THE FIRST MESOSIDERITE-LIKE CLAST IN A HOWARDITE. M. T. Rosing¹ and H. Haack², ¹Geological Museum, University of Copenhagen, Øster Voldgade 5-7, DK-1350 Copenhagen K, Denmark. E-mail: minik@savik.geomus.ku.dk, ²Geological Museum, University of Copenhagen, Øster Voldgade 5-7, DK-1350 Copenhagen K, Denmark. E-mail: hh@savik.geomus.ku.dk

**Introduction:** Mesosiderites and HEDs are two groups of meteorites with close affinities. Both groups plot on the same oxygen isotope fractionation line and breccias from the two groups include silicate fragments that are nearly identical in petrology. The most striking difference between the two groups of meteorites is the occurrence of approximately 50% metal in mesosiderites. Other features observed in mesosiderites but not in HEDs include the occurrence of some silicate inclusions that are reduced relative to the HEDs, and evidence of late recrystallization – possibly in connection with the introduction of molten metal. Mesosiderites are breccias composed of angular silicate fragments and metal. The silicate fragments in mesosiderites include howardite, eucrite, and diogenite like material. Howardites are breccias composed of eucritic and diogenitic fragments but so far no mesosiderite-like clasts have been reported in a howardite. This has been used as one of several arguments in favor of separate parent bodies for these two closely related groups of meteorites.

Here we report the discovery of the first mesosiderite-like clast observed in a Howardite.

**DaG 779** was found in Libya in September 2000. With a mass of 19 kg it is the second largest howardite ever found. We have studied a 670 g slice of the meteorite measuring 20 by 25 cm. Most of the slice displays a typical howardite texture with up to cm sized angular fragments of orthopyroxene and basalt embedded in a fine-grained matrix. Unique to this slice is a cm-sized metal rich fragment. Although small metal particles are common in howardites no other inclusions like the one reported here has ever been described in a howardite.

The **metal rich inclusion** includes metal domains with tetrataenite regions up to 20 μm across and tridymite – features that are otherwise only observed in mesosiderites. Minor metal fragments in the matrix outside the inclusion also include large areas of tetrataenite akin to mesosiderites.

We have studied the metal rich inclusion in order to constrain its petrogenesis and possible relationship to mesosiderites.

The metal-rich inclusion measures 10 by 15 mm and is exposed on only one side of the slice. The inclusion is composed of metal (30 – 40 %), coarse olivine fragments, anorthite, orthopyroxene, and minor chromite, tridymite, and troilite.

**Metal texture:** The metal is occurring as a network of mm-sized inter-connected patches. The larger patches of metal are composed of Ni-poor kamacite (~3 wt% Ni) and tetrataenite (~55 wt% Ni) (Fig. 1).

**Silicates in the iron-rich inclusion:** The silicate groundmass within the iron-rich inclusion consists of a heterogeneous assemblage of crystal fragments (Fig. 2), which are partially bounded by crystal faces and in part by irregular fractures. Olivine vary in composition within the range Mg# = 0.53-0.63 and orthopyroxene within the range Mg# = 0.61-0.77. The more iron-rich olivines in the range Mg# = 0.53-0.56 are partially pseudomorphed by domains of poikiloblastic orthopyroxene (Mg# ~ 0.65) with frequent troilite chadacrysts. The modal composition of the opx-troilite domains suggests that the Mg and silica densities are equal to that in adjoining olivine domains.

**Discussion:** The petrography of the metal-rich clast show evidence of some metasomatic reactions in its parent body. We suggest that the poikiloblastic orthopyroxene - troilite domains formed in response to partial sulfidation of the fayalite component of an olivine precursor, conserving Mg and SiO₂ and giving rise to a higher Mg# orthopyroxene and troilite. These replacement textures have only been observed within the metal-rich clast, and not in the howardite matrix, which suggests that the reaction must have taken place in response to a transient fluid phase prior to incorporation of the clast in the howardite matrix. The fluid phase was able to infiltrate along grain boundaries and fractures in the olivine crystals. Groundmass orthopyroxene and Mg-rich olivine were not sulfidized. This constrains the sulfur activity during reaction to have been lower than that defined by the reaction: olivine (Fo ~ 0.63 ) + S = troilite + orthopyroxene (En ~ 0.65 ) and higher than that defined by the reaction olivine (Fo ~ 0.55 ) + S = troilite + orthopyroxene (En ~ 0.65 ). The coexistence of tridymite and olivine and the lack of equilibration by Mg/Fe exchange between olivine and orthopyroxene suggests that the metasomatic event was shortlived and that the fluid phase had poor transport characteristics for Si, Mg and Fe. We suggest that the metasomatic event may have been caused by sulfur vapour. Although poorly constrained the shortlived nature of this process is consistent with evidence based on olivine coronas in mesosiderites that the metal-silicate mixture was rapidly cooled after the mixing.
event [1]. Similar textures have been observed in Emery [2] and Budulan [3].

Further, the presence of the iron-rich clast in the howardite matrix raises the question: How did it get there? The occurrence of a mesosiderite-like fragment in a howardite suggests a closer link between the two groups of meteorites. Alternatives are, as discussed below, that the entire meteorite is mis-classified or that the inclusion is an ejected fragment from the mesosiderite parent body.

**Misclassification?** DAG 779 may not be a howardite – it could be a howardite-like fragment from a mesosiderite. The brecciated nature of mesosiderites and HEDs and their many similarities raises the possibility that a fragment of a metal-free brecciated polygenic silicate clasts from a mesosiderite could be classified as a Howardite. Such clasts have been described in Mt Padbury [4]. If this is the case DAG 779 could come from the mesosiderite parent body - thus explaining the occurrence of a metal-rich inclusion. The presence of slowly cooled metal grains in Dhofar 007, which is classified as a eucrite, has also suggested a link to the mesosiderites [5].

**Ejection?** The fragment could have been ejected from the mesosiderite parent body and incorporated into the regolith on the HED parent body. The occurrence of chondritic fragments in howardites shows that material from other parent bodies was included in the HED regolith. It does, however, seem unlikely that the first discovery of a foreign mesosiderite clast is in a meteorite from the parent body with the closest ties to the mesosiderite parent body – but the possibility cannot be excluded. If the inclusion is an ejected fragment the existence of smaller fragments of mesosiderite parentage outside the metal-rich inclusion would require that the mesosiderite fragment was brecciated after or as it landed on the HED parent body.

**Same parent body?** Mesosiderites and HEDs could come from the same parent body. The many similarities between HEDs and mesosiderites and the possibility that they come from a common parent body have been discussed in a number of papers [6,7]. If the metal inclusion is indeed a fragment of the mesosiderite parent body and DAG 779 is not a misclassified howardite, one of the arguments in favor of separate parent bodies may no longer be valid.