ZONED AND UNZONED METAL GRAINS IN THE CH CHONDRITES ALH 85085 AND PCA 91467. A. J. Campbell and M. Humayun, Dept. of the Geophysical Sciences, University of Chicago, 5734 S. Ellis Ave., Chicago, IL 60637 (a-campbell@uchicago.edu).

Introduction: CH chondrites are metal rich, fine-grained meteorites that have undergone relatively little thermal metamorphism [1]. Meibom et al. [2] proposed that the radially zoned metal grains found in CH and also in some CB chondrites recorded the formation of these grains by condensation of metal in the solar nebula. This conclusion was based on measured profiles of the minor elements Ni, Co, Cr, and P. However, redox processes could have the same effect on these elements as condensation processes, creating uncertainty in interpretation of the profiles. Campbell et al. [3] used trace element microanalysis of key siderophile elements (e.g., Pd, Ir) to verify that the zoned metal in the CB_b chondrites [1] were nebular condensates.

In this report we present analogous measurements on metal in two CH chondrites, extending earlier work [4], and show that the Ni-zoned metal in these meteorites also contain nebular condensate metal, similar to the results of the CB_b chondrites [3]. We further examine the Ni-unzoned metal in CH chondrites, and show that it is commonly zoned in Cu, a volatile element.

Experimental: Sections of two CH chondrites, Allan Hills (ALH) 85085 and Pecora Escarpment (PCA) 91467, were examined by SEM and optical microscopy, and metal grains were selected for laser ablation ICP-MS analysis based on their size and Ni zoning. The zoned and unzoned grains studied were 50-200 µm across, and included some of the largest in the section. Laser ablation ICP-MS analysis followed procedures similar to those of [3]. Because of the relatively small size of metal grains, the analyses were optimized for high spatial resolution by reducing the laser spot size to 13 µm diameter (~10 µm depth) and restricting the isotopes analyzed to only ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{101}Ru, and ^{105}Pd. The trace elements Cu, Pd, and Ru were chosen to represent a range of volatilities relative to that of Fe (Cu>Pd≈Fe>Ru). Errors at each point were dominated by counting statistics and were typically 5-15%. In addition to the profile measurements on zoned and unzoned grains, several smaller grains were also selected for "bulk" analyses using laser spots of 50 µm.

Results: The metal grains in PCA 91467 and ALH 85085 that were zoned in Ni were found also to be zoned in Co and Ru, sometimes in Cu, but not in Pd (Figure 1). Refractory siderophile compositions at the grain rims tended to be chondritic in the relative abundances of the siderophiles, while the grain cores were enriched in Ru and Co, strongly depleted in Cu, and unzoned in Pd. In the zoned grains studied, Co/Ni ratios were approximately chondritic and Ru/Ni ratios were chondritic or moderately superchondritic. There was very weak correlation observed between Pd and Ni, and Cu was anticorrelated with Ni. The Ru-Ni and Pd-Ni correlations in the Ni-zoned metal are similar to the calculated trend of metal condensing in a solar gas [3].

Profiles of siderophile element concentrations were measured in four ALH 85085 metal grains that were unzoned in Ni. These grains had lower mean Ni contents (5.2-7.3 wt%) and lower Ru (1.2-4.9 ppm) than was commonly observed in the Ni-zoned metal. These grains were unzoned not only in Ni but also in Co, Pd, and Ru; however, they all were strongly zoned in Cu, with Cu enrichments at the rims (50-440 ppm) similar to or greater than those observed in the Ni-zoned grains (<7 to 130 ppm). Cu at the cores of the Ni-unzoned grains also tended to be higher than that at the cores of Ni-zoned grains. There was no systematic difference between sizes of the Ni-zoned and Ni-unzoned grains.

Mean Ru and Pd compositions of the Ni-unzoned and Ni-zoned metal in the CH chondrites are plotted against Ni in Figure 2. The results are similar to the calculated equilibrium condensation trend from a gas of solar composition [3], although some Ru depletion is evident at low Ni contents. No systematic difference was observed between the metal in ALH 85085 and PCA 91467.

Discussion: The observed correlations among siderophile elements in zoned metal grains in ALH 85085 and PCA 91467 are similar to those observed in QUE 94411 [3] and imply that the PCA 91467 zoned metal formed by condensation in the solar nebula. As described in [3], Ru, Ni, and Co are more refractory than Fe and should be expected to correlate positively with one another during condensation of Fe-rich metal. Due to its having a volatility similar to that of Fe, Pd is unzoned in these grains, and the volatile siderophile Cu is strongly depleted in the grain cores but sometimes increases rapidly toward the grain rims, suggesting that the temperature at which metal was deposited onto the rims of the metal sometimes (but not always) approached the condensation temperature of Cu. The observed Cu-Ni trends within individual grains show a significant degree of scatter about the calculated condensation trajectory, and may have been disturbed by a small degree of post-condensation diffusion. This set of siderophile element trends cannot be produced by other processes, such as those involving metal/melt equilibration or redox reactions [3], and recent experiments indicate that extensive diffusion within the zoned grains would be expected to produce elemental fractionations that are not observed [5].

The core Ni (and Co and Ru) contents vary among Ni-zoned grains, implying that different grains may have begun growing at different temperatures (although sectioning of the grains must also have contributed to this variability). Consequently, there may be grains that began to form at lower temperatures; these would display little or no zoning in Ni and other refractory siderophiles as they grew. However, these low-T grains would still be expected to develop strong zoning in volatile siderophiles such as Cu, because the equilibrium volatile content will continue to depend strongly on T even below the temperatures at which the refractory element contents have stabilized.

The Ni-unzoned grains in ALH 85085, for which LA-ICP-MS profiles are available, display zoning only in the volatile element Cu; this is qualitatively consistent with a formation by condensation in a cooling solar nebula gas. The Ru depletion found in these grains may be the result of Ru sequestering in high-T processes, depleting the gas in highly refractory siderophiles. This depletion may result from fractional condensation, perhaps related to formation of the Ni-zoned grains, or from an earlier volatilization stage, perhaps similar to that which has been described for Renazzo chondrule rim metal [6]. An alternative interpretation of the Cu profiles, involving Cu diffusion into metal grains on the parent body, has also been considered. In this scenario a correlation would be expected between core Cu content of the metal grains and grain size, but no such correlation was observed. (As mentioned above, diffusion of Cu over short scales may still have perturbed the Cu-Ni trends recorded within a grain from the condensation trajectory.) Furthermore, Cu contents are higher in the cores of the Ni-unzoned metal grains, and in general there is a correlation between Cu and Ni in the grain cores (Figure 3) supporting the notion that both the Ni-unzoned metal and Ni-zoned metal could have formed by the same condensation process with various initial and final temperatures.

References: [1] Weisberg M. K. et al. (2001) *MAPS, 36*, 401-418. [2] Meibom A. et al. (1999) *JGR, 104,* 22053-22059. [3] Campbell A. J. et al. (2001) *GCA, 65,* 163-180. [4] Campbell A. J. and Humayun M. (2002) *MAPS, 37*, A29. [5] Righter K. et al. (2003) this volume. [6] Humayun M. et al. (2002) *LPSC XXXIII*, Abstract #1965.

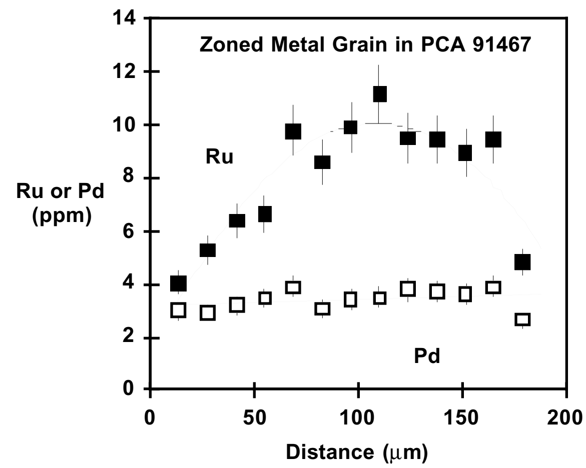

Figure 1. LA-ICP-MS data across a Ni-zoned metal grain.

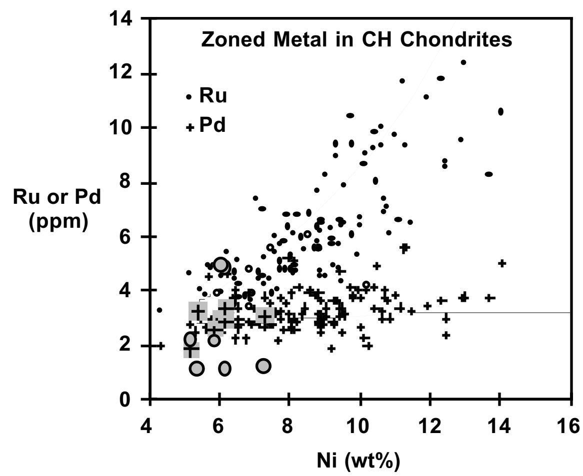

Figure 2. Ru (circles) and Pd (crosses) across multiple zoned metal grains in ALH 85085 and PCA 91467. Shaded symbols = Ni-unzoned metal. Curves = condensation paths at 10^{-4} bar.

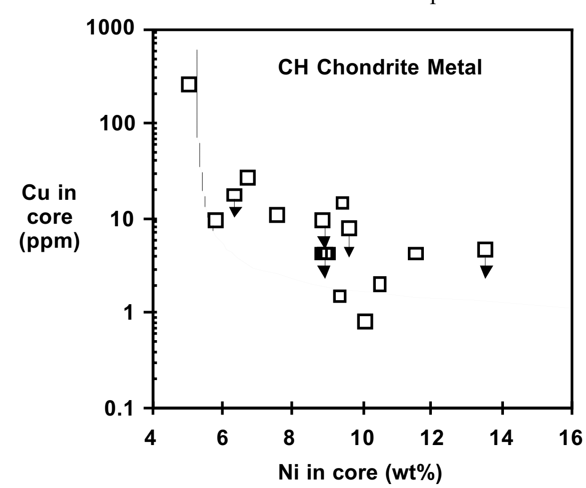

Figure 3. Cu vs. Ni contents in the cores of metal grains in CH chondrites. Curve = condensation in 10^{-4} bar solar gas.