DARK INCLUSIONS IN THE ABBOTT, CYNTHIANA AND ABEE CHONDRITES. Derek W. Sears and John T. Wasson, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024, USA.

Five dark inclusions from three chondritic meteorites have been analyzed by instrumental neutron activation analysis (INAA). The data, shown in Fig. 1-3, have been normalized to Cr (we do not yet have data for a more conventional normalizing element) and appear in order of decreasing condensation temperature within two crude geochemical divisions.

ABBOTT is an H5 chondrite containing dark xenoliths with CM-like mineralogy and petrology (Foder et al., 1976). Two inclusions (Nos. 9 and 10) were made available by K. Keil; No. 9 differs from others studied by Fodor et al. in not containing CM quantities of inert gases. Except for Na and K, data on the two clasts agree closely (Fig. 1). Mean CV, CO and CM-group abundances (Kallemeyn and Wasson, 1981) are shown comparison. Abundandance ratios for the refractory lithophiles Sc, Sm and Lu are near 1.14, indicating a CO or CM classification for the two clasts, while Mn - an element that resolves the groups well - indicates CM. The low abundance ratios of Na and K are similar to values observed in other carbonaceous xenoliths. The refractory and common siderophiles Ir, Ni, Co and Fe do not resolve the groups, but the abundances of 2 moderately volatile siderophites Ga and Zn are consistent with a CM classification, whereas others Au, As and Se are 10-20% lower than CM values. The weight of the evidence favors the interpretation that these inclusions are CM-like materials.

CYNTHIANA is an L4 chondrite in which Van Schmus (1967) found a dark inclusion that he suggested was CM material. We studied the same section by electron microprobe and carried out an INAA on a similar dark inclusion in a sample from Harvard University. Both our probe and our INAA data indicate that the inclusion is not related to any carbonaceous chondrite group. The inclusion and whole-rock sample have ordinary chondrite lithophile element abundances, but, as observed in whole-rock Cynthiana by Tandon and Wasson (1968) and confirmed by our study, siderophiles are lower than the normal L-group range. Abundances of Ni, Co, Au and As in the inclusion are 50-70% of those in the whole-rock sample, but Fe and Ga are present in about the same abundance. These data suggest that the inclusion lost 30-50% of its original metal, since a major fraction of the Fe and Ga but a negligilbe fraction of the siderophiles reside in the oxide phases of L and LL chondrites. Such metal-loss many well have been associated with melting, but the petrology of the inclusion does not suggest complete melting, since tiny metal grains and small chondrule-like silicate grains with L group composition (Fa 24.4) are dispersed throughout the very fine, dark matrix. Our favoured interpretation is that the inclusion is a residue remaining after removal of a small amount of metal-rich shock melted L group material. An abundance of small inclusions of this kind could explain the low siderophiles in Cynthiana whole-rock, but the possibility remains that the Cynthiana parent body originally had lower siderophiles than the

DARK CHONDRITIC INCLUSIONS

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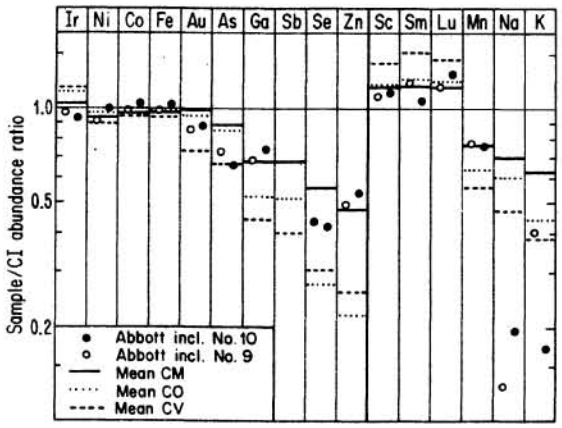

Figure 1

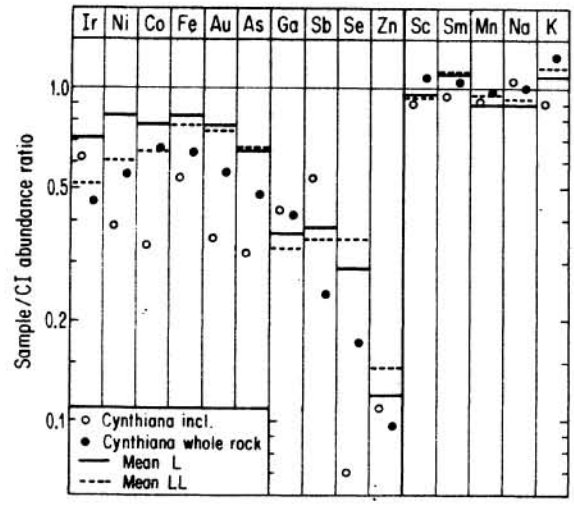

Figure 2

normal L group parent body.

ABEE. Two dark inclusions were analyzed, one from the consortium slab at UCSD (9,13,1) and one from a Smithsonian sample (SI 2096) at Caltech. The most striking feature of the two sets of data is that their rare-earth -element (REE) abundances are high (2.5X CI values) but accompanied by a negative Eu anomaly, the Eu abundance ratios being near unity (Fig. 3). Rare-earth abundances in the two inclusions are similar. In contrast, rare-earths in whole-rock Abee are generally ∿10% lower than CI levels. Enstatite chondrites show a much greater total range in REE than ordinary chondrites (X4 vs. ∿X1.25; Nakamura and Masuda, 1973); inclusions like these may be important components of samples at the upper end of the range. There is little evidence concerning mineralogical siting of the REE in E chondrites; pyroxene and phosphates are sites in ordinary chondrites but in these chondrites phases like phosphides and sulfides may be more important (Frazier and Boynton, 1980). According to Rubin and Keil (1980) the dark inclusions are not significantly enriched in any mineral phase although metal is somewhat low and radiating pyroxene chondrules are much more abundant than in typical Abee (25-28 vol % vs. 1-4 vol % for bulk Abee). The Eu depletions in these inclusions probably reflect loss of plagioclase, although +2 Eu may also enter phases such as oldhamite (CaS). A possible explanation for the REE in the Abee dark inclusions is that they are located primarily in pyroxene chondrules that are so highly abundant in the inclusion, but we cannot confidently identify the missing phase that carried the Eu. The low (0.6X CI) abundance of refrac-

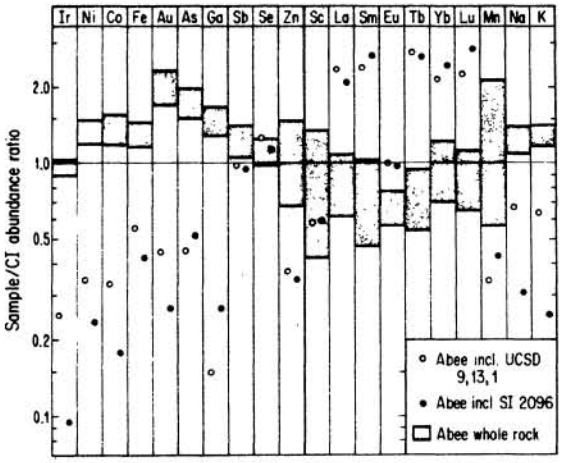

Figure 3

tory Sc in the inclusions show that the REE did not result from incorporation of refractory materials such as those found in the Allende chondrite. The moderately volatile lithophiles Mn, Na and K are 2-6X lower than typical Abee values; the alkalis are ~2.5X higher in the UCSD than in the SI inclusions.

The non-lithophiles show much variation in their abundances in these inclusions. There is a suggestion of a trend of refractory-depletion and volatile-enrichment in both, although Ga and Zn lie well off these trends. Clast 9,13,1 shows a steeper slope than 2096, perhaps reflecting the lower degree of matrix contamination in this sample. These trends probably imply metal depletion and sulphide enrichment, but the low Zn would require an additional process.

In summary, we report data indicating that dark inclusions in Abbott are CM-like material, those in Cynthiana are shock-melted and slightly altered whole rock, and those in Abee are complex materials whose origins are presently poorly constrained. We will report data on additional xenoliths separated from the Enshi, Fayetteville, Mezö-Madaras and Weston ordinary chondrites.

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