XENON IN THE ANOMALOUS EUCRITES BUNBURRA ROCKHOLE AND IBITIRA. J. L. Claydon, S. A. Crowther and J. D. Gilmour, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL, UK (jennifer.claydon@postgrad.manchester.ac.uk).

Introduction: Howardite-eucrite-diogenite (HED) meteorites are igneous rocks related by their mineralogy and chemistry. Oxygen isotope ratios of HEDs indicate that they originated on the same parent body or related parent bodies [1]. The asteroid 4 Vesta (and its family of Vestoids) has been proposed to be the HED parent body due to the similarities of its reflectance spectra to those of eucrites and diogenites [2]. However, several basaltic achondritic meteorites (including Ibitira [3] and Bunburra Rockhole [4]) that show major element chemistry and mineralogy similar to eucrites deviate from the HED oxygen isotope mass fractionation line. This suggests they either originated on a separate parent body [5] or that Vesta and the Vestoids retain some heterogeneity [6].

Xenon is a useful trace element as isotopic anomalies are easily detected due to its scarcity in solid materials. Isotopic excesses of Xe found in ancient meteorites are produced by several reactions: ^{244}Pu /^{238}U → $^{132-136}$Xe by spontaneous fission; ^{129}I → ^{129}Xe by radioactive decay; Ba/light rare earth elements (LREE) → $^{124,\ 126}$Xe by cosmic-ray spallation; ^{127}I→ ^{128}Xe, and Ba/Te→ ^{131}Xe by neutron capture reactions. By looking at the isotopic signatures of Xe in anomalous eucrites Ibitira and Bunburra Rockhole (IB and BR hereafter) and comparing them to those of normal eucrites we seek to understand more about the origins of normal and anomalous eucrites.

Methods: Two whole rock fragments of IB (masses 1.63 & 4.60 mg) and four whole rock fragments of BR (masses 0.98, 1.76, 3.07 & 3.38 mg) were loaded in the sample port of the RELAX [7, 8] mass spectrometer. The gases were released by laser step-heating and xenon isotope ratios were measured. Absolute amounts of gas were calculated, and a sensitivity correction made, by reference to measurements of terrestrial air interspersed throughout analyses. The procedural blank was measured throughout and subtracted from the calculated isotope abundances of the samples.

Results: Samples showed mixing between a trapped component (attributed to terrestrial air) and a fission signature consistent with either ^{238}U or ^{244}Pu with no apparent significant spallation contribution to ^{134}Xe (Figure 1). ^{244}Pu dominated the production of fission xenon at times consistent with the Ar-Ar age of 4.4858 ± 0.015 Gyr [9] for IB (no age has yet been reported for BR) and so a correction has been made based on fission of ^{244}Pu. Concentrations of Pu at closure to Xe loss range from 0.3 – 0.5 ppb in IB and 0.3 – 0.6 ppb in BR, comparable to abundances in normal eucrites [10-12]. In the following discussion we have compared our Xe isotope ratios of IB and BR to those of normal eucrites and Ibitira reported in [13]. We have applied the same fission correction to our data and to the data from [13] as all fell on the same air-fission mixing line (Figure 1).

Excesses in the lighter Xe isotopes were seen in all samples of IB and BR analysed. These have been attributed to a mix of cosmic-ray induced spallation of Ba and LREE and neutron capture on Ba. The data show different fractions of cosmogenic Xe produced from Ba and from LREE (Table 1) implying a variation in Ba/LREE between samples.

Pu-Xe ages of IB and BR have been calculated relative to the age of Angra dos Reis (ADOR) angrite using the method given in [13] but using the xenon isotope signature to set the Ba/LREE ratio [14] rather than separate measurements. Cosmic-ray exposure ages used in these calculations are from [15 and references therein]. ADOR has a Pb-Pb age of 4.5578 Ga [13] and negative Pu-Xe ages indicate the sample is younger than ADOR. All samples show Pu-Xe ages younger than ADOR (except for BR1 which shows an erroneously old age thought to be due to the high Ba/LREE ratio) (Table 1) that are consistent with Pu-Xe ages for normal eucrites [13]. Pu-Xe ages of Ibitira given in [13] of + 37 ± 22 and + 6 ± 23 Myr are older than the IB ages reported here of – 98 ± 27 and – 85 ± 23 Myr.

^{129}Xe*/^{126}Xe* ratios above the cosmogenic composition of 1.6 ± 0.4 given by [14] were seen in IB and BR. ^{129}Xe* can be produced from Te however Te is scare in eucrites (~6 ppb [16]) and is not expected to contribute significantly to ^{129}Xe* so the elevated ^{129}Xe ratios indicate the presence of ^{129}Xe* from ^{129}I decay, either in situ or inherited. Concentrations of ^{129}Xe (~1 $\times 10^{-11}$ cc STP g^{-1}) are consistent with those in [13] though IB and BR show higher ^{129}Xe/^{132}Xe$_{AIR}$ ratios than normal eucrites (Figure 2).

Discussion: Pu-Xe ages of IB and BR are consistent with those of normal eucrites reported in [13] indicating that they closed to Xe loss at the same time. However our Pu-Xe ages for Ibitira differ from those reported in [13]. We saw that the Ba/LREE ratio varied throughout our samples and that this contributed to the erroneously old age calculated for BR1 (Table 1). This indicates that Xe from Pu is not well associated with Ba and LREE in these eucrites (or at least not in samples of these sizes) and resulted in the different Pu-Xe ages for Ibitira reported here and in [13].

IB and BR show higher $^{129}Xe^*/^{136}Xe^*$ ratios than normal eucrites (Figure 2). This could reflect either earlier closure to Xe loss (^{129}I has a shorter half life than ^{244}Pu) or a higher I/Pu ratio on the parent body. As IB and BR have similar Pu-Xe ages to those of normal eucrites Bereba, Jonzac, Sioux County & Vetluga [13], the $^{129}Xe^*/^{136}Xe^*$ ratios appear to reflect the volatile content of the source material rather than the time of closure to Xe loss. We therefore suggest that IB and BR originated on a more volatile-rich (or less devolatised) parent body than that of the normal eucrites.

Conclusions: IB and BR show Pu-Xe ages consistent with those of normal eucrites. The erroneously old Pu-Xe age of BR1 and the different Pu-Xe ages of Ibitira reported here and in [13] can be attributed to a less than perfect correlation between $^{136}Xe^*$ from Pu and the Ba/LREE ratio of the sample. This may reflect either the presence of inherited $^{136}Xe^*$ or geochemical differences between Pu and LREE.

IB and BR show evidence of the former presence of ^{129}I. $^{129}Xe^*/^{136}Xe^*$ ratios of the samples indicate that IB and BR originated on a more volatile-rich (or less devolatised) parent body. I-Xe analyses of irradiated samples of IB, BR and normal eucrites Bereba and Juvinas are planned to test this conclusion by obtaining more detailed understanding of the Xe systematics.

Acknowledgements: The authors would like to thank P. A. Bland of Imperial College London for providing samples of Bunburra Rockhole and the AMNH for providing samples of Ibitira. This work was funded by the STFC.

References: [1] Clayton R. N. & Mayeda T. K. (1996) *GCA* 60, 1999-2017. [2] McCord T. B. et al. (1970) *Science* 168, 1445-1447. [3] Bland P. A. et al. (2009) *Science* 325, 1525. [4] Mittlefehldt D. W. (2005) *MAPS* 40, 665-677. [5] Scott E. R. D. et al. (2009) *GCA* 73, 5835-5853. [6] Wiechert U. H. et al. *EPSL* (2004) 221, 373-382. [7] Gilmour J. D. et. al. (1994). *Rev. of Sci. Inst.* 65, 617-625. [8] Crowther S. A. et al. (2008) *J. Anal. Atom. Spectrom.* 23, 921-1044. [9] Bogard D. D. & Garrison D. H. (1995) *GCA* 59, 4317. [10] Miura Y. (1993) *GCA* 57, 1857-1866. [11] Miura Y. et al. (1998) *GCA* 62, 2369-2387. [12] Park J. & Nagao K. (2005) *Antartc. Meteorite Res.* 18, 213-224. [13] Shukolyukov A. & Begemann F. (1996). *GCA* 13, 2453-2471. [14] Hohenberg C. M. et al. (1981) *GCA* 45, 1909-1915. [15] Strashnov I. et al. *GCA (submitted).* [16] *MetBase* 7.3.

Sample	Mass (mg)	% $^{126}Xe^*$ from Ba[a]	Pu-Xe age (Myr) ΔADOR[b]
BR1	0.98	99	+ 313 ± 210
BR2	1.76	59	– 146 ± 66
BR3	3.07	56	– 153 ± 76
BR4	3.38	55	– 142 ± 60
IB1	1.63	76	– 98 ± 27
IB2	4.60	86	– 85 ± 23

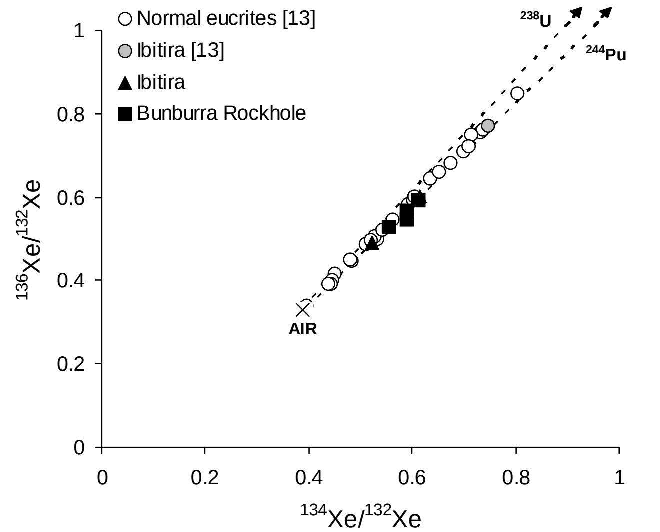

Figure 1. 3-isotope plot of total ^{136}Xe, ^{134}Xe and ^{132}Xe for Bunburra Rockhole and Ibitira samples reported here and normal eucrites and Ibitira from [13]. Also shown are mixing lines between terrestrial air and Xe produced by spontaneous fission of ^{244}Pu or ^{238}U. The data show mixing between a trapped composition consistent with air and a fission component consistent with Pu or U. Fission Xe in ancient meteorites, such as Ibitira, is expected to be dominated by Pu fission.

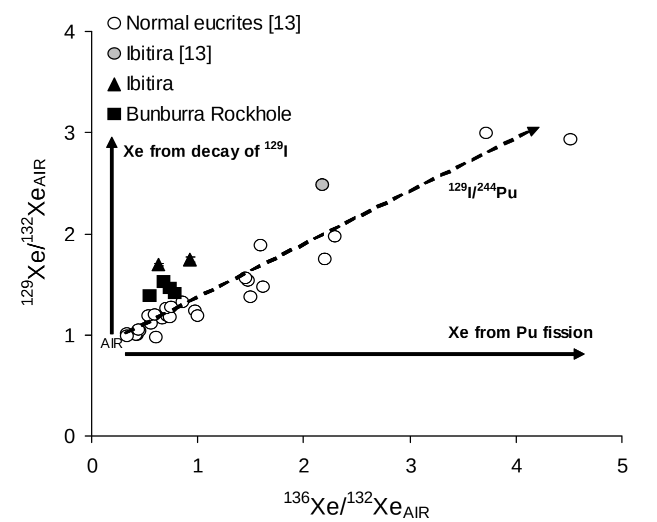

Figure 2. 3-isotope plot of total ^{129}Xe, ^{136}Xe and $^{132}Xe_{AIR}$ (corrected for a contribution from Pu fission) for Bunburra Rockhole and Ibitira samples reported here and normal eucrites and Ibitira from [13]. BR and IB show higher $^{129}I/^{244}Pu$ ratios than normal eucrites with similar Pu-Xe ages. This indicates they formed on a more volatile-rich (or less devolatised) parent body.

← **Table 1.** Table showing Bunburra Rockhole and Ibitira sample masses, percentage of cosmogenic $^{126}Xe^*$ from Ba, and Pu-Xe ages relative to Angra dos Reis (ADOR) which has a Pb-Pb age of 4.5578 Ga [13] (a negative age indicates the sample is younger than ADOR). The erroneously old age of BR1 is thought to be due to the high Ba/LREE ratio. [a] Assuming $^{126}Xe^* = ^{126}Xe_{Ba} + ^{126}Xe_{LREE}$. [b] Calculated using method given in [13] using the xenon isotope signature to set the Ba/LREE ratio [14] and cosmic-ray exposure ages from [15 and references therein].