

Mapping with Imaging Spectrometer Data
Using the Complete Band Shape Least-Squares Algorithm
Simultaneously Fit to Multiple Spectral Features from Multiple Materials

By

Roger N. Clark¹, Gregg A. Swayze¹, Andrea Gallagher¹,
Noel Gorelick¹, and Fred Kruse²

¹ U. S. Geological Survey
Box 25046 Federal Center
Denver, CO 80225

² Center for the Study of Earth from
Space (CSSES), CIRES
and Dept. of Geological Sciences
Univ. of Colorado, Boulder, CO 80309

The algorithm for least squares fitting spectroscopic absorption bands with features from library reference spectra, first reported by Clark, Gallagher and Swayze (1990, Proceedings of the Second Airborne AVIRIS Workshop, JPL Publication 90-54, pp. 176-186), has been substantially extended. The same basic algorithm is still used, but multiple absorption features are fit at one time, and the fits from multiple minerals are compared to determine what mineral absorption features are present in the spectrum. While the method works equally well on any material having diagnostic absorption features, this abstract considers discrimination and mapping of minerals.

This new method substantially increases the ability to discriminate between two minerals. The algorithm has been thoroughly tested using mineral spectra where controlled amounts of noise have been added. For example, the minerals calcite and dolomite have very similar, mostly overlapping absorption bands near 2.3 μm . Noise was systematically added to spectra of calcite and dolomite and the spectra fit with reference spectra of calcite and dolomite, as well as a suite of other minerals. It was found that calcite can be separated from dolomite at a signal-to-noise of about 7 at AVIRIS spectral resolution. Other minerals are separated at much lower signal-to-noise levels. Other mineral combinations have been separated at similarly low signal-to-noise levels. Use of multiple diagnostic absorption features should allow discrimination at even lower signal to noise levels.

When mapping multiple minerals and multiple features, spectral regions are grouped. For example, the 2.3- μm region may be analyzed for chlorites, carbonates, Mg-bearing clays, and other minerals having diagnostic features in the 2.3- μm region. Then the 2.2- μm region is analyzed for minerals such as montmorillonites, muscovites, illites, kaolinites, and other minerals having 2.2- μm features. The 1.0- μm region is analyzed for minerals having diagnostic electronic transitions, like hematite, goethite, ferrihydrite, nontronite, jarosite and others. Thus, the analysis of the whole spectrum may find multiple minerals, one in each spectral region. Mineral mixtures may also be analyzed by using reference library spectra of mixtures.

The multiple feature, multiple material algorithm has been applied to mapping minerals at Canon City, Colorado, as well as at Cuprite, Nevada.

At Canon City, 10 minerals have been mapped using AVIRIS data from September, 1989 where the signal-to-noise is typically 25 at a reference albedo of 50%. The minerals hematite, goethite, Na-montmorillonite, Ca-montmorillonite, well-crystallized kaolinite, poorly crystallized kaolinite or halloysite, calcite and dolomite are the primary minerals mapped. Also mapped is a medium crystalline kaolinite and a ferrihydrite or amorphous iron. The mineral maps differentiate shales, sandstones, conglomerates, dolomites and limestones, and subtle variations within the units. Field work has confirmed most minerals mapped, although verification of ferrihydrite or amorphous iron is proving difficult.

At Cuprite, Nevada, 19 minerals have been mapped and 14 additional minerals were searched for but not detected using 1990 AVIRIS data. Minerals found are: hematite, goethite, jarosite, potassium alunite, two natroalunites containing 65 and 80 mole percent Na, highly-crystalline and medium-crystalline kaolinite, poorly crystalline kaolinite or halloysite, dickite, Na-montmorillonite, Ca-montmorillonite, calcite, dolomite, buddingingtonite, ammonium illite smectite, opal, Fe-chlorite, and paragonite.

The alteration mapped at Cuprite spectrally corresponds closely to previously published studies. The differentiation of members of the alunite solid solution series and the gradational trend from well-crystallized kaolinite to poorly crystallized kaolinite with increasing distance from the alunite zones shows the alteration in more detail than has previously been mapped. Although complete field verification of these minerals will take considerable work, some minerals have already been confirmed using a field portable spectrometer (Huntington, personal communication): dickite, potassium alunite, natroalunites, and variation in kaolinite crystallinity. Field samples have been analyzed and jarosite, kaolinites, alunites, buddingingtonite, ammonium illite smectite, calcite, hematite, and goethite are verified in at least some localities in the image.

This new mapping algorithm can be used to map spectral features in imaging spectrometer data in both emission and absorption, and should be applicable to all disciplines using spectroscopy: geology, botany, oceanography, ice and snow research, and atmospheric research.