Refractory Element Fractionations in CV3 Carbonaceous Chondrites: What Role do CAIs Play?

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Abstract

Several studies, primarily Kornacki and Fegley (1986) and Munker et. al. (2003), suggested that calcium-aluminum-rich inclusions (CAIs), which are common to the CV3 subclass of chondritic meteorites, contain significantly lower Nb-Ta ratios than the accepted bulk solar system value. These studies have lead me postulate that; *CV3 carbonaceous chondrites display, on average, low Nb/Ta values because of the low Nb/Ta values in the CAIs.* Calcium, titanium, niobium, tantalum, zirconium, and hafnium abundances were measured via LA-ICP-MS analysis on five chondrules, two CAIs, and the matrix from the CV3 carbonaceous chondrite Allende. The matrix displayed average Nb/Ta and Zr/Hf ratios near the accepted bulk solar system values of 19.9 ± 2 and 34.3 ± 3.5 respectively. The chondrules extracted from Allende displayed variable Nb/Ta values that ranged from 3.8 to 24.2 (1σ = 10%), and Zr/Hf values that ranged from 30.4 to 41.0 (1σ = 10%). The CAIs displayed consistently low Nb/Ta values that ranged from 0.9 to 12.7 (1σ = 10%), and erratic Zr/Hf values that ranged from 12 to 73 (1σ = 10%). The Nb-Ta ratios in comparison with the Zr-Hf ratios show evidence that fractionation of Nb and Ta occurred independently of any Zr and Hf fractionation. Furthermore, within CAIs, there is evidence that as the Nb/Ta values decrease, the Zr/Hf values become more erratic. The reasons behind these low Nb/Ta ratios, and erratic Zr/Hf ratios found within these CAIs are not clear. Inaccuracy in the currently accepted 50% condensation temperatures of these refractory elements may provide insight into the mechanisms behind the observed fractionations.

Background Information

•Refractory Elements - Elements with 50% condensation temperatures lower than that of metallic iron (<1350K).

•Meteorite - Some portion of an extraterrestrial rock body that survives the passage through the Earth's atmosphere.

•Chondrite - A meteoritic body that exhibits no evidence of planetary differentiation, and is composed of a mixture of matrix, chondrules, and, commonly in carbonaceous chondrites CAIs.

•Carbonaceous Chondrite - A chondrite that is generally formed in more oxidizing environments, and has the largest proportion of volatile elements.

•Chondrule - A small millimeter-sized igneous sphere that has both melted and crystallized within the realm of space.

•Calcium-Aluminum-rich Inclusions - Clasts within chondrites that contain different chemical and mineralogical characteristics than all other chondritic components, primarily a relatively high abundance of refractory elements.

•Meteoritic Matrix - The cement that holds both the chondrules and the CAIs together within the chondrite, primarily a constituent of very fine-grained material containing fragments of CAIs and chondrules, as well as sulfides, metals, organic material, alteration products, and presolar grains.

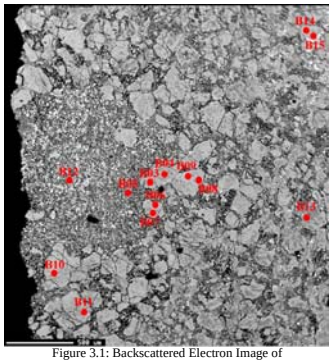


Figure 3.1: Backscattered Electron Image of the CAI in sample 3529-63-RR1. The red circles represent the points examined via LA-ICP-MS and qualitative microprobe analysis.

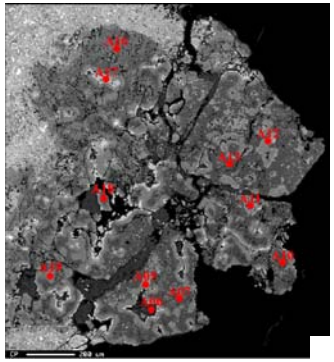


Figure 3.2: Backscattered Electron image of the CAI in sample 6529-61-RR1. The red circles represent the points examined via LA-ICP-MS and qualitative microprobe analysis.

Refractory Element Ratios for the Various Chondritic Constituents in Allende

Chondritic Constituent	Point Name	Nb/Ta (1σ = 10%)	Zr/Hf (1σ = 10%)
Matrix	Matrix1	16.2	34.7
	Matrix2	20.5	41.0
CAI in Sample 3529-63-RR1	B03	3.5	46.7
	B04	3.5	52.7
	B05	5.7	n.d.
	B06	2.7	63.8
	B07	3.3	49.7
	B08	7.1	56.8
	B09	4.9	39.1
	B10	4.0	41.1
	B11	3.4	46.2
	B12	4.6	n.d.
	B13	7.0	28.7
	B14	12.2	44.9
	B15	n.d.	n.d.
	B16	2.9	n.d.
CAI in Sample 3529-61-RR1	A05	2.0	n.d.
	A06	2.4	11.8
	A07	1.6	61.4
	A10	0.9	43.9
	A11	2.5	48.8
	A12	1.6	73.1
	A13	3.2	65.3
	A16	12.7	31.2
	A17	10.2	37.2
	A18	5.2	41.4
	A19	9.8	51.0
Chondrules	A7	22.3	38.1
		24.2	41.0
	A6	17.7	39.2
		16.3	39.2
	A5	10.4	30.4
	A4	3.8	39.4
	A3	10.0	37.6
		7.5	34.8
Bulk Solar System	Chondritic	19.9	34.3

Table 6.1: Refractory element ratios for single analysis points on the various chondritic constituents within the CV3 chondrite Allende obtained via LA-ICP-MS.

Nb/Ta vs. Zr/Hf for the Various Chondritic Constituents in the Chondrite Allende

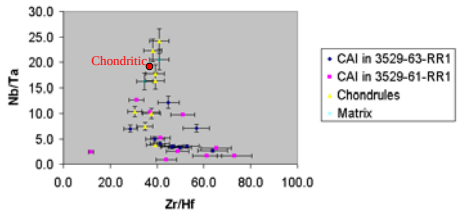


Figure 2.1: Nb/Ta values versus Zr/Hf ratios obtained via LA-ICP-MS for the various chondritic constituents studied.

Results

•The matrix displays chondritic Nb/Ta and Zr/Hf ratios.

•The chondrules display variable Nb/Ta ratios and relatively chondritic Zr/Hf ratios.

•The CAIs have variable Nb/Ta and Zr/Hf ratios.

Nb/Ta Histogram

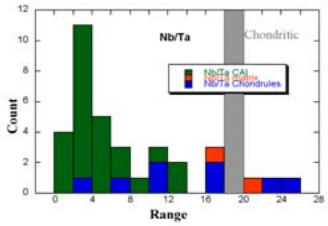
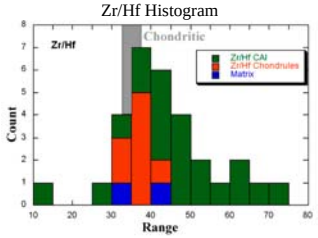


Figure 1.1: Histogram of the Nb/Ta ratios measured via LA-ICP-MS analysis on the three major chondritic constituents in Allende.

Zr/Hf Histogram



ıre 1.2: Histogram of the Zr/Hf ratios measured via ICP-MS analysis on the three major chondritic stituents in Allende.

Procedure

•Obtained polished, thick-sections of CAIs in Allende.

•Determined phases present via petrographic analysis.

•Performed qualitative microprobe analysis for normalizing the LA-ICP-MS data.

•Measured Ca, Ti, Nb, Ta, Zr, and Hf concentrations via LA-ICP-MS analysis on matrix, CAIs, and chondrules from the meteorite Allende.

Interpretations

•The meteoritic matrix displays near-chondritic values for both Nb/Ta and Zr/Hf.

•The chondrules display consistent Nb/Ta and Zr/Hf values internally. However, they display significant variation when compared to each other.

•The CAIs display consistently low Nb/Ta values both internally and in comparison to one another, and display erratic Zr/Hf ratios.

•Any Nb/Ta fractionations observed appear to be completely independent of any Zr/Hf fractionations (Figure 2.1).

•CAI Zr/Hf values appear to be more erratic in areas that have low Nb/Ta values (Figure 2.1).

•Inaccuracy in the currently accepted 50% condensation temperatures of these refractory elements may provide insight into the mechanisms behind the observed fractionations.

Acknowledgments

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