GEOLOGY OF THE NAKHLITE METEORITES: CUMULATE ROCKS FROM FLOWS AND SHALLOW INTRUSIONS Allan H. Treiman, Geology Department, Boston University, Boston MA 02215

The nakhlite meteorites, augite-rich cumulate igneous rocks, are part of the SNC suite which may have originated on Mars [1]. It is important to infer the original geological settings of the nakhlites to improve our understanding of their parent planet. Based on comparison of mineral textures of the nakhlites and comparable Earth rocks, the meteorites originated in thick flows and shallow intrusions of ultrabasic (picritic magma). One Earth environment where such rocks form, above mantle hot spots, is known from Mars.

The nakhlite meteorites (Nakhla, Lafayette, and Governador Valadares) are igneous rocks composed predominately of cumulus augite, with minor cumulus olivine and mesostasis (crystallized intercumulus magma) composed primarily of pyroxene, olivine, plagioclase, and magnetite [2,3]. The nakhlites (and Chassigny, a related olivine-rich cumulate) all crystallized at 1.25 Æ [4], and have similar parental magmas [3], similar initial isotope ratios [4,5], and similar cosmic ray exposure histories [6]. Although the nakhlites are similar, they are enough different that they must have come from separate igneous bodies. Nakhla and Governador Valadares have different initial Sr isotope ratios [4]; both meteorites have more (and finer grained) mesostasis than does Lafayette [2].

A critical feature in understanding the geology of the nakhlites is the texture of the mesostasis. If the rock cooled rapidly, its mesostasis will be abundant and glassy. If cooling was slower, the mesostasis will be less abundant and crystalline; the slower the rock cooled, the coarser-grained the mesostasis minerals (e.g., [7]). With very slow cooling, no mesostasis will preserved and the final rock may be an adcumulate. Cooling rate can be related to depth of emplacement and thickness of the parent igneous body.

The textures of the nakhlite meteorites may be compared with those in igneous cumulate rocks from Earth, where the geologic setting and depth of emplacement are known. Augite-rich cumulate rocks are well preserved in portions of the Abitibi greenstone belt (Archaean age) of northern Ontario, and show textures nearly identical to those of the nakhlites. Augite cumulates comprise the lower half of a 125m thick flow [8], and their textures (Figure 1) are near identical to those of Nakhla (Figure 2) and Governador Valadares. Augite cumulates also comprise the middle third of a 300m thick sill [9], and their textures are adcumulate, with essentially no mesostasis material (Figure 3). These textures are comparable to those of Lafayette (Figure 4).

From comparison with Earth rocks, the nakhlites crystallized in thick flows (>125m) or in shallow intrusions (probably less than a kilometer deep) of basaltic to picritic magma. These conditions are reasonable if the nakhlites came from Mars, as volcanoes with thick lava flows and indirect evidence of shallow intrusions are common in the Tharsis region. The tectonic setting of Tharsis, a bulge above a mantle hot-spot, is better defined than those of greenstone belts [10]. Hot spot tectonics has been suggested as a cause of greenstone belt volcanism, and comparison of Tharsis with greenstone belts on Earth may provide insights into the tectonic development of both planets.

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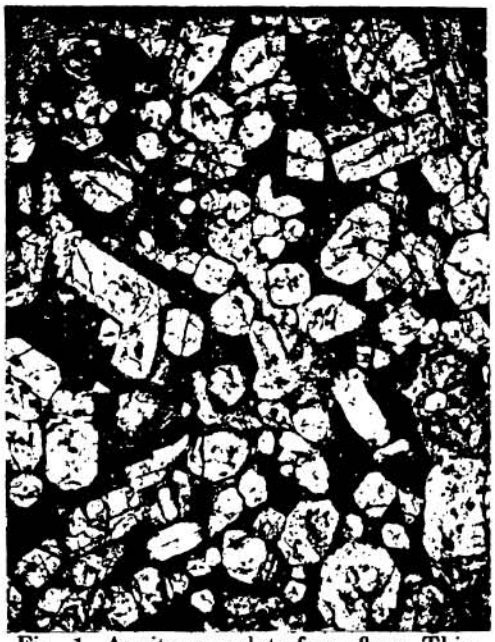

Fig. 1. Augite cumulate from flow. Thin section in plane light, 4 cm vertical size. Augite crystals in dark, altered glass (?).

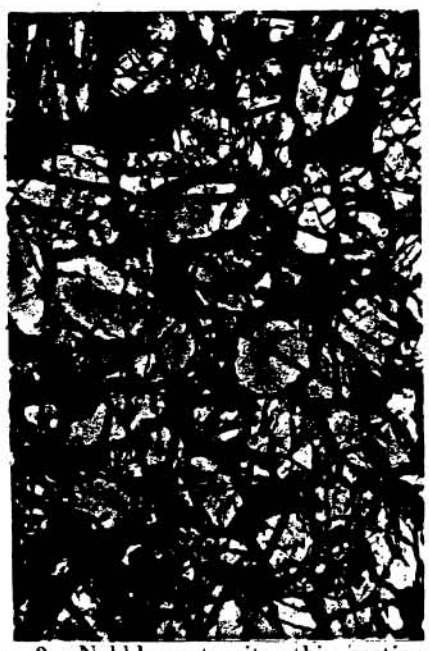

Fig. 2. Nakhla meteorite, thin section in plane light, 2.3 cm vertical size. Euhedral augite crystals in finely crystalline mesostasis.

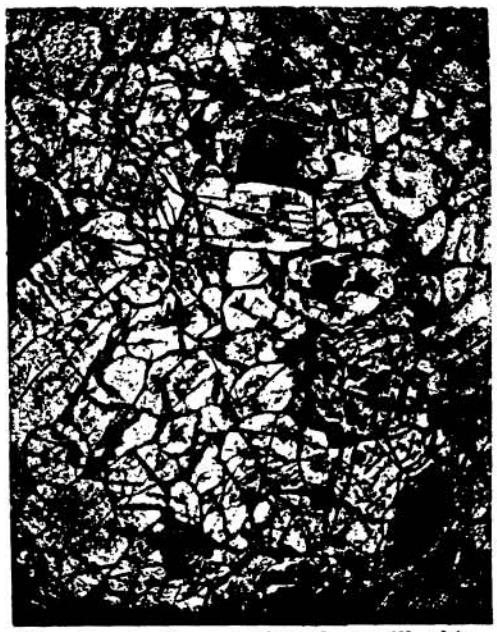

Fig. 3. Augite cumulate from sill, thin section in plane light, 1.8cm vertical size. Augite and altered olivine crystals (spotted) in adcumulate texture.

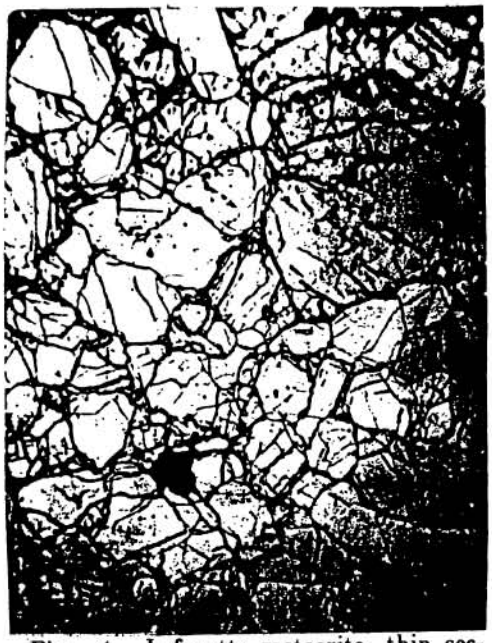

Fig. 4. Lafayette meteorite, thin section in plane light, 2.3 cm vertical size. Augite and olivine crystals in adcumulate texture.

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