ASSESSMENT OF THE MESOSIDERITE-DIOGENITE CONNECTION AND AN IMPACT MODEL FOR THE GENESIS OF MESOSIDERITES.

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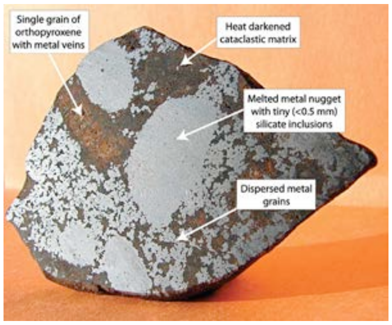
Introduction: Among well-recognized meteorite classes, the mesosiderites are perhaps the most complex and petrogenetically least understood. Previous workers have contributed important information about “classic” falls and Antarctic finds, and have proposed several different models for mesosiderite genesis [1]. Unlike the case of pallasites, the co-occurrence of metal and silicates (predominantly orthopyroxene and calcic plagioclase) in mesosiderites is inconsistent with a single-stage “igneous” history, and instead seems to demand admixture of at least two separate components.

Here we review the models in light of detailed examination of multiple specimens from a very large mesosiderite strewnfield in Northwest Africa. Many specimens (totaling at least 80 kilograms) from this area (probably in Algeria) have been classified separately by us and others; however, in most cases the individual specimens were of insufficient size to fully appreciate the diversity in mineralogy and texture. Previously [2] we suggested based on studies of the first few specimens available that there might be two separate meteoroids responsible. We now discard that notion after more thorough work, and then propose a mechanistic model for mesosiderite petrogenesis.

Petrography: Our mineralogical and textural assessment draws mainly on our own detailed analyses of classified specimens (NWA 1817, 1827, 1878, 1879, 1882, 1912, 1951, 1979, 1982, 2042, 3055, 5312) augmented by examination of large slices of related material from the same strewnfield. The overall texture (see Figures 1 and 2) consists of relatively large, metal-rich “nuggets” within a finer grained, heterogeneous matrix composed of orthopyroxene, plagioclase, rare olivine and pigeonite, kamacite (23–52 vol. %) with rounded to subrounded taenite inclusions, tetrataenite, phosphates (mostly merrillite),chromite, schreibersite and troilite. Irregular to lath-shaped orthopyroxene fragments may reach 3.8 cm in size. In addition, minor amounts of subrounded cm-sized igneous-textured orthopyroxenite and noritic clasts are sparsely distributed throughout. Overall, this is a clastic breccia texture where the original clastic assemblage experienced extensive subsequent annealing (yet not to an extent whereby triple grain junctions developed). Noritic clasts show only minor annealing and range in plagioclase (An_{90-96}) content from 12 to 48 vol.%. Orthopyroxene ($Fs_{26-31}Wo_{2-4}$; FeO/MnO = 24-34) is the most abundant silicate mineral and in some clasts contains inclusions of FeS, tetrataenite, merrillite and silica. Three of the ten norite clasts contain a few tiny grains of olivine (Fa_{24-32}). A single, fine-grained breccia clast was found in NWA 5312 (see Figure 2).

Figure 1. **a** ***(above)*** *Etched slice of NWA 1879 showing polycrystalline metal nuggets and brown silicate-rich matrix.* **b** (***below***) *Slice of NWA 1979 (width 8.5 cm) illustrating characteristics similar to those produced in frictional shear experiments.*



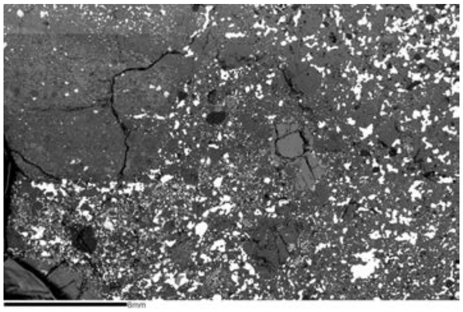


Figure 2. *BSE image of NWA 5312. Breccia clast (left; olivine+orthopyroxene+chromite+troilite with no plagioclase), orthopyroxene (medium gray), large olivine grain (center) and metal+troilite (bright).*

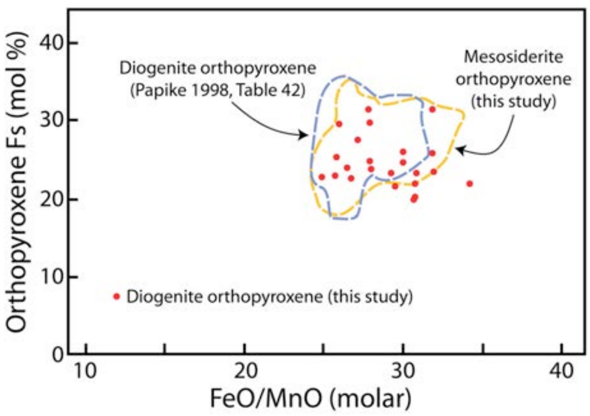


Figure 3. *Fe-Mg-Mn systematics of orthopyroxenes in mesosiderites and diogenites.*

Comparisons with Diogenites: It is well known that orthopyroxene and plagioclase in mesosiderites are essentially identical in composition to the same phases in most diogenites (see Figure 3). This comparison also extends to olivine, especially with the recent recognition of olivine-rich (harzburgitic) diogenites [3]. Diogenites and mesosiderites are indistinguishable in terms of both O and Cr isotopic compositions [4, 5].

Although rare clasts of eucritic and ultramafic lithologies occur in some mesosiderites [1], we have not found a single example within the many kilograms of the NWA mesosiderite material we have carefully examined. This is in marked contrast to the predominance of eucrite over diogenite clasts in howardites and polymict eucrites (although not in the much rarer polymict diogenites). Thus, the silicate component in mesosiderites seems to derive from a diogenitic source lacking much associated eucrite.

The difficulties from phase equilibria studies [6] to relate diogenites to eucrites, and the evidence for a much more ancient formation age for diogenites [7], cast doubt on the concept that diogenites and most eucrites derive from the same parent body. Although spectral studies of 4Vesta [8] have identified abundant eucritic surface material, the existence of any diogenite component at all is far from established. This leaves open the possibility that there is (or was) a separate diogenite-rich parent body (or even more than one).

Discussion: We propose a new petrogenetic model for the genesis of mesosiderites that incorporates some aspects of previous models, but also takes note of the alleged connection with diogenites. We propose that an iron-rich asteroid collided obliquely into a layered diogenitic body at modest speeds (<6 km/s). As the two bodies collided, the oblique angle reduced the peak pressures but increased the role of frictional shear. Experiments detailing the consequences of frictional shear in meteorites [9] demonstrated that such a process redistributes the ductile fractions (metals) into small molten spherules and generates an end-stage mixture of fragmental, stony/metal debris.

With reference to the above experimental observations, we envision a smallish, iron-rich asteroid at a low incident angle, plowing into a layered diogenitic body with a ***warm*** brecciated crust. As the metallic material moved through the silicate layers, it fragmented into subangular, rotating pieces that disrupted the plagioclase-bearing diogenitic target material into various size fractions and incorporated some into the rotating impactors. Mechanical abrasion (aided by heating) continued to transform the metal into smaller and smaller lumps, and ultimately into an end-stage mixture of fragmented stony debris.

This model resolves several perplexing problems with regard to mesosiderite petrogenesis:

(1) It does not require a hot, molten impacting iron core, as evidenced by the residual original metal textures. One or more small bodies impacting at <6 km/s (reflecting estimated simple cosmic velocities at 4.5 Ga) and at a low angle will do some damage, but will not produce high shock energies, resulting in only limited melting and no solid-state shock features.

(2) Pyroxene thermometry [1] implies that the parent body lithologies were already warm (~800°C) during the iron encounter, and remained at moderate temperatures (~400°C) thereafter for a very long time based on metallographic cooling rates [1]. This latent heat, plus that provided from fragmentation/crushing of the target rocks with assumed post-impact burial, possibly was sufficient to generate temperature gradients across the resulting debris that partially annealed the fine-grained matrices, but was insufficient to recrystallize large clasts of diogenitic material.

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