

EVIDENCE FOR DISCONTINUOUS EVOLUTION OF THE MARTIAN METEORITES NAKHLA AND Y000593.

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Introduction: The Nakhrites are clinopyroxenites with minor FeO-rich olivine and crystallized intercumulus melt (mesostasis). Nakhla and Y000593 clinopyroxenes consist of large rather homogeneous augite cores with FeO-rich rims. Fe/Mg zoning of olivines and the Fe-rich rims of augites are commonly explained by diffusive re-equilibration with an FeO-rich late stage melt [1,2,3]. At present, recent discussions on the thermal evolution of the cumulus minerals focus on a more or less continuous evolution in respect to cooling and fO_2 [4]. Our detailed combined SEM and TEM investigation of clinopyroxene microstructures and the application of pyroxene thermometry for Nakhla and Y000593 provide compelling evidence for a discontinuous history of the studied Nakhrites.

Clinopyroxene thermometry: We estimate a minimum temperature of 1150°C required to form the core clinopyroxenes ($En_{44-46}Wo_{34-35}Fs_{20-22}$ for both Nakhrites) based on the phase diagram of Lindsley [5]. The widespread homogeneous chemical composition of the large pyroxenes requires a longer equilibration under these conditions. The minimum temperature required for the FeO-rich rims range from 1050 to 1150°C for Nakhla and 1000-1150°C for Y000593, and for clinopyroxenes in the mesostasis 850 to 1150° (Nakhla: $En_{22-35}Wo_{30-34}Fs_{30-47}$; Y000593: $En_{14-35}Wo_{30-34}Fs_{30-55}$). The irregularity of the FeO-rich rims indicate that they were not simply formed by continuous growth or diffusive re-equilibration with an evolving melt.

TEM-Microstructure: Our TEM study revealed that the FeO-poor cores of the clinopyroxenes are free of lamellar low-Ca pyroxene exsolutions. In contrast, the FeO-rich rims and the late stage clinopyroxenes in the mesostasis show extensive exsolutions parallel (001) and (100). With increasing FeO-content the width of the exsolution lamellae increase which is opposite to the trend expected from experimental data [6].

Discussion and Conclusions: If we simply apply the calibration of time-temperature vs. microstructure by [7], the absence of exsolution in the clinopyroxene cores will indicate fast cooling rates, more than several degrees per hour [7]. In contrast the type and size of exsolution lamellae in rims and mesostasis pyroxenes would require cooling rates lower than 0.005°/hr. Obviously, it is not possible during a single cooling process to cool rims and matrix pyroxenes slower than FeO-poor cores. Thus, in this case, we had to assume local reheating of rims and mesostasis, which seems difficult to explain. Another possibility would be that the controlling parameter of microstructure evolution in clinopyroxene is composition and fO_2 rather than cooling rate. Probably changing fO_2 will trigger the exsolution mechanism, as a higher point defect concentration will enhance diffusion.

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