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GEOCHEMISTRY OF CHONDRULES FROM CARBONACEOUS, ORDINARY, AND E CHONDRITES.

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Major, minor, and trace element data of individual chondrules show a remarkable variability of chondrule compositions (1, 2). This variability apparently reflects a variety of fractionation processes which were active before, during, and after the chondrule forming event. Data are now available for chondrules from a variety of chondrites. Major and minor element data have been discussed already by several authors (e.g.2-5). Here I make an attempt to compare trace element data of chondrules from a few chondrites: Allende (6), Qingzhen (7), Tieschitz (8,9), Chainpur (9,10), and Semarkona (11,12). Selected elemental patterns - normalized to CI (13) - are shown in Figs. 1-3.

Lithophile elements display generally complex distribution patterns. The refractory lithophile elements (RLE) are normally enriched in chondrules as compared to CI (Table). Chondrules from ordinary chondrites (OC) and enstatit chondrite (EC) Qingzhen have RLE abundances mostly between 1x and 2x CI. Allende chondrules are on average clearly more refractory (2-8x CI). They also show uniform enrichments of RLE which is commonly not the case in all other chondrites. Several anomalies in elemental abundances are frequently observed: Ca/Sc,La shows commonly positive and negative anomalies in most OC's and in EC, except for Semarkona and Allende. There are no Eu/Sm anomalies in Allende, very common - in EC and common + or - in OC's. Interestingly, there are only few and mostly weak Yb/Lu anomalies, most of which are unrelated to the Eu-anomaly. The moderately volatile lithophile elements Cr and Mn are either unfractionated as compared to the RLE (most OC chondrules) or regularly depleted (Allende and refractory OC and E chondrules) or show complex patterns. EC chondrules generally show strong - Cr/Lu anomalies, which are also present but weaker among some OC chondrules. Cr/Mn is mostly unfractionated among EC and OC chondrules except for the refractory chondrules and a few others which show either + or - anomalies.

The volatile lithophile elements Na and K show characteristical fractionations. Na/Sm is always - in Allende, always + in Qingzhen, commonly + or - in Chainpur and unfractionated in Tieschitz and Semarkona (with exceptions). Na/K fractionation is strong in Qingzhen (all K-), common among Chainpur chondrules (K+ and K-), and weak or not present among Allende and Semarkona chondrules. The Na/K fractionation appears to be related to halogen abundances in Allende and Qingzhen chondrules (6).

Siderophile elements are generally strongly depleted in chondrules as compared to CI and are almost always fractionated (Figs.1-3). The most common fractionation is that of Ir/Ni which ranges from highly - to highly +. Most chondrules from all chondrites show Ir-, except those of Qingzhen which have mostly chondritic Ir/Ni, similar to some chondrules from Allende and some metal-rich chondrules from OC's. Refractory chondrules from OC's tend to show Ir $>$ Ni, some chondrules from Allende and OC's have Ir $\gg$ Ni. Ni/Co fractionations are less common and well developed mostly only among chondrules with very low metal contents: Chainpur, Semarkona and Allende - all with Co $>$ Ni. The Fe/Co ratio is chondritic only in most Allende chondrules. All other chondrules and two RP chondrules from Allende show variably strong Fe+ anomalies. Au contents are surprisingly high and the Au/Ni ratio is mostly close to CI, despite the very strong Ir/Ni fractionations. Only some refractory chondrules show Au-, and RP chondrules from Allende and a few others Au+.

Conclusions: Trace element contents of chondrules from CV, E, and ordinary chondrites reflect complex fractionation processes before, during and after chondrule formation:

1) Partitioning of trace elements into different pre-chondritic phases and subsequent non-representative sampling (anomalies among RLE, Cr/Mn fractionation, Na/K fractionation and link with halogen abundances, very strong Ir+ anomaly, siderophile-lithophile element fractionation (?)).
2) Vapor fractionation via evaporation (depletions of Na and K, Cr and Mn, Ir $>$ Ni,Co-fractionation) and via condensation (Sc,Lu $<$ RLE,Ir $<$ Ni $<$ Co $<$ Au).
3) Metal-silicate fractionation during melting event (Ir RLE).
4) Oxidizing conditions are indicated by Ir $<$ Ni $<$ Co $<$ Fe (all OC chondrules, some Allende chondrules). Reducing conditions are indicated by (Ir) $\sim$ Ni $\sim$ Co $\lesssim$ Fe (Qingzhen and some Allende chondrules).

References: (1) For references see: Kurat,G.(1984), Proc. 27th Internat.Geolog.Congress, vol.11, 155-197. (2) Ikeda,Y. (1983), Mem.Nat.Inst.Polar Res.,Spec.Iss.30, Tokyo, 122-145. (3) Dodd,R.T. and L.S.Walter (1972), In: L'Origin du Systeme Solaire, H.Reeves (ed.) Paris, C.N.R.S., 293-300. (4) Fredriksson,K.(1982) Lunar Planet.Sci. XIII, 233-234. The Lunar Planet.Inst.Houston, TX. (5) Dodd,R.T.(1981), Meteorites. Cambridge Univ.Press, Cambridge, 368 pp. (6) Kurat,G., H.Palme, F.Brandstätter, B.Spettel, and V.P.Perelygin (1985), Lunar Planet Sci.XVI, The Lunar Planet. Inst.Houston, TX, in the press (7) Grossman,J.N., A.E.Rubin, E.R. Rambaldi, R.S.Rajan, and J.T.Wasson (1984), preprint. (8) Gooding,J.L.(1979), Ph.D.Thesis, Univ.New Mexico, Albuquerque, 392 pp. (9) Unpublished data, MPI Heidelberg (10) Kurat,G., E. Pernicka, and I.Herrwerth (1984), Earth Planet.Sci.Lett.68, 43-56. (11) Grossman,J.N. and J.T.Wasson (1983), Geochim.Cosmochim. Acta 47, 759-771. (12) Grossman,J.N. and J.T.Wasson (1984), preprint. (13) Unpublished data, MPI Mainz.

Table 1 : Common lithophile element fractionations in chondrules.

Fractionation	Allende (CV)	Qingzhen (E-3)	Tieschitz (H-3)	Chainpur (LL-3)	Semarkona (LL-3)
Refractories/CI	2-8x	mostly 1-2x, a few up to 3x	1-2.5x	1-2x rare up to 5x	1-2x a few up to 3x
Ca/Sc,La	weak Ca-common	common Ca+ and Ca-	common Ca+ and Ca-	very common Ca-	very common no anomaly
Eu/Sm	no	very common Eu-	common weak Eu-, a few Eu+	Eu+ and Eu- common	common weak Eu+
Yb/Lu	no one strong Lu-	mostly no, some weak Yb+,Yb-	mostly no, some Yb+,Yb-	mostly no, some weak Yb+	mostly no, some weak Yb+,Yb-
Cr/Lu	mostly strong Cr-	mostly strong Cr-, one strong Cr+	mostly no, a few Cr+,Cr-	mostly no, a few Cr+,Cr-	mostly no, a few Cr-
Cr/Mn	mostly strong Mn-	unfractionated some Mn+, a few Mn-	unfractionated few Mn+,Mn-	unfractionated, few Mn+, one Mn-	unfractionated few Mn+.Mn-
Mn/Na	RP weak Na-, others strong Na+	mostly strong Na+, few unfr. or Na-	mostly Na+ or Na-	unfract. and Na+,Na-	unfract. common Na-, rare Na+
Na/Sm	all Na-	all Na+	common unfract. or weak Na+,Na-	common Na+,Na-	unfract. Na+,Na-
Na/K	unfract.weak K+,K-	all K-	-	unfract.K+,K-	mostly unfract. few K+,K-

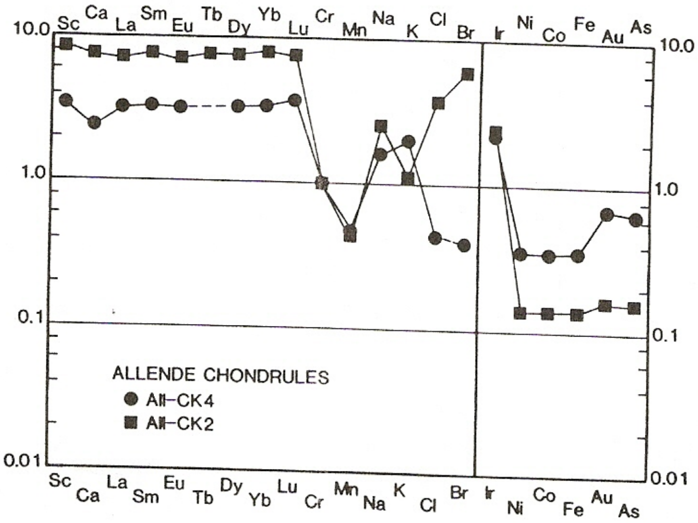

Fig.1(left): CI-normalized elemental abundances of two chondrules from Allende (6).
Fig.2(lower left): CI-normalized elemental abundances of refractory chondrules from Chainpur (9,10).
Fig.3(lower right): CI-normalized elemental abundances of K-rich chondrules from Chainpur (9,10).