MAIN FEATURES IN GEOLOGY AND METALLOGENY OF THE PANAGYURISHTE ORE REGION

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ABSTRACT

The Panagyurishte ore district is located in the Central Sredna Gora and partly in the Stara Planina mountains. It is an element of the Upper Cretaceous Apyseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt. Forming of this ore region is determined by the development of intensive Upper Cretaceous volcanic and magmatic activity. Magmatic rocks belong to two petrochemical series: calc-alkaline and subalkaline ones. Magma generation took place in enriched upper mantle with variegating participation of crustal component. It is established following well expressed volcano-intrusive complexes: Elatsite-Chelopech, Krassen-Petelovo, Vrankamik, Assarel-Medet, Svoboda-Ovchinulm, Elshitsa and Pesovetz. Magmatic activity is realised during Conniasian-Santonnian and the distinct migration from north to south is established. Ore fields include Elatsite-Chelopech, Krassen-Petelovo, Assarel-Medet, Radka and Elshitsa. Metallogenic specialisation of the region is determined by numerous Cu, Cu-Mo and Cu-Au porphyry deposits associating with high to intermediate sulphidation epi- to mesothermal massive sulphgide Cu-Au, Cu-Pyr-Au and Cu-Pyr deposits. Intermediate to low sulphidation Cu, Pb-Zn-(± Au), Au w Ba deposits related to brittle faulting are developed in the marginal parts of the ore fields. Mn ore occurrences type "silicified umbra" are found in volcano-sediment rocks in the region.

INTRODUCTION

The Panagyurishte ore region is located 55 – 95 km east from Sofia. Its territory involves parts from the Central Srednogorie and the Stara Planina Mountain between towns of Pazardzhik and Etropole with total area of 1500 km². Its geological position is determined by the area of development of an intensive Upper Cretaceous magmatic activity and related to it mineral deposits (Georgiev, 1939; Konstantinov, 1952; Dimitrov, 1960; Bogdanov, 1987; Popov & Popov, 1997).

The Panagyurishte ore region is an element of the Apuseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt as it was determined the last years (Popov et al., 2000). The belt is commented by different authors as "Banat-Srednogorie zone", "Banatite belt" or a part of Carpathian-Balcanides. This belt is formed as a result of extentional processes in relation to the manifestation of the post-subductional and intra-collision mantle diapirism in the zone of transformation of subducted fragments from the oceanic crust. (Popov, 1981, 1987, 1996; Berza et al., 1998)

Over 150 ore deposits, ore occurrences and mineral indications are found in the Panagyurishte ore region. It is characterized mainly by presence of porphyry copper and massive sulphide copper deposits. Small gold, gold-polymetallic, baryte lead-zinc and manganese deposits are established as well. 489 555 400 t ore and respectively 3 946 092 t copper (in ore), 665 185 t sulphur (in pyrite concentrate), 46 507 kg gold (in ore), about 13 000 t Mo (in ore)and about 195 900 t baryte re extracted from the district within 1942 and 1995 years. Current mining activity is on going in Elatsite, Assarel and Chelopech deposits.

GEOLOGY

The main features in the geology of the Panagyurishte ore region that control development of the metallogenic processes in the space and time are determined by the characteristics and evolution of the Upper Cretaceous magmatic complexes. The effusive rocks united in the Panagyurishte volcanosedimentary group (K. Popov, 2001a) overlay on Turonian sediments and in the most southern part on the rocks from Pre-Mesozoic basement. They are overlapped by post-volcanic Upper Santonian-Maastrichtian carbonate and flish sediments.

Petrochemical data show that Upper Cretaceous magmatic rocks belong to two petrochemical series: calc-alkaline and subalkaline (Popov, 1981; Popov & Popov, 1997). Calcalkaline rocks have dominant distribution. The volcanic rocks are mainly with andesitic and less dacitic composition, while hypabyssal and subvolcanic hypabyssal varieties are mainly granodiorite and granodiorite porphyrites. Calc-alkaline rocks are of high potassic type (Ignatovski & Bayraktarov, 1996) and in some complexes the content of alkaline oxides is increased which suggest transition to subalkaline ones. Subalkaline rocks are presented mainly by latite and trachyandesitebasalt rarely trachybasalt, trachyriolite and trachite. The different petrochemical type of the rocks lead to conclusion that magma generating take place in different depths. The last studies or ratio 87Sr/86S for some representatives of the calc-alkaline serie was determined as following: for the effusive rocks from the Chelopech volcano the ratio is between 0.7049 и 0.7054 (Stoykov et al., 2003)., for the intrusive rocks from Elatsite between 0.70492 u 0.70571 (Von Quadt et al., 2002) and for the intrusive rocks at Elshitsa - between 0.70514 и 0.70583 (Peytcheva et al., 2003). These data show for enriched mantle

source, mixed in varying proportions with crustal material. It could be presumed that subalkaline magma are entirely a product of the upper mantle.

Detail structural-volcanic studies in the district establish that the volcanic activity is dominantly central type. Following volcanoes are determined in the region: Elshitsa (Bogdanov et al., 1970, 1974), Chelopech (Popov & Moutafchiev, 1980; Popov et al., 1983), Assarel (Angelkov & Parvanov, 1980; Popov & Petkov, 1994; Popov et al., 1996), Pesovetz (Bogdanov et al., 1974), Ovchihulm and Svoboda (Popov & Popov, 1997, 2000), Vrankamik (Ignatovski & Bayraktarov, 1996), as well as Tangur, Petelovo and Smilets (Popov & Popov, 1997, 2000). Slavov et al. (1978), Angelkov & Staikov [1980] and Ignatovski & Bayraktarov (1996) suggest a little bit different interpretations for some parts of the district which are not confirmed.

On the base of the studies provided and analysis of data obtain in could be concluded that as a result of the Upper Cretaceous magmatic activity an unit of well individualised volcano-intrusive complexes is formed on the territory of the Panagyurishte ore region (Popov & Popov, 1997, 2000). Recent studies established following volcano-intrusive complexes: Ealtsite-Chelopech, Krassen-Petelovo, Vrankamik, Assarel-Medet, Svoboda-Ovchihalm, Elshitsa and Pesovetz (Fig. 1). These magmatic complexes are set up by accumulative volcanic structures formed during the effusive processes and also by the associating comagmatic subvolcanic to hypabissal intrusive bodies and dykes. The intrusives cut effusive rocks and the rocks from the basement. In some of the complexes on the davlight surface intrusives are presented only by subvolcanic bodies they could be determined as volcanic-subvalcanic. Accumulative parts of the described complexes usually are characterised as well individualised stratovolcanoes of central type often elongated along the magma channel faults. In some cases volcanoes are located closely to each other in space and time and they formed complicated accumulative structures from the volcanogenic "brachianticlines" type. Presence of some smaller separated or satellite volcanoes is not excluded. Differentiation of the volcanoes is based on the spatial development of magmatic rocks from different facieses, lateral relations of the effusive rocks with sediments and volcanosediment depositions, their position in the Upper Cretaceous column and the specific features in petrological and chemical composition of their rocks.

Characteristic feature in the evolution in the different magmatic complexes and the whole volcanic activity is the intensive volcano-tectonic faulting. This process takes place during the entire period of magmatic activity and it is most effective after the end of effusive activity in separate magmatic complex and before introduction of subvolcanic intrusives. This faulting determines block separation of the volcanic structures and movement of rocks formed at different depths to one and the same level. As a result effusive rocks that are products of later formed volcanoes lay over different levels of the older effusive units. These Intra-Santonian fault movement are demonstrated as well as by the fact that Upper Santonian-Maastrichtian postvolcanic depositions overlay on eroded in different grade volcanic structures formed during different stages. Intrusive bodies as a rule are present by two sequentially formed groups: subvolcanic and subvolcanic-hypabissal to hypabissal. They are intruded the most often after volcanotectonic faulting and block separation of the volcanic cones. The Elshitsa pluton is an exception that is formed after effusive activity but before volcano-tectonic faulting. Small intrusive bodies formed before the effusive activity are known as well in the Elatsite-Chelopech complex.

The forming of volcano-magmatic complexes could be divided into four stages (Popov & Popov, 1997, 2000; K. Popov, 2001a). Distinct migration of the magmatic activity from north to south is established.

Elatsite-Chelopech volcano-intrusive complex is formed during the first stage in the most northern part of the regiont. Krassen—Petelovo volcano-intrusive complex formed by several interfingering volcanoes (Petelovo, Tangur, Smiletz) is formed during almost the same time between Panagyurishte and the villages of Smiletz and Ovchepolzi. The Vrankamic volcano-intrusive complex is formed northwest from Panagyurishte during the same stage.

Assarel-Medet volcano-intrusive complex which partly overlays on Vrankamic and Krassen-Petelovo volcanoes could be divided as second stage. Forming of Ovchihalm and Svobodinski volcanoes that overlay on the rocks of Petelovo and Smiletz volcanoes also could be nominated as a part of the second stage.

Third stage is marked by forming of the Elshitsa volcanointrusive complex which includes Elshitsa volcano, Elshitsa intrusive and numerous subvolcanic bodies. It overlays on the Ovchehalmski volcano to the north and on the rocks from the basement to the south.

The forming of Pesovetz volcano marks the fourth stage. It overlays on different levels of the Krassen-Petelovo, Svobodino and Slshitsa complexes.

Paleonthological data conclusively prove that magmatic activity took place almost entirely during the Coniacian and Santonian (88 -83 Ma). It is confirmed also by the fact that effusive rocks overlay on Turonian and they are overlapped by Upper Santonian-Maastrichtean sediments (Vrublyanski et al., 1961; Karagjuleva et al., 1974; Moev & Antonov, 1978; Dimitrova et al., 1984; Jelev et al., 1999). The last few years were realised determinations of the absolute age of the magmatic rocks. The age of the Elatsite intrusive is determined as 91.72+0.70 - 90.78+0.44 -90.78+0.44 Ma based on 40Ar/39Ar method, Vosdol neck (north from Chelopech) - 89.95+0.45 Ma, Medet intrusive is aged as 85.70+0.35 Ma and andesites from St. Nikola Hill (south from Panagyurishte) 80.21+0.45 Ma (Hander et al., 2002). Based on ²⁰⁶Pb/²³⁸U zircone method the age of the intrusive rocks in Elatsite is determined as 92.1+0.3 - 91.84+0.31 Ma (Von Quadt 2002), The Elshitsa granite is aged 86.62+0.02 Ma and Elshitsa subvolcanic dacites-86.11+0.23 Ma (Peycheva et al., 2003). Data from the absolute age determinations show increasing of the results compared to the paleothological data but they confirm the known fact that the migration of the magmatic activity is developing from north to south.



Figure 1. Geological Map of Panagyurishte Ore Region (compilated by K. Popov) Ore Fields: I - Elatsite-Chelopech; II - Assarel-Medet; III - Krasen-Petelovo; IV - Radka; V - Elshitsa

METALLOGENY

Metallogenic characteristics of the Panagyurishte ore region is determined mainly by development of numerous porphyry copper and massive sulphide copper deposits. Smaller copper, gold, gold-lead-zinc and gold-copper-lead-zinc deposits and ore occurrences of vein type associate very often

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with them. Several manganese ore occurrences are also established in the region. Forming and spatial distribution of these mineral deposits is controlled by the position, evolution and structural features of the Upper Cretaceous volcanointrusive complexes. The ore fields are localised within the frames or parts of these complexes (Fig. 1). The boundaries of the ore fields are determined by the area of development of the late subvolcanic and subvolcano-hypabyssal intrusions and large dykes. Five ore fields (districts) are established in the region: Elatsite-Chelopech, Assarel-Medet, Krassen-Petelovo, Radka and Elshitsa ore fields, involving unified ore-magmatic systems. Porphyry copper, massive sulphide and vein deposits and ore occurrences which are a result of the evolution of one and the same ore magmatic system within the frames of each ore fields are developed.

The Elatsite-Chelopech ore field is located in the most northern part of the region within the frames of the volcanoplutonic complex with the same name. It is set up by Early small intrusives, the Chelopech volcano (including the Vosdol monovolcano) and Later small intrusives. Ore deposits Elatsite, Chelopech, Negarshtitsa, Kashana, Dolna Kamenitsa, Vosdol, Karlievo and probably Svishti plaz are developed in this ore field.

The Assarel-Medet ore field is located northwest from the town of Panagyurishte within the area of the Assarel-Medet volcano-intrusive complex. It includes Assarel volcano, Medet, Assarel, Lisa Mogila and numerous smaller intrusives. Porphyry copper deposits Medet, Assarel, Orlovo Gnesdo as well as numerous ore occurrences are found in this ore field.

The Krassen-Petelovo ore field is located south-east from the town of Panagyurishte in the central part of the volcanoplutonic complex with the same name. It is set up by Petelovo and Tangur volcanoes and Petelovo intrusive. Ore deposits in it are Krassen, Petelovo and Kominsko Chukarche.

In the most southern part of the ore region is located the Elshitsa volcano-intrusive complex which includes Radka ore field in its northern part and Elshitsa ore field in its southern part. Their spatial development is controlled by two sheaves of linear subvolcanic bodies cutting respectively southern and northern slopes of the Elshitsa stratovolcano. Ore deposits Radka, Tzar Assen and Chervena Mogila belong to the Radka ore field and Elshitsa, Vlaykov Vruh and Popovo Dere are within the frame of Elshitsa ore field.

Porphyry copper ores are found in Medet, Assarel, Elatsite, Vlaykov Vruh, Tzar Assen deposits as well as in subeconomical deposits Orlovo Gnesdo, Karlievo, Popovo Dere, Kominsko Chukarche, Petelovo and numerous ore occurrences The lateral distribution of porphyry copper deposits is controled by Upper Cretaceous hipabyssal to subvolcanic-hipabyssal porphyritic intrusives and dyke sheaves. They are usually members of the different volcanointrusive complexes described above. The porphyry copper deposits are located in some cases in the central parts of the volcanoes and in the rocks from the basement in other cases. The ore bodies are present by column-like ore cone-like inclining, rarely linear elongated stockwerks formed by disseminated ore mineralisation.

Porphyry copper deposits in the region could be divided into two groups on the base of their specific features. The first group includes ore mineralisations and hydrothermal alterations developed mainly in the apical parts of intrusive bodies and partly in the rocks from the frame (Medet, Elatsite). The second group includes deposits in which ore mineralisation and hydrothermal alterations affect not only the upper part of the small porphyritic intrusives but the largest part of it is developed in the effusive rocks and volcanic neck of the complexes (Assarel, Tzar Assen). The development of the hydrothermal systems in the first group is characterised by relatively limited participation of meteoric waters and higher temperatures of the ore-forming processes. The early stages of the evolution of the systems is determined by the large forming of K-silicate alterations of the host rocks mainly in the central parts of the deposits gradually changed to propilitisation in the marginal parts. Fluids separated in the initial stage of the hydrothermal process are characterized by high salinity (up to 50 wt. % NaCl equiv.) and temperatures above 450° C (Strashimirov et al. 2002) which suggest their mostly magmatic origin The next stages of the evolution of the systems are characterised by gradually dicreasing of the temperature and salinity of brunes due to the removement of the generating source in depth and large participation of meteoric waters in the systems. Hydrothermal alterations of the host rocks that accompanied ore precipitation are mainly of sericitic type.

The second group of porphyry cooper deposits are characterised by hydrothermal processes developed relatively closer to the daylight surface and the ore-bearing small porphyritic bodies are intruded in volcanic accumulative cones. K-silicate alterations are developed in significantly limited scale compared to the first group deposits. Dominating hydrothermal alterations are present by sericitic to propylitic types. These alterations are developed much intensively in the upper parts of the deposits in lower temperature conditions. Such alterations in the Assarel deposit are overlapped on earlier acid-silphate alterations formed during the effusive activity (Arnaudova et al., 1991).

Specific conditions of mineralisation in different porphyry systems in the region reflect to the composition of precipitated ore associations. The first group of porphyry copper deposits mentioned above is characterised by larger presence of Fe-Ti oxide association formed in the initial stage of the ore forming, distinct presence of quartz-molybdenite association, presence of Co-Ni mineral assemblages and relatively higher content of gold as trace element in ores (Strashimirov et al., 2002). Particular interest represents minerals from PGE established in the Elatsite deposit (Petrunov & Dragov, 1993) that suggest for deeper source of the brines probably with many basic geochemical characteristics.

Data from fluid inclusions studies in quartz determine the evolution of hydrothermal systems from type H_2O -NaCl \pm FeCl₂ to types H_2O -NaCl-KCl and H_2O -NaCl and gradually decreasing of salinity about 10 wt.% NaCl equiv. The precipitation of the main economic association quartz-pyrite-chalcopyrite in all deposits practically takes place within temperature range $350 - 250^{\circ}$ C. Later well-shaped veins of quartz-pyrite are formed in the intermediate and upper part of the deposits. Quartz-sphalerite-galena associations developed as short veins in the most upper and marginal parts of deposits

are typical for the later stages of the hydrothermal systems evolution.

Final of the hydrothermal activity is marked by precipitation of carbonates and zeolites as vein and veinlets that cut all formed before mineral associations.

Differences in mineral composition of deposits located in the apical parts of intrusive bodies and those located mainly in effusive rocks from paleovolcanic structures is underlined by appearance of polyelement associations including enargite (Assarel, Petelovo), goldfildite, colusite, aikinite, hessite and other sulphosalt minerals typical for high sulphidation style of mineralisation (Assarel, Petrunov et. al. 1993). Forming of well expressed cementation zone of secondary copper sulphide enrichment (Assarel, Orlovo gnesdo, Kominsko Chukarche) a result of intensive development of exogenic processes, which realisation is stimulated by the high grade of tectonic rework of the host rocks during the processes of volcano-tectonic faulting is another significant difference between both groups of porphyry copper deposits in the region.

Massive sulphide ores are found in Chelopech, Krassen, Elshitsa, Radka, Chervena Mogila deposits as well as in numerous ore occurrences such as Stiptsata, Varnichka Chukara, Isgorelia Vruh, Kaleto and others. These are epigenetic mineralisations which spatial distribution is controlled by the position of subvolcanic intrusives cutting the central parts or scopes of volcanic structures, as well as by the volcano-tectonic faults. Massive sulphide ores are located the most often in tectonic breccia or zones with intensive fracturing. They are developed mainly along the exocontact zones of linear or arc-like subvolcanic bodies, also in and around volcanic necks rarely in the explosion pipe. Ore bodies are with column-like, stock-like, lense-like or nest-like shape. Almost all of them are discordant to the layering in the effusive units. Typical are massive texture ores formed generally by metasomatic replacement of hydrothermal altered fractured and brecciated volcanic rocks. Low grade disseminated ores present as hallo around the massive ores. Tendency of precipitation of later formed and low temperature mineralisations in marginal and upper part of the ore bodies is established.

Massive sulphide ore deposits in the district could be divided into two groups according the type of ore mineralisation and hydrothermal alterations of the host rocks. The first group is represented by typical high sulphidation epithermal coppergold deposits. Chelopech deposit is one remarkable example for this group with its mineral composition including large scale of sulphosalt minerals and advanced argillic alteration of the host rocks. Hydrothermal mineral forming process is preceding by limited in volume hydrothermal-sedimentary precipitation of pyrite-marcasite association. Typical for the high sulphidation deposits ore associations including enargite, lusonite, famatinite, goldfildite, colusite, native gold, tellurium, bismuth and numerous minerals in Cu-Pb-Bi-S-Se, Pb-Bi-Hg-Te-Se and Cu-Au-Ag-Te systems are formed during the main ore forming process. Precipitation of large crystals of enargite marks the temperature conditions (280 - 300° C) within the range typical for the high sulphidation systems (Bonev et. al., 2000). Hydrothermal alterations include forming of zones of propylitic, sericitic, sericitic-advanced argillic, advanced argillic, propylitic-sericitic as well as representatives of the secondary quartzite formation – quartz-dickitic and quartz-alunite facieses.

The second group is represented by intermediate sulphidation epi- to mesothermal copper-pyrite and copperpyrite-gold deposits. The first variety includes Elshitsa and Radka deposits and the second one includes Krassen and Chervena Mogila deposits. The evolution of ore forming processes is similar in both subtypes - initial stages are marked by precipitation of iron-sulphide associations followed by copper sulphide and polymetallic associations. The final of hydrothermal activity includes forming of significant quantity of gypsum and anhydrite. Temperature range of mineralisation is a broad one. Hydrothermal alterations start at about 400° C and the end of hydrothermal activity is probably about 160° C (Strashimirov & Kovachev, 1992). Kouzmanov et al. (2002) determined through infrared microthermometry of pyrite from Radka deposit temperature of its precipitation 360 - 320° C and low bulk salinity 3.5 - 4.6 wt. % NaCl equiv. Sulphosalt minerals found in these deposits are not so various like those established in the first group, the quantity of enargite is significantly low. Distinct differences are also found in the hydrothermal alterations of the host rocks. Typical for the group discussed are propylitic, propylitic-sericitic and sericitic alterations while the advanced argillic type is not developed except as minor occurrence in Chervena Mogila deposit. All these differences give a reason for differentiation of both groups in epithermal deposits from the district.

Vein type ore deposits are developed in the marginal parts of porphyry and massive sulphide deposits and they could be accepted as integral part of ore magmatic systems. They could be determined as brittle-fault related veins and silicified breccia ore deposits. Based on the type of are mineral associations and hydrothermal alterations presented in them they could be classified as intermediate to low sulphidation epi- to mesothermal mineralisations. Their composition is different – copper, lead-zinc (<u>+</u> Au) (Dolna Kamenitza deposit), copper-lead-zinc (<u>+</u> Au) (Vosdol deposit), gold (Negarshtitsa) or baryte (Kashana).

An other specific feature of the Panagyurishte ore region is a development of manganese mineralisations type "silicified umbra". This type is presented by ore occurrences Momin Skok, Toplika, Milkova Chesma, Dulgi Rid (Oborishte) and other.They are banded-like or lense-like ore bodies localized concordant to layering along the contact between andesite and argillic rocks that cover it. Their composition includes pyrolusite, psilomelane, manganite and braunite with which associate chalcedony, quartz, baryte, calcite and zeolites (Dimitrov & Kostov, 1954).

CONCLUSIONS

Combined lateral distribution of described above two types copper deposits and associating with them vein deposits within the frames of distinct expressed ore fields is one remarkable feature of the Panagyurishte ore region suggesting unified source and well established sequence in evolution of ore bearing systems from which mineralisations are precipitated in the different ore fields. Isotopic studies of fluid systems in

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Radka, Elshitsa and Vlaykov Vruh deposits provides strong evidences for existing of unified ore-magmatic systems within the frames of single ore fields (respectively volcano-intrusive complexes) (Kouzmanov et al., 2001). Within the frame of these systems forming of porphyry copper and epithermal deposits is established as a result of consecutively developed processes. The migration of magmatic activity in general from north to south in different ore-bearing volcano-intrusive complexes it is established larger participation of crustal material in magma which mark much shallow levels of magma generation. Significant content of gold and presence of PGE minerals in the most northern part of the district (Elatsite-Chelopech ore field) is probably connected to the deeper generating of the magma chambers that are related to the ore mineralisations. The gold content decreases and PGE minerals are not found in the ore fields from the southern part of the region.

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