QUANTITATIVE MICROANALYSIS EXPLORER: A WEB-BASED VISUALIZATION SOFTWARE FOR VISUALIZATION OF OPTICAL, ELECTRON, AND QUANTITATIVE X-RAY MAPS A. Minocha[1,3], R. C. Ogliore[1,3], P. K. Carpenter[2,3], B. L. Jolliff[2,3]. [1]Department of Physics, Washington University in St. Louis, St. Louis, MO 63130, USA, [2]Department of Earth and Planetary Sciences, Washington University in St. Louis, St. Louis, MO 63130, USA, [3]McDonnell Center for the Space Sciences, Washington University in St. Louis, St. Louis, MO 63130, USA.

Introduction: High-resolution optical, electron, and x-ray imaging of extraterrestrial materials is used to characterize the origin and history of the sample. Modern imaging techniques can acquire very large image mosaics, up to hundreds of gigapixels in size. These images contain important mineralogic information at micrometer to centimeter size scales, but are often too big to load into computer memory, and cannot be easily shared between collaborators. Previously we described a set of software tools to acquire and display large electron and qualitative x-ray images of meteorite thin sections [1]. Here, we describe an improvement and extension of this set of software tools to allow for the interrogation of quantitative EPMA data and the multi-modal visualization of very large optical, electron, and X-ray images. This tool, named Quantitative Microanalysis Explorer or "Q-tool" for short, is used to interrogate sections 6015, 6016, 6017, and 6018 of the Apollo 17 ANGSA core sample 73002. We present this tool as a "next generation" method for the preliminary examination of - and tool for further analysis of - precious planetary sample-return materials.

OpenSeadragon Viewer: Quantitative Microanalysis Explorer is a web-based tool (Figure 1) based on OpenSeaDragon (*"An open-source, web-based viewer for high-resolution zoomable images, implemented in pure JavaScript, for desktop and mobile"*) (https://openseadragon.github.io/). Since only the field of view of the image is loaded into memory, very large images can be explored with seamless panning and zooming. Q-tool includes the following features: 1) a scale bar is displayed and changes with magnification; 2) a unique URL for each field-of-view that can be shared with collaborators; 3) user-selectable element RGB maps. Optical, electron, and x-ray images are saved as image pyramids in the dzi file format using libvips [2]. Further details of the viewer are described in [1], though we have made several recent improvements. For example, switching between images is done smoothly by changing opacity.

Image Registration: All images are registered to the high-resolution BSE image (1.5 μm/pixel). Another BSE image is collected simultaneously along with the EPMA X-ray compositional maps (9.0 μm/pixel), so this is used to register all X-ray maps to the high-resolution BSE image. Control points for these images are identified automatically using feature detection in Matlab (detectORBFeatures). The low-resolution BSE is warped to the high-resolution BSE using a projective transformation and nearest-neighbor interpolation. About 50 control points are picked manually to register the optical images (plane-polarized, cross-polarized, and reflected light) to the high-resolution BSE image. Distortion in either imaging modality causes imperfections in the rigid-transformation registration. In the future, we will explore non-rigid image transformation algorithms using a Python implementation of OpenCV to further improve image registration.

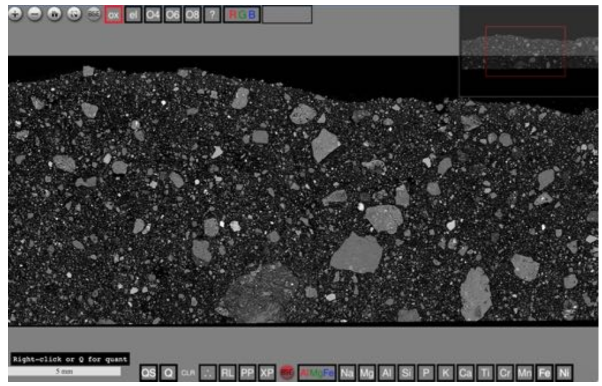

Figure 1: Q-tool web interface.

EPMA Data Retrieval and Display: Our technique for quantitative compositional mapping by EPMA is described in another abstract in these proceedings. Individual element maps are saved as 32-bit floating-point tiff files. We used Geotiff.js, a JavaScript library, which reads tiff images of any data type (https://geotiffjs.github.io/geotiff.js/). For these ANGSA sections, each element tiff file contains over 5 million pixels. Image data is first loaded onto the user's computer (with a fast internet connection, this takes less than ten seconds). To read data from the tiff files rapidly, we used Geotiff's implementation of object pooling. Object pooling allows the browser to use the maximum number of processors available on the user's computer. We implemented the pool to read raster data from the 11 quant tiff images. After selecting a region of interest, retrieving quant data using the Geotiff pool is also very fast: a million pixels are extracted in a few tenths of a second.

Q-tool allows users to extract quant data for regions in the image using three possible tools: 1) single-pixel extraction (with right-click); 2) rectangular select over a region of interest (click and drag); 3) polygon select over a region of interest (click points to define a polygon). In the latter two cases, the mean (not density corrected) and standard deviation of all pixels in the selected area is reported to the user (Figure 2). The data is automatically copied to the user's clipboard so that it can be easily saved and analyzed in Excel or other software.

Quantitative information is displayed in either oxide weight percent, element weight percent, or on a 4-, 6-, or 8-oxygen basis, as selected by the user. The calculated total weight percent is displayed when oxide or element weight percent is selected. The total number of cations is displayed when the oxygen basis is selected.

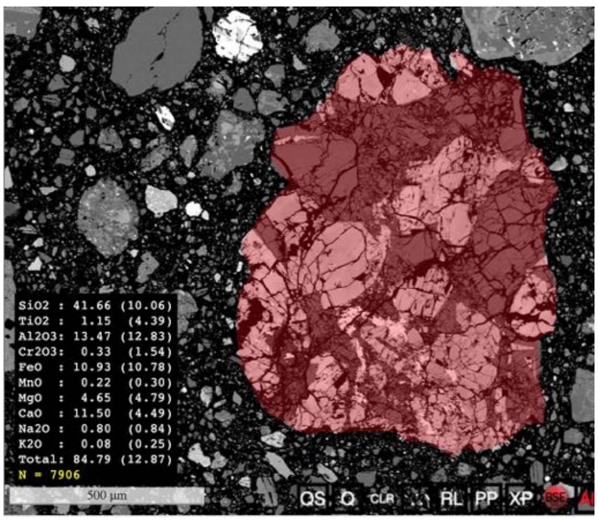

Figure 2: Polygon selection (pink region) and quant information displayed as oxide weight percent for 7,906 individual pixels in 73002,6016.

Cluster Analysis: To more easily identify distinct phases in the section, we employed cluster analysis using Matlab's kmedoids function. We initialized the clustering algorithm with 25 clusters identified through segmentation of the BSE map. We found that the cityblock distance metric most efficiently identified distinct mineral phases with minimal noise. Clustering of an array of five million pixels, each with ten elements, requires a large amount of RAM and a processing time of several hours. After the cluster analysis was complete, we sorted the clusters by total cation number (per 24 oxygens), then assigned each cluster a color according to the jet colormap: low-cation phases (e.g. silica=12) are blue, high-cation phases (e.g. olivine=18) are red. The user can select the cluster image (three dots in a triangle in lower button bar), which is also registered to the high-resolution BSE map. An example is shown in Figure 4.

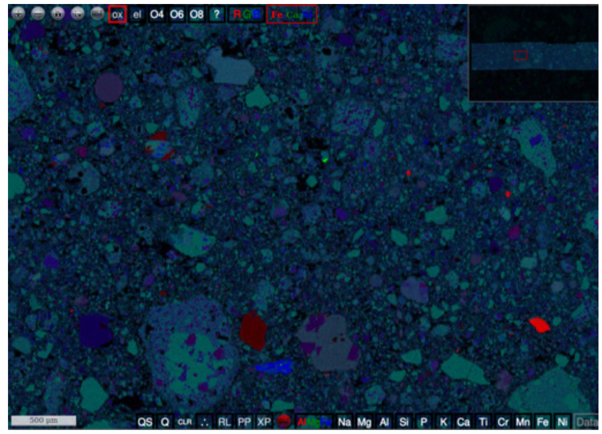

Figure 3: A user-selected RGB image (Fe-Ca-Si) in 73002,6016.

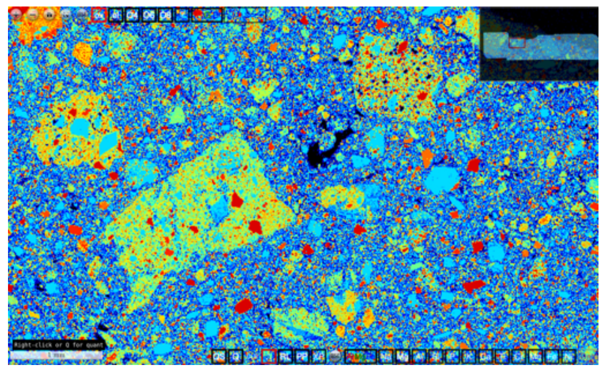

Figure 4: Cluster analysis showing distinct clasts in 73002,6017.

Conclusions: We have developed Q-tool to allow for interrogating EPMA, SEM, and optical imaging data sets conveniently and efficiently. This tool will allow more researchers to be involved with detailed mineralogic and compositional studies of rare and precious materials, such as the Apollo 17 ANGSA samples.

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References: [1] R. C. Ogliore. *Earth and Space Science* 8.7 (2021), e2021EA001747. [2] K. Martinez and J. Cupitt. *IEEE International Conference on Image Processing 2005*. Vol. 2. IEEE. 2005, pp. II–574.