HIGH-RESOLUTION BACKSCATTERED ELECTRON AND X-RAY MAPS OF METEORITE SECTIONS.

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Introduction: Hayabusa2 returned mm-sized and larger stones from Ryugu that may possibly be prepared in thin section. OSIRIS-REx will likely return stones from Bennu at least this large that may also allow for thin sections. One of the immediate questions concerning the returned Bennu and Ryugu samples will be: is this material similar to any known meteorites? The closest analogs to Bennu and Ryugu will likely be the CI, CM, and CY chondrites. Comparative asteroid mineralogy is most efficiently done with open meteorite data sets.

The "first look" data that is most often critical for cosmochemists is a detailed mineralogic and petrographic description of the sample. For a sample prepared as a thin or thick section, backscattered electron and elemental maps acquired at the effective resolution limit for these two modalities (50 nm/pixel and 2 μm/pixel, respectively) are critical for determining if a given sample can answer a given scientific question. However, thin sections of precious extraterrestrial samples are rare and often difficult to acquire and expensive or logistically challenging to analyze by FEG-SEM techniques. Here I describe a technique to acquire BSE maps and the associated elemental maps of an entire one-inch section, and display these maps conveniently online.

Methods: The meteorite section is mounted on a large SEM stub with clips to ensure the sample does not move during the long acquisition. A Tescan Mira3 FEG-SEM is tuned for optimal BSE image acquisition at high magnification and 15–30 kV accelerating voltage. First, I acquire a "focus map" before the high-resolution BSE acquisition. The x, y and working distance values for the full-resolution BSE scan are calculated from a coarse-grid map. These coordinates are fed into a Matlab function that writes an acquisition file for collection of the high-resolution BSE scan. Each individual tile in the full-resolution BSE scan is acquired as a 16-bit BSE image in png format, 4096×4096 pixels, 200 μm field of view, and 2–4 μs/pixel dwell time.

We then re-optimize the SEM conditions for X-ray acquisition (higher beam current, 15 mm working distance). We acquire a new focus map and write a multi-field X-ray acquisition file using Matlab. We acquire a 512×400 pixel images over a 1024×800 μm field of view (2 μm/pixel). It takes 5–10 days to acquire X-ray maps over the entire thin section using the 30-mm^2 EDAX SDD X-ray detector on our SEM.

Individual images are then assembled using a Matlab script. Identifying features in the overlap regions of neighboring images are found using detectBRISKFeatures which uses uses the Binary Robust Invariant Scalable Keypoints algorithm to detect multi-scale corner features. Neighboring images are matched using a similarity transformation matrix.

The list of transformations for each image (relative to an origin image) is then fed to a Python script which uses vips, a demand-driven, horizontally threaded image processing library, to apply the transformation and brightness corrections, and assemble the tiles into the final mosaic. The BSE and registered X-ray maps are saved as dzi image pyramids (BSE mosaics are >100 gigapixels in size). These images can be viewed seamlessly (panning and zooming) online using OpenSeaDragon, with javascript code that allows for easy switching between BSE and X-ray maps. 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 and shared with colleagues.

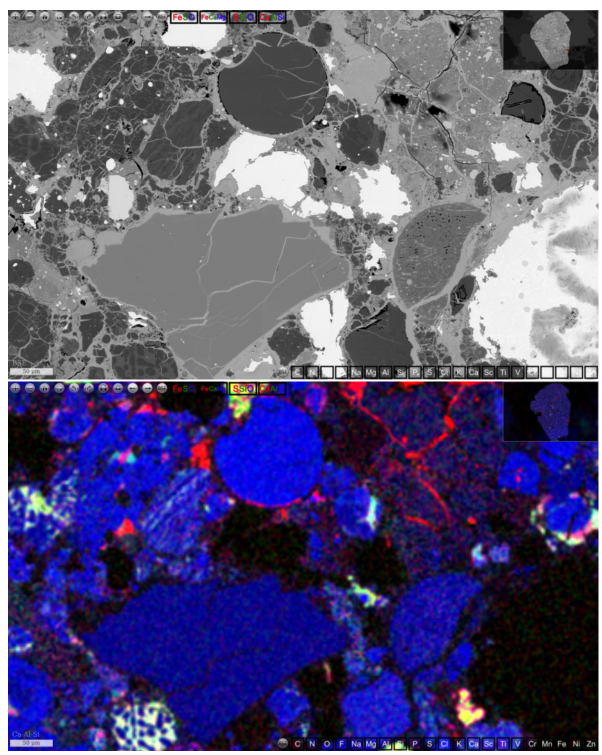

Figure 1: BSE image (top) and Ca-Al-Si RGB image of a portion of a 160 gigapixel image of Acfer 182 (CH3). 50 μm scale bar is visible at lower-left

Example Images and Source Code: Example images are available: https://presolar.physics.wustl.edu/meteorite-deep-zoom/. Source code is: https://github.com/ogliore/DeepZoomSEM. Techniques are described in detail: https://doi.org/10.1029/2021EA001747.