Shock-darkening in Ordinary Chondrites: Pressure-Temperature Conditions Determination by Shock Physics Mesoscale Modeling

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INTRODUCTION

Shock-darkening in ordinary chondrites is the melting of iron sulfides and metals into a network of veins (Fig. 1). It renders the lithology darker and alters the reflectance spectra [1]. We used the shock physics code iSALE [2,3] to determine the pressure range of such shock event.

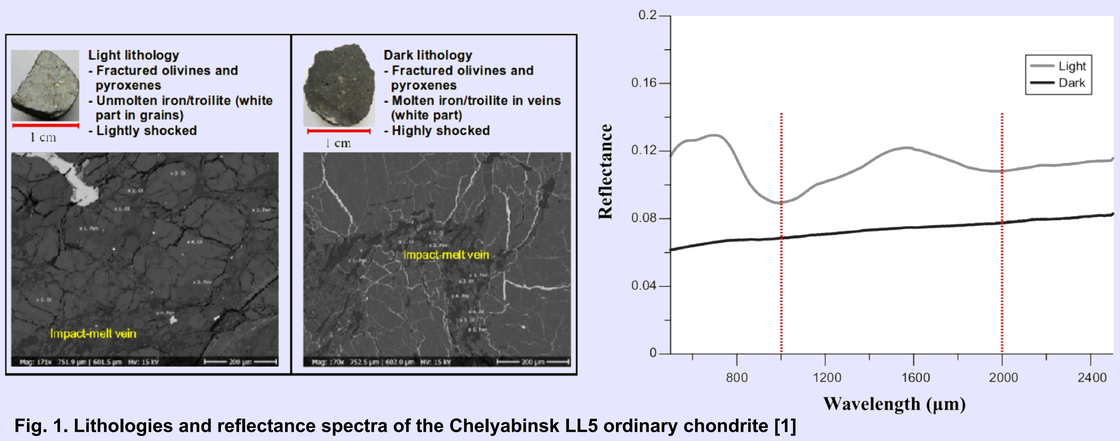

Fig. 1. Lithologies and reflectance spectra of the Chelyabinsk LL5 ordinary chondrite [1]

METHODS

We used a mesoscale setup [4] in which we embedded grains of troilite and iron in olivine (Fig. 2) to mimic ordinary chondrites compositions (type H, L and LL). By producing a planar shock wave, we assessed peak shock pressures, post-shock temperatures (PST) and melt fractions for each material (using tracers). We generated these planar shock waves through porous and non porous olivine. Iron/troilite ratios varied accordingly to ordinary chondrites types H, L and LL [5].

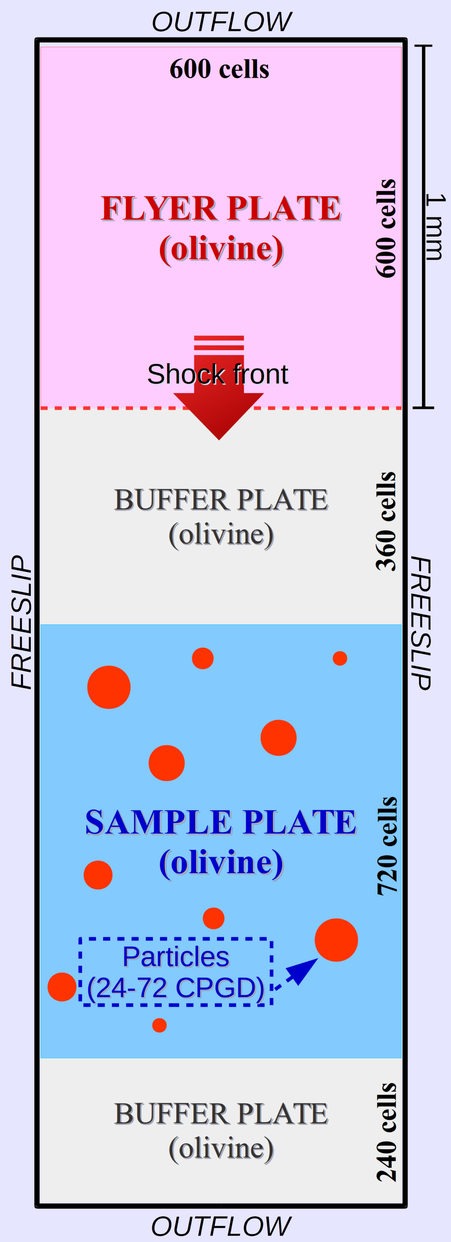

Fig. 2 Mesoscale (meso-grains) setup.

RESULTS

Our results are summarized in Fig. 3 and Fig. 4.

We observed:
1) Complete melting of troilite at 50 GPa (shock wave induced only).
2) Partial melting of olivine at ~50 GPa. It melted due to strong reflections from nearby iron grains.
3) Limited melting of iron starting at >55 GPa. It only melted due to specific grains disposition (relative to some elongation)

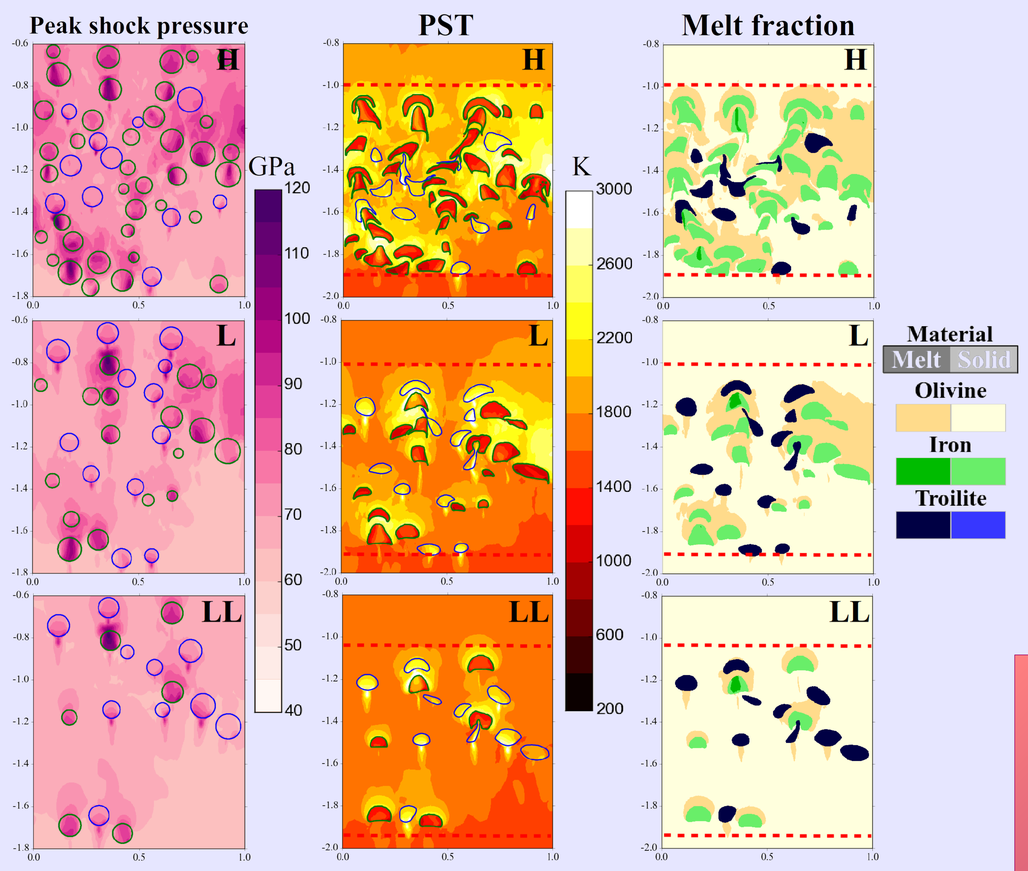

Fig. 3. Peak shock pressures, post-shock temperatures (PST) and melt fractions after a 61 GPa nominal shock pressure for various ordinary chondrite materials.

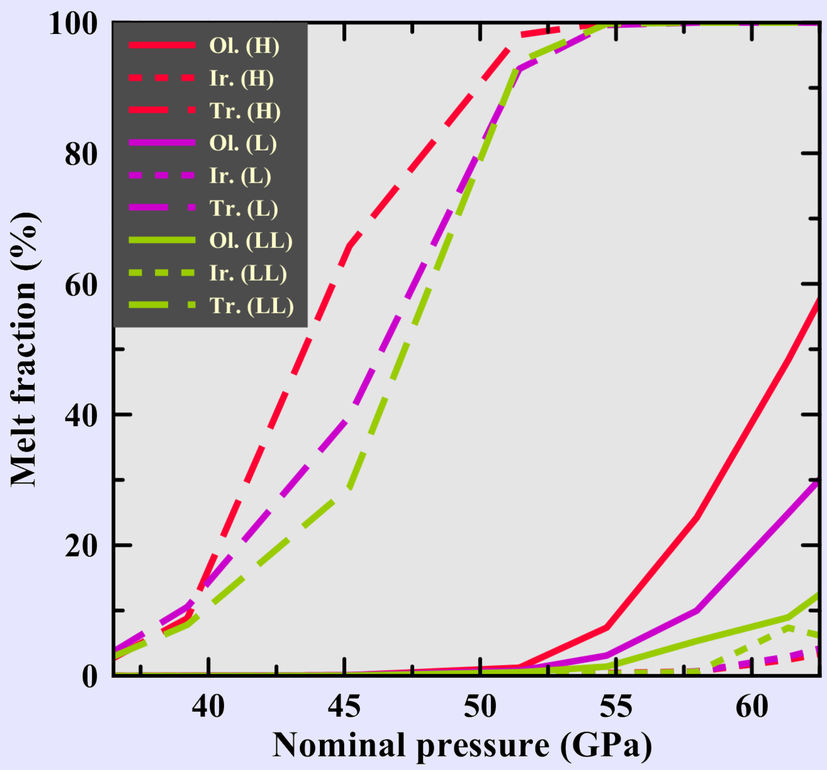

Fig. 4. General results in all ordinary chondrite types (porous olivine)

DISCUSSION

Our study offers a better understanding of shock thermodynamics implied in shock compression of ordinary chondrites. It resembles well what is observed in meteorites [6-8]. However, iron is a phase hard to melt under shock compression only. In our work we discussed about heat transfer, shapes of grains, eutectic melts and frictional melting as possible triggers for iron melting.

CONCLUSIONS

We observe that shock-darkening is happening between shock pressures of 40-50 GPa. It implies complete melt of troilite. We do not observe the melting of iron at these pressures.
This study is the first step to help quantify shock-darkening on asteroids and to carry on shock-recovery experiments.

Acknowledgements

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[1] Kohout *et al.* (2014), [2] Wünnemann *et al.* (2006), [3] Moreau et al. (2017) submitted,
[4] Bland *et al.* (2014), [5] McSween *et al.* (1991), [6] Stöffler *et al.* (1991), [7] Schmitt (2000), [8] Xie *et al.* (2014)