PETROLOGY OF THE MAGMATISM OF THE ASSAREL COPPER-PORPHYRY DEPOSIT

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The Assarel porphyry-copper ore deposit is situated in the central part of Srednogorie zone near Panagurishte town. Srednogorie zone is a part of the Carpathian-Balkan metallogenic province and it is characterized by Upper Cretaceous magmatism and disposition of numerous copper, gold-copper, copper-molybdenum and copper-base metal deposits and occurrences.

Recent investigations on the magmatism and ore deposits in Central Srednogorie (Lilov & Chipchakova, 1999; Heinrich & Noebauer 2003; Kamenov et al., 2004) demonstrated that the magmatism evolved in space and time rejuvenating from north to south. The study also showed that the specificity of each ore deposit is closely related to its magmatic centres. That makes actual the investigation of the individual magmatic centres.

Geology

Central Srednogorie comprises the following major composite elemets: Palaeozoic basement, Mesozoic-Tertiary cover and predominant faults with W-NW direction.

The Paleozoic basement of Panagurishte ore region comprises metamorphites (gneisses, amphibolites) formed in amphibolite facies and granodiorite-granitic plutons (Smilovenski, Koprivshtenski, Strelchanski). The Mesozoic cover consists of Triassic and Cretaceous sediments and volcanites (E. Karaguleva et al 1978) disposed in strike-slip basins (Ivanov et al., 2001) with WNW direction where volcanites form anticlinal stripes with same direction (C. Dimitrov, 1983) in a transpressional geological setting (Ivanov et al., 2001). At the end of Senonian magmatic activity subvolcanic to hypabyssal small intrusives and dykes crosscut the volcanites and the rocks from the basement. Synchronous and postmagmatic hydrothermal alteration took place preceding or together with the ore formation.

The copper-porphyry deposit in the Assarel magmatic centre is controlled by the intersection of volcanic stripes (emplaced in strike-slip basins formed by faults with ESE-WNW direction – 100-130^o) with the deep faults of Panagurishte corridor (Tzvetkov et al., 1978) with NNW direction. The Assarel copper-porphyry deposit occurs in the most eastern part of the Assarel volcanic stripe.

The basement in the Assarel deposit is presented by biotite or two mica gneisses, granodiorites, granites, pegmatites, and aplites of the Smilovene pluton. Smilovene pluton is built up by coarse grained granodiorites, fine grained granite and small pegmatite and aplite veins. The Senonian volcanics are presented by: 1) Hb andesites to latites; 2) Px-Hb to Hb-two pyroxene basaltic andesites with small mafic rounded enclaves; and 3) subvolcanic Bi-Hb to Hb-Bi andesites, Q-andesites to dacites. A small porphyritic subvolcanic to hypabyssal plutonic body is intruded in the central part of the deposit. Dykes in the northern part of the deposit less affected by alteration distinguish three intrusive phases: 1) Fine to medium porphyritic quartz-diorite to granodiorite; 2) Q-monzonite porphyries; 3) Q-porphyry (granite porphyry).

Rockforming minerals

Plagioclase is a major mineral presented in all the analysed rocks. Two or three plagioclase generations are present in the volcanic rocks. The first generation is rounded or deeply corroded in all its volume, sometimes forming spongy texture of the phenocrysts. The magmatic corrosion of plagioclase – I is probably due to magma mixing processes in the intermediate magmatic chamber, where more primitive mantle derived magma has been injected. The already crystallized plagioclase generation I is not in equilibrium with the new mixed, hotter magma. The second generation plagioclase is presented by clear, zoned, euhedral phenocrysts. Some of the plagioclases generation II shows reverse or oscillatory arrangement, which is often disposed as external clear zones on the plagioclase of the first generation. The plagioclase microliths in the groundmass are of the third generation. Plagioclase II often has melt inclusions.

Amphibole phenocrysts are present in all of the analysed rocks. Classified after Leake et al., (1997), the amphiboles are calcic. The amphibole in Hb-andesites to latites is chermakite (Mg# =0.55-0.82). In Px-Hb basaltic andesites the amphibole is chermakite, magnesio-hornblende, or magnesio-hastingsite (Mg# = 0.60-1). In Bi-Hb andesites it is chermakite and magnesio-hornblend (Mg# = 0.61-0.99). The amphiboles are rarely zoned but often with melt (up to 50 m) and sulphide inclusions (up to 35 m). In the external zones they are with higher Mg and Ti contents.

Pyroxene is established mainly in basaltic andesites. It is mainly clynopyroxene (diopsides to augites Mg# = 0.61- 0.79) and orthopyroxene is established only in one sample (enstatite Mg# = 0.78). Optically the pyroxenes are homogenous with melt and sulphide inclusions. Microprobe analyses show Mg and Al enrichment in the peripheries probably due to magma mixing in the intermediate magmatic chamber. Pyroxenes which are from the enclaves do not differ significantly from the phenocrysts of the host rock.

Biotite is established in Paleozoic granodiorites and granites and in late Cretaceous Bi-Hb andesites. In andesites biotite is slightly altered with K_2O content less than 6 wt%. Biotites are typical for the calc-alkaline suites. The magnesial number of biotite decreases with the increase of the rocks acidity. Mg# for the andesites is 0.63-0.73 while it is 0.48-0.52 for the Paleozoic granodiorite and granites.

The accessory minerals in the studied volcanites are presented mainly by titanomagnetite and apatite. Zircon is established in Bi-Hb andesites. Very small rounded sulfide inclusions (up to several tens of microns) with pyrothite and rarely chalcopyrite composition were established in the amphiboles and less in pyroxenes from Hb andesites, Px-Hb basaltic andesites and Bi andesites. This could be interpreted as a result of the high S potential of the magma.

Petrology

Petrologic investigations were carried on the volcanic and plutonic rocks from Assarel volcanic stripe and Assarel ore-magmatic centre. The volcanic structures are practically not preserved and epiclastic rocks predominate in the volcanic stripe. Pyroclastic rocks and lava flows are rarely preserved. Subvolcanic bodies, dikes, and necks are relatively well preserved and their concentration in some places gives the possibility to locate the volcanic centres and to follow the magmatic evolution. The succession of the magmatic event is as follows: 1) Firstly Hb andesites to latites have been formed, which are presented by epiclastic rocks and rare lava flows and pyroclastic rocks. These rocks build up the major part of the Assarel volcanic stripe; 2) the second volcanic event is related to the formation of several necks with isometric or oval form in cross section, and column bodies of clinopyroxene-amphibole to amphibole two pyroxenes basaltic andesites with small mafic rounded enclaves. Rare pyroclastic rocks (psammitic tuffs), dikes, and epiclastic rocks are distinguished as well. The small mafic enclaves which are evidence for magma mixing consist mainly of euhedral clinopyroxene and hornblende and plagioclase (andesine – labradorite) in smaller quantities, with rare presence of small biotite crystals. 3) The third volcanic event is related to the formation of subvolcanic bodies (isometric or elongated in WNW direction) of biotite-amphibole to amphibole-biotite andesites and quartz-andesites to dacites.

The existing magmatic series were deduced from the K_2O – SiO_2 diagram of Peccerillo & Taylor (1976). The volcanic rocks plot in the fields of the calc-alkaline (CA), high-potassium calc-alkaline (HKCA) to shoshonitic (Sh) series (amphibole andesites to latites plot in the CA, HKCA and the Sh series; the amphibole-pyroxene basaltic andesites plot in the CA and HKCA series; the biotite-amphibole andesites plot in the HKCA and the Sh series; dacites plot in the CA and the HKCA series). Porphyritic intrusive rocks plot in the HKCA series.

The content of the alkaline oxides increases through the magmatic evolution whilst the TiO_2, Al_2O_3, FeO, Fe_2O_3, MgO and CaO contents decrease. Trace elements behaviour show decreasing of Co, Ni, Li, Sc, V, Ga, Y, Zr, Nd, Y content and increase of Rb and Th content during the magmatic evolution. The content of Pb, Zn, Cu, Cr, Ba, As, La, Ce, Nb, and Hf is relatively constant but Cu demonstrates a slight upward inflexion at the end of the evolution process.

The hondrite-normalized distribution patterns of REE for (a) Hb andesites and latites (La_n/Yb_n = 6.8), (b) Px-Hb basaltic andesites (La_n/Yb_n = 7.4 – 8.7), (c) Bi-Hb andesites (La_n/Yb_n = 9.8 – 10.2), and (d) porphyritic intrusive rocks (La_n/Yb_n = 14.2) are characterized by a slope from light to heavy REE (enrichment in light REE), lack of negative Eu anomaly and a successive increase of the La_n/Yb_n ratio during the magmatic evolution. That could be explained with fractionation of pyroxenes and amphiboles during the magmatic evolution and without the participation of plagioclase in the fractionation.

The hondrite-normalized distribution patterns of REE for the Paleozoic granodiorites are characterized with a slightly negative Eu anomaly and a relatively higher REE content compared to the Senonian magmatic rocks from Assarel.

Discrimination diagrams of the series Nb – Zr - Y for the basaltic andesites (after Meshede, 1986) and Rb - Y+Nb (after Pearce et al, 1984) for the porphyritic late Cretaceous granitoides, indicate a volcanic arc tectonic setting for this magmatism.

The pressure in the crystallization process was estimated with the amphibole geobarometer of Johnson & Rutherford (1987) as 4 – 5 kbars for Hb andesites, latites and Hb-Bi andesites, and 6 – 7 kbars for basaltic andesites. Pressure estimation after the Schmidt (1992) geobarometer for the Pz granodiorite is 4.5 – 6 kbars. Crystallization temperatures determined with the Blundy and Holland (1990) geothermometer based on the equilibrium between Hb and Pl are in the range of: 790-940°C for Hb andesites and latites, 780-910°C for basaltic andesites, 730-810°C for the Hb-Bi andesites and 760°C for the Palaeozoic granodiorites.

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