# SIDEROPHILE ELEMENT PROFILE MEASUREMENTS IN IRON METEORITES USING LASER ABLATION ICP-MS.

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**Introduction:** Understanding the behaviour of siderophile elements during cooling of iron meteorites can lead to insight into the general thermal histories of the meteorites as well as their respective parent bodies. Traditionally trace element analyses in meteorites have been done using techniques that only measure the average concentration in each phase. With these methods, all of the spatial information with respect to the distribution of an element within one phase is lost. Measuring concentration *profiles* of trace elements in meteorites is now possible, with the advent of high-resolution analytical techniques such as laser ablation, inductively coupled plasma mass spectrometry (LA-ICP-MS) with spatial resolution <20 microns. [e.g. 1,2] and secondary ion mass spectrometry [3]. These profiles can give more insight into both the partitioning and diffusive behavior of siderophile elements in metal systems relevant to iron meteorites, as well as parent body cooling rates.

**Analytical Technique:** Cape York is a type IIIAB medium octahedrite, with taenite lamellae that measure about 100μm-500μm across, and may be considered broadly representative of the type IIIAB irons. A sample of the Cape York (Agpalilik) meteorite was mounted in epoxy, ground flat and then polished. It was subsequently etched with ~1 % nital ($HNO_3$ in ethanol) solution to expose the well-defined Widmanstätten texture. Laser ablation analyses were performed on the sample at the University of Maryland with an Element 2 (ThermoElectron - Finnigan MAT) magnetic sector ICP-MS utilizing a frequency quintupled Nd:YAG laser ablation system operating at 213 nm (UP213 from New Wave Research). Line profiles were performed with laser pulse rates of 8-10 Hz and a spot size of 12-20 microns, moving at a rate of 5-15 microns/second. Spots ranging in size from 20-60 microns were also ablated in the neighboring kamacite grains and in the centre of the taenite grains to gain further precision on the absolute concentrations at both ends of the profiles. A typical time resolved analysis involved ~20 seconds of background acquisition with the ablation cell being flushed with He, followed by laser ablation for 120 seconds. The time-resolved spectra were processed off line using a spreadsheet program to apply the background subtraction and calculation of absolute trace element abundances (modified version of LAMTRACE by Simon L. Jackson) and then averaged using a box-car averaging technique. A series of analyses consisted of a group of 20 line scans or spot analyses, with the first two, and last two being analysed on the standard (Coahuila meteorite). As a check for interfering isobars, element concentrations were determined using multiple isotopes, when possible. All scans were analyzed for the following isotopes: $^{65}Cu$, $^{71}Ga$, $^{74}Ge$, $^{95}Mo$, $^{97}Mo$, $^{99}Ru$, $^{101}Ru$, $^{103}Rh$, $^{108}Pd$, $^{110}Pd$, $^{85}Re$, $^{189}Os$, $^{190}Os$, $^{191}Ir$, $^{193}Ir$, $^{194}Pt$, $^{195}Pt$, and $^{197}Au$. $^{63}Cu$ was used as an internal standard. The profiles are on the order of 100-500 microns in length, and the concentrations range from < 0.5 ppm for Au to about 2000 ppm for Cu. A sample of the Coahuila meteorite was used as an external standard, and line profiles on this standard are in good agreement with known concentrations [4]

**Results:** Using the above technique, we measured typical "M-shaped" profiles on several taenite grains. Figure 1 shows typical time resolved profiles for Pd and Au, covering a broad range of the concentrations observed.

Figure 1



Typical Profiles for Pd and Au
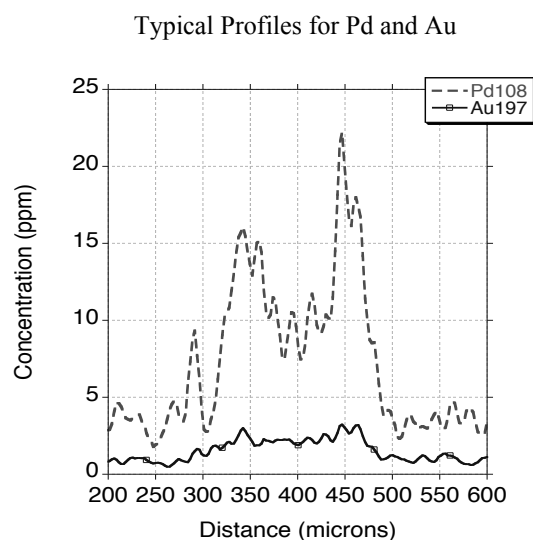
Many studies of partitioning behavior in iron meteorites find partition coefficients based on the average value of concentrations in both phases [e.g.

5,6,7]. In light of these measured profiles, it is evident that previous partition coefficient measurements may not reflect true equilibrium values. The only point where there appears to be equilibrium is immediately adjacent to the interface. The ratio of these values ($C_\alpha/C_\gamma$) at the interface represents the equilibrium partition coefficient at the temperature at which diffusion ceased to be effective, generally considered to be about 400$^o$C. The average value, even in the center of the taenite grain, may not be a meaningful value for determining partition coefficients beyond their sign (more compatible in kamacite, or taenite). This is due to the impingement effect, causing the central value to rise, as a concentration profile from the other side of the grain encroaches. However, a comparison of the "M-shaped" profiles to flat ones (e.g., elements such as P that diffuse much faster) may give insight into both the equilibrium partition coefficient at low T (interface) and a limit on the high temperature state (central taenite value). At very high cooling rates, and/or very long impingement lengths, the central taenite value may represent the original concentration at the time of kamacite nucleation, but this is unlikely to be the case for realistic cooling rates and initial crystal sizes.

The difference in measured partition coefficients can be drastic, depending on the area on which the taenite measurements are made (either the interface or the lamella center). Preliminary partition coefficients representing equilibrium at 400$^o$C were measured by averaging the edge values of 10 laser profiles that were close together along the same taenite grain, with a spot size of 20 microns Figure 2 shows a comparison of these values with previously determined partition coefficients ($D_{k/t}$) in the Cape York sample measured at the center of the grain [5].

**References:** [1] Campbell, A. J. and Humayun, M. (1999) *Anal. Chem.* 71, 939-46. [2] Campbell, A. J. et al. (2001) *GCA* 65, 163-80. [3] Hsu, W. B. et al. (2000) *GCA* 64, 1133-47. [4] Petaev, M. I. and Jacobsen, S. B. (2004) *Meteoritics & Planet. Sci.* 39, 1685-1697. [5] McDonough W.F. et al. (1999) *LPS* XXX, abstract #2062. [6] Cavell, R. G. et al. (2004) *Am. Min.* 89, 519-526. [7] Hirata, T. and Nesbitt, R. W. (1997). *EPSL,* 147, 11-24.

Figure 2



**Partition Coefficients**