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Incipient amorphization of metastable α-quartz induced by ultrahigh pressure (>15 GPa?): first report in an eclogite

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Pressure-induced amorphization (PIA) in the solid state ($i.e.$, without melting) is a well-known process that has been experimentally observed for several materials and minerals[1−2], including α-quartz[1−4]. Apart from meteorite impacts[5], it has been predicted as irrelevant under natural P-T conditions because it can develop only under high pressures ($e.g.$, 15–40 GPa for α-quartz[1−4,6]), in metastable materials, either at very low temperature or during a shock. Such pressures can only be found at extreme depths within the Earth, at which crystal-crystal transitions are expected rather than amorphization[1−2], because of the high temperatures.

The present study reports the first discovery of incipient PIA of α-quartz in an eclogite from the Lanterman Range (Antarctica)[7]. It was found in 50-μm-sized monocrystalline quartz enclosed in omphacite, which shows a clear-to-opalescent lustre. In-situ Raman spectroscopy (Siena) and X-ray micro-diffraction using a synchrotron radiation source (ESRF, ID13; Grenoble) allowed to evidence some anomalies in this quartz. The "anomalous" quartz is characterized by weak α-quartz modes, the broadening of the main α-quartz peak at 465 cm^{-1}, and additional vibrations at 480–485, 520–523, and 608 cm^{-1}. X-ray diffraction circular patterns display irregular and broad α-quartz spots, some of which show an anomalous d-spacing tightening of about 2%. They also show some very weak, hazy clouds that have d-spacing compatible with coesite but not with α-quartz.

These results are evidence of (a) disordering and incipient amorphization, (b) slight densification of the lattice, together with (c) the development of cryptic coesite. Disorder and incipient amorphization of α-quartz are revealed by the decrease of the main A_1 Raman mode at 465 cm^{-1} and the appearance of the 480–485 (D_1) and 608–cm^{-1} (D_2) Raman defect bands[8]. These peculiarities are known to occur in quartz during experimental PIA[1,3,9]. Actually, the Raman spectra are very similar to those obtained for quartz partly amorphized during shock experiment[9]. The d-space tightening revealed by X-ray is the evidence of the slight lattice densification. Development of cryptic coesite is also suggested by a weak Raman peak at about 521 cm^{-1} and by broad, weak spots in X-ray diffraction patterns[8].

This is interpreted as the first record of incipient pressure-induced amorphization of a mineral formed in the Earth. The geological mechanism that has produced such incipient amorphization still remains unexplained. A shock (due to a seism?) is preferred to a local overpressure at the inclusion scale (due to expansion mismatch between quartz and its host mineral[10]). This finding throws new light on the modality of the quartz-coesite transition and on the pressure regimes (non-lithostatic vs. lithostatic) during ultrahigh-pressure metamorphism.

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