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THE METALLOGENIC PROVINCE OF BANAT AND ITS PLATE-TECTONIC POSITION IN THE BALKAN PENINSULA

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ABSTRACT

The metallogenic province of Banat represents one of the most interesting mineralization zones of the European continent. The present work represents the first attempt to classify all of the ore deposits of Banat from the plate-tectonic viewpoint, taking into consideration the tectonomagmatic premises which defined the structure of the thin Carpathian section.

The superposition of the Alpine metallogeny over the Protezoroic-Paleozoic basement is primarily responsible for the complexity and the diversity of the mineralization of the Banat metallogenic province. The suggested classification separates the Banat into two subprovinces, which are:

— The Old-Carpathian province, with Proterozoic and Paleozoic ensimatic ore deposits.

— The Laramide province of banatites, with porphyry copper, iron and copper tactites.

INTRODUCTION

The present work represents the first attempt to classify all known ore deposits from Banat, taking into consideration the plate-tectonic premises which define the structure of this Carpathian section.

Metallogenic relations between the ore deposits of Banat and those in eastern Serbia were also unterlined by VON COTTA, [1864, and 1878]. The problem of the petrochemical, geotectonic and metallogenic relations between Banat and those in Serbia, was clarified by SCHNEIDERHŐHN [1928]. He considered that both zones belong to the same copper province.

PETRASCHECK [1942] studied the metallogenic province in the Srednogorie Mountains in Bulgaria and later he extended his researches to the foot of the Caucasus at Hopa. Recent work published by DONATH [1952], CISSARZ [1967], POLLAK [1966], SUPERCEANU [1969], GIUŞCĂ [1967] a.o. brought many important contributions to the exact form of this metallogenic province.

The superposition of the Laramide subduction and metallogeny over the Proterozoic — Paleozoic crustal units, constitutes the main cause for the complexity and diversity of the mineralization from the metallogenic province. The classification suggested separates the Banat area into two subprovinces, which are:

— The Old-Carpathian province, with the Danubian Autochton, the Getic-, and Supragetic crustal units.

— The Laramide banatitic province.

THE OLD-CARPATHIAN PROVINCE

This province consists of Proterozoic-Paleozoic crustal units, which were regenerated by the Laramide subduction of the Moesian plate. The geotectonic evolution of the Banatian South-Carpathians was controlled by the subduction of the Archean

Carelian microcontinent, and consists of the basement of the Moesian Plate, below the mobile zone of the South-Carpathians. The differentiated major crustal domains of the Old-Carpathian province are as follow:

— the middle pericontinental-paleooceanic Danubian Autochthon
— the western Getic and Supragetic crustal units
— the Moesian plate, in the east *(Fig. 1)*.

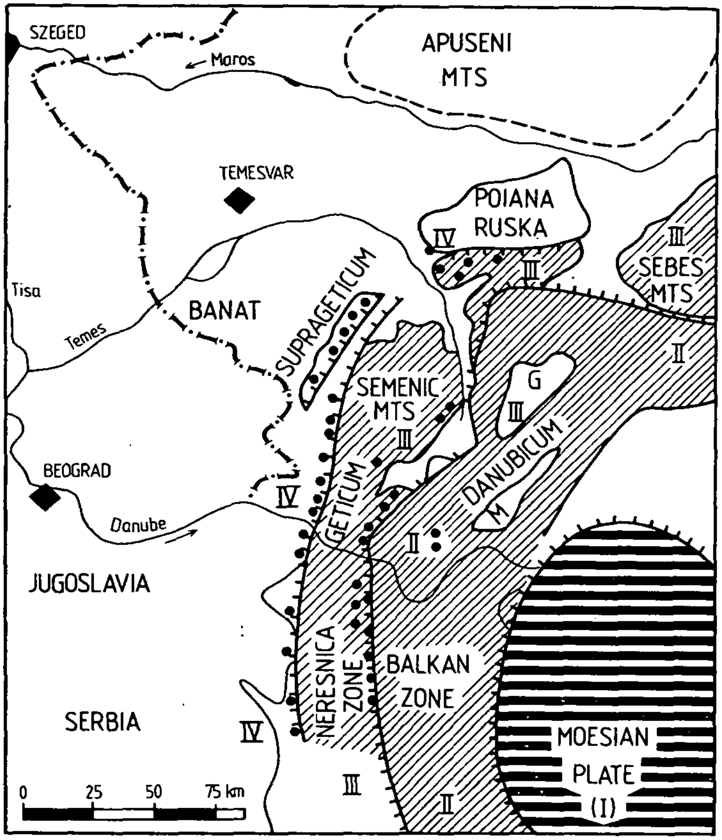

Fig. 1. The metallogenic province of Banat and eastern Serbia, and the concentric arrangement of geotectonic—metallogenic units around the Moesian plate

I The Moesian plate
II The pericontinental—paleooceanic Danubian Autochthon
III The Getic crustal nappe
G = Godeanu sheet
M = Mehedinți sheet
IV The Supragetic unit
● Laramide — banatitic ore deposits

Metallogeny of the pericontinental-paleooceanic Danubian Autochthon

The Danubian Autochthon is a pericontinental crust, thereby constituting a lateral transition between the paleooceanic crust of the west and central part of the Danube and the continental crust of the Moesian plate which at that time was part of the margin of the European continent [GRUBIC, 1974]. The Proterozoic Danubian pericontinental crustal unit, with important fossil upper mantle intercalations, with an intensive ophiolitic magmatism, occupies the southern and eastern part of Banat (Almăj, Cerna, Ţarcu, Muntele Mic and Retezat Mountains).

Proterozoic and Bretonic ensimatic ore deposits. This Danubian Autochthon contains Proterozoic metasomatic-metamorphosed deposits of iron and manganese carbonates intercalated in the carbonatitic level of the Jelova zone at Rudăria-Bănia (Fe—Mn carbonates), Topleţ (oxides, silicates, apatite) [PAPP, 1915], Sadova, Ilova, Căleanu Mountains (magnetite) and other areas. The ensimatic ore deposits of the ultrabasic magma derived from the upper mantle are localized in the Jelova—Mărul zone (dunites, wehrlites, peridotites, serpentinites, hypersthenites, gabbros and amphibolites). The Bretonic ophiolites contain chromite bodies (hundreds of occurrences) Cu—Ni mineralizations, Ni-bearing serpentinites, magnesite deposits in the Tisoviţa-Eibenthal-Plavişeviţa, Bretonic serpentinite-gabbro lopolith, numerous chrysotile and apmhibole asbestos occurrences in the Rudăria — Urda Mare Proterozoic ultrabasic lineament in magnetic serpentinite (with Pt) ranges *(Fig. 2., 4)*.

Ensialic mineralizations. The Danubian Autochthon contains ensialic mineralisation which was derived the Assynthian granites (Sfîrdinul and Cherbelezul plutons) generated from sialic mobilization up the converging margins of the Moesian plate and the Eurasian plate. The ensialic mineralization of the Danubian Autochthon are represented by the polymetamorphic iron deposit (Jablaniţa), barite lenses (Topleţ), numerous pegmatites, aplites with red feldspar and Cu, Ti, Zr, Mo, Sn mineralizations (Rudăria, Putna, Prigor) and red carbonatites with apatite, magnetite, sphene, pyrite, chalcopyrite (Rudăria) as well as Alpine quartz veins (crystals, with Cu—Pb—Zn mineralization) derived from the granite pluton of Muntele Mic (Sadova, Ilova, Arjena and Ţarcu Mountains). Pegmatites and aplites with molybdenite occur at Rudăria and Bucova. [VENDL, 1939] *(Fig. 2)*.

Periplatformal sedimentary deposits. The Paleo-Mesozoic Svinecea-Sviniţa cover contains Bathonian (limonitic) oolitic iron deposits [PAPP, 1915] at Rudăria — Bănia — Debeli Iug — Sviniţa in the Almăj Mountains and in the Stara Planina (eastern Serbia).

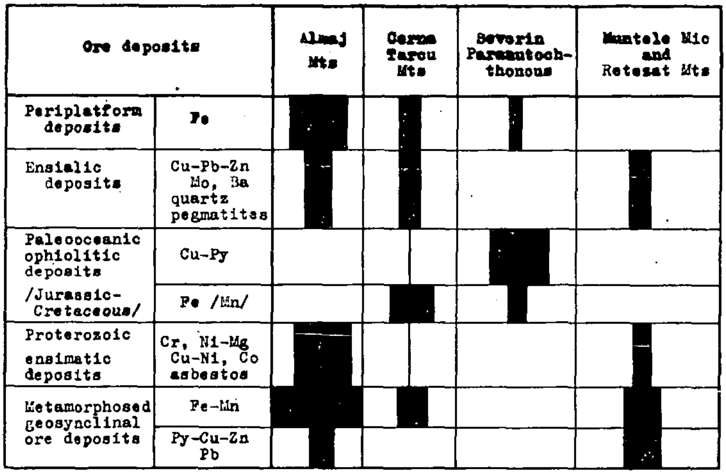

Fig. 2. Metallogenic types and ore deposits in the geotectonic units of the Danubian Autochthon

Jurassic ophiolitic ore deposits. The Upper Jurassic paleooceanic ophiolite province, is developed in the eastern external part of Banat (Severin Para-autochthon) and extends into Serbia in the Miroc Planina zone. The simatic ophiolite complex is a relict of the Upper Jurassic — Lower Cretaceous paleomicroocean ("mesoparatethys", after GRUBIC, 1974) elongated in a NE — SW direction, created by the divergence of the Eurasian plate and the lately formed Getic island arc. These relicts of oceanic crust consists of ophiolites throughout the Sinaia-Azuga beds (diabases, spilites, serpentinites, dunites, basic tuffs and cherts) named the Severin .Para-autochthon [CODARCEA, 1940], where it contains the following ore deposits:

- The volcanogenic-hydrothermal, massive pyrite-copper deposit at Baia de Aramã ($\delta S^{34} - 3.2‰$, upper mantle origin), Balta and Ponoarele.
- Disseminated magnetite nodules (5—15 cm) with Cu, Co, Fe sulphides in serpentinites at Podeni (Suliţa and Plătica Mountains), Isverna, Obîrşia Cloşani, and chrysotile asbestos occurrences.
- Exhalative-sedimentary iron and manganese mineralization (Balta Cireşul).

This ophiolitic complex extends to Eastern Serbia, to the known Deli Jovan Mountains, which is considered a typical contemporaneous and fossil oceanic crust, with chromite and Cu—Bi—Au mineralizations. The Danubian Autochthon continues southwards into Serbia, passing in the Balkan zone, where it contains iron deposits connected with granites (Rudna Glava, Trnaica), copper-bismuth mineralization (Aldinaţ, Jasicovo), tungsten (Tanda), molybdenum (Gornjane), gold (Deli Jovan) and Pb—Zn—Ag—Sb mineralization *(Fig. 5)*.

Metallogeny of the crustal Getic nappe

The Getic crystalline area is a typical Proterozoic continental crustal unit and has been developed by the central and northeastern Banat (Semenic, Pioana Rusca and Godeanu Mountains, *Fig. 1)*. The Getic crystalline formations were folded and metamorphosed during the Dalslandian metamorphism [SAVU, 1978]. The Getic meso-katazonal polymetamorphic crystalline schist (gneisses, mica schists, amphibolites) anticline include in the axial zone the Sicheviţa-Poniasca-Gosna granite pluton and numerous pegmatites generated through the Dalslandian anatectic migmatization in the deeper parts of the sialic crust and the collision and subduction processes of the Moesian plate under the Carpathian mobile zone *(Fig.1)*. The Dalslandian Getic crystalline area contains the following deposits:

Regional-metamorphic, kyanite deposits, in kyanite-staurolite mica schists (Semenic Mountains), sillimanite gneisses (eastern Semenic and Godeanu Mountains) and graphite occurrences (Bozovici).

Geosyncline-metamorphosed ore deposits. The Getic nappe contains Proterozoic geosyncline-polymetamorphic iron deposits (magnetite) Armeniş, Băuţari, Valea Fierului, connected with the Dalslandian initial magmatism (amphibolites) and crystalline dolomites, in the lower Getic nappe level, manganese deposits (silicates, carbonates, jakobsite) in the northern part of the Semenic Mountains (Delineşti, Lindenfeld, Rugi, Ohabiţa) connected with amphibolites and quartzite (median level of the Getic crystalline basement) *(Fig. 3)*.

Ensialic deposits. A characteristic feature of the Getic continental crust are the numerous Dalslandian pegmatites, oriented NE—SW N—S and concentrically situated around the boundaries of the Moesian plate. These anatectic migmatization pegmatites (hundreds of occurrences) with feldspar, muscovite, beryl, columbite, tantalite, montebrasite, apatite, and other minerals are situated at Teregova, Armeniş, Mehadica, Topleţ, Pătaşi, Crîjma, Băuţeri; concordant and discordant in the lower gneiss level. Kyanite and graphite pegmatite occur at Dalci (eastern Banat).

Polymetamorphic tactites, with diopside, epidote, phlogopite, biotite and Cu, Pb, Zn, Mo mineralization at Armeniş, Sadova, Godeanu Mountains, in contact zones between aplites, pegmatites with crystalline dolomites.

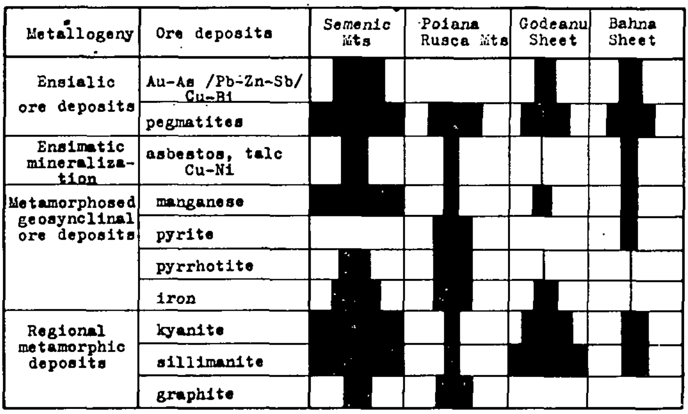

Fig. 3. Metallogeny and ore deposits in the geotectonic units of the Getic crystalline mass

The hypothermal gold mineralizations (veins, lenses) in gneisses with quartz, arsenopyrite and Pb—Zn—Sb mineralizations at Văliug Bozovici and Cocora Mountains (Godeanu Mountains) connected with the acid differentiates of the Proterozoic granite [Codarcea, 1972]. In the upper Buceaua ensimatic level, the Getic nappe contains nickel ore veins (chrysoprase a. o.) at Bozovici (Lighidia, Agris, Tăria valley).

The Getic crystalline area continues southwards, passes the Danube into eastern Serbia and crosses into the Neresnica zone, which also contains numerous pegmatites and Au—W (scheelite), Sn, Pb—Ag—Zn—Sb mineralization (Vlagoev Kamen, Tanda, Bosilkovac, Zeleznic, Brodite, Seliste) [Cissarz, 1967]. *Fig. 5* presents the comparison between the metallogeny of Neresnica and the Getic Semenic zones.

Metallogeny of the Supragetic crystalline

The Supragetic intra-Carpathian epizonal schists zone contains Hercynian and Caledonian crustal units (Locva Mountains, Dognecea Mountains and the northern part of Poiana Rusca) *(Fig. 1)*. This geotectonic unit contains in the south geosyncline (volcanogenic-sedimentary) iron-carbonate deposits (Teliuc, Ghelar, Vadul Dobrii), connected with albite-chlorite schists (Devonian, initial diabase volcanites) [Kräutner, 1970] and metamorphosed hematite deposits (Poieni, Tomeşti, Iazuri, Lahn-Dill type) [Papp, 1915]. The northern part of Poiana Rusca contains in the Padeş schists level, volcanogenic-hydrothermal metamorphosed lead — zinc deposits (Rammelsberg-type) at Muncelul Mic, Muncelul Mare with metarhyolites and copper mineralization at Veţel *(Fig. 3. 4.)*.

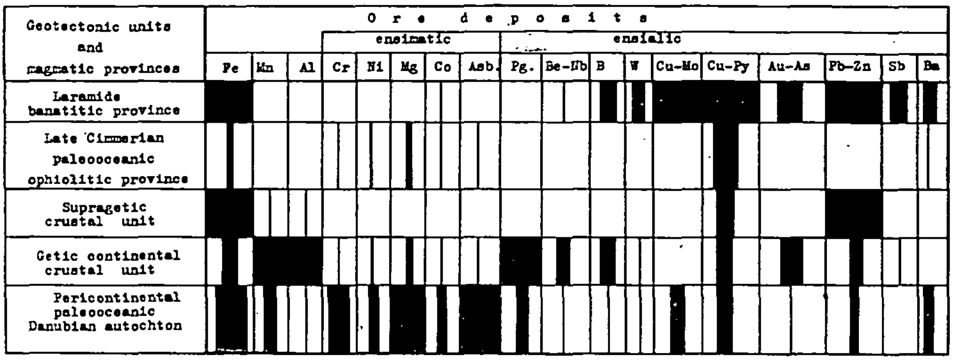

Fig. 4. The principal plate tectonic — metallogenic units of the Banat and the extension of ore deposits

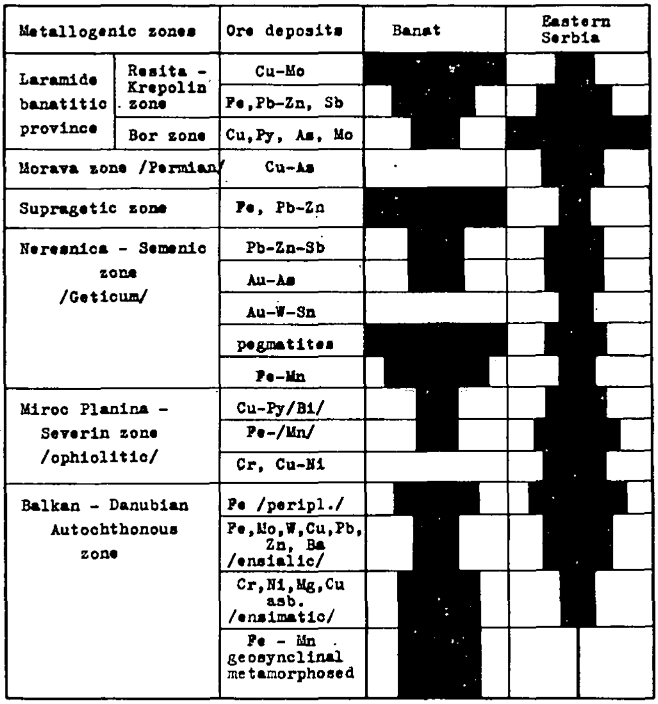

Fig. 5. The metallogenic zones and extension of ore deposits in Banat and eastern Serbia

THE LARAMIDE — BANATITIC PROVINCE

The Laramide province of the banatites forms the northwestern part of the Tethyan panglobal copper-molybdenum belt. The seismo-tectonomagmatic lineaments of the banatitic province are tectonically generated on the marginal zones on the deep fractured Proterozoic-Paleozoic crustal scales (Geticum, Suprageticum, Danubicum) as a result of the Laramide subduction *(Fig. 1)*. The copper tactites and porphyry copper deposits are localized in the Laramide igneous rocks (mainly in subvolcanic granodiorites and monzodiorites) and the contacts with the Mesozoic limestones of Reşiţa zone.

The origin of the hybrid, copper rich banatitic multiphase and polyfacial magmatism is genetically related to the Laramide subduction of the pericontinental and paleo-oceanic crust of the Danubicum and the Moesian plate under the Geticum island arc. Further in the Backzone of the subduction, under the Reşiţa-Krepolin fault zone *(Fig. 1)* banatitic magmas were generated by the same process but at greater depth (plutonic granodiorites).

The Sr^{87}/Sr^{86} and Al_2O_3/K_2O ratio of banatites indicates contamination of initially upper mantle simatic material by remelted pericontinental crust material (magmatic crust/mantle mixture). The generation of the calc-alkaline banatitic igneous complex and the associated ore deposits occurred also with the partial melting of subducted oceanic crust and the penetration, along deep fracture (West- and East-Banatian Lineaments, oriented N—S and NE—SW, above the Banatian Benioff-zone. The important seismo-tectonomagmatic lineaments of the banatitic province (Carpathian longitudinal deep fractures) concentric with the boundaries of the Moesian plate, are as follows:

The west Banatian main lineament ("Oraviţa lineament")

This lineament, oriented N—S *(Fig. 1)* is a deep crustal fracture with seismic geothermal and magmatic-metallogenic manifestations in the western part of the Reşiţa zone, in tectonic contact with the Suprageticum (epizonal schists), contains two segments:

The Bocşa-Surduc Segment (NE—SW) with plutonic banatites (granodiorites, granites, diorites, gabbros) generated the classical pyrometasomatic iron deposit at Ocna de Fier (including ludwigite, copper, lead-zinc and gold mineralization) [Codarcea, 1931; Kissling, 1968] and the lead-zinc deposit at Dognecea (in hedenbergite skarns). The gabbros with (vanadium-bearing) titanomagnetite disseminations explored at Surduc, are derived from the upper mantle.

The Oraviţa — Moldova Nouă Segment (N—S) with subvolcanic banatites (porphyric quartz-monzodiorites, granodiorites) generates copper tactites and porphyry coppers:

The Moldova Nouă ore deposit complex (at Danube, 40 km NW from Majdanpek) with the great porphyry copper deposits of Suvorov Valley (open pit) in silicified argillitized and sericitized porphyritic quartz diorites. The mineralization contains chalcopyrite impregnations and veinlets, bornite, pyrite, molybdenite, tetrahedrite and titanomagnetite. The Moldova Nauă mining district contains copper-pyrite tactite bodies at Suvorov (paragenesis: pyrite-chalcopyrite–magnetite) realgar-auripigment occurrences (Florimunda Mine) and Cu—Pb—Zn mineralizations at Vărad ar Danube [Gheorghiţă, 1970].

The Stinăpari Plateau. The stratiform copper tactite deposits ("Manto type") are found between Jurassic limestones and a horizontal banatite sill (porphyritic biotite-hornblende granodiorite). The copper ores of the Stinăpari Plateau are characterized by the high temperature paragenesis: pyrite-charlcopyrite-pyrrhotite-magnetite-hematite in andradite-epidote tactites. The Cu—Mo mineralization of porphyry type has been reported in the banatite.

Sasca Montana. The well known ancient copper tactite deposit of Sasca Montana (George valley) is a classical pyrometasomatic copper deposit (Clifton Morenci type) with the paragenesis: bornite-digenite-chalcocite-tetrahedrite-molybdenite in garnet-vesuvianite tactites. The colloform textures between bornite-chalcopyrite-digenite-tetrahedrite-sphalerite-melnicovite are uncommon in pyrometasomatic copper deposit around the world [SUPERCEANU, 1969]. The molybdenite of high rhenium content (0.13%Re) and associated with colloform tetrahedrite, melnicovite, jordisite, chalcopyrite and bravoite, formed at low temperature.

Ciclova Montana. The copper tactite deposit at Ciclova, connected with sienodioritic, monzodioritic and sienogabbroidal banatites contains pyritic copper bodies (Lobkowitz Mine), gold-bearing arsenopyrite bodies with scheelite and Co, Bi, Te, Ni, Mo mineralization (Baron and Speis ore bodies) in polyascendent garnet-diopside-wollastonite- and berylium-bearing vesuvianite skarns (0.2—2.5% BeO), accompanied by sulphurous geothermal springs (Lobkowitz Mine) and porphyry copper.

Oravița an old mining district with the Clementi Mine, Cu—Mo mineralizations in banatites, aplites, veins and skarns [SUPERCEANU, 1975], Racovița valley (Cu—Mo—Co-scheelite) and the Rochus Mountains with Cu—Co—Ni—Bi—Te—Au—W (scheelite) mineralization (Elisabeth Mine).

The Maidan (Bradisorul de Jos) area, with porphyritic Cu—Mo mineralization in pyritized and silicified porphyritic biotite-granodiorite (Fruntea, Miclea Mountain, Maidan banatite open pit) and hydrothermal pyrite-arsenopyrite (cobalt-bearing)-galena-sphalerite-antimonite-berthierite veins in crystalline schists (Perciului and Cuptorului valley).

The gabbro enclaves (with vanadium-bearing titanomagnetite disseminations) especially the spheroidal olivine gabbro nodules (0.1—2.0 m^3) in the banatites (Surduc, Bocșa, Oravița), the Fe—Co—Ni mineralization in skarns and the cobalt content in the pyrites and arsenopyrites is an argument for the prinordial upper mantle origin of the banatitic magma.

The west Banatian main lineament, which continues southward from the Danube in Serbia, passes to the Ridanj — Krepolin lineament, with the Cu—Fe deposits (Ridanj-Golubac), Kukaina (Pb—Zn—Au—Ag), Mo (Reșcovița) and Brezovac-Osanica (Sb) in subsequent banatitic dacites.

The East Banatian Lineament (Rudăria-Majdanpek lineament)

This NE—SW oriented metallogenic lineament is concentric with the boundaries of the Moesian plate and delimits the Danubian Autochthon and the Getic crustal units. The Geticum were subducted at the Danubicum *(Fig. 1)* with generation of banatitic hydrid magma. The banatites are represented by shallow consolidated subsequent subvolcanites (porphyritic quartz-monzodiorites, porphyritic quartz-diorites, dacites, andesites and tuffs).

The east Banatian lineament is continued southwards into Serbia *(Fig. 1)* to the Timoc (Bor) eruptive complex and copper province, with the re-known copper deposits at Bor, Majdanpek, Veliki Krivali a.o. The East-Banatian lineament contains the following ore deposits:

The Liubcova ore deposit is located 30 km north of Majdanpek and is connected by porphyritic quartz-monzodiorites and contains the pyritic copper tactite deposit at Ilileci Mountain in Upper Cretaceous (Cenomanian) marble, associated with porphyry coppers. The tactite ore contains pyrite, chalcopyrite, pyrrhotite, sphalerite, hematite and other minerals. In Prasnic valley there are the gold-bearing arsenopyrite occurrences. The porphyry mineralisation contains pyrite, chalcopyrite, bornite and molybdenite in silicified and epidotized porphyritic hornblende-monzodiorites.

The Sopotul Vechiu — Ravensca district contains the pyritic complex and barite mineralizations at Purcar Mountain and Nasovăţ valley in epidote-bearing porphyritic quartz-monzodiorites and andesites in contact with the Cenomanien marbles of the Culmea Sicheviţii Cretaceous syncline in epidote-garnet skarns. Porphyry copper mineralizations are identified at the Purcar Mountain.

The Lăpuşnicul Mare ore deposit contains porphyry copper in the Cornilor Mountains, in silicified quartz-diorites and epidote hornfels with pyrite, chalcopyrite, pyrrhotite, specularite and arsenopyrite.

Borlovenii Vechi. The pyritic occurrences at Borloveni, in the Nera valley (Botul Calului, Nergăniţa valley and Bănieşu valley) contains pyrite, pyrrhotite, chalcopyrite and arsenopyrite ores in andradite skarns, generated by subvolvanic andesites, in contact with crystalline schists.

The Luncaviţa-Mehadia area in eastern Banat contains small porphyry copper mineralizations in silicified and chloritized-sericitized andesites and quartz-diorites [GUNNESCH, 1975] in the Dalia and Satului valley.

The Poiana Mraconia — Dubova zone in southern Banat, in the internal part of the Danubicum, contains:

— Porphyry Cu—Mo mineralization in porphyritic biotit-granites and granodiorites, accompanied by molybdenite-bearing aplites and pegmatites. Accentuate analogies with the Clementis molybdenum mineralization from Oraviţa [SUPERCEANU, 1975] exist. Important occurrences of Poiana Mraconia, Faţa Strîmba, Stafetsky valley a.o.

— Iron tactite mineralization, with hematite, magnetite, pyrrhotite in epidote-garnet tactites (Satului valley, Dubova).

— Caledonian stratiform pyritic Cu—Pb—Zn—As—Sb—Au-ankerite-barite in the crystalline schists of the Corbu zone with crytalline limestone intercalations Poiana Mraconia [NICKMANN, 1900].

THE POSITION OF BANATITIC PROVINCE IN THE TETHYAN PANGLOBAL COPPER—MOLYBDENUM BELT

The Laramide banatitic province is a northwestern part of the Tethyan (Eurasian) copper-molybdenum belt. It is located at the southern of the Eurasian plate up to 10.000 km. The Laramide-Pyrenean and late volcanic copper deposits are associated with the volcanic-intrusive complexes, composed of the calc–alkaline suites. The behind trench lineaments and the island arc environments are principal geotectonic conditions for metallogenic provinces [SUPERCEANU, 1971].

This copper belt consists besides numerous of porphyry copper deposits, massive stratiform copper deposits, copper tactites and replacement Cu—Fe—Pb—Zn—Sb deposits accompanied by gold.

The main metallogenic provinces of this copper belt are as follows: the Banat province, the Eastern Serbian (with porphyry copper at Majdanpek, Veliki Kriveli, massive replacement copper deposits at Bor), the Srednogorian province (Medet, Assarel, Elacite, Radka), the Eastern Pontids (Murgul, Bakirkay, Ulutas), the Lesser Caucasus (Young Alpidic porphyry Cu—Mo deposits at Ancavan, Agarac, Kadjaran, Daskakert and others), the Iranian province (Talmesi, Meskani, Sar Cheshmeh), the Pakistan province (Chagai, Saidak, Robak) and the Tibetan-Burmese province (Monywa) on Sumatra in connexion with the Pacific copper belt.

The Tethyan belt is comparable with the Pacific copper belt, which contains numerous great porphyry copper deposits in the western Canada Rocky Mountains, Mexico, Chile, Peru and Philippines.

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