Understanding quartz polymorphs' formation during impact events using dynamic compression

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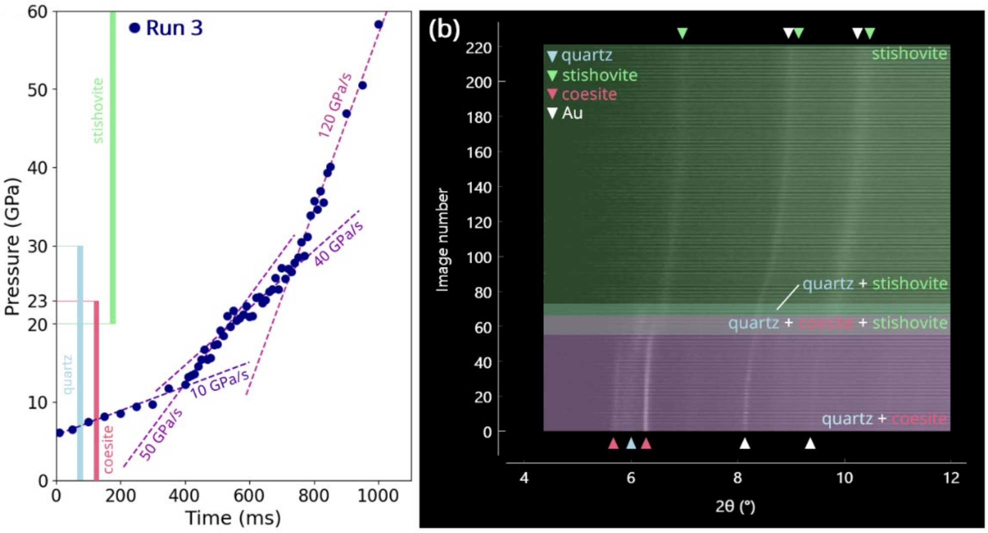
Abstract

Asteroid impacts are known to have played a crucial role in the early stages of our planet, being involved in the formation of the Earth – Moon system and in the delivery of water. Therefore, the study of the remaining traces of such events on the Earth's surface is a key to understand its evolution to the present day. Since quartz (SiO_2) is an abundant component of the Earth's lithosphere, fingerprints of shock in its crystallographic structure are nowadays routinely used as impact barometer, by comparing the composition of the shocked sample with SiO_2 polymorphs stable at extreme pressure and temperature conditions.

Upon compression, quartz undergoes solid – solid phase transitions into a wide variety of polymorphs. Among them, *coesite* is stable in the range 2 – 10 GPa, while *stishovite*, is stable in the span 10 – 80 GPa. In natural shocked silica samples, high contents of coesite and stishovite can be found, but the way they form under such conditions remains to this day elusive and cannot be fully explained experimentally. Investigating the behaviour of quartz upon fast compression is therefore essential to understand the presence of these polymorphs in natural shocked samples.

In our work we performed isothermal, rapid compression ramps in the range 10 – 1000 GPa/s with m-DACs, to bridge the gap between the low and the ultrafast compression rates investigated so far, and to reach timescales comparable to those of natural impacts. Using time-resolved X-ray diffraction (XRD), we were able to follow the structural changes in the sample throughout the compression ramp.
Our results show direct transformation of quartz into stishovite, by-passing coesite, alongside clear extension of metastability of quartz toward higher pressures (Fig. **1**). It is at odds with the composition of natural shocked silica sample showing high contents of coesite and it rules out the direct transformation of quartz into coesite upon compression during the impact. Possible explanations may involve amorphization and back-transformation into coesite on pressure release, and post-shock temperature increase.



1. Left : pressure vs. time curve during an experimental run. Vertical rods represent the metastability domains of the SiO_2 polymorphs upon compression. Right : Colormap of XRD patterns collected along the experimental run. Coloured areas represent the metastability domains of the SiO_2 polymorphs.