

Iron metal and its compounds in the Almahata Sitta and Antarctic ureilites. Y. Aoyagi¹, T. Mikouchi¹, C. A. Goodrich², and M. E. Zolensky³, ¹Dept. of Earth&Planet. Sci., University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, aoyagi@eps.s.u-tokyo.ac.jp, ²Planet. Sci. Inst., Tucson, AZ 85719, USA, ³NASA-JSC, Houston, TX 77058, USA.

Introduction:

Ureilites are ultramafic achondrites whose origin and history are still controversial. Ureilites are mainly composed of olivine, low-Ca pyroxene (pigeonite), Fe-Ni metal, Fe sulfides and carbon phases. Almahata Sitta (AS), having fallen on the earth in October 2008, was classified as a polymict ureilite and consists of cm-to-mm fragments of many different ureilitic lithologies with various chondritic lithologies [1,2].

Fe-Ni metal is one of the major components of ureilites. Metal in most AS ureilite fragments, as in other ureilites, exists as primary grain boundary metal, and also as secondary reduction metal at silicate rims. Some grain boundary metals in AS ureilites show unique textures, not found in main group ureilites [3,4]. In particular, metals in AS #44 show complex assemblages with various combinations of α -iron (*bcc*), γ -iron (*fcc*), cohenite ($[\text{Fe,Ni}]_3\text{C}$) and schreibersite ($[\text{Fe,Ni}]_3\text{P}$).

We continued to observe grain boundary metals in more AS fragments in order to look for features resembling those in #44. Consequently, we discovered metal grains in other AS samples, showing complex assemblages similar to #44 [5,6].

Because those mineral assemblages have not been reported in other ureilites [3-7], it is of great interest whether such assemblages are really absent in other ureilites. If it is the case, the formation event of such assemblages only occurred in the AS parent body. In order to better understand the formation and thermal history of AS metal together with the formation of ureilite parent body (UPB) in general, we observed several Japanese Antarctic ureilites to search similar assemblages composed of Fe metal and its compounds.

Samples and Analytical Methods:

We studied five thin sections of Japanese Antarctic ureilites (MET78008, Y-792663, Y-82100, Y980851, Y981810) because their degrees of terrestrial weathering are weaker than other samples and metal grains are fresh and unoxidized. Y-792663 is fine-grained, and the others are coarse-grained samples. Their metal grains were analyzed by FEG-SEM (Hitachi S-4500) with EDS and electron backscattered diffraction (EBSD) detectors. To identify mineral phase in metal assemblages, we used EBSD to obtain Kikuchi patterns and analyzed them by using a software developed by [8]. We also performed quantitative analysis and elemental mapping of the metal grains by using EPMA (JEOL JXA-8900L and JXA-8530F).

Results:

A survey of the grain boundary metals in AS ureilites by SEM and elemental mapping revealed that some metals in these samples contain mixtures of various phases similar to those in #44. Especially, in AS #44, #S138 and H1, complex textures and clear contrast variations in BEI and remarkable compositional differences in elemental mapping were observed within some metal grains (Fig. 1).

Based on identification by EBSD, the brighter areas in BEI correspond to α -iron while the darker areas correspond to γ -iron (Fig. 2) although both phases have low-Ni compositions corresponding to "kamacite". In H1, intergrowths of lathy α -iron and interstitial γ -iron areas are obviously seen (Fig. 3). The compositional difference between the two iron phases can hardly be seen as those in other samples. In addition, EBSD analysis in the darkest areas within metal grain revealed that they had patterns different from those of γ -iron and they are either cohenite or schreibersite (Fig. 2). The BEI contrast among γ -iron, cohenite and schreibersite is not strong, but each area is easily distinguished in carbon and phosphorus elemental maps (Fig. 1). Besides, cohenite is present as euhedral crystal while schreibersite is intergrown with other unknown phases.

In AS #27, #49 and MS#154, we also confirmed similar metal textures as well as in #44, #S138 and H1. However, iron and iron compound textures were not pronounced in these samples. Although there are varying degrees in this way, it is suggested that characteristic iron phase assemblages can be seen generally in all AS ureilites.

In Japanese Antarctic ureilites, such unusual metal textures were not common as they are rare in AS #27, #49 and MS#154. Fe carbide was discovered only in a few grains in MET78008, Y82100 and Y980851 (Fig. 4). Also, based on chemical mapping, we found metals surrounded by Fe phosphide. The grains showing contrast in BEI despite homogeneity of Fe composition with low-Ni compositions were observed. This contrast may be derived from coexistence of α -iron and γ -iron, which we are going to characterize in future analysis.

Discussions and Conclusions:

Most metal grains in main group ureilites appear to be pure kamacite, and do not usually show coexisting α -iron and γ -iron as they are remarkable in some AS ureilites [9]. The coexistence of these two iron phases in AS metals suggests a more complex history that did not occur in other ureilites, involving shock-reheating. By shock, metal grains were

reheated till stable temperature of γ -iron and then they were quenched to crystallize lathy α -iron upon cooling. Because cooling was rapid and the presence of C enhanced the γ -iron stability [7], a part of γ -iron areas remained in interstitial areas. Rapid cooling is consistent with the ureilite thermal history.

In AS ureilites, the assemblage of α -iron, γ -iron, cohenite and schreibersite was observed in metal grains. In #44, the assemblage of α -iron and γ -iron (without cohenite and with/without schreibersite) was also found [3,4]. As for other AS samples, the proportions and combinations of iron and iron compound were variable. In a few Japanese Antarctic ureilites, we found Fe carbide existing within the metal grain or Fe-phosphide enclosing around the metal grain. Further, iron compounds are distributed throughout the grain, or distributed to only a portion of the grain. Therefore, we consider that local shock re-melting of different amounts of primary metal and surrounding materials (graphite, Fe phosphide and other Fe compounds) is responsible for the variation of mineral assemblages seen in those ureilites.

These mineral assemblages tend to be less found in elongated metal grains and more in large rounded metal grains. This is probably because elongated metal has no gap between silicates, namely, there is no material which could be mixed with metal. On the other hand, there was enough space for rounded

metal to be mixed with materials existing around them.

As already mentioned, the iron carbides and phosphides were found in a small part of the Japanese Antarctic ureilites. That is, more or less, it is indicated that distinct metal textures are seen in all ureilites as well as AS ureilites. Consequently, local remelting of metal which produced iron compounds may have happened on the UPB.

Fine-grained ureilites are believed to be highly shocked and their silicates show mosaiced textures. From the fact that these metal textures are seen in both coarse-grained and fine-grained ureilites, the event that shocked the silicates and the event that shocked the metal may be separate.

References:

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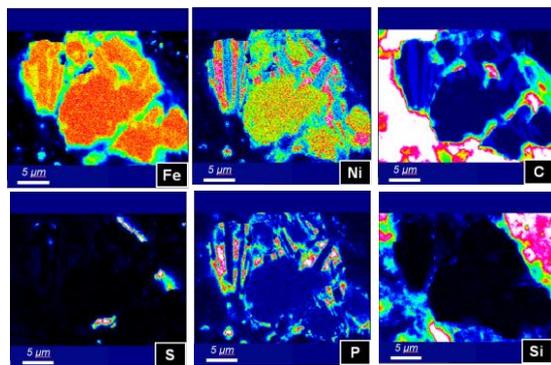


Fig. 2. The Kikuchi bands obtained from four spots (A,B,C and D in BEI of Fig. 1). The calculated patterns (below of each obtained Kikuchi bands) indicate that A is α -iron, B is γ -iron, C is cohenite and D is schreibersite, respectively.

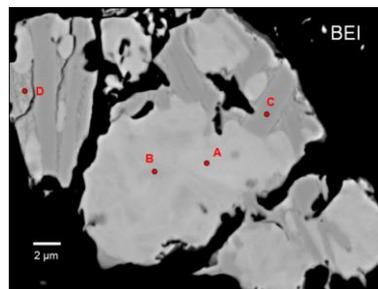


Fig. 1. X-ray mappings (Fe, Ni, C, S, P, Si) and BEI of one of the metals in AS #S138. BEI shows clear contrast. High C and high P areas are cohenite and schreibersite, respectively.

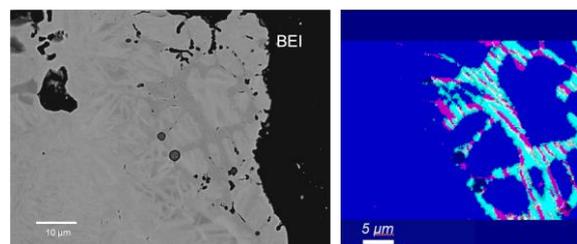
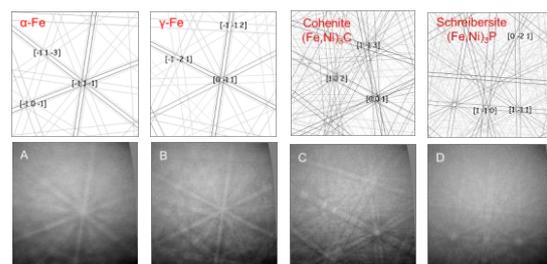


Fig. 3. BEI and combined elements X-ray map (Red=C, Green=P, Blue=Fe, Right blue=Fe+P, Violet=Fe+C) of AS H1. Intergrowths of lathy α -iron and interstitial γ -iron are obvious. Schreibersite exists among cohenite.

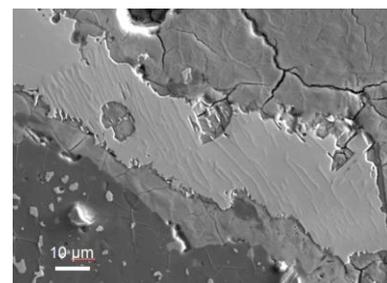


Fig. 4. SEI of Y980851. The relief areas correspond to Fe carbides (probably cohenite).