A TRACE ELEMENT/PETROGRAPHIC STUDY OF REFRACTORY INCLUSIONS IN KABA (CV3): Y.-G. Liu[a], R. A. Schmitt[a], B. A. Holmén[b], J. A. Wood[b], D. A. Kring[b]. [a]Depts. of Chemistry and Geology and The Radiation Center, Oregon State University, Corvallis, OR 97331; [b]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138

Kaba is one of the least-metamorphosed and least-studied CV3 chondrites. We isolated 67 objects that appeared to be refractory inclusions from Kaba, and studied them first by instrumental neutron activation analysis to determine major and trace element concentrations. Twenty-seven of these were then studied by backscattered electron microscopy and electron microprobe analysis to establish their petrographic character.

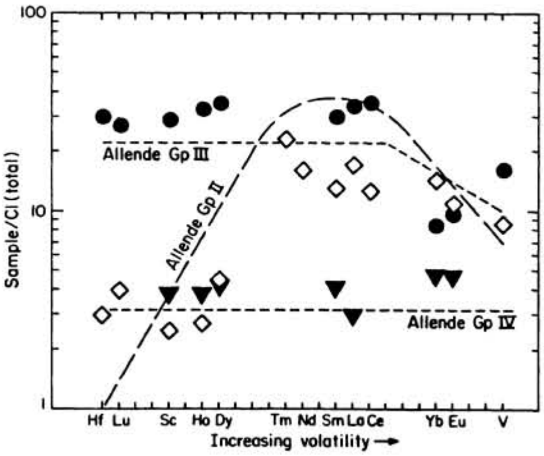
Twenty-two of the objects really were refractory inclusions (the others being chondrules or masses of matrix). Seven of the inclusions show Group III REE patterns (filled circles in Fig. 1). All have similar textures and mineralogies, being aggregates of concentric objects of ~100 μm diameter (except for KI 60, which consists of a single rounded object of ~300 μm diameter). The cores of these objects are spinel and gehlenitic melilite. Surrounding the cores are rim sequences (outward) of phyllosilicate, diopside and/or Al-pyroxene, perovskite, and hedenbergite. These correspond to the Allende "fluffy" Type A inclusions of [1] or Type 3A of [2]. Their phyllosilicate contains more Al_2O_3 than its counterpart in Allende CAI's (~44% vs. ~20% [3]).

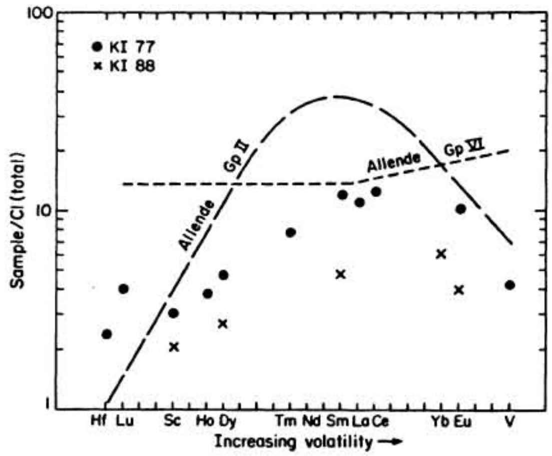
Twelve inclusions with lower refractory-element abundances (1-5.5x chondritic) show flat REE patterns (filled triangles in Fig. 1) like those of Allende Group IV inclusions. Their major minerals are olivine, pyroxene, and/or Al-diopside. Anorthite is present in some inclusions. Texturally, these inclusions are similar to amoeboid olivine aggregates in Allende.

One inclusion studied (KI 53) shows a Group II REE pattern (open diamonds in Fig. 1), in which both the most refractory and the most volatile elements are depleted. KI 53 is a fine-grained aggregate of unrimmed, sub-rounded objects 10-50 μm in diameter, texturally similar to the Allende Type 2 inclusions of [2]. Major mineral constituents are Al-diopside, spinel, and high-Al phyllosilicate, with minor perovskite, hedenbergite, and ilmenite. The presence of ilmenite and significant amounts of phyllosilicate suggest that extensive alteration and metasomatism occurred.

Of greatest interest are two inclusions, KI 77 and KI 88, which are unusual in their chemistry and petrography. Their patterns of refractory trace element and REE abundances (Fig. 2), to the extent that they have been measured, do not correspond to any of the patterns defined by [4,5] in their studies of Allende inclusions. Abundances increase almost monotonically with volatility. The textures of KI 77 and KI 88 appear to be igneous, consisting chiefly of anorthite (~50%), diopside (~20%), and enstatite (~10%) (Fig. 3). Finer-grained areas (~20%) of diopside, anorthite, a Si-rich phase (glass?, "Si" in Fig. 3), minor wollastonite, and tiny Fe-rich metal/oxide blebs encroach upon the coarser An-Di-En assemblage. Enstatite, grading into more Ca-rich pyroxene at its grain boundaries, is enclosed by anorthite. The anorthite is pitted and averages An_{94-95}. Diopside is poorer in Al (<6.2% Al_2O_3) and Ti (<1.9% TiO_2) than in Allende. Spinel is absent. This mineralogy differs from Type C CAI's and CA chondrules described by [7]. This is a relatively Si-rich mineral assemblage, one not encountered anywhere in the condensation sequence. Both the Si abundance and the refractory element pattern suggest these objects condensed from a gas enriched in elements of moderate volatility, either as liquids or as solids which were subsequently remelted. It is interesting that the REE patterns in these inclusions are similar to those in Allende EK 1-4-1 [8], and to the pattern of REE that [9] showed would remain in the gas phase after partial condensation ($\sim F_{La}=0.002$) had occurred.

[1] G. J. MacPherson and L. Grossman (1979) Meteoritics 14, 479. [2] A. S. Kornacki and J. A. Wood (1983) Proc. Lunar Planet. Conf. 14B, 573. [3] A. Hashimoto and L. Grossman (1987) G.C.A. 51, 1685. [4] B. Mason and P. M. Martin (1977) Smiths. Contr. Earth Sci. No. 19, 84. [5] B. Mason and S. R. Taylor (1982) Smiths. Contr. Earth Sci. No. 25, 1. [6] A. S. Kornacki and B. Fegley (1986) E.P.S.L. 79, 217. [7] D.A Wark (1987) G.C.A. 51, 221. [8] H. Nagasawa et al.(1982) G.C.A. 46, 1669. [9] W.V. Boynton (1975) G.C.A. 39, 569.





Figures 1 (left) and 2 (right). Refractory trace element abundances in Kaba inclusions studied, plotted in order of increasing volatility (as in [6]). Filled circles (left): average of 7 inclusions with Group III properties. Filled triangles: average of 3 inclusions with Group IV properties. Open diamonds: inclusion KI 53. Dashed lines: distinctive REE patterns found by [4,5] in Allende inclusions (schematic).

Fig. 3. BSE image of KI 77. An, anorthite; En, enstatite; Di, diopside; Si, glassy (?) Si-rich phase.