MESOSIDERITE SILICATES VS. HED POLYMICT BRECCIAS.

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Introduction: The silicate portions of mesosiderites are _broadly_ like howardites [1], and this has led to persistent interpretations that mesosiderites and howardites are derived from the same parent asteroid [2]. Yet, when examined carefully, one finds that there are substantial petrological and compositional differences between these polymict breccias. These differences indicate that separate parent asteroids are more probable [3, 4]. I will document the distinctions between these groups based on my data and literature information [5] and discuss their origins.

Petrology: The suite of polymict breccias from the howardite, eucrite and diogenite (HED) parent asteroid extends from polymict eucrites, through howardites to polymict diogenites. The former are dominated by material derived from the upper crust of the asteroid while the latter are dominated by debris from the lower crust. Modal data on HEDs show that this suite extends from ~89 to ~9 vol% plag+cpx (debris from basalt and gabbro; upper crust) and from ~6 to 91 vol% opx+oliv (debris from orthopyroxenite, harzburgite and possibly dunite; lower crust/mantle?). In contrast, mesosiderite silicates contain a maximum of ~41 vol% plag+cpx and a minimum of ~44 vol% opx+oliv. Compared to the entire HED polymict breccia suite, mesosiderites are notably skewed by including a greater lower crustal/mantle component.

The textural nature of the breccias are also distinct. Most HED polymict breccias are fragmental breccias composed of angular mineral and lithic clasts, some showing slight to moderate metamorphic recrystallization. Impact-melt clasts and veins are present in many, but few are impact-melt breccias. Some subtypes of mesosiderites are impact-melt breccias [6, 7]; >20% of well-classified mesosiderites are such. Furthermore, even the least-recrystallized mesosiderites contain numerous impact-melt clasts [8] and much of the fine-grained matrix is quench-textured impact melt.

There are also differences in mafic clast components. The majority of basaltic clasts and many of the cumulate gabbro clasts in mesosiderites are of secondary origin, having formed through remelting of upper crustal basalts and cumulate gabbros [9]. One key indicator of this is low Fe/Mn in pyroxene caused by reduction after metal-silicate mixing [3]. Few, if any, of the mafic clasts from HED polymict breccias are thought to be secondary in origin.

Composition: Mesosiderite bulk silicates similarly show compositional distinctions from HED polymict breccias, particularly for incompatible lithophile trace elements. Mesosiderites partially overlap fields for HED polymict breccias in Eu/Sm vs. La/Yb but the former have higher median Eu/Sm (1.32) than the latter (0.88). Furthermore, some mesosiderites have Eu/Sm well within the range of cumulate eucrites. This observation suggests that mesosiderite silicates sample deeper into the asteroid upper crust where cumulate gabbros are more common and significantly undersamples basaltic layers that might have compensating low Eu/Sm. The low median Eu/Sm for HED polymict breccias indicates the opposite is true of them; they undersample the deeper cumulate gabbros.

Discussion: Bulk silicate compositions of mesosiderites have significant differences from those of HED polymict breccias. Amongst HED polymict breccias, a subset of them are thought to be true regolith breccias that are representative of the crustal lithic types being gardened [10]. We cannot be confident that mesosiderite silicates are true regolith materials because many of the indicators of this would have been degraded by the intense metamorphism they experienced; they could be simpler polymict breccias. Regardless, modeling of impact ejecta on asteroids [11] and observations by Dawn at Vesta [12] show that asteroid-wide distribution of ejecta occurs, which then gets mixed by gardening. This supports the hypothesis that the many differences between mesosiderite silicates and HED polymict breccias reflect origin on different parent asteroids. This is strengthened by the lack of polymict breccias intermediated between the most metal+troilite poor mesosiderite and HED polymict breccias.

Caveat: Only ~40 of the 279 named mesosiderites have been studied in detail, and several of these are paired. A new comprehensive study of mesosiderites using modern techniques would provide new insights into the nature and origin of these rocks and their relationship, if any, to HEDs.

References and Notes: [1] Prior G. T. (1918) *Mineralogical Magazine* 18:151-172. [2] Haba M. K. et al. (2019) *Nature Geoscience* 12:510-515. [3] Mittlefehldt D. W. (1990) *Geochimica et Cosmochimica Acta* 54:1165-1173. [4] Rubin A. E. and Mittlefehldt D. W. (1993) *Icarus* 101:201-212. [5] Too many literature sources for data have been used to cite them here; only references for ideas are cited. [6] Floran R. J. et al. (1978) *Proceedings of the Ninth Lunar and Planetary Science Conference*, pp 1083-1114. Pergamon Press. [7] Hewins R. H. (1984) *Journal of Geophysical Research: Solid Earth* 89:C289-C297. [8] Floran R. J. (1978) *Proceedings of the Ninth Lunar and Planetary Science Conference*, pp 1053-1081. Pergamon Press. [9] Rubin A. E. and Mittlefehldt D. W. (1992) *Geochimica et Cosmochimica Acta* 56:827-840. [10] Warren P. H. et al. (2009) *Geochimica et Cosmochimica Acta* 73:5918-5943. [11] Housen K. R. et al. (1979) *Icarus* 39:317-351. [12] Ammannito E. et al. (2013) *Meteoritics & Planetary Science* 48:2185-2198.