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Beyond Equilibrium: Amorphous Precursor-Mediated Ti Uptake and Its Implications for TitaniQ Thermobarometry

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Abstract:

Titanium-in-quartz (TitaniQ) thermometry and barometry are widely applied to volcanic and plutonic systems, yet experimental calibrations differ in pressure sensitivity and in their treatment of TiO_2 activity ($aTiO_2$; Wark & Watson, 2006; Thomas et al., 2010; Huang & Audétat, 2012). Reported discrepancies are commonly attributed to pressure effects or $aTiO_2$ assumptions, but may also reflect differences in experimental design, including starting materials (silica glass vs. quartz seed) and Ti sources (rutile vs. anatase). We conducted piston-cylinder time-series experiments following established high-pressure quartz-growth approaches (Acosta et al., 2020), systematically varying run duration on silica glass and TiO_2. Focused ion beam (FIB) cross-sections and lift-outs were analyzed by transmission electron microscopy (TEM) to resolve nanoscale phase relations at quartz growth interfaces. Anatase-bearing experiments contain a distinct amorphous SiO_2–TiO_2 layer absent in Ti-free control experiments. This layer thickens from ~150 µm after 1 day to ~250 µm after 4 days and is interpreted as a migrating crystallization front capable of advecting Ti during quartz growth. Metastable, precursor-mediated Ti uptake provides a mechanistic explanation for inter-laboratory calibration variability and carries implications for TitaniQ thermometry calibration, Ti diffusion chronometry (Cherniak, 2007; Jollands et al., 2020), and interpretations of magmatic storage conditions.

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