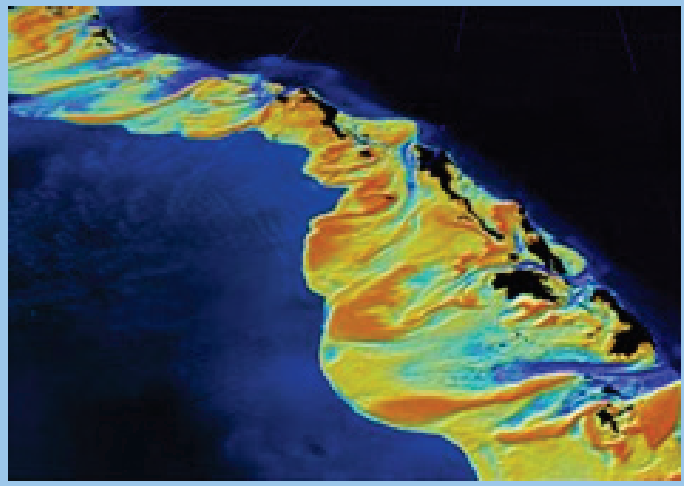
Using Remote Sensing & GIS To Create New Geologic & Environmental Opportunities

James Ellis
Ellis GeoSpatial, California
UB Geology Pegrum Lecture



Reasons to Try?

Remote sensing & GIS tools are remarkable!

You can use these tools to make you a better knowledge worker

Several data types can provide unique information

- **Hyperspectral**
- **Thermal**
- **DEMs**

Data is everywhere…. think “big data”

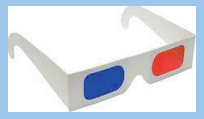
Outline – Case Histories….

Mineral Exploration

Onshore Oil Spills & Seeps

Scanned Core

Modern Carbonate Environments

DEMs 

Environmental - Landcover

Mineral Exploration
Thermal IR
ASTER Satellite
Afghanistan

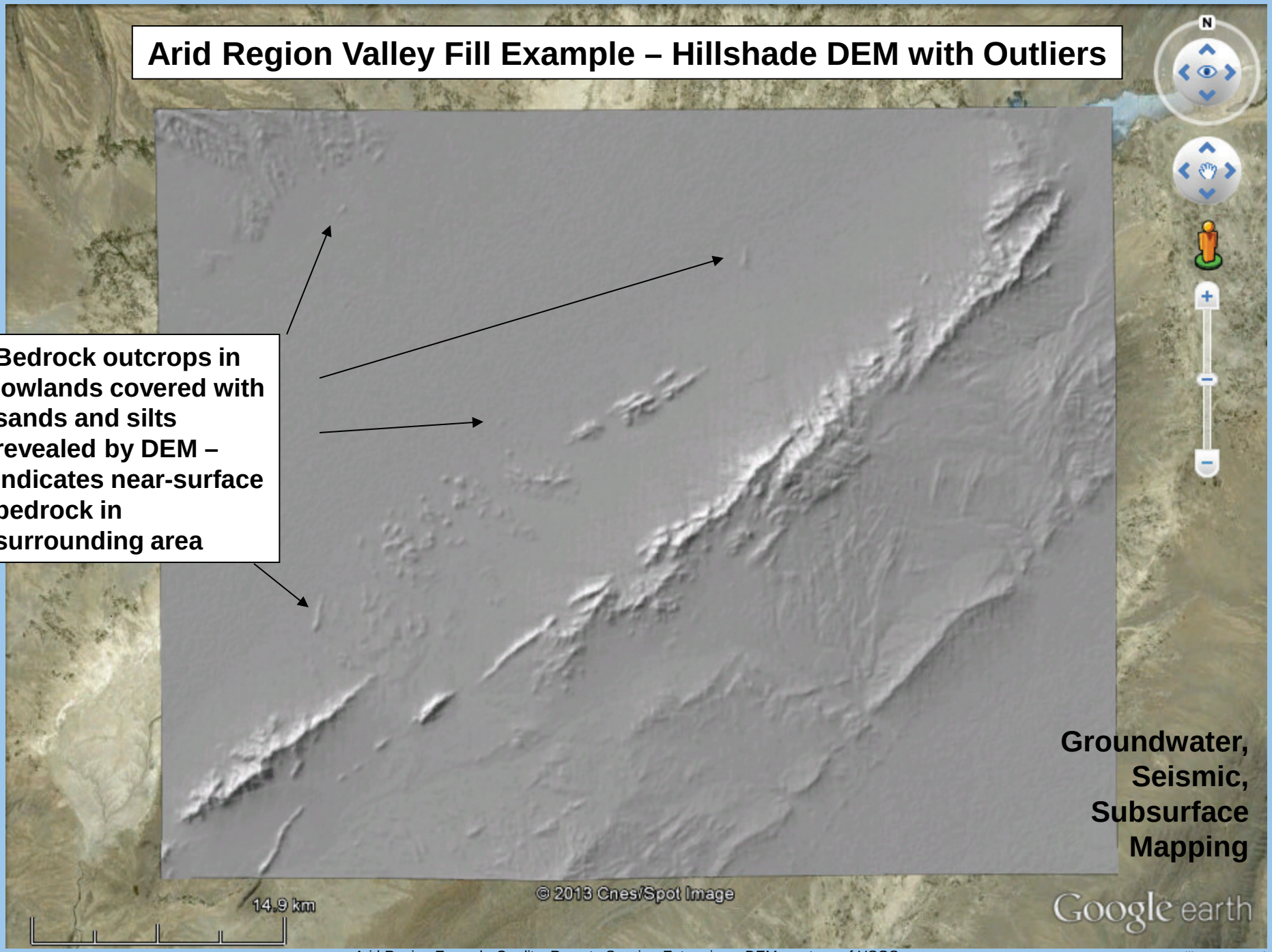
Thermal

Emitted Energy

Arid Region Valley Fill Example – GoogleEarth Image

Groundwater, Seismic, Subsurface Mapping

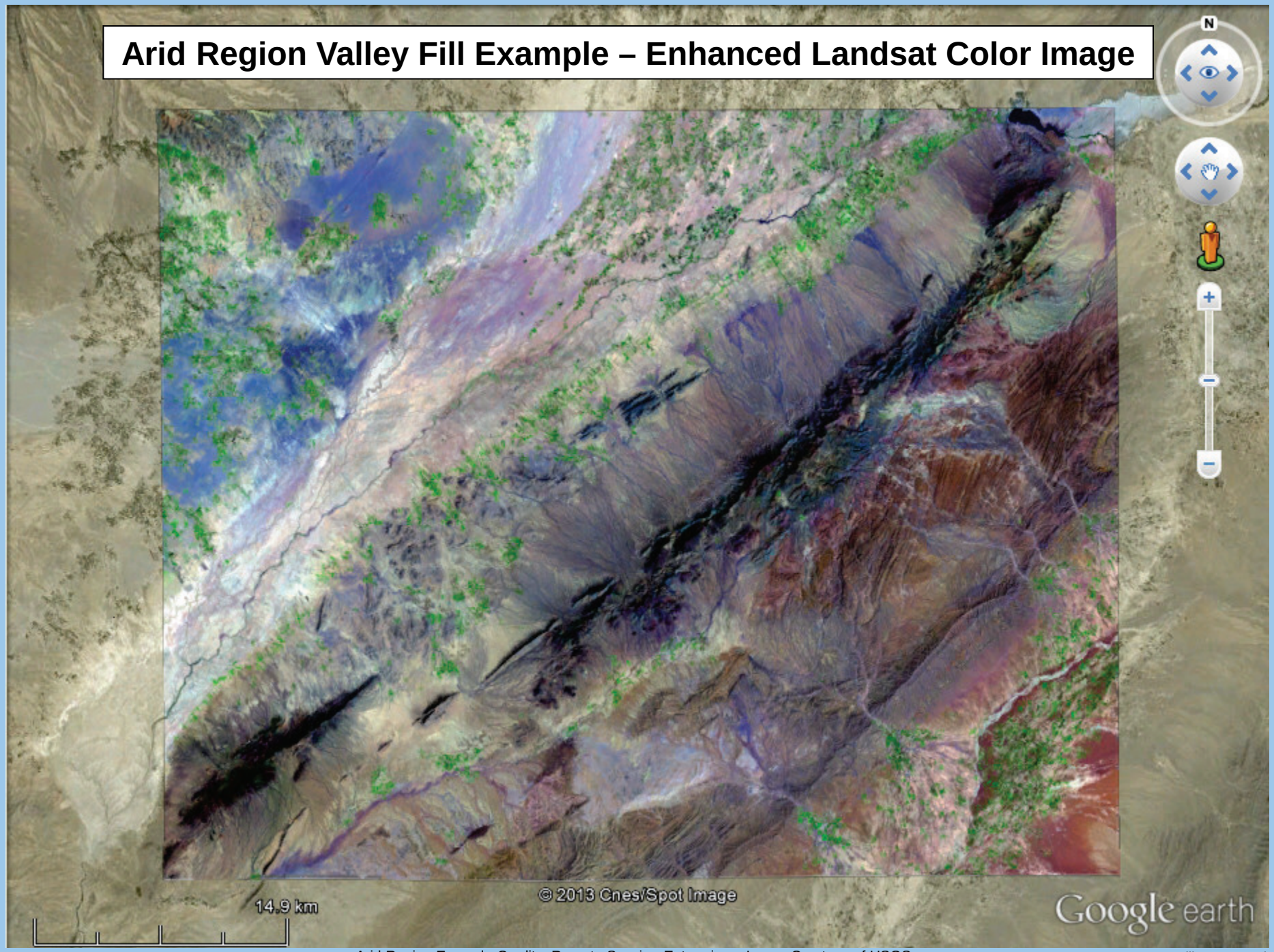
Arid Region Valley Fill Example – Hillshade DEM with Outliers



Groundwater, Seismic, Subsurface Mapping

Arid Region Example Credits: Remote Sensing Enterprises, DEM courtesy of USGS

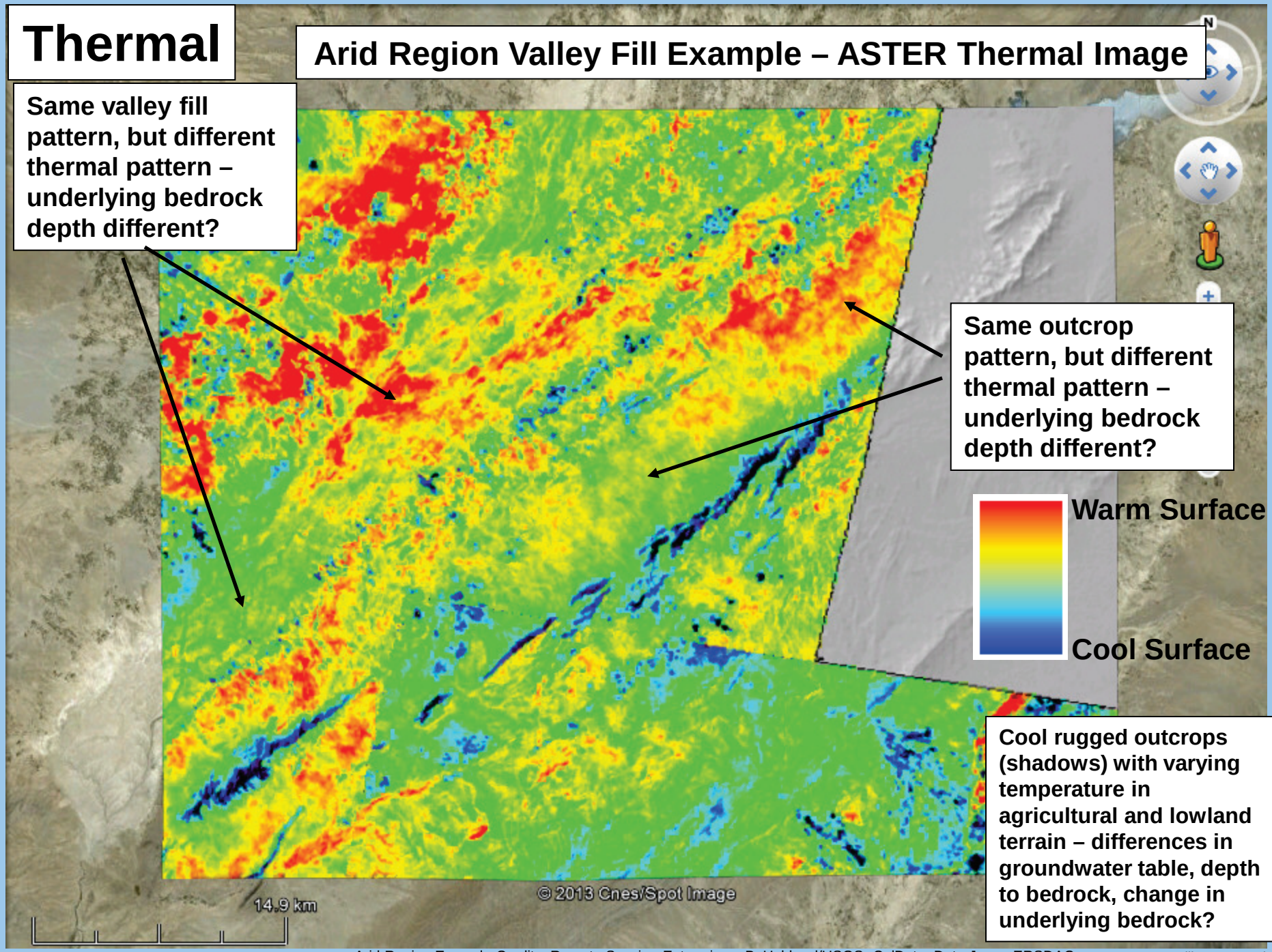
Arid Region Valley Fill Example – Enhanced Landsat Color Image



Arid Region Example Credits: Remote Sensing Enterprises, Image Courtesy of USGS

Thermal

Arid Region Valley Fill Example – ASTER Thermal Image



Arid Region Example Credits: Remote Sensing Enterprises, B. Hubbard/USGS, CalData, Data Japan ERSDAC

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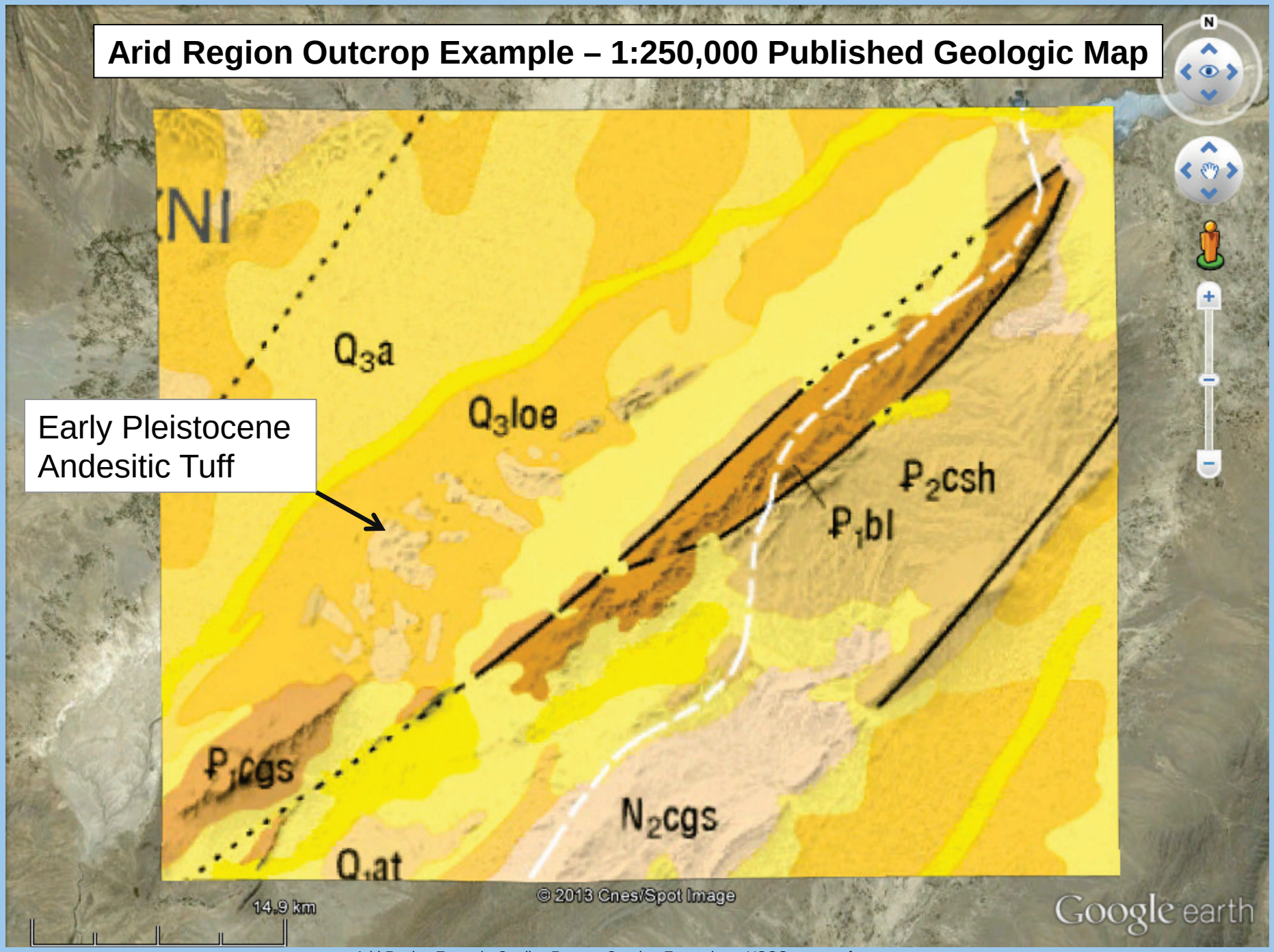
Arid Region Outcrop Example – 1:250,000 Published Geologic Map



Arid Region Example Credits: Remote Sensing Enterprises, USGS source of map

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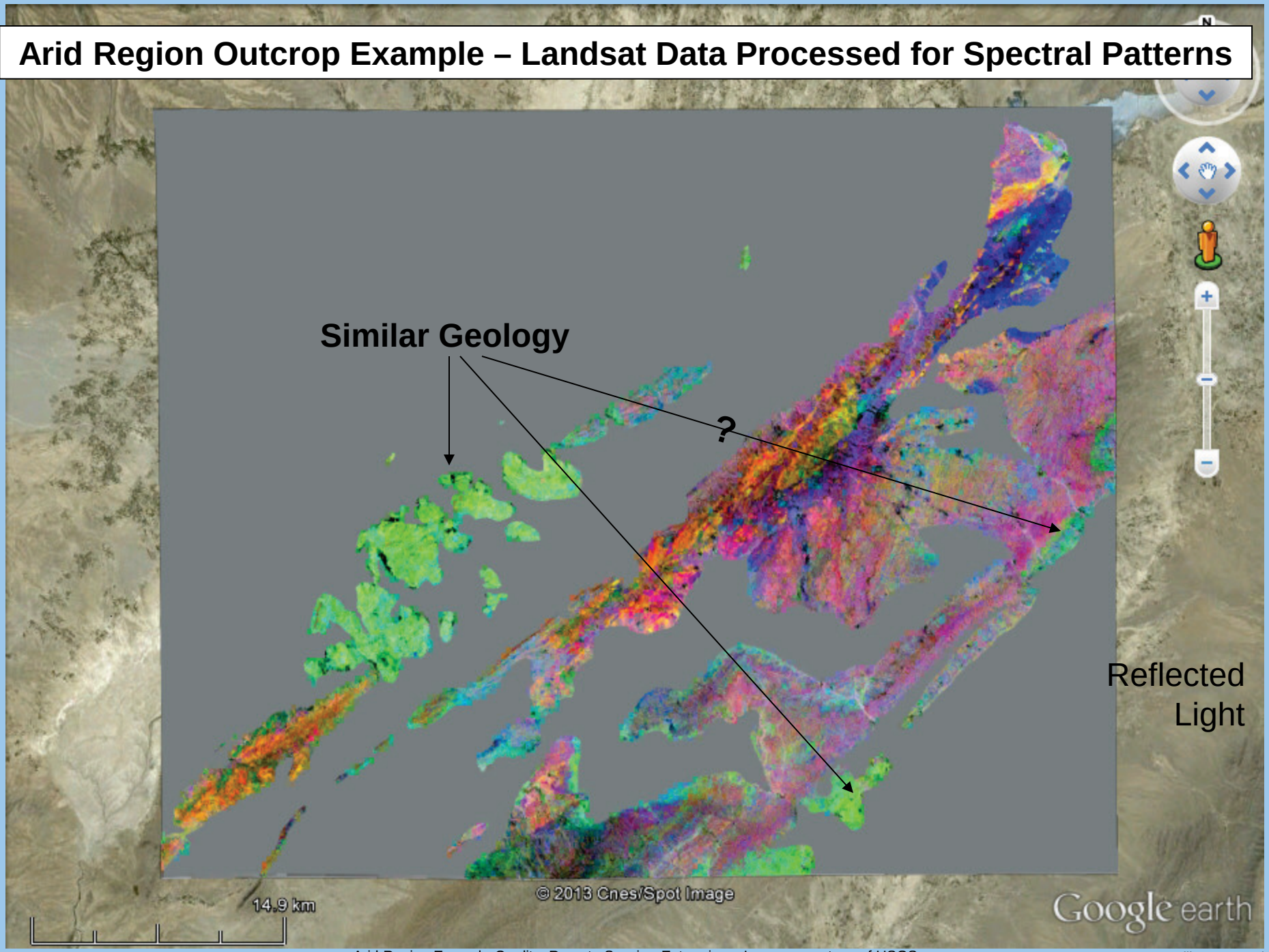
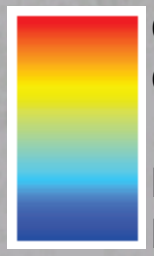
Arid Region Outcrop Example – Landsat Data Processed for Spectral Patterns



Arid Region Example Credits: Remote Sensing Enterprises, Imagery courtesy of USGS

Thermal

Arid Region Outcrop Example – ASTER



Carbonate-Rich Outcrop

Low Carbonate Potential

Bernard Hubbard
USGS
Ward Kilby
CalData

ASTER band ratio 13/14

Emitted Energy

Mars & Rowan, 2011, GeoSphere, v.7, p 1-14

14.9 km

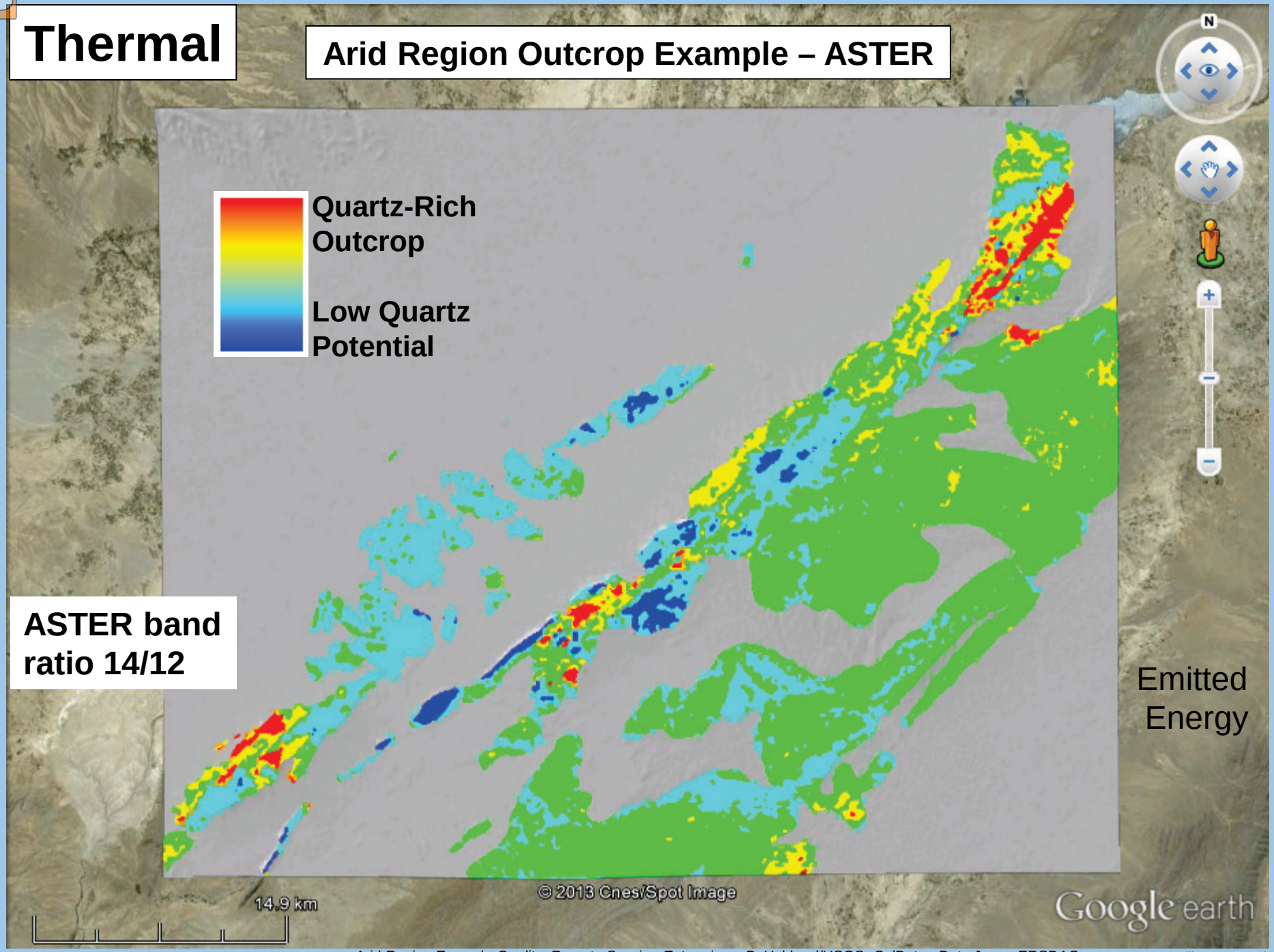
Google earth

Arid Region Example Credits: Remote Sensing Enterprises, B. Hubbard/USGS, CalData , Data Japan ERSDAC

Ellis GeoSpatial

Thermal

Arid Region Outcrop Example – ASTER

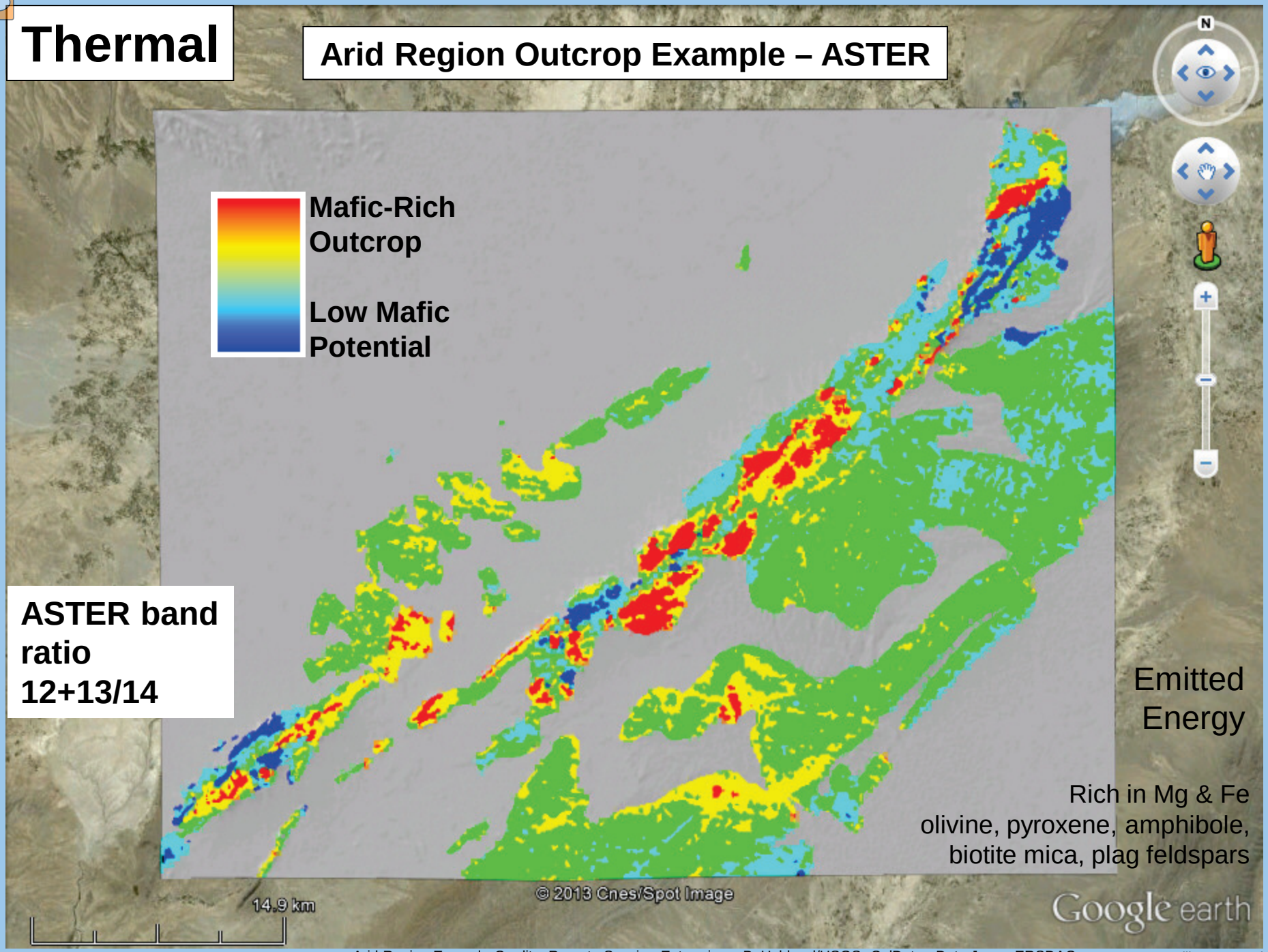


Arid Region Example Credits: Remote Sensing Enterprises, B. Hubbard/USGS, CalData , Data Japan ERSDAC

Ellis GeoSpatial

Thermal

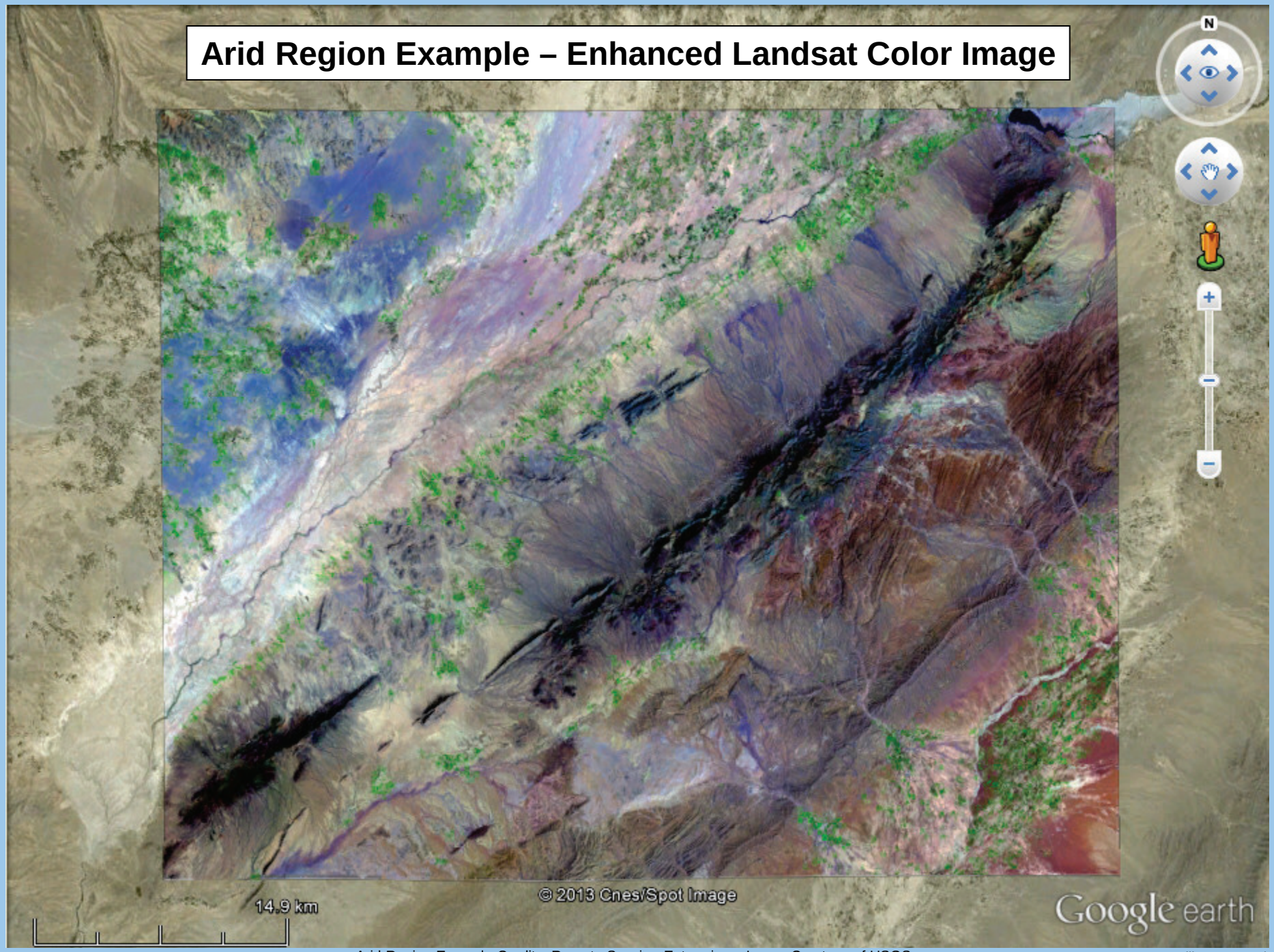
Arid Region Outcrop Example – ASTER



Arid Region Example Credits: Remote Sensing Enterprises, B. Hubbard/USGS, CalData , Data Japan ERSDAC

Ellis GeoSpatial

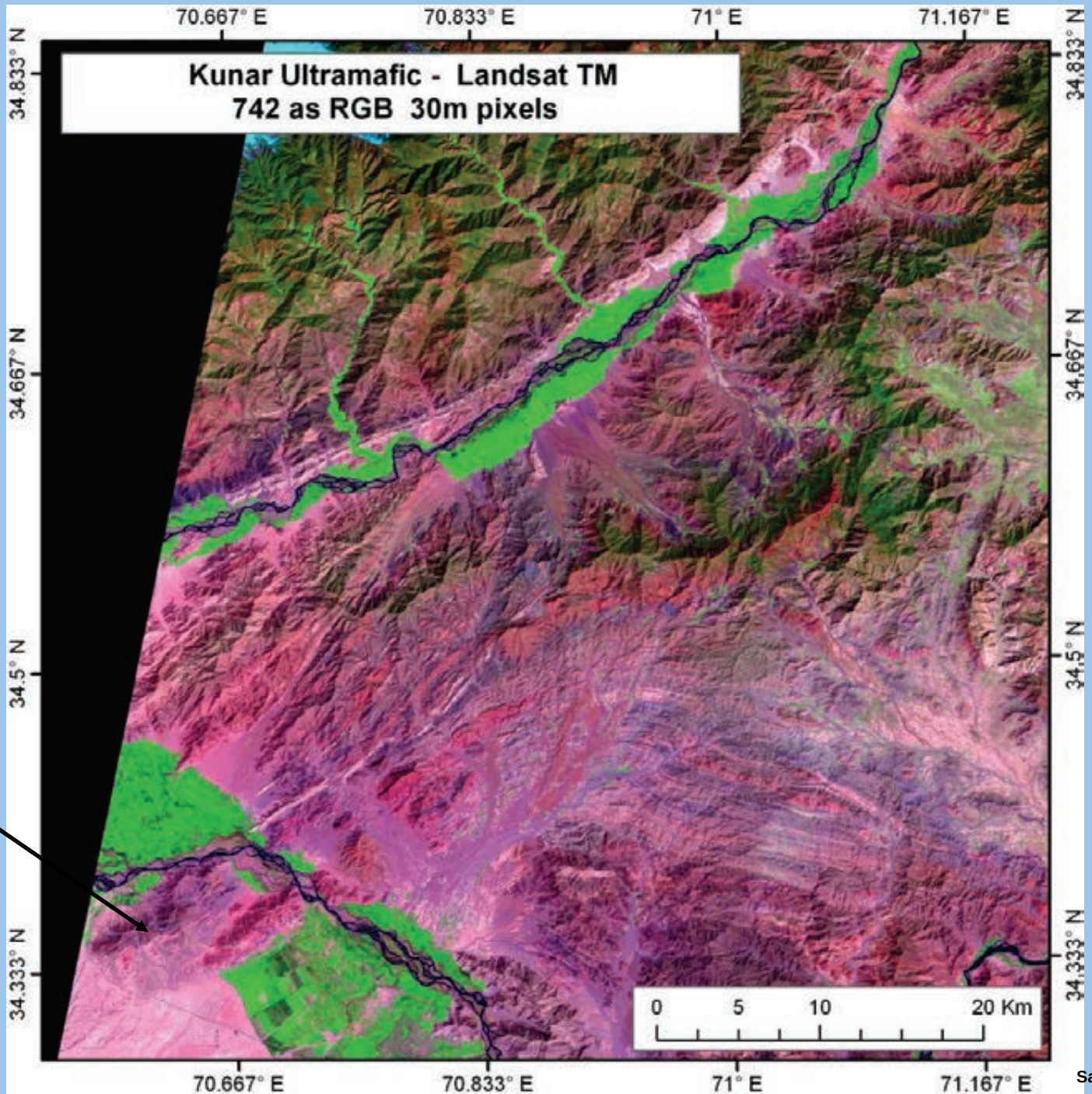
Arid Region Example – Enhanced Landsat Color Image



Arid Region Example Credits: Remote Sensing Enterprises, Image Courtesy of USGS

Thermal

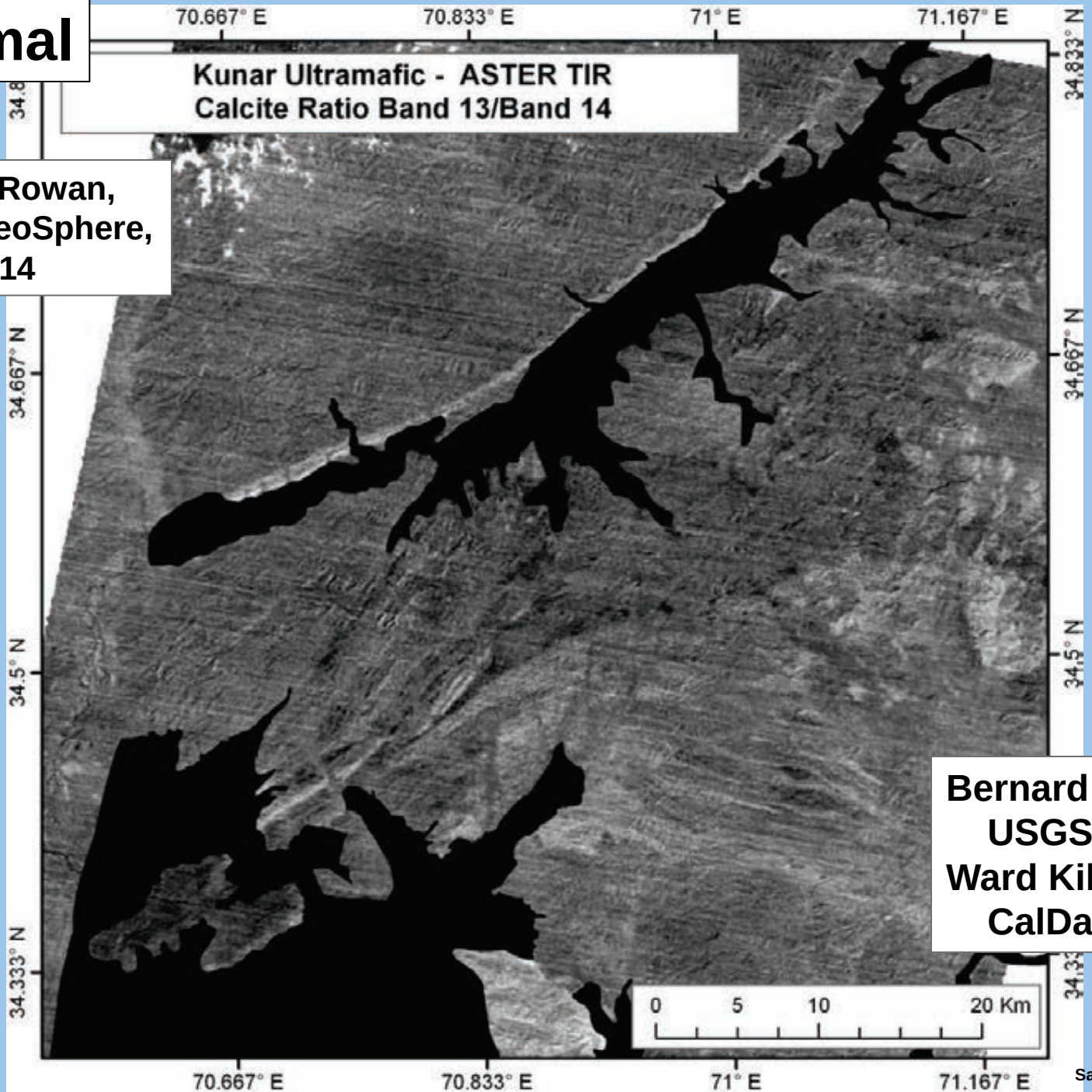
Chromite in Ultramafics



Sabins - Ellis 1 May 2012

Thermal

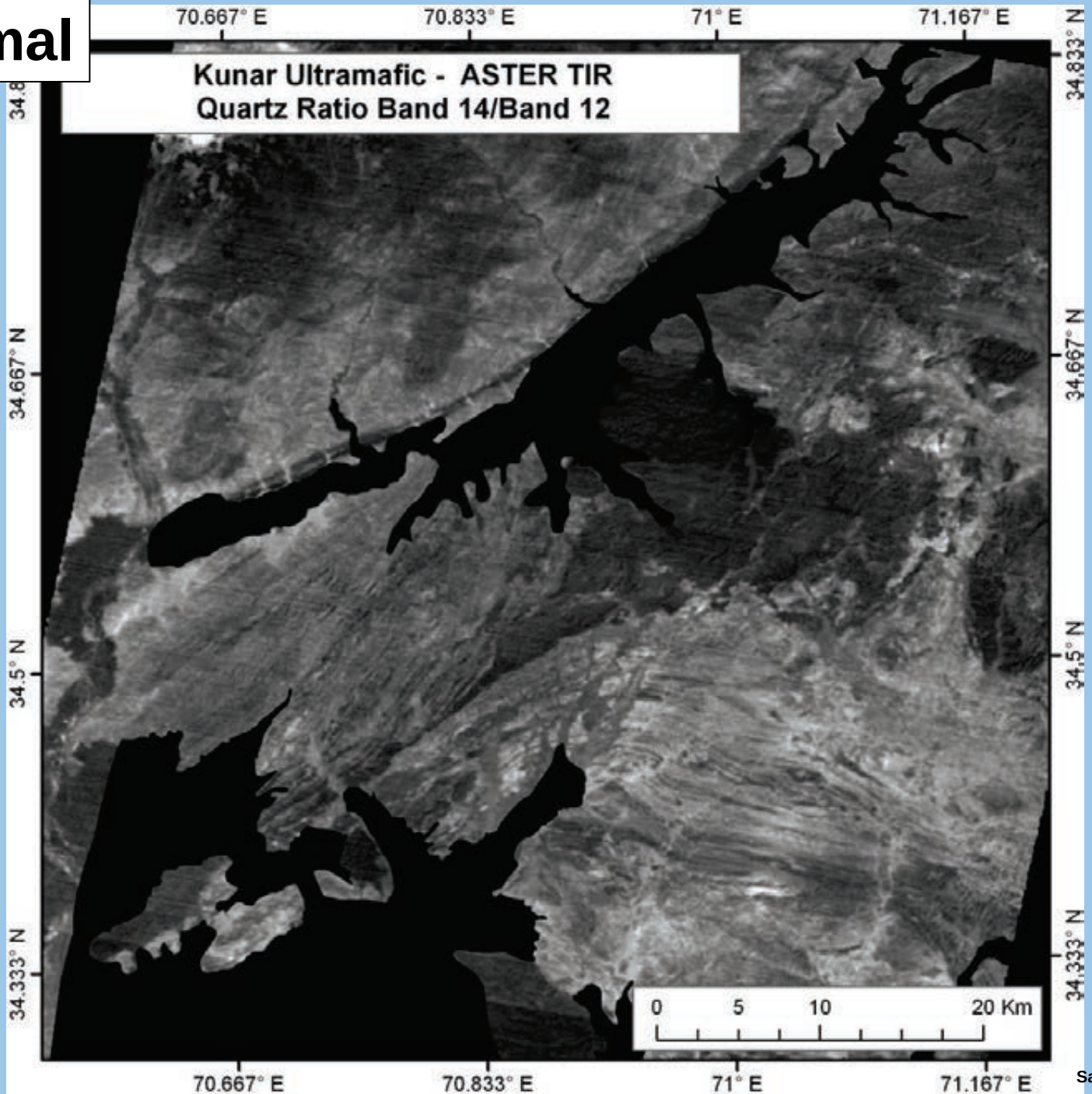
Mars & Rowan, 2011, GeoSphere, v.7, p 1-14



Emitted Energy

Bernard Hubbard
USGS
Ward Kilby
CalData

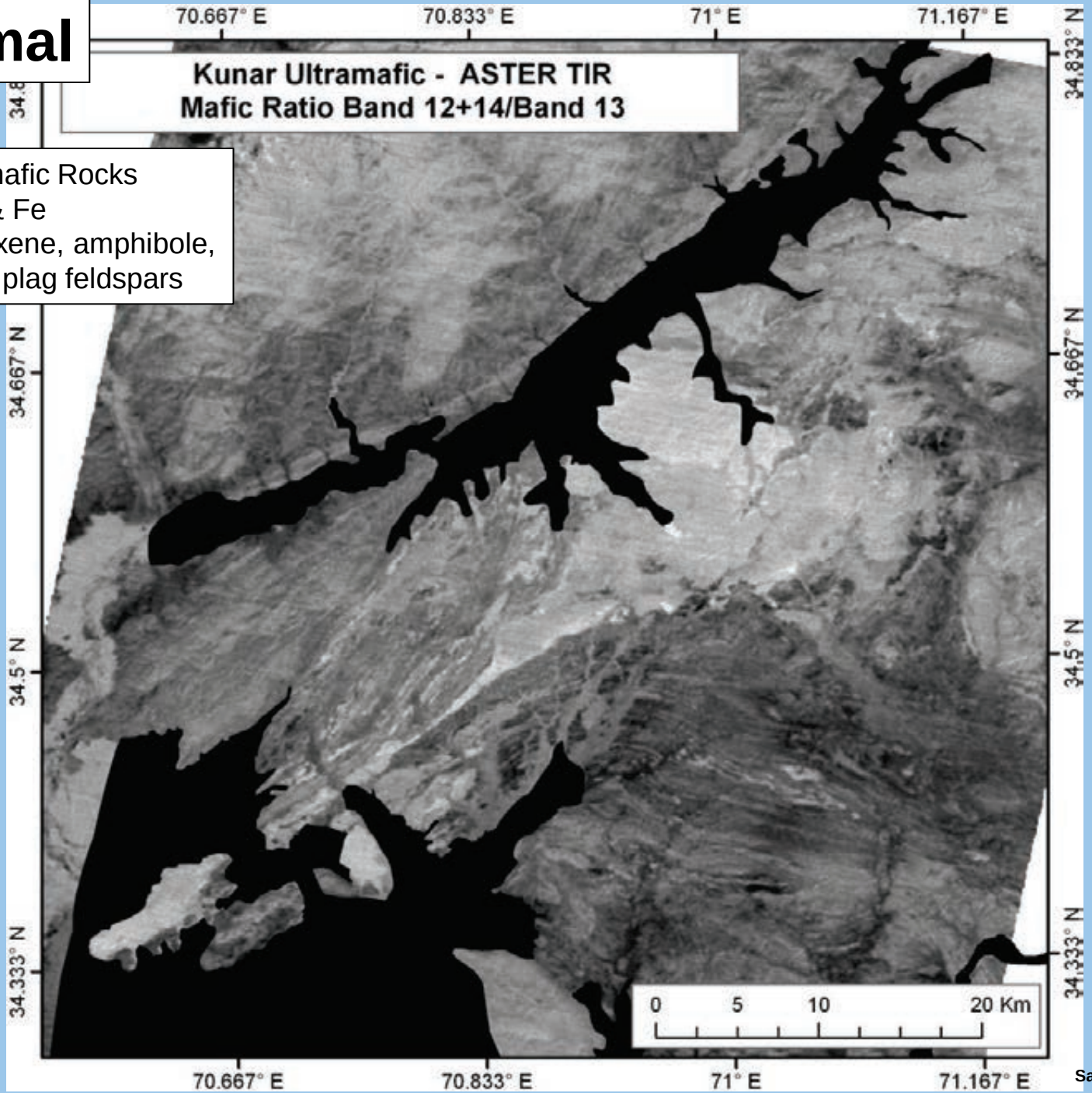
Thermal



Emitted Energy

Thermal

Mafic-Ultramafic Rocks
Rich in Mg & Fe
olivine, pyroxene, amphibole,
biotite mica, plag feldspars



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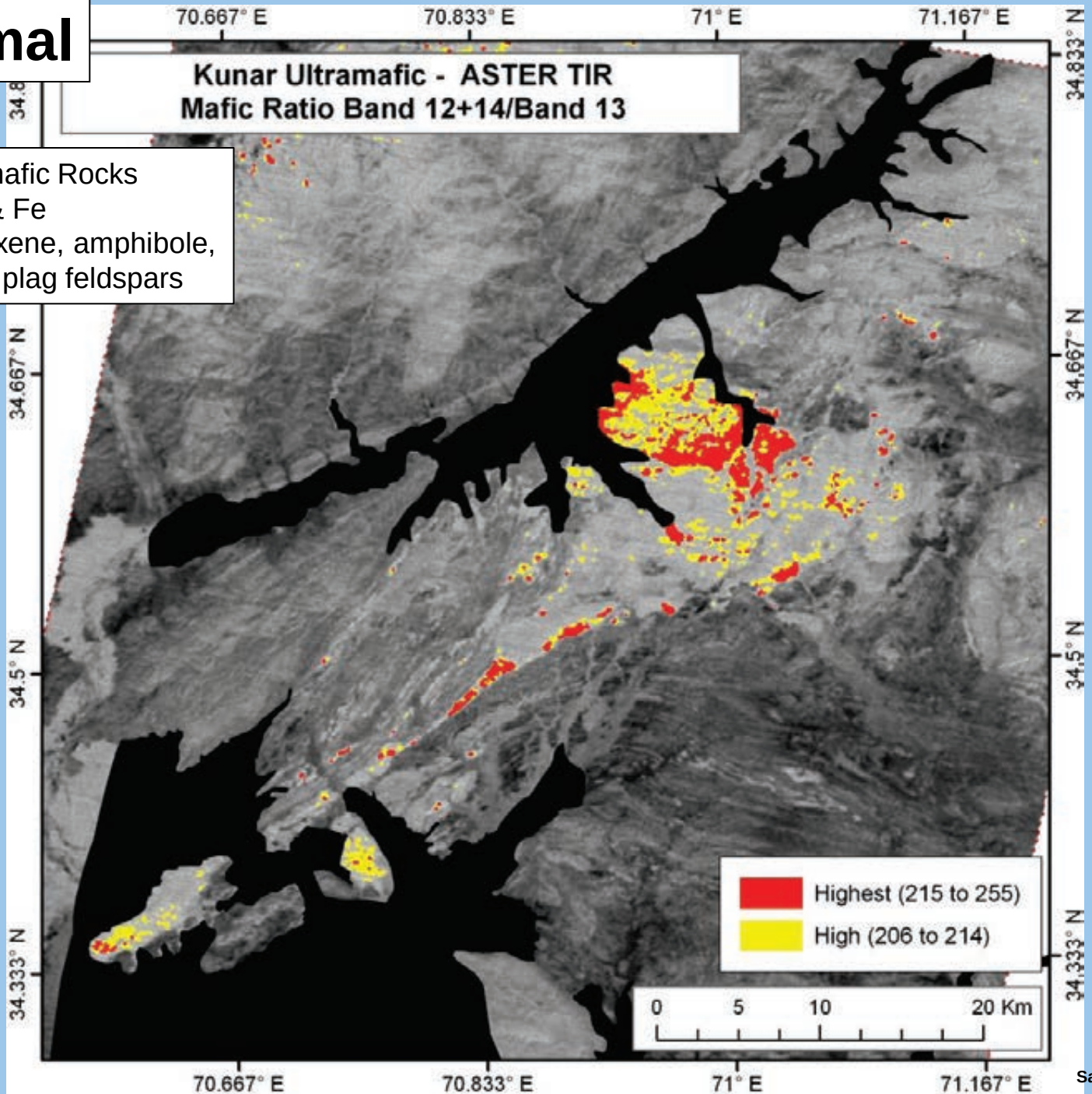
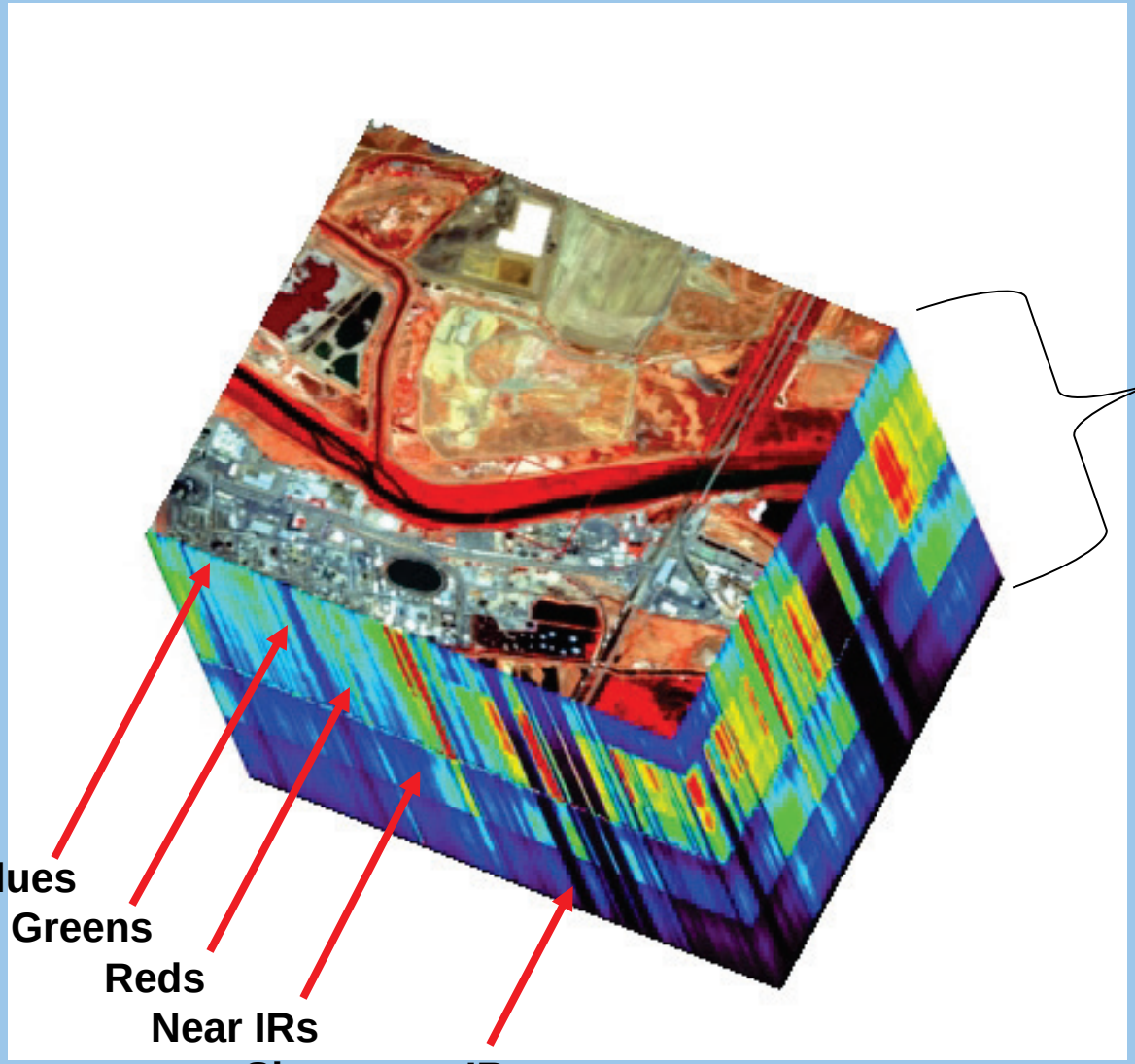


MAPPING OIL SPILLS & SEEPS WITH HYPERSPECTRAL

HYPERSPECTRAL DATACUBE
Continuous spectrum collected

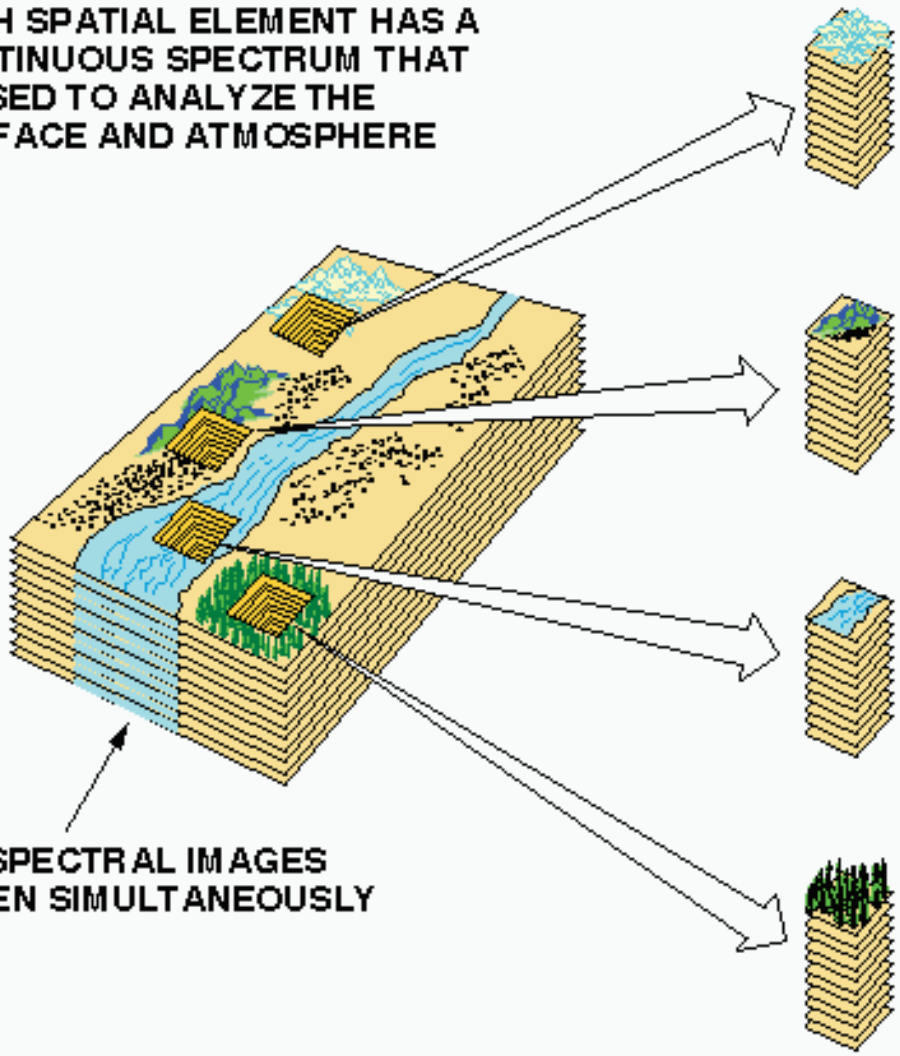


Stack of B&W images, each a narrow wavelength band - from reflected visible Blue to shortwave IR

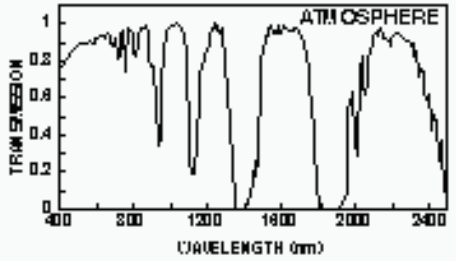
~50 - 300 bands

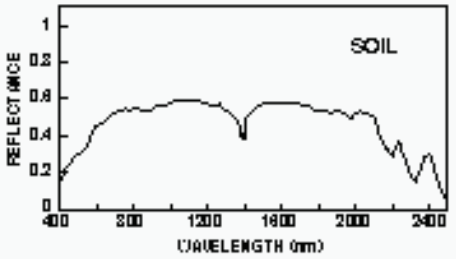
HYPERSPECTRAL

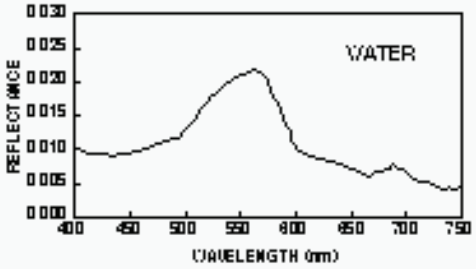
EACH SPATIAL ELEMENT HAS A CONTINUOUS SPECTRUM THAT IS USED TO ANALYZE THE SURFACE AND ATMOSPHERE

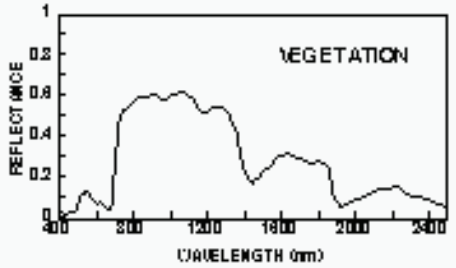


224 SPECTRAL IMAGES TAKEN SIMULTANEOUSLY

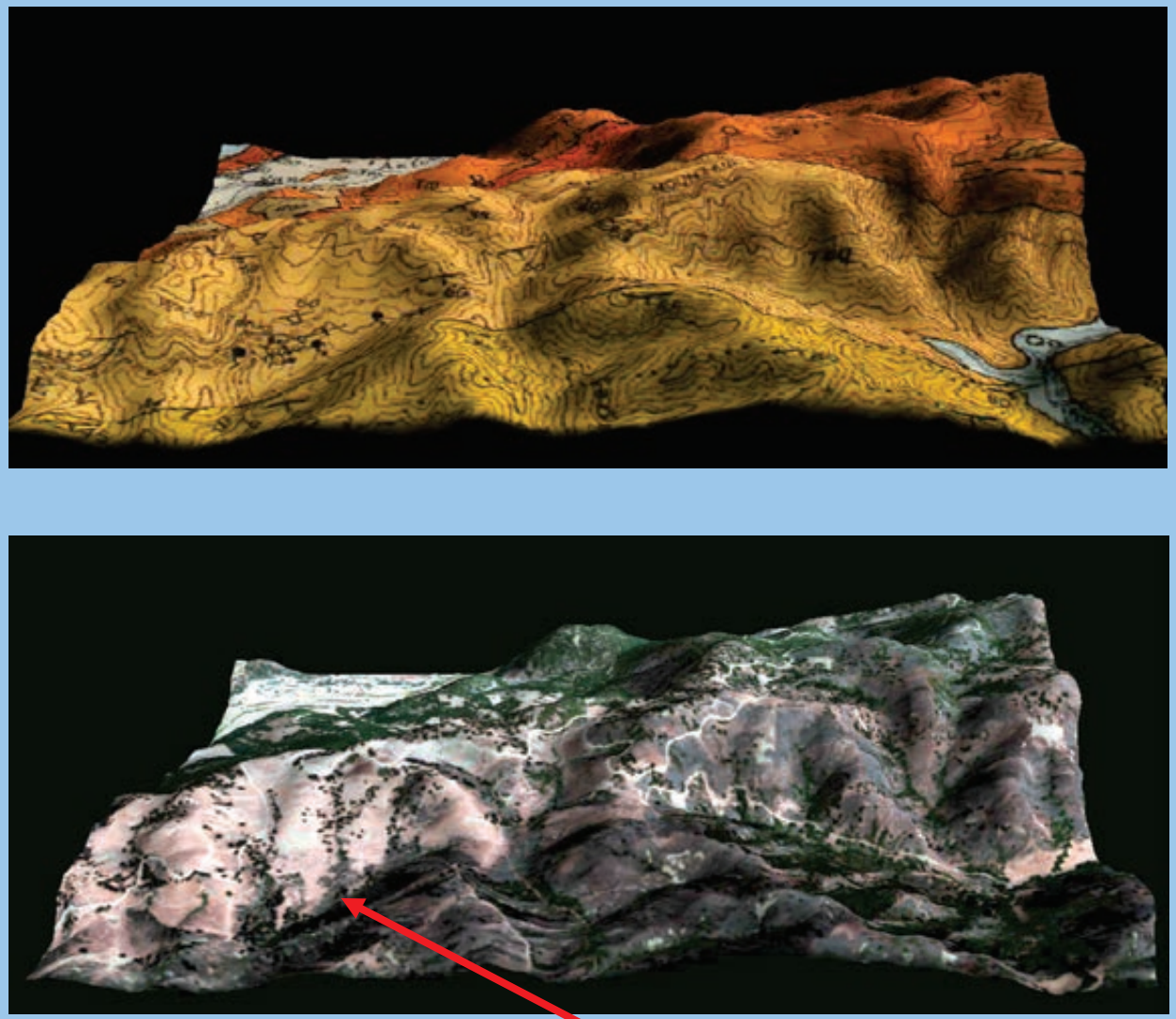








DETECTING OIL SEEPS WITH HYPERSPECTRAL

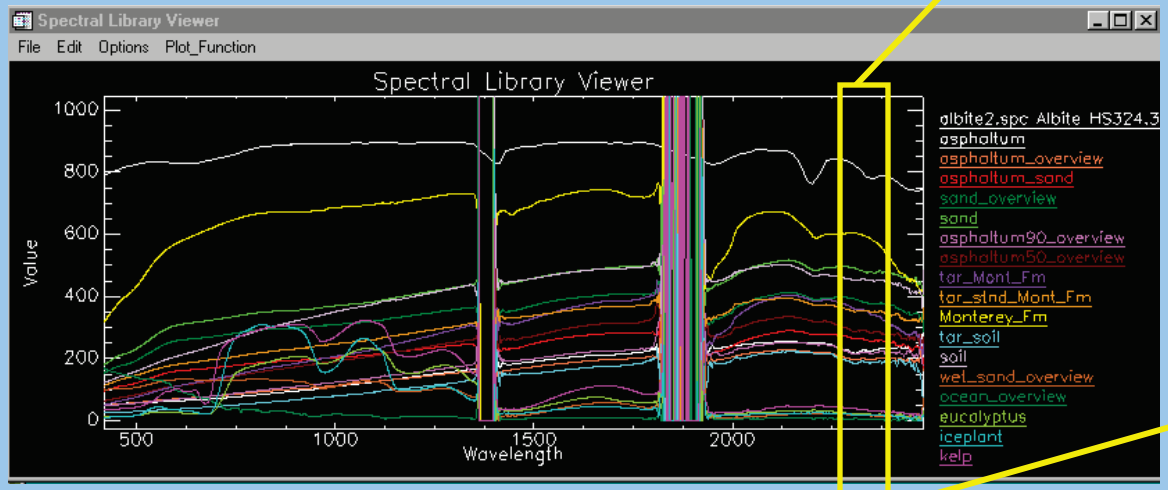


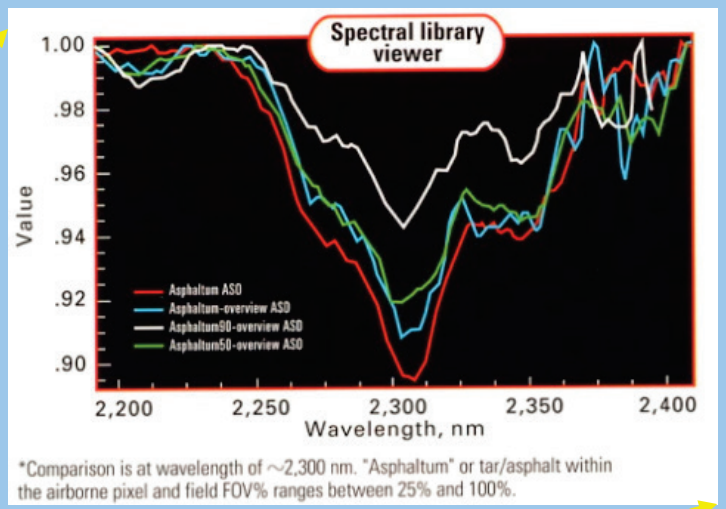
"Dibblee Oil Seep"

OIL SEEP IN AREA

DIBBLEE OIL SEEP

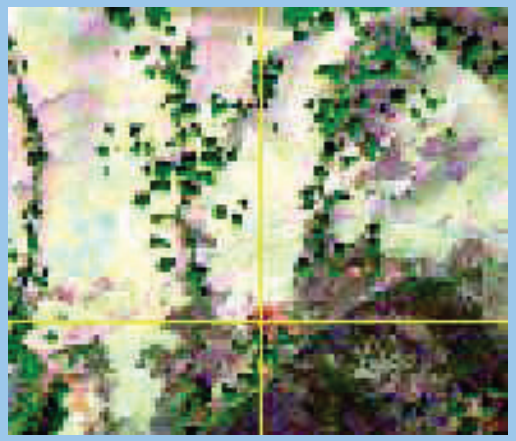
BUILDING AN OIL SPECTRAL LIBRARY BASED ON FIELD MEASUREMENTS





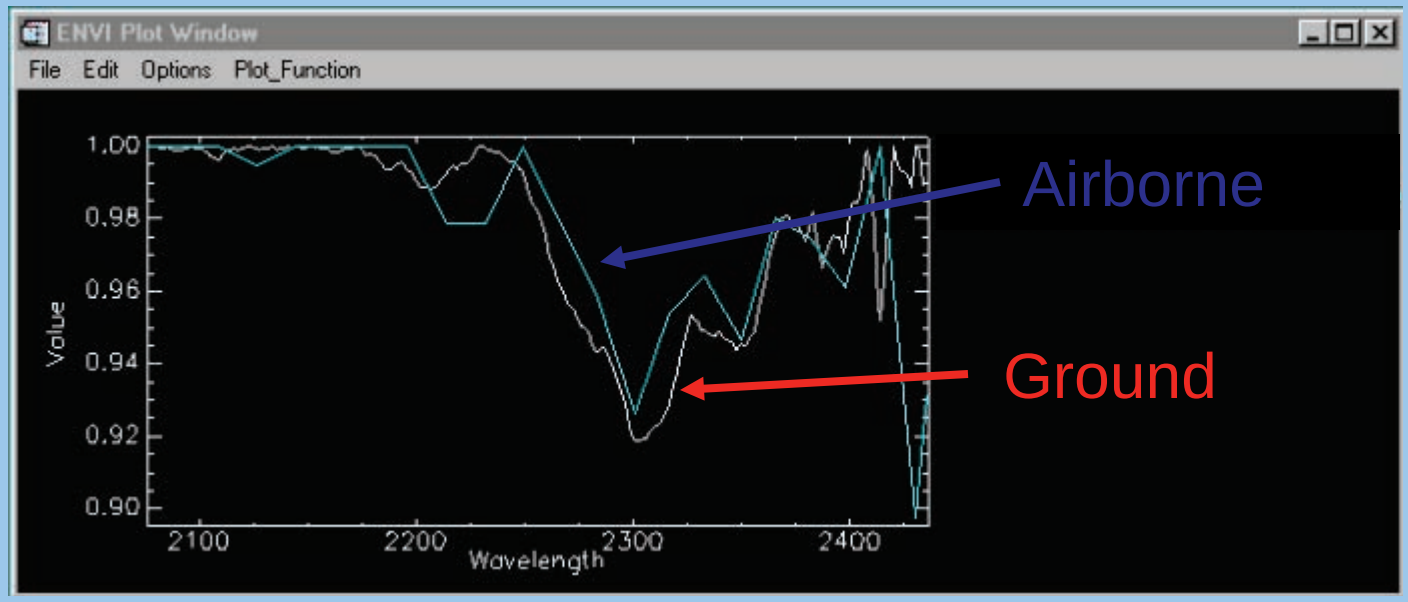
PROVING AIRBORNE SENSING MATCHES GROUND MEASUREMENT

Geologic Map

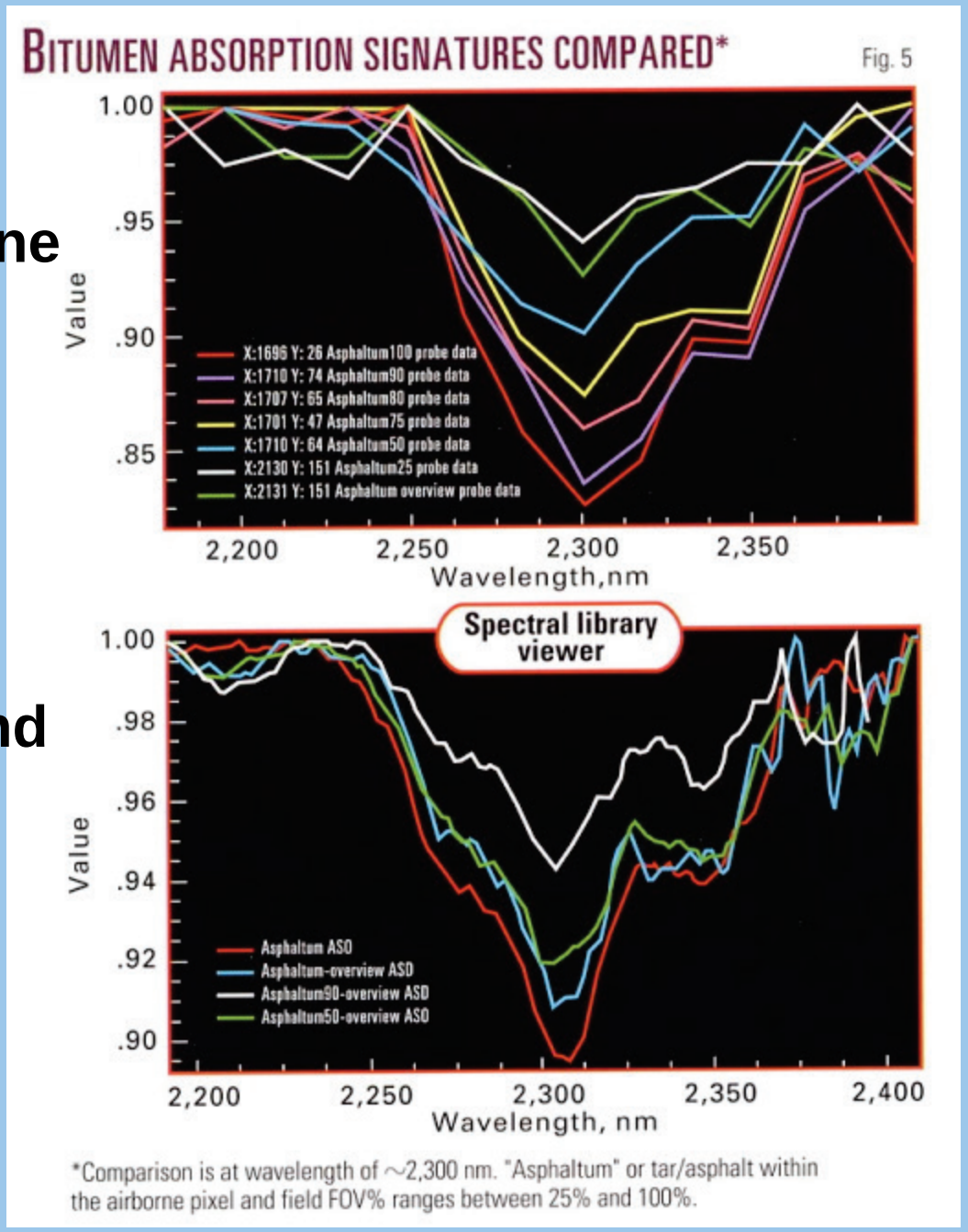


Hyperspectral Image

Zoom-in to pixel



Airborne



Increasing distance from pure tar site

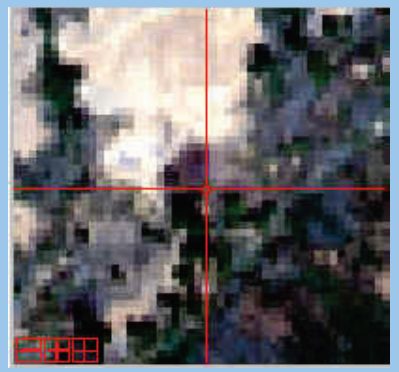
Increasing mixture of non-tar with tar in airborne pixels

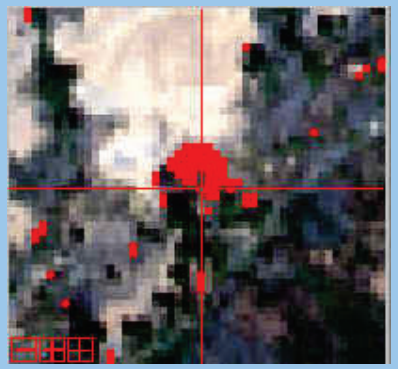
Ground

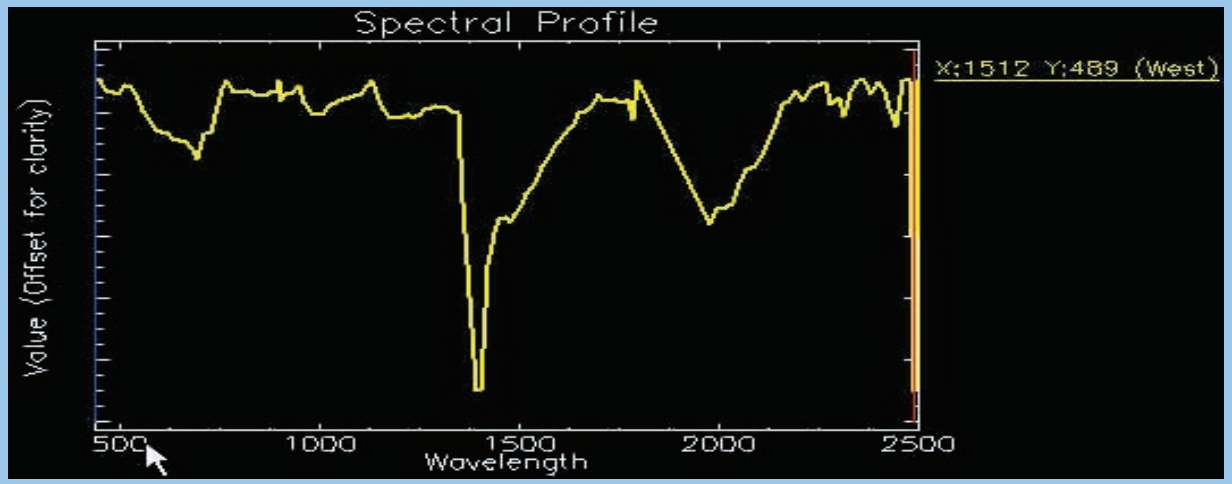
Increasing distance from pure tar site

Increasing mixture of non-tar with tar in ground field of view

USING SPECTRAL SIGNATURE CONFIRMED IN FIELD TO FIND OTHER AIRBORNE PIXELS THAT HAVE OIL





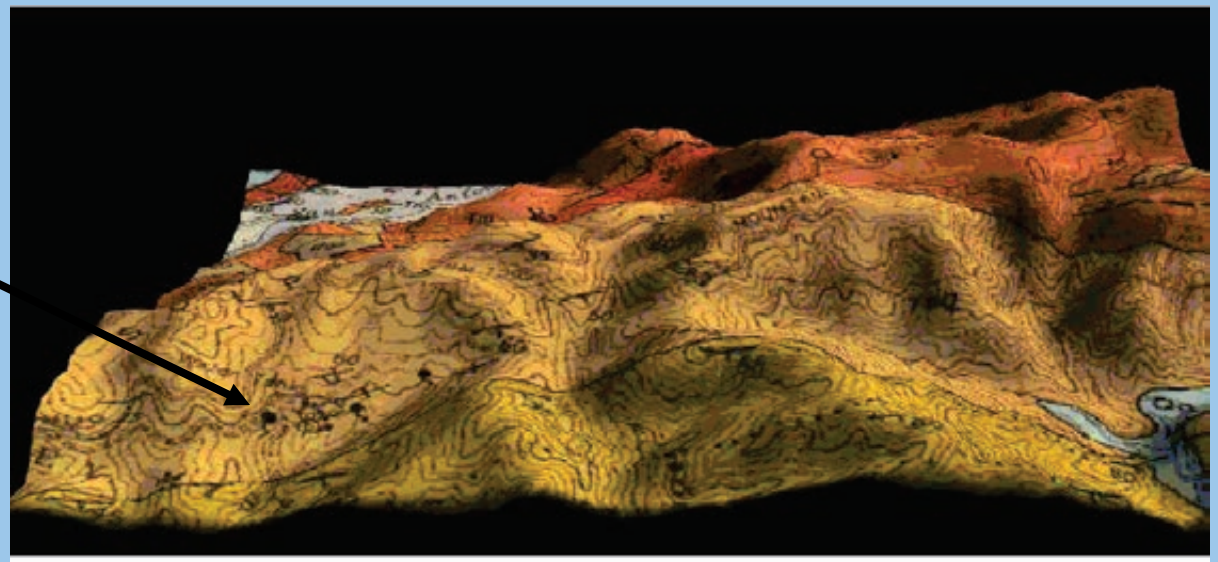


Hydrocarbon Spectral Signature

Extrapolation of Dibblee oil seep.

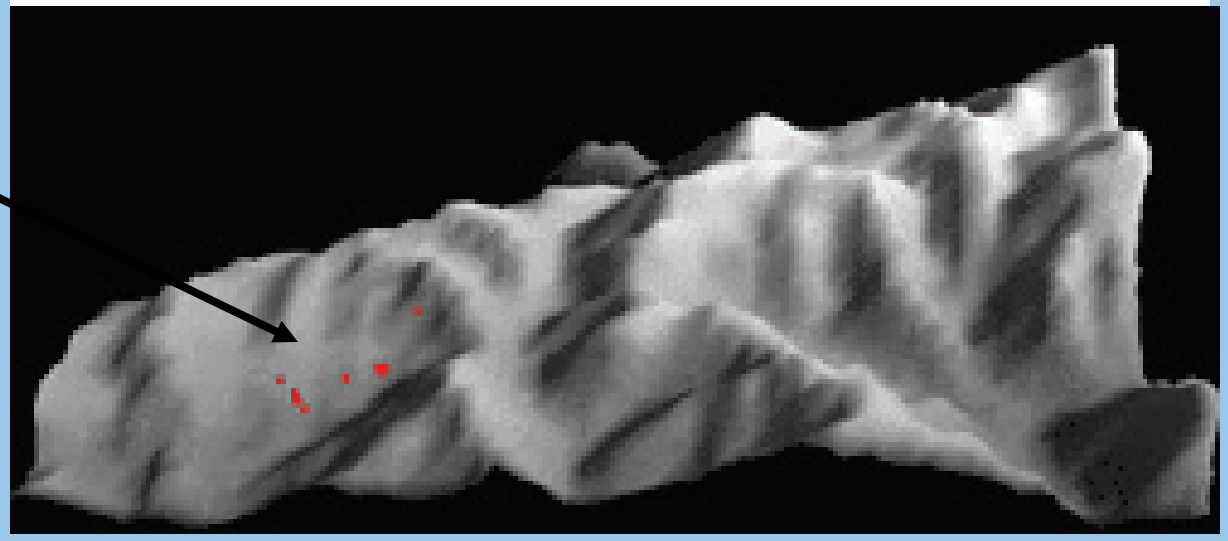
Spectral signature from training site pixel extrapolated to surrounding area.

OIL SEEP DETECTION & MAPPING



Original Map

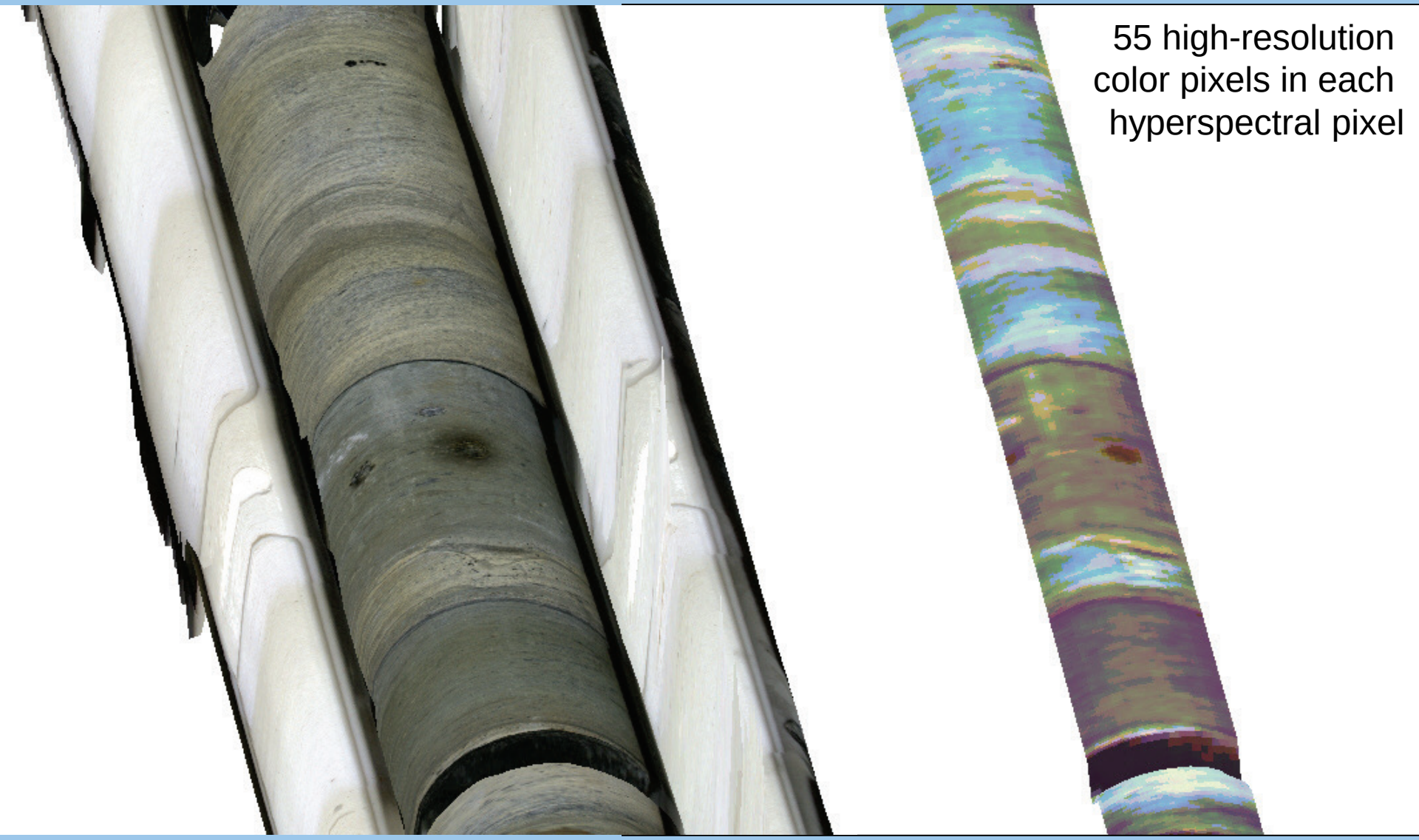
Red Dots Mapped As Oil Seeps



Actual Locations Of Oil Seeps

MAPPING CORE WITH HYPERSPECTRAL

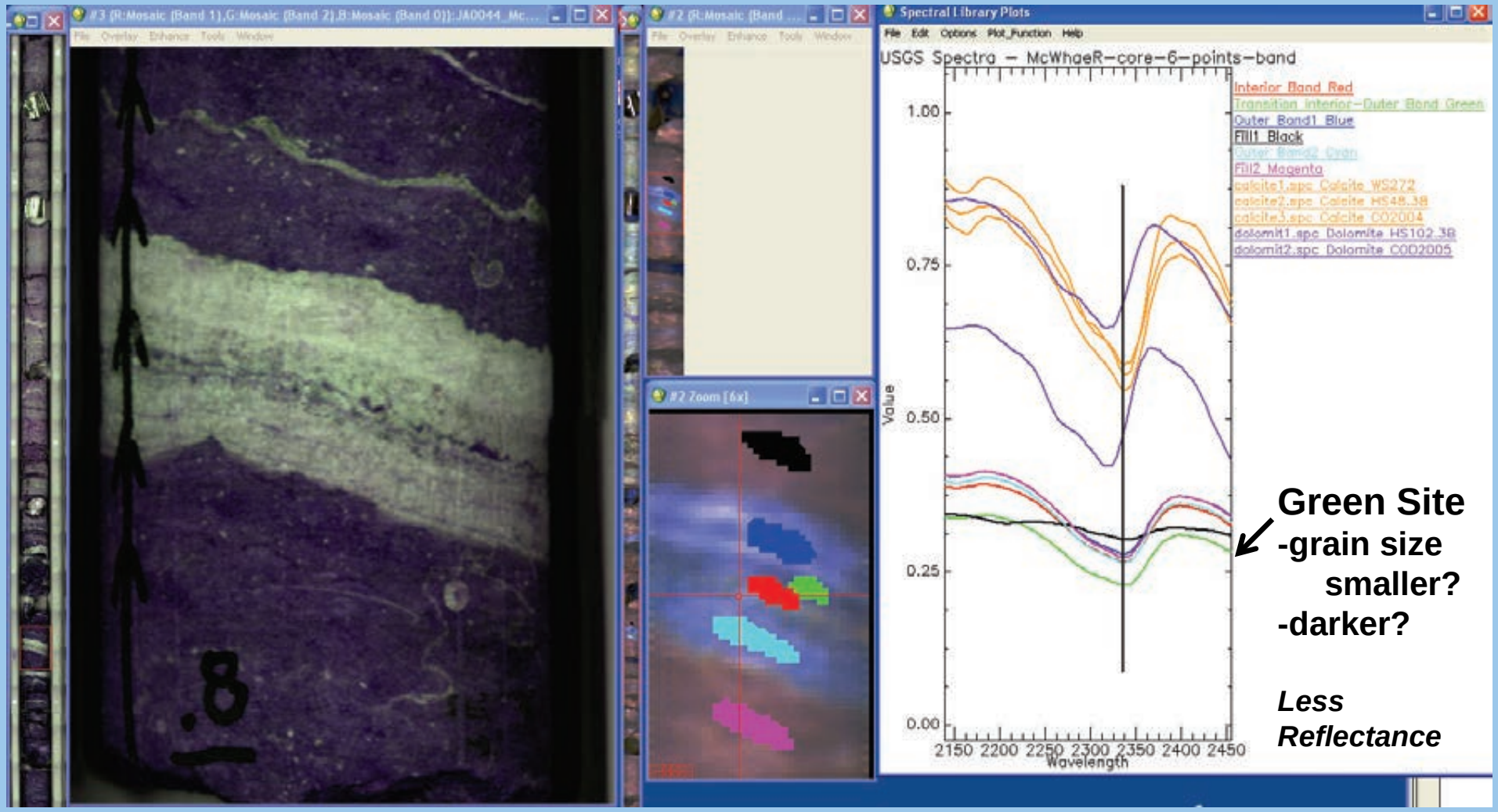
Core Scanning for Mineralogy



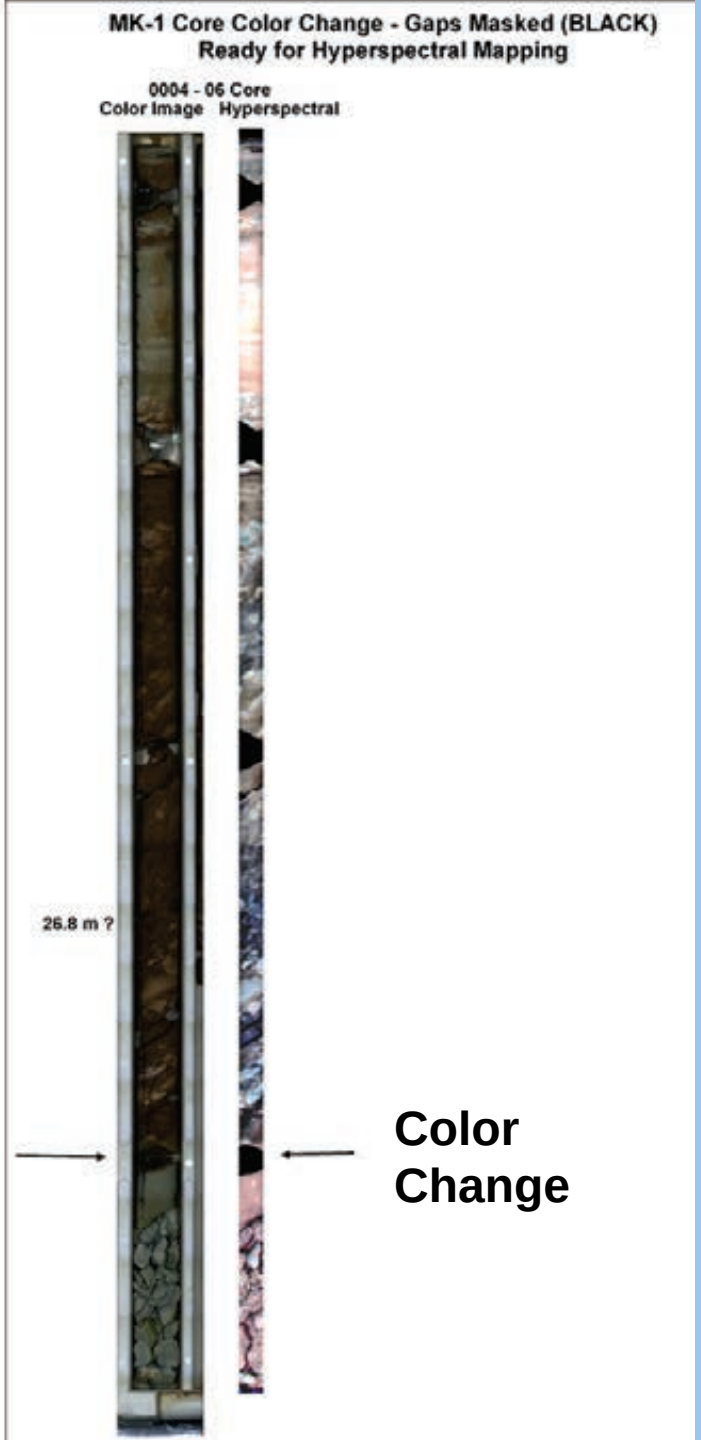
55 high-resolution color pixels in each hyperspectral pixel

Each pixel = 0.5 x 0.5 mm

Core Section with Training Sites



MR-1
0004-06
Analyzed



Color Change

Spectral Classification – 20 classes

#2 ROI Tool

File ROI_Type Options Help

Window: Image Scroll Zoom Off

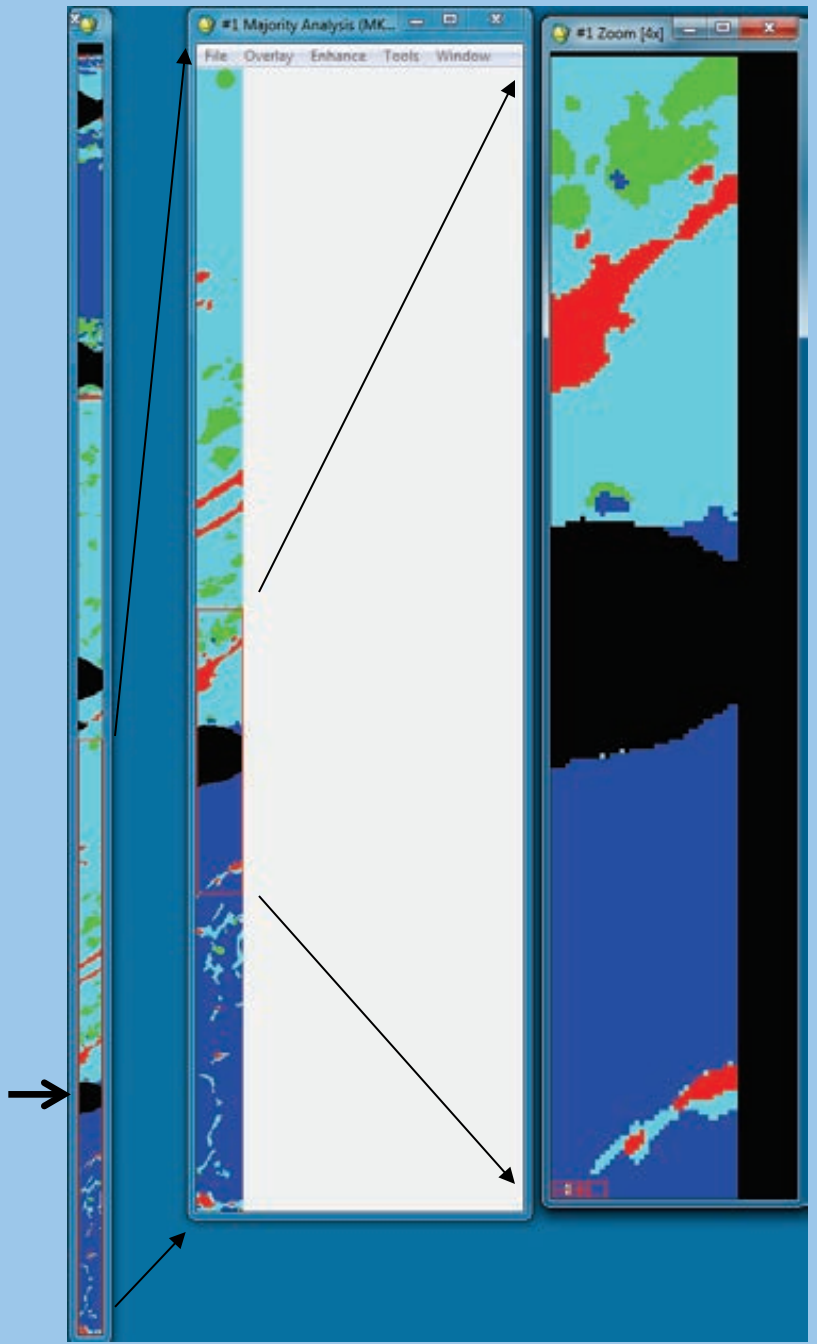
ROI Name	Color	Pixe
MK-1_0004-06_PC-iso_Class1	Red	1,764
MK-1_0004-06_PC-iso_Class2	Green	4,184
MK-1_0004-06_PC-iso_Class3	Blue	6,043
MK-1_0004-06_PC-iso_Class4	Yellow	5,195
MK-1_0004-06_PC-iso_Class5	Cyan	4,444
MK-1_0004-06_PC-iso_Class6	Magenta	3,269
MK-1_0004-06_PC-iso_Class7	Maroon	2,855
MK-1_0004-06_PC-iso_Class8	Sea Green	4,633
MK-1_0004-06_PC-iso_Class9	Purple	2,131
MK-1_0004-06_PC-iso_Class10	Coral	3,469
MK-1_0004-06_PC-iso_Class11	Aquamarine	1,981
MK-1_0004-06_PC-iso_Class12	Orchid	3,498
MK-1_0004-06_PC-iso_Class13	Sienna	2,342
MK-1_0004-06_PC-iso_Class14	Chartreuse	3,241
MK-1_0004-06_PC-iso_Class15	Thistle	2,208
MK-1_0004-06_PC-iso_Class16	Red1	2,552
MK-1_0004-06_PC-iso_Class17	Orange1	2,764
MK-1_0004-06_PC-iso_Class18	Orange3	2,424
MK-1_0004-06_PC-iso_Class19	Purple2	4,177
MK-1_0004-06_PC-iso_Class20	Sienna3	4,866

New Region Goto Delete Part

Stats Grow Pixel Delete ROI

Select All Hide ROIs Show ROIs

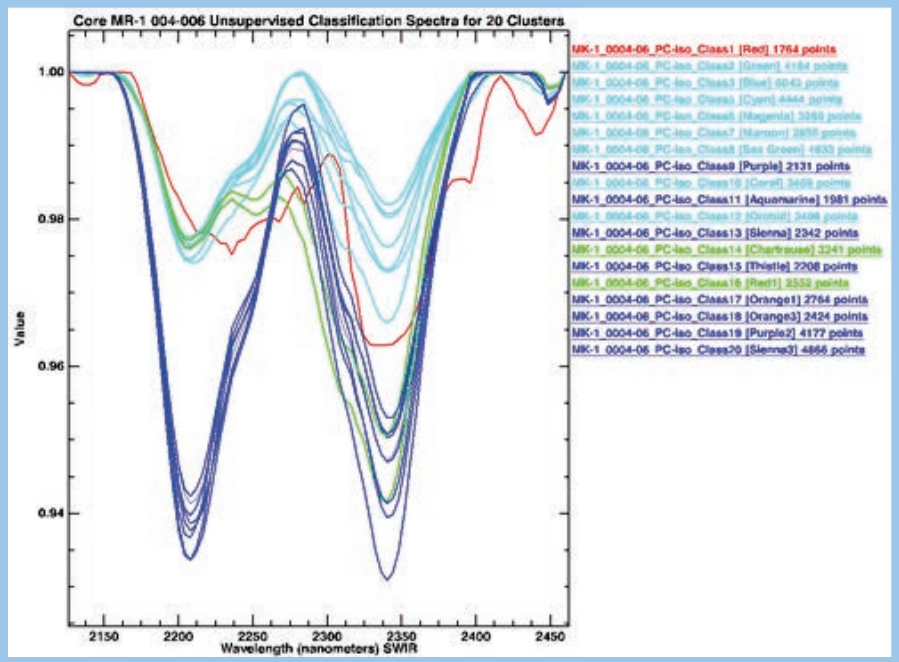
Each pixel = 0.5 x 0.5 mm



Roll-Up Classification into Four Classes

Red pixels relate to open fractures, shadows and other noise in the core.

Cyan pixels have moderate absorption in both clay and carbonate, blue pixels have strong absorption in both clay and carbonate, while green pixels have weak clay with stronger carbonate absorption



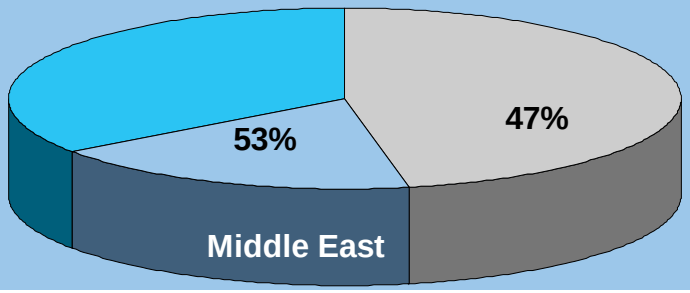
Using Multispectral Remote Sensing To Better Understand Modern Carbonate Environments

-for Improved Subsurface Reservoir Modeling-

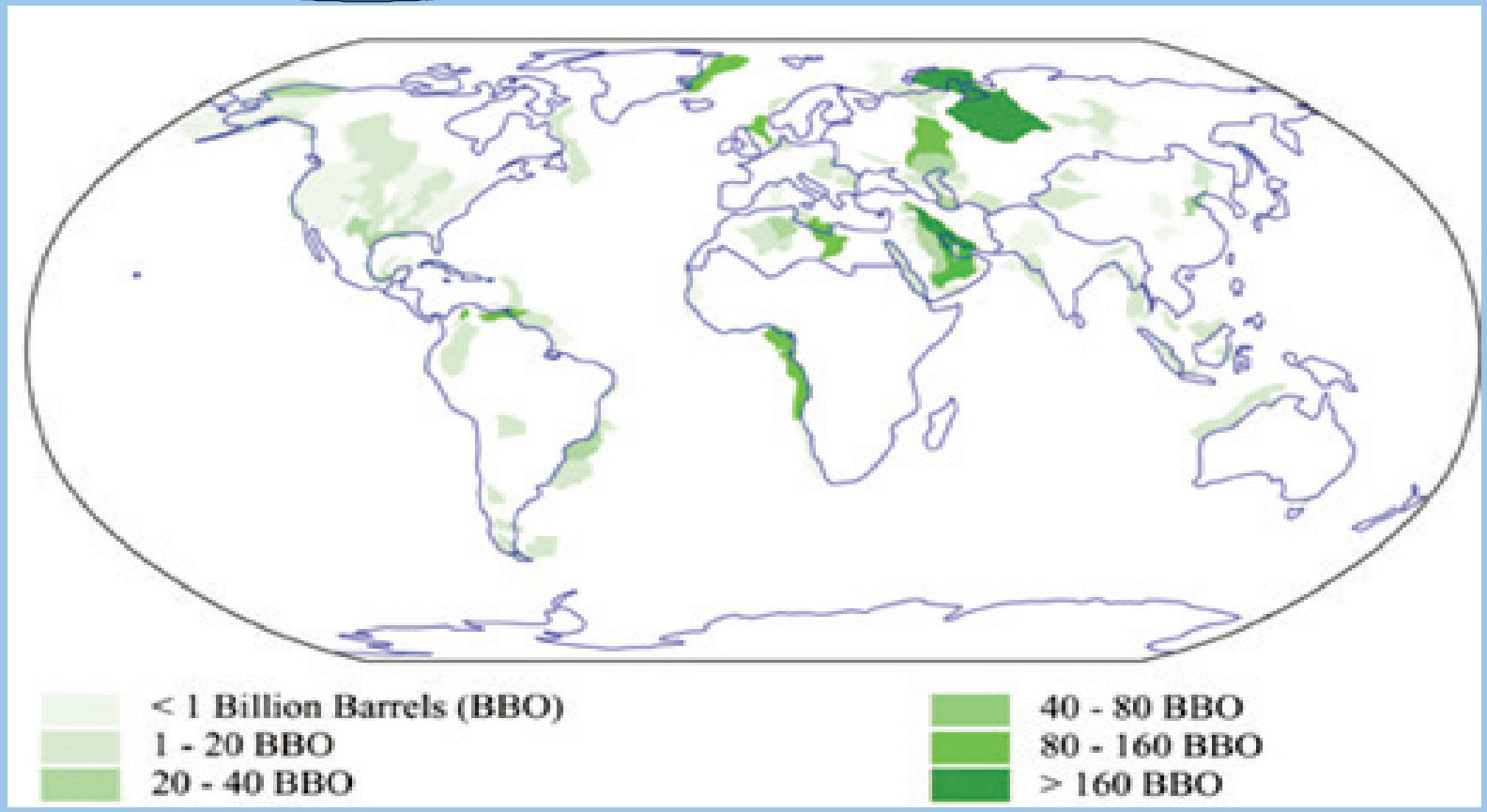
Paul (Mitch) Harris, Chevron
Sam Purkis, National Coral Reef Institute
Jim Ellis, Ellis GeoSpatial

Ellis GeoSpatial

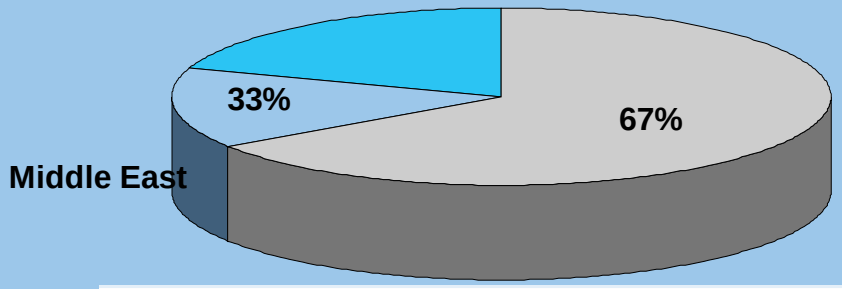
Over Half of the World's Oil Comes from Carbonate Reservoirs



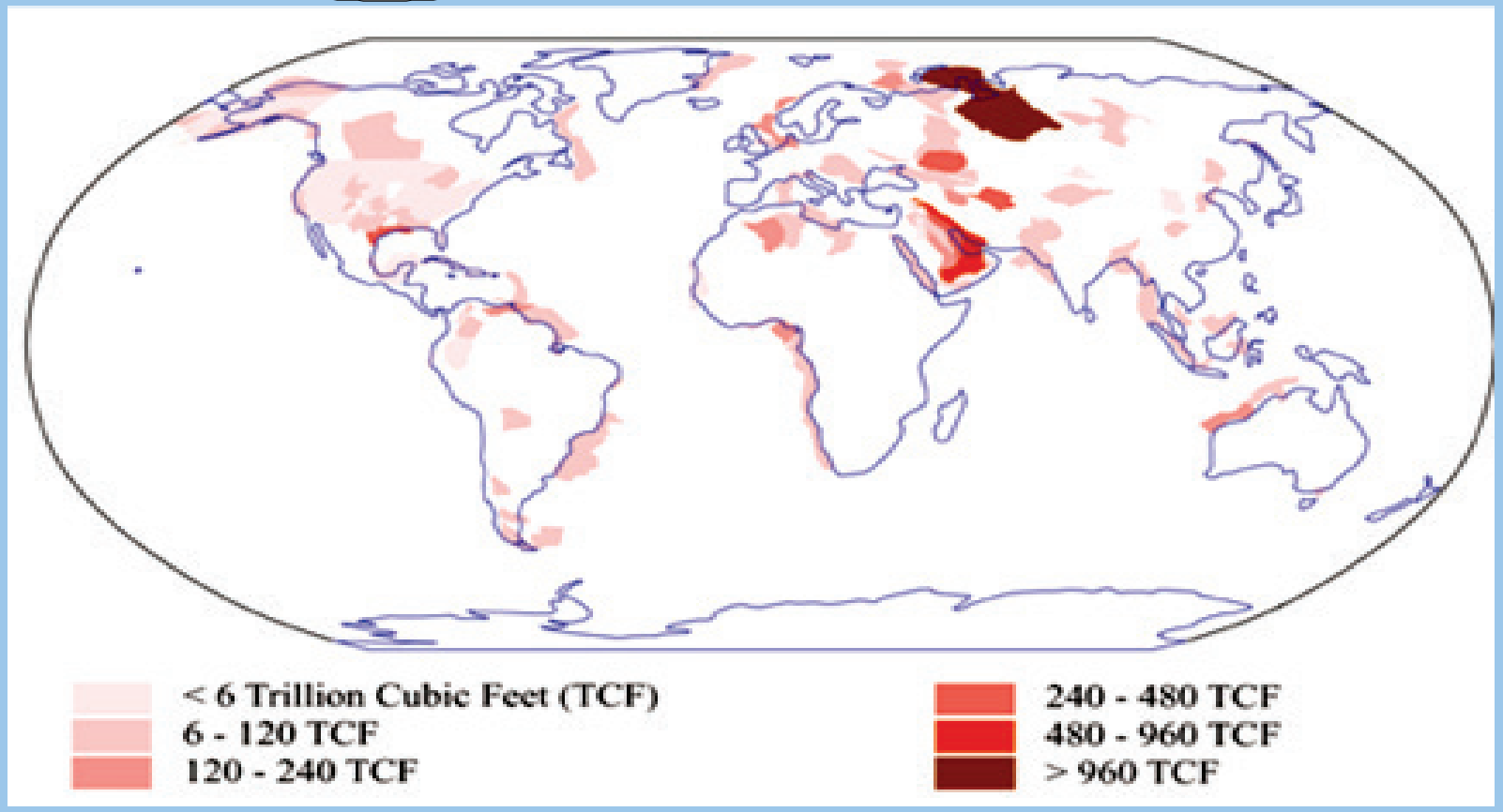
Based on Data from 17 Giant Provinces Accounting for 80% of World Oil Reserves



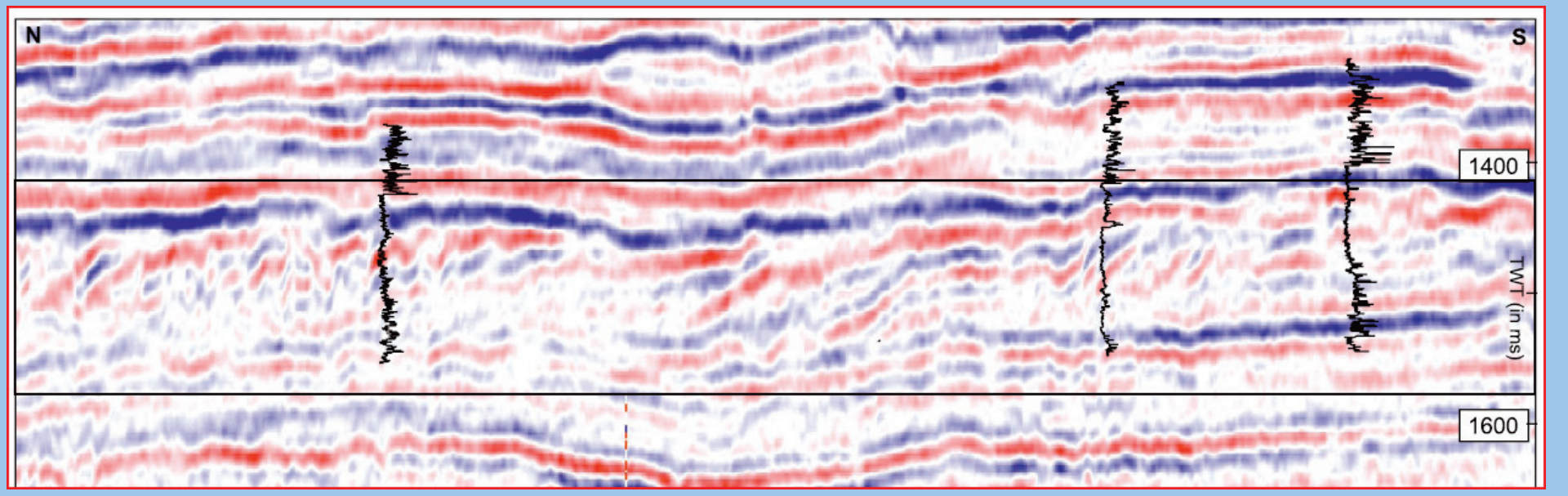
One Third of the World's Gas Comes from Carbonate Reservoirs



Based on Data from 16 Giant Provinces Accounting for 80% of World Gas Reserves

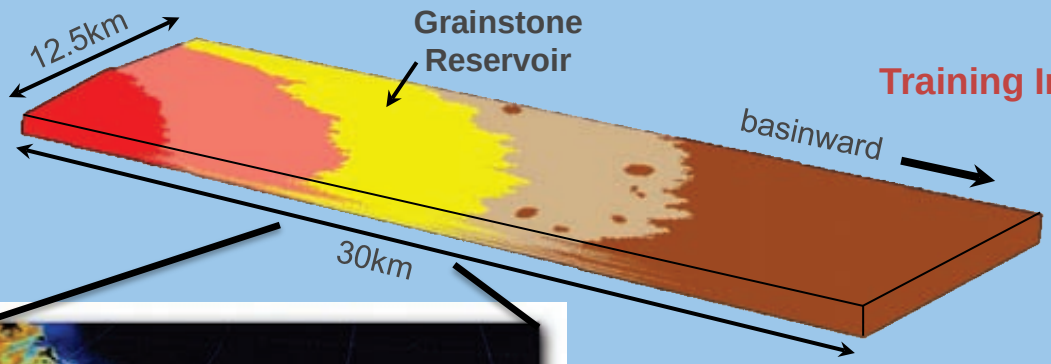


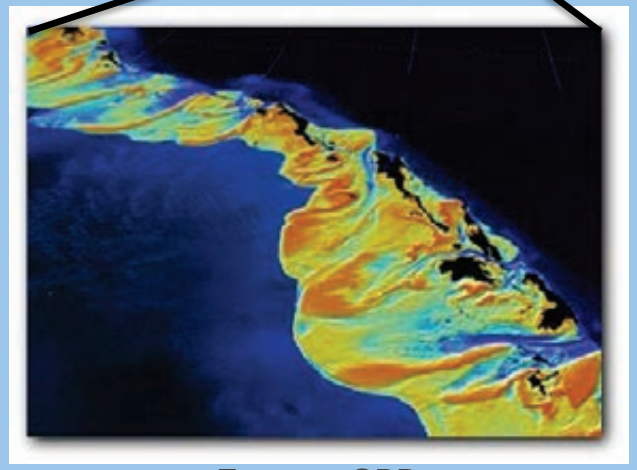
Modern Analogs Help Refine Subsurface Interpretations



Modified after Droste & Van Steenwinkel (2004)

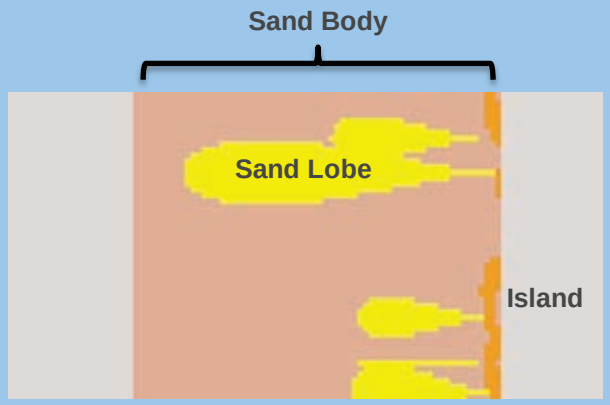
Modern Analogs Can Provide Key Inputs for Reservoir Modeling

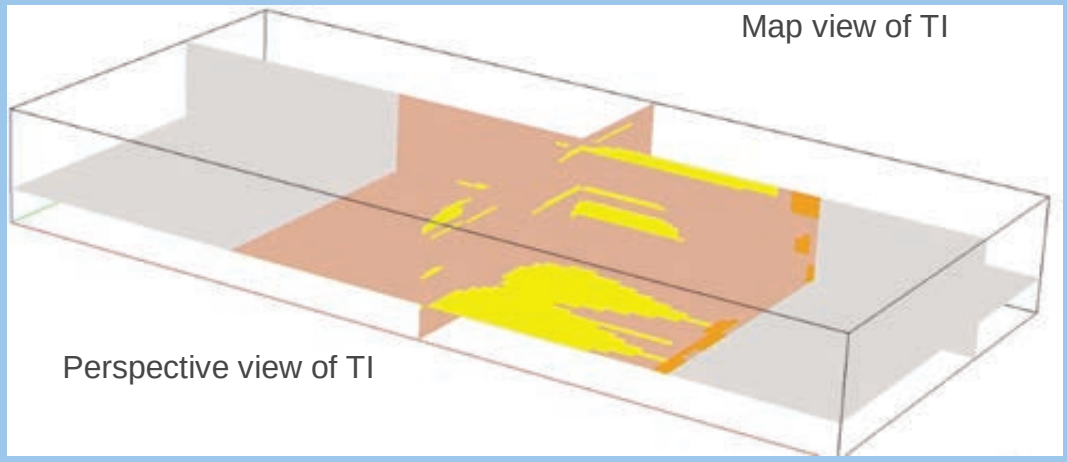




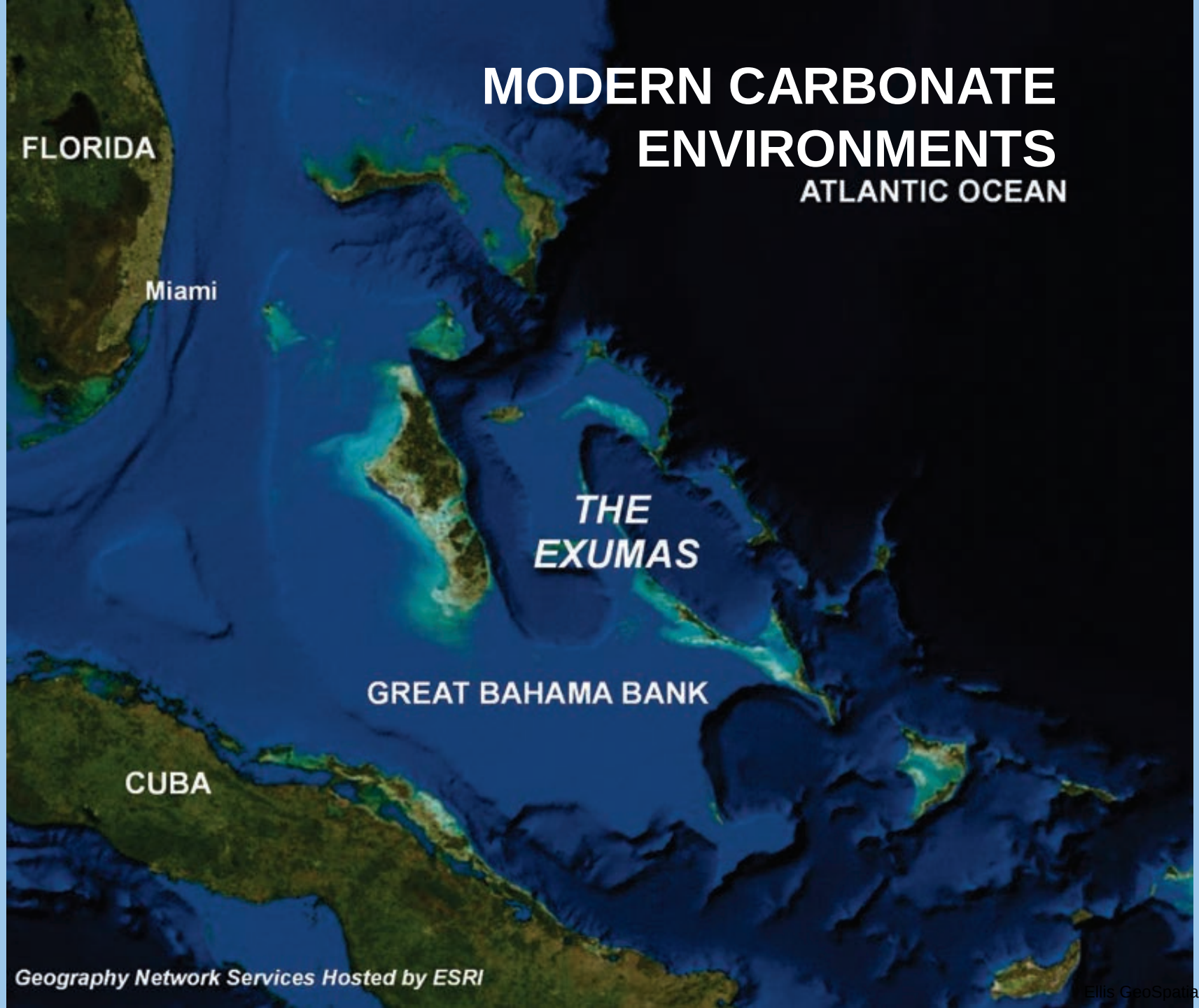
Exumas, GBB

Training Images Based on Modern Analogs

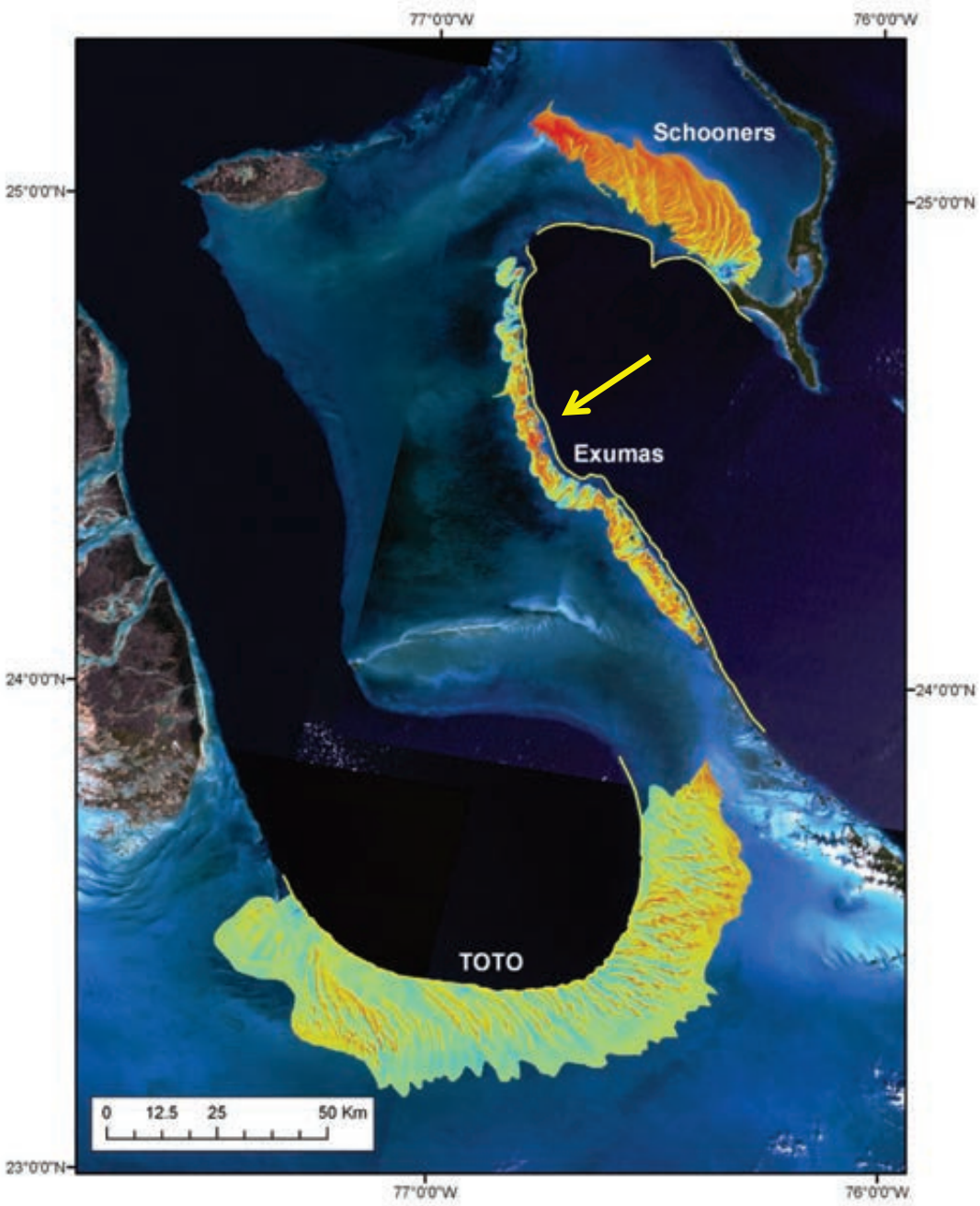




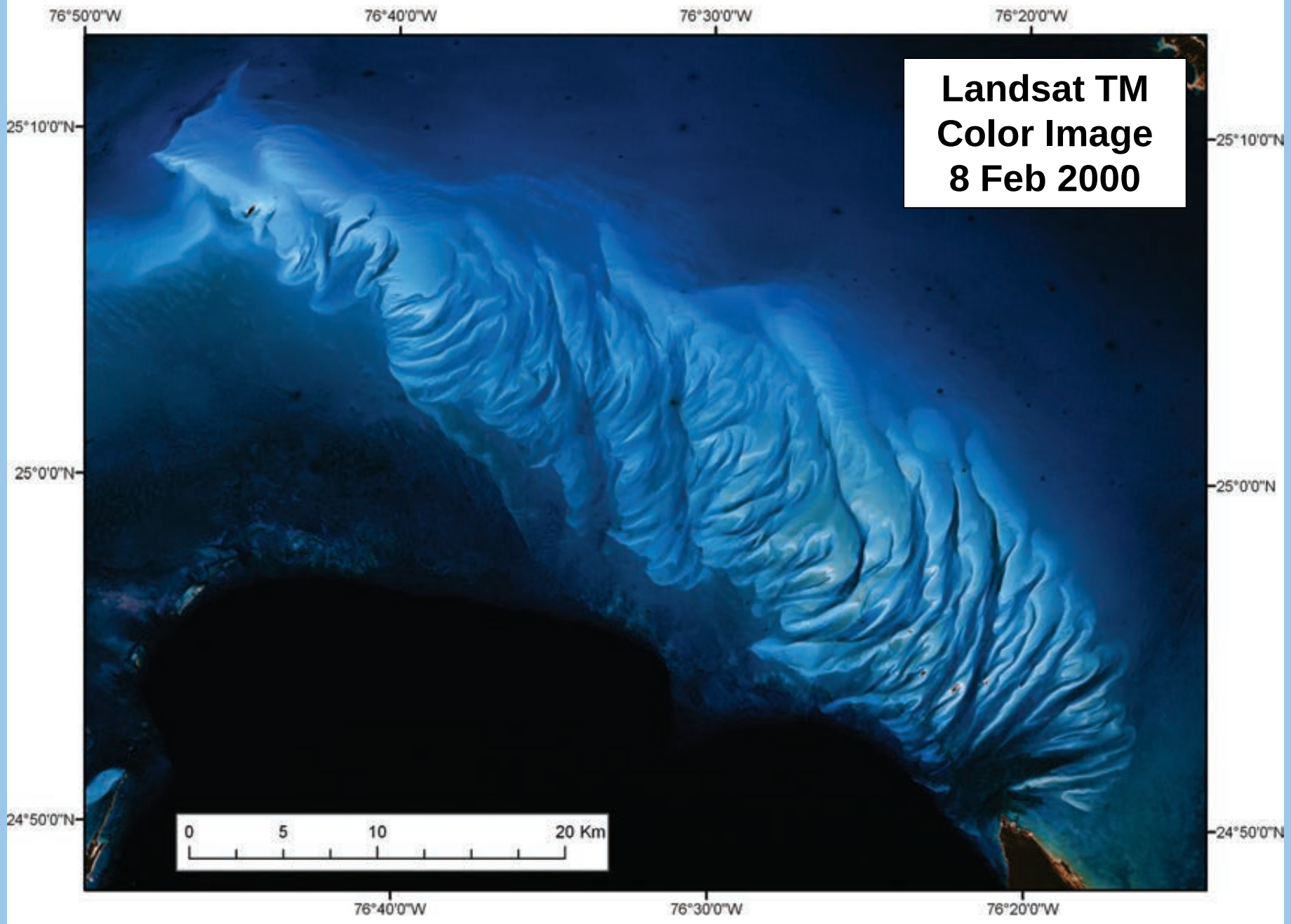
architectural property


MODERN CARBONATE ENVIRONMENTS
FLORIDA
ATLANTIC OCEAN
Miami
THE EXUMAS
GREAT BAHAMA BANK
CUBA
Geography Network Services Hosted by ESRI

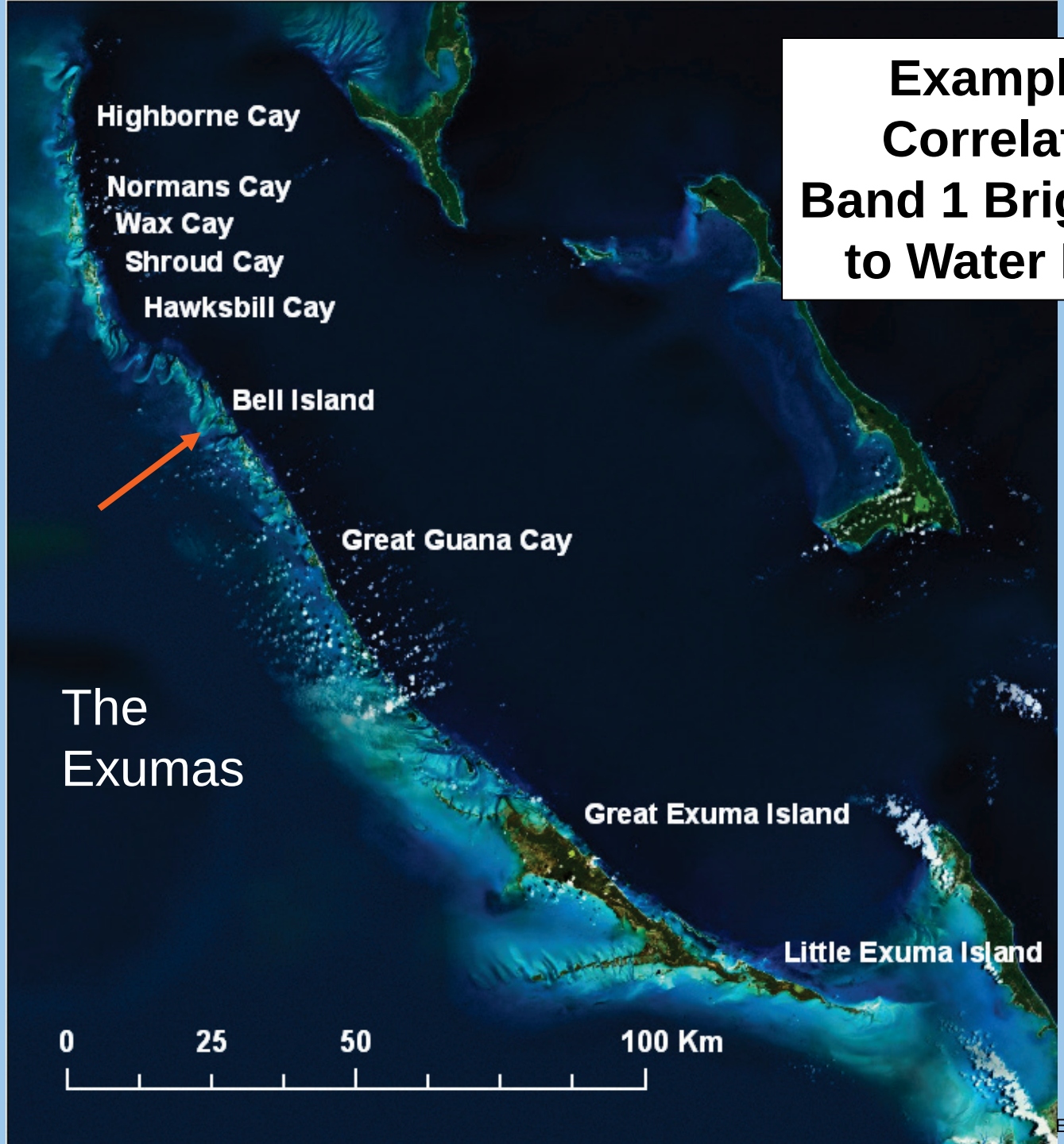
What can be done with multispectral images?



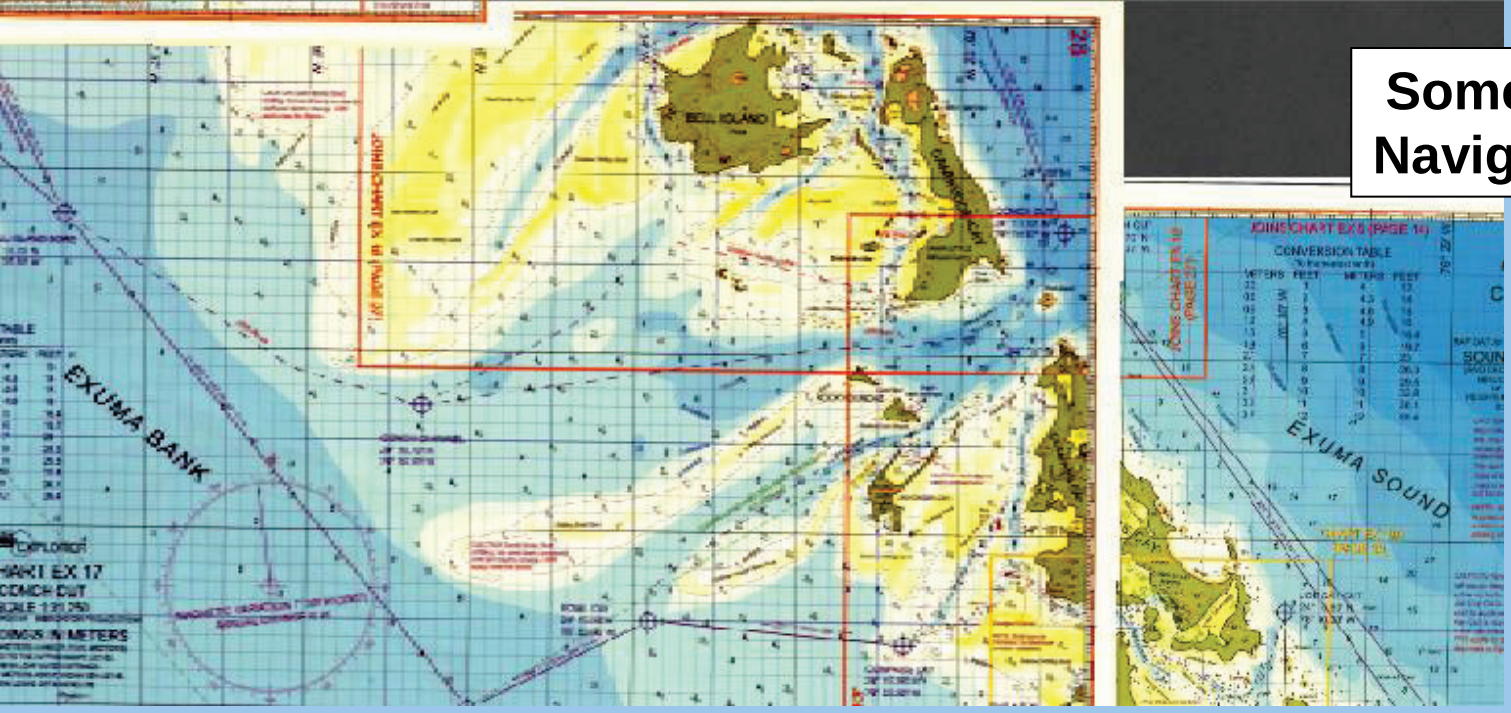
Navigation Chart


Landsat TM
Color Image
8 Feb 2000
76°50'0"W
76°40'0"W
76°30'0"W
76°20'0"W
25°10'0"N
25°0'0"N
24°50'0"N
0
5
10
20 Km

Example of Correlating Band 1 Brightness to Water Depth



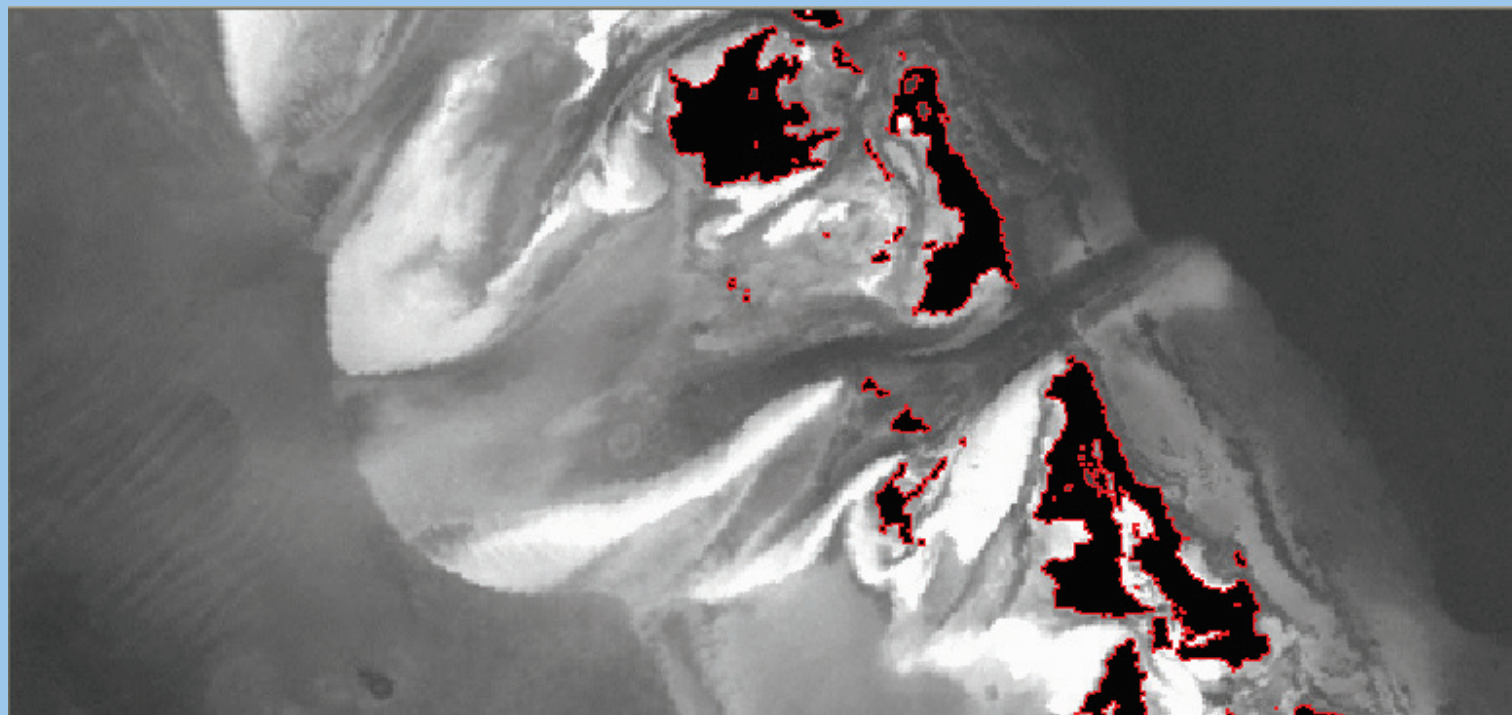
Some Areas had Navigation Charts



Navigation Chart with Soundings (1:32,000)

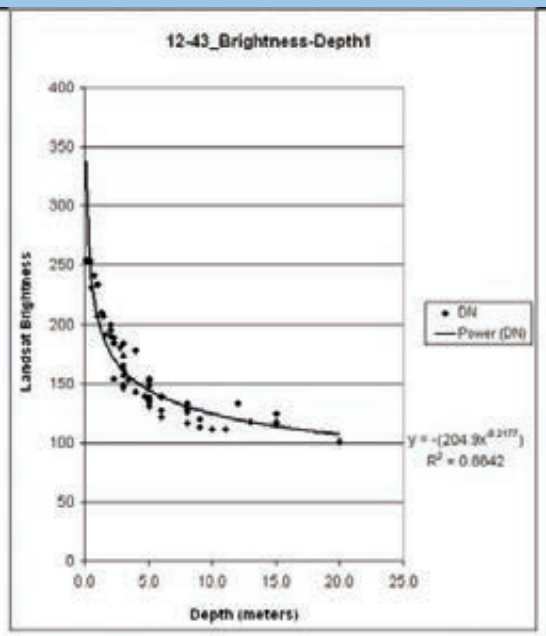
Landsat image of reflected blue light as a grayscale image

Islands masked black using Space Shuttle Radar Image

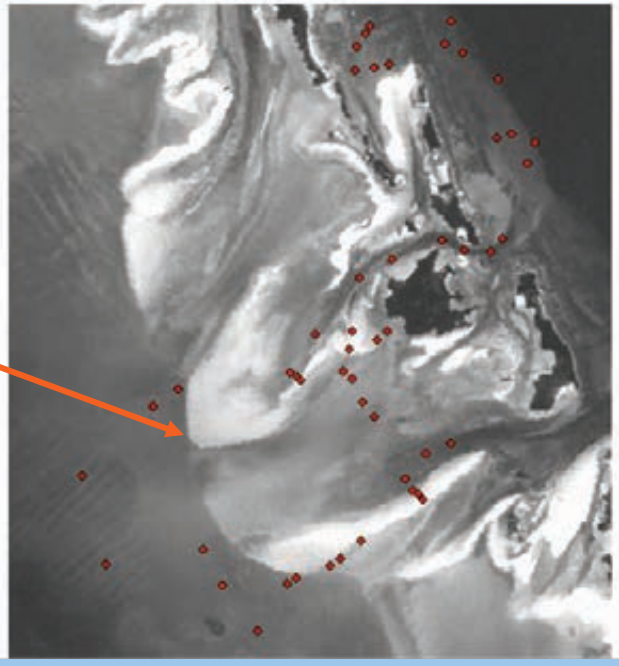


Using Imagery and Soundings to make an Offshore DEM

Navigation Chart with Soundings (1:32,000) ©Lewis Offshore Ltd



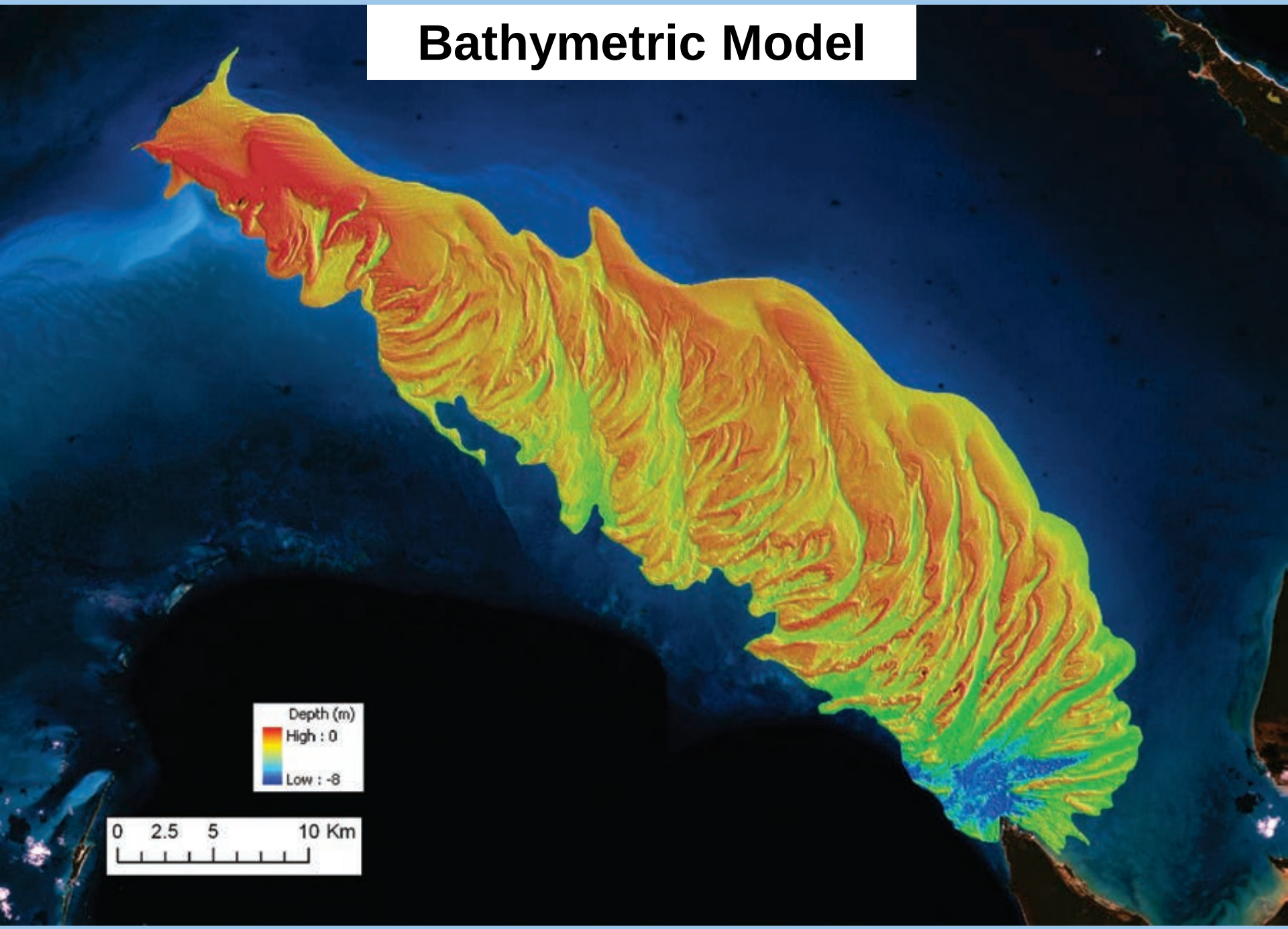
Depth	Brightness
0.1	254
0.2	254
0.4	252
0.4	254
0.5	231
0.7	242
1.0	207
1.0	233
1.0	234
1.3	210
1.4	209
1.5	207
1.6	192
2.0	195
2.0	190
2.0	200
2.3	154
2.3	184
2.3	188
2.8	180
3.0	184
3.0	165
3.0	157
3.0	162
3.0	149
3.0	173
3.0	146
3.4	153
4.0	178
4.0	143
4.7	139
4.8	138
5.0	152
5.0	130
5.0	138
5.0	134
5.0	136
5.0	148
5.0	154
5.0	138
6.0	122
6.0	138
6.0	139
6.0	127
8.0	133
8.0	126
8.0	116
8.0	129
9.0	113
9.0	120



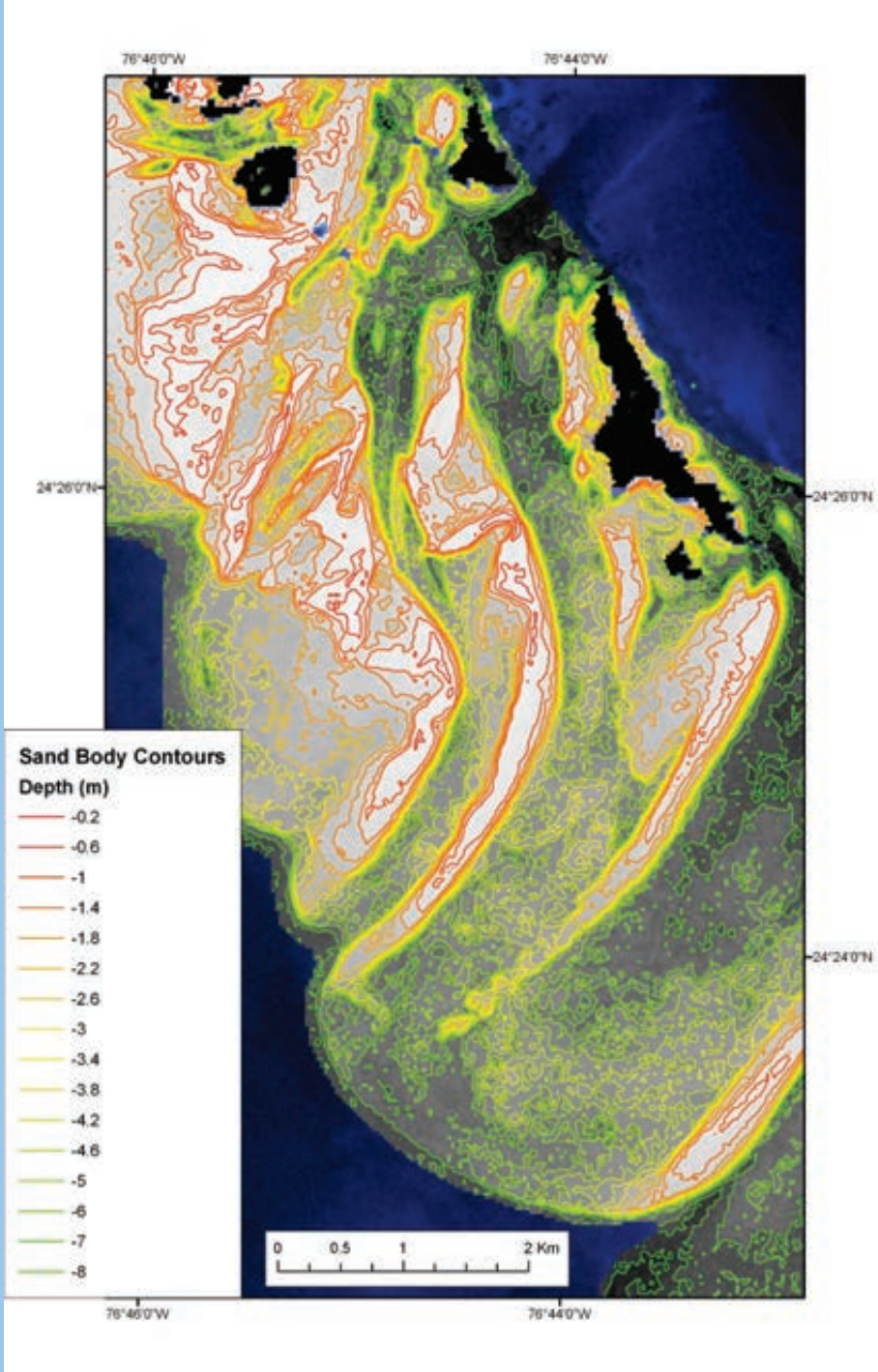
Landsat Band 1 (reflected blue light)

ENVI Band Math

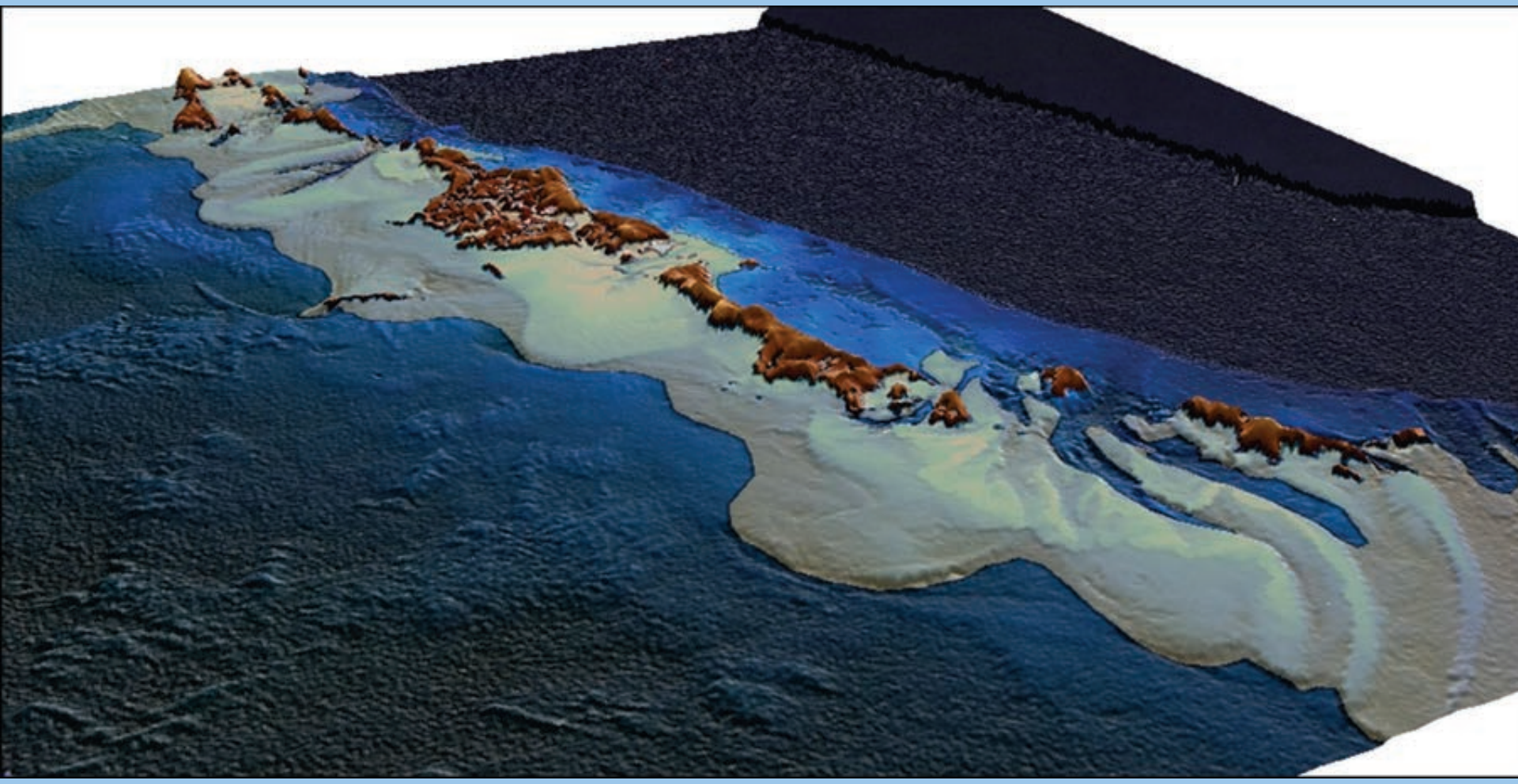
Bathymetric Model

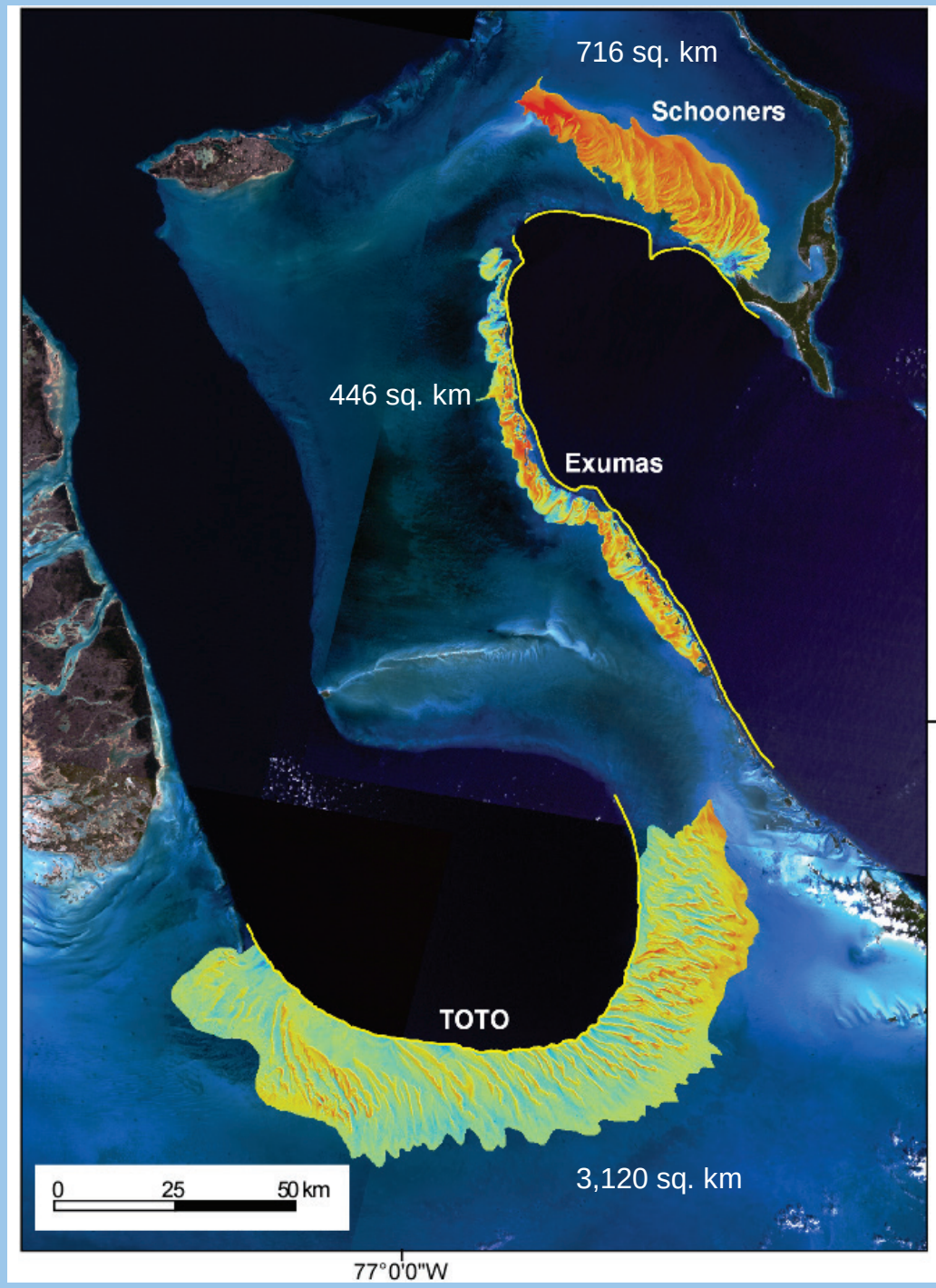


Bathymetric Contours (Selected Contours from 0.2 meter interval)



DEMs Enable Perspective Views - Visualization

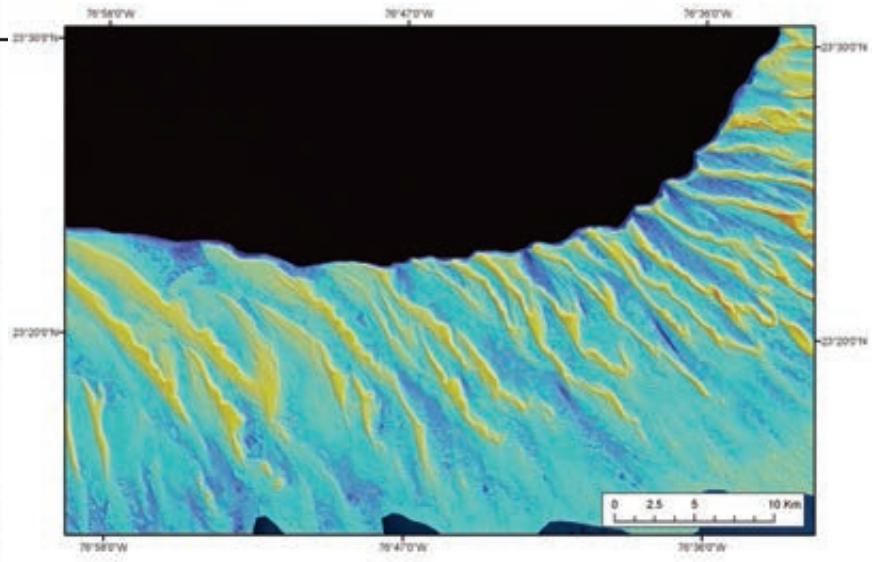




Sand Bars

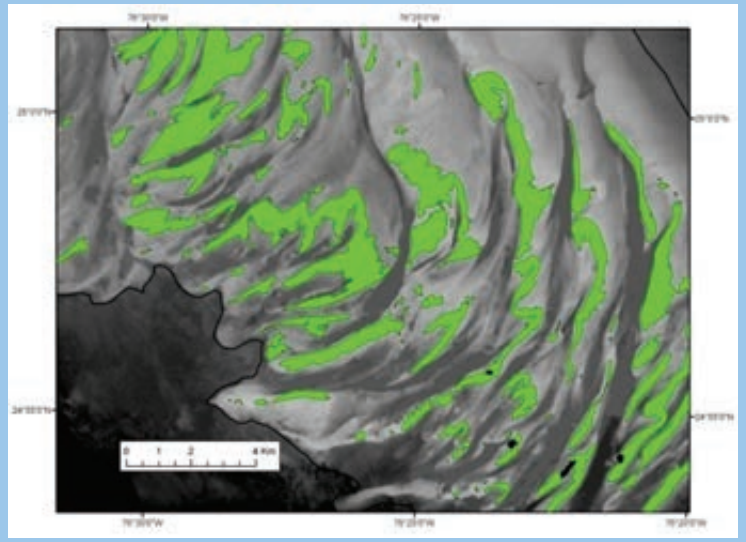
3 sites
4,282 sq. km

1,175 GIS polygons partitioned to: Sandbars (547) and Bar-crests (628)

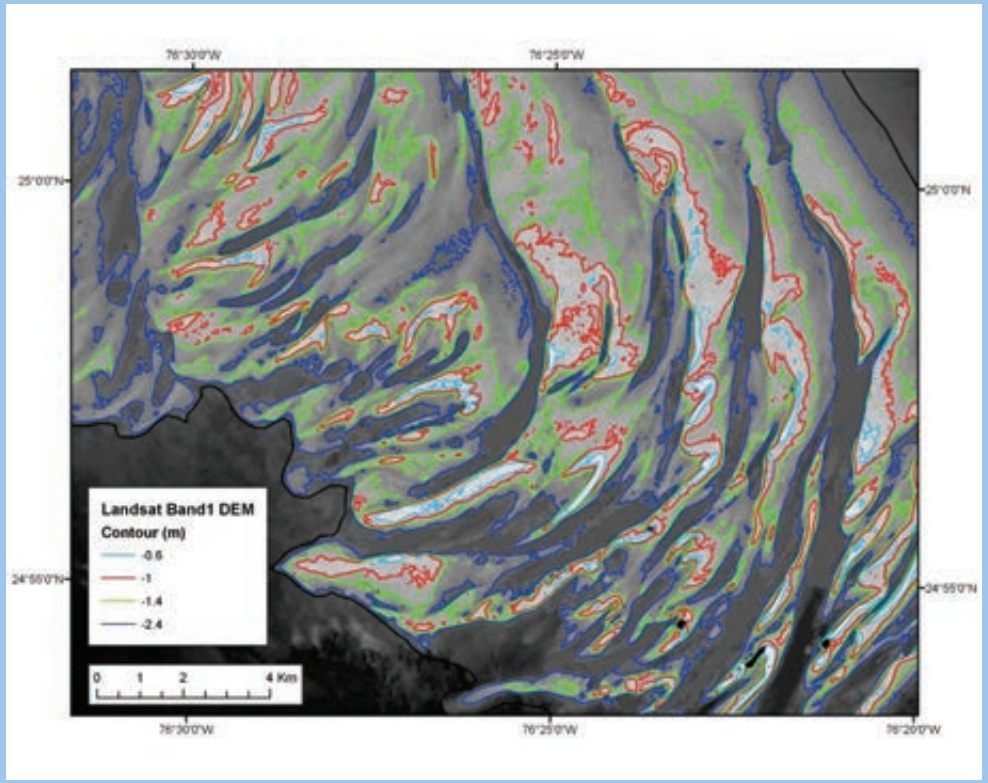


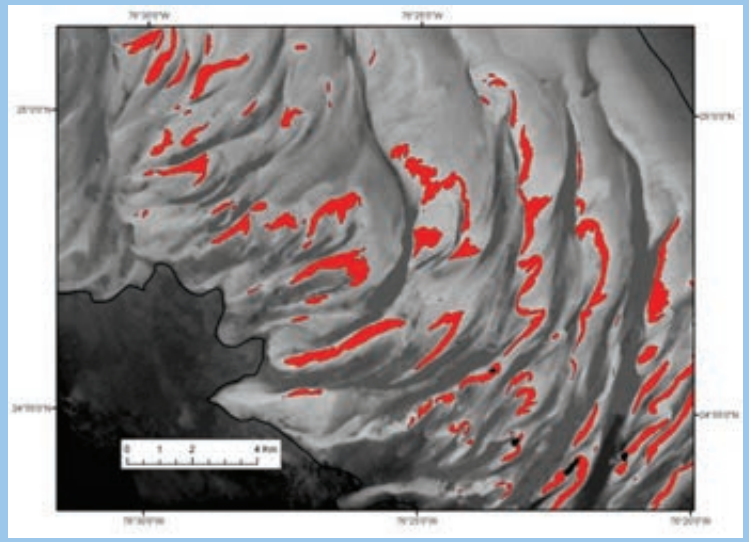
Sandbars and Bar Crests

Sandbars

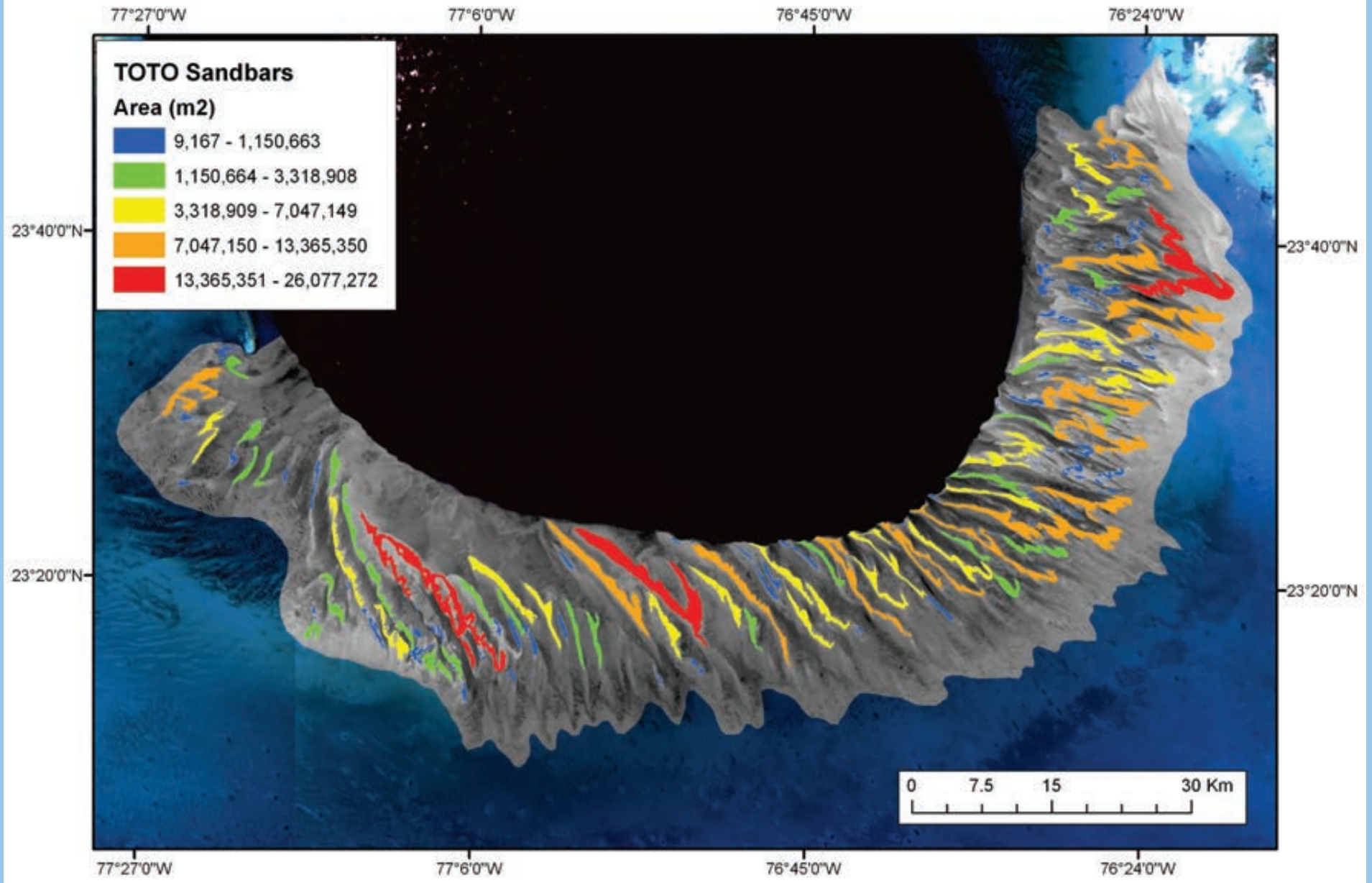


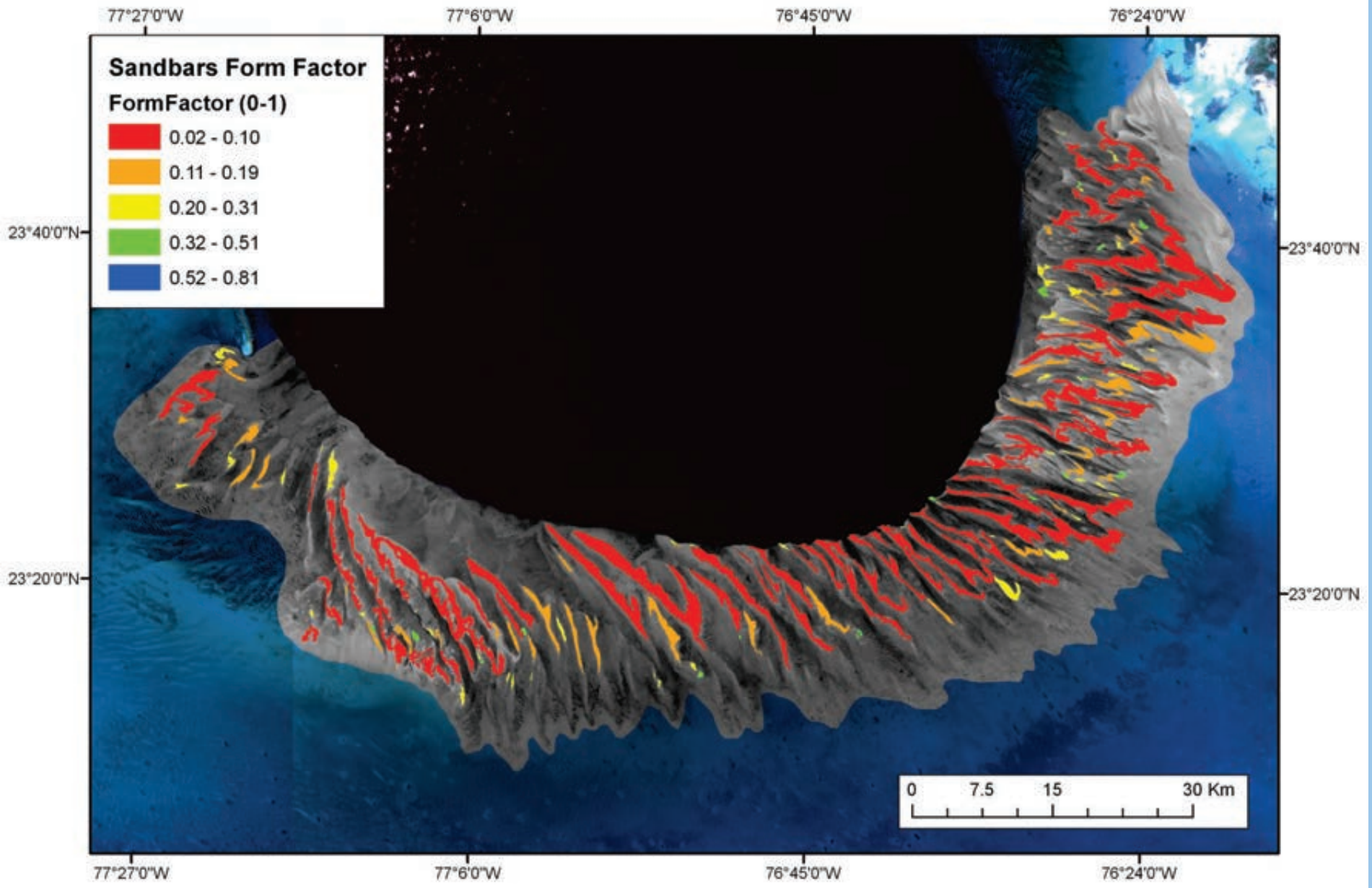
Select Contours of DEM



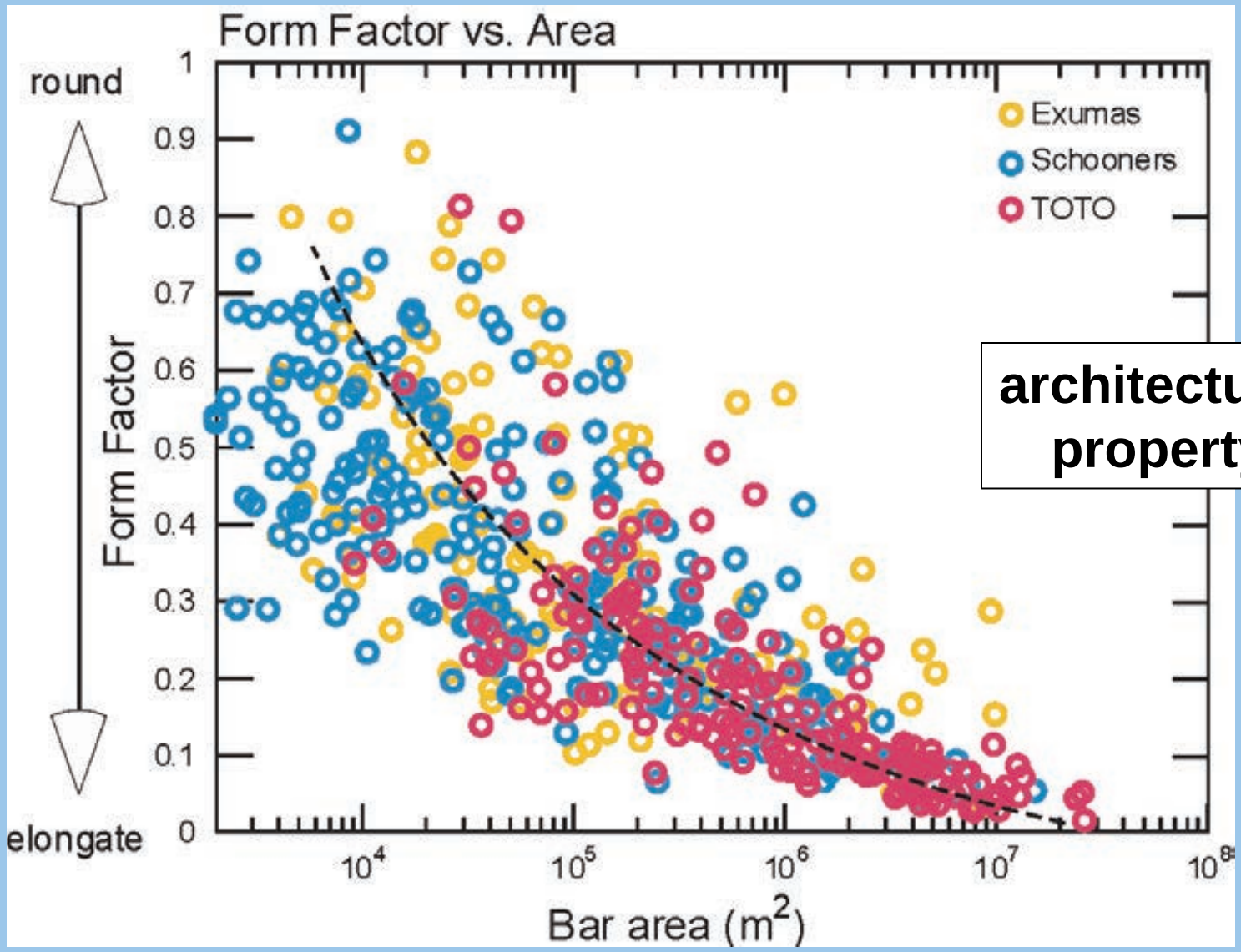


Bar Crests


77°27'0"W
77°6'0"W
76°45'0"W
76°24'0"W
TOTO Sandbars
Area (m2)
9,167 - 1,150,663
1,150,664 - 3,318,908
3,318,909 - 7,047,149
7,047,150 - 13,365,350
13,365,351 - 26,077,272
23°40'0"N
23°20'0"N
0
7.5
15
30 Km


77°27'0"W
77°6'0"W
76°45'0"W
76°24'0"W
Sandbars Form Factor
FormFactor (0-1)
0.02 - 0.10
0.11 - 0.19
0.20 - 0.31
0.32 - 0.51
0.52 - 0.81
23°40'0"N
23°20'0"N
0
7.5
15
30 Km

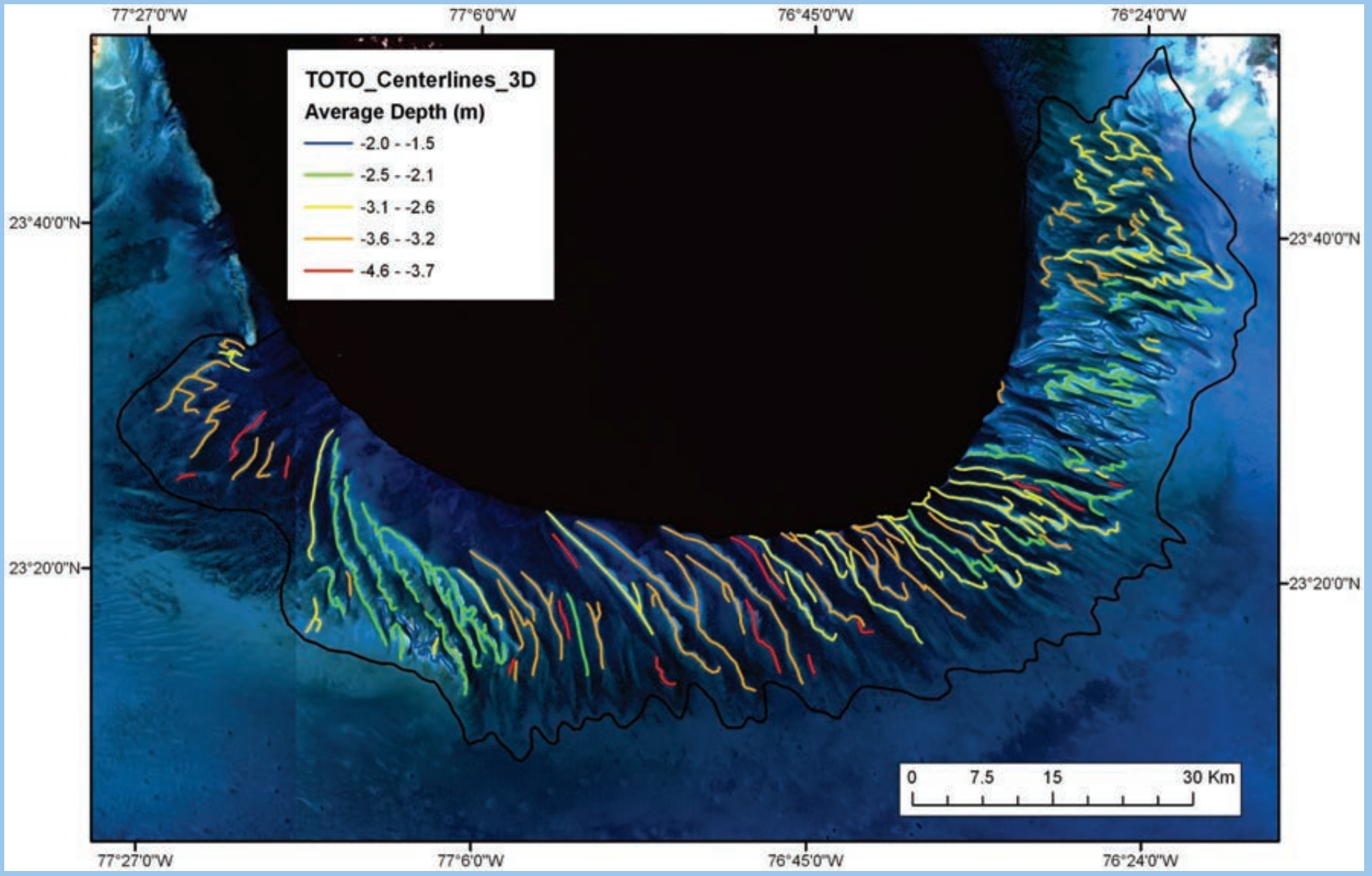
Form Factor – Sand Bar Area Distribution

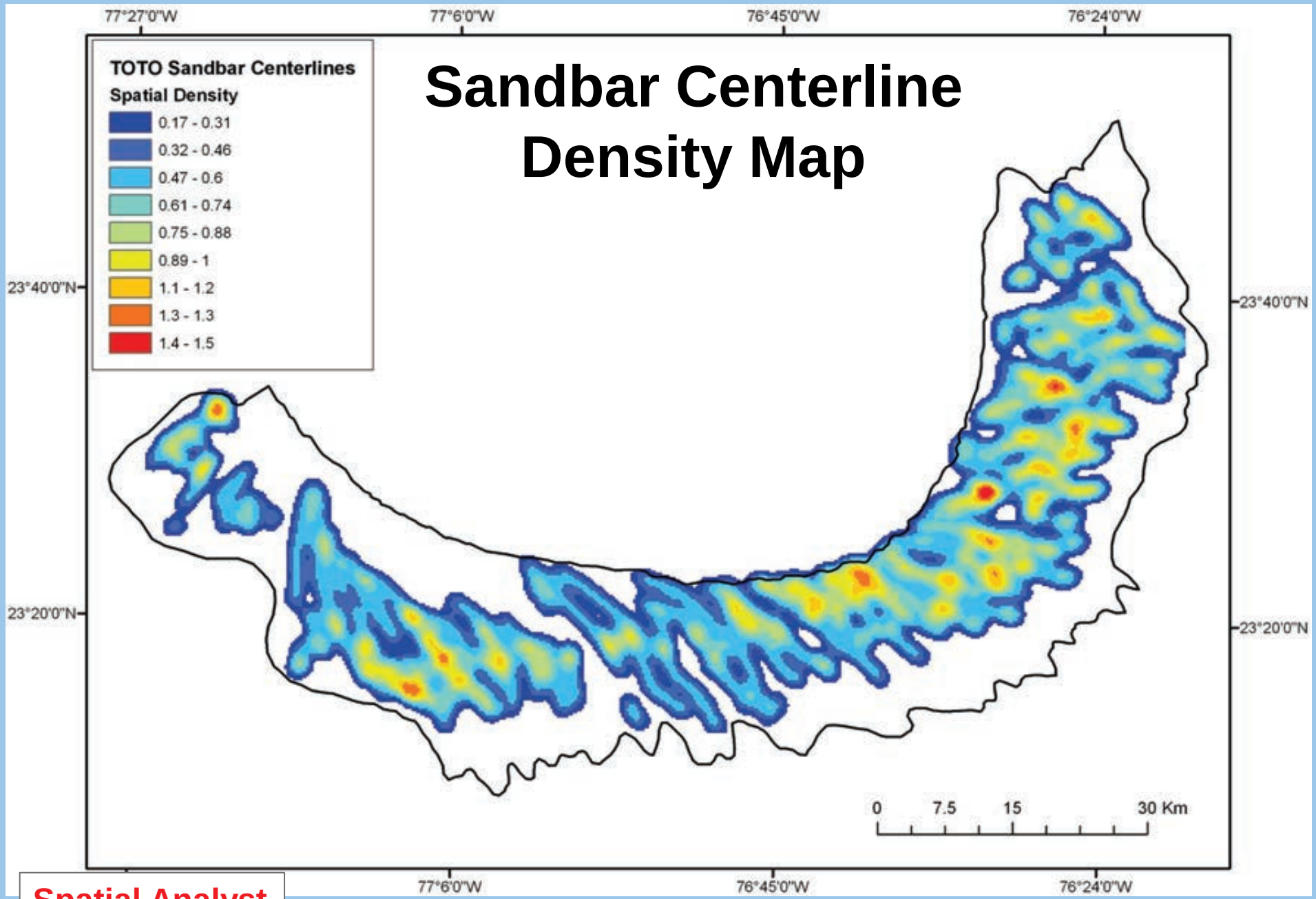


architectural property

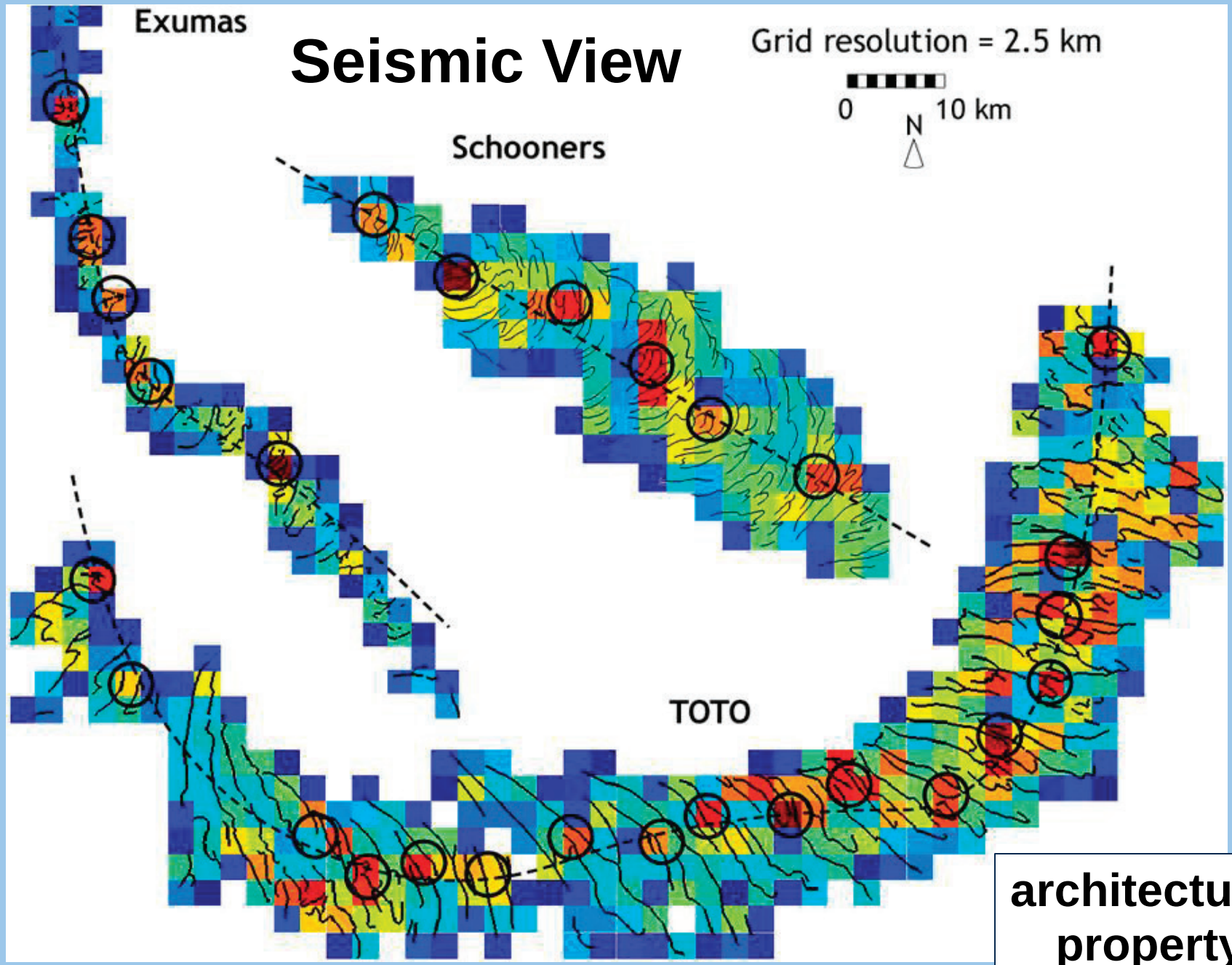
ArcMap ⟷ MatLab

Sandbar Centerline Density Map



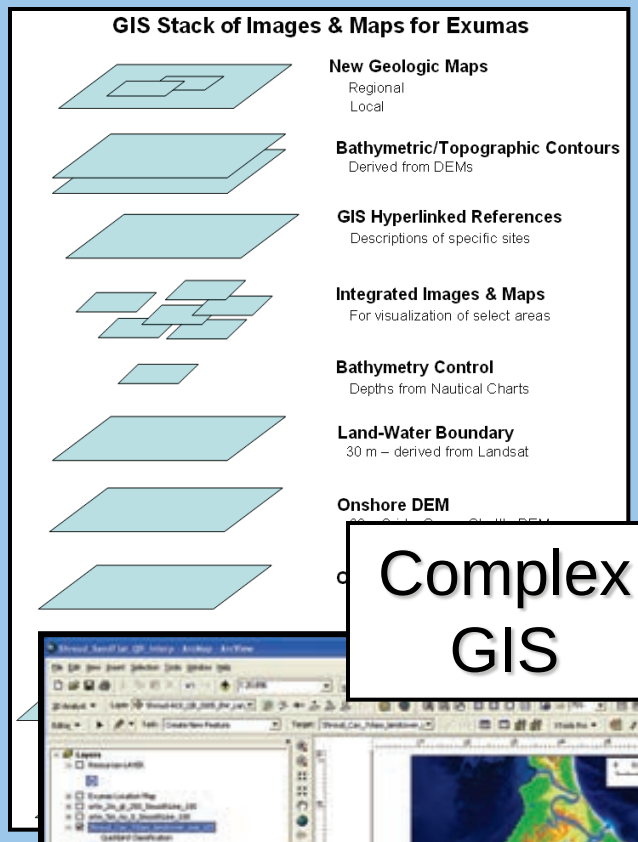


Spatial Analyst



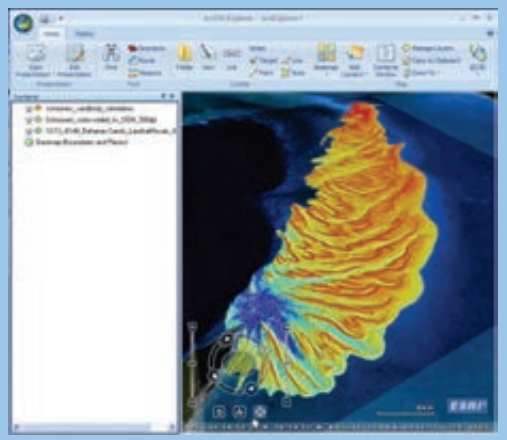
architectural property

Information Distribution

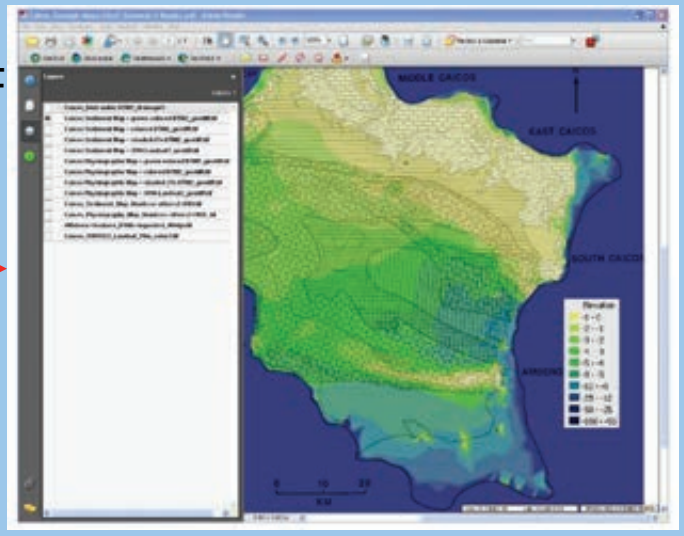


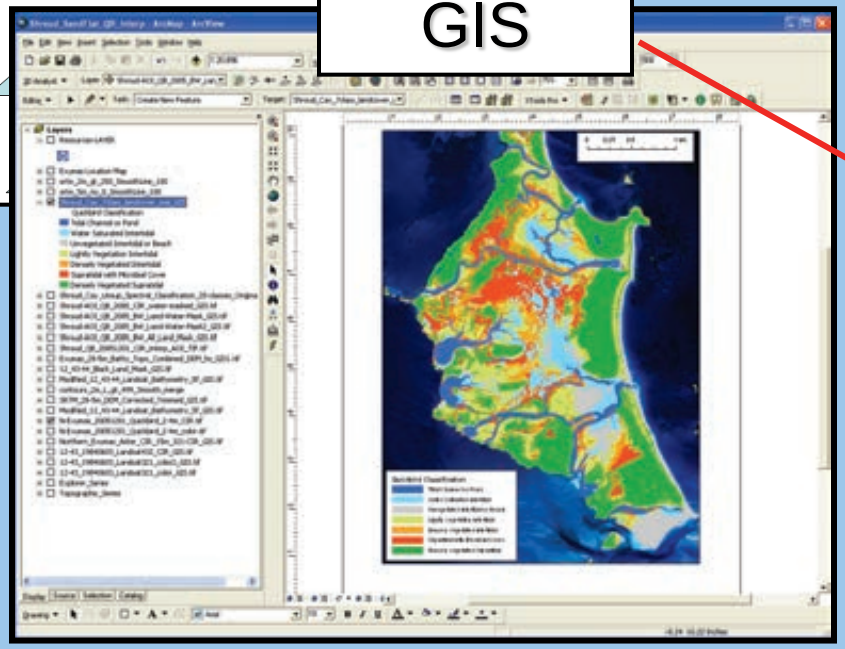
Complex GIS

ArcGIS Explorer & Online

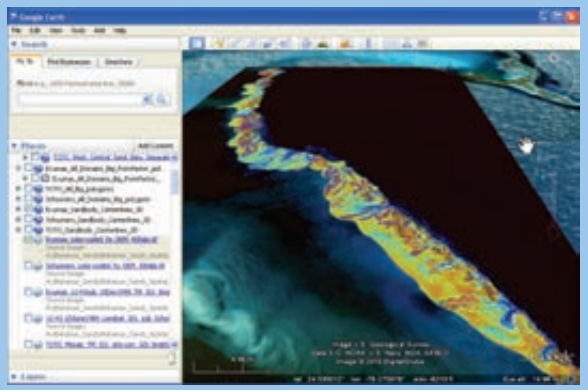


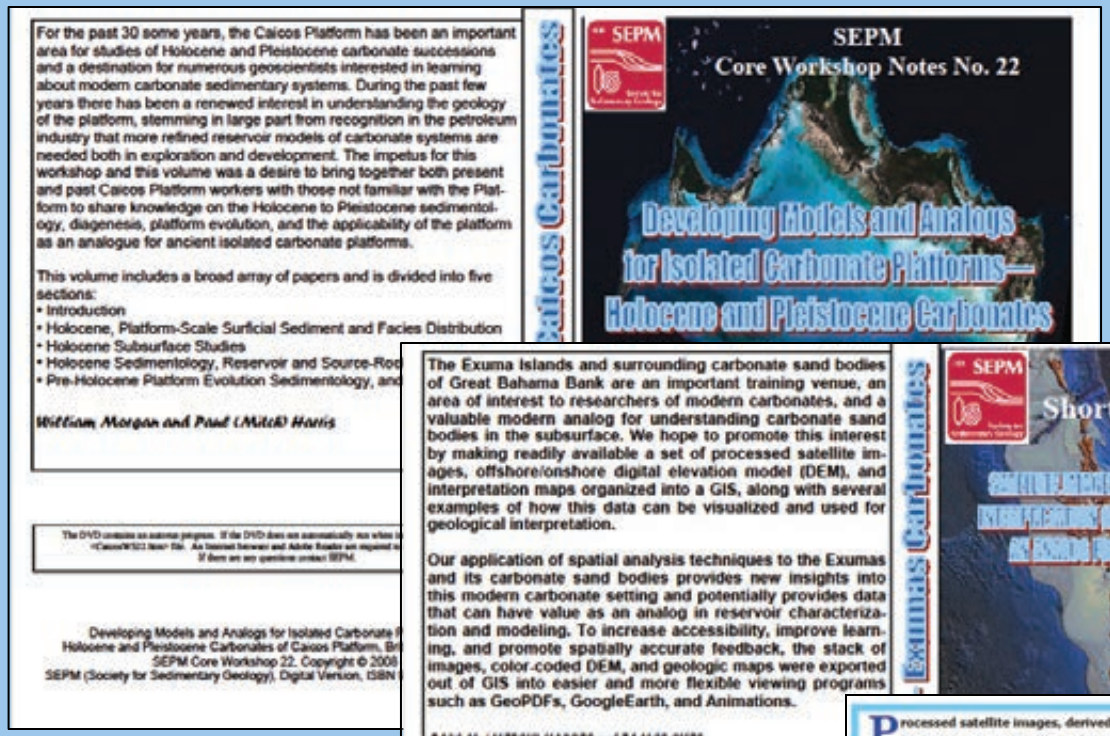
GeoPDF

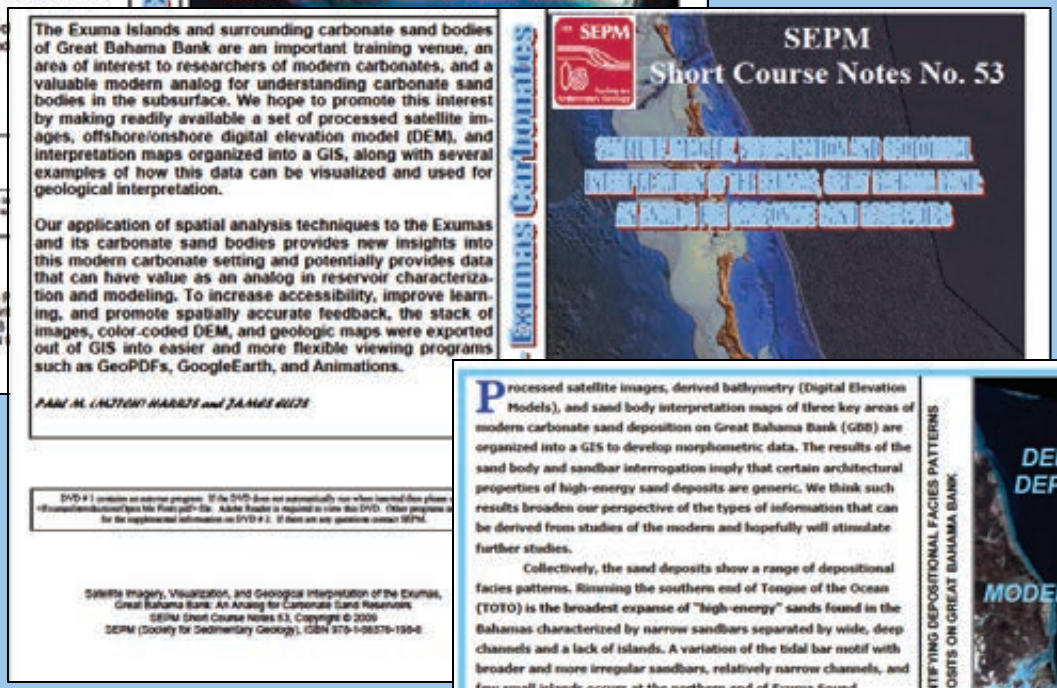


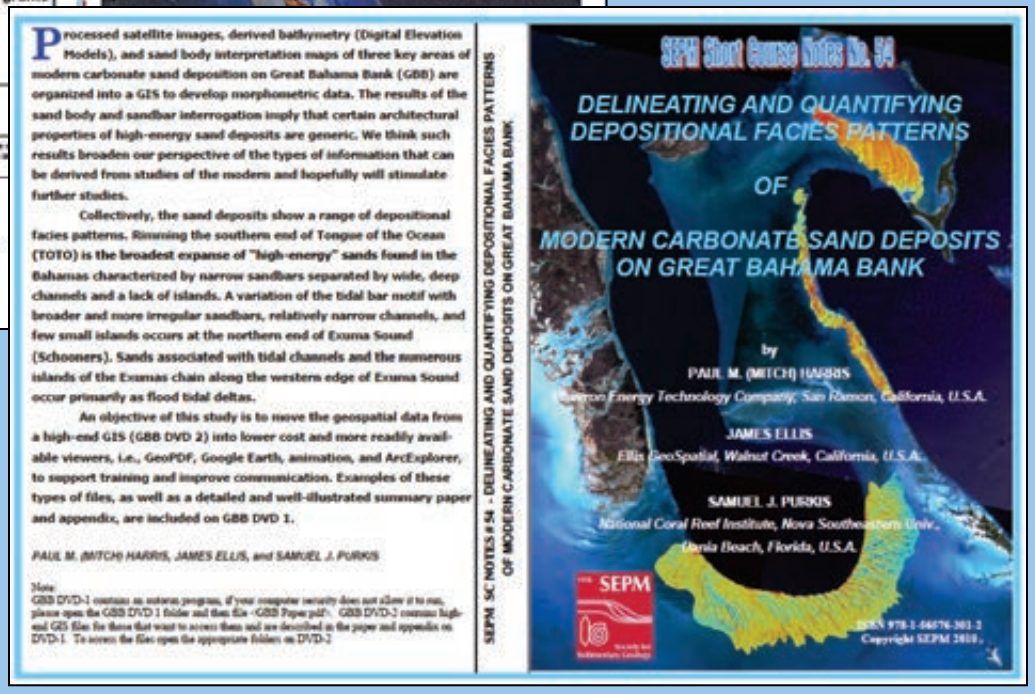


.kmz's for GoogleEarth









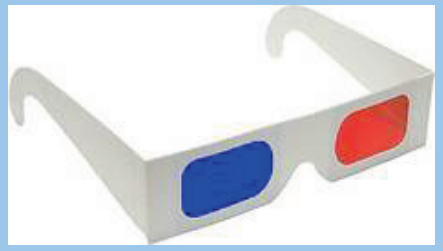
SEPM 2-DVD Sets with Entire GIS Database, GeoPDFs, kmz, ArcGIS Explorer, Animations, & Research Paper

$34 each

2-Day Workshops at 2011 & 2012 AAPG National Conferences

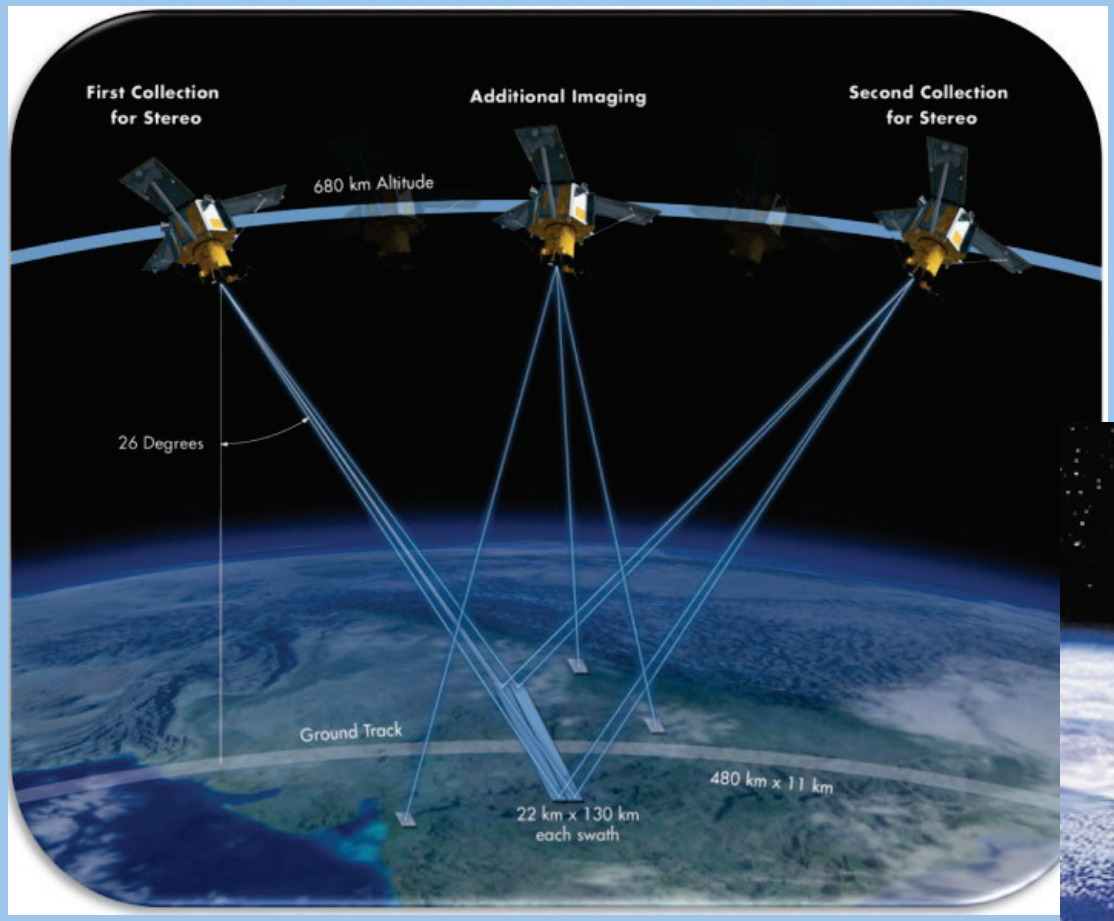
Examples available via DropBox

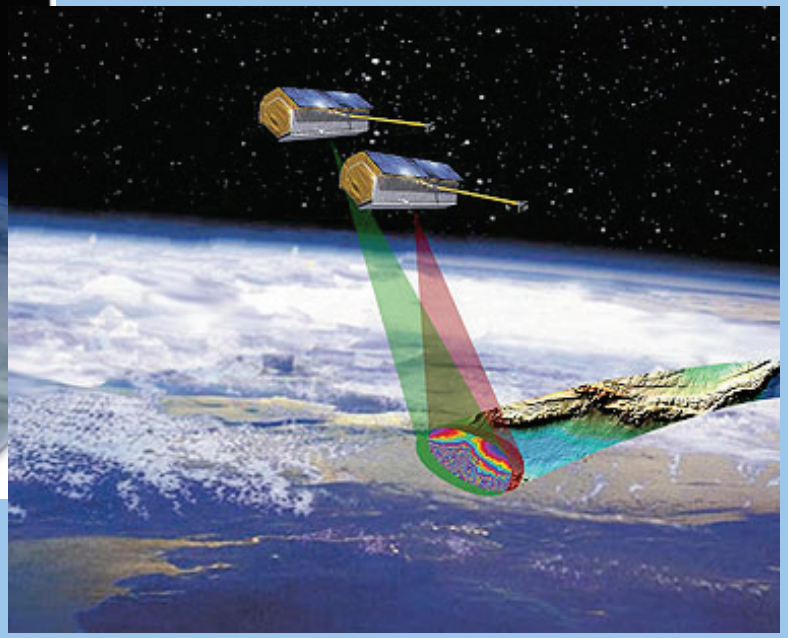
Digital Elevation Models
DEMs



Acquiring Images with Off-Nadir and Fore & Aft Viewing

Enables stereoscopic 3D viewing & building surface elevation models

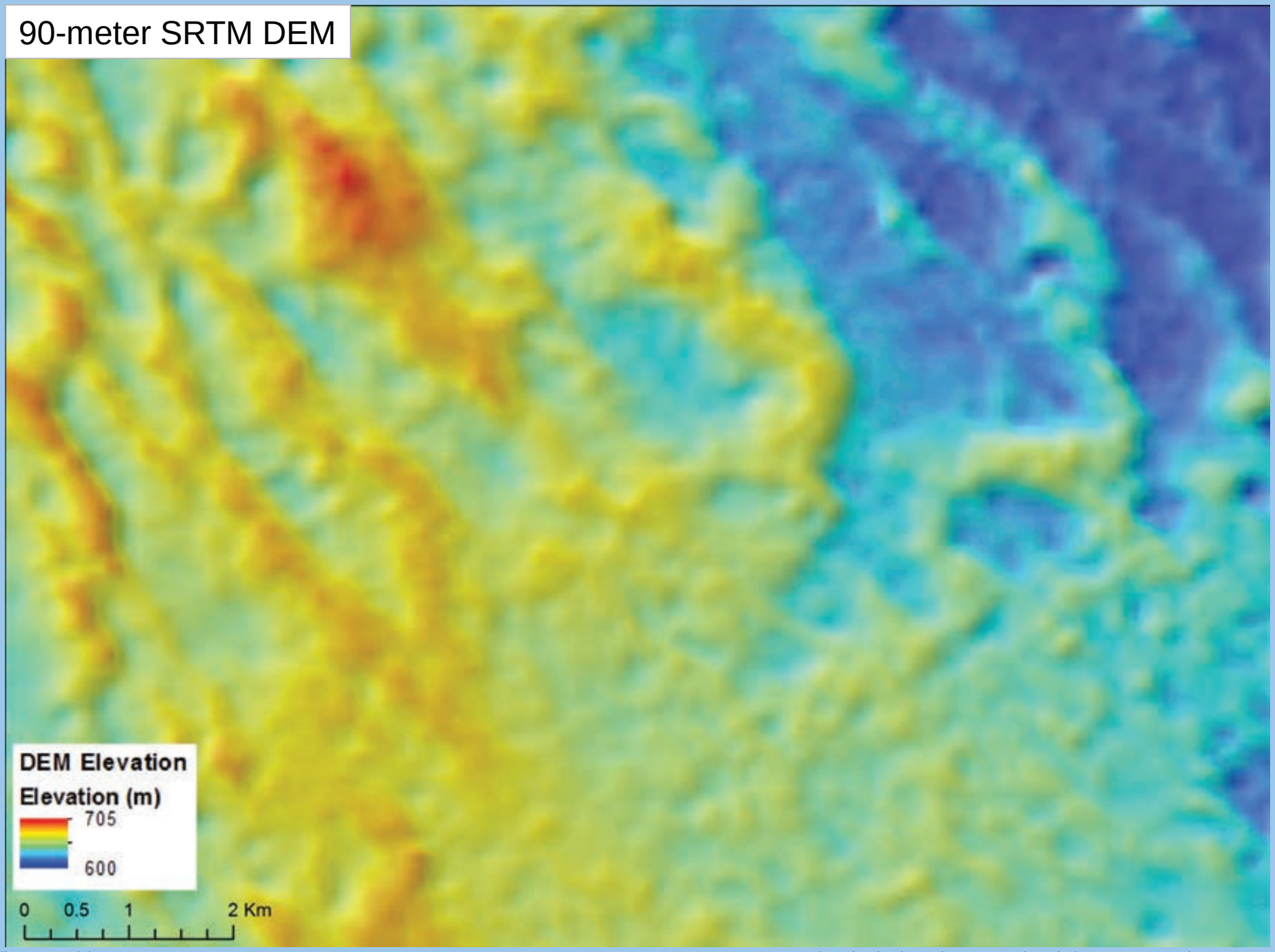




Source: DLR http://www.dlr.de/en/desktopdefault.aspx/tabid-1/86_read-4553/

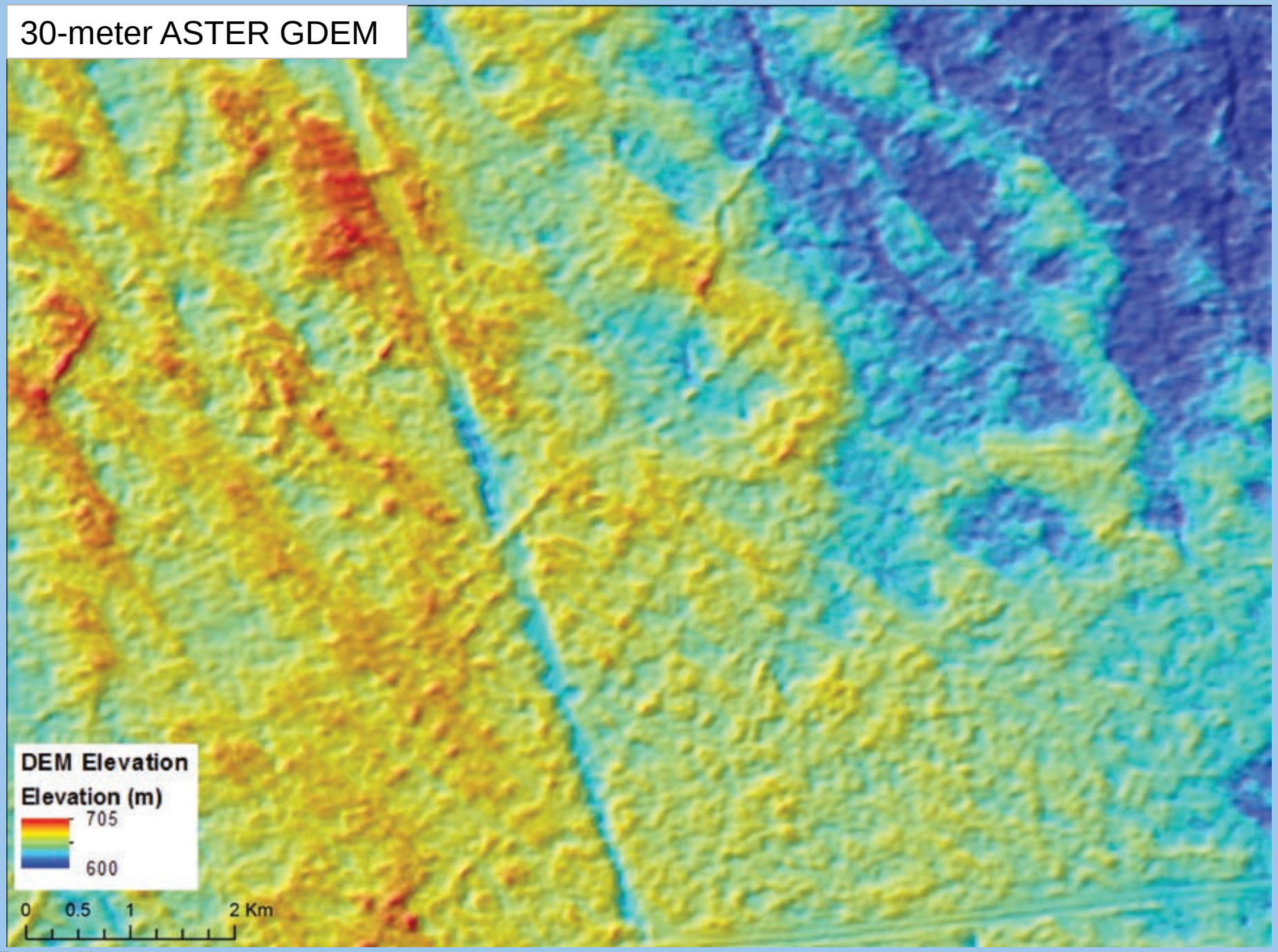
Satellite Image

90-meter SRTM DEM

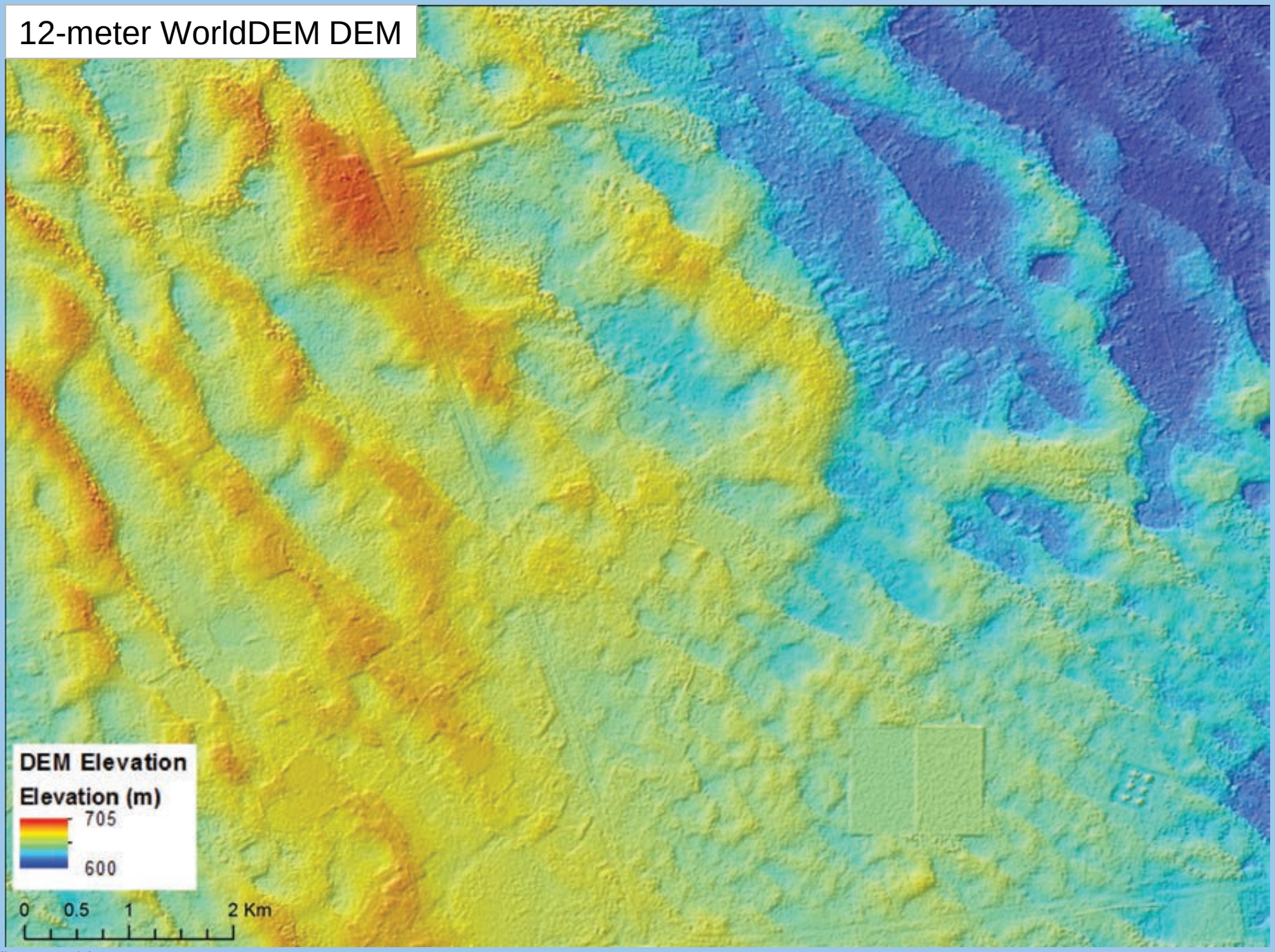


USGS (2004), Shuttle Radar Topography Mission, 1 Arc Second scene SRTM

30-meter ASTER GDEM



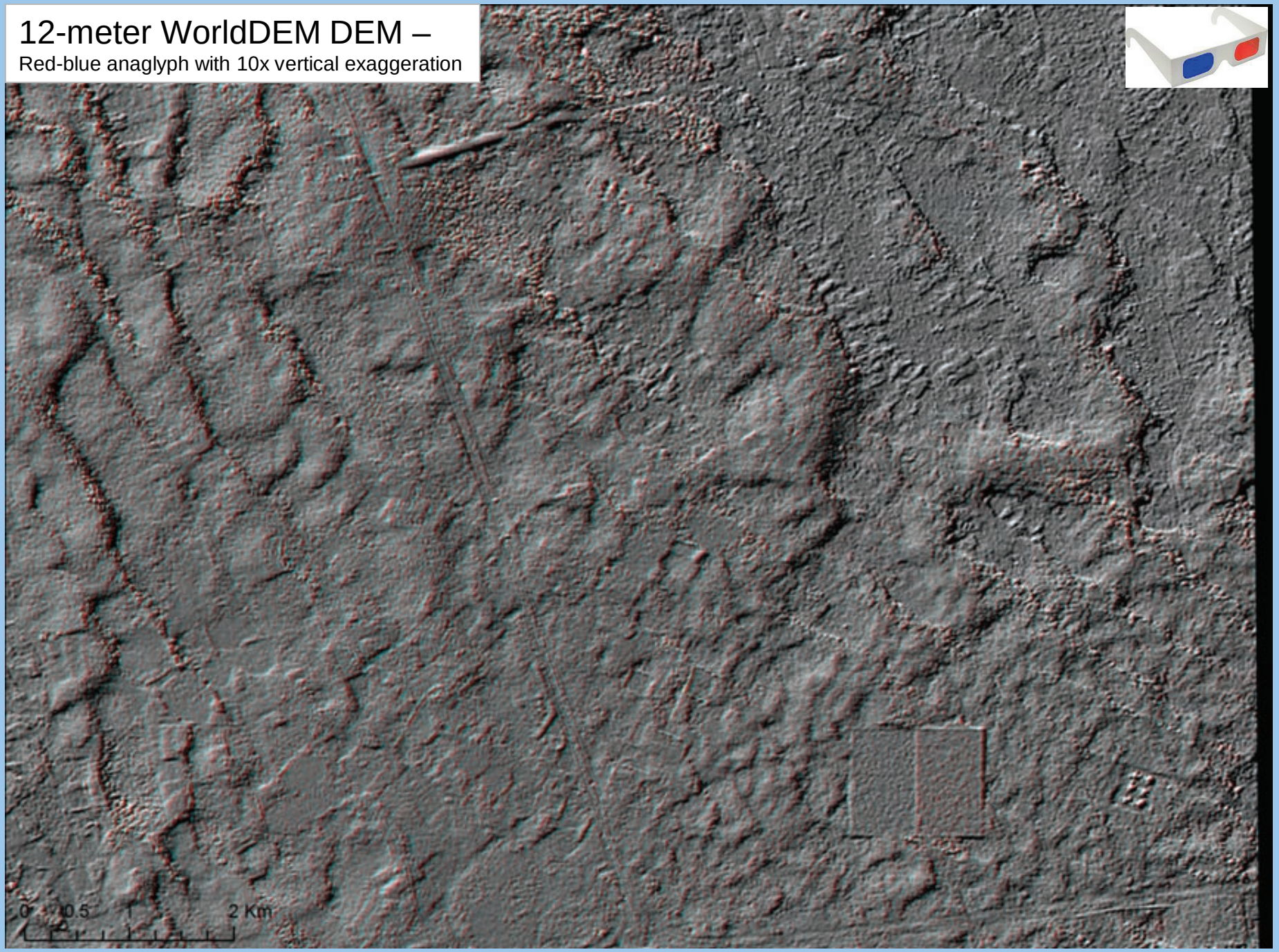
12-meter WorldDEM DEM



Source: http://www.astrium-geo.com/na/5455-experience-the-quality-and-accuracy-of-the-worlddem.php#buraydah

12-meter WorldDEM DEM –

Red-blue anaglyph with 10x vertical exaggeration



Source: http://www.astrium-geo.com/na/5455-experience-the-quality-and-accuracy-of-the-worlddem.php#buraydah

ENVIRONMENTAL

MAPPING LAND COVER Using Multispectral Satellite Data

Satellite: Landsat, ASTER, SPOT, RapidEYE
IKONOS, Quickbird,WorldView-2, GeoEYE, Pleiades,

Airborne: UltraCAM, Leica ADS, Z/I DMC, ADSI

Building a Land Use/Land Cover (LULC) Map from Imagery

Scope → Acquire → Produce → Implement → Validate → Manage

Consult With Area Experts

Acquire Image & DEM Data

Establish LULC Classes

Process Image & DEM

Document Training Sites

Map LULC Classes

Verification Sites

Accuracy Assessment

Add Metadata

Add Images, Maps, Accuracy Assessment to GIS Database

Summary Report

Spatial Analysis

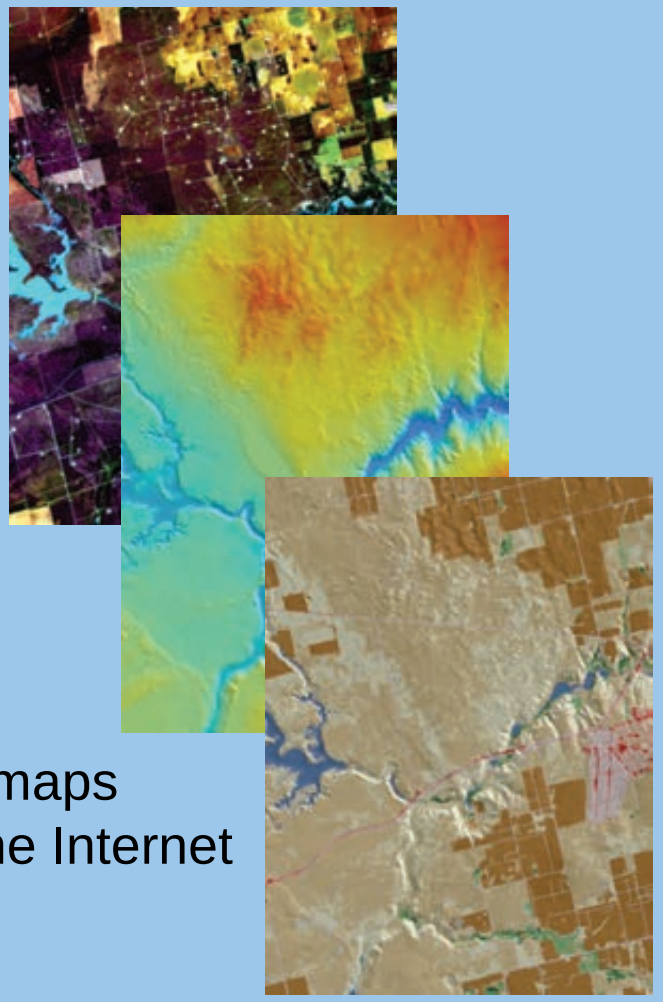
Visualization

GIS Stack of Images & Maps

Building Knowledge of Company Footprints

Oil and mining companies with land acreage can use remote sensing to most efficiently:

- develop environmental metrics,
- establish an environmental baseline,
- monitor/model change through time
- demonstrate environmental stewardship



The work process can include:

- satellite & airborne images
- digital elevation models (DEMs)
- leveraging existing maps & SME knowledge
- building up-to-date, fit-for-purpose land cover maps
- serving up the imagery, DEMs, & maps over the Internet
- coordination with engineering & exploration

ENVIRONMENTAL

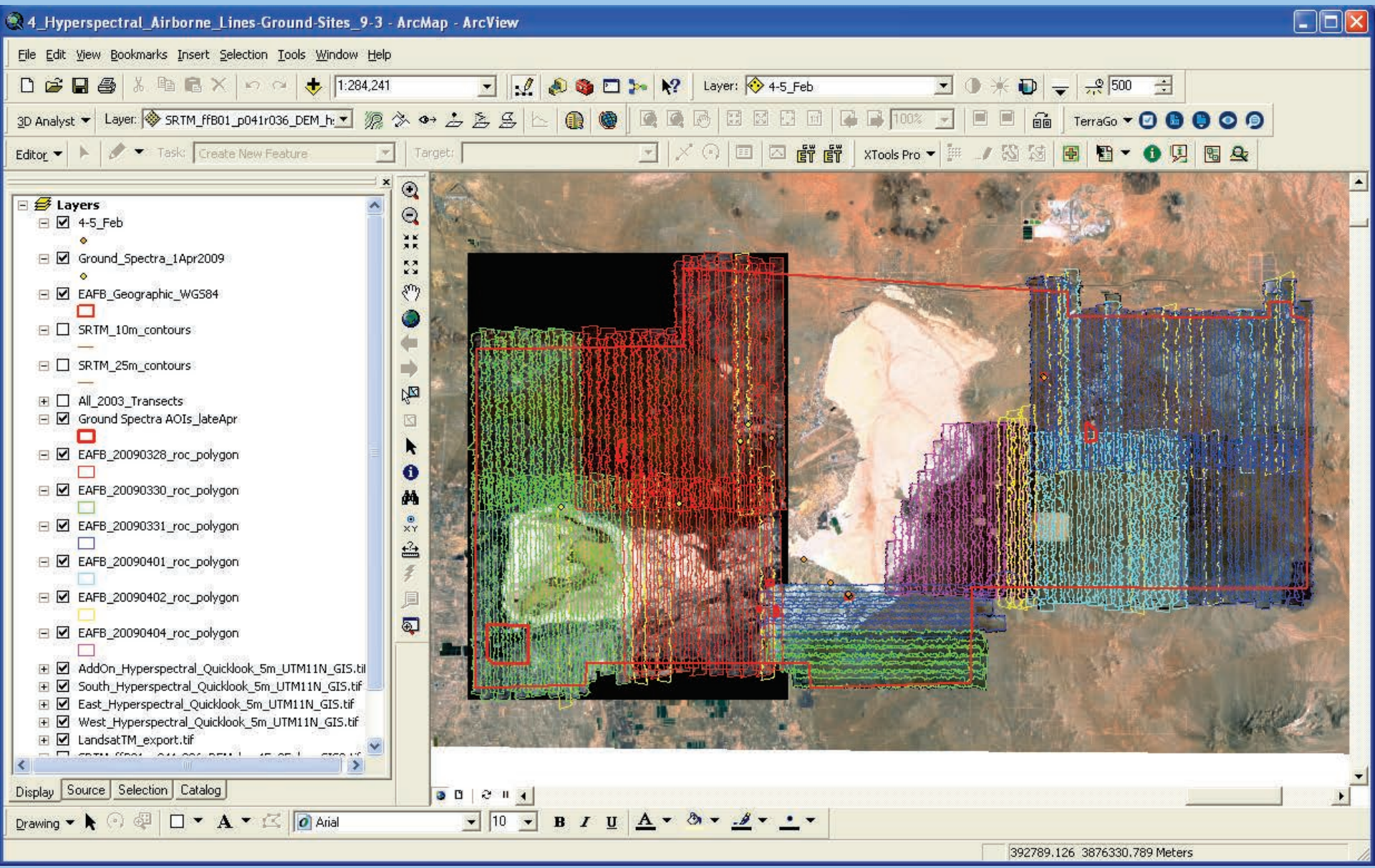
MAPPING LAND COVER Using Hyperspectral Airborne Data

Edwards Air Force Base

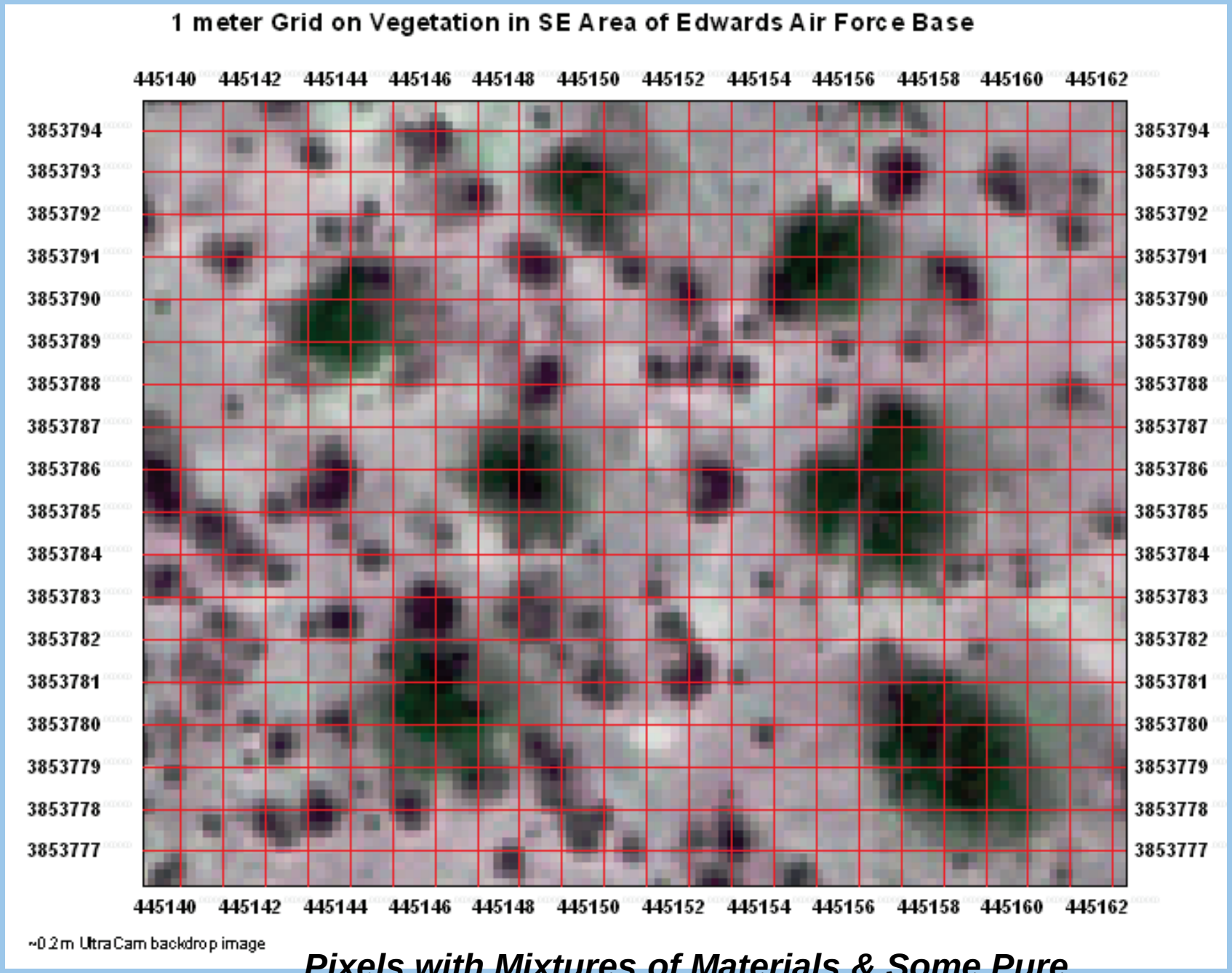
1-meter pixels
Visible – Near-Infrared (VNIR) Wavelengths

EAFB EM, Tetra Tech, Galileo, Ellis GeoSpatial

Airborne Hyperspectral Flight Lines in GIS



EAFB EM, Tetra Tech, Galileo, Ellis GeoSpatial

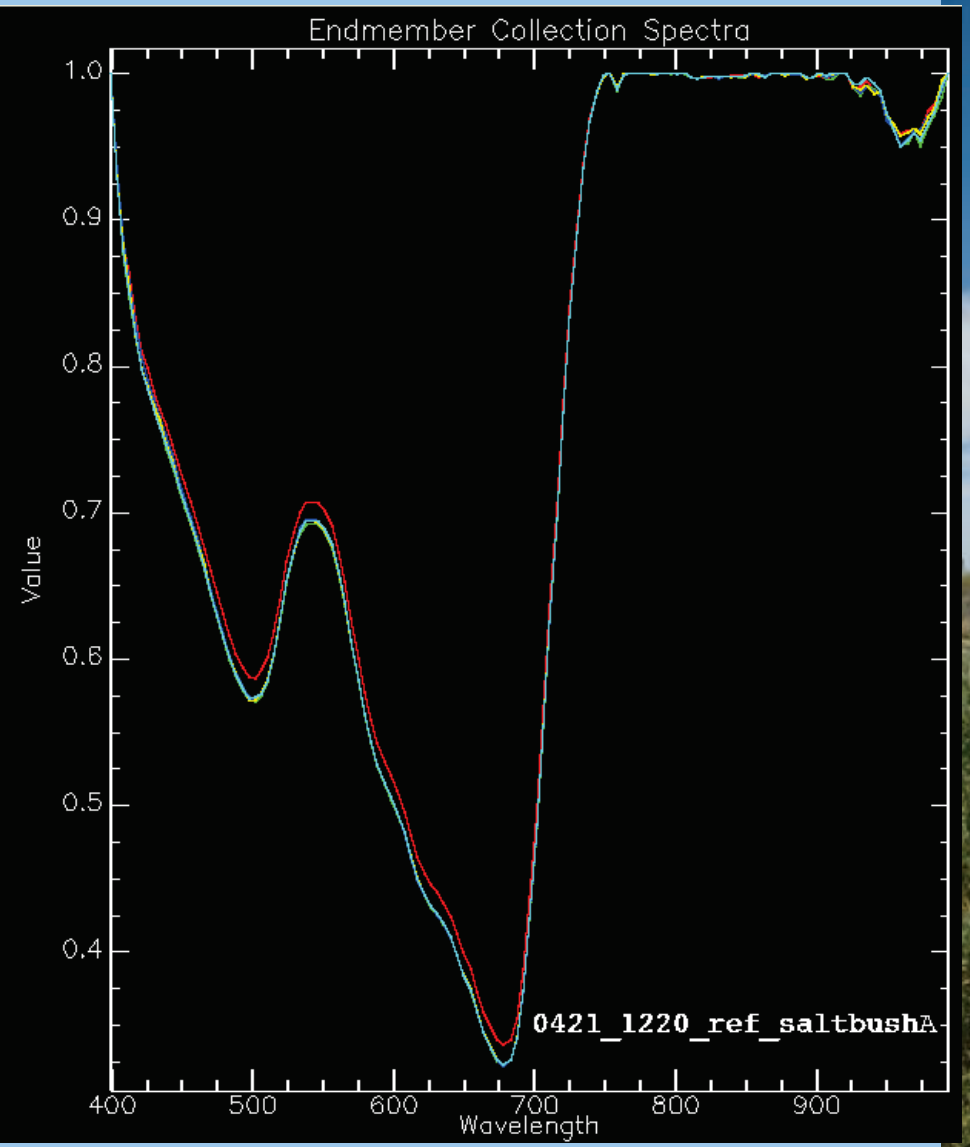


Pixels with Mixtures of Materials & Some Pure

Calibrating Ground Spectrometer

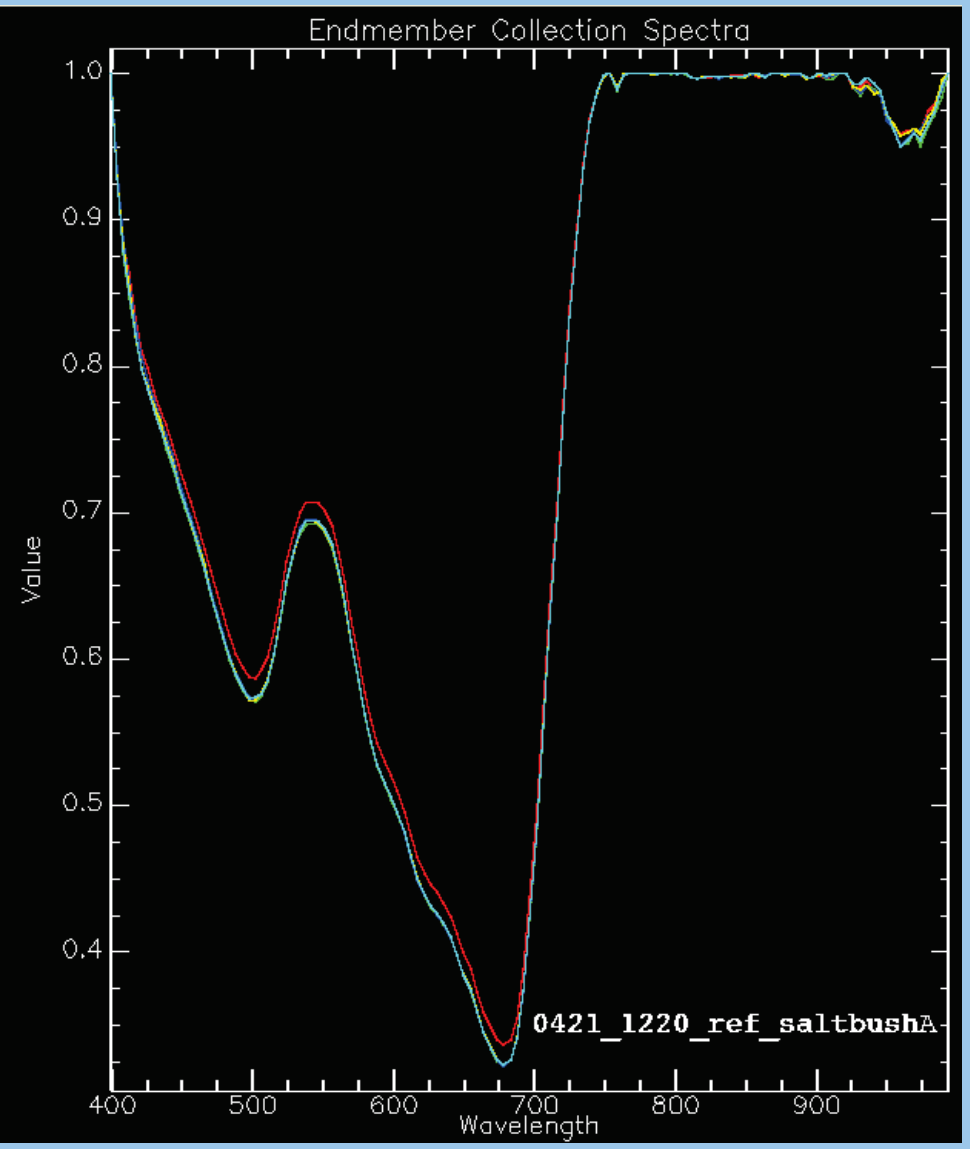
VNIR Sensor

Ground Spectra for Saltbush

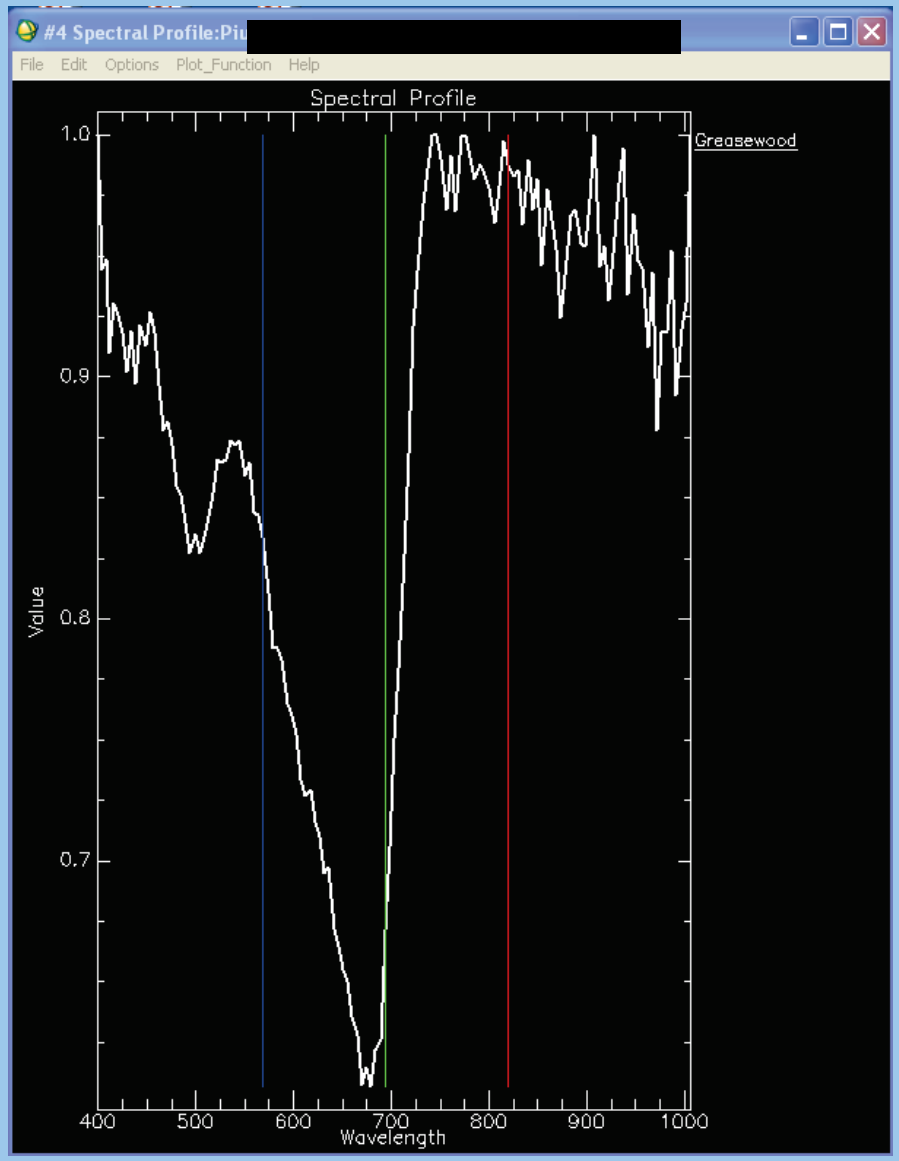


EAFB EM, Tetra Tech, Galileo, Ellis GeoSpatial

Ground Spectra for Saltbush



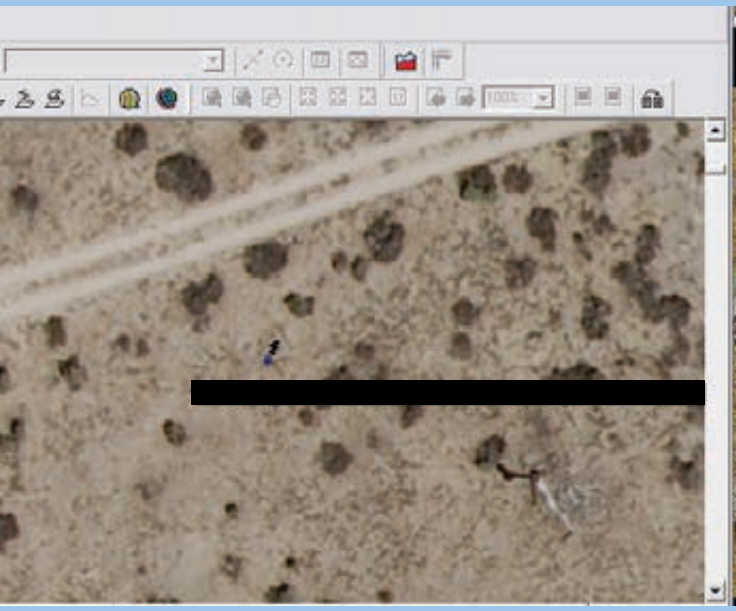
Airborne Spectra for Saltbush

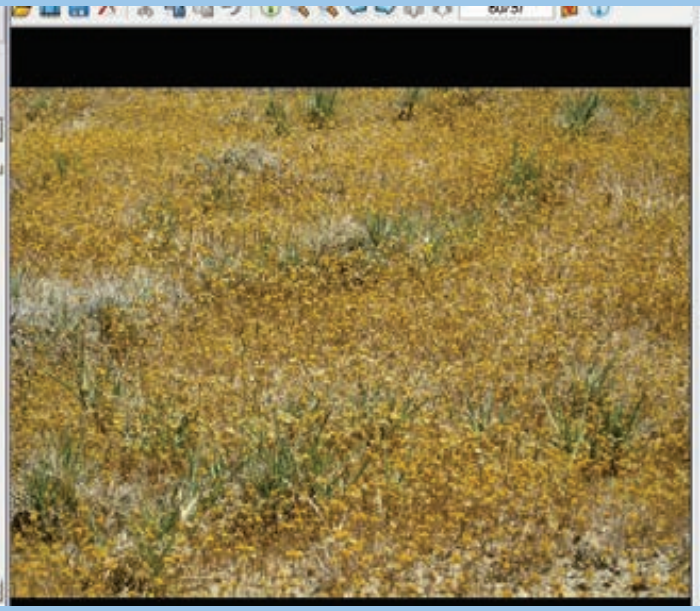


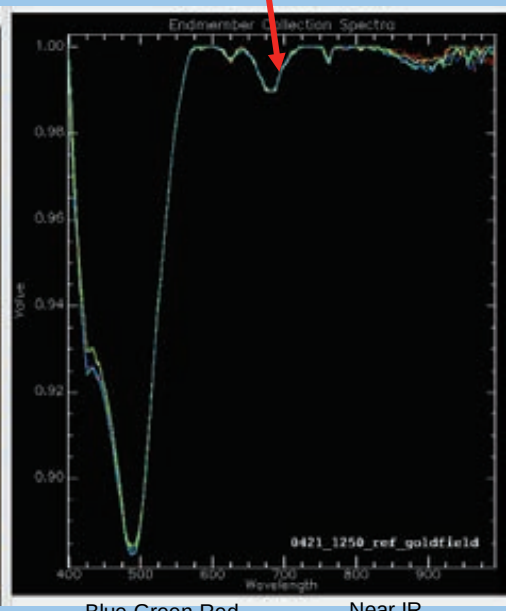
VNIR Sensor

Gold Fields

Sampling site, ground photo, and ground spectra in GIS







UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

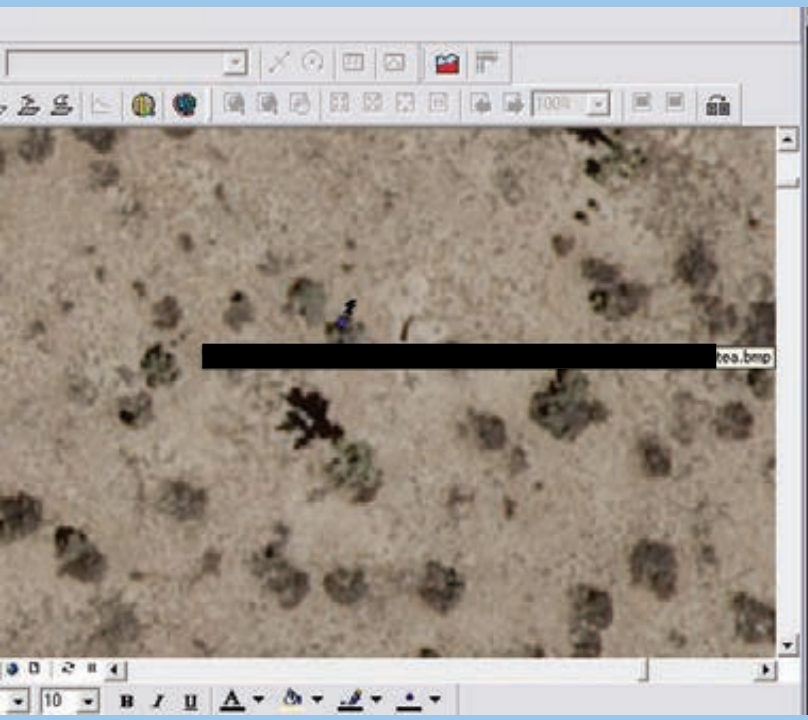
Field photograph of feature where Visible-Near IR spectral signature collected

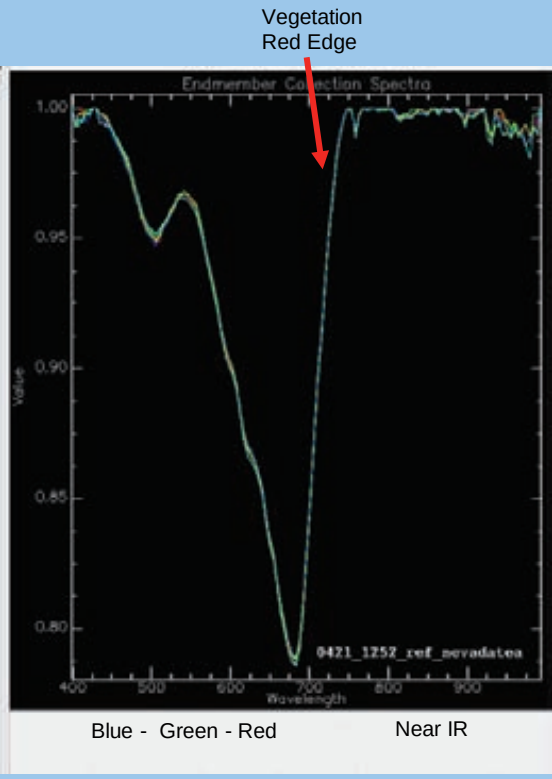
Visible-Near IR spectral signature of feature shown on left

VNIR Sensor

Morman Nevada Tea

Sampling site, ground photo, and ground spectra in GIS





UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

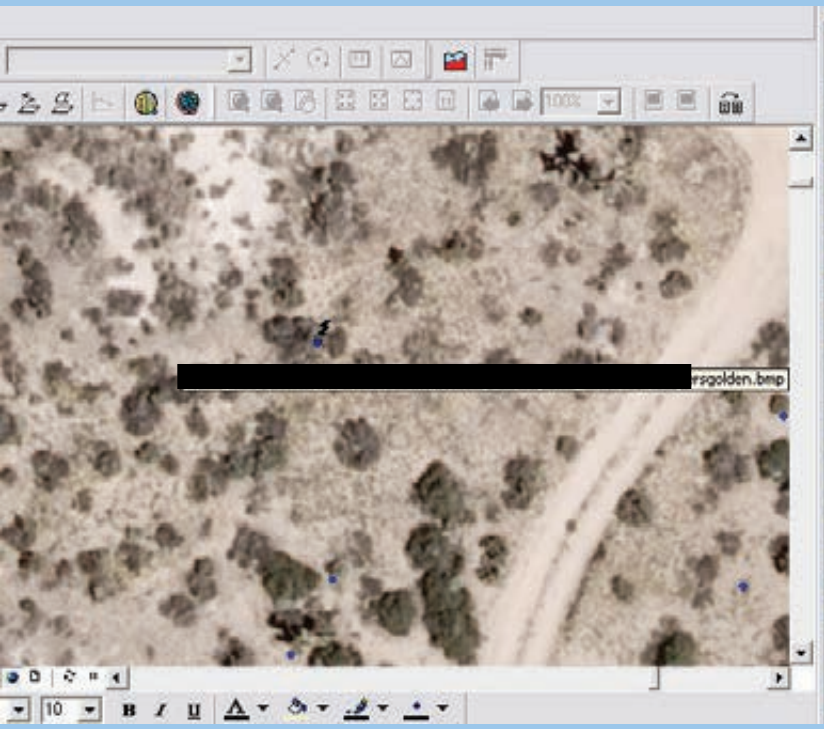
Field photograph of feature where Visible-Near IR spectral signature collected

Visible-Near IR spectral signature of feature shown on left

VNIR Sensor

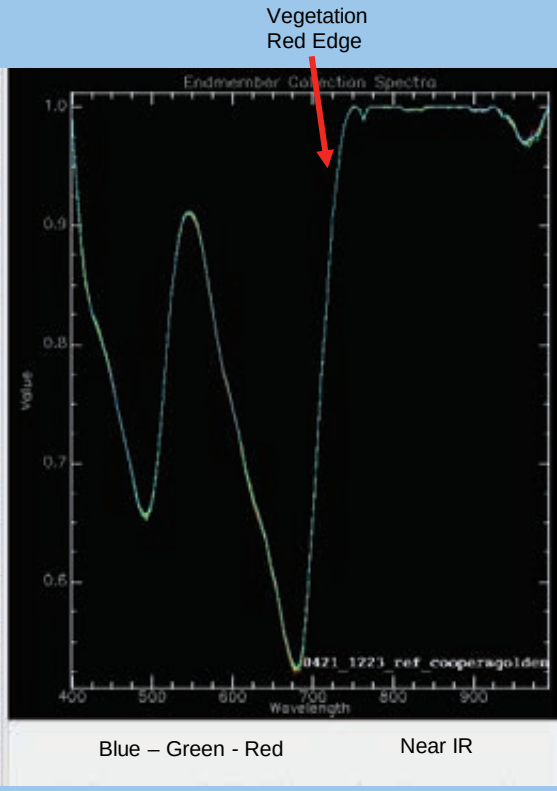
Coopers Goldenbush

Sampling site, ground photo, and ground spectra in GIS



UltraCam natural color image In GIS with hyperlink lightning bolt showing path to displayed graphics on right

Field photograph of feature where Visible-Near IR spectral signature collected



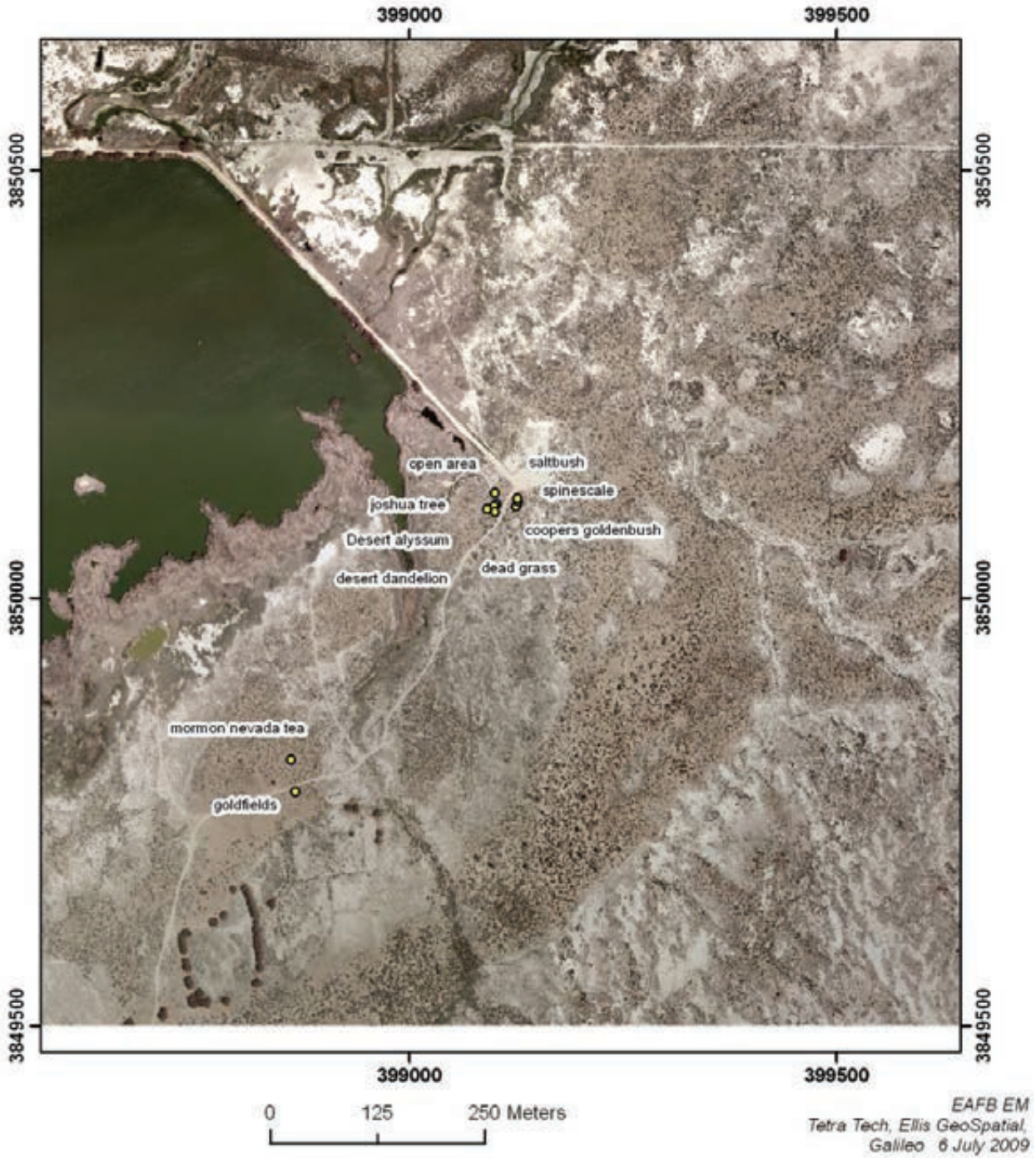
Visible-Near IR spectral signature of feature shown on left

VNIR Sensor

East Piute Ponds - Spectra Evaluation
Natural Color UltraCAM
Apr-Jun 2008

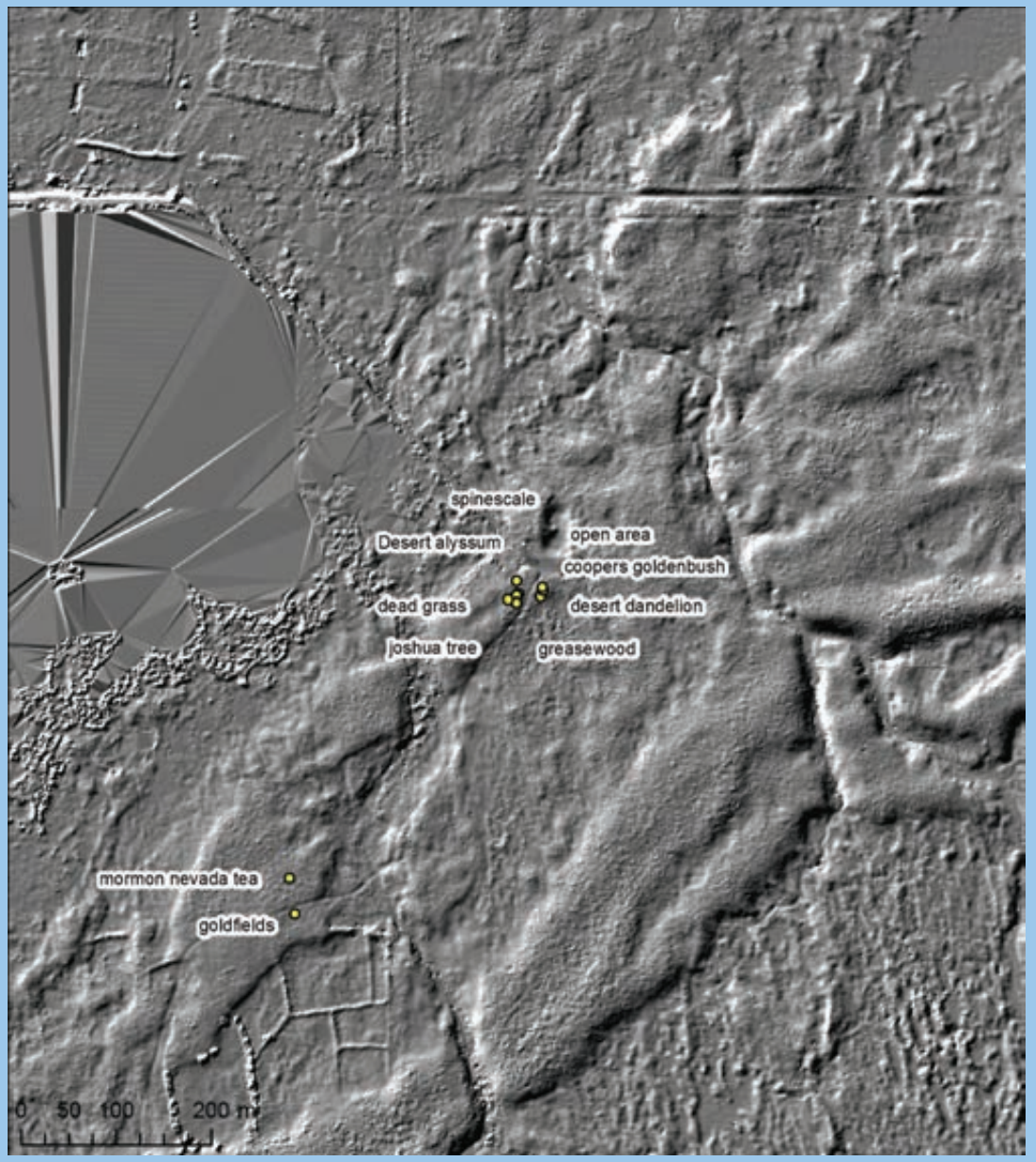
Ground spectra sites shown.

Ground Sample Locations on Airborne Orthorectified Base Image 4” pixels



Airborne LiDAR DEM

Illuminated from NW
10° above horizon



Airborne LiDAR DEM

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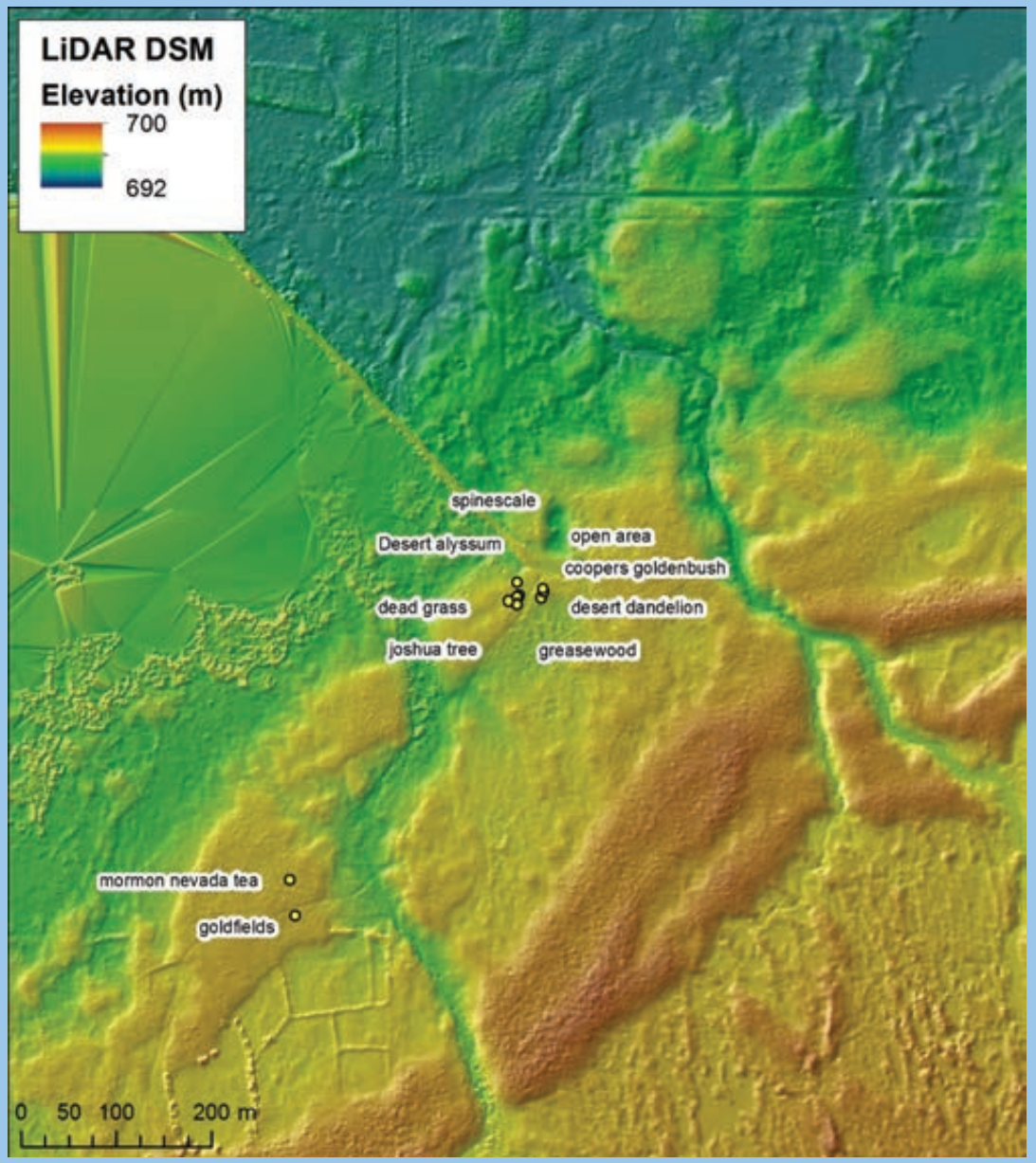
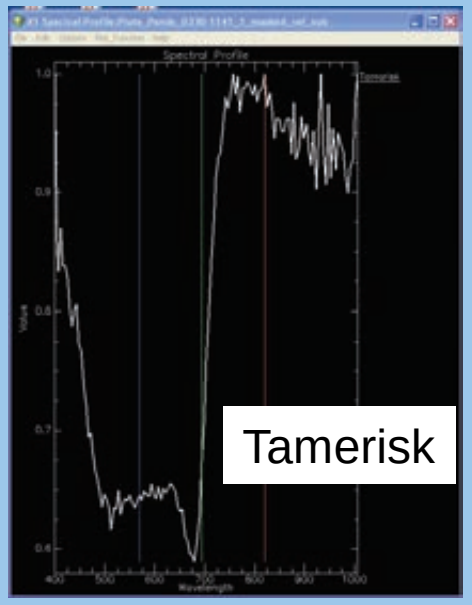
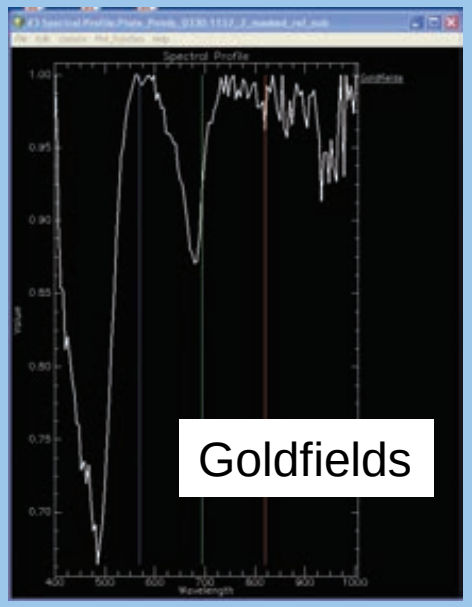


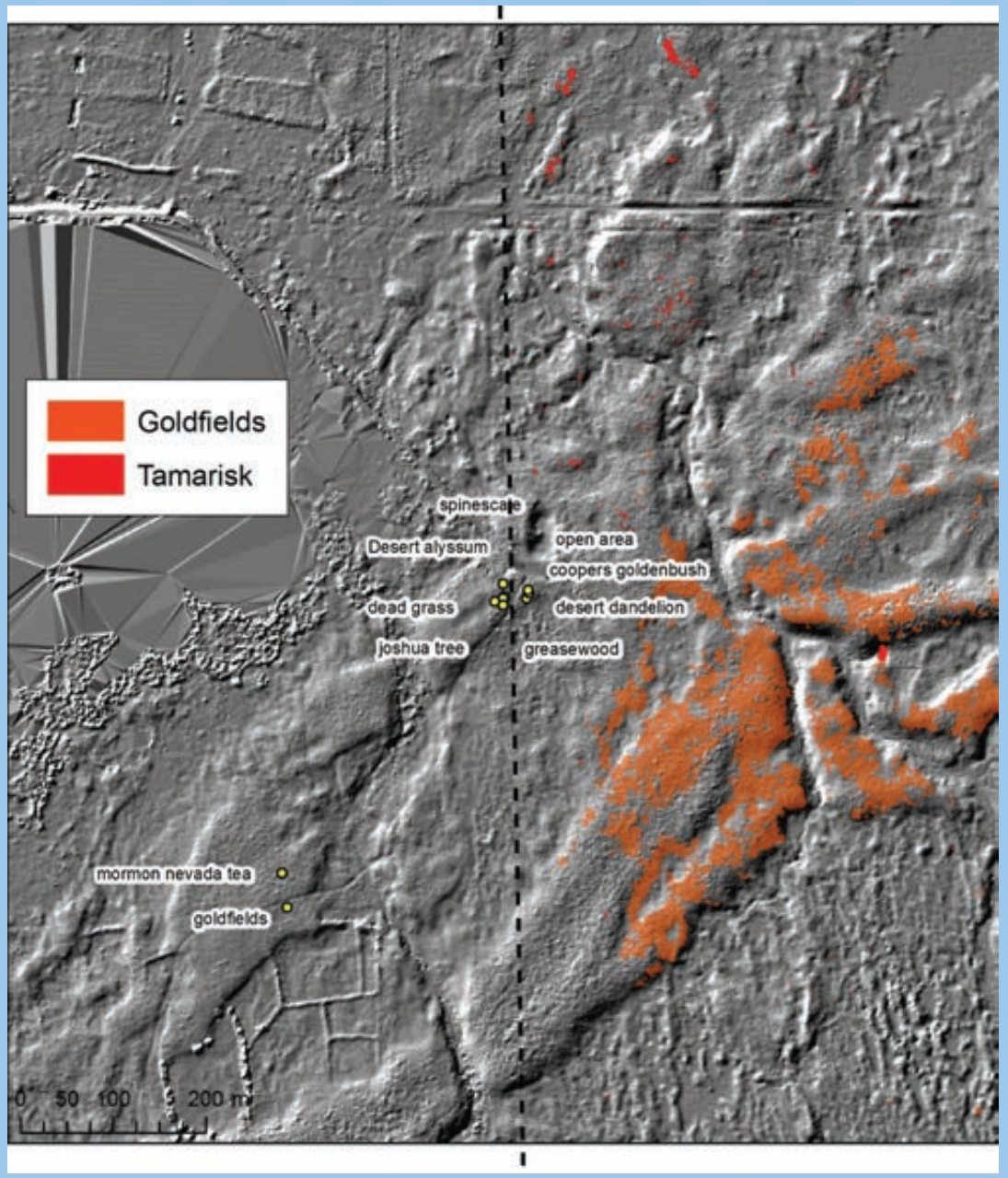
Species Map



Tamerisk



Goldfields



Habitat - replicate

MAPPING in the USA

LiDAR from NOAA

Cambria, WNY

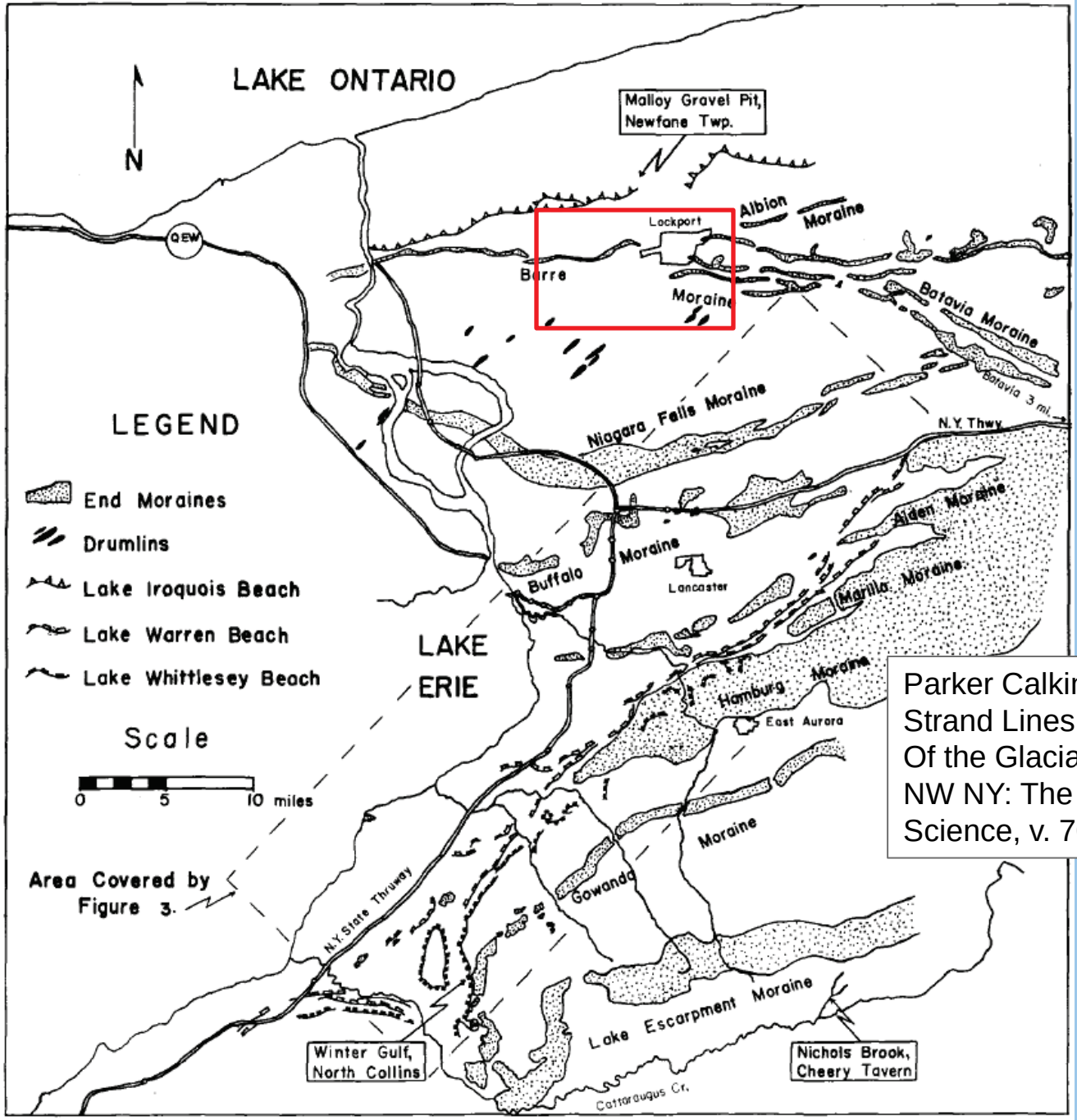
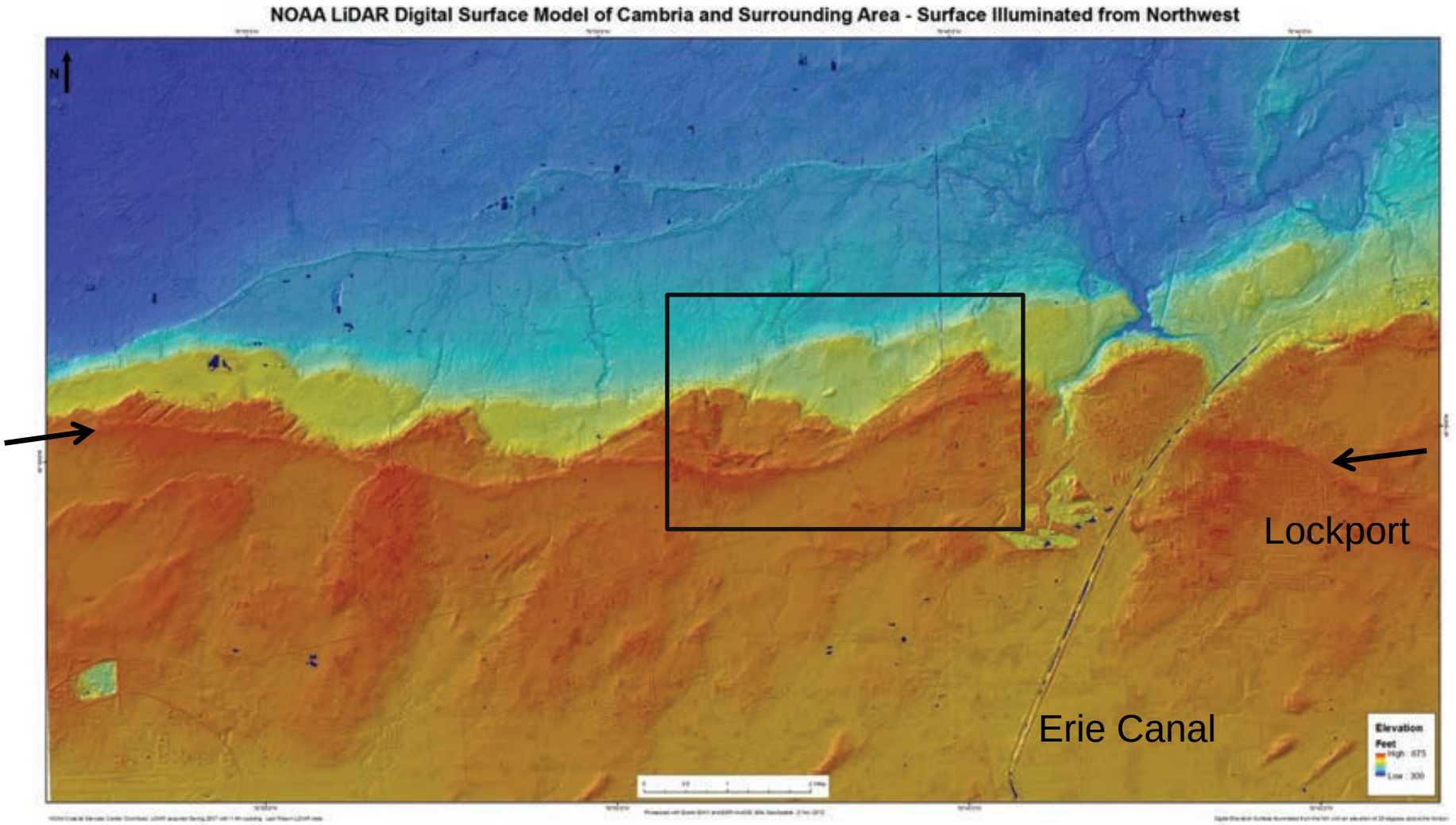


FIGURE 1. Location map of study area showing end moraines and major strand lines of northwestern New York.

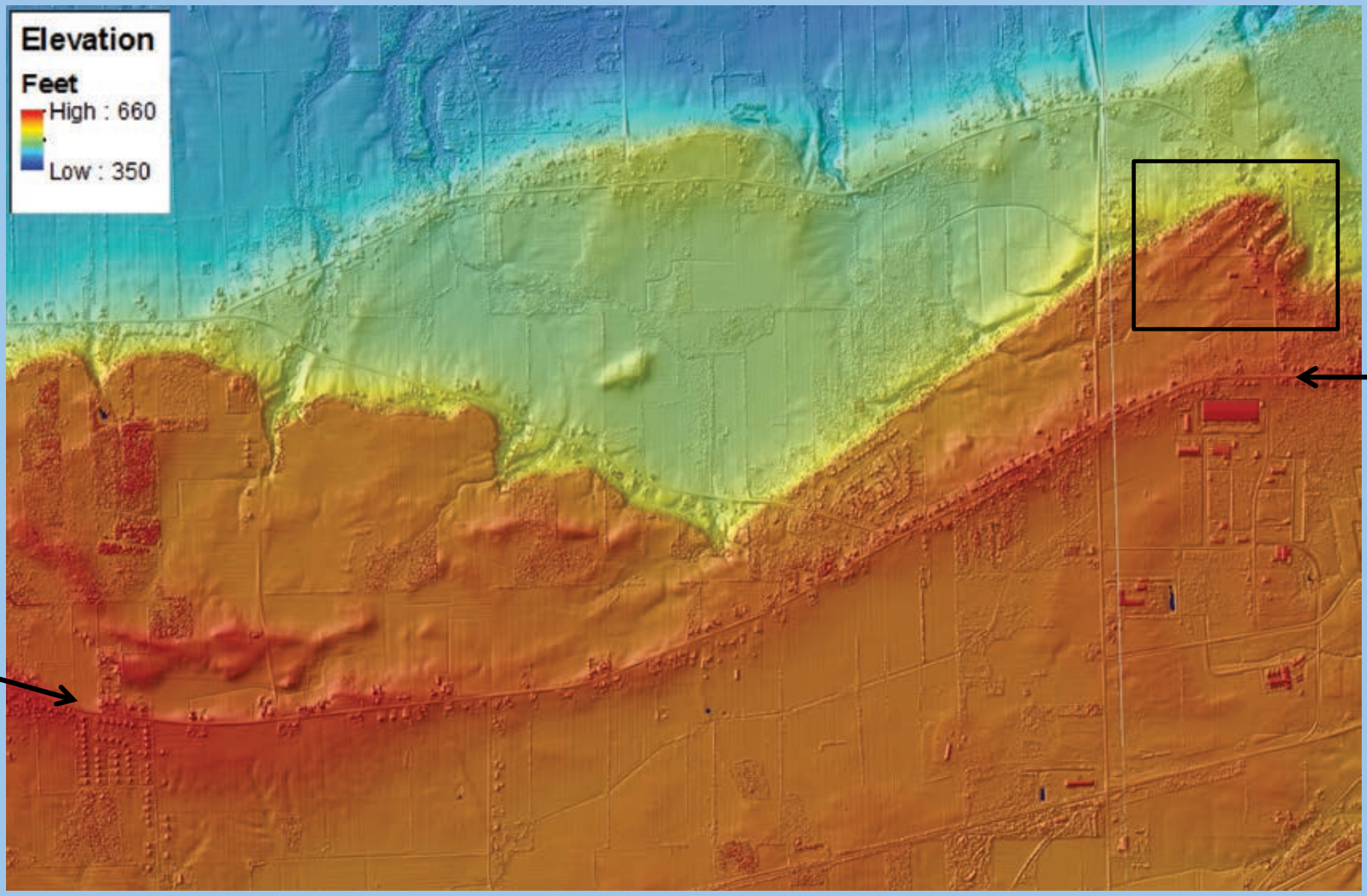
Parker Calkin, 1970, Strand Lines and Chronology Of the Glacial Great Lakes in NW NY: The Ohio Journal of Science, v. 70, n2, p. 78-96.

Awesome Geomorphology – Barre Moraine!



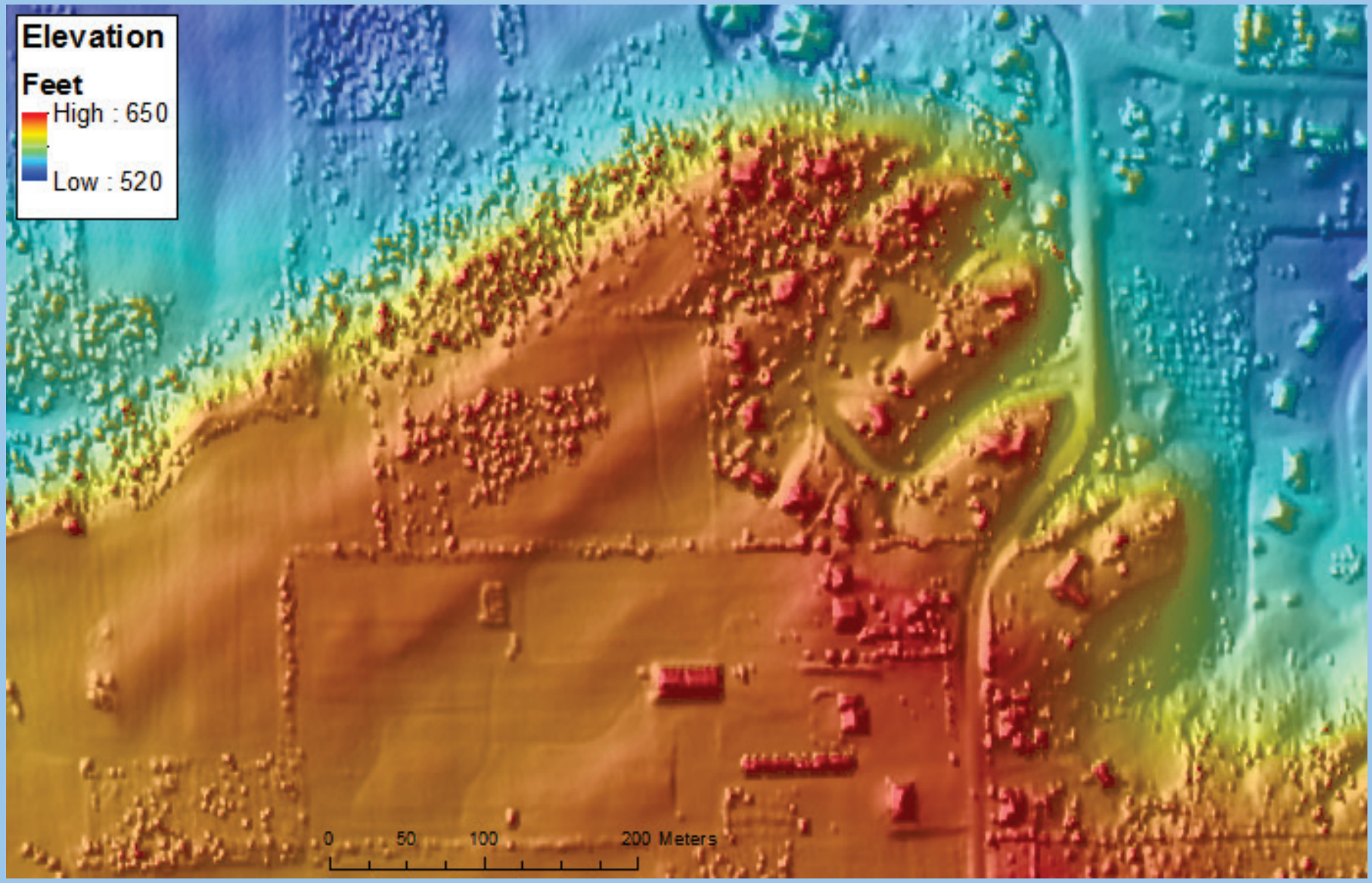
NOAA Coastal Services Center Download; LiDAR acquired Spring 2007 with 1.4m spacing. Last Return LiDAR data

Niagara Escarpment with Glacial Deposits



NOAA Coastal Services Center Download; LiDAR acquired Spring 2007 with 1.4m spacing. Last Return LiDAR data

Streamlined Glacial Landforms?
More Exposure of Niagara Escarpment



NOAA Coastal Services Center Download; LiDAR acquired Spring 2007 with 1.4m spacing. Last Return LiDAR data

Conclusions

Learn **to use remote sensing & GIS tools**

Leverage **these tools to make you a better knowledge worker!**

Try **using the geologically-revealing data types**

-Hyperspectral

-Thermal

-DEMs

Stereo overlapping satellite/aerial images

Radar

LiDAR

Thanks!!

Questions & Comments Welcomed

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