THE BULK COMPOSITION OF "FREMDLINGE" FROM A CA,AL-RICH ALLENDE INCLUSION. H. Palme, I. D. Hutcheon*, and B. Spettel. Max-Planck-Institut für Chemie, D-6500 Mainz, F.R.Germany; *CALTECH, Pasadena, CA 91125, USA.

One of the most unusual components of Ca,Al-rich Allende inclusions are metal-sulfide-oxide assemblages containing large amounts of refractory metals (e.g. W, Ir, Os). These opaque assemblages were named "Fremdlinge" by El Goresy (1), indicating an origin independent of the formation of the host inclusion. Blum et al. (2), however, suggested that these objects may have formed by oxidation and sulfurization of refractory metal-rich alloys inside the host inclusion. The origin of "Fremdlinge" is of some importance, since refractory metal alloys are among the first phases to condense from a gas of solar composition (3). To clarify the relationship of "Fremdlinge" to the host inclusion requires the knowledge of their bulk composition.

Several large "Fremdlinge" were recovered from the CAI EGG-6. The largest object, ZELDA (1 mm diameter), was previously described (4). Bulk compositional data for another large object, ZORBA, were reported recently (5). Bulk compositions for seven "Fremdlinge" (including ZELDA), were obtained in this study (Table 1). The abundances of refractory metals, normalized to CI and Ni, are plotted in Fig. 1. Elements are arranged in the order of decreasing condensation temperatures. A smooth pattern is observed for most "Fremdlinge". FLORENCE, with a more fractionated pattern, is incompletely sampled. All other "Fremdlinge" (except E 2, Fig.1) have spherical shapes. All samples plotted in Fig. 1 are strongly depleted in W. For two of them only upper limits could be obtained. Although simultaneous depletion of Mo and W is not uncommon in bulk CAIs (6), the strong depletion of only W has never been observed before.

The otherwise smooth pattern of refractory metals would suggest an origin by condensation from a gas of solar composition (3), as the metals are essentially plotted according to their vapor pressures. Although these metals (e. g. Mo and Ir) have **similar physical** properties (i.e. vapor pressures), they are **chemically dissimilar,** leading to the formation of a variety of different phases and redistribution of the refractory metals during cooling, oxidation and sulfurization. The phase assemblages and the partitioning of refractory metals into various phases in four different "Fremdlinge" were essentially the same as those reported for ZELDA (4):

1) Mo is entirely concentrated in MoS_2; no other phase containing more than 0.1% Mo was observed.

2) Pt and Rh are concentrated in NiFe. Their contents in metal are constant in a given "Fremdling" but variable among "Fremdlinge". The Rh points plotted in Fig. 1 were obtained from EMP data on these metals by assuming Pt/Rh in the metal to be the same as in the bulk (all other data by INAA). Occasionally, local enrichments of Pt were found (up to 15%) associated with sulfurization of NiFe, similar to what is observed in ZELDA (4).

3) Os and Ru are predominantly contained in tiny ($\sim$1-2 μm) Os-Ru alloys.They are found to be included in all other phases.

The extensive redistribution of elements requires, for example, diffusion of Pt in NiFe over distances of 50 μm. Nevertheless, individual "Fremdlinge" appear to have retained their bulk refractory metal patterns despite this extensive oxidation and sulfurization of the original metal alloy. The differences in the depletion of Pt and Rh among "Fremdlinge" (Fig. 1) points to a different nebular history of individual "Fremdlinge". Some have ceased to equilibrate with the nebular gas at a lower temperature than others.

The large W depletions may, however, be attributed to the metamorphic history of the "Fremdlinge", within the CAI. Fig. 2 shows the refractory

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siderophile element patterns for three bulk samples of EGG-6. Tungsten is obviously not lost from the bulk inclusion. It rather appears to be more uniformly distributed than the other refractory metals. This would suggest redistribution of W during metamorphism, perhaps as WO_3. This conclusion is supported by INAA analyses of single mineral grains from EGG-6. These data also indicate that the bulk of the refractory siderophiles in EGG-6 is not provided by big "Fremdlinge".

Summary: The EGG-6 "Fremdlinge" formed by condensation from a gas of solar composition. Their refractory metal patterns are variable suggesting formation under slightly different nebular conditions. Equilibration of these "Fremdlinge" with a Ca,Al melt, oxidation and sulfurization occurred inside the inclusion (2). Loss of W from the "Fremdlinge" is probably a result of extensive alteration (oxidation, sulfurization).

Ref.: (1) El Goresy A. et al. (1978) PLSC 9th, 1279. (2) Blum J.D. et al. (1988) Nature 331, 405. (3) Palme H. and Wlotzka F. (1976) EPSL 33, 45. (4) Armstrong J.T. et al. (1987) GCA 51, 3155. (5) Grossman L. et al. (1986) LPSC XVII, 295. (6) Fegley B.,Jr. and Palme H. (1985) EPSL 72, 311.

Bulk Composition of "Fremdlinge" from EGG-6
(all data in ppm)

Table 1

	EGG-1		EGG-2		EGG-4		EGG-5		EGG-6		FLOR		ZELDA
mg	0.01*	s	0.01*	s	0.01*	s	0.01*	s	0.01*	s	0.01*	s	0.504
Na	80	15	121	16	791	5	137	7	137	7	18230	3	545
Cr	1300	33	14000	21	19000	12			4400	30	31000	6	13600
Mn	3.2	13	12.5	11	450	3	55	7	17	10	168	4	22
Fe	78200	20	190000	34	889000	10	130000	22	119000	15	167000	16	491800
Co	1960	7	4720	11	7450	4	6970	4	2640	5	2420	6	3400
Ni	38700	11	189000	7	146000	7	204000	5	44700	10	43800	14	97600
Cu	<250		<700		1310	9	331	15	189	10	<900		763
Mo	1920	8	2800	11	5200	6	<530		3050	6	5950	9	4690
Ru	1080	10	3690	9	4610	7	1990	9	2120	12	2760	10	2510
Pd			400	27	320	39					<240		<15
W	87.5	7	<15		76	12	<8.6		83.6	8	32	24	7.8
Re	85.6	11	269	5	342	4	410	4	121	4	134	6	200
Os	1180	4	4225	3	5230	3	6320	6	1970	5	1880	15	2540
Ir	1130	4	3950	4	4290	4	6282	2	1870	4	2200	3	2189
Pt	1200	13	7120	6	2490	13	2430	18	2510	8	5180	6	2960
Au	42.3	6	161	3	79	4	158	2	46	7	48	4	58

* assumed weight; s=standard deviation in %

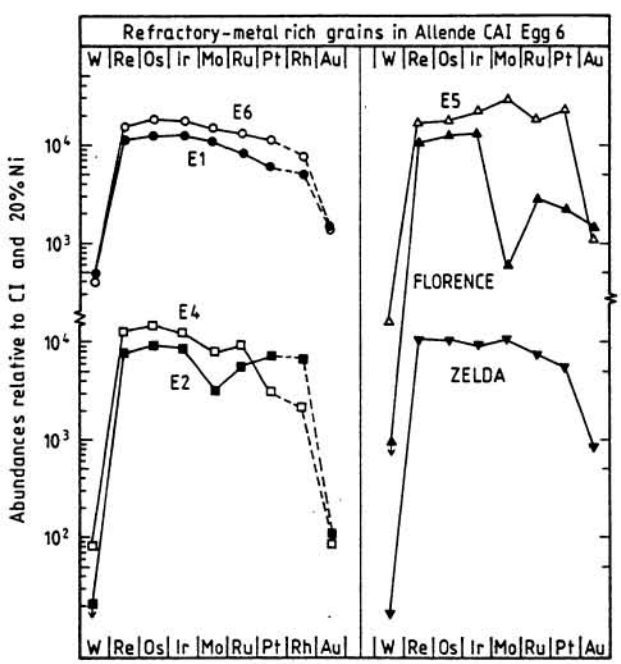

Fig. 1

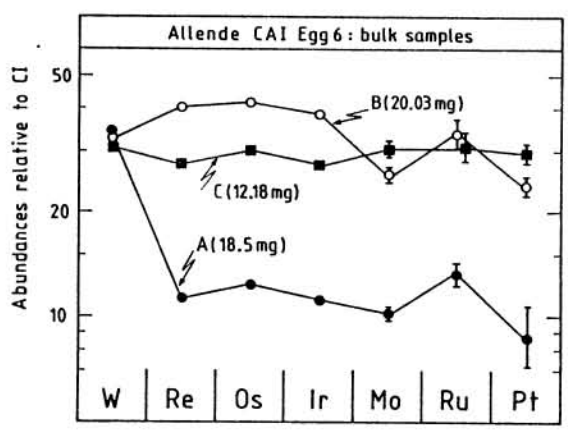

Fig. 2

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