ORIGIN OF CAI RIMS--II: THE EVIDENCE FROM REFRACTORY METALS, MAJOR ELEMENTS AND MINERALOGY; D.A. Wark and W.V. Boynton, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721

In a number of recent papers [1,2,3] we have shown that the rims of five different Ca-Al-rich inclusions (CAI's) of various Types and Groups all show substantial (2 to 5 times) enrichments of the Rare Earth Elements (except Eu) over the REE abundances in the interior. This REE enrichment in the rims appears to be independent of the CAI formation process because it is found in both condensate (Type A) CAI's and evaporative residue (Type B) CAI's. The rim REE enrichment is also independent of the parental material, as it occurs on CAI's formed from both unfractionated Group I and fractionated Group II materials. These facts suggest that rims were produced at some time after the CAI's had been formed.

Since the shape of the REE pattern in each rim is essentially the same as in the interior (except for depletion in the rim of the most volatile REE, Eu and often Yb), each rim appears to have formed from the same material as its CAI. We hypothesized [1] that the surfaces of the precursor CAI's were strongly but briefly heated, causing volatilization of the more volatile constituents and leaving a refractory residue as a rim.

In addition to the REE analyses, we have investigated other chemical and mineralogical tests of our hypothesis, in each case checking whether or not there is an enrichment of refractory elements (or depletion of more volatile elements) in the rim relative to the interior. The seven tests are listed in the lefthand column of Table 1. The results of tests (1) and (2), showing that the ultra-refractory elements Zr and Hf are enriched respectively in rim perovskite and bulk rim, are consistent with the hypothesis. To counter possible objections that Zr, Hf, and REE enrichments might simply reflect a mineralogical enrichment of perovskite in the rim rather than a real refractory enhancement, we investigated the rim enrichments of ultra-refractory Sc and more volatile V, since these elements are not chiefly sited in perovskite. The table shows typical relative Sc enrichments and V depletions in the rim, again consistent with the hypothesis. Tests (5) and (6), based on the enrichments of the refractory metals Os and Ir, and depletions of the more volatile metals Fe and Ni, are completely independent of perovskite and again typically support the evaporative hypothesis.

In the final test, (7), the enrichment of refractory Al_2O_3 and depletion of volatile SiO_2 in the rim relative to the interior are consistent with the hypothesis. However, the decrease of refractory CaO and the increase of volatile MgO in rim relative to interior are not consistent with a simple evaporation model. In this connection, the available isotopic data [4], which show that Mg in the rim has almost normal Mg isotopic composition, also do not support simple volatilization, but both the isotopic data, and our chemical data, would be consistent with an influx of normal Mg following the evaporative stage of rim formation.

In conclusion, then, we believe that the various mineralogical and trace element results we have obtained provide strong evidence that a major part of the rim formation process involved production of a surface refractory residue, but that additional, unknown processes later partly modified certain isotopic and major element properties of the rims.

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Table 1. Ratios of rim:interior abundances for various parameters.

Parameter	Abundance in Rim/Abundance in Interior					
CAI Group & Type	IA	IB	IC	IIA	IIB	IIC
1. ZrO_2 % in perovskite	0.55/0.15 0.40/0.18	0.6/0.15	0.34/0.1	0.5/0.2	--	--
2. Bulk Hf ÷ CI	54/10	25/20	--	11/1.1	--	--
3. Bulk Sc ÷ CI	33/17 19/15	7/22	--	4.1/1.1	4.5/1.2	
4. V_2O_3 % in spinel	0.1/1.5 0.2/0.8	0.18/0.21	0.4/0.77	0.1/0.6	0.44/0.18	0.5/0.2
5. Bulk Ir ÷ CI	14/9 16/8	57/20	--	2.8/0.16	108/0.8	--
6. Metal grains (mean)						
(Fe + Ni) %	56/70 30/73	12/10	45/15	33/63	51/51	--
(Os + Ir) %	10/3 16/9	28/30	20/20	12/<1	20/20	
Mo %	5/6.5 14/5	15/21	6/19	10/7	5/4	--
7. Bulk major elements						
MgO %	19/4 19/3	22/6	19/5	11/7	--	24/8
CaO %	15/30 14/39	8/34	13/25	15/32	--	6/21
Al_2O_3 %	39/34 43/31	56/36	40/31	46/39	--	53/37
SiO_2 %	21/29 16/26	8/23	22/36	20/22	--	15/32

REFERENCES.

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