CRYSTAL SIZE DISTRIBUTION ANALYSIS OF NEW NAKHLITES AND LOS ANGELES: HOW DO THEY COMPARE WITH SNCs OF OLD? R.C.F. Lentz[1] and H.Y. McSween, Jr.[1], [1]Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410; rlentz@utk.edu.

Introduction: Crystal size distribution (CSD) analysis is a useful technique for quantifying textural information and linking petrographic texture to original crystallization conditions [1]. In previous studies we have conducted CSD analyses of multiple thin sections of nakhlite meteorites [2], and several basaltic and mixed shergottites [3,4]. Based on results of these analyses, we derived crystallization scenarios for some of these meteorites.

With the addition of Los Angeles to the basaltic shergottite group and identification of two new nakhlites (Yamato 000593/000749, and NWA 817), new CSD analyses seem in order to test the validity of previous interpretations and perhaps to lend new insight into the crystallization histories and relationships within these meteorite groups.

Crystal Size Distribution: CSD analysis involves quantifying petrographic textures by calculating grain population densities in different size bins [1]. Theory predicts that steady-state growth would generate a negative linear correlation between grain size and the log of grain number density, where the slope of such a line is inversely related to the growth rate and crystallization time ($m = -1/G\tau$) [1]. Deviations from linearity suggest the involvement of such geologic processes as multistage growth, grain accumulation, or solid-state ripening (annealing). The primary crystallizing phase in these martian meteorites is pyroxene, so all measurements represent pyroxene grain sizes. (Plagioclase actually co-crystallized with pyroxene in the basaltic shergottites, but since it has been shocked to glass, grain boundaries are obscured.) Since pyroxene is an elongate crystal, we have chosen to define grain size by width, to minimize any geometric bias due to the two-dimensional view of the thin section [2].

The Los Angeles meteorite is coarse-grained, so we analyzed three non-serial thin sections to ensure that a statistically significant number of grains were measured (313 in all). One complication of determining the boundaries of the pyroxene grains in Los Angeles is the presence, within some otherwise subhedral pyroxene boundaries, of an intergrowth of fayalite, hedenbergite and silica [5]. This has been interpreted to be a late-stage breakdown product after a pyroxenoid [6] or after Fe-rich pigeonite and Ti-magnetite [6]. Since the origin of these intergrowth patches remains unclear, we considered only unaltered pyroxene material in determining the grain boundaries. In most cases, however, this issue was not a factor.

Another complication in measuring Los Angeles pyroxenes was one also encountered while analyzing other shergottites. The high levels of shock experienced by the meteorites has obscured crystallographic boundaries, which would normally be obvious based on extinction under crossed-polarizing nicols. Therefore, subjectivity was required in some cases.

The other samples examined were sections of the new paired Yamato nakhlites, Y000593 and Y000749. There were no complications analyzing these low-shock pyroxenites and each section had an adequate number of grains (>400).

Results: Figure 1 shows CSD plots for (a) Los Angeles and (b) Y000593. For comparison, representative CSD plots of other basaltic shergottites and nakhlites, respectively, are also shown. Los Angeles displays a generally linear pattern, although with a small concave-downward curvature, particularly at the small grain sizes. Yamato, shows a much shallower pattern, with a more pronounced drop-off at smaller grain sizes, as well as a minor depletion at the largest sizes. Important CSD numbers are shown in Table 1.

Discussion: *Los Angeles:* Interpretations of CSD plots for the other multiply-saturated basaltic shergottites (QUE 94201 and EET A79001 lithology B) noted that both meteorites show a decided concave-downward curvature [3]. This shape was only observed with these two meteorites, both of which show co-crystallization of pyroxene and plagioclase. Therefore, we concluded that the presence of the plagioclase hindered the full growth of the pyroxene, producing a depletion at the largest grain sizes and hence the curvature of the plot. The CSD curve for Los Angeles (Fig. 1a) seems consistent with this, plotting nearly identically with QUE 94201, despite representing twice as many grains (313 vs. 149). Like QUE and EETB, LA shows only a minor falloff at the smallest grain sizes. That fact with the generally smooth nature of the curve suggests one continuous crystallization stage for pyroxene grains, with little annealing, or continuous growth once nucleation stopped. Stone 2 of Los Angeles is apparently much finer grained than stone 1 [5], so we plan to do a CSD of stone 2 for better comparison with the finer-grained EETB.

Nakhlites: With the recent identification of the Yamato nakhlites and NWA 817, the character of the nakhlite group is broadening. In several properties (e.g. olivine compositions and zoning, pyroxene composition, volume percent mesostasis, mesostasis min-

eralogy; [7,8]), there seems to be a progression amongst these five meteorites from Lafayette to Governador Valadares/Nakhla to Yamato to NWA 817. Several authors [e.g. 7, 8] have suggested that this progression relates to original depth in a cumulate pile, with Lafayette being the deepest, NWA 817 the shallowest. If true, one would expect CSD results to demonstrate a progression as well, since cooling, growth, and nucleation rates should all be affected, to a degree, by depth in a pile.

In several ways, our results do show a progression (Table 1). Grain density (or # grains/area) tracks the increase in mesostasis noted by other authors, with Lafayette at the highest density, followed by Governador, Nakhla and Y000593. Similarly, there is a progressive shallowing in slope of a best fit line to the CSD plot, from Lafayette to Nakhla to Yamato. In this trait, the Governador Valadares CSD falls out of order, showing the steepest slope (Table 1). This implies a slightly slower growth rate or shorter crystallization time. It would be interesting to see if a different Governador sample would substantiate this finding.

Figure 1b illustrates that Yamato also has a much flatter profile at the finest grain sizes (little turnover), suggesting it has experienced far less alteration by subsolidus processes like annealing, which depletes the distribution of the finest grains. This is consistent with the idea that Yamato may have been higher in the cumulate pile and experienced faster cooling rates. Also consistent with greater undercooling is the faster growth rate implied by the shallow slope of the Yamato plot (since $-1/m = G$). Interesting to note is the fact that average grain size seems to *decrease* with assumed depth in the pile (Table 1). Since deeper in the pile implies longer crystallization time (i.e. slower cooling), a decrease in grain size suggests that growth rates must drop dramatically with cooling rates.

We plan to further investigate these trends by analyzing the current "end member" of the group, NWA 817, to see how it plots in comparison to these other nakhlites. We predict that if it did cool closest to the surface, it should have an even shallower slope than Yamato and display even less of a turnover at the finest grain size range.

References: [1] Marsh B.D. (1988) *Contrib. Min. Pet., 99,* 277-291. [2] Friedman-Lentz R.C. et al. (1999) *Meteoritics & Planet. Sci., 34*, 919-932. [3] Lentz R.C.F. and McSween, H.Y., Jr. (2000) *Meteoritics & Planet. Sci., 35*, 919-927. [4] Lentz R.C.F. et al. (2001) *LPS XXXII*, Abstract #1742 [5] Rubin A.E. et al. (2000) *Geology 28*, 1011-1014. [6] Xirouchakis D. et al (2002) *GCA 66*, 1867-1880. [7] Sautter V. et al. (2002) *Earth Planet. Sci. Lett. 195*, 223-238. [8] Mikouchi T. et al. (2003) *Antart. Meteorite Res. 16* (s).

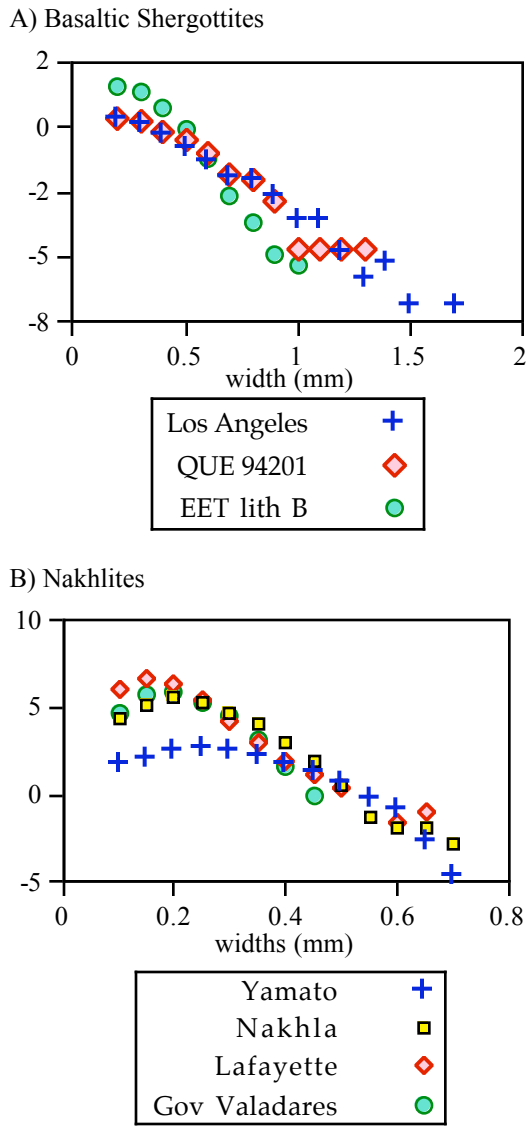

Figure 1: CSD plots showing new analyses of a) Los Angeles and b) Yamato nakhlites in comparison with previously measured CSDs of basaltic shergottites and nakhlites, respectively.

Table 1: Crystal Size Distribution Results

	Lafayette	Gov. Val.	Nakhla	Yamato
slope	-20.47	-27.38	-20.13	-8.47
intercept	10.35	12.5	10.74	4.99
area (mm^2)	56.3	88.0	249.5	108.7
# grains	810	852	2292	459
#density ($\#/mm^2$)	14.4	9.7	9.2	4.2
avg size (mm)	0.187	0.200	0.233	0.275