Metamorphic evolution of the amphibolites from the Polish part of the Staré Město Zone (SW Poland, Sudetes)

W. BARTZ

Institute of Geological Sciences, University of Wrocław, Pl. M. Borna 9, 50-204 Wrocław, Poland, wbar@ing.uni.wroc.pl

Introduction

The Stare Město Zone is the lowermost part of the Orlica-Śnieżnik Dome and separates East and West Sudetes. The unit consists of several tectonically separated zones of different lithology, trending NNE-SSW. At the base of the Stare Město Zone spinel peridotites occur (Štipska et al. 1995, Parry et. al 1997, Štipska et al. 1998). Above them the leptyno-amphibolite complex is located. It consists of banded amphibolites with intercalations of quartzites, calc-silicate rocks and gneisses. This complex was intruded by tonalite and granodiorite during Variscan times (339 ± 7 Ma; Parry et al. 1997). Above the mylonitic gabbro occurs (Parry et al. 1997). The top of the Stare Město Zone is marked by occurrence of the Hraničná Unit, made up of schists and metavolcanites. The tectonic slice of mylonitic gabbro occurs below the leptyno-amphibolite complex and spinel peridotites in the northern part of the Staré Město Belt.

The larger part of the Stare Město Zone crops out in the Czech Republic. Small part of the Zone is located within the area of Poland, in the vicinity of Bielice village. The banded amphibolites with tonalitic and granodioritic sills are exposed within this area (Wierzchołowski 1966).

Petrography and mineral chemistry

The following two main types of amphibolites occur within the Polish part of the Stare Město Zone: dominant – medium grained, and scarce – coarse grained one. The coarse grained amphibolites are enriched in amphiboles, and occur only locally. They form thin layers, up to several centimeters thick within the medium grained amphibolites.

The banded amphibolites are composed of variable amounts of amphibole and plagioclase. Subordinates are quartz and locally K-feldspar. Accessories are apatite, sphene, zircon, garnet and biotite. Secondary chlorite and prehnite fills fissures and replaces amphibole or plagioclase, respectively. Macroscopically the amphibolites are dark-green, strongly banded, and include numerous leucocratic layers, patches and nests. Locally, abundant leucocratic material disrupts original layering.

The main constituents are segregated into dark amphibole rich layers, alternating with leucocratic ones, rich in plagioclase. The leucocratic layers are up to 1.0 cm in thickness and consist mainly of subhedral plagioclase, anhedral quartz with sparse subhedral amphibole and K-feldspar. The dark layers are up to 1.5 cm thick and composed of amphibole prisms forming small elongated aggregates oriented parallel to the layering. Subhedral plagioclase grains are located between them. Sparse subhedral K-feldspar and anhedral quartz are accompanied with plagioclase.

Amphibole has pale to olive-green pleochroism and has the composition of tschermakite or hornblende. The zoning is not frequent. Amphibole grains exhibiting initial silica increase followed by decrease towards margins are the most abundant. Amphiboles characterized by opposite zonation are sparse. Part of amphibole grains demonstrate weak silica decrease towards rims, others are characterized by its increase towards rims. A large majority of plagioclase grains are not twinned, and weakly sericitized, not or weakly zoned. Normally zoned grains are oligoclase (30→25% An) or andesine (43→38% An, 38→34% An), while inversely zoned plagioclase is andesine (43→45% An, 34→40% An) or oligoclase (19→23% An). Unzoned albite (7–8% An) is sparse. Scarce plagioclase grains show initially reverse zoning followed by normal zoning.

Opaques are mainly ilmenite and iron hydroxides. They usually form individual subhedral or anhedral grains concentrated within amphibole-rich layers, are less common within light ones. Intergrowths of ilmenite within amphiboles are common, too. Apatite, sphene and zircon occupy interstices among main rock-forming minerals. Garnet is uncommon and forms crystals up to 5.0 mm in diameter. Smaller crystals are not zoned, however larger grains exhibit weak zonation from $Alm_{61}Spe_4Py_{16}Gr_{19}$ in cores to $Alm_{63}Spe_4Py_{17}Gr_{16}$ in rims. The large garnets include numerous intergrowths of quartz, feldpars, biotite and opaques. The smaller ones are free of inclusions. Biotite is very uncommon and occurs only locally. It forms single subhedral plates, often displaying faded, pale-brown pleochroism or diversely chloritized.

Secondary prehnite is ubiquitous, completely replacing plagioclase in zones of several millimetres in diameter, or fills monomineral fissures. Chlorite commonly replaces amphiboles forming radial aggregates, or fills monomineralic fissures.

Metamorphic evolution

The banded amphibolites from the Polish part of the Stare Město Zone were subjected to a multistage metamorphism, with a clock-wise PT path. The first stage M_1 of metamorphism was marked by an increase of metamorphic condition from greenschists facies to those of amphibole facies. Plagioclase grains, showing reverse zoning followed by normal zoning, document an initial progress of metamorphism followed by it's regression. The same is suggested by an initial silica decrease followed by silica increase towards rims in some of the amphibole grains. The peak of metamorphic conditions was estimated using plagioclase-amphibole thermometry (Blundy and Holland 1990, Holland and Blundy 1994) with corrections published by Dale et. al. (2000) at 650–720 °C. The Grt-Hbl-Qtz-Pl geobarometer (Kohn and Spear 1990) yields pressures within the range of 8.0–9.5 kbar. A semiquantitative geothermobarometer (Ernst and Liu 1998) yields slightly higher temperatures and pressures, within the range of 750–800 °C and 7–11 kbar (TiO_2=0.95–1.90 wt. %, Al_2O_3= 9.6–13.1 wt. % content for amphibole cores). The titanium and aluminum content of rims (TiO_2=0.6–1.8 wt. %, Al_2O_3=8.2–12.3 wt. %) yields temperatures within the range of 600–780 °C and pressures 7–10 kbar (op. cit.). The M_1 prograde metamorphic event was followed by retrograde M_2 metamorphic event. The garnet-amphibole geothermometer, (Graham and Powell 1984), gives temperature range of 615–670 °C for this metamorphic event. Retrogression led to M_3 metamorphic event, accompanied with uplift and cooling under the conditions of greenschist and prehnite-pumpelyite facies. This metamorphism is documented by the presence of chlorite and prehnite within the amphibolites.

References

Blundy, J. D. – Holland, T. J. B. (1990): Calcic amphibole equilibria and new amphibole-plagioclase geothermometr. Contrib. Mineral. Petrol. 104, 208–224.

Dale, J. – Holland, T. – Powell, R. (2000): Hornblende-garnet-plagioclase thermobarometry: a natural assemblage calibration of the thermodynamics of hornblende. Contrib. Mineral. Petrol. 140, 353–362.

Ernst, W. G. – Liu, J. (1998): Experimental phase-equilibrium study of Al and Ti contents of calcic amphibole in MORB-semiquantitative thermobarometer. Am. Mineral. 83, 952–969.

Graham, C. M. – Powell, R. (1984): A garnet-hornblende geothermometer: calibration, testing and application to the Pelona schists, Southern California. J. Metam. Geol. 2, 13–31.

Holland T. – Blundy J. (1994): Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry. Contrib. Mineral. Petrol. 116, 433–447.

Kohn, M. – Spear, F. (1990): Two new geobarometers for garnet amphibolites with applications to southeastern Vermont. Am. Mineral. 75, 89–96.

Parry, M. – Štipská, P. – Schulmann, K. – Hrouda, F. – Ježek, J. – Kröener, A. (1997): Tonalite sill emplacement at an oblique plate boundary: northeastern margin of the Bohemian Massif. Tectonophysics 280, 61–81.

Štipská, P. – Kröner, A. – Jaeckel, P. – Schulmann, K. (1995): Tectonics of the intraplate boundary (Staré Město Belt). Thermal and Mechanical Interactions in Deep Seated Rocks – post conference excursion guide, 61–69.

Štipská, P. – Schulmann, K. – Kröner, A. (1998): From cambro-ordovician rifting to Variscan collision at NE margin of the Bohemian Massif: petrological, geochronological and structural constraints. Paleozoic Orogenesis and Crustal Evolution of European Litosphere – post conference excursion guide, 84–89.

Wierzchołowski, B. (1966): Bielice granitoids in Sudetes and their metamorphic mantle. Arch. Miner. 26, 509–635 (in Polish with English abstract).