NEW OBSERVATIONS ON GRAIN BOUNDARY METAL IN UREILITIC FRAGMENTS OF ALMAHATA SITTA. Y. Aoyagi[1], T. Mikouchi[1], [2]C. A. Goodrich, [1]Dept. of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan (aoyagi@eps.s.u-tokyo.ac.jp), [2]Planet. Sci. Inst., Tucson, AZ 85719, USA.

Introduction: 2008 TC_3 is the first asteroid to be discovered before falling on the earth. It exploded at 37 km altitude and fell in the Nubian Desert of northern Sudan [1], where it was recovered as meteorite fragments and named Almahata Sitta.

Almahata Sitta was classified as a polymict ureilite and consists of cm-to-mm fragments of many different ureilitic lithologies, as well as various chondritic lithologies [2-3]. Ureilites are ultramafic achondrites mainly composed of olivine and low-Ca pyroxene, with accessory metal, sulfides and carbon phases.

Fe-Ni metal is a major component of meteorites formed under reducing condition, and is found in all types of ureilites. Metal in most Almahata Sitta ureilite fragments, as in other ureilites, exists as primary grain boundary metal, and also as secondary reduction metal (tiny metal particles in silicate rims formed by in situ reduction by carbon). Some grain boundary metals in Almahata Sitta ureilites show unique (i.e., not found in main group ureilites) textures both structurally and chemically [4-6]. Metals in sample #44 in particular, show more complex assemblages than in other Almahata Sitta fragments or typical ureilites [7], with various combinations of α-iron, γ-iron, Fe-carbide, Fe-phosphide and Fe-sulfide. These assemblages were interpreted to be products of shock re-melting of original assemblages having differing amounts of Fe + C, P, S, etc. [4-6].

We studied grain boundary metals in four more fragments of Almahata Sitta in order to look for features similar to those in #44, and/or other unique textures [4-6]. Results will contribute to a better understanding of the formation of metal in ureilites, and ureilite thermal histories. Almahata Sitta is an ideal sample for studying metal because the recovered fragments are fresh and essentially unweathered.

Samples and Analytical Methods: We prepared polished thin sections of Almahata Sitta ureilites #27, #44, #49 and #S138. After polishing with 1 μm diamond paste, samples were polished with colloidal silica to obtain better surface conditions. Metal grains were first observed by reflection microscopy. They were then analyzed by a scanning electron microscope (SEM) (Hitachi S-4500) with an energy-dispersive X-ray spectrometer (EDS) and electron backscattered diffraction (EBSD) detector. The EBSD was used to identify mineral phases by Kikuchi lines. The obtained Kikuchi patterns from EBSD were analyzed using software developed by [8]. We also performed quantitative analysis and elemental mapping of the metal grains by using an electron probe micro analyzer (EPMA) (JEOL JXA-8900L).

Results: All of the studied samples are typical coarse grained ureilites composed of olivine, pigeonite and accessory Fe-Ni metal, graphite, and troilite. The Fo values for each sample are: ~Fo 86 in #27, ~Fo 80 in #44 and #49, and ~Fo 84 in #S138, by EPMA. A survey of the grain boundary metal in these samples by reflection microscopy and elemental mapping revealed that some metals in #S138 are probably mixtures of various phases similar those in #44. No previous study has been done on the #S138 metals. Therefore, we investigated #S138 intensively. Based on chemical mapping, we confirmed that metals in #27 and #49 include Fe sulfide and phosphide at least.

Our new observations show that some metal grains in #S138 have contrast variations (in backscattered electron images, or BEI) and internal textures similar to those in #44 (Fig. 1). Small compositional differences were observed within metal grains by elemental mapping (Fig. 1). Based on identification by EBSD, the areas that are brighter in BEI correspond to α-iron (Fig. 2). However, slightly darker areas than the others among the brighter areas are observed and identified as γ-iron (Fig. 2) although the difference in BEI contrast between the two iron phases can hardly be seen. On the other hand, EBSD analysis in the darker areas showed patterns corresponding to either the iron-carbide, cohenite ($[Fe,Ni]_3C$) or the iron phosphide, schreibersite ($[Fe,Ni]_3P$) (Fig. 2). The BEI contrast between schreibersite and cohenite is not strong, but areas of schreibersite are easily distinguished in phosphorus elemental map (Fig. 1).

Discussion: In Almahata Sitta #44 [4-5] and #S138 the assemblage of α-iron and γ-iron (+ schreibersite), as well as the assemblage of α-iron, γ-iron and cohenite (+ schreibersite) were observed in metal grains. Metal in typical main group ureilites appears to be pure kamacite, and does not show coexisting α-iron and γ-iron [7]. Nor has cohenite ever been reported in grain boundary metal in main group ureilites. Therefore, we consider that local shock re-melting of different amounts of primary metal (kamacite, as in typical main group ureilites) + graphite + Fe phosphide (+ Fe sulfide) is responsible for the variety of cohenite + α-iron + γ-iron assemblages seen in #44 and #S138. Because the α-iron and γ-iron show no difference in Ni content, they may be martensite.

Future work: In order to study the nano-scale distribution of phases in these assemblages in greater detail we are planning sample preparation by FIB and observation by TEM. In addition, we will continue intensive observation of metal in #27 and #49 by SEM-EBSD. We will add fine-grained Almahata Sitta and other ureilite samples to our work as well.

References: [1] Jenniskens P. M. et al. (2009) *Natur, 458*, 485. [2] Bischoff A. et al. (2010) *MAPS 45*, 1638. [3] Zolensky M. et al. (2010) *MAPS 45*, 1618. [4] Goodrich C. A. et al. (2010) *73rd Ann. Met. Soc. Mtg*, #5319. [5] Mikouchi T. et al. (2011) *Antarct. Met., 34*, 49. [6] Ross A. J. et al. (2011) *LPS 42*, #2720. [7] Goodrich C. A. et al. (2012) *GCA, in press.* [8] Kogure T. (2003) *J. Crystal. Soc. Japan, 45*, 391-395.

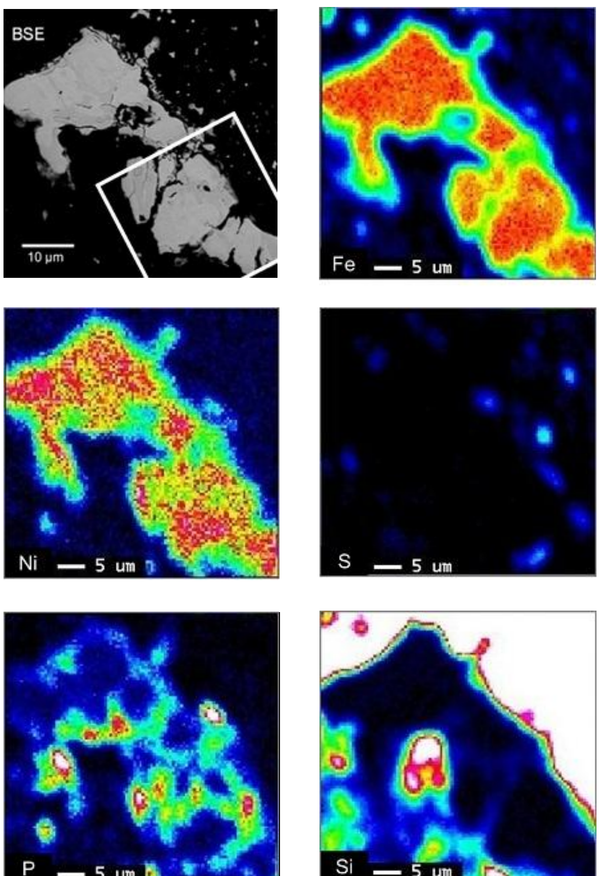

Fig. 1. BEI and X-ray mappings (Fe, Ni, S, P, Si) of one of the metals in Almahata Sitta #S138. BEI shows slight contrast. Although Fe concentration is almost homogeneous, Ni and Si show faint contrast compared to Fe. The map of P suggests a presence of Fe phosphide (red to white areas).

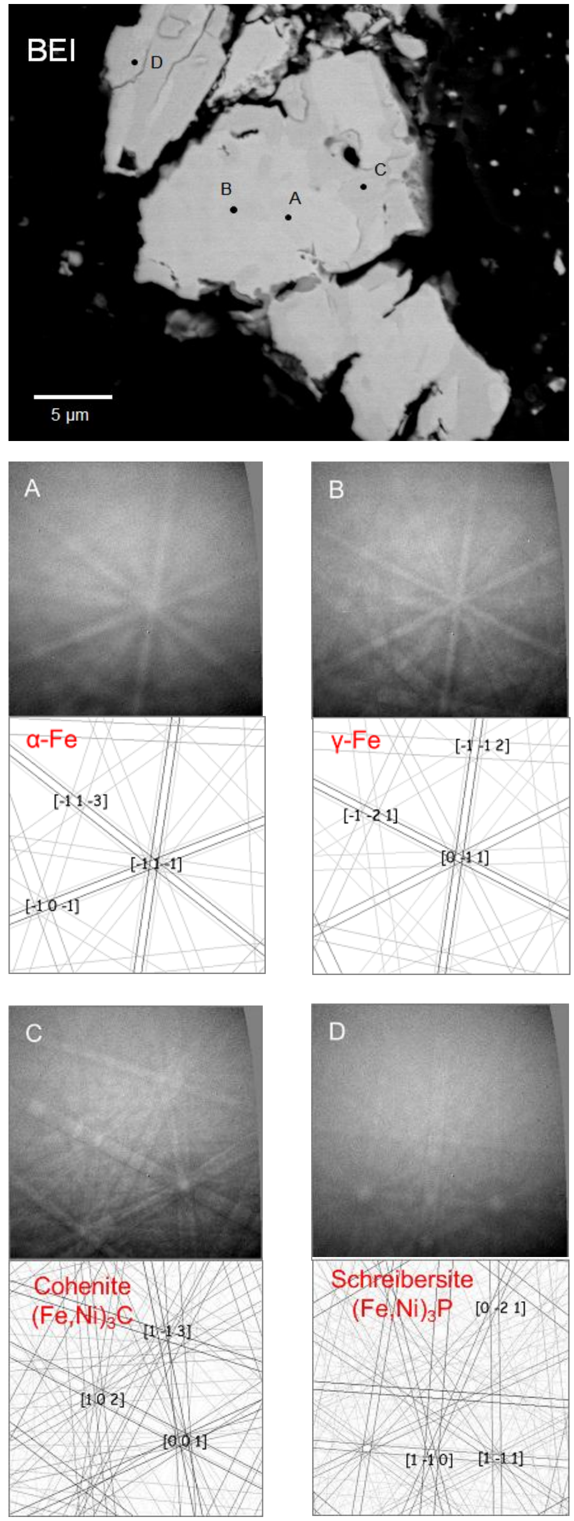

Fig. 2. Higher-magnification BEI of the outlined area of Fig. 1. The Kikuchi bands obtained from four spots (A,B,C and D in BEI) are shown. The calculated patterns (below of each obtained Kikuchi bands) indicate that A is α-iron, B is γ-iron, C is cohenite and D is schreibersite, respectively.