Cooling rates of mesosiderites at intermediate temperatures. N. Sugiura[1] and M. Kimura[2], [1]Department of Earth Planetary Science, Univ. of Tokyo, Japan, [2] Faculty of Science, Ibaraki University, Japan.

Introduction:

Mesosiderites were reheated after the mixing of silicates and metal. The heat source is not known. The cooling after the reheating at high temperatures as recorded by silicates was rapid suggesting that they resided in the regolith layer near the surface of the parent body. Cooling at lower temperatures (~400 C) as recorded by metal is considered to be very slow [1]. Taenite and schreibersite form at intermediate temperatures (from 700 C to 400 C). Thus, they may elucidate the relationship between the high and low temperature cooling rates. Here, we report morphological and compositional features of taenite and schreibersite. We note that such a study has not been made on mesosiderites though comprehensive studies have been made on iron meteorites [2].

Experimental:

Mesosiderite samples included in this study are Dong Ujimqin Qi (A1), Vaca Muerta (A1), NWA 2924, Estherville (A3/4), NWA 1878, ALH 77219 (B1), Crab Orchard (A1), NWA 1242 (A2) and Asuka 882023. NWA 1878 is a primitive mesosiderite for which we classified B0 [3]. Polished sections were observed and phosphide compositions were measured with a SEM/EDS. Modal abundances of metal, phosphide and phosphate were estimated based on EPMA mapping for five mesosiderites (NWA 2924, Estherville, NWA 1878, ALH 77219 and NWA1242).

Taenite morphology:

Four types of taenite occurrence are recognized. (1) Comb structure taenite is similar to those in iron meteorites, suggesting relatively rapid cooling below ~700 C. This is observed in large metal grains in Dong Ujimqin Qi and Vaca Muerta. (2) Elongated taenite is often observed in NWA 2924 and Estherville (Fig.1). We suggest that this taenite formed by somewhat slower cooling than the comb taenite. (3) Isolated taenite in silicate-rich area is often observed in NWA 1878, ALH 77219, Crab Orchard and NWA 1242. We think that this is related to phosphide/phosphate reaction which produces excess metallic Fe during cooling. (4) Tiny taenite is often observed on metal grains in NWA 1878, ALH 77219 and Asuka 882023. This is formed by the Agrell effect.

Schreibersite morphology:

Three types of schreibersite occurrence are recognized. (1) Isolated schreibersite is observed in kamacite. This is rather rare and limited to schreibersite-rich mesosiderites. (2) Schreibersite is found close to but not in contact with taenite (Fig.2). The gap between the two phases is filled with kamacite. This is observed in Dong Ujimqin Qi, Vaca Muerta, NWA 2924 and Estherville. In some cases where taenite and schreibersite are very close to each other, the edge of taenite is depleted in Ni. This taenite composition and the schreibersite/taenite morphology suggest that nickel in schreibersite was derived from taenite. We note that there was a lot of P in kamacite at ~800 K which has to form schreibersite at lower temperatures [2]. (3) Schreibersite is in direct contact with taenite, showing appearance as if it replaced taenite (Fig.3). This is observed in NWA 1878, ALH 77219, Crab Orchard, NWA 1242 and Asuka 882023. Schreibersite grains of this occurrence are generally smaller than those of the previous category. We suggest that those with morphology (2) cooled faster than those with morphology (3).

Schreibersite composition:

Nickel concentrations in schreibersite are known to increase with a decrease in temperature [4]. Because P diffusion in schreibersite is not very fast, Ni concentrations at the center of schreibersite grains should be dependent on grain sizes and cooling rates. Therefore, we measured Ni/Fe ratios as a function of grain size (Fig.4). As expected, Ni/Fe ratios at the center of grains decrease with an increase in grain size. In addition, mesosiderites with the schreibersite morphology (2) shown by solid symbols tend to have lower Ni/Fe ratios compared with those of the morphology (3) shown by open symbols, suggesting that the former cooled faster than the latter.

Modal abundances of metal, phosphide and phosphate:

Modal abundances of phosphide and phosphate are plotted against metal abundances (Fig.5). Weathering might have somewhat affected metal abundances in ALH 77219, NWA 1242 and NWA 2924. Igneous phosphate abundances are negligibly small compared with the phosphate produced during reheating. The variation of the phosphide/phosphate ratios is noticeable.

Discussion:

Taenite morphology suggests that there may be slight differences in cooling rates at intermediate temperatures. Schreibersite morphology and central nickel concentrations confirm this. We suggest that Dong Ujimqin Qi, Vaca Muerta, NWA 2924 and Estherville cooled faster than NWA 1878, ALH 77219, Crab Orchard, NWA 1242 and Asuka 882023.

Ratios of modal abundances of phosphide to phosphate (Fig.5) are explained by a metal grain-size effect. Although defining a typical metal size is difficult, it is ~ 5 mm and ~1 mm for Estherville and NWA 2924, respectively. It is much less than 1 mm for the remaining three mesosiderites. If the metal grain sizes reflect the peak reheating temperatures (as suggested by the small metal size in NWA 1878 which is the most primitive mesosiderite), there may be an interesting relationship: the higher the peak reheating temperatures, the faster the cooling rates.

At present we are checking if this relationship holds for all mesosiderites and if there are other (better) explanations for our observations.

References:

[1] Goldstein J.I., et al. (2009) *Chemie der Erde 69*, 293-325. [2] Clarke R.S. Jr. and Goldstein J.I. (1978) *Smithsonian Contri. Earth Sci.* No.21. [3] Sugiura N. et al., (2013) *Meteorit. Planet. Sci., 48,* 5093.pdf. [4] Doan A.S. Jr. and Goldstein J.I. (1970) *Metall. Trans. 1,* 1759-1767.

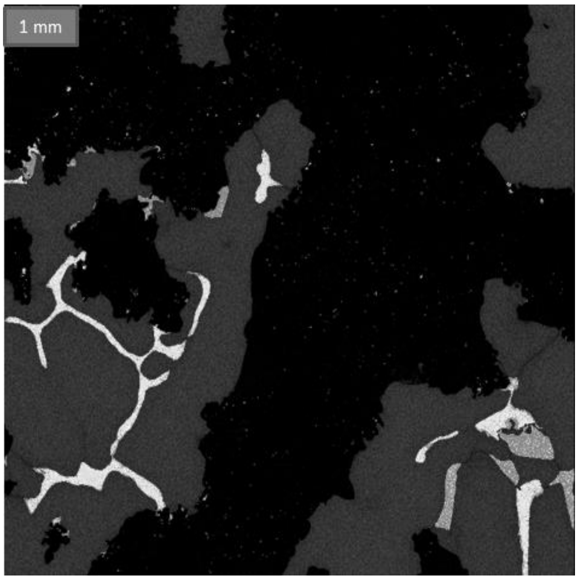

Fig.1 Elongated taenite (white) in Estherville. Grey is schreibersite, dark grey is kamacite and black is silicates. Note that schreibersite is not in contact with taenite as shown in more detail in Fig.2.

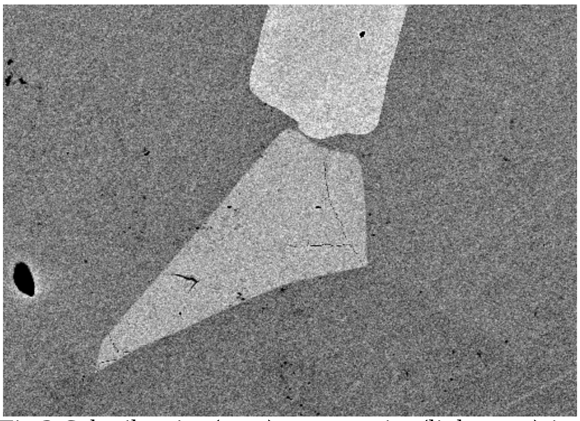

Fig.2 Schreibersite (grey) near taenite (light grey) in NWA 2924. Background is kamacite. Note that schreibersite is not in direct contact with taenite. Field of view is 360 µm wide.

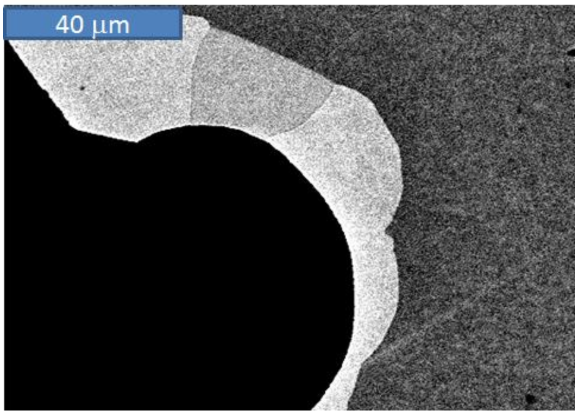

Fig.3 Schreibersite (grey) in contact with taenite (light grey) in Asuka 882023. Dark grey is kamacite and black is silicates.

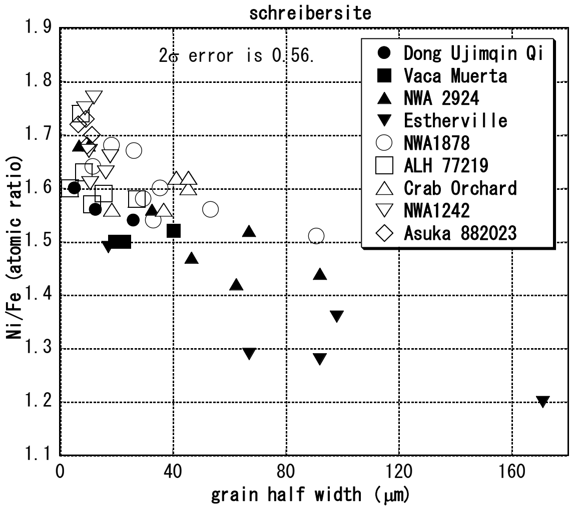

Fig.4 Central Ni/Fe ratios plotted against grain half width. Mesosiderites with the schreibersite morphology (2) are plotted with solid symbols whereas those with the morphology (3) are plotted with open symbols.

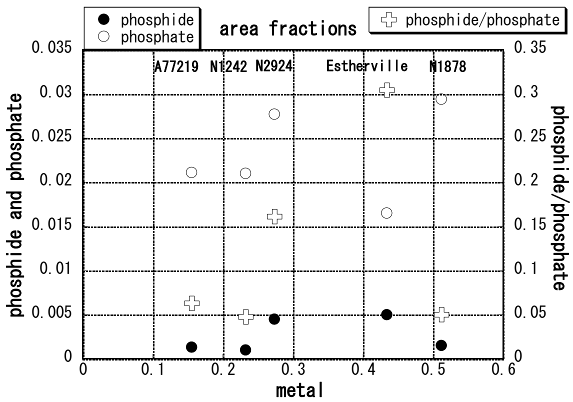

Fig.5 Modal abundances of phosphide and phosphate are plotted against the metal abundance for 5 mesosiderites. Phosphide/phosphate ratios are also shown.