Copper ore Deposits in Bulgaria

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With 1 Figure

Zusammenfassung

Die Kupfererzlagerstätten Bulgariens liegen in der Srednogorje-Zone, die als Rift-Zone bezeichnet wird, vor allem in ihrem mittleren Abschnitt um Panagjurište (Fig. 1). Der oberkretazische Magmatismus ist teils andesit-basaltisch, teils trachybasaltisch (im Osten). Wenig jünger sind gabbro-syenitische Intrusionen. An diesen Magmatismus sind Porphyrie-Kupferlagerstätten, massive Sulfiderzkörper, polymetallische Gänge (bei Burgas) und Skarnerze gebunden. Alle Lagerstättentypen werden charakterisierend beschrieben.

The copper ore deposits on the territory of Bulgaria have been known for ancient times. According to the archaeological data, the oldest copper mines in Europe were located in the central part of the country, near the town of Stara Zagora (CHERNIH, 1978). The archaeological investigations discovered 11 open pits, situated along the vein type ore body, known under the Turkish name "Aibunar", where 4 thousand years B.C. the oxide copper ores were yielded. The length of the open pits varied from several tens to 100 m, the width–from 3 to 10 m, and the depth was up to 20 m from the surface. Two meltings pots filled with malachite and azurite were discovered in the vicinity of this oldest mine (KONYAROV, 1953), which was exploited till 2000 years B.C.

Besides this famous copper mine, more than 100 points with traces of ancient mining and metallurgical activities have been fixed on the territory of the country. One of the largest coppermelting centers, existing from II to I century B.C., was located near to the Black Sea coast, north from the contemporary active Rossen copper ore deposit. It is considered (KONYAROV, 1953) that the bronze statue of Appolo-

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nius, erected in the ancient Greek colony Appolonia (the present-day town of Sozopol) was made of copper from this metallurgical center.

People's Republic of Bulgaria occupies today one of the first places in copper production in Europe. The discovered new large copper ore deposits during the last 20 years made possible developing the modern copper mining, refining and smelting industry.

Brief information concerning the genetic types of the industrial copper deposits in Bulgaria, their geological setting and mode of formation is given below.

Genetic types of Copper ore Deposits

The majority of the industrial copper ore deposits in Bulgaria occurs in the Srednogorie metallogenic zone (Magm. & Metall. of CBA, 1983). It is a part of the global Thetyan-Eurasian metallogenic belt (JANKOVIĆ, 1976). During the Upper Cretaceous a secondary geosynclinal trough was formed in Srednogorie zone, along the rift structures between Moesian plate to the north and Rhodope massif to the south (BONCHEV, 1974; TVALCHRELIDZE, 1972; BOGDANOV, 1977). In connection with the magmatic activity which took place during the Senonian time, the various types of copper ore deposits were formed. The Srednogorie metallogenic zone is characterized by intensive development of predominantly Ca-alkaline volcanism represented mainly by two volcanic formations—basalt-andesite-rhyolitic in the central part of the zone and trachybasalt-trachyandesitic in the eastern part, where the K-alkaline-basaltoid formation is locally deveoped as well (STANISHEVA, 1971, 1980; POPOV et al., 1979). The intrusive type of magmatism is manifested in various volcano-plutonic centers, in which almost simultaneously with the volcanic activity two intrusive formations were developed—gabbro-diorite-granodiorite and gabbro-monzonite-syenite formations.

The Upper Cretaceous copper mineralizations are the main peculiarity of the Srednogorie metallogenic zone. The copper ore deposits can be subdivided into the following genetic types or ore-formations (Fig. 1, Table 1): 1. porphyry copper, 2. massive sulphide, 3. vein copper and copper-gold-polymetallic and 4. aposkarn copper molybdenum-sheelitic. Besides the four main types of copper deposits there are also several non-commercial mineralizations which have to be mentioned, such as native copper-zeolitic in andesitic rocks, copper-nickel type in ultrabasic rocks, copper-bearing sandstones, stratiform lead-zinc-copper deposits in Triassic limestones and stratabound copper-polymetallic deposits in Paleozoic volcanic-sedimentary rocks. The last two types are subject to exploitation as copper-polymetallic deposits and have very low significance for the copper production. The present paper deals with the Upper Cretaceous copper deposits of the above mentioned four ore formations. Among them the porphyry copper deposits are of greatest economic importance. They supply more than 90% of the copper in the country and are considered as most perspective type for increasing the copper production in the future. The other types are of less industrial significance, but the higher copper content and presence of other valuable metals makes them interesting for the copper industry.

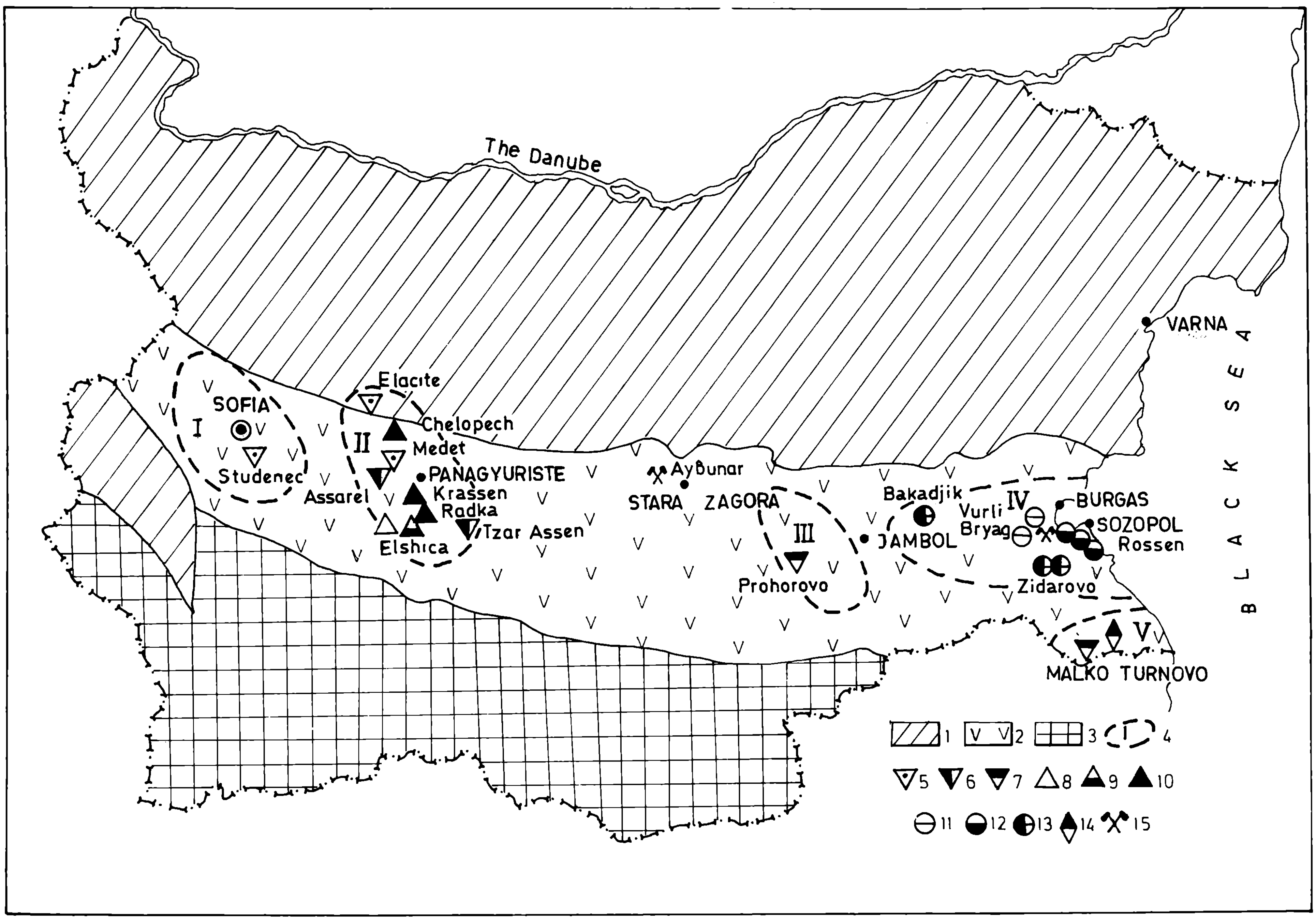

Fig. 1. Upper Cretaceous industrial copper deposits in Srednogorie zone. — 1 = Moesian plate including Forebalkan, Stara Planina and Kraishtide zones; 2 = Srednogorie zone; 3 = Rhodope zone; 4 = Copper ore districts: I = Sofia, II = Panagyurishte-Etropole, III = Jambol, IV = Burgas, V = Malko Turnovo; 5, 6 and 7 = Porphyry copper deposits: 5 = Medet type, 6 = Assarel type, 7 = Prohorovo type; 8,9 and 10 = Massive sulphide deposits: 8 = pyrite type, 9 = chalcopyrite-pyrite type, 10 = chalcocite-bornite-tennantite gold bearing type; 11, 12 and 13 = Vein copper deposits: 11 = copper type, 12 = copper molybdenum type, 13 = copper-gold-polymetallic type; 14 = aposkarn-copper-molybdenum-sheelitic deposits; 15 = ancient mines and metallurgical centers.

Table 1. The Main Formation Types of Copper Ore Deposits in Srednogorie Zone

Formation types of copper deposits	Subformation and mineralogical types	Magmatic associations	Representative or deposits and orefields	Metals & Elements of industrial significance
1	2	3	4	5
1. Porphyry copper	1. Porphyry-copper-molybdenum	Hypabyssal Q-monzodiorites	Medet, Elacite, Studenec	Cu, Mo, S
	2. Porphyry-copper-alunite	Subvolcanic Q-diorite porphyrites and andesites	Assarel, Tzar Assen	Cu, S
	3. Porphyry-copper-skarn	Q-diorite-granite small intrusions	Prohorovo, Burdceto	Cu, S (Mo)
2. Massive sulphide	1. Massive-pyrite	Andesite-dacite volcanites and their pyroclastics	Elshica	S
	2. Massive-chalcopyrite-pyrite	The same + subvolcanic	Elshica, Radka, Krassen, Chelopech	Cu, S, (Pb, Zn)
	3. Massive-chalcocite-bornite-tenantite (gold bearing)	rhyodacite dykes		
3. Vein copper and copper-gold-polymetallic	1. Vein copper 2. Vein copper-molybdenum	Dykes of monzodiorite porphyrites and volcanic rocks of trahybasalt-	Vurli Bryag, Rossen	Cu, S (Bi) Cu, Mo (Co)
	3. Vein copper-gold-polymetallic	trahyandesite and andesite formations	Zidarovo, Bakadjik	Cu, Bi, Pb, Zn
4. Aposkarn-copper-molybdenum-sheelitic	?	Granodiorite-granite porphyrites	Malko Turnovo	Cu, Mo, W (Bi)

Some Peculiarities of the Upper Cretaceous Copper ore Deposits

Porphyry copper deposits

The majority of the porphyry copper deposits is situated in Panagyurishte-Etropole ore district in the central part of the country. Medet, Assarel, Elacite and Tzar Assen deposits are under exploitation now by open pits. In the same area there are also several small and low grade deposits or mineralizations of this type which are under prospecting and economic evaluation, such as Popovo dere, Petelovo, Tzar Assen-2, Kominsko Chukarche and others. Moreover some new porphyry copper deposits were discovered in the western part (the Studenec deposit in Sofia ore district) and in the eastern part of the Srednogorie zone (the Prohorovo deposit in Yambol ore district and the Burdceto deposit in Malko Turnovo ore district).

The oxide ores from the upper parts of Tzar Assen and Vlajkov Vruh deposits are subjected to acid-bacterial leaching and some quantity of copper has been produced over the last ten years.

The formation of the porphyry copper deposits is related to the last stage of the Upper Cretaceous magmatic activity, manifested by intrusion of subvolcanic to hypabyssal small bodies and dykes of quartz-monzodiorite, granodiorite to granite porphyric rock types. A typical feature of them is the stock-like shape of the ore bodies, tapering out in depth. The ore mineralizations occupy the apical parts of the hypabyssal intrusions (the Medet, the Studenec, the Prohorovo, the Burdceto ore deposits), ore penetrate into the cover of effusive rocks over subvolcanic bodies (the Asserel, the Tzar Assen, the Petelovo, the Kominsko Chukarche deposits). In some cases the ore mineralization impacts the upper parts of the small intrusions and penetrates into the Paleozoic and Mesozoic metamorphic intrusive and sedimentary rocks from the cover (the Elacite, the Prohorovo, the Burdceto deposits). The ore mineralization is of veinlet-impregnated type.

The main ore minerals are pyrite and chalcopyrite, the subordinate ones—bornite and molybdenite, but there are also small quantities of magnetite, specularite, sphalerite, galena, tenantite, native gold, electrum etc., which can be found in all porphyry copper deposits. The gangue minerals are represented by quartz, K-feldspar, sericite, chlorite, epidote, carbonates, zeolites, anhydrite etc.

The ore forming processes in the porphyry copper deposits can be subdivided into three stages—preore stage, during which the hydrothermal alteration of the country rocks took place, ore stage, characterized by deposition of copper, iron, lead, zinc and other sulphide minerals accompanied mainly by quartz as a gangue mineral and postore stage, represented by low temperature sulphate minerals (anhydrite, gypsum), zeolites (lomontite, stilbite, habasite, natrolite etc.), carbonates (calcite, dolomite, rhodochrosite, Mn-calcite, ankerite), superimposed on the sulphide mineralization of the ore stage.

Three subformation types of porphyry copper deposits can be distinguished among them in Srednogorie zone: 1. porphyry-copper-molybdenum deposits or Medet type; 2. porphyry-copper-alunite deposits or Assarel type and 3. porphyry-copper-skarn deposits or Prohorovo type. The main peculiarities of subformation types of porphyry copper deposits are given in Table 2.

Table 2. Subformation Types of Porphyry Copper Deposits

Type and representative deposits	Structural-geological setting	Magmatic associations	Typical mineral parageneses			Temperature of formation of the main parageneses
			Preore stage	Ore stage	Postore stage	
1. The Medet type (Medet, Elacite, Studenec)	Horst-anticlinal structures of Precambrian and Paleozoic metamorphic and intrusive rocks	Hypabyssal intrusions of quartz-monzodiorites, quartz-diorites and quartz-syenodiorites	Q-felspar-biotite, Q-magnetite	Q-molybdenite, Q-chalcopyrite, Q-pyrite, Q-sphalerite-galena	Zeolite-carbonate	Q—C_{py}—320—350° C Q—Mo—300—320° C
2. The Assarel type (Assarel, Tzar Assen, Petelovo, Kominsko Chukarche)	Volcanogenous graben-synclinals of Upper Cretaceous andesites and their pyroclastics	Subvolcanic small bodies and dykes of quartz-dioritic to granodioritic porphyrites	Alunite-secondary quartzites, Q-sericite, Q-kaolinite	Q-chalcopyrite, Q-pyrite, Q-sphalerite-galena	Anhydrite-gypsum, zeolite-carbonate	Q—C_{py}—290—310° C
3. The Prohorovo type (Prohorovo, Burdceto)	Anticlinal structures built-up of low-metamorphic and sedimentary rocks of Mezozoic age	Hypabyssal intrusions and dykes of granodiorite-granite composition	Epidote-scapolite-garnet skarn, K-felspar + magnetite, Q-sericite	Q-molybdenite, Q-chalcopyrite, Q-pyrite, Q-sphalerite-galena	Zeolite-carbonate, anhydrite-gypsum	Q-Mo—340—360° C Q—Py—320—340° C

The Medet type of porphyry-copper deposits originated in cases when the small hypabyssal intrusions of Ca-alkaline type were imbedded into a crystalline core of residual horst-anticlinal structures (the Medet deposit) or were intruded into the metamorphic rocks from the framework of the zone (the Elacite deposit). Typical for them are the commercial contents of molybdenum, potash-alkali alteration of the rocks, represented by K-feldspathization and biotitization and zeolite-carbonate type of postore mineralization.

Porphyry-copper deposits of Assarel type were formed in close connection with the central part of a satellite volcanic structure, the central core of which is built-up by subvolcanic small intrusions of quartz-dioritic and granodioritic porphyrites.

The most characteristic peculiarities of these deposits are the following: localization in graben-synclinal volcanogenic structure, absence of commercial content of molybdenum, acidic type of preore hydrothermal alteration of the volcanic and subvolcanic rocks, represented by alunite secondary quartzites, accompanied by diaspore, kaolinite, dickite, pyrophyllite, and surrounded by zones of quartz-sericite rocks and propylites. The postore stage is manifested by deposition of anhydrite-gypsum and zeolite mineralizations.

The Prohorovo type of the deposits is typical for the area built-up by low grade metamorphosed and sedimentary rocks with calcareous layers, intruded by small hypabyssal granodiorite-granite bodies. The copper-porphyry mineralization there is superimposed on the skarns and affects the metamorphic halo around the intrusive bodies.

These three types of porphyry copper deposits show some differences in temperature and depth of formation. The Medet and Prohorovo types of ore deposits were formed at greater depth and higher temperature than the Assarel type of porphyry copper deposits (Table 2).

By the author's opinion the differentiation of three subformation types of porphyry-copper deposits results mainly from their various geological and structural settings and the different character of the intrusive bodies, associated with them.

Massive Sulphide Deposits

They are of hydrothermal-metasomatic origin. Their formation is related to the development of the hydrothermal system at the end of the andesite-dacite stage of volcanic activity in Panagyurishte-Etropole ore district (BOGDANOV, 1984). They are represented usually by massive ore bodies surrounded by haloes of veinlet-disseminated ores. The ore bodies are of stock-like and lense-like shape and occur amidst volcanic rocks, andesite agglomerate tuffs (Chelopech), ash tuffs or along the contact and tectonic fractured zones between andesite and dacite volcanic rocks (Radka). Some of them are controlled by the contact of the rhyodacite dykes cut off through the volcanites (Elshica).

Three types of massive sulphide ore bodies can be distinguished in Panagyurishte-Etropole ore district (Table 1): 1. massive-pyrite, 2. massive-chalcopyrite-pyrite and 3. chalcocite-bornite-tenantite (gold-bearing) type. They were formed during two stages of development of hydrothermal system, connected with the same Upper Cretaceous volcanic chamber. The first stage was manifested at the end of the volcanic activity, when the massive pyrite ores formed. The fragments of these ores, the so called "oreclastics" are included in dacite agglomerate tuffs (BOGDANOV et al., 1970). The second stage of massive sulphide ore deposition occured after the end of the volcanic activity and penetration of the rhyodacite dykes into the volcanic rocks.

The massive chalcopyrite-pyrite and the massive chalcocite-bornite-tenantite ore bodies were formed during the second stage of development of the hydrothermal system (BOGDANOV, 1985). The massive chalcopyrite-pyrite ore bodies are typical for the Elshica deposit, while the chalcocite-bornite-tenantite ore bodies represent the main type of massive sulphide mineralization in Radka, Krassen and Chelopech deposits. The last two types for ore mineralizations are superimposed on the massive pyrite ore bodies. The following mineral paragenetic associations were formed during them: chalcopyrite-pyrite, enargite-bornite-pyrite, bornite-chalcocite-tenantite, sphalerite-galenite, quartz-pyrite-chalcopyrite (vein type), marcasite-pyrite and anhydrite-gypsum. They cut off or replace one another and determine the complex type of the ores from these deposits. Gold and silver are disseminated as rare minerals in complex enargite-bornite-chalcocite-tennantite ores (BOGDANOVA, 1973).

Vein Copper and Copper-polymetallic Deposits

They are wide-spread in the eastern part of the Srednogorie zone in the framework of the Burgas ore district and can be grouped in four ore fields, closely connected with the volcano-plutonic centers of the Upper Cretaceous magmatic activity. These are the Rossen, the Vurly Bryag, the Zidarovo and the Bakadjik ore fields. The Rossen ore field is the best known and very well studied among them.

Three subformation (mineralogical) types of vein-copper and copper-polymetallic deposits can be distinguished, belonging to the various ore fields: 1. vein chalcopyrite-pyrite in Vurly Bryag ore field; 2. vein chalcopyrite-molybdenite in Rossen ore field and 3. vein chalcopyrite-gold-polymetallic in Zidarovo and Bakadjik ore fields.

The geological structure of the Rossen copper-molybdenum ore field was a subject of investigation of several authors (BOGDANOV et al., 1969; POPOV, 1980; STANISHEVA-VASSILEVA, VASSILEFF, 1981).

According to the last investigations it can be interpreted as a large volcano-plutonic structure of central type, formed in Upper Cretaceous time. The central caldera part of the volcano-plutonic structure is occupied by the Rossen pluton, built up of gabbro-monzonite-syenite intrusive formation. This intrusive core is encompassed by trachyandesite and andesite volcanic rocks and their volcanoclastic materials, represented by interbedded agglomerate tuffs, clastolavas, ash tuffs and lava flows. The volcanic and intrusive rocks are cut off by dykes of monzodiorites, syenodiorites, leucosyenites and the subvolcanic bodies of trachydiorite porphyrites.

The ore veins are built up of chalcopyrite, cobalt-containing pyrite, molybdenite, magnetite, hematite, scheelite, lineite, bornite, nickeline, galenite, sphalerite etc. Vein minerals are represented mainly by carbonates and quartz. The ore veins were formed in two stages: 1. pneumatolytic, with deposition of scapolite, biotite, phlogopite, apatite etc., and 2. hydrothermal, when all above mentioned minerals were deposited (BOGDANOV et al., 1968).

The vein chalcopyrite-pyrite deposits of Vurly Bryag ore field are in many respects similar to those ones of Rossen ore field. The differences are connected with the mineral composition—the main minerals are chalcopyrite and pyrite. In the Zidarovo and Bakadjik ore fields the main peculiarities of the veins consist in the higher content of lead, zinc, gold, silver and bismuth mineralizations (Table 1).

In the frame of the Burgas ore district the regional lateral zonality was established, expressed by the replacement of the copper-molybdenum mineralization from east to west by copper-bismuth and copper-gold-polymetallic-bismuth mineralizations (VASSILEFF).

Skarn-Copper Deposits

Skarn-copper deposits are situated in the Malko Turnovo ore district in the southeastern part of the country (VASSILEFF et al., 1964; Magm. & metall. of KBA, 1983). They are related to the imbedding of the Malko Turnovo hypabyssal intrusive body into the Paleozoic and Mezozoic marbles, shists and marls. On the contact zone of the intrusive body with the carbonate rocks several iron-skarn deposits as Burdceto, Mladenovo, Propada, Gradishteto and s. o. were formed. The copper mineralization accompanied by some molybdenite and sheelite is superimposed on the iron-skarn ore bodies. The iron-skarn mineralization is connected with the first gabbro-monzodiorite stage of magmatic activity, while the sulphide copper-molybdenum and sheelite mineralizations were formed later on, during the next granodioritic and granitic intrusive stages. They are of hydrothermal origin.

The skarn bodies are of andradite-grossular-pyroxen composition with wollastonite, skappolite, forsterite and other minerals. They are accompanied by magnetite and hematite. The superimposed hydrothermal copper-molybdenum-scheelite mineralization form the nest-like, column-like and irregular ore bodies. As a result of replacement of the iron-skarn ore bodies by later hydrothermal mineralization, the chalcopyrite-magnetite, chalcopyrite-specularite, chalcopyrite and chalcopyrite-bornite ore bodies were formed. They are accompanied usually by pyrite and disseminated molybdenite, scheelite, bismuthinite, vitehinite and other rare minerals. The copper ore mineralization can be traced up to 100 m from the surface.

Sequences of the Copper ore Deposition in Srednogorie Zone

The copper mineralizations in Srednogorie zone are connected with Paleozoic (?) and Upper Cretaceous magmatic activity. During the Upper Cretaceous the commercial copper ore deposition appeared in several stages, when the massive sulphide, porphyry copper, vein-copper and skarn copper deposits were formed. According to the available data of absolute age determination and development of the magmatism in Srednogorie zone, the following four types of Upper Cretaceous copper ore mineralizations, connected with various stages of magmatic activity, can be distinguished: 1. massive sulphide, related to the andesite-dacite stage of magmatic activity in Panagyurishte ore district, with absolute age of 82–77 my (CHIPCHAKOVA, LILOV, 1976); 2. porphyry-copper, associated with subvolcanic stage of granodiorite and quartzdiorite porphyrites in Srednogorie zone with absolute age of 75–72 my (BOGDANOV, 1982); 3. skarn-copper, connected with the granodiorite-granite porphyrites in Malko Turnovo gabbro-diorite-granite intrusive body (no data about absolute age determination are available), and 4. vein-copper and copper-gold polymetallic, related to the last postdyke stage of development of subalkaline magmatic activity in Burgas ore district, with absolute ages of 50–60 my (AMOV et al., 1976).

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