SIDEROPHILE ELEMENT DISTRIBUTIONS IN THE METAL-RICH CHONDRITE GRO 95551. A. J. Campbell and M. Humayun, Department of the Geophysical Sciences, The University of Chicago, 5734 S. Ellis Ave., Chicago, IL 60637 (acampbel@midway.uchicago.edu).

Introduction: Grosvenor Mountains (GRO) 95551 is a metal-rich chondrite that has been linked petrographically to the Bencubbin-like meteorites, but which has oxygen isotopic compositions that are very different from Bencubbin and are similar to those of ordinary chondrites [1]. Siderophile element data from metal clasts in Bencubbin and related meteorites have revealed an origin by volatilization or condensation from gas enriched in metal relative to solar gas, but which does not appear to reflect equilibrium with the solar nebula [2]. In contrast, individual zoned grains in the similarly metal-enriched chondrites QUE 94411 and HH 237 have been shown to be consistent with condensation in a rapidly cooling gas of approximately solar composition [3-5]. Metal in Renazzo reveals the effects of volatilization/recondensation as well as redox processing [6]. To extend our understanding of the formation of these meteorites, we have measured the distribution of siderophile, and moderately siderophile, elements in metal in GRO 95551.

Experimental: A polished thin section, GRO 95551,12, was examined optically and by SEM (JEOL 5800-LV). Point-counting on the SEM images was used to estimate the volume fraction of silicate, metal, and sulfide. Compositions of each phase were measured by EDX, and locations were selected for trace siderophile element analysis by LA-ICP-MS. A CETAC LSX-200 laser ablation peripheral was used with a magnetic sector ICP mass spectrometer, the Finnigan Element™ [5]. Each point analysis on the sample produced a pit 50-160 µm in diameter, depending on the grain size, and approximately 15 µm deep. The isotopes ^{25}Mg, ^{29}Si, ^{31}P, ^{34}S, ^{53}Cr, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{69}Ga, ^{74}Ge, ^{75}As, ^{95}Mo, ^{101}Ru, ^{103}Rh, ^{105}Pd, ^{118}Sn, ^{121}Sb, ^{182}W, ^{185}Re, ^{192}Os, ^{193}Ir, ^{195}Pt, and ^{197}Au were monitored during some or all of the measurements. Instrumental sensitivity factors for each isotope were determined by measuring signal intensity from standards which have known concentrations of the elements of interest [2]; Hoba (IVB iron), Filomena (IIAB), and NIST SRM 1263a were used for calibration. Precision of the LA-ICP-MS measurements varied with spot size and concentration, and was typically 5-20% (2σ).

Results: The section GRO 95551,12 is approximately 8 mm x 8 mm in size, and is dominated by a large (approximately 9 mm x 5 mm) silicate nodule, which runs diagonally through the section and takes up 65 % of the area. This nodule has a barred olivine texture, with olivine laths (Fo_{99}) typically 5 µm in width. The remainder of the section consists of chondrules (24 vol%), metal (10 vol%), and sulfide (1 vol%). Metal grains typically range in size from 50 to 500 µm. Sulfides, up to ~200 µm in size, are usually associated with metal. Barred olivine, cryptocrystalline, and porphyritic chondrules are present in roughly equal proportions.

The compositions of the metal grains fell into two distinct groups. One, the "high-Ni" group, has about 7.2 ± 0.8 wt% Ni and 0.32 ± 0.03 wt% Co; metal in the other, "low-Ni" group has about 3.7 ± 0.3 wt% Ni and 0.45 ± 0.04 wt% Co (errors are 2 standard deviations, LA-ICP-MS analyses). The high-Ni:low-Ni volume ratio of metal grains, based on EDX analyses of 46 grains in the section, is approximately 70:30. The average siderophile element compositions of the two metal groups are plotted in Figure 1, normalized to Fe and H chondrites [7]. Normalized in this way, it is seen that in GRO 95551 metal the refractory siderophiles, with the exception of W, are nearly unfractionated from one another and are depleted relative to Fe and H chondrites by 30-40%. Likewise, the volatile elements As, Ga, Sb, and Ge are uniformly depleted by 15-20%; Cu and Sn show larger depletions. The weighted Co/Ni ratio is about 15% higher than chondritic.

Discussion: The relative abundances of minor and trace elements between the high-Ni and low-Ni metal groups in GRO 95551 suggest that these two metal compositions may have been established by kamacite/taenite partitioning at high temperatures. The high-Ni metal contains low Co, Mo, W, and P, and high Pd, Au, and Cu relative to the low-Ni metal; the refractory PGEs are nearly unfractionated between the two metal groups. This pattern is the same as one observes in kamacite/taenite partitioning in iron meteorites [8,9], although the degree of partitioning is lesser in GRO 95551, as one would expect if the metal phases equilibrated at higher temperature than is inferred from kamacite exsolution in irons. The Ni contents of the two metal groups in GRO 95551 suggest equilibrium between the two phases at ~1020 K [10]; in contrast, iron meteorites display continued equilibration to <800 K [9].

If the composition of the two metal groups does reflect equilibrium at ~1020 K, then it should be expected that the silicate portion of GRO 95551 would exhibit equilibration at similar temperatures. Application of the two-pyroxene thermometer [11] to a few chondrules produces a range of temperatures, from ~1150 to ~1550 K, indicating that the chondrules and metal in GRO 95551 are not equilibrated. However, the observed excesses in Fe and W, relative to the highly siderophile elements, could have been produced by reduction of silicates, implying that metal-silicate equilibrium played some role in the formation of GRO 95551 metal.

The high Co/Ni ratio (~1.15 x chondritic) in mean GRO 95551 metal is incompletely understood. It may have resulted from nonrepresentative sampling of the meteorite, due to large grain sizes relative to the area of the section. For example, the mean Co/Ni ratio becomes chondritic if the high-Ni:low-Ni metal ratio is increased to 85:15 from the observed 70:30. Alternatively, there could be an additional phase with low Co/Ni ratio, such as schreibersite, that is absent in section GRO 95551,12. However, addition of schreibersite, which has large fractionations among PGEs (e.g., [12]), may perturb the flat siderophile element pattern in Figure 1.

GRO 95551 has previously been compared to Bencubbin and related meteorites, because its high metal content and other petrographic features, including the large silicate nodules, are similar to those of Bencubbin [1]. It was also shown in [1] that GRO 95551 differs from Bencubbin in several important ways, including oxygen isotope compositions, presence of interstitial sulfides, and olivine compositions. To these differences we can add the siderophile element compositions of the metal (Figure 1). Bencubbin metal, taken as the average of analyses in [2], is enriched in refractory siderophiles and strongly depleted in volatile siderophiles (a discussion of the Sb content in Bencubbin is found in [2]), a chemical signature very different from that of GRO 95551. Furthermore, Bencubbin metal has chondritic Co/Ni ratios and a wide range of Ni contents, rather than the clustering of Ni contents, with inversely correlated Co, found in GRO 95551. In particular, the relative lack of volatile siderophile depletions in GRO 95551 is a feature that cannot be produced by subsolidus re-equilibration, and requires an origin distinct from that of metal in Bencubbin or related metal-rich meteorites, such as QUE 94411.

Kallemeyn [13] suggested that the siderophile element composition of GRO 95551 may be closer to that of ALH 85085 than to that of Bencubbin. Whole rock data from ALH 85085 [14] is compared to the GRO 95551 metal in Figure 1. The ALH 85085 data bear a closer resemblance to GRO 95551 than Bencubbin does, particularly in the absence of a strong depletion of volatiles such as Ga. Nevertheless, GRO 95551 metal still shows a systematic depletion in the refractory siderophiles Os, Ir, and Ru, relative to ALH 85085. Also, the positive Ni-Co correlation found in ALH 85085 [15] is not observed in GRO 95551.

References: [1] Weisberg M. K. et al. (2001) *Meteort. Planet. Sci., 36,* 401-418. [2] Campbell A. J. et al. (2001) *GCA,* in press. [3] Meibom A. et al. (1999) *JGR, 104*, 22053-22059. [4] Campbell A. J. et al. (2000) *Meteorit. Planet. Sci., 35, A38-A39*. [5] Campbell A. J. et al. (2001) *GCA, 65,* 163-180. [6] Humayun M. and Campbell A. J., this volume. [7] Wasson J. T. and Kallemeyn G. W. (1988) *Phil. Trans. R. Soc. London A, 325,* 535-544. [8] Campbell A. J. and Humayun M. (1999) *LPSC XXX,* #1974. [9] Narayan C. and Goldstein J. I. (1985) *GCA, 49,* 397-410. [10] Chuang Y.-y. et al. (1986) *Metall. Trans. A, 17A,* 1361-1372. [11] Lindsley D. H. (1983) *Am. Mineral., 68,* 477-493. [12] Kurat G. et al., this volume. [13] Kallemeyn G. W. (2000) *Meteorit. Planet. Sci., 35,* A85. [14] Wasson J. T. and Kallemeyn G. W. (1990) *EPSL, 101,* 148-161. [15] Weisberg et al. (1995) *Proc. NIPR Symp. Antarct. Meteorit., 8,* 11-32.

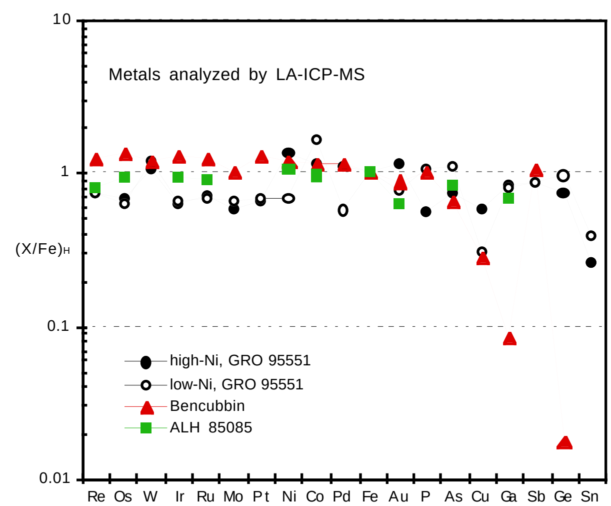

Figure 1. Siderophile element abundances, normalized to Fe and H chondrites [7], in metal in GRO 95551 (this work), Bencubbin [2], and ALH 85085 [14].