Magnetic, In Situ, Mineral Characterization of Chelyabinsk Meteorite Thin Section. L. Nabelek[1,2], M. Mazanec[1,2], S. Kdyr[1,2], and G. Kletetschka[1,2,3], [1]Charles University in Prague, Faculty of Science, Prague, Czech Republic, nabelekl@natur.cuni.cz, [2]Institute of Geology, Academy of Science of the Czech Republic, v.v.i., Prague, Czech Republic, kletetschka@gmail.com [3]Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Introduction: Our objective is to obtain, analyze and interpret the magnetic data above a geological thin section. Magnetic properties of the meteorite are of growing interest, as magnetism becomes practical when exploring asteroid belt with the objective of mining the asteroids [1,2]. In order to understand magnetic properties of asteroid and how to use this feature for landing of the spacecraft and/or moving asteroid objects on its surface by magnetic force, it requires in situ knowledge of magnetic coercivity of remanence (CR) for magnetic minerals contained within the asteroid. Here we focus on establishing of the level of CR in situ in Chelyabinsk meteorite, which will provide a key parameter for a future design of electromagnetic structures, capable to transport fragments of asteroid over the mining surface [3,4]. Micro-magnetic properties of magnetic minerals in the geological thin section give us a new direction for exploration of individual magnetic moments of visible magnetic grains or magnetic bodies in meteorites and/or asteroids [5] **.**

Material: Sample (4,418 g) was removed from the Chebarkul lake, Chelyabisnk region, Russia, during (2013). This rock was used to create a geological thin section. Material was classified as LL5, S4, W0 ordinary chondrite [6]. Magnetic properties of Chelyabinsk meteorite revealed kamacite and taenite as a major magnetic carriers [7,8].

Scanning magnetic microscopy: The dominant technique for imaging magnetization distributions in geological samples is scanning magnetic microscopy (SMM) [9]. We used a magnetic sensor assembled by Youngwood Science and Engineering (YSE) (Hall probe and 2D motorized stage). The output is a 2D image of magnetic anomaly map.

Coercivity of remanence (CR) spectra: The sample was scanned after each of the stepwise magnetic acquisition by ASC pulse magnetizer. The sample was magnetized first with a predetermined direction with the 1T magnetic field and was then gradually demagnetized in opposing direction to reach the saturated magnetization in opposing direction (sample went through demagnetization, while we observed rotation of the dipole by 180 °) in increments of 1 mT. It reached saturation when applying -40 mT of pulse field intensity. The same procedure was applied in the reversed direction. The magnetic scan of the thin section identified 6 major magnetic anomalies. Program was able to keep track of the coordinate of the center of magnetic anomaly (transect between positive and negative magnetic readings), while we observed a rotation of the magnetic dipoles in the field detected above the thin section. Each of the scans and the resulting data created the base for determination of the coercivity of remanence for each of the anomaly source and values for rotational remanence were plotted based on the dipole angle deflection from the direction of the original saturated state. The actual values for (CR), were determined.

Microscopy: For optical image, we photographed meteorite thin section on a light table and combined this image with the magnetic scan images. The mineral analyses and major element distribution maps were obtained using the scanning electron microscope.

Results: We introduced for the first time magnetic scanning on the Chelyabinsk meteorite and obtained robust magnetic signatures caused by taenite and kamacite magnetic minerals and we produced more than 80 magnetic scans that created a magnetic characterization database for all grains that produce magnetic anomalies. Magnetic scan analysis allowed observation of the rotation of the magnetic dipole directions at the moment of magnetic reversal. Observation of this new parameter allows more simple determination of the coercivity of remanence. Sources of magnetic anomalies generated in microscale over the thin section of the meteorite are taenite with composition of Nickel (27-40 %), Cobalt (0.65-1.48 %) and Iron (59-70%), and kamacite with composition of Nickel (4-6%), Cobalt (2.07-3.11%) and Iron (89-91%). Magnetic grains of taenite and kamacite (0.1-1.0 mm in diameter) are associated with specific magnetic coercivity of remanence for 6 significant magnetic anomalies and ranges from 3.6 to 7.4 mT.

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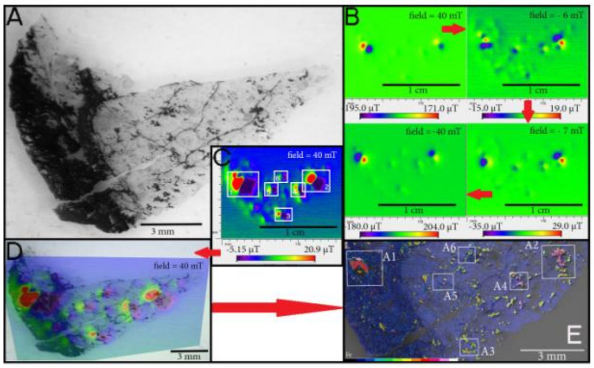

Figure 1: Overlap analysis of the optical transparent image with the magnetic scan image. A) An optical image of a thin section C01. B) Demagnetization of saturated sample (by left pointing 40 mT field) results in magnetic anomaly rotation (top right when –6 mT is used) and subsequent magnetization in opposing direction (field of -7 mT and -40 mT). Magnetic anomalies rotate. C) Smaller magnetic anomalies interact with the larger ones, we identified just 6 largest anomalies from the image magnetized by 40 mT. D) Juxtaposition of the scan obtained with the field of 40 mT with the optical image. E) Identification of the material composition under magnetic anomalies by Scanning Electron Microscope (SEM). The color range characterizes the concentration of Fe.