# Volatile loss from mesosiderites

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## Introduction

Silicate parts of mesosiderites are generally similar to those in eucrites. Eucrites generally contain both apatite and merrillite. In contrast, mesosiderites (type A and B) are mostly devoid of apatite. (Rarely, apatite exists in central parts of large clasts of some mesosiderites (Kimura+, 1991)). Therefore, if the type A and B mesosiderites formed by mixing of metal and eucrite-like materials, apatite, which is the main carrier of volatiles, must have been lost from such mesosiderites. Here, we describe phosphates (merrillite and apatite) in mesosiderites (type A, B and C) and discuss if and how volatile was lost from mesosiderites. We also show textures of vesicular pyroxenes in some mesosiderites which may be a smoking gun evidence of a volatile loss process.

## Samples and experimental procedure

Seventeen mesosiderites, Vaca Muerta(A1), Crab Orchard(A1), Mount Padbury(A1), NWA1242(A2), Asuka882023(A2/3), Estherville (A3/4), NWA2924(A), NWA1878(B0), ALHA77219(B1), Dong Ujimquin Qi(B1), Bondoc(B4), , NWA1827(C), NWA1951(C), NWA8234(C2), Asuka881154, Asuka84106 and NWA4747 were examined. The sizes of the polished sections are typically 1 inch, and the sizes of included pebbles are typically less than 5 mm. Petrographic observations were made with a scanning electron microscope (JSM6510). It was operated at 20kV/1nA. Quantitative chemical analyses were made by nominal EDS without standards with a count time of ~100 seconds. H and REE were not included and the results were normalized to 100%.

## Apatite

We could not find apatite in the type A and B mesosiderites. This is not unexpected because pebble sizes in our specimens are small. All three type C mesosiderites contain fluorapatite (Fig.1). They are large (~500 μm in long dimension) and unevenly distributed. For instance, in NWA1951, all apatite (~5 grains) exists in a small area (~4% of the whole section). Apatite and merrillite do not coexist. This is curious because disintegration of apatite would have produced merrillite. It is also noted that apatite is often associated with metal grains. This is unexpected unless apatite was produced from merrillite.

## Merrillite

All the merrillites contain less Na than the stoichiometric proportion. This is consistent with the report by Ward (2017). Within each type A and B mesosiderite, merrillite compositions are nearly homogeneous with respect to Na. But the Na concentrations vary significantly (from 0.35 to 0.85 mol.%) among these mesosiderites. Estherville (A3/4) contains the highest Na. NWA1878(B0) contains the second lowest Na. It appears that Na contents depends on the degree of reheating. The lowest Na is observed in Dong Ujimquin Qi which contains the highest amount of merrillite among the present mesosiderites. Therefore, the low Na content is explained by dilution effect.

In contrast to type A and B, merrillites in type C show Na concentration variation within a mesosiderite. For instance, Na contents in merrillites in NWA 1827 range from 0.45 to 0.85 mol.%. As shown above, type C mesosiderites contain apatite, and apatite disintegration could result in merrillite with low Na. Therefore, the low Na merrillite in a type C is considered to be newly produced merrillite by disintegration of apatite. High Na merrillite in the same mesosiderite is considered as seasoned one that experienced many reheating events. (As explained in Sugiura+(2017), mesosiderites were reheated multiple times.)

In summary, intra/inter mesosiderite variation in Na contents is significant and meaningful. Na partition among plagioclase, silicate melt and merrillite is the underlying cause of the variation. But the actual Na distribution is controlled by kinetics (diffusion), and disintegration of apatite produces low-Na merrillite.

## Vesicular pyroxene

Vesicular pyroxenes are found in several mesosiderites, including three type C (Fig.2), NWA1242(A2), Estherville(A/3/4) and ALHA77219(B1). The vesicle sizes range from 10 to more than 100 micrometers. They seem to be produced from olivine because (1) in some cases, remnant olivine exists next to the vesicular pyroxene, and (2) they show chromite necklace which is well known to be produced around olivine in mesosiderites. Since the most conspicuous vesicular pyroxenes are observed in type C mesosiderites, and since vesicles were probably made of volatile-rich gases, we consider that the vesicular pyroxenes were produced by a reaction of olivine and halogens. If this is true, then one expects that silica, which is a non-negligible constituent in most mesosiderites, should also have reacted with halogens. Three type C mesosiderites in this study contain little silica minerals. (Also, most type C mesosiderites in the meteoritical bulletin database appear to contain little silica minerals.) This was a puzzle because abundant silica minerals should be produced by the reaction that produced merrillites

(Harlow+, 1982). Therefore, the near absence of silica in type C mesosiderites may have resulted from a reaction of silica with halogens, and may be considered as supporting evidence for the formation of vesicular pyroxene via olivine and halogen reactions. (Note that if abundant olivine existed initially, the absence of silica may be explained that silica and olivine annihilated by reheating.)

Summary

Type C mesosiderites are quite distinct from type A and B mesosiderites, in that they contain large fluorapatite, contain merrillite with variable Na contents within a mesosiderite and contain abundant/conspicuous vesicular pyroxenes. They retained some volatiles though a siginificant amount of volatiles has been lost by reheating after mixing with metal. In the case of some type A and B mesosiderites, subtle volatile loss is suggested based on the presence of vesicular pyroxene. But either because of the low initial inventory, or because the loss occurred early in their history, the vestige is not easily recognized in most of type A and B mesosiderites.

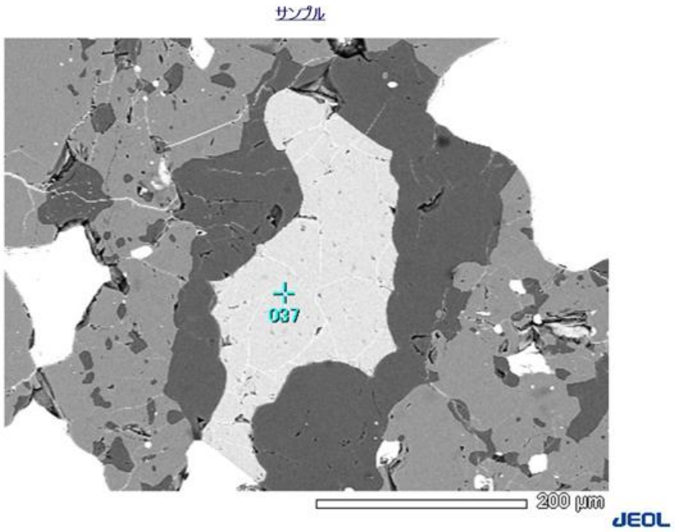


Figure 1. Backscattered electron image of NWA1951. A fluorapatite is at the cente (light grey). It is surrounded by plagioclase (dark grey). The apatite is attached to a metal (white) at the lower end. The rest (medium grey) is pyroxene.

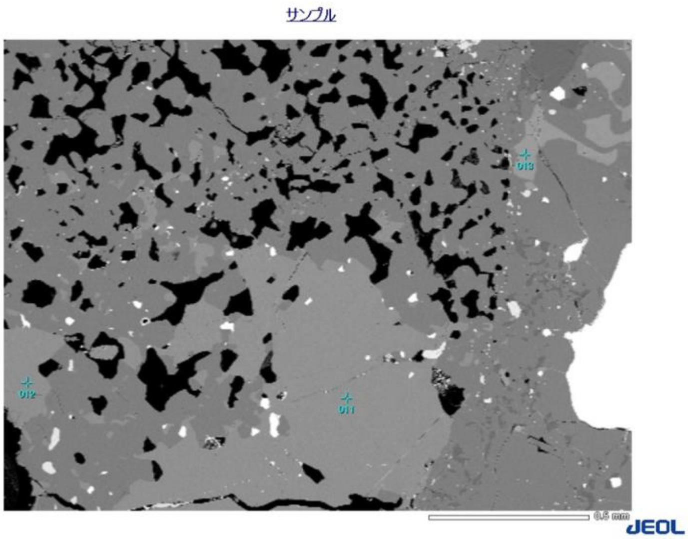


Figure 2. Backscattered electron image of NWA1827. Light grey grains in the lower half of the image is olivine. Darker grey is pyroxene. In the upper left area, pyroxene contains vesicles (black).Light grey, irregular-shaped grains in the upper right corner is merrillite.

**References**

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