ACTINIDE MICRODISTRIBUTIONS IN ENSTATITE CHONDRITES; M.T. Murrell and D.S. Burnett, California Institute of Technology, Div. of Geol. & Planet. Sciences, Pasadena, CA 91125

The unusual mineralogy of the enstatite chondrites indicates that these meteorites formed under highly reducing conditions. Yet, the trace element content of the E4 enstatite chondrites is similar to that found in the C1 carbonaceous chondrites which suggests a simple chemical history. If both uranium and plutonium were trivalent (1,2) for the reducing conditions under which the enstatite meteorites presumably formed, then the reduced possibility of Pu-U-lanthanide chemical fractionation may make these objects well suited for Pu-U cosmochronology and for relative age determinations. In order to better evaluate this possibility and to aid in our understanding of the history of the enstatite chondrites, we are in the process of investigating uranium and thorium distributions in these objects. We report here results to date for uranium.

Previous fission track studies of St. Marks (E5)(3) and Abee (E4)(4) have reported discrete uranium-rich regions; however, the mineralogy of the phase(s) was not determined. The neutron activation determination of uranium and thorium in enstatite chondrites by Morgan and Lovering (5) show Th/U to scatter above and below the generally accepted average solar system value of 3.8. This was an additional incentive for our study of enstatite chondrites. Matsuda et al. (6) determined uranium and thorium in acid-leached fractions from enstatite chondrites using neutron activation. They found uranium to be chalcophile while thorium exhibited both chalcophile and lithophile behavior. Recently Stapanian et al. (7) mapped the uranium distribution in Hvittis (E6) using fission track radiography. They report essentially all the uranium to be localized in oldhamite (CaS) grains at a fairly uniform concentration of 350±85 ppb.

In this study we have determined uranium microdistributions in Khairpur (E6) and Daniel's Kuil (E6) using fission track radiography. Mica-covered polished sections were irradiated for a total fluence of $3 \times 10^{18} n/cm^2$ at the University of Missouri reactor at Columbia, Missouri. The etched micas reveal strongly localized uranium distributions in both meteorites. In Khairpur nearly every track localization is associated with either an oldhamite or alabandite ((Mn,Fe)S) grain. Conversely, all oldhamite and alabandite grains are associated with track-rich regions. Twenty-five oldhamite grains from Khairpur ranging in size from 40-100 microns yield an average uranium content of 425 ppb with a total range of ±150 ppb. Ten alabandite grains ranging in size from 50-150 microns gave an average uranium content of 20±2 ppb. A similar uranium distribution was observed in Daniel's Kuil; however, mica slippage during irradiation complicates quantative analysis of the uranium content of these areas. In Hvittis (7), Khairpur, and Daniel's Kuil no significant uranium localization is found in any minerals other than oldhamite and, in at least Khairpur, alabandite.

The actinide distribution and content of the enstatite meteorites may have remained fixed since the time of formation, or the observed pattern may be due to subsequent chemical fractionation during thermal metamorphism. If the oldhamite grains are high temperature condensates (8), the actinides, as refractory elements, may have condensed along with the oldhamite. The factor of twenty enrichment of uranium in oldhamite over alabandite, as seen in Khairpur, might then represent a condensation sequence. On the other hand, the observed uranium distribution may represent metamorphic redistribution into these minerals with uranium substituting for calcium in oldhamite. The

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relative uranium contents of oldhamite and albandite would then reflect uranium partitioning.

We have re-examined the mica-covered sections of Abee and St. Marks which were part of the Hvittis experiment of Stapanian et al. (7). The interpretation of these results is complicated by large plucked regions ($\leq$100μ) and the total lack of oldhamite grains larger than ~10 microns. The plucked regions may represent oldhamite grains that were lost during sample preparation. Nevertheless, the uranium distribution in these sections is not strongly localized. In St. Marks there is some localization of uranium in fine-grained sulphide-silicate inclusions within large enstatite grains. In Abee there is a general correlation between broad areas (300μ) of diffuse tracks and plucked regions in which lie small (~10μ) oldhamites. Further discussion of the actinide distribution in E4 and E5 enstatite chondrites must await future irradiation of sections containing larger oldhamite grains. We have recently prepared new sections of St. Marks and Abee as well as Hvittis, Khairpur, Daniel's Kuil, and Pillistfer (E6). In the near future, we hope to report Th+U distributions and Th/U in these sections using proton-induced fission. The Th-U ratio of the oldhamite grains may provide additional insight into the history of the enstatite chondrites. For example: Th/U < 3.8 for an oldhamite grain might indicate chemical fractionation due to a preference of U^{+3} (if it exists in the solar system) over Th^{+4}. A Th/U > 3.8 might indicate a nebular fractionation due to the suggested higher volatility of uranium compared to thorium (1).

The present study permits generalization of the conclusion of Stapanian et al. (7), drawn from Hvittis alone, that under strong reducing conditions uranium will partition into something other than silicate, oxide or metal phases. Microprobe studies of Hvittis show potassium to be localized only in feldspars. Thus, while uranium is localized in oldhamite, under the same conditions potassium has remained lithophile. It is dangerous to generalize our results to questions of heat sources for planetary Fe-FeS cores, but the existence of natural potassium sulfides has previously been used as an argument for potassium in the earth's core (9). However, our data show that uranium can display chalcophilic character, although it did not concentrate in troilite. (In Hvittis the uranium concentrations in metal or troilite are less than 0.1 of that in oldhamite, and much lower limits could be set with additional work). Partitioning studies done in this laboratory (10) have shown that Pu, U and Th, but not Sm or Na, are alloyed with Pt or liquid Pt-Si under reducing ($fO_2 \leq 10^{-14}$) conditions but no measurable partitioning ($\leq 10^{-2}$-10^{-5}) into Fe-C or Fe-Si liquids was observed.

Speculating beyond the range of the present data base, it appears to us that there is no evidence for actinide partitioning into troilite or iron metal alloys (C or Si) sufficient to be a heat source for planetary cores. Further, when silicate phases are present, it appears even more difficult to reduce or alloy alkali metals than actinides. Thus, we feel that potassium is even less likely as a core heat source than thorium or uranium, and one must appeal to hypothetical pressure effects on the chemistries of these elements to maintain heating by dissolved radioactive elements in in planetary cores.

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