit may use the data and information obtained through the works done, with the approval of the National Agency for Mineral Resources, under the conditions established into the prospecting permit.

The prospecting permit does not assure any right for granting an exploration or exploitation license.

Art. 11 Based on the exploration license studies and works necessary for the identification of mineral resources deposits, their quantitative and qualitative evaluation, and also to determine the technical and economic conditions for capitalization may be carried out.

The purpose of the exploration works is to determine the decision regarding the opportunity to develop the deposit, to issue the data necessary to design and carry out the works to open, prepare and explore, and also to maintain a certain level of safety for an exploitation with proved reserves.

The exploration works include the mining works (ditch, shallow wells, experimental open pits, mining shafts, galleries, etc.), drilling (from the surface and from the underground), corresponding documentation, studies and technical researches in laboratory, pilot and semi-industrial phase, and also experimental exploitation, in special conditions for extraction.

Art. 12 Public institutions and Romanian or foreign legal persons which are interested to obtain the exploration license, may exercise their right to initiate the process of obtaining such a license, stipulated in Art.9, of the Mining Law, any time during the calendar year.

Art. 13 NAMR publishes the list containing the perimeters under administration or concession for exploration into the Official Monitor, within maximum 30 days upon the request.

Art. 14 The proposals (offers) for administration or concession for exploration are made, according to the Law, within 60 days after the list with the perimeters was published into the Official Monitor.

NAMR will analyze the proposals within maximum 30 days and will open immediately the negotiations with the winners.

In the case of the existence of only one applicant, this will be considered winner of the bidding process.

In maximum 30 days from the beginning of the negotiations, the license for exploration will be concluded.

Art. 15 The exploration license establishes the exploration perimeter, the work program, including also all the environmental measures that will be applied, the phases and rhythm of work, the documentation needed and the rights and obligations of the titleholder, according to the Law.

The adjustment or modification of the work program during the execution of the mining activities can be done at any time, with the consent of NAMR.

Art. 16 In the case of the exploration license, the Bank guarantee for environment rehabilitation is set no less than 0.5% of the value of the work program, through negotiation and is deposited on an annual basis, in the first month of the reference year.

The Bank Guarantee will be deposit in a bank agreed by NAMR.

Art. 17 The titleholder of an exploration license will submit to NAMR annual reports and a final report within 90 days from the end of the period they refer to.

Failure to do this will result in penalties according to the provisions of the art. 42, a), from the Mining Law.

The reports will include the research method used, the work done and the results obtained and also the evaluation of the resources of useful mineral substances, as the case may be.

Art. 18 Based on the exploitation license, can be carried out the work needed to materialize the mines and open pits, to build and assemble installations, equipment and other specific utilities needed to extract, process, transport, temporarily store the mining products obtained in specific forms and also the barren and residual products, works carried out at the surface and/or in the underground to extract mineral reserve process and deliver them in specific forms.

Art. 19 Public institutions and the Romanian or foreign legal entities that show the interest for an exploitation license can exercise the right of initiative, stipulated in Art. 10 of the Mining Law, all along the calendar year.

The initiative to offer exploitation perimeters through public offering may also belong to NAMR.

Art. 20 NAMR prepares the list of perimeters, which are given under administration or are concessioned for exploitation and publishes it in the Official Monitor within 30 days from the date of the application or every six-month if it is its initiative.

Art. 21 The proposals for giving under administration or concession are submitted, according to the Law, within 90 days from the date of publishing the list in the Official Monitor.

In a maximum of 30 days, NAMR will analyze the proposals and start the negotiations with the winner of the public offering.

The negotiations for the administration or concession contracts for exploitation must take less than 30 days.

Art. 22 The application for giving under administration or concession for exploitation can be submitted any time during the year, but observing Art. 10(2), lit (a) of Mining Law and other legal requirements (Art. 10(3)).

NAMR will analyze the offer, will start the negotiations and will issue the exploitation license within 90 days from the date of the application.

Art. 23 The exploitation license stipulates the period for which the license is valid, the exploitation perimeter, the amount of reserves proposed to be exploited, the obligations of the titleholder resulting from the development plan and the environmental rehabilitation program, the phases and the rhythm of work and other rights and obligations of the titleholder, according to the Law.

The Title Holder of an exploitation license can not be held responsible of the environmental damages that occurred prior to the effective date of the exploitation license, the former owner being responsible for the remediation.

Art. 24 The exploitation license is granted to Romanian and foreign legal persons, according to the Law, based on an application accompanied by the feasibility study (which must ensure an optimal capitalization of the reserves of useful mineral substances and the protection of the deposits), the development plan of the exploitation, the environmental impact study (environmental audit), approved according to the Law, and the plan of environment rehabilitation together with a bank guarantee.

Art. 25 The administration or concession contract for exploitation shall be concluded in writing and it will come into force after the Government's approval.

Art. 26 The documentation with the calculation of the reserves of useful mineral substances to be exploited, checked and registered by NAMR, in accordance with the provisions of the art. 40, c) from the Mining Law and the documentation for instituting the exploitation perimeter are appendices to the feasibility study.

The expert validation of the above mentioned documentation will be made only at the request of NAMR, according to the technical instructions issued by it.

Art. 27 At the beginning and during the activity, the development plan will be detailed in exploitation technique-economic studies that must be agreed by NAMR.

Art. 28 The bank guarantee for environment rehabilitation is established, in the exploitation license, no less than 1% of the value of the development plan and related provisions of the environmental impact study (environmental audit and rehabilitation plan), through negotiation and is deposited on an annual basis, in the first month of the reference year.

The Bank Guarantee will be deposit in a bank agreed by NAMR.

NAMR will issue technical instruction regarding the application and implementation of the measures established in the environmental impact study (environmental audit) and of the environmental rehabilitation program.

Art. 29 In order to get the authorization to start the mining, the titleholders shall submit to NAMR the legal documents provided by art. 6, para. 1 from the Mining Law, which allows the legal occupancy only of the lands, which will be affected, enclosed in the instituted perimeters.

During the execution of the mining activities, whenever the annual exploitation programs are approved, the titleholders will present documents concerning the legal occupancy of the lands affected in that year.

Art. 30 The exploitation permits regime mentioned in Art. 18 of the Mining Law shall be regulated through technical instructions issued by NAMR.

Art. 31 The approval to transfer an exploration or exploitation license to another titleholder, as stipulated in art. 14 of the Mining Law, will be given to the new titleholder, in order to achieve the mining activities mentioned in the license, by NAMR.

NAMR can give the approval in a maximum of 30 days from the date of the application.

Art. 32 The exploitation license titleholders will prepare exploitation annual preliminaries, as well as the research detailed programs necessary to conduct exploitation, in accordance with the instructions for environmental protection and for rational exploitation of deposits and they will be submitted to the territorial inspectorates of NAMR for approval no later than December of the previous year.

Art. 33 NAMR will issue technical instructions regarding the content of the technical documentation stipulated by the Mining Law, art. 8, art. 9 (working program) and art. 10 (feasibility study, exploitation development plan, environmental impact study, environment rehabilitation plan) and art. 29, b (annual exploitation program).

Art. 34 The suspension or the withdrawal of the rights assured through the license, according to the Art.23 and 24 of the Mining Law, will become effective only follow-up the successive application of the contravention fines provided by the Art. 42 and 43 of the Mining Law, the notification submitted by National Agency for Mineral Resources, concerning the non-observance of the provision of the Art.23 and/or 24 and the final court decision, according to art. 25 of the Mining Law.

Art. 35 The annexes and the technological facilities of the exploitation which will become state property, according to Art. 27, para. 2 from the Mining Law, are those for which the closure might prejudice the further capitalization of the deposit, as follows: industrial buildings, administrative buildings, special surface constructions, special underground constructions, technological installations belonging to the extraction, aeration, water disposal category, with the measurement, control and regulation equipment.

Art. 36 Technological facilities and annexes of the exploitations, transferred into the property of state following the decision to cease the concession or the administration, according to art. 27 from the Mining Law, will be used in the following conditions:

- free of charge, as facilities needed in the exploitation process, by the new titleholders of the exploitation license obtained according to the law. In this case, these facilities and technological annexes will be included into a contract annex.
- preserved by the economic agent, with the approval of the Specialized Ministry, at the location of the mines and open pits for which the temporary cessation of the exploitation activity and their preservation were decided by Government Decision
- capitalized through legal procedures for the benefit of the State budget after the Government Decision to close the mine/quarry permanently.

The titleholder of the cancelled exploitation license will remain responsible for the integrity of the annexes and technological facilities of the exploitation which become State property, for a maximum of 3 month from the cessation of the administration or concession, as stipulated by art. 27, para.4 from the Mining Law.

FEES, TARIFFS AND MINING ROYALTIES

Art. 37 The titleholders of the administration or concession contracts (prospecting permit, administration license for exploration and exploitation, concession license for exploration and exploitation, exploitation permit) shall pay to the State budget the fees provided by art. 30 from the Mining Law, starting with the effective date of it, as follows:

- a) For the first year of activity, starting with the date of receiving the administration or concession license, proportional with the remain months by the end of the year. For the titleholders of the administration or concession license provided by art. 46 of the Mining Law, the first year will be considered, by taxation point of view, the year 1998.
- b) For the following years of activity, until December 20 of the current year, for the following one.

Art. 38 The fees provided by art. 30 of the Mining Law are to be applied to the prospecting, exploration or exploitation perimeters surface, registered in the administration or concession license, taking in consideration also the reduction of exploration perimeters provided by art. 9, para. 4 of the Mining Law.

The public institutions, national companies/societies and commercial societies, which benefit by the provisions of the Art.46 of the Mining Law, starting with the day of coming in force of the Mining Law, will pay the taxes provided by the Art. 30, within 60 days from the date when the administration or concession act will become effective.

Art. 39 The titleholders of the administration and concession contracts (giving under administration license for exploitation, concession license for exploitation, exploitation permit, exploration license through which are realized mining products by experimental

exploitation) shall pay to the State budget the mining royalty as stipulated by art. 31 from the Mining Law, starting with the effective date of it.

The public institutions, national companies/societies and commercial societies, which benefit by the provisions of the Art.46 of the Mining Law, starting with the day of coming in force of the Mining Law, will pay the mining royalty provided by the Art. 31, within 60 days from the date when the administration or concession act will become effective.

Art. 40 The calculation of the mining royalty is based on the value of the realized mining production established according with the prices used during the calculation period.

Art. 41 The mining products realized by the titleholder, depending on the exploited mineral resources, are listed in the administration or concession contracts and updated through additional documents approved by the titleholder and NAMR, if the case may be.

Art. 42 The titleholders of the administration or concession contracts for exploitation, which have to pay the mining royalty, are obliged to calculate and register monthly the mining products and the royalty value and pay it quarterly, by the 20th day of the first month of the following quarter.

Art. 43 The titleholders of administration or concession contracts for exploration, which are realizing mining production through experimental exploitation, are subject of mining royalty payment, according to the law and present norms.

The payers are obliged to submit to the appropriate fiscal office, the quarterly statement of expenses, by the 20th day of the first month of the following quarter, date until which the mining royalty shall be paid.

Art. 44 Within 15 days from the effective date of the Mining Law or of the administration or concession contracts for exploitation, the titleholders have the obligation to calculate and register the declaration of the mining royalty payer, with the appropriate fiscal office.

Art. 45 NAMR and the appropriate fiscal State agencies will verify the data, on which the calculation of the fees and the mining royalty was based, and will prepare specific instructions.

The state agencies, with responsibilities in the financial control domain, verify the correctness of the above calculation and make sure that the settling day stipulated by the Mining Law and the present norms is observed.

Art. 46 Fees application on the prospecting, exploration and exploitation activity of the mineral resources, as well as the mining royalty will be made in accordance with the art. 30, 31 32 and 33 of the Mining Law and current norms, and the resulted funds will become income for the State budget.

Apart of the provisions of the Mining Law, no other public institution or economic agent shall apply fees on the prospecting, exploration and exploitation activities for mineral resources or mining royalty.

Failure to pay in time the fees and the mining royalty, shall entail the application of penalties provided by art. 33, para. 2 of the Mining Law.

Art. 47 The value of the fees provided by art. 30, para. 2, 3 and 4, of the law will be up-graded at NAMR proposal through Governmental Decision, according to the inflation rate, in accordance with the art. 30, para. 5 of the law.

Art. 48 The titleholders shall benefit of all fiscal facilities provided by art. 36 of the Mining Law. Equipment, installations and apparatus provided by art. 36, para. 1, d) will be nominated within an annex to the license, agreed by the Ministry of Industry and Commerce.

THE CLOSURE OF MINES

Art. 49 The final closure of a deposit, provided by the art. 37 of the Mining Law, will be made based on the specific instructions issued jointly by NAMR and the Ministry of Industry and Commerce.

Art. 50 Temporarily closure, according to the art.37, para. 3 of the Mining Law, will be approved by NAMR, based on the technical instructions regarding the content of the documentation necessary for closure.

These instructions will include compulsory the conservation and maintenance phase in case of temporarily closure.

MINERAL RESOURCES AND RESERVES

Art. 51 NAMR will issue technical instructions regarding the classification of the reserves in categories based on the certitude grade and economic criteria, and also the technical conditions of classification in categories and groups, respectively the frame content of the mineral resources evaluation.

The resources and reserve registration will be made by NAMR based on the evaluation documentation verified, according to the art.40, c) of the Mining Law.

The mining activities of development and exploitation stipulated by the license can be carried out only on registered reserves and mineral resources capitalized conjectural.

Art. 52 NAMR will establish the National Geological Database and National Reserves Database, based on the registered reserves and annual movement of the geological resources and reserves, determined by the mining activities carried out and submitted by the titleholders of an administration or concession contract.

NAMR will issue technical instruction concerning the way of organizing and monitoring the National Reserves Database and the way of reporting the data linked to it.

Art. 53 The titleholders of the license have the obligation to obtain, prepare, and keep up to date and to submit to the Competent Authority, all data, information, and documentation, concerning the mining activities carried out and the results obtained, necessary to up-date the Mining Book. They have also the obligation to up-date the necessary topographical measures and to complete the plans of all the works carried out during the mining activities.

Art. 54 NAMR will issue technical instruction regarding the detailed content of the Mining Book and the specific obligations of the license holders, the detailed content of the mining cadastre and the obligations related to it of the titleholders.

Art. 55 NAMR, in order to cease the exploitation, will ascertain the exhaustion of the reserves, according to the law, based on the Mining Book registrations, at the titleholder of an exploitation license initiative.

Art. 56 NAMR will issue technical instructions regarding the content of the documents necessary for exploitation cessation, in view of final open pit or mine closure.

TRANSITORY AND FINAL PROVISIONS

Art. 57 The public institutions, the national mining companies and other economic agents which will not request to NAMR, within 90 days, an administration or concession license for those locations where they conduct exploration, development and production operations, according to art. 46 of the Mining Law, will loose their legal rights, the above mentioned locations becoming free for concession to another Romanian or foreign legal persons, according to the law.

The documentation preparation and the award of the direct concession license for exploitation perimeters, as stipulated by art. 46, para. 1 of the Mining Law will be achieved within 12 months from the effective date of the law.

The application of given under administration or concession, as provided by art. 46, para. 1 and 2, will be accompanied by the scheme of the new requested perimeter, defined according to art. 3, para. 19 of the Mining Law.

NAMR, during the perimeter application analysis, will confirm the legality of the exploitation perimeter establishment and also the steps of submitting the concession documentation.

Art. 58 Ministry of Industry and Commerce will continue to manage the execution of National Geological Program, financed from budgetary resources. The establishment of geological research perimeters as well as their regime will be in accordance with the provisions of the Mining Law.

By the effective day of the exploration and/or exploitation licenses, the provisions of the norms regarding the approval-agreement of the exploitation and/or exploration annual programs are in force within the limits of established perimeters.

Art. 59 The approval of income and expenses budgets of the national companies/societies, as well as the selection of the mining products of which exploitation is realized with funds from state budget, shall be made at the proposal of the Ministry of Industry and Commerce and with the agreement of NAMR and the Ministry of Finance, through a Governmental Decision.

Art. 60 The State preemption right of mining product acquisition, according to the art.29, para.1, g) of the Mining Law, can be invoked only based on special laws, with the observance of the commercial legislation, the prices being regulated through exploitation license.

Art. 61 The international classification of the mineral resources and reserves and the establishment of the National Reserves Database according to the above mentioned classification, shall be applied as experimental by December 31, 2000.

By that date, parallel the evidence and the movement of the reserves according to the existing classification, will be kept.

Art. 62 Prior to the effectiveness of the Mining Law, the following matters will be considered, during the closure program of an open-pit or a mine:

NAMR will organize a public offering for the concession of exploitation perimeters, within 30 days after the titleholder application for activity cessation.

If, within 30 days from the public offering, no legal person shows its interest in the concession, NAMR will issue and submit for Governmental approval the decision for open-pit or mine closure.

The provisions of this article shall be applied only to the mines or open-pits which are going to be closed entirely and not parts of them.

Art. 63 The public institutions, which can be awarded with an exploitation administration license may be also local administrations bodies, according to the Mining Law.

Art. 64 The income in local and foreign currency obtained pursuant to the charged tariffs stipulated by art. 34 from the Mining Law, shall be administrate by the NAMR as extra-budgetary regime.

The budget of the extra-budgetary incomes and expenses shall prepared by the NAMR, in accordance with the legal provision.

The extra-budgetary income, which was not spent until the end of the budget year, shall be transferred to the following year, according to the provisions of the art. 34, para.2 from the Mining Law.

The technology transfer from foreign partners shall be regulated through the exploitation license.

Art. 65 The technical instructions provided by Art. 2, 4, 26, 28, 49, 51, 52, 54 and 56 of the present Norms, will be developed with the assistance of interested ministries, issued through the Order of the President of National Agency for Mineral Resources and published in the Official Monitor.

GEOLOGICAL AND MINERALOGICAL MUSEUMS AND COLLECTIONS

The mineralogical museums and collections in the country represent further sources of information in hosting both numerous and unique samples from famous ore deposits in Romania as well as many other data regarding historical mining, evolution of knowledge of minerals and mineral deposits etc. The largest exhibition of minerals, ores, and rocks is hosted by the Geological Museum in Bucharest, thought to represent a "book on geology". The museums or collections in Bucharest (of the Geological Institute of Romania), Baia Mare, Brad and Ocna de Fier (the largest private collection in Romania) are open for visitors, whereas those of the universities (Bucharest, Iasi, Cluj-Napoca) can be visited by appointment.

Geological Institute of Romania (IGR), Bucharest Geological Museum

Collection and exhibition: The total number of samples is of about 70,000, from which one third represents minerals, collected by the staff geologists of the institute, brought from travelling in other countries, obtained through exchanges and by purchase. Mineralogically interesting are especially three rooms, i.e. the biggest one, hosted by the former "Collection room", in which only "mine flowers" from Romanian occurrences are exposed (about 200 specimens), with wonderful mineral samples, such as stibnite, quartz, barite, pyrrhotite, garnets, wolframite, agates etc.

The "Mineralogy section" includes a systematic presentation of minerals from different countries (about 600 specimens), next to supplementary samples illustrating the properties of minerals, their use, synthetic equivalents of minerals etc. The minerals first described in Romanian occurrences are separately exhibited. Mineral samples also exist in the section "Mineral deposits", especially ore minerals and associated host rocks. The museum was fully prepared for visitors in 1990.

Bucharest University, Department of Mineralogy

Collection: The greatest part of the samples (about 3,000) belong to the so-called Ludovic Mrazec collection, including samples of mineral and rocks gathered by him or by donation of late Prof. *Gregoriu Stefanescu*, by *Anton Raky* (the "Klippstein" and "Ochsenius" collections), by purchasing from the Krantz Mineral Company in Germany or by addition of the collection of the late Prof. *Nicolae Petruian* from the Polytechnic Institute (some 1,400 specimens). The total number of the specimens within the systematic collections is of about 5,500. They are on exhibit in the "Collection Room", in the showcases in the Department halls and in the teaching laboratories.

Some special collections are worth mentioning. First of all the nagyagitte collection including 10 specimens from Săcărâmb, collected and studied by late Prof. *Dan Giusca*. These specimens are mentioned in the new edition of Dana's System of Mineralogy. Partly

exhibited is the "Native gold and nagyagite" collection, comprising some 60 samples from the Metaliferi Mts., Baia Mare area and from the alluvia of the Olt Valley to which the "Native gold tellurides" (61 samples) of late Prof. *Nicolae Petrulian* adds. The *Bela Fulopp* collection includes some 50 samples from the Banat iron ore deposits and Rodna base metal deposit.

There are also several regional collections with minerals from the Baia Mare area (120 specimens), minerals and rocks from the Metaliferi Mts., mainly from Brad (some 70 specimens), metamorphic and magmatic rocks from Romania (some 400 specimens).

Mineralogy Museum, Baia Mare

The *Collection* consists of 16,000 mineral, rock and ore specimens, all from Baia Mare region. The mineral collection is divided, as follows: native elements 0.3%; sulphides, arsenides, sulphosalts 28%; halides 0.4%; oxides and hydroxides 0.9%; carbonates 26%; sulphates and tungstates 18%; phosphates 0.4%; quartz 26%, reflecting in general the composition of the ore veins.

Exhibition contains about 1,500 specimens which are exhibited permanently on a 900 m² area.

Ground floor:

A) Basic introduction to petrography and geological structure of the north-western part of Romania, illustrated by geomorphological relief mode (scale 1:50,000) and by magmatic, sedimentary and metamorphic rock samples.

B) Basic introduction to mineralogy, main properties of the minerals and systematic classification of the hydrothermal minerals of the Baia Mare region. The last showcase presents the minerals first found in the Baia Mare region (semseyite, andorite, fizelyite, fuloppite etc.).

C) Presentation of the ore deposits from Baia Mare region (Baiut, Căvnic, Herja, Baia Sprie, Suior, Ilba, Nistru, Turt, Sasar, Răzoare and Borsa. Each showcase presents ore samples from the mines.

First floor:

Presentation of the largest and most aesthetic specimens, known in the area as "Mine flowers" ("flori de mină"). Some of the most spectacular or valuable specimens are galena, sphalerite, stibnite from Baiut and Baia Sprie, tetrahedrite, marcasite, calcite (pink or black), rhodochrosite, barite (bluish, red or yellow) scheelite from Căvnic, vivianite from Ilba, fizelyite, semseyite, quartz, gypsum from Herja etc.

Gold Museum, Brad

Collection and exhibition: The samples were collected by geologists working in different mines in the Metaliferi Mts., mostly around Brad (about 80%), from which the great majority represents native gold and other gold minerals. The total number of samples is of about 2,000. Besides the systematic presentation of gold samples from different ore deposits in the Brad area, the museum also contains a room exhibiting old mining tools, a model of typical "gold stamp" (in Romanian "steamp") earlier used in this historical gold mining area, as well as a small room containing systematically exhibited minerals, with samples from

other deposits in Romania and abroad. In the "Gold rooms" there are some gold samples that are unique, i.e. gold crystals up to 1 cm in size, fine-grained gold aggregates building up "snakes", a "little dog" etc.

Worth mentioning are also the samples showing the associations of native gold with calcite, barite, quartz, native arsenic etc. There are also numerous samples with gold, silver and lead tellurides from the famous deposits belonging to the "Golden Quadrangle", i.e. Săcărâmb, Stănija, Zlatna, Rosia Montana, Botes, Caraci etc.

Although the native gold and gold-bearing minerals occupy most of the museum space, there are also two rooms for other minerals. There is a small room with the systematic presentation of mineral classes including mineral properties with samples from different mining areas in Romania and few ones from abroad. Agates from Techereu, Valea Muresului, pyrite and sphalerite from Rodna, skarn minerals from Banat etc. are also on exhibit. A special showcase contains mineral species and mineral varieties first described in the area and in Romania as well, such as nagyagite, sylvanite etc.

"Babes-Bolyai" University, Cluj-Napoca Mineralogical Museum

Collection: The museum consists now of about 16,000 mineral samples: the most substantial collections are the systematic one (with about 10,000 samples) and the regional one (about 1,500 samples). Crystals, gems, and radioactive minerals, as well as meteorites form distinctive collections, partly exhibited.

Systematic and regional collections of rocks from Romania and from abroad are also partly exhibited on the main hall of the Department (38 m²) and in "V. Stanciu" Hall. A large collection (1,000 pcs) of rocks from the Carpathian region, Germany, Switzerland, Norway, Sweden and Ditrau (Romania) collected by Gy. Szadeczky-Kardoss is displayed in the old furniture in the basement.

Exhibition: The exhibition parts of the mineralogical collection are hosted by two rooms (126 m²). The *systematic collection* of minerals (4,000 pcs) is based on the classification by H. Strunz (1982) and illustrates, at this moment, about 750 mineral species displayed in 36 showcases.

The *regional collection* (1,500 pcs) groups the mineral assemblages representing the main ores and occurrences from the Transylvanian Basin, the volcanic frame of the East Carpathians, the Apuseni Mts. and the Banat area.

The *gold collection*, included in the systematic collection, is Romania's second one in size (450 samples), crystallographic variety (octahedral crystals, filiform, dendritic, platy, scaly habits) and importance, after the Gold Museum, Brad.

The *collection of meteorites* is, with its 205 samples (of which 68 are domestic and 137 from abroad) of all compositional types of meteorites and also tectites, the most important collection of this type in Romania. The largest piece of the Mocș/Mociu chondritic meteorite weighs 35.7 kg and is displayed in our museum.

The *collection of minerals* is described for the first time from Romanian occurrences (23 mineral species).

The *gemstone collection* contains almost 250 manufactured brilliants and cabochons of precious and semiprecious stones, in the original 19-th century cabinet.

The Mineralogical Museum is not open for the public, but may be visited by groups from schools and individuals by appointment.

"Alexandru Ioan Cuza" University, Iasi
Department of Mineralogy and Geochemistry
Mineral and Rock Collection

Collection: At present, there are about 16,000 mineral and rock samples in the collection, mainly from the Carpathian region, including specimens from the famous mineral occurrences in Romania, where about 30 minerals have their type locality. Butureanu's handwritten catalogue is also available.

Exhibition: The collection is arranged in three large rooms following the modern classifications of rocks and minerals, but only 4,819 mineral and rock specimens are exhibited: 1,409 minerals, 1,301 magmatic rocks, 975 metamorphic rocks, 79 sedimentary rocks, 1,007 ore and gangue minerals and 48 ore texture specimens.

The *first room* contains 20 glass-cases representing personal collections from which 14 are the result of PhD studies of the staff. A spectacular collection here is that donated by Prof. Ion Harjoaba, representing mineral and rock specimens from Shaba, Zaire.

The *second room* contains a systematic mineralogical exhibition and an ore and gangue mineral structures exhibition displayed in 26 glass-cases.

The *third room* has 17 glass-cases with a systematic rock collection.

Several selected specimens are also shown in 16 glass-cases on the *second entrance corridor* of the department.

County Museum, Resita
Mineralogical Collection "Constantin Gruescu"
Ocna de Fier

The collection started in 1945 with some samples which Constantin Gruescu, a former mining foreman, inherited from his grandfather and great-grandfather.

During his activity in the Banat mines, Mr. Gruescu continued to collect and purchase minerals. The collection includes about 2,300 samples of which 800 are permanently displayed in his house, which was enlarged for the purpose of becoming open for visitors, especially after his retirement. This is the largest collection with specimens from the Banat skarn deposits, mainly from Ocna de Fier-Dognecea area, but also from other occurrences in Romania. Exchange samples from other countries are present, too.

Worth mentioning are the pseudomorphs, magnetite after garnet, dolomite after magnetite, large diopside and garnet (mostly andradite) crystals, huge crystals of phlogopite, rarities such as palygorskite and ludwigite, as well as the peculiar coaxial twins of columnar quartz.



Geological Muzeum - Geological Institute of Romania



Historic geology room (location of mineral resources accumulation)

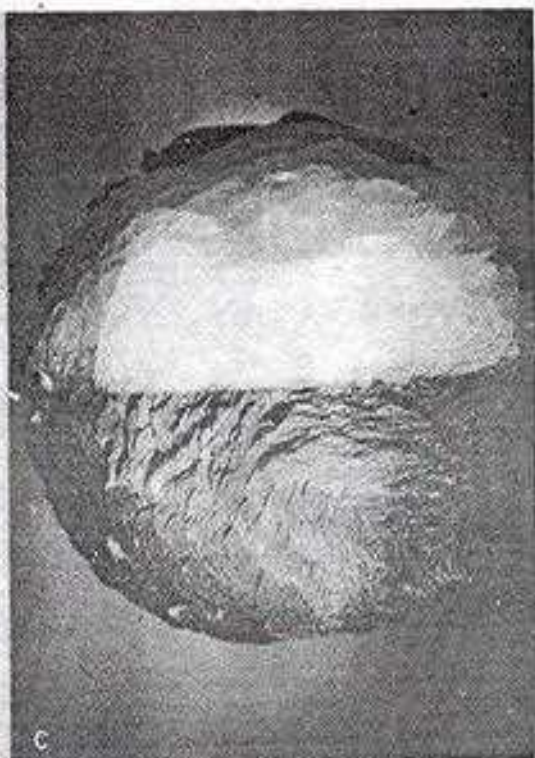
Muzeul de Mineralogie Baia-Mare



A



B



C



D

E

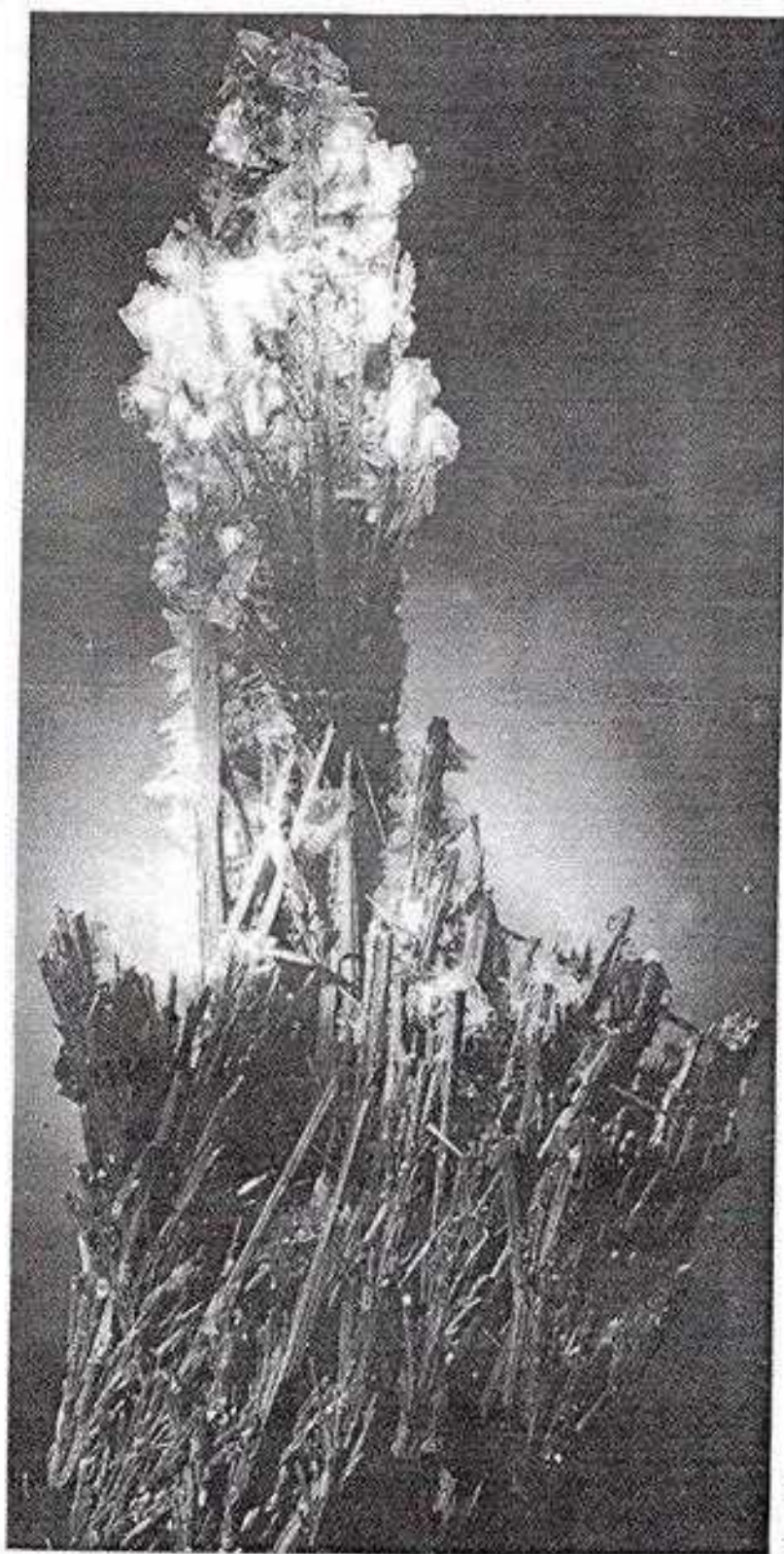


F

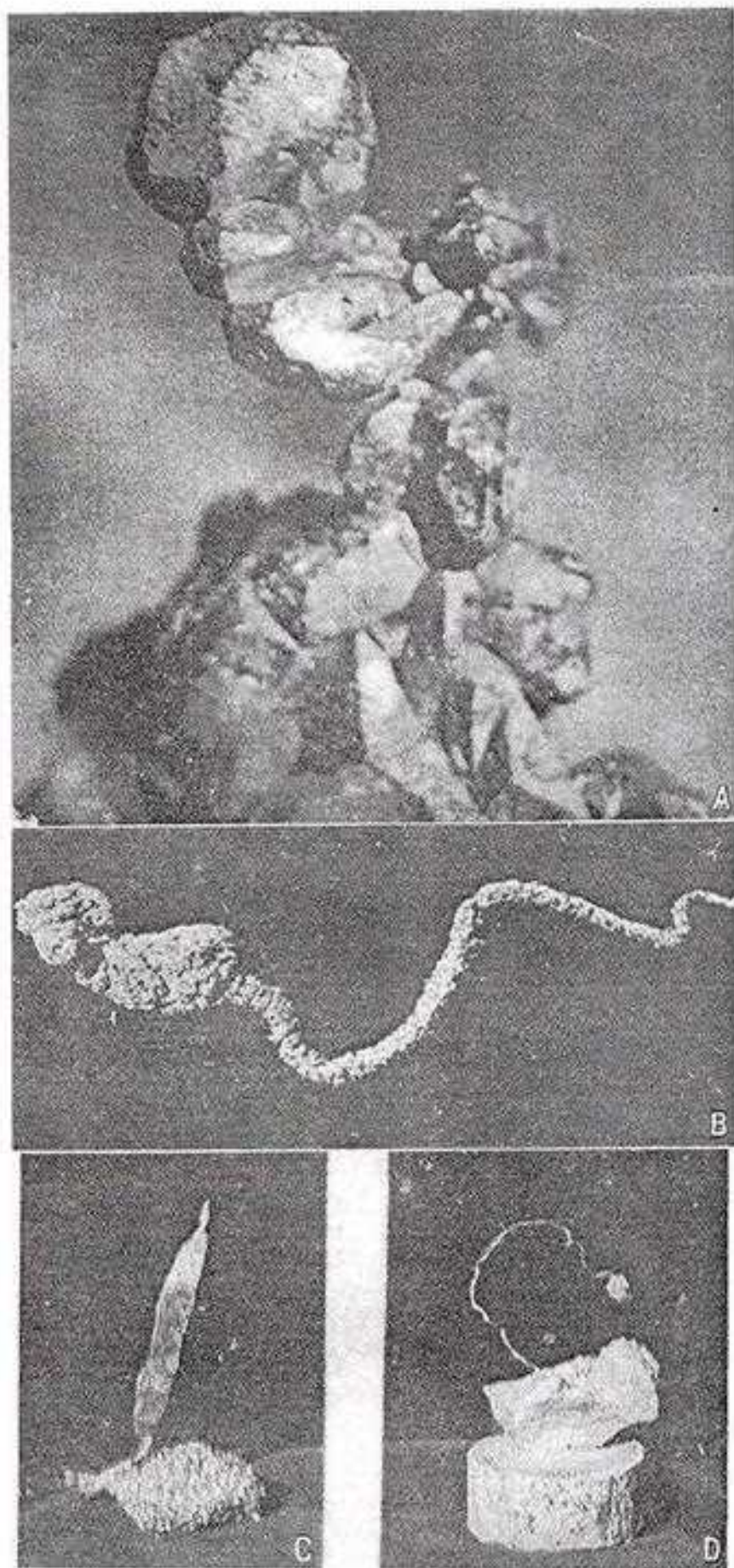


G

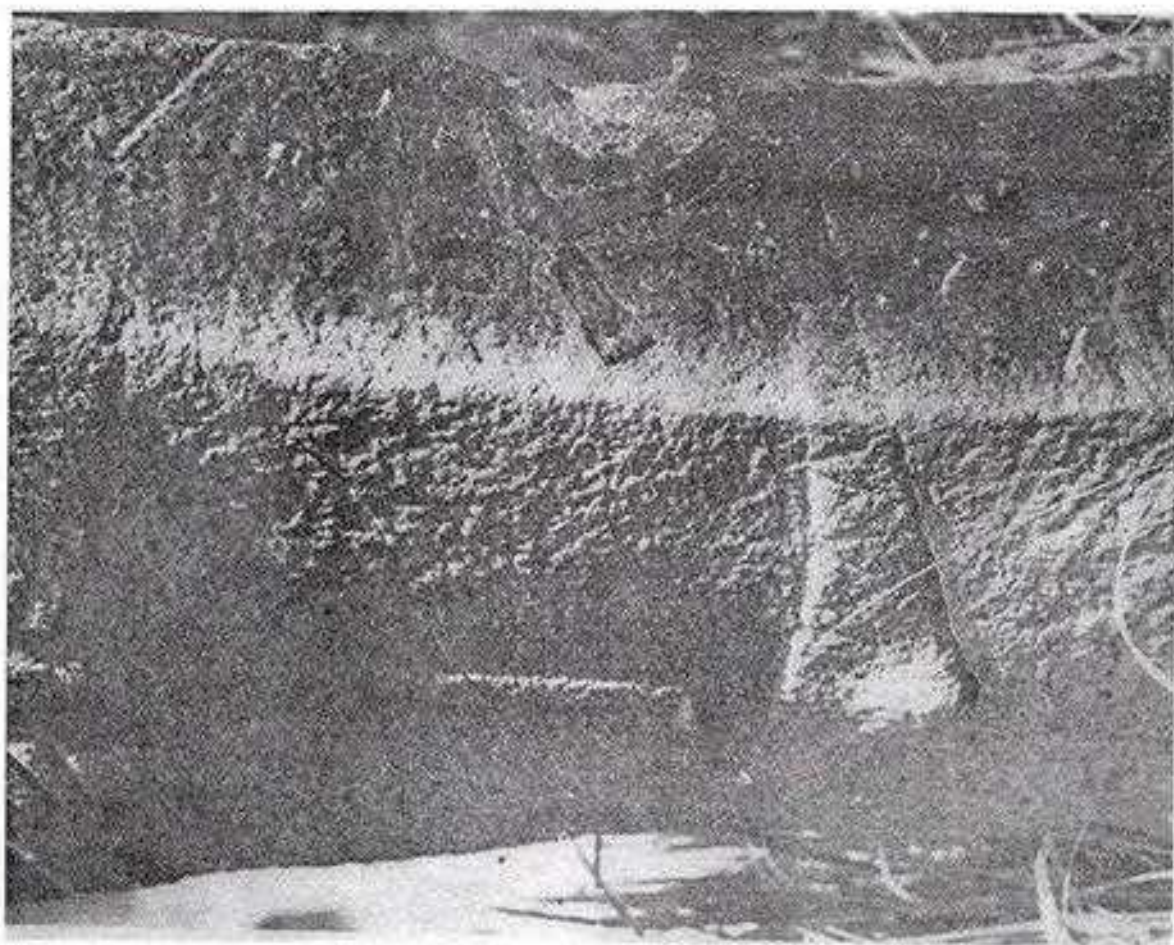
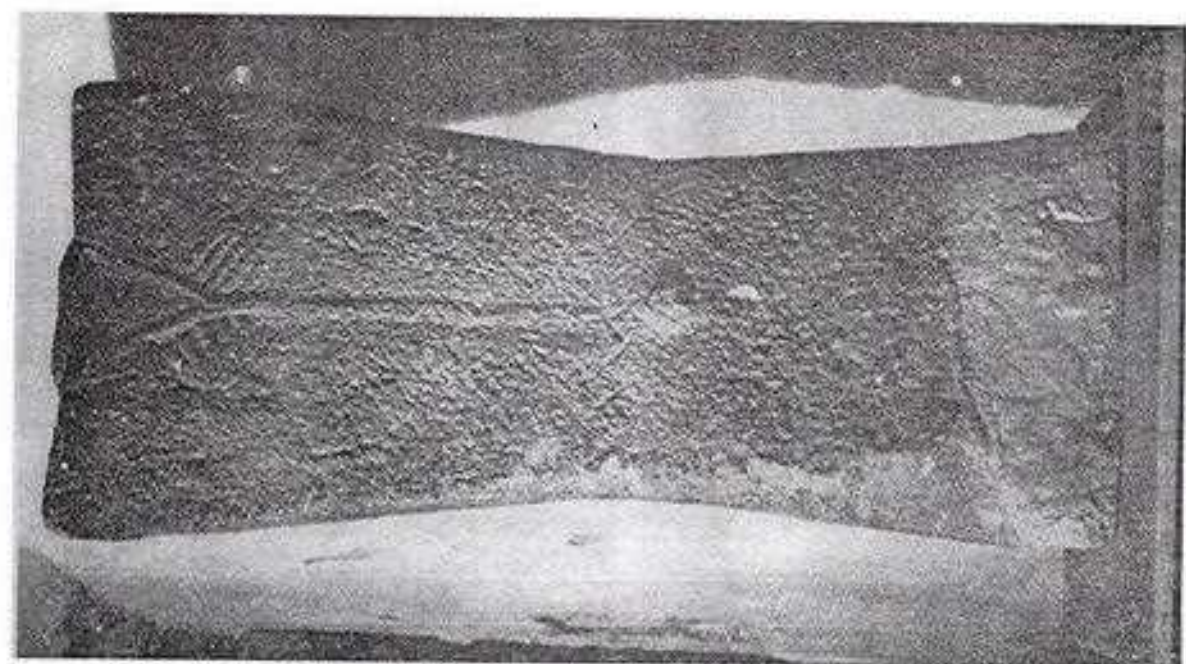
A. Mineralogical Museum, Baia Mare; B. Quartz from Cavnic; C. Calcite from Herja; D. Calcite, barite from Cavnic; E. Tetrahedrite from Cavnic; F. Barite from Cavnic; G. Pyrite from Tibleș.



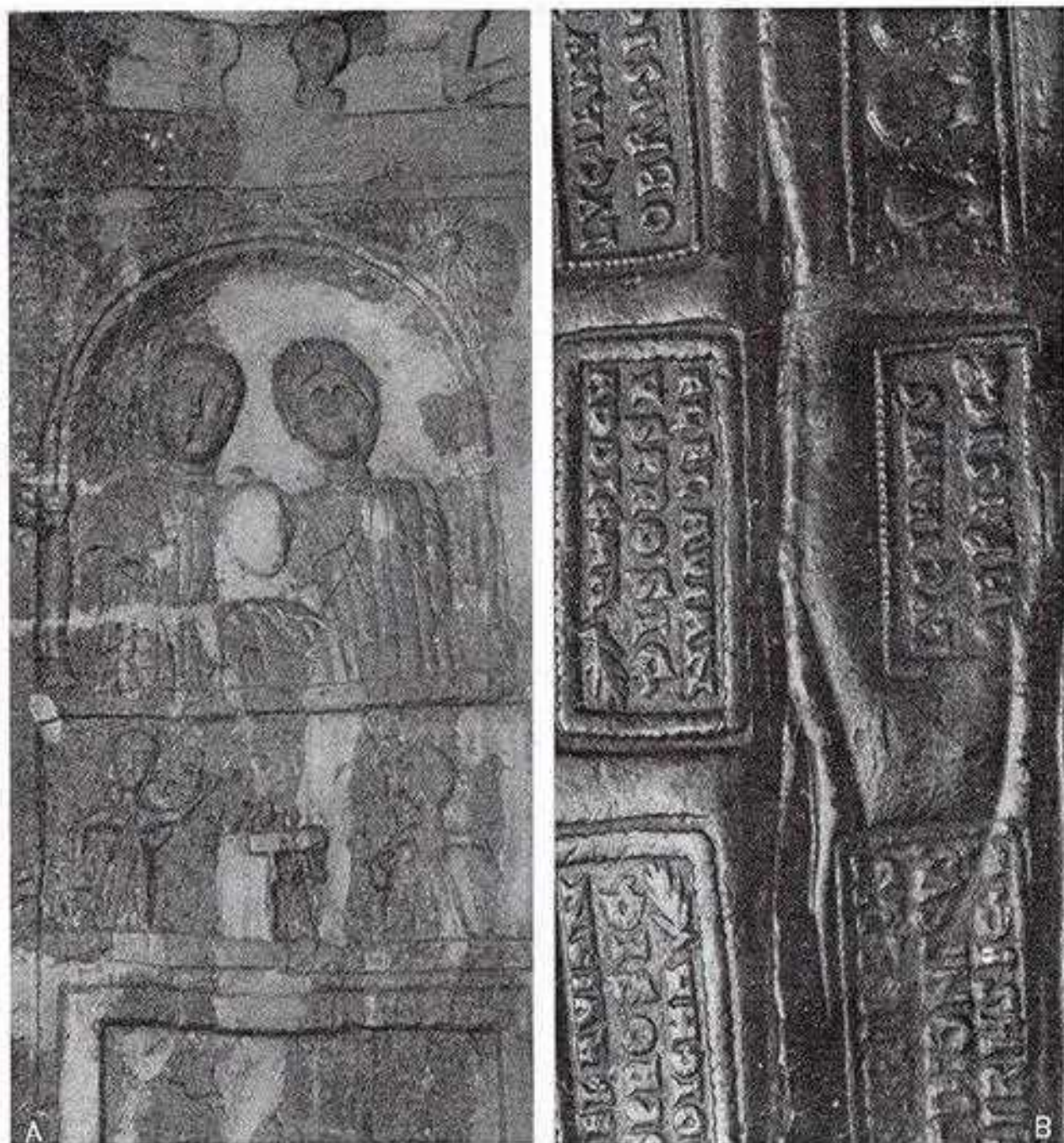
Stibnite, barite from Herja
- Mineralogical Museum Baia Mare



A. Gold crystals;
B. The gold lizard;
C, D. Lamellar and wire line gold
- Gold Museum Brad



Antropomorphous statues indicating the beginnings of the mining activity in the Brad zone
(Metaliferi Mts) - Gold Museum Brad



A. Roman calcareous sandstone monument over a tomb (roman period)
 B. Romans fold ingots produced in the Metaliferi Mts
 Gold Museum Brad

The Publications

The library of the Geological Institute of Romania is the largest in the country and represents the National Library of geological publications. It contains about 300,000 volumes as a result of exchange agreements with about 250 institutions worldwide as well as by purchasing of the most representative books and journals.

The basis of the exchange agreements is assured by the GIR Publishing House which produces both periodicals and occasional journals and/or books. The periodical issues include 6 series (one volume per year):

- Romanian Journal of Mineralogy
- Romanian Journal of Mineral Deposits (starting with 1999: Romanian Journal of Mineral Deposits & Environmental Geology)
- Romanian Journal of Petrology
- Romanian Journal of Paleontology
- Romanian Journal of Stratigraphy
- Romanian Journal of Tectonics & Geophysics

superseding the old journal series "Dări de Seama ale Sedințelor/Comptes rendus des Séances". On a regular basis is also appearing "Anuarul Institutului Geologic al României" which includes in fact the annual activity report and the main events in the scientific life of the institute. All the publications contain papers in English (about 90%), French and Romanian languages, the "Anuarul I.G.R." being bilingual (English-Romanian).

In addition, our institute is publishing the "Geological Bibliography" (each 4-5 years), "Memoriile I.G.R." containing mainly monographic papers and "Excursion Guides".

GEOLOGICAL ATLAS SCALE. 1:1 000 000

Romanian Journal of
STRATIGRAPHY

Romanian Journal of
MINERALOGY

Romanian Journal of
MINERAL DEPOSITS

Romanian Journal of
PETROLOGY

Romanian Journal of
GEOPHYSICS

Romanian Journal of
PALEONTOLOGY

Romanian Journal of
TECTONICS AND REGIONAL
GEOLOGY

Memoriile
INSTITUTULUI
GEOLOGIC AL ROMÂNIEI

ANUARUL
INSTITUTULUI GEOLOGIC
AL ROMÂNIEI

MAP OF ANTEVEAANTIAN
FORMATIONS, 1969

METALLOGENETIC MAP OF
ROMANIA, 1969

MAP OF ANTEWESTPHALIAN
FORMATIONS, 1970

MAP OF THE SOILS FROM
ROMANIA, 1970

MAP OF THE QUATERNARY
FORMATIONS FROM ROMANIA, 1971

MAP OF MINERAL AND THERMAL
WATERS OF ROMANIA, 1981

MAP OF THE MAGNETIC VERTICAL
COMPONENT ΔZ , 1983

GEOTHERMAL MAP OF ROMANIA,
1985

MAP OF THE ANTEOCCIDENTAL
FORMATIONS, 1969

HYDROLOGICAL MAP OF
ROMANIA, 1969

TECTONIC MAP OF
ROMANIA, 1970

MAP SHOWING THE GRANULOMETRY
OF SOILS IN ROMANIA, 1970

NEOTECTONIC MAP OF
ROMANIA, 1971

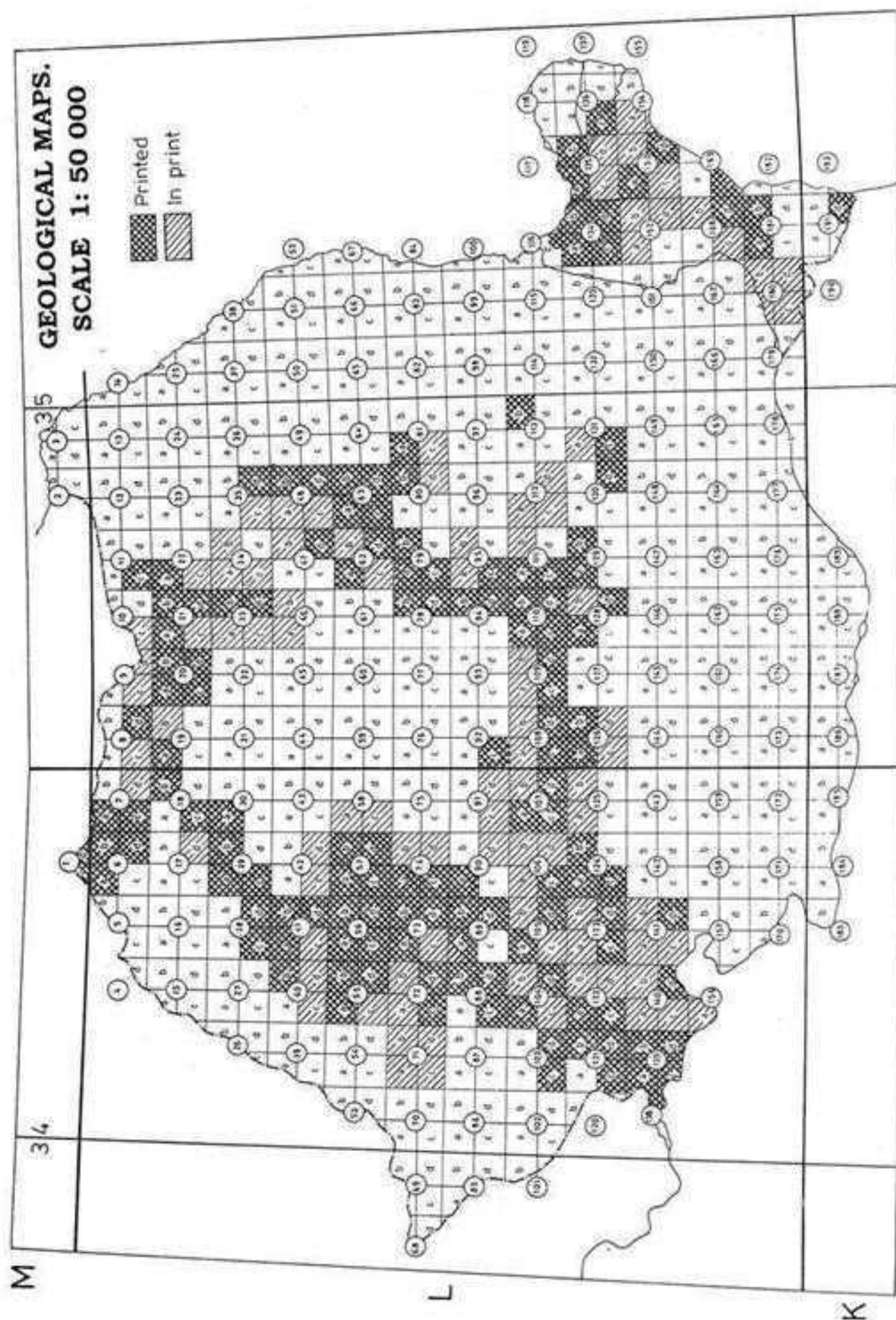
GEOBOTANIC MAP OF
ROMANIA, 1973

MAP OF MAGNETIC
ANOMALY ΔZ_a , 1983

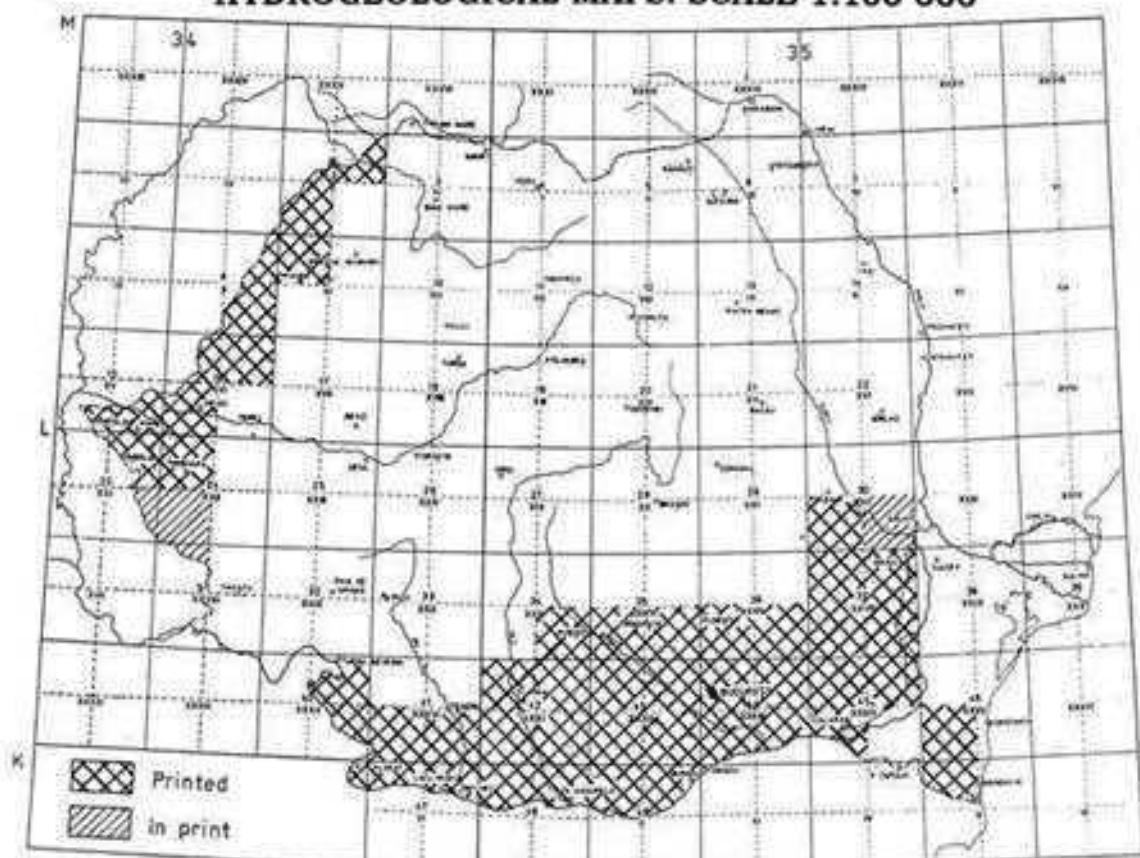
MAP OF MINERAL
RESOURCES, 1984

GEOLOGICAL MAP OF ROMANIA, 1978

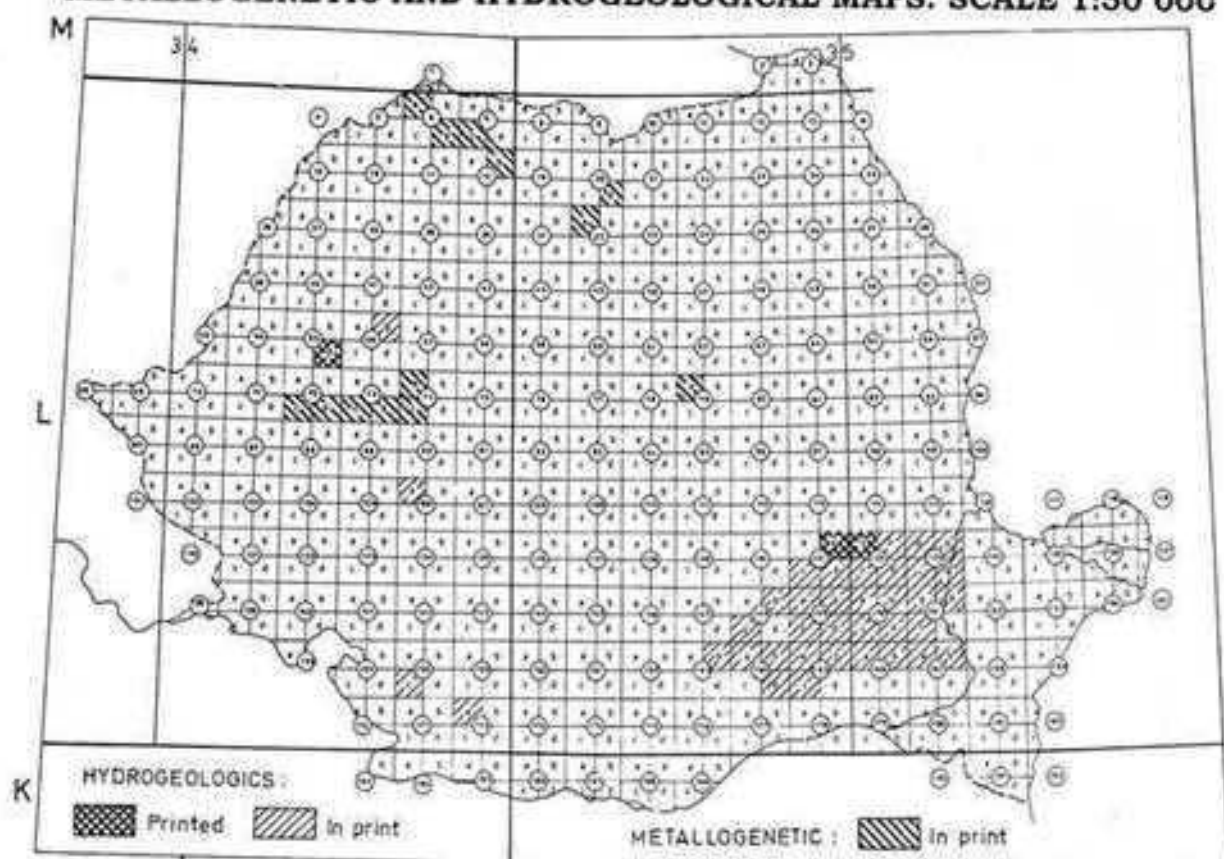




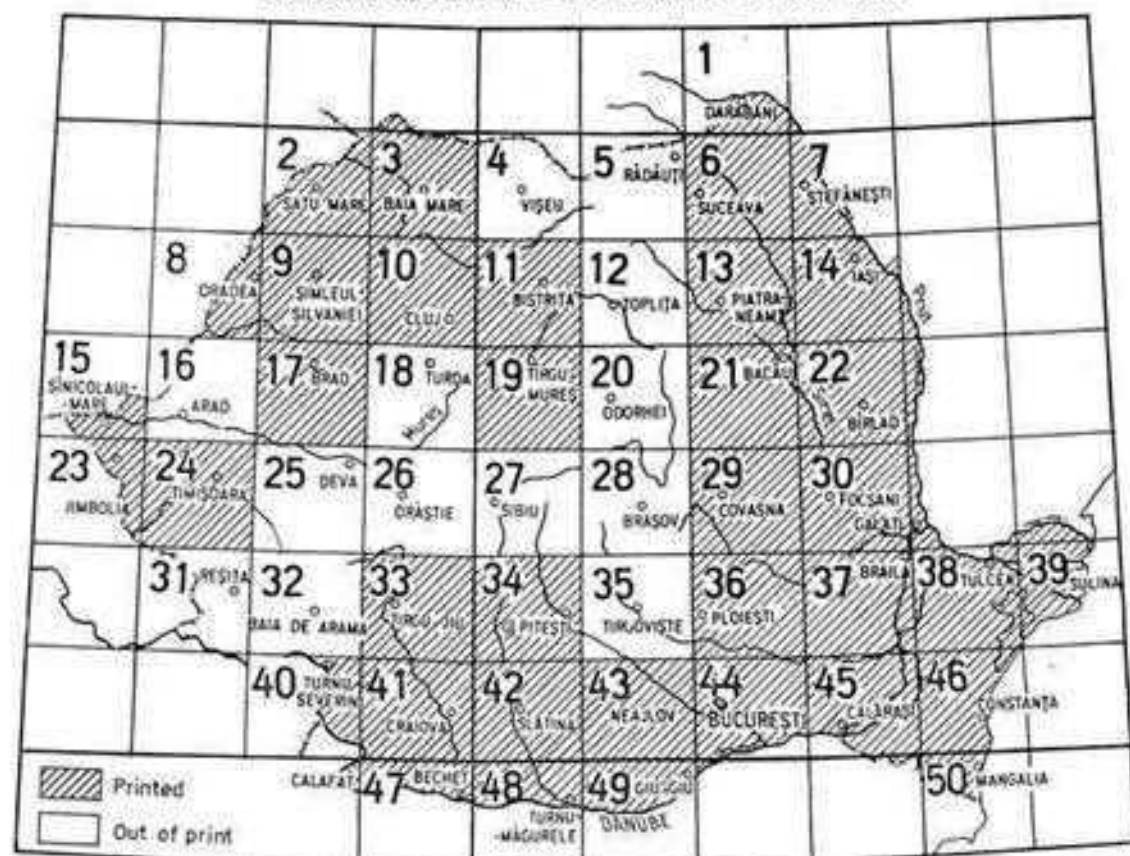
HYDROGEOLOGICAL MAPS. SCALE 1:100 000



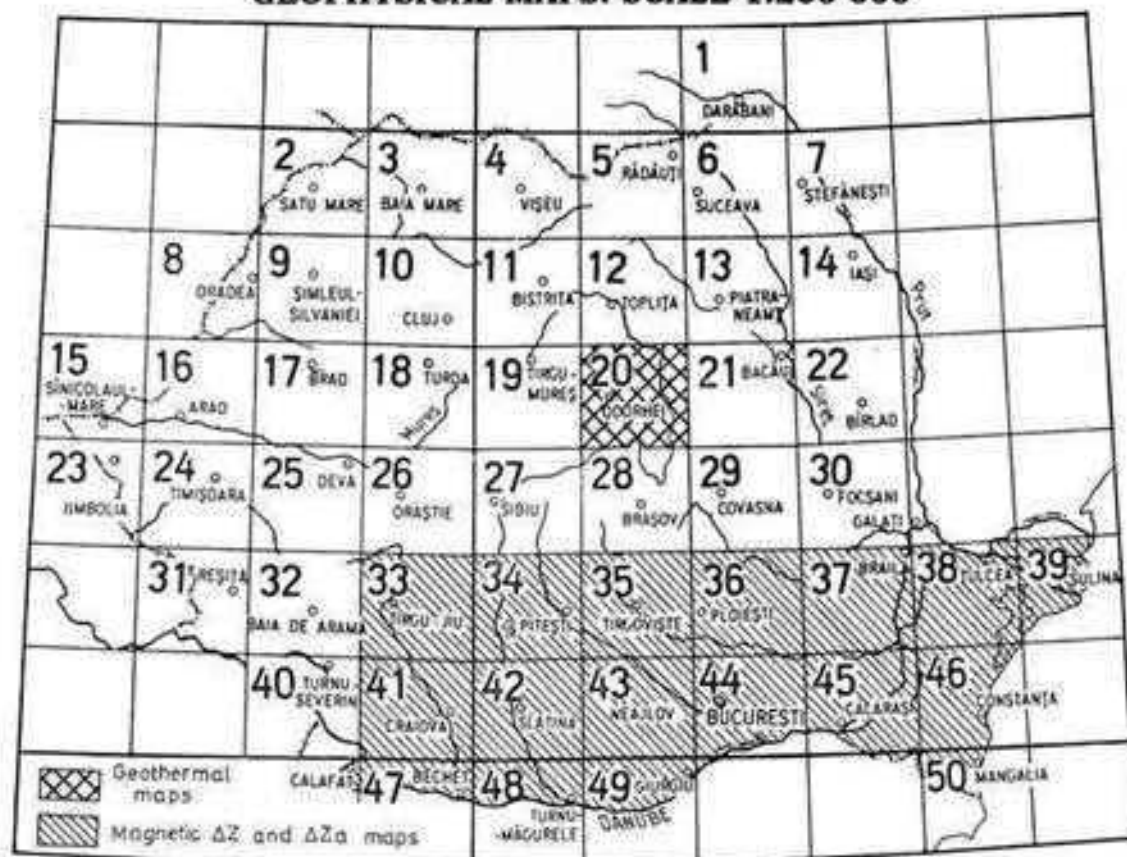
METALLOGENETIC AND HYDROGEOLOGICAL MAPS. SCALE 1:50 000



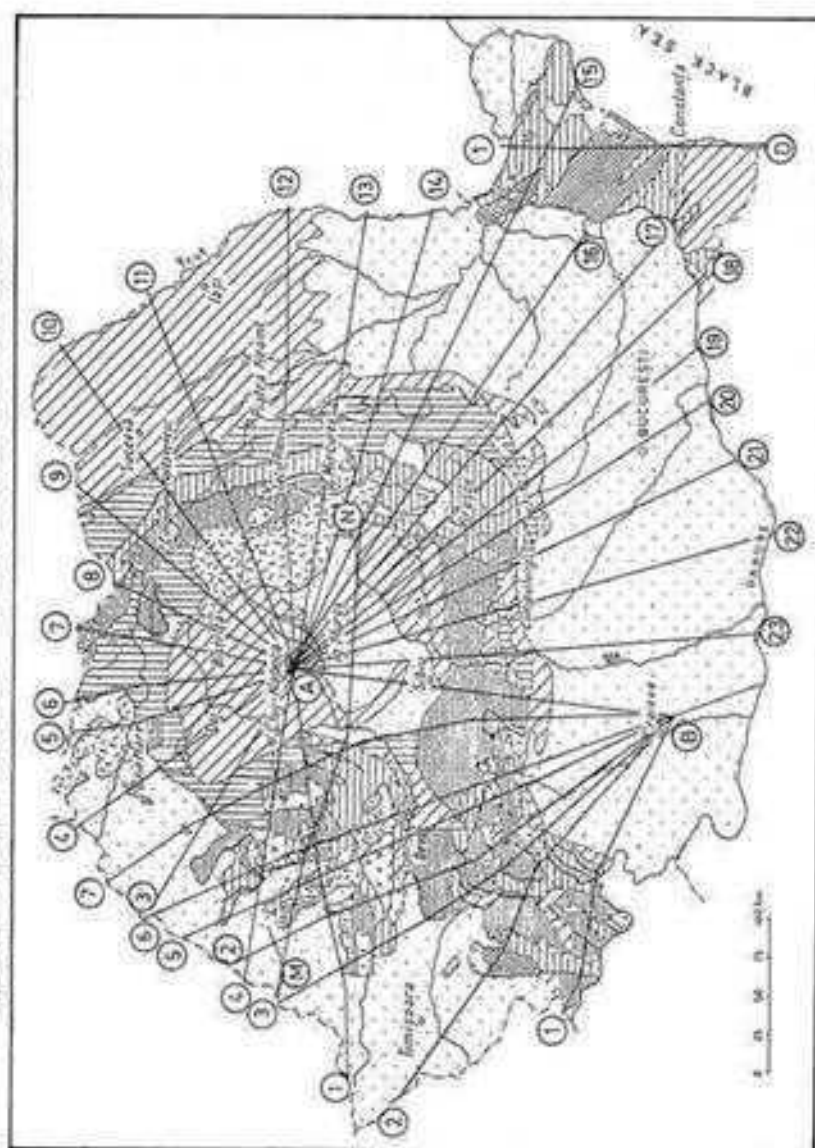
GEOLOGICAL MAPS. SCALE 1:200 000



GEOPHYSICAL MAPS. SCALE 1:200 000



GEOLOGICAL CROSS - SECTIONS. SCALE 1:200 000



Recenzii - Book reviews - Buchbesprechung

G. Sposito - Bodenchemie (Chimia solului). Traducere din limba engleză de J. Niemeyer și A. Eifert. Editura F. Enke, Stuttgart, 1998, 230 p., 54 fig., 128 DM.

Cunoscuta editură pentru cărți științifice "Ferdinand Enke" din Stuttgart a publicat de curând acest manual de chimia solului, care vine să completeze tratarea aproape exhaustivă a pedologiei moderne din cartea "Lehrbuch der Bodenkunde" de Scheffer et al. (vezi recenzia din *Rom. J. Mineral Deposits*, 78, Suppl. 1, 1998, p. 102). Autorul cărții este prof. Garrison Sposito de la University of California din Berkeley.

Conținutul cărții este prezentat în 13 capitole, cu volume de text echilibrate, urmate de anexe care cuprind constante fizice utilizate în chimia solului și de un foarte util index de termeni. Este de subliniat, în mod deosebit, faptul că fiecare capitol are în final mai multe probleme, pentru care se recomandă rezolvarea lor înainte de a parcurge capitolul următor.

Capitolul 1 - "Compoziția chimică a solurilor" (p. 1-16) - cuprinde date esențiale privind participarea elementelor chimice în sol în ansamblu și diversele orizonturi de sol, precum și date comparative privind chimismul scoarței și al solului, la care se adaugă factorii de îmbogățire în sol. Urmează modul de prezentare a elementelor chimice, i.e. în faze solide (minerale, acizi - humic și fulvic), în aerul și apa din sol (CO_2 , NO, N_2O , NH_3 , CH_4 , și H_2O) și evoluția proceselor de transformare a mineralelor din sol prin hidroliză, schimb de cationi, oxidare-reducere și hidratare-deshidratare.

Capitolul 2 - "Mineralele din sol" (17-33) - reprezintă o introducere în mineralogie, cu elemente de cristalochimie, structuri ale mineralelor și descrierea principalelor minerale din sol, i.e. silicați, oxizi și hidroxizi, carbonați și sulfati, subliniind în fiecare caz stabilirea lor și procesele de transformare.

Capitolul 3 - "Substanțe organice din sol" (35-53) - conține date esențiale privind existența și frecvența diversilor acizi organici (aminoacizi, acetic, citric), mono- și polizaharidelor, a substanțelor humice și modul în care aceste substanțe influențează reacțiile acido-bazice din sol și cele de complexare a metalelor. Mai departe este explicată capacitatea de schimb cationic (CSC, în originalul KAK) și importanța ei pentru tamponarea acidității solului, sunt prezentate reacțiile cu moleculele organice, prin care unele pesticide, îngrășăminte etc. pot fi neutralizate și/sau transportate în orizonturile inferioare ale solului.

Capitolul 4 - "Soluțiile din sol" (54-71) - tratează faza apoasă cu substanțe dezvoltate în cadrul unui sistem deschis, modalitățile de izolare și de studiu al soluțiilor din sol, echilibrele de "speciere" ca modalitate de evaluare a concentrației substanțelor dizolvate, constantele de stabilitate termodinamică pentru formarea diverselor substanțe etc.

Capitolul 5 - "Solubilitatea mineralelor" - include informații asupra cineticii de solubilizare prin prisma difuziei intergranulare, diagrame de stabilitate în funcție de pH și concentrația diverselor elemente, reacțiile îngrășămintelor fosfatice în soluri calcaroase, semnificația adaosului de gips în solurile acide, alterarea mineralelor argiloase etc.

Capitolul 6 tratează "Fenomenele electrochimice" (88-106), i.e. reacțiile de oxido-reducere, relația pH-pE (logaritmul negativ al activității electronilor liberi), cu conturarea câmpurilor în care microorganismele se pot dezvolta, fenomenele care se petrec în solurile inundate și, în final, măsurarea valorilor pH și pE.

Capitolul 7 - "Suprafețele (active) componentelor solului" (106-124) - intră deja în probleme speciale, care privesc grupările funcționale de la suprafața particulelor de humus și componente minerale, printre care se numără carboxilul, carbonilul, imidazolul, OH fenolic etc. (pentru humus), silanolul, aluminolul etc. (pentru minerale), cu rol decisiv în complexarea suprafețelor active. Adsorbția, sarcina (electrică) de suprafață, punctul de

sarcină zero și apa adsorbită sunt alte probleme explicate clar, care influențează înțelegerea multor proprietăți esențiale ale solurilor.

Capitolul 8 - "Procese de adsorbție în soluri" (124-143) - pătrunde în domeniul cineticii adsorbției și echilibrului chimic aferent, incluzând și adsorbția cationilor metalici, a anionilor, modele de adsorbție moleculară etc.

Capitolul 9 - "Ioni interschimbabili" (144-159) - tratează capacitatea de schimb a solului, izotermele de schimb ionic, reacțiile de schimb ionic, echilibrele de schimb cationic și moleculele acestuia, toate menite să fundamenteze specierea suprafețelor active ale particulelor din sol.

În capitolul 10 - "Fenomene coloidale în sol" (160-177) - se definesc coloizii, stabilitatea suspensiilor coloidale, inclusiv coagularea și flocularea, apariția domeniilor coloidale în illit, a quasicristalelor în smectit, concentrația critică de coagulare (ccc, KKK în original) și modelul DLVO (Derjaguin-Landau-Verwey-Overbeek) privind stabilitatea suspensiilor coloidale.

Capitolul 11 este dedicat "Activității solului" (178-191), cu toate componentele sale, rolul deosebit al compușilor ce conțin Al (III) privind solurile acide, precum și metodelor de neutralizare a acidității solului, în special prin prisma conceptului de "necesar de calciu".

Capitolul 12 - "Salinitatea solului" (192-208) - cuprinde definiția unui sol sărat în funcție de conductivitatea electrolitică a soluțiilor din sol și parametrii care o influențează, i.e. schimbul cationic, alterația diferențială a mineralelor, rolul borului, calitatea apelor utilizate pentru irigații etc.

Capitolul 13 - "Fertilitatea solului" (209-223) - tratează caracterul esențial al unor elemente pentru calitatea solului (H, B, C, N, O, Mg, P, S, Cl, K, Ca, Mn, Fe, Cu, Zn și Mo) sau toxic în raport cu plantele și animalele din sol (Hg, Cd, Pb, Ni), disponibilitatea biologică a elementelor, cinetica preluării substanțelor nutritive ale solului, precum și efectele pE și pH.

Cartea reprezintă un compendiu de chimie a solului, foarte bine echilibrat pe capitole. Referințele bibliografice sunt specifice fiecărui capitol, ușurând identificarea lor. Informațiile prezentate sunt de primă importanță pentru pedologi (în special studenți), dar și pentru geologi, interesați atât de mineralogia solurilor, cât și de procesele mineralogenetice care au loc în sol.

Cartea "Chimia solului" trebuie să fie prezentă în orice bibliotecă de științe naturale.

Prof. Dr. Gheorghe Udubașu

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Translation:
Adriana Năstase

Editorial Staff:
Mariana Borcoș, Gabriela Ioane

Illustration:
Paraschiv Toader, Natalia Călțan, Gabriel Baralia

Printing:
G. Bădulescu, D. Gavril, N. Păleanu, S. Iacoblovici, F. Dumitru

Historical Development of the Mineralogical Knowledge of the Săcărâmb Ore Deposit

1717	Koleseri's "Auraria Romano-Dacica" is probably one of the first assessment of the Transylvanian gold.
1744-1745	Born's chance to receive a sample of gold-rich ore which contained the "future nagyagite".
1772	Born and Scapoli named the mineral "aurum galena".
1783	Hacquet: first crystallographic record of the Săcărâmb gold ("Mineralogische Rhapsodien"). Also the first report on the gold in the area by Muller von Reichenstein.
1800	Beudant: a further name of nagyagite: "elasmose".
1803	Stutz: systematic presentation of many minerals.
1832	Karsten gave the future nagyagite the name "Blattererz".
1842, 1845	Haidinger gave the name nagyagite; first description of petzite, previously described by Petz as "Tellursilber".
1857	Hingenau: new mineral data.
1866	Hofer: further mineralogical data.
1877	Krenner in Budapest and von Rath in Bonn simultaneously described a new mineral, named by Krenner "Bunsenit". Neatly and frankly, G. von Rath gave the mineral the name "krennerite". Previously used names: Gelberz, Weissstellur, Mullerin, Kottonerz.
1878	Schrauf: detailed crystallographic data on nagyagite; first description of stuetzite; the latter has been discredited by Thompson in 1951, but lately redefined.
1885	Sipöcz: chemical analyses of nagyagite.
1887	Inkey: first geological monography of the area, with many data on the minerals.
1894	Vrba: crystallographic study of sylvanite (28 forms).
1897	Privoznik: chemical analyses of nagyagite.
1911	Haidinger: first description of muthmannite. Thompson (1949) failed to synthesize muthmannite and considered it as doubtful species. Later data showed that muthmannite is, however, a valid mineral species.
1924	Boldirew: chemical analyses of nagyagite.
1930	Tokody: description of xanthoconite and proustite.
1934	Helke: first modern ore microscopy study.
1935	Gossner: structural data on nagyagite (tetragonal symmetry).
1935, 1936, 1937	Giuscă: many ore microscopical and chemical data on tellurides; his nagyagite formula $AuPb_2(TeSb)_2S_8$ seems to be the most appropriate.
1941	Ghitulescu and Socolescu - first monography of the Metaliferi Mts; many data on Săcărâmb.
1958	Binder: Historical data on mineralogical discoveries in Transylvania, in the Săcărâmb area included.
1970	Stumpfl: microprobe analyses of nagyagite; his formula implies substitution $Te = S$ rather than $Te = Sb$, as Giuscă proposed.
1973	Ramdohr and Udubasa: frobergite identification.
1975	Fontan, Orliac, Permingeat: discovery of krautite.
1986	Udubasa: step-by-step decomposition of nagyagite.
1992	Popescu and Simon: record of coloradoite and tellurantimony.
1996	Discovery of an As-nagyagite (Simon et al., 1996).

Săcărâmb (Nagyag; Szekeremb) Ore Deposit. Vein systems in a complex volcanic structure of Neogene age (andesite prevails). One of the best known Romanian ore deposits, very rich in Au-Ag tellurides, type locality of many tellurides, i.e. nagyagite, krennerite, petzite, muthmannite, stuetzite. Also type locality of krautite (recently described), tellurite. First European occurrence of frobergite. Over 80 minerals described; very frequently found is the association gold tellurides+rodochrosite+alabandite. Crystals of bourmonite, nagyagite (biggest in the world - 6 cm long, hosted by the Naturhistorisches Museum in Wien), silver sulfosalts, sphalerite (iron-poor), galena etc. were found here. Pseudomorphs of calcite after quartz crystals.



Old mining activity in Sacaramb ore deposit (1817)

