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First I-Xe Ages of Rumuruti Chondrites and the Thermal History of Their Parent Body

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Aim: Determine I-Xe ages of R-chondrite material of varying metamorphic grade to test the validity of the onion shell model for the R-chondrite parent body.

Introduction

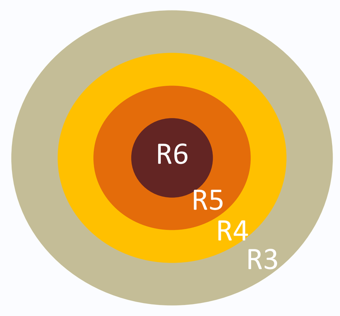
Rumuruti (R) chondrites

- Oxygen isotope ratios and high oxidation state distinguish them from other meteorite groups [1, and references therein].
- Most are regolith breccias, sampling several lithologies [2].
- Contain material that experienced varying degrees of metamorphism [2]:

  R3 (least metamorphosed) → R6 (most metamorphosed).
- ^{129}I decays to ^{129}Xe* (half-life = 16 Myr). ^{129}Xe* has been detected in R-chondrites [3-5] but the I-Xe system has not been investigated previously.
- Chronology not well examined: only Ar-Ar [6] and Mn-Cr [7] systems.

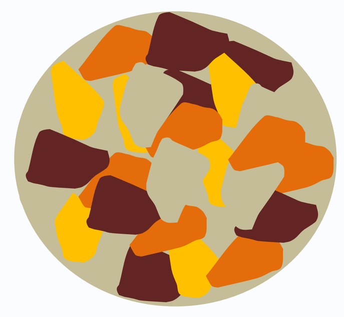
Thermal Processing and Closure Ages

"Onion shell" –



- Internal heat source (e.g. ^{26}Al) → layered parent body.
- Interior hotter, cools slower.
- Metamorphic grade should correlate with closure age, seen in ordinary chondrites [8, 9].

"Rubble Pile" –



- Early, layered planetesimals fragmented.
- Reassembled, as a "rubble pile" continued cooling.
- Closure age (e.g. length of cooling time) does not correlate with metamorphic grade [10].

Methods

Table 1. Sample details

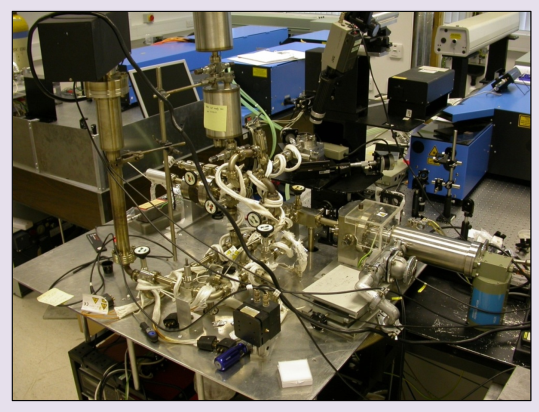
Meteorite	Sample name	Metamorphic grade	Sample type
NWA 6492	RA1	Low R3	Clast
	RA2	Mid R3	Clast
	RA3	High R3	Clast
	RA4	Mixture	Matrix
	RA5	R5-R6	Clast
	RA6	R5-R6	Clast
NWA 3364	RB1	R5	Whole-rock

Metamorphic grades of NWA 6492 were determined using optical microscopy at Cascadia Meteorite Library.

Irradiation

- Samples were weighed, wrapped in aluminium foil, loaded into quartz tubes, sealed & evacuated.
- Irradiated at Petten reactor, Netherlands.
- Exposed to thermal neutrons (6.42×10^{18} n cm^{-2}).

Refrigerator **E**nhanced **L**aser **A**nalyser for **X**enon



Xe isotopic analyses

- Samples were laser step-heated.
- Xe isotopic analyses carried out using the **RELAX** RIMS instrument [11-13].
- Samples RA5 and RA6 released very large amounts of hydrocarbons rendering the mass spectrometer unusable for several days.

  → RA5 and RA6 are still awaiting analyses.

  → Data from analyses of NWA 3364 (R5) (included in the same irradiation) are reported here to allow comparison of R3 and R5 material.

Results

Figure 1. I-Xe isochron plot

Only high-temperature steps that show a consistent correlation between ^{128}Xe* and ^{129}Xe, are included here.

Low-temperature steps (not shown) released uncorrelated ^{128}Xe* that can be attributed to terrestrial contamination, late-stage addition of ^{127}I or loss of ^{129}Xe* from low-T sites.

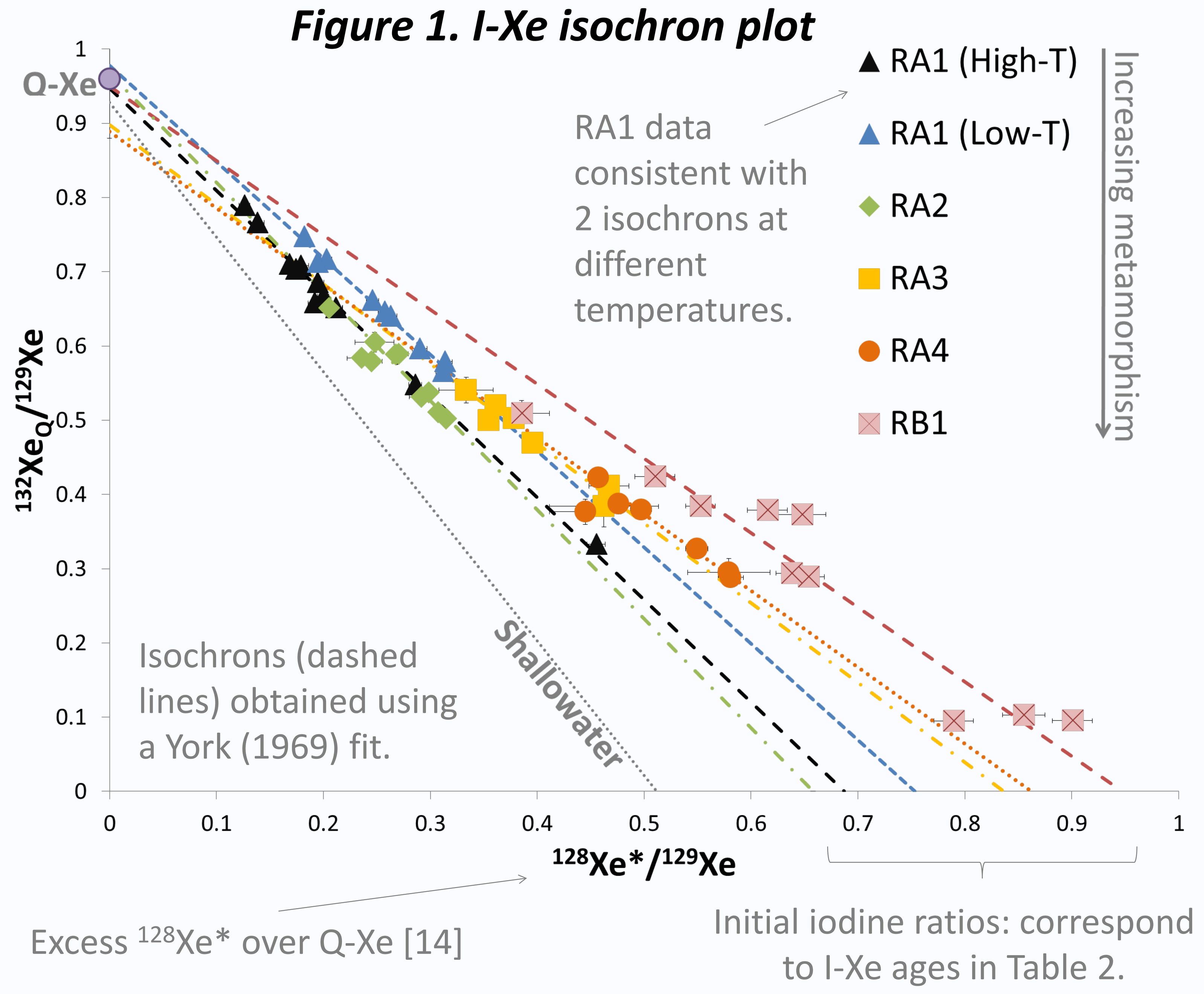


Table 2. I-Xe ages (Myr)

Sample	I-Xe age relative to Shallowater (-ve ages indicate later closure)	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

I-Xe ages (Myr) are given relative to the I-Xe irradiation standard: enstatite from the aubrite, Shallowater, absolute (Pb-Pb) age of 4562.3 ± 0.4 Myr [15].

Discussion

R3 samples show earlier closure to Xe loss than R5 sample, consistent with the onion shell model.

- Primitive, type R3 samples show older I-Xe ages than R5 sample.
- Matrix sample RA4 appears to record later resetting, consistent with a higher metamorphic grade.
- The oldest ages (~4556 Myr) appear to be too late to date chondrule formation:

  → secondary processing occurred in even the most primitive samples.

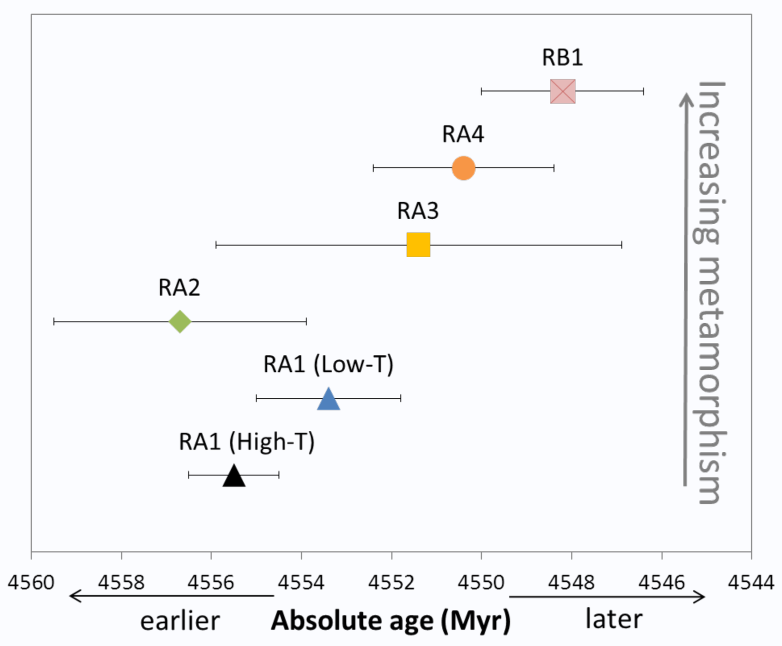
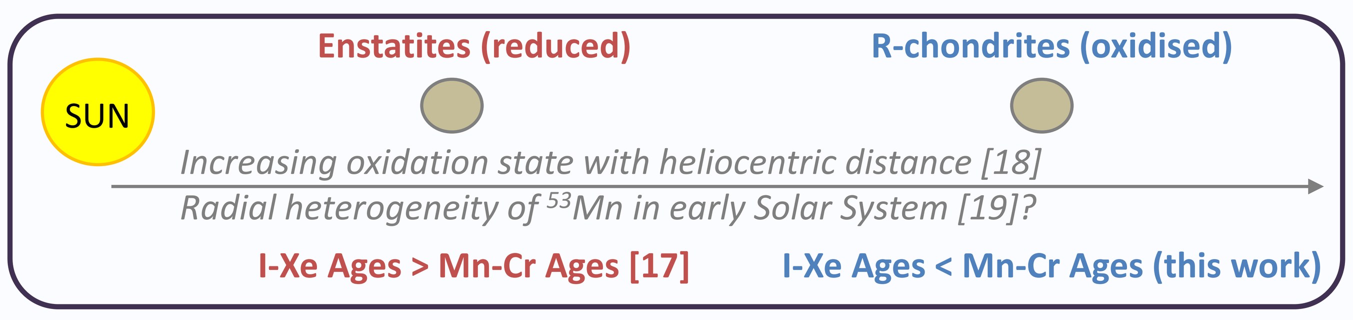


Figure 2. I-Xe ages appear to correlate with metamorphism

More I-Xe analyses are needed (including R5-R6 samples of NWA 6492) before confidence can be placed on this correlation.

Closure to Xe loss occurred at 4556 ± 1 – 4548 ± 2 Myr ~5 Myr younger than Mn-Cr ages [16] → heterogeneity of ^{53}Mn?



- I-Xe ages are *older* than Mn-Cr ages in *enstatite* chondrites [17] but *younger* in *R-chondrites*.

  → do differences between chronometers indicate ***radial heterogeneity of ^{53}Mn*** [19]?
- Application of a correction factor based on proposed radial heterogeneity of ^{53}Mn in the early Solar System improved the correlation between I-Xe and Mn-Cr ages in enstatites [17].

  → however, [20] re-examined Mn-Cr system and found homogenous Mn isotopes; attributed apparent heterogeneity to terrestrial ^{54}Cr/^{52}Cr ratio used in data correction.

To test this hypothesis, I-Xe and Mn-Cr analyses should be carried out on mineral separates from the same R-chondrite material.

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References: [1] Kallemeyn G. W. et al. (1996) *GCA 60*, 2243-2256. [2] Bischoff A. et al. (2011) *Chem. Erde-Geochem. 71*, 101-133. [3] Busemann H. et al. (2011) 42nd *LPSC* #2793 (abstract). [4] Nagao K. et al. (1999) *Ant. Met. R. 12*, 81-93. [5] Schultz L. et al. (2005) *MAPS 40*, 557-571. [6] Dixon E. T. et al. (2003) *MAPS 38*, 341-355. [7] Sigiura N. and Miyazaki A. (2006) *Earth Planets Space 58*, 689-694. [8] Göpel C. et al. (1994) *EPSL 121*, 153-171. [9] Trieloff M. et al. (2003) *Nature* 422, 502-506. [10] Grimm R. E. (1985) *J. Geophys. Res. 90*, 2022-2028. [11] Crowther S. A. et al. (2008) *J. Anal. Atom. Spectrom. 23*, 938-947. [12] Gilmour J. D. et al. (1991) *Meas. Sci. Technol. 2*, 589-595. [13] Gilmour J. D. et al. (1994) *Rev. Sci. Instrum. 65*, 617-625. [14] Busemann H. et al. (2000) *MAPS 35*, 949-973. [15] Gilmour J. D. et al. (2009) *MAPS 44*, 573-579. [16] Sigiura N. and Miyazaki A. (2006) Earth Planets Space 58, 689-694. [17] Busfield A. et al. (2008) *MAPS 43*, 883-897. [18] Rubin A. E. and Wasson J. T. (1995) *Meteoritics 30*, 569 (abstract). [19] Shukolyukov A. and Lugmair G. W. (2004) *GCA 68*, 2875-2888. [20] Trinquier A. et al. (2008) *GCA 72*, 5146-5163.