PROCESSES IN THICK LAVA FLOWS: NAKHLITES (MARS) AND THEO'S FLOW (ONTARIO, EARTH); R.C. Friedman, G.J. Taylor (HIGP, SOEST, Univ. of Hawaii, Honolulu, HI 96822), A. Treiman (LPI, Houston, Texas, 77058)

Nakhlites are medium-grained pyroxenites that may have erupted as lava flows on Mars. To elucidate the crystallization environment of the nakhlites, we have begun to examine a terrestrial analog, Theo's flow. This 120-m thick, Archean lava flow contains a 54-m thick pyroxenite zone which bears a striking resemblance to the nakhlite meteorites in texture (Fig. 1), with large euhedral augite grains and a fine-grained mesostasis. To quantify these textural similarities, we used crystal size distribution (CSD) analysis on three nakhlite sections, on a sample of the pyroxenitic zone of Theo's flow, and on two thinner pyroxenitic flows associated with Theo's. The similar numeric results support using Theo's flow as an analog for the nakhlites. Calculations made from CSD data of a 5-m thick pyroxenitic flow gave a pyroxene growth rate of 6.1 x 10^{-10} cm/s, in agreement with estimates for other silicates. Applying this growth rate to the thicker flows and nakhlites, we found that all had experienced steady-state growth periods of about 0.3 yr. Subsequent accumulation and liquid phase sintering, or Ostwald ripening, must then have occurred to produce the final textures observed.

Nakhlite Analog: Theo's flow, located in Munro township, Ontario, Canada, is a highly mafic flow 120 m thick in places and comprises three distinct compositional zones [1], formed during *in situ* differentiation: a basal peridotite (now serpentinized), a 54-m thick pyroxenite, and an overlying 45-m thick gabbro (Fig. 2). A capping breccia indicates that Theo's flow was a surface flow and not a shallow sill. Samples from the pyroxenitic zone of Theo's flow are remarkably similar to the nakhlites: both have a marked superabundance of augite; both have cumulus grains up to 1 mm; and both exhibit a fine-grained, plagioclase-rich mesostasis.

We have applied CSD analysis to augites in the nakhlites and Theo flows to quantify the obvious textural similarities. Plots of CSD results reveal whether crystallization occurred as a steady state phenomenon (yielding a straight line of negative slope) or whether other processes such as accumulation or differentiation were involved [e.g. 2]. Our results (Fig. 3) demonstrate that the nakhlites, Theo's flow, and the associated pyroxenitic flows all experienced some period of steady-state nucleation and growth: each shows a linear trend for the bulk of the grain sizes. In addition, each sample shows a distinct depletion of the finest grain sizes (< 0.15 mm). The overwhelming similarity between the nakhlites and Theo's flow shows that the Canadian flow to be an excellent analog for the processes that formed the nakhlites. More important, it improves the possibility that the nakhlites formed as surface lava flows.

Quantitative Implications: We can apply the numeric information from the CSDs to examine further the crystallization histories of Theo's flow and the nakhlites. The thinnest pyroxenite flow (5 m) is the simplest system represented and shows virtually no fall-off at small grain sizes, so we can use its parameters to calculate a growth rate for the pyroxenes. Using a simple cooling model [3] to determine the crystallization time $t(yrs) = [x(m) / 5.8]^2$, and using the slope of the CSD line (-1/Gt), we get a growth rate of 6.1 x 10^{-10} cm/s, in good agreement with other growth rate estimates for crystals in silicate melts [4,5]. We can apply this growth rate to the other samples to find periods of steady-state nucleation and growth; surprisingly, the nakhlites and Theo flows all show growth periods of about 0.3 yr. We suggest this time limit indicates the end of steady nucleation as crystals were removed from an upper level of the flow. Separation of the crystal population probably occurred as grain clusters sank as melt suspensions or pockets of mush. Individual crystals sinking by Stoke's settling was not the dominant processes since the CSD plots are linear; some curvature would have been imparted had the grains been partly sorted by size. Also, the population must have sunk as a whole or else some lag of fine crystals would remain near the top of the flow, something we do not see in the Theo flows.

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The average grain size measured now is greater than the average implied by the 0.3 yr growth period. We believe subsequent growth by liquid-phase sintering, or Ostwald ripening, took place after settling, prompting the resorption of fine grains. We see signs of this in the turnover of the CSD plots at the small grain sizes. Although the growth seems significant (quadrupling the size in some cases), calculations of the time necessary to complete this grain growth indicate ripening took place for less than a year. This is surprising because Theo's flow should take about a century to solidify completely [3]. Perhaps evolution of the interstitial melt or crystallization of other phases besides augite retarded grain coarsening.

References: [1] Arndt, N.T. (1977) *Can J. Earth Sci.*, 14: 2620-2637; [2] Marsh, B.D. (1988) *Contrib. Mineral Petrol.*, 99: 277-291; [3] Jaeger, J.C., (1968) *in* Basalts, 503-536; [4] Lofgren, G. (1980) *in* Physics of Magmatic Processes, 487-551; [5] Cashman, K.V. and B.D. Marsh (1988) *Contrib. Mineral Petrol.*, 99: 292-305.

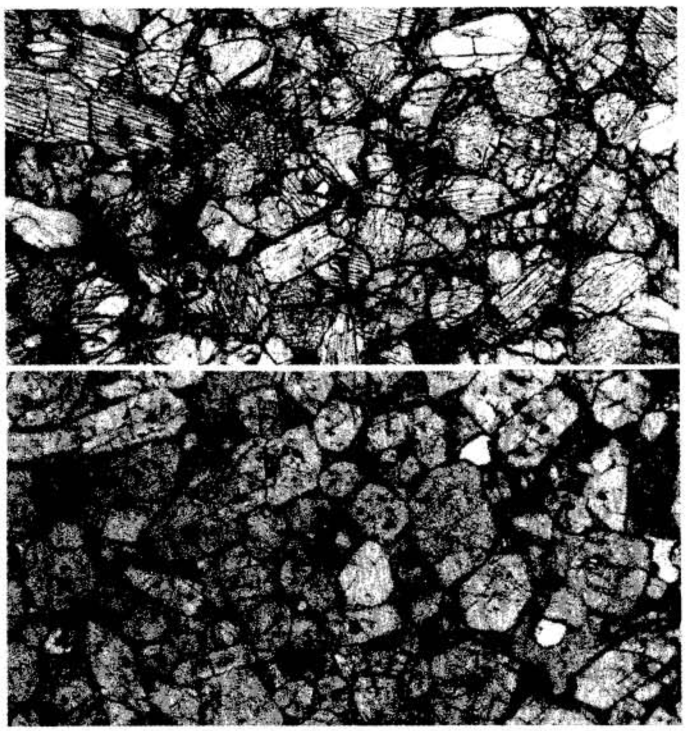

Fig. 1: Photomicrographs (FOV 4 mm) of Nakhla (above) and Theo's flow pyroxenite (below)

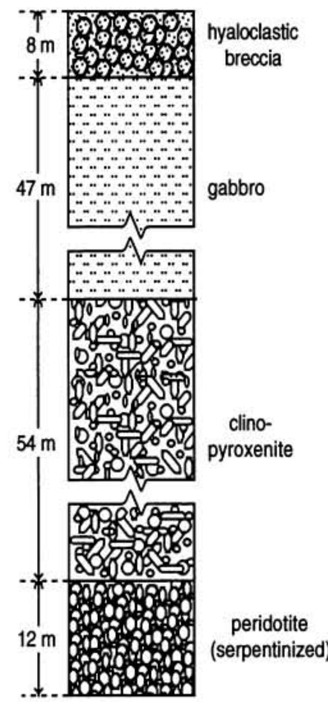

Fig. 2: Stratigraphic column of Theo's flow

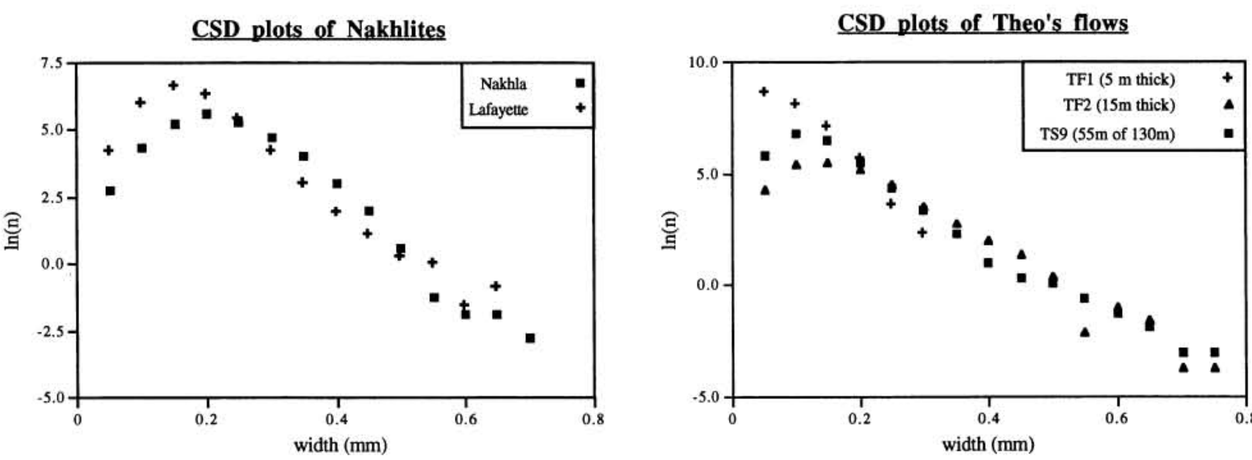

Fig. 3: Comparitive CSD plots of augite widths in nakhlites and Theo flows