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DEPOSITS AND OCCURRENCES OF MOLYBDENUM IN SURDULICA ERUPTIVE MASSIVE AREA IN SOUTHEAST SERBIA

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ABSTRACT

In the area of Surdulica eruptive massive and its margin several deposits and occurrences of molybdenum are known. Mačkatica molybdenum deposit, within this complex, according to the number of its ore bodies, belongs to significant deposits, not only in Serbia and Europe, but in the world also. In the geotectonic sense this area belongs to Serbian-Macedonian mass, and in metallogenetic view it is a part of Besna Kobila-Osogove zone.

Metallogeny of this zone is connected with the processes on Neo-Alpine tectonomagmatic activity, actually Tertiary (Oligocene-Miocene) magmatism of granodioritic composition, featured by the presence of Mo, Cu, W, Zn, Pb mineralizations, with significant ore reserves, especially molybdenum, lead and zinc.

Mo-mineralizations are spatially found in dacites and schists or in their contact, and rarely in granodiorites. Concentrations of molybdenum as a rule increase in hydrothermaly altered rocks, meaning that the altered rocks are geochemicaly most favorable environment for the deposition of molybdenum. From the aspect of genetic features and morphostructural types of mineralizations, the occurrences and deposits in Surdulica eruptive massive area belong to: hydrothermal stockwork-impregnation, vein and porphyry type of mineralizations.

INTRODUCTION

The rim of Surdulica eruptive massive represents an interesting area in view of molybdenum deposits. It covers a surface of approximately 220 km^2 in southeast Serbia, stretched about 25 km along its longer axis that strikes almost north-south. In places its width is up to 12 km. The massive continuously extends from Vrla river in the north to Novi Glog in the south (Fig. 1). Geotectonically the massive belongs to Serbian-Macedonian mass, while metallogenetically it belongs to BesnaKobila-Osogovo zone. This ore zone begins near Ruplje village and Bistrica and Vlasina river in the north, and extends over Mačkatica, Besna Kobila and Osogovo to Thasos in Greece where it disappears in Aegean sea. (Janković, 1967, 1990; Jelenković, *et al*., 1997; Serafimovski, 1993; Simić, 2001). It is featured by numerous metal deposits, especially lead, zinc and molybdenum.

Surdulica massive was intruded during Neoalpine cycle, unconformably into crystalline schists of Vlasina complex. It is mostly composed of medium to coarse grained granodiorites and monconite granites that make up the basis of the massive. In places they are intruded by granodioriteporpyrites and quartzdioriteporphyrites, the vein varieties of granodioritic magma. Weakly eroded granites of Crnook in the vicinity of Na area is also composed of crystalline schists of Vlasina complex, granitic rocks of Božica and Doganica, as well as Tertiary volcanics, mainly of dacitic composition. In the east part remnants of Devonian, Permian and Triassic sediments, and in the valley of Pčinja and Morava, deposits of Senonian (Fig. 1). of the area, towards Bulgarian border, there are erosional remnants of Devonian, Permian and Triassic sediments, and in the valley of Pčinja and Morava, deposits of Senonian (Fig. 1).

Erosional remnants of Devonian, Permian and Triassic zarica and Dukat villages are similar in age and partly petrologically to granodiorites of Surdulica (Babović, *et al*., 1977; Petrović, *et al*., 1973).

Besides the Surdulica granodiorites and Crnook granites, the Granodiorites of Surdulica, as well as crystalline schists of Vlasina complex are intruded by numerous veins and smaller masses of dacites and quartzlatites, rarely by andezite and latite, that hardened in subvolcanic to hypoabyssal levels. Dacites mostly occur in the northern part, while quartzlatite is situated in the middle and southern part of this ore zone.

The deposits and occurrences of molybdenum in this ore zone are genetically connected to dacitic-andezitic rocks. The Mo-mineralization is deposited in hydrothermally altered (silicified, sericitised, K-feldspar) dacites and schysts and their contact, rarely in granodiorites. The general occurrence of mineralization in rocks, that compose this area, is conditioned by pre ore tectonics, mainly by length and width of faults and fault zones. In places where they are dense and intersected, stockwork bodies are formed with dissemination between the veins. In places where fractures are scarce or wide apart from each other ore veins are developed, smaller or larger in size (Milovanović, Ilić, 1953/54; Simić, 1993).

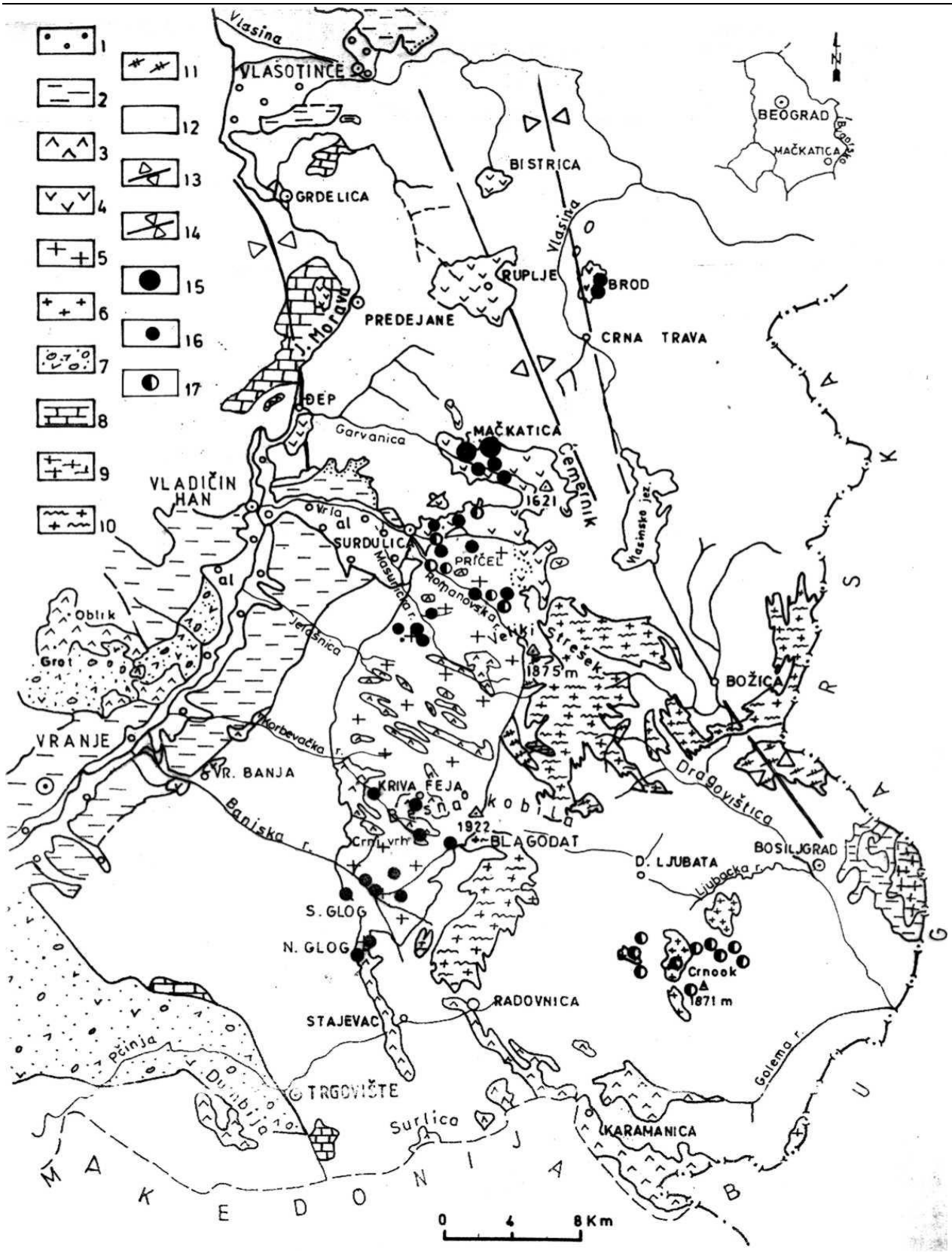

Figure 1. Geological sketch map of the Surdulica granodioritic massif with Mo – occurrences
1. Alluvium, 2. Miocene-Pliocene sediments, 3. Quartzlatites and latites, 4. Dacites and andezites, 5. Surdulica granodiorites, 6. Crnook granites, 7. Eocene sediments, 8. Cretaceous sediments, 9.Triassic sediments, 10. Doganica and Božica granitoides, 11. Gabbros, 12.Metamorphites of Vlasina complex, 13. Anticlinorium, 14. Synclinorium, 15. Mo-deposits, 16. Mo-occurrences, 17. W-occurrences

From the aspect of genetic features and morphostructural types of mineralizations, the deposits and occurrences of molybdenum in the Surdulica eruptive masive can be divided into three groups: hydrothermal stockwork-disseminated type of mineralization that is characterized by extensive mineralization and low grade of molybdenum ore (usually under 0.1 % of Mo). Mačkatica and Borovik deposits belong to this type of mineralization. The second type of mineralization are hydrothermal quartz-molybdenite veins of small size and thickness under 0.5 m (Stari Glog, partly Masurička and Romanovska rivers). The third is porphyry type of mineralization discovered in Novi Glog and Kriva Feja in exocontact part of granodiorites and quartzmonconiteporphyrite, with low Mo and Cu content and small reserves.

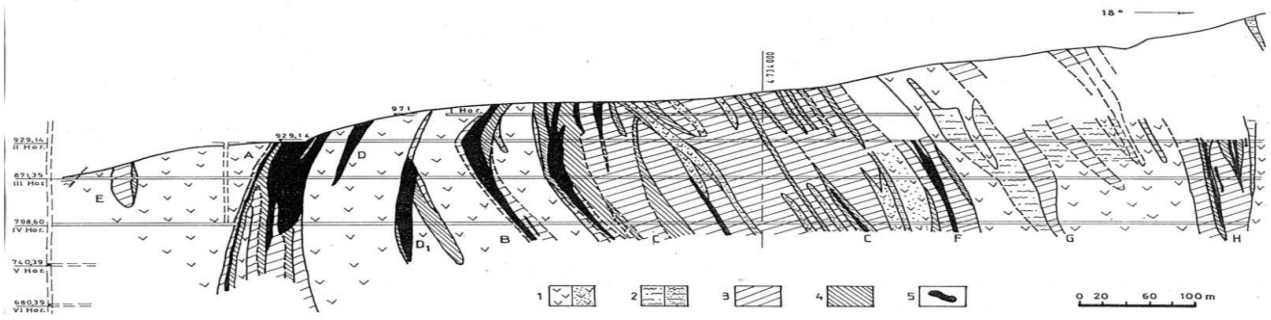

Figure 2. Cross section – Mačkatica

1. Fresh, locally slightly mineralized dacite (<0.04%Mo), 2. Fresh, locally poorly mineralized micaschists (<0.04%Mo), 3. Ore with Mo contents less than 0.08%, 4. Ore with Mo contents less than 0.14%, 5. Ore with Mo contents more than 0.14%.

MOLYBDENUM OCCURRENCES AND DEPOSITS

In Surdulica eruptive area and its rim, in Besna Kobila metallogenetic zone, there are several economically interesting deposits and occurrences. The Mo-mineralizations occur beginning from Brod, north of Crna Trava, and extend towards the south over Mačkatica, Surdulica, Kriva Feja up to Stari Glog and NoviGlog (Fig. 1).

The occurrences of molybdenum in **Brod area** are found in Belčinski potok, in the zone of intensively silicified and kaolinised dacites in form of rare quartz veins up to 5-10 cm thick. The quartz veins are composed of coarse quartz crystals, pyrite, flaky molybdenite and chalcopyrite. The molybdenum content in quartz veins, widely ranges from 0.02-0.8 %, while copper content in the same veins ranges from 0.01-0.1 % (Simić, 1994, 2001).

Mačkatica molybdenum ore field is situated about 7 km southeast of Surdulica in Čemernik mountain complex. The deposit of the same name is found within this ore field in the region of Popova dolina as well as Borovik deposit on Borovik. Besides Mačkatica and Borovik deposits, molybdenum mineralizations are known in other localities of this ore field: Kučišnjak, Pavlova dolina, Meča dolina, Groznatova dolina, Troskački potok, Đokanov potok, Malikina dolina, Garvanica and other (Simić, 1993, 1994, 1994a, 1995, 1996, 2001; Milovanović, Ilić 1953/54).

This ore field is composed of crystalline schists of Vlasina complex in Serbian-Macedonian mass and Tertiary magmatic rocks, among which dacites are predominant. Muscovite and albite-muscovite schists of Riphean-Cambrian age are most frequent metamorphic rocks (Petrović, *et al*., 1973).

The molybdenum mineralization is deposited in lithologicaly various environments, and mineral assemblages. It belongs to stockwork-disseminated type and is closely connected with silicification, K-feldspar and sericitization. Hydrothermally altered zones, actually the mineralized zones, are featured by low content of N_2O and an increased content of K_2O with a high ratio of K_2O/N_2O.

The Mo-mineralization in Mačkatica ore field occurrs in all ore bodies and mineral zones in more or less the same way. Dense network of veins and veinlets of quartz with pyrite and molybdenum are deposited in tectonically determined zones of east-west strike. The more the pre-ore tectonics fractured the area the more it was favorable for ore deposition. The boundaries of ore bodies towards the surrounding rocks is not sharp but transitional, drawn on the basis of geochemical analyses.

The molybdenite ore bodies are usually elongated, lenticular shape with a strike E-W to WNW-ESE, rarely irregular and isometric, with mild tendency of dipping towards the N and NNE. The length of some ore bodies amounts to 100-350 m, with a thickness up to 250 m (Fig. 2).

The mineral composition of Mo-ore in Mačkatica ore field is simple. Quartz, pyrite and molybdenite are basic mineral components which occur either as joined or complex, or they form monomineral veins. Pure molybdenite veins are rare, while quartz ones are the most frequent. The mentioned minerals are accompanied by insignificant quantities of chalcopyrite, haematite, scheelite, sphalerite, galena and rarely wolframite. Scheelite is fairly extensive in Mo-mineralizations in Mačkatica ore field but with a low content.

The content of Mo in Mačkatica ore field varies from on to another deposit and occurrence. In Mačkatica deposit the Mo content is 0.091% in 25,000,000 t of ore, while in Borovik deposit its content is 0.05% in 70,000,000 t of ore. In other localities the MO content varies from 0.03-0.1%, rarely over 0.4%. In the ore concentrate of Mačkatica deposit there is also about 150 g/t of rhenium. In Mo-ore in Mačkatica and Borovik copper is either absent or is present in small quantities (40-70 ppm). The content of tungsten is also low, up to 0.026% WO_3 (Vujanović, 1959; Simić 1993, 2001a).

In the area of **Surdulica-Masurička reka** several molybdenum and tungsten occurrences have been registered in the vicinity of Ćurkovica-Studenički potok, Masurička reka and Romanovska reka. The Mo-mineralization mostly occurrs in hydrothermaly altered granodiorites in the vicinity of small dacite intrusions. The Mo as well as W-mineralizations are related to tectonic zones, sometimes fairly large (100-200 m), with ENE-WSW strike. They are usually vein type quartz-molybdenite and vein-disseminated type of mineralizations of small dimensions and mineral content of Mo and W (Simić, 1994a, 1996a, 2001a).

In the Ćurkovica-Studenički potok area, in one tectonic zone 100-200 m wide and almost E-W strike, extensive vein-disseminated type of mineralization was found, where 10 intervals were identified, 0.5-1.7 m wide with Mo content of 0.02-0.13%. The tungsten occurrences in Studenički potok that are found in form of individual scheelite veins or zones up to 7 m wide have WO_3 content of 0.05-0.15%.

W is much more frequent than Mo in the valley of Romanovska reka. Larger mineralizations of W and Mo are found in the area of Donji Romanovci, Lokvanjski potok, Pričel and mid part of Romanovska reka. The mineralizations occur along fault zones with a strike WNW-ESE to NW-SE in hydrothermaly altered, limonitized, silicified and pyritic zones in granodiorites with a thickness of up to 10 m. The Mo-content is up to 0.1%, while W-content is up to 0.07% of WO_3.

In Opalenički rid and Koštinjak, in the vicinity of Masurička reka, the Mo-mineralizations have similar occurrences as in previous localities. Molybdenite is found in form of veinlets and disseminations near small dacite intrusions in granodiorite that is silicified, partly pyritized. The Mo-content ranges from 0.03-0.1%, with Cu-content that ranges from 0.02-0.1% (Simić, 1994a).

The **Mo-Cu mineralizations on Kriva Feja**, found in the vicinity of Crnovrška reka and Gornja reka, belong to porphyry type related to hydrothermaly altered porphyroid varieties of granitic magma (granodioriteporphyrite, quartzmonconiteporphyrite and other). The Mo-Cu mineralizations of vein-disseminated type on Kriva Feja are composed of pyrite, magnetite, chalcopyrite, molybdenite, quartz and rarely calcite.

The mean content of Cu ranges from 0.04-0.08%, with Mo content of 20-80 ppm. The contents of Au and Ag, elements characteristic for this type of mineralization, range from 0.02-1.31 g/t of Au and 0.6-6 g/t of Ag (Simić, 1992).

In **Crni vrh, near Stari Glog and Prvonek**, there are several occurrences of molybdenum. Molybdenite occurs in quartz veins whose thickness varies from 5 to 10 cm, maximally 40 cm. The edges of quartz veins are coated with thin films of molybdenite. These veins are rare and therefore although with high Mo-content, they are of little economic interest. Mo-mineralization is genetically connected with the dacites that intrude crystalline schists, and partly granodiorites. Small adits were excavated within these ore occurrences before World War II. The data from these investigations reveal that the content of Mo ranges from 1-4%, rarely from 0.65%. Besides Mo in some localities (Tanka Rtina) high content of 3 g/t of Au was found with 11.9 g/t of Ag (Simić, 2001).

Little more south of Stari Glog in the area of **Novi Glog**, in the left tributary of Mala reka, and uppermost part of Petrogorski potok there are several occurrences of Mo and Cu. The Mo-Cu occur in exocontact part of granodiorites, in dacites and schysts that are intensely hydrothermaly altered, fractured and brecciated. The Mo-Cu mineralization is accompanyed by silification, pyritization, K-feldspar and rarely biotitization and sericitization. Molybdenite and chalcopyrite, together with quartz and pyrite, are mostly found in form of veins and films along fractures and fissures of diverse strike and dip, and rarely as individual grains and aggregates.

The best results of Mo and Cu were obtained from Mala reka where low grade, vein, dissemination, and porphyry mineralization was found with contents of Mo that ranges from 0.025-0.07% and Cu content that ranges from 0.047-0.15%. The similar are Mo-Cu mineralizations in the uppermost part of Petrogorski potok (Simić, 1991).

In **Crnook** area several scheelite occurrences are found, while Mo is absent. The most interesting are scarn type of scheelite mineralizations in Bresnica and Blenski del, in the gneiss serie intruded by pegmatitic veins. These are ore bodies of small dimensions, but with high content of WO_3. In Bresnica the average content of W is 3% (ranging from 2-19%), while in Blenski del the average content is 4.7% (Marić, *et al*., 1959: Simić, 2001, 2001a). The occurrences of W of hydrothermal type that are also found in Crook ore field are of lesser importance (Dukatska reka, Crnoštica). In whole this ore field is poorly investigated, so that it is hard to asses its potential in relation to mineral raw materials.

CONCLUSION

In Surdulica eruptive massive and its rim there are numerous occurrences and deposits of molybdenum. In the first place these are hydrothermal deposits represented by vein, stockwork-disseminated and porphyry, as well as vein-disseminated types of mineralizations. Geotectonically they belong to eastern part of Serbian-Macedonian mass and metallogenetically they are a part of Besna Kobila-Osogovo zone.

The metallogeny of this zone is related to the processes of neo-Alpine tectonomagmatic activity, actually Tertiary (Oligocene-Miocene) magmatism of granodiorite composition, featured by Mo, Cu, W, Zn, Pb, Sb mineralizations with significant ore reserves, especially molybdenum, lead and zinc.

According to the number of occurrences and deposits in Surdulica eruptive massive outstanding is Mačkatica ore field. This ore field belongs to the largest ones according to the number of ore bodies and their dimensions. Regarding the numerous occurrences found, in Mačkatica ore field as well as in other parts of this ore zone, it is certain that the

reserves of molybdenum are much larger than the calculated ones.

Taking into account the rising demand for molybdenum as a metal that has wide application in modern industry, it is only a question of time when will this mineral raw material be utilized from this area in future.

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