LARGE METAL GRAINS IN ORDINARY CHONDRITES. B. G. Radoman-Shaw[1], M. Humayun[2], R. P. Harvey[1] and James Karner[1], [1]Department of Earth, Environment, and Planetary Science, Case Western Reserve University, 10900 Euclid Avenue Cleveland, OH 44106 (bgs21@case.edu). [2]Department of Earth, Ocean and Atmospheric Science, Florida State University, Tallahassee, FL 32310.

Introduction: A metal nodule is a metal grain that is greater than 3mm, much larger than the more typical dispersed metal in chondrites[1]. Several chondritic meteorites have been catalogued with these unusually large metal grains and analyses conducted in order to understand their origin has typically consisted of measurements of the relative abundance of siderophile elements [1,2]. The meteorites previously studied include ordinary chondrites ranging from H to LL illustrating that shear abundance of metal is not directly related to or a trigger for the formation of these nodules[3].

The work presented here focuses on a comparison between nodules in a recently characterized meteorite and other nodule-bearing chondrites either available in our lab or described in the literature. Our goal is to provide a comparison of siderophile element concentrations and ratios between normal metal grains and nodules in these samples.

Samples: Our samples consisted of several thin sections and potted 1-inch samples (A-G). For this study 2 potted 1-inch rounds and 1 thin section were used as they have the largest metal nodules available for chemical analysis. The thin section C has one large metal grain called C1. Samples F and G were made using water saw cut sections of the meteorite and epoxy. Sample F has three large grains labeled F1-3. There are two pieces of the meteorite in sample G. The first section is G1 and it has a large metal grain. The second section is G2 and this is just a rectangular piece of the meteorite that has several areas of fine metal grains to provide a comparison with the chemistry of the large metal nodules

Methods: These samples were subjected to Electron Microprobe Analysis (EMPA) and laser ablation ICPMS (LA-ICPMS). EMPA was used to examine texture and major element distribution, using well-characterized standards to quantify the latter. Three standards were used to calibrate the LA-ICPMS instrument: a piece of the IIA iron meteorite Filomena which has no widmanstatten patterns, high Ga and Ge, 2% isotopic Fe, a IVB iron meteorite Hoba with Ni, low Ga and Ge, 26% isotopic Ni, and elemental abundances for Os, Ir, Pt, Pd, and Ru, and a Nist 1263 Steel Cr-V modified sample with elemental abundances for Cr, V, As, W, and Au. A total of 12 spot samples were taken in G2. EMPA analysis shows other high nickel regions around the metal nodules that are also sampled by the LA-ICPMS: 2 Spots for F1, 2 Spots for F2, and 1 Spot for F3. The final sum for the study is three separate samples, 5 large metal nodules, and 17 fine grain metal samples.

Results: Five large metal grains are present in the recently characterized sample; not all of them have the sample texture under reflected light. Sample C has one large metal grain called C1. This nodule is rectangular in shape and is approximately 4 mm along the largest axis.

Sample F has three nodules that are named F1-3. F1 is roughly spherical with irregular borders and some sulfide formation around its edges. Its texture and color are fairly uniform suggesting a homogenous kamacite character. F2 is the largest nodule in the study at 6 mm in length on its longest axis. Under reflected light and the SEM electron beam the nodule has very little distinguishing textures or silicate inclusions. EMPA of the nodule shows a taenitic region near the lower lobate region of the sample where the number of Ni counts increases (Figure 1). F3 is similar in size, shape, and texture to F1 with many small silicate inclusions and a relatively homogenous surficial texture and chemical composition (kamacitic). The distinguishing feature of this nodule is the large sulfide crystal along its center.

In sample G the first section is G1 and it has a large metal grain. The shape of this nodule is roughly lobate in nature similar to nodule F2 but it is only 5.5mm along its longest axis. The texture of this nodule does not display any structural or chemical variation and is most likely a homogenous kamacite region.

Sample C line profile 1 shows the highest values of antimony and tin. Line profile 2 shows a large M-shaped profile in the nickel concentration pointing to a second taenitic region in the metal nodules of the meteorite[4]. The taenitic region is high in Ga and Ge and low in As with Pd, Sn, and Au following an M-shaped profile similar to the Ni.

Sample F1 Spot 1 has the highest nickel of any region which is 5 times chondritic values reaching almost 18% taenite. Spot 2 is not as enriched in nickel but still holds chondritic values in all other elements. Sample F2 line profile shows rhodium and molybdenum under the detection limit of the spectrometer. No statistically relevant amounts of phosphorus, sulfur or vanadium were in the section yet germanium and gallium are present. Line 3 shows a higher than normal amount of nickel. This part of F2 is roughly 8% Ni. The F3 metal nodule only has one line profile, which goes straight through a sulfide region and is most likely troilite at about 30% sulfur.

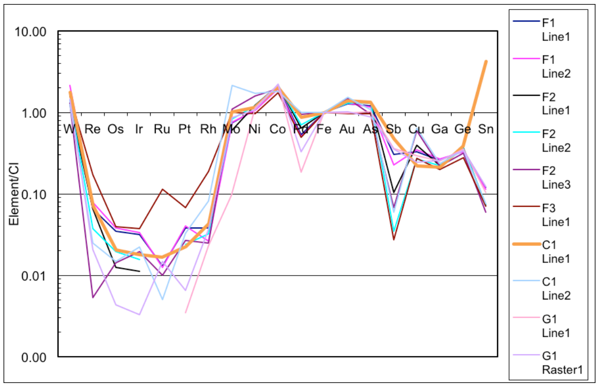

Figure 1: This chart is a tabulation of all large metal nodule chemical data acquired with the LA-ICPMS.

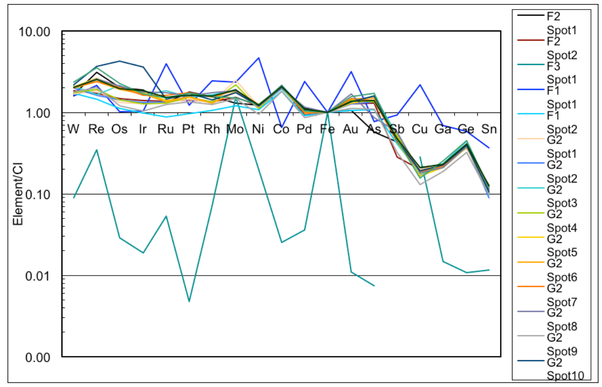

Figure 2: This chart is a tabulation of all fine metal grain chemical data acquired with the LA-ICPMS.

Line profile 1 through G1 shows that it is depleted in Os and Ir like the C1 nodule and all three F sample nodules. There are some siderophiles, which are below detection limits in the sample. With the LA-ICPMS the deeper the pit the higher the resolution. A deep 100-micron pit Raster 1 of G1 shows that Ir and Os are very low in this and all metal nodules in this meteorite.

Discussion: The textures of the metal grains in samples F and G show mainly homogenous regions of kamacite with a few taenite domains. Sample C has a quenched texture under reflected light with sulfide metal surrounding circular iron metal grains. This might be unique to nodule C1 or it might just have a better-polished surface than the potted samples and therefore it shows a higher level of detail. There is also evidence for schleiren textures in certain regions of this grain. Further EMPA work is necessary to see if grain C1 is indeed different from the other grains in texture and what implications this has for the meteorite.

The results of the LA-ICPMS analysis show a marked distinction in the siderophile element composition between large metal nodules and the fine metal grains in the chondrites studied. The metal nodules are depleted in Rhenium, Osmium, Iridium, Ruthenium, and Platinum. These depletions are similar to those seen in the Jilin (H5)[2] meteorite. However, Kong et al. (1986) states that Cu is strongly depleted. This is not the case for the nodules we studied (Figure 1). In fact the fine metal grains are more depleted in Cu than the metal nodules; nodules are actually strongly depleted in Sb more than Cu. Rubin (1999) describes the depletion of Re, Os, Ir, Ru, Pt, and Rh in metal nodules rich in kamacite (such as C1) as a transition of these refractory elements into the taenite Ni-rich metal leaving them depleted in the large kamacite grains.

The analysis of nodule C1 and the other metal nodules supports this depletion seen in other metal nodule meteorites[3]. This nodule has a quenched texture in the reflected light image in with sulfide metal surrounding circular iron metal grains. This might be unique to nodule C1 or it might just have a better-polished surface than the potted samples and therefore it shows a higher level of detail.

An interesting aspect to the depletion of the metal nodules is that no other nodules appeared to be enriched in these elements. Taenitic regions such as F2 Line 3 and C1 Line 2 do not show any kind of enrichment in the refractory siderophile elements like Os and Ir. The G2 fine metal grains are fairly chondritic in composition and not depleted like the large metal nodules indicating their absence in whatever process created the large metal nodules. The result of these absences of Ir and Os hints to a large scale melting and fractionation of these elements from the large metal grains that might even be larger than the size of the meteorite itself. This type of process supports the origin of the metal nodules by melting and fractionation by diffusion[2].

Some event, such as impact heating, causes melting and mobility of the melt into large pockets, allowing diffusion of the refractory siderophile elements from the large metal grains into another region, depleting the metal nodules. This suggests large scale melting and depletion and transport of high refractory elements such as Ir, Os, Re, Ru, and Pt. This also supports the conclusion that a diffusive process is allowing mobility of these elements away and out of the metal nodules into some other portion of the meteorite.

References: [1] Widom, E., Rubin, A. E., and Wasson, J. T. *GCA, 50,* 1989-1995. [2] Kong. P., Ebihara, M., and Xie X. (1998) *Meteoritics & Planet. Sci., 33,* 992-998. [3] Rubin, A. E. (1999) *JGR, 104,* 30,799–30804. [4] Hutchinson, Robert. *Meteorites: A Petrologic, Chemical, and Isotopic Synthesis*. Cambridge University Press: New York City, NY (2004). Pg. 150, 328.