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MAGNETITE-NICKEL SULPHIDES-AWARUITE ASSOCIATION IN SERPENTINITES FROM BRASZOWICE-BRZEŹNICA MASSIF (SUDETIC OPHIOLITE, SW POLAND)

Abstract: The Braszowice-Brzeźnica serpentinites were investigated. Antigorite and lizardite-chrysotile serpentinites from studied massif are usually poor in primary opaque minerals but contain rich opaque minerals association genetically related to serpentinization. The latter association include: Cr-bearing magnetite (Fe_3O_4; up to 5% Cr_2O_3), heazlewoodite (Ni_3S_2), awaruite (Ni_3Fe) and scarce millerite (NiS) and godlevskite (Ni_7S_6). All Ni-sulfides contain up to 7 at.% Fe. Described association probably has formed at temperatures at least 300^oC.

Keywords: magnetite, nickel sulphides, awaruite, antigorite serpentinite, serpentinization, Braszowice-Brzeźnica massif, Sudetic ophiolite

INTRODUCTION

Serpentinite is a metamorfic rock that is formed by low-grade metamorfizm (up to greenschist facies) of ultramafic rock. Serpentinization causes alteration of olivines and pyroxenes into minerals of serpentine group (lizardite, chrizotile, antigorite) and affects chromian spinels to some extent. Several secondary opaque minerals are formed as a result of serpentinization processes. The major phases are following: Cr-bearing magnetite and Fe-bearing nickel sulphides; minor phases are following: native metals (awaruite, taenite, native iron and native copper). Mineral composition of secondary opaque minerals assemblages depends on serpentization environment. Main factors that control the process of assemblage formation are: bulk composition, temperature and oxygen and sulphur fugacity. These factors transform while serpentinization advances (Misra, Fleet 1973).

Mineral composition of secondary opaque minerals assemblages together with chemical composition of minerals and serpentinite textures could be a useful tool for reconstructing of low-grade metamorphic processes. The aim of this study is to describe opaque minerals assemblages from Braszowice-Brzeźnica serpentinites and reconstruct on this basis metamorphic processes that affected studied rocks after their formation in the upper mantle.

Braszowice-Brzeźnica serpentinite massif is considered as a part of Sudetic ophiolite (*e.g.* Majerowicz 1979). The massif mainly consists of antigorite serpentinites in western part and antigorite serpentinites with enclaves of lizardite-chrysotile serpentinites in eastern part (Fig. 1). All serpentinite varieties locally contain randomly distributed olivine grains. The Braszowice-Brzeźnica serpentinites formed at the expense of harzburgites and lherzolites, although serpentinized wehrlites and dunites were also present (Gunia 1992).

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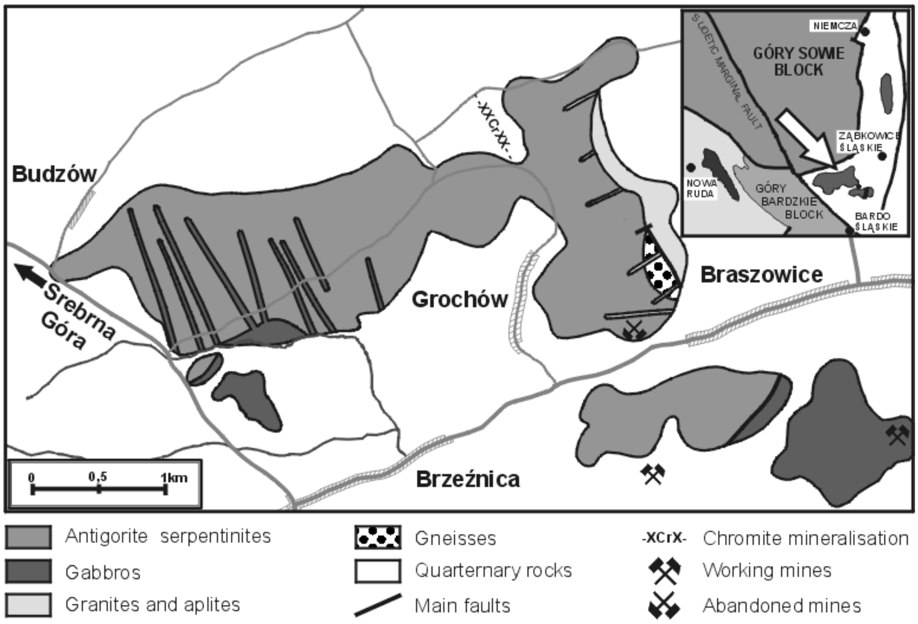

Fig. 1. Geologic sketch-map of the Braszowice-Brzeźnica massif (after Gunia 1992, modified).

Numerous metagabbroic dykes are present within the antigorite serpentinites at the western part of the massif. Serpentinites from the eastern part of the massif are magnesite rich. All serpentinite varieties are weathered near the surface.

RESULTS

Mineral assemblages of the Braszowice-Brzeźnica serpentinites were determined on the basis of detailed examination of thin sections using reflected and transmitted light microscopy combined with electron microprobe determinations, using electron microprobe JEOL-JXA-840A – AN-10000/85S at Institute of Geological Sciences, PAS, Warsaw.

The Braszowice-Brzeźnica serpentinites represent antigorite and lizardite-chrysotile varieties. The studied serpentinites typically display interpenetrating texture (antigorite

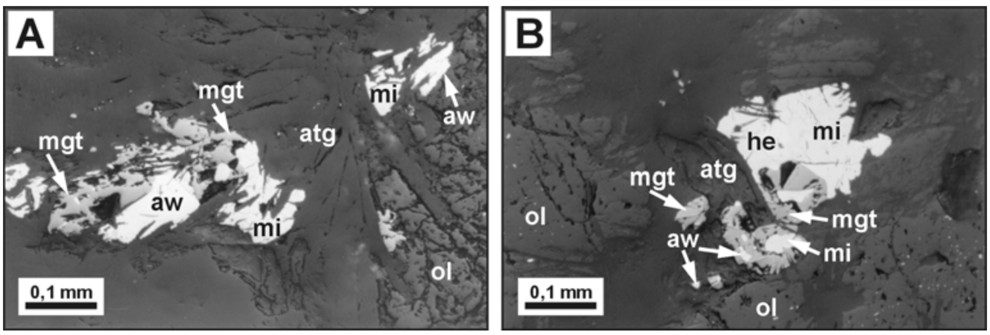

Fig. 2. Microphotographs of the Braszowice-Brzeźnica antigorite serpentinites. A. magnetite-millerite-awaruite-antigorite assemblage with olivine, reflected light; B. magnetite-heazlewoodite-millerite-awaruite-antigorite assemblage with olivine, reflected light. atg – antigorite, aw – awaruite, he – heazlewoodite, mgt – magnetite, mi – millerite, ol – olivine.

variety) or pseudomorphic texture (lizardite-chrysotile variety) as defined by Wicks, Whittaker (1977). Both varieties contain opaque minerals represented by oxides, i.e. chromian spinel and Cr-bearing magnetite (up to 5% Cr_2O_3); antigorite serpentinite contains also minor Ni-sulfides, i.e. heazlewoodite, millerite, godlevskite, and awaruite (Fig. 2). Lizardite-chrysotile serpentinite contains scarce Ni-sulfides and does not contain any awaruite. Moreover, the antigorite variety commonly contains olivine grains (Fo 87-94). Olivine grains can display well-developed pseudocleavage. Chromian spinel is the main primary opaque mineral relict. Scarce primary pentlandite occurs as inclusions in Cr-bearing magnetite. Cr-bearing magnetite, Ni-sulfides and awaruite are by-products of serpentinization processes. Magnetite forms either minute grains (<100μm) or laths or isometric aggregates (up to 0,5mm). Heazlewoodite is the major Ni-sulfide, while millerite and godlevskite are minor phases. Magnetite, Ni-sulphides, awaruite and antigorite usually form aggregates, up to 0,5mm in size (Fig. 2A, 2B). Scarce pseudomorphic replacement after pentlandite composed of heazlewoodite and millerite were also found. Single grain of native iron was observed within magnetite-heazlewoodite aggregate (Fig. 3). Very scarce native copper frequently forms intergrowths with antigorite.

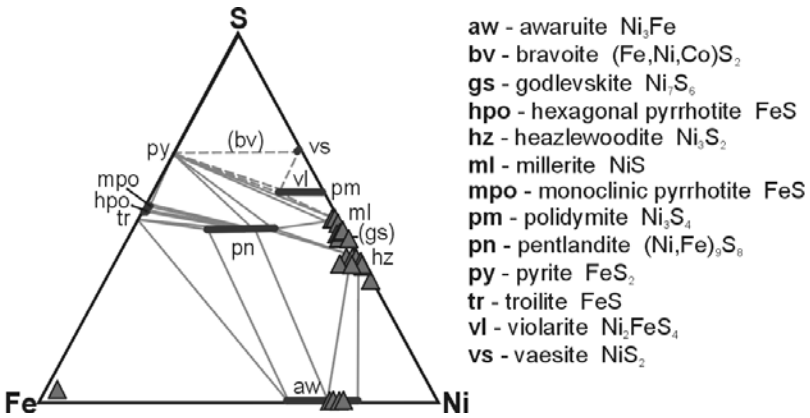

Fig. 3. Phase diagram for the Fe-Ni-S system (after Misra, Fleet 1975) showing chemical composition of nickel sulphides and awaruites from Braszowice-Brzeźnica massif.

Ni-sulphides from Braszowice-Brzeźnica antigorite serpentinites are usually Fe-enriched (up to 7 at.% Fe; Fig. 3). Their S content is low (up to 50 at.% in millerite). Native metals contain Ni (up to 70 at.% in awaruite). Pure native iron is extremely rare.

DISCUSSION AND CONCLUSIONS

The investigations revealed frequent Cr-bearing magnetite–heazlewoodite–awaruite assemblage associated with antigorite serpentinite containing minor olivine at Braszowice-Brzeźnica massif. Interpenetrating texture of these serpentinites could develop due to (1) the recrystallization of pseudomorfic serpentinite or (2) directly during the serpentinization due to ultramafic protolith seawater penetration at temperature above 300^{o}C (Palandri, Reed 2003). The first possibility is supported by the occurrence of pseudomorphic serpentinite enclaves within Braszowice-Brzeźnica antigorite serpentinites. The occurence of Mg-olivine (Fo 91-94) accompanied by magnetite-heazlewoodite-awaruite assemblage in serpentinites with interpenetrating texture, however, is an argument for the second conception (Palandri, Reed 2003). On the other hand, most of the studied serpentinites show no pseudomorphic textures and contain Fo 86-90 olivine, which could be indicative for deserpentinization (at least 400^{o}C). Nozaka (2003) argues, that during deserpentinization magnetite and awaruite are consumed. Fe and Ni released subsequently are consumed by newly formed olivine. Therefore, deserpentinization of Braszowice-Brzeźnica serpentinites is less probable process, but it could take place as indicated by Fo≈87 olivines.

Native metals (awaruite) occurrence is typical for peridotites that have undergone initial serpentinization (Frost 1985). Moreover, occurrence of awaruite records reducing conditions during serpentinization and is dependent of protholit's bulk composition. Olivine occurence in serpentinites is essential to retain reducing conditions. On the other hand, low sulphur fugacity and occurence of olivine Fo≤92 are necessary for awaruite crystallization during serpentinization. Three above factors are more probable to occur within temperature exceeding 300^{o}C. This thesis is also supported by native iron occurrence in magnetite-heazlewoodite assemblages from Braszowice-Brzeźnica massif. Frost (1985) suggested that above assemblage is typical for serpentinization temperatures >300^{o}C. Fe-enrichment in Ni-sulfides (Fig. 3) confirms that they formed at temperature exceeding 300^{o}C (after Misra, Fleet 1973). Low content of sulphur in the studied Ni-sulfides suggests low sulphur fugacity and/or reducing conditions during serpentinization Braszowice-Brzeźnica ultramafites.

The magnetite–nickel sulphides–awaruite assemblage found in the studied antigorite serpentinites probably was formed during initial serpentinization. The process occurred in reducing conditions at temperature ≥300^{o}C. Subsequently, the serpentinites could have been slightly heated. The heating resulted in dehydratation of antigorite and initiated deserpentinization locally consuming awaruite, Ni-sulfides and magnetite. Deserpentinization probably took place in the limited volume of antigorite serpentinites and could be connected with mafic dyke intrusions.

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