The Romanian Carpathians: Alpine Geotectonic Evolution and Metallogeny

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With 10 Figures

Zusammenfassung

Die sehr komplexe Struktur der rumänischen Karpaten wird auf der Basis der plattentektonischen Interpretation dargestellt. Der tektonischen Entwicklung werden die magmatischen und metallogenetischen Phasen und Bezirke zugeordnet. Das triassische Rifting bewirkt die Bildung von Ba-Fe-Lagerstätten in den Ostkarpaten; durch das seafloorspreading zur Unterkreidezeit wurde im Bereich der Südkarpaten ein schmaler Streifen von Ozeanboden frei gelegt, an den kleine Erzvorkommen gebunden sind. Die laramische Subduktion begann mit der Produktion erzfreier Vulkanite und anschließend erzbringender Intrusiva (Banatite), denen wichtige Kupferlagerstätten der Südkarpaten und des Apuseni-Gebirges zu verdanken sind. Eine neogene Subduktionsphase bewirkte die Entstehung von weiteren Cu-Porphyrie-Lagerstätten und von Buntmetallgängen mit Gold. Auch die junge Kontinent-Kontinent-Kollision erzeugte eine schwächere Gangvererzung.

Abstract

The structure of the Romanian Carpathians was accomplished during the Alpine orogenic cycle. Their metallogenetic evolution during Alpine times developed from unevolved intracontinental rifting (Triassic Fe ores, Jurassic-Lower Cretaceous Ba and Mo ores in the East Carpathians) to spreading areas (Lower Cretaceous Cu-pyrite ores in the South Carpathians) and subduction-related settings (Jurassic-Cretaceous Fe-Ti-V, Ni, Cu-pyrite, Mn ores in the Southern Apuseni Mountains, Laramian Mo, Bi, W, Cu, Co, Ni, Pb, Zn, B, Fe ores in the Apuseni Mountains and the western part of the South Carpathians, neogene Au-Ag, Cu and base-metal ores in the East Carpathians and the Southern Apuseni Mountains).

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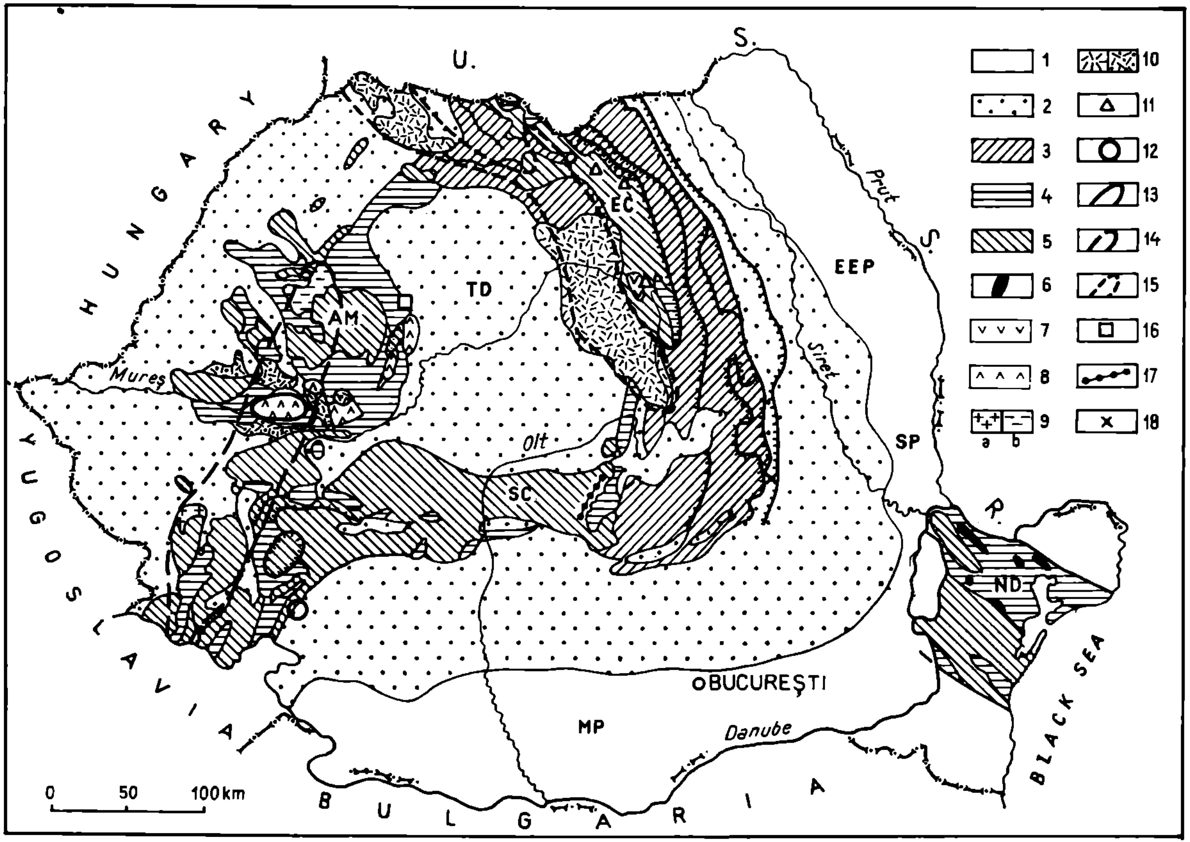

Fig. 1. Alpine structure and metallogeny in the Romanian Carpathians. 1 = foreland, 2 = molasse, 3 = flysch nappes, 4 = Mesozoic-Cainozoic cover, 5 = pre-Mesozoic basement including North Apusenides Nappes, Central East Carpathian Nappes, Supragetic and Getic Nappes, 6 = Triassic basalts of the short-lived intracontinental rift of North Dobrogea, 7 = island arc volcanics and active marginal basin spilites of the South Apuseni Mountains (Jurassic-Cretaceous), 8 = Ditrău alkaline massif related to intracontinental rifting (Jurassic-Cretaceous), 9 = subduction-related Laramian magmatism (Banatites) (a = plutons, b = volcanics), 10 = subduction-related Neogene volcanism (a = volcanics of the external arc; b = volcanics of the back-arc reactivization rifting areas), 11 = metallogenesis related to intracontinental rifting, 12 = metallogenesis related to ocean-floor spreading areas, 13 = metallogenesis related to Jurassic-Cretaceous island arc volcanics, 14 = Laramian (Banatitic) metallogenesis, 15 = Neogene metallogenesis, 16 = metallogenesis in passive margin-related settings, 17 = metallogenesis in continental collision-related settings, 18 = metallogenesis in post-collisional-related settings. EC = East Carpathians, SC = South Carpathians, AM = Apuseni Mountains, TD = Transylvanian Depression, EEP = East European Platform, SP = Scythian Platform, MP = Moesian Platform.

Minor Fe occurrences of Paleogene age are related to a passive margin of the Northern Apuseni Mountains and restricted Helvetian base-metal ores to post-collisional setting in the East Carpathians. A continental collision-related belt with Co, Ni, Bi, Cu mineralization connected with the Cretaceous deformation was inferred from geological-geophysical data in the eastern part of the South Carpathians.

The Structure of the Romanian Carpathians

The Romanian Carpathians, located of the southern boundary of the Eurasian Plate, originated during pre-alpine and especially alpine deformations. This significant orogenic structure is built up of inner units (Apuseni Mountains), moulded by the external Carpathian Arc (the East Carpathians, proceeding beyond the Romanian territory to the West Carpathians, and the South Carpathians, proceeding to Eastern Serbia, Yugoslavia). The Carpathian Foreland is represented by the Moesian Platform in the south, the Scythian Platform in the east and the East European Platform in the north and northeast. The North Dobrogea region lies within this cratonic environment, between the Moesian and Scythian Platforms. It has no connection with the Carpathians, but proceeds to Crimes and the Greater Caucasus, USSR (Fig. 1).

The Internides contain the Southern and the Northern Apusenides. The Southern Apusenides comprise thrust units with ophiolites and Mesozoic sediments covered by Neogene molasse in the west, south of the Mureş Valley, and in the east, within the basement of the Transylvanian Depression. The continuation of this structure towards the Vardar Zone was discussed by various authors and interpreted in different ways (e. g. SĂNDULESCU, 1983). The Northern Apusenides are built up of basement nappes (crystalline schists, pre-Mesozoic granitoids) and in fact represent the prolongation of the Austroalpine structure of the Eastern Alps (SĂNDULESCU, 1983).

The Carpathian Arc with external position is built up of three successive groups of nappes of different ages and origin; besides them, the East Carpathians contain the Transylvanian Nappe Group. The innermost region of the East Carpathians, namely the Crystalline-Mesozoic Zone, contains various nappes formed during Hercynian and Mesocretaceous deformations (BALINTONI et al., 1983). These Central East Carpathian Nappes correlate with Supragetic and Getic Nappes of the South Carpathians, which were involved in Laramian deformations too. The Transylvanian Nappes with Mesozoic ophiolites and sediments resulting from the basement of the Transylvanian Depression (SĂNDULESCU and VISARION, 1978) were obducted upon the above mentioned nappes of the Crystalline-Mesozoic Zone. Beyond the inner nappe assemblage, the Flysch Nappes built up of Upper Jurassic-Lower Cretaceous flysch sediments and ophiolites arose during Mesocretaceous and Laramian deformations. They comprise the Black Flysch Nappe, the Ceahlău Nappe and the Baraolt Nappe within the East Carpathians as well as the Severin Nappe within the South Carpathians (e. g. SĂNDULESCU, 1983). The Moldavides have the outermost position, confined to the East Carpathians; they represent cover nappes built up of Paleogene flysch sediments and Miocene molasse.

It is worth mentioning that the South Carpathians comprise a significant region of continental type (mainly crystalline schists and pre-Mesozoic granitoids), the Danubian Realm, early considered as Autochthon (e. g. CODARCEA, 1940). According to recent interpretations, it can be subdivided into the Lower Danubian Unit and the Upper Danubian Unit, both involved in pre-Alpine and Alpine (Mesocretaceous and Laramian) thrustings (BERZA et al., 1983). On the other hand, new data provide evidence of Danubian thrusting over the Moesian Platform during intra-Sarmatian deformations (MOTAŞ, 1983).

Besides the above mentioned ophiolites, two major petrogenetic associations of calc-alkaline character are found in the Carpathians: the Laramian (Banatitic) igneous rocks in the west (Apuseni Mountains and South Carpathians) and the Neogene volcanics in the South Apuseni Mountains and the East Carpathians.

Alpine Geodynamic Evolution of the Romanian Carpathians

The post-Paleozoic geodynamic evolution which promoted the present-day Carpathian architecture is associated with the development of the Tethyan trench system. Both short-lived and more evolved rifts are characteristic of this setting and yielded various types of magmatic and metallogenetic products. Thus, Triassic intracontinental rifting in the North Dobrogea region gave rise to an aulacogen-like failed arm linked with the Tethys through Crimea and the Greater Caucasus (VLAD, 1978). In places riftings along reactivated proto-Carpathian alignments were rapidly aborted, but commonly promoted ocean-floor spreading. Accordingly, narrow elongated troughs with oceanic crust developed around sialic blocks. It is likely that the distensional tectonics of the Lower Mesozoic period and the subsequent motion of resulting microplates were promoted by triple junctions; the Carpathian curvatures are interpreted as evidence of this kind (VLAD, 1980). According to geological and geochemical data the Severin Nappe ophiolites represent ocean-floor tholeiites (CIOFLICA et al., 1981). Similar recent studies on South Apuseni Mountains ophiolites strongly suggest that the oceanic crust of the paleo-basin was consumed; inferred oceanic crust remnants are to be found in the basement of the Transylvanian Depression (e. g. CIOFLICA et al., 1980, CIOFLICA and NICOLAE, 1981).

Following this, significant westward pulsatory compressions gave rise to Andean or island arc subduction-related magmatic arcs. Neokimmerian deformations promoted tholeiitic and calc-alkaline island arc magmatism in the South Apuseni Mountains (CIOFLICA et al., 1980, CIOFLICA and NICOLAE, 1981).

Mesocretaceous deformations gave rise to numerous thrust nappes accomplished in places during Laramian times when continental collision was reached. These deformations yielded eastward obduction of ophiolites in the East and South Carpathians. On the other hand, a Laramian westward subduction-related belt of calc-alkaline character (partly of Andean type) runs from the Apuseni Mountains to

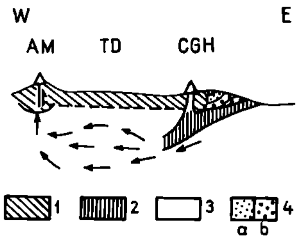

Fig. 2. Plate tectonic model of the Neogene reactivation in the Apuseni Mountains (according to VLAD, 1980). 1 = continental crust, 2 = westward subducted oceanic crust, 3 = upper mantle, 4 = nappes (a = flysch nappes, b = Moldavides), 5 = energetical eddies that promoted heat of the base of the lithosphere and behind-arc diapirism. CGH = Căliman-Gurghiu-Harghita Mountains with island arc volcanics, AM-TD = behind arc environment (TD = Transylvanian Depression with turbidite apron-like sedimentation, AM = back-arc region with extensional tectonics characterized by mainly andesitic volcanism and related metallogenesis caused by heat transfer from external Carpathian subduction and reactivization of the Apuseni Mountains hot spot).

the South West Carpathians ("Banatitic Province") and further south to the Eastern Serbia (Yugoslavia).

Following the suture of the South Apusenides to the North Apusenides sialic block, the north-western part of that internal paleobasin acted as a passive continental margin.

The Neogene calc-alkaline island arc volcanism of the East Carpathians (BOCCALETTI et al., 1973, BLEAHU et al., 1973) is related to deformations that yielded the Moldavides Nappe System. The similar volcanism of the South Apuseni Mountains cannot be satisfactorily explained by subduction. The South Apuseni Mountains contain three superposed magmatic products with distinctive lineation, that is Jurassic-Lower Cretaceous island arc volcanics, Laramian (Banatitic) igneous rocks and Neogene volcanics. The pulsatory magmatism that acted within a restricted area was presumably controlled by a deepseated hot spot (VLAD, 1980). It seems likely that hot spot reactivization yielded rifting along Laramian transverse faults and promoted the Neogene volcanicity. The reactivization resulted during the above mentioned westward subduction in the East Carpathians; energetical eddies promoted heat of the base of the lithosphere and back-arc diapirism with volcanism (Fig. 2).

As an significant post-collision event, intra-continental rifting yielded basaltic volcanicity during late Neogene times (RĂDULESCU et al., 1981).

Alpine Metallogenesis and Plate Tectonics in the Romanian Carpathians

The metallogenetic characteristics of the Romanian Carpathians have recently been taken into account by various authors; among them IANOVICI and BORCOŞ (1982) studied in detail the time-space distribution of numerous ore deposits and

CIOFLICA and VLAD (1984) discussed the Alpine metallogeny of Romania in terms of plate tectonics.

The structure of the Romanian Carpathians, accomplished during the whole Alpine cycle, provides opportunities to outline their metallogenetic evolution in association with tectonic and magmatic events (Fig. 1). Accordingly, the Alpine metallogenesis developed during post-Paleozoic times from early aborted intracontinental rifting to spreading areas, subduction-related settings, collision- and post-collision-related settings that are listed below.

Metallgenesis related to intracontinental rifting. The Central East Carpathian Nappes represent a preferential site of Ba-Pb-Zn, Fe, Mo occurrences related to Mesozoic sedimentary and igneous rocks.

At Delniţa dolomitic limestones of Triassic age contain stratabound Fe ores associated in places with barite and base-metal ores. The lens-like bodies are prevailingly sideritic-ankeritic in the east and hematitic in the west.

Along the Ostra-Gemenea-Slătioara alignment barite and witherite accumulations are associated with base-metal ores (IANOVICI et al., 1966). At Ostra, N-S striking veins cross the metamorphic basement and the Mesozoic sedimentary cover (Fig. 3). At least two barite generations as well as witherite, pyrite, sphalerite, galena, tetrahedrite were recognized; at depth the penetrated gneisses are impregnated with barite. It seems likely that early barite occurrences were remobilized during post-Jurassic rifting, before major middlecretaceous deformations. The mineraliza-

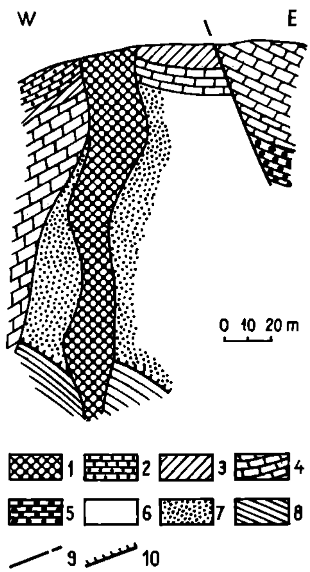

Fig. 3. Cross-section through the Ostra barite deposit (according to IANOVICI et al., 1966). 1 = barite vein, 2–5 = Triassic-Jurassic sediments (2 = sandstones, 3 = jasperoid rocks, 4 = dolomitic limestones, 5 = siliceous conglomerates), 6 = Rarău gneisses, 7 = barite impregnated gneiss, 8 = epimetamorphic rocks, 9 = fault, 10 = thrust.

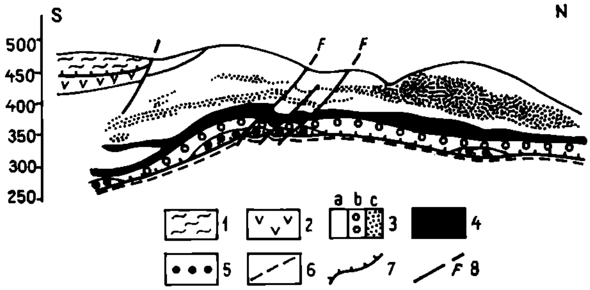

Fig. 4. Section through Cu-pyrite ores from Baia de Aramă (according to CIOFLICA et al., 1980). 1 = Getic Nappe, 2 = serpentinite protrusion, 3 = ophiolite complex (a = upper ophiolites, b = lower ophiolites, c = mineralization), 4 = Cretaceous black argillite, 5 = Cretaceous flysch of the Severin Nappe, 6 = Cretaceous flysch of the Danubian realm, 7 = thrust, 8 = fault.

tion is found discontinuously up to Gemenea and Slătioara where base-metal and barite veins cut the crystalline schists (IANOVICI and BORCOŞ, 1982).

The Jurassic-Lower Cretaceous ring-like intrusion of alkaline character from Ditrău exhibits a zonal structure (ANASTASIU and CONSTANTINESCU, 1980): its inner part consists of foidites, surrounded discontinuously by syenite and monzonite rocks. Hornblendites and diorites as well as granites and alkali granites occur marginally. Numerous lamprophyre, microsyenite, alkali granite and aplite dykes cut the massif. Albitite segregations and carbonatite veins are found in places. Mo-bearing carbonatites occur especially in the north (Jolotca). They are hosted by diorite and hornblendite rocks and contain usually ilmeno-rutile, ilmenite, monazite, tapiolite, columbite and sulphides as well as by alkali syenite rocks when xenothime, sulphides and niobo-tantalates are the common minerals.

Metallogenesis related to ocean-floor spreading areas. The Severin Nappe of the South Carpathians contains ophiolites with Cu-pyrite ores. During early Mesozoic times an elongated basin with oceanic crust acted between the Getic and the Danubian realms (RĂDULESCU and SĂNDULESCU, 1973). The resulting basaltic flows and pyroclastics associated with Lower Cretaceous flysch sediments of the Severin Nappe were obducted eastwards during Laramian compressions when the Getic and the Danubian realms collided. The ophiolite-related mineralization occurs at Baia de Aramă (Fig. 4). CIOFLICA et al. (1981) provided geological and geochemical evidence to characterize these ophiolites as tholeiitic ocean-floor basalts formed in a small ocean setting; the related ore deposits were ascribed to the Joma type of PEARCE and GALE (1977). They occur in basalts as small size strati-form pods of massive chalcopyrite, with subordinate amounts of pyrite and sphalerite in quartzose gangue. The massive ore is commonly underlain by pyrite + chalcopyrite + spalerite stockworks.

Metallogenesis in subduction-related settings. Jurassic-Cretaceous, Laramian and Neogene subduction events promoted ore deposition associated with island arc or Andean type magmatic belts.

The earlier event is represented by tri-stadial magmatism of the South Apuseni Mountains, that is tholeiite series and subsequent calc-alkaline series representing island arc products and final spilitic complex associated with active marginal basin (CIOFLICA et al., 1980; CIOFLICA, NICOLAE, 1981). The related metallogenesis consists of Fe-Ti-V and Ni late magmatic segregations in gabbroic intrusions and Cu-pyrite veins and stockworks in basaltic lavas of the tholeiite series (e. g. CIOFLICA et al., 1980). The calc-alkaline series comprises Mn-volcano-sedimentary ores (e. g. CIOFLICA et al., 1980); such a setting encloses virtual Kuroko-porphyry copper systems too (VLAD, 1983).

The Fe-Ti-V segregations are found as titanomagnetite and ilmenite nests, lenses and grains within layered gabbroic bodies (CĂZĂNEŞTI-CIUNGANI). The Ni ores are confined to the Ciungani gabbroic body wherein pyrrhotite, pentlandite with associated chalcopyrite and magnetite occur as a small size pod.

The Cu-pyrite volcanogenic ores are related to basalts and were considered by CIOFLICA et al. (1981) of Gjersvik type (PEARCE and GALE, 1977). Various veins and stockworks (CĂZĂNEŞTI-CIUNGANI, ALMĂŞEL, ROŞIA NOUĂ) are controlled by brecciated basalts. At Pătîrş the mineralization is located in the upper part of a basaltic unit and contains an inner zone with pyrite + chalcopyrite veinlets and a massive pyrite pod, surrounded by a disseminated pyrite aureole (Fig. 5).

Minor Mn volcano-sedimentary ores associated with jaspers occur in Lower Cretaceous sediments at Soimuş-Buceava, Pîrneşti and Godineşti.

A significant subduction event yielded the Laramian calc-alkaline magmatic belt (banatites). The magmatism is represented by two major stages (CIOFLICA and VLAD, 1973, 1980) that is the senonian volcanicity depleted of metallogenetic interest and the subsequent intrusive stage divided into three phases: early minor diorite bodies; plutons and subvolcanic bodies related commonly to monzodiorite, diorite → granodiorite and granodiorite → granite evolution trends; final acidic dykes and concurrent basic dykes and lamprophyre dykes. The main intrusive event promoted ore deposition inside and around shallow intrusions, plutons or subsequent dykes. Porphyry copper and skarn deposits prevail, whereas vein deposits occur scarcely (CIOFLICA and VLAD, 1980). The monzodiorite, diorite-granodiorite magmatism

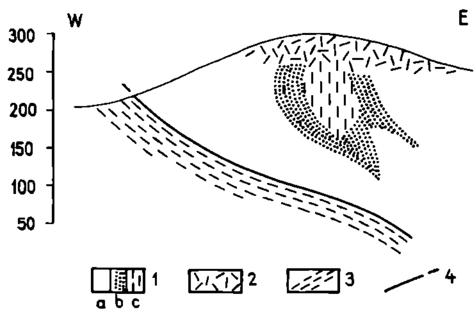

Fig. 5. Section through Cu-pyrite ores from Pătîrş (according to CIOFLICA et al., 1980). 1 = basalts (a = unmineralized, b = pyrite impregnations, c = pyrite + chalcopyrite stockwork), 2 = Gossan, 3 = Cretaceous flysch, 4 = reversed fault.

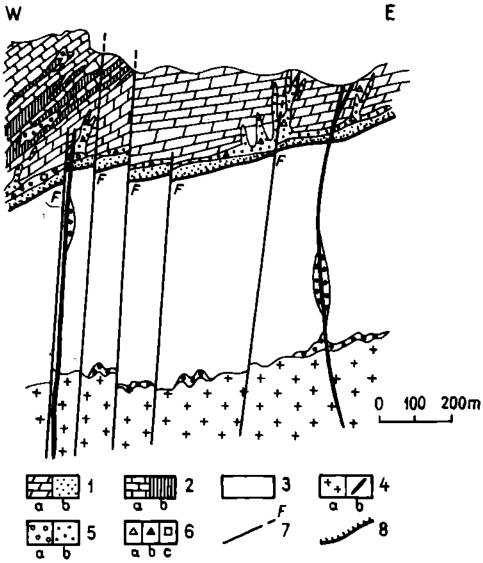

Fig. 6. Cross-section through the Crişul Negru Valley, North Apuseni Mountains (according to Cioflica and Vlad, 1980). 1 = recrystallized Carnian sediments of the Băiţa Unit (a = dolomitic marble, b = apodetrital hornfels), 2 = recrystallized Norian sediments of the Băiţa Unit (a = calcareous marble, b = apodetrital hornfels), 3 = recrystallized Cretaceous limestones of the Bihor Autochthon, 4 = Laramian (Banatitic) igneous rocks (a = granite, b = andesite), 5 = skarns (a = Ca-skarns, b = Mg-skarns), 6 = mineralization (a = Pb-Zn-B, b = Cu-W-Bi, c = Mo-W), 7 = fault, 8 = thrust.

yielded Cu deposits, whereas the granodiorite-granite magmatiam especially base-metal ores.

The North Apuseni Mountains sub-belt is characterized by granodiorite-granite magmatism and widespread base-metal metallogenesis (Ianovici et al., 1977). The ore zoning is expressed by the complex zone of the Bihor-Gilău Mountains (Mo, Bi, W, Cu, Co, Ni, Pb, Zn, B, Fe ores in skarn environment) (Fig. 6), followed landwards by the base-metal zone of the Vlădeasa Massif (hydrothermal Pb-Zn ores).

The South Apuseni Mountains sub-belt is represented by monzonite, diorite-granodiorite magmatism with Cu-impregnated and Fe skarn deposits and granodiorite-granite magmatism with Pb-Zn and Mo vein deposits (Cioflica and Vlad, 1984).

The Banat-Poiana Ruscă Mountains sub-belt is represented by the inner zone (South Banat) with monzodiorite, diorite-granodiorite magmatism and Cu-Mo porphyry copper deposits of Lowell and Guilbert model, stockwork type, monoascendant evolution (e. g. Suvorov, Moldova, Nouă, Fig. 7) as well as Cu-Mo skarn deposits (e. g. Sasca); the North Banat-Poiana Ruscă zone located landwards consists of granodiorite-granite magmatism and Fe, Pb-Zn skarn deposits (e. g. Dognecea, Onca de Fier) or restricted Mo-porphyry occurrences (e. g. Oraviţa). The well-

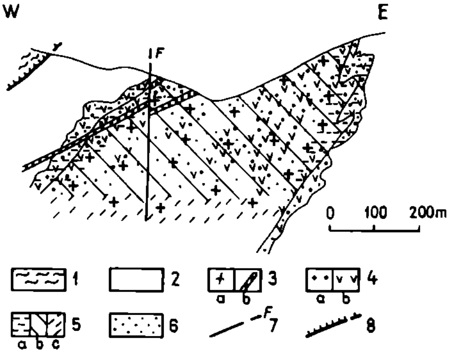

Fig. 7. Cross-section through the Suvorov porphyry copper deposit, Moldova Nouă, South Banat (according to VLAD, 1983). 1 = Supragetic Nappe, 2 = Mesozoic limestones converted into marble, 3 = Laramian (Banatitic) ingenous rocks (a = quartz diorite porphyry, b = lamprophyre), 4 = apocalcic metasomatites (a = grandite skarn, b = propylitic zone), 5 = apoalumosilicate metasomatites (a = argillic zone, b = phyllic zone, c = potassic zone), 6 = copper mineralization, 7 = fault, 8 = thrust.

expressed Cu-Mo-Fe, Pb, Zn transverse zoning and Cu-Pb line that delineates the magmatic-metallogenetic zones are characteristic of the Andean subduction type (VLAD, 1979).

The Neogene subduction gave rise to various volcanics that occurred rhythmically from Helvetian to Pliocene times. Among them the Sarmatian volcanics are commonly of metallogenetic significance. The petrogenetic and metallogenetic characteristics of the Neogene volcanicity were summarized by various authors (e. g. GIUŞCĂ et al., 1968; CIOFLICA et al., 1973; RĂDULESCU et al., 1981; IANOVICI and BORCOŞ, 1982).

The East Carpathian volcanic arc of mainly andesitic composition developed within the Oaş-Gutîi-Ţibleş-Bîrgău-Rodna-Căliman-Gurghiu-Harghita Mountains and contains hydrothermal ore deposits of Au-Ag and base-metal type with subordinate amounts of Hg, exhalative S and hydrometasomatic Fe ores. It is to be suggested that such setting may promote porphyry copper occurrences at depth, near root zones of Au-Ag and base-metal veins. The northern part of the Oaş Mountains contains base-metal veins between Tarna and Bicsad. The southern part of the Gutîi Mountains locates significant Au-Ag and base-metal veins (Fig. 8) along the WNW-ESE Baia Mare metallogenic zone (e. g. Ilba, Săsar, Herja, Baia Sprie, Capnic, Băiuţ). In the Ţibleş-Bîrgău Mountains base-metal veins are related to subvolcanic bodies, whereas in the Rodna Mountains they are connected with breccia pipes or replace marbles. The Căliman-Gurghiu-Harghita Mountains contain minor S (Căliman), siderite (Vlăhiţa), Hg (Sîntimbru), Au-Ag and base-metal ores. The root zones of the volcanic structures may enclose more significant ore occurrences.

Back-arc reactivazion rifting areas trending NW-SE and E-W in the South Apuseni Mountains promoted Au-Ag and base-metal deposits associated with andesite volcanics within the Brad-Săcărîmb, Almaj-Stănija, Roşia Montană-Bucium

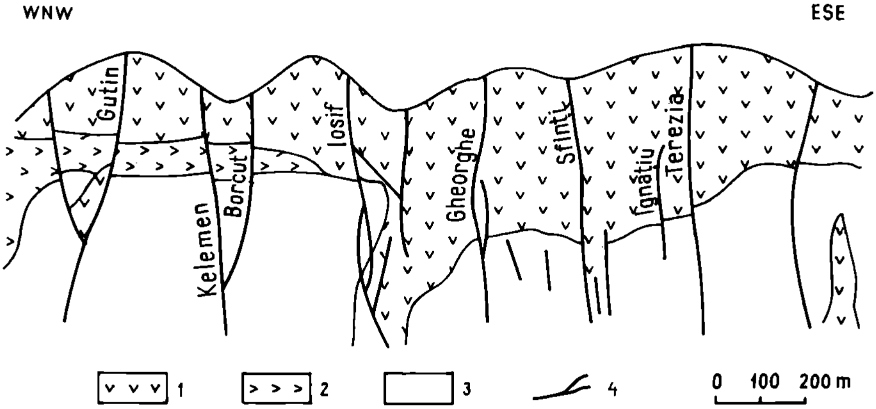

Fig. 8. Cross-section through the Cavnic ore deposit (according to IANOVICI and BORCOŞ, 1982). 1 = Pontian pyroxene andesite, 2 = Pannonian-Pontian quartz andesite, 3 = Tertiary sedimentary rocks, 4 = base-metal veins.

and Baia de Arieş districts. Subvolcanic bodies of andesitic-microdioritic composition which penetrated the volcanic piles contain polyascendant porphyry copper deposits of the diorite model. They contrast with Laramian porphyry-copper systems by lack of skarnified halo which is replaced by peripheral Au-Ag and Pb-Zn veins. The porphyry copper systems show a Cu-Au character at Tarniţa, Rovina, Valea Morii, Musariu and a Cu-Mo character at Deva and Roşia Poieni (IANOVICI et al., 1977). At Baia de Arieş significant base-metal replacement ores occur within marbles in similar setting with the above mentioned Rodna Mountains occurrences (Fig. 9).

Metallogenesis in passive margin-related settings. Restricted Fe occurrences of Paleogene age are found at Căpuş (Gilău Mountains) within epicontinental sediments. The ores are represented by limonitic oolites found in carbonatic, chloritic and glauconitic cement (VINOGRADOV et al., 1964). Such sedimentary Fe

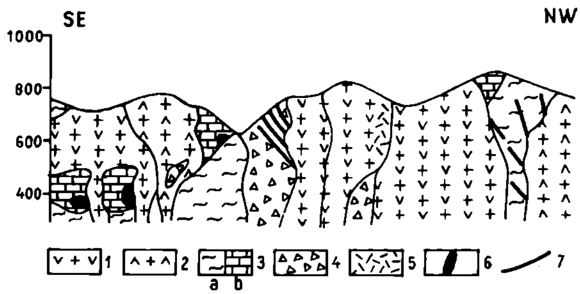

Fig. 9. Cross-section through the Baia de Arieş ore deposit (according to IANOVICI and BORCOŞ, 1982). 1 = Sarmatian amphibole subvolcanic andesites, 2 = Sarmatian biotite-amphibole subvolcanic andesites, 3 = metamorphic rocks of the basement (a = crystalline schists, b = marbles), 4 = brecciated andesitic bodies, 5 = Au-Ag breccia pipes, 6 = Pb-Zn metasomatic bodies, 7 = fault.

ores were considered to be formed on the north-western passive continental margin of the Transylvanian paleo-basin after suture of the South Apuseni island arc to the North Apuseni sialic block (CIOFLICA and VLAD, 1984).

Metallogenesis in the continental collision-related settings. Supragetic and Getic crystalline schists of the East Făgăraş and Leaota Mountains (South Carpathians) are cut by minor veins with Bi minerals, Co-Ni sulphides and arsenides, Cu minerals, galena, sphalerite, pyrite, pyrrhotite, silver and gold. VLAD and DINICĂ (1984) suggested that ore deposition took place during remobilisation connected with major Cretaceous deformations (Dobšina type). On the other hand, geophysical evidence, the NNE-SSW regional distribution of the ores and indications of metallic periplutonic arrangement in both Leaota and East Făgăraş Mountains may suggest that mineralization is provided by a deep-seated continent-continent collision belt of Erzgebirge or Cornwall type (Fig. 10).

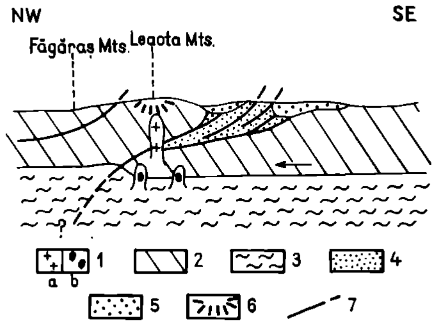

Fig. 10. Presumed continental collision magmatism and related metallogenesis in the eastern South Carpathians (according to VLAD and DINICĂ, 1984). 1 = deep-seated plutons (a = granite-alkali granite, b = ultrabasite, anorthosite), 2 = continental crust, 3 = upper mantle, 4 = Lower Cretaceous flysch ± obducted ophiolites, 5 = molasse, 6 = Co-Ni-Bi-As-Cu ores.

Metallogenesis in the post-collisional-related settings. It seems likely that a post collisional event acting in the South East Carpathians promoted sedimentary base-metal ores in Helvetian sandstones of molasse type at Jitia. On the other hand, late post-collisional rifting yielding Pliocene basalts lacks in metallogenetic importance.

Conclusions

The Carpathian structure was accomplished during the Alpine orogenic cycle. Magmatic as well as other factors intimately controlled the formation of metallic mineral deposits during the Mesozoic-Cainozoic sequence of intra-continental rifting, ocean-floor spreading, subduction, collision and eventual post-collision rifting. The major metallogenetic events are definitely associated with Laramian and Neogene subduction-related settings. It is suggested that the Laramian monzodiorite, diorite-granodiorite magmatism extracted Cu from depth and carried it upwards, whereas sialic contaminated granodiorite-granite magmatism mobilized Mo, Pb, Zn from the continental crust. On the other hand, Cu-Au and Cu-Mo differentiation of the Neogene porphyry copper seems to be explained by Au remobilization from early Mesozoic island arc tholeiites and Mo from the crystalline basement. The spatial superposition of three magmatic-metallogenetic events in the South Apuseni Mountains suggests that the inheritance-reactivization concept is to be taken into account (VLAD, 1980).

Besides the abundant Laramian skarn-porphyry copper deposits and Neogene vein-porphyry copper deposits, relations between plate tectonics and mineralization during Alpine times emphasized that numerous settings are potentially favourable for additional ore bodies. Thus mature island arc structures of the South Apuseni Mountains may contain Kuroko-porphyry copper systems whereas the roots of the East Carpathian volcanic structures porphyry copper mineralization; the geological-geophysical considerations suggest that a deep-seated continental collision-related belt may be found in the eastern part of the South Carpathians and, eventually, geological guides indicate that the Helvetian molasse of the East Carpathians could contain additional occurrences of Jitia type.

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