INJECTION OF MOLTEN IRON SULFIDES AND METALS INTO ROCKS: DEVELOPING A TECHNIQUE TO STUDY SHOCK MELT VEINS IN ORDINARY CHONDRITES.

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Introduction: In several studies numerical modeling was used to investigate the specific pressure and temperature conditions of shock-induced exclusive melting of metal and iron sulfide phases in ordinary chondrites [estimated at 40–60 GPa of shock with <15% porous meteorites, 1–3]. The investigated shock related effect is called shock-darkening when metal and iron sulfide melt migrates through silicates cracks [4]. The darkening of the ordinary chondrite suppresses the characteristic absorption bands of reflectance spectra in the near infrared range (NIR) typical for major Fe–bearing silicate minerals at 1 and 2 microns wavelengths [4]. The same band attenuation is observed where complete rock melting occurs. This observation might affect the current interpretation of Main Belt asteroid distribution, which is mainly based on NIR data [5]. The range of shock-darkening depends on temperature gradients between the respective sulfide, metal, and silicate phases, the porosity of the chondrite before shock, and the time scale of the shock event itself [6]. In order to enable melt migration into cracks and pores, the molten metal and sulfide phases must remain liquid before cooling rates increase too steeply by heat diffusion and inhibit migration of the melt into the cracks. Furthermore, observations of the metal and sulfide melt veins within natural meteorites show a sulfide/metal fractionation where sulfides are disseminated, assum-

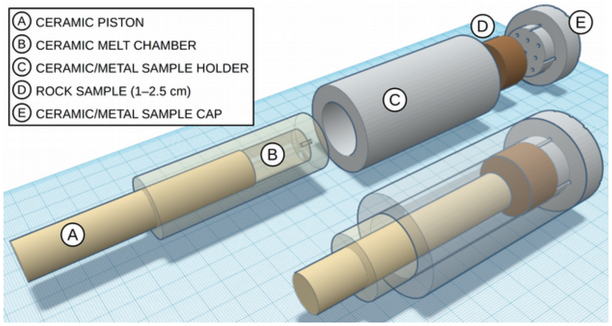

Fig 1. 3-D model of the injection system. Proposed materials are steel or tungsten for (C) and (E), and a corrosive, oxidation, and heat resistant ceramic for (A) and (B). The sample holder has drilled holes to let gas escape upon injection. Apparatus is ~2.5–4 cm in diameter. This apparatus is designed to fit in a tube furnace of 5 cm diameter chamber.

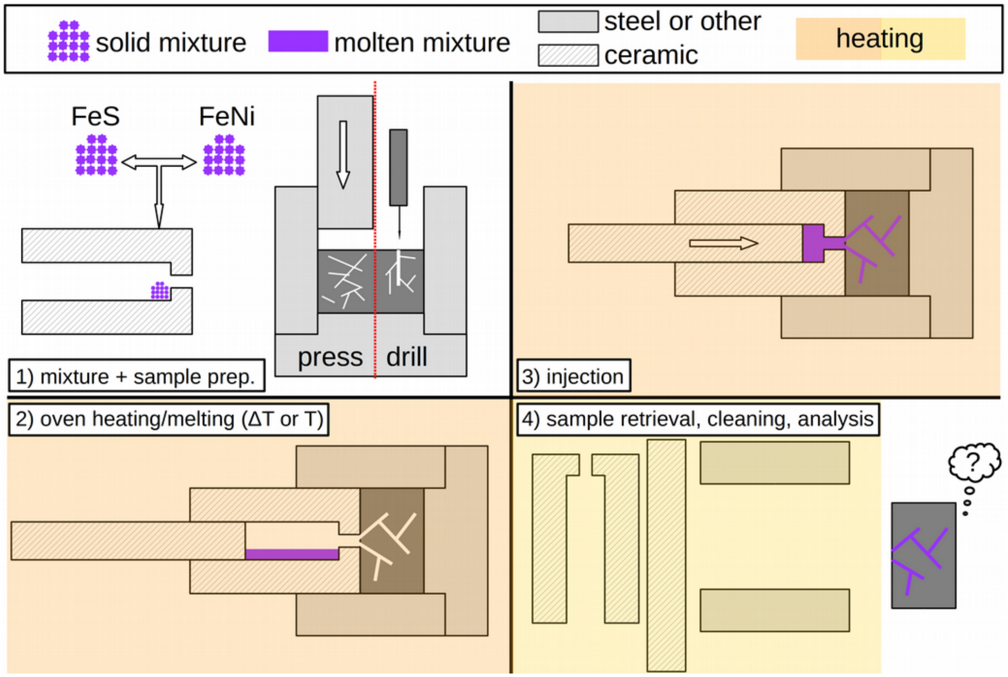

Fig 2. Sequence of actions of the melt-rock injection apparatus. The sample is prepared by fracturing it within the sample holder (cap and cuff) either with a press or a drill (1). The mixture is weighted and deposited in the melt chamber (1). The whole apparatus is heated in an oven until the mixture melts (2) before the piston is pushed to inject the molten mixture into the fractured sample (3). The elements are then cleaned at higher temperatures and the sample is analyzed (4).

ingly by capillary action, into tiny silicate cracks, whereas less viscous metals remain in larger cracks [7].

Concept: To study the distribution of metal and iron sulfide melt into cracks, we are designing a piston-like apparatus (Fig. 1). A chamber (B) will serve as a sulfide/metal reservoir from which the melt will be injected into the rock sample (D) located within a sample holder (C,E). Parameters, like temperature and oxygen fugacity (fO2), are controlled using an inert gas atmosphere and placing the assembly in a high-temperature tube furnace. The melt is composed of fractions of iron sulfides (troilite or pyrrhotite) and metals (pure iron or kamacite) in such proportions that an eutectic melt is obtained. The temperature of the experiment ranges between 1100–1600 K depending on the eutectic melting temperature. The chemically inert apparatus material will also have to tolerate thermal stress (e.g. alumina ceramics). The rock sample (dunite) which is fractured in situ in the apparatus is protected by a steel or adequately heat resistant material (C). Melt injection will either be performed at constant T or within a ΔT between the melt and the rock. Fig. 2 illustrates the different experimental set-up steps: powder preparation and sample fracturing (1), melting (2), injection (3) and, eventually, high heat cleaning and recovery of the sample (4).

To better our understanding of melt migration into the dunite rock, we will also proceed with static experiments in which the metal and iron sulfide mixtures are layered on a fractured dunite, or on loose olivine grains. Thereby, we hope to understand melt migration behavior triggered by gravity (metal/sulfide layer on top of rock) and/or capillary forces (metal/sulfide melt layer placed underneath the rock).

To prepare the mixture we synthesize near-stoichiometric troilite by heating pyrite at 750°C for 4 hours (see Fig. 3, [8]) and we retrieve the metal (FeNi) phase from an iron meteorite.

Goals: Our experimental method will provide direct observation of the distribution mechanism of metals and iron sulfides into cracks from a known point of injection. We will observe: the fractionation of the two phases along the fractures, the possible chemical diffusion between the iron-rich melt in contact to the magnesium-rich silicate minerals (olivine, pyroxene), the darkening of the lithology and, finally, the efficiency of the injection process itself, as well as the respective “repeatability” and feasibility.

These experiments will constrain more on the importance of metal and iron sulfide melt veins as a tracer for impact events, their intensity, and the possible origin of metals and iron sulfides in stony meteorites. The chemical diffusion/ respective partition coefficients between silicates and metal-sulfides can serve as a tool to constrain the cooling history of metal-sulfide veins with the hypothesis that the degree of diffusion can tell us about the possible ejection of asteroidal fragments during asteroid collision or the thermodynamics of the shock, taking into account the precursor porosity of the chondrite. Diffusion models and microprobe analyses on natural, experimentally shocked, and experimentally injected rocks will contribute to respond to this hypothesis. X-ray computed tomography will also offer us a better view of the spreading of metal-sulfide veins and their composition, and micro (μ-FTIR) and bulk spectral analyses will finally tell us the contribution of metal or sulfide melt to the darkening of the chondrite lithology. Spectral results will also aid in better understanding remote spectral data.

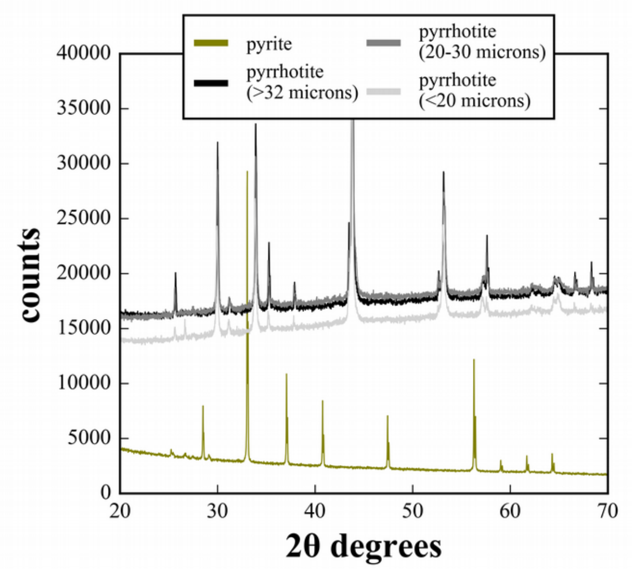

Fig 3. X-ray diffraction analysis of a synthesized pyrrhotite (39.2 Wt.% S). A pyrite sample, grounded into 3 size fractions (< 50 microns), was pre-heated at 380°C for 45 minutes and at 750°C for 4 hours in an argon flushed (300 ml/min) tube furnace.

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