ANALYSIS OF SEGREGATION TRENDS OBSERVED IN IRON METEORITES USING MEASURED DISTRIBUTION COEFFICIENTS

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Iron meteorites are considered to be fragments of solidified asteroidal parent bodies. The measured trace (Ge, Ga, Ir, etc.) and minor (P and Co) element compositions of these metallic fragments have been plotted traditionally against their Ni content in an effort to classify these iron meteorites on the basis of chemistry (1). The distribution of these iron meteorite compositions indicates several recognizable chemical groups. Scott (1) proposed that solute redistribution during liquid-solid transformation of a molten iron pool in a parent body was responsible for the observed compositional trend within a chemical group.

In order to develop this proposal, several workers (2-4) have measured the distribution coefficients of various trace and minor elements in laboratory Fe-Ni alloys. These authors showed that either the S or the P content of these alloys may strongly influence the value of the distribution coefficients of various elements.

Recently, using a plane front solidification technique, we have determined the distribution coefficients of Ni, P, Ge and Ir in Fe-Ni alloys containing combinations of both S and P (5,6). In order to characterize the effects of the S-P interactions in the liquid on the distribution coefficients of Ni, P, Ir and Ge, we have examined three alloys (1. Fe-6.9 wt% Ni-0.78 wt% S-0.30 wt% P, 2. Fe-7.7 wt% Ni-2.25 wt% S-0.3 wt% P, 3. Fe-7.2 wt% Ni-2.90 wt% S-0.15 wt% P) with wt% S to wt% P ratios of 2.6, 7.5 and 19.3 in the initial melt. The distribution coefficient for each solute element as a function of wt% S and wt% P in the liquid is given below:

$$K_{Ni} = 0.9 + \exp\,[0.23\ C_S\ (C_P)^{0.1} - 5.94] \quad (1)$$

$$K_P = \exp\,[-3.0 + 0.8\ C_S^{0.4}/C_P^{0.24}] \quad (2)$$

$$K_{Ir} = \exp\,[0.1 + 0.12\ C_S + 0.16\ C_P + 0.16\ (C_S\ C_P)^{0.1}] \quad (3)$$

$$K_{Ge} = \exp\,[-0.2 + 0.09\ C_S - 0.9\ C_P] \quad (4)$$

where C_S and C_P are the liquid compositions (wt%) of S and P, respectively.

In this study, we have used the above distribution coefficients to calculate the compositional trends in various iron meteorite groups. In the analysis, we have employed the same computational procedure described by Willis and Goldstein (3). In order to obtain a match between the observed and calculated compositional trends, the initial S and P contents were varied appropriately.

Figures 1 to 3 show the excellent agreement between the calculated P, Ir and Ge vs. Ni distributions, and the observed data for the three largest, magmatic, iron meteorite groups. The P trends (Figure 1) are comparable with those calculated by Willis and Goldstein (3), and Jones and Drake (4). The Ir trends (Figure 2) are comparable with those of Jones and Drake (4). The agreement between computed and observed Ge-Ni trends (Figure 3) was obtained because we have measured the distribution coefficient of Ge more accurately, and have established the functional relationship between K_{Ge} and the S and P contents in the liquid. Equation 4 shows that the functional relationship of S and P is not additive. The non-additive relationship is responsible for the change in the slope of the Ge trend for III AB irons.

Table 1 compares different sets of data for the initial bulk liquid compositions of the IIAB, IIIAB and IVA chemical groups. Since we were able to obtain a good match for P, Ir and Ge vs. Ni, we prefer our initial bulk compositions to those of Willis and Goldstein (3), and Jones and Drake (4).

Based on the above calculations, we conclude that each of the three meteorite groups was originally a single molten pool in the parent body with significant S and P contents, which subsequently transformed to solid upon cooling. During this liquid-solid transformation, solute partitioning had occurred, giving rise to the observed compositional trends within a single chemical group.

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Table 1 Comparison of various calculated data

Element	II AB			III AB			IV A		
	a	b	c	a	b	c	a	b	c
Ni(%)	6.1	5.1	5.7	8.3	7.6	7.8	8.4	8.4	8.4
S(%)	0.2	17.	10.	1.4	5.0	4.2	0.8	1.0	1.8
P(%)	2.0	1.0	.27	.93	.56	.19	.33	.24	.05
Ge(ppm)	173	64.	120	40.	35.	31.	.21	.15	.11
Ir(ppm)	11.	1.3	13.	5.0	5.0	9.0	2.0	1.8	2.0

a Willis & Goldstein (3), b Jones & Drake (4), c Present study.

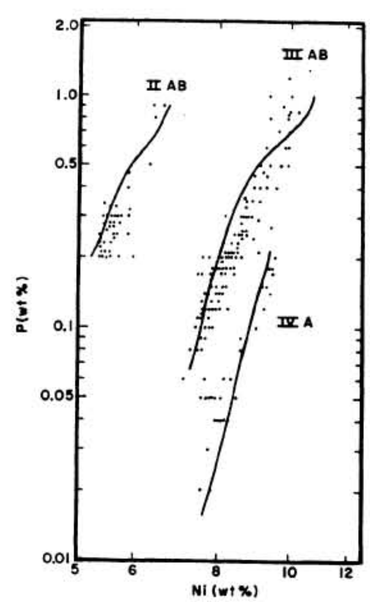

Fig. 1. P-Ni trend

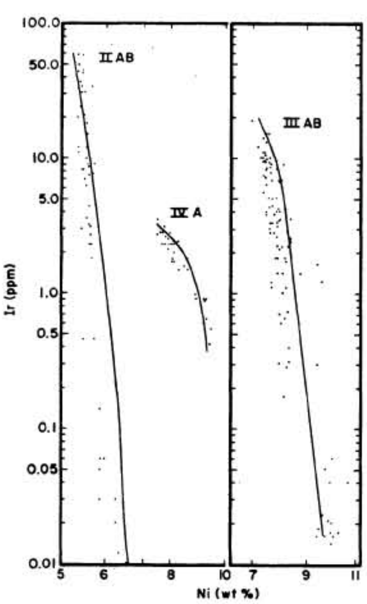

Fig. 2. Ir-Ni trend

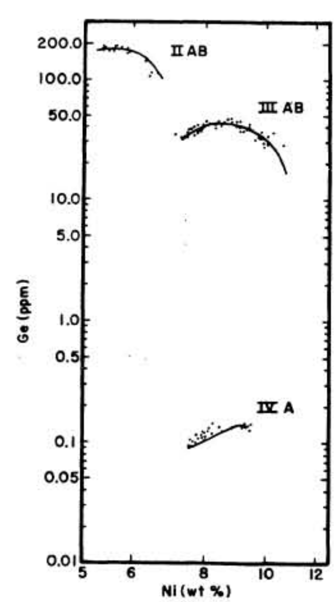

Fig. 3. Ge-Ni trend