TRACE ELEMENT DISTRIBUTION AMONG MATRIX, CHONDRULES, METAL AND SULFIDES IN SAHARA 97072 EH3.

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Introduction: Several hypotheses exist for the nature and origin of chondrite matrix: that it consists of chondrule fragments [1], is primarily composed of CI-like material and is similar in all groups [2, 3], is remnant material from the parent molecular cloud [4-6], represents products of direct nebular condensation [7, 8], or that it contains components of several of these sources combined with material that evaporated from chondrules and recondensed [9].

No consensus exists as to what proportion, if any, of matrix material formed in a different environment from the chondrules and large clasts, and whether the chondrules and matrix were subjected to the same processes in localized regions. Matrix composition similar to chondrules implies that both, or their precursors, were subjected to similar processes. Complementary chondrule and matrix compositions suggest that chemical transfer occurred from one to the other, or that both derived from the nebular gas by sampling different regions, perhaps at different times [9]. If matrix contains a large proportion of chondrule fragments but has a unique trace-element signature, it suggests a portion of the matrix originated in another location and was mixed with chondrules. We report here results of trace-element measurements that suggest a choice among these competing ideas for Sahara 97072, which is one of the most primitive EH3s and thus of particular interest [10]. Preliminary results of a TEM mineralogical study were reported previously [11].

Methods: Matrix from petrographic thin sections was measured using laser-ablation, inductively-coupled plasma mass spectrometry (LA-ICPMS) for 42 elements, as were chondrules, sulfides, schreibersite, and kamacite. Also, to contribute to the bulk composition data obtained from other techniques, 4 line scans up to 6 cm were ablated as a proxy for meteorite bulk composition using a 100-µm laser spot. The primary standard was National Bureau of Standards glass 610. The internal standards were based upon electron microprobe measurements adjacent to the laser pits with a 15-µm defocused beam.

Other analyses contributing to the bulk meteorite composition data set involved pulverizing 1.5g of Sahara 97072 in an agate mill. Four aliquots of 0.06g were fused with lithium borate and dissolved in nitric acid for analysis with inductively-coupled plasma atomic-emission spectroscopy (ICP-AES) and inductively-coupled plasma mass spectroscopy (ICPMS). Total C and S were determined on a 0.4g aliquot using a LECO direct-combustion infra-red detection system. The remaining ~ 0.75g was dissolved using a four-acid digestion for analysis with ICPMS. The multiple analyses of individual elements were averaged with results from the LA-ICPMS line scans mentioned above.

Results: Normalized to CI, Sahara 97072 chondrules are enriched in refractory lithophile elements, highly depleted in siderophile elements, and somewhat depleted in moderately volatile elements except for the alkali metals. By contrast, the matrix composition is close to CI for refractory elements and slightly enriched in moderately volatile to volatile elements (Fig. 1). Bulk Sahara 97072 is enriched in W, U, Bi and various refractory elements when normalized to Si and CI (Fig 2).

The REE are enriched in oldhamite up to 60x CI, and refractory lithophile elements are enriched except for Nb. Troilite is enriched in Ti, Nb, Cr, and Cu. Niningerite is depleted in REE and most refractory lithophile elements except Zr, Sc, and Yb and is enriched in moderately volatile Mn, Cu, Zn and S. The metal is enriched in siderophiles W, Au, Pt, Pd, and Ga, with Mo near CI concentration.

Discussion: Sahara 97072 matrix and chondrule compositions are different from one another and non-complementary (Figs. 1, 3). To test whether the matrix consists primarily of chondrule fragments, we calculated a hypothetical matrix composition by combining the compositions of chondrules with metal, sulfides, and minor minerals in the optimal proportions. The result should approximate the measured matrix composition if matrix consists primarily of chondrule, sulfide, and metal fragments. The percentage of sulfides and metal must be enough to dilute the mixture in refractory lithophile elements contributed by chondrule fragments and yet increase siderophile elements to matrix values. The metal percentage was calculated to match matrix Ni, troilite for S, niningerite for Mn, schreibersite for P, djerfisherite for K, oldhamite for Pb, and sphalerite for Zn. The resulting mixture is consistent with TEM observations and close to the matrix composition for all siderophile and moderately volatile to volatile elements. However, the refractory lithophile elements are substantially enriched over matrix composition (Fig. 4), indicating the matrix can not be explained as a mixture of chondrule fragments, sulfides, metal, and phosphide. The silicate proportion of the matrix must have formed from material more depleted in refractory elements than the chondrule precursors.

Conclusions: Trace element measurements reveal the matrix of this primitive enstatite chondrite has a composition that indicates it formed separately from the bulk of the meteorite. It has a unique trace-element signature, suggesting a portion originated in a separate location and was subsequently mixed with chondrules, metal, and sulfides.

References: [1] Alexander, C.M.O., R. Hutchison, and D.J. Barber, 1989, E&PSL, 95, 187-207. [2] Alexander, C.M.O., 2005, 36 LPSC, Abst 1348. [3] Alexander, C.M.O., A.P. Boss, and R.W. Carlson, 2001, Science, 263, 64-68. [4] Huss, G.R., 2004, Antarctic Meteorite Research, 17, 132-152. [5] Huss, G.R. and R.S. Lewis, 1995, GCA, 59, 115-160. [6] Huss, G.R. et al., GCA, 67, 4823-4848. [7] Larimer, J.W. and E. Anders, 1967, GCA, 31, 1239-1270. [8] Larimer, J.W. and E. Anders, 1970, GCA, 34, 367-387. [9] Huss, G.R. et al., In *Chondrites and the Protoplanetary Disk*, A.N. Krot, E.R.D. Scott, and B. Reipurth, Eds. 2005, Astronomical Society of the Pacific: San Francisco. 701-731. [10] Weisberg, M.K. and M. Prinz., 1998, 29th LPSC, Abst 1741. [11] Lehner, S.W. and P.R. Buseck, 2010, 41st LPSC, Abst 1855.

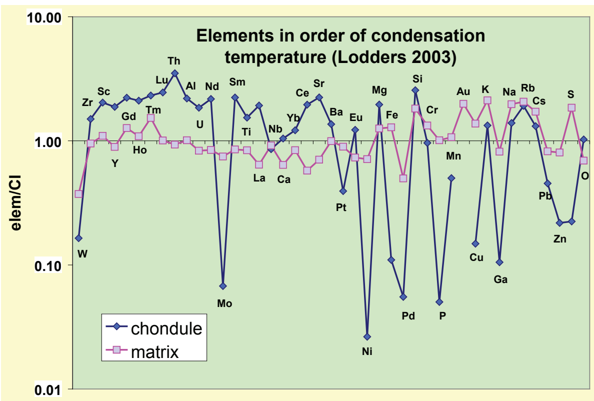

Fig.1. *Plot comparing CI-normalized trace element composition of the matrix with the chondrules in Sahara 97073 (EH3).*

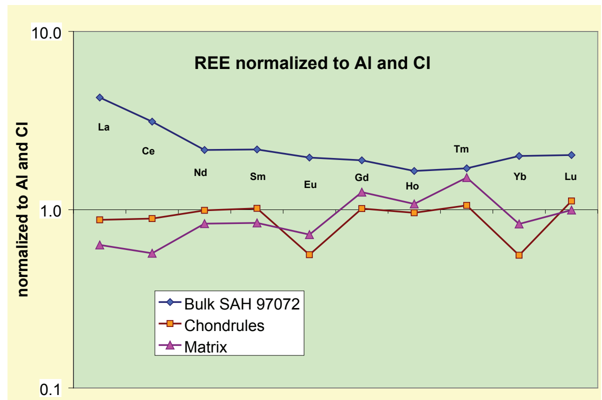

Figure 3. *Plot comparing REE in the matrix, chondrules and the bulk indicating a lack of complementarity between the chondrules and the matrix.*

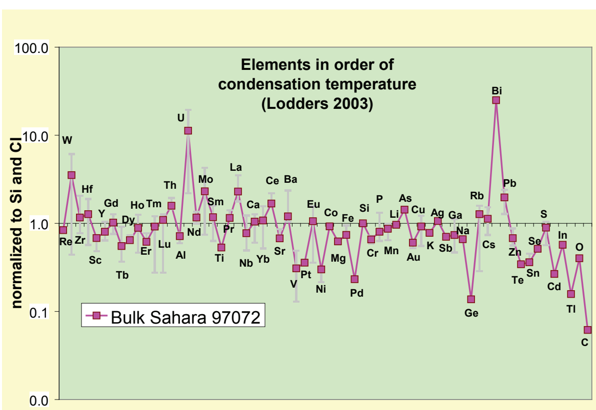

Fig. 2. *Plot of Sahara 97072 (EH3) bulk composition normalized to Si and CI. Note the enrichment in certain refractory elements and Bi. The dotted lines represent the range of measurements, and the symbols represent the mean.*

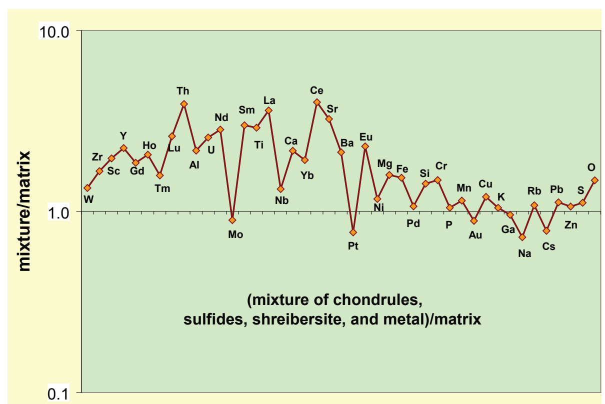

Figure 4. *Graph of the difference between the matrix composition and a mixture of ~ 53% chondrule fragments, 16% metal, 26% troilite, 2% niningerite, 1.3% schreibersite, and 0.5% djerfisherite,0.6% oldhamite, and 0.06% sphalerite. These proportions were calculated to bring chondrule siderophile and chalcophile elements to matrix values and are in agreement with TEM observations.*