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Sodium metasomatism of chondrules and Ca-Al-rich inclusions in the Ningqiang carbonaceous chondrite

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Chondrules and Ca-Al-rich inclusions (CAIs) in CV and CO chondrites contain various amounts of Na-rich nepheline and sodalite. Previous studies revealed that these minerals formed by replacing primary Ca-Al rich minerals (mesostasis glass, plagioclase, and melilite) in chondrules and CAIs [1, 2]. More recent studies showed that amounts of nepheline and sodalite in chondrules and CAIs in CO 3.0-3.7 chondrites increase with increasing degree of thermal metamorphism of the host meteorites [3, 4]. These results suggest that formation of nepheline and sodalite is related to alteration that occurred in the meteorite parent bodies. Na and Ca are highly mobile in aqueous activity, thus the alteration may have occurred in the presence of aqueous solutions. Our recent study revealed that the Ningqiang carbonaceous chondrite contains abundant nepheline and sodalite in matrix (Matsumoto et al., JpGU meeting 2012). Chondrules and CAIs in Ningqiang also contain nepheline and sodalite. However, detailed mineralogy and abundance of these minerals in chondrules and CAIs remain unknown. Here, we report the results of mineralogical and petrological study of nepheline and sodalite in Ningqiang chondrules and CAIs.

Although 97 % of the observed chondrules in Ningqiang contain mesostases, volume proportions of mesostases in individual chondrules are remarkably small (5.4 vol. % on average) compared to other CV chondrites. Our SEM, TEM and STEM observations show that plagioclase in mesostases has been extensively altered to fine grains (~10 micron) of mainly nepheline, sodalite, Fe-rich olivine, and minor hedenbergite. In relatively large chondrules (>1 mm in diameter), the alteration occurred preferentially along the outer margins, and plagioclase in the cores remains unaltered. However, in relatively small (<1 mm in diameter) chondrules, plagioclase was completely replaced.

The abundance of CAIs in Ningqiang is very low (1 vol. %). All of the CAIs studied also exhibit abundant evidence of alteration. Melilite was replaced by fine grains (<5 micron in diameter) of nepheline, sodalite, hercynite and Fe-rich olivine. This alteration proceeded preferentially from the outer margins of CAIs. Our TEM and STEM observations revealed that some of the nepheline and Fe-rich olivine contain small (<100 nm in size) relicts of melilite.

The results of the present study showed that fine-grained Na-rich minerals (nepheline and sodalite) and Fe-rich minerals (Fe-rich olivine, Ca-Fe-pyroxenes, and hercynite) formed simultaneously by replacing mesostases in chondrules and melilite in CAIs. All of these secondary minerals also occur in the Ningqiang matrix (Matsumoto et al., JpGU meeting 2012). We infer that nepheline, sodalite, and the Fe-rich minerals in Ningqiang matrix were supplied from Na-metasomatized chondrules and CAIs, although we are yet uncertain of actual processes responsible for mixing the Na-metasomatized materials with matrix materials.

References:
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