

REHEATING OF THE MOUNT PADBURY MESOSIDERITE

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Introduction: Reheating after mixing of metal and silicates in mesosiderites is well known but the heat source is not well established. A brief summary on the subject as of early 2013 was given in [1]. Since then, a few progresses have been made. (1) A very primitive (experiencing least reheating) mesosiderite was found [2]. (2) Anti-correlation between the peak reheating temperatures and the following cooling rates was observed, suggesting a near-surface heat source [3]. (3) Cooling rates at intermediate temperatures were estimated from phosphide/phosphate abundance ratios and phosphide morphology [4]. They correlates with cooling rates at high temperatures recorded in silicates. In spite of recognizable variation among mesosiderites in cooling rates at high and intermediate temperatures, cooling rates at lower temperatures (below 400 °C) recorded by Fe-Ni grains are identical (very slow) for all mesosiderites. (4) The reheating age is estimated to be ~4530 Ma [5,6], which cannot be explained easily by conventional heating mechanisms. Here we report petrologic observations on Mount Padbury (MP) which is a sulfide-rich, phosphide-poor mesosiderite.

Sample description: MP is classified as A1 mesosiderite (primitive and plagioclase-rich). It contains ~7.5 wt. % FeS [7] which is significantly higher than the average for mesosiderites. FeS abundances in mesosiderites range from <1 wt. % to more than 10 wt. % [8]. The FeS in MP is not aggregated with the metal phase and is finely interlaced with the silicate mineral fragments [7].

Observations: The volume fraction of phosphide in MP is ~0.0002, which is the second lowest among 11 mesosiderites we studied. At face value this indicates slow cooling at high and intermediate temperatures. Phosphide in MP is in direct contact with taenite and the compositions are Ni-rich, indicating slow cooling [4]. Therefore, there is no doubt that MP cooled slowly. Quantitatively, however, the phosphide abundance in MP is much smaller than those in mesosiderites (e.g. ALH 77219 and Crab Orchard) which show comparable phosphide texture and compositions. Therefore, the low phosphide abundance in MP requires an explanation.

Discussion: FeS in MP probably formed by sulfidation of metallic Fe-Ni prior to the peak of the reheating event. The formation from Fe-Ni is inferred from the high Ni concentrations (11.9 wt. %, [7]) in the MP metal. The observation that FeS is not aggregated with the metal phase suggests that the peak reheating temperature was less than the Fe-FeS eutectic. The low abundance of phosphide suggests that the P activity was high in the temperature range where phosphates were formed (normally from 800 °C to 1100 °C, [9], but see below). (Alternatively, a very slow cooling rate in this temperature range could explain the phosphide paucity. But, as the A1 designation suggests, the MP petrology does not indicate excessively slow cooling.) The high P activity could be explained if the sulfidation had occurred before phosphate formation. Two explanations for the high P activity are possible. (1) Because of the sulfidation of metal, the remaining metal abundance is low, which causes high P concentrations (and activities) in the metal. But quantitatively this is a minor effect unless the activity is highly non-linear with the concentration. (2) Because of the high Ni in the metal due to sulfidation, taenite is stable at lower temperatures (<700 °C) than usual. Lower P solubility in taenite than in kamacite means that the P activity in MP was high during heating through ~700 °C, possibly producing phosphate efficiently. In a previous study [4] it was implicitly assumed that the reheating temperature was high enough to revert all pre-existing phosphate to P dissolved in metal at the peak reheating temperature and all observed phosphate in mesosiderites formed during cooling from the peak temperature. But, because MP is type A1, the peak reheating temperature could be low enough that a significant amount of phosphate could remain at the peak of reheating, conducting to the very low phosphide abundance after the reheating episode. This study suggests that the framework of phosphide-phosphate systematics is resilient and applicable to sulfur-rich mesosiderites.

References: [1] Sugiura N. (2013) LPS XXXIV, 1176.pdf. [2] Sugiura N. et al. (2013) Meteorit. Planet. Sci., 48, 5093.pdf. [3] Sugiura N. and Kimura M. (2015) LPS XXXVI, 1646.pdf. [4] Sugiura N. and Kimura M. (2014) NIPR 5th Symp. Polar Sci. [5] Haba M. et al., (2013) Min. Mag., 77(5) 1239. [6] Koike M. et al. (2013) NIPR 4th Symp. Polar Sci. [7] McCall G.J.H. (1966) Min. Mag., 35, 1029-1060. [8] Powell B.N. (1971) GCA, 33, 789-810. [9] Harlow G.E. et al. (1982) GCA, 46, 339-348.