Shock-Darkening in Ordinary Chondrites: Mesoscale Modeling of the Shock Process and Comparison with Shock-Recovery Experiments

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I SHOCK-DARKENING NUMERICAL MODELING

Shock darkening is a shock process that involves melting of iron sulfides and metals. It darkens the lithology and alters the reflectance spectra [1]. Using the iSALE shock physics code [2], our research [3-5] shows that shock-darkening happens between 40 and 60 GPa with shock melting of iron sulfides dominating shock melting of metals (those melt under very specific shock conditions). Numerical models (setup in Fig. 1) proved efficient to also estimate post-shock temperatures comparable to the shock classification (see Fig. 2).

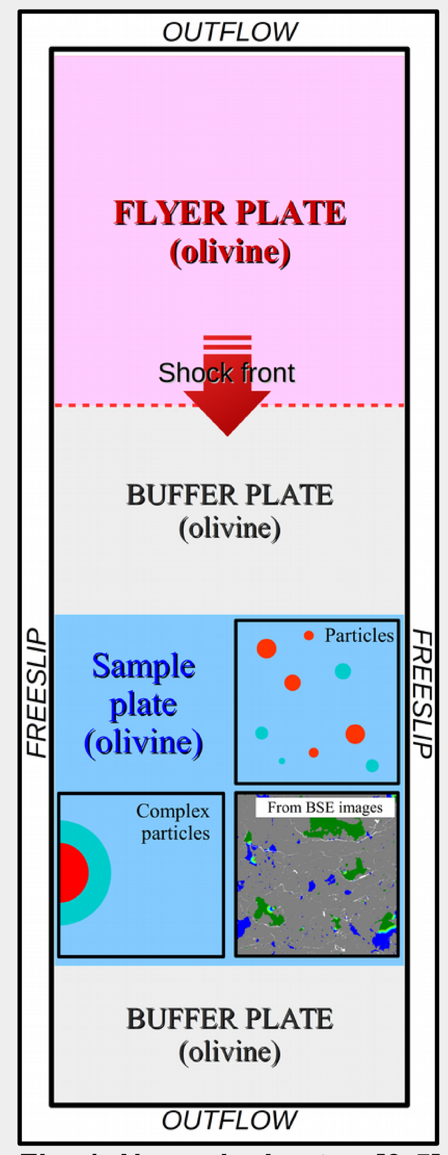

Fig. 1. Numerical setup [3-5] with samples bearing iron/troilite particles, and pores (BSE image)

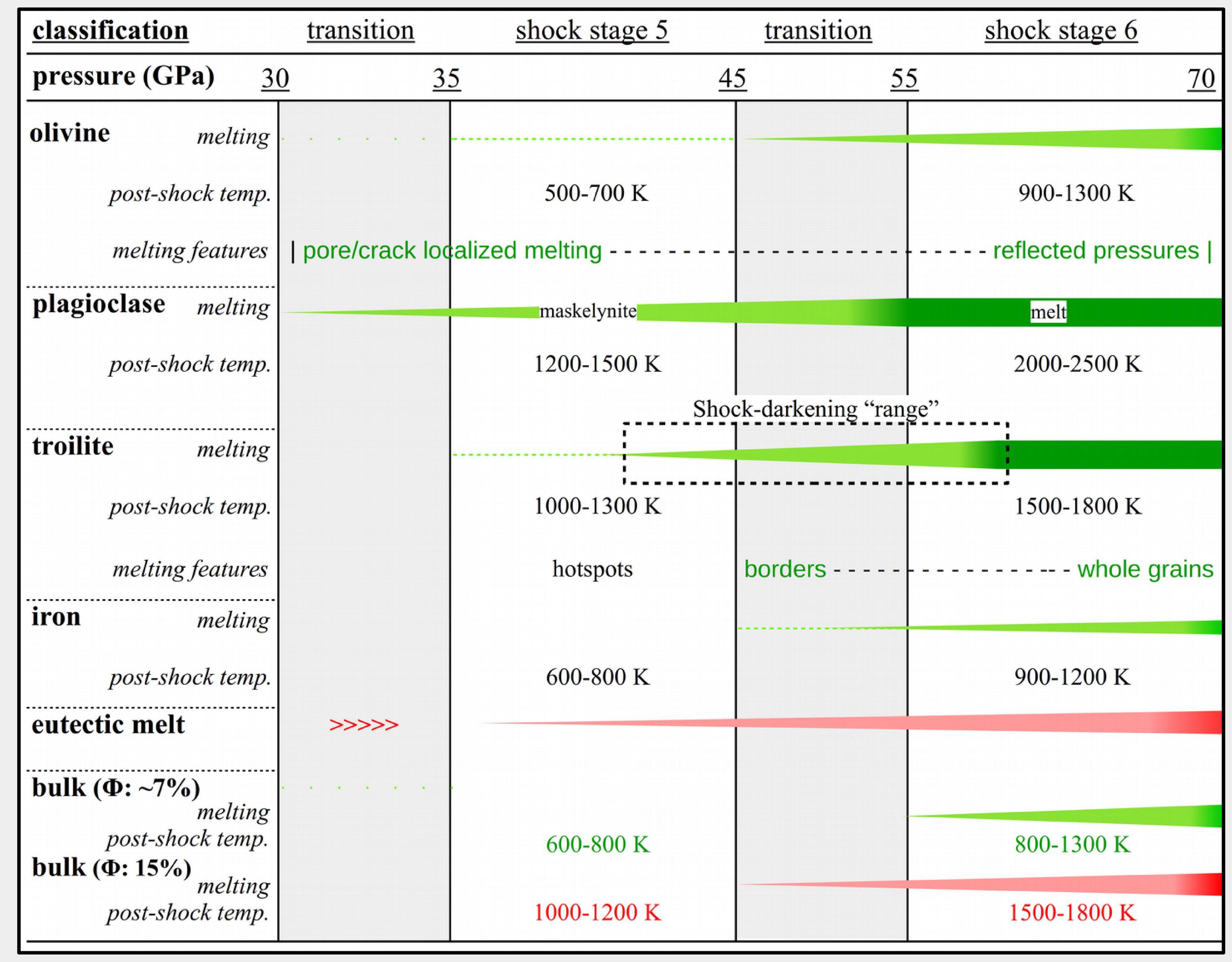

Fig. 2. Numerical model results compared to the shock classification [5]. Green is correlated, red requires further considerations in the numerical modeling or in the shock classification

II SHOCK EXPERIMENTS + NUMERICAL MODELING

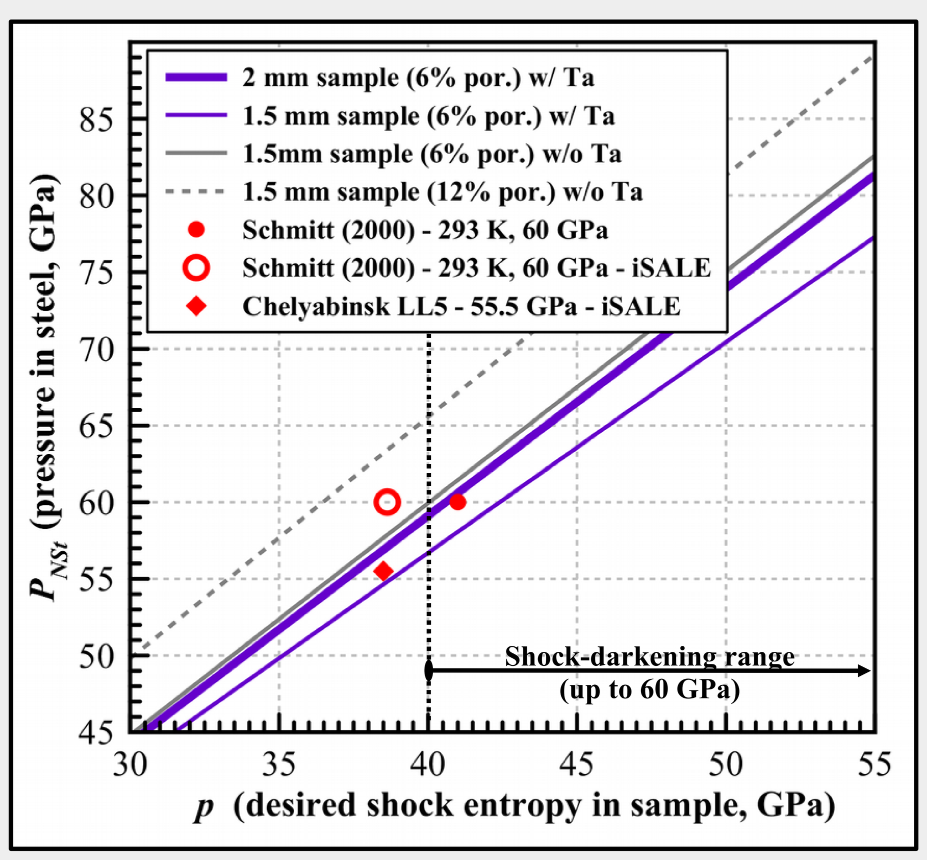

Fig. 3. The reverberating shock-recovery experiment, with 55.5 GPa of shock pressure in steel, was not sufficient to reach entropy for shock-darkening in our experiment on the Chelyabinsk LL5 ordinary chondrite (red diamond).

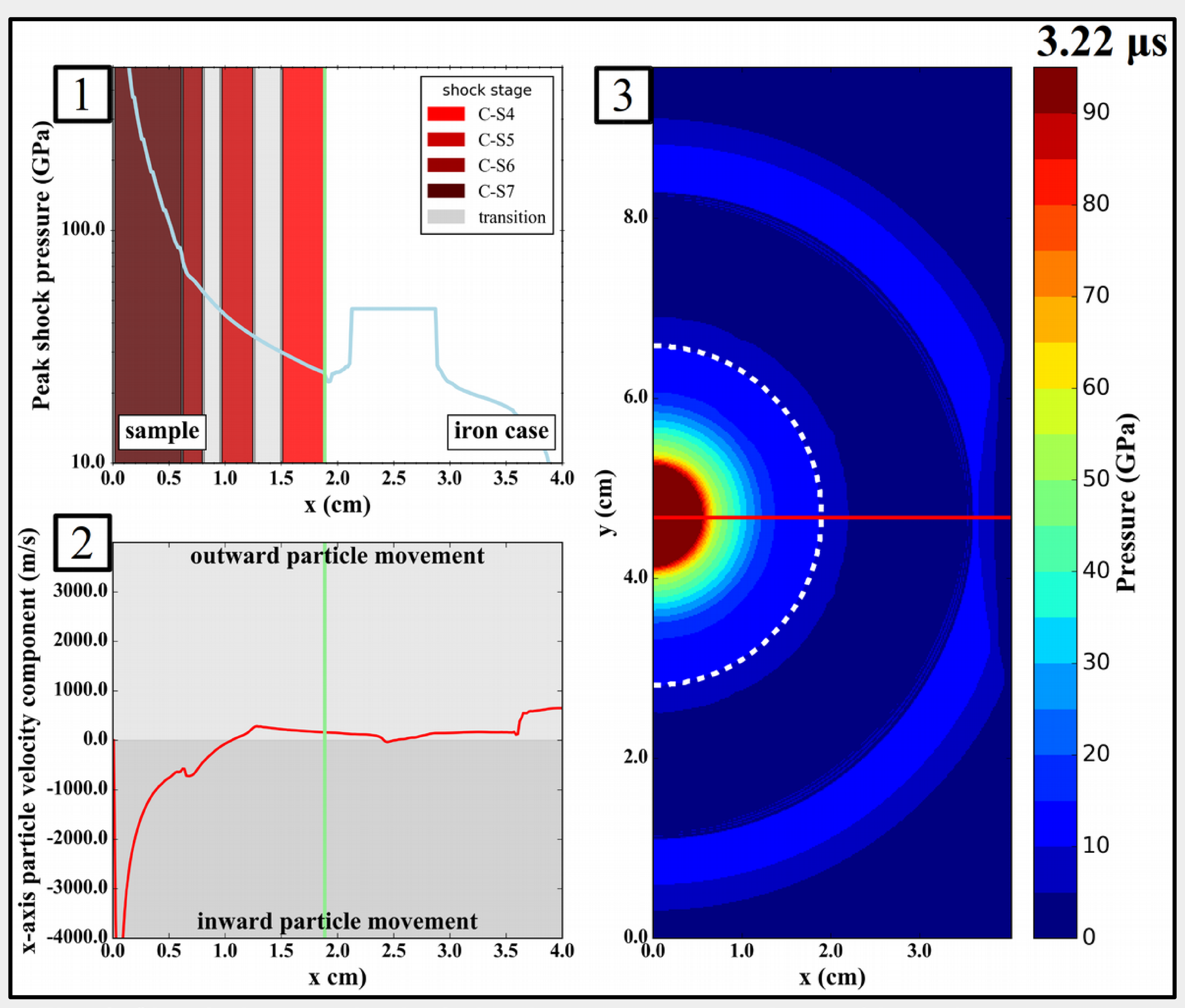

Fig. 4. Simulating a spherical shock-recovery experiment (time since pressure load is 3.22 µs). Progressive shock metamorphism in olivine sample (meteorite) (1), pressures (1, 3), and particle velocities (2) are shown. In such experiments, the sample is shocked at a pressures range including that for shock-darkening.

We wanted to reproduce shock-darkening in a 6% porous LL ordinary chondrite with a reverberating shock-recovery experiment. Numerical models show that this technique is inappropriate for attaining shock entropy for shock-darkening in most cases (no shock-darkening in our experiment, red diamond in Fig. 3; small patches of shock-darkened zones in another experiment, red circle in Fig. 3). However, additional models (Fig. 4) showed that spherical shock-recovery experiments are best suited to reproduce shock-darkening.

III IMPACT CRATERING NUMERICAL MODELING

Shock-darkening happening at 40-60 GPa might be a reasonable explanation for a mismatch in the Main Asteroid Belt distribution, with S-complex asteroids intruding C-complex asteroids (darkened reflectance spectra). We tested impact models and found out that 10 km/s impacts on porous and nonporous targets produced volumes of material, shocked at 40-60 GPa, 1.5-3 times the volume of a 30% porous projectile (see Fig. 5 and 6).

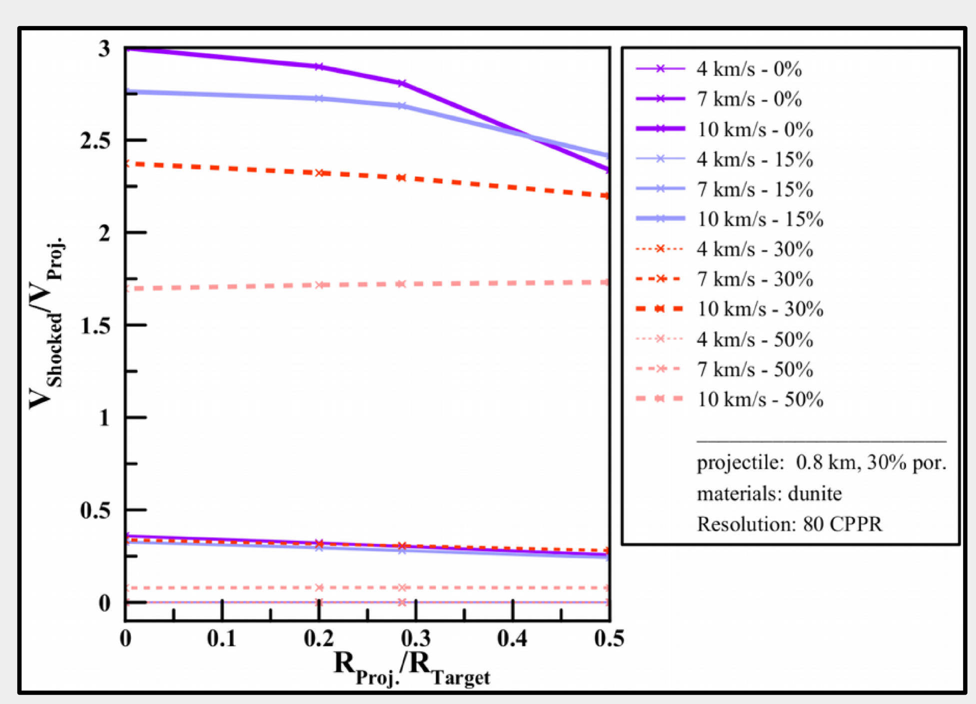

Fig. 5. Series of iSALE asteroid collision simulation results comparing ratios of shocked material and projectile volumes (V) and ratios of projectile and target radii (R). The volume of shocked material is between 40 and 60 GPa. Percent values are the dunite target porosity.

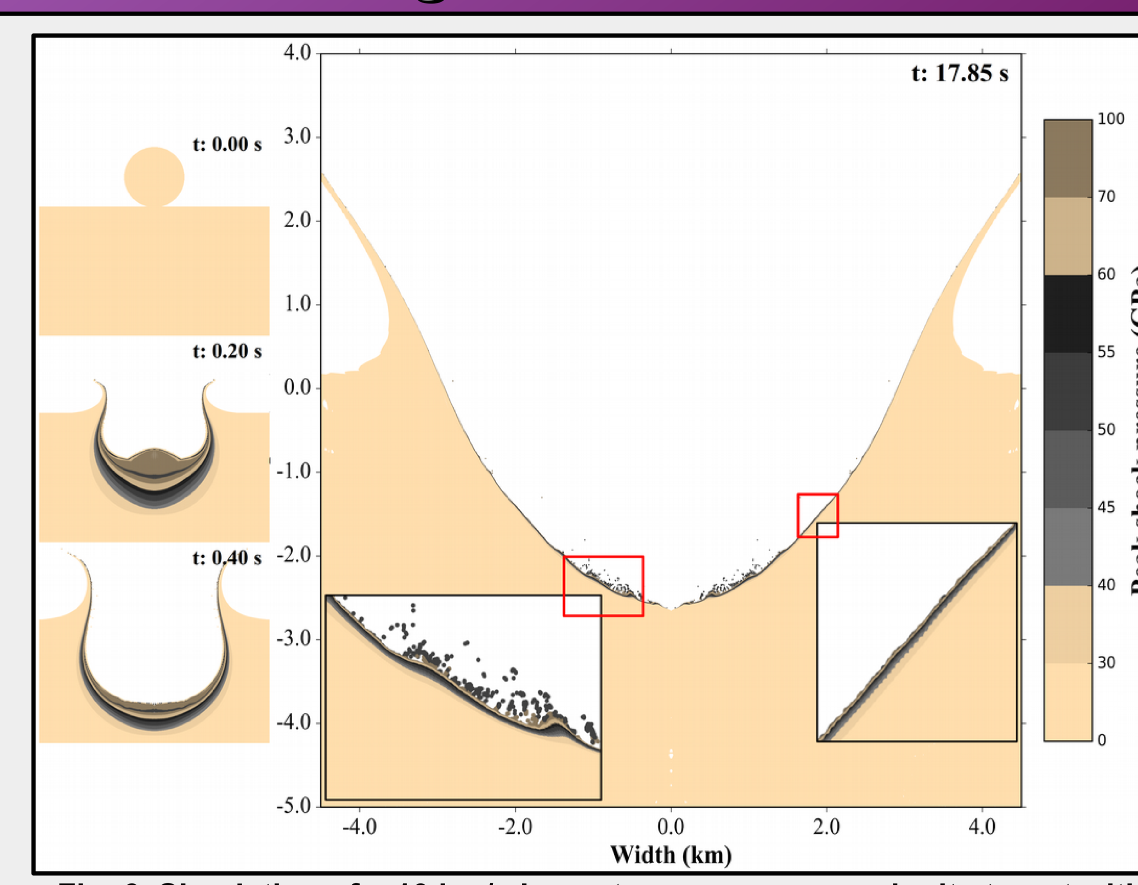

Fig. 6. Simulation of a 10 km/s impact on a nonporous dunite target with position of material shocked between 40 and 60 GPa.

Acknowledgements

Our thanks go to the iSALE developers, the team of the Museum für Naturkunde in Berlin for sharing their knowledge with us. This work is supported by the Academy of Finland.

IV? See you on the next poster :-) !

[1] Kohout et al. (2014), *Icarus*, 228, 78-85. [2] Wünnemann et al. (2006), *Icarus*, 180, 514-527. [3] Moreau et al. (2017), *MAPS*, 52(11), 2375-2390. [4] Moreau et al. (2018), *PEPI*, 282, 25-38. [5] Moreau et al. (2019), *Icarus*, submitted.

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