MAGMATISM OF THE BOROV DOL COPPER OCCURRENCE

Violeta Stefanova[1], Rossen Nedialkov[2], Robert Moritz[3]

[1] Faculty of Geology and Economic geology, Stip, Macedonia
[2] Sofia University "St. Kliment Ohridski", FGG, Bulgaria
[3] Geneva University, Switzerland

The small metallogenic area of Bucim-Damjan-Borov Dol (150 km^2) in the Republic Macedonia is characterized by deposits and mineralizations of iron, copper, gold and base metals. The Bucim-Damjan-Borov Dol area is divided into two tectonic blocks. The Bucim tectonic block in the northern part of the area is an integrated part of the Serbo-Macedonian Massive (SMM). The southern tectonic block Damjan is a part of the Vardar zone. The blocks are divided by a fault of first order with SE direction (approximately 150^o). Despite of the disposition in two different tectonic blocks, the metallogenic area is unified based on the similarities of Tertiary magmatism and the analogous ore mineralizations. In the northern block occurs the Bucim copper-porphyry deposit with additional gold mineralization.

Geology

The volcanic activity of the Damjan tectonic block is characterized by the formation of three volcanic ring structures with caldera type of evolution disposed in a zone with SE direction (T. Serafimovski, 1990). The major volcanic structure disposed in the central part of the area has a small caldera (about 1 km in diameter) disposed in the apical parts of the volcano east of the village of Brest. The two minor volcanic structures are disposed south (SE of the village of D. Vrashtitza) and north (east of Shopur village) of the Borov Dol volcano. The volcanic rocks outcrop on a surface of about 50 km^2 (S. Karamata et al., 1992). The magmatic rocks of the Damjan block crosscut Alb-Cenomanian and Paleogene sediments (Karamata et al., 1992).

The basement of the Damjan block comprises Precambrian and Paleozoic metamorphic rocks (gneisses, calc schists, metacarbonates). They are covered by Cretaceous sediments and Tertiary volcanics, carbonate flish sediments and conglomerates.

The volcanic structures of the Damjan block are built up of pyroclastic and epiclastic andesites and mainly latites, quartz latites and trachytes, rarely preserved small lava flows and cupolas. The thickness of the volcanic rocks is estimated to be approximately 500 m (Tudzarov, 1993).

Petrography

Andesites essentially occur as dikes and sills controlled by faults in the volcanic structure. They have been established mainly in the vicinity of the Damjan deposit. They have porphyritic texture with large phenocrysts of plagioclase, amphibole and biotite, rarely pyroxene.

Latites are grey to light grey with porphyritic texture and recrystallized groundmass. Phenocrysts (up to 35-40%) are presented by plagioclase (andesine-oligoclase – An_{42-12}), amphibole (edinitic hornblend, fero edinitic hornblend and fero pargasite), biotite and rarely pyroxene (diopside and augite) and sanidine. They occur as pyrroclastic and epiclastic rocks, lava flows, dikes, necks and subvolcanic bodies in all the volcanic area.

Quartz latites are similar to latites but they have quartz phenocrysts in addition and less mafic minerals in comparison with the latites.

Trachytes are two types – porphyritic (as latites) and afanitic. Afanitic trachytes are grey with rare small phenocrysts of sanidine (Or_{68-55} Ab_{39-26} Cn_{1-6}). The groundmass is recrystallized. They form lava flows, dikes and sills.

Mineralogy

Plagioclase in latites and trachytes is present in two generations. The first one is represented by large phenocrysts (0.7 up to 1.5 cm) with not quite evident zonal arrangement. In most of the cases the zonal arrangement is normal with increasing of the Ab component toward the periphery. In some cases no chemical zonality exists. In other cases oscillatory or reverse zonality has been established with small variation in the andesine composition (core An_{29-31}, rim An_{38-39}). The Or component in plagioclase is constant and with small variations (Or_{1-4}). No Cn component has been established in plagioclase in latites (without Ba in their composition). Large phenocrysts often include small biotites and amphiboles.

The second generation of plagioclase is presented by smaller phenocrysts and groundmass minerals. They are andesine to oligoclase (An_{31-14}) without zonal arrangement. Their composition corresponds to that from the most external zones of the big phenocrysts with normal zonal arrangement.

Biotites are euhedral to subhedral - up to 1,4 mm in size. They show clear pleochroism and Mg# 0.53-0.64. Biotites belong to the phlogopite – annite succession. In a latite from Pamukluk biotite shows chemical zonality with more magnezial central parts (Mg# = 0.7) than their periphery (Mg# = 0.55). The trachytes with small phenocrysts from Damjan are characterized by relatively high and constant Mg# = 0.64 in biotites. The biotites in the trachytes from Pamukluk have low Al_2O_3 contents.

Amphiboles are euhedral, greenish with clear pleochroism and C:x = 21-27^o. They are up to 2 mm in size and include plagioclase or biotite in rare cases. They are not zonally arranged and Mg# varies between 0.62 and 0.33. They are the less magnesial mafic minerals in the latites. Amphiboles from the northern part of the volcanic area (Pamukluk) show the highest amplitude of Mg# variation and the highest Al_{total} content. In the classification scheme for amphiboles (Leake et al., 1998) they are determined as calcic amphiboles. Amphiboles from latites show higher contents in Al_2O_3 and MgO than those in trachytes. In relation with the crystallization process three types of amphiboles could be distinguished: 1 – rare, small

Hb with relatively high Mg# (0.7) and Al_2O_3 contents (edenite, pargasite), trapped in plagioclase phenocrysts; 2 – relatively large phenocrysts including plagioclase, potassic feldspar and biotite, with moderate Al_2O_3 content and relatively low Mg# (0.35 – 0.45) ploting in the fields of edenite, ferroedenite, pargasite and ferropargasite in the classification diagram; 3 – small euhedral phenocrysts in the groundmass with relatively low Al_2O_3 content and low Mg# (ferroedenite).

Pyroxenes have been established and analyzed only in one trachyte sample from the area of the Damian skarn-iron deposit. They are monoclinic - diopsides and one augite (pigeonite). They are small - up to 0.5 mm in size and with high Mg# = 0.72-0.90. Clinopyroxene is the most magnesial mafic mineral in the latites and is probably first crystallized. The unique augite (pigeonite) is probably a xenocryst preserved during the melting of the source rocks

Potassic feldspars in latites and trachytes have been analyzed from Damjan, Tzarkvishte and Borov Dol. Sanidine phenocrysts are euhedral or corroded showing chemical zonality related to the Ba content increasing toward the core of the minerals. BaO content is relatively high up to 3.21% of the chemical composition of sanidine.

Major and trace element geochemistry of the volcanites

On the TAS classification diagram analyses plot in the fields of the andesites, dacites, latites and mainly trachytes (one analysis determines a vulcanite as a trachydacite, Q_{norm} = 25%). On the diagram K_2O – SiO_2 all the rocks plot in the high – K series. The predominant part of the volcanites is Q – normative. Those volcanites with normative Q over 15% are corundum normative. A few numbers of trachytes (4 analyses) are olivine normative and one of them is nefeline normative showing their undersaturation in SiO_2. Through the magmatic evolution the contents of CaO, MgO, FeO+Fe_2O_3, P_2O_5, TiO_2 decrease, K_2O contents slightly increase and those of Al_2O_3 do not show any tendencies. Na_2O content increases through the evolution up to 61 % SiO_2 and then it slightly decreases. These tendencies in the behavior of the major oxides could be explained with the fractionation of mafic minerals (clinopyroxenes and amphiboles), titanomagnetite and apatite. The behavior of Na_2O and K_2O is probably controlled mainly by the fluid factor influencing the magmatic evolution.

Ni, Co, Sr and Zn decrease through the magmatic evolution that confirms the fractionation of mafic minerals, apatite and magnetite. The contents of Rb, Y, Pb (incompatible behavior) increase in the same way. An inflexion in the trends of Nb, Th and Cu has been observed.

On the MORB-normalized spidergram well pronounced positive anomalies for Th and Y (interpretation) and slight negative anomaly for Nb and TiO_2 have been observed what is characteristic for subduction related magmas. The trachyte from Tzarkvishte (afanitic - sample N 5) differs from the other volcanites in the Damjan block by the higher K_2O, Rb and Nb values, and the conspicuous negative Sc anomaly.

The Sr-Rb diagram shows that the geochemical evolution has been influenced by the behavior of biotite.

Discussion

In previous studies (Boev et al., 1992; Boev and Yanev (2001) on the Tertiary magmatism of the Republic of Macedonia the volcanic activity of the Bucim-Borov Dol area is determined as subduction-related in an active continental margin. The MORB-normalized trace element distribution and the discrimination diagram based on biotite chemistry confirm the synsubductional volcanism.

The notable presence of hydrous minerals (amphiboles and biotites) indicates the relatively high water content in the magma. Early crystallization of biotites and potassic feldspars, trapped in large amphibole phenocrysts indicates the high K potential in the magma.

The magma crystallization temperature has been determined on the basis of the equilibrium between the crystallizing plagioclase - amphibole with the Blundy & Holland (1990) geothermometer. The pressure conditions of the crystallization process have been determined with the Hb geobarometer of Johnson & Rutherford (1987). The relation between the minerals and the obtained results about the pressure estimation let us suppose a three stage crystallization process. The first stage of the crystallization process probably occurs in deeper part of the earth crust 17-21 km (P = 6 – 7 kbars and T = 765 - 780 ^oC) where clynopyroxenes and the early first type of amphiboles crystallize. The pegonite is probably a xenocryst preserved from the melted source rocks (MORB ?).

The second stage of the crystallization is probably at depth of 11 – 14 km (P = 3.5 – 4.5 kbars and T = 715 – 740^oC) where most of the amphiboles have crystallized.

The third last stage of crystallization when the small amphibole phenocrysts (subporphyres) have been formed is at depth of 5 – 6 km (P = 1.8 – 2 kbars). This is a shallower level of the magmatic chamber where degassing of the water-saturated magma occurs during the crystallization.

References

Blundy, J.B., T.I. Holland. 1990. Calcic amphibole equilibria and a new amphibole-plagioclase geothermometer. Contrib. Mineral. Petrol., 104:208-224.

Boev, B., V. Cifliganec, R. Stojanov & S. Lepitkova. 1992. Oligocene – Neogene magmatism in the region of Bucim block. Geol. Maced., 6, 1, 23-32.

Boev, B. & Y. Yanev. 2001. Tertiary magmatism within the Republic of Macedonia: a review. Acta Vulcanologica, vol. 13, 1-2, 57-71.

Johnson, M.C. and M.J. Rutherford. 1989 Experimental calibration of aluminium-in amphibole geobarometer with application to Long Valley caldera (California) volcanic rocks. Geology, 17, 17, 837-841.

Karamata, S., R. Stoyanov, T. Serafimovski, B. Boev & M. Alexandrov. 1992. Tertiary magmatism in the Dinaride and the Serbo-Macedonian massive. Geol. Maced., 6, 2, 127-186.

Serafimovski, T. 1990. The metallogeny of the Lece-Chalkidiki Zone. Ph.D. Thesis, Rudarsko-Geol. Fac., Stip. 264 pp.

Tudzarov, N., 1993: Metalogenija na naogalisteto na Bakar Borov Dol. Doktorska disertacija, Rudarsko-Geol. Fac., Stip.