EVIDENCE FOR SUBSOLIDUS QUARTZ-COESITE TRANSFORMATION IN IMPACT EJECTA FROM THE AUSTRALASIAN TEKTITE STREWN FIELD

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Introduction: Coesite, a high-pressure silica polymorph, is a diagnostic indicator of impact cratering in quartz-bearing target rocks. The formation mechanism of coesite during hypervelocity impacts has been debated since its discovery (in impact rocks) in the 1960s. In impactites, coesite is preserved as a metastable phase in crystalline rocks that experienced peak shock pressures above ~30-40 GPa [1], and in porous sedimentary rocks shocked at pressures as low as ~10 GPa [2]. There is a general consensus that coesite within impactites originates by crystallization from a dense amorphous phase during shock unloading, when the pressure release path passes through the coesite stability field. The precursor amorphous phase may be a silica shock melt [1] or a densified diaplectic silica glass [3]. We present in turn evidence for direct solid-state quartz-to-coesite transformation in shocked coesite-bearing quartz ejecta from the Australasian tektite/microtektite strewn field, which is the largest and youngest (~0.8 Myr old) on Earth. These findings contradict conventional models for coesite formation, but appear consistent with recent observations from the Kamil crater, the smallest coesite-bearing impact crater reported so far [4].

Samples and methods: We used field emission gun - scanning electron microscopy (FEG-SEM) and μRaman spectroscopy to study four shocked silica ejecta particles associated with the Australasian microtektite (AAMT) layer, from two deep-sea sediment cores both located in the South China Sea: ODP-1144A and SO95-17957-2. We used focused-ion beam (FIB) instruments for the extraction of five electron-transparent lamellae from a particle with very prominent shock features. Lamellae were investigated by transmission electron microscopy (TEM), three-dimensional electron diffraction (3D ED) [5] and phase/orientation maps using the precession-assisted crystal orientation mapping technique (PACOM) [6] (similar to electron backscatter diffraction).

Results: All FIB lamellae consist of a mixture of coesite and quartz in variable proportions, the latter showing planar deformation features (PDFs) with typical {10-11} and {10-12} orientations. Quartz shows a common crystallographic orientation in the whole FIB cut, indicating each lamella and probably the whole particle was a single quartz crystal of the parent rock. Coesite crystals range in size from ~500 nm to few nanometres, with rounded or elongated habit. Twinning and planar disorder are rather evident along (010) planes. Where quartz and coesite are in contact, no appreciable amorphous or 'glassy' volume was detected. Instead, quartz boundaries are always lobate or sawtooth-like, with euhedral coesite crystals penetrating through the quartz boundaries. 3D ED and PACOM analysis show a recurrent pseudo iso-orientation between the (1-11) vector in quartz and the (010) vector of neighbouring coesite crystals. Moreover, PDFs in quartz clearly extend in the coesite domains, suggesting that the latter forms directly at the expence of the shocked quartz crystal.

Discussion: Our observations indicates that quartz transforms directly to coesite after PDF formation and through a solid-state process without enetering the silica liquid stability field. Mutual orientation and crystallographic similarities between quartz and coesite structures point to a martensitic-like transformation that involves a relative structural shift of {-1011} quartz planes, which would eventually turn into coesite (010) planes. This mechanism would explain the relation between the characteristic (010) twinning of impact coesite [7] and the common {10-11} PDF set in shocked quartz. Arguably, solid-state martensitic-like process could represent the dominant mechanism of coesite formation in a wide range of cratering events, at least for those with porous target rocks like at the Barringer [8] and Kamil craters [4]. This implies lower peak impact pressure and temparture conditions for the formation of impact coesite than previously thought.

References: [1] Stöffler D. and Langenhorst F. (1994) *Meteoritics* 29:155–181. [2] Kowitz A. et al. (2016) *Meteorit. Planet. Sci.* 51:1741–1761. [3] Stähle V. et al. (2008) *Contrib. to Mineral. Petrol.* 155:457–472. [4] Folco L. et al. (2018) *Geology* 46:739–742. [5] Mugnaioli E. and Gemmi M. (2018) *Zeitschrift für Krist. - Cryst. Mater.* 233:1–16. [6] Viladot D. et al. (2013) *J. Microsc.* 252:23–34. [7] Bourret A. et al. (1986) *Phys. Chem. Miner.* 13: 206–212. [8] Kieffer S. W. et al. (1976) *Contrib. Mineral. Petrol.* 59: 41–93.

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