Jet Propulsion Laboratory
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The Cuprite Project: Mineral Unmixing in the Longwave Infrared

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Mineral detection ranges

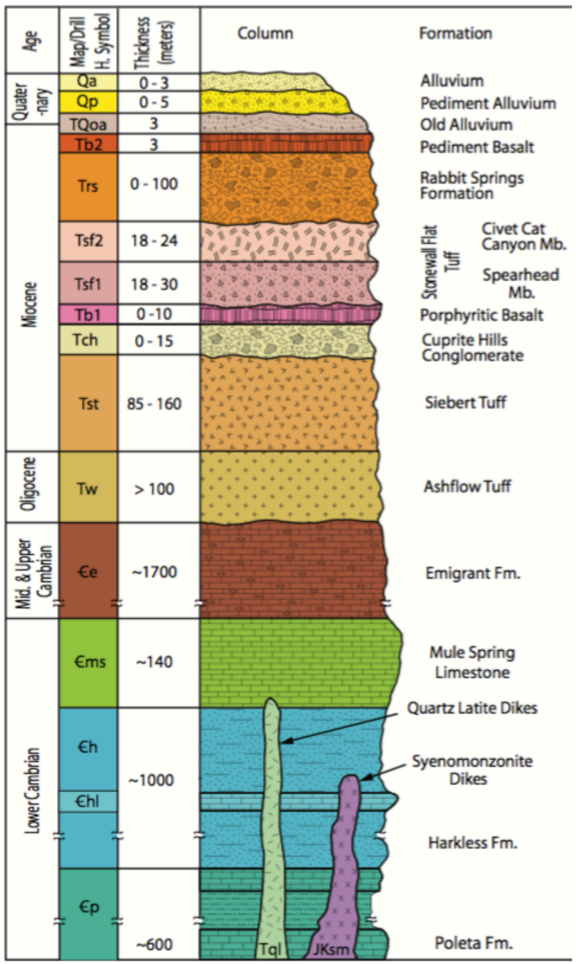
	Structure	Mineral Group	Example	VNIR Response	SWIR Response	LWIR Response
Silicates	Inosilicates	Amphibole	Actinolite	Non-Diagnostic	Good	Moderate
Silicates	Inosilicates	Pyroxene	Diopside	Good	Moderate	Good
Silicates	Cyclosilicates	Tourmaline	Elbaite	Non-Diagnostic	Good	Moderate
Silicates	Nesosilicates	Garnet	Grossular	Moderate	Non-Diagnostic	Good
Silicates	Nesosilicates	Olivine	Forsterite	Good	Non-Diagnostic	Good
Silicates	Sorosilicates	Epidote	Epidote	Non-Diagnostic	Good	Moderate
Silicates	Phyllosilicates	Mica	Muscovite	Non-Diagnostic	Good	Moderate
Silicates	Phyllosilicates	Chlorite	Clinochlore	Non-Diagnostic	Good	Moderate
Silicates	Phyllosilicates	Clay Minerals	Illite	Non-Diagnostic	Good	Moderate
Silicates	Phyllosilicates	Clay Minerals	Kaolinite	Non-Diagnostic	Good	Moderate
Silicates	Tectosilicates	Feldspar	Orthoclase	Non-Diagnostic	Non-Diagnostic	Good
Silicates	Tectosilicates	Feldspar	Albite	Non-Diagnostic	Non-Diagnostic	Good
Silicates	Tectosilicates	Silica	Quartz	Non-Diagnostic	Non-Diagnostic	Good
Non-Silicates	Carbonates	Calcite	Calcite	Non-Diagnostic	Moderate	Good
Non-Silicates	Carbonates	Dolomite	Dolomite	Non-Diagnostic	Moderate	Good
Non-Silicates	Hydroxides		Gibbsite	Non-Diagnostic	Good	Moderate
Non-Silicates	Sulphates	Alunite	Alunite	Moderate	Good	Moderate
Non-Silicates	Sulphates		Gypsum	Non-Diagnostic	Good	Good
Non-Silicates	Borates		Borax	Non-Diagnostic	Moderate	Uncertain
Non-Silicates	Halides	Chlorides	Halite	Non-Diagnostic	Uncertain	Uncertain
Non-Silicates	Phosphates	Apatite	Apatite	Moderate	Non-Diagnostic	Good
Non-Silicates	Hydrocarbons		Bitumen	Uncertain	Moderate	Uncertain
Non-Silicates	Oxides	Hematite	Hematite	Good	Non-Diagnostic	Non-Diagnostic
Non-Silicates	Oxides	Spinel	Chromite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic
Non-Silicates	Sulphides		Pyrite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic

Source: TerraCore Africa, with permission.

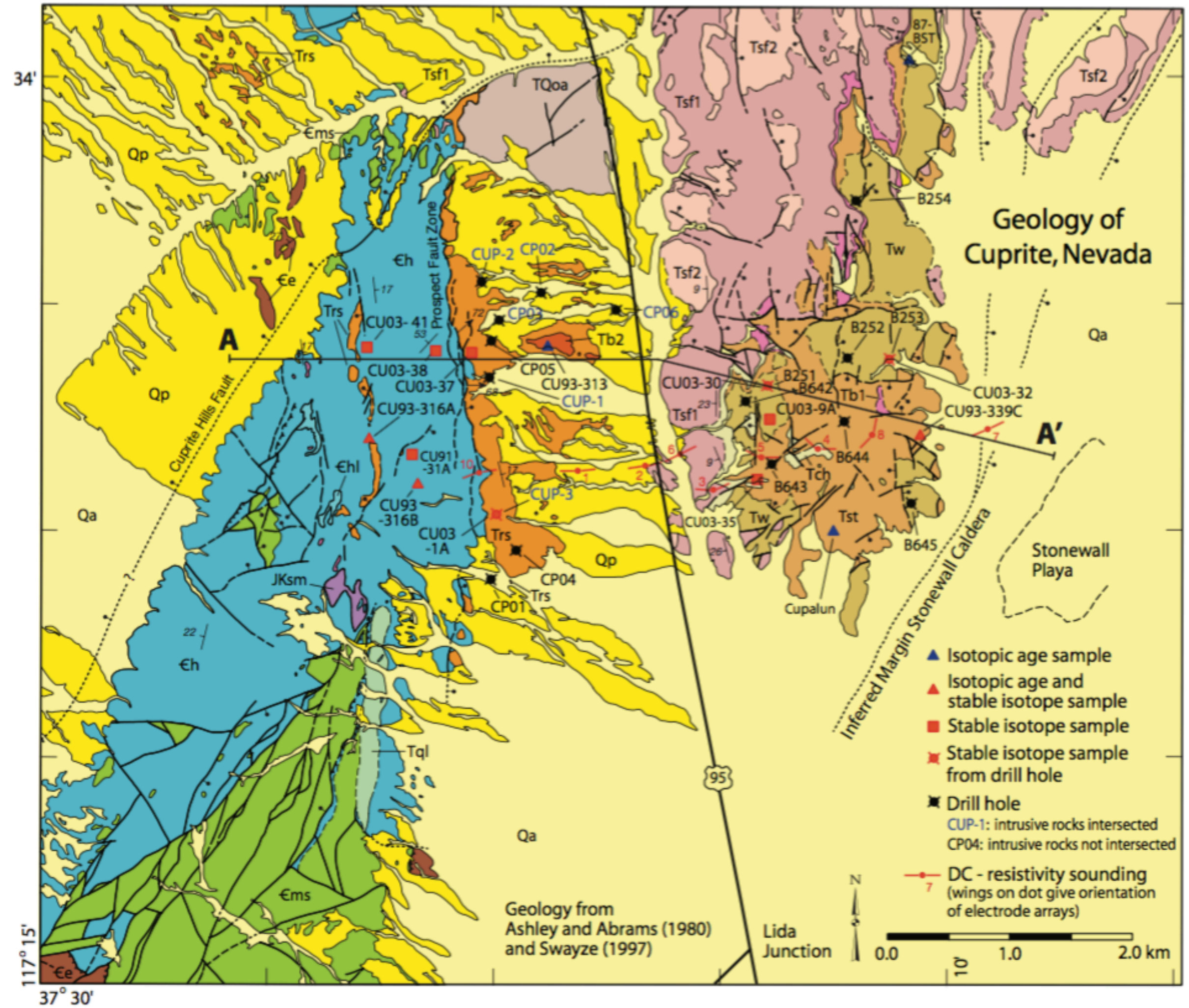
HyTES

Instrument Characteristic	HyTES
Mass (Scanhead)	12kg
Power	400W
Volume	1m x 0.5m (cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5 - 12 µm
Spectral Sampling Interval	4.5µm/256, i.e. 17 nm
Frame speed	35 or 22 fps
Integration time (1 scanline)	28 or 45 ms
Total Field of View	50 degrees
Calibration (preflight)	Full Aperature Blackbody
Detector Temperature	40K
Spectrometer Temperature	100K
Slit Length and Width	20 mm x 39 µm
IFOV	1.7066
Pixel Size/Swath at 2,000 m flight altitude	3.41m/1868.33m
Pixel Size/Swath at 20,000 m flight altitude	34.13m/18683.31m

Cuprite

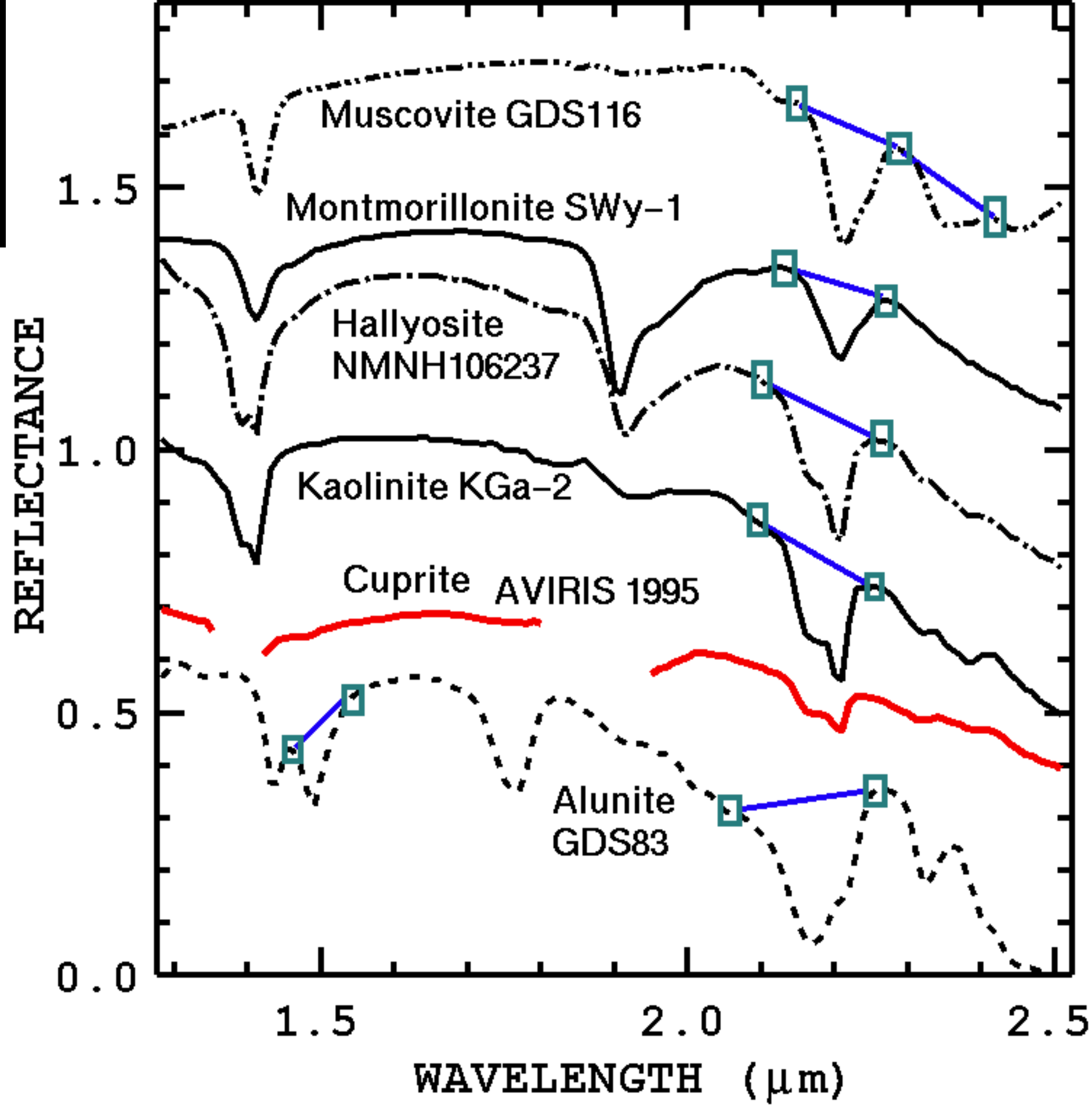


Age
Map/Drill H. Symbol
Thickness (meters)
Column
Formation
Quaternary
Qa
0 - 3
Alluvium
Qp
0 - 5
Pediment Alluvium
TQoa
3
Old Alluvium
Tb2
3
Pediment Basalt
Miocene
Trs
0 - 100
Rabbit Springs Formation
Tsf2
18 - 24
Stonewall Flat Tuff
Civet Cat Canyon Mb.
Tsf1
18 - 30
Spearhead Mb.
Tb1
0 -10
Porphyritic Basalt
Tch
0 - 15
Cuprite Hills Conglomerate
Tst
85 - 160
Siebert Tuff
Oligocene
Tw
> 100
Ashflow Tuff
Mid. & Upper Cambrian
Єe
~1700
Emigrant Fm.
Lower Cambrian
Єms
~140
Mule Spring Limestone
Quartz Latite Dikes
Єh
~1000
Syenomonzonite Dikes
Єhl
Harkless Fm.
Єp
~600
Poleta Fm.
Tql
JKsm



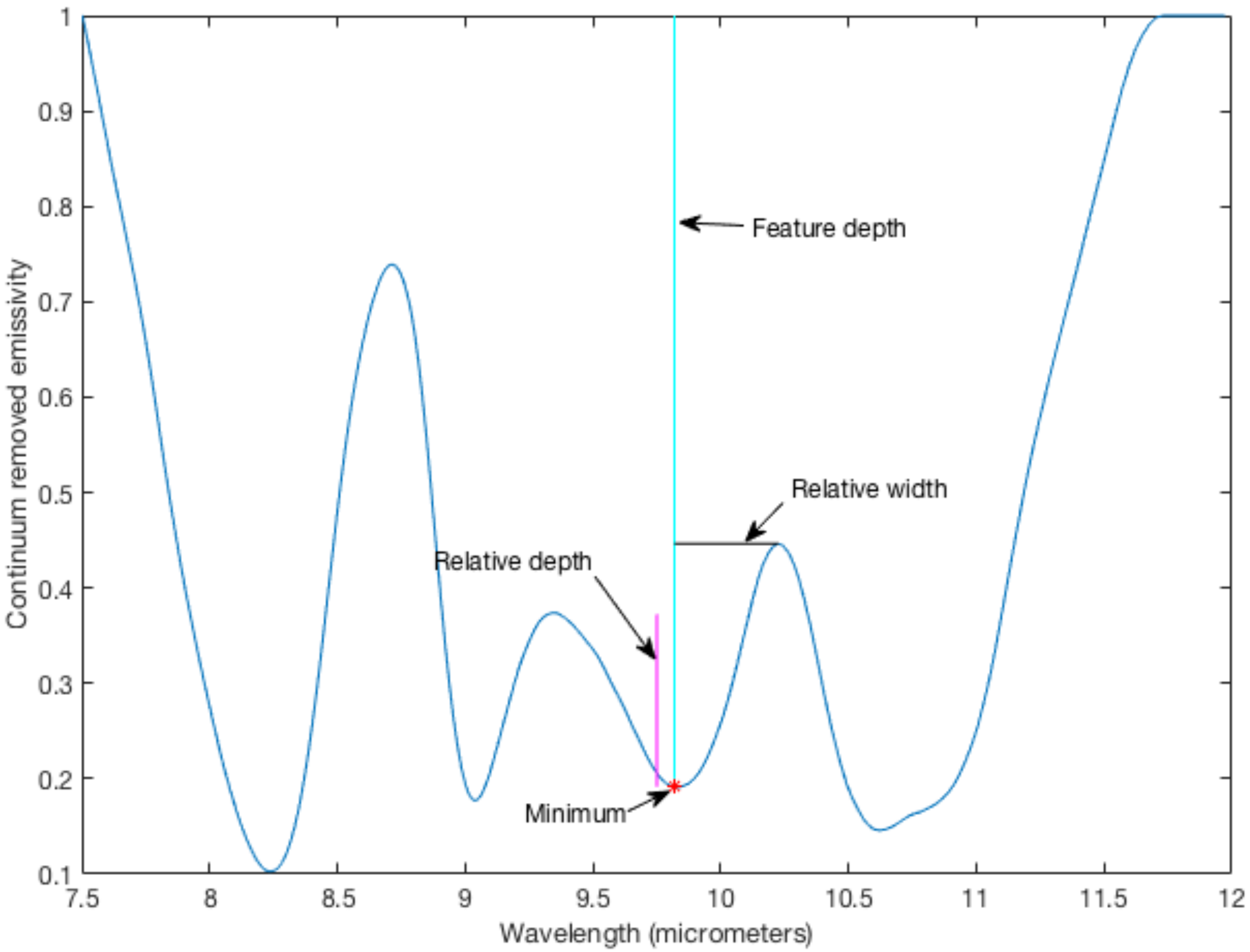
Geology of Cuprite, Nevada
34'
117° 15'
37° 30'
10'
A
A'
Qp
Qa
Qoa
TQoa
Єms
Єe
Єh
Єhl
JKsm
Tql
Trs
Tsf1
Tsf2
Tb1
Tb2
Tw
Tch
Tst
Cuprite Hills Fault
Prospect Fault Zone
Inferred Margin Stonewall Caldera
Stonewall Playa
Cupalun
95
CUP-2
CP02
CP03
CP06
CP05
CU93-313
CUP-1
CU03-41
CU03-38
CU03-37
CU93-316A
CU91-31A
CU93-316B
CU03-1A
CUP-3
CP04
CP01
CU03-30
CU03-9A
CU03-35
CU03-32
CU93-339C
B251
B252
B253
B254
B642
B643
B644
B645
87-BST
Isotopic age sample
Isotopic age and stable isotope sample
Stable isotope sample
Stable isotope sample from drill hole
Drill hole
CUP-1: intrusive rocks intersected
CP04: intrusive rocks not intersected
DC - resistivity sounding (wings on dot give orientation of electrode arrays)
N
0.0
1.0
2.0 km
Geology from Ashley and Abrams (1980) and Swayze (1997)
Lida Junction

Mineral features

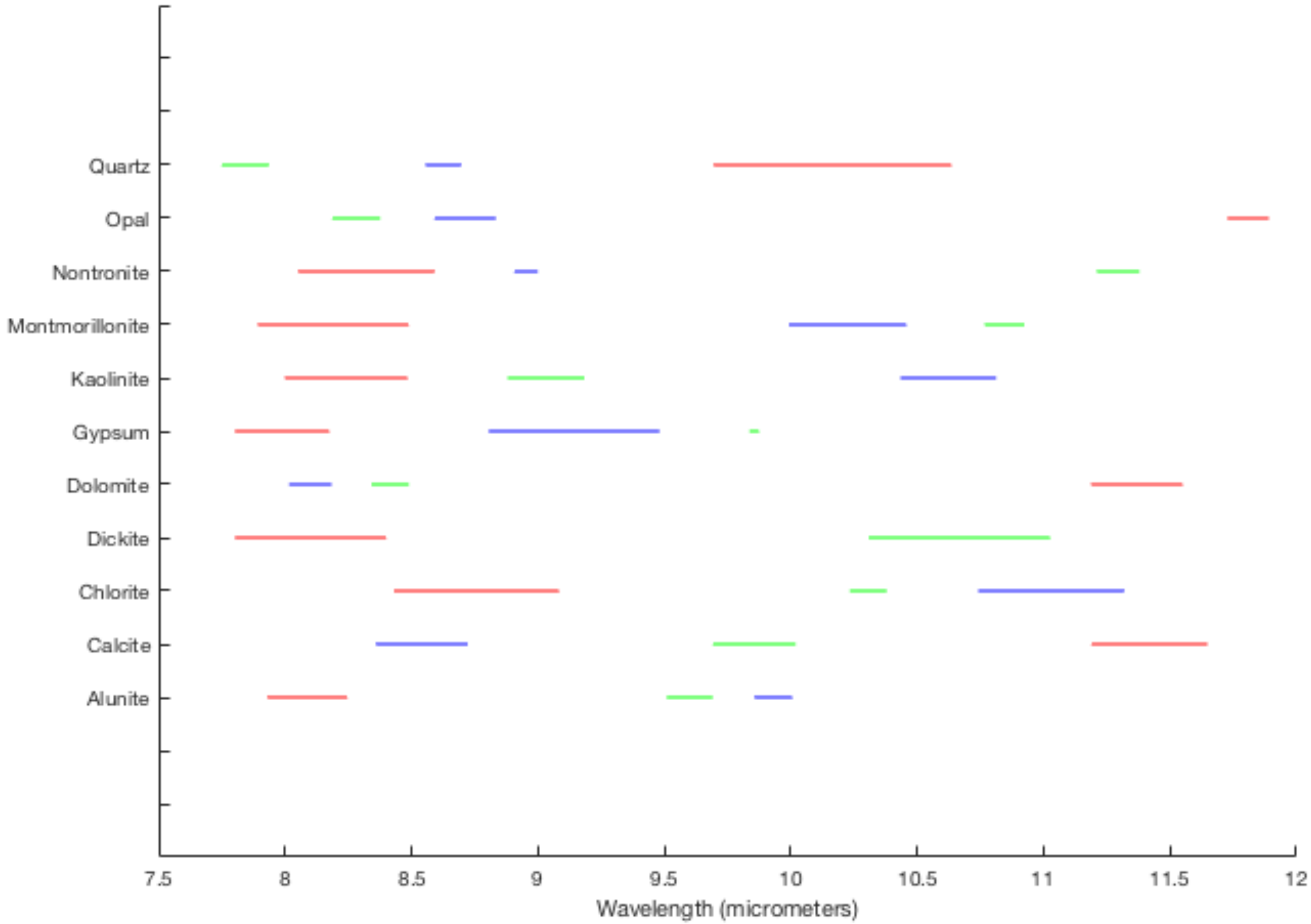


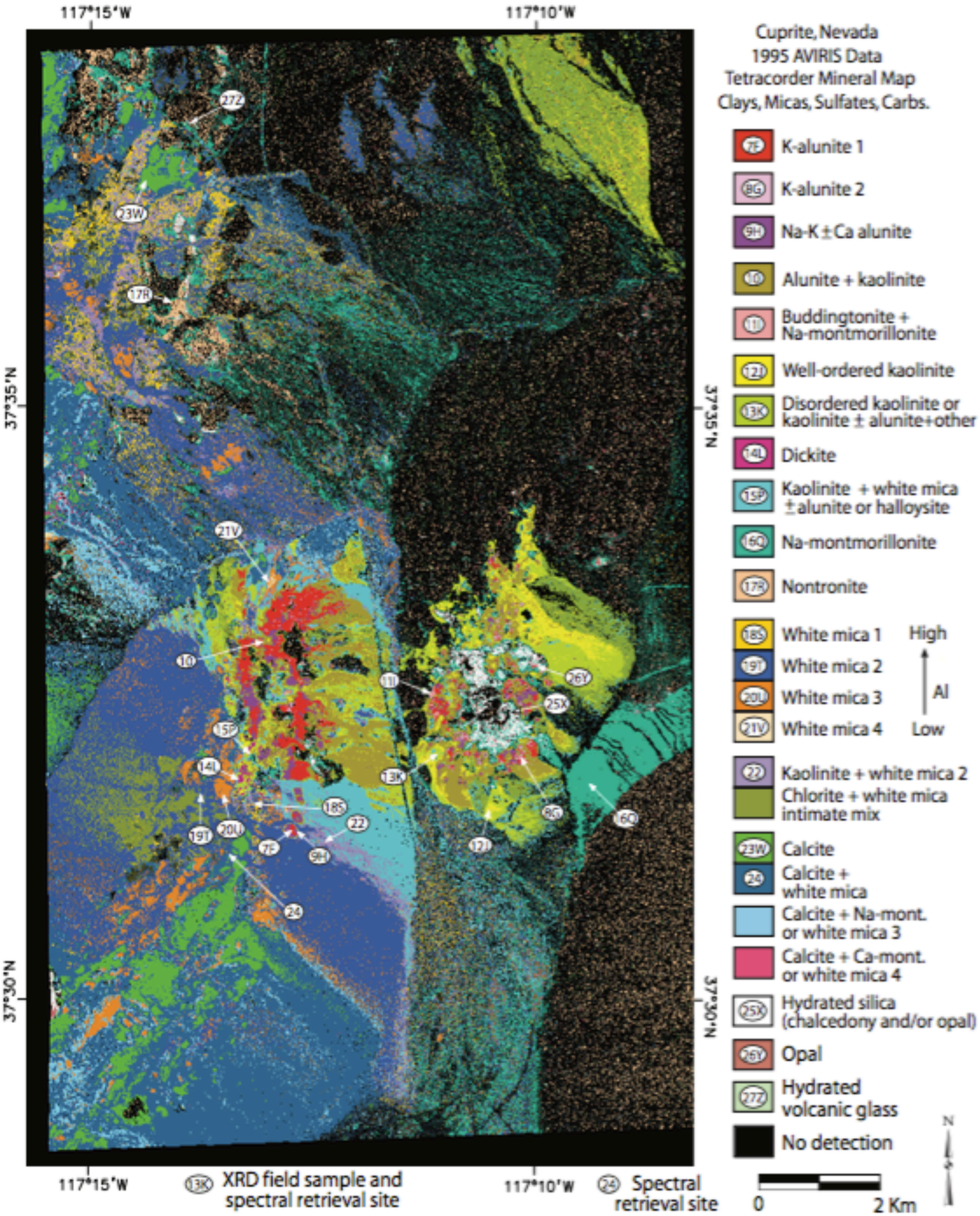
Clark et. al. Imaging Spectroscopy: Earth and Planetary Remote Sensing with the USGS Tetracorder and Expert Systems. *Journal of Geophysical Research*, 2003

Mineral features



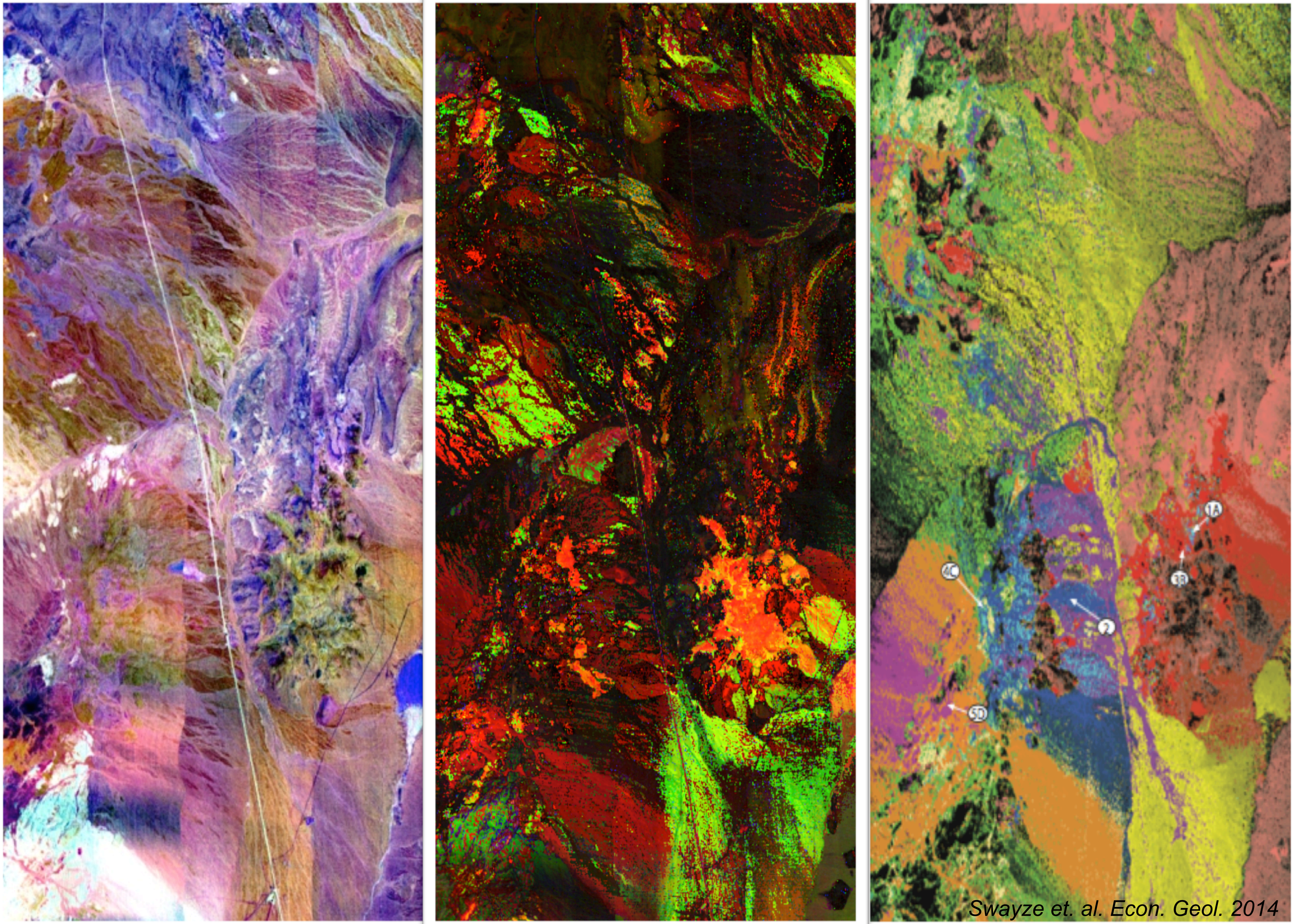
Mineral features

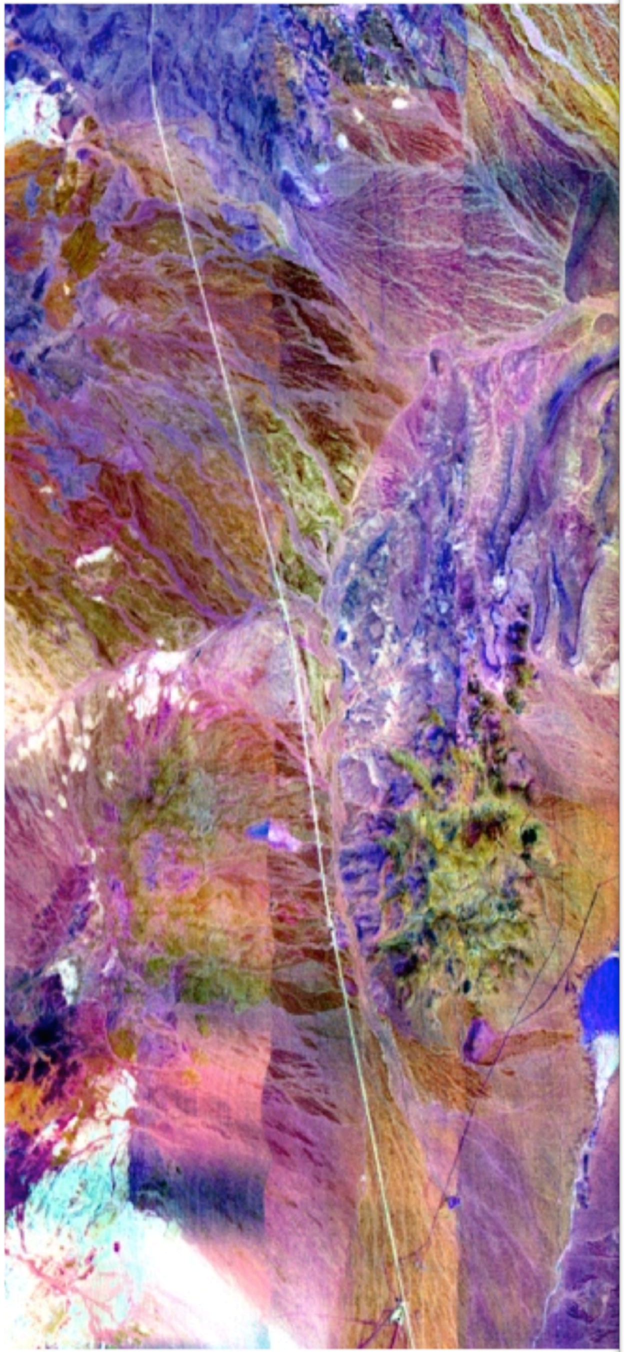


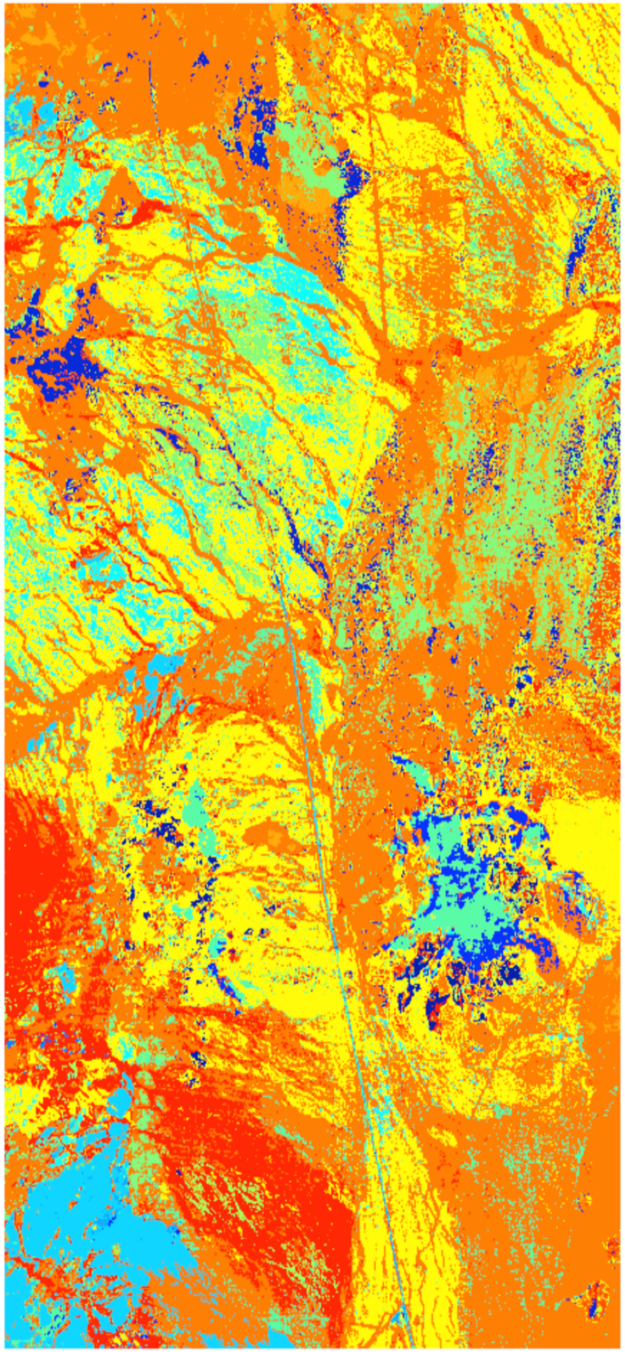


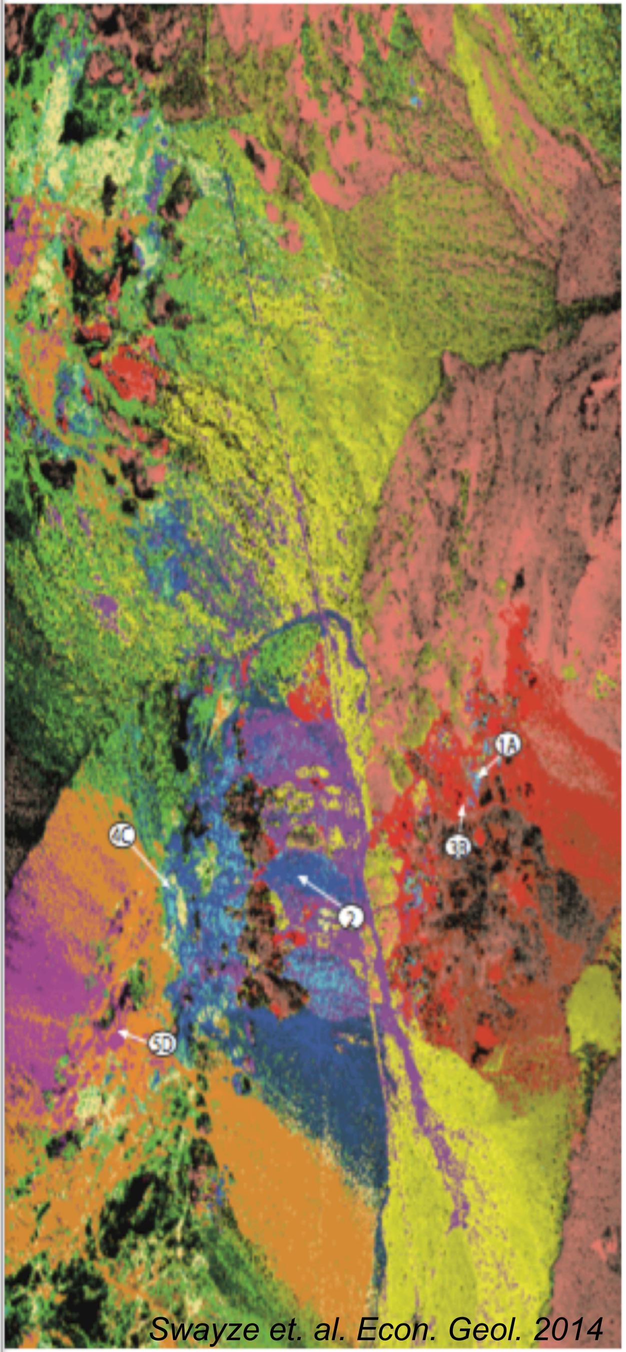
Tetracorder

- Tetracorder (Clark, Swayze and Livo, et al. 2003), is perhaps the best-known rule-based mineral mapping system.
- The algorithm first removes the continuum of the spectrum.
- Next, diagnostic wavelength ranges (the range containing local minima unique to a particular mineral type) are used along with an extensive library of minerals to identify mineral classes.
- A number of other rules avoid false matches, including a comparison at both reflectance and continuum-removed level.


1A
1B
4C
2
5D
Swayze et. al. Econ. Geol. 2014






1A
3B
4C
2
5D
Swayze et. al. Econ. Geol. 2014

Summary

- The long-wave infrared needed to accurately map silica and feldspar minerals.
- However, it is complimentary to the short-wave infrared for mineral mapping. Ideally, an extended spectral range is needed.
- Unsupervised mineral mapping techniques show promising preliminary results when using spectral feature separation.

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