

HOW USEFUL ARE HIGH-PRECISION $\Delta^{17}\text{O}$ DATA IN DEFINING THE ASTEROIDAL SOURCES OF METEORITES?: EVIDENCE FROM MAIN-GROUP PALLASITES, PRIMITIVE AND**DIFFERENTIATED ACHONDRITES:** R. C. Greenwood, I. A. Franchi, and J.M. Gibson Planetary and Space Sciences Research Institute, Open University, Milton Keynes, MK7 6AA, UK. E-mail: r.c.greenwood@open.ac.uk;

Introduction: Largely as a consequence of the pioneering studies of Clayton and coworkers [1, 2,] oxygen isotope measurements are an indispensable tool in attempting to understand meteorite diversity and at a more fundamental level the processes that operated in the early Solar System. A critical task in this endeavor is using such measurements to define relationships between groups with distinct mineralogies which may be cogenetic and hence from the same parent body.

One inherent problem with this work is the limited oxygen isotope variation shown by a diverse range of meteorites that plot in a narrow zone immediately below the terrestrial fractionation line (TFL) on an oxygen three-isotope plot [2]. Laser fluorination analysis provides the level of precision [3] needed to resolve overlaps between groups. However, a number of issues need to be addressed before this potential can be fully exploited. Firstly, the inherent oxygen isotope heterogeneity of some groups, particularly the primitive achondrites, is significantly greater than analytical precision, hence overlaps between different groups are inevitable [2, 4]. Secondly, many meteorite groups are represented largely by finds [5]. Weathering effects in these samples need to be removed in order to study intrinsic isotopic variation [4]. Thirdly, even for groups which have undergone protracted high-temperature processing, and ought therefore to be isotopically homogenous, there is debate about the effectiveness of high-precision analysis in resolving apparent overlaps [6]. Finally, it is entirely possible for two distinct groups to have identical oxygen isotope compositions. To improve our understanding of these issues we have undertaken further analysis of various meteorite groups that plot in the region immediately below the TFL.

Analytical techniques: Oxygen isotope analysis was performed by infrared laser-assisted fluorination following the procedures outlined by [3]. Analyses of main-group pallasites were undertaken on individual separated olivine grains that were physically removed from the exposed surfaces of hand specimen samples. This technique was also used in our previous study [7], although the sample details erroneously indicated that the grains were homogenized prior to analysis, which was not the case. As a consequence, data from this study [7] (37 replicate analyses) can be combined with more recently acquired data (30 analyses) (Fig. 1).

Analysis of primitive achondrite samples was performed on ~2mg aliquots of powder taken from

crushed and homogenized 50-100mg rock chips. To reduce the influence of weathering a number of the more altered primitive achondrite samples were leached using a solution of ethanolamine thioglycollate [8] and then washed and dried prior to fluorination. This treatment removes iron oxides, hydroxides and metallic iron, but not silicate-bound iron. Oxygen isotope analysis of differentiated basaltic achondrites is the subject of a companion abstract [9].

Results: Results are shown on Figs. 1, 2 and 3. In all cases quoted values for $\Delta^{17}\text{O}$ were calculated according to the method of [10].

Pallasites: In our earlier study it was concluded that main-group pallasites have $\Delta^{17}\text{O}$ values less negative and fully resolvable from those of both the HEDs and mesosiderites [7]. It was concluded that main-group pallasites were derived from a distinct, partially disrupted parent body. More recently these conclusions have been disputed on the basis that average $\Delta^{17}\text{O}$ values for HEDs, mesosiderites and main-group pallasites are indistinguishable within analytical uncertainties [6]. It was further suggested that main-group pallasites show a bimodal distribution with respect to $\Delta^{17}\text{O}$ [6]. Our new pallasite data (Fig. 1), combined with that from our previous study [7], does not support the conclusions of [6]. These data indicate that the samples studied are from a single population with an average $\Delta^{17}\text{O}$ of -0.187 ± 0.018 (2σ), which is clearly resolvable from either the HEDs $\Delta^{17}\text{O} = -0.239 \pm 0.014$ (2σ) [11], or mesosiderites $\Delta^{17}\text{O} = -0.245 \pm 0.020$ (2σ) [7]. Consistent with the conclusions of [7], the new data indicate that main-group pallasites were not derived from the same source as either the HEDs or mesosiderites.

Primitive Achondrites: Preliminary results of a detailed study of the oxygen isotope variation displayed by brachinites ($n=8$), winonaites ($n=10$), acapulcoites/lodranites ($n=21$) and various related samples ($n=5$) have been reported previously [4]. In view of the weathered nature of many of these samples further work has been undertaken to assess the influence of such secondary processes. The winonaites and acapulcoites/lodranites show the most extensive evidence of terrestrial alteration [4]. The acapulcoites/lodranites show distinct isotopic shifts correlated to find location, with Antarctic specimens displaced to lower $\delta^{18}\text{O}$ values compared to leached samples and non-Antarctic finds displaced to higher values (Fig. 2).

Differentiated basaltic achondrites: Results of analysis of various basaltic achondrites are presented in a companion abstract [9]. This study provides evidence that basaltic achondrites with near-identical oxygen isotope compositions may be from distinct sources.

Discussion and conclusion: The results of our new analyses of main-group pallasites again indicate that this group is resolvable from either the HEDs or mesosiderites and are therefore derived from distinct parent bodies. The results of leaching experiments on primitive achondrites emphasize that in trying to assess primary isotopic heterogeneity it is important to eliminate the effects of terrestrial weathering. However, even if this could be fully achieved overlaps due to intrinsic oxygen isotope variation can never be totally eliminated. Thus, the HEDs, mesosiderites and angrites plot within the brachinite field (Fig. 3). However, these overlaps are all but eliminated if Brachina is considered to be an anomalous sample and excluded from the brachinites [4]. Multiple basaltic achondrite parent bodies with overlapping and hence irresolvable oxygen isotope compositions are also a very realistic possibility [9].

As a technique high-precision oxygen isotope analysis is capable of revealing important information about the relationship between different meteorite groups. However, it cannot be used in isolation and needs to be carefully combined with information from other analytical techniques.

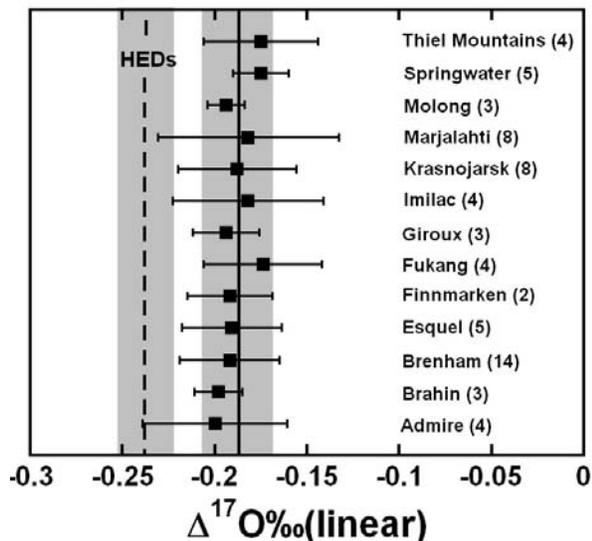


Fig 1. Oxygen isotope composition of main-group pallasite olivines. All error bars 2σ . Shaded boxes 2σ error on group mean value.

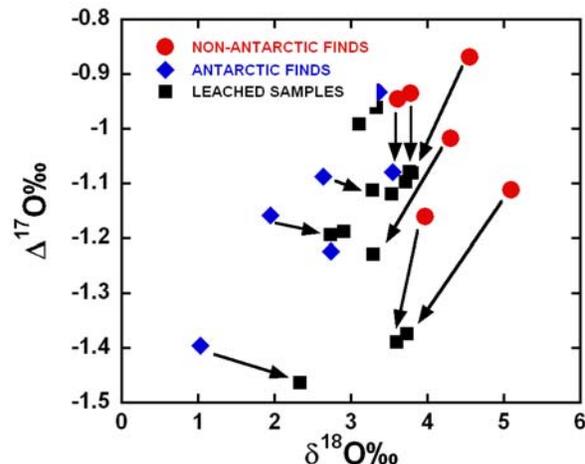


Fig. 2 Acapulcoite/Iodranite leached and unleached samples. The oxygen isotope variation displayed by this group is considerably reduced once the effects of weathering have been at least partially eliminated.

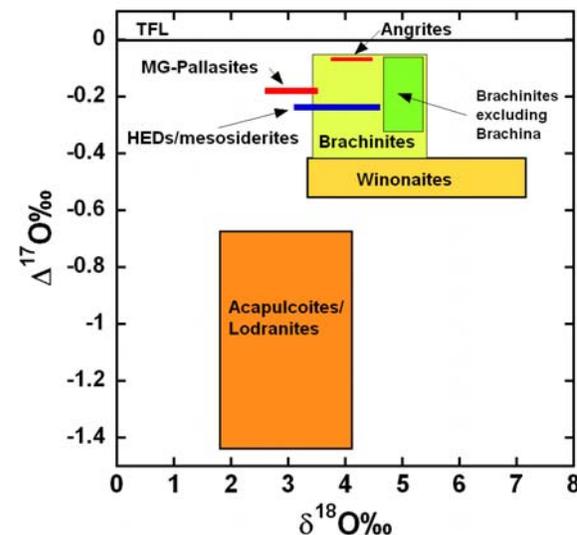


Fig 3. Primitive and differentiated achondrites. 2σ variation on group mean values. Data this study and [4, 7, 11].

References: [1] Clayton et al. (1973) *Science* 182, 485-488 [2] Clayton R. N. and Mayeda T. K. (1996) *Geochim. Cosmochim. Acta* 60, 1999-2018. [3] Miller M. F. et al. (1999). *Rapid Commun. Mass Spectrom.* 13, 1211-1217. [4] Greenwood et al. (2007) *LPSC XXXVIII* abstract #2163 [5] Middlefehldt D.W. et al. (1998) *Reviews in Mineralogy* 36. [6] Ziegler K. et al. (2007) *LPSC XXXVIII*, abstract # 2021 [7] Greenwood R.C. et al. (2005) *Science* 313, 1763-1765. [8] Cornish L. and Doyle A. (1984) *Palaeontology* 27: 421-424. [9] Scott E.R.D. et al. (2008) *LPSC XXXIX* [10] Miller M. F. (2002) *Geochim. Cosmochim. Acta* 66,1881-1889. [11] Greenwood et al. (2005) *Nature* 435, 916-918.