Lab14.2 Hyperspectral Analysis for Geologic Minerals

Requirement

提交作业内容如下：

1. Exercise 1.2 作业图 1
2. Exercise 2 作业图 2
3. Exercise 5 作业图 3 和图 4
4. Exercise 6 作业图 5

上述图片截图即可，放在一个 word 文档中。

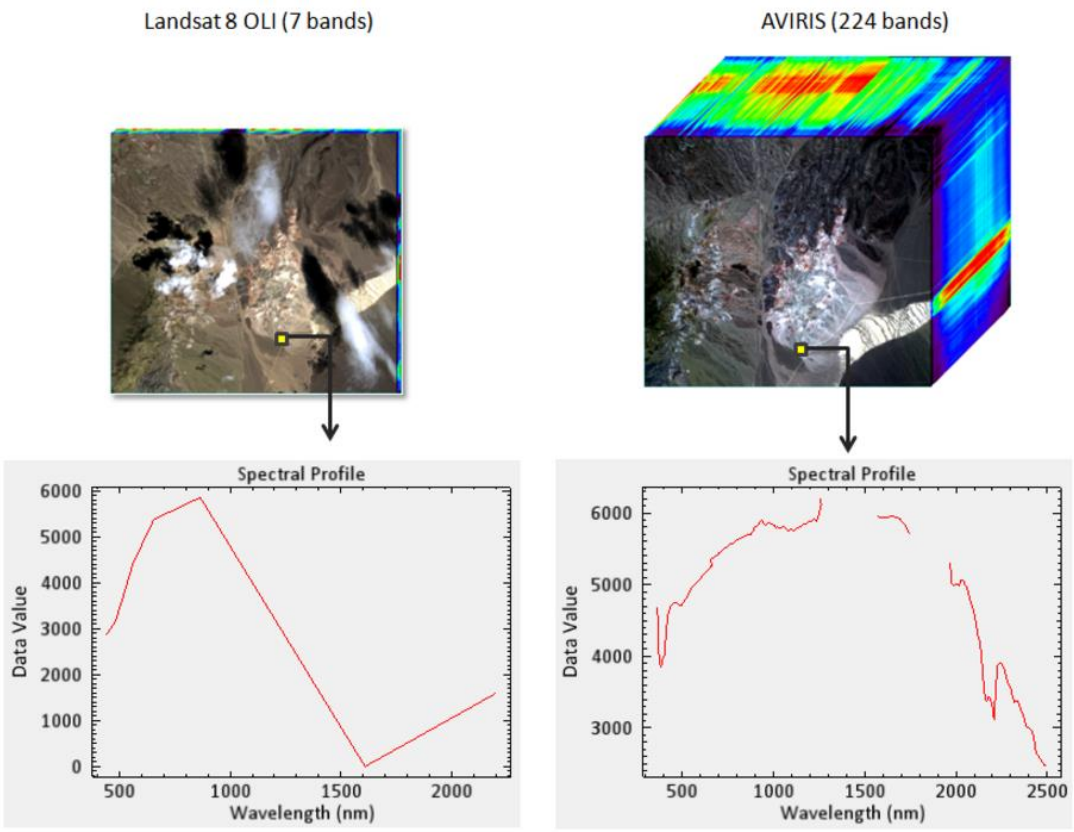
Background

Hyperspectral sensors—more commonly known as imaging spectrometers—collect spectral information across a continuous spectrum by dividing the spectrum into many narrow spectral bands. Airborne and satellite imaging spectrometers can have up to several hundred bands with a spectral resolution of 10 nanometers (nm) or narrower. Compare this to broadband multispectral sensors such as Landsat 8 OLI, which has nine spectral bands and a spectral resolution of 106 nm.

Spectral resolution refers to the width of each band within the captured spectrum. More specifically, it refers to the width of an instrument response (band pass) at half of the band depth. This is known as the full-width-half-maximum (FWHM). Spectral sampling is a separate concept that refers to the band spacing, or the quantization of the spectrum at discrete steps. Quality spectrometers are usually designed so that the band spacing is approximately equal to the FWHM, which explains why spectral sampling is often used interchangeably with spectral resolution.

The following figure shows how a given pixel from a multispectral image only covers discrete spectral bands. Although it can have many bands covering the visible to

thermal spectrum, it cannot produce a continuous spectrum of an object like a hyperspectral sensor can.



The spectral resolution required for a specific sensor depends on the spectral characteristics of the material you are trying to identify. Each material exhibits a unique spectral signature across the electromagnetic spectrum. Factors that influence a material's spectrum include composition, structure (crystallinity), grain size, viewing geometry, and mixture.

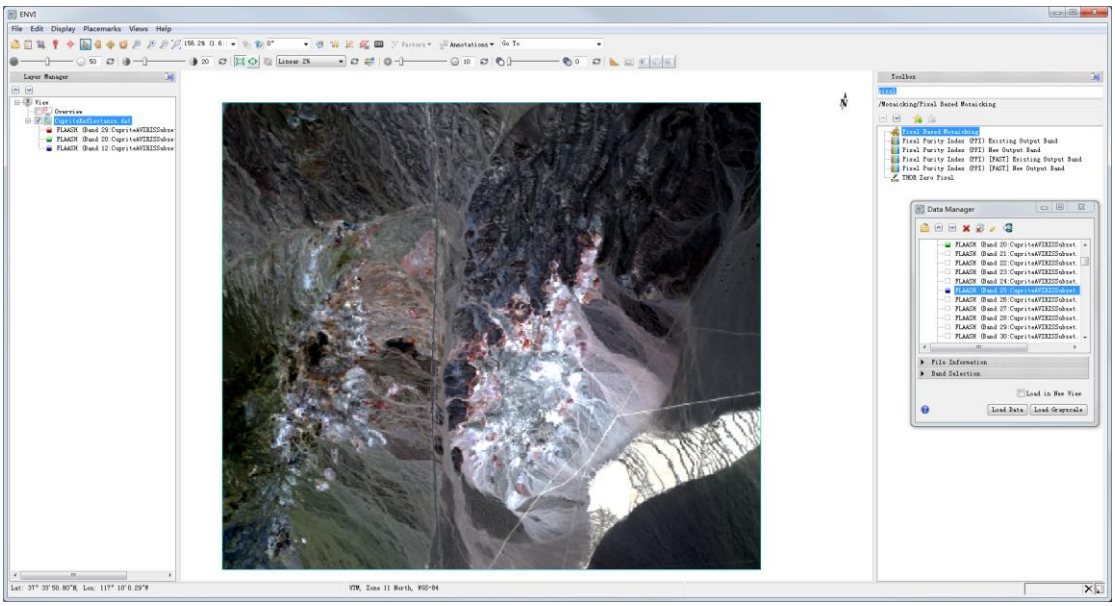
The high spectral resolution from an imaging spectrometer allows you to identify materials, whereas broadband sensors such as Landsat TM only allow you to discriminate between materials. We will demonstrate these concepts in the steps that follow.

Exercise 1: View Material Spectra

In this exercise, you will analyze spectral profiles of pixels within a reflectance

image, then compare them to library spectra of known materials. Hyperspectral data analysis commonly involves apparent reflectance data, where the imagery may have variations in illumination due to topography. With reflectance data, pixel values typically range from 0 to 1 but are often scaled by some factor to yield integer data. The apparent surface reflectance image you will view next has been scaled by 10,000.

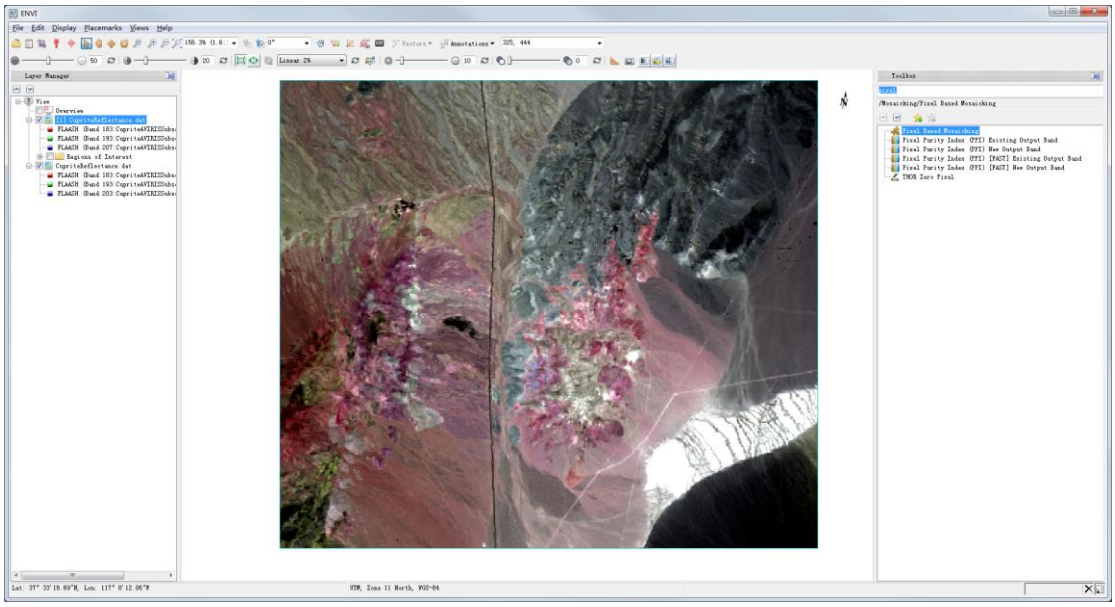
1. Start ENVI.
2. Click the Open button in the toolbar.
3. Select the file CupriteReflectance.dat and click Open. Out of the 224 bands of this AVIRIS scene, ENVI automatically determines the best bands to approximate a true-color display. In this case, it assigns Band 29 to red, Band 20 to green, and Band 12 to blue. This band combination does not offer a good color contrast among the different materials within the scene. You will change the band combination in the next few steps.



4. Open Data Manager, scroll through the list of bands in the image. Click on the following band names, in order, to assign them to the red, green, and blue channels, respectively:

- FLAASH (Band 183...)
- FLAASH (Band 193...)
- FLAASH (Band 207...)

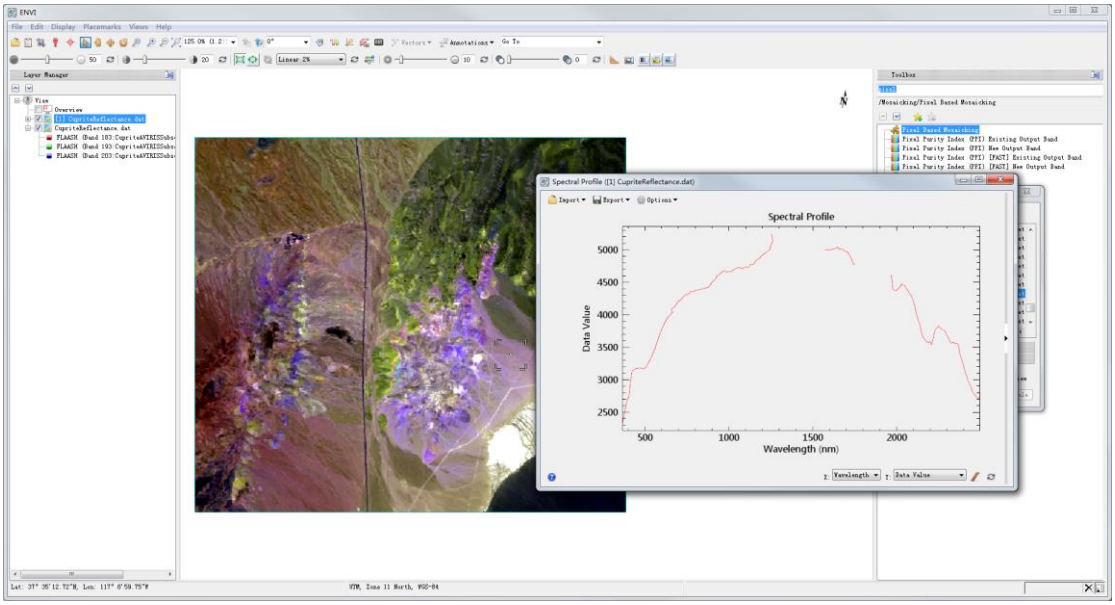
5. Click the Load Data button in the Data Manager. The resulting band combination provides a better color contrast throughout the scene.
6. Close the Data Manager.



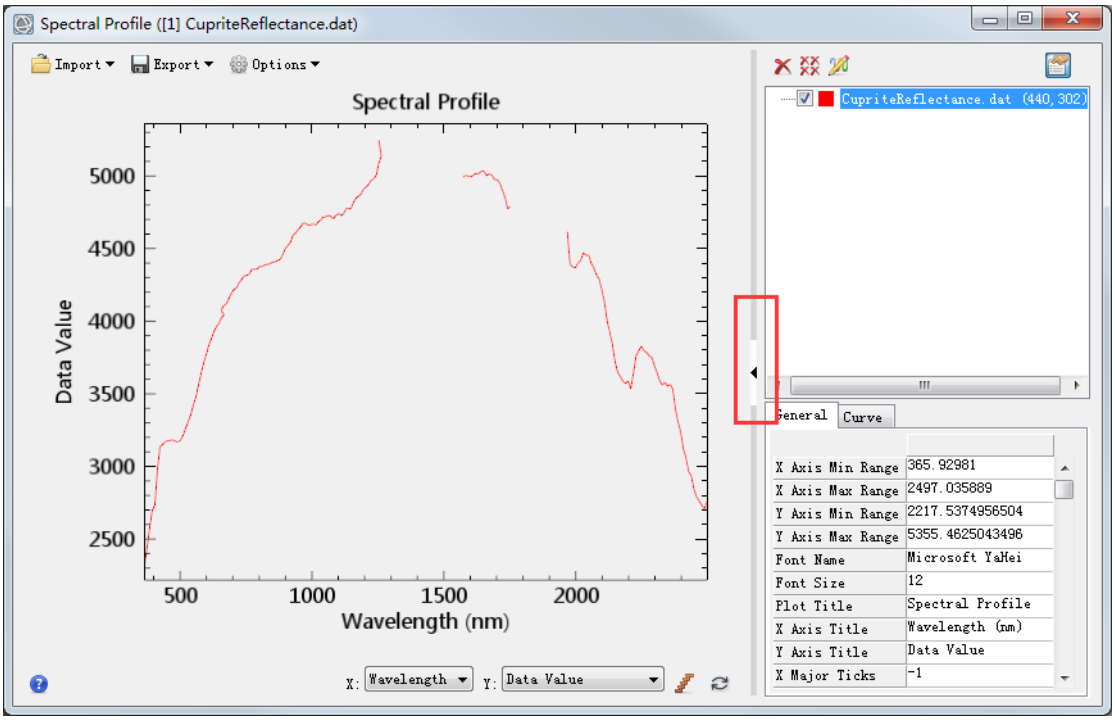
1.1 View Image Spectra

ENVI can extract horizontal (x), vertical (y), and spectral (z) profiles from any image display. Hyperspectral data analysis is primarily concerned with extracting spectral profiles, which take spectral information from the whole file and not just the bands displayed on the screen. For example, the file CupriteReflectance.dat contains 170 bands of "good" data, so a spectral profile for any given pixel will show the reflectance values for all 170 bands.

1. In the Layer Manager, right-click on **[1] CupriteReflectance.dat** and select Profiles > Spectral Profile. Within the image is a small white dot surrounded by four white corners. The dot represents the selected pixel, and the Spectral Profile shows the spectrum for that pixel.
2. Note the shape of the reflectance curve in the Spectral Profile window; the gaps indicate the bands marked as "bad" in the ENVI header file. These are primarily water vapor bands that would have caused spikes in the reflectance curve.

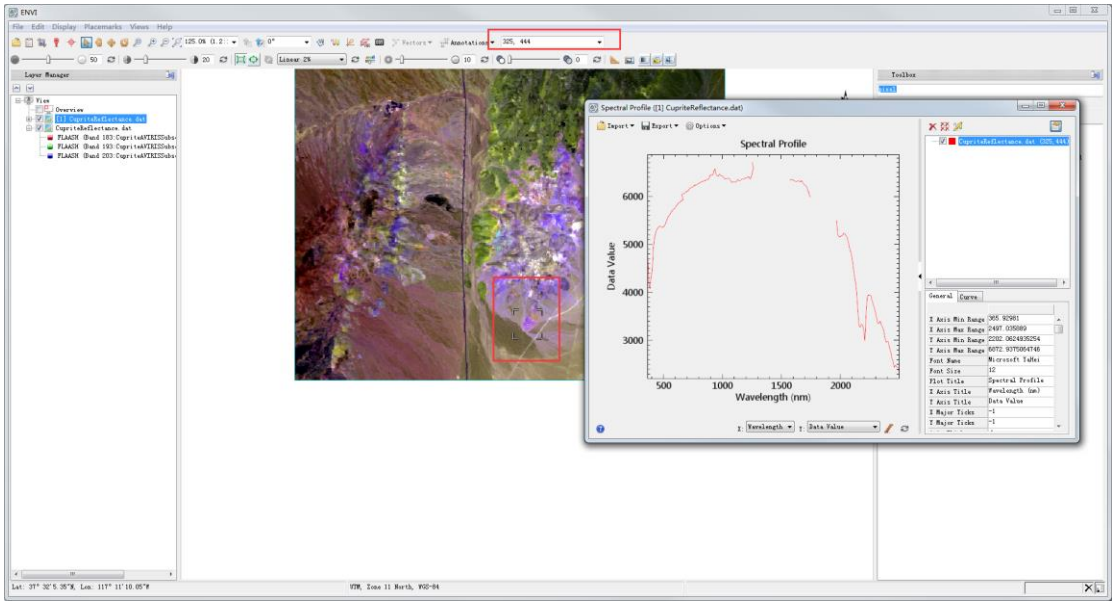


3. Click anywhere inside of the image to select a different pixel. The Spectral Profile updates to show the spectrum for that pixel.
4. Click the Show arrow on the right side of the Spectral Profile. A plot key appears with the spectrum name and pixel location: for example, CupriteReflectance (261, 393). You can also use this panel to set the plot properties. For more tips on working with spectral profile plot windows, see the Spectral Profile topic.



Click the Remove All button above the plot key to clear the Spectral Profile.

In the Go To field of the ENVI toolbar, type pixel coordinates 325, 444 and press the Enter key. The display centers over a pink area in the lower part of the image. The Spectral Profile updates with the spectrum of that pixel location. This spectrum represents an unknown material. Next, you will compare this spectrum to a library spectrum that represents ground-truth data.



1.2 View Library Spectra

A common workflow in hyperspectral data analysis is to compare spectra derived from image data to those collected in the field or laboratory. This lets you quickly compare image spectra to the spectra of known materials. Absorption and reflectance features are easy to compare when the spectra are plotted in the same window.

Included with your installation of ENVI are several groups of laboratory spectra from the NASA Jet Propulsion Laboratory (JPL), Johns Hopkins University (JHU), and the U.S. Geological Survey (USGS). Data provided courtesy of courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. Copyright © 1999, California Institute of Technology. All Rights Reserved.

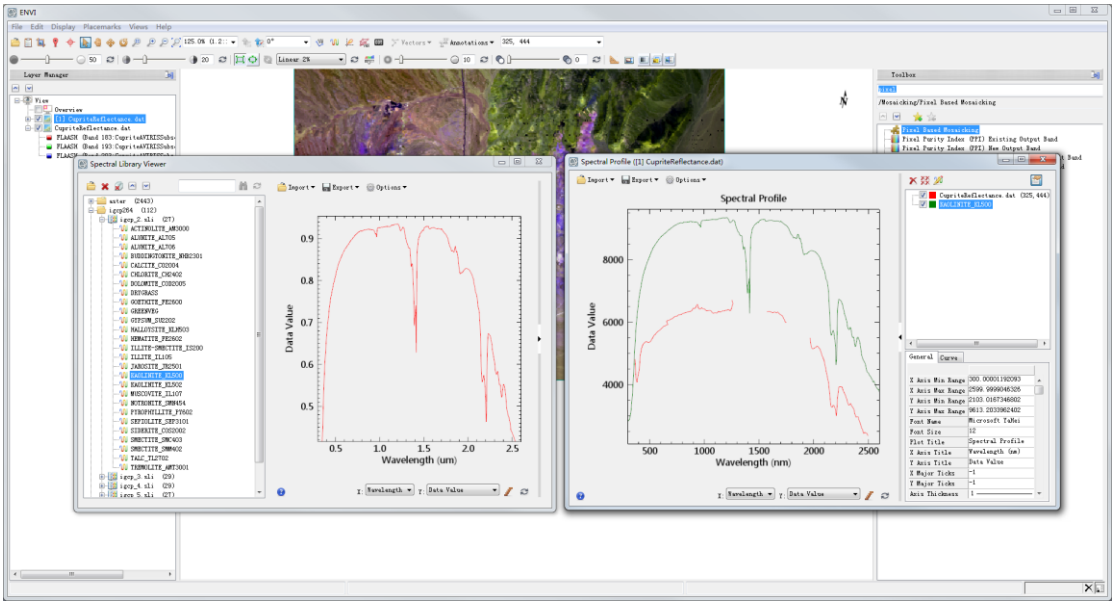
The aster folder contains the ASTER Spectral Library (version 2), which includes thousands of laboratory spectra from natural and man-made materials covering 400 to

1540 nm (Baldridge et al., 2009). This folder contains the JPL and JHU spectra.

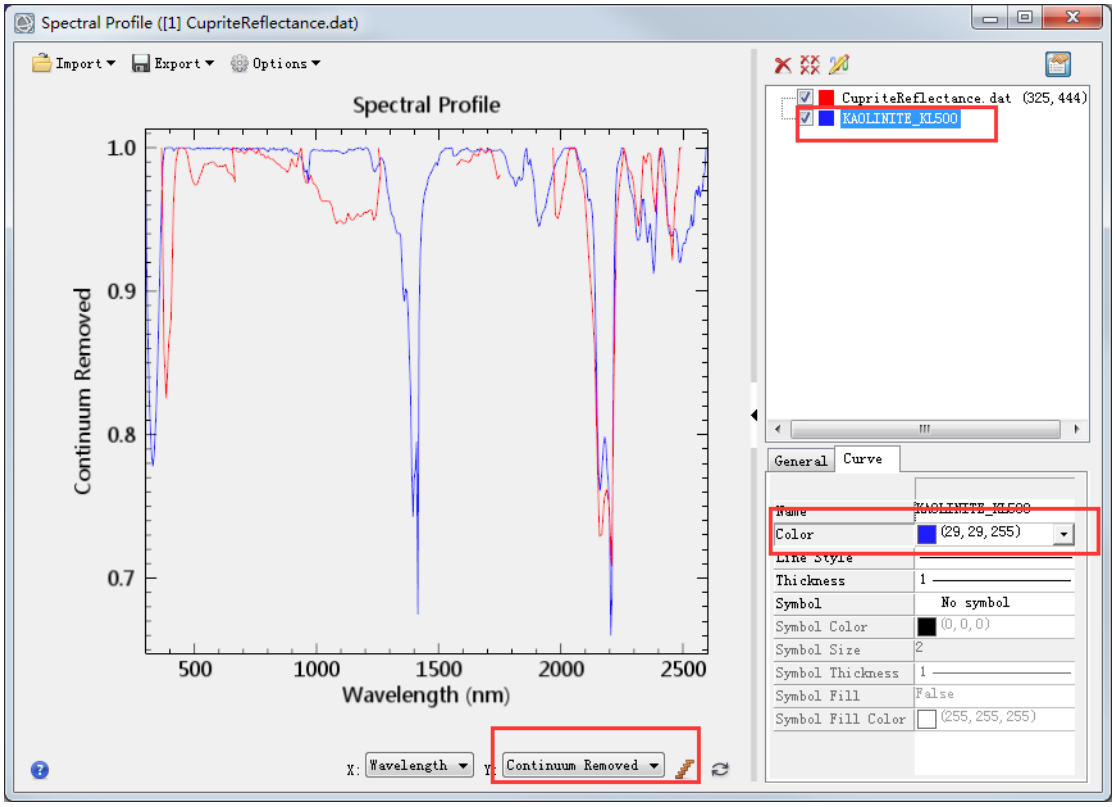
Reference: Baldridge, A. M., S. J. Hook, C. I. Grove, and G. Rivera, 2009. The ASTER Spectral Library Version 2.0. Remote Sensing of Environment, Vol. 113, pp. 711-715.

Spectral libraries are stored in ENVI spectral library (.sli) format, with each line of the image corresponding to an individual spectrum and each sample corresponding to an individual spectral measurement at a specific wavelength.

1. From the menu bar, select Display > Spectral Library Viewer.
2. On the left side of the Spectral Library Viewer, expand the igcp264 folder.
3. Expand the igcp_1.sli collection.
4. Click on the KAOLINITE_KL500 spectrum and note the shape and detail of the reflectance curve. Also note how the X and Y units of the spectral library plot are scaled differently from those of the image spectra in the Spectral Profile.
5. Click the Show button in the Spectral Library Viewer to see the plot key for the kaolinite spectrum that you selected.
6. Select the KAOLINITE_KL500 spectrum name from the plot key of the Spectral Library Viewer, and drag it to the Spectral Profile dialog. The Spectral Profile automatically scales the Y-axis to accomodate the two spectra, for direct comparison.

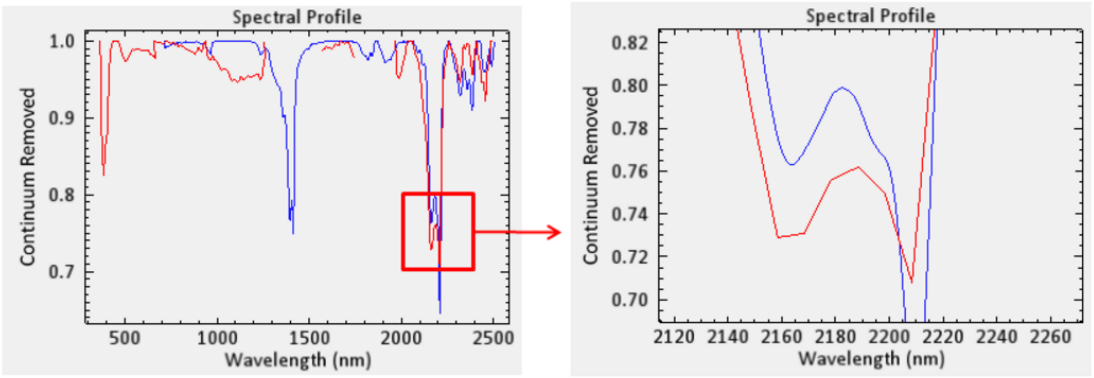


7. Select the KAOLINITE_KL500 spectrum in the plot key of the Spectral Profile, and select the Curve tab. Change its color to blue.
8. Continuum removal is a powerful visualization tool for spectral analysis, especially for absorption features. It normalizes the spectral signature so that you can compare individual absorption features from a common baseline. Select the Y: Data Value drop-down list and select Continuum Removed. The Spectral Profile should look like the following figure:



（作业图 1）

9. Zoom into the wavelength range of 2000 to 2500 nm shown in the figure below. If your mouse has a scroll wheel, click inside the plot window and roll the wheel to zoom in. Or, click-and-drag the scroll wheel to draw a box around the area you want to zoom into.



The double absorption features near 2200 nm offers a good reference point for comparing image spectra to library spectra. In the example above, the shape of the reflectance curve of the mineral kaolinite closely matches that of the image spectrum.

You could plot the spectra of other known materials from the spectral library, but

with hundreds of spectra available, that process could be time-consuming. ENVI has advanced spectral tools such as Spectral Feature Fitting (SFF), Spectral Angle Mapper (SAM), and Spectral Information Divergence (SID) that can measure the similarity between an unknown material and a reference material.

Another way to extract spectral profiles from an image is to create regions of interest (ROIs). Up to this point, you have extracted image spectra from a single pixel. With an ROI, you are extracting the mean spectra from all the pixels that comprise the ROI.

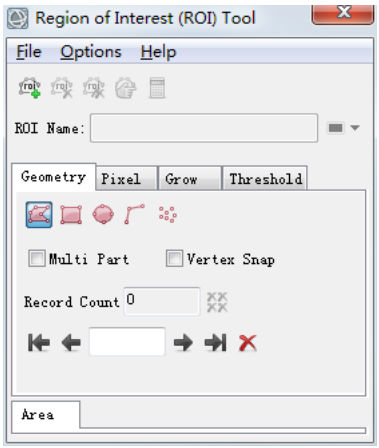
Close the Spectral Profile and Spectral Library Viewer in preparation for the next exercise.

Exercise 2. Extract Mean Spectra from ROIs

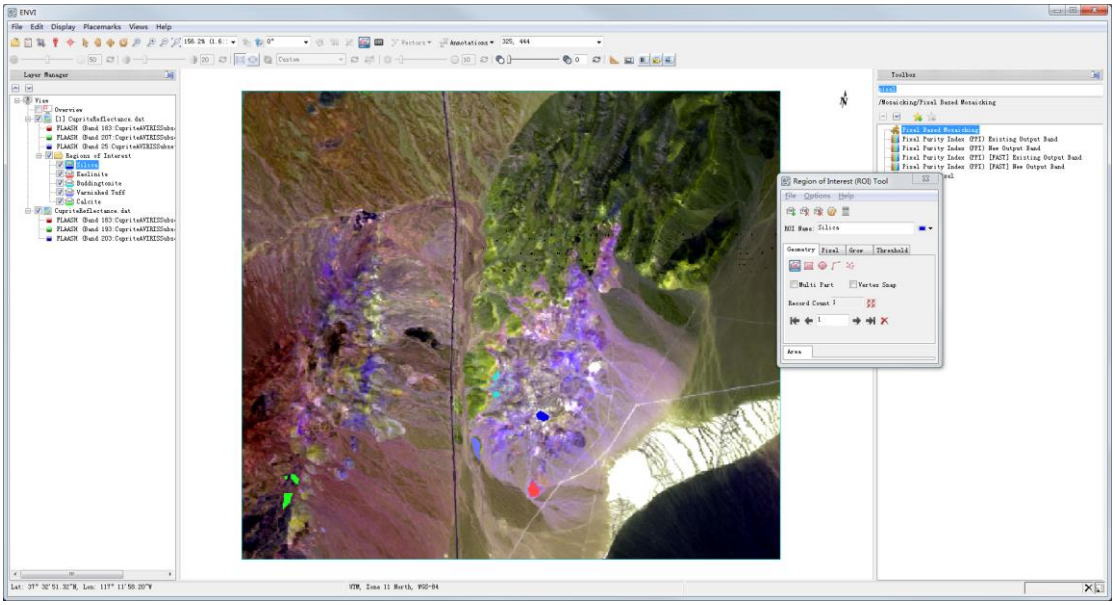
You can use ROIs to extract statistics and average spectra from groups of pixels. You can define as many ROIs as desired in a displayed image. See the Region of Interest Tool (ROI) topic for details on drawing ROIs.

In this exercise, you will view ROIs of known mineral types and extract mean spectra from the ROIs.

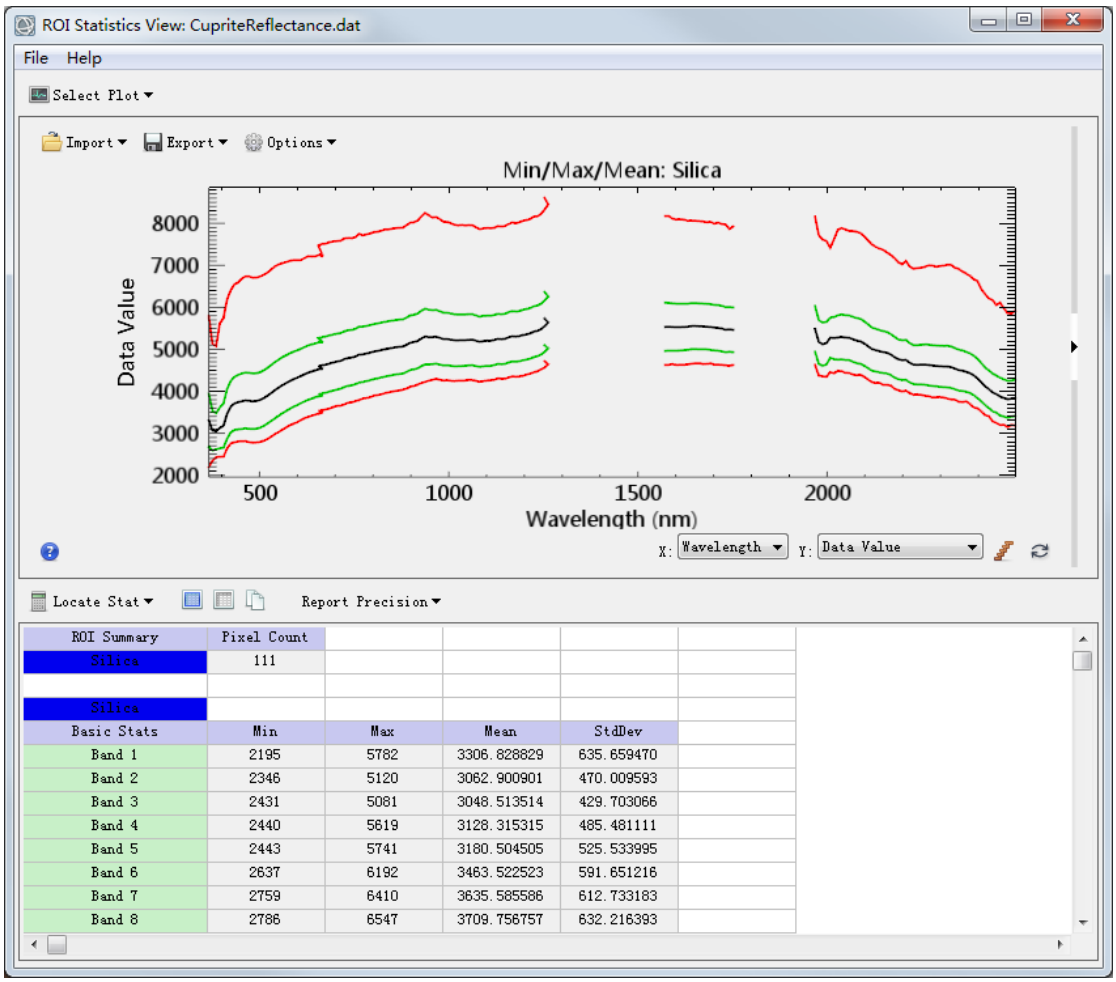
1. Click the Region of Interest Tool (ROI) button  in the toolbar.



2. From the ROI Tool menu bar, select File > Open.
3. Select the file CupriteMineralROIs.xml and click Open. This ROI file represents pixels where specific minerals are known to occur.

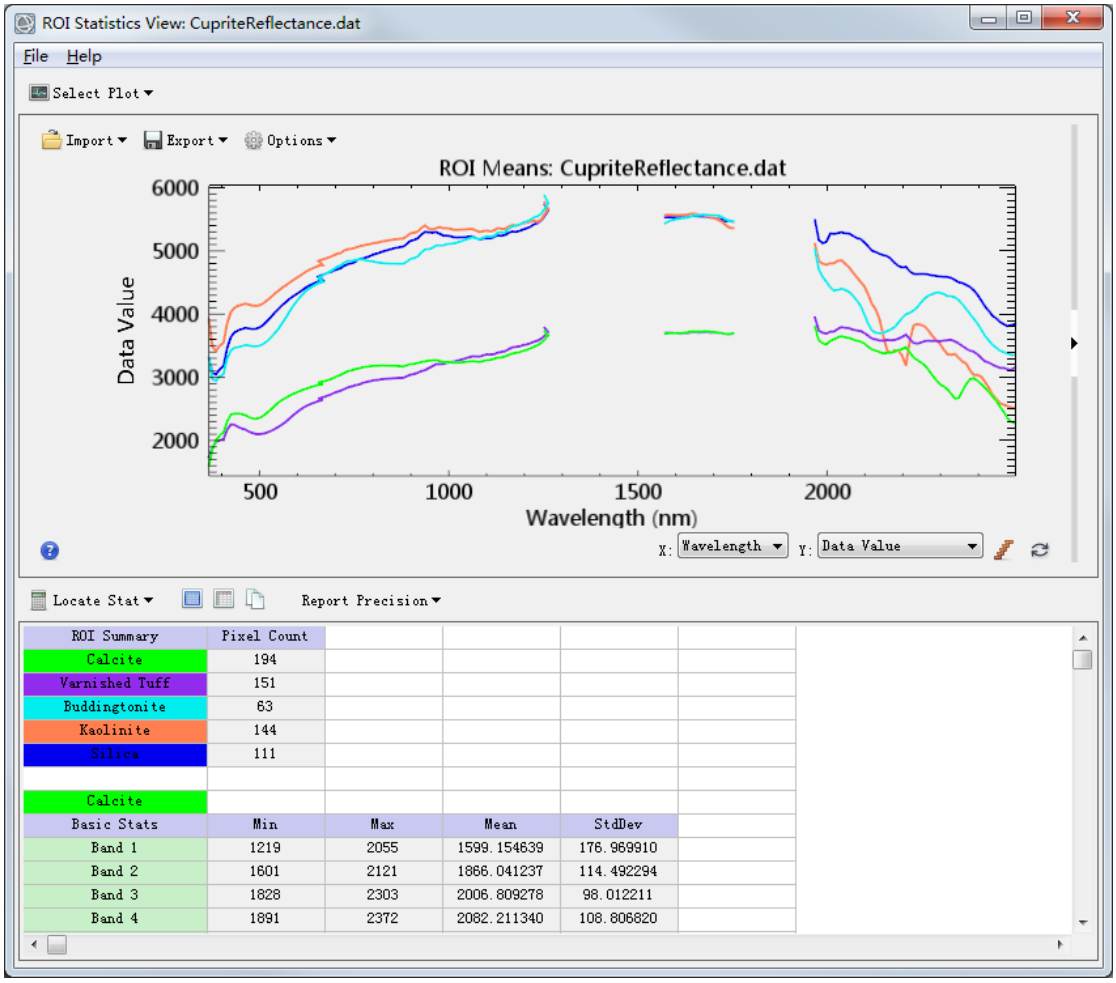


4. In the Select Base ROI Visualization Layer dialog, select CupriteReflectance, and click OK. The ROIs for each mineral type are listed in the Layer Manager. If the ENVI preference Auto Display File on Open is set to True, the ROIs will display on the image.
5. Right-click on any ROI in the Layer Manager and select Statistics. An ROI Statistics Results dialog appears with an embedded plot window that shows the following:



ROI Summary	Pixel Count				
Silica	111				
Silica					
Basic Stats	Min	Max	Mean	StdDev	
Band 1	2195	5782	3306.828829	635.659470	
Band 2	2346	5120	3062.900901	470.009593	
Band 3	2431	5081	3048.513514	429.703066	
Band 4	2440	5619	3128.315315	485.481111	
Band 5	2443	5741	3180.504505	525.533995	
Band 6	2637	6192	3463.522523	591.651216	
Band 7	2759	6410	3635.585586	612.733183	
Band 8	2786	6547	3709.756757	632.216393	

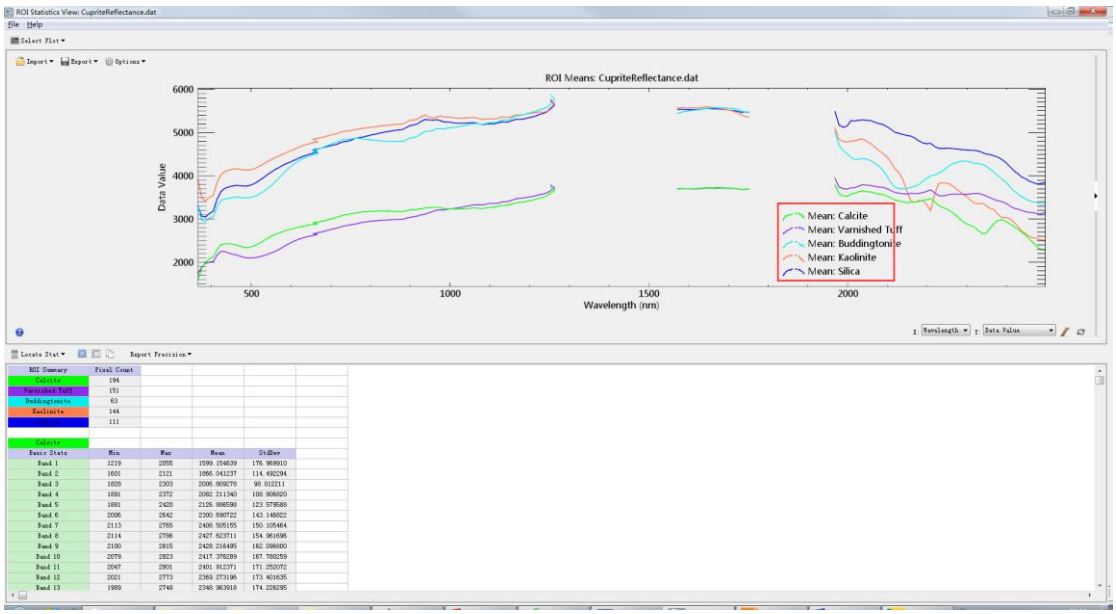
6. Close the ROI Statistics Results dialog.
7. Right-click on the Regions of Interest folder in the Layer Manager and select Statistics for All ROIs. The plot window shows the mean spectra for all ROIs.



ROI Summary	Pixel Count
Calcite	194
Varnished Tuff	151
Buddingtonite	63
Kaolinite	144
Silica	111

Calcite				
Basic Stats	Min	Max	Mean	StdDev
Band 1	1219	2055	1599.154639	176.969910
Band 2	1601	2121	1866.041237	114.492294
Band 3	1828	2303	2006.809278	98.012211
Band 4	1891	2372	2082.211340	108.806820

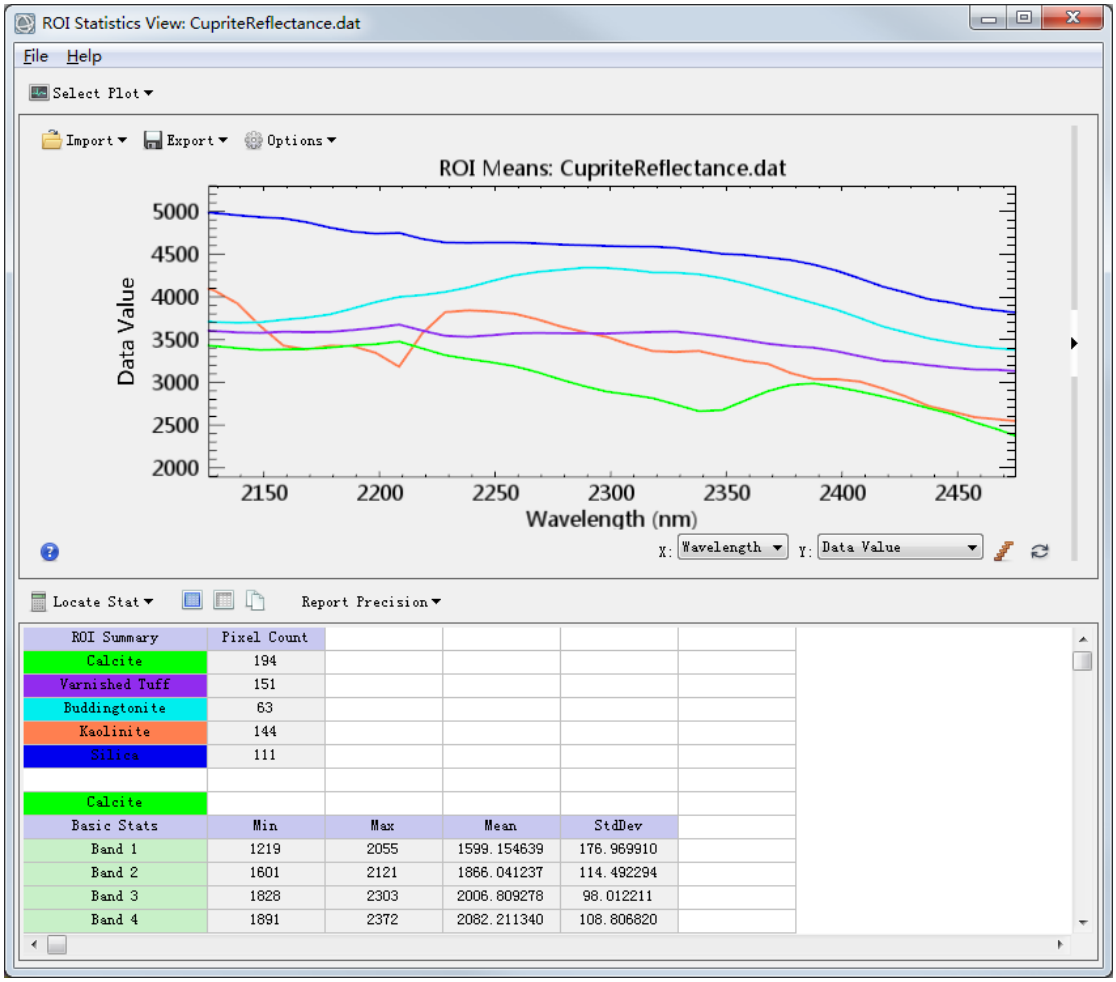
8. Right-click inside the plot window and select Legend.



（作业图 2）

9. Zoom into the wavelength range of 2000 to 2500 nm. If your mouse has a

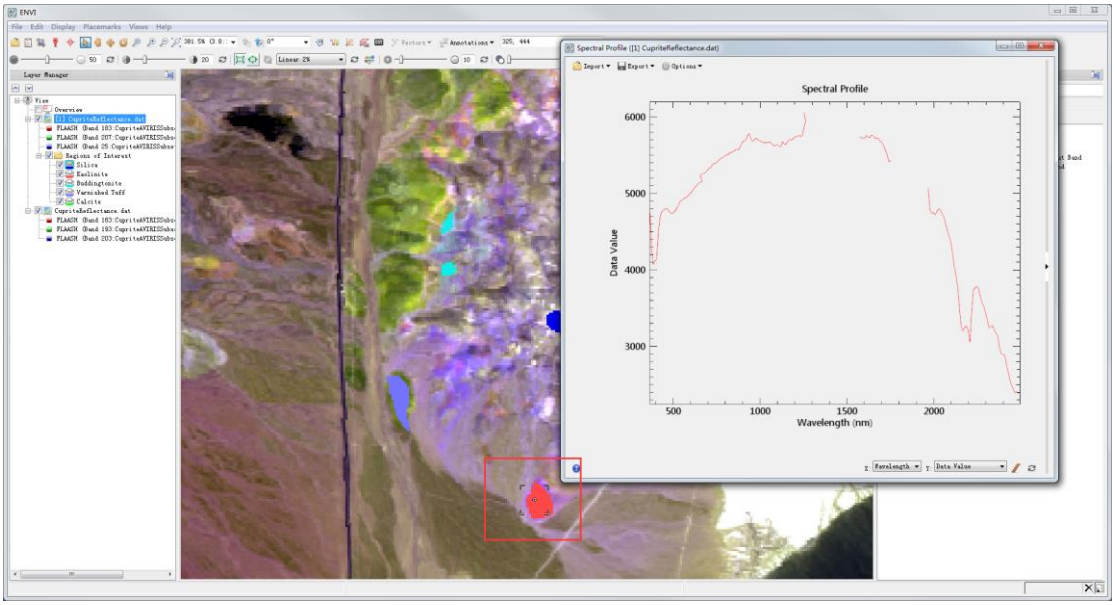
scroll wheel, click inside the plot window and roll the wheel to zoom in. Or, click-and-drag the scroll wheel to draw a box around the area you want to zoom into. The plot should look similar to the following figure:



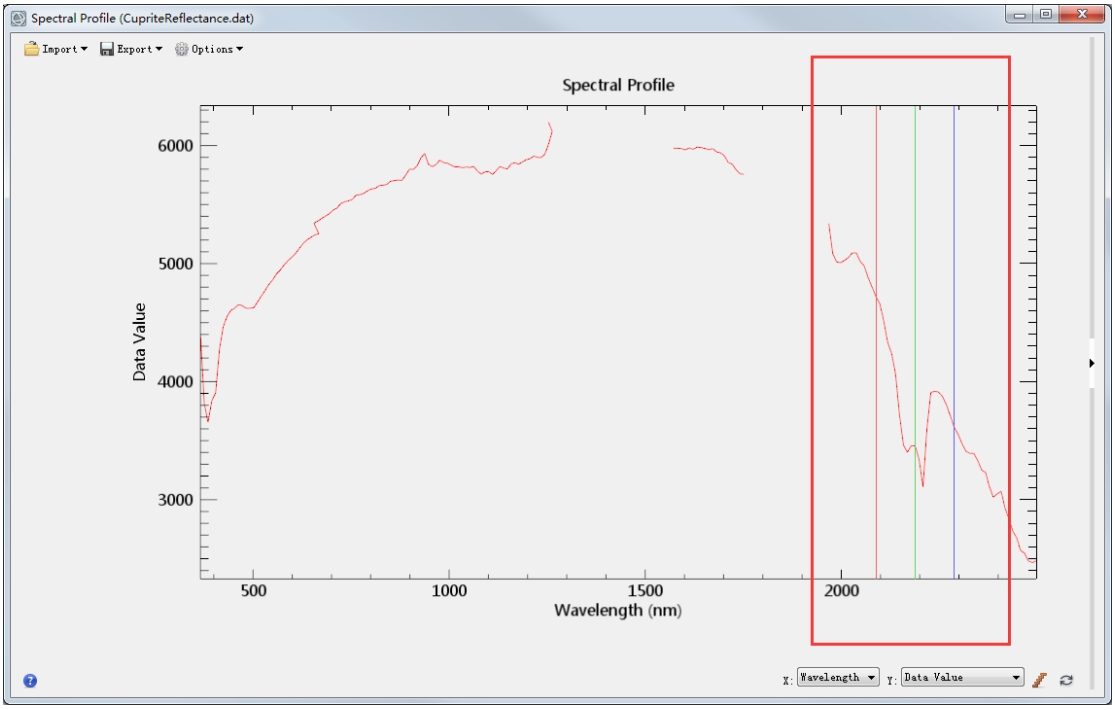
Exercise 3. Extract Mean Spectra from ROIs

In this exercise, you will design color images to help discriminate minerals.

1. Right-click on **[1] CupriteReflectance.dat** in the Layer Manager and select Profiles > Spectral Profile.
2. Click the Select button  in the ENVI toolbar.
3. Click inside of the red ROI that represents kaolinite in the lower/center part of the image. The Spectral Profile shows the spectrum for that pixel location.



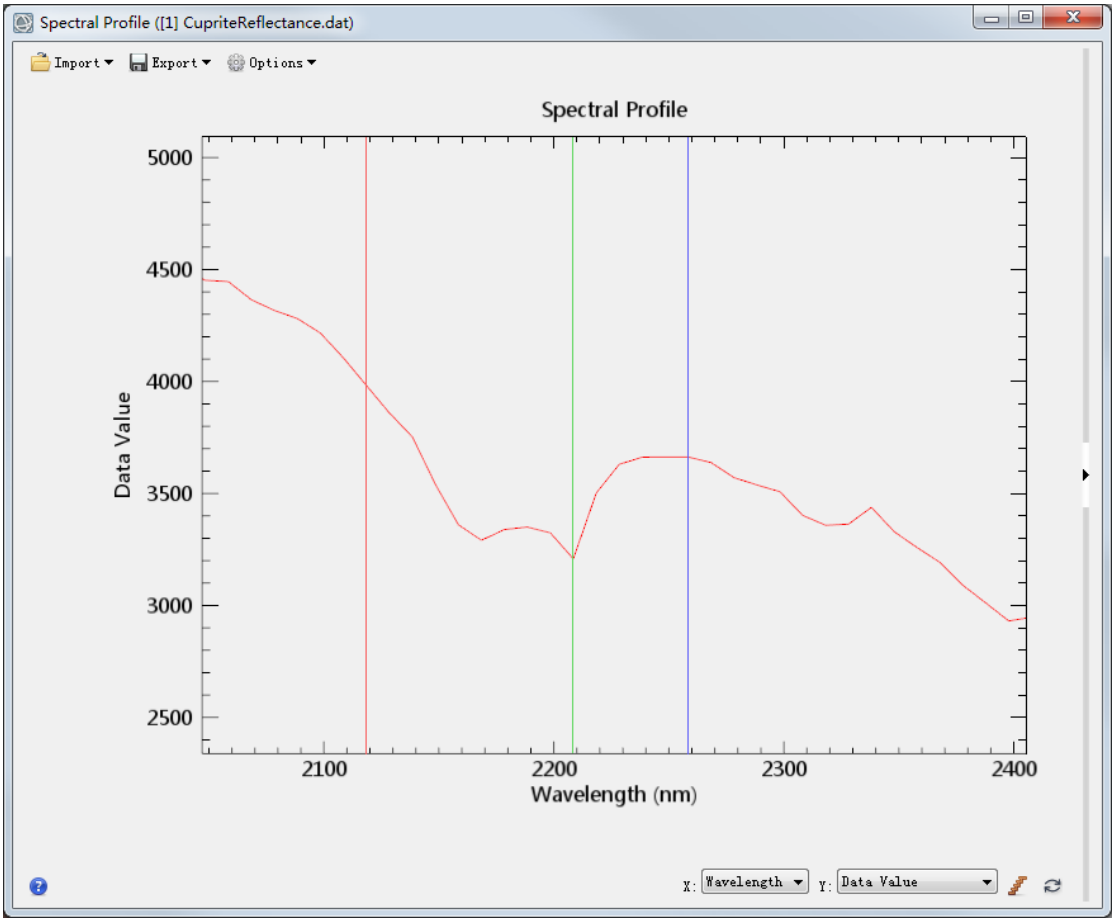
4. Right-click inside the Spectral Profile and select RGB Bars. Red, green, and blue vertical bars appear inside of the plot to show the wavelengths assigned to each channel. This is a quick visualization tool. If you look at the **[1] CupriteReflectance.dat** layer in the Layer Manager (you may need to scroll to the right in the Layer Manager), you can see the specific bands assigned to red, green, and blue: 2088.4851 nm, 2188.4890 nm, and 2328.1069 nm, respectively. The colored bars in the spectral profile plot confirm this.



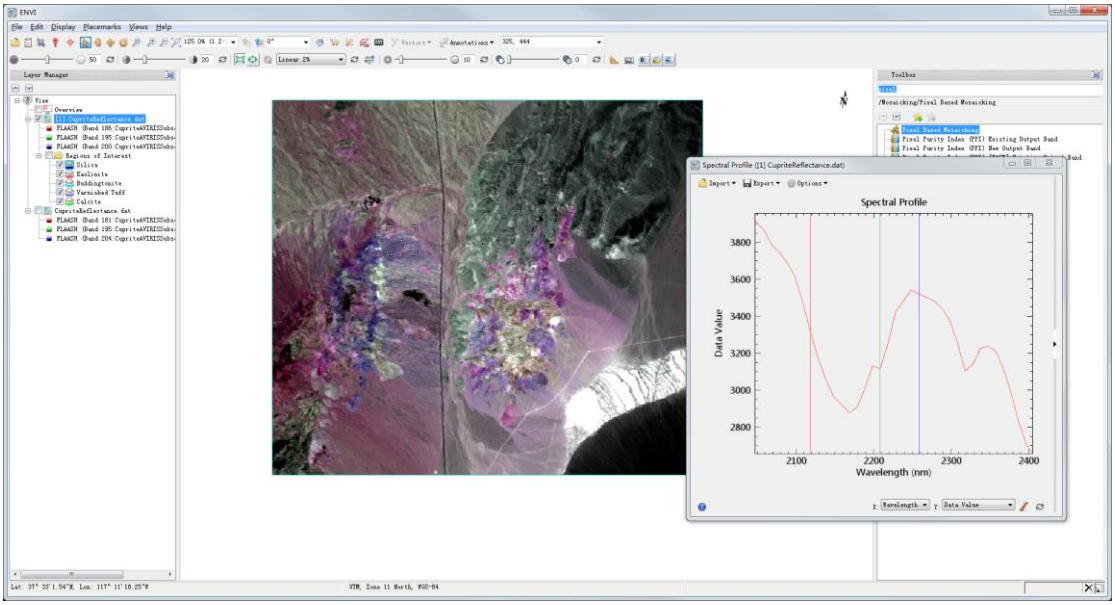
You can click and drag the colored bars to change them to other bands. This is a good

way to enhance specific minerals by centering one color bar in an absorption feature and the other two on opposite shoulders of the feature.

5. Zoom into the wavelength range of 2000 to 2500 nm. If your mouse has a scroll wheel, click inside the plot window and roll the wheel to zoom in. Or, click-and-drag the scroll wheel to draw a box around the area you want to zoom into.
6. Disable the Regions of Interest layer in the Layer Manager to hide the ROIs.
7. Click and drag the red, green, and blue bars to the location shown in the figure below.



8. Right-click in the Spectral Profile and select Load New Band Combination. Because the green channel falls within the absorption feature, green values will be low. The red and blue channels have a higher (and nearly equal) reflectance, resulting in a purple display in areas where kaolinite is abundant.



Exercise 4. SAM Classification

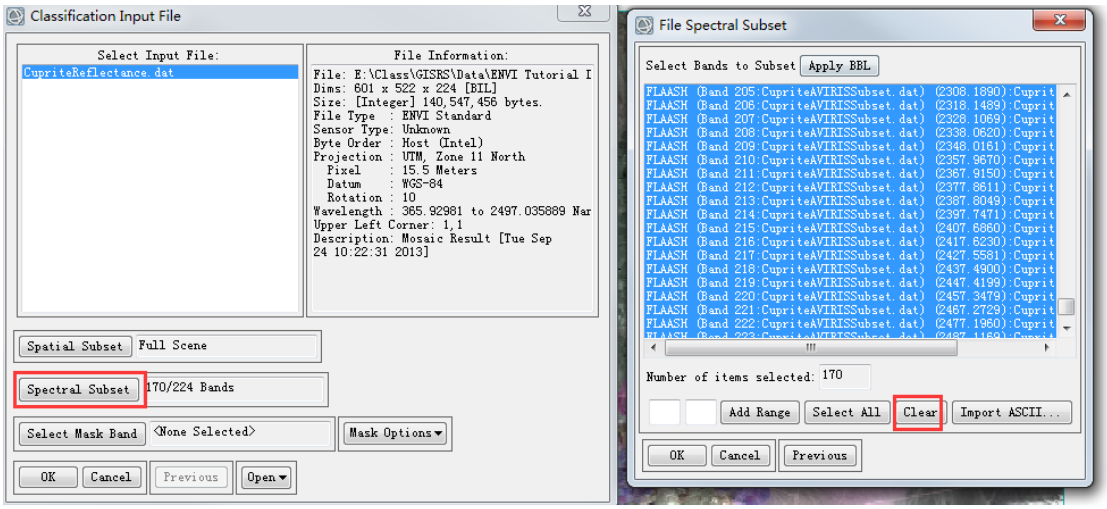
Several methods have been developed to identify ground-cover types in remote sensing imagery. Basic methods such as supervised classification produce a thematic map of the input image by measuring the similarity of image spectra to known references. Results from methods such as this are referred to as whole-pixel analysis methods because they attempt to answer the question, "Is a given material present in this image pixel?"

ENVI provides two whole-pixel analysis methods that are specially suited to hyperspectral imagery: SAM and SFF. Both are based on different principles and provide independent analyses of the same scene.

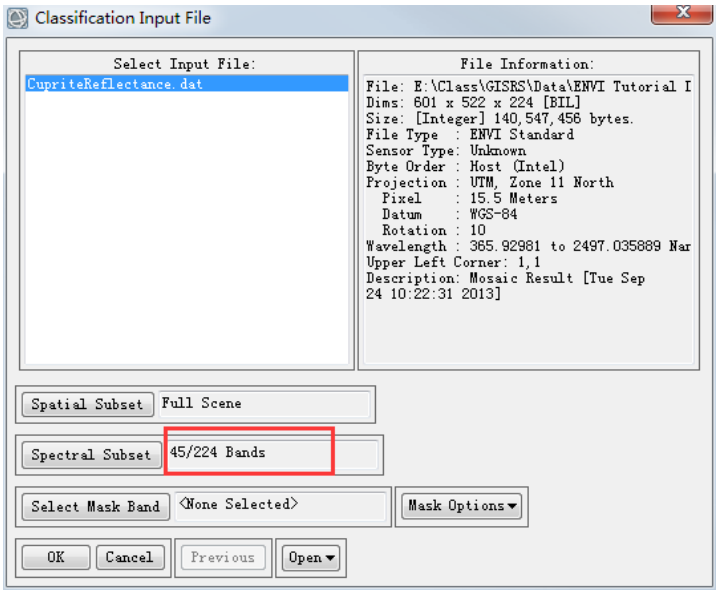
This exercise shows how to use SAM to classify different minerals in an AVIRIS image. For training data, you will import a region of interest (ROI) file of known mineral types in this image.

1. In the search field of the Toolbox, type spectral angle.
2. Double-click the Spectral Angle Mapper Classification tool name that appears.
3. In the Classification Input File dialog, select CupriteReflectance.dat but do not click OK yet.

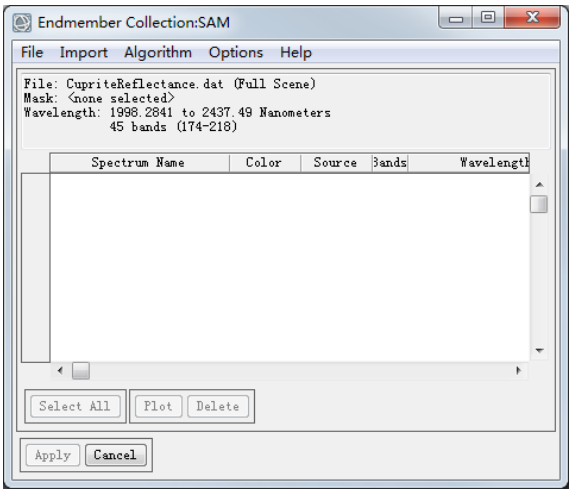
4. Click the Spectral Subset button.
5. Click the Clear button to clear the selection list.



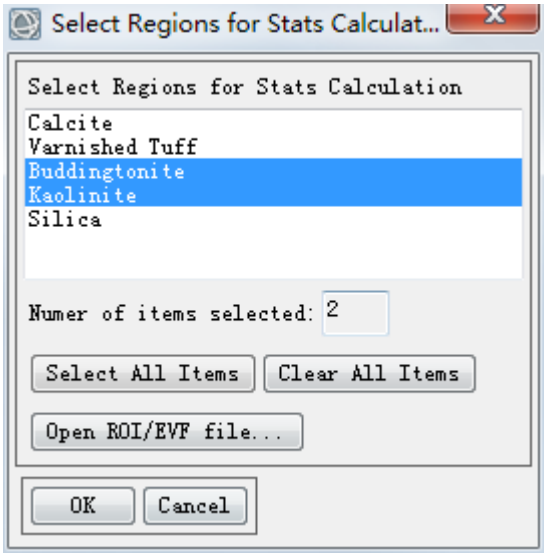
6. In this step, you will select bands that encompass characteristic absorption features of minerals in the range of 1998 to 2437 nanometers. Click Band 174, hold down the Shift key on your keyboard, and click Band 218.
7. Click the Add Range button, then OK in both the File Spectral Subset dialog and the Classification Input File dialog.



8. Click OK:

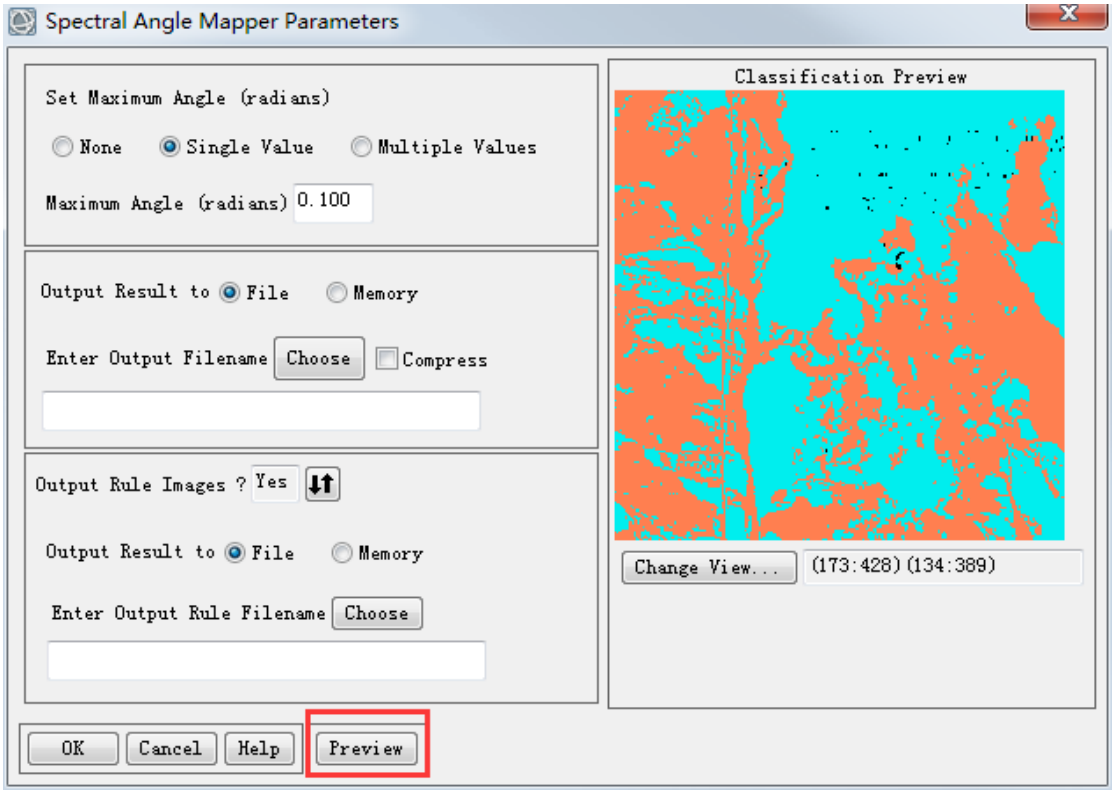


9. The Endmember Collection dialog is used for any classification and mapping tool that requires you to specify reference spectra. Using the Algorithm menu, you can apply any classification method to the selected image and reference spectra. Notice that Spectral Angle Mapper is the selected method under the Algorithm menu.
10. From the Endmember Collection dialog menu bar, select Import > from ROI/EVF from input file. The next dialog lists the individual ROIs that are available.
11. For this exercise, you will just analyze two minerals. Use the Ctrl key on your keyboard to select Buddingtonite and Kaolinite, then click OK.



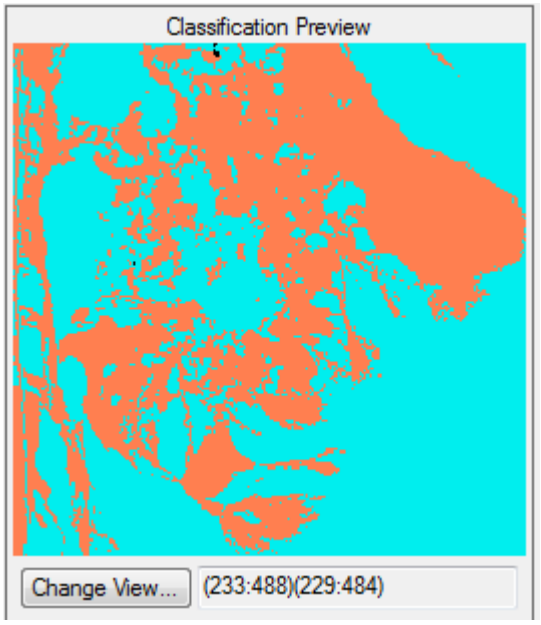
12. Click the Select All button in the Endmember Collection dialog, then click Apply.

13. In the Spectral Angle Mapper Parameters dialog, you can preview the initial classification before continuing. Click the Preview button.

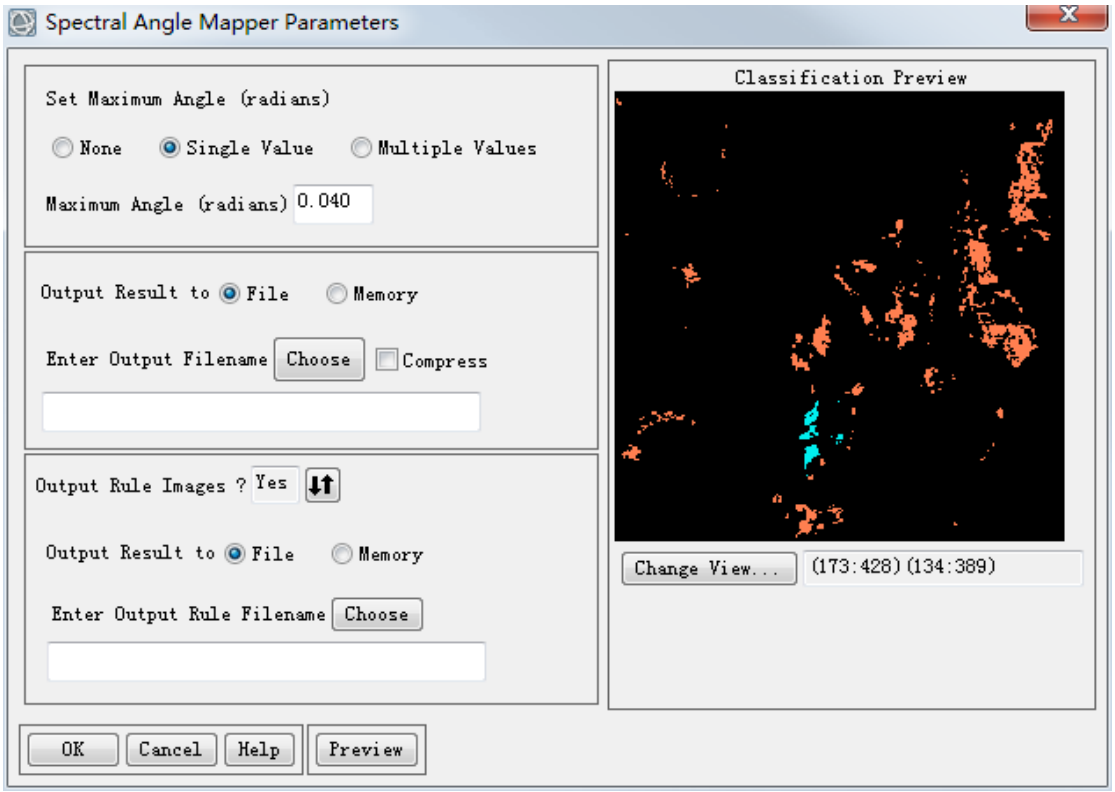


14. The preview is restricted to a 256 x 256 pixel bounding box. Follow these steps to change the location of the bounding box:
    a) Click the Change View button underneath the preview.
    b) Click the Image button in the Select Spatial Subset dialog.
    c) Move the red bounding box to a different location.
    d) Click OK in the Subset by Image dialog, then again in the Select Spatial Subset dialog.

The preview updates to show the new location. Notice that the initial classification image is comprised entirely of the buddingtonite and kaolinite classes, as the following example shows. This is not accurate, so you need to lower the spectral angle so that the SAM classification is more restrictive.

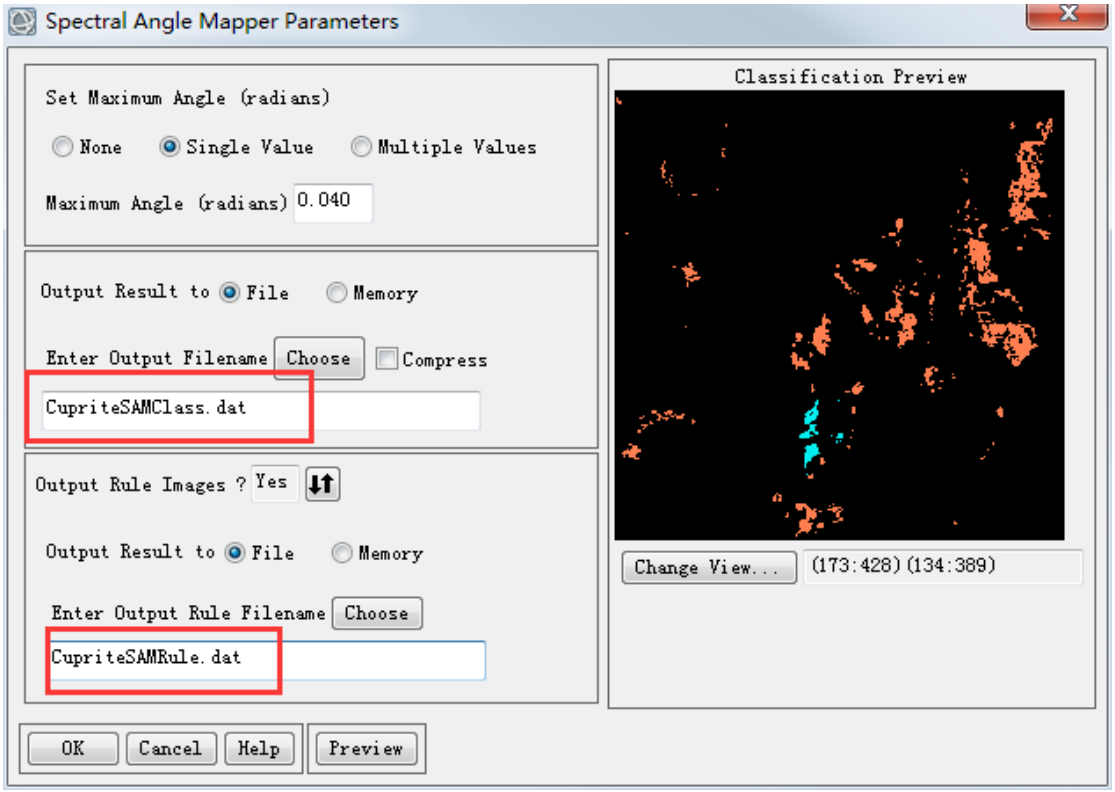


15. In the Spectral Angle Mapper Parameters dialog, change the Maximum Angle (radians) value to 0.04.
16. Click Preview. Now more pixels are unclassified (black), leaving the buddingtonite and kaolinite classes with fewer pixels:

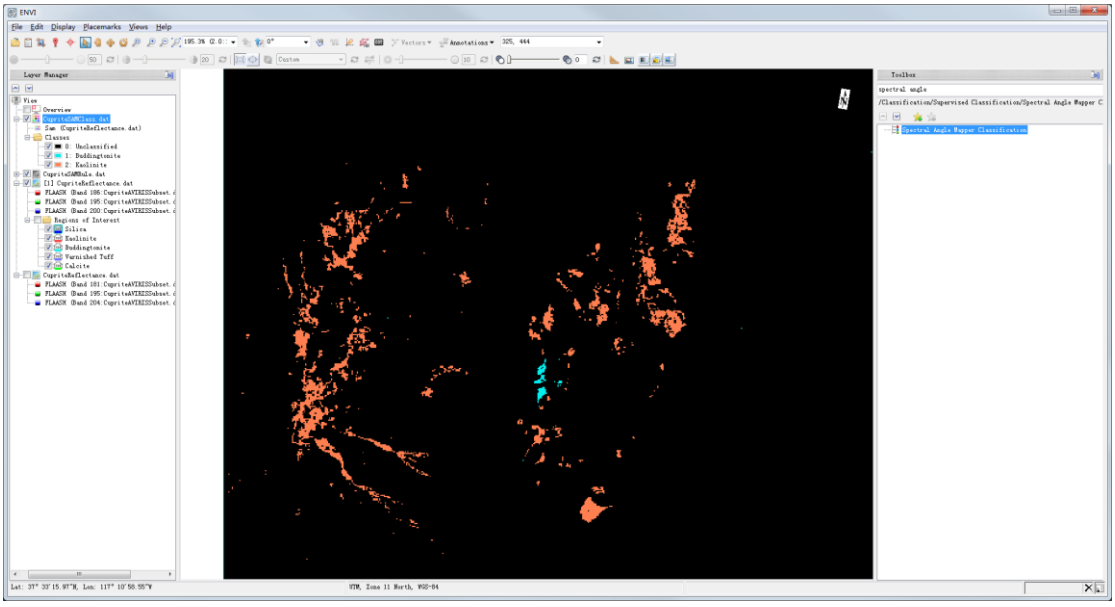


17. Experiment with a different value to apply to both classes (using the Single Value button), or click Multiple Values and assign different maximum angle values to each class.

18. In the center part of the Spectral Angle Mapper Parameters dialog, enter the filename CupriteSAMClass.dat for the SAM classification image.
19. Leave the default selection of Yes for Output Rule Images?, then enter the filename CupriteSAMRule.dat for the rule file.



20. Click OK to start the classification. When processing is complete, the Layer Manager lists the classification image and buddingtonite rule image. The classification image appears in the display.



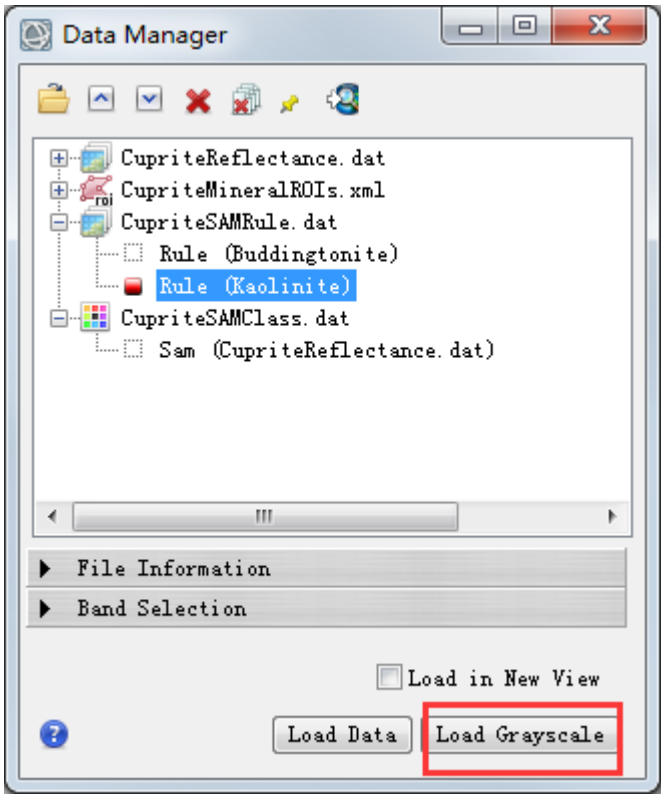
21. Close the Endmember Collection dialog.

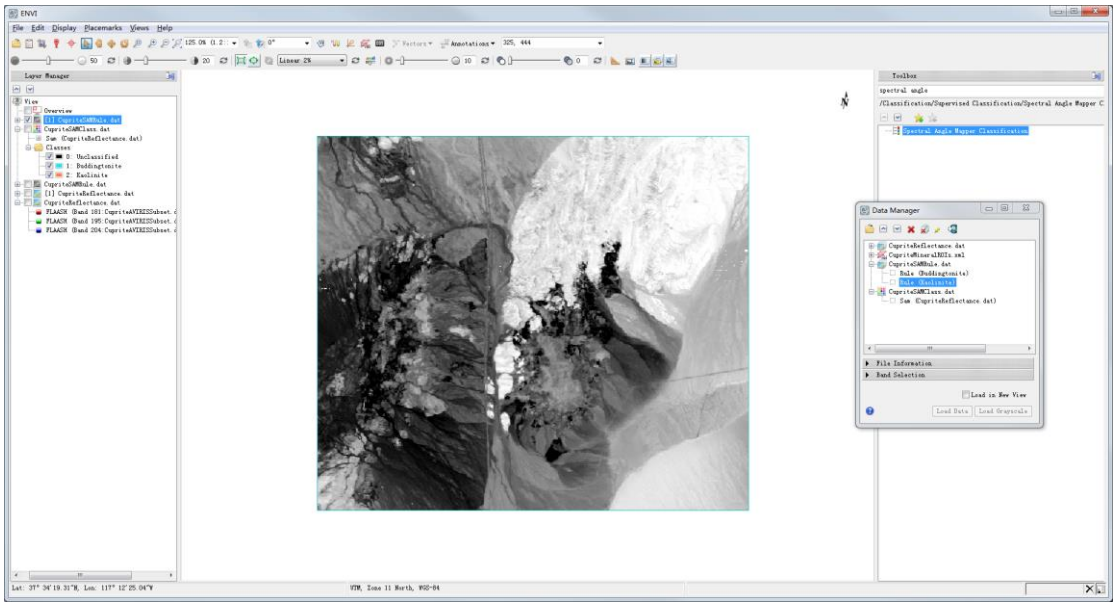
Exercise 5. View Rule Images

Rule images are helpful in interpreting classification data. For the SAM classifier, rule images show the similarity between the image pixel's spectrum and the reference spectra from training data. Darker pixels in the rule images represent smaller spectral angles and thus image spectra that are more similar to the reference spectrum.

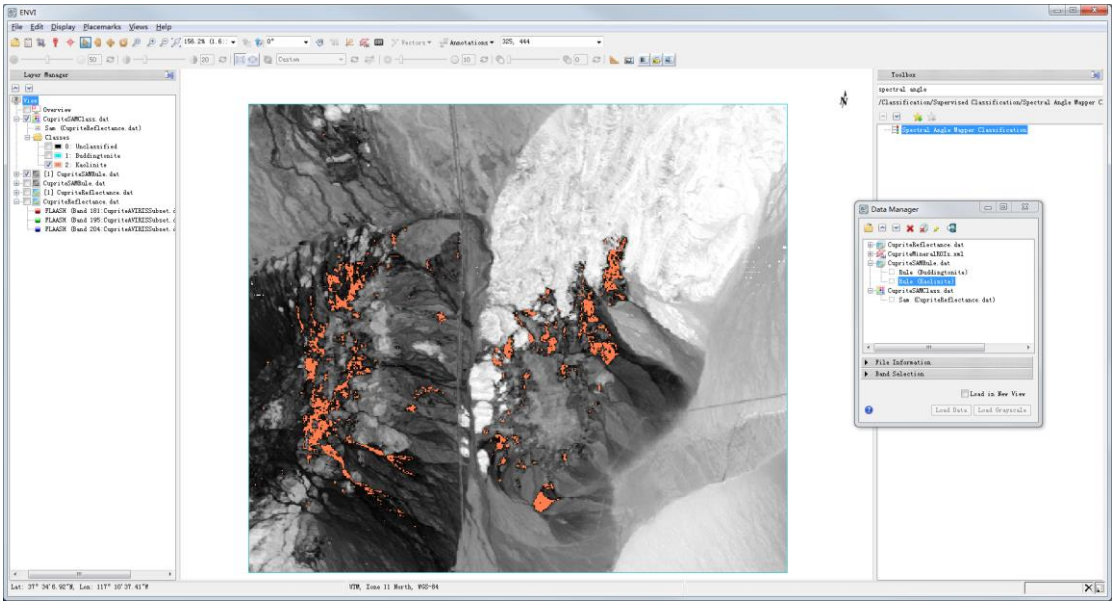
The rule file that you just created (CupriteSAMRule.dat) contains two bands: one each for the buddingtonite and kaolinite rule images. ENVI only lists one band in the Layer Manager (buddingtonite).

1. Before you view the rule images, use the check boxes to turn off the following layers in the Layer Manager:
   - Unclassified and Buddingtonite classes, under the Classes folder of CupriteSAMClass
   - CupriteReflectance.dat
   - Regions of Interest
2. Click the Data Manager button in the toolbar. Scroll to the bottom of the file list until you see CupriteSAMRule.
3. Select Rule (Kaolinite) and click the Load Grayscale button. The kaolinite rule image appears in the display.



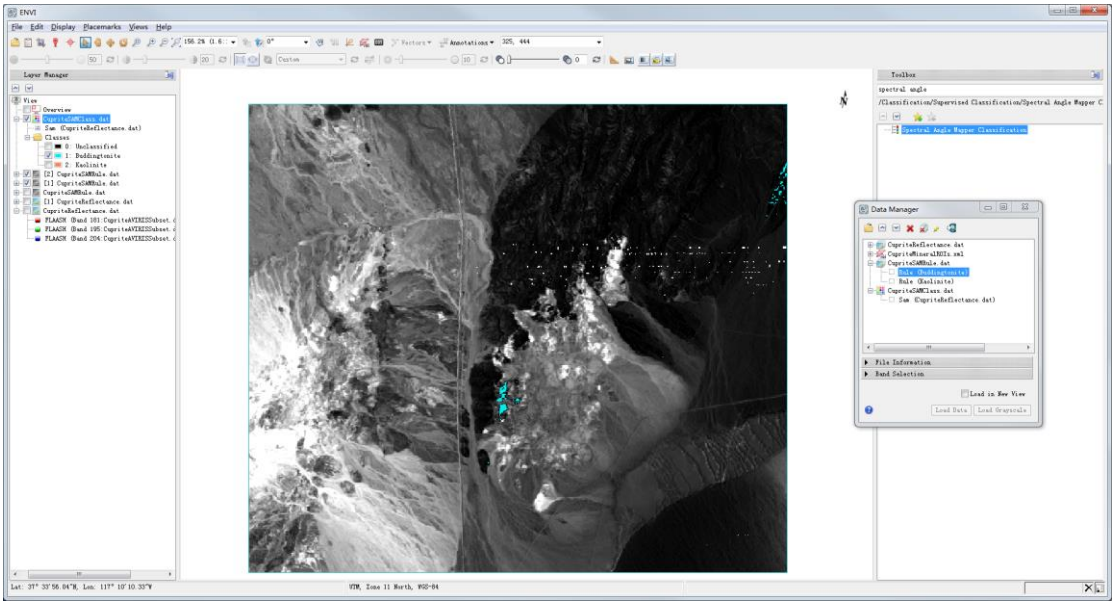


4. Select the CupriteSAMClass layer in the Layer Manager, and drag it above the layer that contains the kaolinite rule image. The kaolinite class from the SAM classification image displays on top of the kaolinite rule image. The following figure shows an example



（作业图 3）

5. Toggle the Kaolinite class on and off, to compare the classification results against the rule image. The darkest pixels in the rule image represent the closest matches to the ROI training data, in terms of spectral angle.
6. Repeat the previous two steps for the Buddingtonite class. Compare the classification results against the buddingtonite rule image.



（作业图 4）

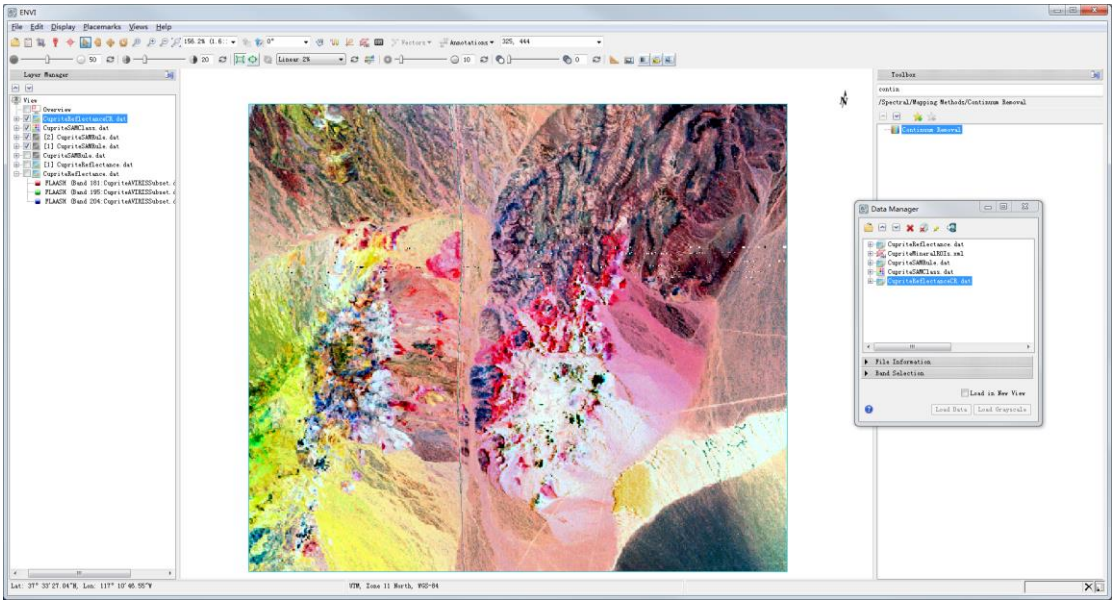
7. To prepare for the next exercise, open the Data Manager and close all files except for CupriteReflectance.dat.

Exercise 6. Spectral Feature Fitting

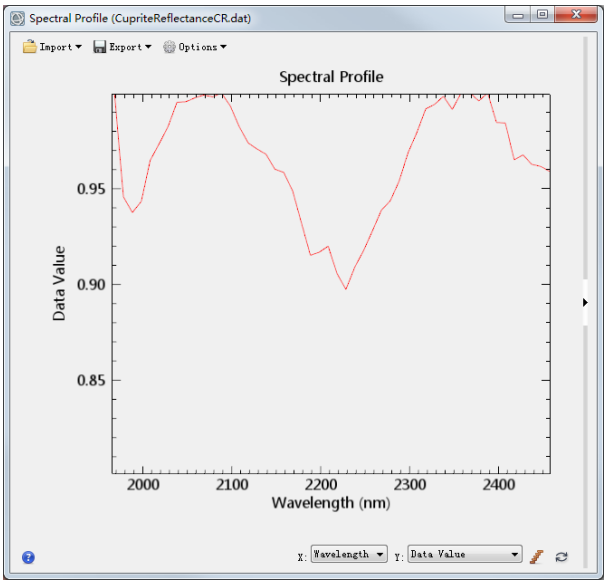
Spectral Feature Fitting (SFF) compares a specific absorption feature from each image pixel to that of a known reference spectrum. Pixels whose absorption feature spectra match well in width and depth are likely to have a higher abundance of the material of interest. SFF works best with materials that have unique and detailed absorption features such as minerals and some man-made features. In contrast, it does not work well with general categories of materials such as vegetation and water. The reference spectra for this exercise come from spectral libraries of minerals.

In this exercise, you will remove the continuum spectrum from the AVIRIS scene, plot a library spectrum of the mineral alunite, then create SFF scale and RMS images that show how well the image spectra match the absorption feature of the library spectrum.

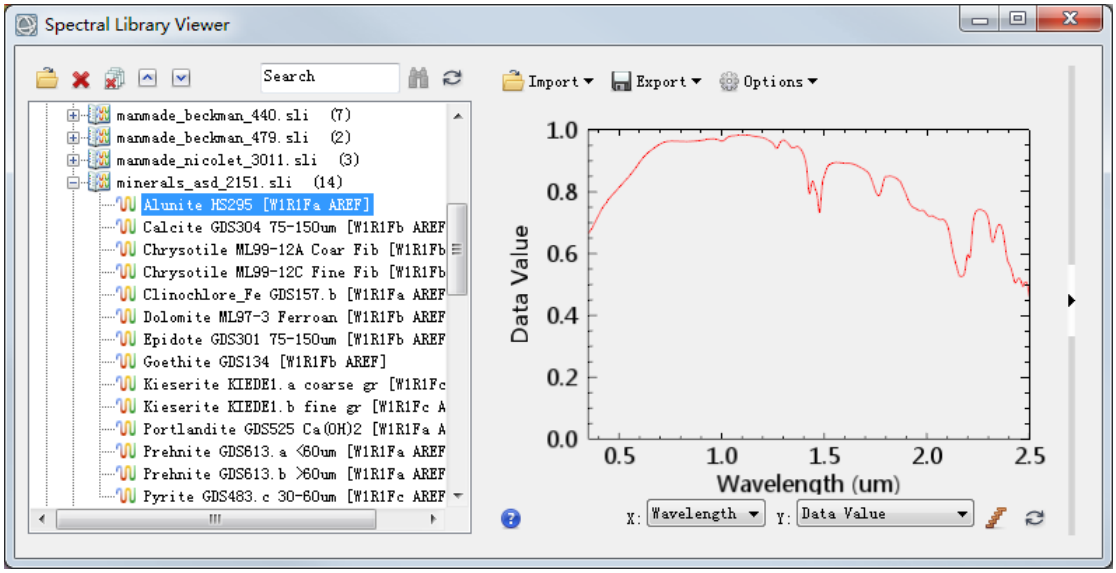
1. In the search field of the Toolbox, type contin.
2. Double-click the Continuum Removal tool name that appears.
3. In the Continuum Removal Input File dialog, select CupriteReflectance.dat and click OK.
4. In the Continuum Removal Parameters dialog, enter an output filename of CupriteReflectanceCR.dat and click OK.



5. When processing is complete, right-click on the CupriteReflectanceCR.dat layer in the Layer Manager and select Profiles > Spectral.
6. Zoom into the wavelength range of 2000 to 2400 nm. The following example shows the spectrum from pixel location (391, 307). If your mouse has a scroll wheel, click inside the plot window and roll the wheel to zoom in. Or, click-and-drag the scroll wheel to draw a box around the area you want to zoom into. Notice how the absorption features are enhanced by removing the continuum from the image spectrum:



7. Collect Reference Spectra
   a) From the ENVI menu bar, select Display > Spectral Library Viewer.
   b) On the left side of the Spectral Library Viewer, expand the usgs (1994) folder.
   c) Expand the minerals_asd_2151.sli collection.
   d) Select the Alunite HS295 spectrum.



8. Run Spectral Feature Fitting

   a) In the search window of the toolbox, type spectral feature.

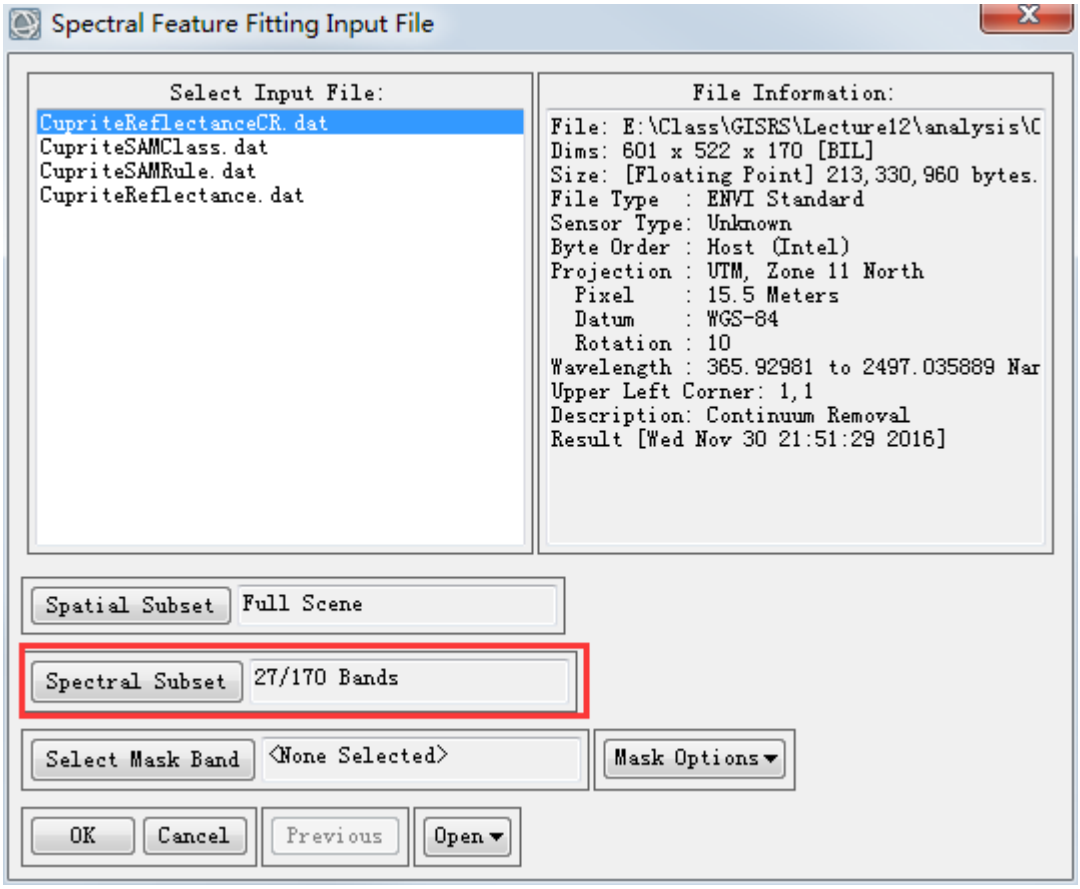
   b) Double-click the Spectral Feature Fitting tool name that appears.

   c) Select the input file CupriteReflectanceCR.dat, but do not click OK yet.

   d) Click the Spectral Subset button.

   e) Click the Clear button.

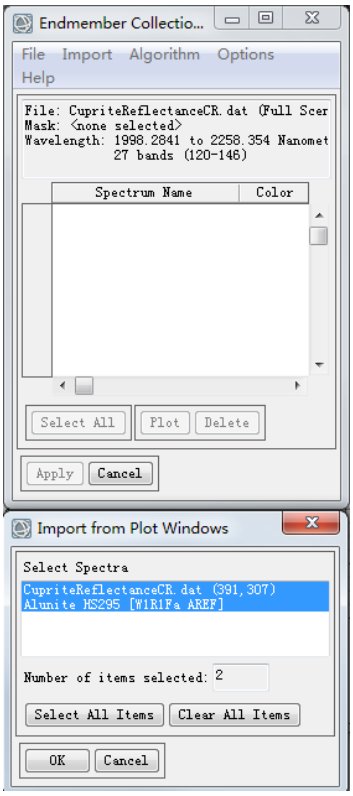
   f) You will obtain best results from SFF if you narrow the spectral range to include only one absorption feature of interest. In this step, you will select bands that encompass the characteristic absorption feature from 2000 to 2250 nanometers. ClickBand 174, hold down the Shift key on your keyboard, and click Band 200.



g) Click OK in the Spectral Feature Fitting Input File dialog.

h) In this step, you will import reference spectra from the spectral library. From the Endmember Collection dialog menu bar, select Import > from Plot Windows.

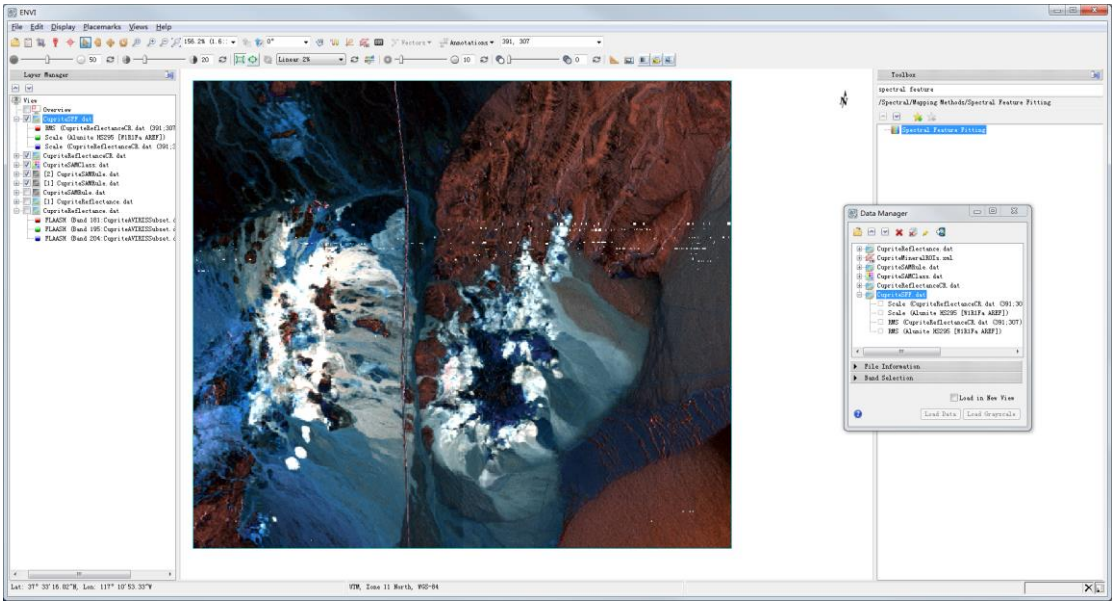
i) In the Import from Plot Windows dialog, click Select All Items, then OK.



j) Click Apply in the Endmember Collection dialog.

k) In the Spectral Feature Fitting Parameters dialog, the toggle button is set to Output separate Scale and RMS Images, which is correct for this exercise. With this option, ENVI creates a Scale and RMS image for each spectral endmember.

l) Enter an output filename of CupriteSFF.dat, then click OK.



m) Close the Spectral Library Viewer and Endmember Collection dialogs.

9. View Scale and RMS Images

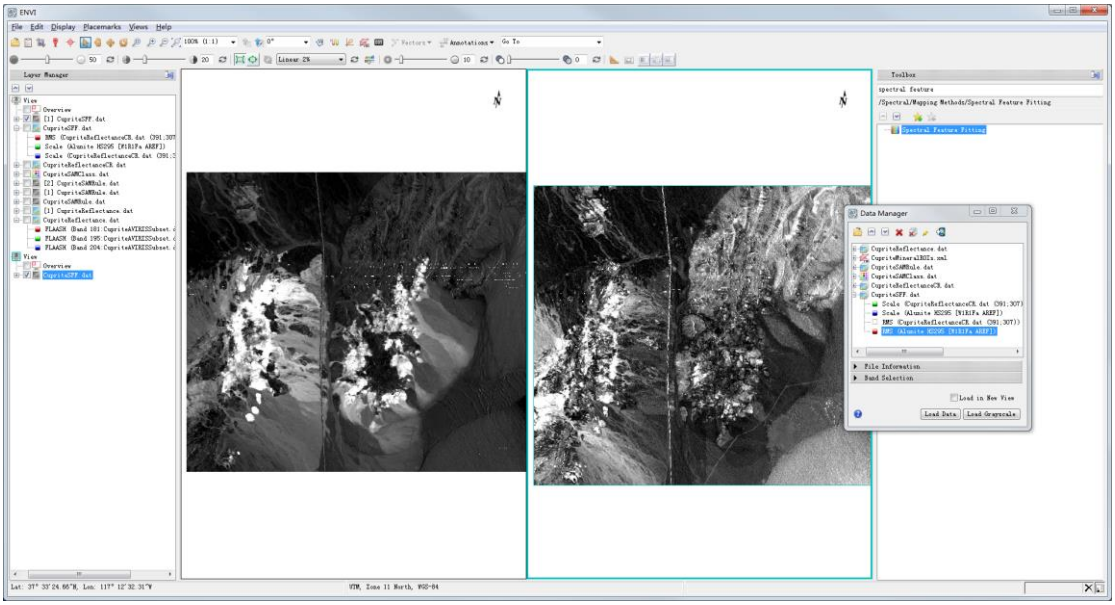
a) Un-check all layers in the Layer Manager.

b) From the ENVI menu bar, select Views > Two Vertical Views.

c) Click the Data Manager button in the toolbar. Scroll to the bottom of the file list until you see CupriteSFF.dat.

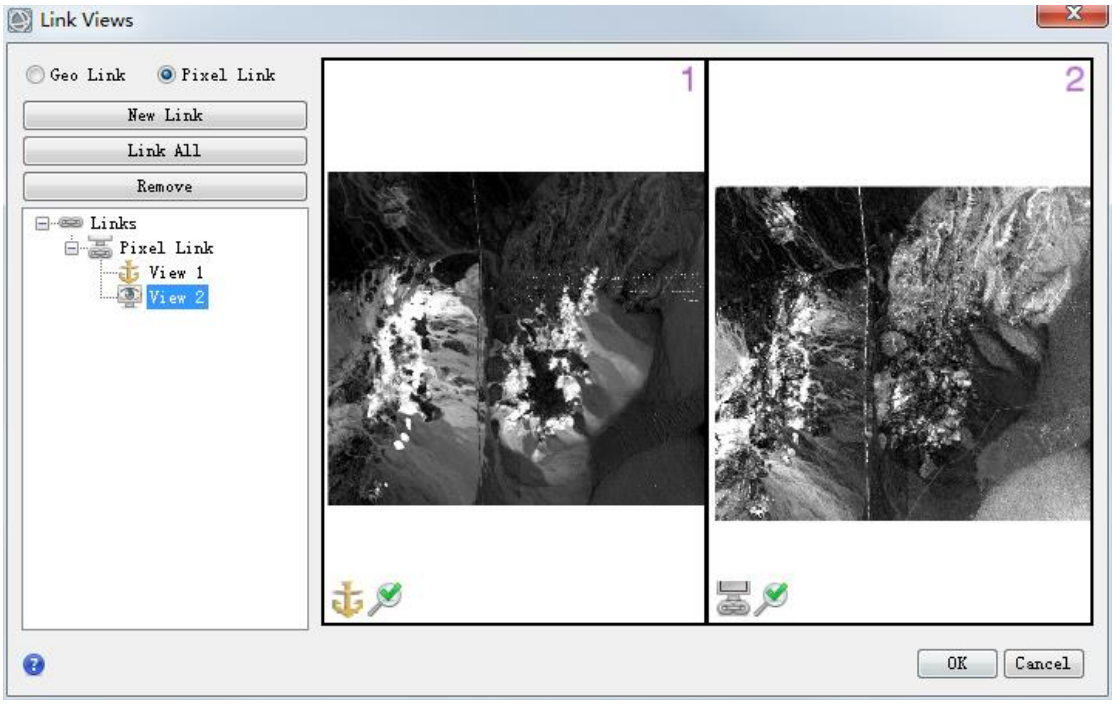
d) Drag and drop the Scale band name into the left view.

e) Drag and drop the RMS band name into the right view.



f) From the menu bar, select Views > Link Views. You will create a geographic link between the views.

g) The Geo Link option is already selected in the Link Views dialog. Click the Link All button, then OK. Now when you pan around one view, the other view pans accordingly.

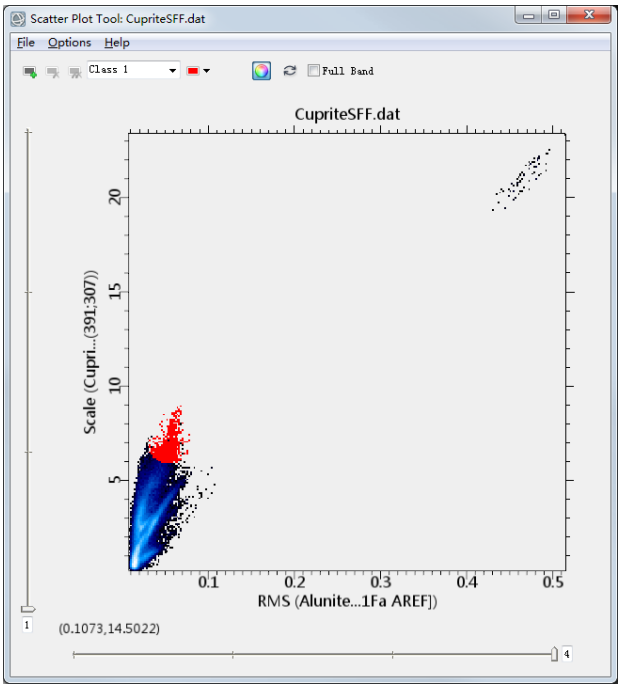


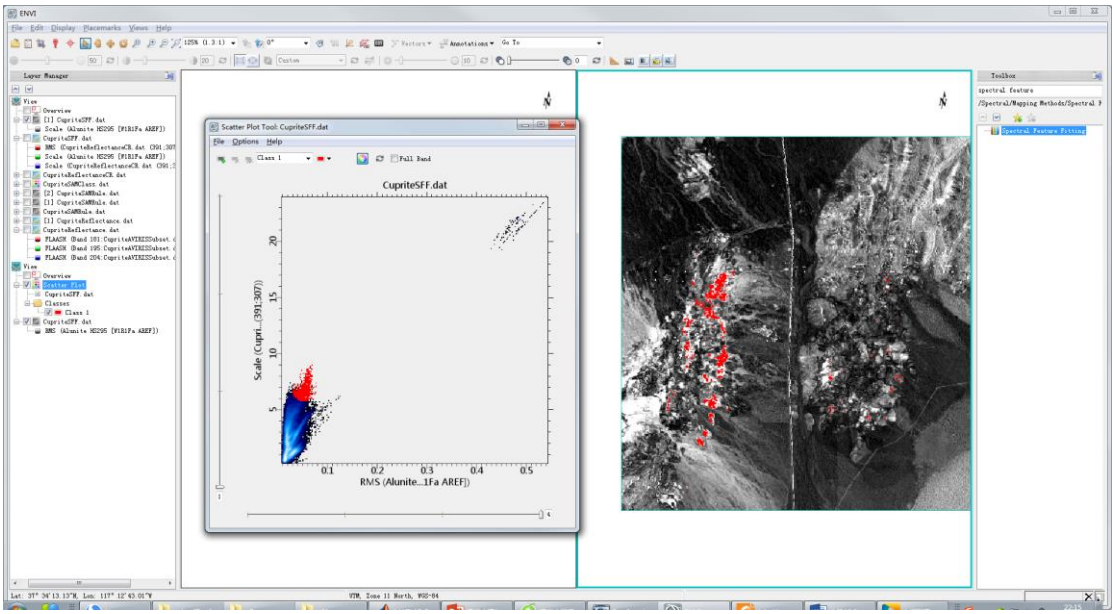
Bright areas in the Scale image indicates pixels whose absorption features are similar in depth and width to those of the alunite library spectrum. Dark areas in the RMS image indicate low RMS errors. A better analysis technique is to compare the Scale image against the RMS image. You have two options for this: (1) create a band-ratio image of the Scale and RMS images, and (2) create a scatter plot between the Scale and RMS images. For this exercise, you will create a scatter plot to look for areas where the spectral fit is good.

10. Create a Scatter Plot of Scale vs. RMS Image

    a) From the menu bar, select Display > 2D Scatter Plot. In the Scatter Plot Tool dialog, note that the RMS band is assigned to the x-axis. The Scale band is assigned to the y-axis.

    b) Draw a polygon around a group of pixels where the RMS values are low and the Scale values are high. You can click repeatedly to define segments of a polygon, or hold down the left mouse button to draw a continuous polygon. Right-click to accept the polygon. Pixels in the image that correspond to the scatter plot points are highlighted in red. These pixels have a good spectral fit for the alunite absorption feature. The following figure shows an example.


Scatter Plot Tool: CupriteSFF.dat
File Options Help
Class 1
Full Band
CupriteSFF.dat
Scale (Cupri...(391:307))
RMS (Alunite...1Fa AREF])
(0.1073,14.5022)



（作业图 5）