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P.6

CAUSES OF SPURIOUS FEATURES IN SPECTRAL REFLECTANCE DATA

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ABSTRACT

Several techniques are becoming common in the analysis of imaging spectrometer data that can lead to spurious absorption features or to changes in the position, width, and shape of actual absorption features. It is a common practice to calibrate AIS or other imaging spectrometer data by averaging each pixel along the flight line. The average is used to calibrate the spectral data by dividing the spectrum at each pixel by the average. If some pixels in the data set contain an absorption, then the average will also show an absorption. Some AIS data has had problems with wavelength stability from one scan line to the next (e.g. Vane, 1986 and references therein) which can produce spurious features with some analysis methods. If a pixel has a spectrum with an absorption having a different position or width than the spectrum used in a ratio, then the ratio can produce a spurious absorption at a different position and width than the true absorption feature. An average spectrum ratioed to each pixel will produce band shifts, and changes in width or shape. If continuum removal is performed by subtraction rather than division, band positions can also be shifted.

SPURIOUS BAND SHIFTS AND FEATURES

Consider two spectra that are to be ratioed. In the analysis of imaging spectrometer data, the spectrum on the numerator would likely be a spectrum from an individual pixel or a small group of pixels having similar spectral features. The spectrum on the denominator usually represents some form of calibration data set. The calibration could consist of an average of all pixels in the scene or the log residual (e.g. Green and Craig, 1985). In cases such as these the denominator spectrum could have residual features in the spectra due to the minerals on the surface. The denominator spectral features can be different than those in the numerator if there is a wavelength instability in the instrument from pixel to pixel, or if there are minerals with slightly different absorptions that when combined will have features that are broadened and/or shifted from the spectral features in individual spectra.

The denominator spectrum could also result in spectral errors if the calibration for the imaging spectrometer data was based on field spectrometer and/or laboratory spectra of samples for which the spectral resolution and/or wavelength calibration was different than that of the imaging system. Errors could also occur if the small spot(s) measured by the field spectrometer or the laboratory samples were not spectrally representative of the much larger pixel(s) measured by the imaging instrument.

Example of the spectral errors produced by the above mechanisms are shown in Figures 1, 2 and 3. If the denominator spectral feature is shifted from the numerator spectrum, a "dip/rise" is observed (Figure 1). The resulting absorption band is shifted in wavelength, as in the case of Figure 1, to shorter wavelengths. If the demoninator spectrum has a broader feature than the numerator spectrum, but no wavelength shift, then the ratio shows a feature at the same position but it is narrower than the characteristic absorption of the mineral (Figure 2).

If the denominator and numerator spectra have an absorption edge as in hematite at visual wavelengths and there is a wavelength shift or instability, then the ratio can produce absorption features that are not real (Figure 3). In Figure 3, the strongest spurious feature is located at 0.56 μm.

BAND POSITION MEASUREMENTS

In the analysis of band positions, a strongly sloping continuum influences the wavelength of minimum reflectance. For example, in lunar spectra, the slope of the continuum is often so strong the 1-μm pyroxene absorption has no minimum in reflectance. Thus, it is a common practice to remove the continuum to find the correct band center (see Clark and Roush, 1984 and references therein). Clark and Roush (1984) showed that for reflectance spectra, it is theoretically correct to remove the continuum by division, not subtraction.

While the analysis of imaging spectrometer data is increasingly done by computer, "paper and pencil techniques" are still common when trying to understand individual spectra. A common practice to remove a continuum graphically is to draw a continuum and then draw a parallel line that is tangent to the lower part of the curve (Figure 4A). In this case, the tangent occurs near 1.35 μm. However, this method is a subtraction method. Figure 4B shows the spectrum with the continuum subtracted while Figure 4C shows it with the continuum removed by division. The division method shows a minimum near 1.1 μm. The continuum removal methods are not comparable.

CONCLUSIONS

Spurious features can be produced in the spectral data from imaging spectrometer instruments if there are instrumental wavelength instabilities or from various calibration techniques. Spurious features could cause misidentification of minerals or plant species. If there are wavelength instabilities in the instrument, the wavelengths should be registered (e.g. by using known absorption bands such as atmospheric lines that do not shift) before any other operations are performed on the data.

The analysis of band positions should use the same methods. If laboratory comparison data were analyzed for band position with one method, and imaging spectrometer data with another, there could be

misidentification of species. As the composition of mixture changes, the continuum slope could change and the band position would appear to change if analyzed by the subtraction method. Similarly, the shape of a band and its continuum can change as a function of grain size, again causing a spurious band shift if analyzed by the subtraction method.
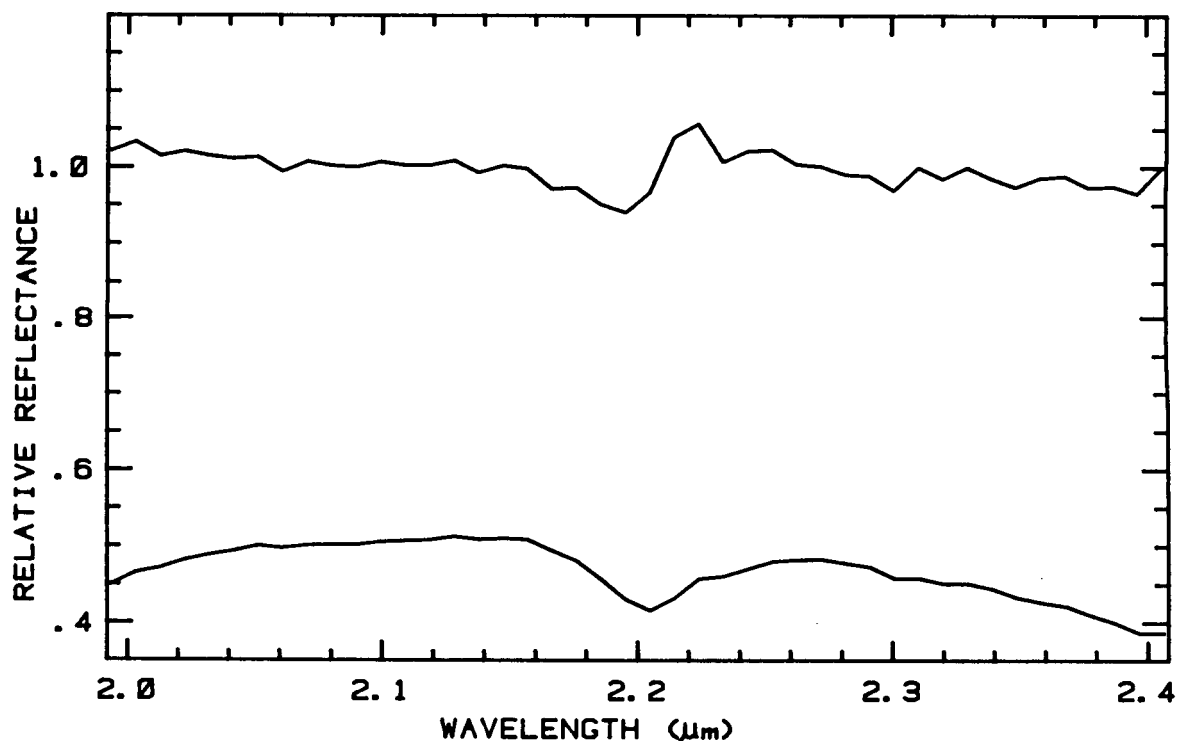

Figure 1. This figure shows one of the possible spectral errors that can result from pixel shifting in calibration images. The lower spectrum in this figure is a laboratory spectrum of montmorillonite convolved to AVIRIS spectral resolution. The upper spectrum represents the laboratory spectrum of montmorillonite convolved to AVIRIS spectral resolution divided by the same spectrum which has been shifted one data channel to the right (longer wavelengths). This (upper) spectrum results in a dip/rise feature near 2.2-μm region which is not representative of the characteristic absorption feature of montmorillonite. The presence of these features could lead the analyst to incorrectly identify mineralogy.
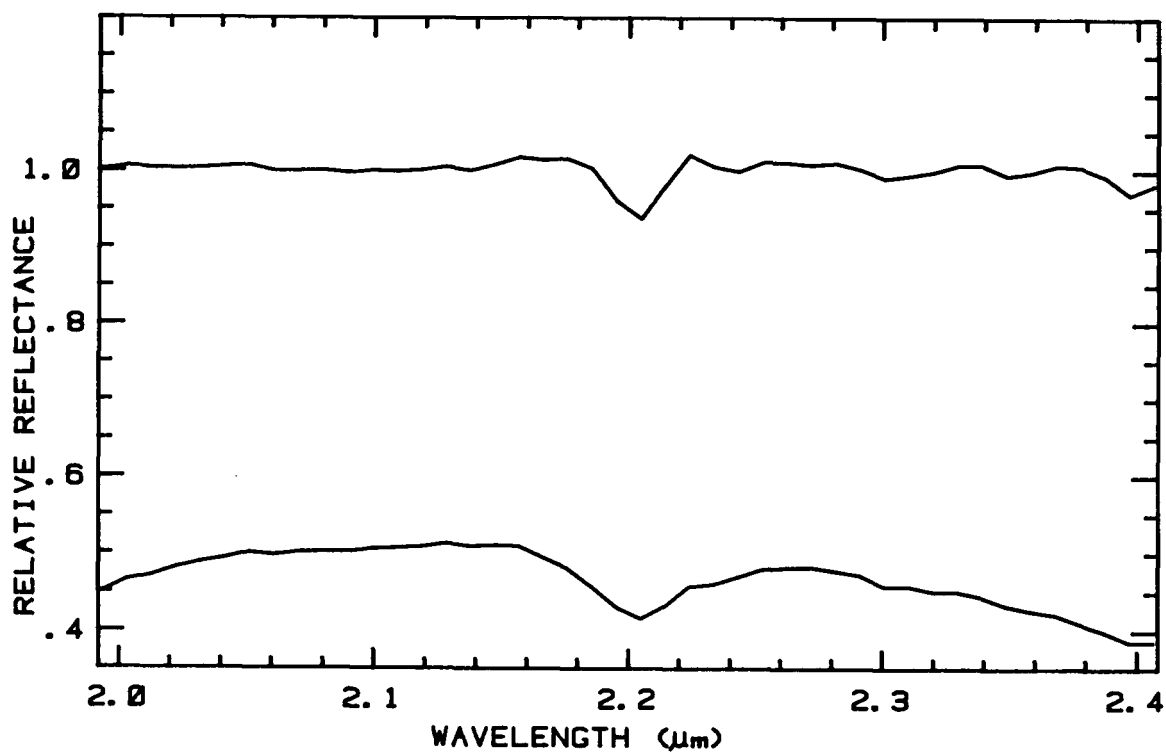
Figure 2. This figure shows that the width of an absorption band can be altered by incorrectly determining calibration images. The lower spectrum in this figure represents a standard laboratory montmorillonite that has been convolved to AVIRIS spectral resolution. The upper spectrum results from dividing the laboratory montmorillonite convolved to AVIRIS resolution by the average of the montmorillonite (AVIRIS resolution) and the same spectrum shifted two data channels to the right plus the montmorillonite (AVIRIS resolution) shifted two data channels to the left (short wavelength). The resulting spectrum shows that the minimum of the 2.2-μm absorption has not shifted, but the absorption feature is narrower than in the standard montmorillonite (AVIRIS spectral resolution) spectrum.
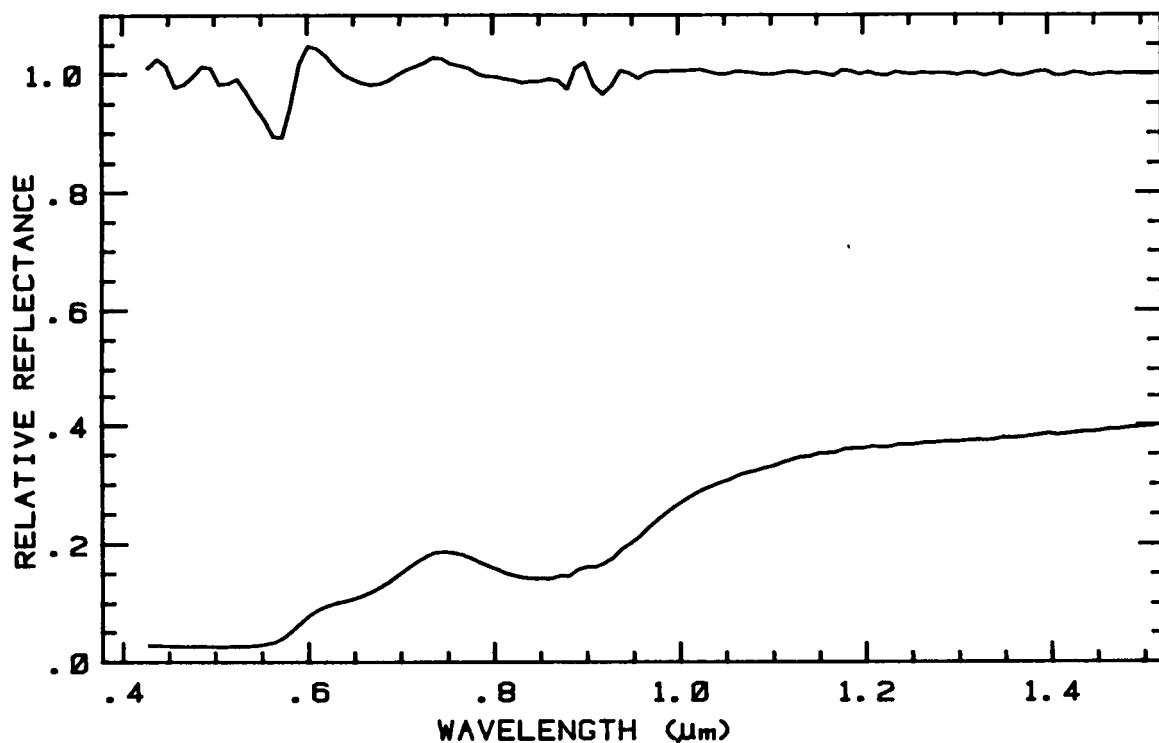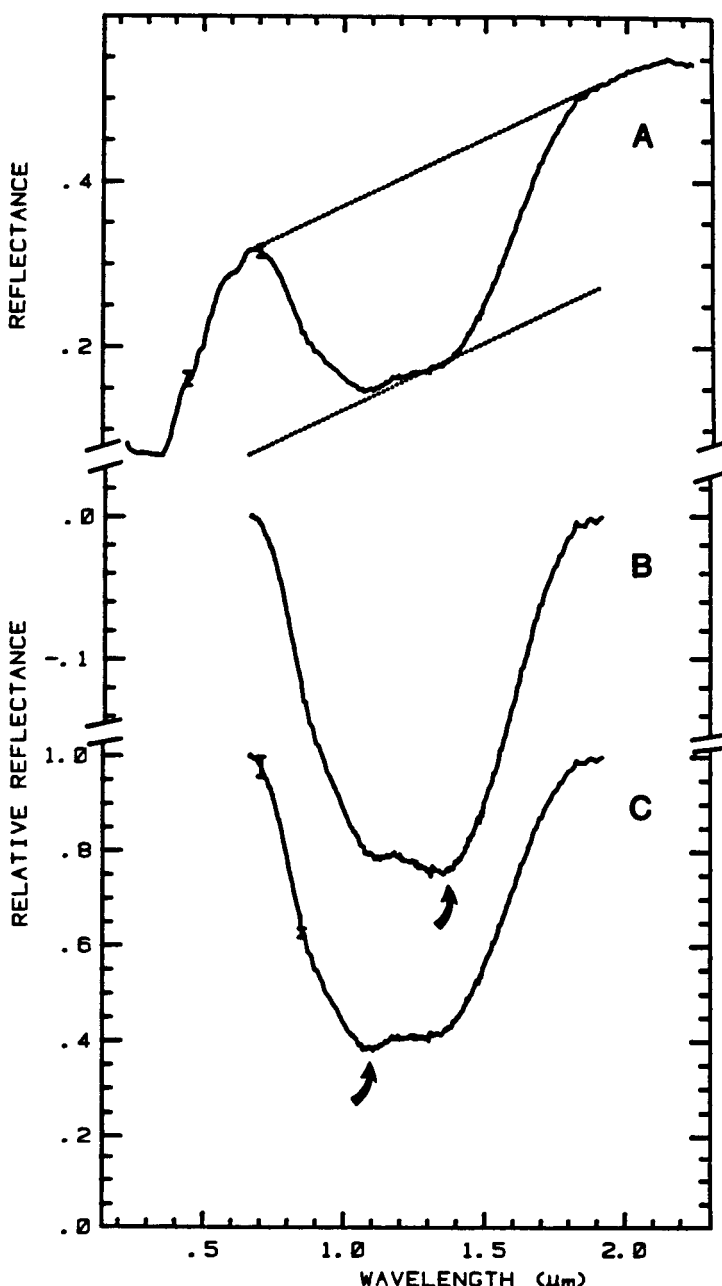
Figure 3. The upper spectrum in this figure shows an additional type of spectral error that can result from using incorrect calibration files in the data reduction process. The lower spectrum represents a laboratory sample of hematite that has been convolved to AVIRIS spectral resolution. The upper spectrum results from dividing the laboratory hematite (AVIRIS resolution) by the average of the same hematite spectrum plus ones that have been shifted two data channels to the left and right. Spurious features are produced at wavelengths less than 1 μm. The strongest spurious feature is located at 0.56 μm. The position and widths of the absorption features in the upper spectrum would not allow for the correct identification of hematite.

Figure 4. This figure illustrates differences in band center determinations depending on the method used in continuum removal in the data reduction process. Figure 4A shows a spectrum of olivine using a graphical method for continuum removal. The upper·line is a straight line continuum whose end-points are defined by the reflectance on either side of the absorption band. The bottom line is drawn parallel to the upper continuum line and is tangent to the absorption feature. Figure 4B shows the resulting spectrum when the continuum is removed by subtracting the continuum from the original olivine spectrum. This method determines that the band center is located at 1.35 μm. Figure 4C illustrates the spectrum of olivine with the continuum divided. This method is the correct method for band center determination. This method determines that the band center occurs at 1.05 μm.

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