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Shock-darkening in a shock-recovered ordinary chondrite? Numerical model of the experiment

J. Moreau (1), T. Kohout (1,2) and K. Wünnemann (3)
(1) Department of Geosciences and Geography, University of Helsinki, Finland, (juulia.moreau@helsinki.fi), (2) Institute of Geology, The Czech Academy of Sciences, Prague, Czech Republic, (3) Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany

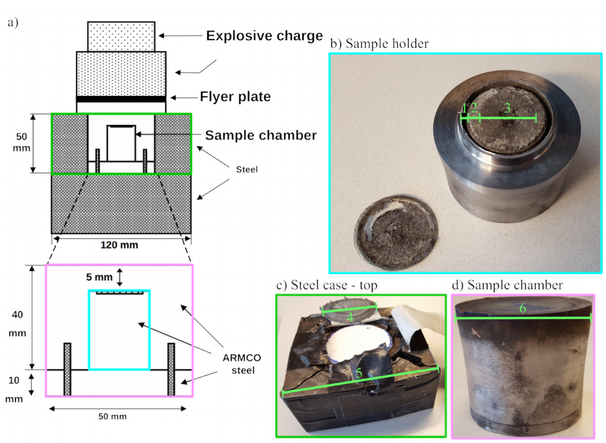

Fig. 1. a) schematic of the experiment, b) the sample holder with the shocked Chelyabinsk LL5 meteorite that are both encased in c) the steel case, top, and then in d) the sample chamber. Colored boxes link b-d) to a). The green lines and numerals respectively show 1) a shocked deformation gap between the sample and sample holder, 2) the outer light rim of the sample, 3) the darker inner sample, supposedly shock-darkened, 4) the remnant of the flyer plate, 5) the shattered steel box, and 6) the deformation effect of the shock on the sample chamber. Image a) is modified from [8] and displays the current experiment dimensions.

Abstract

Shock-darkening in ordinary chondrites is the melting of iron sulfides and metals that spread into a network of veins, rendering the lithology darker. A shock-recovery experiment was carried on the Chelyabinsk LL5 meteorite. Using the shock physics code iSALE, we observed the distribution of peak shock pressures in the sample at a pressure of 55.5 GPa in steel (to obtain 40-50 GPa in sample, the pressure range for shock-darkening). The shock-recovered meteorite showed a darkening of lithology.

1. Introduction

Shock-recovery experiments are used to shock load rock samples [1,2]. The experimental setup (Fig. 1a) allows for a reverberating shock wave to travel in the sample and, eventually, equilibrate with the pressure in steel. Shock-darkening is a shock-metamorphic process in ordinary chondrites [3,4], thus a shock-recovery experiment was carried to shock a light-lithology sample of the Chelyabinsk LL5 meteorite and we carried numerical models to understand the shock wave propagation and peak shock pressures distribution in the sample.

2. Methods

To study the shock wave propagation in the shock recovery experiment, we used the shock physics code iSALE [5]. In a mesoscale model (Fig. 2a) of a planar shock wave in 2D-cylindrical mesh made of 1000x934 cells, we studied the complex interaction of the shock wave between different phases (iron, olivine and tantalum). The sample is represented by olivine, the major silicate component of ordinary chondrites, with rock strength properties. Tantalum was used in the experiment as an hermetic foil for the sample and included in the numerical model. Iron represented the ARMCO steel case [6] and possessed equivalent strength properties in iSALE. Porosity of the (numerical) sample was 6%. Additionally, we used peak shock pressures and peak temperatures recorded in tracers in the sample to determine the pressure needed in steel [7]. The shock-recovery experiment was done at the Ernst Mach Institute, Germany.

3. Results

The shock-recovered sample, encased in the sample chamber, is shown in Fig. 1b. Pending further results, one can observe that the sample has a darkened lithology with a lighter rim. Several deformation features are displayed in Fig. 1. In addition we provide the resulting peak-shock pressures distribution from the numerical model in the sample and steel case, shown in Fig. 2b. The shock pressure in the steel was 55.5 GPa, entry pressure in sample was ~32.8 GPa and peak pressures in sample, after reverberations, were heterogeneous and displayed a value of 47.6 GPa (s.d. 4.7 GPa).

4. Discussion & Conclusions

First, the peak shock pressures in the sample are very heterogeneous and this is due to the short pulsation time of the shock wave that decays already in the sample plate while a first reflection occurs from the bottom of the sample. The resulting distribution of pressures seen in Fig. 2b and the resulting deformation in Fig. 1b and 1d are, somehow, related. The generated pressures in the sample may have generated shock-darkening, pending further investigation.

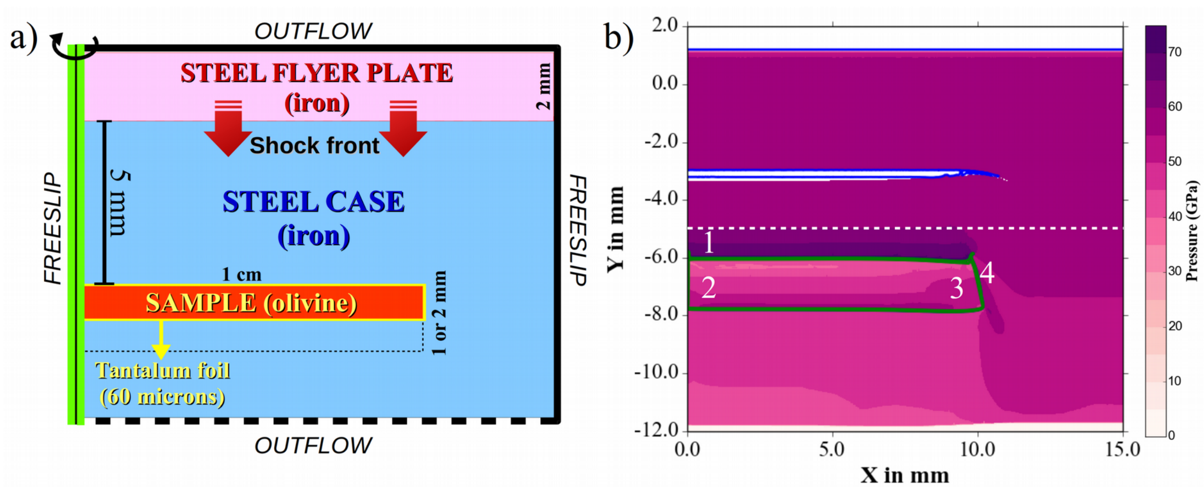

Fig. 2. a) schematic of the numerical model and b) resulting peak shock pressures in the steel and sample (green box). The shock pressure in steel was 55.5 GPa. Numerals are 1) the reflected pressures from the tantalum foil, 2) the heterogeneous distribution of pressures in the sample, 3) concentration of pressures at the edge due to complex reflections, and 4) deformation of the sample, possible explanation of a gap in the sample holder, Fig. 1b-1.

Acknowledgements

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