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# Direct quartz-coesite transformation in shocked sandstones from Kamil Crater (Egypt)

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## Abstract

We show that coesite in shocked porous sandstones forms through direct subsolidus transformation from quartz, in contrast to what suggested for crystalline quartz-bearing targets. This work documents the role of pore collapse in producing localized pressure-temperature-time gradients in shocked porous targets, as predicted by numerical models in the literature, and raises the question of the kinetics of the direct quartz-coesite transformation induced by shock.

## 1. Introduction

The presence of coesite in quartz-bearing target rocks experiencing shock conditions beyond the limits of the coesite stability field is a controversial issue [1, 2, 3, 4]. Coesite was identified in shocked sandstone ejecta from the 45-m-diameter, less than 5,000 years old Kamil Crater in Egypt [5, 6]. The exceptional state of preservation of Kamil Crater and, in particular, the lack of evidence for post-shock thermal overprint and alteration due to hydrothermal activity typically observed in shock metamorphic rocks from larger impact structures [e.g., 4, 7], prompted us to test current models for formation of coesite in the shocked sandstone ejecta through a combined scanning electron microscopy, Raman spectroscopy and electron diffraction microstructural study.

## 2. Results

The shocked sandstone studied in this work is a medium-grained quartzarenite dominated by heavily shocked, equigranular quartz grains with an average grain size of 1 mm (~78 vol%) and including accessory tourmaline and zircon [6]. Intergranular veins and pockets (up to 1 mm across) of silica glass contain microcrystalline coesite. These domains are microstructurally analogous to the so-called symplectic regions first described in the Coconino Sandstones from the Barringer Crater, USA [1]. Orientations and frequency of PDF in shocked quartz ({10-13}, 23%, and {10-12}, 14% [6]) and amount of silica glass (~22 vol%) indicate shock pressures of 20- 25 GPa [8, 9].

Intergranular symplectic regions show microstructural zoning. From the core of the quartz crystals to the core of the symplectic regions, we can distinguish a "quartz zone", a "coesite zone" and a "silica glass" zone. The quartz zone consists of PDF-bearing shocked quartz. The coesite zone, up to several tens of µm in thickness, typically consists of polycrystalline aggregates of micro-to-nanocrystals (<5 µm) coesite set in pure silica glass, i.e. lechatelierite. Coesite shows fine polysynthetic twinning parallel to the (010) plane. Polycrystalline aggregates arranged along planes that are nearly parallel to PDF of the quartz crystals in the adjacent quartz zone consists of fine coesite plus quartz intergrowths. This indicates topotactic growth of coesite at the expense of the PDF-bearing quartz crystals. Flame-like corrosion textures at the margins of the coesite aggregates indicate subsequent melting of the pre-existing crystalline silica phases. The silica glass zone consists of homogeneous lechatelierite with usually one central bubble up to several tens of µm across.

## 3. Discussion

Petrographic data confirm that, in porous sedimentary rocks, coesite forms locally in symplectic regions, as reported in the literature from other impact structures (e.g., Coconino Sandstone from Barringer Crater [1]). This localization and the petrographic zoning of the symplectic regions attests to significant heterogeneity in the space-time distribution of P-T conditions within the rock. These gradients are associated with shock wave reverberations due to pore collapse in shocked porous sedimentary rocks, as derived from recent numerical simulation of shock-induced pore collapse by [10].

The most straightforward explanation for the topotactic growth of coesite at the expense of the PDF-bearing quartz crystals is direct quartz-coesite subsolidus transformation. Shock-front reverberation caused by the presence of pores and discontinuities in the shocked material could last long enough to allow the transformation of quartz into coesite. This transformation may be energetically and topologically facilitated by the ubiquitous and pervasive twinning in shocked coesite. Although such subsolidus transformation has been recently hypothesized for impact coesite in shock veins of metaquartzites from the ~300-km-diameter Paleoproterozoic Vredefort impact structure [11], this mechanism is in contrast with what proposed for crystalline targets, i.e. that coesite forms during shock unloading through crystallization from a silica shock melt [e.g. 2, 4] or subsolidus nucleation from highly densified diaplectic silica glass [3]. These differences suggests that different coesite formation mechanisms act in different targets.

# 4. Conclusions

Mineralogical and petrographic data from shocked Kamil Crater sandstones thus document the effective role of pore collapse in producing heterogeneous pressure-temperature-time (P-T-t) distributions in porous targets, as predicted by numerical models in the literature. This is relevant in defining of the P-T-t paths of shock metamorphic rocks, and therefore the shock classification of impactites and impact scenarios.

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