The diversity of bulk chemical compositions of chondrules from least equilibrated ordinary chondrites

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Chondrules, the major component of chondrites, were solidified by rapid cooling of molten precursor materials in the early solar system. Tachibana et al. (2003) reported that there may be a correlation between 26Al-26Mg relative formation ages and bulk chemical compositions, in particular Si/Mg ratios, of ferromagnesian chondrules in unequilibrated ordinary chondrites. For better understanding of the age-composition correlation of chondrules, we have started a systematic study for bulk chemical compositions and Al-Mg ages of chondrules from unequilibrated ordinary chondrites. Here we report the chemical diversity of 89 chondrules as part of a broader study.

We chose all chondrules in two polished thin sections of unequilibrated ordinary chondrites (UOCs), Bishunpur and Krymka (both LL3.1). The non-biased selection of all the chondrules was to make statistical discussion. Bulk chemical analyses have been done for 52 and 37 chondrules in Bishunpur and Krymka, respectively, with an electron microprobe.

Among the 52 chondrules from Bishunpur, there are 44 ferromagnesian porphyritic chondrules (84 %) (31 FeO-poor and 13 FeO-rich), 5 ferromagnesian non-porphyritic chondrules (10%), and 3 Al-rich chondrules (6 %). In Krymka, there are 33 ferromagnesian porphyritic chondrules (89 %) (15 FeO-poor and 18 FeO-rich) and 4 radial pyroxene chondrules (11 %).

Bulk chemical analyses showed that ferromagnesian chondrules in both chondrites have wide varieties of chemical compositions, which are consistent with the chemical variations of UOC chondrules reported in previous studies. The compositional ranges of FeO-poor chondrules in Bishunpur and Krymka are almost the same, and their average compositions are also quite similar to each other. Iron-rich chondrules in both chondrites also show the similarity of chemical variety and average composition.

It is also seen that the average compositions of FeO-poor chondrules show a relatively flat pattern for the elements that are more refractory than Cr (Si, Mg, Ca, Ti, and Al) although refractory elements are slightly depleted compared to Si and Mg. Volatility-controlled depletion pattern can also be seen in FeO-poor chondrules for the elements, more volatile than Cr (Cr, Mn, K, Na, and Fe (FeO)). On the other hand, average compositions of FeO-rich chondrules show a flat pattern for most of elements except for Na and Fe (FeO). Note again that refractory elements are slightly depleted relative to Si and Mg. Comparison between average compositions of FeO-poor and FeO-rich chondrules shows that the elemental abundance patterns of both chondrule types are almost coincident with each other on average for Al, Ti, Ca, Mg, Si, and Cr, while, for relatively volatile to volatile elements (Mn, K, Na, and Fe), FeO-rich chondrules contain them more than FeO-poor ones. We also noticed, for both types of chondrules, that the abundance of refractory element moderately correlates with the abundance of Na.

The depletion of volatile elements from chondrules may be able to be explained by evaporation at chondrule-forming high temperatures. However, neither the depletion of refractory elements compared to CI abundance nor the correlation between refractolies and alkali elements can be explained by a simple kinetic evaporation/condensation process from CI-like precursor materials. An additional elemental fractionation process is required to explain the observed chemical variety such as removal of CAI-like components from UOC chondrule forming region.