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Formation of Garnet Granulite in the Lower Crust of a paleo-Island Arc

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The Jijal complex (Kohistan paleo-island arc complex, NW Pakistan) is a unique occurrence of high-pressure (HP), mafic, opx-free, garnet granulite formed in the lower crust of an island arc. The upper part of the Jijal Granulitic Gabbro Unit (GGU) records the arrested transformation of hornblende gabbronorite to garnet granulite, involving the coeval breakdown of amphibole and orthopyroxene, and the formation of garnet and quartz. Close to the transformation front (2-3 cm), clinopyroxene from the granulite displays a strong Ca-tschermak zoning with lower Al-contents at rims. REE zoning of clinopyroxene and pseudosection diagrams indicate that only clinopyroxene rims reflect chemical equilibrium with garnet in the reaction front (P = 1.1 $\pm$ 0.1 GPa, T = 800 $\pm$ 50 °C), whereas the cores retained high-Al contents inherited from precursor gabbronorite clinopyroxene and remained in chemical disequilibrium within a few centimeters of the garnet granulite assemblage. Clinopyroxene of garnet granulites from the Jijal lower GGU are completely re-equilibrated with garnet (P = 1.5 $\pm$ 0.1 GPa, T = 800 $\pm$ 50 °C). If ferric iron corrections are disregarded, equilibration pressure and temperature are highly overestimated yielding exceedingly high pressures for an island arc setting. The pressure difference between the upper and lower Jijal GGU granulites ($\sim$0.4 GPa) and its current thickness (<5 km) implies delamination of the denser parts of Jijal crust. Thermodynamically computed phase diagram sections for upper GGU bulk compositions show that, at the equilibration conditions of Jijal garnet granulite, the equilibrium assemblage is orthopyroxene-free and amphibole-free garnet granulite coexisting with melt or a fluid phase, depending on the water activity at the onset of amphibole breakdown. Pseudosections indicate that hornblende gabbronorite assemblages are highly metastable at lower arc crust depths. The transformation to garnet granulite was therefore substantially overstepped in terms of pressure and temperature. Substantial compression from 0.5 GPa to 1.1 GPa may account for the transformation of the hornblende gabbronorite assemblage to high-pressure garnet granulite. This is consistent with a top-to-bottom growth of the island arc crust where shallower intrusions are sequentially foundered into the deeper levels of the arc crust. Isothermal P-M(H_2O) pseudosections show that the compression paths walk through fluid-absent fields until the attainment of melt- or fluid-present amphibole-free, garnet granulite. Altogether this suggests that burial and partial melting at the island arc root conditions are the key factors accounting for the transformation of hornblende gabbronorite to high-pressure granulite observed in Jijal. If common, such processes may have important geochemical and geophysical implications for the stability and intracrustal differentiation of the island arc crust.