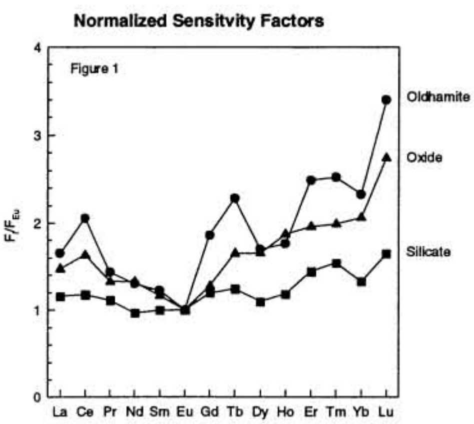
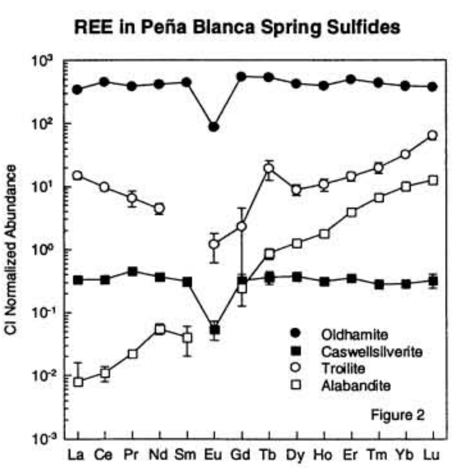
REE ABUNDANCES AND CR ISOTOPIC COMPOSITION OF OLDHAMITE AND ASSOCIATED MINERALS FROM THE PEÑA BLANCA SPRING AUBRITE.
A. Fahey, G. Huss, and G. Wasserburg. Lunatic Asylum, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125. USA
K. Lodders, Dept. of Earth and Planetary Sciences, Washington University, St. Louis, Missouri 63130. USA

The aubrites, or enstatite achondrites, are a class of highly reduced, brecciated meteorites. They contain sulfur-bearing phases such as oldhamite (CaS), and alabandite ((Mn,Fe)S). In order to better understand the origin of these minerals we have begun a detailed study of REE patterns in several sulfide phases from Peña Blanca Spring. Ion microprobe sensitivity factors for the REE and several other trace elements in sulfides were determined by comparison of INAA data on a single oldhamite inclusion. The measured REE sensitivity factors for sulfides are significantly different than the corresponding factors for oxide minerals. In addition, Cr isotopes were measured in alabandite to determine the level of ^{53}Cr present from the decay of ^{53}Mn. An upper limit on $(^{53}Mn/^{55}Mn)_0$ in this inclusion of $\sim 3\times 10^{-6}$ was determined.

REE concentrations for an oldhamite grain recovered from a sample of disagregated Peña Blanca Spring were previously measured by INAA[1]. A 4.1 mg CaS inclusion ~2 mm on a side was used for ion probe analyses. This grain contained inclusions of alabandite, troilite (FeS), and caswellsilverite ($NaCrS_2$). The average value of the REE concentrations measured at 5 positions in the oldhamite were used to compute the sensitivity factors for the oldhamite. These factors are given





by: $F_{REE} = \frac{M^+}{REE^+}\frac{[REE]}{[M]}$ where M^+ and REE^+ are the ion signals of the reference and rare earth element. [M] and [REE] are the known concentrations in ppm of some form of the element, *e.g.* Ca or CaO and the REE. A plot of the sensitivity factors F, for oldhamite (sulfides) with respect to Ca, silicates with respect to CaO, and oxides with respect to CaO is shown normalized to F_{Eu} in Figure 1. The data shows that the sulfide sensitivity factors for the heavy REE are generally larger than those for silicates and oxides. In addition, F_{Ce} is significantly

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higher than F_{Ce} in oxides. These sensitivity factors were renormalized for the appropriate major elements of alabandite, troilite, and caswellsilverite.

A typical REE pattern measured in oldhamite is shown in Figure 2. In addition, REE patterns for alabandite, troilite, and caswellsilverite are plotted. The normalized REE abundance pattern in oldhamite essentially flat from La to Lu except for Eu which is underabundant. The REE's exhibit zoning in the oldhamite from edge-to-edge along two directions, as opposed to concentric zoning. The concentration of La varies from ~50 to 90 ppm across the inclusion, but the REE pattern remains approximately unchanged. Alabandite has a typical fractionated pattern favoring the heavy REE (e.g [2]). The overall abundance of REE is low in this mineral with the highest concentration at Lu of ~7 times chondritic. The REE abundances measured in one trolite grain (shown in Figure 2) are somewhat unusual. The pattern is V-shaped with a very low abundance of Sm ($\lesssim$10 ppb) and a high abundance of Tb relative to the trend defined by the heavy REE. A second troilite grain exhibited a "flatter" REE pattern (not shown) for the light REE yet with a similar increase in abundance from Dy to Lu. The caswellsilverite has a REE pattern similar to that of oldhamite but the absolute abundances are much lower. Calcium was monitored during the measurement to ensure that the magnitude of the contribution to the REE measured in the caswellsilverite from the surrounding oldhamite was negligible.

The isotopic ratios of Cr were determines in several alabandite grains in this inclusion in an effort to quantify any contribution that may be present from the decay of ^{53}Mn. Measurements were made at sufficient resolution to eliminate interferences from molecular ions. The interference from ^{50}Ti at the mass of ^{50}Cr was monitored and corrected for by measuring ^{49}Ti. The correction due to ^{50}Ti was insignificant in the alabandite. The results give $\delta^{53}Cr = 5.2 \pm 7.0‰$ ($2\sigma_{mean}$) with a Mn/Cr of ~400. This puts and upper limit on the $(^{53}Mn/^{55}Mn)_0$ in this inclusion of $\sim 3\times10^{-6}$.

The sensitivity factors measured for sulfides are higher than the corresponding factors for oxides (determined from perovskite) by ~40% for the heavy REE. This is enough to bring the measured abundances of the heavy REE up to the level of the light REE as discussed in by Lodders and Fegley [3] in some of the previously measured REE patterns from meteoritic oldhamite (*e.g.* [4]). In addition, this bring the data into better agreement with the condensation calculations presented in [3]. The REE patterns measured in the alabandite and troilite (shown in Figure 2) are puzzling. These minerals are expected to have formed during low-temperature exsolution from the oldhamite. If this were the case then the very low abundances of Sm in the troilite and of Eu in the alabandite are inconsistent with exsolution. Further measurements must be made in the oldhamite (Figure 2) around the troilite and alabandite to determine if exsolution is a reasonable origin for these minerals. The Cr isotopic composition is consistent with the range of measurements made on other meteorites [5]. However, with the hint of a ^{53}Cr excess at ~1.5σ we are prompted to revisit these alabandites from Peña Blanca Spring.

[1]Lodders *et al.* (1993), *Meteoritics*, **28**, 538. [2]Wheelock *et al.* (1994), *GCA*, **58**, 449. [3]Lodders and Fegley (1993), *EPSL*, **117**, 125. [4]Lundberg et al. (1991), *LPSC* **XXII**, 285. [5]Hutcheon et al. (1992), *LPSC* **XXIII**, 565. K. Lodders was supported by NASA grant NAGW-2861, others by NASA grant NAGW-3297. Division contribution No. 5490(884)

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