Evaluating Minerals of Environmental Concern Using Spectroscopy

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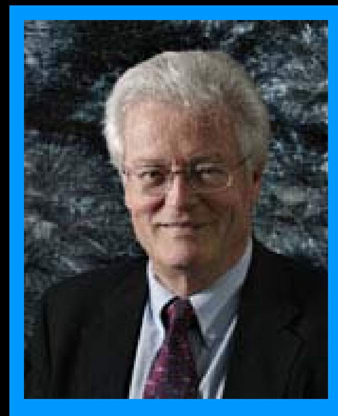
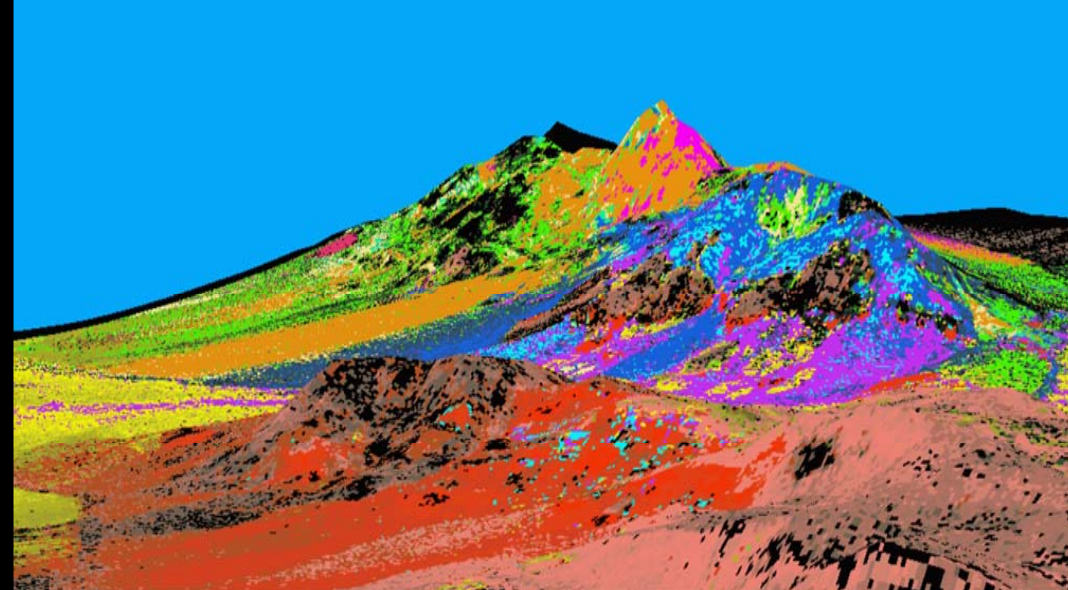
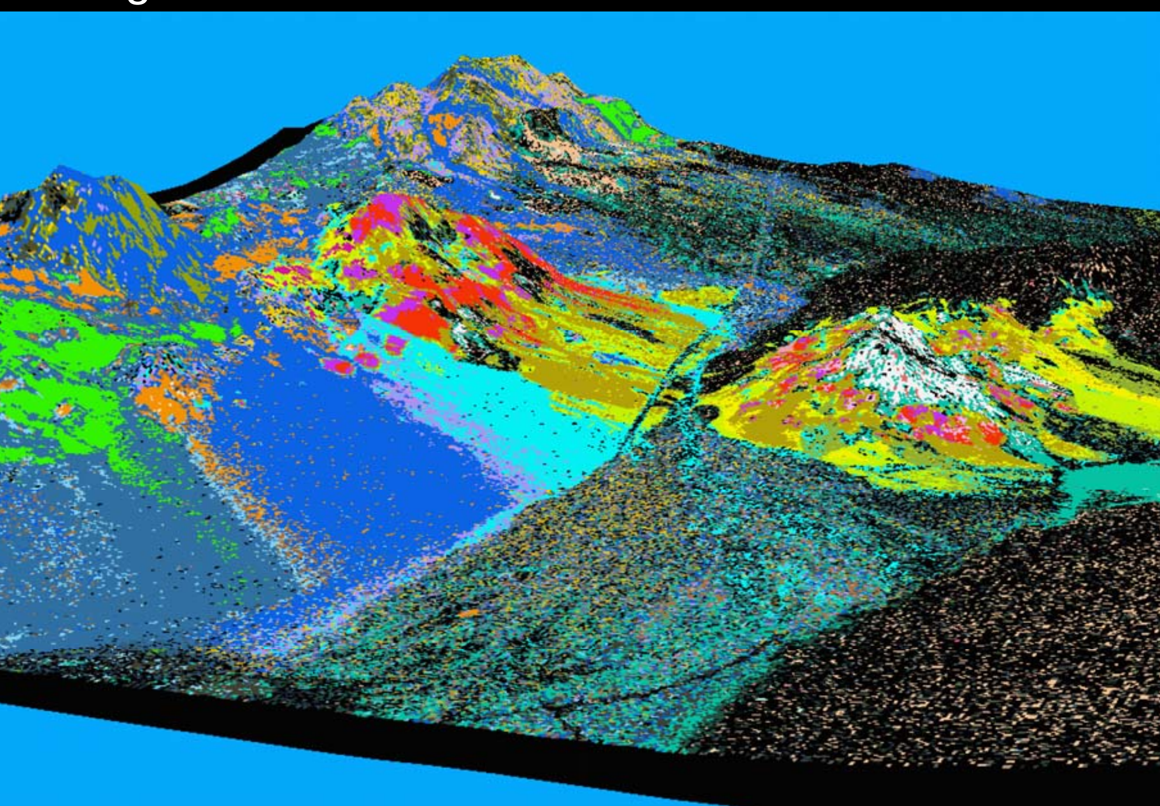
The hydrothermal and structural history of the Cuprite Mining District, southwestern Nevada (CU-Dissertation: Alex advisor)

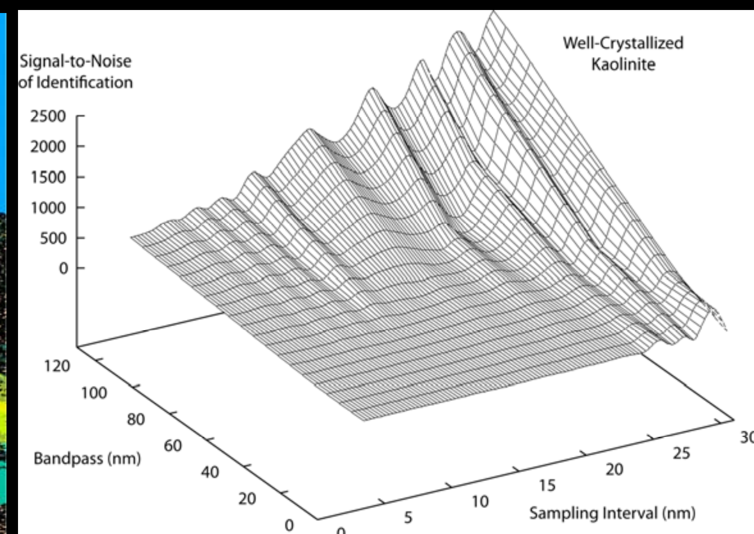
Geology and genesis of advance argillic alteration at Cuprite, Nevada (Econ. Geol., in review)

Alex, thanks for your guidance!

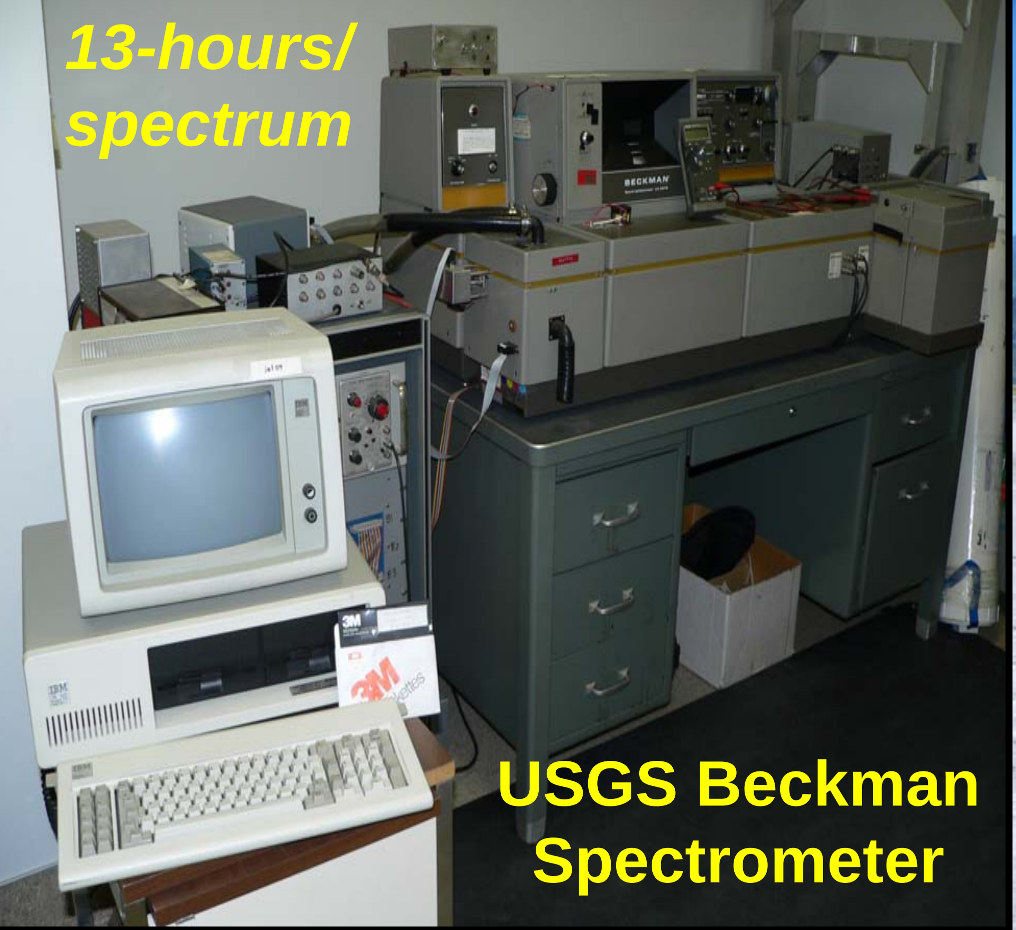








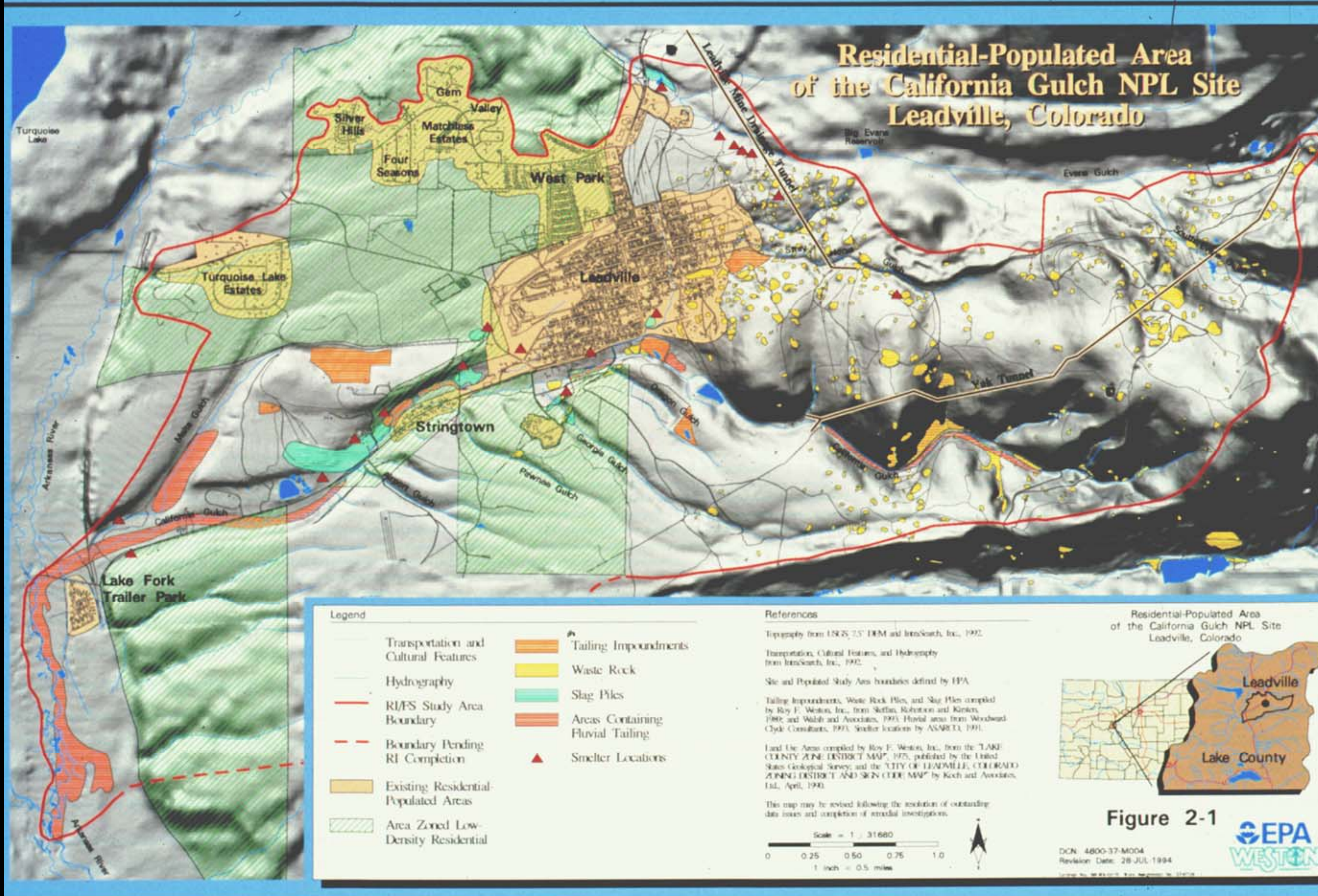
Effects of spectrometer band pass, sampling, and signal-to-noise ratio on spectral identification using the Tetracorder algorithm. (JGR, 2003).



Try hauling a 300 lbs (136 kg) spectrometer out to the field for ground calibration! Alex has simplified work for countless remote-sensing scientists with the ASD spectrometer!

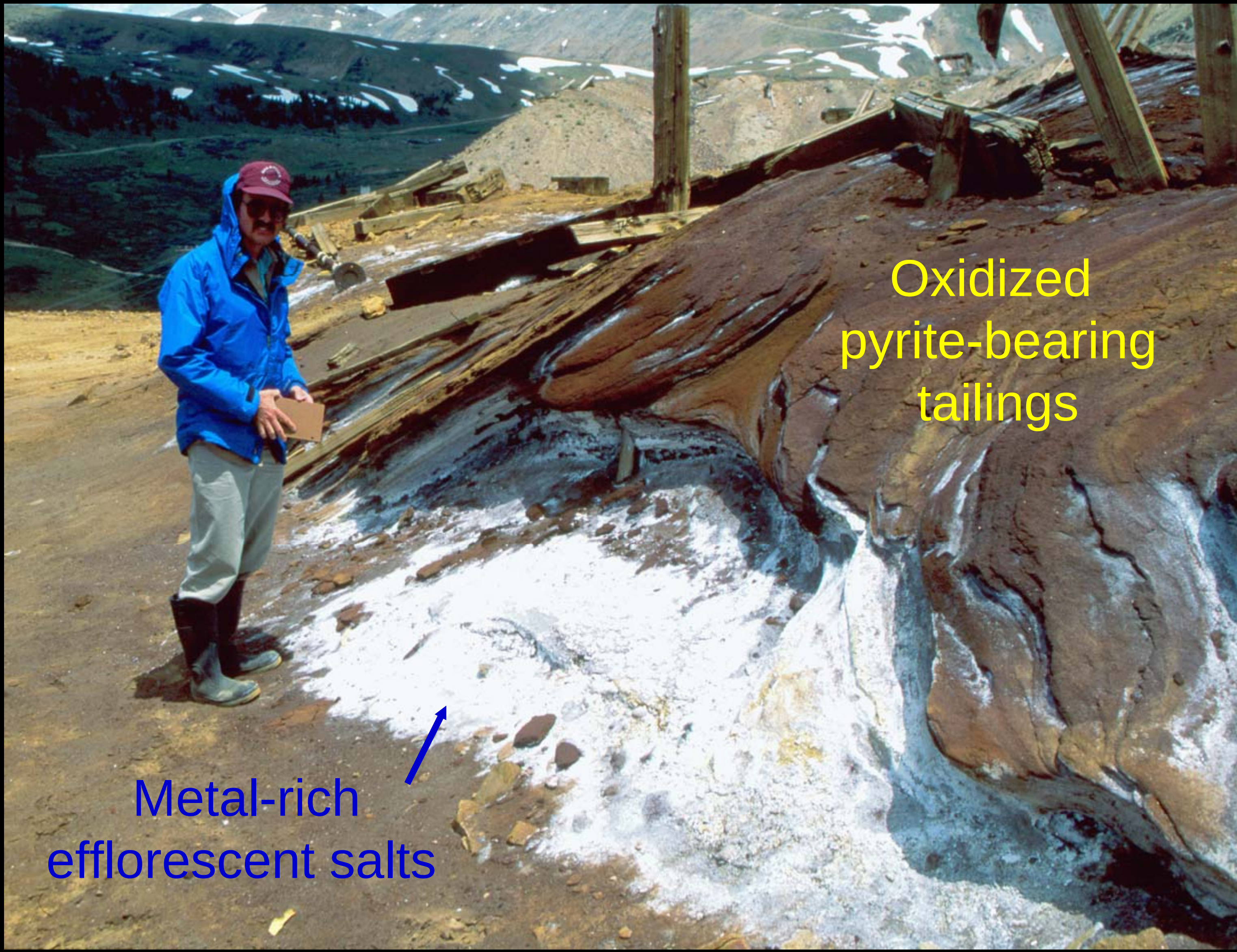
Using Imaging Spectroscopy to Map Acidic Mine Waste

Swayze, Smith, Clark, Sutley, Pearson, Vance, Hageman, Briggs, Meier, Singleton, and Roth, 2000, Envir. Sci. and Tech.



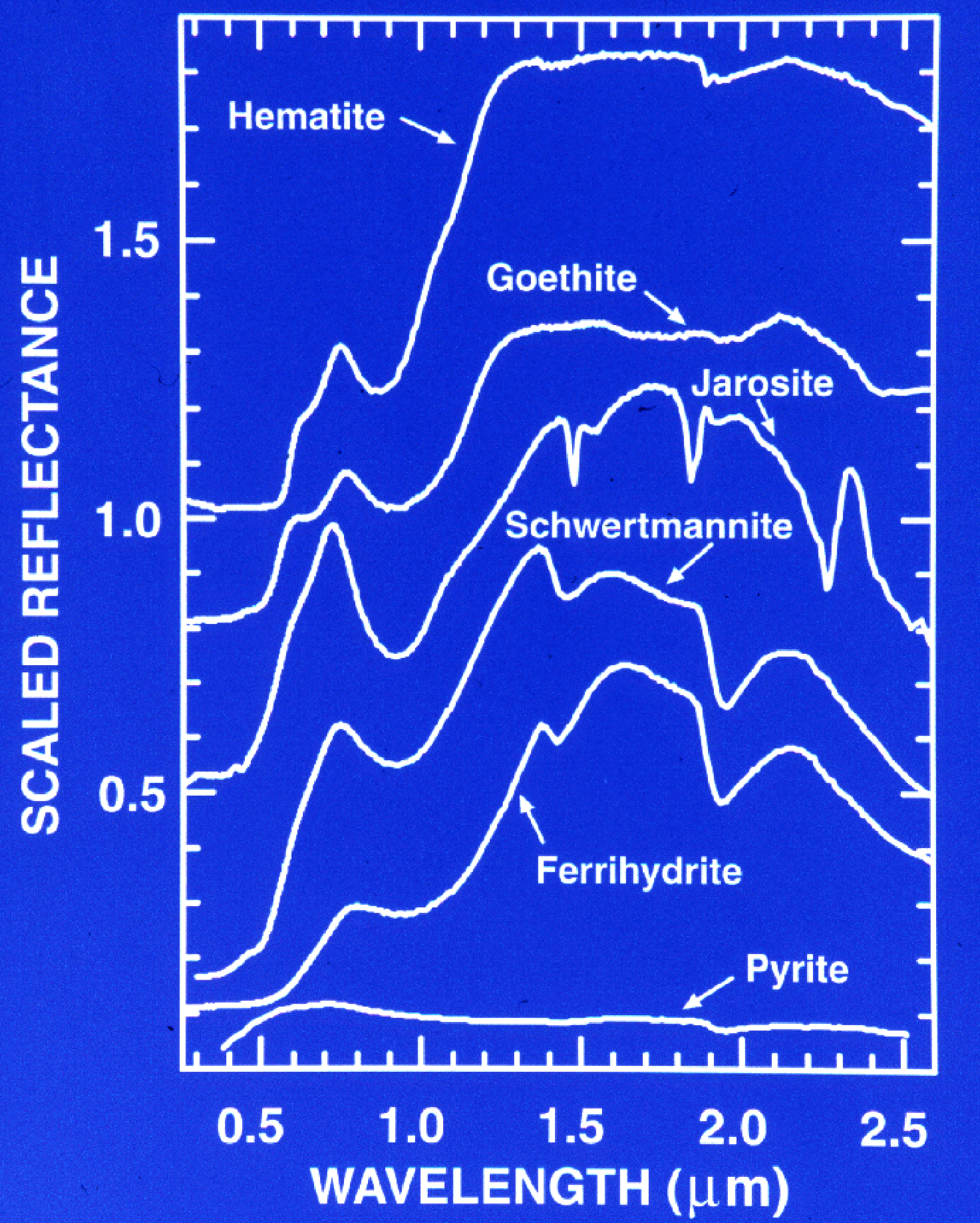
Leadville is located in central Colorado about 130km SW of Denver. The mining district covers a 30 sq. km area above 3000 m. Parts of the district were declared the California Gulch Superfund site by the U.S. EPA because of AMD.

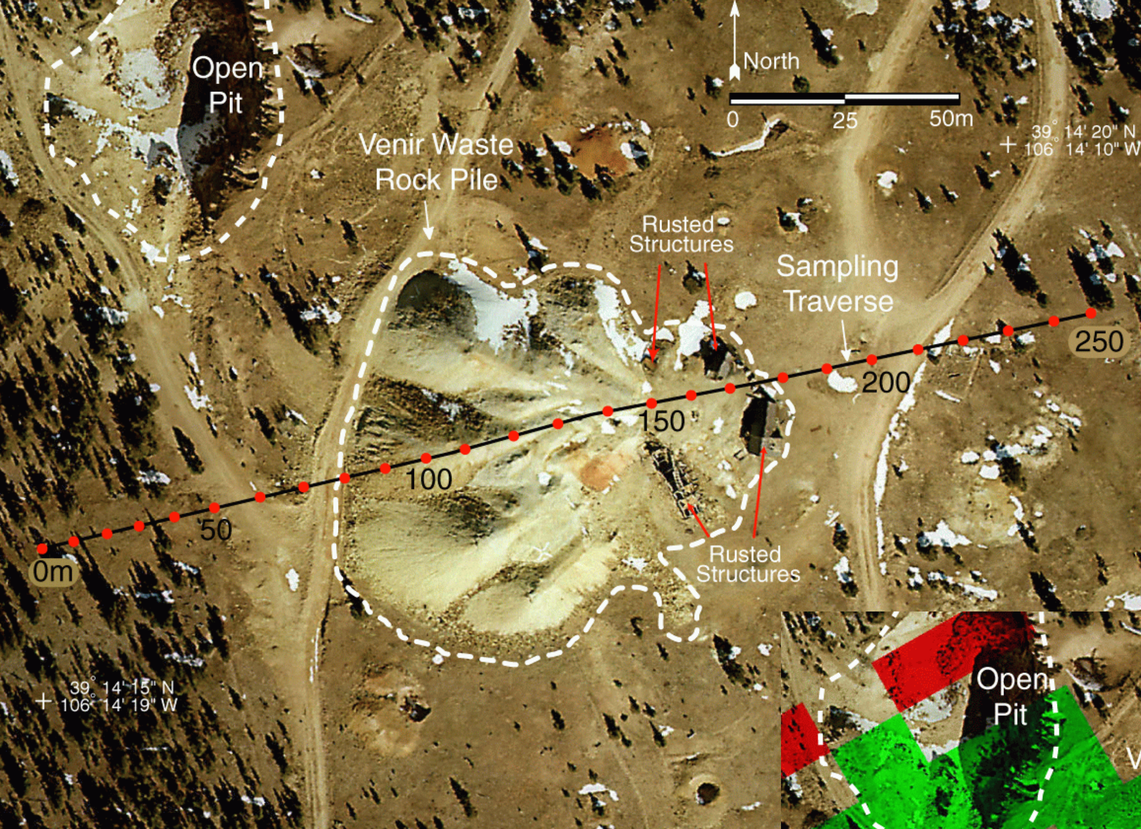
Efflorescent salts are an easily dissolved source of heavy metals (e.g., Cu, Pb, As, Zn) that get into surface runoff, which eventually finds its way into urban and agricultural water supplies.

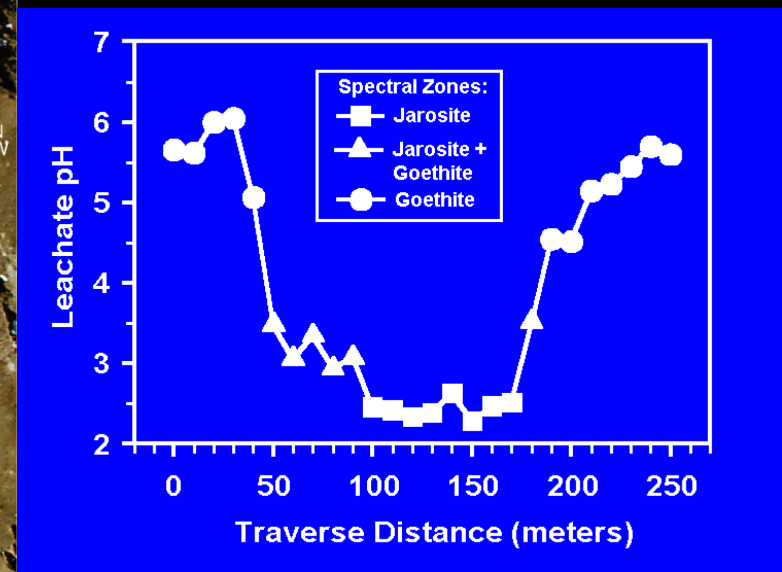


Secondary minerals that form from oxidation of sulfides in waste rock have diagnostic spectral features in the 1.0-micron region.

Each of these minerals is a sensitive indicator of surface pH and their distribution can be used to map the extent of AMD-generating mine waste.

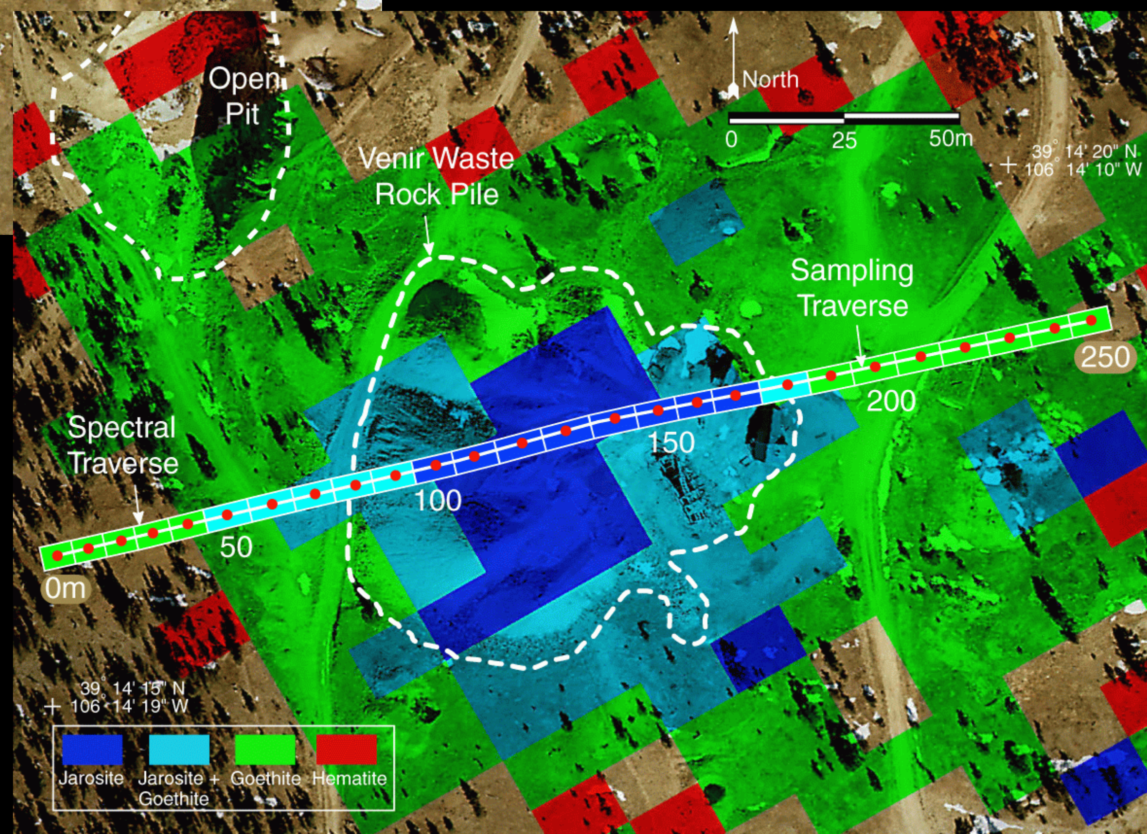






These secondary minerals are deposited in roughly concentric zones emanating from the mine-waste piles.

Leach tests indicate that areas with jarosite at the surface produce the lowest pH (~2.5) values.



AMD-Comments

- *Spectral mineral maps accelerated remediation efforts by 2 years saving over $2 million in investigation costs at Leadville.*
- *Imaging spectroscopy can be used to rapidly screen entire mining districts for potential sources of surface acid drainage.*
- *Other AMD Studies:*

Ong et al., 2003, Proceedings of the 3rd EARSel Workshop on Imaging Spectroscopy;

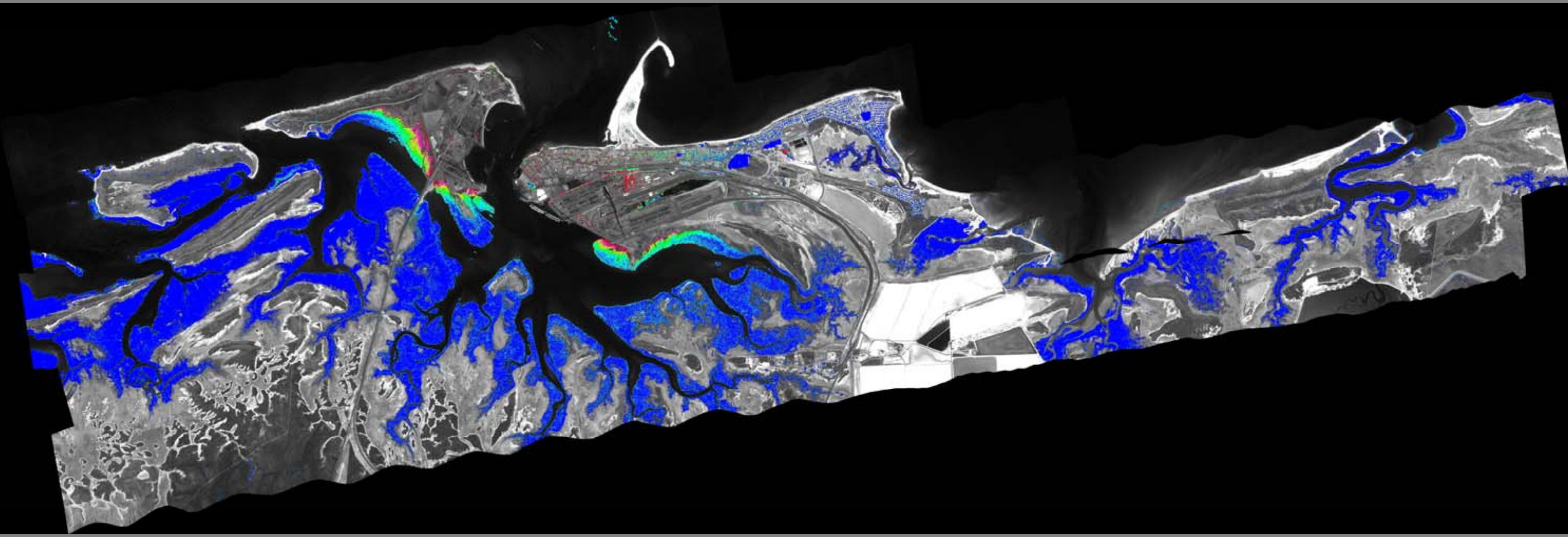
Montero et al., 2005, Chemical Geology;

Riaza et al., 2005, International Archieves of the Photogrammetry, Remote Sensing and Spatial Information Sciences, v.34, Part XXX;

Dalton et al., 2004, Scientific Investigations Report 2004–5203;

Rockwell et al., 2004, Scientific Investigations Report 2004-5241.

Deriving quantitative dust measurements related to iron ore handling from airborne hyperspectral data



Ong, Cudahy, Caccetta, and Piggott, 2003, Mining Technology, v. 112.

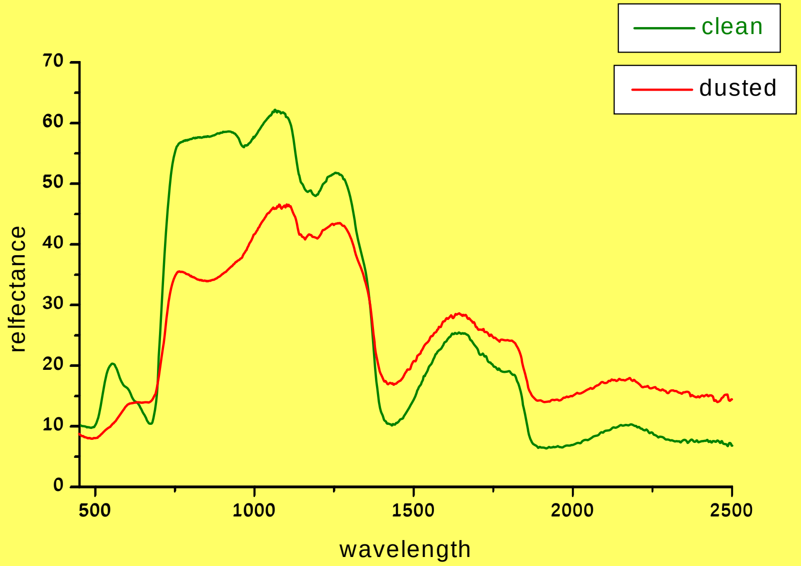
Environmental Problem: dust deposited by ore handling operations at Port Hedland, Australia have the potential to impact surrounding ecologically sensitive mangroves.

Relationship between physicochemical/biophysical properties and spectral data

Independent Measurements of Enviromental parameter

Dust loads

Spectral measurements



Pre-processing

statistical analysis

Ore dusted mangrove leaves can be spectrally distinguished from clean leaves in field measurement.

The same spectral differentiation can be done with HyMap data collected over the affected areas.

Multi-temporal map of iron oxide dust on mangroves

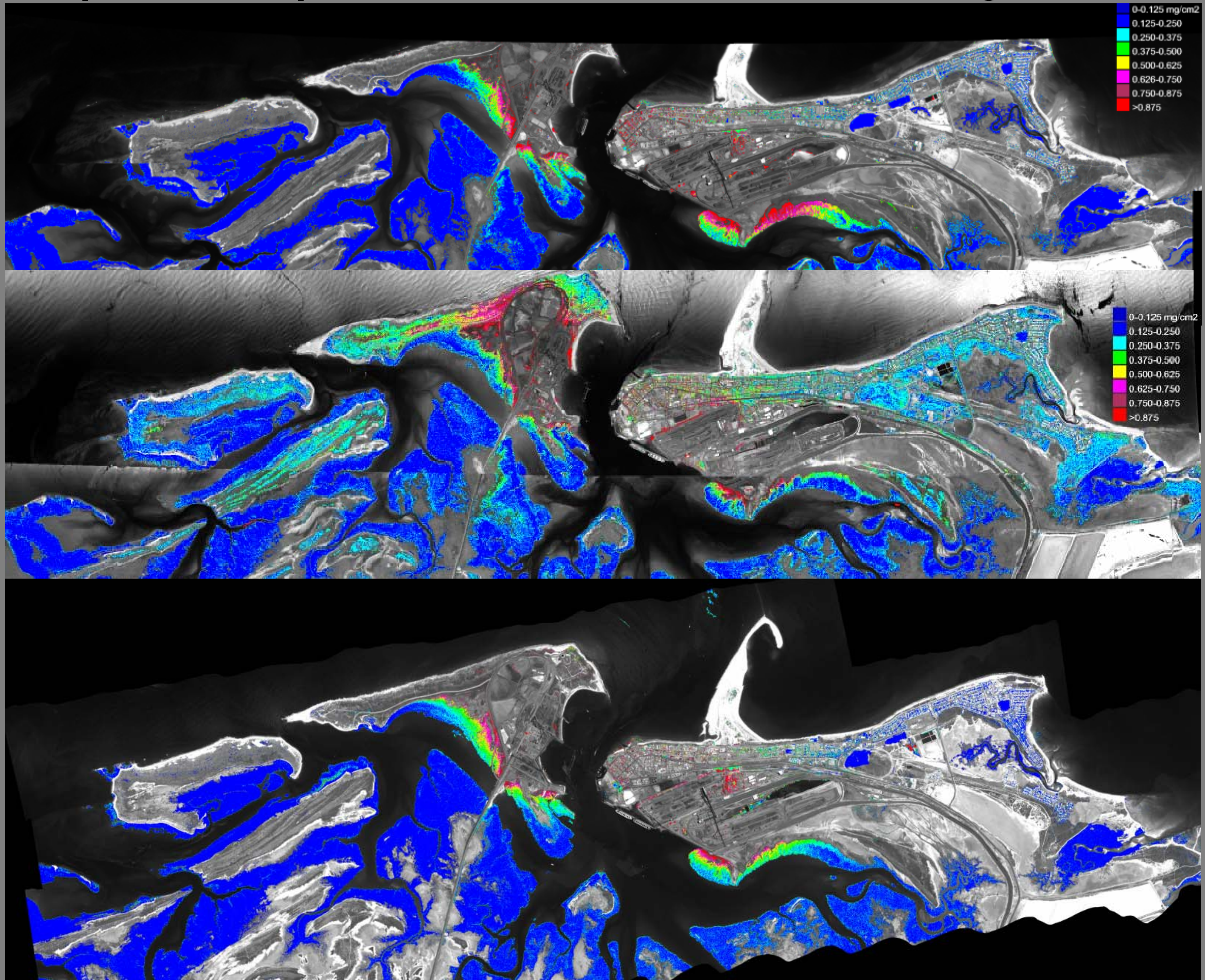
1998
Pre-wet

Blue: less dust

Red: more dust

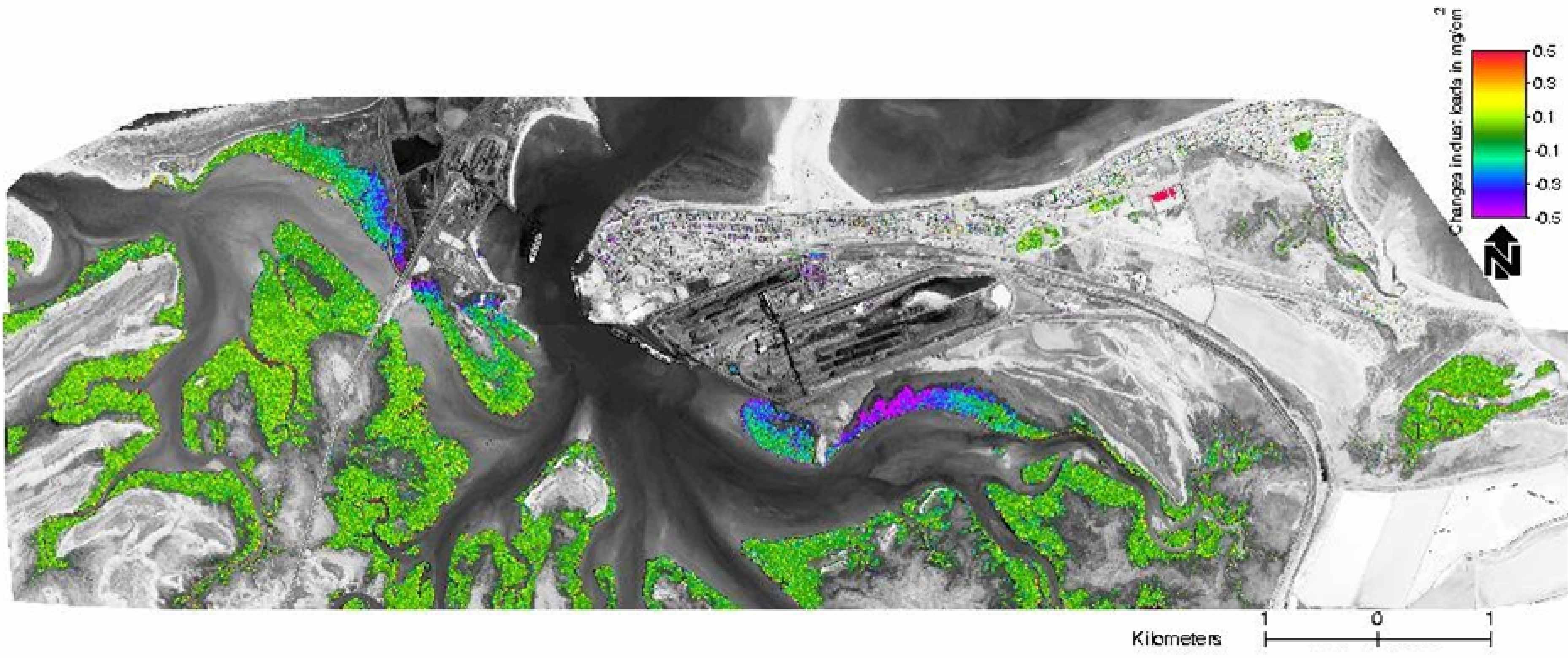
1999
After cyclone

2002
Pre-wet



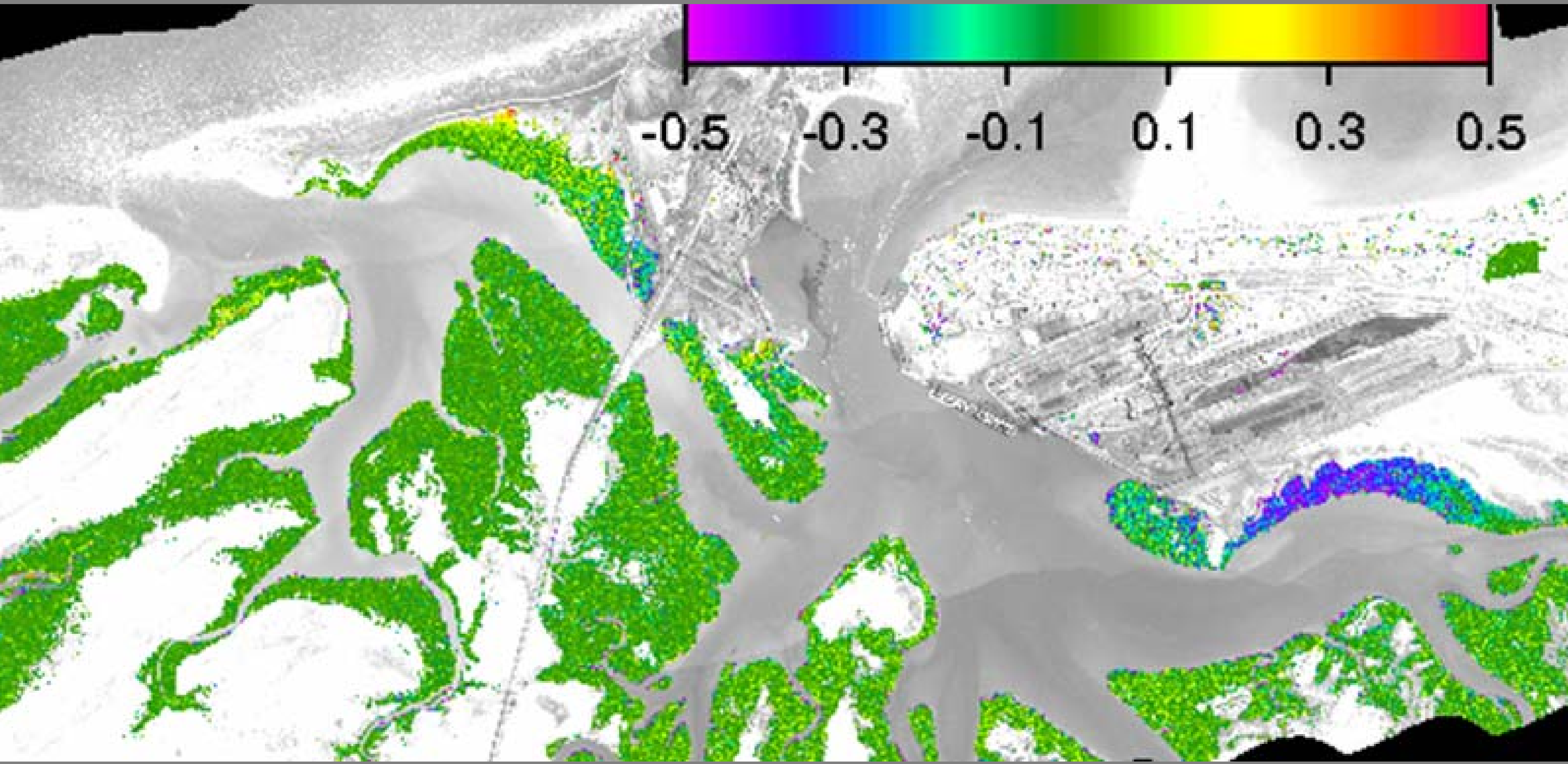
Impacts of natural environmental phenomenon

Magenta = less dust Green = no net change



This is a difference image between the dry season (Nov. 1998) and the start of the wet season (April 1999) right after Cyclone Gwenda (category 2) washed the dust off the mangroves.

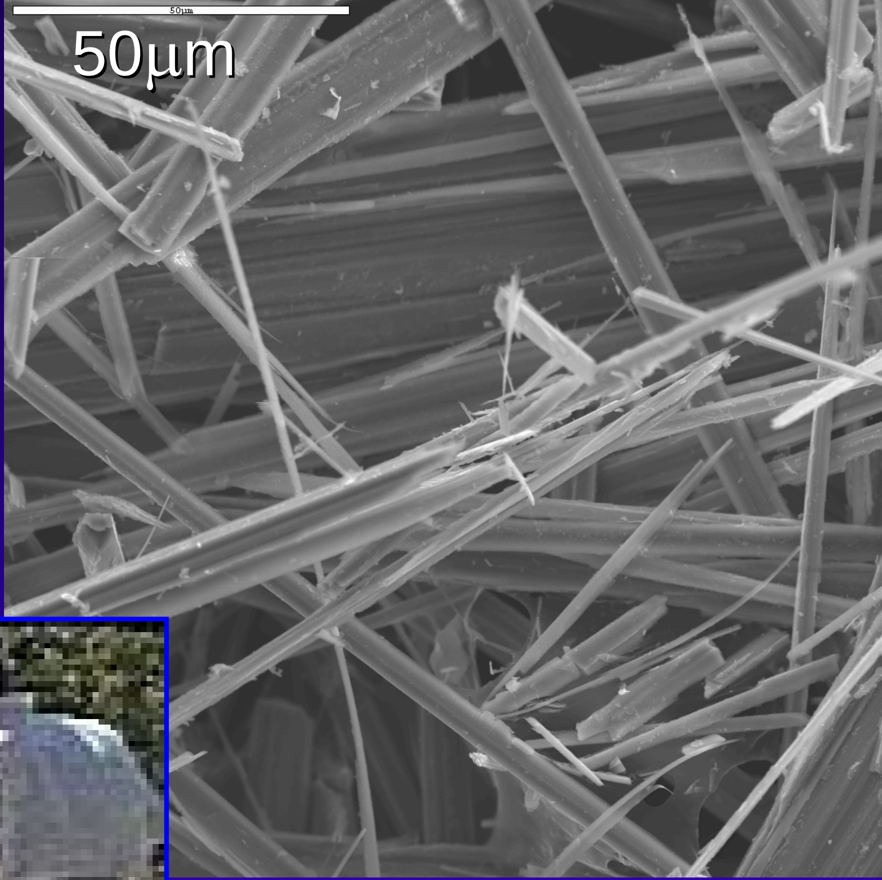
Impacts of dust management



Dust management decreased the amount of dust on the mangroves as measured between Nov. 1998 and Nov. 2002 (during similar meteorological conditions for both years) as measured form by difference map. This work was awarded the **Golden Gecko Award** for developing a non-invasive monitoring technique.

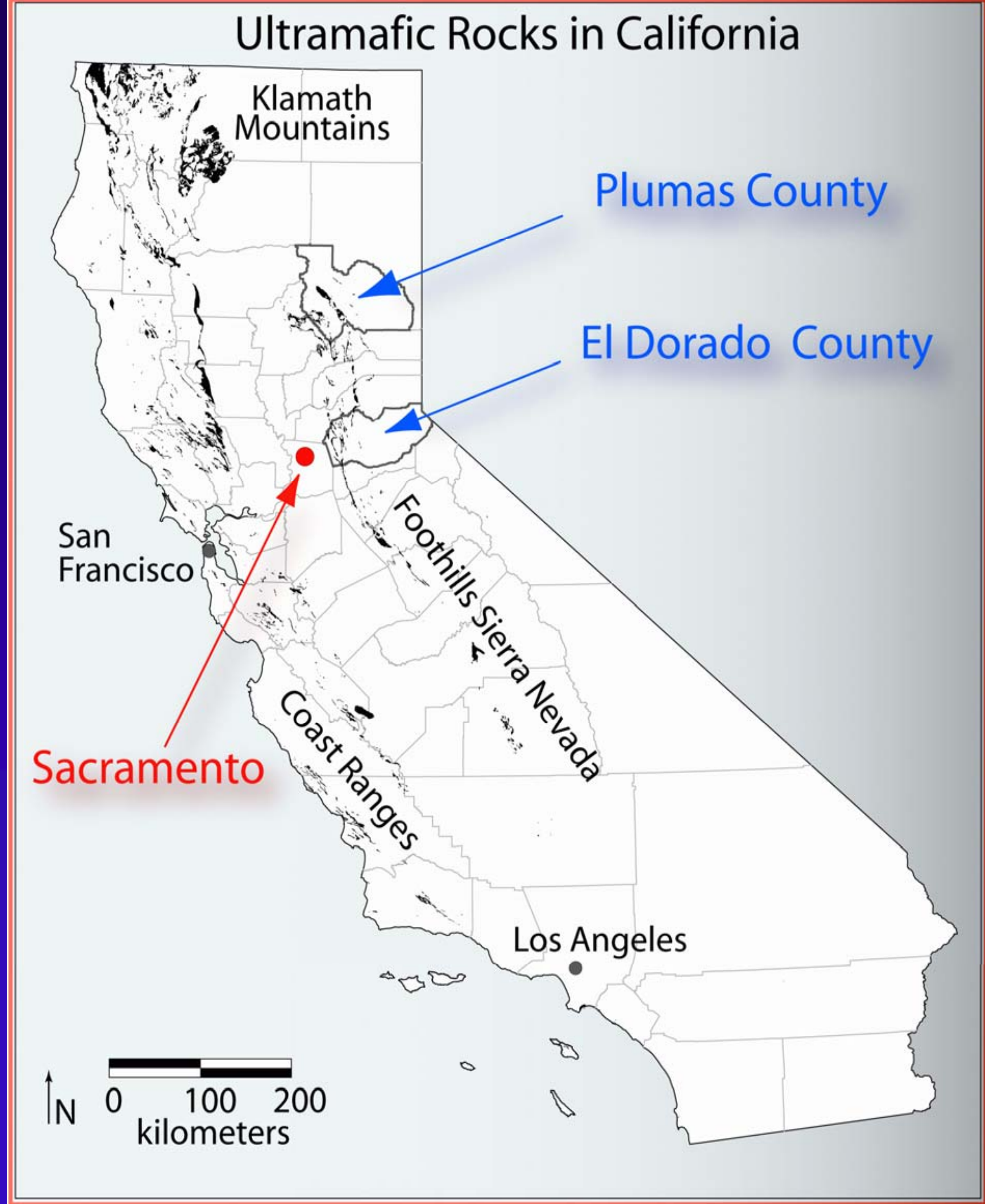
Mapping Naturally Occurring Asbestos with Imaging Spectroscopy

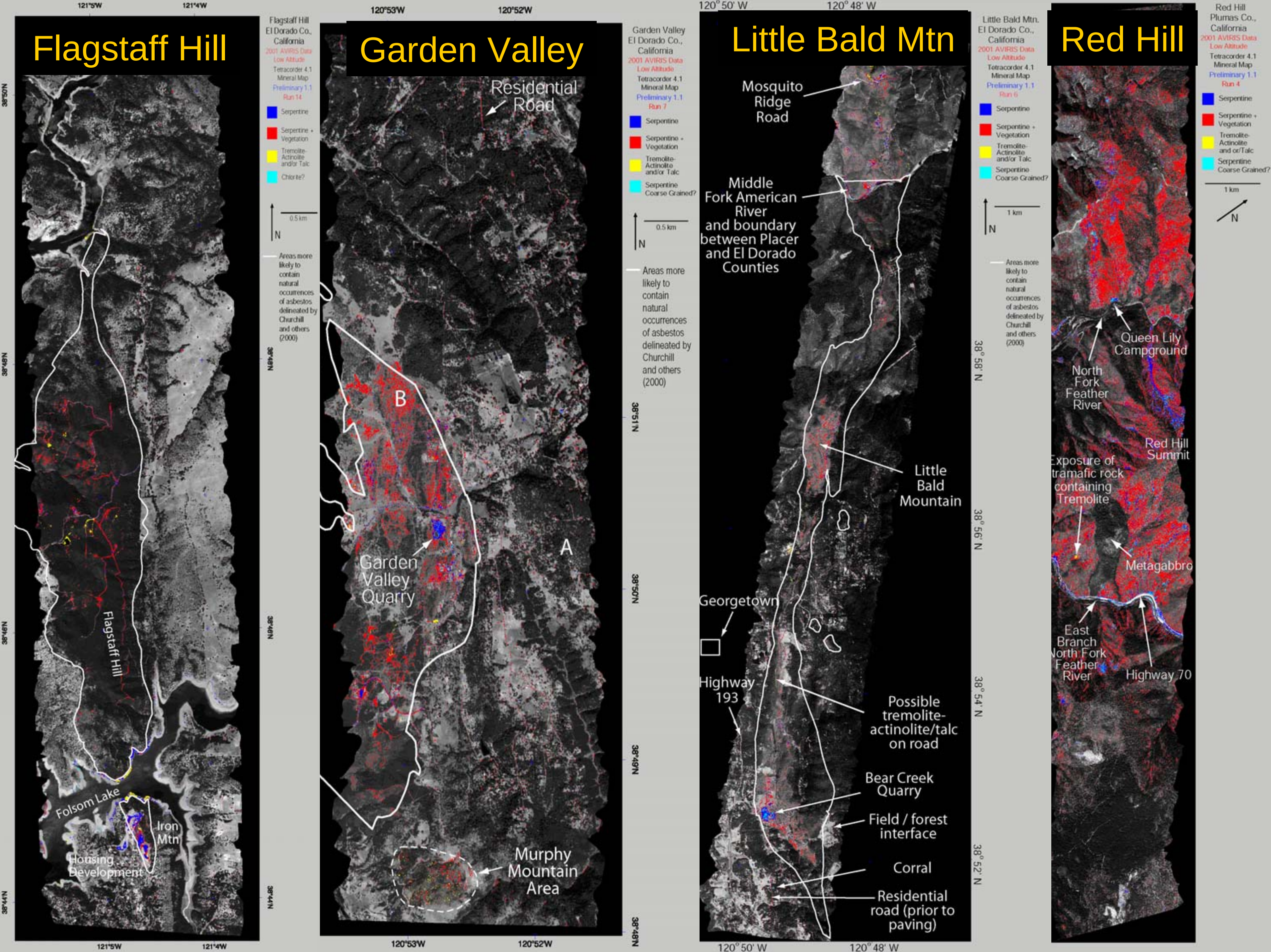
Swayze, Kokaly, Higgins, Clinkenbeard, Clark, Lowers, and Sutley, in prep., Geology



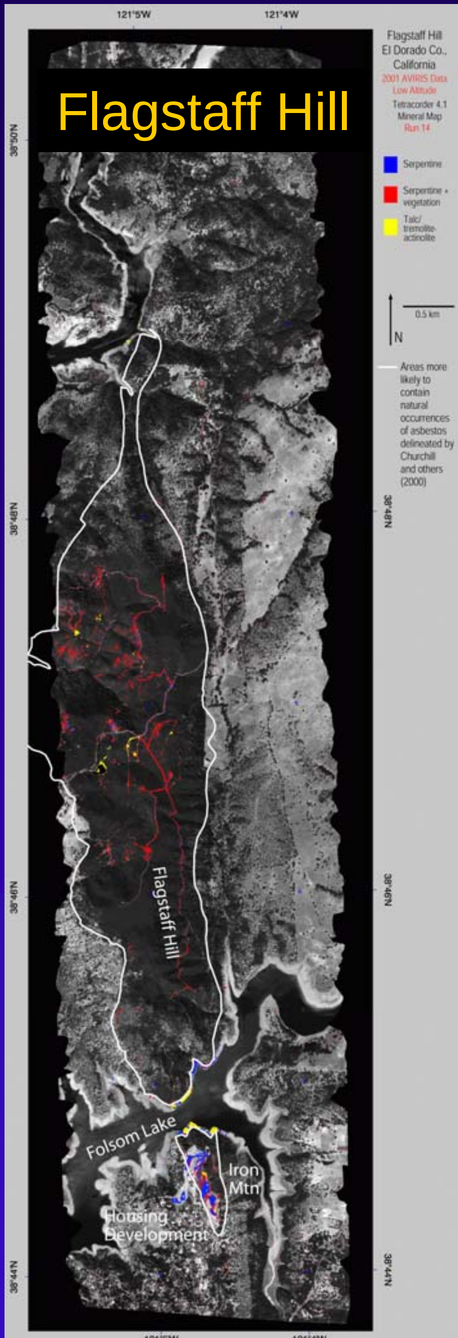
California NOA

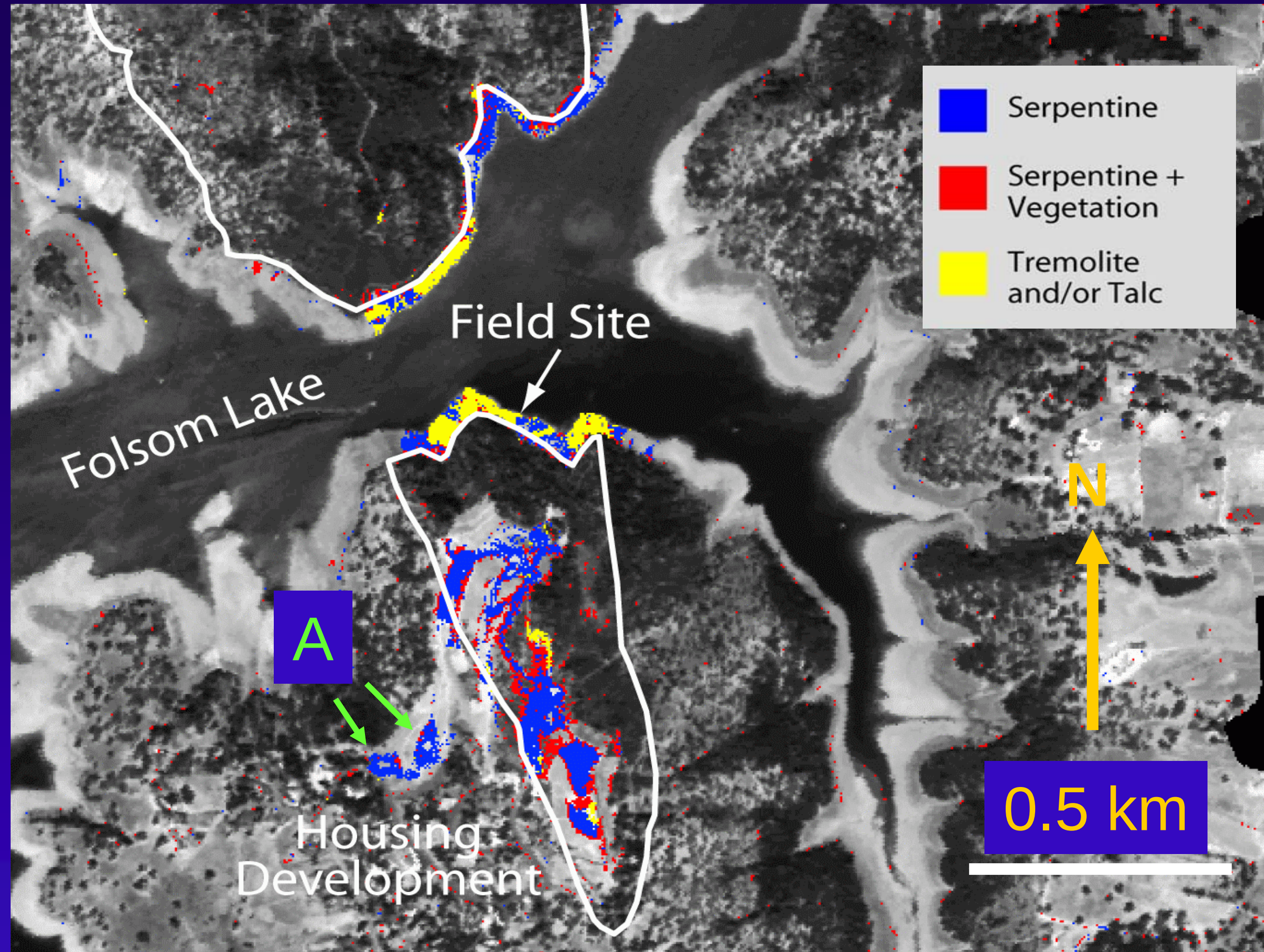
- Ultramafic rocks contain most of the naturally occurring asbestos
- Three main belts of ultramafic rocks
- 43 of 55 counties in California have NOA





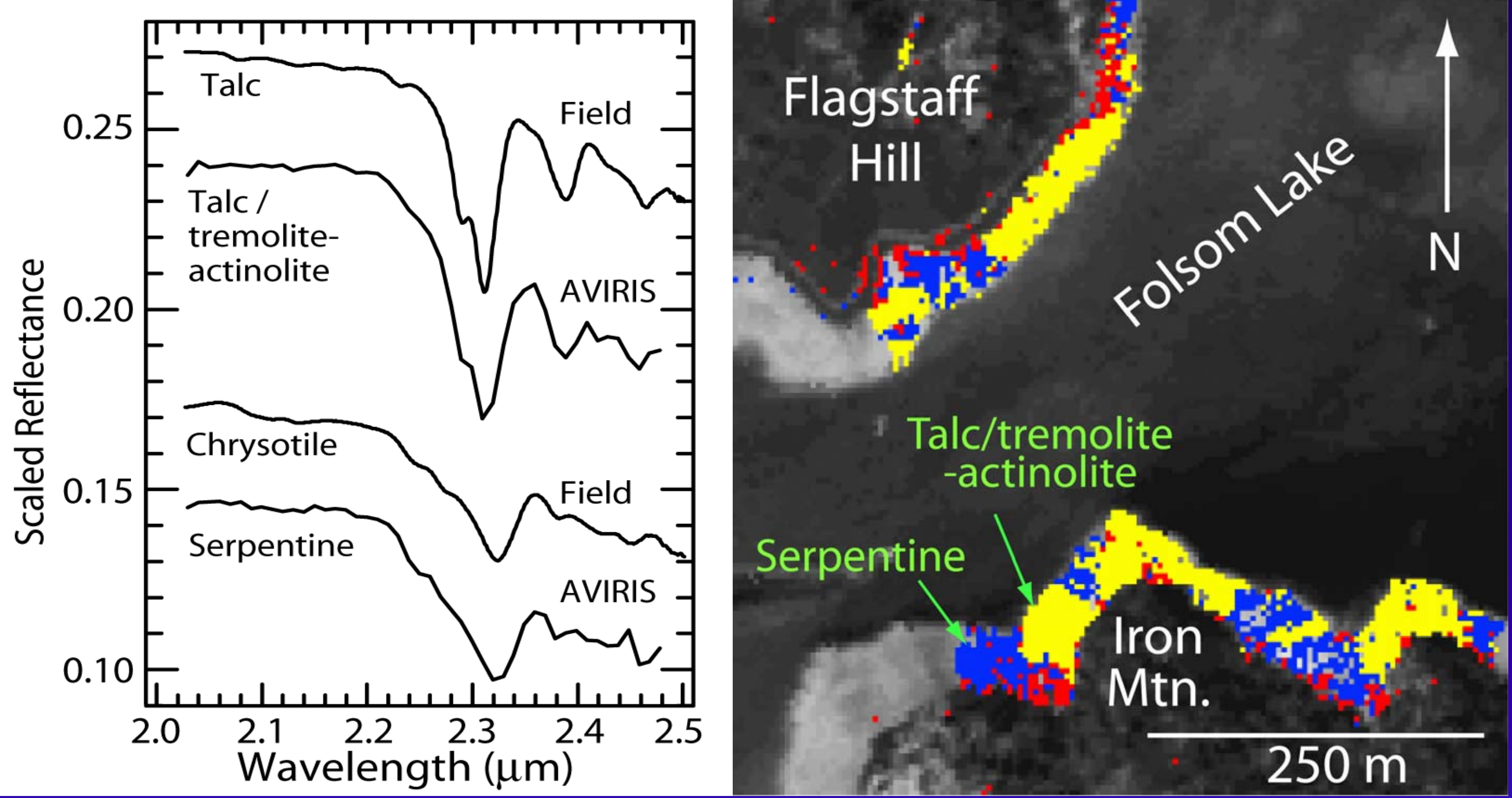
Flagstaff Hill
Flagstaff Hill
El Dorado Co., California
2001 AVIRIS Data
Low Altitude
Tetracorder 4.1
Mineral Map
Preliminary 1.1
Run 14
Serpentine
Serpentine + Vegetation
Tremolite-Actinolite and/or Talc
Chlorite?
0.5 km
N
Areas more likely to contain natural occurrences of asbestos delineated by Churchill and others (2000)
Flagstaff Hill
Folsom Lake
Iron Mtn
Housing Development
121°5'W
121°4'W
38°50'N
38°48'N
38°46'N
38°44'N
Garden Valley
Garden Valley
El Dorado Co., California
2001 AVIRIS Data
Low Altitude
Tetracorder 4.1
Mineral Map
Preliminary 1.1
Run 7
Serpentine
Serpentine + Vegetation
Tremolite-Actinolite and/or Talc
Serpentine Coarse Grained?
0.5 km
N
Areas more likely to contain natural occurrences of asbestos delineated by Churchill and others (2000)
Residential Road
B
A
Garden Valley Quarry
Murphy Mountain Area
120°53'W
120°52'W
38°51'N
38°50'N
38°49'N
38°48'N
Little Bald Mtn
Little Bald Mtn.
El Dorado Co., California
2001 AVIRIS Data
Low Altitude
Tetracorder 4.1
Mineral Map
Preliminary 1.1
Run 6
Serpentine
Serpentine + Vegetation
Tremolite-Actinolite and/or Talc
Serpentine Coarse Grained?
1 km
N
Areas more likely to contain natural occurrences of asbestos delineated by Churchill and others (2000)
Mosquito Ridge Road
Middle Fork American River and boundary between Placer and El Dorado Counties
Little Bald Mountain
Georgetown
Highway 193
Possible tremolite-actinolite/talc on road
Bear Creek Quarry
Field / forest interface
Corral
Residential road (prior to paving)
120° 50' W
120° 48' W
38° 58' N
38° 56' N
38° 54' N
38° 52' N
Red Hill
Red Hill
Plumas Co., California
2001 AVIRIS Data
Low Altitude
Tetracorder 4.1
Mineral Map
Preliminary 1.1
Run 4
Serpentine
Serpentine + Vegetation
Tremolite-Actinolite and or/Talc
Serpentine Coarse Grained?
1 km
N
Queen Lily Campground
North Fork Feather River
Red Hill Summit
Exposure of ultramafic rock containing Tremolite
Metagabbro
East Branch North Fork Feather River
Highway 70



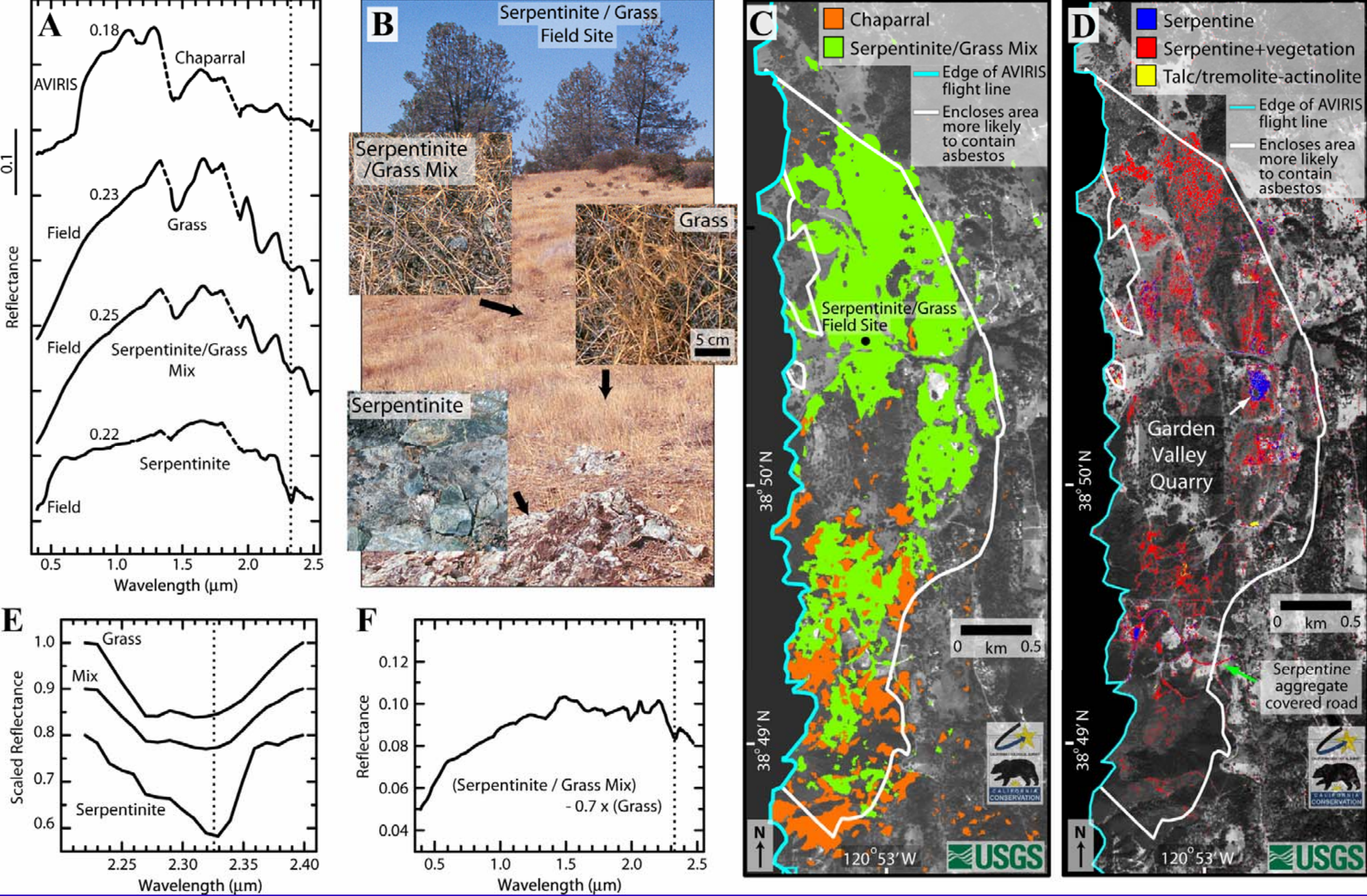


White lines from a previous study enclose areas with a higher potential to contain asbestos. They stop at the high water mark but the asbestos-bearing units continue under the water.

New homes being constructed on the side of a hill cut into serpentine-bearing rock.



Spectrally differentiating between serpentine and talc/tremolite-actinolite is straight forward. Differentiating between talc and tremolite-actinolite is considerably more challenging because of their spectral similarity.

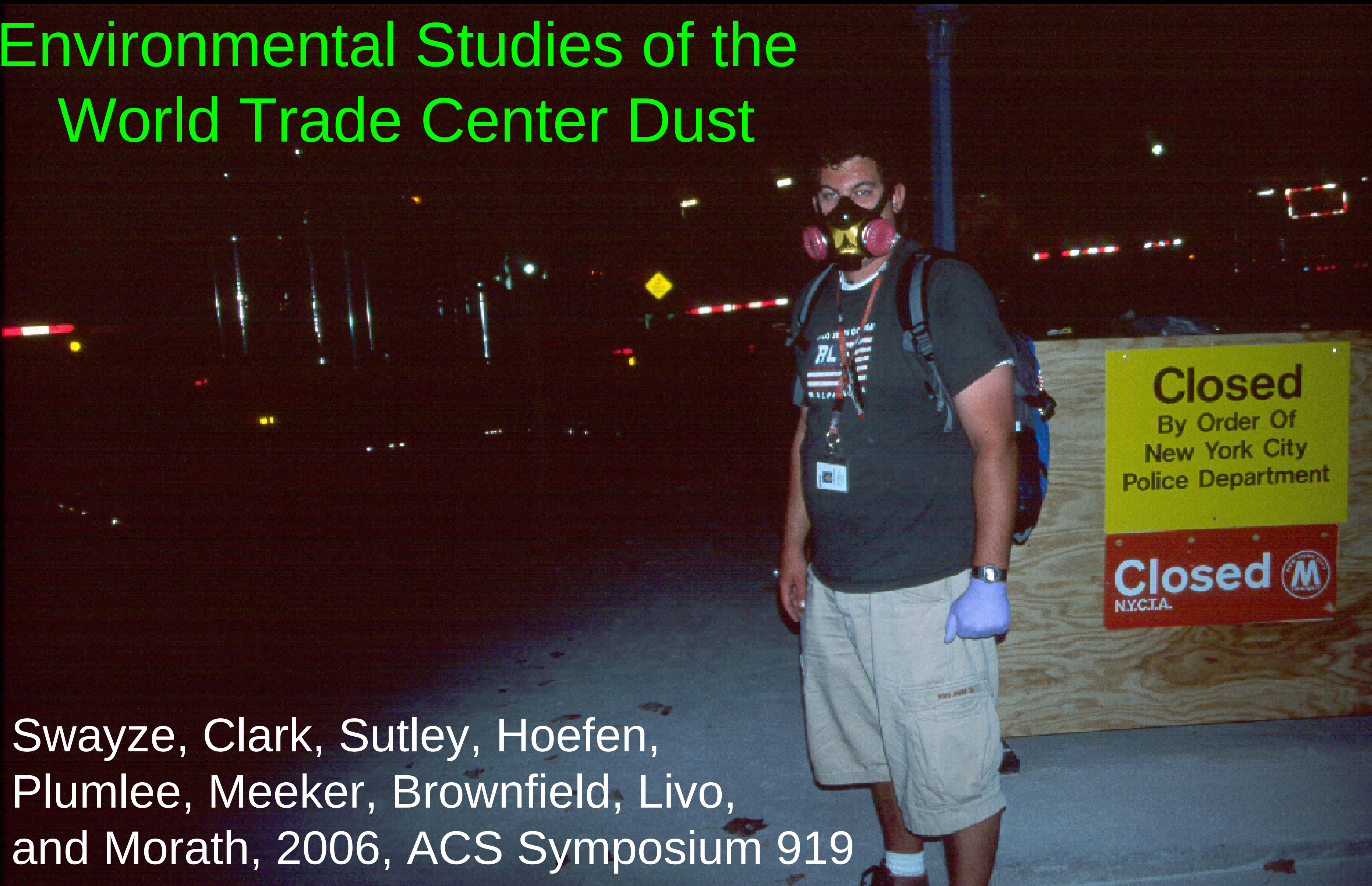


Grass+serpentine spectral signatures can be used to map serpentine in areas with up to 80% grass cover. Chaparral can also be used to locate serpentine.

NOA-Comments

- AVIRIS maps agree well with previous California Geological Survey mapping.
- The method mapped potentially asbestos-bearing rocks in areas with up to 80% dry grass cover and is independent of rock type.
- Other serpentine-based features recognized (roads, quarries, fill areas, etc.).
- Spectral maps are an important step in the development of tools for mapping NOA in many of the other 42 counties.

Environmental Studies of the World Trade Center Dust



Swayze, Clark, Sutley, Hoefen, Plumlee, Meeker, Brownfield, Livo, and Morath, 2006, ACS Symposium 919

Working Nights at WTC

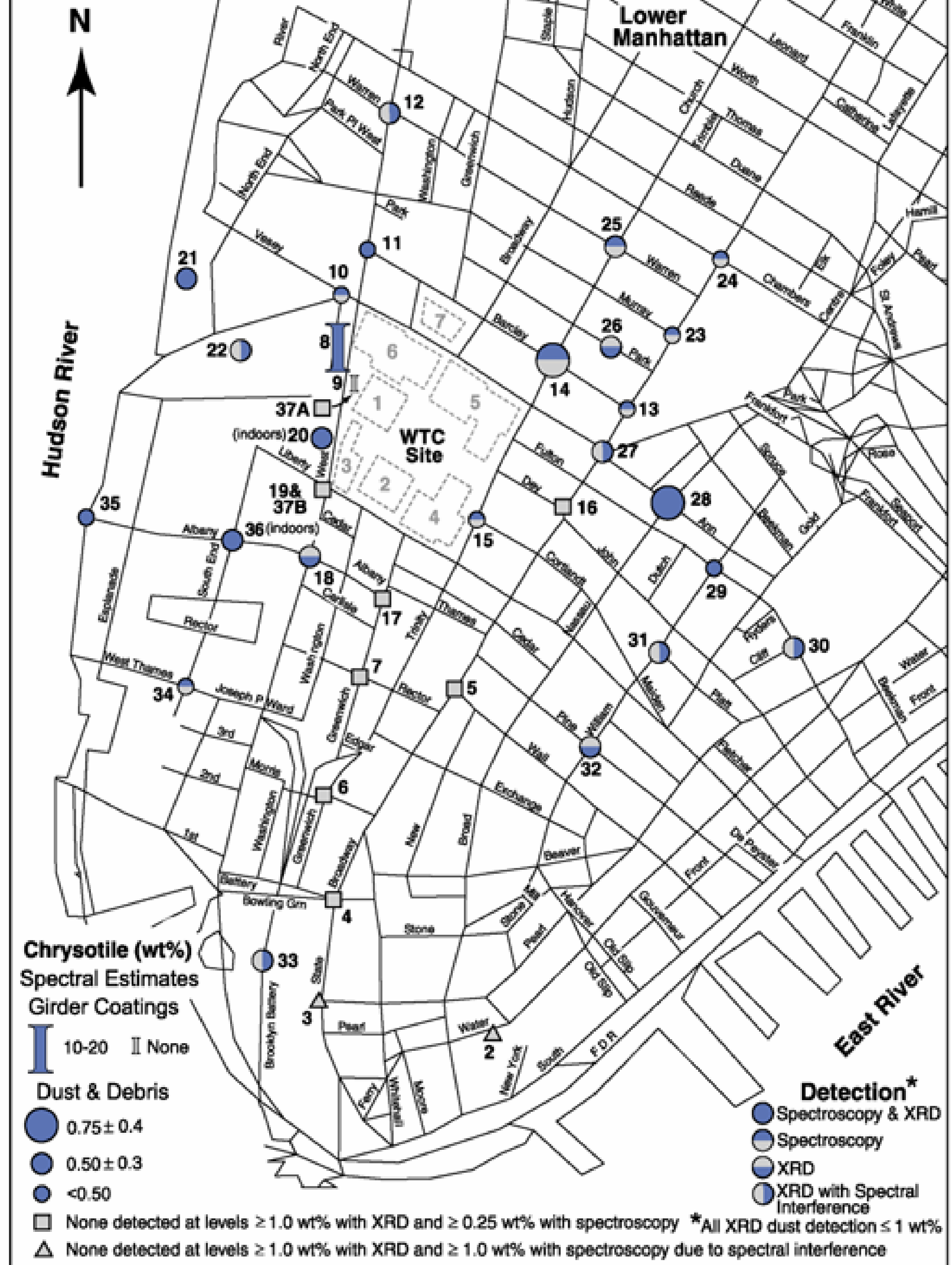
- 33 bulk dust samples were collected within a 1 km radius of ground zero Sept. 17 – 19th.
- No dust samples contained greater than 1 wt% chrysotile based on spectroscopic and XRD analysis.


Jeep
POLICE LINE DO NOT CROSS
POLICE LINE DO NOT CROSS

Chrysotile content in the WTC surface samples

This map is based on both spectroscopic and X-ray diffraction analysis of the bulk samples.

Two-thirds of the dust contain asbestos but at concentrations below the AVIRIS detection threshold which is about ~ 5 wt%.



WTC-Comments

• Spectra of dust samples indicates that chrysotile asbestos was not distributed uniformly during collapse of the WTC towers being lower to the south perhaps due to this area's proximity to Tower 2, which did not have chrystotile-bearing fireproof insulation.

• Spectra with a SNR=1:28,000 were needed to detect chyrsotile at levels below 1wt% in the WTC dust. The need for detecting concentrations of hazardous materials at this level and, perhaps, at even lower levels presents an extraordinary challenge for imaging spectrometers designed for emergency response.