Highly Siderophile Elements in H Chondrites

Jonathan Tino, Senior Thesis, 393

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Chondritic Meteorites and H Chondrites

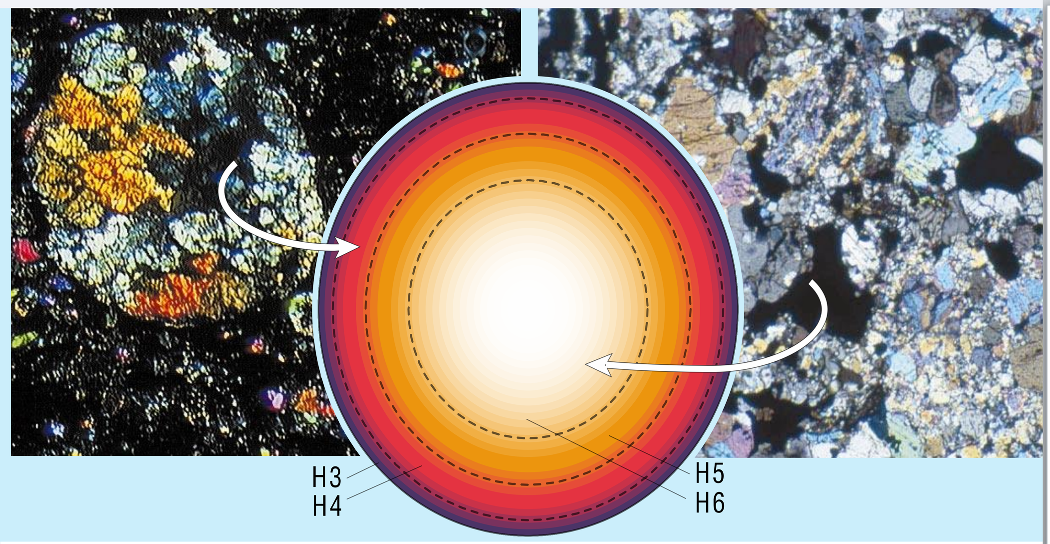


Figure 1: From Woods (2003), this illustrates the higher metamorphic grade H chondrites as having originated at a deeper (hotter) location within the parent body than H3 and H4 chondrites. Temperature and pressure are greater within the parent body than they are near the surface. Thin sections demonstrate the high degree of recrystallization in H6 relative to H4.

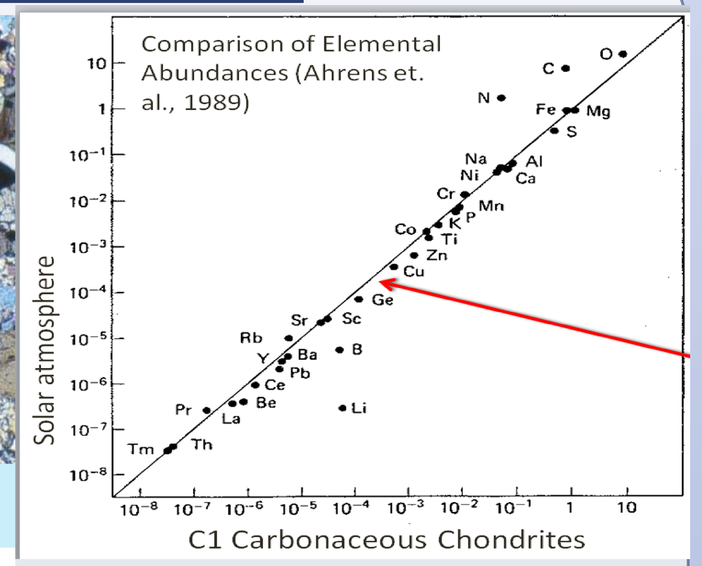


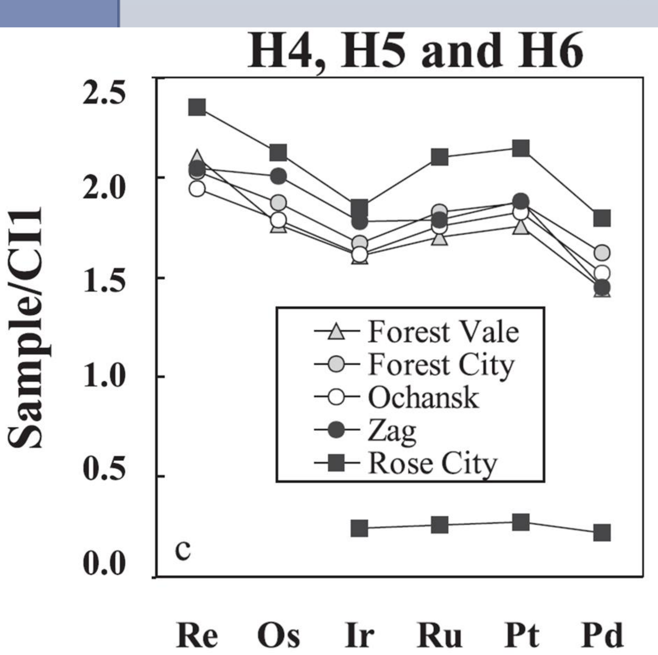
Figure 2: Comparison of elemental abundances in C1 carbonaceous chondrites and the solar photosphere demonstrates an approximate 1:1 correlation. Solar atmosphere elemental abundances are derived using spectroscopy.

- **Chondritic meteorites are stony, undifferentiated rocks from the early solar system**
- **Chondrites are "cosmic aggregates" formed of previously unrelated components**
- **Chondrites typically contain chondrules, silicate matrices, and refractory inclusions and metal grains**

- **H chondrites are an iron metal rich subset of chondritic meteorites**
- **They are proposed to have come from one parent body (Fig. 2)**
- **Sorted by thermal metamorphic grade, with H3 seeing minimal metamorphism (Peak T: 400°C -- 600°C), and H6 seeing high grade metamorphism (Peak T: 700°C - 750°C) (McSween, 1987)**

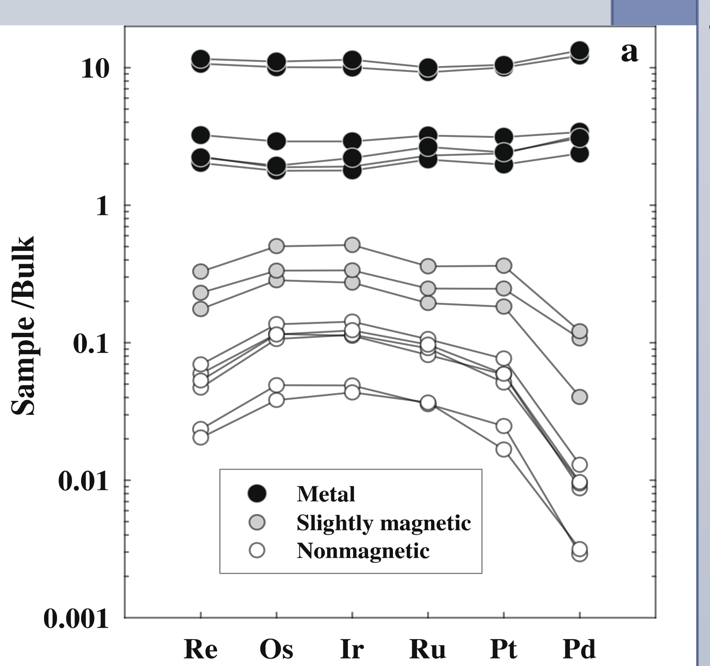
Highly Siderophile Elements

Rhenium (Re), **Osmium (Os)**, Iridium (Ir), Ruthenium (Ru), Platinum (Pt) and Palladium (Pd)



Right(4): Abundance of HSEs in the H4 chondrite Ochansk. Each fraction is isolated by magnetic separation. Additional sieving is done in order to separate fine metal (<25 micron) and medium (125-25 micron) metal from coarse (>250 micron) metal. [Horan Et Al (2009)]

Left (3): Data from Horan et. al (2003) representing concentrations of HSEs in H chondrites from 4-6. Forest Vale (H4), Forest City (H5), Ochansk (H4), Zag (H3-6), Rose City (H5) are represented. These data are bulk rock analyses normalized to CI chondrite values.



HSEs strongly partition into iron metal over silicates

Metal/silicate concentration ratio (D value) $>10^4$ for all HSE

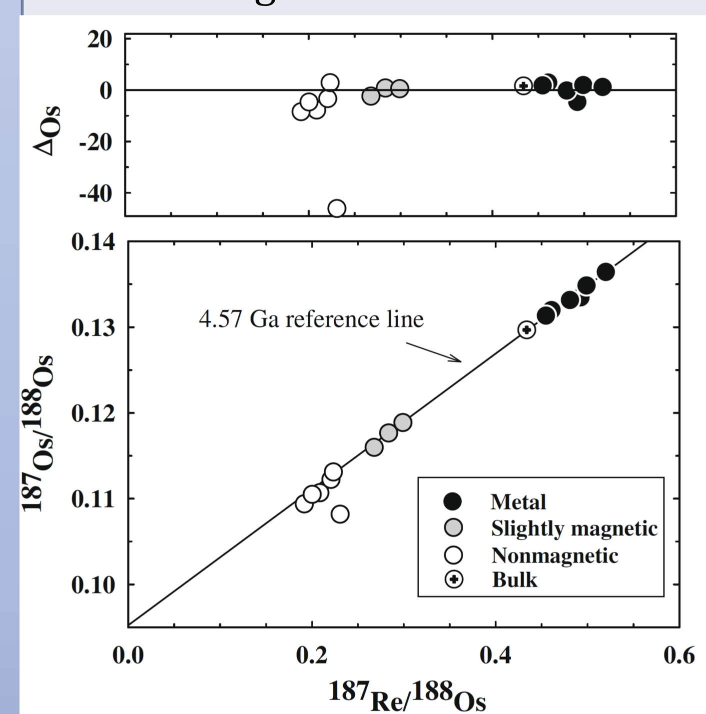
Abundance ratios of HSEs in metal relative to silicates constrains the extent of metal-silicate equilibration for various rock types and metamorphic grades

^{187}Re-^{187}Os isotope systematics allow assessment of possible open system behavior after the meteorite was initially metamorphosed.

Purpose

Assessing the extent of HSE equilibration between metal and silicate in H Chondrites

- The goal is to measure HSE abundance in H4, H5, and H6 chondrites and to assess whether equilibration occurred for any of the metamorphic grades
- HSE abundances in metal and silicates in H5 and H6 chondrites have not been previously measured
- With limited silicate data, a good indicator of equilibration would be a trend of increasing HSE concentration in metals with increasing metamorphic grade



- Will compare Re-Os data to a primordial ~4.57 Ga isochron from Horan et. al. (2009) in figure 4 in order to assess potential open system behavior.

Figure 5: Graph of ^{187}Re/^{188}Os vs ^{187}Os/^{188}Os for Ochansk, an H4 Chondrite, with reference isochron calculated from iron meteorite data to 4.57 Ga. Assumed initial ^{187}Os/^{188}Os composition of 0.09517. The decay constant (λ)=1.666*10^{-11} a^{-1}. Top plot shows per mil deviation of Os from reference line.

Hypothesis

A) Increasing thermal metamorphic grade in H chondrites will correlate with increasing concentration ratios in metal relative to silicate approaching or exceeding the D value of 10^4 that we expect to see for equilibrated HSEs. I predict that H4 chondrites will not be equilibrated, (metal/silicate<10^4) and H6 chondrites will be equilibrated (metal/silicate>10^4).

B) Fine-grained metals (<150µm) will have a higher concentration of HSEs than coarse-grained metals (>150µm) relative to silicates. This phenomenon has been observed in previous studies of metal grains in chondrites [Rambaldi et. al (1997) and Campbell and Humayun (2003)].

Works Cited

- Ahrens, et al, 1989 *Formation of atmospheres during accretion of the terrestrial planets,* in Origin and Evolution of Planetary and Satellite Atmospheres, S.K. Atreya, et al, editors, University of Arizona press, Tucson.
- Campbell, Andrew J., and Munir Humayun. "Formation of Metal in Grosvenor Mountains 95551 and Comparison to Ordinary Chondrites." *Geochimica Et Cosmochimica Acta* 67.13 (2003): 2481-495.
- Horan, M. "Highly Siderophile Elements in Chondrites." *Chemical Geology* 196.1-4 (2003): 27-42.
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Analytical Methods

Phase 1: Sample Processing

-Crush sample and purify it using magnetic separation in order to obtain distinct silicate, coarse-grained metal, and fine grained metal from each sample.

Phase 2: Isotope Dilution chemistry for Osmium

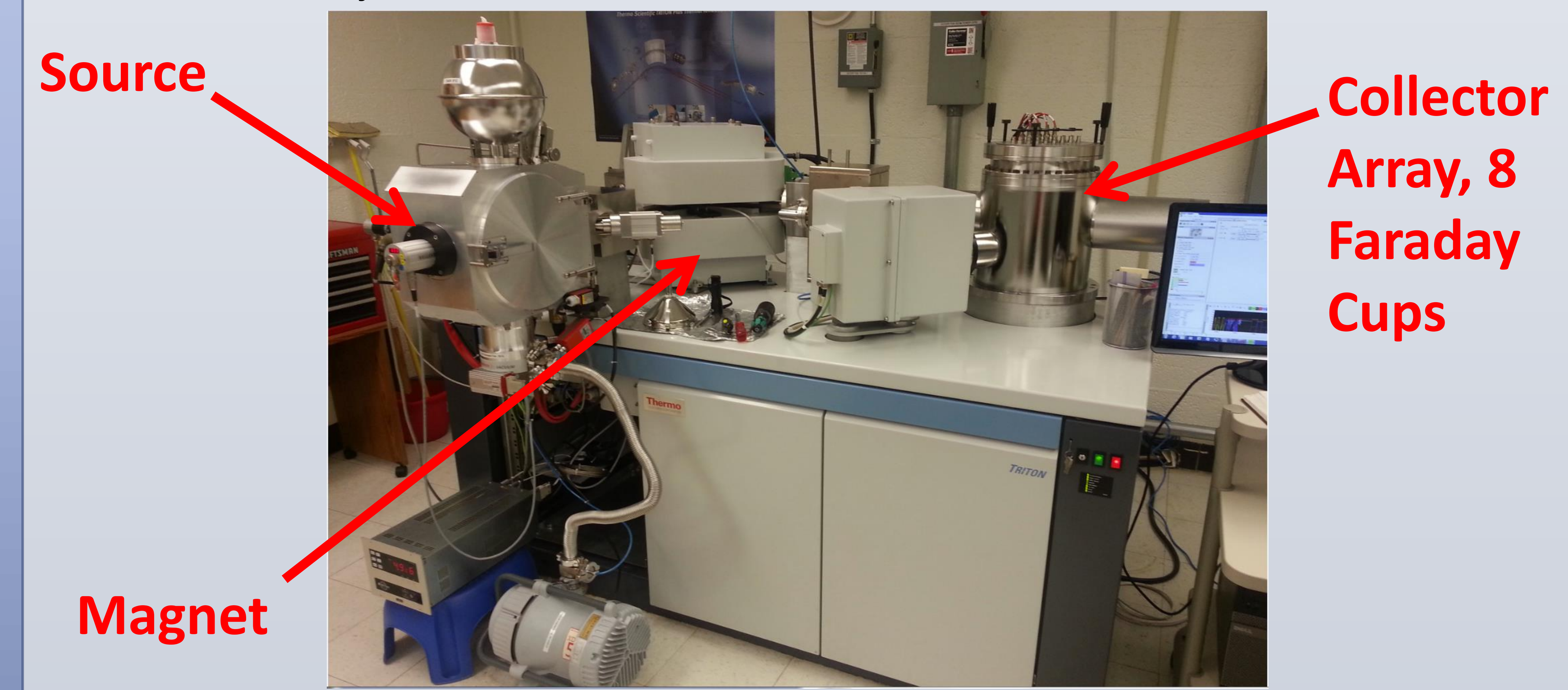
-Samples are dissolved by aqua regia(2:1 mixture of HNO_3 to HCl) in sealed Pyrex tubes while being heated at 240 °C over night.

-They are separated using CCl_4 in a centrifuge tube, and vigorously shaken to ensure that the oxidized OsO_4 is separated from the rest of the HSEs.

-Next, the CCl_4 is mixed with HBr and heated to reduce the OsO_4 and isolate the Os. The CCl_4 is removed, now devoid of Os, and the HBr is dried to a small amount (40 µL) and prepared for micro distillation.

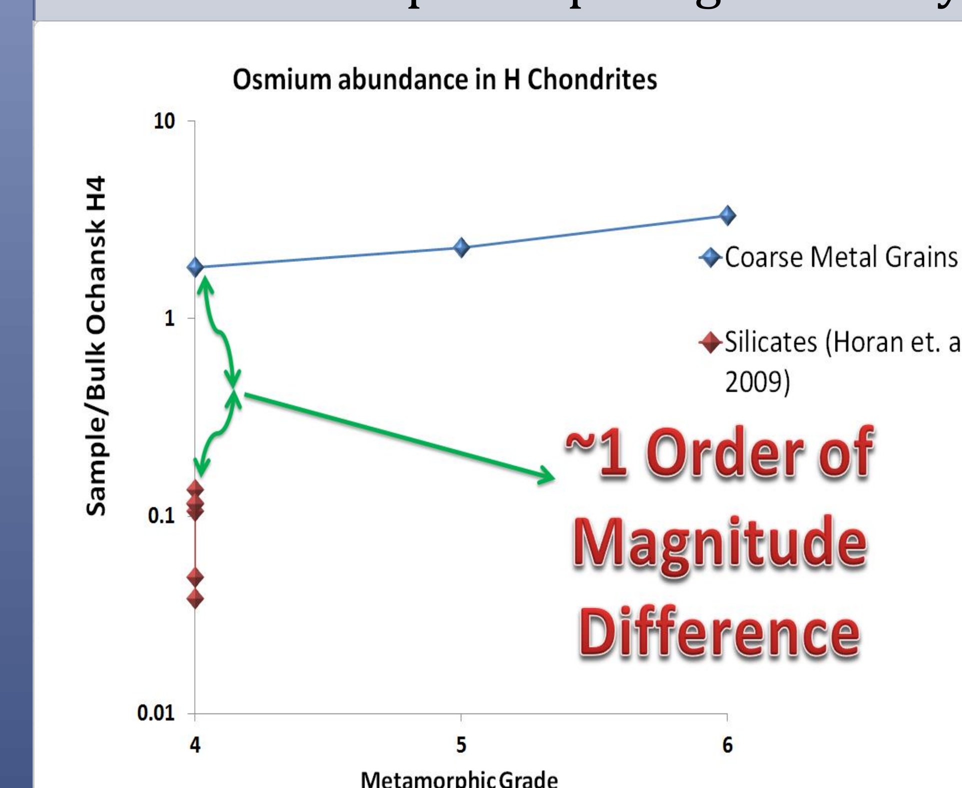
-Cr_2O_7 (Dichromate) is used to oxidize the Os once more, where it will collect and be reduced in a 15 µL drop of HBr. It is dried until it is a powder.

Phase 3: TIMS analysis for Osmium



Preliminary Data

Proof of concept comparing this study to Horan et. al (2009)



	187Os/188Os	2SE%	Os ng/g	2SE%
Avanhandava:	0.13693	0.14	**1490**	8.2E-03
Richardton:	0.13416	0.09	**1871**	5.2E-03
ALHA78115:	0.13274	0.05	**2743**	4.3E-03
			Os ng	
TAB:	0.13391	1.3	1.21E-03	0.30

- Overall trend of increasing Osmium concentration with increasing thermal metamorphic grade.
- Figure 3 shows that the concentration ratio of metal/silicate is less than 10^4 for low thermal metamorphic grade meteorites.
- Both of these confirm the plausibility of hypothesis A.

Figure 6: The blue symbols shows measured osmium concentration data for coarse grained metals from Avanhandava (H4), Richardton (H5), and ALHA 78115 (H6) normalized by the bulk concentration of osmium in the Ochansk (H4) chondrite from Horan et. al. (2009). This is being tentatively compared to silicate data from the Ochansk meteorite from the same study, represented in red symbols.