

#GWF2020



# GWF

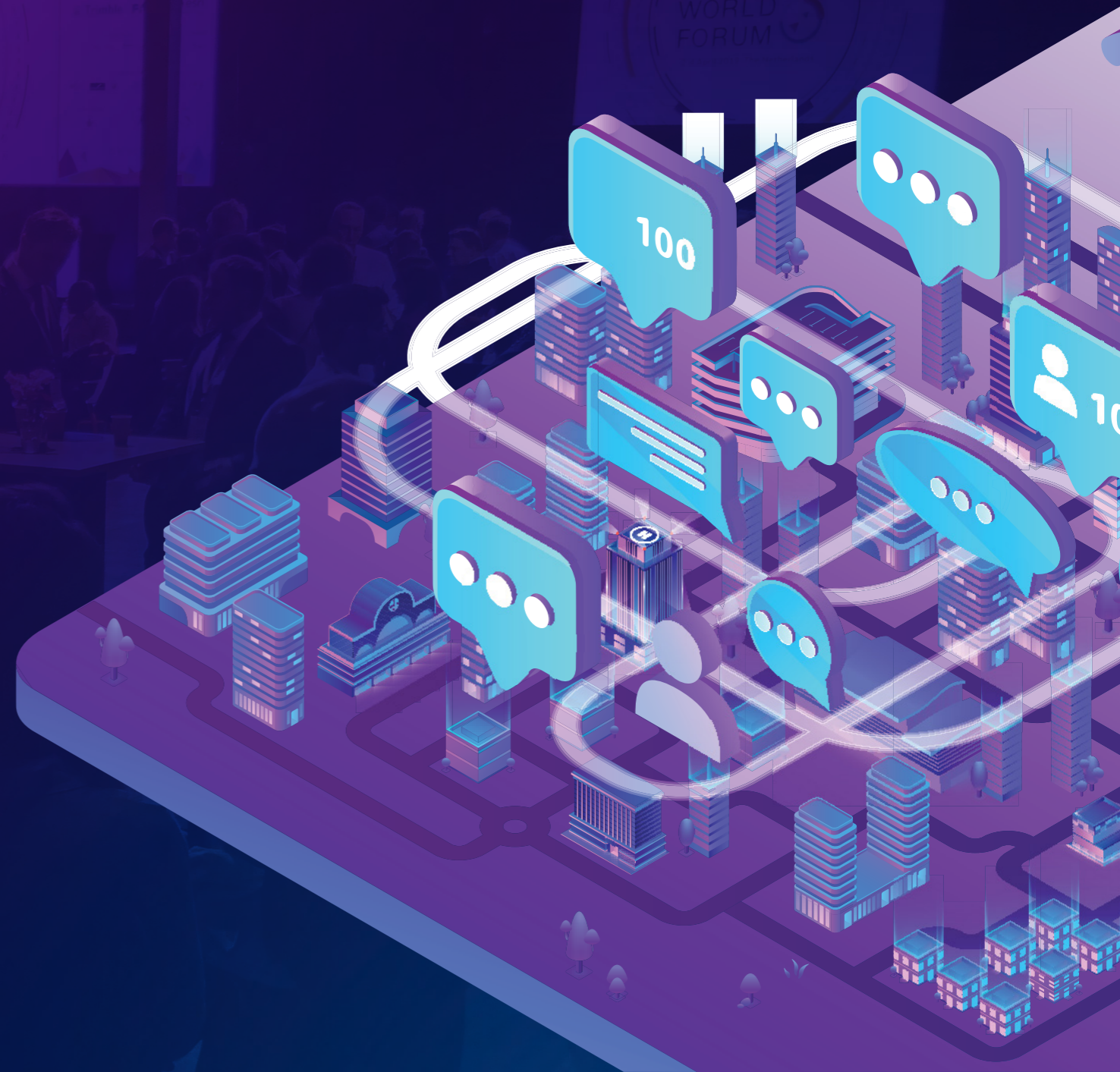
GEOSPATIAL WORLD FORUM

**TRANSFORMING ECONOMIES IN 5G ERA**

*The Geospatial Way!*

**7-9 April 2020 /// Amsterdam**

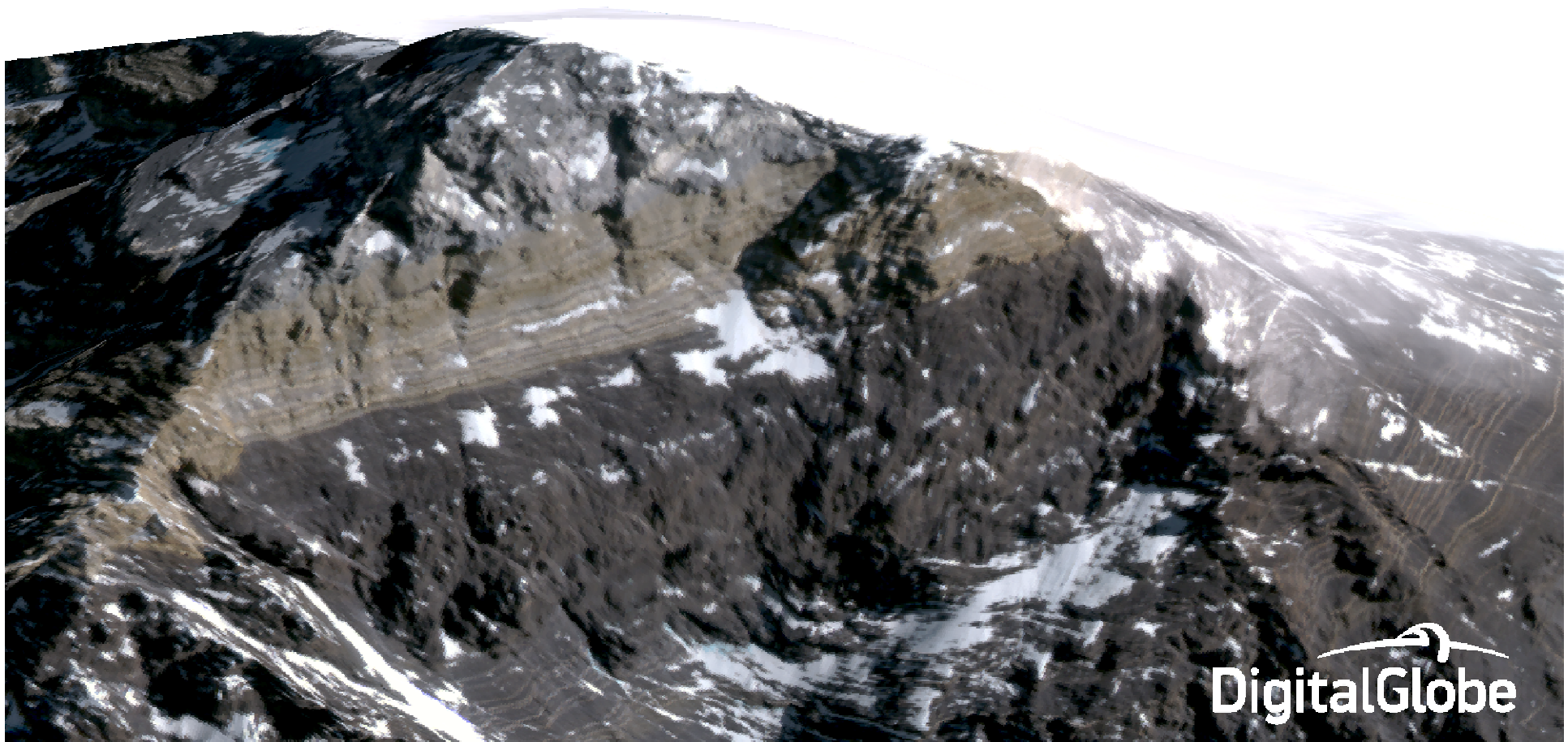
[www.geospatialworldforum.org](http://www.geospatialworldforum.org)





# Geology, Exploration, and WorldView-3 SWIR

Kumar Navulur, PhD

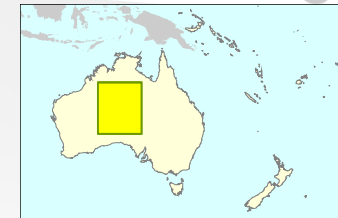


# Agenda

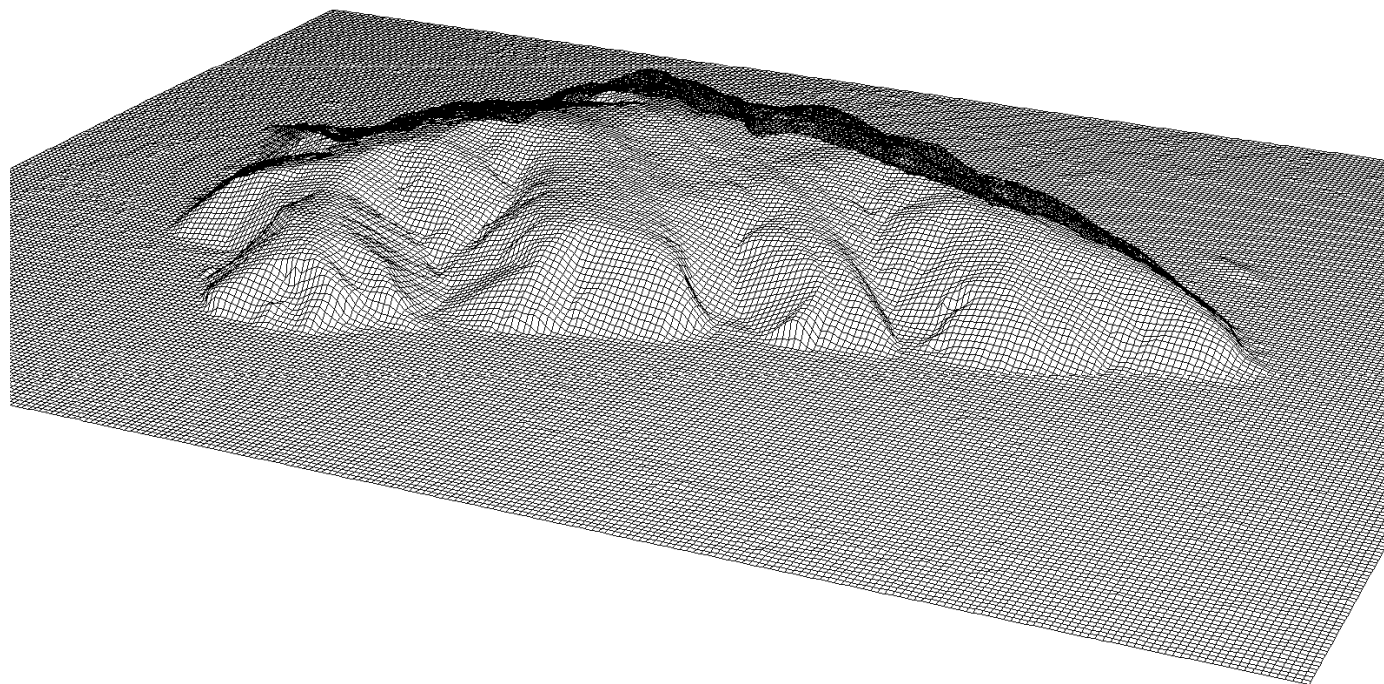
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1. Uluru Rock, Australia
2. Theory:
  - a. Reflectance
  - b. SWIR
  - c. WV-3 and CAVIS
3. Applications:
  - a. Cuprite, USA
  - b. Nunavut, Canada
  - c. Lisbon Valley, USA

# Uluru Rock, Australia

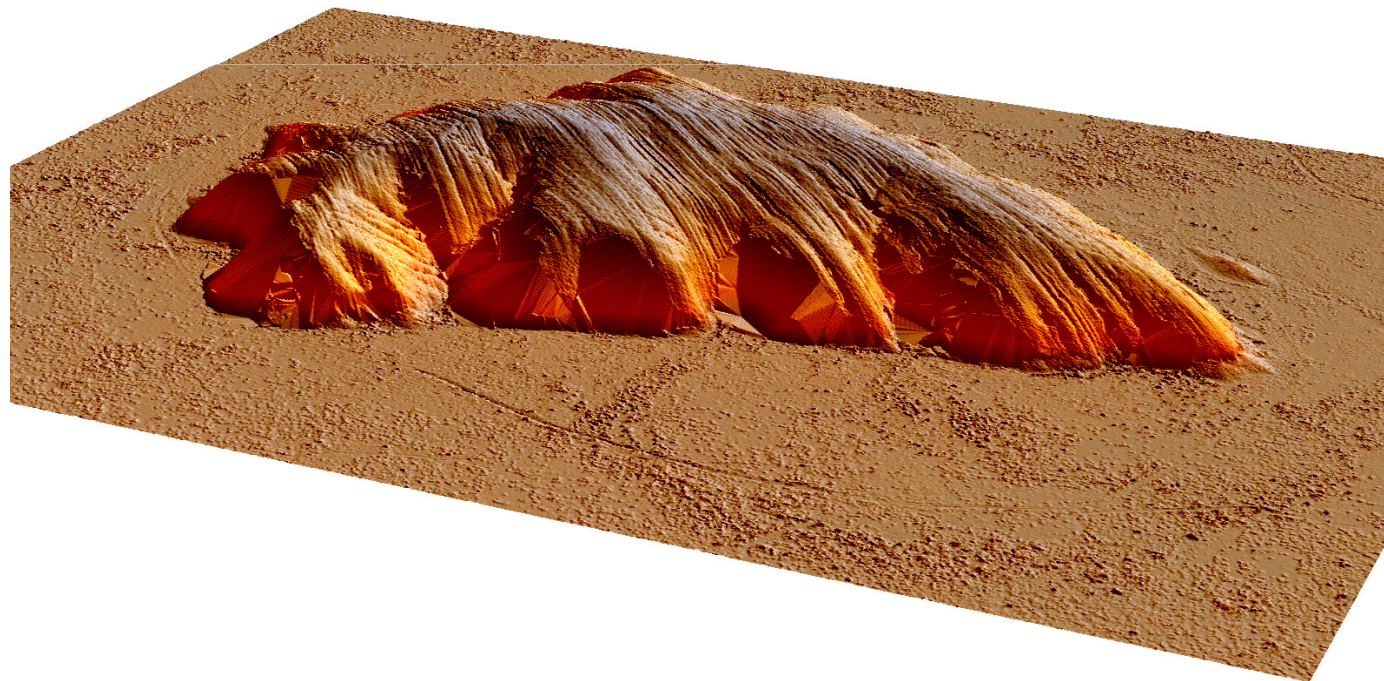
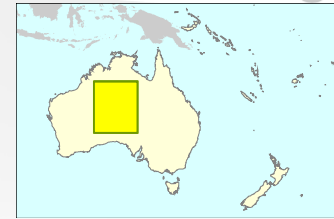


*DEM + spectral analysis = useful data fusion!*

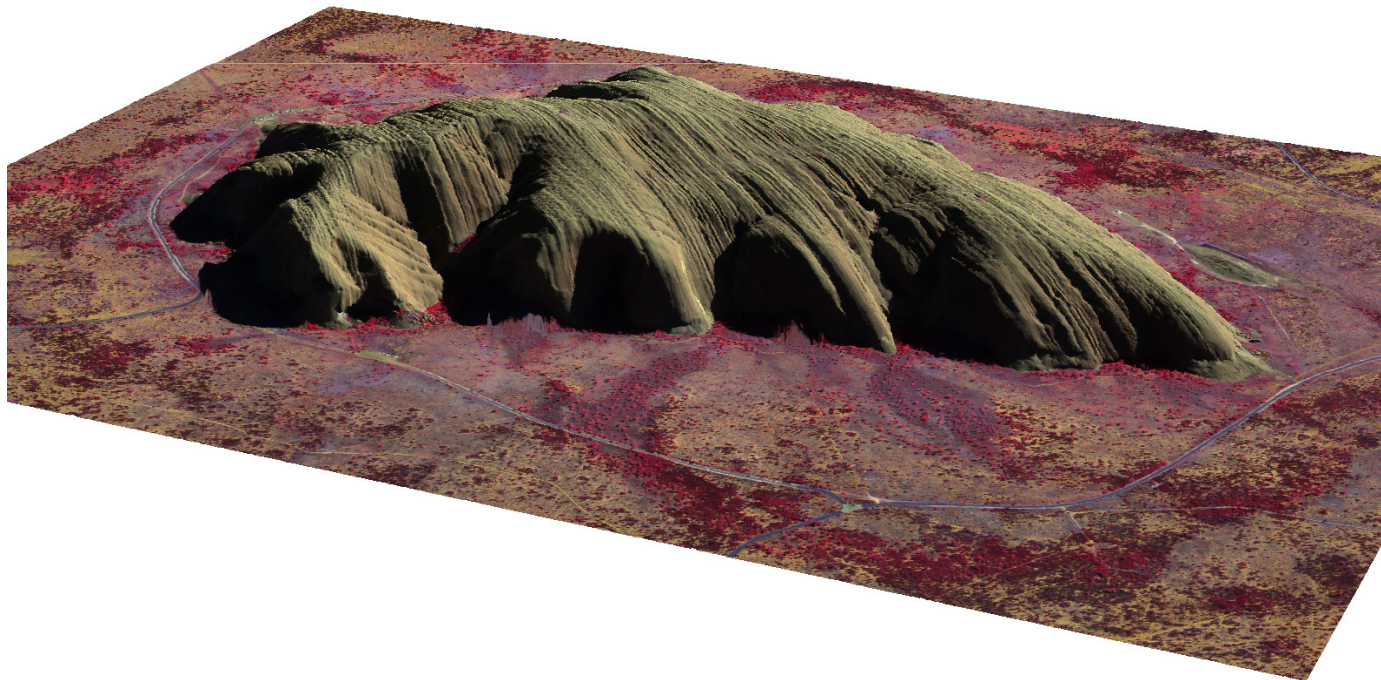
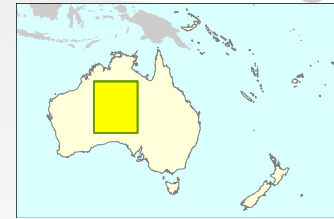




# Uluru Rock, Australia

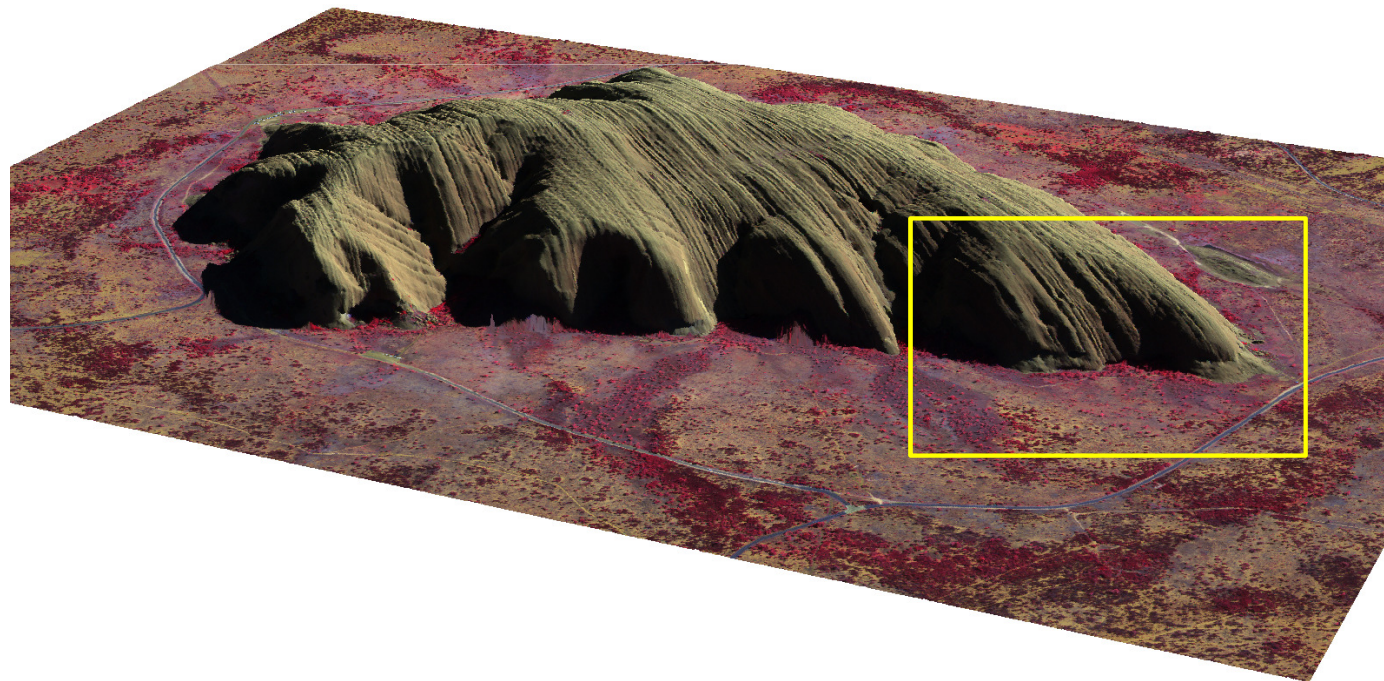
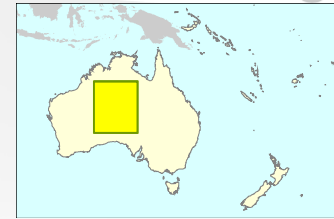


# Uluru Rock, Australia

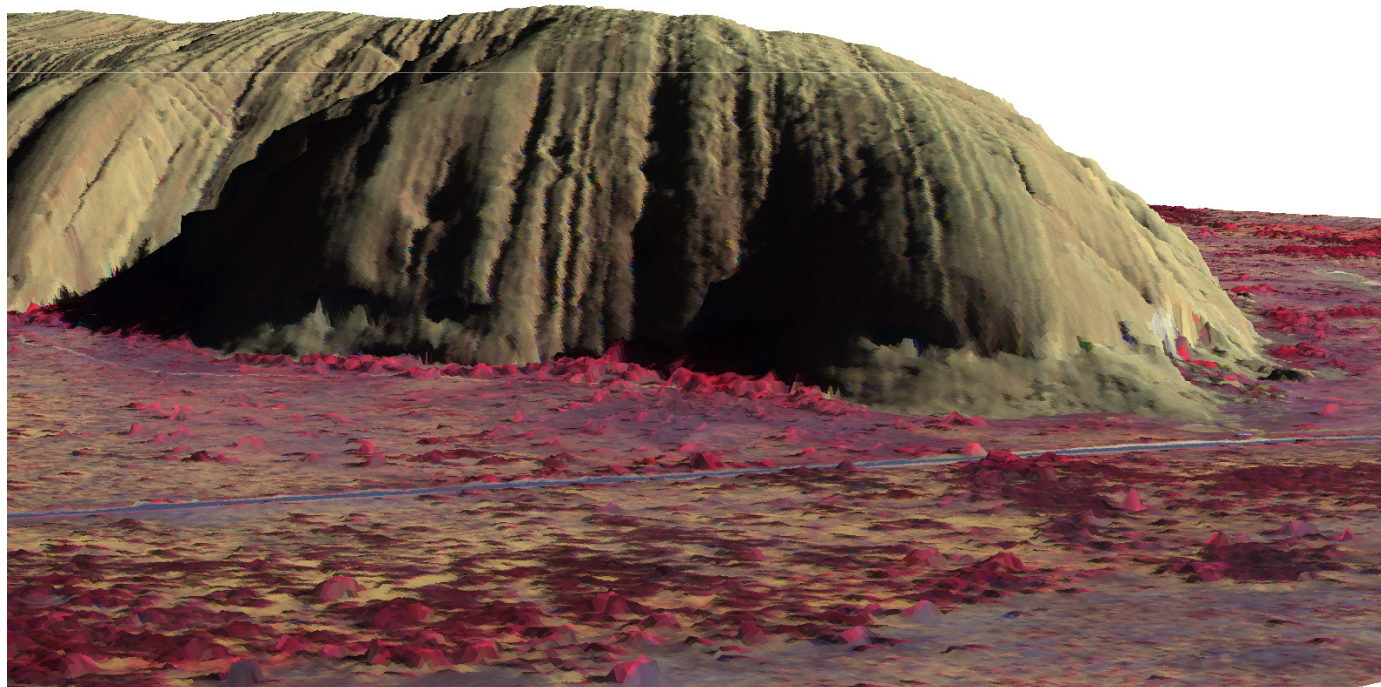
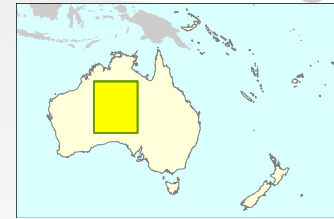




# Uluru Rock, Australia

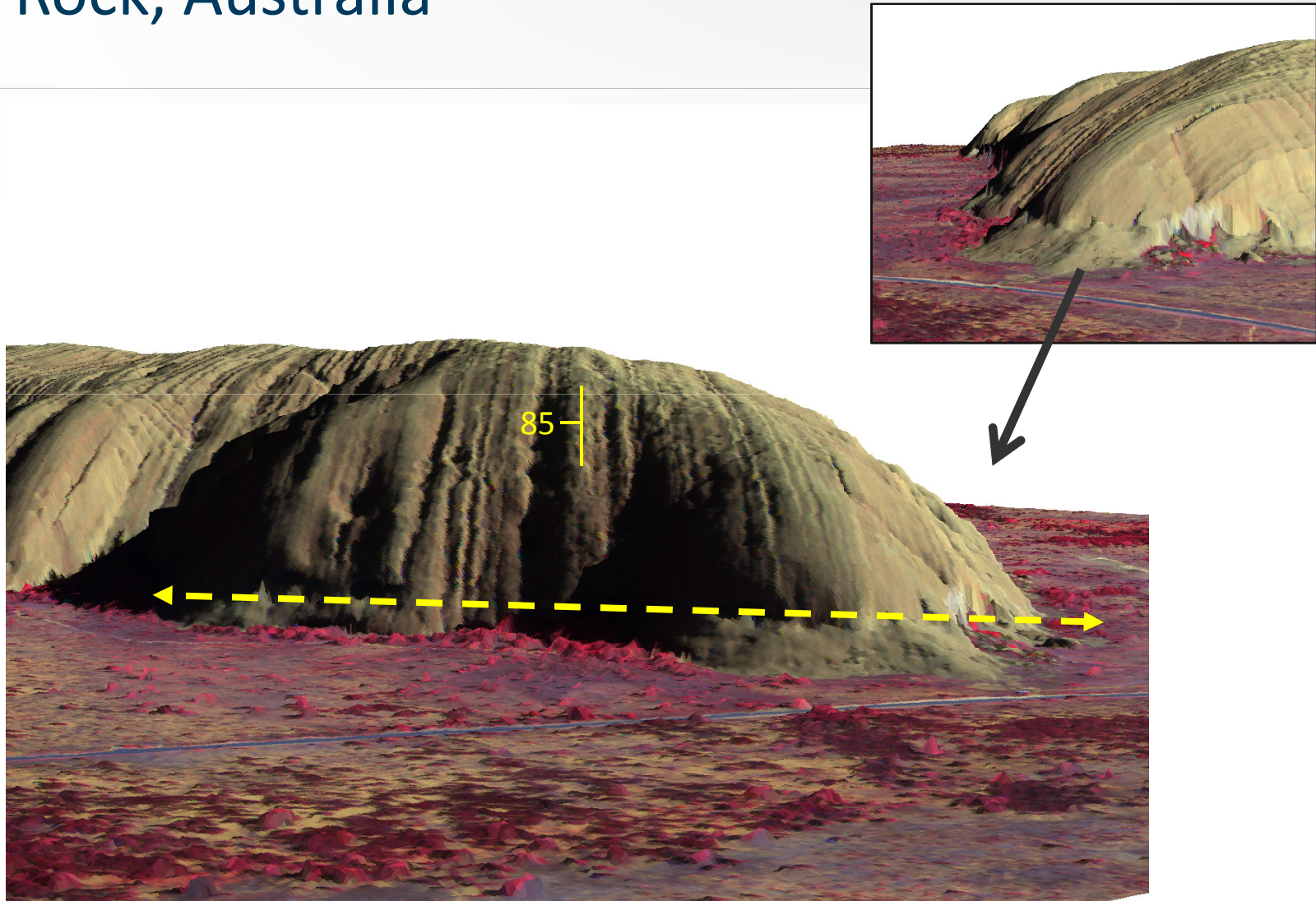


# Uluru Rock, Australia

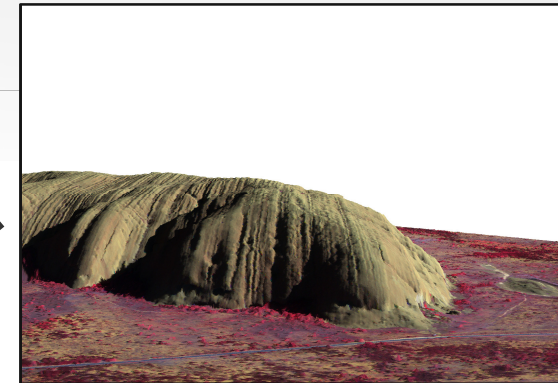
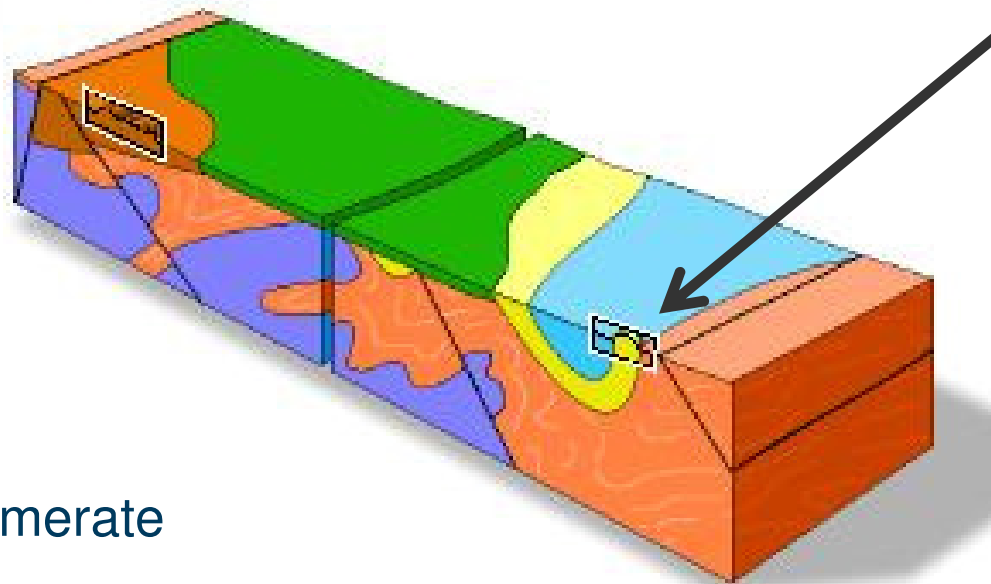










# Uluru Rock, Australia



# Uluru Rock, Australia



## Legend

-  Conglomerate
-  Arkose
-  Folded Proterozoic sedimentary rocks
-  Igneous and metamorphic rocks
-  Palaeozoic rocks
-  Alluvial sediments

Graphic Source:



Australian Government  
Department of Sustainability, Environment,  
Water, Population and Communities



# Why Reflectance?

## radiance vs reflectance

The fine print:

- Reflectance has a lot of moving parts
- Sun-Earth distance.
- Sun-Target-Sensor geometry.
- Atmospheric effects.
- Calibration.
- BRDF
- etc, etc.



# What is SWIR?

(Short Wave Infrared)

Examples, there are many more applications!



Landsat 8  
(30 m)



ASTER  
(15/30 m)



WV 2 - 3  
(1.2 / 3.7)



WV 3 only





# Sensor Introduction

## AVIRIS:

- Imaging Spectrometer: 224 bands VNIR-SWIR.
- Pixels vary: 2 to 20 m.
- Used to generate WV3 simulated spectra.

## ASTER

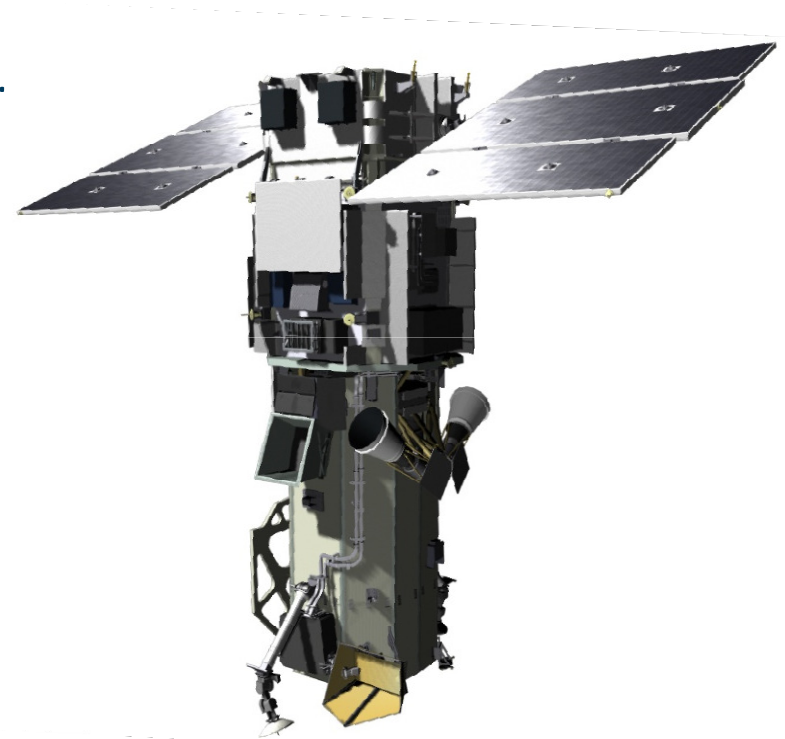
- Multispectral: 10 bands VNIR - SWIR.
- Pixels: 15, 30 m.
- SWIR failed.

## Landsat (8)

- Multispectral: 8 bands VNIR - SWIR.
- Pixels: 30 m.

## WorldView 3

- Multispectral: 16 bands VNIR-SWIR.
- Pixels: 1.2, 3.7 m.
- CAVIS instrument for atmospheric retrievals.



CAVIS is a new instrument on WorldView3

# CAVIS → Reflectance

## Atmospheric Retrievals on WorldView3

### CAVIS Band Names

Desert Clouds

**Aerosol-1**

Green

**Aerosol-2**

**Water-1**

**Water-2**

**Water-3**

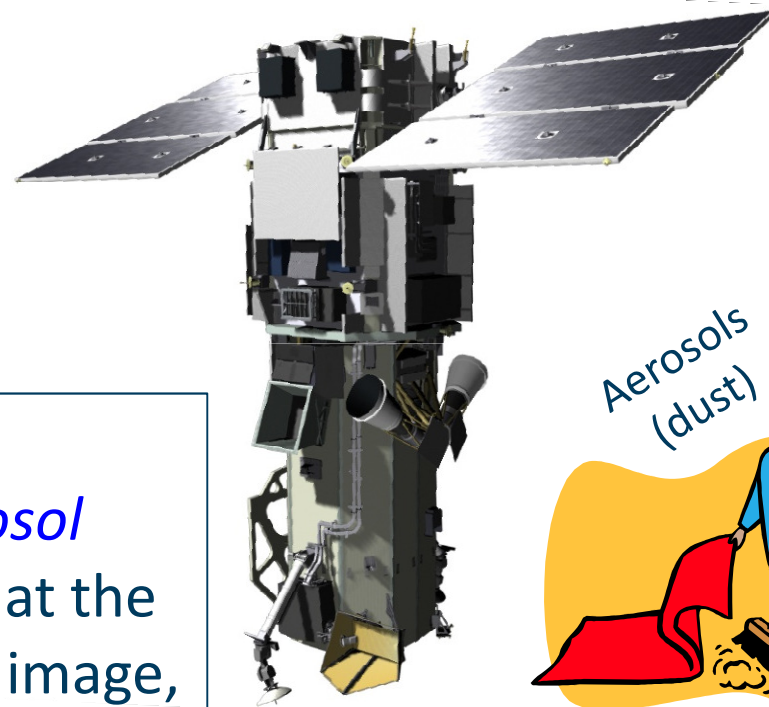
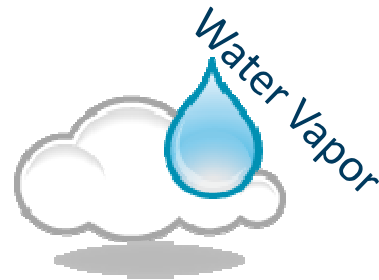
NDVI-SWIR

Cirrus

Snow

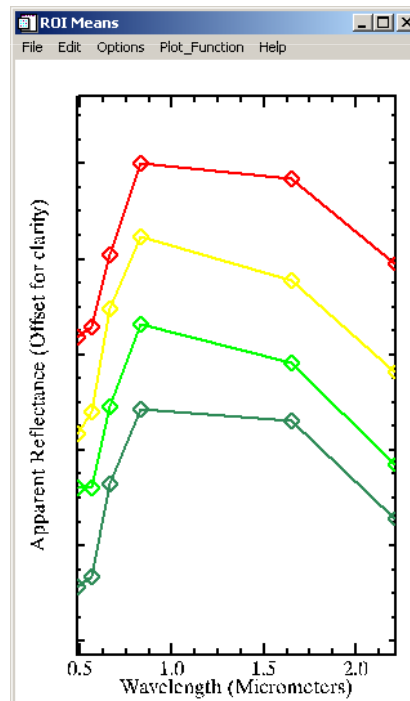
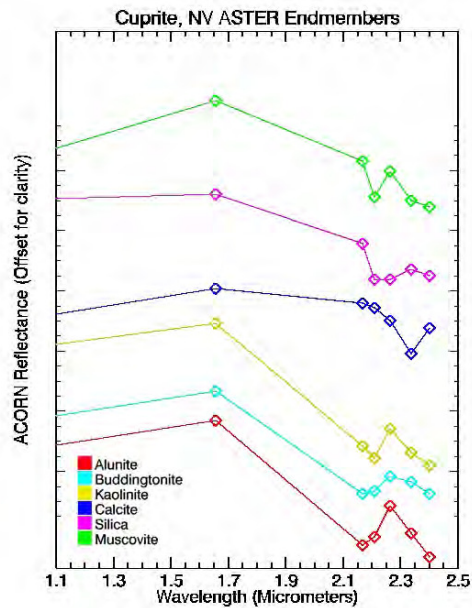
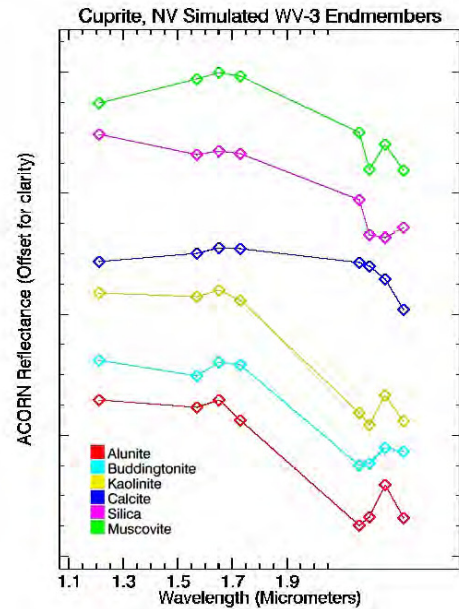
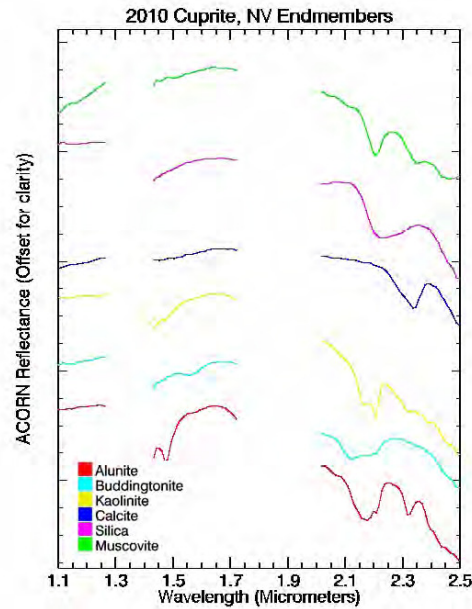
**Aerosol-3**

**Aerosol-3**



CAVIS retrieves atmospheric *Aerosol* and *Water Vapor* at the same time as the image, making reflectance calculations easier.





## Compare Spectra:

- AVIRIS
- WV-3
- ASTER
- Landsat TM

Graphic Source: Kruse and Perry, 2012

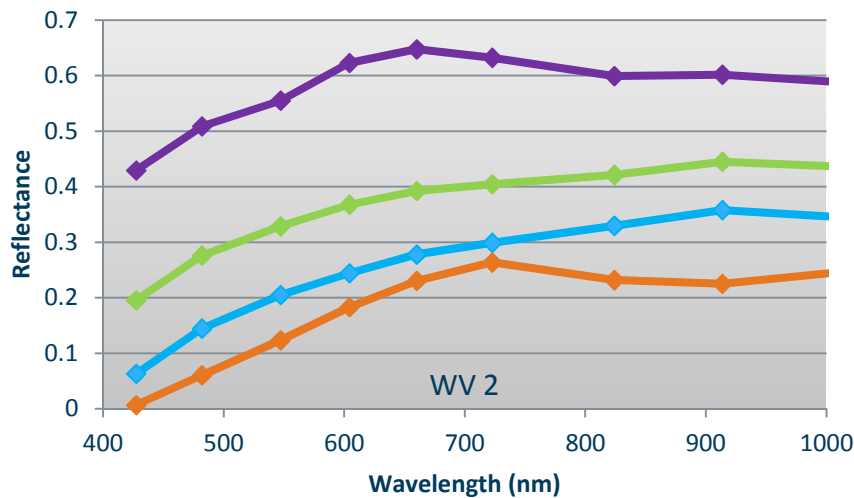
# Spectral reflectance of rocks

AVIRIS resampled to WV2, WV3 response

*“these are remote sensing minerals”*

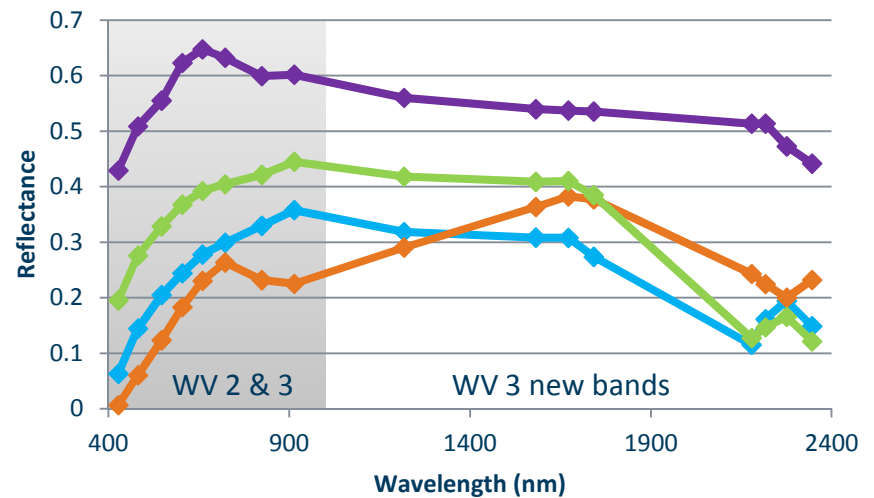
- ◆— Calcite
- ◆— Alunite
- ◆— Jarosite
- ◆— Kaolinite

**Calcite-Kaolinite-Alunite-Jarosite**



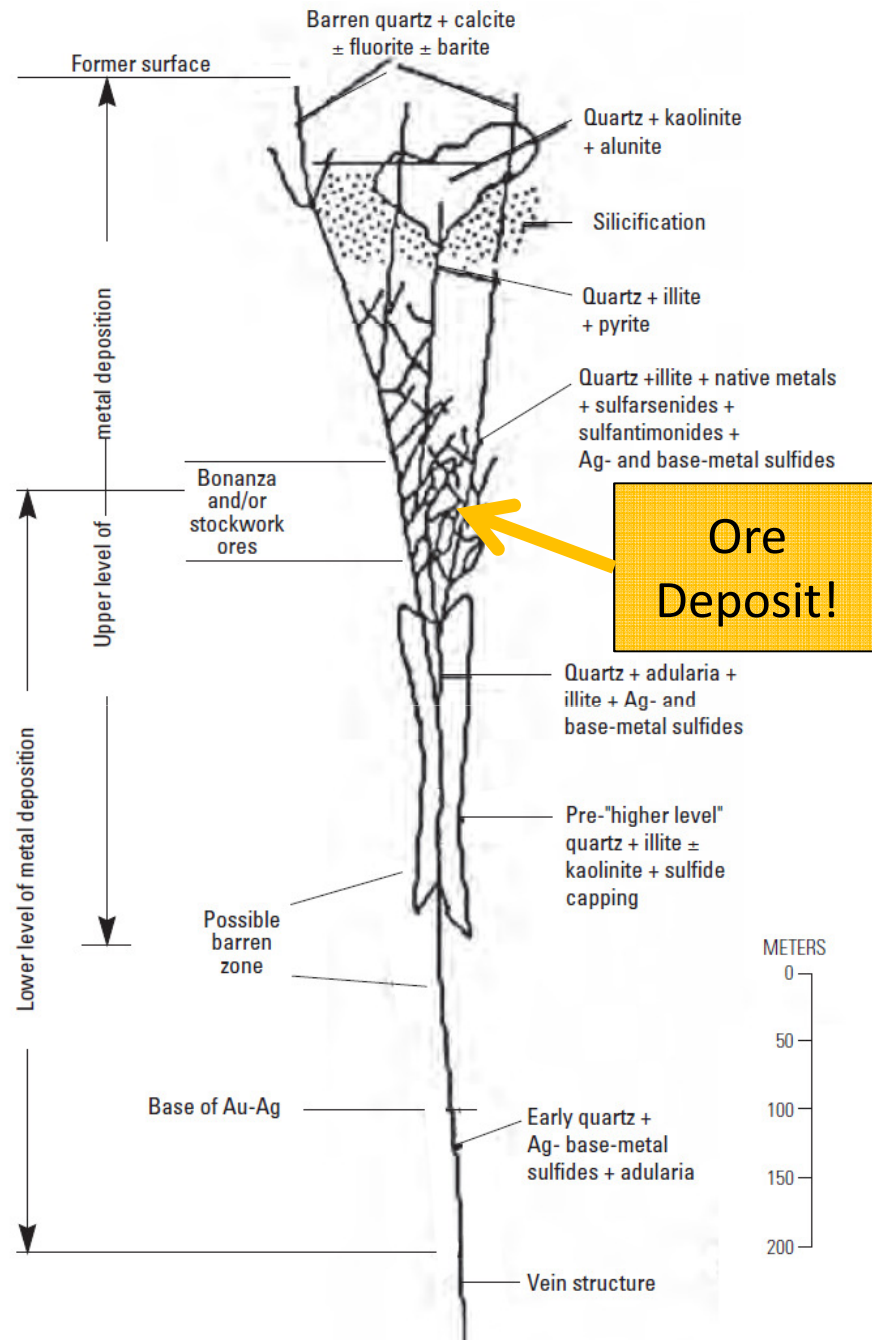
WV2: Similar in VNIR

**Calcite-Kaolinite-Alunite-Jarosite**



WV3: Differentiated in VNIR-SWIR





# Hydrothermal Ore Deposit Model

Typical for acid-sulfate systems

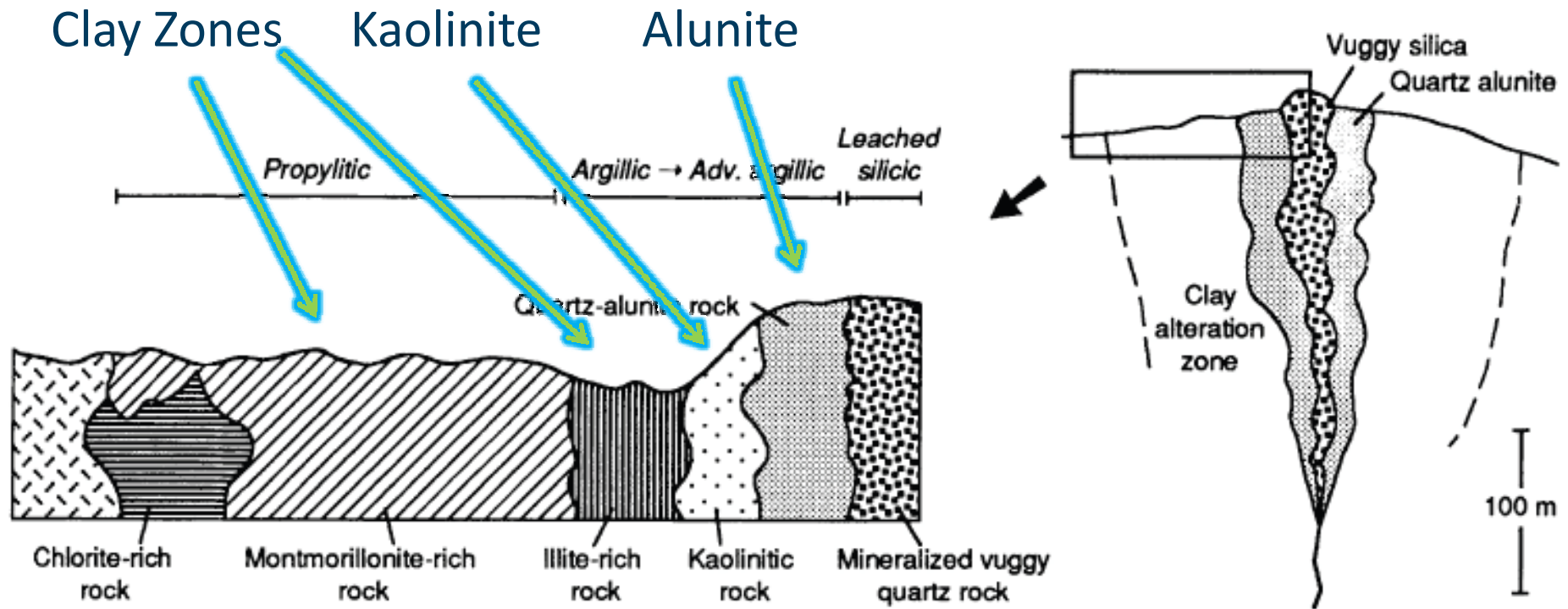
Note patterns of: *Alunite*, *Calcite*, *Illite*, and *Kaolinite*.

Understanding patterns can help us find the ore deposit!

Graphic Source: Livo, et al.,  
USGS PP 1717

*Zonation aids in predicting location of precious metals.*

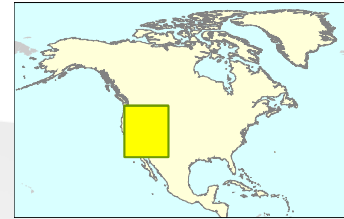
# Hydrothermal Ore Deposit Model



Graphic Source: Taranik, et al., 2010.

# Hydrothermal Ore Deposits

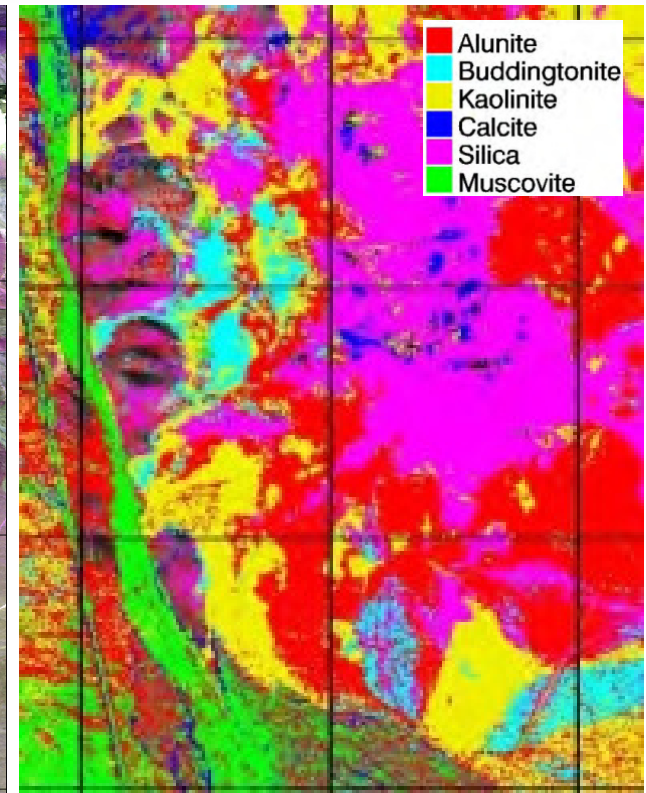
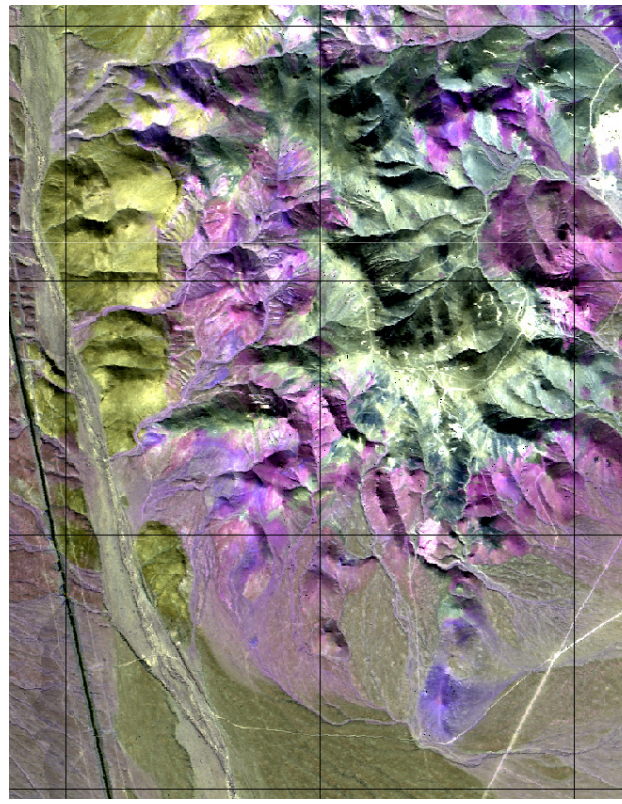
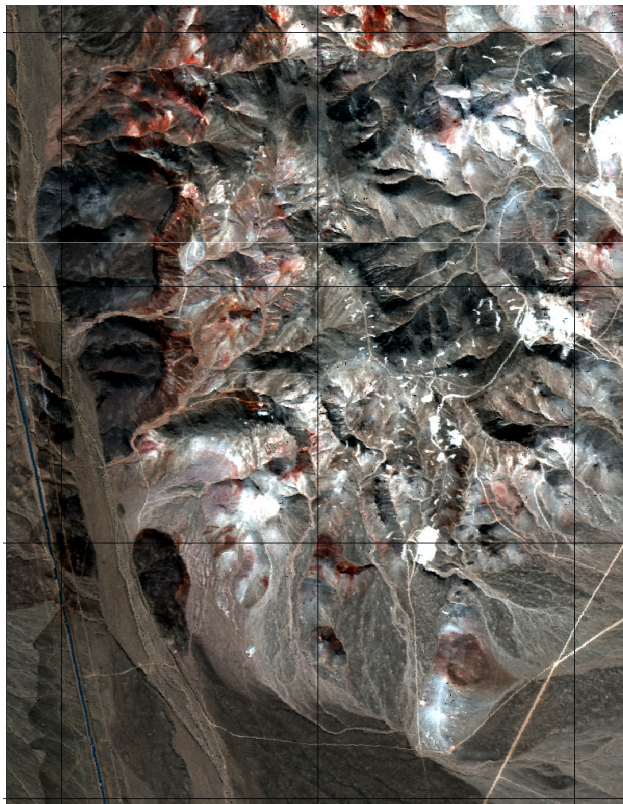
Cuprite, Nevada, USA.



True Color: R, G, B

WV3: S7, S5, S4

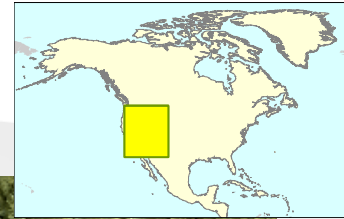
WV3: Mineral Classification



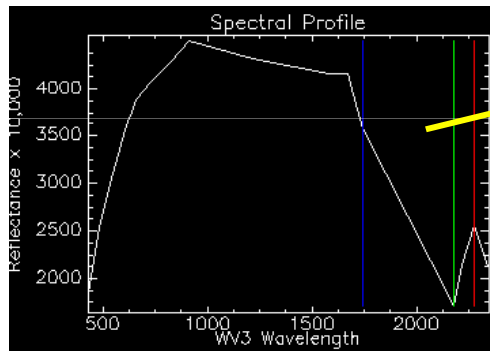
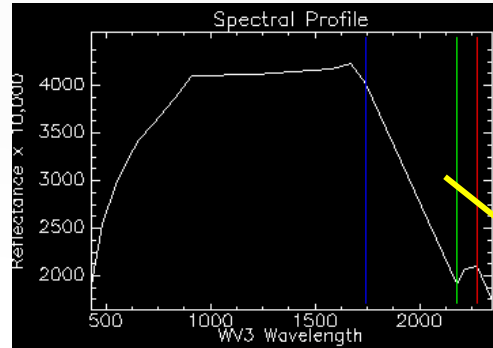
Classification Source: Kruse and Perry, 2012.



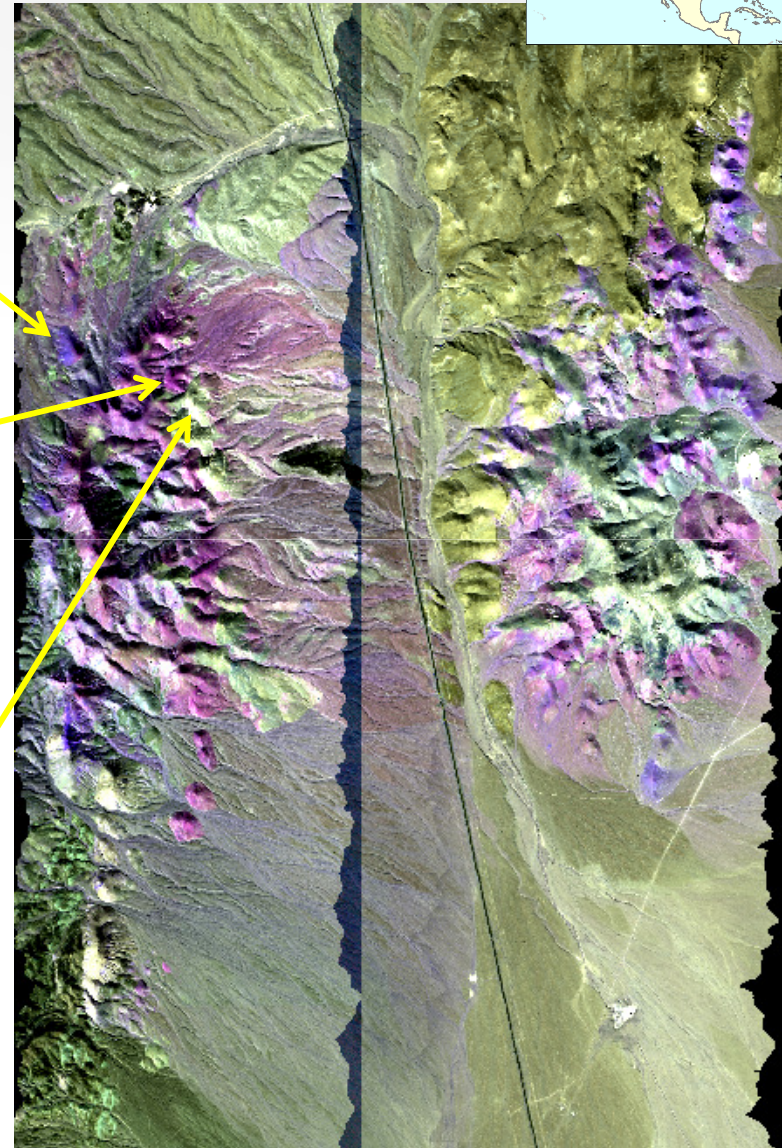
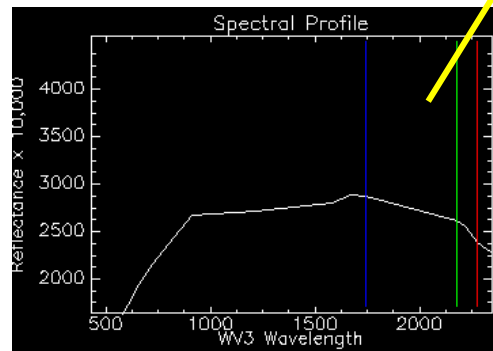
# Spectral reflectance of rocks



Cuprite, Nevada, USA;



Colors due to position of 2200 nm absorption feature.

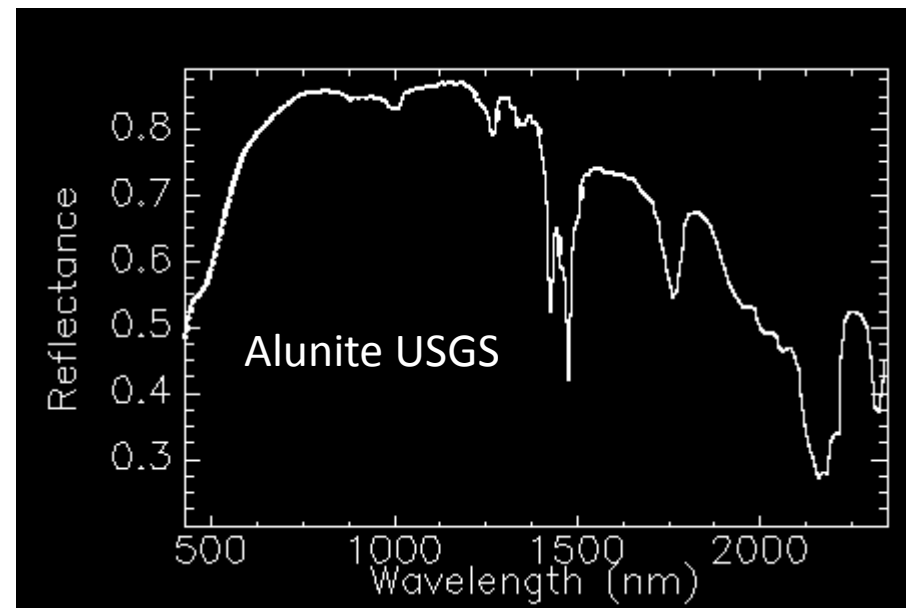
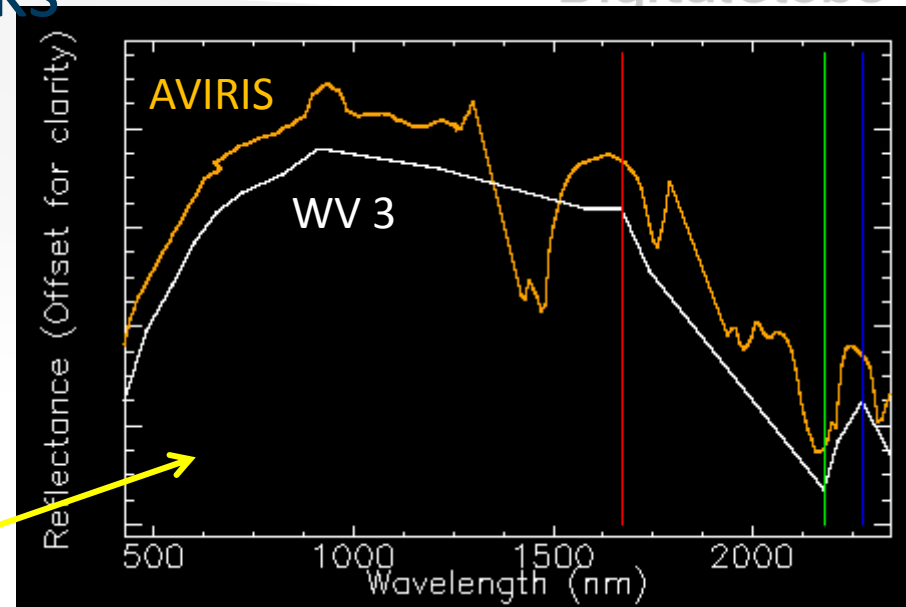
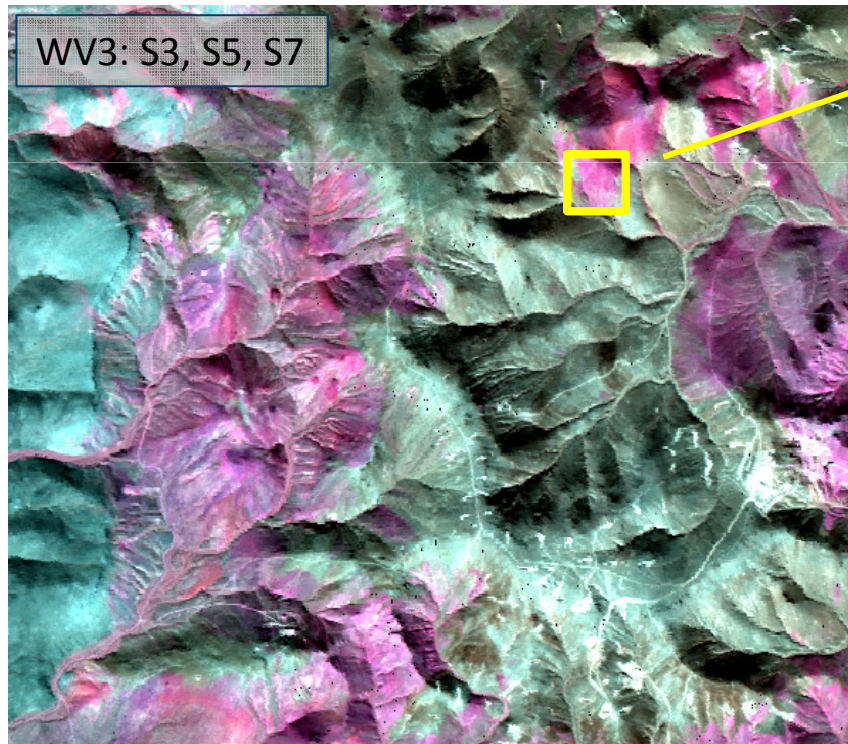


# Spectral reflectance of rocks

## Alunite

Cuprite, Nevada, USA

WV3, AVIRIS and Laboratory

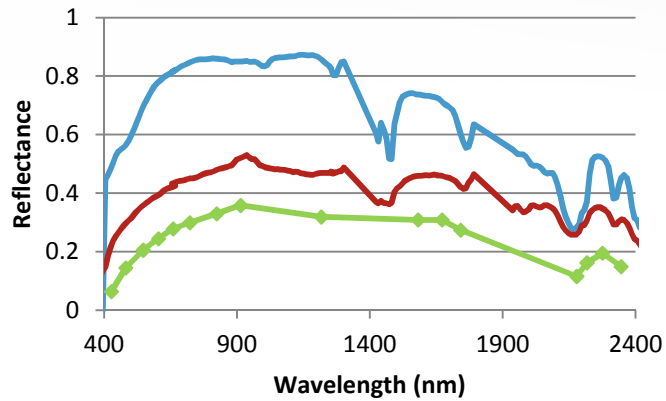


# Spectral reflectance of rocks

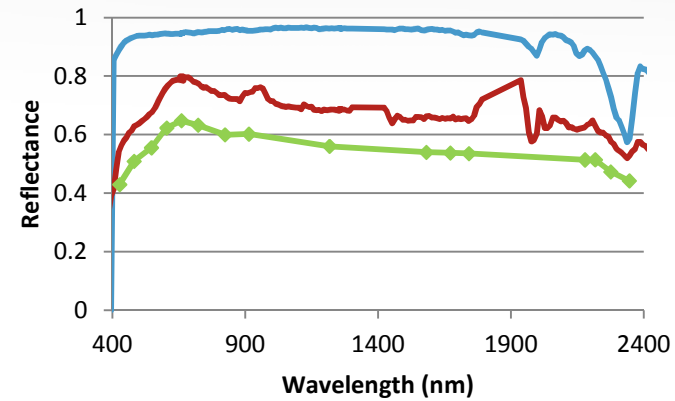
## AVIRIS resampled to WV3 response

- Lab Spectra
- AVIRIS
- WV3\*
- \* Offset for Clarity

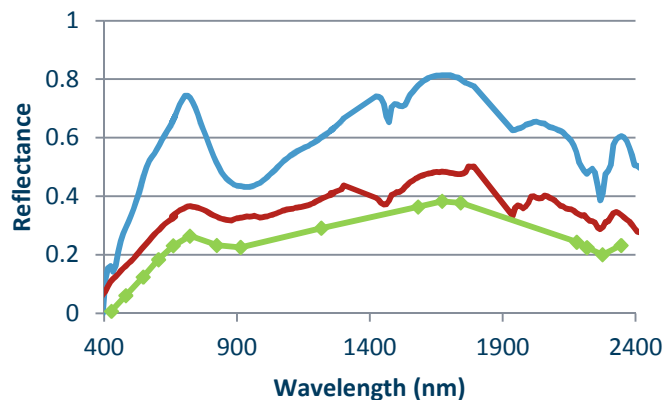
### Alunite



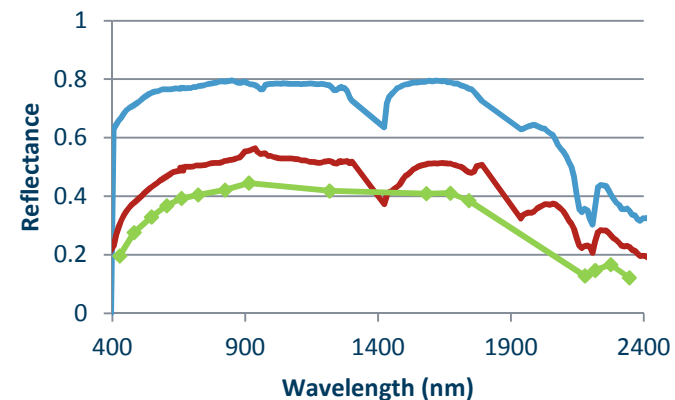
### Calcite



### Jarosite

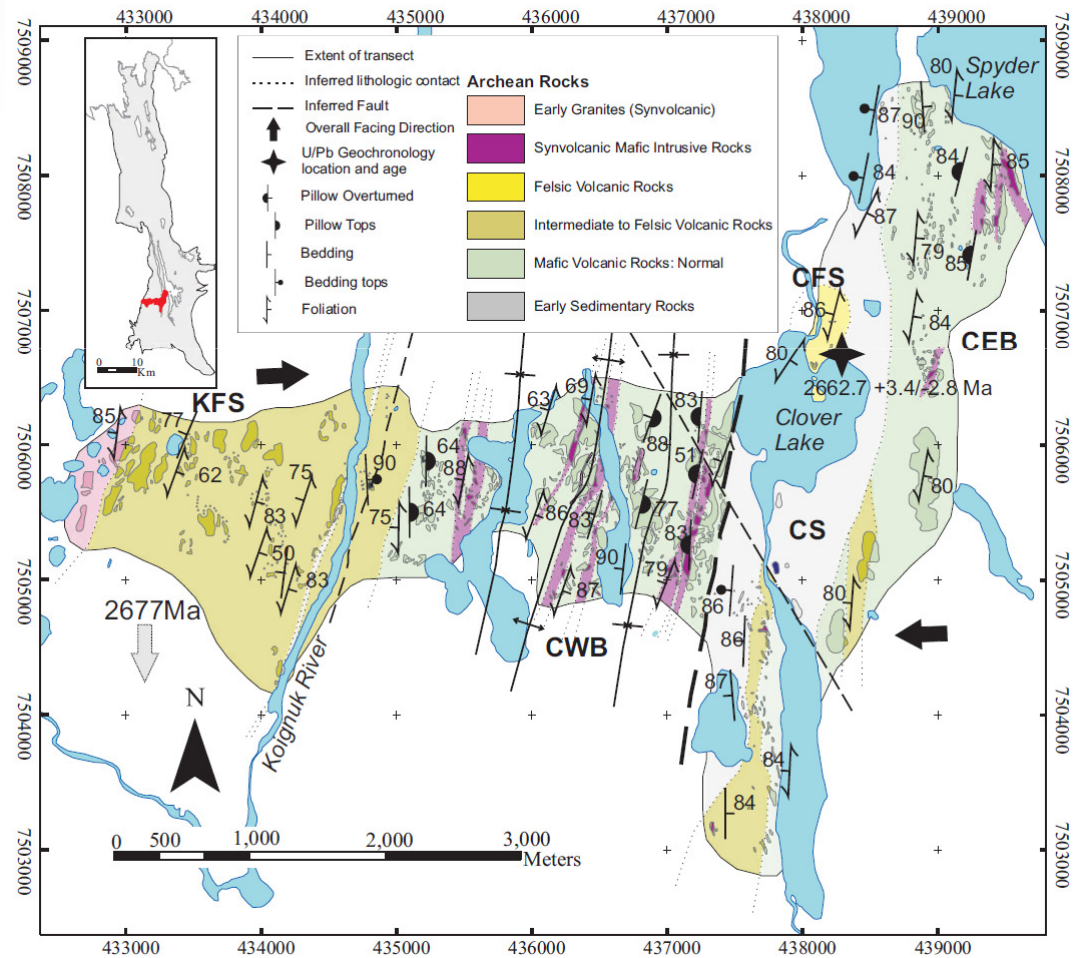
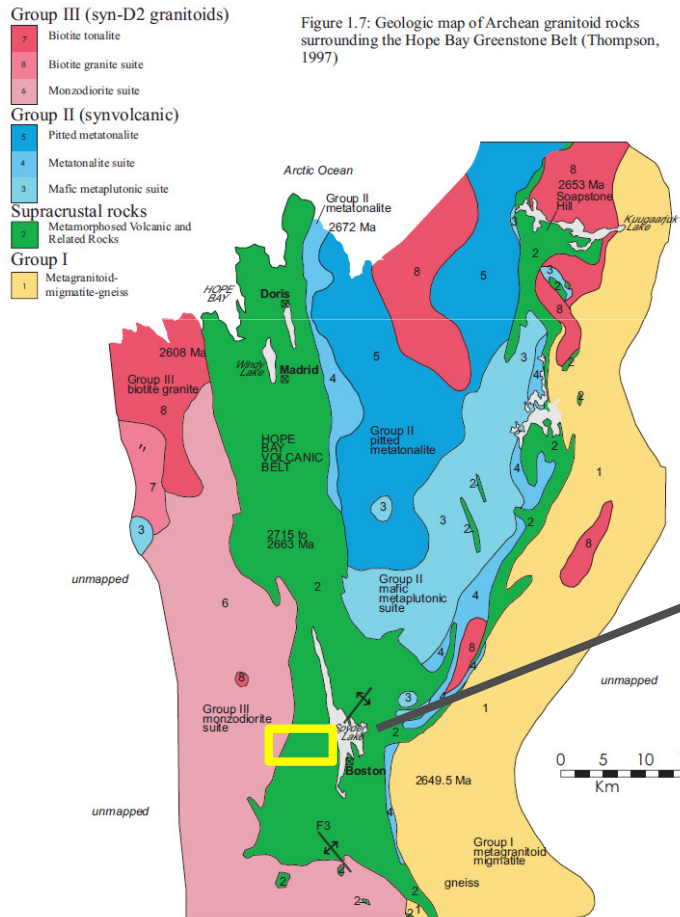
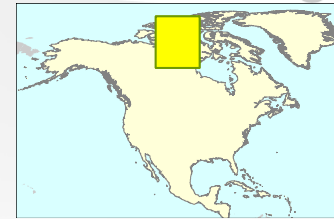


### Kaolinite



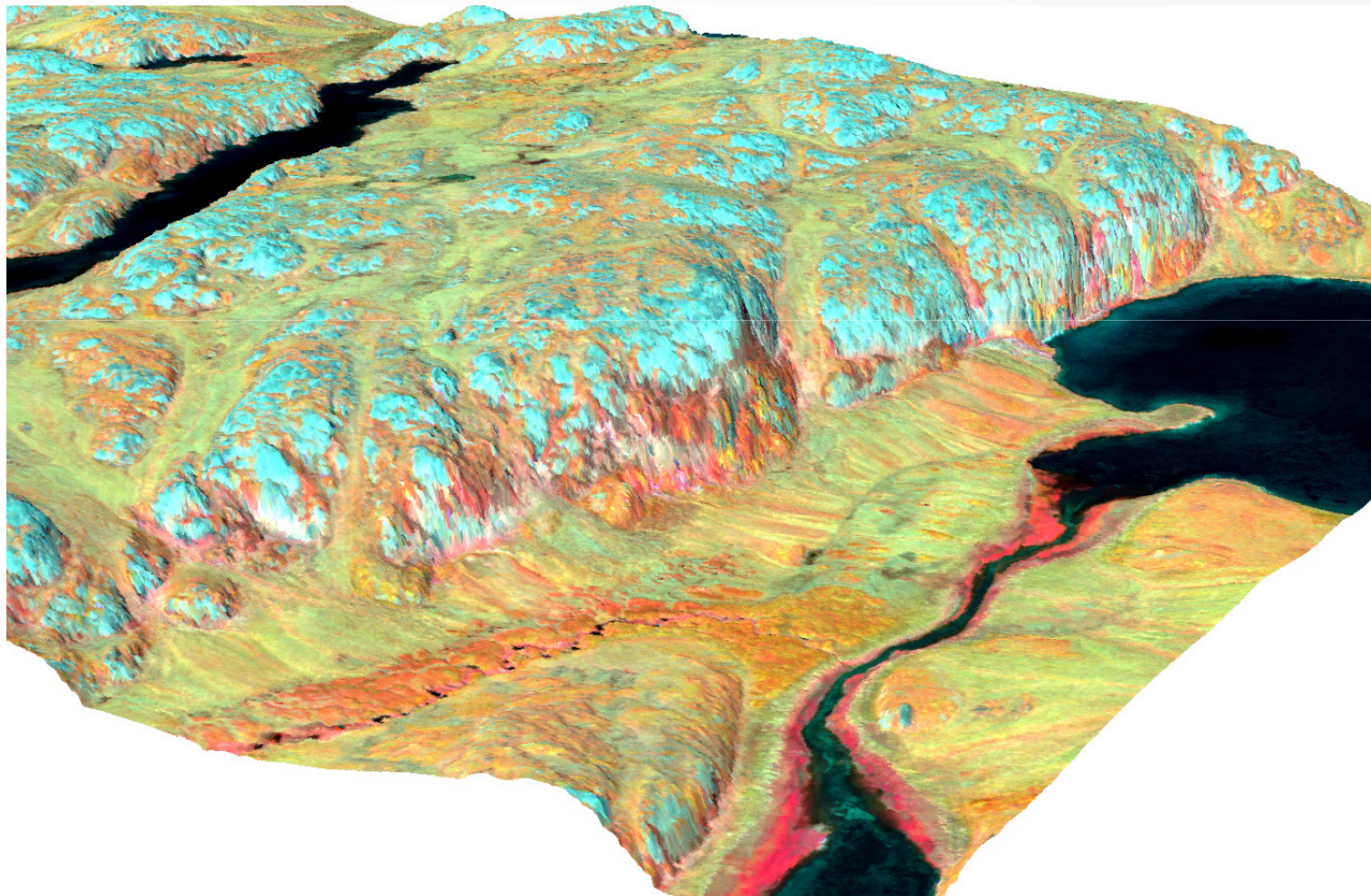
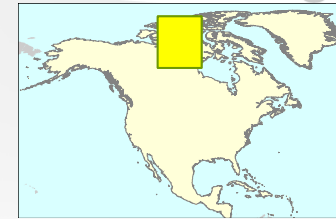


# Hope Bay area, Nunavut, Canada



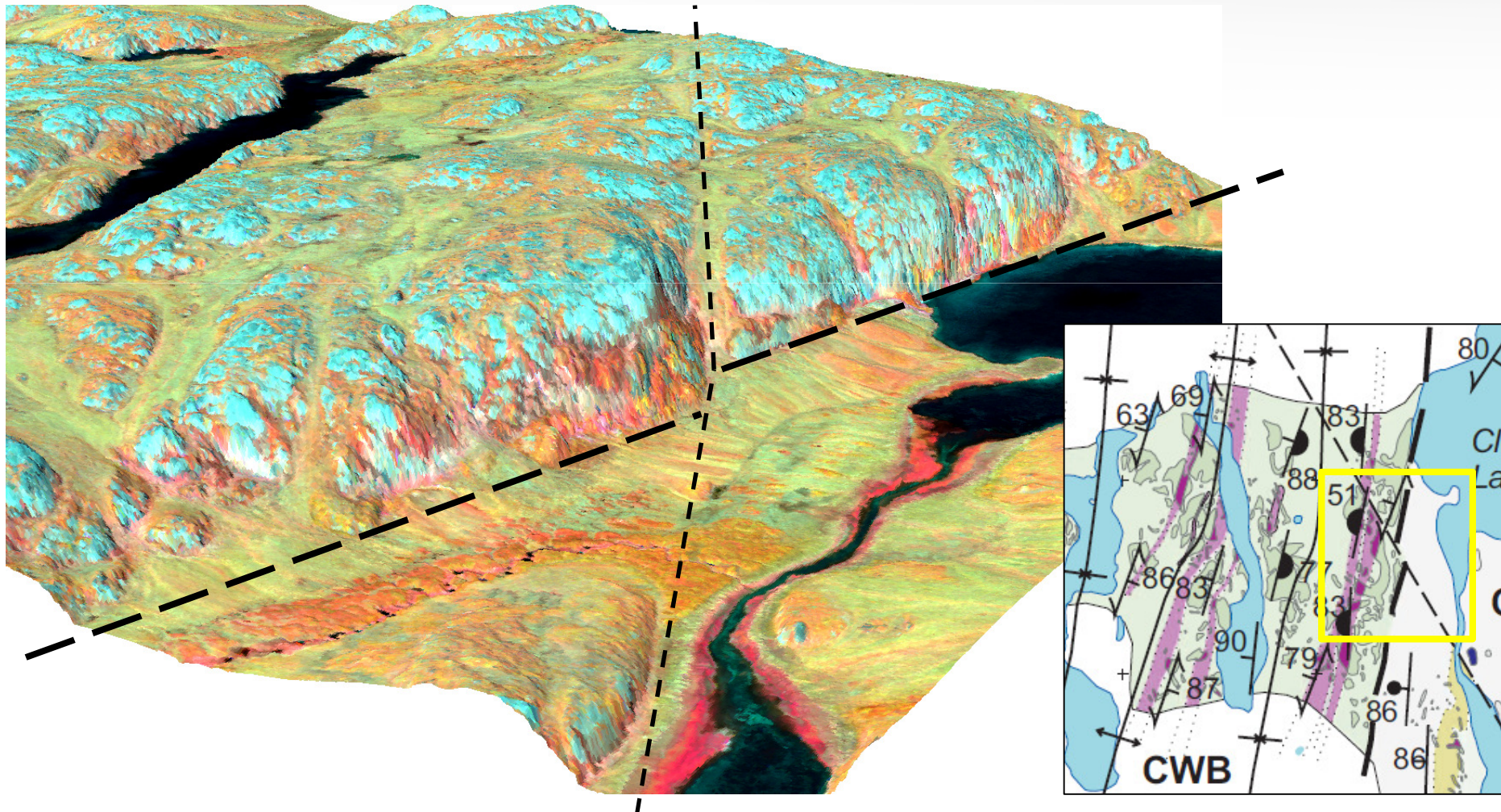
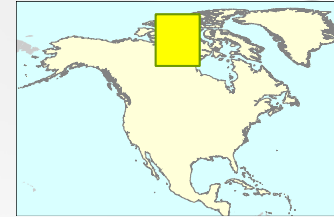
Graphic Source: Shannon, 2008

# Hope Bay area, Nunavut, Canada





# Hope Bay area, Nunavut, Canada



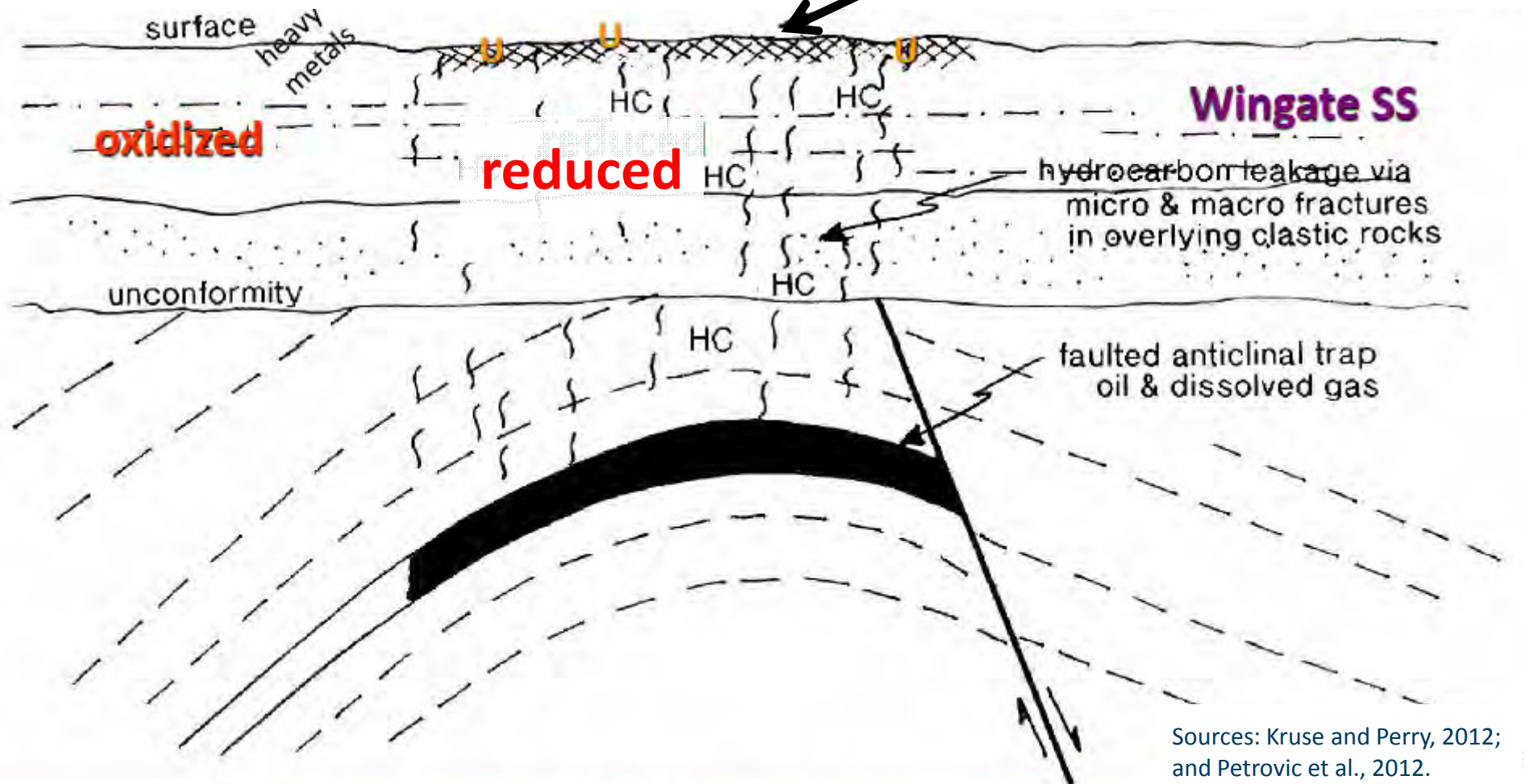


# Hydrocarbon Alteration

Lisbon Valley, Utah USA

*Red un-altered surface rock*

*Bleached surface rock, higher  
Calcite, Hematite, Kaolinite*

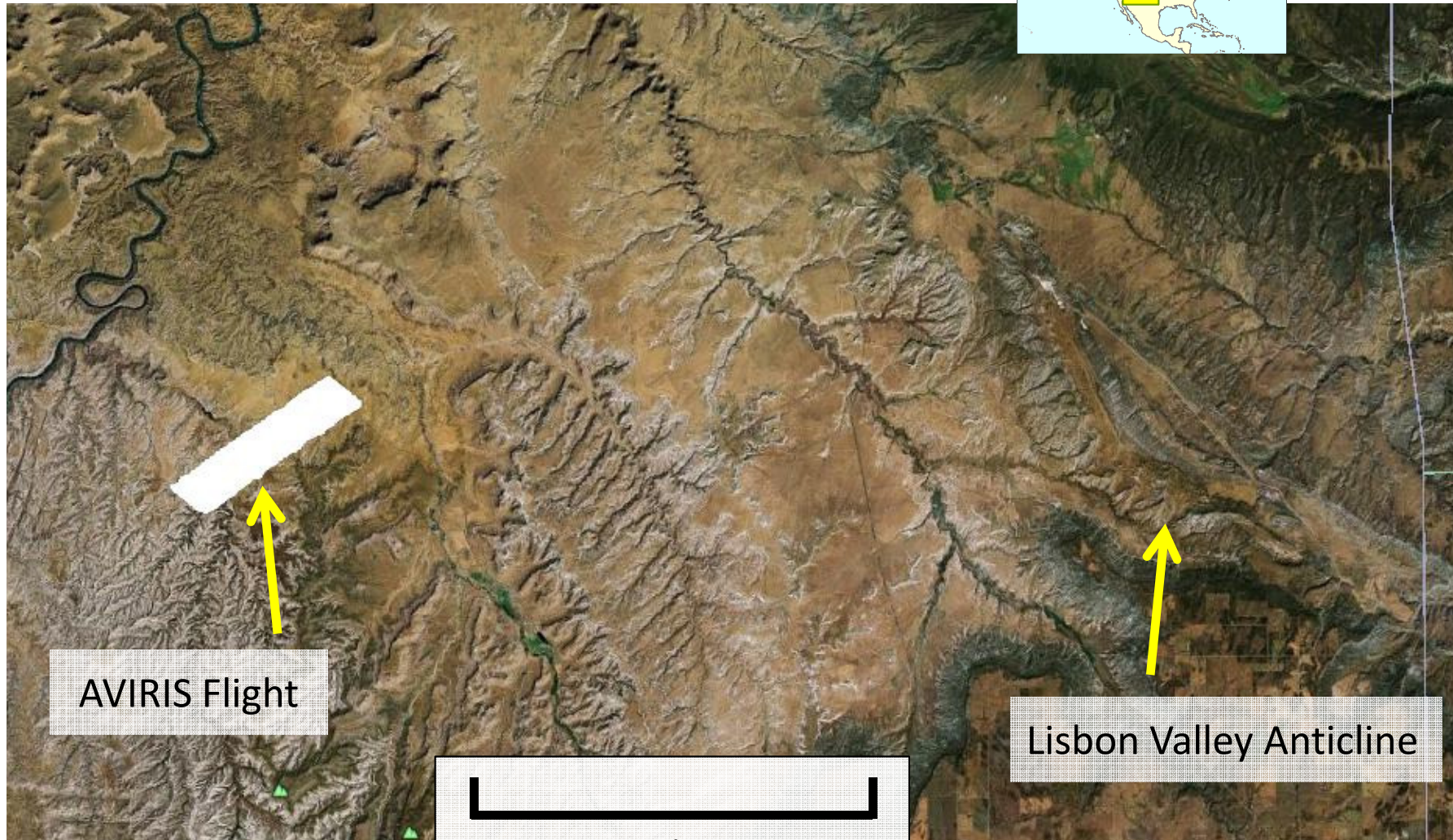
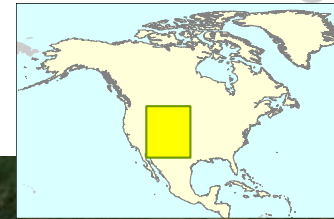


Sources: Kruse and Perry, 2012;  
and Petrovic et al., 2012.



# Hydrocarbon Alteration

Lisbon Valley, Utah USA



AVIRIS Flight

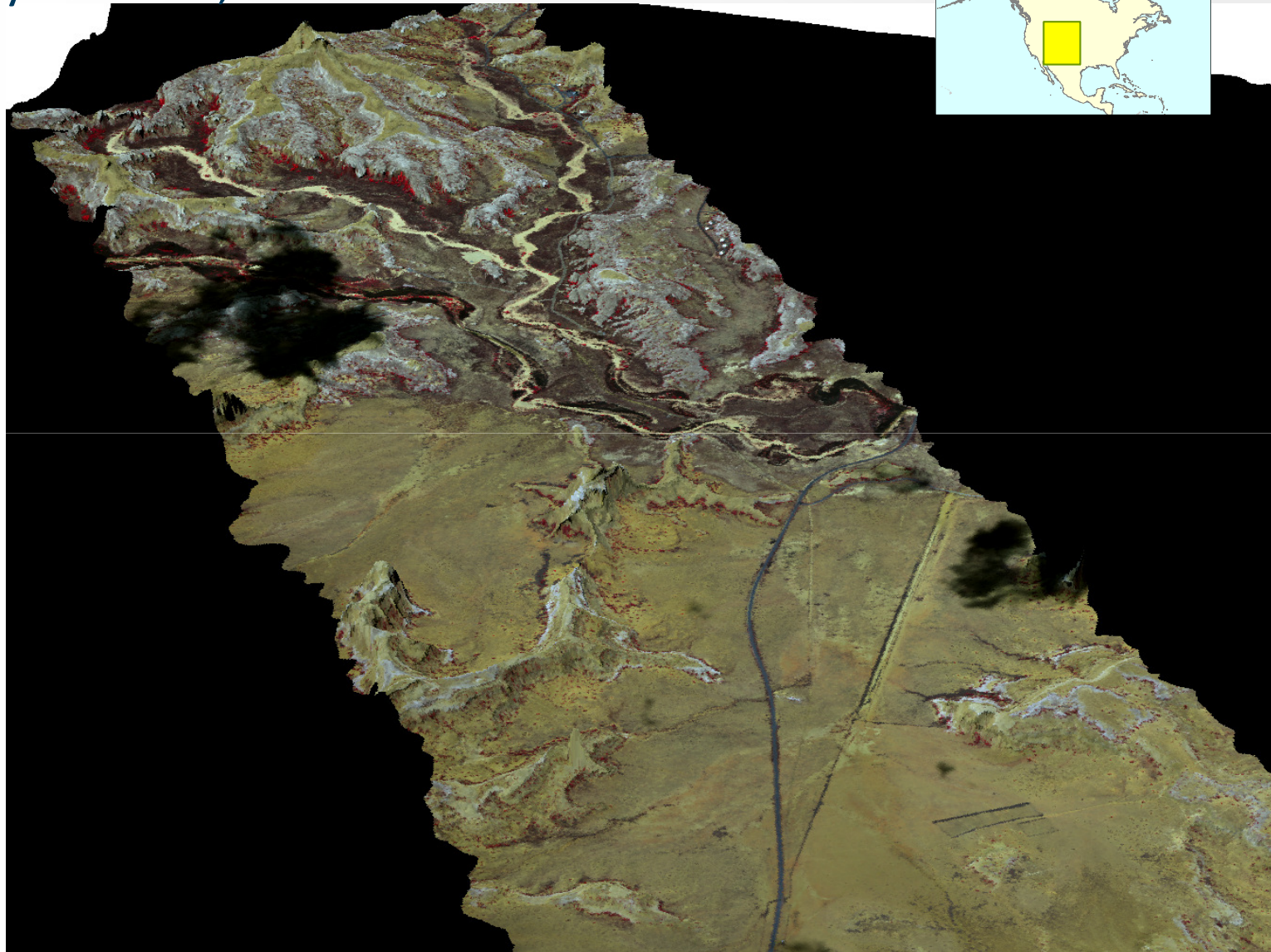
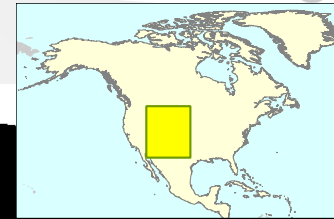
Lisbon Valley Anticline

20 km



# Hydrocarbon Alteration Method

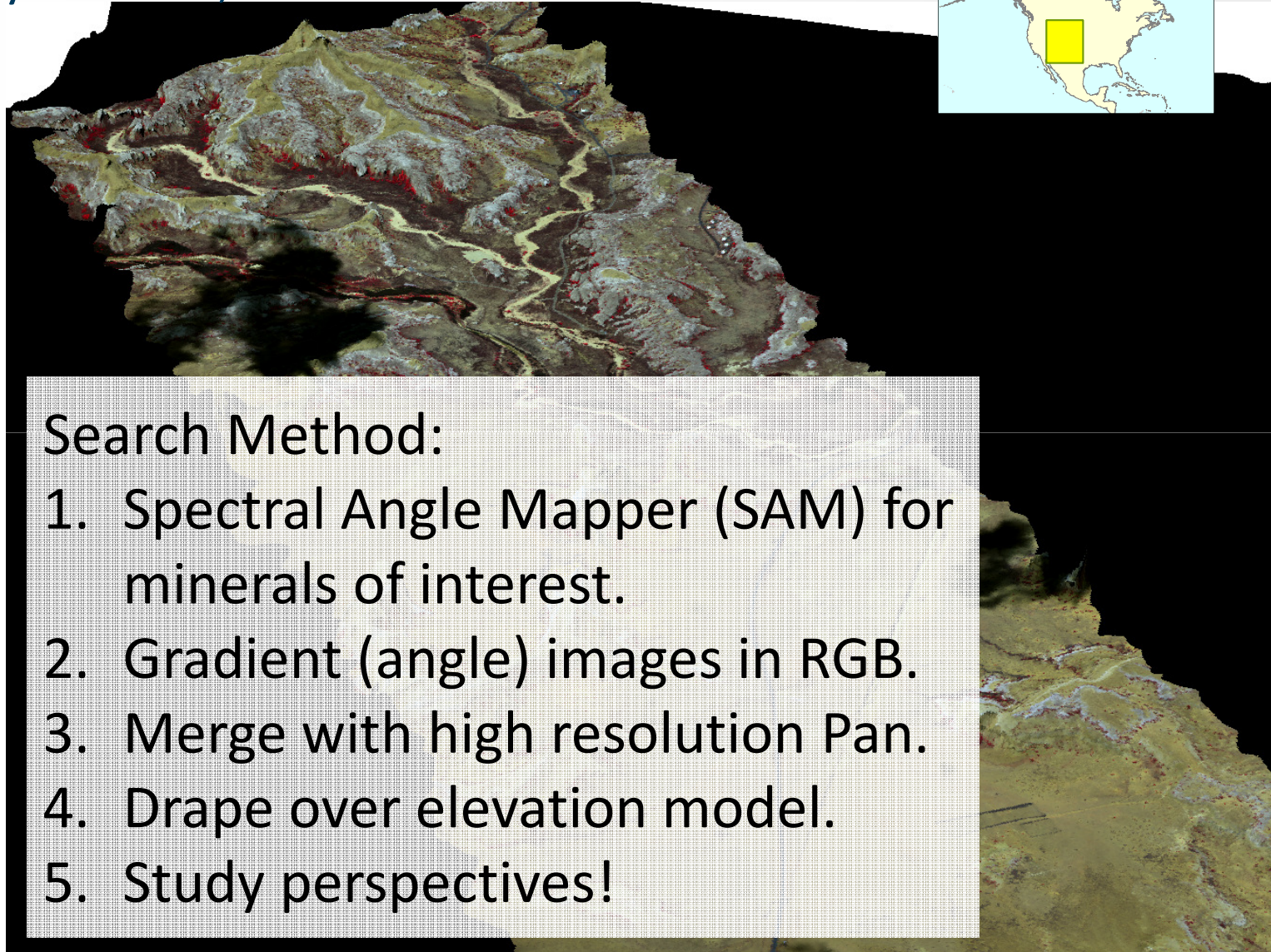
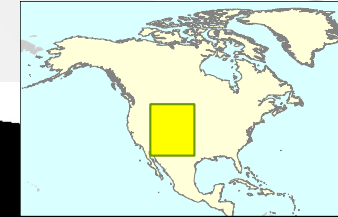
Canyon Lands, Utah USA





# Hydrocarbon Alteration Method

Canyon Lands, Utah USA



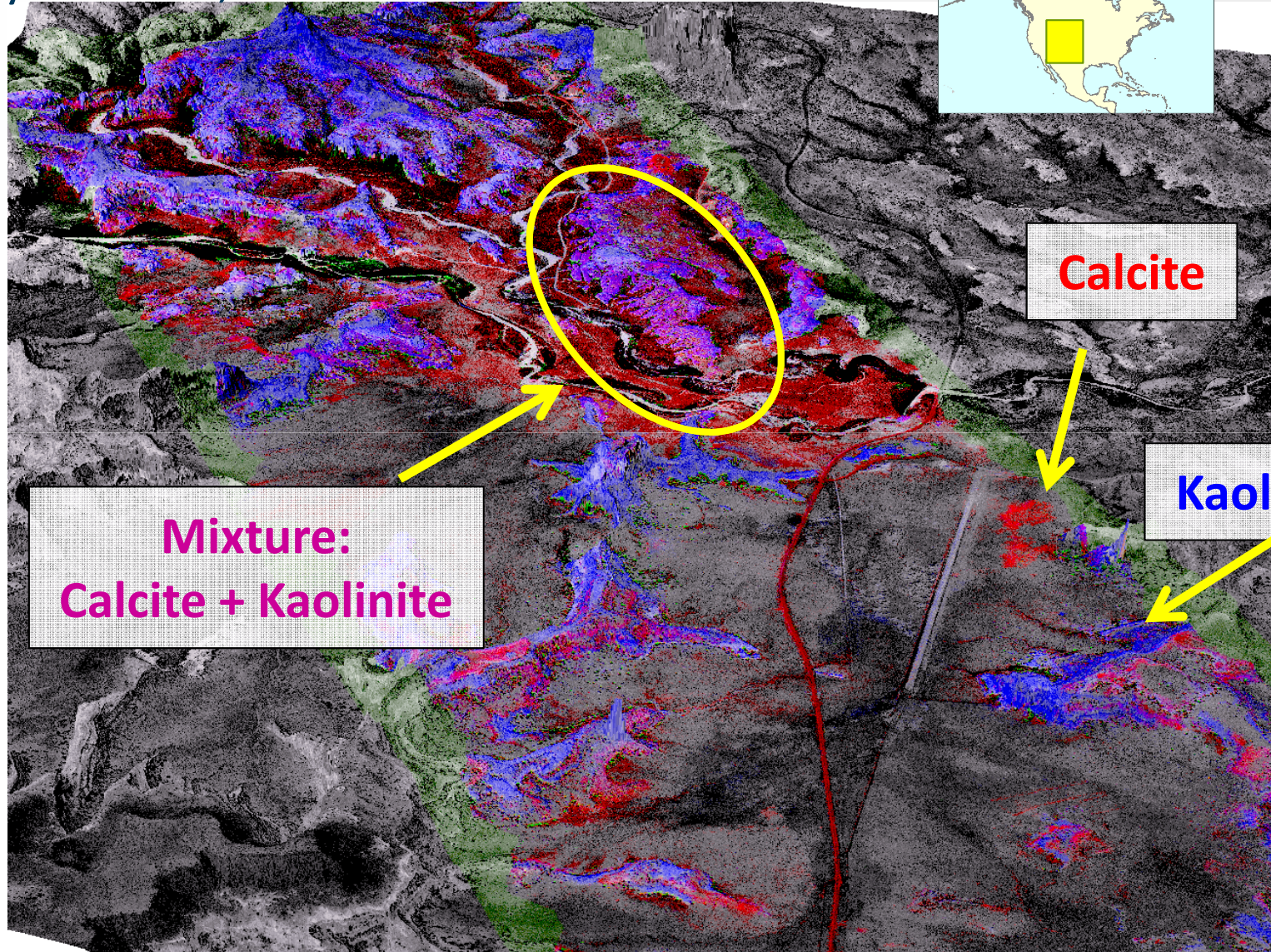
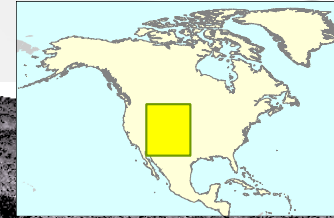
## Search Method:

1. Spectral Angle Mapper (SAM) for minerals of interest.
2. Gradient (angle) images in RGB.
3. Merge with high resolution Pan.
4. Drape over elevation model.
5. Study perspectives!



# Hydrocarbon Alteration Method

Canyon Lands, Utah USA





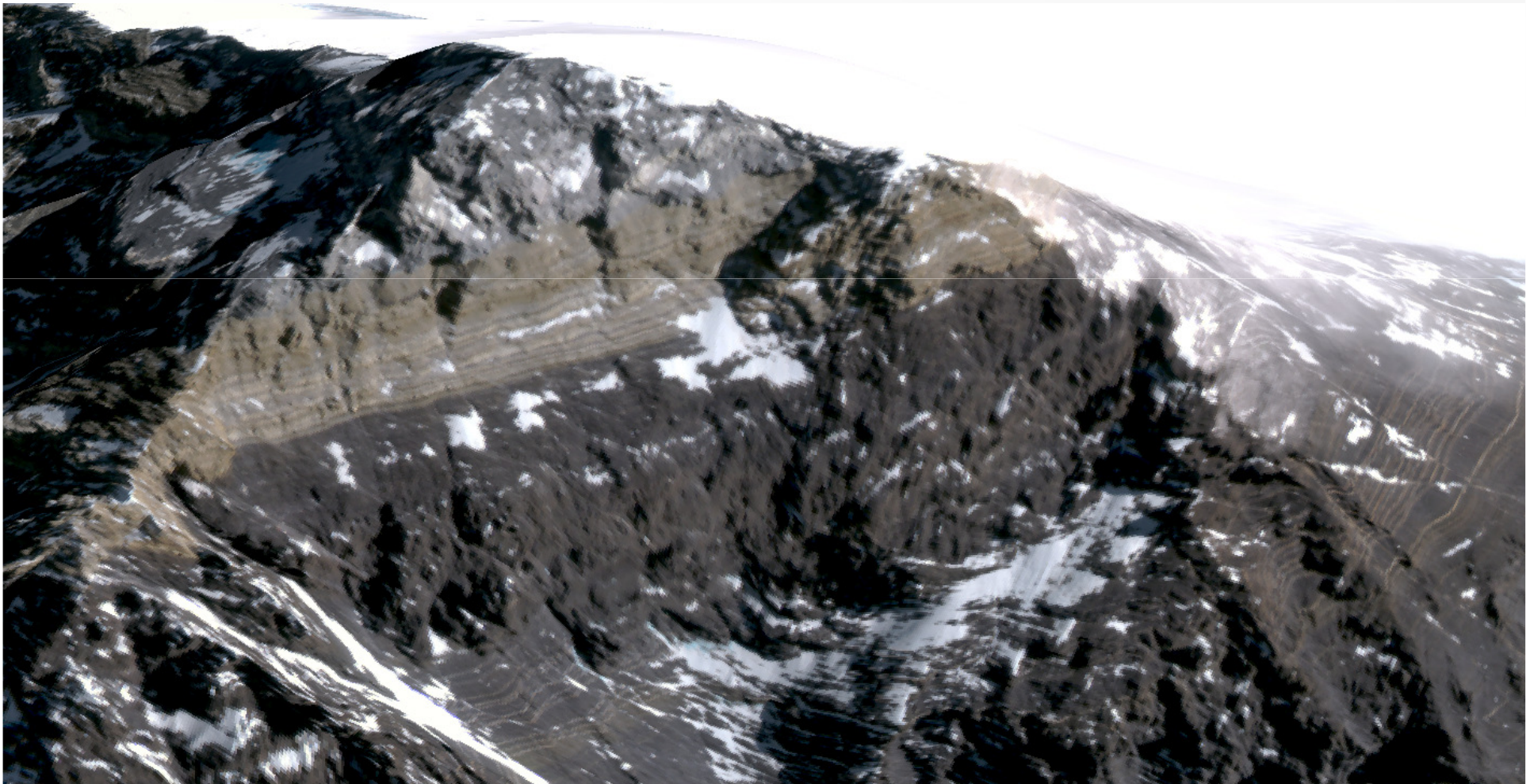
# Summary

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- WV-3 has ASTER-like SWIR bands at high spatial resolution.
- Reflectance is Crucial!
- CAVIS helps calculate reflectance.
- SWIR tells us about rock type and materials.
- High resolution DEMs can be made from 1+ satellite passes.
- DEM + spectral analysis = useful data fusion.
  - Texture
  - Structure
  - Vertical and horizontal relationships
  - Rock categories or types
  - Alteration assemblages
  - Remote field logistics



# Discussion



## Acknowledgements

- Chad Bleiler
- Chuck Chaapel
- Jennifer Johnson
- Milan Karspeck
- Ozy Sjahputera



[www.digitalglobe.com](http://www.digitalglobe.com)

## References

1. <http://www.environment.gov.au/parks/uluru/nature/geology.html>
2. Kruse, F.A. and S.L. Perry, 2012, Mineral Mapping using Simulated Short-Wave-Infrared bands planned for DigitalGlobe WorldView-3, Presented at *Optical Remote Sensing of the Environment (ORS)*, 24-28 June 2012, Monterey, California, United States.
3. Livo, K.E., F.A. Kruse, R.N. Clark, R.F. Kokaly, and W.C. Shanks, III, year?, Hydrothermally Altered Rock and Hot Spring Deposits at Yellowstone National Park—Characterized Using Airborne Visible- and Infrared-Spectroscopy Data, in *Integrated Geoscience Studies in the Greater Yellowstone Area-Volcanic, Tectonic, and Hydrothermal Processes in the Yellowstone Geocosystem*, Edited by Lisa A. Morgan, U.S. Department of the Interior, U.S. Geological Survey, Professional Paper 1717.
4. Taranik, J.V., W.M. Calvin, and F.A. Kruse, 2010, Reflectance Spectroscopy Applied to Exploration for Mineral Deposits and Geothermal Systems, and to the Remediation of Mined Lands in the Great Basin of the Western United States. Proceedings of *ASD and IEEE GRS; Art, Science and Applications of Reflectance Spectroscopy Symposium, Vol. II*, 38pp, Boulder, CO.
5. Shannon, A.J., 2008, Volcanic framework and geochemical evolution of the archean Hope Bay greenstone belt, Nunavut, Canada. *Master's Thesis*, University of British Columbia.
6. Petrovic, A., S.D. Khan, and A.K. Thurmond, 2012, Integrated hyperspectral remote sensing, geochemical and isotopic studies for understanding hydrocarbon-induced rock alterations, *Marine and Petroleum Geology*, v. 35, p. 292-308.

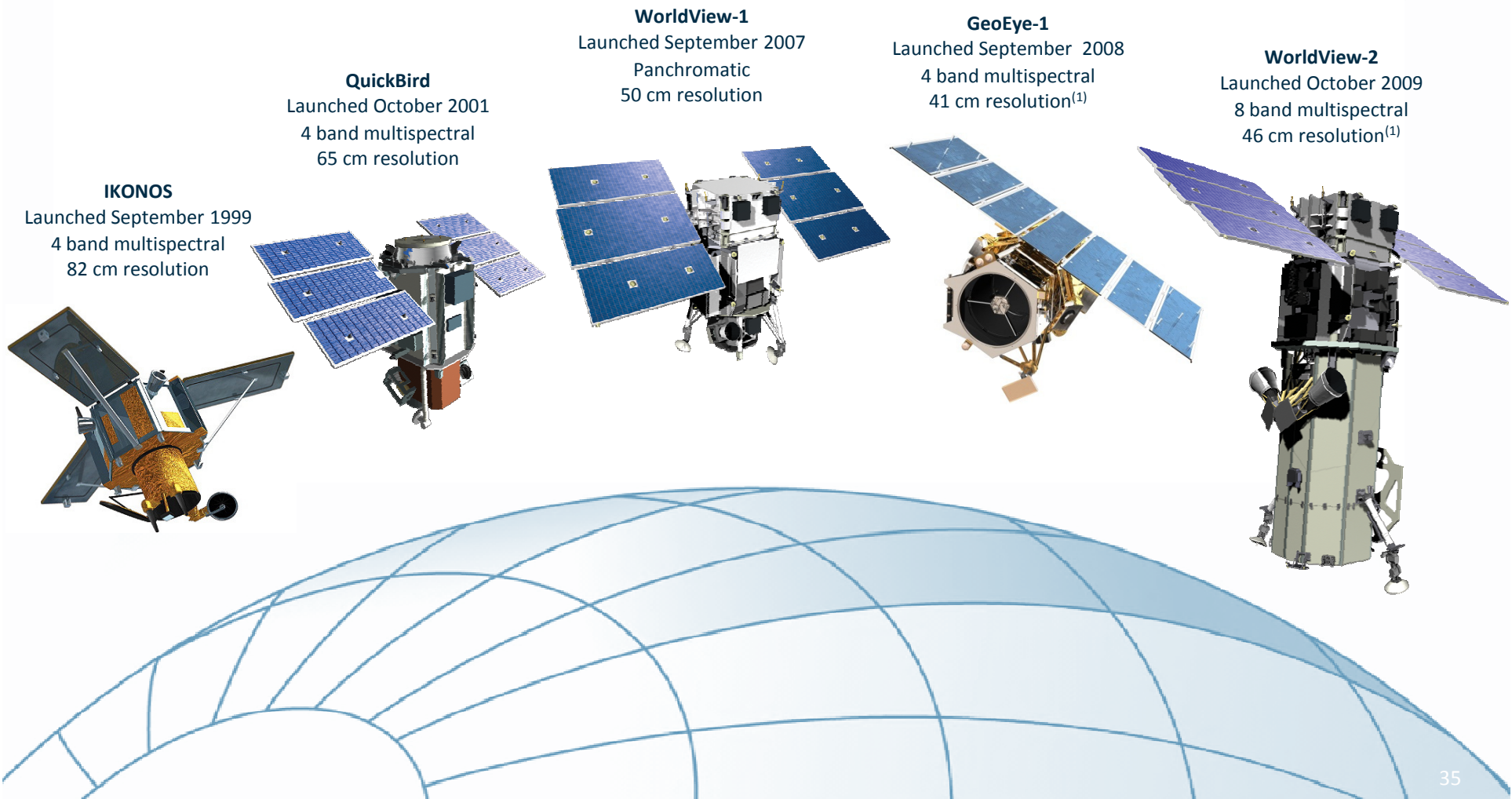


## Reference Slides

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1. DigitalGlobe satellite constellation
2. Spectra and satellite band details
3. SWIR smoke penetration

# The Current DigitalGlobe Constellation



# Satellite Spectral Comparison

**MODIS**  
(250+ m)



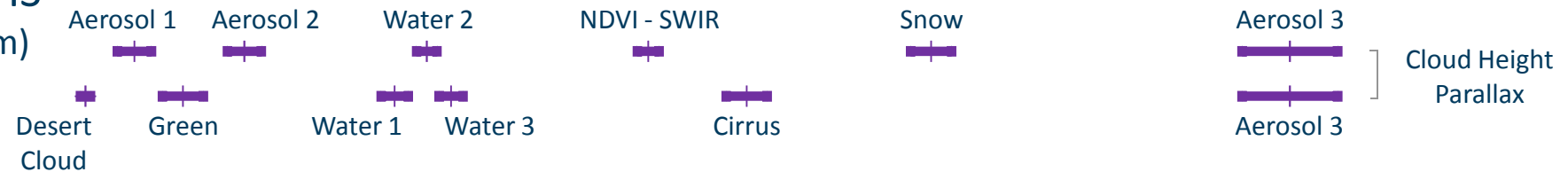
**ASTER**  
(15/30 m)



**WV-3**  
(1.2 / 3.7)



**CAVIS**  
(30 m)





# Smoke Penetration in SWIR

- Station Fire, Los Angeles National Forest, CA
- Advanced Land Imager (ALI) 03 SEP 2009

