EPSC Abstracts
Vol. 12, EPSC2018-316-2, 2018
European Planetary Science Congress 2018

(S)TEM analysis of quartz-coesite relations in impact ejecta from the Australasian tektite strewn field

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Abstract

Scanning and transmission electron microscopy observations on shocked silica mineral grains from the Australasian tektite/microtektite strewn field suggest that coesite crystals form directly in contact with quartz grains through a subsolidus reconstructive transformation. This finding is in contrast with the current mainstream view, which considers coesite as the product of a rapid crystallization from a dense silica melt or glass during shock unloading.

1. Introduction

Quartz is one of the most common mineral in Earth's continental crust. The study of shock metamorphic features in quartz and its shock induced silica polymorphs, i.e., coesite and stishovite, is thus relevant for defining the physical conditions attained during the majority of hypervelocity impacts of cometary or asteroidal bodies on Earth.

In endogenic geological processes, which typically involve equilibrium reactions and time-frames from years to thousands of years, coesite forms from quartz at pressures between ~3 and ~10 GPa. In impactites, coesite is preserved as a metastable phase in non-porous crystalline rocks that experienced peak shock pressures above ~30-40 GPa [*e.g.* 1], and in porous sedimentary rocks shocked at pressures as low as ~10 GPa [2]. There is however a general consensus that the characteristic twinned impact coesite [3] is the result of crystallisation from a dense amorphous phase, either from a silica shock melt [*e.g.* 1, 4] or from a highly densified diaplectic silica glass [5], during shock unloading, when the pressure release path passes through the coesite stability field.

Conversely, we show here STEM and TEM/EDT evidence of direct quartz-to-coesite transformation in microscopic shocked coesite-bearing quartz ejecta from the Australasian tektite/microtektite strewn field - the largest (~15% of Earth's surface) and the youngest one (~0.8 Myr old) on Earth.

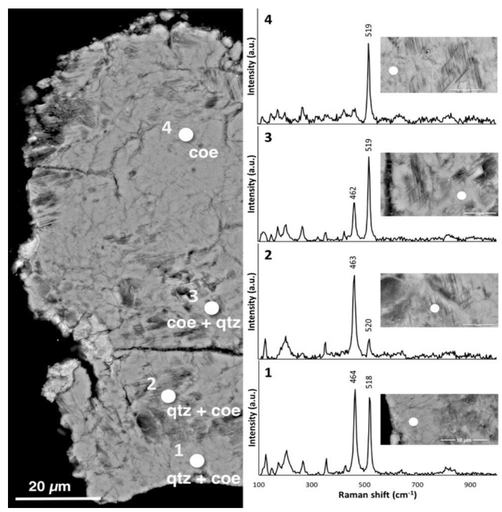

Figure 1: Microscopic shocked ejecta composed by coesite and PDF-bearing quartz.

2. Samples and methods

The samples studied in this work consist of ~400 µm in size shocked silica ejecta found in the Australasian microtektite layer from two cores located within 2000 km from a hypothetical impact location in Indochina (~17°N, 107°E). They were first studied with field emission gun - scanning electron microscopy (FEG-SEM) and Raman spectroscopy. Then, electron-transparent thin sections were prepared for transmission electron microscopy (TEM) and scanning-TEM (STEM) using focused ion beam (FIB) micromachining. Additionally, electron diffraction tomography (EDT) and ASTAR (EBSD-like) analyses via (S)TEM are currently in progress.

3. Results and discussion

FEG-SEM coupled with µRaman analyses revealed that shocked silica grains are composed by coesite including domains of quartz, with at least two diffuse cross-cutting sets of planar deformation features (PDFs) (Fig. 1).

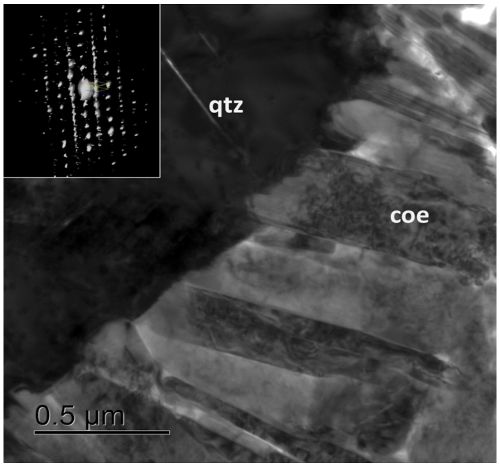

Figure 2: TEM image showing twinned elongated coesite grains growing at the expense of a single quartz grain. Inset: typical 3D diffraction pattern of a twinned coesite along 111.

The direct quartz-coesite contact is apparent at the nanometer scale (Fig. 2). Several intensely twinned coesite grains nucleate and grow without a specific orientation (EDT and ASTAR data) at the expense of quartz. This is strong evidence of direct quartz-to-coesite subsolidus transformation in contrast to what has been suggested for impact-produced coesite in crystalline targets [*e.g.* 1, 4, 5].

The ongoing investigation of key features like the quartz-coesite mutual crystallographic orientations and the twinning in coesite is expected to provide clues for better understanding formation mechanisms and the kinetic of impact-produced coesite - a crucial issue for the correct definition of P-T-t shock metamorphic conditions in impactites.

4. Conclusion

The shocked coesite-bearing quartz grains studied in this work represent an excellent opportunity to investigate the mechanism and the kinetics of the direct subsolidus quartz-to-coesite transformation in shock metamorphic events. Supposedly this could be the dominant mechanism of coesite formation in porous quartz-bearing target rocks, like at Barringer [5] and Kamil craters [6].

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