COMPOSITIONAL AND PETROGRAPHIC CONSTRAINTS ON THE ORIGIN OF CHAINPUR CHONDRULES. J. N. Grossman*, A. Kracher+ and J. T. Wasson*, *Institute of Geophysics and Planetary Physics, Univ. of Calif., Los Angeles, CA 90024, USA and +Naturhistorisches Museum, Vienna, Austria.

Thirty-six individual chondrules, fine sieve fractions, and a crushed whole rock sample from the Chainpur (LL3) meteorite were analyzed by instrumental neutron activation analysis (INAA). Ten of these (Nos. 1,2,3,4,5,7,8, 9,10,16) have also been analyzed by radiochemical neutron activation analysis (RNAA), as well as by microprobe analysis of thin sections (1). INAA data for the last 17 chondrules, the fine fraction (ffr) and the whole rock sample (wr) are presented in Table 1; RNAA and microprobe studies of these are in progress. Our suite of elements includes 6-7 more volatile than Na, the most volatile element studied by previous researchers in this field (2,3). The combination of data on highly volatile elements and refractory elements with petrographic data offers new insights into the problem of the chondrule origins.

The highly volatile elements Ge, Ga, Zn, and Cd are not strongly depleted in Chainpur chondrules relative to the average LL chondrite composition or to whole rock. In addition, mean concentrations of the moderately volatile lithophile elements Mn, Na, and K are slightly higher in chondrules than in the wr. These volatile element data seem to preclude any direct condensation model for the origin of chondrules, since condensation would necessarily have occurred at too high a temperature to condense out significant fractions of these elements. The volatile element concentrations can be explained by a sudden melting of pre-existing grains, with minor-to-negligible loss of volatiles during a brief molten period.

The siderophile elements Co, Ni, Ge, As, Ir, and Au correlate strongly with each other in the chondrules. We infer that their concentrations depend largely on the total amount of metal in the chondrules. Even the most volatile siderophile, Ge, is higher than whole rock concentration in the metal rich chondrules 8 and 10. A correlation also exists between siderophiles and chalcophilic Se, indicating a covariation of metal and troilite.

Figure 1 shows a previously unreported correlation between the fayalite content of olivine with two refractory elements, Sm and Sc. This unexpected correlation provides insight into the origin of the wide range of Fe/(Fe+Mg) ratios found in the chondrules of unequilibrated chondrites. An examination of Dodd's study on Manych (L3) chondrules (4,5) shows that this relationship is also resolvable in his data. It is well known that equilibria in the solar nebula result in Fe being in metallic form at high temperature, and oxidized at lower temperatures. The low Fa values and high (up to 3.5X wr concentrations) refractory contents of the refractory-rich chondrules are consistent with a high temperature origin. The observed trend cannot be explained by the addition of FeO to these refractory chondrules. Even if one ignores the very high refractory content of chondrule 7, the maximum reduction in refractory content resulting from dilution by FeO is about 20%, not the observed factor of 2.

It appears more likely that the correlation resulted from the mixing of a coarse-grained, high temperature, refractory-rich component with a fine grained, lower temperature, refractory poor component prior to chondrule formation. The fine component could have equilibrated with the nebula down to lower temperatures than the coarse component, thus producing the oxidized Fe. There is no correlation between volatile elements and refractories or olivine composition. Thus, the volatiles distribution was not controlled by this mix-

ing of coarse- and fine-grained components. Chondrule No. 28 has an especially high refractory component, 1.8X higher than the highest value found by Osborn et al. (3) in 22 Chainpur chondrules. The Al/Sc and Al/V ratios in No. 28 (1.46 and 0.24) are very close to the ratios measured by Wänke, et al. (6), in a coarse grained refractory inclusion from Allende (1.46 and 0.28). If the refractory component of chondrule 28 is essentially the same as the refractory Allende inclusion, then it was formed from a mixture of 3 parts refractory-poor material and one part refractory-rich material.

Chondrule 1-16 were numbered approximately in order of decreasing mass. Fig. 1 shows a correlation between chondrule mass and fayalite composition, and an anticorrelation between mass and refractory content. The latter correlation had been previously noted in chondrules by Osborn et al. (3). This probably indicates that the mean particle (a particle may consist of many grains) size of the low temperature component was somewhat greater than that of the refractory component. The Al, Sc, and V data in Table 1 are intercorrelated and also show the refractory to mass anticorrelations, but no olivine composition data is available as yet.

REFERENCES:
(1) Grossman J.N., Kracher A. and Wasson J.T. (1978) Geophys. Res. Lett., submitted.
(2) Schmitt R.A., Smith R.H. and Goles G.G. (1965) J. Geophys. Res. 70, 2419
(3) Osborn T.W., Smith R.H. and Schmitt R.A. (1973) Geochim. Cosmochim. Acta, 37, 1909
(4) Dodd R.T. (1978a), Earth Planet. Sci. Lett., 39, 52
(5) Dodd R.T. (1978b), Earth Planet. Sci. Lett., 40, 71
(6) Wänke H., Baddenhausen H., Palme H. and Spettel B. (1974) Earth Planet. Sci. Lett., 23, 1

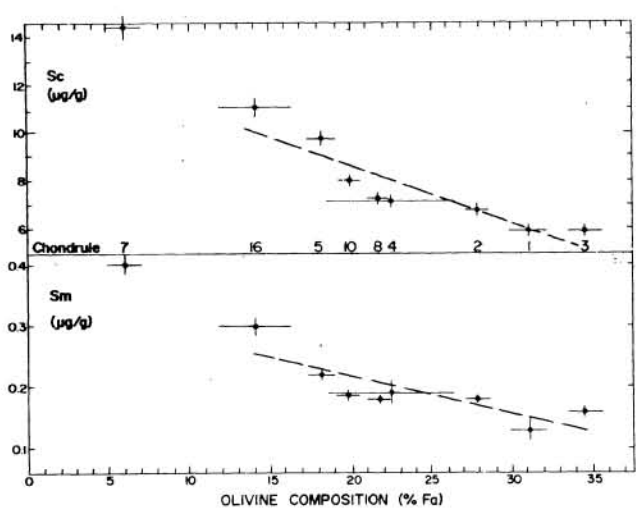

Fig. 1. Bulk concentration of the refractory elements Sc and Sm are inversely correlated with the fayalite content of the olivine. Chondrules are numbered approximately in order of decreasing mass. Thus, the largest chondrules have the lowest refractory and the highest Fa contents.

Table 1: Elemental concentrations determined by INAA for 17 Chainpur chondrules. μg/g, except Na, Mg, Al, K, Ca, Cr, Mn, Fe, Ni(mg/g), and Au, Ir(ng/g). Mass in mg.

No.	Mass	Na	Mg	Al	K	Ca	Sc	V	Cr	Mn	Fe	Co	Ni	Zn	Ga	As	Se	Sm	Ir	Au
20	32.88	3.03	195	8.62	0.32	11	6.5	85	2.2	1.16	66	80	1.72	<10	2.3	0.17[c]	<1.1	<1.0	226	394
21	14.02	8.1	155	11.5	1.06	-	6.7	76	4.1	0.69	266	1300	22.6	11	1.2[c]	2.2	23[c]	1.7	680	464
22	3.22	7.6	187	14.0	1.11	-	9.1	96	4.1	3.15	83	110	3.88	16[b]	4.0	0.35[c]	6.3	<4.1	96	84[b]
23	2.93	11.1	239	16.7	1.89	-	11.4	131	4.4	5.06	108	116	2.00	30	10.	<0.77	3.7[b]	<4.1	35	53[c]
24	2.82	11.6	237	19.6	1.50	-	11.8	188	2.2	1.84	200	1160	25.1	107	5.0[b]	2.2[b]	11.6	<5.8	1550	454
25	2.66	0.99	193	23.4	<0.14	17	13.2	116	5.2	2.22	137	211	3.80	38	0.52[c]	0.42[b]	<2.9	2.8[b]	384	72[b]
26	1.97	6.9	198	15.2	1.16	-	10.3	105	4.8	3.82	120	302	5.92	40	5.0	1.4[b]	12.7	<3.4	156	133[b]
27	1.84	7.7	247	15.7	1.40	-	10.4	125	4.5	3.24	195	444	11.2	55	5.1	1.9[b]	17.	<2.7	355	258
28	1.83	5.5	226	42.1	<0.42	-	28.9	177	2.7	1.38	183	620	8.10	46	8.0	1.7[b]	16.4	3.2[b]	1380	154[b]
29	1.69	8.1	189	12.8	2.18	10	8.2	107	3.6	5.20	124	93	1.57	<13	7.5	<0.93	<1.4	2.8	19	52[c]
30	1.56	1.53	232	17.6	<0.10	20	10.0	100	3.0	2.42	152	94	1.20	26	1.4[b]	<0.29	<1.8	4.0	45	<69
31	1.24	10.7	198	25.9	0.85	-	11.7	155	4.3	4.74	125	196	4.34	<32	10.	<0.90	6.9[b]	3.8	84	102[b]
32	1.13	6.0	280	19.5	0.44	-	12.1	124	4.2	2.56	51	111	2.67	16[b]	3.9[b]	<0.70	<3.3	<3.1	98	78[b]
33	1.09	4.8	138	15.2	0.88	17	5.5	120	4.3	5.03	196	359	7.40	<66	2.7[b]	1.4[b]	<5.1	<1.9	280	174
34	1.03	11.9	172	17.5	2.98	12	11.8	132	4.0	4.26	121	29.8	1.71	30	19.	<1.5	<3.9	3.1[b]	18	39[c]
35	0.79	9.9	273	18.9	1.94	23	12.1	129	4.5	3.80	109	173	3.66	41	8.3	<1.1	5.2[b]	2.3[b]	80	94[b]
36	0.65	11.1	338	26.4	1.26	17	13.7	168	4.3	2.94	97	367	15.3	33[b]	3.2[c]	1.3[c]	<6.9	4.9	384	360
ffr	7.27	5.5	169	11.4	0.78	-	7.8	83	3.28	2.77	180	530	10.5	32	6.9	1.3	8.1	<2.4	285	277
w.r.	7.91	6.0	168	11.7	0.78	-	8.0	82	3.49	2.86	188	550	10.4	43	4.3	1.8	9.2	<4.1	370	286
Unc. (%)[a]		4	4	5	10	25	4	8	5	4	5	5	5	20	20	10	9	20	8	8

a) 70% confidence limits on a single determination of a 10 mg chondrule having the ffr composition

b) Uncertainty about twice as large as normal

c) Uncertainty about four times as large as normal