ALMAHATA SITTA AND BRECCIATED UREILITES: INSIGHTS INTO THE HETEROGENEITY OF ASTEROIDS AND IMPLICATIONS FOR SAMPLE RETURN. A. J. Ross[1,2], J. S. Herrin[3], L. Alexander[1], H. Downes[1,2], C. L. Smith[2] and P. Jenniskens[4]. [1]Centre for Planetary Sciences, Joint UCL/Birkbeck Research School of Earth Sciences, London, UK (aidan.ross@ucl.ac.uk), [2]IARC, Department of Mineralogy, The Natural History Museum, London, UK, [3]NASA Johnson Space Center (ESCG), Houston, TX 77058, USA. [4]SETI Institute, CA, USA.

Introduction: Analysis of samples returned to terrestrial laboratories enables more precise measurements and a wider range of techniques to be utilized than can be achieved with either remote sensing or rover instruments. Furthermore, returning samples to Earth allows them to be stored and re-examined with future technology. Following the success of the Hayabusa mission, returning samples from asteroids should be a high priority for understanding of early solar system evolution, planetary formation and differentiation.

Meteorite falls provide us with materials and insight into asteroidal compositions. Almahata Sitta (AS) was the first meteorite fall from a tracked asteroid (2008 TC3) [1] providing a rare opportunity to compare direct geochemical observations with remote sensing data. Although AS is predominantly ureilitic, multiple chondritic fragments have been associated with this fall [2,3]. This is not unique, with chondritic fragments being found in many howardite samples (as described in a companion abstract [4]) and in brecciated ureilites, some of which are known to represent ureilitic regolith [5-7]. The heterogeneity of ureilite samples, which are thought to all originate from a single asteroidal ureilite parent body (UPB) [5], gives us information about both internal and external asteroidal variations. This has implications both for the planning of potential sample return missions and the interpretation of material returned to Earth. This abstract focuses on multiple fragments of two meteorites: Almahata Sitta (AS); and Dar al Gani (DaG) 1047 (a highly brecciated ureilite, likely representative of ureilite asteroidal regolith).

Ureilite fragment compositional heterogeneity: We have examined six unbrecciated ureilite fragments of Almahata Sitta. These have varying olivine core compositions between samples but little variation within a single fragment. Combining our data with that of [2] and [3] we find that the distribution of olivine Mg# in AS spans almost the entire range seen in all previous unbrecciated ureilites [5]. This means that the ~4m diameter asteroid from which AS originated encompasses the entire range of ureilite compositions represented in meteorite collections. Examination of DaG 1047 reveals that the entire range of ureilitic olivine compositions are present in a single cm-sized sample [8], agreeing with other ureilitic breccias [5,6].

Chondritic fragments in ureilites: Chondritic clast types previously recognized in ureilites include: ordinary chondrites, R-chondrites, E-chondrites and dark clasts that may represent carbonaceous chondrites [5,6]. We have identified multiple chondritic clasts of different types in DaG 1047. We classify a chondritic fragment associated with AS (#41) as an EH impact melt. The wide variety of chondritic fragments in ureilites contrasts with HED samples, where CM and CR chondrites are the most abundant impactors [4,9].

Asteroidal inferences: The asteroid from which Almahata Sitta originated (2008 TC3) has been determined to be a rubble-pile representing an aggregation of fragments from the UPB post-break-up [10]. Itokawa was the first confirmed rubble-pile asteroid [11] with several other small asteroids also thought to be rubble-piles. It is possible that these asteroids may share a similar history to AS [10], namely accretion and (some) differentiation followed by break-up (whether catastrophic as in the case of the UPB or through a series of small disruptions) and re-accretion to form rubble-piles incorporating foreign materials.

Implications for sample return: Given the high cost of sample return missions, it is vital to maximize the amount of data that can be extracted from samples. Whilst interior samples, such as those exposed at impact craters, may lead to more useful material for determination of asteroidal processes, sampling of regoliths can yield a wider range of compositions from less material. However, any returned regolith material would probably include exogenic contaminants, which would dilute the material from the target asteroid and complicate the interpretation of data. Hence there is a trade-off between sampling of a wider range of asteroidal material and keeping the samples returned free of unwanted impactor material. Sampling rubble-pile asteroids would enable access to a wider variety of accessible surface material then solid asteroids.

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