FIRST I-XE AGES OF RUMURUTI CHONDRITES AND THE THERMAL HISTORY OF THEIR PARENT BODY. J. L. Claydon[1,2], A. Ruzicka[3], S. A. Crowther[2], M. Y. P. Lee[2], A. Bischoff[4], H. Busemann[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, Manchester, M13 9PL, U.K. [3] Cascadia Meteorite Laboratory, Department of Geology, Portland State University, Portland, Oregon, 97207, U.S.A.[4]Institut für Planetologie, Universität Münster, 48149 Münster, Germany. (email: j.claydon@nhm.ac.uk.).

Introduction: Rumuruti (R) chondrites are distinguished as a group from other chondrites by their oxygen isotope ratios and high degree of oxidation [1, and references therein]. Most R chondrites are regolith breccias sampling several lithologies that contain clasts of varying metamorphic grade (3-6) [2]. Previous work on *ordinary* chondrites has established a correlation between the degree of metamorphism and the age of the sample [3-4]. This supports the "onion shell model" of thermal processing, whereby an internal heat source (e.g. decay of ^{26}Al) produces a layered parent body with the centre reaching higher peak temperatures, and cooling more slowly, than the outer layers. In the contrasting "rubble-pile" model, early, layered planetesimals were fragmented and reassembled before final cooling [5]. Whether the onion shell is the common pattern for other meteorite groups is unknown.

The chronology of the R-chondrite parent body is not well established: only the Ar-Ar [6] and Mn-Cr [7] systems have been examined. Here, we are studying the I-Xe system in R-chondrite samples of varying metamorphic grade to establish the chronology of their parent body and investigate whether I-Xe ages correlate with extent of thermal processing as predicted by the onion shell model. Excesses of ^{129}Xe* have been reported in R-chondrites [8-10], however, the I-Xe [11-12] system in R-chondrites has not been studied previously.

Experimental Methods: Metamorphic grades of clasts in a polished section of NWA 6492 were determined using BSE imaging and optical microscopy at Cascadia Meteorite Laboratory, Portland State University. Six thin disks (3 mm diameter) were then extracted from chosen clasts and matrix. Prior to Xe analysis each disk was split into aliquots ~1 mm diameter. Only one aliquot of each has so far been analysed.

Samples (Table 1) were weighed, wrapped in aluminium foil and loaded into quartz tubes that were evacuated and sealed. The samples (along with the irradiation standard: enstatite from the Shallowater meteorite) were then included in irradiation MN11c at the Petten reactor in the Netherlands and exposed to thermal neutrons (6.42×10^{18} n cm^{-2}) to convert the stable isotope ^{127}I to ^{128}Xe*. This allows simultaneous measurement of the ^{129}I (half life 16 Myr) decay product (^{129}Xe*) and a stable iodine isotope (^{127}I as ^{128}Xe*). A correlation between ^{129}Xe* and ^{128}Xe* during step-heating of a sample indicates that ^{129}Xe* is derived from iodine. By measuring the ratio of ^{129}Xe* and ^{127}I, the relative age of the material can be determined. This is then referenced to a standard of a known age (4562.3 ± 0.4 Myr for Shallowater enstatite [13]) to calculate an absolute age. In addition, irradiation produces ^{131}Xe from Ba or Te and ^{131}Xe, ^{132}Xe, ^{134}Xe and ^{136}Xe from neutron-induced fission of ^{235}U.

Table 1. *Samples of R-chondrite meteorites included in I-Xe analyses. *Samples RA5 and RA6 released very large amounts of hydrocarbons during low-temperature heating which rendered the mass spectrometer unusable for several days. Analyses of these two samples are incomplete.*

Meteorite	*Sample name*	*Metamorphic grade*	*Sample type*
NWA 6492	RA1	Low-subtype 3	Clast
	RA2	Mid-subtype 3	Clast
	RA3	High-subtype 3	Clast
	RA4	Mixture	Matrix
	RA5*	5-6	Clast
	RA6*	5-6	Clast
NWA 3364	RB1	5	Whole-rock

Following irradiation the samples were laser step-heated and xenon isotopes analysed using the resonance ionization mass spectrometer RELAX (Refrigerator Enhanced Laser Analyser for Xenon) [14-16].

Samples RA5 and RA6 released very large amounts of hydrocarbons during low-temperature heating which rendered the mass spectrometer unusable for several days. These large releases have been attributed to remnants of the epoxy the samples had been encased in during preparation. An attempt was made to remove the epoxy from remaining aliquots of RA5 and RA6 by washing the samples in acetone in an ultrasonic bath for 3 hours before RELAX analyses; however, this was unsuccessful. The type 5-6 samples from NWA 6492 are therefore still awaiting analysis. To allow comparison pending completion of these analyses, we report here results from a metamorphosed R-chondrite, NWA 3364 (type 5), also included in irradiation MN11c.

Results: Previous xenon analysis of unirradiated samples of R-chondrites NWA 755, NWA 830 and NWA 3364 by this group [17] showed the presence of ^{129}Xe*, a trapped component consistent with Q-Xe

Table 2. *I-Xe ages (Myr) of samples listed in Table 1, excluding RA5 and RA6. Negative relative I-Xe ages indicate samples are younger than the Shallowater aubrite (4562.3 Myr [13]). Sample RA1 produced two isochrons at different temperatures (T).*

Sample	*I-Xe age relative to Shallowater*	*Absolute I-Xe Age*	*Error*
RA1 High-T	*-6.8*	*4555.5*	*1.0*
RA1 Low-T	*-8.8*	*4553.4*	*1.6*
RA2	*-5.6*	*4556.7*	*2.8*
RA3	*-10.9*	*4551.4*	*4.5*
RA4	*-11.9*	*4550.4*	*2.0*
RB1	*-14.1*	*4548.2*	*1.8*

(probably modified by atmospheric-Xe) and fissiogenic-Xe, attributed to spontaneous fission of ^{244}Pu. No evidence for spallation-Xe (target elements Ba and rare earth elements) or solar-wind Xe was seen. In the irradiated R-chondrites reported here, excess ^{131}Xe* above a fission component was observed in all samples. This is attributed to neutron-capture on Te, rather than Ba due to the high abundance of sulfides in R-chondrites (up to 11 wt% [1]) with which Te has an affinity. The lack of spallation-Xe also implies low Ba concentrations, since reported cosmic-ray exposure ages are similar to those of eucrites [18] that do contain spallation-Xe [17]. The contribution from fissiogenic-Xe is larger in irradiated samples (~10^8 atoms ^{134}Xe* g^{-1}) than in unirradiated samples (~10^7 atoms ^{134}Xe* g^{-1} [17]) indicating neutron induced fission of ^{235}U.

$^{132}Xe_Q$ (corrected for fission-Xe) and ^{128}Xe* (above the $^{128}Xe/^{132}Xe_Q$ ratio) released from each heat-step were normalised to ^{129}Xe and 3-isotope diagrams plotted to examine the relationship between ^{129}Xe* and ^{127}I (via ^{128}Xe*). All samples showed uncorrelated ^{128}Xe* at low temperatures. This can be explained by loss of ^{129}Xe* from low-temperature sites over time, late-stage addition of iodine on the parent body or contamination by terrestrial iodine. At high-temperatures, consecutive heat-steps fell on isochrons indicating the presence of *in situ* ^{129}Xe* from ^{129}I. RA1 data are consistent with two isochrons at different temperatures. The I-Xe ages and corresponding absolute ages associated with these isochrons are shown in Table 2.

Discussion: The I-Xe ages show that closure to Xe-loss in these R-chondrites occurred between 4556 ± 1 - 4548 ± 2 Myr ago. The oldest ages (~4555 Myr) of samples RA1 and RA2 appear to be too late to date chondrule formation, suggesting some secondary processing occurred in even the most primitive samples. A trend of more recent resetting of the I-Xe system with increasing degree of thermal processing is seen between samples RA1, RA2 and RA3 (type 3), and sample RB1 (type 5), with the strongly metamorphosed sample showing the youngest I-Xe age; this is consistent with the onion shell model. Mixed sample RA4 appears to record late resetting consistent with the higher type. However, further analyses of I-Xe ages of R-chondrite material (including type 5-6 material from NWA 6492) is required before confidence can be placed on a correlation between closure to Xe-loss and thermal processing. This work is in progress.

The I-Xe ages reported here are *younger* (reset more recently) than Mn-Cr ages of type 3 material (~4560-4562 Myr) and metamorphosed material (~4552 Myr) [7] by ~5 Myr; as both systems date silicate materials this is not expected. I-Xe ages systematically *older* than Mn-Cr ages have been reported in enstatite chondrites [19] but when a correction factor based on the proposed radial heterogeneity of Mn in the early Solar System [20] was applied, the correlation between I-Xe and Mn-Cr ages improved. R-chondrites are much more oxidised than enstatite chondrites, suggesting they formed at a greater radial distance from the sun. It follows that radial heterogeneity of Mn could produce younger I-Xe ages than Mn-Cr ages in R-chondrites (further from Sun) and older I-Xe ages than Mn-Cr ages in enstatite chondrites (closer to Sun). However, [21] re-examined the Mn-Cr system and found Mn isotopes to be homogenous and argued that using a terrestrial $^{54}Cr/^{52}Cr$ ratio to correct the data had produced the apparent radial heterogeneity. To test this hypothesis, further I-Xe and Mn-Cr analyses should be carried out on mineral separates from the same R-chondrite material.

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