

# Mineralogical investigation of enclaves present in calc-silicate rocks from Novo Selo-Kriva Lakavica, Eastern Macedonia

Tena Sijakova-Ivanova, Blazo Boev, Vojo Mircovski

Faculty of Natural and Technical science, University Goce Delcev, Stip, Republic of Macedonia; tena.ivanova@ugd.edu.mk, blazo.boev@ugd.edu.mk, vojo.mircovski@ugd.edu.mk

**Key words:** enclaves, calc silicate rocks, gabbro

This paper deals with the mineralogical investigation of mafic enclaves, which are present in metamorphic calc-silicate rocks from the area of Novo Selo-Kriva Lakavica (Macedonia). The host calc-silicate rocks are situated in the Vardar zone, which occupies the central part of the Republic of Macedonia. The rocks in this part of the Vardar zone suffered amphibolite facies Abukyma type regional metamorphism at medium to high temperatures and low pressures. The Abukyma type metamorphism is associated with the existence of paired metamorphic belt in the Vardar zone (Mircovski, V., 1997). The calc-silicate rocks are composed of calcite, diopside-hedenbergite, augite, actinolite, pargasite, K-feldspar, plagioclase, quartz, titanite, vesuvianite, clinozoisite, andradite-grossular, scapolite, prehnite (Sijakova-Ivanova 2000, Sijakova-Ivanova at all 2012). There are different opinions about the origin of the calc-silicate rocks, namely: carbonatites (Ivanov, 1987-88); skarns (Stojanov and Svesnikova, 1985); and regional metamorphic calc-silicate rocks (Sijakova-Ivanova, 2000; Sijakova-Ivanova et al., 1997, 2012).

Mafic enclaves of different shape and size (5 to 25 cm) are present in the calc-silicate rocks. The samples of study represent different types of enclaves according to their macroscopic appearance. Chemical, optical and X-ray analyses were performed for identification of enclaves rock types. The following types of enclaves were found based of the obtained results: finer granular amphibolic gabbro; medium-grained amphibolic gabbro; coarse-grained amphibolic gabbro; and serpentinitic wehrlite.

*Finer granular amphibolic gabbro* is composed of hastingsite, diopside, and plagioclase. Accessory minerals are titanite, apatite and zircon. Hastingsite appears in partially idiomorphic grains with size from 0.2 to 0.4 mm. All grains of hastingsite are fresh with no traces of chemical alteration. Diopside was classified using the pyroxene classification of Morimoto et al. (1988). The results from chemical investigation show that the diopside component ranges from 93.53% to 94.4%, while the hedenbergite component is from 5.6% to 6.55%. The grains of plagioclase display often completely altered central parts and crisp edges. Two generations of apatite could be distinguished by colour and crystal shapes. Some are bright-yellow, while the other are milky-white. Both are present in equal proportion. Milky-white apatite grains (probably originated from gel according to Tröger, 1969), have short-pillar shape with poorly developed (1011) faces. Zircon occurs as pale-pink and colourless grains. The latter are more abundant. It is characteristic that none of the populations have radioactive edges. This means that both populations are poor in uranium and thorium or are relatively young.

*Medium-grained amphibolic gabbro* comprises the following major minerals: tschermakite hornblende, diopside, K-feldspar and plagioclase. Zircon, titanite, and apatite appear as accessory minerals. For tschermakite hornblende the classification of amphiboles by Leek et al. (1997) was used. Unlike tschermakite, diopside is scarce, but it is bigger in size. Plagioclase appears in idiomorphic grains and they often show two, three or more types of twinning at the same location. K-feldspar appears in xenomorphic grains, whose size ranges from 0.2 to 0.6 mm. The relations of K-feldspar with basic plagioclase, amphibole, and pyroxene, as well as its size, suggest that it was formed after the crystallization of all the minerals. The origin was related to solution, most probably rich in K<sub>2</sub>O, which affected the rock immediately before the final consolidation. The epidote is the most abundant secondary mineral. It occurs exclusively in veins of different thickness.

*Coarse-grained amphibolic gabbro* consists of tremolite and plagioclase. Epidote, zircon, apatite and ilmenite are accessory minerals. Tremolite appears in xenomorphic grains. Cell dimensions:  $a = 9859(2) \text{ \AA}$ ,  $b = 18.134(5) \text{ \AA}$ ,  $c = 5287(2) \text{ \AA}$ ,  $\alpha = \gamma = 90^\circ$ ,  $\beta = 104.78(3)^\circ$ ,  $V = 913.9(3) \text{ \AA}^3$ . Plagioclase occurs most frequently as xenomorphic grains, but also as hypidiomorphic ones. The results from chemical investigation show that the albite component ranges from 47.9 to 62.4%, while the anorthite varies from 36.4 to 49.4% corresponding to andesine and labradorite (Deer et al., 1962).

*Serpentinic wehrlite* is greenish to black in colour. Texture is porphyroblastic and structure is massive. Based on optical and chemical examinations, the presence of the following minerals was established: serpentine, diopside, olivine, and ilmenite. Diopside appears as xenomorphic and cracked grains with sharp edges. Sometimes there is ilmenite or serpentine in the cracks. Bastite appears parallel to the cleavage plain. Olivine occurs as small islands, surrounded by serpentine, or in nests. Ilmenite was formed after the cracking of the other minerals, but also appears in small idiomorphic crystals.

On the contact between enclaves and calc silicate rocks often appear reaction zones which are on some place clearly visible while on the other place they are absent. The zonality appears only along the contacts where the fluids circulation is larger and all pores are filled with CO<sub>2</sub>-H<sub>2</sub>O solutions. Mobility of H<sub>2</sub>O, does not depend on the composition of rocks and increases with increasing temperature, while the mobility of CO<sub>2</sub> increases with the increasing of the pressure. Based on the results obtained from our examinations in the reaction zones, the presence of the following minerals was established: actinolite, diopside-hedenbergite, prehnite, and calcite. Also, between enclaves and calc silicate rocks were determined the following reaction zones:

I-actinolite+albite, II-diopside+albite, III-diopside+prehnite, IV-diopside+prehnite+calcite, V-calc silicate rock.

Obtained results from our investigation are in addition of our claim that the carbonate rocks of the Novo Selo – Kriva Lakavica are regional metamorphic calc silicate rocks, not carbonatites or scarns.

## References

- Deer, W. A., Howie, R. A., Zussman, J. 1962. *Rock-Forming Minerals: Framework Silicates, Vol. 4*, Longmans, Green & Co., London, 435 pp.
- Ivanov, T., 1987-88. Carbonatite from Kriva Lakavica. – *Geologica Macedonica*, 3, 1, 79–102.
- Leake, B. E., Woolley, A. R., Arps, C. E. S., Birch, W. D., Gilbert, M. C., Grice, J. D.; Hawthorne, F. C., Kato, A., Kisch, H. J., Krivovichev, V. G., Linthout, K., Laird, J., Mandarino, J. M. A., Maresch, W. V., Nickel, E. H., Rock, N. M. S., Schumacher, J. C., Smith, D. C., Stephenson, N. C. N., Ungaretti, L., Whittaker, E. J. W. & Youzhi, G. 1997. *Nomenclature of amphiboles: report of the subcommittee on amphiboles of the International Mineralogical Association Commission on new minerals and mineral names.* – *Canadian Mineralogist*, 35, 219–246.
- Morimoto, N. 1988. Nomenclature of pyroxenes. – *Mineralogical Magazine*, 52, 535–550.
- Mircovski, V., 1997. Metamorphic rocks formed under conditions of high pressures on the territory of the Republic of Macedonia. PhD thesis, University Kiril and Methody, Skopje, 255-256pp.
- Sijakova-Ivanova, T., Boev, B., Korikovsky, S. 1997. Metamorphism of the Impure Calcite Marbles from the Kriva Lakavica. – *Proceedings of Symposium annual meeting. Magmatism, metamorphism and metallogeny of the Vardar zone and Serbo-Macedonian Massif*, Dojran, 243–244.
- Sijakova-Ivanova, T. 2000. *Mineralogy of carbonate complex Novo Selo–Kriva Lakavica*. PhD thesis, University Kiril and Methody, Skopje, 151–163.
- Sijakova-Ivanova, T. Boev, B. Panov, Z. Bermanec, V. Korikovsky, S. 2012. New data on mineralogy, petrology and the origin of calc-silicate rocks from Novo Selo-Kriva Lakavica, Eastern Macedonia. – *Proceedings of the Bulgarian Academy of Sciences*, 5, 1109–1116.
- Stojanov, R., E. Svesnikova. 1985. Granites and contact-metamorphic rocks in Madenska Reka on the way Stip-Radovis, Makedonija. – *Geologica Macedonica*, 1, 2, 165–168.
- Tröger, W.E. 1969. Optische Bestimmung der gesteinsbildenden Minerale Teil II.: Textband. 2. Aufl. E. p 168. Schweizerbartische Verlagsbuchhandlung, Stuttgart.

