

distribution of the ablation values and the iso-track density contours on the plane of the slab imply asymmetric ablation of the Abee chondrite during its atmospheric transit. The track data are consistent with a spherical pre-atmospheric shape for the meteorite with radius 28 ± 2 cm, corresponding to a mass of 320 ± 70 kg. The mass loss due to atmospheric ablation (for a recovered mass of 107 kg; Dawson *et al.*, 1960) is thus $\sim 66\%$ of the initial mass of the Abee meteorite.

Dawson, K.R. *et al.*, 1960. *Geochim. Cosmochim. Acta.* **21**, 127.

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INTERRELATIONSHIPS OF PETROGRAPHY, MINERALOGY, AND CHEMISTRY IN CHAINPUR CHONDRULES

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Chemical, mineralogical, and petrographic data on a suite of 36 separated chondrules from the Chainpur (LL3.4) (Melcher *et al.*, 1980) chondrite have been the subject of a multi-variate analysis. The data comprise: elemental concentrations of Na, Mg, Al, K, Sc, V, Cr, Mn, Fe, Co, Ni, Zn, Ga, Ge, As, Se, Sm, Ir, and Au, modal abundances of olivine, pyroxene, glass, metal, and sulphide, as well as individual chondrule weights and the Fe/(Fe+Mg) ratios in the ferromagnesian silicates.

Factor analysis reveals the following groups of elements: 1) Co, Ni, Zn, Ge, As, Se, and Au (siderophile and chalcophile elements); 2) Mg, Al, Sc, V, and Sm (non-volatile and refractory lithophiles); 3) Na, K, and Ga (moderately volatile lithophiles). Ir and Fe mainly behave as group 1 elements, although they also display some affinity for group 2; Fe anticorrelates with other group 2 elements. Mn and Cr are weakly associated with both groups 1 and 2, being anticorrelated with the elements in those groups.

The assignment of modal amounts of minerals to these groups by factor analysis helps in the interpretation of elemental data. Metal and sulphide belong to group 1, showing that the variance in group 1 elements is due to varying amounts of those phases. The modal amount of glass belongs to group 3, so Na, K, and Ga must be associated with any glass that is present. Modal olivine and pyroxene anticorrelate, and are essentially independent of other variables, although the pyroxene rich chondrules tend to be enriched in Mn and Cr, and the olivine rich chondrules contain more refractories. The fayalite content of olivine and mass also anticorrelate with the group 2 elements.

The three main groupings of variables extracted by the factor analysis are linearly independent. If these groups represent the only components of chondrules then they would have to be mutually dependent. Therefore chondrules must be composed of more than three components. The lack of strong Mn and Cr associations with other groups, combined with their restricted ranges of concentration compared to other elements suggests that they mainly reside in a fourth component. This component may be a Si- and O-bearing group that was not analyzed in this study.

The analysis implies that chondrules are composed of random mixtures of a low-temperature metal/sulphide component, a high-temperature lithophile component enriched in forsteritic olivine, and a low-temperature lithophile component; these groups together will display a negative correlation with a fourth Mn- and Cr-bearing, Si and O component. Despite significant variations in chondrule chemistry, factor score plots revealed no clear relationships between chondrule compositions and internal textures. It seems that chondrule textures are determined independently of the precursor material.

Melcher, C.L., L.M. Ross, A.A. Mills, J.N. Grossman, and D.W. Sears, 1980. *Meteoritics* **15**, 332-333.

A CORUNDUM-RICH INCLUSION IN MURCHISON

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An inclusion in which corundum is a major phase has been discovered in the Murchison C2 chondrite. It is a deep blue spheroid, ~ 250 μm in diameter, that was recovered from the $\rho > 3.5$ fraction upon heavy liquid separation of the products of freeze-thaw disaggregation of the meteorite. After an 8 μg fragment was removed for trace element analysis, the rest was made into a polished thin section for petrographic and electron and ion microprobe investigations.

The inclusion, labeled BB-5, consists of only three phases: hibonite — 77% by area, corundum — 23% and traces of perovskite. Corundum occurs in masses ~ 50 μm in size

surrounded by blue pleochroic hibonite blades, 30-70 μm in length and 10-20 μm in width. Perovskite grains are interstitial to the hibonite blades and elongated parallel to their length. The corundum is virtually pure Al_2O_3 , the only impurity being 0.32% TiO_2 , and the hibonite is noteworthy for its low MgO and TiO_2 contents, 0.65 and 2.5 wt %, respectively. The bulk chemical composition of BB-5, 91.9% Al_2O_3 and 6.2% CaO , melts at 2120-2230 K. Because of the difficulty of achieving such extreme temperatures, BB-5 was probably never molten, but, instead, may be a direct vapor-to-solid condensate from a gas of solar composition. Its mineralogy and texture suggest that, prior to condensation of melilite and spinel, corundum condensed and then hibonite and perovskite. Thermodynamic data for hibonite are lacking. Calculations show that corundum reacts with a cooling solar gas to form melilite first, then spinel. This cannot explain blue spherules in Murchison that contain hibonite + perovskite + spinel, with no melilite. If, however, as indicated by BB-5, hibonite was the phase that reacted with the gas, perhaps spinel actually formed before melilite. The blue spherules are then easily explained as higher-temperature condensates than Type A Allende inclusions. In any case, BB-5 is the most refractory major phase assemblage observed so far. The REE pattern is flat, except for a large negative Yb anomaly which, because it is not accompanied by a similar Eu anomaly, is difficult to explain by conventional condensation calculations.

The Mg isotopic compositions of hibonite and corundum were measured with the ion microprobe. Both phases show small excesses of ^{26}Mg : $\delta^{26}\text{Mg} = 7 \pm 2^\circ/\infty$ ($\pm 2\sigma$ mean) with $^{27}\text{Al}/^{24}\text{Mg} = 138 \pm 5$ for hibonite and $\delta^{26}\text{Mg} = 3 \pm 8^\circ/\infty$ with $^{27}\text{Al}/^{24}\text{Mg} = (1.4 \pm 0.2) \times 10^4$ for corundum. The large error in the corundum data is due to low count rates arising from the exceptionally low Mg content and the reduced primary beam current ($\sim 2\text{nA}$) used to ensure that individual phases were spatially resolved during analysis. These data suggest that BB-5 is uniformly enriched in ^{26}Mg and show unmistakably the absence of the linear correlation between ^{26}Mg excesses and $^{27}\text{Al}/^{24}\text{Mg}$ ratios common to most Allende refractory inclusions. An isochron extending from normal Mg at $^{27}\text{Al}/^{24}\text{Mg} = 0$ through the BB-5 hibonite datum would predict $\delta^{26}\text{Mg} \sim 700^\circ/\infty$ at an $^{27}\text{Al}/^{24}\text{Mg}$ ratio corresponding to the corundum. The uniform enrichment in ^{26}Mg independent of the $^{27}\text{Al}/^{24}\text{Mg}$ ratio suggests that BB-5 either formed from a reservoir containing $\sim 7^\circ/\infty$ excess ^{26}Mg but no live ^{26}Al or that hibonite and corundum were isotopically re-equilibrated after decay of ^{26}Al .

THE ORIGIN OF ABUNDANT TRIDYMITE AND PHOSPHATE IN MESOSIDERITES: FEASIBILITY OF POSSIBLE REACTIONS

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The conspicuous abundances of tridymite and phosphate [merrillite, $\text{Ca}_3(\text{PO}_4)_2$] in most mesosiderites (up to 9.8 and 3.7 wt %, respectively, of the "silicate" portion; Prinz *et al.*, 1980) relative to all other achondrites has raised the question of their origin. Nehru *et al.* (1978) discussed petrologic evidence and the possibilities of production by igneous fractionation and by redox reactions between P-bearing metal and calcic pyroxene. Agosto *et al.* (1980) have suggested a specific redox reaction. Due to the lack of evidence for fractionation (*e.g.* enriched alkali or rare earths), we have examined the thermodynamic constraints on reactions producing tridymite and merrillite for the mesosiderites. The invariant point, reaction curves, and T-fO₂ relations for the system Fe-P-O-CaO-SiO₂ (and Fe-P-O-CaO-SiO₂-MgSiO₃) were calculated for the set of phases: I, metallic Fe in solid solution; P, dissolved in metallic Fe-Ni; Wo, CaSiO₃ (or Di, CaMgSi₂O₆) in cpx solid solution; Fs, FeSiO₃ in opx solid solution; M, merrillite; T, tridymite (or En, MgSiO₃). The following reactions result (indifferent phases are in brackets):

1. $\text{Wo} + \text{P} + \text{O} = \text{M} + \text{T}$ (Di + P + O = M + T + En) [Fs, I]
2. $\text{Wo} + \text{P} + \text{I} + \text{O} = \text{M} + \text{Fs}$ (Di + P + I + O = M + Fs + En) [T]
3. $\text{I} + \text{T} + \text{O} = \text{Fs}$ [Wo, P, M] ([Di, P, M, En])
4. $\text{Wo} + \text{P} + \text{Fs} = \text{M} + \text{T} + \text{I}$ (Di + P + Fs + M + En + T + I) [O]

While there are problems with the equilibrium calculations due to lack of data (*e.g.*, activities of Wo in cpx), solid solution complexities and variable phase compositions in mesosiderites, some useful relationships and T-fO₂ limits are possible: (1) Both redox and O₂ "buffering" reactions offer the flexibility of producing variable tridymite to merrillite ratios as two independent reactions (1 and 3) are involved. The ratio will be dependent upon local compositional variations in the