Late Alpine metallogeny of Western and Central Rhodopes

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The geological structure and tectonic features of the Rhodope massif are dominated by extensional processes that were superimposed during the Late Alpine stage (Ivanov, 2000). As a result of these processes metamorphic core complexes (domes) were formed. Due to mobilization of the lower ductile crust, in the initial stage of extension granitoid intrusions (K_2-Pg) were emplaced in the upper brittle crust of the domes. During the later stage of extension the core complexes were exhumed and tectonic depressions developed between them (Georgiev, 2005). The depressions are filled with Paleocene-Oligocene sediments and Eocene-Miocene acidic and intermediate volcanics.

Two first-order positive structures can be recognized in the discussed part of the Rhodope massif — West Rhodope and Central Rhodope complex domes. They are separated by the Bratsigovo-Dospat, Smolyan and Vitinya depressions.

Practically there are no exposures of the lower migmatite complex in the West Rhodope complex dome (including Rila and Pirin Mts.) and for that reason the core of the dome cannot be traced. This dome has the thickest crust (Boykova, 1999) and was intruded by abundant granitoids of the early extensional stage. Its western periphery is deformed by the younger (Neogene) Struma graben. The internal structure of the West Rhodope complex dome is complicated by the "crestal" Mesta graben filled with Paleogene sediments and intermediate and acid volcanics. Three domes are located to the NNE, SE and SW of the Mesta graben, namely the Rila-West Rhodope, the Barutin-Elatia and the Pirin domes, respectively.

The Madan-Davidkovo dome is the main unit in the Central Rhodope dome. Its periphery is deformed by the Shiroka Laka, Lyaskovets and Dobralaka second-order domes and the Hvoina depression developed between them. The North Rhodope depression is located in the northern periphery of the Madan-Davidkovo dome.

Metallogenic stages

Practically all commercial endogenic deposits in the region are related to the Late Alpine processes of extension and magmatism.

Late Cretaceous-Eocene metallogenic stage

The mineral deposits of this stage are genetically and paragenetically related to granitoid plutons.

Mo hydrothermal and skarn mineralizations. They are of first-order significance. In the most cases the ore mineralization is only Mo one, less commonly W one dominated by sheelite, and wolframite (a common mineral for the Mo-W vein deposits) is practically absent. The ore bodies are of vein type. Skarn-type deposits are related only to the Bezbog pluton at the contacts with marbles.

The most essential Mo accumulations are concentrated in the Babek ore field. It is located in the western periphery of the Rila—West Rhodope batholith and genetically related to its late phases. The ore bodies are represented by veins. Mineral composition: quartz (>90%), calcite, molybdenite, pyrite, galena, sphalerite, chalcopyrite. Minor minerals are mainly sulphosalts. The peripheral zone of the ore field contains Pb-Zn mineralization. The Babek ore field has two unconventional features: 1) higher content of gold (up to 2 g/t Au), which is not characteristic for Mo deposits; 2) the related metasomatites are of sericite but not of greisen or K-feldspar type that are typical of Mo vein deposits.

W hydrothermal and skarn mineralizations. Typical example is the Grancharitsa ore field. It includes the deposit of same name and several ore occurrences mainly with Pb-Zn mineralization, which form the outer lower-temperature zone. The ore bodies are emplaced in granitoids of the Rila-West Rhodope batholith. The ore mineralization is in the form of veins. Mineral composition: major minerals — quartz (>80%), calcite, pyrite, sheelite, orthoclase; minor — galena, sphalerite, chalcopyrite; rare —

magnetite, molybdenite, bismuthinite, etc. The deposit differs from the traditional type of W vein deposits by the following: 1) ore veins are very shallow dipping — at about 30°; 2) W vein deposits are usually quartz-wolframite in composition with associated greisen metasomatites whereas in Grancharitsa they are quartz-sheelite ones with microcline metasomatites; 3) high content of pyrite in the ores — in fact this is a quartz-pyrite-sheelite deposit.

Fluorite hydrothermal deposits. They are located in the Yugovo ore field in close relation with granitoids of the same name. The ore bodies are of vein type, less commonly metasomatic (apomarble-metasomatic). Mineral composition: major minerals — quartz; minor — fluorite, pyrite, sphalerite, galena, chalcopyrite, molybdenite, etc.; non-metallic — calcite, barite, etc. Some deposits contain higher amounts of galena and sphalerite and are in fact Pb-Zn deposits.

Pb-Zn hydrothermal mineralizations. According to their distribution they compete with Mo ones. In all cases, however, they are a part of other deposits (Mo, W and fluorite) that have been already discussed.

Au-Ag hydrothermal mineralizations. The Srebren deposit, located in the SE periphery of the Rila-West Rhodope batholith, is the most typical example. The ore bodies are zones mineralized mainly by quartz, pyrite, arsenopyrite, chalcopyrite, galena and sphalerite. Native gold and silver minerals are also found. The mineral paragenesis indicates that this is an independent plutonogenic gold type.

Fe (magnetite-skarn) mineralizations. Undoubtedly, they are genetically related with intrusives (the Central Pirin pluton) — Debrevo-Krushevo (Gotse Delchev area). The ore bodies are irregular, lens-shaped, less commonly layered in form. The skarns are garnet-pyroxene varieties with superimposed magnetite mineralization. Minor minerals are pyrite, pyrrhotite, rare chalcopyrite, etc.

Cu-skarn mineralizations. Independent copper-skarn mineralization occurs only in the area of Kapitan Dimitrievo village, Northern Rhodopes. It is related to the pluton of the same name. The skarns are garnet-pyroxene with superimposed impregnated mineralization of chalcopyrite, magnetite and insignificant amounts of sphalerite, galena, etc.

U hydrothermal mineralizations. The ore mineral is nasturanium deposited in quartz veinlets and mineralized zones with sulfides. The mineralization is located in the host rocks of the Yugovo and Barutin-Elatia plutons.

Feldspar and muscovite pegmatite deposits. Small pegmatite veins composed mainly of quartz, feldspar and muscovite (Selishte) occur in the Smilyan pluton. Feldspar and muscovite pegmatite deposits are related to the 1st phase of the Rila-West Rhodope batholith located in the area of Velingrad, Dobrinishte and Vishteritsa (Western Rhodopes). Mineral composition: quartz, microcline, albite and muscovite with superimposed rare minerals — beryl, columbite, etc.

The granitoid body near Dolno Vlahovo village (Smolyan district) contains allanite (orthite) mineralization rich in cerium and other rare earth elements. The allanite mineralization is related to the process of feldspatization. These are probably albitite metasomatites hosting some of the most important rare earth deposits in the world.

Oligocene stage

Pb-Zn hydrothermal and skarn mineralizations. The ore bodies of vein and aposkarn-metasomatic type are emplaced in metamorphics from the Madan-Davidkovo dome. The ore mineralization is concentrated in the Madan ore field which is considered to be one of the largest in size occurrences of this type. Mineral composition: major minerals — quartz, galena, sphalerite in metasomatic bodies and johannsenite; minor — carbonates (calcite, rhodochrosite, etc.), pyrite, chalcopyrite, arsenopyrite in some deposits. Most common rare minerals are tetrahedrite and tennantite. According to their mineralogical and geochemical features, the Central Rhodope Pb-Zn deposits are similar to the analogous deposits of this type in the world. Skarns are an exception. They are manganese-bearing (mainly johannsenite) ones and by its large amount are a unique case.

Sb hydrothermal mineralizations. The Ribnovo ore field includes the deposit of the same name and several ore occurrences with Sb-Pb-Zn and Pb-Zn mineralizations. The ore field is located in metamorphics from the eastern border of the Mesta graben. It is related to a fault zone along the boundary gneiss-marble. The mineralization belongs to the relatively rare jasperoid type. Its characteristic feature is the high Au content (up to 2 g/t). The ore bodies are of lenticular and sheet-like forms. Mineral composition: major minerals — quartz, antimonite; minor — pyrite, arsenopyrite; rare minerals — bertierite, realgar, auripigment, etc. The carbonate mineral is mainly calcite. A genetic relation to the Mesta rhyolites is most logical.

U hydrothermal mineralizations. They are located in the southern parts of the Smolyan and Bratsigovo-Dospat depressions and in the western periphery of the Borovitsa depression. Most significant accumulations are concentrated in the Smolyan deposit. The mineralization is emplaced in rhyolites and tuffogenic-sedimentary rocks. The ore bodies are lenses, veins, loads, columns. The mineralization belongs to the quartz-nasturanium type with pyrite, markasite and calcite being the main additional minerals. The metasomatites around the ore bodies are of argillic type. The deposit corresponds to the model of volcano-hydrothermal uranium deposits, subtype without significant amounts of molibdenite and galena.

Fluorite hydrothermal deposits and mineralizations. They are located in the Mihalkovo ore field within metamorphics from the eastern borderline of

the Bratsigovo-Dospat depression. Fluorite occurs in the form of lenses, nests and irregular bodies emplaced within jasperoid breccia at the contact marbles-gneisses. Mineral composition: major minerals — quartz, fluorite; minor — calcite. Galena, sphalerite, pyrite, markasite, chalcopyrite, barite, etc. are in insignificant amounts. The close location to the rhyolite-type volcanics from the Bratsigovo-Dospat depression suggests that the deposits are most probably paragenetically related with them.

Stomanovo alunite hydrothermal deposit. It is located in the area of Stomanovo village (Devin region) within rhyolites from the Bratsigovo-Dospat depression. It is similar to analogous deposits in the world — metasomatic quartz and alunite.

Pliocene stage

Mineral resources from this stage are the diatomites from the Mesta graben (Ognyanovo village).

Holocene-Quaternary stage

Infiltration deposits in terrigenous sedimentary rocks. They are of particular importance for the uranium (sandstone-type deposits). One of the largest U infiltration deposits in Bulgaria is located in the area of Eleshnitsa village, Mesta depression. Main U mineral is coffinite. The deposit is similar to analogous deposits in the world. Weathering processes in uranium-bearing leptinites from the northern part of Central Rhodopes are evidently one of the sources of infiltration uranium deposits in this region.

Sedimentary deposits. Small placer gold accumulations have been found along the Mesta River valley.

Metallogenic zonation

The discussed region reveals a very distinct spatial ore distribution: Late Cretaceous-Eocene mineralizations — mainly in the West Rhodope complex dome, and Oligocene mineralizations — dominantly in the Central Rhodope complex dome.

West Rhodope complex dome — W, Mo (Au, Ag, Pb, Zn, Cu, Sb, Fe). The West Rhodope complex dome is characterized mainly by lithophyllic ore mineralizations related to granitoids. There are also, however, some independent Au-Ag (Srebren, Obidim, Lehovo areas) and Sb (Ribnovo ore field) chalcophyllic deposits.

Granitoid intrusions (K_2-Pg_2) and genetically related with them W-Mo ore mineralizations (Maneva et al., 1994) are typical for the region. Two ore regions can be subdivided — Rila-West Rhodope and Pirin, associating with second-order domes of the same name. The Ribnovo ore field is outside of them and probably is genetically related to the late extensional magmatism in the Mesta graben.

A concentric zoning can be traced within the Rila-West Rhodope ore region. W ores (Grancharitsa ore field) dominate in its central parts and Mo±W ores (Babyak ore field, Yurukovo-Dragonovo and Velingrad area) - around them. Au-Ag occurrences are located in its southeastern periphery (Srebren). This zonal pattern is "sheared" in the NW part of the ore region.

Concentric zoning is observed also in the Pirin ore region. Skarn iron ore mineralizations dominate in its central parts and W and Mo mineralizations — Musomishte ore field and Bezbog, Kresna and South Pirin areas (skarns with sheelite and molybdenite) occur around The periphery of the region contains gold-silver mineralizations (Obidim and Lehovo sites and some occurrences in Greece).

Central Rhodope complex dome — Pb, Zn, W, Mo (Au, Ag, Cu, Fe, Cr, Fl). A markedly double metallogenic specialization can be traced — chalcophyllic and lithophyllic. The first one (Pb, Zn) dominates. The second one (F, U, W, Mo) is better expressed in respect to F and partially to U whereas W and Mo are not essential.

A zonal pattern is likewise expressed in this dome. The Madan-Davidkovo dome is rich in Pb-Zn ore mineralizations, which are grouped in the Central Rhodope ore region (Maneva et al., 1994). This region consists of about 60 deposits and numerous ore occurrences distributed in six ore fields: Laki, Davidkovo, Enyovche, Termes (Greece) and Ardino. The ore mineralizations are paragenetically related to irregular rhyolite bodies and dikes (Pg_3). It is suggested that they are subvolcanic expression of a pluton that is not exposed on the surface.

In the periphery of the Madan-Davidkovo dome and some smaller parasitic domes, the Late Cretaceous-Eocene granitoid intrusions are not so common as compared to the West Rhodope complex dome. They associate with W-Mo mineralizations ± Fl (Yugovo ore field, Narechen and Mogila-Raikovo areas). The Chereshkite Au-Ag ore occurrences is probably related to the Smilyan pluton. Copper-skarn ore occurrences associate with the Kapitan Dimitrievo pluton.

There are also some ore mineralizations related to the Oligocene acidic magmatism on the periphery of the Central Rhodope complex dome but they are of subordinate importance. The Mihalkovo fluorite ore field is located in the eastern border area of Bratsigovo-Dospat depression. The antimonite-bearing mineralized zones in the Krichim area are paragenetically related to bodies and dikes of Paleogene acidic volcanics.

Several Au-Ag and Pb-Zn ore occurrences are known in the Topolovo-Novakovo area but their genetic relations (with Late Cretaceous intrusions or volcanic complexes) are not established so far.

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Късноалпийска металогения на Западните и Централните Родопи

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Металогенията на Родопския масив е доминирана от късноалпийските процеси на екстензия. В резултат на това се формират метаморфни ядрени комплекси. В резултат на мобилизация в долната пластична кора в началния етап на екстензия, в горната крехка кора на тези куполи се внедряват гранитоидни интрузии (K_2-Pg_2). В покъсния етап на екстензия се осъществява ексхумация на ядрените комплекси. Между тях се налагат тектонски депресии, изпълнени със седименти (Pg_{1-3}) и кисели и среднокисели вулканити (Pg_2-N_1). В разглеждания район се отделят две първоразрядни позитивни структури — Западнородопски и Централнородопски комплексни куполи.

Западнородопският комплексен купол (вкл. Рила и Пирин) е с най-дебела земна кора и е най-обилно наситен с гранитоиди от ранния етап. Металогенията му е доминирана от генетично свързаните с този магматизъм минерализации — Mo, W, Au-Ag, Fe. В него се засебяват два второразредни купола — Рило-Западнородопски и Пирински. В Рило-Западнородопския купол се наблюдава концентрична зоналност: W орудявания в централните части (Грънчарица), Mo±W около тях (Бабяк), Au-Ag проявления в SE му периферия (Сребрен) и Sb проявления (Рибново, вероятно генетично свързано с магматизма в Местенския грабен). В Пиринският купол също се наблюдава концентрична зоналност: Fe-скарнови орудявания в централните части, W-Mo минерализации около тях (Мусомище) и Au-Ag в периферните части (Обидим, Лехово).

Основна единица в Централнородопския комплексен купол е Маданско-Давидковския купол. Периферията му е деформирана от куполи от по-висок ред. Тук също се наблюдава известна зоналност. Маданско-Давидковският купол е наситен с Pb-Zn орудявания, обединени в Централнородопския руден район (Лъкинско, Давидковско, Еньовченско, Термеско и Ардинско рудни полета). Орудяванията са парагенетично свързани с тела и дайки от риолити (Pg_3), вероятно субвулканска изява на неразкрит плутон. С гранитоидните интрузии (K_2-Pg_2) по периферията на Маданско-Давидковския купол и в по-малките паразитни куполи асоциират W-Mo орудявания ±Fl (Юговско рудно поле). Вероятно със Смилянския плутон е свързано и Au-Ag рудопроявление Черешките а с Капитан-Димитриевския — Cu рудопроявления. По периферията на Централнородопския комплексен купол се установяват и флуоритови минерализации свързани олигоценския кисел магматизъм (Михалково).