COMPOSITIONAL AND PETROGRAPHIC CONSTRAINTS ON THE ORIGIN OF CHAINPUR CHONDRULES. J. N. Grossman*, A. Kracher* and J. T. Wasson*, *Institute of Geo-
physics 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 instru-
mental 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 lith-
ophile 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 vola-
tiles 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 vola-
tile siderophile, Ge, is higher than whole rock concentration in the metal rich 
chondrules 8 and 10. A correlation also exists between siderophiles and chal-
cophilic 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 concen-
trations) 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 refrac-
tory 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 for-
mation. 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-
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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:

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.

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| No. | Mass (g) | Na (ppm) | Mg (ppm) | Al (ppm) | K (ppm) | Ca (ppm) | Sc (ppm) | V (ppm) | Cr (ppm) | Mn (ppm) | Fe (ppm) | Co (ppm) | Ni (ppm) | Zn (ppm) | Ga (ppm) | As (ppm) | Se (ppm) | Sm (ppm) | Ir (ppm) | Au (ppm) |
|-----|----------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 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     | <1       | <1       | <1       | <1       | 226      | 394      |
| 21  | 14.02    | 8.1      | 155      | 11.5     | 1.06    | -        | 6.7      | 76       | 4.1      | 0.69     | 266      | 1300     | 22.6     | 1.2      | 2.3      | 2.2      | 23       | 3        | 3        | 8        | 4        | 680      | 464      |
| 22  | 3.22     | 7.6      | 187      | 14.0     | 1.11    | -        | 9.1      | 96       | 4.1      | 3.15     | 83       | 110      | 3.88     | 16       | 4.0      | 0.35     | 6.3      | <4.1     | <4.1     | 35       | 53       |
| 23  | 2.93     | 11.1     | 239      | 16.7     | 1.89    | -        | 11.4     | 131      | 4.4      | 5.06     | 108      | 116      | 2.00     | 30       | 10.0     | <0.75    | 3.7      | <4.1     | <4.1     | 35       | 53       |
| 24  | 2.82     | 11.6     | 237      | 19.6     | 1.50    | -        | 11.8     | 188      | 2.2      | 1.84     | 200      | 1160     | 25.1     | 107      | 5.0      | 2.2      | 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     | 0.42     | <2.9     | 2.8      | 384      | 72       |
| 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      | 12.7     | <3.4     | 156      | 133      |
| 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      | 17.0     | <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      | 16.4     | 3.2      | 1380     | 154      |
| 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     | <4.4     | 28       | 19       |
| 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      | <0.29    | <1.8     | <4.0     | 45       | <69      |
| 31  | 1.24     | 10.7     | 198      | 25.9     | 0.85    | -        | 11.7     | 135      | 4.3      | 4.74     | 125      | 196      | 4.34     | <32      | 10.0     | <0.90    | 6.9      | 3.8      | 84       | 102      |
| 32  | 1.13     | 6.0      | 280      | 19.5     | 0.44    | -        | 12.1     | 124      | 4.2      | 2.56     | 51       | 111      | 2.67     | 16       | 3.9      | <0.70    | <3.3     | <3.1     | 98       | 78       |
| 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      | 1.4      | <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       | 19.0     | <1.5     | <3.9     | 3.1      | 18       | 39       |
| 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      | 2.3      | 80       | 94       |
| 36  | 0.66     | 11.1     | 338      | 26.4     | 1.26    | 17       | 13.7     | 168      | 4.3      | 2.94     | 97       | 367      | 15.3     | 33       | 3.2      | 1.3c     | <6.9     | 4.9      | 384      | 360      |
| ffr | 7.27     | 5.5      | 169      | 11.4     | 0.78    | -        | 7.8      | 83       | 3.282    | 7.7      | 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       | 3.492    | 86       | 188      | 550      | 10.4     | 43       | 4.3      | 1.8      | 9.2      | <4.1     | 370      | 286      |
| Unc. (%) | 25 | 4        | 4        | 5        | 10       | 25       | 4        | 85       | 4        | 5        | 5        | 5        | 20       | 20       | 10       | 9         | 20       | 8         | 8         |

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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