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P-T-t metamorphic evolution of highly deformed metapelites from the Pinkie unit of western Svalbard using quartz-in-garnet barometry, trace element thermometry, P-T-X-M diagrams and monazite in-situ dating

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We present the results of quartz-in-garnet (QuiG) Raman barometry coupled with P-T-X-M diagrams, trace element thermometry, and monazite dating from metapelites of the Pinkie unit on Prins Karls Forland, western Svalbard. This unconventional approach, which combines traditional and novel thermobarometry techniques as well as dating results, provides the opportunity to decipher the pressure-temperature-time (P-T-t) metamorphic evolution of these highly deformed rocks, for which the P-T conditions could not have been obtained using traditional techniques.

The Pinkie unit is comprised of Barrovian-type zones expressed by the following three mineral assemblages: Grt+St+Ms+Bt+Pl+Q, Grt+St+Ky+Ms+Bt+Pl+Q and Grt+Ky+Ms+Bt+Pl+Q. The metamorphic assemblages have been strongly affected by pervasive mylonitization. Two generations of garnet are present. Early garnet-I forms large (up to 2 mm) anhedral and inclusion-rich porphyroblasts that are strongly deformed with resorbed rims. Its composition varies from Alm81Grs5Prp11Sps3 in the core to Alm84Grs4Prp10Sps2 in the rim for a St-bearing sample. St-Ky bearing metapelites contain garnet-I, which is characterized by Alm88Grs2Prp8Sps2 in the core and Alm89Grs2Prp8Sps1 in the rim. In the Ky-bearing sample garnet-I composition is varying from Alm77Grs4Prp11Sps8 in the core to Alm83Grs4Prp9Sps4 in the rim. Garnet-II is characterized by small (up to 0.5 mm) euhedral grains that locally overgrows garnet-I. It contains very scarce inclusions, mostly quartz. Grt-II composition is very similar in all Pinkie unit samples and is characterized by Alm80Grs11Prp8Sps1(0).

The measured maximum shift of the 464 cm-1 Raman band for quartz in garnet-I is 1.05 cm-1 for St-bearing samples, 1.80 cm-1 for St-Ky bearing rocks, and 2.10 cm-1 for Ky-bearing samples, respectively. The highest shift obtained for inclusions in garnet-II is 2.7 cm-1. Monazite-in-garnet thermometry combined with the QuiG yielded P-T conditions of garnet-I nucleation as follows: ca. 590 C at 7.5 kbar for St-bearing metapelites, 570C at 8.5 kbar for St-Ky-bearing rocks, and 630 C at 10 kbar for Ky-bearing samples.
The P-T-X-M diagrams calculated using the Fortran program GIBBS were used to examine how the garnet composition varies as a function of pressure and temperature. These diagrams suggest that a decrease in temperature and increase in pressure after garnet-I growth is needed to produce garnet-II. These results together with the QuiG results for garnet-II are consistent with late garnet nucleating and growing during mylonitization at 450-500 C and 10-12 kbar; thus an anti-clockwise P-T path is proposed for the Pinkie metapelites.

Three monazite populations have been distinguished based on the textural observations and chemical investigations. The first population (high Th) gives an age of ∼373 Ma, which represents initial monazite growth during diagenesis or under low grade conditions. The second population (highest Y) yields an age of ∼359 Ma, and the third population (lower Y) gives an age of ∼355Ma. Monazite dating results coupled with the above P-T data provide constrain the amphibolite facies metamorphism to have occurred between 359–355 Ma.

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