FORMATION OF IAB AND IIICD IRON METEORITES. Derek W. Sears, John Willis and John T. Wasson, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024, USA.

Iron meteorite groups IAB and IIICD differ from the other groups. They often contain clasts of reduced (Fe/(Fe+Mg) <10%) chondritic materials. Relative to the other groups, their metallic portions have a smaller range of most elements but a much greater range of Ni, although they still display significant element-Ni trends (Fig. 1; IAB Oktibbeha County having 585 mg/g Ni omitted). The volatile Ge (and Ga, not shown) and the refractory W and Ir display strong negative correlations with Ni whilst Cu and Sb display strong positive correlations. The remaining four elements seem to display only weak positive correlations. The dashed line shows the CI element/Ni ratio; inclusion of all siderophiles in the metal yields the circled asterisks. Most element trends cross the CI line; only Cu, P and Sb lie appreciably below it. Groups IAB and IIICD clearly did not experience the extreme fractionations observed in other groups generally attributed to fractional crystallization. We have therefore investigated alternative models. We focus our discussion on IAB, but the principles are equally applicable to IIICD.

i) Nebula oxidation/sulfuration model. Various authors have invoked simultaneous oxidation and accretion to explain differences between the degrees of oxidation of meteorite classes (e.g., Larimer, 1973), including iron meteorites (Sears, 1978). It seems probable that variations in Fe/Si in enstatite and ordinary chondrites resulted from the mechanical separation of metal and silicates in the nebula. Wasson (1970) proposed that the low-silicate ($\lesssim$1%) IAB irons formed by this mechanism. We have explored the possibility that the IAB trends resulted from varying degrees of oxidation and sulfuration simultaneously with agglomeration of metal. Fig. 2 illustrates schematically how the Fe, Ni and element/Ni ratios must vary, and how the element/Ni trends could be interpreted in terms of this model. The increase in Ge/Ni and a similar increase in Ga/Ni to about 2X the solar ratio in low-Ni IAB irons requires that at least half the Fe and Ni have been removed from the metal. Equilibrium calculations under nebular conditions show that half the Fe is removed at ∿630 K, primarily as FeS but partly as FeO in silicates. In order to keep the Ni concentration in the metal near the solar value (Fig. 1), it is necessary to suggest that Ni also entered sulfides and silicates to about the same degree. The nebular behavior of Co needs to be intermediate between that of Ge and Ni. The low Ge/Ni and Ga/Ni ratios observed at the high Ni extremes of the groups could be explained if these elements are rapidly oxidized below 630 K, and were mainly ($\geq$99.9%) present in the silicates at the temperature at which these high-Ni meteorites accreted. Such complete oxidation clearly requires a temperature span of >100^o, suggesting that the high-Ni irons accreted at temperatures of ∿500 K if this model is correct.

We see several difficulties with this model. The formation of a Ni sulfide during the temperature range in which FeS forms is not supported by observations of sulfides in highly unequilibrated type 3 H, L, LL chondrites; Ni contents of FeS are $\leq$2 mg/g and other Ni-bearing sulfides are not reported (Dodd et al., 1967). The low Ir contents at the high-Ni extreme of IAB requires that between 630 and 500 K Ir left the metal and entered another phase, in conflict with the general view that Ir is more noble than Ni at these temperatures. Chou et al. (1973) reported that nonmagnetic fractions of ordinary chondrites have higher Ir/Ni ratios than metal-rich fractions. They interpreted this to indicate that refractory condensates were trapped in the si-

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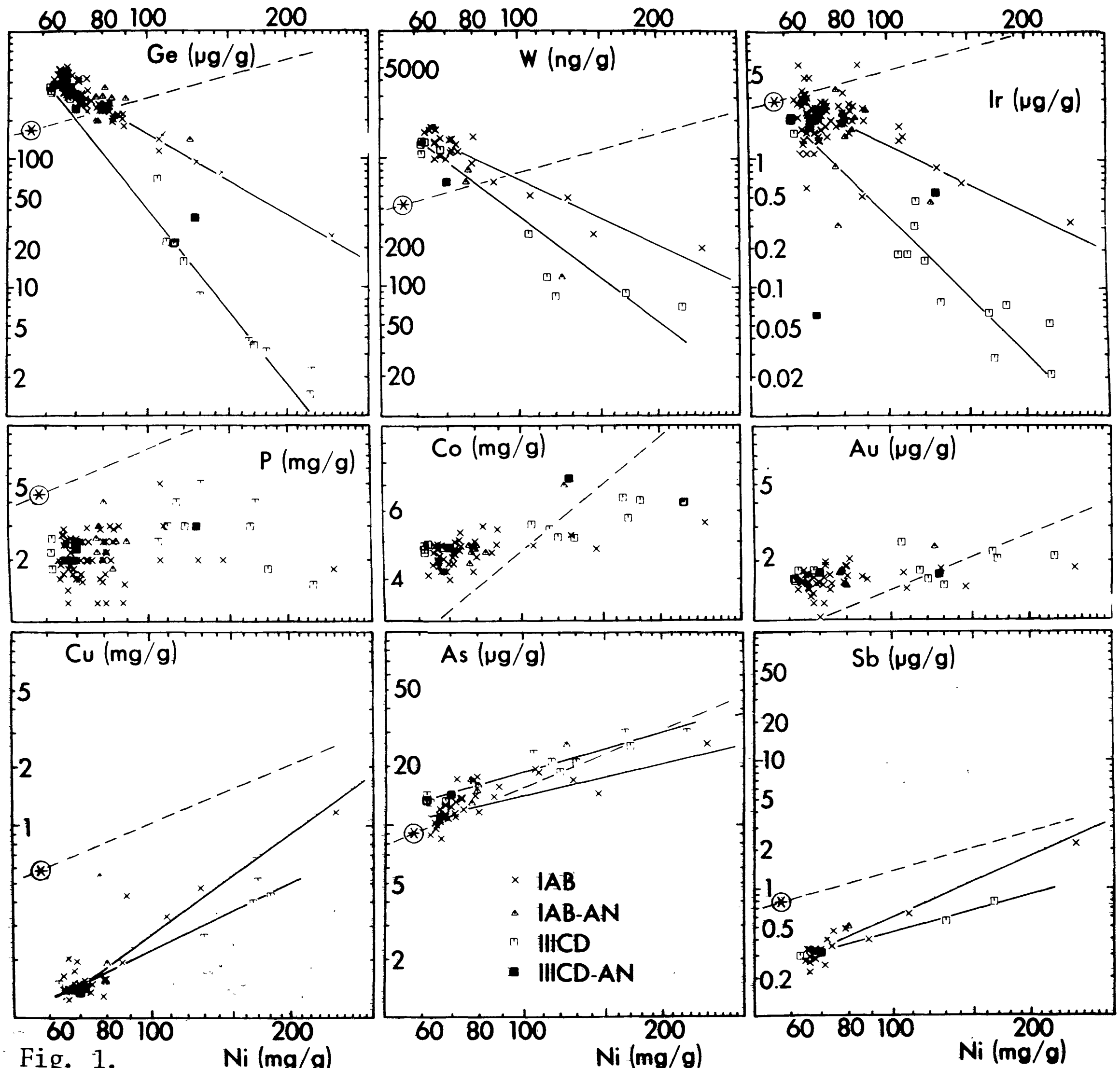

Fig. 1.

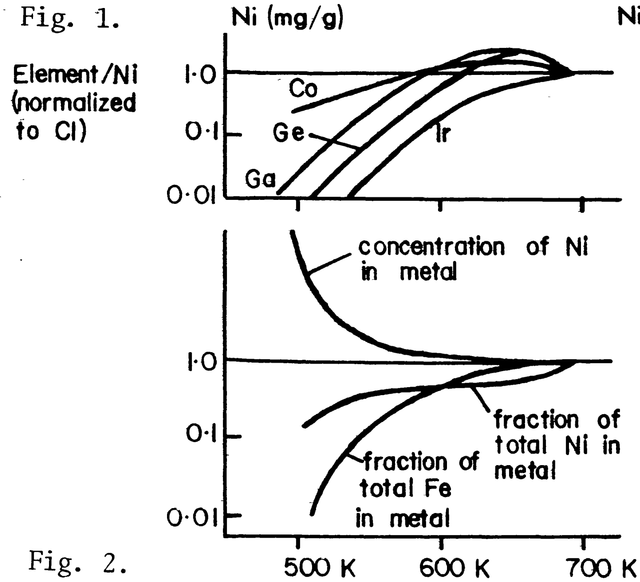

Fig. 2.

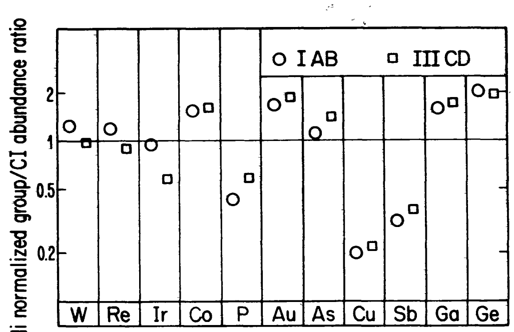

Fig. 3.

licates, but it might also be that the Ir was lost by low-temperature oxidation or sulfuration. The model requires that only about 1% of the condensed solids be metal at the temperature at which Oktibbeha County formed; it seems remarkable that selective accretion could then produce a pure metal mass having dimensions of >5 cm. Finally, chondritic materials do not show the predicted relationship between FeO/(FeO+MgO) metal content or Ni content of the metal.

ii) Shock-melting model. Wasson et al. (1980) proposed that IAB irons were produced as small individual impact melts on a body originally made up of unmetamorphosed equivalent of the IAB chondritic clasts, and suggest that these melts ranged in temperature from ∿1270 K, the FeS-metal eutectic temperature, to ∿1450 K, the melting temperature of plagioclase. The degree of equilibration between melt and unmelted solids ranged from minimal at the lowest to moderate at the highest temperature. Cooling of the generally FeS-rich melts led to precipitation of the Fe-Ni metal. At temperatures near the FeS-metal eutectic, the Ni content of the metal reached the value of 585 mg/g Ni observed Oktibbeha County. A similarly high Ni content has been observed in a clear taenite in a shock-melted FeS nodule in Gibeon, suggesting that high Ni metal tends to form stably or metastably from rapidly cooled melts just on the metal-rich side of the eutectic. At the high temperature extreme, the Ni/Ge ratio in the metal was only slightly higher than that in the melt.

We suggest that most siderophiles were initially in the chondritic metal, but that Sb and Cu were in FeS or in minor sulfide phases associated with it, and that elements having low concentrations in high-Ni irons were present as oxides (Ga, Ge) or trapped in silicates as refractories (Ir, Re, Os, etc.). The oxidation or trapping of these siderophiles in silicates has been observed in unequilibrated ordinary chondrites but our model requires a much larger trapped fraction than observed. The low-temperature melts formed from sulfides and adjacent metal, and was enriched in elements that condensed as sulfides. With increasing temperature, more metal is dissolved into the shock melts, and oxidized or trapped metals are released into the melts. The Ni content of the solids decreased as the proportion of Fe-Ni in the melts increases. Since the high-temperature melts tend to be larger, the model accounts for the observed decrease in average meteorite size with increasing Ni content. Meteorites at the low-Ni end offer the best estimates of siderophile abundances in the parental materials. Fig. 3 shows CI normalized abundances; the resemblance to CI is apparent. In both groups the volatiles As, Au, Ga and Ge are present in excess of CI abundances, perhaps because coarse chondritic metal having low abundances of these elements was not melted in the impact event. The low abundances of P, Cu and Sb may reflect incomplete experimental sampling of minor phases.

This model too has problems. The Ge and Ga contents shock melts might be expected to scatter, since at the temperatures envisaged Ga and Ge are sufficiently volatile to be lost from the liquid phase. The model thus requires high confining pressures until the melts cooled enough to prevent diffusive loss. Second, it remains to be shown that a high-Ni metal can be produced from a FeS-rich melt.

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