LOW TEMPERATURE SIDEROPHILE ELEMENT PARTITION COEFFICIENTS IN IRON METEORITES. H.C. Watson[1] , E.B. Watson[2], W.F. McDonough[3], and R. Ash[3] [1] Lawrence Livermore National Laboratory, L-206, 7000 East Ave. Livermore, CA, 94550 (watson40@llnl.gov), [2] Department of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, Troy, NY, 12180, [3] Department of Geology, University of Maryland, College Park, MD 20742

Introduction: Knowledge of siderophile element partitioning behavior in iron meteorites is essential in the effort to constrain models of thermal histories of meteorites and parent bodies through methods that utilize these trace elements. It has been shown that many siderophile elements distribute themselves (like Ni) in a typical M-shaped profile during Widmanstatten pattern formation [e.g., 1,2]. Measuring these concentration profiles might be the best way to extract reliable partitioning information from natural meteorite samples, and experiments at relevant conditions have proven to be challenging. Several attempts at measuring partition coefficients in iron meteorites have relied on average concentrations in the two phases [3,4,5]; however, given the observed zoning, and our understanding of the development of the Widmanstatten pattern during cooling, the only point where we are likely to see meaningful equilibrium values is immediately adjacent to the taenite/kamacite interface [2]. The ratio of siderophile element concentrations at the interface represents the equilibrium partition coefficient at the temperature at which diffusion ceased to be effective, kamacite stopped growing into the pre-existing taenite grain, and the typical M-shaped profile stopped evolving. This temperature is generally considered to be about 400ºC, but possibly as low as ~300ºC [6]. The average value, even in the center of an average taenite grain, may not be a meaningful value for determining partition coefficients beyond their sign (more compatible in kamacite, or taenite) due to the effect of impingement. This causes the central value to rise as a concentration profile from the other side of the taenite grain encroaches. 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.

In this study, M-shaped concentration profiles across taenite and kamacite have been measured for a number of elements (Cu, Ga, Ge, Mo, Ru, Rh, Pd, Re, Os, Pt, Ir and Au) in the Cape York (Group IIIAB) meteorite, and partition coefficients representing equilibrium at ~400ºC were measured.

Analytical Methods: Analyses were performed 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 20 microns, moving at a rate of 5-15 microns/second. A typical time resolved analysis involved ~20 seconds of background acquisition followed by laser ablation for 120 seconds. A series of analyses consisted of a group of 20 line scans or spot analyses, with the first two, and last two being analyzed on the standard (Coahuila meteorite). As a check for interfering isobars, element concentrations were determined using multiple isotopes, when possible. All scans 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 areas of interest in the profiles are on the order of 100-1000 microns in length, and the concentrations range from < 0.5 ppm for Au to about 1000 ppm for Cu (Fig 1). Each concentration recorded corresponds to a time of approximately 0.5 seconds of a line scan.

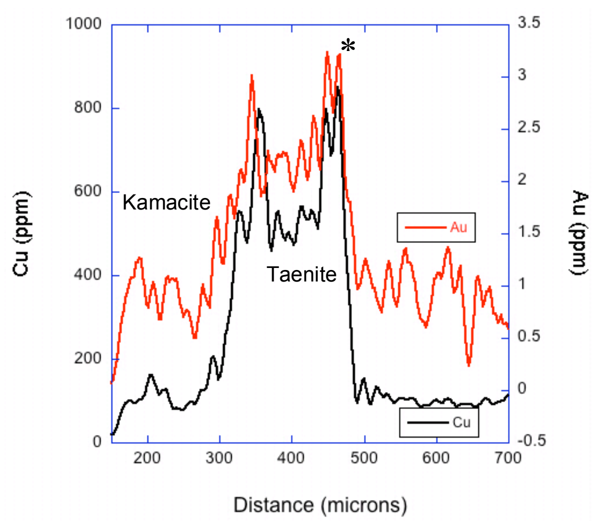

Fig. 1: Typical M-shaped profiles for Cu and Au.

Results and Interpretation: Partition coefficients ($D_{Tae/Kam}$) were calculated by the ratio of the concentration of a given element in taenite to that in kamacite. The values used for taenite were taken as the highest value measured near the interface (*, in Fig. 1), and the kamacite values were taken as the average of the flat portions of the profile. We observe that the partition coefficients are correlated with atomic number (Fig. 2).

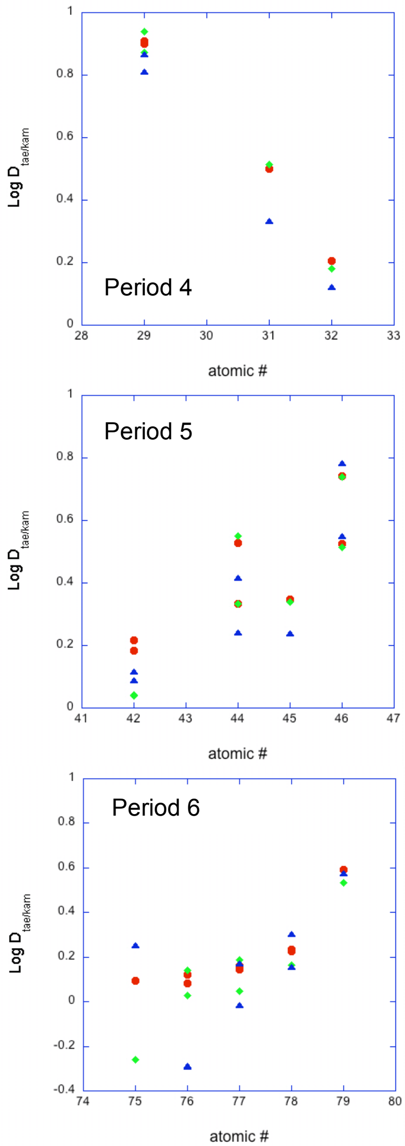

Fig. 2: Measured partition coefficients are correlated with atomic number, periodically. Period 4 elements demonstrate a negative correlation and period 5 and 6 elements demonstrate a positive correlation. The green diamonds and blue triangles represent two individual analyses, and the red circles represent an average of 5 analyses.

There is a negative correlation with the period 4 elements (Cu, Ga, Ge), and slightly less well-defined positive correlation in the period 5 (Mo, Ru, Rh, Pd) and period 6 (Re, Os, Ir, Pt, Au) elements (Fig 2). Attempts have been made to find other atomic properties that demonstrate a correlation with these observed partition coefficients, (e.g.. melting point, atomic radii, atomic weight, volatility etc,) and none lead to as apparent a correlation. The periodicity, and opposite behavior of the period 4 elements in these correlations is indeed interesting, and will certainly require further measurements and consideration. Although these low temperature partition coefficients may not be directly relevant to the entire cooling process during Widmanstatten formation, this is an initial insight that (when coupled with high temperature experimental information) may lead to a much more general understanding of siderophile element partitioning in metal systems relevant to iron meteorites and planetary cores.

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