MESOSIDERITES: (1) REEVALUATION OF COOLING RATES AND (2) EXPERIMENTAL RESULTS BEARING ON THE ORIGIN OF METAL. J. H. Jones, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721.

The mesosiderites are a complex suite of breccias composed of roughly equal portions of Fe-Ni metal and silicate lithic and mineral fragments [1]. Oxygen isotopic analyses of mesosiderites indicate a close relationship with eucrites, howardites and pallasites [2], but other aspects of mesosiderite genesis are not so well understood. (1) Cooling rate estimates based on petrographic criteria and variations in mineral chemistries range from 0.1°C/m.y. to 100°C/day [1]. Cooling rates based on fission track retention [5] are not precisely determinate but are clearly inconsistent with 0.1°C/m.y. metallographic cooling rates [3,4]. (2) The origin of mesosiderite metal is also uncertain. Powell [3,6] could never unambiguously state whether the metal was liquid or solid when mixed with the silicate material. Powell [6] favored mixing solid metal and silicate because the combination of slow cooling rates and high-temperature liquid metal should have produced more metamorphism (and/or anatexis) than he observed. Still, liquid metal appears to be the most straightforward means of explaining the high electrical conductivity (3-D metal connectivity).

It is important that these questions of metal origin and cooling rate be resolved. Recent proposals for the origin of mesosiderites include foundering of basaltic crust which rapidly sinks through a plastic or molten mantle [7]. This crust is then invaded by liquid metal at the core-mantle interface. With the mesosiderite now near the core-mantle boundary, cooling rates of 0.1°C/m.y. may be possible. Certainly, if this model is correct, the mesosiderites provide clues which are fundamental to the geology and tectonics of small planetoids. In the following sections, both (1) mesosiderite cooling rate data and (2) the origin of mesosiderite metal will be critically reviewed and some relevant experimental results will be presented.

COOLING RATES. It is clear that at low temperatures (500-300°C) the mesosiderites cooled slowly, but 0.1°C/m.y. is probably too low. Recent laboratory studies of Widmanstatten growth [8] suggest that conventional cooling rate estimates may be low by a factor of 10-20. This experimental correction is in the direction to make for better agreement with fission track cooling rates which require ≥ 1°C/m.y. to explain the observed track densities [5]. Even so, the environment indicated by this magnitude of cooling rate is unclear. Thermal models indicate that deep burial (50-100 km) on a fairly large (600 km diameter) planetoid is necessary to prevent liquid metal at the core-mantle interface. With the mesosiderite now near the core-mantle boundary, cooling rates of 0.1°C/m.y. may be possible. Certainly, if this model is correct, the mesosiderites provide clues which are fundamental to the geology and tectonics of small planetoids. In the following sections, both (1) mesosiderite cooling rate data and (2) the origin of mesosiderite metal will be critically reviewed and some relevant experimental results will be presented.

POLYMORPHIC RELATIONS. To date, petrographic observations of mesosiderite metal-silicate relations have proven inconclusive [1,3,6] as to metal origin. Although silicate mineral
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boundaries appear more rounded near metal contacts and metal filling of fractures is observed [1]. these textures could have been produced during high-temperature metamorphism. For example, metal-silicate contacts in ordinary chondrites are more rounded than angular but it is unlikely that chondrite metal was added as a liquid.

The critical observations appear to be: (1) that silicates remained largely unmelted and (2) that the metal forms a 3-D interconnecting network. Since there is some doubt as to whether silicates will remain unmelted in hot, liquid metal, an important question to answer is whether a 3-D network of iron metal could be produced under metamorphic (metal subsolidus) conditions. Accordingly, 1:1 mixtures (by weight) of sieved silicates (<10 mesh; olivine, pyroxene and basaltic fragments from a San Carlos ultramafic nodule and host basalt) and iron filings (<40 mesh; Fisher Scientific Company) were mixed, sealed in an evacuated quartz tube and placed in a furnace to simulate metamorphic conditions. Two rather different experiments were performed: (1) 1050°C for 10 days and (2) 850°C for 1 day. There was negligible sintering of the iron filings during the short experiment, but in the (1050°C, 10-day) experiment, significant sintering occurred. Although the (1050°C, 10-day) sample was still somewhat friable, low resistance (<1 ohm) was measured across a 6mm piece of the synthetic mesosiderite--the largest fragment recovered--indicating a 3-D connecting network of metal on a >0.5 cm scale. This result demonstrates that a 3-D metal network can be formed at (or below) the temperatures inferred for mesosiderite metamorphism [19] and on a shorter time scale than necessary--even if cooling rates were as rapid as 1°C/day.

Conversely the slow (~2°C/yr) high-temperature cooling rates inferred from the pyroxene diffusion profiles appear to present a problem for models which postulate that the metal was added as a liquid. The average mesosiderite S, P and Ni concentrations of Powell [6] would lower the liquidus temperature of iron to ~1400°C. If a 1400°C metallic liquid were to invade a porous silicate matrix, partial melting of the silicates seems inevitable unless either cooling rates were very rapid or the metal/silicate ratio was very small. More complex scenarios (using metallic liquids of lower temperature) are possible, but these models require that the composition of the present average metal sulfide-assemblage be nonrepresentative of the original metallic liquid.

CONCLUSIONS. (1) Laboratory results indicate that sintering of metallic iron can occur at metamorphic temperatures on reasonable time scales. (2) Reevaluation of high-temperature cooling rates indicates that cooling may not be sufficiently rapid to prevent the partial melting of silicates immersed in a 1400°C metallic liquid. (3) Low temperature cooling rates are problems for nearly all classes of meteorites. Even though the mesosiderites appear to have cooled very slowly, it is not clear that low-temperature cooling rates really constrain the problem of mesosiderite origin. (4) For these reasons, a regolith origin for mesosiderites is favored, with the heat necessary for metamorphism supplied by a nearby impact or igneous event. This high-temperature metamorphic origin is probably followed by a complex low-temperature history.


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