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Emplacement and formation of Archean anorthosites in the lower crust via hydrous magma underplating and differentiation: Evidence from a new pressure estimator

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The emplacement depth of Archean anorthosites provides a critical constraint on the thermal structure and tectonomagmatic style of the early lithosphere and, by extension, mechanisms of continental crust growth under hotter Archean geotherms. Archean anorthosites are commonly interpreted as shallow, low-pressure cumulates that favor crystallization of highly calcic plagioclase. In contrast, hydrous high-pressure experiments and Phanerozoic arc-root (lower-crustal) complexes suggest that anorthosites can form as deep cumulates within water-rich, thickened crust. We have developed and validated a new pressure proxy based on crystallization sequence—early amphibole followed by late plagioclase—by compiling amphibole and plagioclase datasets from Phanerozoic arc-root complexes and comparing inferred pressures with independent geothermobarometric estimates. The close agreement supports amphibole-early / plagioclase-late sequence systematics as a reliable indicator of high-pressure differentiation in hydrous basaltic magmas.

We apply this pressure estimator to a re-examination of the Archean Fiskenæsset Anorthosite Complex (SW Greenland) using integrated field relations, petrography, and whole-rock and mineral geochemistry. Pressures from the amphibole–plagioclase sequence, corroborated by independent thermobarometers, indicate emplacement at ~25–28 km depth, firmly within the lower crust. Formation of extremely calcic plagioclase (An94–99) in Suite B gabbros further implies crystallization from hydrous basalts with anomalously high CaO/Na_2O (>8), because normal-ratio basalts lack sufficient Ca enrichment to generate such An-rich plagioclase at the inferred pressures. These results support a model in which hydrous basaltic underplating and lower-crustal differentiation generate Archean anorthosite–gabbronorite–hornblendite associations, linking deep crustal magmatism to early crust–mantle interaction and the growth and stabilization of Archean continental lithosphere and cratons.