Formation of corundum megacrysts, related to K-rich fluids infiltration during incongruent melting of plagioclase in SiO_2-undersaturated rocks at high T

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Introduction

The Skattøra Migmatite Complex (SMC, Fig. 1), occurs within the Nakkedal Nappe which belongs to the Uppermost Allochthons of the North-Norwegian Caledonides. The migmatite complex outcrops over an area of more than 200 km^2. It is composed mainly of migmatitic mafic rocks with anorthositic to leucodioritic leucosomes and mesosomes of amphibolite. Locally, lenses and layers of migmatized metagabbro, meta-anorthosite, serpentinite and metasedimentary rocks can be observed (Rindstad 1992, Selbekk et al. 2000). It is believed that the SMC originally represented a SiO_2-undersaturated layered mafic intrusion.

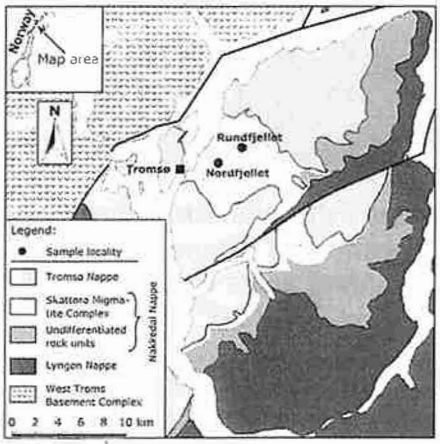

Fig. 1. Tectonostratigraphic map of the Tromsø area, showing sample localities.

Field relationships

Selbekk et al. (2000) described migmatites that vary from metatexites to diatexites according to the terminology of Mehnert (1968) and Ashworth (1985). Low-melt areas commonly show small foliation-parallel leucosomes, but irregular patches of leucosome also occur. The leucosomes and melanosomes often form concordant bands, and the boundary between them varies from sharp and parallel to more irregular and diffuse. High-melt areas form stromatic to schlieric migmatites. In some areas the melt fraction was so high that the migmatite layering was disrupted. The migmatites exhibit drain-out structures, where melts migrated first along grain boundaries into hair-line cracks that are connected to large dykes, and the migmatite complex thus has the appearance of a dyke-root system. The SMC is characterized by an extreme net-veining of anorthositic dykes (Selbekk & Skjerlie 2002). The dykes commonly make up about 50 % of the total of the rock, but may at some localities constitute up to 90 %. The thickness of the dykes varies from a few centimeters up to several meters. In addition to plagioclase, the anorthositic dykes contain 0 – 5 modal % amphibole (ferropargasite).

At one locality within the SMC (Nordfjellet, Fig. 1), up to 5 cm long and 2.5 cm wide crystals of pink corundum can be observed within migmatites of anorthositic to gabbroanorthositic compositions (Fig. 2b). The corundum megacrysts constitute 1 - 8 modal % of the rock within a c. 1.5 m wide and c. 50 m long band, which is oriented parallel to the main schistosity of the migmatite. Outside this band, corundum megacrysts have not been observed. The corundum megacrysts are commonly partly pseudomorphosed, principally by margarite. Within a 40 m^2 large area of the SMC at Rundfjellet (Fig. 1), abundant aggregates of margarite (Fig. 2a) are inferred to represent pseudomorphs after corundum.

Petrography

Most of the corundum megacrysts (and pseudomorphs after corundum) occur within the central parts of leucosomes; however, corundum is also common along diffuse contact zones between leucosome and mesosome. Corundum megacrysts that are cross-cut by thin anorthositic dykes (Fig. 2b), show that the megacrysts formed at an early stage of migmatitization.

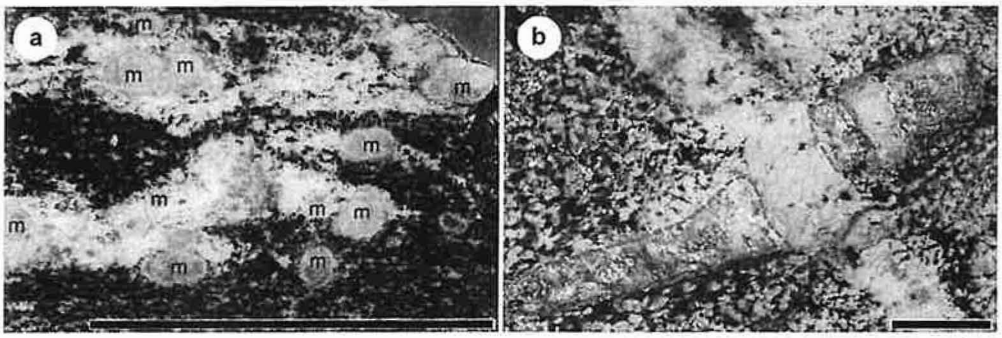

Fig. 2a. Aggregates of margarite (m), inferred to be pseudomorphs after corundum, intimately associated with leucosome. b) Megacryst of corundum (indicated with red dashed line) cross-cut by a 0.8 cm thick anorthositic dyke. Length of bar is 8 cm in the left photo, 1 cm in the right photo.

The corundum-free rock that occurs in contact with the corundum-bearing rock is composed of amphibole and plagioclase, which is partly overgrown by epidote. It should be noted that biotite has not been observed in the corundum-free samples.

In the corundum-bearing rock, corundum (and pseudomorphs after corundum) is commonly barrel-shaped and varies in length between 3 mm to 5 cm. The diameter (perpendicular to the c-axis) of the largest pseudomorph that has been observed is about 2 cm. For the least altered samples, corundum shows well developed crystal faces. In these samples, a 0.2 mm thick reaction corona composed of needles of margarite has formed along the contact between corundum and the surrounding plagioclase. Corundum commonly contains a few small grains of rutile and plagioclase, which probably were trapped during corundum growth. Small grains of margarite and diaspore along internal fractures in corundum are inferred as alteration products after corundum. The matrix is dominated by plagioclase, but hornblende and biotite are abundant.

Whole rock chemistry

For the present study, two samples of corundum-bearing rock and five samples of its adjacent host-rock were analyzed for major and trace elements. Figure 3 shows the variations of a selection of chemical components of the analyzed samples, together with data from Rindstad (1992) and Selbekk et al. (2000).

The two corundum-bearing samples show about 50.5 wt % SiO_2, which is comparable to the average composition of the anorthositic/gabbroanorthositic rocks of Rindstad (1992). However, the corundum-bearing samples show very high concentrations of Al_2O_3, K_2O, Rb and Ba, and low concentrations of CaO compared to the other samples. Anyhow, the very high Al_2O_3 content of the corundum-bearing rocks (about 5 wt % higher than for a pure oligoclase anorthosite) is clearly related to their high content of corundum. Further, the high content of K_2O of the corundum-bearing rocks can primarily be related to their biotite content.

The five samples of the migmatite in contact with the corundum-bearing rock show compositions between the anorthosite/leucogabbro of Rindstad (1992) and stoichiometric oligoclase, suggesting that the samples contained significant amounts of leucosome. In contrast to the corundum-bearing samples, however, theses samples do not show enriched concentrations of Al_2O_3, K_2O, Ba and Rb, and depletion of CaO.

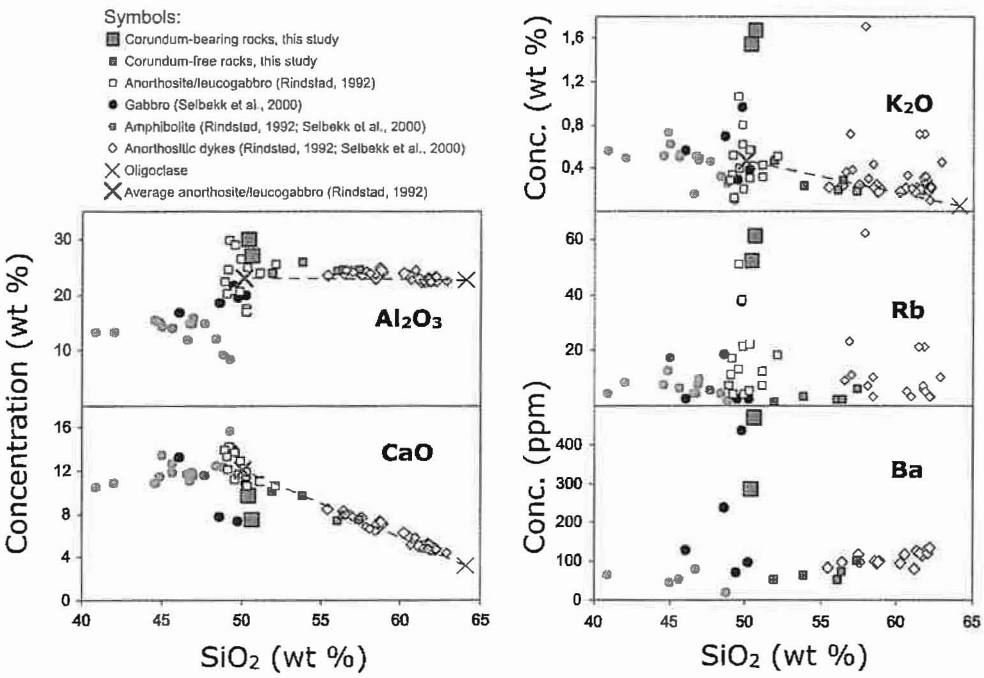

Fig. 3. Variations of a selection of chemical components from different rock-types of the SMC. The corundum-bearing rock shows enriched compositions of Al_2O_3, K_2O, Rb and Ba, but depleted compositions of CaO.

Discussion and conclusions

Selbekk et al. (2002) argued that the SMC underwent anatexis under H_2O-saturated conditions. With reference to their experimental studies, they suggested that the migmatitization of the SMC occurred approximately at P = 1.0 GPa and T = 900-925 °C (Selbekk & Skjerlie 2002).

Experimental work (Goldsmith 1980) has shown that anorthite undergoes incongruent melting and form melt + corundum at pressures above 0.9 GPa at 1570 °C. At 2.0 GPa, plagioclase in the range An_{100}-An_{40} undergoes incongruent melting (Morse 1994). To our knowledge, incongruent melting of plagioclase with the formation of melt + corundum has not been experimentally demonstrated for water-saturated conditions. However, it is reasonable to believe that the melt-forming reactions will occur at much lower pressures and temperatures when water is present in excess. The intimate association between the corundum megacrysts and the leucosomes of the SMC (*e.g.* Fig. 2a) suggests that the formation of corundum was related to migmatitization. The large grain-size of corundum compared to the other minerals of the rock indeed suggests that corundum crystallized in equilibrium with a H_2O-rich melt (*i.e.* the melt subsequently forming the leucosomes), rather than during sub-solidus reactions. Thus, we suggest that the corundum megacrysts formed during incongruent melting, principally of plagioclase of the mafic protolith of the migmatite.

Since partial melting of plagioclase evidently has occurred to a large extent throughout the SMC, one question that rises is: Why has corundum (and pseudomorphs after corundum) only been observed at some small outcrops within the SMC?

Our working hypothesis is that corundum formation was triggered by the introduction of a K-rich hydrous fluid during partial melting of the protolith. Migmatites with biotite-rich melanosomes are described among others by Harris et al. (2004), who inferred that influx of a K-rich fluid stabilized biotite during anatexis, while plagioclase was destabilized. We suggest that the biotite of the corundum-bearing rock formed in a similar way; i.e. in response to K-metasomatism. The intimate association between biotite and corundum suggests that plagioclase under these conditions underwent incongruent melting, resulting in corundum formation.

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