Experimental and thermodynamic approach on aqueous alteration of synthetic chondrite under reducing and low temperature conditions: Implication for aqueous alteration in meteorite parent bodies

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The presence of hydrous minerals in chondrites has been considered as an important evidence for the former presence of liquid water in parent bodies. However, the detailed aqueous evolution history of parent bodies (e.g., temperature, fluid composition, water/rock ratio) are still poorly constrained, partly because the alteration processes of chondritic rock are not well defined and very few relevant experimental data are available. In this study, the alteration process and secondary mineral assemblage of chondritic rock are studied by the combination of alteration experiments and thermodynamic calculations. We especially focused on aqueous alteration at low temperature and reducing conditions, which were indeed suggested for some meteorite parent body but has been rarely experimentally examined in previous studies. The experiments were conducted at temperatures of 25 and 80 ºC for time periods between 1 to 460 days, using synthetic chondrite (mixtures of olivine, enstatite, glass, Fe_{metal}, and troilite) as a starting material.

Our experiments up to 460 days showed that chondrite-water reactions caused a series of mineral dissolution, secondary mineral formation, and changes in water chemistry even at low temperatures and short duration of time. Especially, the formation of pyrrhotite was notable during the first few days of the experiments while the formation of saponite was evident after 100 days in the experiment at 80 ºC. Transmission electron microscope observation revealed that fine-grained saponite and secondary-formed Si-rich amorphous phases densely covered the surface of the primary minerals both at 80 ºC and 25 ºC up to 470 days. The Fe/Mg ratios of the saponites formed at 80 ºC were higher than those formed at 25 ºC, and the highest Fe/Mg ratios were observed in saponites encrusting the primary troilite at 80 ºC. These results suggest that Fe^{2+} provided from troilite induced the formation of Fe-rich saponites, which is consistent with the rapid increase of HS^- in fluid from the start of the experiments and formation of pyrrhotite at 80 ºC. All of the secondary minerals observed from our alteration experiments were consistent with those expected from thermodynamic calculations. However, the formation of serpentine, which is one of the most dominant secondary minerals expected from thermodynamic calculations, was not observed in our experiments up to 460 days, probably because serpentine formation might be kinetically much slower than that of saponite at low temperature. The dominance of pyrrhotite and saponites and their morphological characteristics observed from our alteration experiments show similarities with those in some CV chondrite and micrometeorites, which formation might be explained by their alteration of reducing water at low temperatures and by short duration of time. Therefore, our findings will contribute to better constraints on the temperature and timescales of aqueous alteration in the meteorite parent bodies.

Keywords: chondrite, aqueous alteration, saponite

