**DEMYSTIFYING CRYSTAL SIZE DISTRIBUTION (CSD): A COMPARISON OF METHODOLOGIES USING EUCRITE METEORITES.** S. J. Jaret[1], R. G. Mayne[1], and H. Y. McSween [1]Planetary Geosciences Institute, Department of Earth and Planetary Science, University of Tennessee, Knoxville, 1412 Circle Drive, Knoxville, TN (sjaret@utk.edu).

**Introduction:** Crystal Size Distribution (CSD) allows for a quantitative measure of the kinetics of crystallization based on textural observations of rocks. The crystal size is a function of mean growth rate (G) and residence time (τ), which is inversely related to ln (population density). Ideal CSD plots form a straight line with a slope of -1/Gτ and y-intercept equal to the initial nucleation density. (Figure 1). Therefore, CSD analysis provides insight into the processes and kinetics of crystallization [1].

Formation and crystallization of eucrite meteorites is of particular interest, as they are part of the Howardite-Eucrite-Diogenite (HED) suite believed to be from the asteroid 4 Vesta which will be mapped by the recently launched DAWN mission.

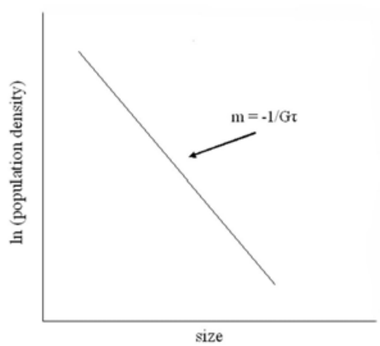


Figure 1: Theoretical CSD plot for continuous nucleation and growth. Residence times can be calculated from the slope, where m = -1/Gτ. The y-intercept = initial nucleation density; G = growth rate. and τ = residence time.

One inherent complication of CSD analysis is that grain sizes measured in thin sections represent orientation dependent 2D apparent sizes rather than 3D measurements of the actual crystal shapes [2,3]. Methods for 3D correction include:

Method 1: Area-to-volume Correction $N_v = (N_A)^{1.5}$ where $n_v$ is the number of crystals per unit volume and $N_A$ is the number of crystals per unit area [4,6].

Method 2: CSDCorrections program [3]

Method 3: CSDSlice and CSDCorrections [5].

The CSDCorrection program compensates for the 2D-3D intersection probability effect (a random section is more likely to intersect a large grain) and the 2D-3D cut section effect (one grain can produce different sized sections depending on orientation) [3]. CSDSlice compares the distribution of size measurements to a database of known crystal shapes and determines the most likely aspect ratios of the grains [5].

Using four unbrecciated eucrite meteorites from Mayne et al. [7], 3D correction models were compared in order to determine the relative effect that 3D correction techniques have on calculated crystal residence times and the interpretation of growth history.

**Methods:** CSD analysis was performed via a three step process (Figure 2) [3,8]. For each sample, data were corrected using each of the 3D conversion methods above. Using an estimated crystal growth rate for basaltic magma, residence times were calculated in order to determine the effect of stereological corrections [7,9]. Other CSD studies use a range of growth rates for basaltic crystallization to calculate residence times [2,9]. Here however, one value from this range was used because this study is only assessing the effect of 3D correction methods which is independent of the growth rate used. For petrologic interpretation of the eucrite CSD data see Mayne et al. [10]

**Results and Discussion:** Residence time calculations assuming a growth rate of 1x10$^{-8}$ mm [9] are listed in Table 1. Calculated residence times using CSDSlice in conjunction with CSDCorrections were

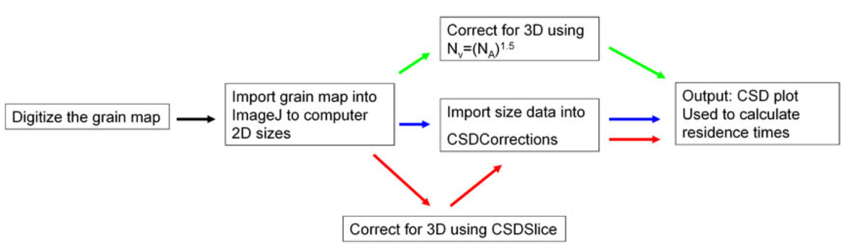


Figure 2: Three different correction methods were used: area-to-volume (follow green arrows), CSDCorrections (blue arrows), and the combination of CSDSlice and CSDCorrections (red arrows).

greater than just CSDCorrections alone or the area to volume correction method (Figure 3).

The different 3D correction methods do affect both the CSD plot and the calculated residence times (Figure 3). Plots based on area-to-volume corrections suggest a greater residence time than those which use CSDCorrections and CSDSlice. CSDCorrection (method 2) and CSDSlice (method 3) yield similar initial nucleation densities, but CSDSlice plots have a shallower slope.

**Implications:** CSD has been used to study martian shergottites [6], nakhlites [11,12], lunar meteorites [9], and lunar mare basalts [13]. 3D correction methodology, however, has not been consistent. Taking the nakhlites as an example, Nakhla, Lafayette and Governador Valadares [11] were corrected using the area-to-volume correction whereas MIL 03346 was corrected using CSDSlice and CSDCorrections [12]. Results of these studies suggest that residence times differ by nearly a factor of 2 or greater. However, because of the variation associated with 3D correction methods, it is not clear whether differences in residence times reflect processes of crystallization or are an artifact of the 3D correction. CSD plots produced using area-to-volume correction are not comparable to those which use CSDCorrection and CSDSlice.

In order to have a comparable dataset of planetary materials a standard method of 3D correction is necessary. Method 3 (using both CSDCorrections and CSDSlice) is favored because it accounts for 2D-3D effects and estimates 3D crystal aspect ratios. This produces a more accurate estimation of 3D crystal shape and thus should allow for a more accurate estimation of crystal growth.

**References:** [1] Marsh BD (1988). *Contrib. Min. Pet.* 99: 277-291 . [2] Cashman, KV and Marsh BD (1988). *Contrib. Min. Pet.* 99: 292-305. [3] Higgins, Michael (2000). *Am. Min.* 85: 1105 - 1116 [4] Cashman, KV and Ferry, JM (1988). *Contrib. Min. Pet.* 99: 401-415. [5] Morgan D and Jerram D (2006). *J. Volcan. Geotherm Res 154*: 1-7. [6] Lentz, R. C. and McSween, H. Y. (2000). *Meteoritics & Planet Sci* 35: 919-927. [7] Mayne GCA (in press) [8] Higgins, M (2005). http://geologie.uqac.ca/~mhiggins/Quick_thin_section_digitisation.htm [9] Day J. M., and Taylor, L. A.(2007). *Meteoritics & Planet Sci.* 42 No. 1: 3-17. [10] Mayne et al. (2007) Lunar and Planet. Sci. this volume [11] Lentz et al. (1999) *Meteoritics & Planet Sci.* 34 919-932. [12] Day et al (2006). *Meteoricis & Planet Sci.* 41. No 1: 581-606 [13] Oshrin, J, and Neal C.R. (2007). Lunar and Planet Sci. Conf. XXXVIII No. 1338.

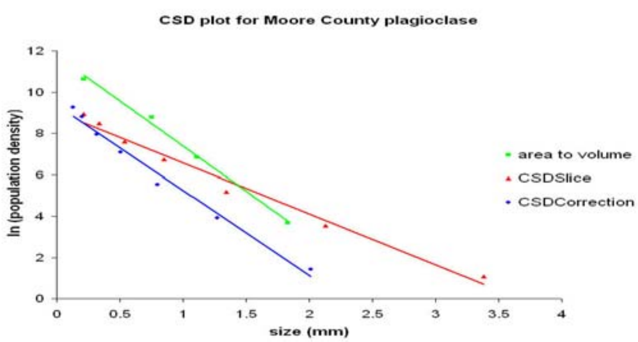


Figure 3: CSD plot of plagioclase in Moore County, using each correction method. Area-to-volume corrections (method 1 in green) and CSDCorrections (method 2 in blue) have similar slope, but area-to-volume correction changes the initial nucleation density. CSDCorrection and CSDSlice (method 3 in red) have similar initial nucleation density, but 3D estimations of crystal size from CSDSlice decreases the slope.

Table 1 Residence Times Calculated from Multiple 3D Correction Methods

| Sample | τ (yrs): $N_A^{1.5}$ correction | τ (yrs): CSDCorrection | τ (yrs): CSDSlice | % Difference between $N_A^{1.5}$ and CSDSlice |
|---|---|---|---|---|
| Moama plagioclase | 0.72 | 0.70 | 1.01 | 40.64 |
| Moore County plagioclase | 0.72 | 0.77 | 1.29 | 77.61 |
| Ibitira pyroxene | 0.09 | 0.11 | 0.12 | 31.49 |
| GRA 98098 pyroxene | 0.42 | 0.50 | 0.67 | 56.89 |
| MAC 02522 plagioclase | 0.52 | 0.59 | 1.07 | 107.01 |
| BTN 00300 pyroxene | 0.29 | 0.40 | 0.58 | 100.00 |

Residence time calculated for each correction method. Growth rates were assumed to be $1x10^{-8}$ mm/s [2,9].