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Thermal history of nakhlites: a comparison between MIL03346 and its terrestrial analogue Theo's flow

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Miller Range (MIL03346) is a nakhlite found in Antarctica [1, 2], and interpreted as an igneous cumulate erupted onto the surface of Mars [3, 4].

A single-crystal X-ray diffraction (SC-XRD) and Mössbauer spectroscopy study on the intracrystalline cation distribution of an augitic core-crystal from MIL03346 ($\sim Wo_{40}En_{36}Fs_{24}$) performed by [5] clearly showed a high degree of order in the Fe^{2+}-Mg distribution in agreement with [6] corresponding to a closure temperature T_c=500(100)˚C newly calculated using the geothermometer by [7]. Because the T_c of the ordering process depends both on the kinetics of the Fe^{2+}-Mg exchange reaction and on the cooling rate of the host rock, it allows to retrieve information on the cooling rate of the sample: lower T_c would correspond to slower cooling rate. The slow cooling rate inferred for MIL03346 is in disagreement with petrologic evidences (i.e. [1,8]) that indicate this sample to belong to a fast cooled lava flow (i.e. 3-6˚C/h [1, 9]).

In order to clarify this discrepancy we undertook a SC-XRD study of an augite ($\sim Wo_{41}En_{49}Fs_{10}$) from a pyroxenite (TS-7, [10]) of Theo's flow, a 120-m-thick, lava flow (Ontario, Canada, [11]) regarded as a terrestrial analogue of MIL03346 [12]. Sample TS-7 is in the middle of the pyroxenite unit, about 85m below the top of the sequence. The volcanic sequence records a very low-grade metamorphic alteration in the chlorite to prehnite-pumpellyite facies.

SC-XRD data from TS-7 augite yields a T_c= 600(20)˚C, consistent with the cooling rate expected at 85m below the surface. This T_c is higher, although similar within error, to the T_c=500(100)˚C obtained for MIL03346 thus suggesting a relatively slower cooling for MIL03346 with respect to TS-7. This result appears inconsistent with the very shallow depths of origin (e.g. <2m) assumed for MIL03346 [13], further supporting the discrepancy between MIL03346 textural and petrologic evidences of fast cooling and the augite geothermometer results. A tentative scenario, is that, soon after eruption and initial quench, while still at relatively high-T (e.g 500-600˚C) MIL03346 was blanketed with subsequent lava flows, that slowed down the cooling rate and allowed augite Fe^{2+}-Mg exchange reaction to proceed. This scenario is being experimentally tested.

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