# ACQUISITION AND DISPLAY OF ULTRA HIGH-RESOLUTION BACKSCATTERED ELECTRON IMAGES OF METEORITE SECTIONS

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**Introduction:** Backscattered electron (BSE) imaging in a scanning electron microscope (SEM), where image contrast mainly depends on atomic number, is used to understand the mineralogy and petrology of a polished meteorite thin/thick section. Mineralogic heterogeneity in a 1-inch round meteorite section can be on the scale of nanometers to centimeters. A BSE image covering the entire $\sim$2×2 cm sample, at a resolution of $\sim$50 nm per pixel, could be used understand the small- and large-scale mineralogy of the meteorite sample. A catalog of digital BSE images of entire meteorite thin sections could be used by researchers to choose a sample that best suits their project. Additionally, this would save time, money, and beam damage to the sample (especially critical for fragile or volatile-containing samples) as each researcher would not have to reacquire BSE images. Much of the reconnaissance work to find certain interesting mineral phases could be done remotely. However, acquisition and digital on-line display of such a large BSE image is challenging for the following reasons: 1) Variation of the sample height across the thin section is much larger than the SEM depth-of-field ($<50$ $\mu$m) under normal operating conditions. 2) BSE contrast must be kept constant over the entire sample. 3) Stitching $\sim$40,000 images together using commercial software is very challenging. 4) The size of the final panorama is 10–150 gigapixels, which consumes up to 50 gigabytes of memory (3 bytes/pixel). Here we describe software algorithms to acquire and display large BSE images of meteorite sections, and show an example of a large BSE image from the ungrouped carbonaceous chondrite Acfer 094.

**Methods:** The meteorite section is mounted on an SEM stub with clips to ensure the sample does not move during the long BSE acquisition. The SEM is tuned for optimal BSE image acquisition at high magnification. First, we acquire a "focus map" before the high-resolution BSE acquisition. The sample is scanned over a coarse grid ($\sim$50×50 images) using the Image Snapper software on a Tescan Mira3 FEG-SEM with the SEM's auto-working-distance function enabled. The optimal working distance for each image (recorded in a header file) are used to build a focus map that is sampled at each position in the coarse grid. Outliers are removed, then the remaining points are fit to a two-dimensional, second-order polynomial (to account for curvature of the sample from polishing). The $x, y$ and working distance values are then calculated for the full-resolution BSE scan from this polynomial (including a user-defined overlap fraction, $\sim$20%). These coordinates are fed into a Matlab function that writes an Image Snapper acquisition file for collection of the high-resolution BSE scan. Images are only acquired over the actual sample (defined as the perimeter of points that the user defined in the focus map), minimizing wasted acquisition time. Next we optimize the BSE brightness and contrast for the sample we are analyzing. With auto-working-distance and auto-brightness-contrast disabled, we acquire BSE images over the entire sample using Image Snapper and the acquisition file written in the previous step (acquisition takes $\sim$3 days). After acquisition, images are renamed to their locations in the scan grid.

Individual images are then assembled using a combination of Matlab for feature matching and pyvips for stitching. In Matlab, we find identifying features in the overlap regions of each image using the function detectFASTFeatures. The position of each image in the final stitched panorama is calculated from matching features and computing the geometric transform between overlapping images. Each image is assigned an affine transform matrix which encodes its position in the final panorama. The computation time for this process is $\sim$2-3 hrs. The affine transform and image list is then fed into a Python function which uses the vips affine transform function and logical image overlay with a transparency mask to assemble these images into the final BSE panorama. The final panorama (at the same nm/pixel as the original acquisition) is written as a deep zoom format image using dzsave in pyvips.

The assembled BSE panorama in deep zoom format is displayed on a website using the OpenSeadragon open-source, web-based viewer. Various tools are added to the web display of the image, including a scale bar. Each field-of-view has a unique url so the positions of interesting features can be recorded.

**Results:** An example BSE mosaic image of Acfer 094 is available on our lab's website https://presolar.physics.wustl.edu. The code used in this project is freely available at https://github.com/ogliore/DeepZoomSEM.

**Future Work:** Future improvements include display of 16-bit images with user-defined maximum, minimum, and gamma parameters, simultaneous acquisition and display of different SEM imaging modalities (e.g. secondary electrons, cathodoluminescence, X-ray) and annotation capabilities.