THE I-Xe SYSTEM IN THE EARLY SOLAR SYSTEM. Jamie Gilmour[1], Olga Pravdivtseva[2], Alexis Busfield[1] and Charles Hohenberg[2] School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom. Jamie.gilmour@manchester.ac.uk, [2]McDonnell Center for the Space Sciences and Physics Department, Washington University, St Louis, Missouri 63130, USA. olga@wuphys.wustl.edu

Introduction: [129]I was the first decay product of a short-lived radionuclide to be identified in the early solar system[1] The methodology set the precedent for future identification of other extinct radioisotopes; excesses of the decay product, [129]Xe, were identified and the magnitude of these excesses was shown to correlate with iodine content.

It is unsurprising that [129]I was the first radioisotope identified – its decay product, xenon, is a noble gas so it is extremely depleted in solid phases. In fact, xenon is depleted by four orders of magnitude relative to elements of comparable mass in CI chondritic material (Fig. 1). Since the relative isotopic abundance of [129]I, like that of other extinct short-lived radioisotopes, is $\sim 10^{-4}$, this means that the atomic abundance of [129]Xe from [129]I decay is similar to that of stable isotopes of xenon in solid samples that have retained xenon from the early stages of the evolution of the solar system.

Methodology: The methodology of I-Xe analysis has recently been described in detail [3]. Briefly, samples are subject to neutron irradiation along with aliquots of pyroxene from the anomalous enstatite achondrite Shallowater. This is used as a monitor of the efficiency with which [127]I is converted to [128]Xe by neutron capture followed by beta decay, because it has a reproducible initial iodine ratio. Step heating analysis is usually employed; samples are heated in a sequence of increasing temperatures, the gas released at each temperature being analysed. The principle employed is that different sites release xenon at different temperatures. Where the same ratio of excess [129]I (from [129]I decay) to excess [128]Xe (from neutron capture on [127]I in the reactor) is observed across consecutive releases, this is identified as corresponding to a reproducible initial iodine ratio for the sample being analysed. Such ratios are compared to the same ratio obtained from analyses of the Shallowater aliquots irradiated at the same time as the sample. From this comparison, the time of closure to xenon loss relative to the closure age of Shallowater can be calculated directly. Strictly, the initial iodine ratio is deduced as a fraction or multiple of that in Shallowater – chronological interpretation of variations in initial iodine ratio assumes isotopic homogeneity across the region of the solar system under consideration, but there is no evidence of variation.

Relative I-Xe Chronology: Early studies of the I-Xe system focused on analyses of whole rock samples of meteorites [e.g. 4]. These proved hard to relate to macroscopic properties of the meteorites analysed, with the notable exception of enstatite chondrites [5]. When technological advances allowed finer scale examination the reason for this became apparent; many of the host phases of iodine that dominated whole rock analyses of ordinary and carbonaceous chondrites proved to be secondary [e.g. 6,7,8]. The case of enstatite chondrites can be understood because iodine trapped in enstatite dominates the high temperature releases in these meteorites.

To a significant extent, then, the I-Xe chronometer provides a record of the timing and nature of processing that occurred on parent bodies. In Fig. 2 we summarise the distribution of I-Xe ages of clasts, chondrules and single mineral phases from the recent literature. Each well defined I-Xe age with associated error has been used to generate a unit area Gaussian, and these have been summed together to provide a relative
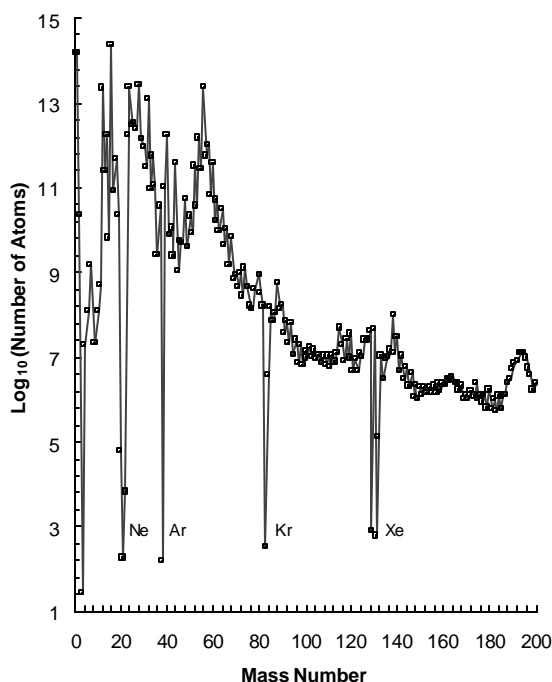

Fig. 1. Number of atoms at each mass number in a 10 micron sphere of CI material. Mass numbers corresponding only to a noble gas isotope exhibit severe depletion. Data from [2].

frequency plot as a function of time relative to Shallowater. It is apparent that the earliest processes recorded by the chronometer (chondrules, igneous clasts and dark inclusions) predate Shallowater closure by around 5 Ma, while the rate of events recorded by the system declined by a factor of 10 within about 10Ma after Shallowater closure and by a factor of ~100 within a further 20 Ma.

Absolute I-Xe Chronology: A major advance in the field of I-Xe dating came when the closure age of Acapulco phosphates was determined relative to Shallowater enstatite [9,10]. Since the Pb-Pb age of Acapulco phosphates was known [11], this provided an absolute age of Shallowater enstatite – there is no need to replace the radiation monitor with one which can itself be directly dated. This calibration in turn provides absolute I-Xe ages for all samples referenced to Shallowater. Subsequent consideration of a variety of samples with I-Xe and Pb-Pb ages showed coherent evolution (Fig. 3) and led to refinement of the absolute age of Shallowater enstatite closure to 4563.3 ± 0.4 Ma[3] .

With this calibration, the highest initial I-Xe ages correspond to closure of clasts and the earliest chondrules at around 4568 Ga – adopting a 2 Ma offset for CAI formation based on the ^{26}Al system would lead to the earliest solar system ages being around 4570Ga. It is encouraging that this age, deduced on the assumption that the I-Xe system was a reliable chronometer[12], was subsequently verified by other means[13].

See also abstracts by Pravdivtseva *et al.*, Filtness *et al.* and Holland *et al.* at this meeting.

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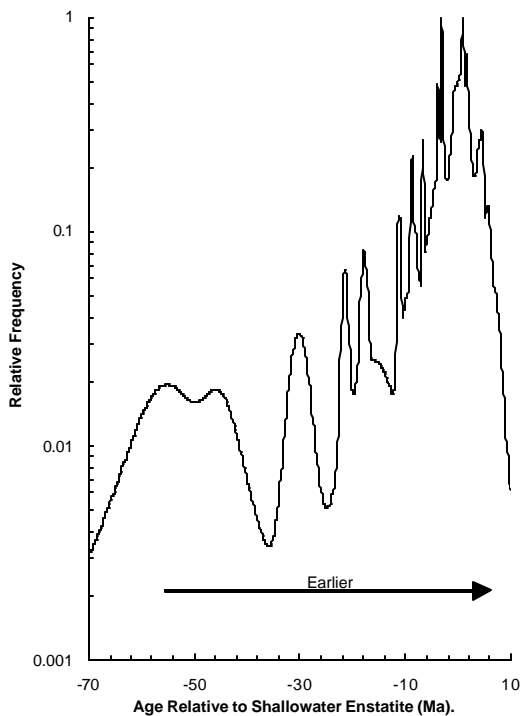

Fig. 2. Relative frequency of literature I-Xe ages relative to Shallowater ("whole rock" ages are not included) produced by summing unit-area Gaussian distributions.
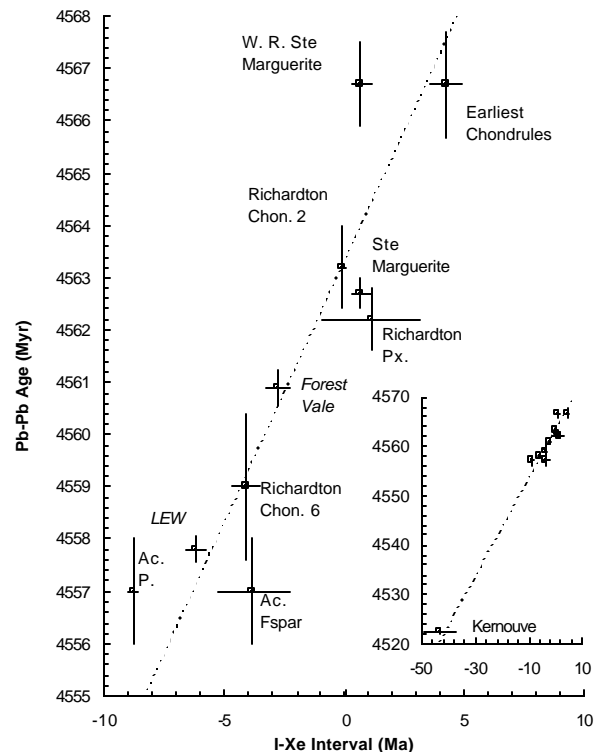

Fig. 3. Comparison of closure intervals relative to Shallowater in the I-Xe system with Pb-Pb data from the same or arguably similar samples. A gradient 1 line is a reasonable fit to the data, suggesting coherent evolution of these two isotopic systems and allowing a precise closure age for Shallowater in the Pb-Pb system to be determined. After reference [3] where data sources are listed.