THE I-PU-XE SYSTEM IN ANOMALOUS AND VESTAN EUCRITES: WAS VESTA UNUSUALLY LARGE? J. L. Claydon[1,2], S. A. Crowther[2] and J. D. Gilmour[2], [1]Department of Earth Sciences, Natural History Museum, Cromwell Road, London, SW7 5BD, U.K. [2]School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL, UK (j.claydon@nhm.ac.uk).

Introduction: Eucrites are basaltic meteorites with oxygen isotope signatures [1] indicating formation on a single parent body, thought to be the asteroid 4 Vesta [2]. However, several meteorites that have similar major element chemistry and mineralogy to eucrites deviate from the oxygen isotope mass fractionation line [3-5], suggesting a non-Vestan origin. Of these six anomalous eucrites [3, 4] two may originate on one body [3] whilst the other four appear to have originated on separate differentiated bodies. This suggests that differentiated asteroids chemically and geologically similar to Vesta, were once more common in the Solar System but have since been catastrophically disrupted.

Xenon is a useful trace element as its scarcity in solid materials makes isotopic anomalies easy to detect. $^{131-136}$Xe are produced by spontaneous fission of ^{238}U and ^{244}Pu, whilst $^{124-130}$Xe are produced by cosmic-ray spallation on target elements: Ba and light rare earth elements (LREE). Previous work [6-9] on Xe in eucritic meteorites (Vestan and anomalous) has focused on the Pu-Xe dating system, which utilises the spontaneous fission of ^{244}Pu to $^{131-136}$Xe with a half-life of 80 Myr. This work also showed the presence of excesses of ^{129}Xe* in several eucritic meteorites. ^{129}Xe* is produced by radioactive decay of ^{129}I with a half-life of 16 Myr and has been shown to be a reliable early Solar System chronometer [10-11]. By irradiating samples with thermal neutrons, stable ^{127}I is converted to ^{128}Xe*, allowing simultaneous measurement of ^{129}Xe* and ^{127}I (via ^{128}Xe*). A consistent relationship between ^{129}Xe* and ^{128}Xe* during step-heating indicates the ^{129}Xe* has remained *in situ* in iodine sites and therefore the ^{129}Xe*/^{127}I ratio is representative of the age of closure to Xe. I-Xe ages are referenced to a standard, enstatite from the aubrite Shallowater, which has an absolute age of 4562.3 ± 0.4 Myr [12].

Here we examine the isotopic signatures of Xe produced from short-lived isotopes ^{244}Pu and ^{129}I in the anomalous eucrites Ibitira [3] and Bunburra Rockhole [4] and the Vestan eucrites Juvinas and Béréba, in order to understand more about the history of differentiated asteroids in the early Solar System.

Methods: Xenon isotopic ratios in two sets of whole-rock samples (one unirradiated, one irradiated) from Ibitira, Bunburra Rockhole, Juvinas and Béréba were measured using the RELAX (Refrigerator Enhanced Laser Analyser for Xenon) mass spectrometer [13-15]. Sample masses ranged from 1.0-4.5 mg. The gases were released by laser step-heating. 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 isotopic abundances of the samples. Before Xe analyses, the irradiated samples were wrapped in aluminium foil and placed in glass vials that were evacuated and sealed before being exposed to thermal neutrons (6.82×10^{18} n cm^{-2}) at the Petten nuclear reactor, Netherlands, to covert ^{127}I to ^{128}Xe*. Samples of Shallowater enstatite were included in the same irradiation to monitor conversion of ^{127}I to ^{128}Xe. During this process heavy Xe isotopes are also produced from neutron-induced fission of ^{235}U.

Results and discussion: *Xenon components* Unirradiated samples show excesses of $^{124-130}$Xe consistent with spallation of material with a chondritic Ba/LREE ratio [16], and excesses of $^{131-136}$Xe indicating fission of ^{244}Pu and/or ^{238}U (the data do not allow distinction between the two). ^{244}Pu is thought to dominate the fission component in ancient samples [17] so the fission-Xe seen here has been attributed to ^{244}Pu, consistent with previous work [10-13]. A small contribution from trapped Xe was seen ($0.2\text{-}5.6\times10^{-12}$ cc atoms ^{132}Xe at STP g^{-1}) only at low-temperatures (except in Ibitira). This is consistent with adsorption of terrestrial

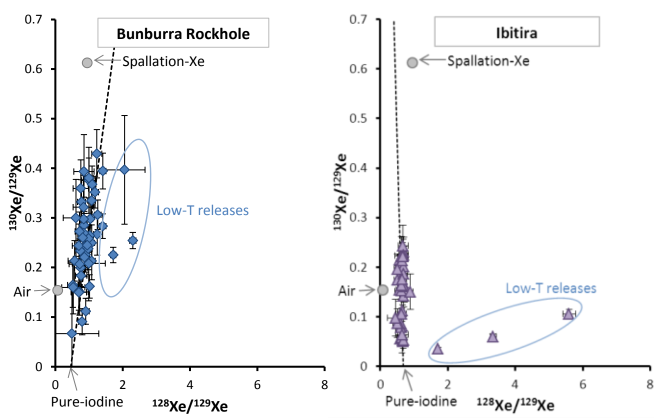

Figure 1. *Isochron plots for irradiated samples of Bunburra Rockhole and Ibitira. Uncorrected ^{130}Xe and ^{128}Xe are normalized to ^{129}Xe. Data from both meteorites form coherent isochrons (dashed lines) between spallation-Xe and pure-iodine end-members. The initial iodine ratios correspond to I-Xe ages of 7 ± 9 Myr and 7 ± 1 Myr after Shallowater for Bunburra Rockhole and Ibitira respectively. Shallowater has an absolute age of 4562.3 ± 0.4 Myr [12]. Samples of Juvinas and Béréba failed to form coherent isochrons.*

atmospheric Xe. High-temperature gas releases were dominated by spallation and fission Xe.

I-Xe system All samples showed excesses of ^{129}Xe*. To determine whether the excesses were produced by in situ decay of ^{129}I the I-Xe system in the irradiated samples was examined. Ordinarily ^{128}Xe, ^{129}Xe and an iodine-free isotope (usually ^{132}Xe or ^{130}Xe), corrected for contributions from spallation and fission are used. In these samples, iodine is released in high temperature steps that contain an insignificant amount of trapped Xe, so uncorrected ^{130}Xe (to which, only spallation-Xe contributes) was used. In the ^{128}Xe, ^{129}Xe, ^{130}Xe system the data reveal mixing between spallation and iodine-derived Xe (Figure 1). All samples showed data points that fell to the right of the spallation-air mixing line indicating the presence of ^{127}I in the samples. The high temperature data appear to form mixing lines between spallation and iodine end-members that can be interpreted as isochrons originating at the spallation composition. Bunburra Rockhole and Ibitira produced more well-defined trends than Juvinas and Béréba (*not shown in Figure 1*). The initial iodine ratios obtained from York fits correspond to I-Xe ages of 7 ± 1 Myr (Ibitira) and 7 ± 9 Myr (Bunburra Rockhole) after Shallowater. This gives an absolute age of 4555 ± 1 Myr for Ibitira which agrees well with Mn-Cr [18], Pb-Pb [19] and Pu-Xe ages [9].

^{244}Pu-^{129}I relationship: It was observed (Figure 2) that in these samples ^{129}Xe* produced from ^{129}I correlates with fission -Xe from ^{244}Pu, indicating co-location of the parent elements. Comparison of the systematics of iodine-derived isotopes and spallation-Xe (from Ba and LREE) confirms that the iodine retained in these rocks behaved as an incompatible element during their formation. Analysis of irradiated samples showed that iodine concentrations and initial I/Pu ratios were comparable among the various samples, demonstrating that variations in ^{129}Xe*/^{136}Xe* seen among the meteorites (Figure 2) correspond to differences in the closure time to Xe loss – lower ratios require later resetting – rather than differences in volatile content. Ibitira and Bunburra Rockhole closed earlier to Xe loss than the Vestan eucrites, suggesting an extended period of processing on Vesta compared to the parent body of the anomalous eucrites.

If a simple open-model is assumed, based on the ^{129}I/^{244}Pu ratios and decay rates of ^{129}I and ^{244}Pu, Xe loss on Vesta continued for ~50-100 Myr after geological activity on the parent body of Ibitira ceased. The faster cooling rate of the anomalous eucrite parent bodies can be explained if they were smaller than Vesta. The larger size of Vesta may therefore be the reason it has escaped catastrophic disruption from collisions that destroyed the other differentiated asteroids in the early Solar System.

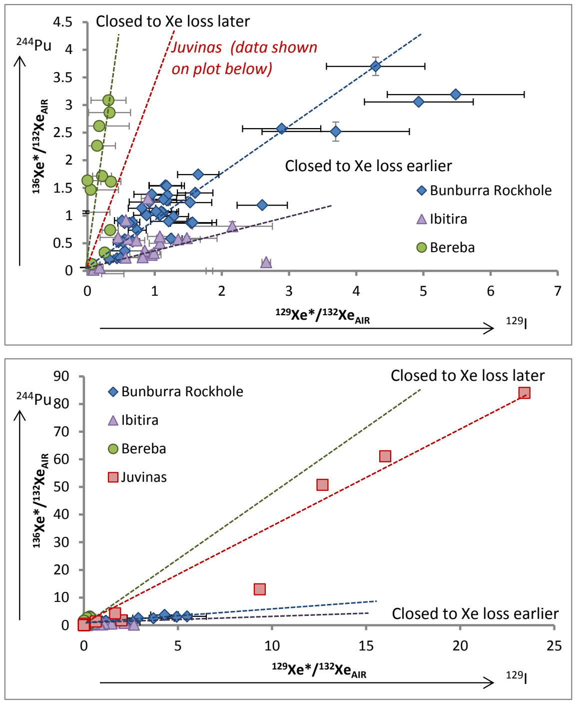

Figure 2. *Three isotope plot showing ^{136}Xe* (from ^{244}Pu), ^{129}Xe* (from ^{129}I) normalised to fission-corrected ^{132}Xe$_{AIR}$ in unirradiated samples. Each sample shows a distinct ^{129}I/^{244}Pu ratio with the anomalous eucrites showing higher ^{129}I/^{244}Pu ratios. Given that ^{129}I has a shorter half-life (16 Myr) than ^{244}Pu (80 Myr) this suggests that anomalous eucrites closed to xenon loss earlier than Vestan eucrites.*

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