Extracting modal abundance data from SEM images

Introduction to Scanning Electron Microscopy – EDS & EBSD

Electron microbeam techniques are now a routine part of petrological analysis, in addition to optical microscopy. Electron microscopes can provide qualitative and quantitative chemical information of small areas of solid samples by exciting X-rays from the solid sample surface using a focused electron beam. This X-ray spectrum contains important information, particularly characteristic X-rays that are unique to every element of the periodic table. These characteristic X-rays can be used to produce an image of the sample. This type of SEM technique is called energy-dispersive spectroscopy (EDS). Another type of SEM analysis, EBSD (electron backscatter diffraction), utilizes the unique crystallography of minerals to identify them.

Pixel-counting SEM maps

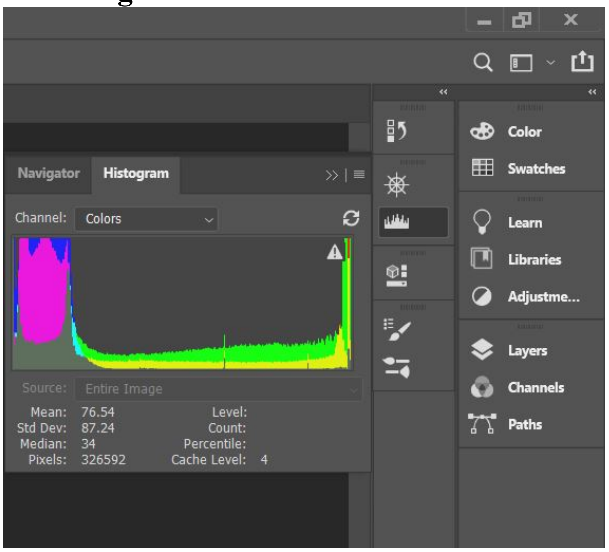
The basic idea behind the pixel counting method is to analyze an image in which the color value of each mineral is unique. When a mineral exhibits a unique color value we may count the number of pixels of that color value in the entire image. Using some basic algebra, we can estimate the percentage of each mineral present. This can be done using plane polarized images of thin sections but is more effective when using EDS maps or EBSD (electron backscatter diffraction) maps. An individual EDS or EBSD map will show the amount of a particular element present in the sample. Areas with a higher abundance of the element analyzed will appear brighter than areas with lower abundances. These maps can be stacked such that each mineral displays a unique color. Generally, these stacks consist of 3 element maps, with each element assigned a primary color (RGB). Minerals will display a color that reflects the relative abundance of the three elements selected for the stack.

A step-by-step guide to pixel counting in Adobe Photoshop

1) Open your image in Adobe Photoshop CC. Two versions of PS are supported on Adobe CC and either will work.

2) **Crop** your image: It is important to remove any unwanted pixels from the image. Depending on the image and how it was acquired there may be pixels on the border of the image which are not useful for counting. The images provided for you in this lab will have been cropped for you.

3) Open your **histogram:**

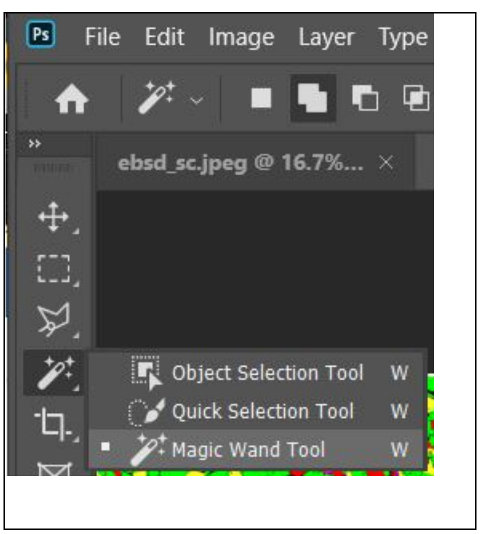


The histogram display will show you how many pixels exist in your image, and as you select pixels it will tell you how many are currently selected. You may open the histogram through the first pane on the right. Keep in mind the image shows the two right panes as they exist in the collapsed view. The double arrows above the pane will expand the pane and reduce the amount of room you have to work with your image. When pixel counting it is best to leave these panes collapsed with exception of the histogram. Beneath the histogram graph you will see a few different values, one of which being "Pixels:"

This value, when nothing in your image has been selected, will show the total number of pixels in your image. Once you have selected pixels this value will represent the number of pixels currently selected.

4) **Count:** Select your **magic wand** tool.

This tool can be found on the left side by right clicking on the fourth icon down and selecting "Magic Wand Tool"(see picture). Before you begin selecting pixels, adjust your sample size and tolerance settings, these can be found at the top of your PS frame once the magic wand tool has been selected. If you are counting near grain boundaries, fractures, or in small grains then it is best to use the "**Point Sample**" for the sample size option.



If you are counting in areas such as grain interiors that are quite homogenous and have many pixels of the same color, it may be appropriate to use the "**3 by 3 Average**" for your sample size. When you click on a pixel with the magic wand, PS will select all other pixels in your image that have a similar color value.

The “**Tolerance**” setting lets you adjust how different those pixels will be from the pixel you are selecting. A low Tolerance setting will select only pixels that are very close in color value to the pixel being selected, this is generally what we want for pixel counting. A tolerance value of ~5 should be appropriate for this lab but feel free to adjust this up and down as you need.

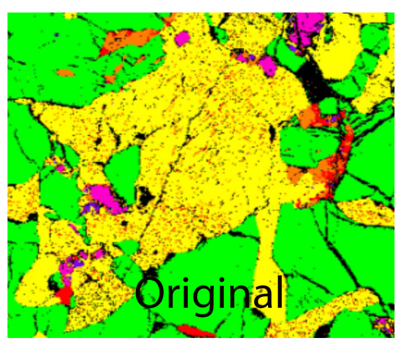
Using the magic wand tool, begin to select pixels until all of the pixels of a particular mineral are selected. Take note of the number of pixels selected. Repeat this process until you have counted pixels for each mineral.

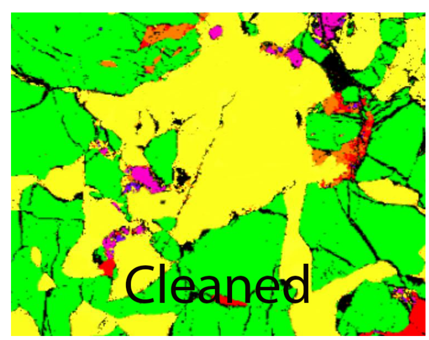
5) **Calculate:** Add up the total pixels that you have counted, this number will be different than the number of pixels that exist in your image; we can refer to this as the “new total”. Some of your pixels will be unaccounted for and that is ok. Read more about how we can properly account for these pixels below. Take the number of pixels for each mineral, individually, and divide it by the new total, multiply by 100 to give a percentage. Do this for each mineral.

While pixel counting can be relatively straightforward, it is important to understand what you are looking at and ensure the image you are pixel counting suits your needs.

- **Producing the best stack -** Depending on the mineral assemblage, at times it is not possible to produce a unique color value for each mineral in a single RGB stack. In this case, two or more RGB stacks may be needed to isolate each mineral and complete the pixel counting. Note, we will not be doing RGB stacks in this lab, since we will be using EBSD maps where each color already corresponds to a unique phase (based on crystallographic orientation data).
- **Cleaning your image** – EDS maps can be a bit messy depending on the parameters with which the map was acquired. In some cases it is necessary to clean your image such that the pixels within a region that represents a particular mineral are a more homogenous color value than the original stack.

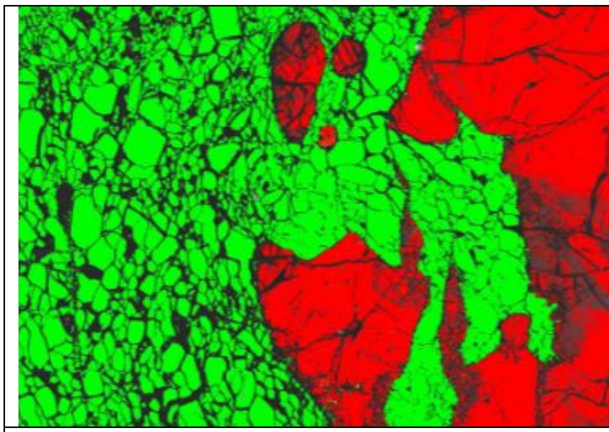
  See example at right:





Notice the original image shows red pixels intermingled with the yellow pixels. In this case, it was necessary to remove the red pixels from the yellow since the red pixels are being counted as a separate mineral phase.

- **Dealing with uncounted pixels:** Regardless of what type of an image you are pixel counting, there will generally be pixels that go uncounted. In an ideal image these pixels would be coincident with grain boundaries and grain boundaries only. If your sample is equigranular, these pixels can be discounted from the total number of pixels in the image. If you're sample is not equigranular some extra care should be taken, considering more of these pixels will exist within the finer grained material than the coarser grained material. If all of your fine grains are one mineral and your coarse grains are a separate mineral then it is not safe to assume the grain boundaries are evenly distributed in the sample.
  This gets slightly more complicated when dealing with uncounted pixels that are coincident with fractures and secondary mineral phases that result from alteration. How you account for these pixels will vary on a case by case basis.



The green phase here is representative of olivine, and the red of pyroxene. Notice the black stringers which run through the olivine, this is alteration which has produced serpentinite replacing the olivine. Since we are concerned with the original olivine content of this sample we can count the black pixels within the green region as olivine.