CARBONACEOUS XENOLITHS FROM THE EREVAN HOWARDITE.

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Preliminary studies of the Erevan howardite [1] showed that the meteorite is a polymict breccia. Here we report on our study of CM-type carbonaceous xenoliths. All of these clasts are enriched in tochilinite and carbonate inclusions as compared to CM chondrites. They also contain a new, P-rich sulphide beside pentlandite. The P-rich sulphide represents a new type of P-bearing phases. It indicates a chalcophile behaviour of P under certain nebular conditions.

RESULTS Carbonaceous clasts in the Erevan howardite are usually less than 1 mm in size .Large clasts contain several textural components enclosed by a fine-grained matrix, whereas small clasts consist of matrix only. The following components were identified: **(i) Isolated olivine and pyroxene grains**. These grains are up to 0.1 mm (usually 20-40 μm) long and have compositions of Fo97-98 and En94-96 which are typical for CM chondrites. However, one olivine grain with as much as 40% Fa was found. Some olivine grains exhibit zoning with enrichment in Cr, Al and Ca towards the surface. **(ii) Carbonate inclusions**. These objects (up to 0.1 mm in size) are rounded aggregates of exceedingly fine-grained crystals. Sometimes thin veins of matrix material cut through the inclusions. In their morphology and texture they are similar to CAIs but they do not contain any relics of CAI phases and consist only of pure Ca-carbonate. In contrast, carbonate veins present in the matrix contain a relatively coarse-grained (20 μm) Ca-carbonate associated with Fe-sulphide. Thus, the observations suggest that the carbonate inclusions are of nebular origin. Similar carbonate objects were described from the CM1 chondrite Y82042 [2] but these objects contain also dolomite beside calcite. **(iii) Tochilinite inclusions** (up to 80 μm) have an irregular shape and consist mainly of tochilinite of the composition 2Fe 0.9S * 1.69(Fe 0.55,Mg 0.23,Ni 0.15,Al 0.07) (OH)2 (Table 1, No 1). Common are veins and inclusions of a S-bearing serpentine phase (Table 1, No 2) in the tochilinite aggregates. Tochilinite (or PCP) is considered to be a characteristic phase of CM chondrites [e.g.,3]. **(iv) Black clasts** (up to 0.1 mm in length) exibit a botryoidal-like texture and consist of a serpentine-tochilinite mixed phyllosilicate (Table 1, No 3) and a black fine-grained matrix. These clasts contain also isolated forsterite grains. Compared to matrices of the Erevan carbonaceous clasts the one dark clast analyzed is richer in S and poorer in Ni (Table 2, No ER-200). **(v) P-rich sulphide**. A unique fragment (40*100 μm) of P-rich sulphide was found in one carbonaceous clast. The sulphide fragment is cut by thin veins of tochilinite and serpentine. In reflected light the sulphide resembles troilite but it is slightly darker and isotropic. The composition of the sulphide (Table 1, No 4) is close to that of pentlandite (Table 1, No 5) found in the matrix of the same carbonaceous clast, but in contrast to the pentlandite, the sulphide contains P,Na,K, and Ca. Its formula: (Fe 4.59, Ni 3.71, Co 0.18, Na 0.24, K 0.08) 8.80 (S 6.90, P 1.40) 8.30, is of a pentlandite-type with a S/P ratio of 5. However, totals are between 95-97 wt.-%, and hence it is possible that the sulphide contains some oxygen. Two small grains (< 5 μm) of the same sulphide were found in the matrix of another carbonaceous clast. **(vi) Matrices**. The matrix material was analyzed in 6 carbonaceous clasts (Table 2). The matrices show some compositional variations but all of them have the chemistry of CM matrices [4] and can be well modelled by a mixing of tochilinite and serpentine. When normalized to CI composition the matrices are significantly depleted in Na, S, and Ca. Similar depletions have been found in other carbonaceous matrices and have been related to aqueous alteration in a carbonaceous parent body [5]. The presence of Ca-carbonate veins in the carbonaceous clasts supports this suggestion.

DISCUSSION The matrix composition and the presence of tochilinite are compatible with the Erevan carbonaceous clasts being a CM-type chondrite. This rock type is the only xenolith present in Erewan. This is in line with observations on other howardites which also contain mainly CM-type chondrite xenoliths [6]. This close association between howardites and CM-type chondrites either suggests a close genetic link between these meteorite classes or a dominantly CM-type chondrite flux around the EPB. CM-type chondrites are rare among terrestrial meteorite falls (e.g., [7]) but a related material apparently dominates the micrometeorite (and probably also the fine-grained dust) flux on Earth [e.g., [8]; [9]). Similar matter should also accrete on the moon but is usually destroyed by the impact. Such impact effects are not apparent in the howardite xenoliths. We have to conclude that the incorporation of CM-type rock fragments into the howardite breccia must have taken place in a very gentle way.

Impact must be excluded leaving the alternative of co-accretion of all components - including the CM-type chondrite - into the Erevan parent body.

In comparison with other CM chondrites, the Erevan carbonaceous clasts appear to be richer in tochilinite and carbonate. Another unusual component of the clasts is the P-rich sulphide which obviously represents a new type of P-bearing compounds. Phosphorus is known to be a siderophile or lithophile element and has never been reported from sulphides associated with metal and silicate. In contrast to pentlandite , the P-rich sulphide appears not to be equilibrated with the matrix. Therefore, this sulphide must have been formed before incorporation into the carbonaceous matrix and must be considered to be of primary origin. The enrichment in Na and K demand the sulphide to be formed under reducing conditions similar to that of the enstatite chondrites where phospate phases are not stable. On the other hand this source region of the sulfide must have been characterized by a high S fugacity in order to prevent precipitation of P-rich metal and phosphide. Thus, the Erevan carbonaceous clasts seem to have sampled a highly reduced region of the solar nebular.

REFERENCES [1] L. Kvasha et al. (1978) Meteoritika, 37, 80 (in Russian). [2] F. Brandstätter et al. (1987) Meteoritics, 22, 336-337. [3] K. Tomeoka and P. Busek (1988) Geochim. Cosmochim Acta, 52, 1627-1640. [4] H. Y. McSween and S. M. Richardson (1977) Geochim. Cosmochim. Acta, 41, 1145-1161. [5] A. J. Brearley (1992) LPSC XXIII, 153-154. [6] T. E. Bunch and R. S. Rajan (1988) In "Meteorites and the Early Solar System", J. F. Kerridge and M. S. Matthews (eds), Univ.Arizona Press, Tuscon, 144-164. [7] R. T. Dodd (1981) Meteorites: A Petrological Chemical Synthesis. Cambridge Univ.Press, London, 366pp. [8] M. Maurette et al. (1991) Nature, 351, 44-47. [9] G. Kurat et al. (1992) Meteoritics 27, 246.

Table 1. Selected EMP analyses (n.d. = not detected)

	Tochil.	Serp.	Phyllo.	P.-Sulph.	Pentl.
Na	.04	.03	.10	.70	n.d.
Mg	3.3	15.1	7.0	.14	n.d.
Al	1.46	1.10	3.0	n.d.	n.d.
Si	.63	16.3	10.9	.04	.12
P	n.d.	.03	.02	5.6	n.d.
S	20.0	2.14	8.7	28.7	32.8
K	.01	.03	.06	.42	n.d.
Ca	.04	.08	.05	.10	n.d.
Ti	.04	-	-	n.d.	n.d.
Cr	.08	.13	.12	.08	.24
Mn	.10	.18	.20	.06	.08
Fe	47.1	28.9	29.1	32.6	32.5
Co	.02	.02	n.d.	1.35	1.27
Ni	4.4	.63	1.34	28.2	32.1

Table 2. Broad-beam analyses of the matrices

	ER-95	ER-100	ER-200	ER-500	ER-600	ER-700	ER-800
Na	.08	.17	.12	.11	.17	.11	.12
Mg	11.0	10.4	11.3	12.1	11.1	11.4	11.0
Al	1.27	1.25	1.52	1.03	3.6	1.21	.95
Si	15.6	14.0	13.3	13.8	12.8	12.6	13.8
P	.03	.07	.04	.03	.06	n.d.	.17
S	1.88	3.1	4.7	2.16	1.55	2.49	2.07
K	.08	.07	.05	.03	.05	.05	.03
Ca	.19	.14	.14	.20	.53	.05	.48
Ti	.10	.09	.10	.04	.19	.05	.02
Cr	.38	.36	.26	.59	.57	.41	.58
Mn	.24	.21	.20	.20	.20	.20	.20
Fe	24.4	23.5	23.2	20.0	23.3	25.2	25.5
Co	.10	.07	.02	.01	.02	.01	.02
Ni	1.15	1.14	.73	1.40	.80	.90	1.21