A THREE-DIMENSIONAL SURVEY OF METAL GRAIN SIZE DISTRIBUTIONS IN ORDINARY CHONDRITES: EFFECTS OF METAMORPHISM

N. V. Almeida[1,2], A. Krzesińska[1,3], C. L. Smith[1], H. Downes[1,2], S. S. Russell[1]. [1]Natural History Museum, London, UK. E-mail: n.almeida@nhm.ac.uk. [2]Birkbeck, University of London, UK, [3]IGS PAS, Wrocław, Poland

Introduction: Metal grains can be used as markers of the temperature-pressure-time path experienced by ordinary chondrites, due to their response to metamorphism and strain. Additionally, samples of low petrological type can provide insight into nebular sorting as they show the closest approximation of metal grain sizes when accreted, with the lowest effect of thermal or impact metamorphism [1]. The petrological scale for classifying ordinary chondrites is predominantly qualitative; however, quantitative textural parameters are increasingly being explored with the development of novel techniques and increasing computing power, e.g. [2]. Previous studies have focused on equilibration with regards to chemical composition but not texture, e.g. [3]. X-ray Computed Tomography (XCT) is a non-destructive technique that can provide three-dimensional data on unprepared fragments, thus removing sectioning bias. Additionally, the data lend themselves to quantitative analysis. XCT has previously been used to illustrate that both the number and the degree of preferred orientation of metal grains in ordinary chondrites increases with increasing shock metamorphism [4]. In this study, we investigated differences in metal grain sizes and size distributions across a selection of 17 H and 15 L chondrites of varying petrological type and shock stage, in order to determine which trends are linked to static or impact metamorphism.

Method: Samples were imaged using a Nikon HMXST225 scanner at the NHM, London, with a voltage of 170-190kV and current of 170-200μA. Sample masses ranged from 0.5-2.4g (140-620mm^3). Resolution of the data sets range from 5-9 μm/voxel. Data were thresholded to segment the metal phase before individual grains were separated and labelled. Grains smaller than 10 voxels in volume (equivalent to ~1250 μm^3) were discarded as noise. The data were then normalised by total metal content to give cumulative volume fraction curves, which highlight the proportion of grains in different size categories.

Results: To parameterise changes in metal grain size and size distribution between petrological types, we compared data for S1 and S2 chondrites and find that the data show metal grain coarsening with increasing degree of thermal metamorphism, but exhibit some complexities. For example, L chondrites do show an overall increase in metal grain size up to type 5, but there is a change towards smaller grains at type 6 (Holbrook). Furthermore, in H chondrites, there is a significant shift in the grain size distribution from type 3 to type 4 samples, characterised by a decrease in the fraction of smaller grains and a greater spread in the range of grain volumes, but, for petrological types 4-6, no regular trend is obvious. Type 3 chondrites show the smallest ranges of grain volume, which is spread from the limits of the technique resolution to a maximum of 1.5 mm^3. Hallingeberg (L3, S1) stands out from other L chondrites with the greatest number of grains, and the lowest maximum grain volume.

To compare between shock stages, we included chondrites of the same chemical class and petrological type only, and find no simple trend with increasing shock pressure. For example, H5 chondrites do not show any significant difference in metal grain size distribution between the S1 and S2 stages; however, we observe an abrupt change in the cumulative volume fraction curve between S2 and S3 samples, and an increase in the number of very small grains, which clearly reflects comminution of grains. With increasing shock stages, the data hint that a new fraction of coarse grains appears. An observed shift towards larger grain sizes between S3 and higher grades indicate that heating is a key driver, leading to melting and coalescence of grains, however, additional samples are required to further elucidate this trend. Unlike in H5 chondrites, we mainly observe a fairly linear size-fraction correlation in L5 samples of lower shock stages. We infer that the effects may be constrained to differences in mechanisms of processes or shock pulse duration.

Conclusions: For ordinary chondrites, the size distribution of metal grains can reflect whether the sample is texturally equilibrated or not. We can separate trends that relate to reaching textural equilibrium due to static metamorphism as well as the loss of equilibrium due to impact events and the onset of shock melting. It is not possible to predict or model the metal grain size distribution as there is clearly significant variation between meteorites of the same shock stage and petrological type. Other factors may influence the metal grain size distribution, for example, the duration of shock pulse, melting due to peak shock temperatures achieved or frictional melting, any subsequent post-shock annealing, and differences in rheology between H and L chondrites.

The results show that metal grain size distributions register the temperature-pressure-time path of the chondrite. Additionally, the results highlight the potential of XCT as an analytical technique, providing quantitative data that can be further interrogated for other applications.

References: [1] Kuebler K. E. et al. 1999. *Icarus*. 141:96-106. [2] Guignard J. and Toplis M. J. 2015. *Geochimica et Cosmochimica Acta.* 149:46–63. [3] Afiattalab F. and Wasson J. T. 1980. *Geochimica et Cosmochimica Acta.* 44:431-446. [4] Friedrich J. M., et al. 2008. *Earth and Planetary Science Letters*. 275:172-180.