NEW OXYGEN ISOTOPE EVIDENCE FOR THE ORIGIN OF MESOSIDERITES AND MAIN GROUP PALLASITES.

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Introduction: Many groups of differentiated achondrites display limited oxygen isotope variation, plotting within a restricted portion of the three-isotope diagram immediately below the terrestrial fractionation line [1,2]. As a consequence, oxygen isotopes have until recently been of only limited value in deciphering the relationships between these meteorite groups. A case in point is the apparent overlap displayed by main group pallasites, mesosiderites and the various lithologies of the howardite-eucrite-diogenite suite (HEDs) [1,2]. These groups formed in distinct environments with the HEDs and mesosiderites having crustal affinities, whereas pallasites appear to be samples from the core-mantle boundary of their parent asteroid [2]. Deriving all three groups from a single source, as might be inferred from the oxygen isotopes [1], is inconsistent with evidence that HEDs are from the relatively intact asteroid 4 Vesta [2]. Liberation of pallasites from the core/mantle interface requires almost total disruption of the source asteroid [3].

The relatively high precision obtained using laser fluorination techniques [4] offer the potential to resolve such overlaps. Following on from an earlier study in which the angrite and HED groups were shown to be from two distinct sources [5] we present here preliminary results of a detailed investigation into the origin of mesosiderites and main group pallasites. In view of the long running speculation that mesosiderites might be derived from the same parent body as the HEDs [2] one of the major objectives of this new study was to compare the oxygen isotope composition of these two groups.

Methods: Oxygen isotope analyses were carried out using an infrared laser fluorination system [4]. O_2 was analyzed using a Micromass Prism III dual inlet mass spectrometer. System precision (1σ) based on replicate analyses of international (NBS-28 quartz, UWG-2 garnet) and internal standards is approximately ±0.04‰ for $\delta^{17}O$; ±0.08‰ for $\delta^{18}O$; ±0.024‰ for $\Delta^{17}O$ [4].

Olivines from the following main group pallasites were analyzed in this study: Brenham, Marjalahti, Molong, Esquel, Springwater, Admire, Giroux, Thiel Mountains, Imilac, and Krasnojarsk. Mesosiderites analyzed were:Eltanin, Estherville, Lowicz, Veramin, Patwar, Barea, Mount Padbury, Morristown, Pinaroo, Emery, Clover Springs, NWA 1951, Dong Ujimqin Qi. In general, mesosiderite analyses were undertaken on well-defined silicate-rich clasts.

Results: The results obtained in this study are shown graphically on Fig. 1. The mesosiderites (filled squares) and main group pallasites (filled circles) are clearly resolved from each other, with each group forming a distinct linear array. The mean $\Delta^{17}O$ value for the main group pallasites is -0.179 ± 0.014 and for the mesosiderites is -0.246 ± 0.011. While the results presented here for the mesosiderites are broadly in agreement with earlier studies [1], our mean $\Delta^{17}O$ value for the pallasites is 0.1‰ less negative than these previously published analyses [1]. There is no simple explanation for this discrepancy. Analysis of both mesosiderites and pallasites were interspersed with terrestrial samples as part of an interlaboratory comparison of the TFL, with good agreement being obtained by both participating laboratories [6]. Results on international and internal standards run throughout the course of this work have given consistent and reproducible results; hence we have a high degree of confidence in the pallasite and mesosiderite data presented here.

Compared with analyses of the HEDs [5] the pallasites and mesosiderites show slightly greater degrees of scatter. This presumably reflects the fact that the HED data was obtained exclusively on meteorite falls, whereas the vast majority of available pallasite and mesosiderite samples are finds.

No consistent compositional control on oxygen isotope variation was observed in the mesosiderites so that the relatively basaltic class A types span the full range of $\delta^{18}O$ values. This is in contrast to the HEDs where there is clear evidence of mineralogical control, with diogenites having lower $\delta^{18}O$ values than the basaltic eucrites [5]. However, the mesosiderites are highly brecciated and so this apparent lack of a correlation is not unexpected. Ongoing work on individual clasts extracted from a single mesosiderite sample display almost as much variation in $\delta^{18}O$ as is shown by all the mesosiderites analyzed in this study.

The pallasites form a tight cluster in terms of $\delta^{18}O$, as would be expected from their relatively homogenous olivine compositions [2]. Marjalahti, the only pallasite fall analyzed in this study, displays a less negative $\Delta^{17}O$ than the other samples, but is still within error of the group mean value.

The previously determined angrite and HED fractionation lines [5] are shown on Fig. 1 for comparison.

The mean $\Delta^{17}O$ value for the mesosiderites obtained in this study is within error and almost identical to the previously determined HED value of -0.238 ± 0.007 [5].

Discussion: It is clear from the results of this study that the silicate portion of the pallasites and mesosiderites are derived from two distinct asteroidal sources. Further, the mean $\Delta^{17}O$ value of -0.179 ± 0.014 for the main group pallasites unequivocally demonstrates that the pallasites are also unrelated to the HED suite. The $\Delta^{17}O$ value obtained for the pallasites is unique and does not correspond to that of any known group of basaltic differentiated achondrites. It would appear therefore that the pallasites sample a disrupted differentiated asteroid in which the higher level crustal material is unrepresented in the meteorite record.

The extremely close coincidence between the mean $\Delta^{17}O$ values for the mesosiderites and HEDs (Fig.1) must further strengthen the case for a genetic link between these two groups. The range in $\delta^{18}O$ values for the mesosiderites and HEDs is also almost identical if data from previous laser fluorination studies of the HEDs are combined [5,7]. It has been shown that mesosiderites must have been derived from a large asteroidal parent body of roughly similar dimensions to that of 4 Vesta [8]. Despite other somewhat contradictory evidence [2], the new oxygen isotope data presented here lends strong support to the view that if HEDs are from 4 Vesta then so are the mesosiderites. This is clearly a testable conclusion and the results from the NASA DAWN mission should help to settle this question once and for all.

References: [1] Clayton R. N. and Mayeda T. K. (1996) *GCA 60*, 1999-2017. [2] Mittlefehldt D. W. et al. (1998) in Reviews in Mineralogy 36, 4-1-195 [3] Cruickshank et al. (1991) *Icarus 89*, 1-13. [4] Miller, M.F. et al. (1999) *Rapid Commun. Mass Spectrom. 13*, 1211-1217. [5] Greenwood R. C. et al.(2005) *Nature 435* 916-918. [6] Rumble et al. (2006) LPS XXXVII this volume [7] Wiechert, U. H. et al. (2004) EPSL 221, 373-382. [8] Haack H. et al (2003) LPS XXXIV abstract 1317.

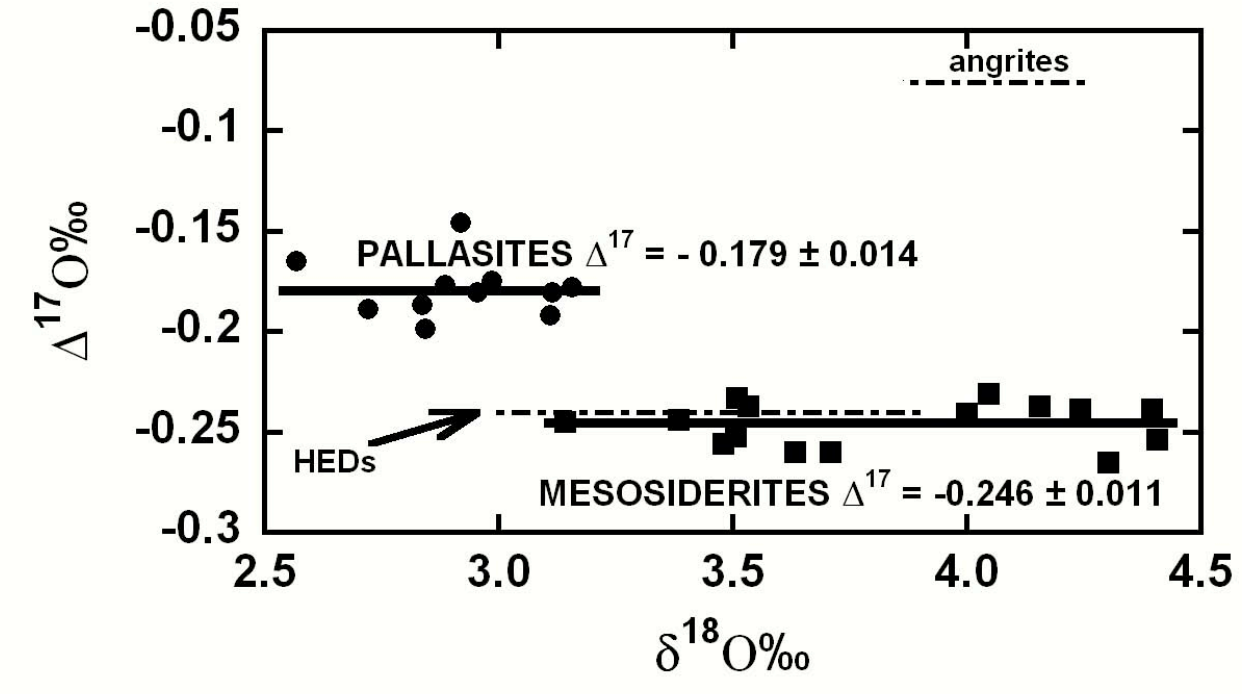

Fig 1. Oxygen isotope compositions of mesosiderites and main group pallasites.