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# MAJOR ALPINE STRUCTURES AND Cu-PORPHYRY MINERALIZATION IN THE SERBO-MACEDONIAN MASSIF

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A b s t r a c t: The geodynamic evolution of the Serbo-Macedonian massif can be reviewed in few geological and geotectonic epochs, but very specific is the Cenozoic evolution from geodynamic, geotectonic, structural, magmatism and metallogenetic point of view. The Cenozoic longitudinal structures are deep in their origin and represent a boundary to the Vardar Zone on the one side and Struma Zone on the other side. Morphostructural forms of different rank and intensity are of high importance for the spatial distribution of the ore mineralization (Kratovo-Zletovo Pb-Zn-Cu ore district, Bucim-Damjan Cu-Au-Fe ore district, Bukovik-Kadiica Cu-Au-Ag-Fe ore system etc.). Predominant structures within the Serbo-Macedonian massif are those with NW-SE direction, which served as orebearing systems too (ore zone Besna Kobila-Osogovo-Tasos and metallogenetic zone Lece-Chalkidiki).

**Key words:** Serbo-Macedonian massif; morphostructures; Cenozoic activization; polymetallic mineralizations; ore systems

## INTRODUCTION

Serbo-Macedonian massif (SMM) represents remarkable geotectonic unitwithin central parts of the Balkan Peninsula (Dimitrijević, 1958) where have been confirmed numerous structures, morphostructures and significant ore mineralizations (Janković and Petković, 1974; Janković et al. 1980; Serafimovski, 1990). From the geological point of view the SMM has been built mainly of gneisses, mica-schists and Paleozoic schists, while the structural construction has been dominated by plicative structures and disjunctive ruptures. Tertiary magmatism, intruded along Cenozoic structures (Arsovski and Ivanov, 1977; Serafimovski, 1990, 1993), has been related to the polymetallic mineralization of Pb, Zn, Cu, Au, Ag, AS, Sb etc. (Serafimovski et al. 1995; Janković and Serafimovski, 1997 etc.). Significant morphostructural forms in the central parts of the SMM have been related to the productive mineralizations of Cu-Pb-Zn (Plavica type), Cu-Au (Borov Dol type) and Cu ± Au ± Ag ± Mo (Bukovik-Kadiica type). Neotoectonic structures are of SW-NE to E-W direction and within this area they are not related to the mineralization, but they are just seismically active.

## REGIONAL GEODYNAMIC EVOLUTION OF THE AREA OF CONSIDERATION

From Paleogene to Recent time, Macedonia was part of the South Balkan exten-sional region, the northern part of the Aegean extensional regime. Extension began in the middle to late Eocene in eastern Macedonia with the formation of a NNW-trending east-tilted half graben lying east of a forearc basin in central Macedonia.

The tectonics of Macedonia from the late Eocene to the present is dominated by two periods of regional extension separated by a short interval of shortening deformation in late Oligocene–early Miocene time. Extensional deformation in Macedonia is part of the broader South Balkan extensional regime that in addition to Macedonia affects northern Greece, Bulgaria, Albania, Serbia, Montenegro, and probably parts of southwestern Romania (Fig. 1; Dumurdžanov et al. 2005).

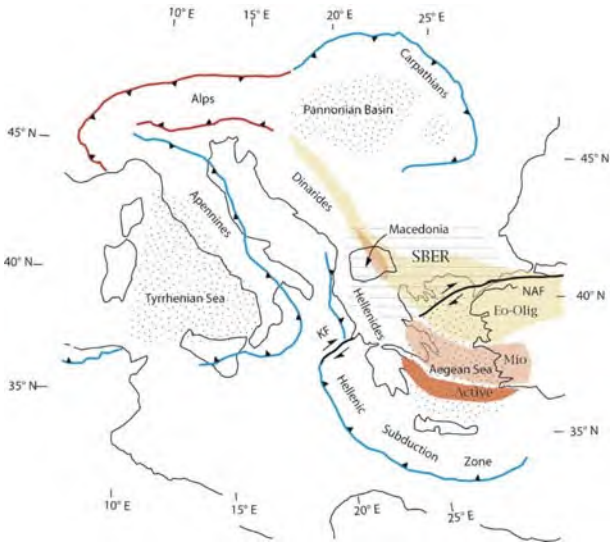


**Fig. 1.** Simplified tectonic map of Eastern Mediterranean region showing Southern Balkan Extensional Region (SBER; horizontal lines) in relation to selected tectonic features (Dumurdžanov et al. 2005).
Retreating subduction zones (blue) and related areas of backarc extension (dotted pattern) and advancing subduction zones (red) are highlighted. In Balkan region, position of the volcanic arcs of Eocene-Oligocene age (Eo-Olig: yellow), Miocene (Mio: pink), and Pliocene to Recent (Active: red-brown) are shown. The location of Macedonia is outlined. KF – Kefalonia fault zone; NAF – North Anatolian fault zone

Development of the extensional system was diachronous throughout the South Balkans and was related not only to changes at the boundaries of the extensional system, but also to changes in lithospheric rheology. This paper develops the late Eocene to Recent tectonic evolution of Macedonia and relates it to our evolving understanding of the regional South Balkan extensional regime.

Most of the understanding of the tectonic evolution of Macedonia comes from the study of the numerous Cenozoic sedimentary basins that contain the record of its extensional history. Unfortunately, the deeper parts of many of the sedimentary basins of Macedonia are poorly exposed and covered by Quaternary deposits. Thus, much of the data from these basins come from drill holes and limited surface exposures, and the three-dimensional framework of these basins is poorly known.

The crust that underlies the Cenozoic basins of Macedonia has had a long and complicated evolution, and structures within the pre-Cenozoic basement rocks have affected the development of some of the basins. Macedonian pre-Cenozoic basement consists of five major tectonic units from west to east: the Chukali-Krasta zone, the Western Macedonian zone, the Pelagonian massif, the Vardar zone, and the Serbo-Macedonian massif.

The Serbo-Macedonian massif (SMM) consists of Riphean/Cambrian mafic plutonic and volcanic rocks and early Paleozoic schist and phyllite all intruded by large bodies of Paleozoic granite. With the exception of the north-plunging nose of the Pelagonian anticlinorium, the structures in the pre-Cenozoic basement rocks are dominated by NW-trending foliation, folds and faults that form an important crustal anisotropy that controlled many of the basin bounding faults in Cenozoic time.

## CENOZOIC STRUCTURES AND MORPHOSTRUCTURES

The detailed scientific studies and morphostructural analysis have enabled us to understand the processes which preceded the formation of the zone of Cenozoic activation. Contribution to the more complete understanding of the Cenozoic activization and definition of real longitudinal structures and large morphostructural segments at the Balkan Peninsula was in given in workings of Janković and Petković (1974); Petković (1978); Kocneva et al. (1978), Janković et al. (1979); Serafimovski (1993); Janković and Serafimovski (1997); Serafimovski et al. (1997); Serafimovski and Jelenković (1998); Tomson et al. (1998); Tomson et al. (2004); Burchfiel et al. (2008.).

The zone of Cenozoic autonomous activation of the Balkan Peninsula is characterized by a specific structural plan, multiphase volcanic-intrusive magmatism and interesting mineral deposits.

Striking transcurrent faults can be recognized from air and satellite pictures, striking in the same direction as the zone of activation, as well as systems of smaller parallel faults, systems of diagonal jagged faults and systems of straight, tension faults. A special characteristic of the zone of autonomous activation is its many ringlike structure. These megastructures correspond to broad, gentle arches, are elliptical or circular in shape and have a diameter of 60 to 100 km (Petković et al. 1982). Their internal structure features a wealth of forms. They are built of concentric ringlike segments, and sometimes have the appearance of a coil. Central parts are usually raised, while the other rings are alternately lowered and raised. The

radially arranged faults separate internal parts of the megastructure into sector blocks. These structures are contoured along the periphery by depressions which are either bow-shaped or oval-shaped. Within the megastructure there are numerous smaller ringlike forms ranging from several hundred meters to a few kilometers in diameter (Fig. 2).

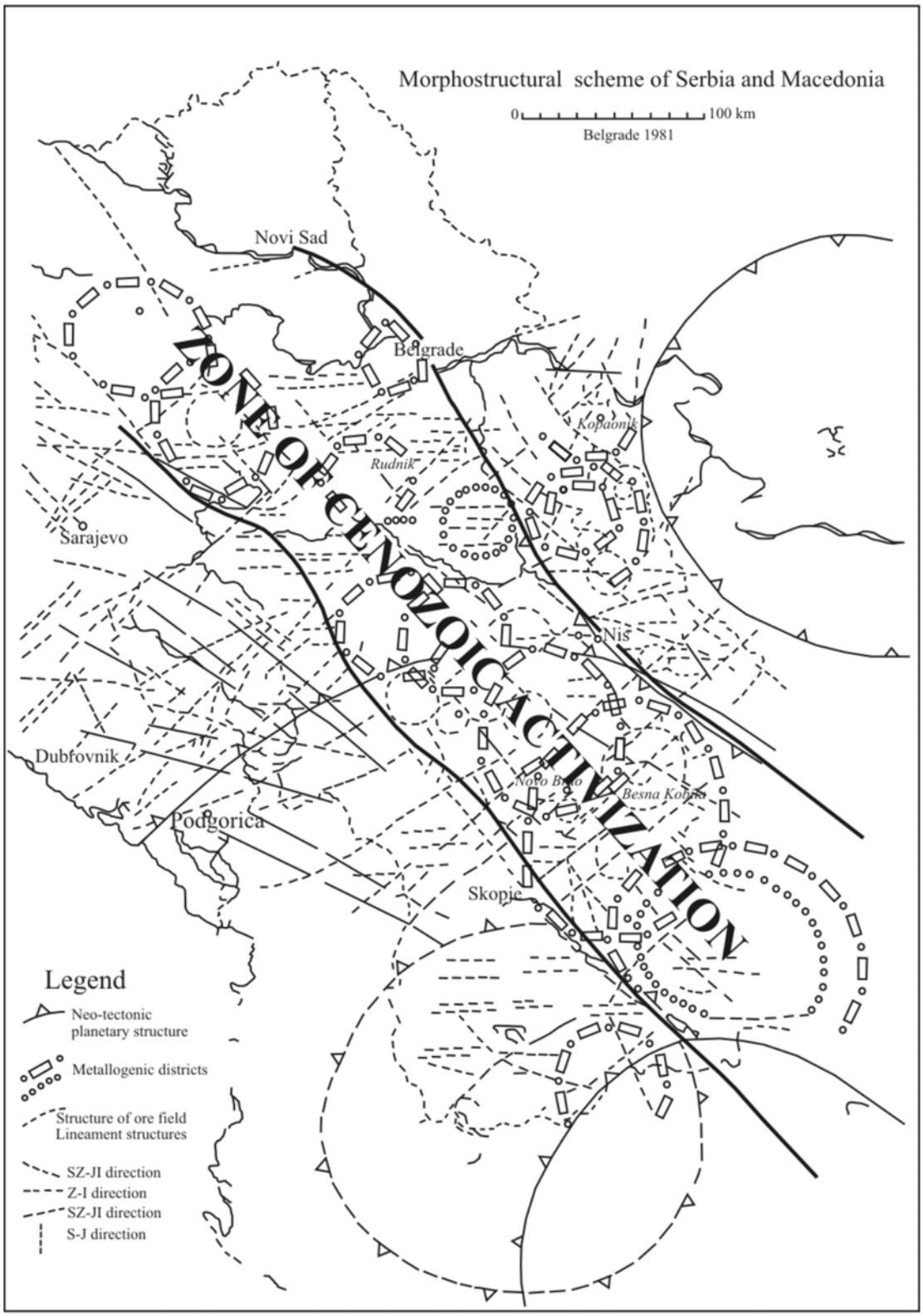


**Fig. 2.** Morphostructural sketch of Serbia and Macedonia (Petković et al. 1982)

The first signs of magmatic activity in the zone of Tertiary autonomous activation had already occurred at the end of the Eocene, but it is still not clear what connection they have with this zone. The magmatism culminated in the Miocene, while it gradually calmed down in the Pliocene, occasionally extending into the Quaternary. The magmatic rocks correspond to the volcanic-intrusive granodiorite complexes chemically they belong to the Ca-alkali rocks and in later phases are rich in potassium. Besides dacite-andesites, we also find trachyandesites, quartz-latites, latites, trachybasalts, trachytes and subordinate leucite roks (lamprophyric facies). The rocks are accompanied by pyroclastics, agglomerates and breccia. Tuffs are extremely rare. Intrusives of quartzdiorite, granodiorite and quartzmonconites are, in principle, synchronous with analogous volcanic rocks. Magmatic rocks are consolidated at the subvolcanic-volcanic level, in the process of which plutons are formed as "high plutons". According to more recent ideas, granites in the zone of autonomous activation were formed by metasomatic transformation of granodioritic plutons.

There are numerous and varied mineral deposits in the zone of Cenozoic autonomous activation. Interesting occurrences of tin and niobic tantalum are the only ones genetically linked with the granites (Cer, Bukulja). All the other endogenous deposits are paragenetically linked with the volcanic-intrusive complexes of granodioritic magma. The magnetite deposits (Suva ruda type) magnetite and hematite (Damjan type) – belong to typical metasomatic scarns. The copper deposits are either porphyric (Bucim) or vein-impregnation (Zlatica, Plavica). The molybdenum deposits are stockwork impregnated (Mackatica). The lead and zinc deposits are of scarn type (Rudnik), hydrothermal-metasomatic (Sasa, Toranica) or vein type (Zletovo). The antimony deposits are usually monomineral (Krstov Dol), but there are also transitions to lead-antimony, arsenic-antimony deposits.

Logical metallogenic analysis was made possible for the first time by the distinguishing of the megastructures in the Tertiary autonomous activation zone. Thus the megastructures correspond to the ore districts and coincide with the centres ofmagmatic activity, while the distribution of mineral deposits in them is found to be distinctly laterally zoned. The lesser ringlike structures correspond to the structure of the ore fileds or mineral deposits, as we are showing that later on the Bukovik-Kadiica polymetallic ore system.

## SOME MORPHOSTRUCTURES RELATED TO THE CENTRAL PART OF THE SERBO-MACEDONIA MASSIF

From the general point of view the Macedonian territory have passed through the detailed geological evolution. One part of the territory of the Macedonia belongs to the SMM and Pelagonian massif as old crystaline complexes. These two complexes are divided by the riftogene Vardar zone, which has been represented by ophiolite melange and Jurassic and Cretaceous molasse sediments. Within the SMM dominate Precambrian, Riphean-Cambrian and Paleozoic rocks.

The Cenozoic tectono-magmatic activizitation happened in the eastern parts of Macedonia and has been manifested by deposited structural elements in the existing relief and occurrence of volcanogene-intrusive magmatic complexes in conditions of disseminated spreading. In frame of the newly formed structures dominate fissure zones of lineament type, riftogene zones with emphasized concentric structures of different sizes etc (Fig. 3).

Serbo-Macedonian massif as a remarkable geotectonic unit has been built of two structural-lithological complexes or more precisely two metamorphic complexes (upper and lower). Lower metamorphic complex is represented by highly metamorphic rocks such as gneiss, amphibolites followed by quartzites, marbles and migmatites. Upper metamorphic complex is lying trangresivelly over the lower complex. It is repreented by greenschist facies, where dominate chlorite, chlorite-sericite, chlorite-amphibolite and graphite schists and quartzites. These complexes were intruded by different types of granitoide intrusions during the Baikal, Caledonian, Herzinian and Alpine cycle. Metamorphic rocks represented as complex forma and cumulates have direction NW-SE and sometimes are forming submeridian flexures.

Cenozoic activization at the territory of the Republic of Macedonia enclosed the most complex geotectonic units such as Vardar zone and SMM. Its occurrence is mainly along fissures of general NW-SE direction and activated meridian cracking zones and faulting systems of general NE-SW direction. In a such conditions came to complete re-

distribution of the lineament structures network when on the main direction of Mesozoic structures NW-SE (340°) occurred fault system of the same direction but slightly different angle (320°). Later ones determined the structural plan of the area of the Cenozoic activization. The results from the satellite images and morphostructural analysis of modern relief allowed determination of three zones of similar direction, mainly NW-SE (Fig. 4).

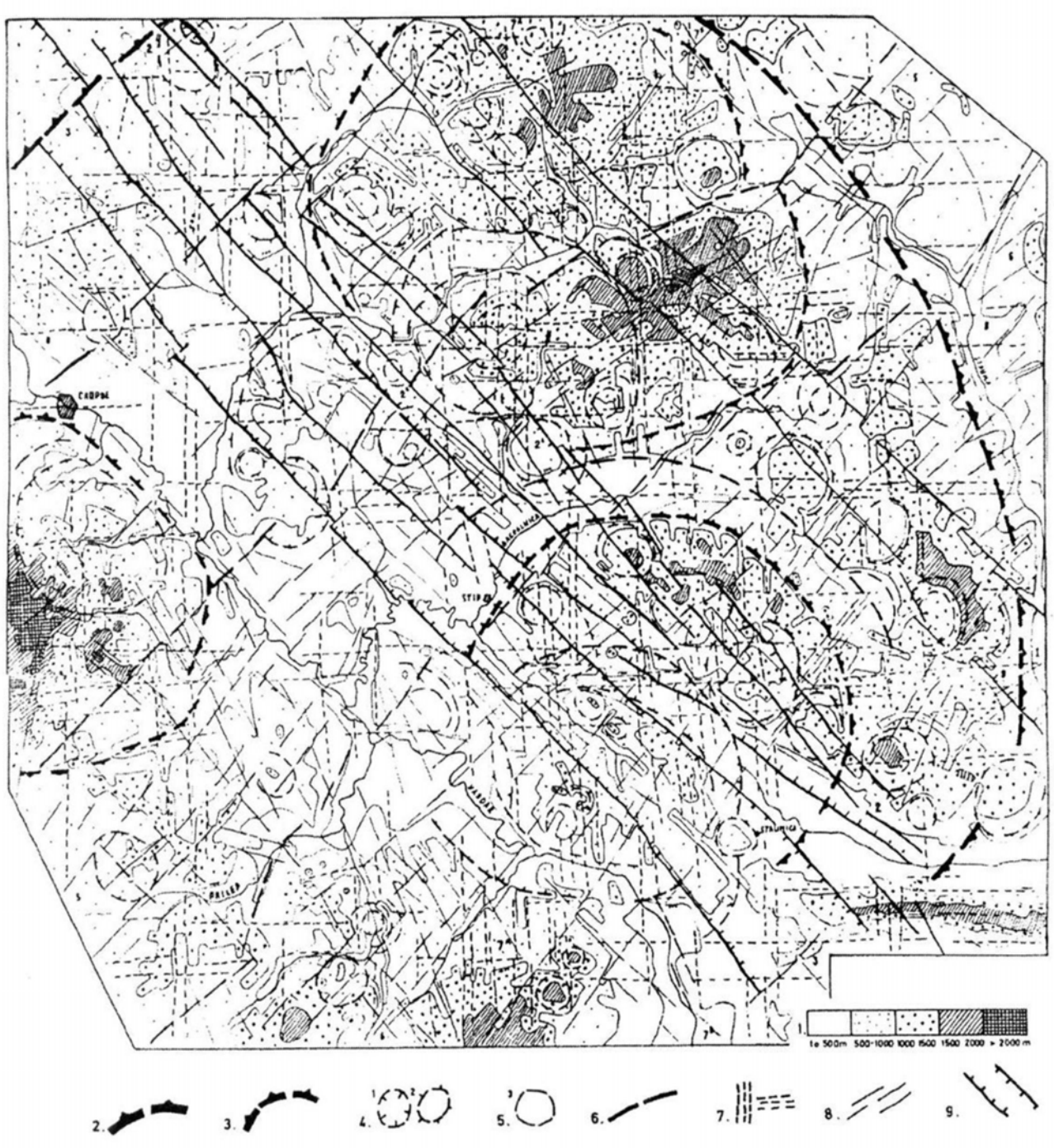


**Fig. 3.** Morphostructural scheme of the Eastern Macedonia
1) Height peak, 2) Boundary of Macedonian dome, 3) Boundary of local dome, 4) Boundary of concentric structures, 5) Occurences of structures by satellite images, 6) Faults, 7) Faults zone systems of ortogonal strike, 8) Zones of oblique cuts of N-W strike.