BULK CHEMISTRY AND MINERALOGY OF A NEW "UNIQUE" METAL-RICH CHONDRITIC BRECCIA, HAMMADAH AL HAMRA 237. J. Zipfel, F. Wlotzka and B. Spettel, Max-Planck-Insitut für Chemie, Abteilung Kosmochemie, Joh.-J. Becher Weg 27, 55128 Mainz, Germany, zipfel@mpch-mainz.mpg.de.

In fall of 1997 a 3.17 kg, unusually metal-rich, carbonaceous chondrite, Hammadah al Hamra 237 (HaH 237), was found in the Sahara. Chemical analyses, petrographic observations and mineral chemical analyses lead to the conclusion that this meteorite is related to metal-rich carbonaceous chondrites, such as ALH 85085 and CR chondrites [1, 2, 3, 4]. With 60 to 70 % metal, HaH 237 is the most metal-rich carbonaceous chondrite yet recovered. A Ca, Al-rich inclusion was found embedded in the Cr-, P-rich metal. The meteorite provides important new evidence for the formation of solid matter in the early solar system.

DESCRIPTION: The meteorite consists mainly of silicate mineral fragments and metallic FeNi. The estimated FeNi metal content is 60 to 70 vol. %. Most of the metal is fine-grained (< 300 µm) and has irregular shapes indicating that it was broken when cold. Sulfide is rare and occurs as rounded inclusions or elongated lenses in metal grains. Some of these sulfide lenses are bent parallel to the irregular grain boundaries of the metal, indicating deformation of the metal while still plastic. Larger polycrystalline metal spheres (chondrules?) and their fragments (up to 4 mm) are present. Most of the silicate fragments are mono- or polymineralic. Small (< 300 µm) complete and fragmented cryptocristalline and microporphyritic chondrules are observed. More often fragments (up to 3 mm) of formerly larger porphyritic chondrules occur. Cryptocristalline and microporphyritic chondrules, fragments, and porphyritic chondrule fragments are similar to those described in Acfer 182 (Acfer) and ALH 85085 (ALH) [1, 2, 3], indicating a relationship to these meteorites. One hibonite-bearing CAI-rich inclusion with an almost complete rim, consisting of spinel, fassaite, and forsteritic-olivine, was found. The CAI is surrounded by metal and weathering products. Material sitting between grain boundaries is mostly altered, probably during terrestrial weathering. Small amounts of silicate-rich melts enclosing tiny (~5 µm) metal droplets and silicate fragments and metal-rich melts enclosing rounded silicate droplets are observed on some fresh grain contacts, either between metal - silicate or metal - metal.

MINERAL COMPOSITION: Olivines analyzed so far are CrO_2-rich (0.38 to 0.68 wt. %) and have compositions varying from Fa 2 to 10 mol% with most olivines having Fa < 5 mol%. Pyroxene is the most dominant silicate phase and has Fs 0.5 to 14 mol%, with a maximum below < 7 mol%. Metal is kamacite with Ni concentrations between 5.8 and 7 wt. %. One grain with a higher Ni concentration of 10.2 wt. % was analyzed. Cobalt (0.19 to 0.27 wt. %) is positively correlated with Ni. The Ni-rich metal grain has Co concentrations as high as 0.41 wt. %. Chromium and P concentrations of the metal range from 0.07 to 0.24 wt. % Cr and from 0.10 to 0.24 wt. % P, respectively. Silicon concentrations are low (<0.025 wt. %).

Metal, fayalite contents and CrO_2 concentrations in olivines as well as Fs contents in pyroxenes are very similar to those of Acfer and ALH [1].

BULK COMPOSITION: A 66.5 mg bulk sample was analyzed by instrumental neutron activation. The bulk Fe and Ni content is high with 74 wt. % and 5.6 wt. %, respectively. This indicates a Fe-Ni content of 80 %, which is higher than estimated from petrographic observation. In Figs. 1 and 2 lithophile and siderophile element abundances are normalized to Mg and CI and compared to bulk chemical data for Acfer and ALH.

Lithophile refractory elements with condensation temperatures above Mg are enriched over Mg and CI abundances by an almost constant factor of 1.3. This enrichment is higher than for the same elements in ALH and Acfer (1 x Mg and CI). Elements more volatile than Cr, such as Mn, K, Na, and Zn are depleted according to increasing volatility. Abundances of K and Na are identical with those of ALHA. Zinc is somewhat less depleted whereas Mn is slightly more depleted than in the ALH and Acfer meteorites. The lithophile abundance pattern of HaH 237 as well as of ALH and Acfer is governed by volatility indicating nebula fractionation as the primary process controlling element abundances.

Chromium is the most enriched lithophile element (2.4x relative to Mg and CI). The average Cr concentration in metal is 0.19 wt. % and the bulk Cr content is 2620 ppm. Mass balance shows that more than 50 % of the total Cr content is contributed by the metal. By subtracting the Cr dissolved in metal a chondritic Cr/Mg ratio is obtained for the silicate fraction.

In Fig. 2 the abundance patterns of the siderophile elements are shown. Siderophile elements with condensation temperatures close to Pd and higher are enriched by an almost constant factor of 13.7 relative to Mg and CI in HaH 237 but only by factor of 2 in ALH and Acfer meteorites. Moderately volatile elements, with condensation temperatures below Pd, are depleted. The depletion increases with increasing volatility. The Mg- and CI-normalized abundances for elements such as Au, As, Cu, and Ga are similar to those in the ALH and Acfer meteorites, except that the HaH 237 depletion pattern is slightly steeper. Bischoff et al. argued that the enrichment of refractory siderophile elements and the high bulk Fe content suggests addition of a metal component. We envision a similar process for HaH 237 except that the added metal fraction is much larger.

IMPLICATIONS: A nebula origin for metal in ALH 85085 has been suggested by [3]. In [5] the authors argued that the features observed in the "tiny" ALH meteorite are not of nebular origin but were produced in a cloud of impact ejecta. Bischoff et al. (1993) [1] argued based on the absence of a Mo-anomaly that such a formation is unlikely since conditions in an impact cloud are rather oxidizing. The presence of a Cr enrichment in bulk HaH 237, indicates that the metal was not formed in the same reservoir where moderately volatile lithophile element abundances were established.

HaH 237 has similar Au/Mg and Na/Mg ratios as ALH and Acfer. The Ir/Mg x 10^5 ratio is, however, 6.55 compared to 0.95 in ALH and Acfer. This implies a similar reservoir for moderately volatile elements for ALH and Acfer and HaH 237 meteorites.

Conventional modelling suggests: Metal (refractory metals and Ni, Co, Fe, and Pd) and silicates (Mg) formed separately by condensation in the solar nebula. In HaH 237 refractory metals apparently condensed with FeNi and not with CAIs. Metal and silicates were then mixed in various proportions to produce HaH 237, ALH and Acfer. The similar Au/Mg ratios in all three meteorites, is, however, difficult to understand in this simple mixing model.

Alternatively, HaH 237 can be regarded as a mixture of a metal-rich chondritic reservoir and a volatile depleted metal component. The chondritic reservoir has refractory and moderately siderophile and lithophile element abundances similar to ALH and Acfer meteorites. The metal component has CI abundances of refractory siderophile elements, Ni, Co, Fe, and Pd, but is strongly depleted in moderately volatile siderophile elements, more volatile than Pd.

Both components have characteristics of condensates. The high metal proportion in HaH 237 implies that there are regions within the solar nebula where metal condensates accumulate.

HaH 237 is the most metal-rich chondritic breccia known so far. Its closest relatives are the metal-rich chondritic breccias ALH and Acfer. Other probably related meteorites are Bencubbin, Weatherford, and the CR chondrites [1, 3, 4, 5].

References: [1] Bischoff et al. (1993) GCA 57, 2631-2648. [2] Scott (1988) EPSL, 91, 1-18. [3] Weisberg et al. (1988), EPSL, 19-32. [4] Grossman et al. (1988) EPSL 33-54. [5] Wasson and Kallemeyn (1990) EPSL 101, 148-161.

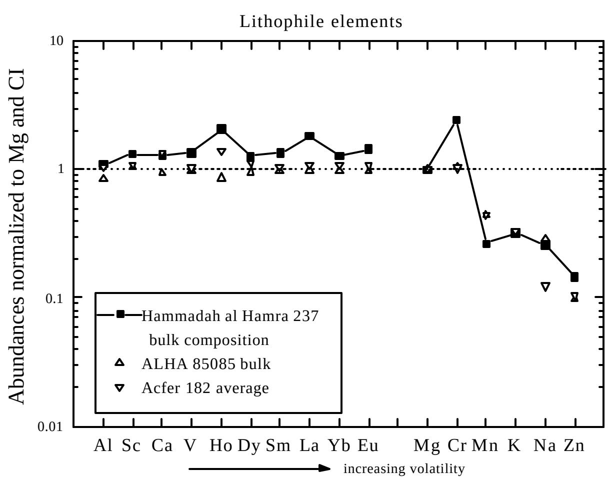

Fig. 1: Lithophile element abundances normalized to Mg and CI. Data for ALHA 85085 and Acfer 182 are taken from [1].

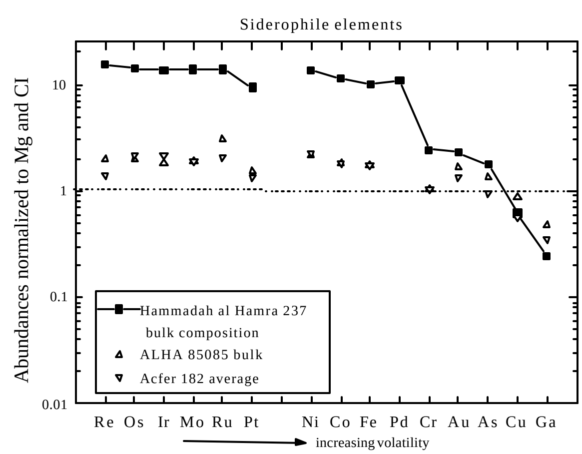

Fig.2: Siderophile element abundances normalized to Mg and CI. Data for ALHA 85085 and Acfer 182 are taken from [1].