REVISING THE ANGRITE FRACTIONATION LINE: NEW INSIGHTS FROM HIGH-PRECISION OXYGEN ISOTOPE STUDIES. B. Rider-Stokes[1], R. C. Greenwood[1], M. Anand[1], I. A. Franchi[1] & L. White[1].
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Introduction: Angrites are a small group of highly alkali-depleted, unbrecciated and relatively unshocked basaltic achondrites [1,2]. Based on Fe/Mn ratios of pyroxenes within angrites, it has been suggested that the angrite parent body (APB) originated from a similar planetary reservoir to the Earth-Moon system [3]. Based on textures and mineralogies, angrites have been principally divided into plutonic and quenched (volcanic) angrites [4]. However, there are some angrites that do not fit into either subgroup. For example, North West Africa (NWA) 8535 has been classified as a dunite (early formed cumulate) and NWA 10463 appears to represent an intermediate stage between the plutonic and quenched angrites [5]. Here we present new bulk oxygen isotopic data for a variety of angrites, including the only known shocked angrite NWA 7203, and the intermediate angrite, NWA 10463, neither of which have been previously analysed for their oxygen isotope compositions [5].

Materials and Methods: O-isotope data were obtained at the Open University using laser-assisted fluorination [6,7]. All samples were first analysed without any pre-treatment. Next, samples were treated with a solution of ethanolamine thioglycollate (EATG), which has been shown to be efficient at removing Fe-rich terrestrial weathering products, without significantly altering the primary oxygen isotope composition of the samples [8].

Results: The mean $\Delta^{17}O$ value of the untreated angrites is -0.062 ± 0.034 ‰ (2σ), whilst the EATG treated samples reveal a $\Delta^{17}O$ value of -0.058 ± 0.038 ‰ (2σ). The mean $\Delta^{17}O$ value of the untreated and treated samples without NWA 12320 is -0.067 ± 0.016 ‰ (2σ) and -0.064 ± 0.018 ‰ (2σ), respectively.

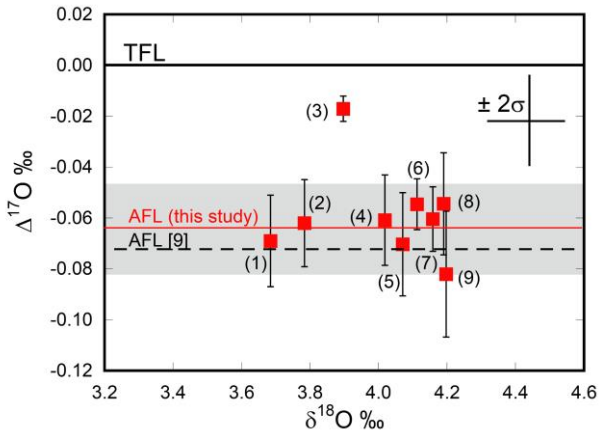

Fig. 1 O-isotope plot of angrites. (1) NWA 8535, (2) Angra dos Reis (3) NWA 12320, (4) NWA 4590, (5) NWA 4801, (6) NWA 7203, (7) Sahara 99555, (8) D'Orbigny (9) NWA 10463. Grey shaded box is ± 2σ error on the mean bulk angrite $\Delta^{17}O$ value (this study). The previously determined mean bulk average value of 0.072 ‰ [9] is within error of our new value. All samples treated with EATG, except NWA 8535. Error bars 2σ. Cross top right shows the overall system precision of the OU laser fluorination line [10].

Discussion: O-isotope analyses by [9] demonstrated that angrites and eucrites have distinct $\Delta^{17}O$ signatures and thus originate from separate parent bodies. These analyses gave the angrites a group mean $\Delta^{17}O$ value of -0.072 ± 0.014 ‰ (2σ) compared to the group mean HED $\Delta^{17}O$ value of -0.239 ± 0.014 ‰ (2σ). O-isotope data for a variety of angrites have also been published in the Meteoritical Bulletin, which provide a mean $\Delta^{17}O$ value of -0.070 ± 0.040 ‰ (2σ). Our EATG treated samples have a mean $\Delta^{17}O$ value of -0.058 ± 0.038 ‰ (2σ), which is somewhat less negative than the results of [9]. This is due to the more positive values displayed by NWA 12320 (Fig 1), plotting close to the terrestrial fractionation line (TFL). Terrestrial contamination can be ruled out as there is little to no difference in $\Delta^{17}O$ values of the untreated (-0.023 ± 0.004 ‰ (2σ)) and treated analyses (-0.017 ± 0.004 ‰ (2σ)) of NWA 12320. This could suggest that the APB is more heterogeneous with respect to oxygen isotopes than previously suspected, or that NWA 12320 does not originate from the same parent body as the other angrite meteorites analysed here. Moreover, there is no observed difference between the plutonic and quenched angrites, indicating that they originate from the same parent body. Finally, NWA 10463 and NWA 7203 display $\Delta^{17}O$ values, consistent with being angrites (Fig 1).

Summary: We provide a new mean $\Delta^{17}O$ (AFL) value of -0.064 ± 0.018 ‰ (2σ) for the angrites (excluding NWA 12320) and clearly demonstrate that NWA 10463 and NWA 7203 are indeed angrite meteorites. The quenched angrite NWA 12320 has a more positive $\Delta^{17}O$ value compared to other angrites, the exact cause of which is being investigated.

References: **[1]** Warren P. H. & Kallemeyn G. W. (1995) *Meteoritical Society*. 30, 593. **[2]** Kruijer T. S. *et al* (2019) *Nature Commncations*.4 (1), 1-9. **[3]** Papike J. J. *et al* (2017) *American Mineralogist*. 102, 1759-1762. **[4]** Kiel K. (2012) *Chemie der Erde*. 72.191-218. **[5]** Santos A. *et al* (2016) *LPSC XLVII. 2590*. **[6]** Miller M. F. *et al* (1999) Rapid *Communications in Mass Spectrometry*. 13, 1211-1217. **[7]** Greenwood R. C. *et al* (2017) *Chemie der Erde*. 77, 1-43. **[8]** Martins Z. *et al* (2007) *Meteoritics & Planetary Science*. 42 (9), 1581-1595 **[9]** Greenwood R. C. *et al* (2005) *Nature*. 435, 916-918. **[10]** Starkey N. A. *et al* (2016) *Geochimica et Cosmochimica Acta*.176, 227-238.