N94-16257

THE GROUP A3 CHONDRULES OF KRYMKA: FURTHER EVIDENCE FOR MAJOR EVAPORATIVE LOSS DURING THE FORMATION OF CHONDRULES. S.Huang, P.H. Benoit and D.W.G. Sears. Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701, USA

Like Semarkona (type 3.0), Krymka (type 3.1) contains two distinct types of chondrule (namely groups A and B) which differ in their bulk compositions, phase compositions and CL properties. The group A chondrules in both meteorites show evidence for major loss of material by evaporation; i.e. elemental abundance patterns, size, redox state, olivine-pyroxene abundances. Group A and B chondrules probably formed from common or very similar precursors by the same processes acting with different intensities, group A suffering greater mass-loss by evaporation and reduction of FeO and SiO_2. While Krymka chondrules share many primary mineralogical and compositional properties with Semarkona chondrules, the minimal metamorphism it has suffered has also had a significant effect on its chondrules.

A new comprehensive classification for chondrules based on the composition of their phenocrysts and mesostases has been proposed[1,2]. The most primitive (type 3.0) ordinary chondrite, Semarkona, contains chondrule groups, A1, A2, A5 and B1, while Krymka (type 3.1), contains groups, A3, B2 and A5. Group A1-3 chondrules contain CaO-rich mesostases and FeO-poor olivine, and sometimes pyroxene, while group B1,2 chondrules are composed of SiO_2-rich mesostases, FeO-rich olivine and are generally pyroxene-free. Group A5 chondrules contain Na_2O-rich mesostases and FeO-rich olivine, and similar to those in equilibrated chondrites. The proportions and abundances of these groups are listed in Table 1, which includes cathodoluminescence data which may also be used for chondrule classification. Here we report our continuing studies of primitive chondrules. We emphasize the A groups[3,4], whose significance in ordinary chondrites has only recently been realized[5,6]. Because of their smaller size and extreme friability[7], we use photographs of the CL of polished sections to select chondrules which are then removed by chiselling[3]. The present report concerns chondrules from Krymka.

The CI-normalized INAA data for each chondrule group are plotted in Fig. 1. Clear compositional differences are seen between the A3 and B2 groups, which resemble those previously observed between group A1,2 and B1 chondrules in Semarkona[3]. Group A3 chondrules are enriched in refractory lithophile elements and depleted in volatile elements with the depletion increasing steadily with volatility along the series Mn-Na. In contrast, group B2 chondrules show a flat pattern of lithophile elements. Both group A3 and group B2 chondrules show depletions in siderophile and chalcophile elements relative to CI, although group A3 chondrules may be slightly enriched in refractory siderophile elements (such as Ir, Co and Ni) relative to group B2 chondrules.

Group A chondrules in both Semarkona[8] and Krymka are generally smaller than group B chondrules, in addition to being depleted in Na and other volatiles (Fig. 2). This is consistent with evaporative loss during chondrule formation. On the basis of many laboratory experiments[9-11], considerable Na loss is to be expected during chondrule formation. The Na contents we now measure are, of course, upper limits for the Na in the chondrule at peak temperature during formation because **(1)** mesostasis profiles indicate Na recondensation[2,12], **(2)** our chondrules may have matrix attached to them, **(3)** aqueous alteration[13] and **(4)** metamorphism[1] may have redistributed Na. We suggest that the stronger correlation in Fig. 2 displayed by Krymka results from metamorphic mobilization of Na. If the size difference between group A and group B chondrules is due to evaporative loss (assuming 35% mass loss), then about 40% loss of Si (and somewhat less Mg) and 60% loss of Fe are indicated. The relevant reactions, which also involve reduction of FeO and SiO_2, are of the sort[3,4,14-17]:

$$2Fe_2SiO_{4(l)} + Mg_2SiO_{4(l)} + 5H_{2(g)} \longrightarrow 2MgSiO_{3(l)} + 4Fe_{(g)} + SiO_{(g)} + 5H_2O_{(g)}$$

$$FeSiO_{3(l)} + 2MgSiO_{3(l)} + 3H_{2(g)} \longrightarrow Mg_2SiO_{4(l)} + Fe_{(g)} + 2SiO_{(g)} + 3H_2O_{(g)}$$

and since the first reaction is the most important there is a net increase in pyroxene, as observed experimentally[4-6,18,19]. It seems unlikely to us that olivine and pyroxene reduction, volatile-loss, size, and the olivine-pyroxene abundance trends could all be due to random fluctuations in precursors[20,21]. Rather, we think that A and B chondrule groups probably had very similar precursor materials and were formed by the same processes acting with different intensities, so that while group A chondrules suffered volatile-loss, group B did not. Jones also suggested that type IA chondrules (a subset of group A) can be derived from type II chondrules (a subset of group B) by reduction and volatilization of major elements such as Si, Fe and Na[22].

The small sample size has made it impossible to obtain oxygen isotope data for group A chondrules, but we can predict that group A1-3 chondrules should show greater mass-fractionated patterns and greater isotope exchange with the surrounding gases than B2 chondrules. However, it is unclear whether the surrounding gas was ^{16}O-rich, as inferred by the inverse correlation between ^{16}O and size for Dhajala (H3.8) chondrules[23], or ^{16}O-poor as inferred by an ^{16}O-depleted Mezö Madaras (L3 breccia) glass fragment[24].

The A1 chondrules of Semarkona differ from the equivalent A3 chondrules of Krymka in the CL of the mesostases, probably due to metamorphism-driven changes in Mn or major structural changes[12,25]. Olivine and mesostasis compositions of A1 and A3 chondrules also differ[1,2], and Krymka lacks the extremely volatile-poor chondrules observed in Semarkona (< 0.2% Na_2O), apparently because of diffusion during Krymka's extremely mild metamorphic episode. While mesostasis compositions of Semarkona B1 chondrules differ significantly from those of Krymka B2, bulk chondrule and phenocryst compositions are similar, presumably because of their relatively sluggish response to metamorphism.

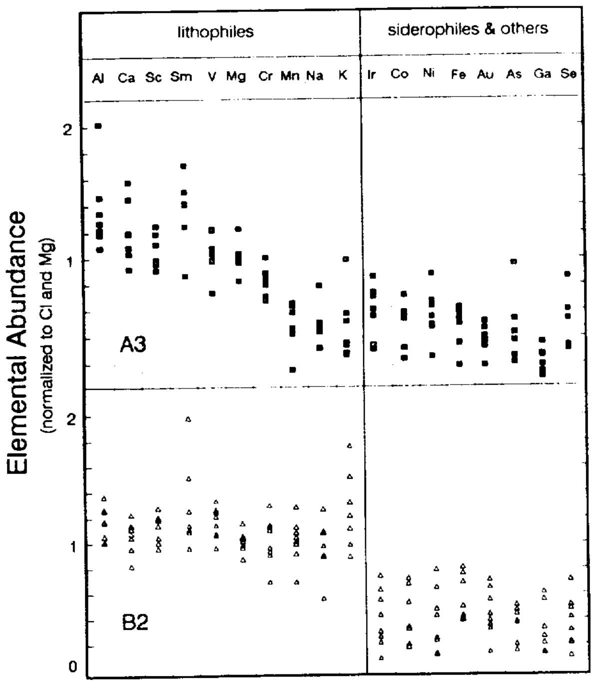

Fig. 1 (above) CI- and Mg- normalized INAA data for chondrules from Krymka. Fig. 2 (upper right) Na vs. diameter for Semarkona and Krymka chondrules.

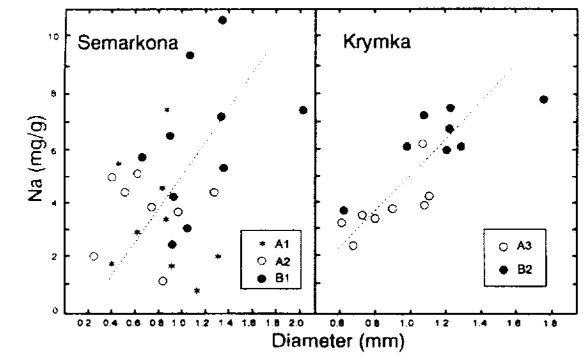

TABLE 1. Cathodoluminescence (CL), mesostasis and olivine compositions and frequency (Freq., %) of chondrule groups in Krymka and Semarkona*.

	Mesos. CL	Mesos. Norm	Ol CL	Ol %FeO	Ol %CaO	Freq. Kry.	Freq. Sem.
A1	yellow	pl(An>50%)	red	<2	>0.17	3.6	10.5
A2	yellow	pl(An>50%)	none/dull red	2-10	0.1-0.2	0.0	25.0
A3	blue	pl(An>50%)	red	<4	>0.2	33.3(9)	0.0
A4	blue	pl(An>50%)	none/dull red	>4	0.16-0.3	7.3	0.0
A5	blue	pl(An<50%)	none	>10	<0.16	14.5(1)	5.0
B1	none	>30% Qtz	none	7-25	0.08-0.3	0.0	56.9
B2	none	30-50% Qtz	none/dull red	10-25	0.08-0.3	36.4(8)	0.0
B3	purple	15-30% Qtz	none	15-20	<0.08	0.0	2.6

*The compositional fields are not rectangular, see ref. 1,2. pl = plagioclase.

In summary, group A3 chondrules in Krymka resemble the group A1,2 chondrules in Semarkona in many respects. They are equally abundant, being ~35% by number, with similar phase and bulk compositions. Semarkona B1 and Krymka B2 chondrules also closely resemble each other. However differences are present which reflect a very mild metamorphic overprint in Krymka, which is especially true for group A chondrules which are more responsive to metamorphism. For both meteorites, the differences between group A and B chondrules suggest to us that they formed from similar starting materials, but that group A chondrules suffered greater evaporative loss of mass, and reduction, during chondrule formation.

1. Sears D.W.G. *et al* (1992) *Nature* **357**, 207. 2. DeHart J.M. *et al* (1992) *GCA* **56**, 3791. 3.Lu J. *et al* (1990) *LPSC* **XIII**, 720. 4. Lu J. *et al* (1992) *LPSC* **XXIII**, 813. 5. Scott E.R.D. & Taylor G.J (1983) *LPSC* **XIV**, 680. 6. Jones R.H. & Scott E.R.D. (1989) *Proc. 19th LPSC* 523. 7. Sears D.W.G. & DeHart J.M.(1989) *Meteoritics* **24**, 325. 8. Lu J. (1992) Ph.D thesis. 9. Tsuchiyama A. *et al* (1981) *GCA* **45**, 1357. 10. Notsu K. *et al* (1978) *GCA* **42**, 903. 11. Gooding J.L. & Muenow D.W. (1977) *Meteoritics* **12**, 401. 12. Matsunami S. *et al* (1992) *GCA* submitted. 13. Hutchison R. *et al* (1987) *GCA* **51**, 1875. 14. Wood J.A. (1985) In "*Protostars and Planets II*" (ed. Black D.C. & Matthews M.S.), 682. 15. Johnson M.C. (1985) *LPSC* **XVI** 402. 16. Kracher A. (1985) *LPSC* **XVI** 467. 17. Rubin A.E. *et al* (1988) In "*Meteorites and the early solar system*" (ed. Kerridge J.F. & Matthews M.S.), 488. 18. Walter L.S. and Dodd R.T. (1972) *Meteoritics* 7, 341. 19. Hashimoto A. (1983) *Geochem. J.* **17**, 111. 20.Grossman J.N. & Wasson J.T. (1983) In "*Chondrules and their Origins*" (ed. King E.A.), 88. 21. Hewins R.H. (1991) *GCA* **55**, 935. 22. Jones R.H. (1990) *GCA* **54**, 893. 23. Clayton R.N. *et al* (1991) *GCA* **55**, 2317. 24. Mayeda T.K. *et al* (1989) *Meteoritics* **24**, 301. 25.DeHart J.M. (1989) Ph.D thesis. Supported by NASA grant NAG 9-81.