TRACE-ELEMENT INVENTORY OF THE ALLENDE (CV3) METEORITE;

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Of particular interest in meteoritics has been the extent to which condensation has played a role in the history of the solar nebula. For example, coarse-grained CAIs may contain the earliest and highest-temperature products of condensation, while fine-grained meteorite matrix contains the lowest-temperature components. In this abstract we report trace element compositions of a number of fractions of the Allende CV3 meteorite and examine the implications for the formation and history of individual components of the meteorite.

The primary separation parameter for the fractions we have analyzed is grain size. Two parent samples of Allende that weighed 8.2 g (A1) and 77.7 g (A2) respectively were gently crushed separately in an agate mortar until the material could pass through a 500 μm mesh or the material was clearly resistant to crushing (10 % olivine chondrules and fragments for A2). Samples with grain sizes ≥ 10 μm were obtained by sieving while smaller grain-size fractions were obtained from ethanol suspensions. Magnetic separation of coarse grained material was also carried out to remove relatively magnetic matrix clumps. The preservation of these clumps in all size fractions greater than 10 μm indicates that the crushing was not severe enough to break chondrules into the sub-10 μm fractions. Samples TDC (hand picked to remove sulfides), TC1C, and TH1C are nonmagnetic fractions while TH1A is a magnetic fraction. While the major contribution to the fine-grained material should be from the matrix, these separates cannot be regarded simply as matrix concentrates. Besides petrologically distinctive types of matrix e.g. accretionary matrix around chondrules and interchondrule matrix, there are probably also contributions from friable fine grained inclusions. The separation procedure makes no distinction as to petrological context.

Each separate was examined in an SEM for mineralogy and major-element chemistry. The two coarse-grained bulk fractions, TD1 and TCB, consist predominantly of unbroken matrix clumps and olivine fragments. Samples TAA1 and TAAA consist predominantly (>90 %) of single grains of olivine of variable fayalite content. Other minerals found in these separates included magnetite, pentlandite, Fe-Ni metal, chromite, clinopyroxene, enstatite, sodalite and nepheline. Samples TEC and TEA show progressive depletion in sulfides and enrichment in a refractory phase, possibly melilite or clinopyroxene although positive identification was not possible because of the extremely fine grain sizes of these two separates. TDC consists predominantly of forsteritic olivine chondrules and fragments with CAI material and pyroxene fragments, while TC1C and TH1C also contain Fe sulfide. The magnetic fraction, TH1A, has high concentrations of pentlandite, Fe-Ni metal, and magnetite.

Results of INAA analyses are given in Table 1. The range in standard deviations for individual analyses are listed in the last column. The high contents of Br, and in some cases W, may in part be due to contamination. The various grain size fractions are in general very similar to each other and also to bulk Allende. All size fractions from 1 to 10 μm have, within 40 %, the bulk Allende contents of such diagnostic elements as Co, Ni, Se (metal and sulfide), Cr, Zn, Ga (chromite and spinel), and Sc, Ir (refractory phases). The major component in all of these fractions is FeO-rich olivine. However, this olivine must be intimately mixed with metal, sulfide, chromite, and refractory phases to ensure approximately bulk Allende abundances of Co, Ni, Cr, Zn, Sc, and Ir even in the 1-2 μm fraction TEC. This is further illustrated in Figure 1 which shows that despite the high volatility of Se a clear correlation exists between Se and Ni in the grain-size fractions as is also the case for other components. This indicates that the abundance of Se in these separates is related to mineralogical association rather than volatility.

It is not clear whether the enrichment in LREE found in several samples is indicative of mobilization of highly incompatible elements or if it reflects a Group II pattern [1]. There is no indication for a volatility-related ultrarefractory-element pattern complementary to the Group II pattern. The abundances of the most refractory elements Hf, Lu, and Sc are not higher than those of the more volatile refractory elements such as La, Sm, etc.

The composition of TDC is very similar to an average chondrule composition previously determined [2]. As well as the highest refractory lithophile element concentrations, TDC also has the highest concentration of volatile Na. The other nonmagnetic fractions are related to this composition by the relative abundance of Se (hence sulfide) and the siderophile elements.

The compositions of the 1-10 μm fractions show good general agreement with those of Allende matrix [3, 4]. All of these samples match the bulk Allende composition within 50 %, but with lower refractory element abundances and higher Fe contents. Since it is unlikely that the fine-grained fractions contain significant amounts of material derived from larger chondrule fragments, chondrules and CAIs are not the only reservoir of refractory elements. Their contribution to the bulk inventory of refractory elements is at most about 30 %.

Sample TEA with a grain-size fraction below 1 μm is different in that it has higher contents of volatile elements (As, Cu, K, Na, Zn, and Sb), but a lower content of Ni, Co, and Se reflecting a lower sulfide abundance (Fig. 2). Lithophile refractory elements are enriched while refractory metals (Ir) are depleted. This sample has lower Mg and Fe than olivine-dominated samples. More than one carrier of volatile elements is required since Na, K, Sb, and Cu are unlikely to reside in a single phase. The sample is, however, so fine-grained that it is difficult to identify individual phases. This separate may contain material from disaggregated fine-grained CAIs. This would explain the increased abundances of the refractory elements as well as volatiles since these inclusions often contain Na-Al-rich alteration products such as nepheline. Allende fine-grained CAIs can also be enriched in Ga, As, Zn, and Br [5] which also have elevated abundances in TEA. However, this fraction is still dominated by olivine, and it does not have the pronounced Group II characteristics typical of fine-grained Allende CAIs. Sm/Lu in Allende CAIs is typically around 50×CI, whereas it is only 1.3×CI in TEA. Olivine analyses have shown elevated REE abundances [6] as well as Ca and Al [7] although the actual site of these elements is not clear. It should be stressed that this separate represents only a very small fraction of the total meteorite and may contribute a negligible amount to the bulk inventory.

References: [1] B. Fegley and A. Kornacki (1984) *LPSC XV*, 262 [2] B. Spettel *et al.* (1989) *Meteoritics*, in press. [3] A. Rubin and J.T. Wasson (1987) *GCA* **51**, 1923 [4] A. Bischoff *et al.* (1987) *Meteoritics* **21**, 328. [5] H. Palme and D. Wark (1988) *LPSC XIX*, 897. [6] G. Kurat and E. Zinner (1989) *Meteoritics*, in press. [7] G. Kurat *et al.* (1989) Z. *für Naturforschung* **44a**, 988.

Table 1: Allende grain size fractions

	parent sample A1 8.2 g						parent sample A2 77.7 g				
sample	TD1	TCB	TDC	TC1C	TAA1	TAAA	TH1C	TH1A	TEC	TEA	s.d.
size*	>85	37-85	>85	37-85	<10	<5	85-500	85-500	1-2	<1	%
%											
Mg	14.32	13.76	19.9	18.65	13.01	11.4			12.3	11.12	3
Al	1.46	1.29	4.45	4.88	1.58	1.25			2.03	2.81	3
Ca	1.62	1.67	3.36	1.74	1.31	1.03	2.7	1.15	1.16	2.43	6-10
Ti	0.088		0.27		0.064	0.11			0.12	0.15	20
Fe	22.34	23.2	6.35	9.56	26.17	25.61	13.8	25.25	24.24	21.77	3
ppm											
Na	2840	2620	8170	7620	3130	3295	5650	2220	2700	9950	3
Cl	250		796	1190		890			564	2060	6-20
K	270	268	750	744	322	580	570	250	343	1550	4-8
Sc	9.94	10.95	27.7	30.6	8.75	8.11	21.39	9.42	9.41	14.7	3
V	80.1	84.9	190	292	68.8	65.8			89.9	93.5	4
Cr	3600	3460	2601	2270	3490	3310	2880	3990	4620	5110	3
Mn	1380	1210	802	778	1545	1490	1056	1450	1435	1460	3
Co	606	678	106	445	655	564	339	758	503	297	3
Ni	15100	16000	2100	10100	16140	12500	7550	19000	10700	5930	5
Cu		141		150	157	145		120	126		15-20
Zn	113	116	99	150	131	150	120	110	194	253	6-14
Ga	6.08	5.36	2.5	2.7	7.27	6.33	4.2	6.32	10.1	11.7	4-15
As	1.39	1.38	0.25	0.62	1.74	1.82	0.72	2.25	1.92	5.59	3-10
Se	8.95	10.9	2	9.78	9.42	9.27	4.89	10.2	6.91	3.6	5-20
Br		1.6	16.7	7.62	3.09	6.94	3.16	2.08	3.17	23.1	4-10
Ru	1.11	1.5	1.8		1.25	1.4	1.73	1.46		1.9	10-20
Sb					0.27	0.48		0.12	0.18	0.75	5-10
La	0.47	0.44	1.52	1.31	0.47	0.74	2.32	0.43	0.52	1.53	4
Ce	1.2		4.3	3.4	1.2		5.7	1.1		3.8	8-20
Sm	0.307	0.3	0.922	0.83	0.268	0.295	1.03	0.278	0.328	0.705	3
Eu	0.106	0.096	0.25	0.209	0.088	0.085	0.215	0.0987	0.098	0.178	6-11
Dy	0.5	0.39	1.12	1.26	0.32	0.53	1.17	0.43	0.55	1	7-25
Ho	0.11	0.11	0.25	0.25	0.1	0.12	0.26		0.12		14-2
Yb	0.32	0.28	0.78	0.688	0.26	0.285	0.64	0.295	0.35	0.545	4-12
Lu	0.048	0.05	0.133	0.11	0.037	0.033	0.083	0.046	0.053	0.083	5-26
Hf	0.19	0.26	0.57		0.18	0.25	0.35	0.18			7-25
W	0.21	0.23	0.25		0.63	3.22		0.24	0.81	2.29	5-20
Re		0.096	0.12		0.08		0.094	0.083			7-20
Os	0.85	1.18	1.19	1.26	0.88	0.78	1.17	1.1	0.834	0.87	5-15
Ir	0.773	1.01	1.033	1.05	0.726	0.61	1.026	1.02	0.646	0.541	3
Au	0.109	0.102	0.041	0.018	0.137	0.178	0.072	0.216	0.08	0.168	3

* grain size in μm

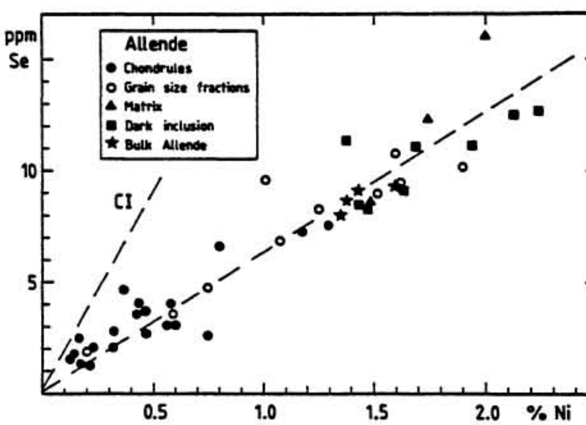

Figure 1.

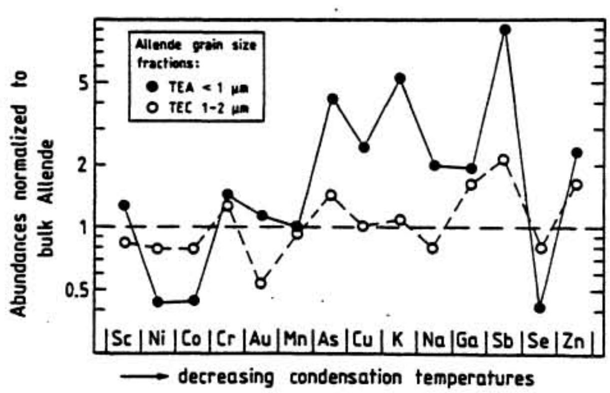

Figure 2.