CHONDRITIC SIDEROPHILES: Bi CONFIRMED AND THE CASE FOR LEAD. Dorothy S. Woolum, R. Mascitelli, Physics Dept., Calif. State U., Fullerton, Fullerton, Ca. 92634; and D.S. Burnett, Div. Geol. & Planet. Sci., Calif. Institute of Technology, Pasadena, Ca. 91125

We earlier (1) reported evidence for the siderophilic behavior of meteoritic bismuth from the Khohar (L3) chondrite. Briefly, in situ determinations of the microdistributions of Bi in a polished section of Khohar yielded strong localizations of Bi in the low-nickel metal phase (kamacite or α phase); enrichment factors relative to bulk Bi varied considerably but ranged primarily between 10 and 100, although for one large kamacite grain we obtained only an upper limit, which was comparable to the bulk value. Here we report new results, which include confirmation of our original results on another section of the original Khohar specimen and data for a separate Khohar sample and the Hallingeberg L3 chondrite. Further, these additional data now indicate that lead exhibits a siderophilic affinity in these meteorites, although the bulk lead does not appear to be dominated by the contributions solely from the Bi-rich metals.

Our experiments involve the irradiation of polished meteorite sections with 30MeV ^{4}He ions to produce the alpha-radioactive nuclei: ^{211}At and ^{210}Po from ^{209}Bi and ^{208}Pb, respectively. The distributions of the induced activities in the samples are mapped with exposures to plastic track detectors, and separation of the ^{211}At and ^{210}Po activities is accomplished using multiple post-irradiation detectors, taking advantage of the large difference in their half-lives (7.2 hr and 138 d, respectively). Absolute concentrations are inferred from standards included in the irradiation. The phase identifications are accomplished with optical reflected light observations and the Caltech electron microprobe. Data presented here have been corrected for Pb contributions to the Bi and for the differences in alpha particle ranges in metals and sulfides relative to their ranges in the NBS glass standard. We have not as yet quantitatively mapped the homogeneity of the cyclotron irradiation; however, visual inspection of the emulsion exposures of the beam degrader show no obvious gradient across the 16 section sample array, so we can confidently exclude gross ($\gtrsim$factor of 2) differences between the cyclotron beam dose of any sample and that of the standard.

Figure 1 summarizes the results of our bismuth and lead analyses for the largest metal grains in the 3 Khohar and 2 Hallingeberg sections. Plotted is the total Bi track density vs. the total lead-208 track density for the individual metal grains of the different meteorites. By total track density we mean that the track densities plotted are those which would be obtained if the detectors had recorded all the induced activity rather than just a fraction of it; thus, the track densities plotted are directly proportional to the Bi and Pb concentrations of the grains. To be explicit, by grain we mean a discrete mass, regardless of whether it is mono- or polycrystalline. We have chosen the largest grains in the sections. In addition to improving the statistics, this is important in minimizing the probability that the grain is significantly thinner than the alpha particle ranges. With relatively few exceptions, the metal grains are of the order of 100μ, at least in one dimension. Uncertainties due to counting statistics typically range from ~10-30% but several of the lowest enrichment grains have uncertainties more like 50-60% and in fact only upper limits are obtainable in some cases. Finally, we have also similarly plotted, for reference, the measured bulk Bi and lead-208 track densities of the sections. The bulk Bi values are based on scans of ~$\frac{1}{3}$ of each section; the bulk Pb value is based on random spot counts encompassing ~5% of the total section area. Considering the gross inhomogeneity of the distributions and the limited volume analyzed, the bulk values are probably best

interpreted as a "factor of ~two estimate". All the enrichments observed are obtained from the kamacite dominated grains (1). Sizeable taenite phases are rare in our sections and their Bi contents are low (≲30 ppb). Observations of a few fortuitous kamacite-taenite binary associations show high track densities in the detector which correspond well in shape and size with the distribution of the kamacite in the association. It is also clear that all kamacites are not created equal. There is a large variation in the kamacite Bi and Pb enrichment factors. In light of the lateral dimensions of the grains analyzed it is highly improbable that the variations could be explained by having many grains thinner than the alpha particle ranges (in fact, among the highest and lowest enrichments are found the smallest and largest, respectively, of the kamacite grains). The major and minor element chemistry of the kamacite, as determined with routine microprobe quantitative analyses of grains is typical of unequilibrated ordinary chondrites although a few grains showed heterogeneous distributions of Cr and we find no obvious correlation of Bi or Pb contents either with the chemistry or with the amount of taenite or sulfide associated in the grains.

Finally, Figure 1 shows a crude correlation of the lead and bismuth densities in these grains, which was not clear in our more limited data previously. The lead contents of the kamacites tend to be higher than the Bi contents for most of the volatile rich grains, but the Pb/Bi ratio varies widely rather than centering uniformily around a value of the order of 10, which would be expected from published bulk analyses. From qualitative observations, as well as our, albeit crude, attempt at mass balance (1) it is clear that the Bi contents of these meteorites are dominated by the Bi-rich kamacite grains; the bismuth exposures show large expanses of essentially track-free regions punctuated by an occasional localization. Such is not the case for lead. Even qualitatively, the distributions in our most Pb-poor sample (Khohar 2), in which the chondrule interiors most clearly stand out as massive blanks, are not overwhelmingly dominated by the lead-rich kamacite localizations. Matrix regions and, in particular, complex sulfide-metal intergrowths (occurring frequently around chondrule rims) show significant lead localizations. Thus, from these observations, it is not possible to unequivocally demonstrate that primordial lead in these meteorites is entirely siderophillic. The most likely alternative is that some of the lead may be sited in the sulfides, as is observed in iron meteorites and terrestrially.

There were two sulfides in the Khohar B section which showed significant enrichments in Pb but the polish of these grains were relatively poor and the distributions of the Pb very heterogeneous, (the grains were rimmed in Pb with blank interiors). Judging from the bulk Pb content and the fact that some of the chondrules show significant lead contents, it may be that this section suffered some lead contamination. The other large sulfide grains (one 0.3mm x 1mm) studied showed Pb (and Bi) contents which are well below or at most comparable to bulk levels.

Work is currently in progress on the Mezo Madaras (L3), Chainpur, Parnallee (both LL3), Sharps (H3), Dhajala (H3,4), and Kesen (H4) chondrites. The preliminary data for one of the Mezo Madaras sections show strong localizations in both Bi and lead. Preliminary observations of bismuth exposures of the H and LL samples indicate significantly lower bulk Bi contents and show no striking localizations of the Bi in these sections.

The siderophile nature of Bi and Pb, was predicted for nebular condensation by Larimer (2), however it would be expected to be a general chemical/thermodynamic property of these elements under reducing conditions. Consequently, as discussed in (1), rather than reflecting nebular processes, we interpret the concentration of these elements into kamacite to be due to re-

distribution during the period of parent body residence of these meteorites, most plausibly during or after the period of kamacite-taenite phase separation. The fact that Bi-rich and Bi-poor metal grains co-exist in these meteorites implies that the meteorite parent bodies contain both volatile-rich and volatile-poor regions.

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References: (1) Woolum D.S., Mascitelli, R. and Burnett, D.S. (1979), to appear in Proc. 9th Lunar Sci. Conf. (2) Larimer, J. (1973) Geochim. Cosmochim. Acta 27, 1603.