

GROUP A5 CHONDRULES IN ORDINARY CHONDRITES: THEIR FORMATION AND METAMORPHISM. Shaoxiong Huang, Paul H. Benoit and Derek W. G. Sears. Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, Arkansas 72701, USA.

The group A5 chondrules in type 3 ordinary chondrites are those containing oligoclase-normative mesostasis and olivine and/or pyroxene with more than a few percent FeO (1,2). With respect to these major properties, they resemble the chondrules in equilibrated chondrites and they represent a distinct chondrule group from the group A1 and B1 (roughly equivalent to the type I and type II chondrules in Semarkona) normally discussed (3,4). About 5% by number of the chondrules in Semarkona (type 3.0) are group A5, and this number increases steadily with increasing petrologic type until all the chondrules in type 5 chondrites are group A5 (1,2). In the present paper we compare group A5 chondrules from low petrologic type 3 ordinary chondrites with A5 chondrules in equilibrated chondrites. We discuss both their formation - arguing for lower peak temperatures during formation than group A1 chondrules and slower cooling following formation than group B1 chondrules - and we discuss the complex changes this chondrule group underwent during metamorphism.

The CaO and FeO of the olivine in the A5 chondrules of several LL chondrites are shown in Fig. 1, with the compositional fields of the other chondrule groups. The A5 chondrules show a decrease in CaO and an increase in FeO with increasing metamorphism, but much less than for the other groups, and the heterogeneity (expressed as the coefficient of variation of FeO in olivine, σ/\bar{x}) increases from 5-20% in Semarkona (3.0) and Krymka (3.1) to 5-50% in ALHA 77214 (3.4), then decreases to <5% in Dhajala (3.8) and <2% in types 4-6. The pyroxenes show similar behavior to the olivine except that the CaO reaches an equilibrium value of 0.8-1.0% and pyroxene lags behind olivine as the metamorphic changes occur. Mesostasis compositions (Fig. 2) are very similar in all A5 chondrules, which are essentially Na-rich feldspar-normative, with few readily delineated metamorphic trends.

We suggest that there are two processes occurring during metamorphism which are driving these compositional trends. First, chondrules which formed originally with mean mesostasis compositions close to the equilibrated values underwent simple internal homogenization as essentially closed systems and olivine/pyroxene in these chondrules migrated to the equilibrated state by losing CaO and gaining FeO. Second, chondrules with mesostasis and olivine/pyroxene compositions far removed from the equilibrated values (the A1 or B1 chondrules) underwent element exchange with other meteorite components during open-system metamorphism to become A5 chondrules. This process can apparently be observed directly in ALHA 77214 (type 3.4) where many chondrules are B3 in their central region and A5 in their outer region (2).

The rate at which equilibration occurred depended on the original chondrule class, group A1-4 chondrules equilibrating faster than group B1-3 chondrules. This difference in rate of equilibration is due to considerable differences in the diffusion rate of olivine and pyroxene and of mesostases of various compositions. Volume diffusion rates in calcic glasses are greater than those of sodic or quartz-normative glasses (5), but more importantly, there are major differences in friability and crystallization rates for glasses of different composition (6) and grain boundary and vapor phase diffusion are thus facilitated. The pyroxenes do not fully achieve their equilibrated compositions until petrologic type 5 (2).

The changes in compositional heterogeneity observed among the olivines and pyroxenes of group A5 chondrules suggest that the group A5 chondrules in Semarkona were not metamorphosed prior to emplacement in the meteorite, and the presence of A5 chondrules in Semarkona is not due to brecciation. Rather, it indicates that the chondrule-forming process was capable of producing chondrules with mineral phase compositions resembling those of chondrules in equilibrated chondrites. There are several lines of evidence, summarized by refs. 3 and 7, which suggest that group A1 chondrules experienced higher temperatures during formation than other chondrules. We have previously argued that this also resulted in their volatile-poor and highly reduced compositions (8,9). Conversely, the volatile-rich, oxidized group B1 chondrules apparently experienced lower peak temperatures during formation. The composition of the mesostasis relative to the olivine/ pyroxene grains infers supercooling in the case of group B chondrules (4,10) but not for group A chondrules (3), including A5. We suggest that the three chondrule groups in Semarkona represent three very different thermal histories; reducing, relatively high temperatures of formation and fast cooling (group A1), oxidizing, low temperatures of formation and fast cooling (group B1) and low temperatures of formation and slow cooling (group A5). The peak temperature experienced during chondrule formation is determined by the intensity of the thermal pulse responsible for the chondrule, but the cooling history must be independent of the heating pulse and depends on the gas and dust density around the chondrule. Lewis *et al.* (11) have found experimental evidence for recondensation of Na into chondrules during

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chondrule formation, and that the Na content of chondrules depends on not only Na vapor pressure, but the cooling rate. This may be the case for the formation of group A5 chondrules, whose bulk Na concentrations are often higher than those of bulk chondrites. Zoned mesostasis and sulfide and metal rich rims around group A chondrules might imply an environment suitable for recondensation of volatiles for group A (12,13,14).

Apparently, the conditions and processes associated with chondrule formation showed considerable variation, as did the responses of the various primary chondrule groups to metamorphism. Clearly, chondrule history is very complicated and diverse and much of the literature discussion of the topic has been oversimplified.

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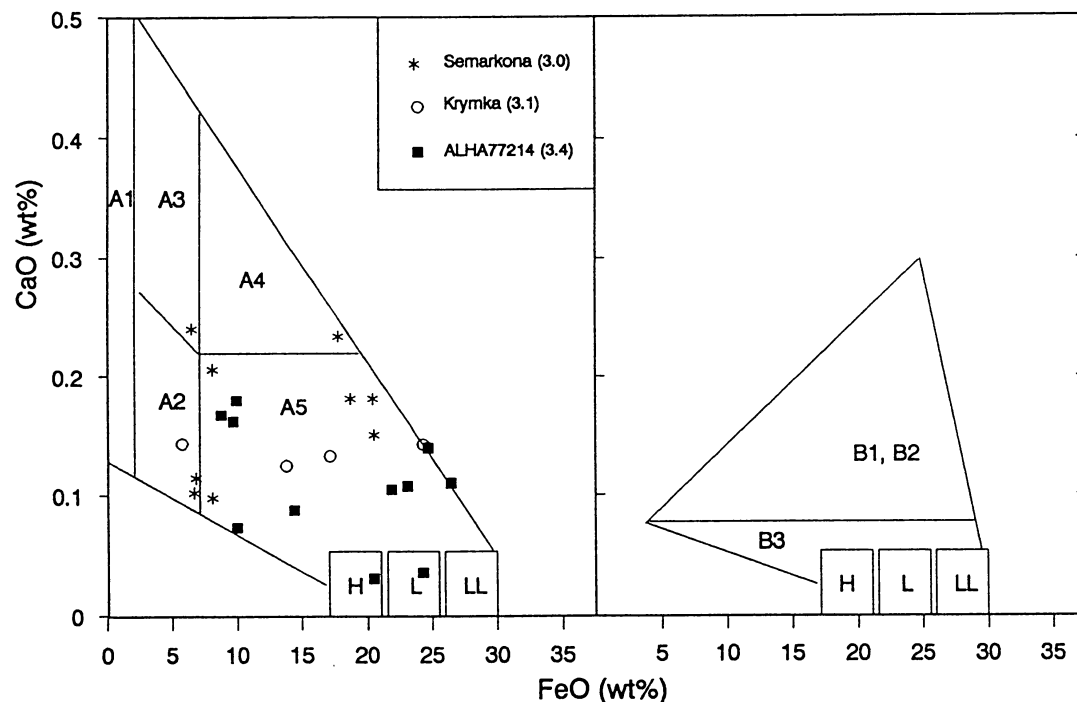


Fig. 1. CaO vs FeO in chondrule olivines with the chondrule class boundaries indicated (After ref. 1,2 with minor simplifications).

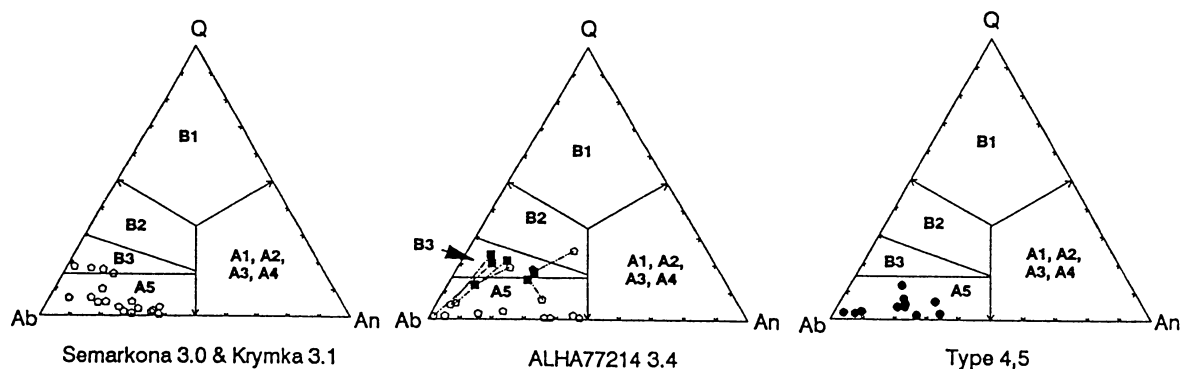


Fig. 2. Quartz-albite-anorthite ternary (normative compositions) for mesostasis compositions with chondrule class boundaries indicated (refs. 1,2). In all cases, data for group A5 chondrules are indicated.