NUMERICAL MODELING OF THE ORDINARY CHONDRITES SHOCK METAMORPHISM TRANSITION FROM SHOCK STAGE 5 TO 6.

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Introduction: To study shock metamorphism in ordinary chondrites, [1] successfully established a shock classification, comprising six shock stages until whole rock melting. In the classification, the shock stage 5 and 6 are defined with specific shock effects in silicates, and observation of localized melt pockets and melt veins. The estimated pressure range for the transition from stage 5 to 6 is 45-55 GPa. By shock physics mesoscale modeling, we gave insight to the post-heating and melting, encompassing the transition, using: olivine, enstatite, troilite, and iron phases. We also considered eutectic melting at contact between iron and troilite. We carried out a systematic study in the 38-68 GPa pressure range and we observed the effects of open pores (macro-porosity) and olivine porosity (distention, micro-porosity [2]). We used backscattered electron microscope (BSE) images of chondrites thin sections, Annama H5 (two models), Neuschwanstein EL6 (two models), and Chelyabinsk LL5, to setup our models. Using BSE images enables to setup more realistic sample meshes and grain distribution in the mesoscale models.

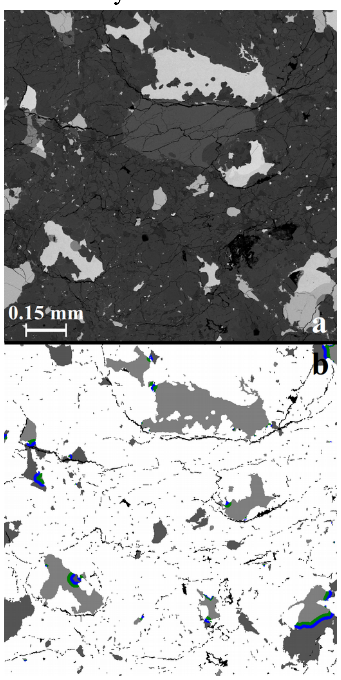

Fig 1. Conversion of a BSE image to a numerical mesh (light gray: iron; dark gray: troilite; white: olivine; black: pores). Green and blue zones are eutectic contact between iron and troilite. We also converted the large phosphate grain from the BSE image to olivine, because we defined only 3 phases for numerical accuracy.

Methods: To study the melting and post-heating of multi-phase models, we used the shock physics code iSALE [2] with a setup similar to [3]. In the mesoscale approach we used an olivine flyer-plate impacting olivine sub-layers between which we intercalated the converted BSE image mesh (analogous to the setup of planar shock wave recovery experiments). In Fig. 1 we illustrate the BSE image conversion of Annama (1) to a BMP image containing one RGB value per chosen phase.

We adapted thermal properties, such as the melting points, heat capacities integration, and heat of fusion, to the material and chondrite original composition. Strength and porosity models followed those from [4, 2, 3].

Results: Fig. 2 displays the mesh after shock compression in term of post-shock temperatures and melt fraction at 55 GPa in Annama (1). In Fig. 3, we compile melt production for troilite, olivine, and the bulk material, for all models, and the resulting bulk post-heating with literature data [5,6]. We also carried out models on Annama (1) in which we varied porosity or the initial temperature.

Discussion: In our work, the transition from shock stage 5 to 6 is illustrated by:

- the melting of troilite from ~40 GPa to ~68 GPa with melt fraction reaching 0.9;

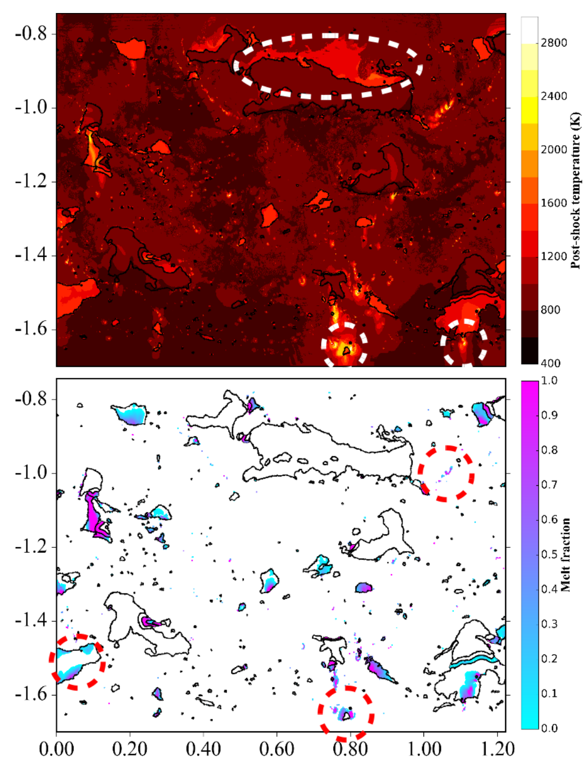

Fig 2. Post-shock temperature and melt fraction panel in the Annama (1) model at 55 GPa. The dashed circles are zones of interest.

- the progressive melting of olivine starting from 50 GPa with low melt fraction from 0.01 to 0.1 at 68 GPa.

In Annama (1), Fig. 2, we highlighted some effects of localized melting and other features:

- heating-melting by pore crushing in olivine;
- heating and melting of olivine at iron boundaries, due to strong pressure reflexions [5];
- melting of troilite at borders of larger grains [7], depending on the grain geometry.

While pure shock melting of olivine, regardless of external factors (e.g. pressure reflexions, pore crushing), is characteristic of the whole rock melt, stage 5 and 6 are characterized by localized melting, such as described by [1] and observed in our work. The transition from shock stage 5 to 6 is also dependent on olivine porosity (10% and 15% porosity tests, Fig. 3).

Conclusion: With the model-based predictions of the shock heating and melting in ordinary chondrites, we provide more insight to the transition from shock stage 5 and 6 of the shock classification. The numerical models based on real meteorites BSE images of chondrites, give realistic results comparable to results of shock experiments.

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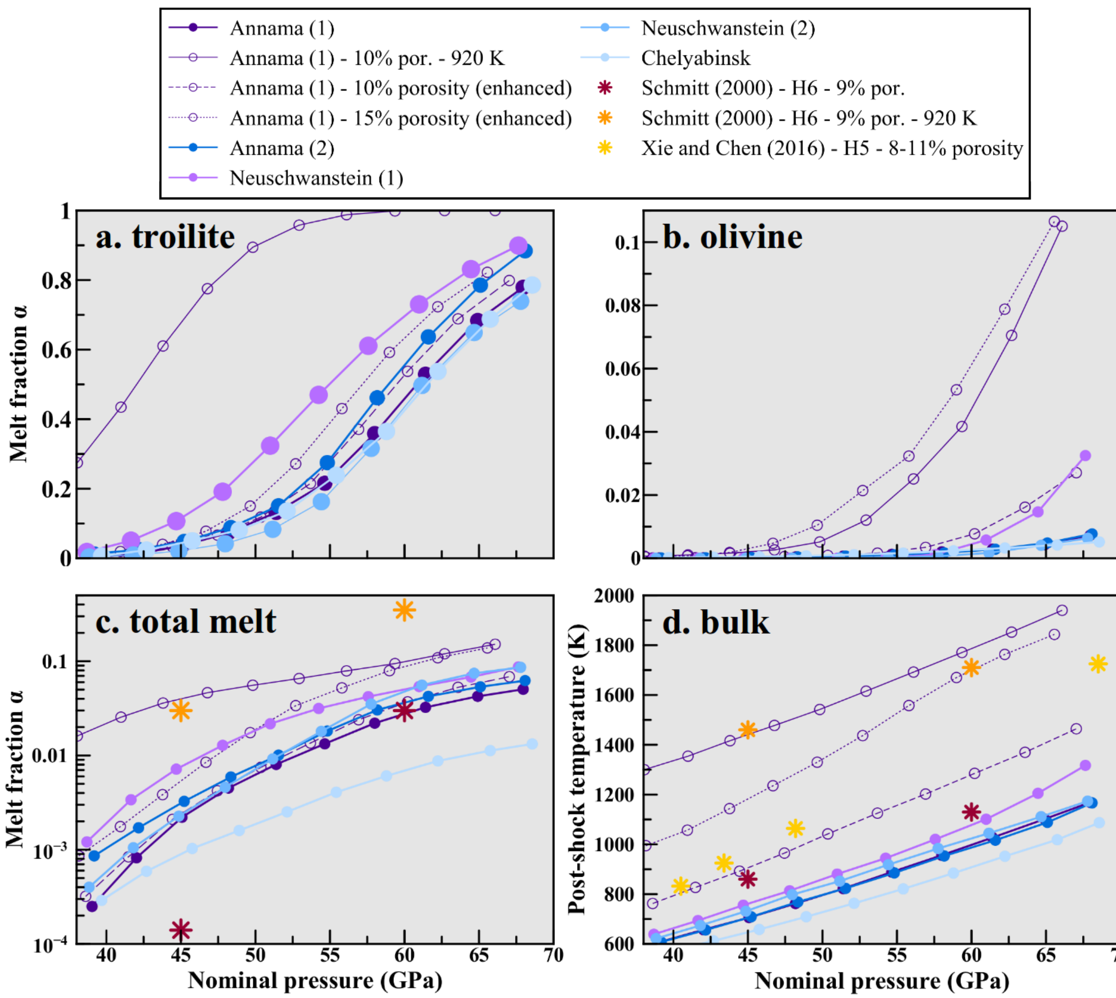

Fig 3. Melt fractions and post-shock temperatures in all models with shock experiment literature data as reference. Graphic c) is in logarithm scale.