On the Significance of Gneissic Enclaves in the 500 Ma Metagranite, the Lądek-Śnieżnik Metamorphic Unit, the West Sudetes

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The Lądek-Śnieżnik Metamorphic Unit (LSMU) in the eastern part of the Orlica-Śnieżnik Dome (OSD), the Sudetes, consists of a variety of fine- to medium-grained biotite, streaky, often migmatitic gneisses and of coarse-grained augen, rodding to layered orthogneisses. The former are commonly referred to as the Gierałtów gneisses, the latter – Śnieżnik gneisses. Their origin, evolution, age and mutual relations are the matter of long-lasting controversies (Fischer, 1936; Don, 1964, 1977, 1982 a, b, 2001; Smulikowski, 1979; Oberc, 1977; Dumicz, 1988; Borkowska et al., 1990, 1996; Don et al., 1990; Turniak et al., 2000). Criteria used so far in order to solve the problem have appeared ambiguous, thus unsatisfactory. Dumicz (1988) observed that while trying to identify the Gierałtów and Śnieżnik types, one often finds that some Gierałtów gneisses are apparently older and some younger than Śnieżnik gneisses, and vice versa. This observation can explain the existing controversies on the gneiss issues and suggests that there are more than merely two types of gneisses in the OSD, hence simple subdivision into the Gierałtów and Śnieżnik types is misleading and unjustified.

Field relationships confirm the above suggestion. Augen gneisses that develop from the c. 500 Ma porphyrytic granite, which we refer to as the Śnieżnik granite, contain isolated enclosures (cms to tens of metres in diameter) composed of gneisses which differ from the host metagranite with grain-size, structure, and mineralogy. Such enclaves occur both in the Lądek Zdrój-Gierałtów and Międzygórze-Idzików area, but they have been overlooked or misinterpreted.

In the Międzygórze-Idzików area, the Śnieżnik granite has been transformed into augen orthogneisses which occur as rodding and flaser to layered variants (L and LS to S-tectonites). They have characteristic lineation marked by conspicuously stretched rock-forming minerals and mylonitic foliation with weak overprint of oblique stretching lineation and occasional folding. Mineral composition includes two feldspars, quartz, two micas, and accessory titanite and very scarce garnet.

Rocks in enclaves range from paragneisses to migmatites. The latter possess two foliations, of which at least one set differs in orientation from that in the enclosing metagranite. The enclave boundaries are either sharp or diffuse. K-feldspar megacrysts grew 1) in random across these boundaries, which testifies to the presence of granitic melt at that time, and 2) within enclaves where they often nucleated at the hinges of folds in still solid rocks, which testifies to porphyroblastesis. Migmatitic enclaves grade to porphyritic granite by obliterating and loosening earlier folded fabric due to both metamorphic and magmatic (re)crystallization. Accordingly, both K-feldspar phenocrysts and porphyroblasts (Vernon, 1986) are in evidence at the diffused contacts between the enclaves and metagranite. In the original syn/late-tectonic granite the megacrysts were either random or aligned parallel to magma flow which also caused parallel arrangement of the longest axes of the enclaves. In such instances the feldspar foliation in the enclosing (meta)granite does not deflect around the enclaves but continues across them, which testifies to similar rheology and HT deformation of both rocks during flow of incompletely consolidated magma. In contrast, the solid-state foliation in the orthogneisses, defined by quartz and feldspar dynamically recrystallized into ribbons, wraps up both the enclaves and megacrysts pointing to higher rigidity of the latter during mylonitic overprint.

Chemical compositions of the rodding to layered orthogneisses and migmatitic gneisses from enclaves are similar although not identical, especially with respect to REE contents. The migmatitic enclaves and the Śnieżnik metagranite are composed of similar mineral assemblages, which differ, however, modally, the enclaves being richer in biotite (often the only mica), plagioclase and also in garnet. Microprobe analyses show that compositions of these minerals differ too. In the enclaves, plagioclase compositions fall into 4 groups: 1) 28–47 up to 51% An, 2) 15–22% An, 3) 5–12% An, 4) 0% An. Group 1) is only found as intergrowths within K-feldspar. Groups 2) to 4) are consistent with the values reported by Borkowska et al. (1990, 1996) and are represented by both individual grains and intergrowths with K-feldspar. Garnets form 2 groups: 1) small uniform grains containing 80–85% Alm+Sps, 15–20% Adr+Grs and 2) zoned grains composed of 40-45% Alm+Sps, 45–55% Adr+Grs in their cores and 58-–65% Alm+Sps, 35–42% Adr+Grs in their rims. Biotites in enclaves have Xmg of 0.24–0.32 increasing toward grain margins. Phengites have 3.13–3.39 Si p.f.u., which decreases outwards. The host Śnieżnik metagranite usually contains plagioclase with 15–22 up to 30% An, more rarely 0-12% An, and garnet composed of c. 60% Alm+Sps, 40% Adr+Grs. Biotites have #mg of 0.32–0.39 increasing outwards. Phengites have Si content between 3.1–3.54 decreasing outwards. Accordingly, the enclaves are compositionally systematically different from the enclosing augen, rodding to layered gneisses.

The high grossular content in the garnets of the migmatites invalidates grt–bt geothermometry. The Si geobarometer (Massonne and Schreyer, 1987) applied to the Międzygórze migmatites yielded the peak pressure of 10–11 kbar at temperature of c. 550 °C obtained from two-feldspar geothermometer used for the suitable mineral assemblages in these rocks (Borkowska, 1996). The same peak pressure was estimated for the enclaves. The garnet-biotite-muscovite-plagioclase geothermometer (Bhattacharya et al., 1992) shows temperature of 508–517 °C at a given pressure of 8–12 kbar, while the garnet-biotite geotherometer calibrated by Hoinkes (1986) yields temperatures of 530–612 °C for garnet cores and of 799–834 °C for garnet rims at P=10 kbar. These results, however, are highly uncertain. Anyway the unusually high content of Ca in garnets hints to high-P metamorphism of these rocks (Borkowska et al., 1990), which is consistent with findings of Grt(Gros30–50)-Zo-Ti(Rt)-Qtz assemblage in gneissic rocks immediately adjacent to eclogites (Bröcker and Klemd, 1996; Stawikowski, this volume, STOP 6). On the other hand, the chemical zircon thermometer (Watson and Harrison, 1983) applied to the metagranite samples yields temperatures of 765–784 °C, which are taken to approximate temperature of the Śnieżnik granite magma while intruding. The presence of unusual Ca-rich garnets in the Śnieżnik metagranite, similar to those in the enclaves, suggests that a parental magma developed via melting of gneissic precursor now preserved in not wholly diffused migmatitic enclaves, because it is unlikely that the granite has ever undergone (U)HP metamorphism.

All the above observations lead to the conclusion that the porphyrytic Śnieżnik granite in the LSMU and likely in the whole OSD developed during important tectonothermal event at least partly at the expense of gneisses now preserved inside the metagranite as relict enclaves. The controversial issue of the Gierałtów and Śnieżnik gneisses has to be reconsidered, especially that the gneissified metagranite has been cut by the 492 Ma undeformed microgranite dyke (Kröner et al., 2001). Apart of the existing controversies and further history of the gneisses, the U-Pb zircon datings performed so far show that the discussed magmatic event occurred at c. 500 Ma (Oliver et al., 1993; Turniak et al., 2000; Kröner et al., 2001) and involved profound melting of the c. 560–540 Ma Neoproterozoic (Cadomian?) crust.

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