NUMERICAL MODELING OF SHOCK WAVE PROPAGATION IN IRON AND TROILITE ASSEMBLAGES IN ORDINARY CHONDRITES. 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 – Freie Universität, Institute of Geological Sciences, Berlin, Germany.

Introduction: We previously studied shock-darkening in ordinary chondrites [1] and determined the pressure range for the melting of iron sulfides to be 40-50 GPa. Shock-darkening is the partial melting of metals and iron sulfides filling cracks within silicate grains and darkening the lithology [2-6]. In this work [7], we investigate the shock wave propagation in assemblages of iron sulfides (troilite) and metals (iron) and try to define under which conditions melting of iron is predictable.

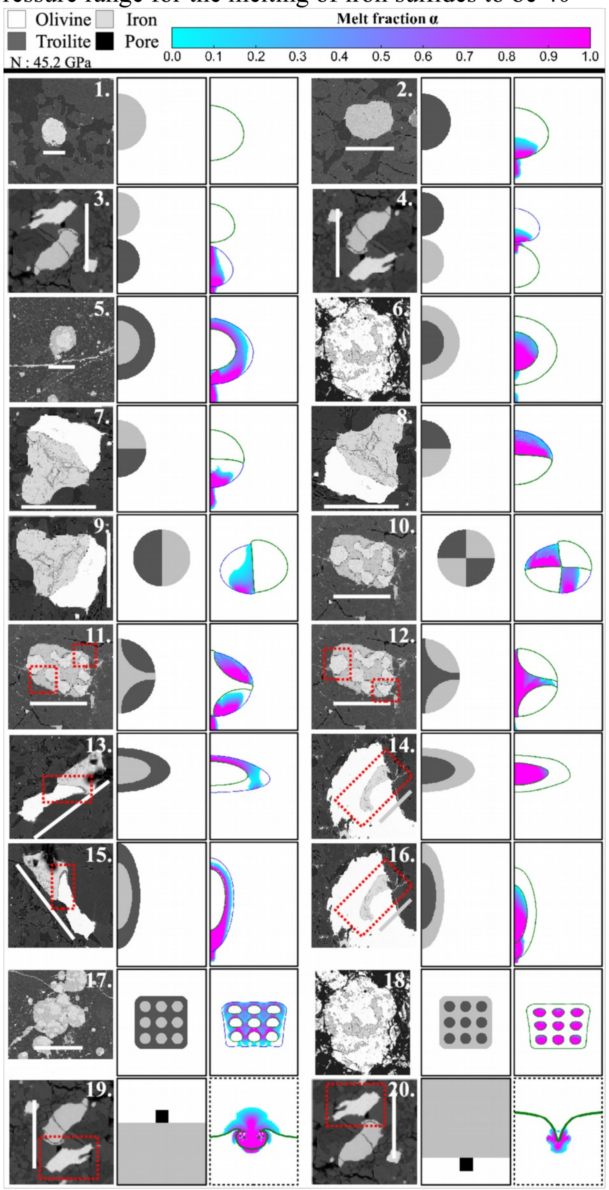

Fig 1. Compilation of all 20 models with a back scattered electron image example, the model (white: olivine, light gray: iron, dark gray: troilite, black: pore) and the resulting melt fraction at compression.Scale (white lines) and origins of the chondrite snapshots are: Annama H5 (3, 4, 19, 20, at 118 µm), Chantonnay L6 (1, at 40 µm; 2, at 76 µm; 5, at 43 µm; 10-12, at 102 µm), and Supuhee H6 (7-9, at 125 µm; 13, 15, at 148 µm; 14, 16, at 57 µm) ordinary chondrites. Model no. 6 and no. 18 snapshots originate from an enstatite chondrite (Sahara 97072, EH3, [9], modified, scale unknown).

Methods: To study the melting and post-heating of multi-phase models, we used the shock physics code iSALE [8] applying a model similar to [1]. In the mesoscale approach we used an olivine flyer-plate impacting olivine sub-layers between which we intercalated the desired configuration of iron and troilite (analogous to the setup of planar shock wave recovery experiments). In Fig. 1 we compile all the models that we carried out, and example images of iron and troilite grains in ordinary chondrites. Each model was numbered.

We adapted thermal properties, such as the melting points, heat capacities integration, and heat of fusion, to the materials – adapted to the eutectic if materials are mixed. We applied strength properties to the materials as well.

Results: We ran each model at 45 GPa. In Fig. 1 are compiled the melt fraction results for each model. Results are:

- troilite melt fraction from 0.14 (model 2) to 0.98 (model 14). Melting of troilite is very efficient once in eutectic mixture with iron;
- very rare melting of iron with maximum melt fraction 0.15 in model 16;
- melting occurs mostly at the rear of grains which is a reason of shock wave propagation;
- localized melting of olivine around a crushed pore nearby an iron layer in model 19 and 20 is illustrated in Fig. 1.

Discussion: Although troilite phase readily melts at 45 GPa pressure within eutectic mixtures, we determine that the melting of iron in ordinary chondrites is difficult to attain by shock; it relies on very localized heating by shock wave concentration in specific configurations of the phases. We illustrate the shock wave propagation in Fig. 2 for model 16. We also determined that the contrast of temperature between iron and troilite (~540 K), which is strongly heated, may lead to melting of iron by heat diffusion in the mixtures. We also illustrated the importance of localized frictional heating by comparing the particle velocity during passage of the shock wave in model 9 (Fig. 3).

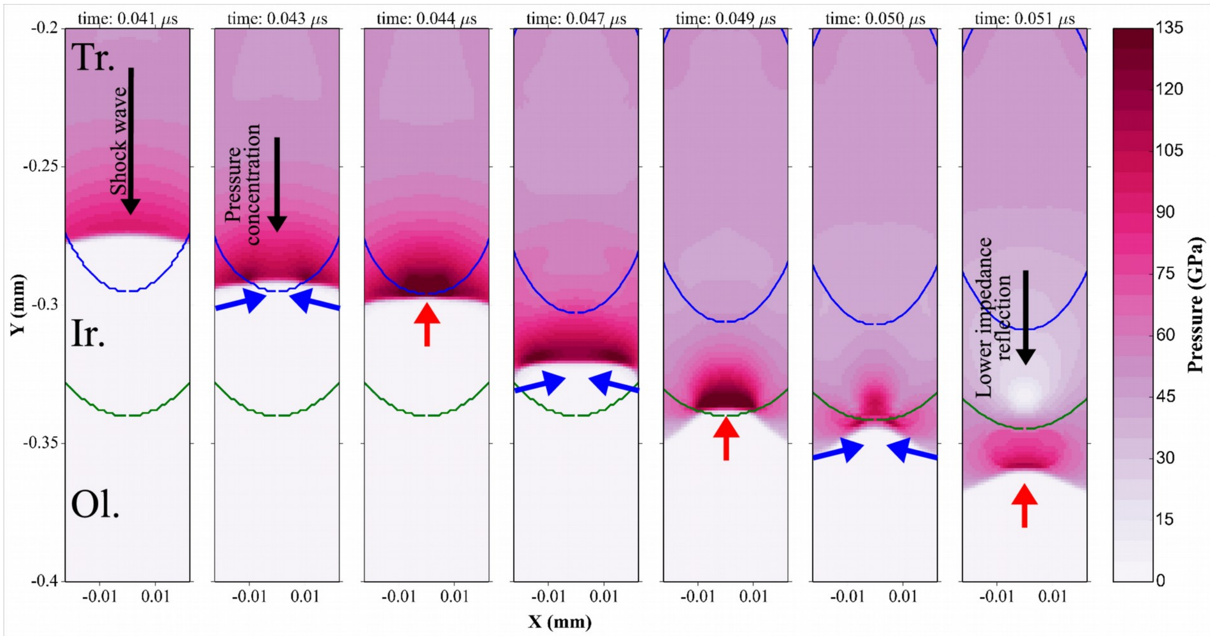

Fig. 2. Snapshots (model no. 16) of a shock wave traveling in the olivine (Ol.) sample plate through a prolate troilite (Tr.) inclusion within an iron (Ir.) prolate grain. The figure is centered to the lower part of the model. It shows concentration of the shock wave due to the cylindrical geometry and collisions due to shock wave velocity contrast (blue arrows) between convergent shock waves, leading to a strong rise in pressure (and temperature) locally (red arrows). The snapshots are manually mirrored from the original model at x: 0.00 to have a better view of the effects.

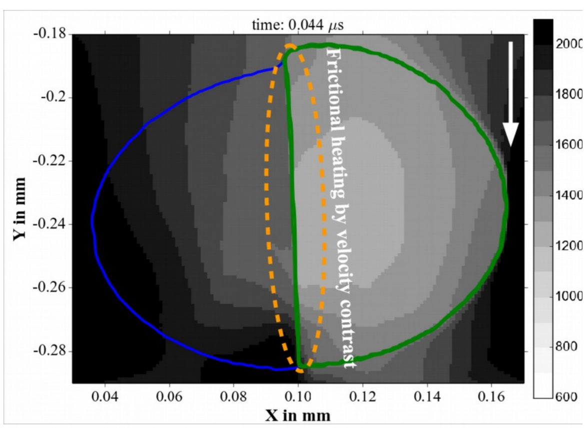

Fig. 3. Y-axis particle velocities of a grain of troilite (delineated in blue) in contact to a grain of iron (delineated in green) surrounded by olivine in model no. 9. The contrast of velocities at the contact between grains could lead to frictional heating. The white arrow indicates the relative velocity direction.

Conclusion: Using customized models of iron and troilite assemblages, we observed shock wave propagation, which are responsible for the melting of iron phases in eutectic mixtures; it explains why we rarely find molten iron phases in the shock-darkening veins in ordinary chondrites.

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

References: [1] Moreau J. et al. (2017) *Meteorit. Planet. Sci.*, 52(11), 2375-2390. [2] Heymann D. (1967) *Icarus*, 6, 189-221. [3] Britt D. T. et al. (1989) Proc. *19th LPSC*, 537-545. [4] Britt D. T. and Pieters C. M. (1989) Proc. *20Th LPSC*, 109-110. [5] Britt D. T. and Pieters C. M. (1994), *Geochim. Cosmochim. Acta*, 58(18), 3905-3919. [6] Kohout T. et al. (2014) *Icarus*, 228, 78-85. [7] Moreau J. et al. (2018). *Phys. Earth Planet. In.*, submitted. [5] Schmitt R. T. (2000). *Meteorit. Planet. Sci.*, 35, 545-560. [8] Wünnemann K. et al. (2006) *Icarus*, 180, 514-527. [9] Lehner S. W. et al. (2010). *Meteorit. Planet. Sci.*, 45(2), 289-303.