

THE CRYSTALLIZATION AND COOLING OF CAPE YORK, REVISITED. J. A. Utas and J. T. Wasson, Dept. of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095-1567, USA; jutas@ucla.edu.

Introduction: As the core of an asteroid crystallizes, incompatible elements are concentrated in remaining melt [1,2]. All large iron meteorite groups ~excluding IAB-mg irons exhibit compositional trends broadly consistent with fractional crystallization [3,4,5,6].

Fractional crystallization leads to significant changes in partition coefficients, especially in melts with high initial concentrations of nonmetals, such as S, C, P, and others [4,6,7,14]. This is especially important in magmatic irons, where differences in initial melt compositions generated significant compositional and density gradients. The text will automatically wrap to a second page if necessary. The running head on the second page of this template has been eliminated intentionally.

Compositional trends within iron meteorite groups suggest that core solidification was complex, and that evolved liquid+solid mixing was occurring (Figs. 1 & 2).

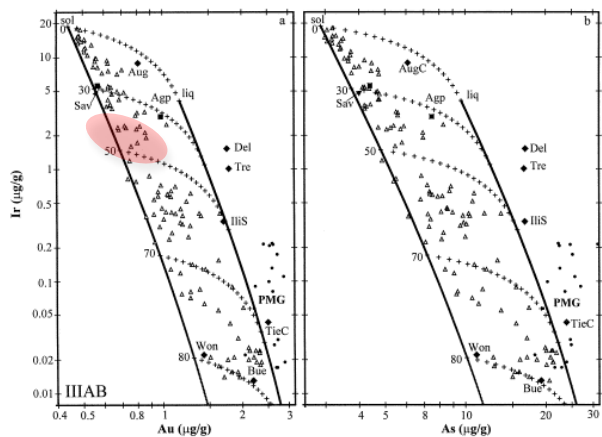


Fig 1. a) Solid (left) and liquid (right) tracks are shown on plots of (a) Ir vs. Au & (b) Ir vs. As. Solid-liquid mixing curves are shown by crosses at 0%, 30%, 50%, 70%, and 80% crystallization; crosses correspond to 5% incremental mixtures of these two materials. [Wasson, 1999]

Diffusion also plays an important role in the bulk chemistry of iron meteorites. Metal immediately surrounding troilite nodules has been shown to preserve evidence of both parent residual melt pockets, and of sub-solidus diffusion of more mobile elements [8,9].

At high temperatures, diffusion within the solid phase(s) and between solid-liquid phase boundaries is nontrivial. Previous work has shown that trace elements (Pd, Ag, and others) diffuse out of S-rich residual melt / troilite nodules in Cape York at the cm-scale,

at temperatures $\geq 550^\circ\text{C}$ [9]. Diffusion rates at higher temperatures are orders of magnitude higher and evidence of diffusion should be detectable in meteorites that exhibit chemical gradients (Figs. 3 & 4) [10].

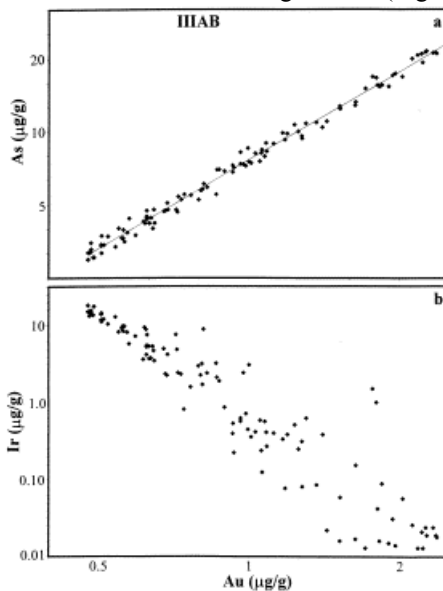


Fig 2. a) As and Au are incompatible elements with similar D values in low-S magmas: differences in trapped melt contents produce negligible deviation from the track of the pure solid. B) Ir is compatible in the solid metal phase; scatter has been inferred to suggest mixing of different proportions of residual melt. [Wasson, 1999]

Elements with higher rates of diffusion homogenize more rapidly as iron meteorites cool and crystallize. This potentially allows for a different interpretation of Figure 2; Ir is one of the least diffusive trace elements in iron meteorites, while As is one of the most mobile analyzed via INAA. Au is intermediately mobile at low pressures (Fig. 3). Higher spread in Ir, versus As data, would be expected if there were initial heterogeneities in both Ir and As

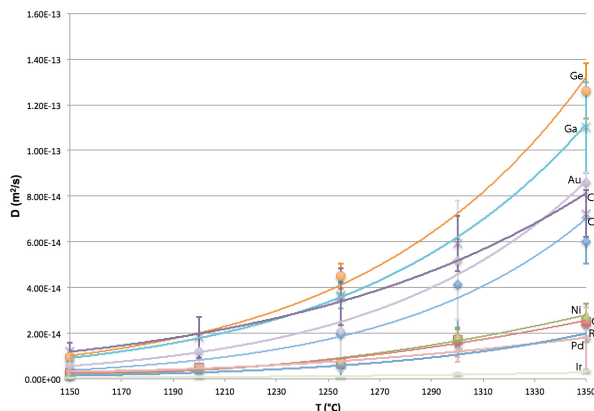


Fig 3. Experimentally derived diffusion constants for samples of Coahuila at 1 bar. Data from [10].

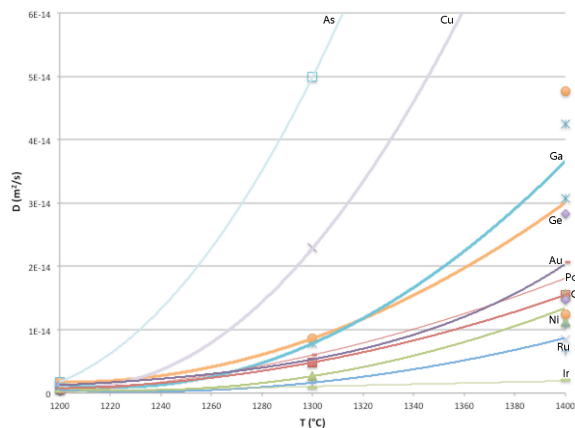


Fig 4. Experimentally derived diffusion constants for samples of Coahuila and Springwater at 10 kbar. Data from [10].

Cape York: Cape York is one of the largest meteorites ever found: two large masses weigh ~31 and 20 tonnes; several smaller fragments bring the total mass recovered to ~60 tonnes. The masses show a gradual but definite chemical gradient, correlating geographically with the find location of each mass (Fig. 1; for more detail, see [8]). The 20 tonne mass, named Agpalilik, has been partially sectioned into ~125 x 180 cm slabs.

These slabs are large enough to exhibit chemical gradation across one axis. This variation is best explained via the mixing reservoirs of early-crystallized solids with a residual liquid enriched in incompatible elements [4,8,11,12]. But how these materials were mixed is not well-understood. S and FeS abundances vary by a factor of 9 across Cape York, from Agpalilik (13mg/g) to Savik (1.4mg/g). Somehow, dense, metallic solids ($\rho=7.1\text{g/cm}^3$) mixed with a buoyant, sulfur-rich melt ($\rho=4.6\text{g/cm}^3$). Possible models for this process are discussed extensively in [4,8,11,12], and dendritic growth is thought to have facilitated melt trapping [8].

Samples and Experimental Procedure: We used INAA to determine abundances of Ni, Cr, Co, Cu, Ga, As, Ru, W, Re, Os, Pt, Ir, and Au. Forty-one 440 – 580 mg samples of clean metal from Cape York were irradiated at UC Irvine’s Mark 1 TRIGA reactor with a flux of $8 \times 10^{11}\text{n/sec} \times \text{cm}^2$ and counted at UCLA per [12,13]. Newer data were compiled with older Wasson lab INAA data for available elements, to improve statistics.

Subsequent diffusion modeling was performed using Matlab. Diffusion was modeled in 1D and 2D over 50 cm, using the difference between Savik II and estimated melt compositions from [8,12] as the opposite endmember (Fig. 7). Diffusion rates were estimated at different temperatures from best-fit lines in Figures 3 and 4.

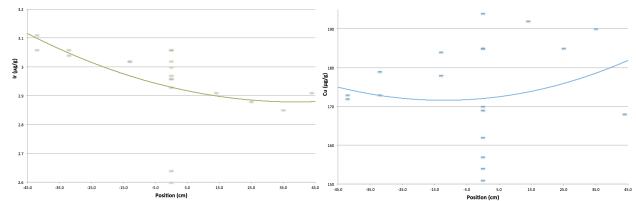


Fig 6. INAA data across Agpalilik for a) Ir b) Cu. More diffusive elements show higher scatter, suggesting that primary, high-temperature diffusive profiles have been overwritten. The relatively low spread in Ir data suggests that late processes occurred at relatively low temperatures – probably below the Fe/FeS eutectic.

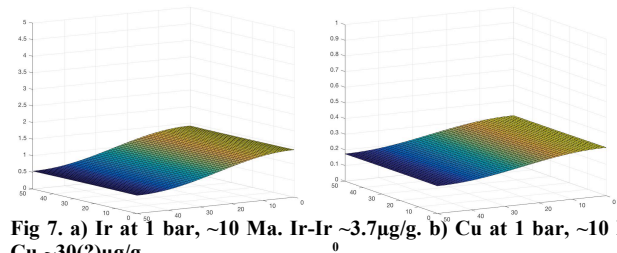


Fig 7. a) Ir at 1 bar, ~10 Ma. Ir-Ir ~3.7 $\mu\text{g/g}$. b) Cu at 1 bar, ~10 Ma. Cu-Cu ~30(?) $\mu\text{g/g}$

Discussion: Iron meteorites start to crystallize at $>2400^\circ\text{K}$, and the increasingly S rich residual liquid finally reaches the FeS eutectic at $\sim 1290^\circ\text{K}$. At accepted cooling rates for IIIABs of $25^\circ\text{C} - 150^\circ\text{C} / \text{Ma}$ [6,9,etc.], this encompasses $\sim 10 - 50 \text{ Ma}$.

Troilite nodules are relatively low-temperature features that form $<1290^\circ\text{K}$. Above this temperature, S is concentrated in an increasingly S-rich Fe-Ni melt. Our data show significant spread adjacent to troilite nodules ($X = 0$, Fig. 6). This is probably due to metal-melt interactions below the liquidus and especially Fe-FeS below the eutectic. Our previous modeling in [15] suggested that diffusion played a large role in generating the smooth Ir gradient we see across Cape York, but was unable to reproduce the cm-scale variations observed in more mobile elements. Work presented at the conference will address this issue.

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