RELATIONSHIPS AMONG CHONDRITE GROUPS AS INFERRED FROM PRESOLAR-GRAIN ABUNDANCES.

G. R. Huss[1,2], A. P. Meshik[3], C. M. Hohenberg[3], and J. B. Smith[1]. [1]Department of Geological Sciences and [2]Center for Meteorite Studies, Arizona State University, Tempe, AZ 85287-1404, USA; gary.huss@asu.edu; [3]Physics Department, Washington University, St. Louis, MO, 63130.

For several years we have been compiling data on the abundances of presolar diamond, SiC, and graphite in primitive chondrites. The ultimate goal of this work is to use the relative abundances of these phases, each of which has different physical and chemical properties, to infer something about the pre- and post-accretionary history of chondritic material and to establish how various types of chondrites are related [1]. We now have sufficient data, including new data reported here, to discern the broad outlines of these relationships.

Abundances of presolar diamond, SiC, and graphite were calculated following the procedures of [1]. For diamond, Xe from diamond separates and etched residues was deconvolved into its components (Xe-P3, Xe-HL, Xe-P6, Xe-P1, Xe-S). The Xe-HL concentration of the diamond separate was then used to convert the Xe-HL concentration of less-processed etched residue into a diamond abundance. For SiC and graphite, Ne data was deconvolved into its components (Ne-E, Ne-P1, Ne-A2, Ne-P3, Ne-Cos., Ne-Solar) following [1]. Since there are more components than isotopes, additional information, such as release temperature, must be used. Ne-E(L) and Ne-E(H) contents were converted to graphite and SiC abundances by assuming gas contents for graphite and SiC of $14,000 \times 10^{-8}$ cc ^{22}Ne-E(L)/g and $16,500 \times 10^{-8}$ cc ^{22}Ne-E(H)/g, respectively [1].

Primitive material: The chondritic materials with bulk compositions closest to that of the solar chromosphere are CI chondrites and CM2 chondrite matrices [2,3]. These materials also have high abundances of diamond, SiC, and graphite (Table 1), and their diamonds have the highest concentrations of low-temperature P3 gases [4]. We have measured new diamond samples and etched residues of Murchison and Murray; these data supercede those reported last year [5]. Matrix-normalized graphite abundances for Murray and Murchison approach that for Orgueil (Table 1). Abundances for SiC appear to be significantly higher in CM2 matrix than in Orgueil, while diamond abundances may be marginally lower. The Xe-P3/Xe-HL ratios for diamonds from Murchison (2.39) and Murray (2.15) are similar to ratios determined previously (2.00-2.37 [6] and 2.53 [7], respectively) and to that for Orgueil diamonds (2.46 [1]). The abundance differences between Orgueil and CM2 matrices may be real, but the graphite abundances and Xe-P3/Xe-HL ratios preclude significant thermal processing of either group. Alternatively, higher apparent SiC abundances ($\equiv$Ne-E(H) abundances) in CM2 matrix actually reflect a second Ne-E(H) carrier (not SiC), which releases gases at high temperature but which was destroyed by the more-intense aqueous alteration experienced by Orgueil.

CV3 and CO3 chondrites have bulk compositions significantly enriched in refractory lithophile elements compared to Orgueil [8]. CV3 and CO3 matrices contain high abundances of diamond, but little SiC and no graphite (Table 1). Diamonds in these meteorites carry little P3 gas, and correcting for mass loss associated with degassing the P3 component gives inferred "initial" abundances of Orgueil-like diamonds that are much higher in CV3s than in Orgueil [1]. These data imply that the matrix precursors of CV3 and CO3 chondrites were processed at moderately high temperatures in the nebula prior to accretion. This processing removed the P3 component of the diamonds and the more-volatile elements from the matrix precursors [1]. The noble-gas release behavior of CV3 diamonds suggests that a small amount of low-temperature component was mixed in after the main processing episode [1]. To test this idea, we prepared diamond separates from Mokoia (CV3.2$_{OX}$) and Colony (CO3.0). Recovered abundances were consistent with other CV3 and CO3 chondrites. The Xe-P3/Xe-HL ratio for Mokoia diamond (0.13) is higher than those for Allende (0.01) and Axtell (0.03), which suggests that Mokoia is less metamorphosed than Allende and Axtell. However, the Xe-P3/Xe-HL ratio is very similar to that for Leoville (0.16), which suggests that the most primitive oxidized CV3s were processed prior to accretion at least as much as Leoville (CV3.0$_R$). The Xe-P3/Xe-HL ratio for diamond from Colony, 0.53, is significantly higher than that for Kainsaz (CO3.2), 0.07, which indicates that Kainsaz experienced more parent-body metamorphism.

The **CR2 chondrites** such as Renazzo are enriched in refractory elements [9] and have experienced mild aqueous alteration [10]. The matrix-normalized diamond abundance for Renazzo is slightly higher than those for Orgueil and Murchison and similar to that for Leoville (Table 1). The SiC abundance is also similar to that of Leoville. There is a hint of residual graphite. The Xe-P3/Xe-HL ratio for Renazzo diamonds (0.14) is again similar to that of Leoville. When the diamond abundance for Renazzo is corrected for loss of the Xe-P3 carrier, the implied initial abundance of Orgueil-like diamonds in the Renazzo matrix precursor is ~70% higher than the abundances for CI and CM2 matrix (Table 1). These characteristics are consistent with Renazzo matrix having experienced a temperature of

300-350 °C, similar to the temperatures experienced by type 3.1-3.2 ordinary chondrites (OCs) [11]. However, this high temperature may not reflect metamorphism in the host meteorite. Renazzo has experienced extensive aqueous alteration. The phyllosilicate assemblage and the absence of tochilinite imply a maximum temperature of ~150 °C for this alteration [10]. The data imply that the precursor of Renazzo experienced more-severe nebular heating than the precursors of OC matrix, but not as much as the precursors of CV3 matrix.

We have obtained new data for the **CH chondrite**, Acfer 214. Our preliminary matrix estimate of 10-15% (uncertain because of a high degree of weathering) results in ranges for matrix normalized abundances (Table 1). Abundances for Acfer 214 matrix are well below those for "primitive material" and imply significant thermal processing. However, the diamonds retain ~70% of the P3 gas found in CI and CM2 diamonds, implying little thermal processing. In order to preserve P3 gases and graphite, the maximum temperature experienced by Acfer 214 after accretion must have been ≤150 °C. Acfer 214 contains ~7% dark, fine-grained, inclusions with mineralogies typically found in CI and CM chondrites [12]. If normalized to the volume of dark inclusions, the abundances become ~1.8 ppm graphite, ~5.8 ppm SiC, and ~1240 ppm diamond. These numbers approach those for "primitive material" and suggest that the presolar grains in Acfer 214 are sited primarily in dark inclusions. If the majority of the presolar grains are in the dark inclusions, then the presolar grains originally in the matrix must have been destroyed by earlier thermal processing, perhaps the processing that generated the CH bulk composition. CH chondrites are enriched relative to CI in refractory lithophiles and in metallic Fe and siderophiles [cf, 2,12]. The presolar grains thus imply a two-stage history. Stage 1, which was hotter than that experienced by CV and CO matrix, destroyed most or all of the original complement of presolar grains. Stage 2 saw mixing in of dark inclusions at low temperature. The final meteorite never saw temperatures above ~150 °C.

The most primitive known **Ordinary Chondrites** (OCs) are Semarkona (LL3.0) and Bishunpur (LL3.1). Adrar 003 (L3.2) is among the most primitive of the L chondrites, and previous stepped-combustion work showed a high abundance of SiC [13]. Our new data (Table 1) show that Adrar 003 had a thermal history similar to that of Bishunpur (LL3.1).

Conclusions: Our data and bulk compositional data show that CI chondrites and CM2 matrix are the most primitive materials in chondrites from the points of view of bulk composition and presolar grains. Matrices of all other types of chondrites have been thermally processed prior to accretion, producing chemical frac-

tionations and destroying presolar grains. The sequence in order of increasing degree of processing is: CI≈CM <OCs<CR<CV≈CO<CH. Presolar grain abundances and bulk compositional data show that carbonaceous chondrites are not all closely related, but instead consist of two very dissimilar types of material: 1) primitive material (CI, CM2 matrices) and 2) highly processed material (everything else). To complicate the picture, CM chondrites contain roughly 50% of the highly processed material and CH chondrites apparently contain clasts of primitive material. It may be more confusing than helpful to lump these two very different types of material under the name "carbonaceous chondrites."

Table 1: Matrix-Normalized Abundances (ppm).

Meteorite	Diamond	SiC	Graphite
Orgueil (CI) [1]	1436±56	14.2±0.8	10.3±0.4
Murch. (CM2)	**1162±62**	**21.2±0.6**	**7.4±0.4**
Murray (CM2)	**1039±24**	**22.3±1.0**	**9.6±0.2**
Renazzo (CR2) [14]	1500±75	0.9±1.8	0.1±0.6
	2450±200*		
Leoville (CV$_R$) [1]	1554±93	1.12±0.07	ND
	3166±230*		
Allende (CV$_{Ox}$) [1]	885±125	0.016±0.013	ND
	1817±278*		
Axtell (CV$_{Ox}$) [14]	820±55	0.46±0.92	ND
	1552±125*		
Kainsaz (CO) [1]	873±304	0.06±0.06	ND
	1733±608*		
Acfer 214 (CH)	**580-860**	**2.7-4.1**	**0.8-1.2**
	1170-1740*		
Semark. (LL3.0) [1]	1134±69	10.0±0.8	0.22±0.02
	1515±111*		
Bishun. (LL3.1) [1]	901±55	9.6±0.6	0.16±0.06
	1555±130		
Krymka (LL3.1) [1]	1008±82	3.5±0.6	<0.066
	1543±230*		
Adrar 003 (L3.2)	**1088±20**	**8.3±0.7**	**0.14±0.12**
	1188±340*		

*Original abundance of Orgueil-like diamonds.

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