

Geology/Geography 4113
Remote Sensing
Lab 06: AVIRIS Spectra of Goldfield, NV
March 7, 2018

We will use the image processing package ENVI to examine AVIRIS hyperspectral data of the Goldfield, NV mining area. First we will examine individual spectra, then we will use band ratio images and band depth images to identify individual hydrothermal alteration minerals which outline the possible location of ore deposits. The AVIRIS instrument was flown on a NASA ER2 (U2) aircraft.

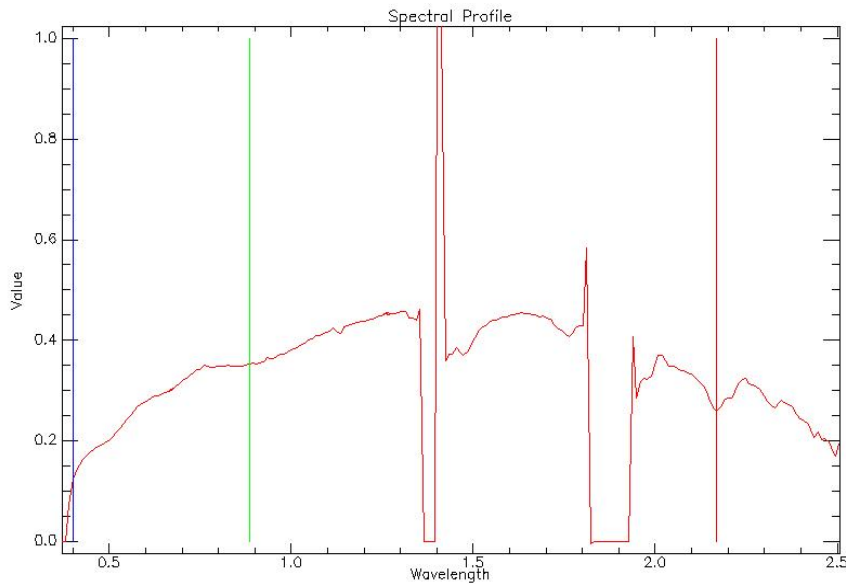
As in Lab 4 and 5, you will prepare an on-line (Word) illustrated report of approximately 5 pages summarizing your results from the various image processing operations explained below. When your report is complete email the *lastname_lab_06.doc* file to Taylor at <tsulli12@uwo.edu>.

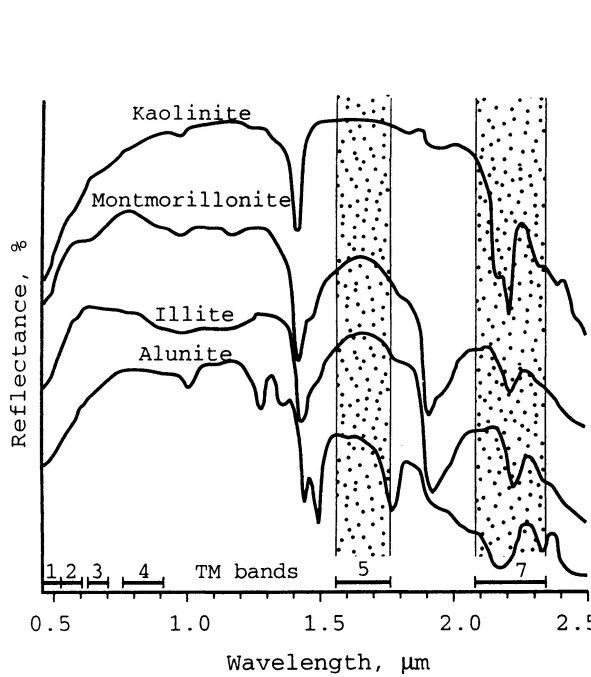
The main data files for this exercise can be found on the class website as **lab_06_data.zip**. As before, you'll want to download the zip file and extract it. However because this hyperspectral data file is so large (160MB zipped, over 250MB once extracted), don't place it on your home or H: drive. If everyone tries to access a file that large from ENVI over the network, the network will slow to a crawl. Instead place the zip file and then the extracted data files in a folder within the local **c:/temp** directory on your machine. However be sure to save any files you will need later on your network **HomeDrive**, as files on C:/temp are deleted when you logoff.

1. Start **ENVI Classic** on your machine.
2. Click on **File>Open Image File>** and navigate to **aviris_goldfield_nevada** in the file dialog. You should then see an available band list which includes 224 bands, ranging from 0.37 to 2.51 microns. The numbers in parentheses are wavelengths, in microns.
3. In the **Available Bands List** window, select the **RGB Color** option, specify bands #190, #56, and #4 for the RGB channels, then click **Load Band** to display it. Drag the corner of the main image window to enlarge it. Once you make it as large as the full **Scroll** image, **Scroll** will disappear as it is no longer needed. Save a copy of the image to include in your report. As we'll see later these specific bands were chosen to correspond to different alteration mineral absorptions, so this display shows a great diversity of colors. As described in Sabins on pg. 366-371 and 378-382, the complex circular structure at the middle right is the location of an small caldera and ring-fracture system emplaced during the Oligocene through Miocene. Hydrothermal fluids circulating along the ring fractures and in the center altered the preexisting minerals and deposited quartz, gold, and other materials. The alteration products consist primarily of clays or sulfates, and they can be used to provide an indication of where ore bodies might be found. (In the following, to keep the names simple I'll refer to these collectively as "clays" even though one of the minerals we'll be investigating, alunite, is really a sulfate. Because it is a hydrated sulfate it has O-H bands similar to those found in clay.)
4. Click on the cyan region near the middle of the main image window to position the cursor, then from the main image window choose **Tools->Profiles->Z Profile (Spectrum)** and a new window will open showing the spectrum. Enlarge the window to a reasonable size by dragging on one corner. Next, to specify more reasonable plot parameters, do the following. From the plot window menu select **Options** and make sure **Auto Scale Y Axis** option is off. (If it is on there will be a check before the menu item. Click on it to toggle it off.) This will keep the system from rescaling the plot every time we display the spectrum of another pixel, which makes it easier to compare

spectra. Next, again from the plot window menu, select **Edit->Plot Parameters**. In the window that opens select the **Y-Axis** using the check circles about ¼ of the way down, then specify the Range from 0 to 1 and click **Apply**. Select the **X-Axis** using the buttons. The **Tick Marks** should already be set as 0.5 to 2.5 inc 0.5. Change the **Minor Ticks** to 4 so the tics will be located at 0.5, 0.6, 0.7, etc. instead of the much less useful default of 0.500, 0.625, 0.750, etc. When done click **Apply**, then close this plot parameter window using the **X** button at the top left.

Your spectrum should now look something like the following. Save a copy to include in your report. The vertical blue, green and red lines indicate which wavelengths are being displayed in your image. The noisy regions near 1.4 and 1.9 microns correspond to strong atmospheric absorptions. This spectrum has been corrected for atmospheric absorption, but in these regions the signal is so low the correction essentially results in zero divided by zero, giving high noise. You need to avoid those noisy bands in the analysis.





A. Laboratory reflectance spectra. TM bands 5 and 7 (stippled) are used to calculate the 5/7 ratio image.

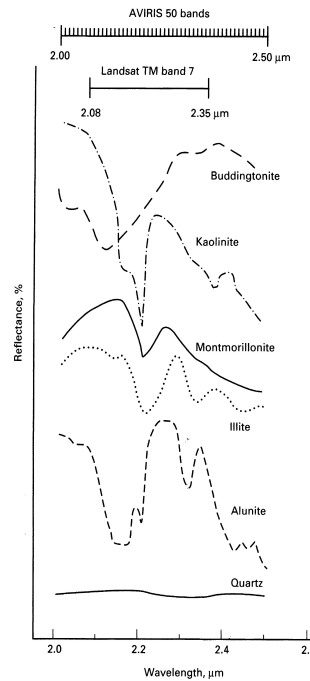


Figure 11-17 Laboratory spectra of alteration minerals in the atmospheric window from 2.0 to 2.5 μm. Spectra are offset vertically for clarity. Bandpasses of AVIRIS and TM band 7 are shown.

Sabins Figures 11-08A and 11-17

5. Move around your image, clicking on different colored regions, and observe the spectrum change. Examine a number of spectra around the various different alteration regions indicated by the different colors. Try to locate in the spectrum regions where various different diagnostic absorptions appear. How do those compare to the absorptions indicated in Sabins Figures 11-8A and 11-17? Try the following areas, and look for the absorption patterns listed. Explore the image to see if you find any other spectrally distinct regions.

Cyan area in middle of image: It should show an absorption feature near 2.32 microns, and a two-minimum absorption in the 2.15—2.20 microns region, with the shorter wavelength dip being deeper – more-or-less matching the spectrum of alunite in figure 11-17.

White area (surrounded by cyan), NE of Goldfield. It should show no feature at 2.32 microns, but a two-minimum absorption in the 2.17 – 2.22 micron range with the longer wavelength deep being deeper, more-or-less matching kaolinite in figure 11-17. As you move around also notice how the 0.9 micron absorption changes.

Salmon colored areas, slightly to SE of the center of the caldera.

Blue areas, slightly S of the above salmon areas. (These form a very incomplete ring around the caldera.)

Save and include in your report at least four distinctly different spectra from the alteration region. To save spectra you can either use the **Alt-PrintScr** or **Alt-F14** keys to copy the active window to the clipboard, then to your report, or you can use the **File->Save Plot As->Image File**, specify jpg format, then specify a file in your directory. When specifying names it is good to add **_spct** to the end to avoid conflicts with similarly named files you might be generating later.

Briefly (in a few sentences) discuss their differences, and any similarities you see to mineral spectra in Figures 11-8A and 11-17. Note within the 16m pixels we will almost always have more than one mineral, so we won't get pure spectra of any specific mineral.

6. Next we want to use band ratio images or slightly more complex “band depth images” to locate the alteration minerals in general, and then locate the specific types kaolinite, alunite, and illite. First we will produce a general map of the alteration mineral (“clay”) locations. Examining the spectra in Figure 11-8A, all are dark at 2.4572 microns (band #219) but bright at 1.1536 microns (Band #84). Therefore a Band 84 / Band 219 ratio image will highlight these locations. From the main ENVI menu select **Transform->Band Ratios** then in the window which opens select band #84 as the numerator and #219 as the denominator, click **Enter Pair** then **OK**. In the next window which opens, **choose** a file, select your working **c:\temp** directory, name the file **clay**, then click **OK** first in the chose window then again in the band ratios one. (Note: After you have selected the directory once for an output file, for later output files you should be able to skip **choose** and simply specify the name.) The file should appear in your **Available Bands** window. Display it in a new window. Enlarge that window so the scroll window disappears, and you can compare it directly to your original data window. You should see clays located in a circle along the ring fractures, and also in what was the resurgent center of the caldera. Save a copy in jpg format for inclusion in your report. To do this, from the Image menu use **File>Save Image as->Image file** then select a JPG format. The system will insist on a name different that **clay**, to avoid conflicts with the above binary image file. Use something like **clay_img**.
7. Examine the spectra in Sabins Figure 11-8A. We want to find a signature of kaolinite which will be different than all the other clays. Kaolinite is the only one of the clays shown which stays high in the 1.9--2.0 micron region. Therefore the ratio of the bands 1.9586 micron (#169) / 2.2086 micron(#194) will be high only for this clay. Repeat the instructions in step 6, but for these two bands, and save the result in a file **kaolinite**. Display this in yet another window and enlarge it till the scroll window disappears. Also save a jpg copy of the image for inclusion in your report. Compare it and the general clay image. How well do they agree, that is, are there clays other than kaolinite present? If so, point out some locations where this occurs.
8. To locate alunite we can use the absorption feature at 2.32 microns in Figure 11-17, as it is present only in this alteration mineral. However to help isolate this mineral from others which do have more subtle spectral structure here, if not clear absorptions, we will use a “band depth image” rather than a simple band ratio image. Band depth images are explained in the appendix at the end.

For alunite the appropriate bands and wavelengths for the left continuum, the band center, and the right continuum, are #202, #206, and #210, or 2.2883, 2.3281, and 2.3679 microns. To compute the band depth map from the main ENVI window select **Basic Tools->Band Math**. In the “Enter an expression” field enter $1-B2 / ((B1+B3) / 2)$ then click **Add to List**, select the expression which now appears in the top part of the window, then click **OK**. The **Variables to Band Pairings** window will appear. You need to tell it that B1 is Band #202 by first clicking on **B1** in the **Variables** field then clicking on **Band #202** in the **Available Band List** field. Repeat this for **B2=Band #206** and **B3=Band#210**. Next, in the bottom of the window tell it you want to output the result to a file (rather than memory) and choose a file alunite in your working directory, then click **OK**. After a few seconds this new Band Depth Image will appear in the available band list. Load it as gray scale into yet another new display, enlarge it, then save it for your report. Compare it to the kaolinite image. There will be places where both alunite and kaolinite are present, but other regions where only one is found. Discuss in a few sentences what similarities and differences to you see.

9. The final clay to map is illite. Unfortunately it does not have any features in regions where other clays will not contribute. Its most diagnostic feature is the absorption at 2.22 microns, but we will have some confusion with kaolinite and also alunite. First, compute another Band Depth Map using the steps above, but enter the expression as $1 - B5 / ((B4 + B6) / 2.)$ and assign B4= Band #189, B5=Band #196, B6=Band #203, (2.1587, 2.2285, and 2.2983 microns). Save the ratio as `illite`. Display it in yet another new window as gray scale, enlarge it, save a jpg copy, and include it in your report. You will notice some bright areas which do correspond to illite, but there will also be dark areas caused by confusion with the other clays. Those clays can depress one of the “continuum” points so much as to produce an artificial “negative” band.
10. Because of the interference from other clays, for illite we will simply try to determine a present/not-present map by seeing if our band depth map is above some threshold. From the illite image menu select **Tools->Cursor Location/Value** to display the data values under the cursor. Determine a typical data value well away from the hydrothermally altered area. If clays are not present it should be close to zero. Enter that in your report as “Background”. Next determine the maximum band depth values in the altered areas, and record those as “Illite Maximum”. Those presumably are the areas with the most illite. Pick a threshold value half way between these levels and record it in your report as “Threshold”. We'll use that in the next step. From the main ENVI menu once again select **Basic Tools->Band Math**. Enter the expression `B7 GT xxx` where `xxx` is your threshold. This expression will return 1 if the band you specify as B7 is greater than the threshold, and 0 otherwise. Tell the system B7 is the illite band depth map you just created, and save the result of this operation as the file `illite_present`. Display this as one more gray scale image and save it and include it in your report.
11. Finally, we will create a combination color image showing our three clay locations. From the Available Bands List window create a new RGB image, with R=kaolinite, G=alunite, and B=illite_present. Save the resulting image for your report.
12. Compare your RGB composite image to Sabins Plate 21 F and your three individual clay images to Sabins Figure 11-18 A,B,C. In those figures more complicated analysis techniques were used to estimate clay abundances, using a slightly earlier AVIRIS data set. Discuss in a paragraph or two how well the results of the simple spectral methods we used compare to those results. Note the absolute colors will likely be different, with the one you generated being “greener”. Don't worry about that as the difference is partly due to the display “stretch” being used. Concentrate on the locations of the different components.
13. Go back to the spectra you saved in step 5 and mark on them the bands and features we have used in this analysis. We picked these “spectral endmembers” by eye, with some hints on what color regions to examine. Discuss in a few sentences how well the features we chose to use match features evident in the laboratory spectra of Sabins Figures 11-08A and 11-17. Looking at the spectra and the component images, discuss whether we have regions purely made of one mineral, or whether all of these regions show mixtures of minerals, with perhaps one major component?

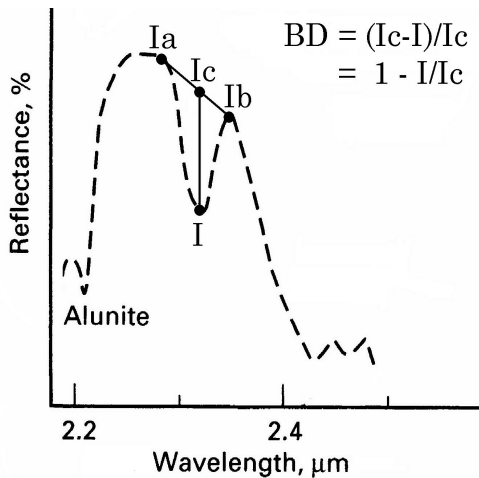
When finished your report should contain:

- An overview image of the area
- The spectrum of the cyan region from step 4.
- Spectra of other spectrally distinct regions from step 5, and a comparison to Sabins Fig. 11-8A and 11.7A, from step 5. (One of the four can be the cyan region above.)
- A copy of the "clay" image from step 6
- A copy of the "kaolinite" image from step 7, and a discussion of the differences between it and the "clay" image.
- A copy of the "alunite" image from step 8, and a discussion of the differences between it and the kaolinite image.
- A copy of the "illite" gray scale image from step 9.
- A copy of the "illite present" image from step 10.
- A copy of the RGB kaolinite, alunite, illite_present image from step 11 and a discussion of how it compares to Sabins Plate 21F and how the three individual clay images compare to Sabins 11-18 A,B,C.
- A final marked copy of the spectrum from step 5, showing the features used, along with a discussion of how well those features match features evident in Sabins Fig. 11-08A and 11-17 and how well we detect individual minerals or combined mixtures of minerals.

Appendix: Band Depth Images

In a band depth image we use information from both sides of the absorption feature. We fit a straight line between the “continuum” on either side of the band and interpolate to find the intensity we would expect at the wavelength of the center of the band, if that band were not present. Call that I_c . We then compute the Band Depth $= (I_c - I) / I_c = 1 - I / I_c$. This will be 0 if there is no band (so $I = I_c$) but will be 1 if the band goes all the way to zero intensity ($I = 0$). The bigger the band depth, the deeper the band. If other minerals are present which just produce a constant slope over this region, we will still get zero for the band depth. For example we will have little confusion with kaolinite. However because illite does have more complicated structure here, we may have some confusion with that mineral. (In later labs we'll use better techniques for distinguishing different minerals.)

To make the algebra easy we will interpolate between two continuum points equally spaced on either side of the band, so if they are labeled I_A and I_B , $I_c = (I_A + I_B) / 2$. If they were not equally spaced we would need to find the equation of the line which passed through them and solve for the value of I_c at the band-center wavelength.



If the continuum points I_A and I_B are not located symmetrically around the band, then the formula for I_c becomes more complicated. We find the equation of the line through (λ_A, I_A) , (λ_B, I_B) then use it to find the expected intensity I_c at λ , the band center wavelength.

$$I_c = I_A + \frac{I_B - I_A}{\lambda_B - \lambda_A} (\lambda - \lambda_A)$$