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GROUND-TRUTHING AVIRIS MINERAL MAPPING AT CUPRITE, NEVADA

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Mineral abundance maps of 18 minerals were made of the
Cuprite Mining District using 1990 AVIRIS data and the Mul-
tiple Spectral Feature Mapping Algorithm (MSFMA) as dis-
cussed in Clark et al. (1991). This technique uses least-
squares fitting between a scaled laboratory reference spec-
trum and ground calibrated AVIRIS data for each pixel. Mul-
tiple spectral features can be fitted for each mineral and
an unlimited number of minerals can be mapped simultane-
ously. Quality of fit and depth from continuum numbers for
each mineral are calculated for each pixel and the results
displayed as a multicolor image.

Cuprite consists of two acid-sulfate hydrothermal
alteration centers straddling highway 95 in southwestern
Nevada, with alteration involving Tertiary volcanic host
rocks in the eastern center and Cambrian metasedimentary
host rocks in the western center. Cuprite spectral mineral
abundance maps of the area show two elliptical zonation pat-
terns. The western center is zoned progressively inward
from sericite, to halloysite-dickite, kaolinite, Na-alunite,
through K-alunite with halloysite in the interior. While
the eastern center is zoned inward from halloysite to kao-
linite, intermediate alunite, through K-alunite, with a cen-
tral core of siliceous sinter.

Many of these minerals had never been mapped before or
in such detail. We have subdivided kaolinite group minerals
into grades of crystallinity, alunites and montmorillonites
into solid solution endmembers, and have differentiated
between jarosite, goethite, hematite, and ammonium minerals.
We collected 60 field samples using the mineral abundance
maps as guides to locate areas with the strongest mineral
signatures. The PIMA II field spectrometer† was used to do
preliminary mineral identification in the field. Natural
weathered surfaces were marked and were measured, along with
rock chips from sample interiors, in reflectance on a
laboratory Nicolet† 740 Fourier transform IR spectrometer.
In all cases the mineralogy of the interior matched that of

the weathered surface indicating that we are mapping the
rock units themselves. An example of a library reference
and field sample spectra for Dickite at lab and AVIRIS spec-
tral resolution is shown along with an AVIRIS spectrum (avg=
8 pixels) extracted from the collection location of the
field sample (Figure 1). This 2.2-μm feature was used to
identify Dickite with the MSFMA. Twenty-eight field samples
of 17 mineral types were submitted for X-Ray Diffraction
(XRD) analysis to verify or disprove our spectral identifi-
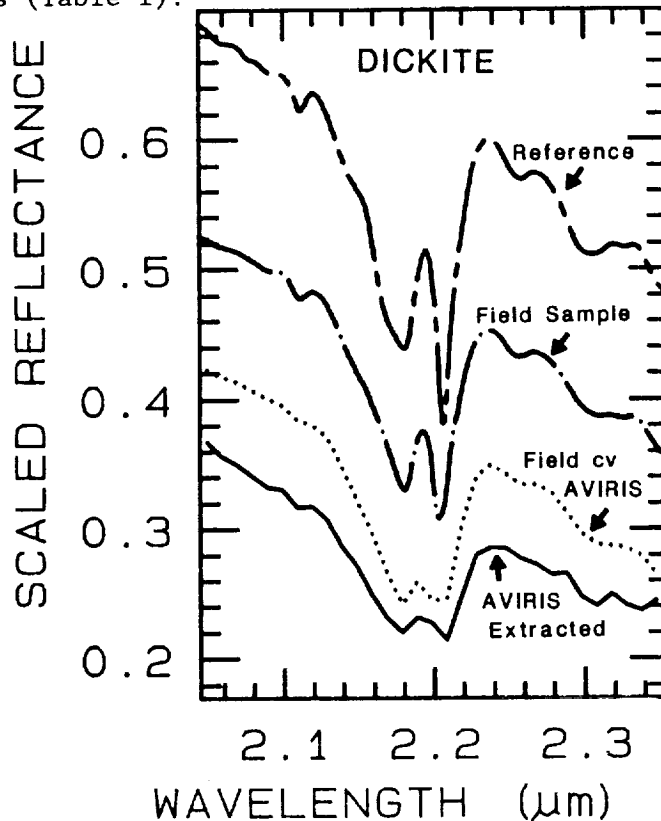cations (Table 1).

Figure 1. Reflectance spectra of a reference dickite and
field sample, from Cuprite, identified as dickite from
analysis of AVIRIS data. Lab spectra (dash-dot and dash-
dash curves) collected on an Fourier transform IR spectrome-
ter at 4 cm^{-1} resolution. Dotted curve is the field sample
spectrum convolved (cv) to AVIRIS spectral resolution.
Solid curve is an average of eight pixel spectra extracted
from AVIRIS data corresponding in location to the field sam-
ple collection locality. Spectra have been vertically
offset for clarity.

At the time of writing 12 spectrally identified
minerals were confirmed by XRD. Since spectroscopy is more
sensitive for identifying small quantities of Fe-oxides and
clays than XRD, we expect that nontronite is present along
with Fe-Chlorite. Chemical analysis will be used to

determine the cation content of K-alunite and Na-montmorillonite samples. The wavelength position of the 2.2-μm band in muscovite appears to be a function of its Al/Fe ratio (Jim Post, pers. comm.) and may explain why we mapped two different muscovites as Na-montmorillonite and paragonite at some locations in the western center. More details on this will be presented. We have also realized that opal and hydroxyl-bearing chalcedony both have Si-OH bands and that we identified chalcedony instead of opal at Cuprite. Overall, our mineral identifications have proven very accurate in those cases where we have adequate reference spectra. Our difficulties arise from subtle wavelength shifts in spectral features of solid solution series minerals, because the MSFMA is sensitive to small band shifts. Such sensitivity to band position coupled with great sensitivity to band shape indicates that the MSFMA may open up a new frontier in remotely sensing subtle chemical changes in surface materials.

†Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

Clark, R.N., G.A. Swayze, A. Gallagher, N. Gorelick, and F. Kruse, Mapping with Imaging Spectrometer Data Using the Complete Band Shape Least-Squares Algorithm Simultaneously Fit to Multiple Spectral Features from Multiple Materials, *Proceedings of the Third Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Workshop*, JPL Publication 91-28, p. 2-3, 1991.

Table 1: Minerals detected by AVIRIS and identified with XRD

AVIRIS Identified	X-Ray Diffraction
K-Alunite	Na-Alunite (submitted for K/Na analysis)
Na-Alunite	Na-Alunite
Buddingtonite	Buddingtonite
Calcite	Not Submitted (occurs as limestone)
Fe-Chlorite	Probably Fe-Chlorite
Dickite	Dickite
Goethite	Goethite
Halloysite	Halloysite (moderately crystallized)
Hematite	Hematite
NH4 Ill/Smectite	Montmorillonite + tr. Illite
Jarosite	K-jarosite
Kaolinite (wxl)	Kaolinite (well crystallized)
Kaolinite (pxl)	Kaolinite (still resolving crystallinity)
Na-Montmorillonite	Ca-Montmorillonite (submitted for anal.)
Ca-Montmorillonite	tr. Smectite and muscovite
Nontronite	Possibly Nontronite
Opal	Quartz (SEM: Qtz + chalcedony[*])
Paragonite	K-Muscovite (submitted for analysis)

[*]Opal and chalcedony are both OH-bearing quartz.