FORMATION OF Na-RICH CHONDRULES BY MELTING OF Na-RICH AND CONDENSED (ULTRA)-REFRACTORY PRECURSORS.

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Introduction: A small portion of chondrules in chondrites are Al-rich (>10 wt% Al_2O_3; e.g., [1-6]). Here, we studied the Na-rich variety again. Earlier, the origin of the Na-distribution in chondrites has been largely ascribed to parent body processes [7,8]. We found that these chondrules must have formed by melting of precursors including Na-rich materials (like nepheline) as well as condensed (ultra)-refractory components.

Results and Discussion: We analyzed 33 Na-rich chondrules (Na_2O >4.0 wt%) from 15 different meteorites (6 H-, 6 L-, 1 R-, and 2 CO3-chondrites). The chondrules have abundant brownish, Na- and K-rich glass enclosing olivine, pyroxene (low-Ca pyroxene, Ca-pyroxene or fassaite (Al_2O_3 >7.0 wt% and TiO_2 >1.5 wt%)), and minor spinel. Defocused-beam electron microprobe analyses revealed that their bulk compositions show Na_2O concentrations varying between 4.3-15.2 wt%. Thus, these chondrules contain up to 65% normative nepheline (CIPW).

Bulk REE obtained by LA-ICP-MS of eight chondrules show REE concentration up to 10× CI. All have a pronounced negative Eu anomaly. Of these, six chondrules show a negative Yb-anomaly (group III-REE pattern), one shows a group II pattern, and two show a slight tendency in having an "ultra-refractory" REE pattern, where the heavy REE is slightly enriched relative to the light REE. Some chondrules show negative anomalies in Sm, which could have been generated by incorporation of highly reduced, ultra-refractory condensates [9].

Conclusions: It was argued that Na entered chondrules during metamorphism or metasomatism [7,8] on their parent body. No significant differences exist between Na-contents of chondrule rims and their interiors. Thus, we see no evidence pointing to Na_2O-enrichment (up to 15 wt%) of a chondrule from such parent body processes. As such, we suggest that the high Na-concentrations in chondrules are caused by the presence of high Na in the chondrule precursor. AOAs and, in particular, fine-grained, spinel-rich CAIs are often rich in Na_2O because melilite has been altered in a Na-rich nebular gas to nepheline (such CAIs have up to 80 vol% nepheline [10]). Such altered early condensates could have contributed to the precursor components leading to the formation of Na-rich chondrules in the chondrule-forming flash heating event in a non-solar environment with a high sodium partial pressure of $>10^{-6}$ atm [11]. Overall, we can rule out that Na-rich chondrules with Na_2O concentrations of up to 15 wt% were formed by collisions between molten planetesimals.

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