UNDERSTANDING THE CRYSTALLIZATION HISTORIES OF MARTIAN AND LUNAR METEORITES

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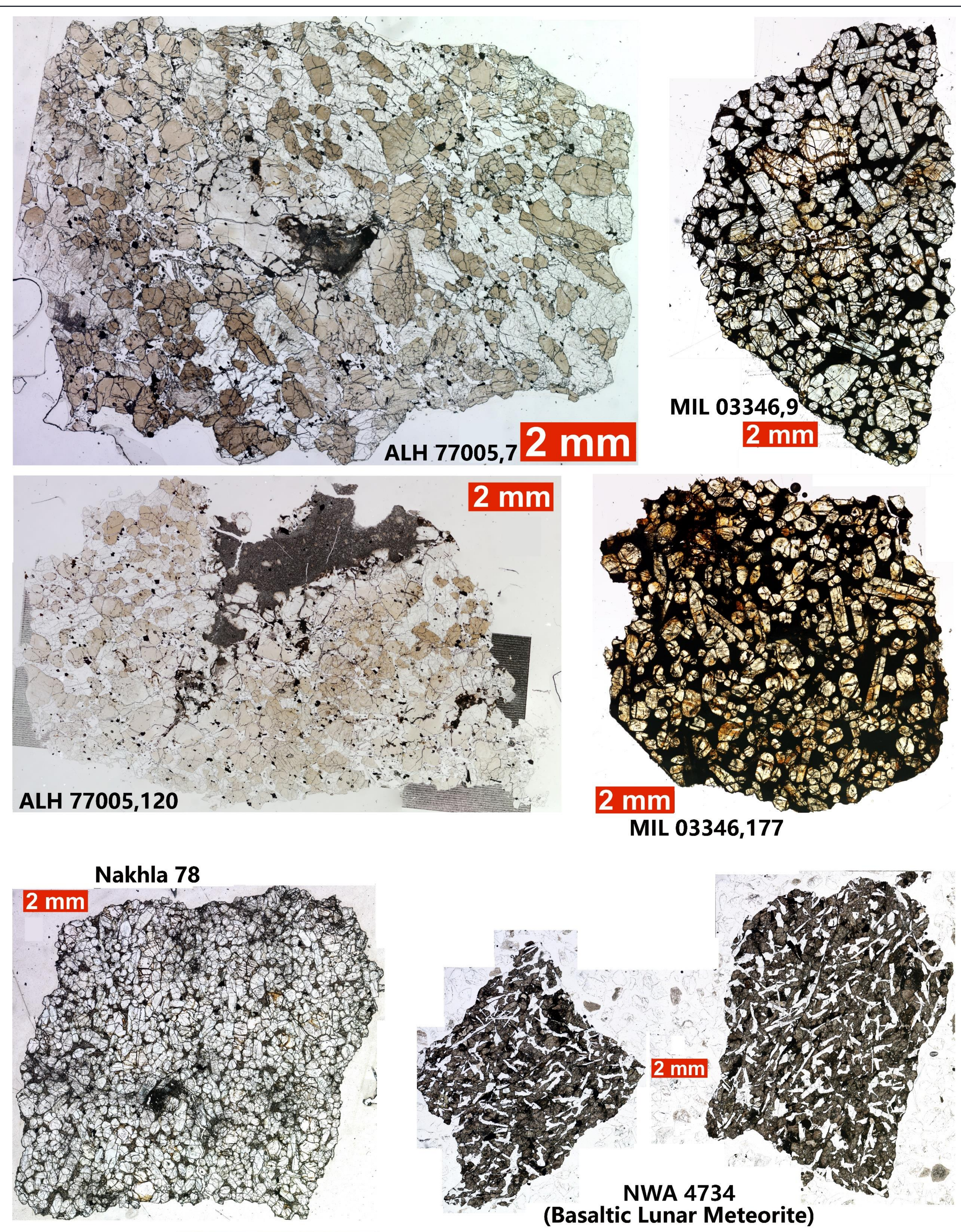
Introduction

- Crystal Size Distribution (CSD) data are a valuable tool for evaluating the crystallization histories of igneous samples [1-3].
- Plotting CSD slope and y-intercept data for different minerals from meteorite samples may also help provide constraints on whether some basaltic lunar meteorites represent impact melts [4,5].
- To date, no crystalline rocks from Mars have been considered serious contenders as impact melts, making them a good test for examining the robustness of CSDs for making this distinction.
- New pyroxene CSD data for martian nakhlite meteorites MIL 03346 and Nakhla are reported together with olivine CSD data for intermediate lherzolitic shergottite ALH 77005. Plagioclase (maskelynite) CSDs are reported for lunar meteorite NWA 4734 and martian thin sections ALH 77005,120 and RBT 04262,26. Some of these meteorites have previously been included in quantitative textural studies (e.g. [6]), but the specific thin sections analyzed in this study have not.



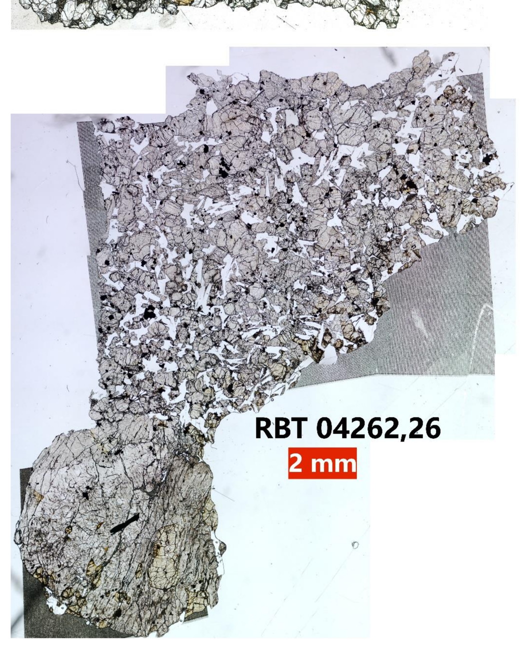


Figure 1. Photomosaics of the thin sections in plane-polarized light. The red bar in each image represents two millimeters.

Methods

- Photomicrographs of the thin sections were obtained in plane-polarized light and cross-polarized light. A 4× objective was used for all images.
- The photomicrographs were then stitched together using Microsoft Image Composite Editor© to create a photomosaic representing the entirety of the sample (Fig. 1). These photomosaics were compared to the original samples to ensure that no significant distortion occurred during stitching.
- These stitched photomosaics were opened in Corel Paintshop© Pro 2019 and crystals of the relevant mineral phase were traced. In the case of intersecting crystals, multiple layers were generated to ensure that each crystal was recorded discretely. The entire sample area itself was also traced.
- Care was taken to trace the absolute maximum number of crystals available in each sample area in order to achieve population density values that are as accurate as possible [7].
- Traces were exported to ImageJ, where the known scale of the images was used to determine the area, best-fit ellipse, and major/minor axis of each crystal and the sample area itself. These data were then input into CSDSlice [2] and CSDCorrections [3] to determine the overall shape and size distribution of the crystals.
- The resulting CSDCorrections data was used to plot the natural log of population density versus the length of each crystal's major axis [Figure 4], and the slope and y-intercept data from these plots were used to compare the CSDs to those of other meteorites and lunar basalts [Figures 2 and 3].

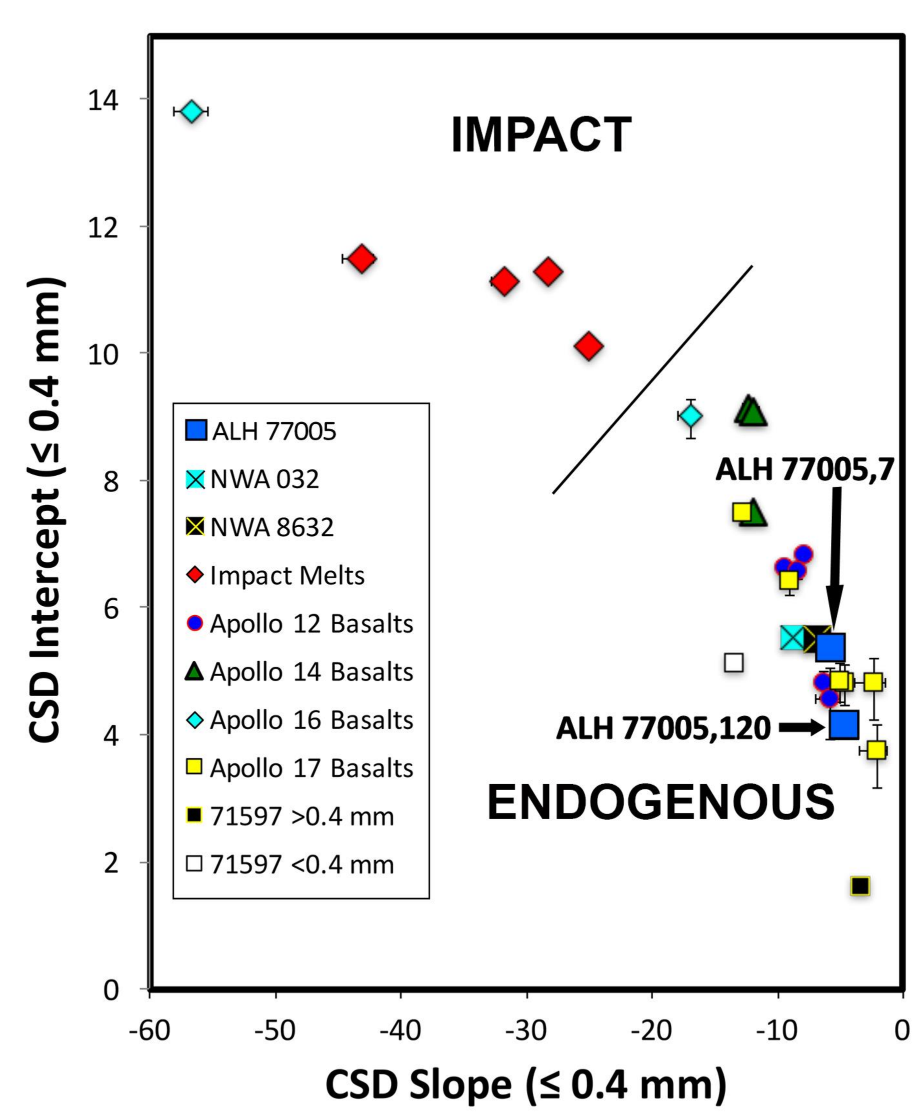


Figure 2. Olivine CSDs from this study plotted with olivine CSDs of lunar meteorites and lunar basalts. All of the CSDs from this study plot in the field of endogenous melts, rather than in the impact melt field (adapted from [4]).

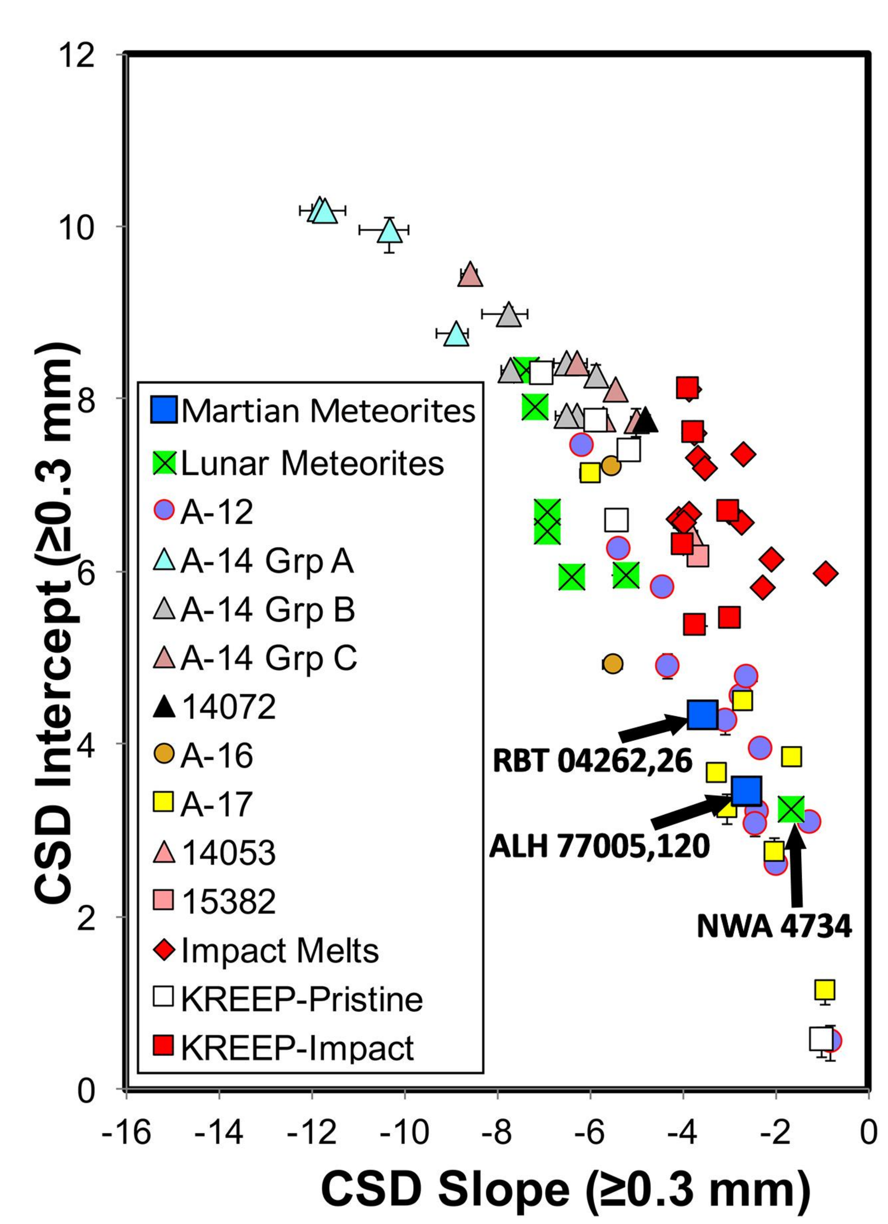


Figure 3. Maskelynitized plagioclase CSDs from this study plotted with plagioclase and maskelynite CSDs from other meteorites and lunar basalts. None of the samples from this study plot within the impact melt field, indicating that they may have cooled from endogenous melts (adapted from [4]).

Results

- ALH 77005 olivine CSDs plot near lunar endogenous melt basalts and meteorites (Fig. 2). The slope and y-intercept results for ALH 77005 are similar to lunar meteorites NWA 032 and NWA 8632, as well as many Apollo 12 and 17 basalt samples.
- The olivine data for ALH 77005,120 exhibits a somewhat lower y-intercept and shallower slope than ALH 77005,7. This can be explained by the large melt pocket and shocked zone present in thin section ALH 77005,120, as it is included in the area of the sample trace but obviously does not contain as high a population density of olivine crystals as the crystalline portion of the sample (Fig. 1).
- All of the maskelynitized plagioclase CSDs from this study plot near plagioclase CSDs of endogenous Apollo 12 and 17 basalts, and none of them plot within the impact melt field (Fig. 3).
- The CSD data for lunar meteorite NWA 4734 maskelynitized plagioclase shows a significantly reduced y-intercept and shallower slope than other lunar meteorite CSD data that has been reported (Fig. 3). This could be due to maskelynitization having obscured the grain boundaries of the original, smaller plagioclase crystals.
- Pyroxene CSD results for Nakhla have a steeper slope and greater y-intercept than the results for the MIL 03346 thin sections (Fig. 4), which is consistent with MIL 03346 having the largest average grain size of the nakhlite meteorites [8].

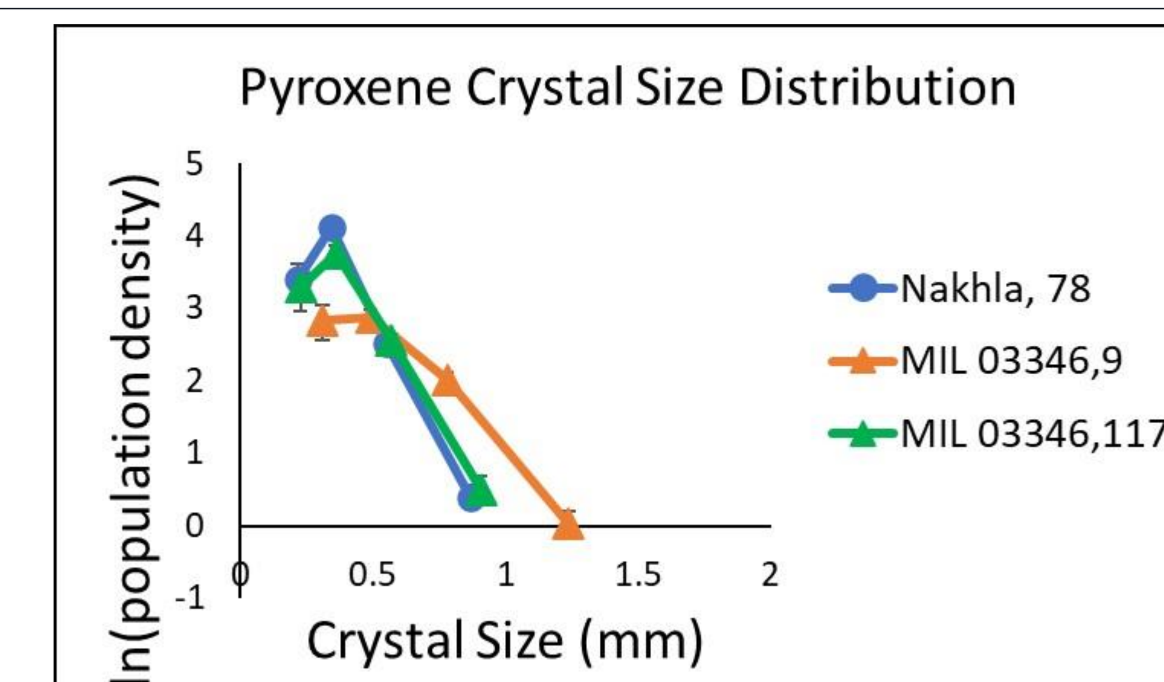


Figure 4. Pyroxene CSDs of martian meteorite samples from this study. If error bars are not visible then they are within the boundaries of the marker.

Conclusions

- All of the martian meteorite CSDs plot near lunar samples that are considered to be endogenous, consistent with the idea that shergottites and nakhlites are melts from the interior of Mars.
- None of the samples in this study plotted in the field that has been established for lunar impact melts [4,5]. Mineral analyses are underway to constrain these conclusions further, but recent HSE abundances and Os isotope compositions also support this result [9,10].
- CSD analysis of additional martian samples, as well as new lunar meteorite samples, can help further constrain the endogenous melt and impact fields for expansion of this method to planetary basalts in general.

References [1] Marsh, B. D. (1988) *Contributions to Mineralogy and Petrology 99*, 277–291. [2] Morgan D. J., & Jerram D.A. (2006) *JVGR 154*, 1-7. [3] Higgins M.D. (2000) *Amer. Min. 85*, 1105-1116. [4] Neal C. R. et al. (2015) *GCA 148*, 62-80. [5] Webb et al. (2019), *LPSC 50*, #2686. [6] Day, J.M.D., et al. (2006) Meteor. *Planet. Sci. 41*, 581-606. [7] Webb et al. (2020) *LPSC 51*. [8] Stopar J.D., et al. (2005) *LPSC 36*, #1547. [9] Brandon et al. (2012) *GCA*, 76, 206-235. [10] Tait and Day (2018) *EPSL*, 494, 99-108.