Relationship between winonaites and IAB irons, and among IAB irons inferred from metal composition and partial melting model calculation. Y. Hidaka[1], M. K. Haba[2], A. Yamaguchi[2, 3] and V. Debaille[1] [1]Laboratoire G-Time, Université Libre de Bruxelles, Brussels, Belgium, [2]National Institute of Polar Research, Tachikawa, Tokyo, Japan, [3]Department of Polar Science, School of Multidisciplinary Science, Graduate University for Advanced Sciences, Tachikawa, Tokyo, Japan.

Introduction:

Winonaites are a group of primitive achondrites that are defined as the partial melting residues of asteroids. Winonaites are thought to share the same parent body with IAB irons, because they have the same O-isotope composition [1], and similar mineralogy and mineral compositions of silicates [2].

In this study, we have performed in-situ chemical compositional analyses of metal grains in primitive achondrites including some winonaites. From the results of these analyses, we found some relationships between winonaite and IAB irons, and among IAB iron subgroups.

Samples and analysis:

We examined thick sections of Y-8005,51-4 and A 10077,51-1 optically and with an electron microprobe (JXA 8200) at National Institute of Polar Research, Tokyo (NIPR). We have determined chalcophile and siderophile element (Fe, Co, Ni, Cu, Ga, Ge, Mo, Ru, Rh, Pd, W, Re, Os, Ir, Pt and Au) abundances of metal grains in winonaites Y-8005 and A 10077 by LA-ICP-MS using a CETAC LSX-213 couple to a Thermo Element XR) at NIPR. Measurements were performed by spot analysis with 100 μm diameter beam and 10 Hz flash rate for Fe,Ni metal phase. Hoba (IVB) (USNM 1334) and North Chile (IIAB) (USNM 1334), and NIST SRM 663 iron meteorites were used as standard reference materials.

Results:

Metal grains in Y-8005 and A 10077 are very large (>5 mm) and enclose many silicate grains. Dominant metallic phase of Y-8005 is kamacite, but that of A 10077 is taenite. Highly siderophile element (HSE; Os, Re, Ir, Pt, Ru and Rh) and W abundances of Y-8005 is nearly chondritic. On the other hand, HSE, W, Ge and Ga abundances of A 10077 are severely depleted (~0.1 in $(X/Ni)_{CI}$ (where $(X/Ni)_{CI}$ is the ratio of each element to Ni in the meteorite, normalized to that of CI)). Chemical compositions of each winonaite metal grain are homogeneous across the thick sections.

Discussion:

In Fig. 1 comparing our winonaite data with literature data of IAB irons [3] in a Ge/Ni-Au/Ni diagram, Y-8005 metals are plotted in the field of IAB-sLL and A 10077 metals are plotted within error in the field of IAB-sLM. Y-8005 is largely composed of very small grain size of silicates [4] and its metal retains nearly chondritic composition, although having very large grain size. These facts indicate that Y-8005 could retain the signature of precursor chondritic materials of IAB-winonaite parent body. If so, IAB-sLL metal can be interpreted as being representative of the primitive metal of the IAB-winonaite parent body rather than IAB-MG metal. On the other hand, we suggest that A 10077 should be reclassified from winonaite to IAB-sLM on the basis of its metal composition and very high (≈50 vol%) abundance of metals [5] in this meteorite.

In order to test the relationship between the different IAB subgroups represented by our 2 winonaites, we performed model calculation of Fe-Ni-S system metallic partial melting with partition coefficient data from [6, 7]. In this calculation, we use the average composition of IAB-sLL as the starting material on the basis of the assumption above and with various S content (20-31 wt%) in the metallic melt. Figure 2 shows chemical compositions of A 10077 metal, IAB irons, and model calculation results of Fe-Ni-S system melting with 20 wt% S and 31 wt% S (eutectic). IAB-MG shows similar trend for Ir vs. Au to 20 wt% S partial melt residue, but is slightly off the model line (Fig. 2a). In Fig. 2b, IAB-MG shows consistency with 20 wt% S partial melt residue for Ge vs. Au, but no compositional trend between Cu and Au is observed (Fig. 2c). It is still unclear if IAB-MG is the partial melting residue of IAB-sLL and/or winonaite metals, but this is a possibility.

Concerning IAB-sLM and A 10077, they are similar to the partial melt liquid curves for both 31 wt% S and 20 wt% S (Fig. 2a, Ir vs. Au). In Fig. 2b (Ge vs. Au) and 2c (Cu vs. Au), IAB-sLM show similar compositional trend to those of 20 wt% S partial melt liquid, but have significantly lower Ge abundance in Fig. 2b and clusters in low Cu region in Fig. 2c. It also seems that IAB-sLH are an extension of IAB-sLM and A 10077 group. In Fig. 2a, IAB-sLM chemical compositions show a large variation range, but more than half of them plot on low Ir abundance field (Ir <0.2 ppm), corresponding to <50 % partial melting. The lowest Ir content member corresponds to <1 % partial melting. On the other hand, Ge and Cu abundances of IAB-sLM do not correspond to this range (<1 to 50 % partial melting). We interpret this inconsistency as being related to evaporative loss of volatile siderophile and chalcophile elements including Ge and Cu. There are two possibilities to explain the evaporative loss of volatile elements. The first one is impact-induced melting and the second one is degassing from parent magma. According to discussion in [8], 20 wt% S contents in metallic partial melt could be produced at around 1300 ºC. This high melting temperature, low degree of partial melting and evaporative loss of volatile elements could support impact melting hypothesis. However, we do not have any solid evidences of shock metamorphism in IAB irons and A 10077. On the other hand, evaporative loss of volatile siderophile and chalcophile elements could also occur by simple degassing process from shallow magmas to the surface [9].

From this study, we cannot conclude on melting process nature of IAB-winonaite parent body, but can suggest that IAB-sLL was actually the primitive metal of IAB-winonaite parent body, while IAB-sLM and possibly IAB-MG, IAB-sLH could represent partial melting products of IAB-sLL. It seems also that the present-day concentration of volatile chalcophiles element is a combination between partial melting process and evaporative loss

References:

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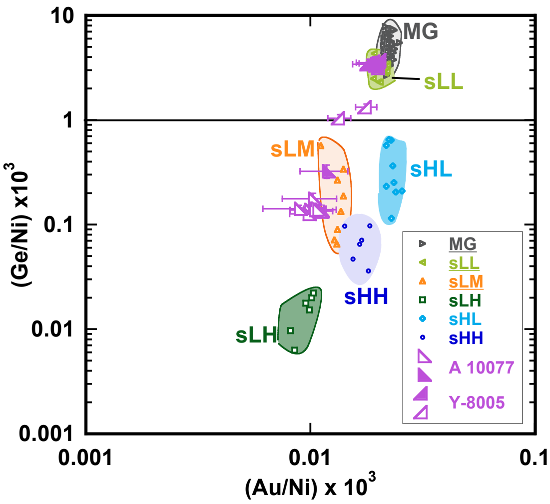

Fig. 1. Ge/Ni-Au/Ni diagram of winonaite metals and IAB irons. IAB iron data are from [3] and sorted according to classification scheme of [3]. MG = IAB main group, sLL = subgroup low Au, low Ni, sLM = subgroup low Au, medium Ni, sLH = subgroup low Au, high Ni, sHL = subgroup high Au, low Ni and sHH = subgroup high Au, high Ni. Filled symbols of winonaite metals indicate kamacite, open symbols of them indicate taenite.

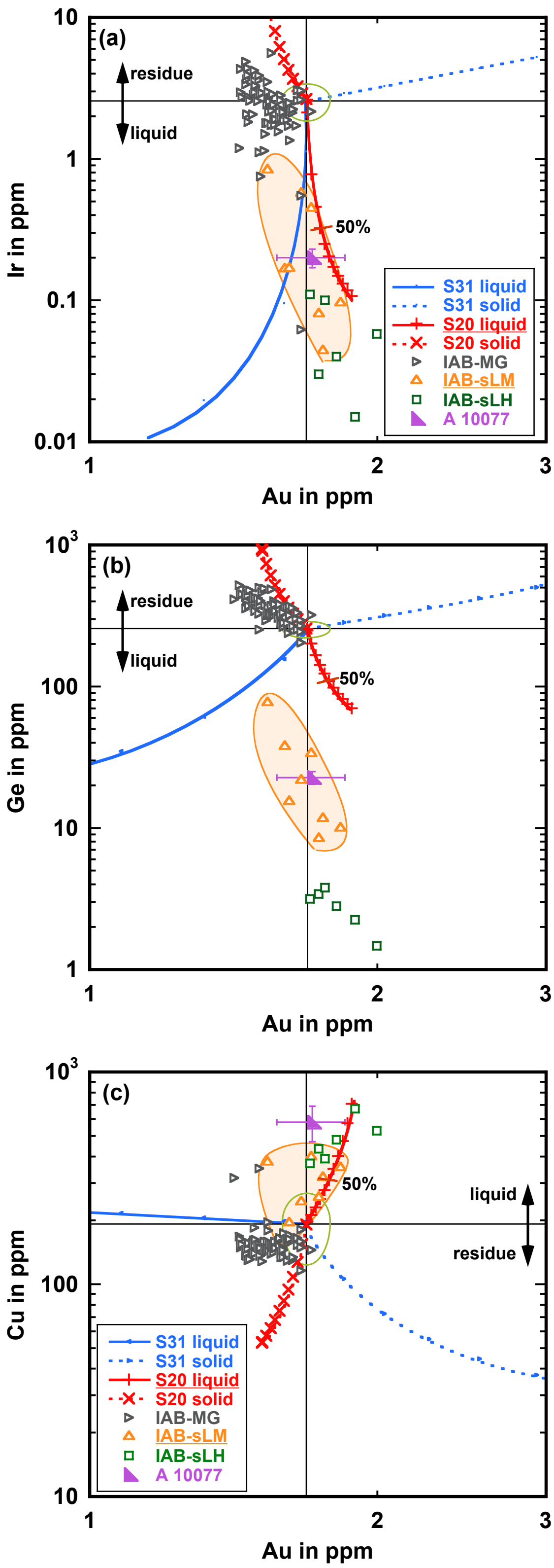

Fig. 2. Element-Au diagrams with A 10077 taenite, IAB-sLM and model calculation results of Fe-Ni-S system partial melting. (a) is Ge-Au, (b) is Cu-Au and (c) is Ir-Au diagram. An ellipse shows compositional range of IAB-sLL. Regression lines show chemical compositional trends of metallic liquids and residual solids depending on S content in metallic liquid.