

A Novel Method for the Rapid Production of Crystal Size Distributions.

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Introduction: Crystal size distributions (CSDs) are a statistical method used to estimate the size of crystals in three-dimensions, using only the two-dimensional cross sections as found in petrographic thin sections [1]. CSD's have traditionally been made using a photomosaic of a thin section (we use a 5x objective) in *Adobe Photoshop*®. Then crystals of the phases of interest (typically plagioclase or olivine for this project) are carefully, and laboriously, traced with a stylus along with the outline of the full sample, using different layers for each. The crystal (or sample) outlines on each layer are then filled with a solid color. The filled crystal layers are then exported as .jpg files and processed using *ImageJ* [2] for quantitative analysis. *ImageJ* applies a best-fit ellipse to each crystal to determine a major and minor axis, and the precise area of each crystal, as well as the sample, is measured to determine modal percentage. Major and minor axes of the crystals are then exported to *CSDSlice* [3] and all data to *CSDCorrections* [4]. The former determines the approximate shape (e.g. rounded, oval, tabular, etc.) of the 2D traced crystals in three dimensions, and the latter sorts the crystals based on the length of the major axes and plots these in size bins based on the number of crystals present versus the natural log (ln) of the population.

Some of these steps use some form of time-saving tool or automation. The crystal outlines are selected all at the same time using the 'magic wand' tool within *Adobe Photoshop*®, and the best fit ellipses are generated by simply giving a handful of simple instructions to *imageJ*.

Yet the act of tracing each crystal is still done by hand. While the methods used to create the crystal traces has improved by using *Adobe Photoshop*® rather than utilizing a lightbox, tracing paper and a pen, it remains the most time-consuming step taking 10 to 20 hours depending on the size of the sample and number of crystals present. Therefore, we propose a method to dramatically reduce the time needed to produce the crystal trace and fill layers. We are demonstrating this method on the terrestrial Boltysh (Ukraine) impact melt B50-685.

Method: First a photomosaic of the sample must be assembled in XP light, and all photos that make up the mosaic must be taken at the same exposure and light conditions, preferably slightly over exposed just so plagioclase is appearing bright white.

Second the Vibrancy and Saturation of the photomosaic are increased to 100% each using *Adobe Photoshop*® this step is used to increase the difference

in color between plagioclase and other mineral phases with similar birefringence colors (see **Fig. 1a**).

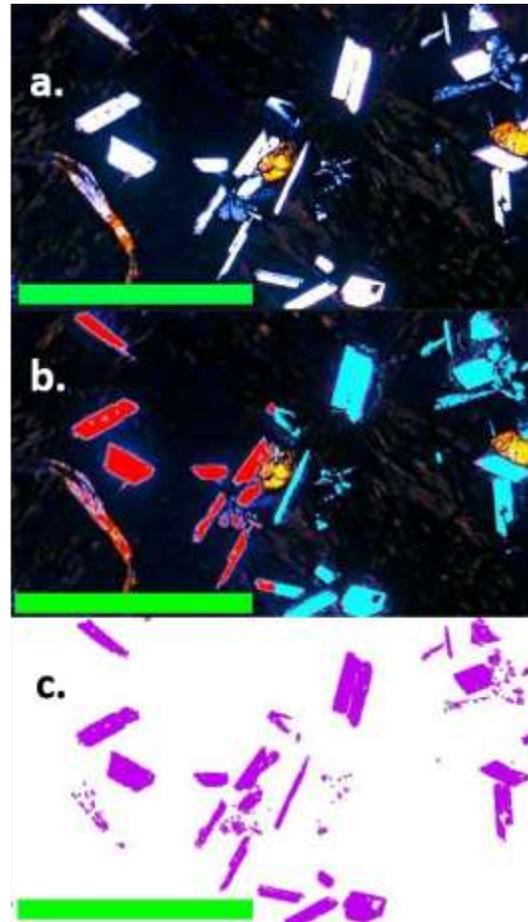


Figure 1: Photo-adjustment and color picker steps carried out on a photomosaic of B50-685. a, photomosaic has been adjusted for Vibrancy and Saturation. b, the two masks are created, one red (excludes the area thought **to not be** plagioclase) and one blue (includes the area thought **to be** plagioclase). c, Purple represents the overlap between the 1st two masks.

Third, two sets of 'masks' are made. Using the *Adobe Photoshop*® 'Color Range' tool the 1st mask is made by selecting all colors that are not present in plagioclase, inverting the selection, and using the 'paint bucket tool' to fill it in red (**Fig. 1b**, red half). The 2nd mask is made by selecting all the colors found in the various plagioclase grains, and then using the 'paint bucket tool' to fill them in blue (**Fig. 1b**, blue half). This leaves us with two masks, the 1st excludes the area that is thought to not be plagioclase, and the 2nd that includes areas thought to be plagioclase.

The computer program is being used to make these selections automatically, rather than manually one at a time (making the reliable identification of each crystal difficult). To remedy this issue, a selection is made of only the areas where the two masks overlap resulting in the equivalent of a "crystal-fill layer" from the previous method (Fig. 1c). *ImageJ*'s 'despeckle' tool is used to remove noise from the layer, before being processed as normal, *imageJ* is then instructed to only measure objects that are at least 0.005 mm².

Results: The novel method described here produced a CSD using 2130 objects (Fig. 2, 3) with a

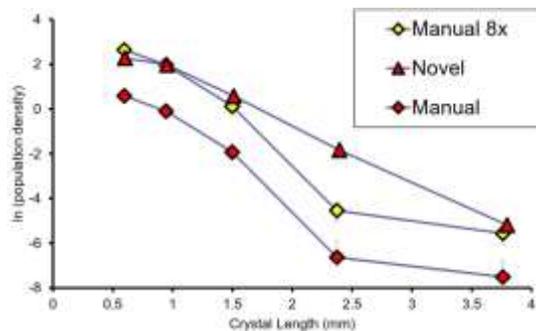


Figure 2: CSD Profile comparison of the new novel method, and the manual method of the same sample. The manual 8x is also shown for comparison.

slope of -2.42 and y-intercept of 4.04. The sample when traced by hand produced a CSD using 265 objects (a minimum of 250 is required to get a statically significant result [5]) with a slope of -2.79 and intercept of 2.02. While the two CSD's have a similar slope, they are outside of 1 σ error. The y-intercepts are well outside of error with each other (a difference of 2.02).

Discussion: The difference in y-intercept may be attributed to the large difference in the number of objects used to generate each CSD profile. By counting more crystals of every size category, the novel method generated profile will have a higher y-intercept simply by having a larger population density. If the greater number of crystals counted is spread proportionally across the different size-bins it should only affect the y-intercept and not the slope (as the y-axis is ln (population density) increasing the population will raise the y-intercept). By repeating each traced object of the manual method eight times (for a total of 2120 objects, now known as Manual 8x) a CSD is made, it has a slope of -2.80 and y-intercept of 4.11 (Fig. 2, 3). The slope of the novel and manual 8x methods are outside of 1 σ error, their y-intercepts are statistically similar (within 1 σ).

Additional differences are attributed to the novel method itself. This is the 1st iteration of the method and we have not refined the plagioclase selection process

to insure no other objects are selected. Since the 'color range' tool is an automated tool, it may have missed the extinct plagioclase, and cannot differentiate between two plagioclase crystals when they are touching each other. This would cause some crystals

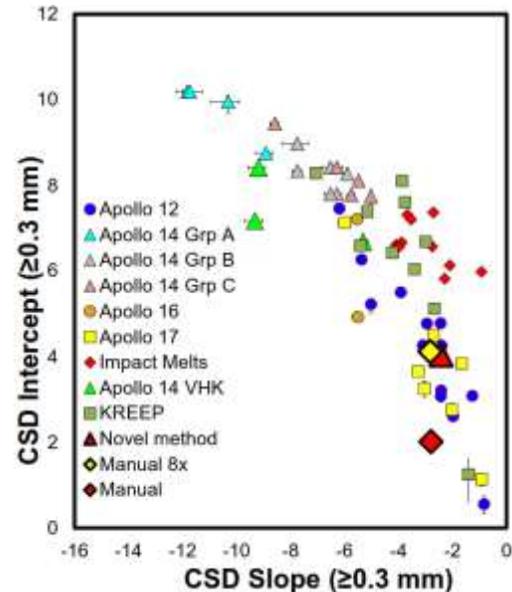


Figure 3: CSD slope intercept plot after [5]. And used to compare different CSD profiles. Note that the Novel and Manual method possess similar CSD slopes but notably different y-intercepts. Whereas the manual 8x and Novel method are similar in both. (CSD data can be found in [5] and [6])

to not be counted and some intergrowth/close growing crystals to appear as one (both result in undercounting). Although this sample was chosen because it has a high population of distinct plagioclase crystals, with few crystal clusters that may disrupt the counting method, it still has several plagioclases that are in extinction. This issue can be remedied if we use a ¼ wave plate to make the light circularly polarized, thus making the "extinct" plagioclase visible. When crystal count by hand is proportionally increased, the novel method becomes statistically significant. As this process is refined, it may additionally provide a more statistically accurate plot, due to a much higher crystal count across the sample. We plan to present an improved version of this method at LPSC 49.

References: [1] Marsh, B. D. (1998). *J. of Petro*, 39(4) [2] Schneider, C. A., et al., (2012). *Nature methods*, 9(7). [3] Morgan, D. J., & Jerram, D. A. (2006) *J. of Volc. & Geoth. Rsrh.*, 154(1). [4] Higgins, M. D. (2000). *Amr. Min.* 85(9). [5] Neal, C. Ret al., (2015). *GCA*, 148, 62-80. [6] Cronberger K. & Neal C. R., (in prep) KREEP basalt CSDs