DUNITE DARKENING BY FeS TROILITE MELT IMPREGNATION COMPARED TO THE SHOCK-DARKENED CHELYABINSK LL5 CHONDRITE. J. Moreau[1], A. Jõeleht[1], A. N. Stojic[2], J. Plado[1], P. Somelar[1], T. Kohout[3], S. Hietala[1,4]. [1]Department of Geology, University of Tartu, Estonia (juulia.moreau@ut.ee), [2]Institut für Planetologie, Universität Münster, Germany, [3]Department of Geosciences and Geography, University of Helsinki, Finland, [4]Geological Survey of Finland.

Introduction: The transition between shock stages 5 and 6 of the shock classification of chondrites [1,2] promotes the darkening of ordinary chondrites by pervasive iron sulfide and metal (FeS-FeNi) shock melt [3] as seen in Fig. 1a with the spreading of veins into silicates that remained solid upon shock in the Chelyabinsk LL5 chondrite, and Fig. 2, with the darkened lithology fragment of the chondrite. Conditions for the pervasive melt are pressures between 40-60 GPa in low porous chondrites (<15%) and short shock events (<400 µs) or ~10 GPa lower in more porous chondrites and longer shock events (~15-30%) [1,4]. The darkening of the lithology permanently alters reflectance spectra of the meteorites; the 1- and 2-microns silicate absorption bands are suppressed. On a larger scale, it may affect the accepted distribution of asteroids because shock-darkened S-complex asteroids, ordinary chondrites hosts, will look similar to C/X-complex asteroids, carbonaceous chondrites hosts [5].

Mechanisms for the pervasive melt are still investigated [6] and include pressure jetting of the melt at opening of cracks from shock release and capillary forces, which induce FeS-FeNi impregnation of the rock. To distinguish between the two dynamics, which cannot be discriminated in shock-darkened ordinary chondrites, we propose a study where ultramafic rocks are impregnated with a troilite (FeS) melt at atmospheric pressure. We aim to compare the veins morphology between the shock-darkened Chelyabinsk meteorite and the impregnated rocks, study the vein composition with scanning electron microscope, elemental mapping, and microprobe analyses of the veins, and finally to produce near-infrared reflectance spectra at the macro and micro-scale. The comparative study will help to discriminate between the two modes of darkening by coupled pressure jetting and melt impregnation (Chelyabinsk meteorite).

Method: For the experiments, we used dunite rocks composed in the majority of olivine (Tulppio dunite, [7]) and synthesized troilite mineral grains with meteoritic composition [8]. Troilite was placed in drill holes atop the middle of dunite cubes of ~1.5 cm sides. The samples were placed into a high-temperature nitrogen-purged oven for 1 hour to 2 hours at 1325°C with 10°C/min heating and 5°C/min cooling. The samples were retrieved and cut for analyses. To establish a comparison, we also analyzed two Chelyabinsk thin sections [3] on a variable pressure Zeiss EVO MA15 SEM equipped with an Oxford X-MAX energy-dispersive detector system (EDS).

Results & Discussion: In Fig. 1 are SEM image and elemental mapping of a selected zone in the Chelyabinsk dark lithology thin section and in Fig. 2 are shown the light and dark lithology of the meteorite. In Fig. 1, the veins are easily distinguished once Ni and S elements are separately looked at. These FeS and FeNi

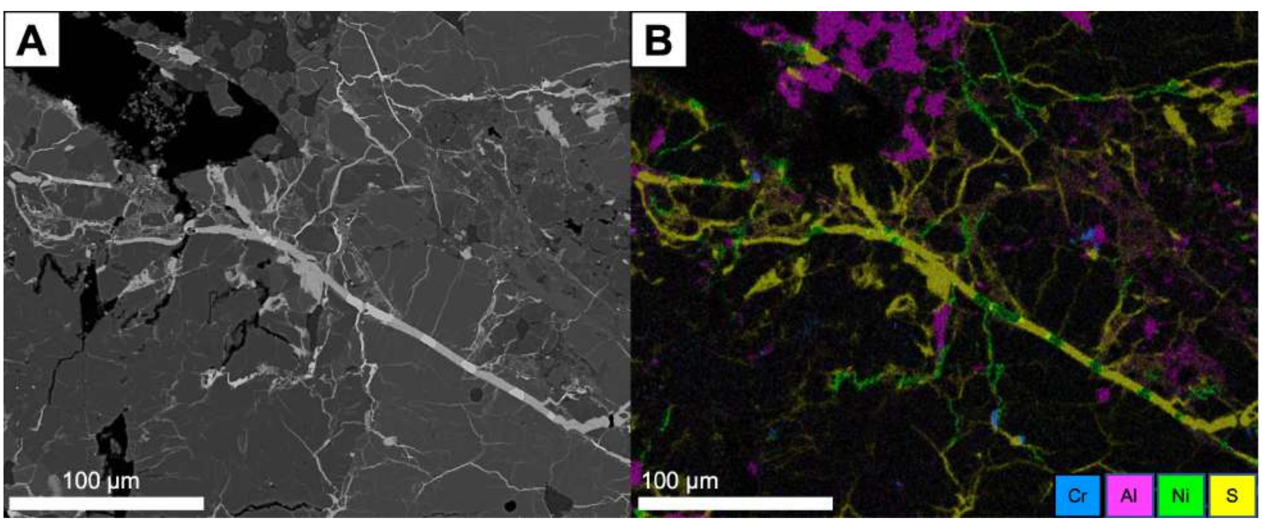

Fig. 1. a) Scanning electron microscope backscattered electron image of shock-darkened Chelyabinsk LL5 chondrite and b) the EDS elemental map. The EDS highlights elements discriminating FeS (S) and FeNi (Ni) veins, chromite (Cr) and plagioclase (Al) mineral species. The FeS-FeNi veins are composite and in b) possible zoning from recrystallization is observable between nickel and sulfur in the larger sulfur vein.

veins are absent in the few plagioclase minerals highlighted in magenta (Al) because plagioclase is impervious to the melt from shock melting [3]. Elemental mapping of the sample shows composite veins where FeS and FeNi minerals coexist. The composition of larger veins is richer in metals which hints at possible partitioning of the eutectic mixture from impregnation and wetting properties of troilite to silicate [6]. Within the larger veins, the Ni and S seem to form small zoning areas (bright spots in Fig. 1b).

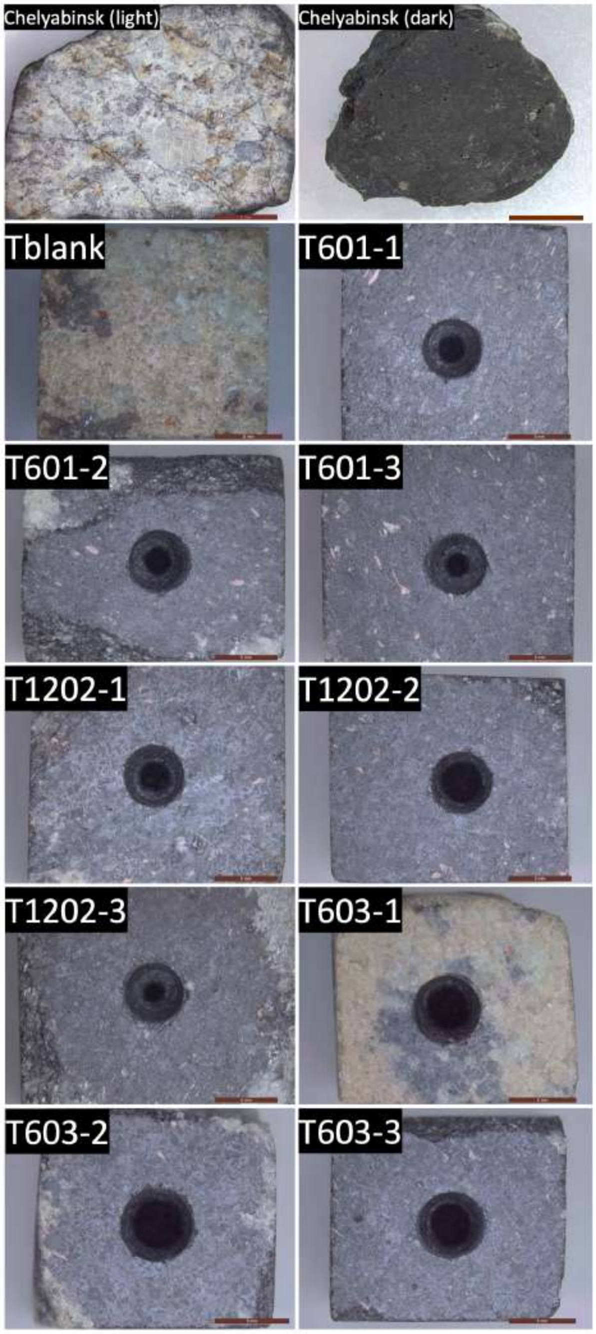

Fig. 2. The dunite rocks darkened from troilite melt impregnation, such as seen in the dark lithology of the Chelyabinsk LL5 chondrite. Synthesized troilite grains [8] were deposited in drill holes; the dunite cube were heated for 1 (T60) to 2 hours (T120) at 1325°C in a nitrogen-flushed oven. Amounts of troilite were 0.12 g in all T601 cubes, 0.13, 0.12 and 0.12 g in T1202-1/3, and with increasing values of 0.03, 0.05, 0.08 g in T603-1/3. Estimated vol.% in FeS of each sample are 0.7, 0.8, 0.7 / 0.8, 0.9, 0.6 / 0.2>0.5>0.7. Dark red scale bars: 5 mm.

The results for the melt impregnation experiments on dunite rocks are shown in Fig. 2 where all samples (but the blank) were impregnated by troilite melt from thermal treatment, inducing darkening of the dunite cubes. The darkening doesn't affect pink inclusions analyzed to be a form of spinel (e.g. T601-3) which have formed from magnetite in an oxygen-free environment at high temperature [9]. The lack of troilite impregnation of the pink inclusions in dunite is not readily comparable with the plagioclase imperviousness to the melt in shock-darkened meteorites as mechanism may differ.

Volumetric darkening is function of the amount of troilite inserted into the cube (T603-1 to T603-3). However, the darkening observed on the dunite samples is not as pronounced as the darkening observed on the Chelyabinsk LL5 meteorite, even if the dunite samples show a rougher surface. The dissimilarity in darkening intensity between the meteorite and the impregnated dunite hints at additional mechanisms of melt migration or differences in the vein densities or FeS-FeNi vein compositions. SEM-BSE observations of the dunite samples and their reflectance spectra analyses will partially answer to these interrogations.

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