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Redox-driven exsolution of iron-titanium oxides in magnetite in Miller Range (MIL) 03346 nakhlite: Evidence for post crystallization oxidation in the nakhlite cumulate pile?

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Abstract

The Miller Range (MIL) 03346 nakhlite contains ~20% mesostasis, which contains skeletal titanomagnetite. The titanomagnetite contains trellis-type {111} lamellae of ilmenite similar to those found in terrestrial titanomagnetites that have experienced subsolidus redox reactions during cooling of their host rocks. We have characterized the MIL 03346 titanomagnetite-ilmenite intergrowths by a combination of focused ion beam (FIB), energy-dispersive spectroscopy (EDX), and high-resolution transmission electron microscopy (TEM). The resulting structural and chemical analyses have been combined with temperature and f_{O_2} data from previous studies of MIL 03346, as well as previous work on two-oxide thermobarometry of nakhlites. Our calculations show that as MIL 03346 and other nakhlites cooled below 800 °C, they recorded increasingly reducing conditions, such that the lowest temperatures calculated correspond to f_{O_2} conditions as low as 4 log f_{O_2} units below the FMQ buffer. However, the MIL 03346 lamellae must have formed by oxidation and thus record a very late stage low-temperature (<350 °C) oxidation event. When considered together with previous studies of MIL 03346 and nakhlites in general, the overall cooling history could be explained by early oxidation followed by intermediate stage reduction caused by S_2 loss by degassing, followed by late loss of Cl by degassing.

Keywords: Fe-Ti oxide, nakhlite, Mars, oxygen fugacity