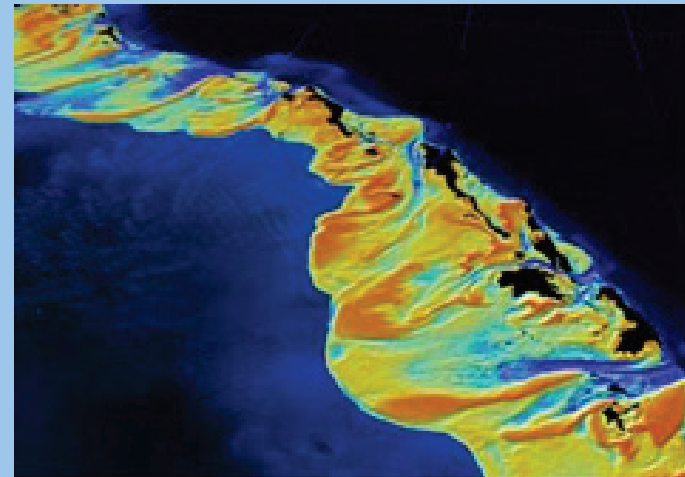


Using Remote Sensing & GIS To Create New Geologic & Environmental Opportunities

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

Google earth

© 2013 Cnes/Spot Image

14.9 km



Arid Region Valley Fill Example – Hillshade DEM with Outliers

Bedrock outcrops in lowlands covered with sands and silts revealed by DEM – indicates near-surface bedrock in surrounding area

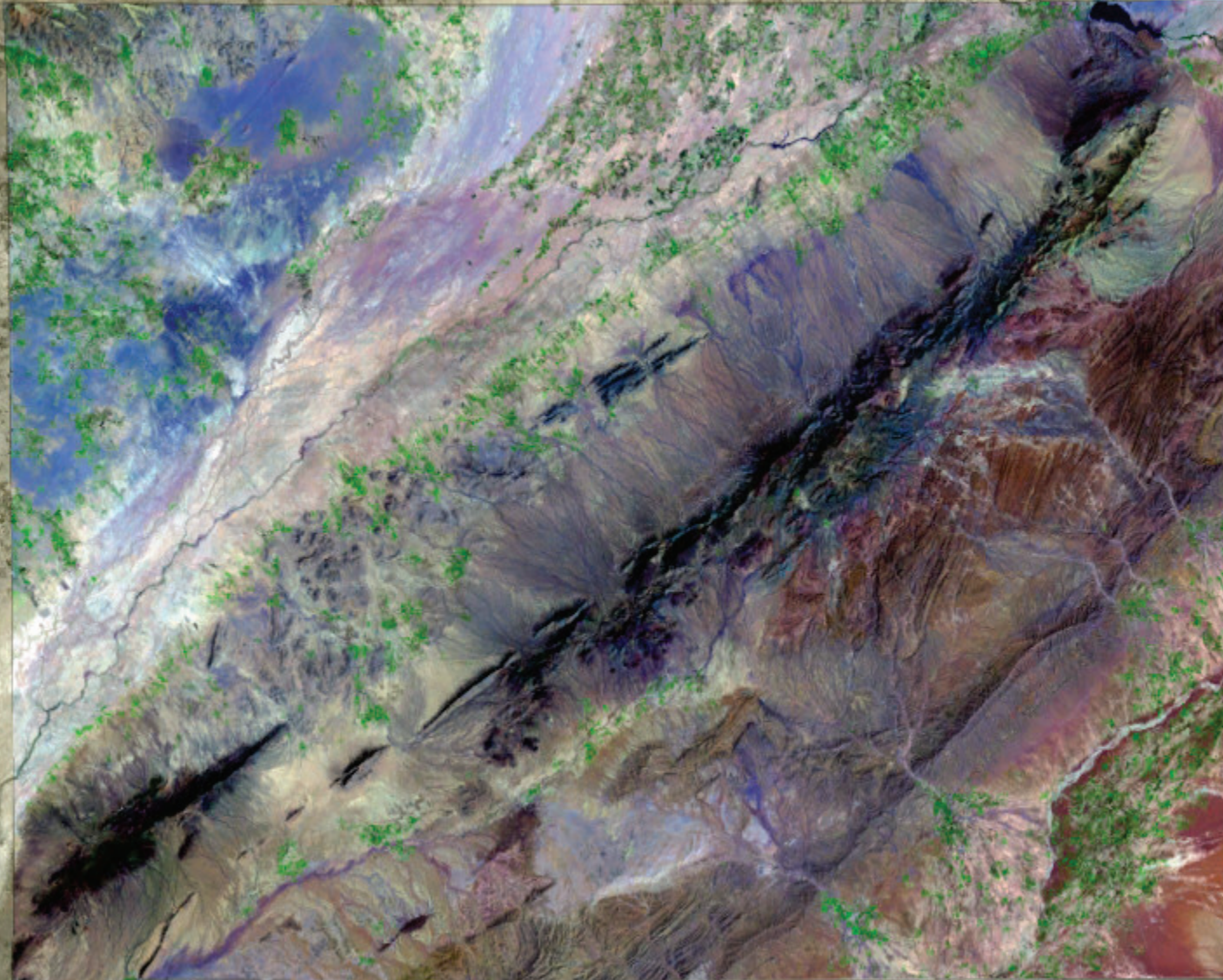
Groundwater,
Seismic,
Subsurface
Mapping

14.9 km

© 2013 Cnes/Spot Image

Google earth

Arid Region Valley Fill Example – Enhanced Landsat Color Image



14.9 km

© 2013 Cnes/Spot Image

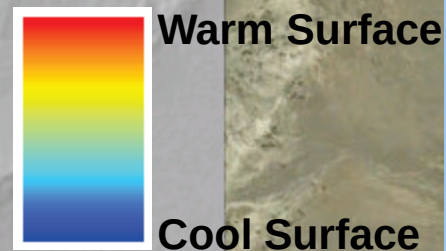
Google earth

Thermal

Arid Region Valley Fill Example – ASTER Thermal Image

Same valley fill pattern, but different thermal pattern – underlying bedrock depth different?

Same outcrop pattern, but different thermal pattern – underlying bedrock depth different?



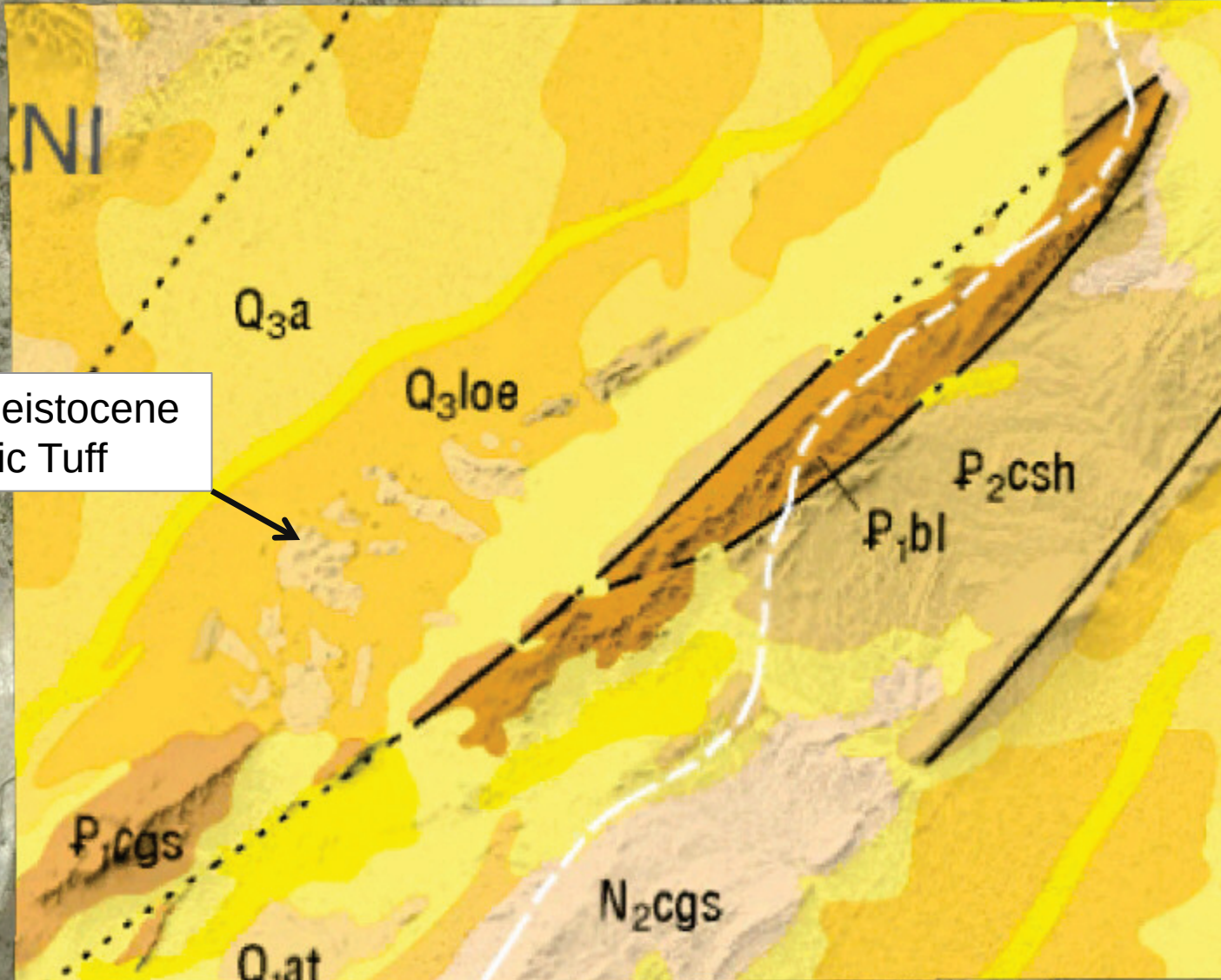
Cool rugged outcrops (shadows) with varying temperature in agricultural and lowland terrain – differences in groundwater table, depth to bedrock, change in underlying bedrock?

14.9 km

© 2013 Cnes/Spot Image

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

Early Pleistocene
Andesitic Tuff

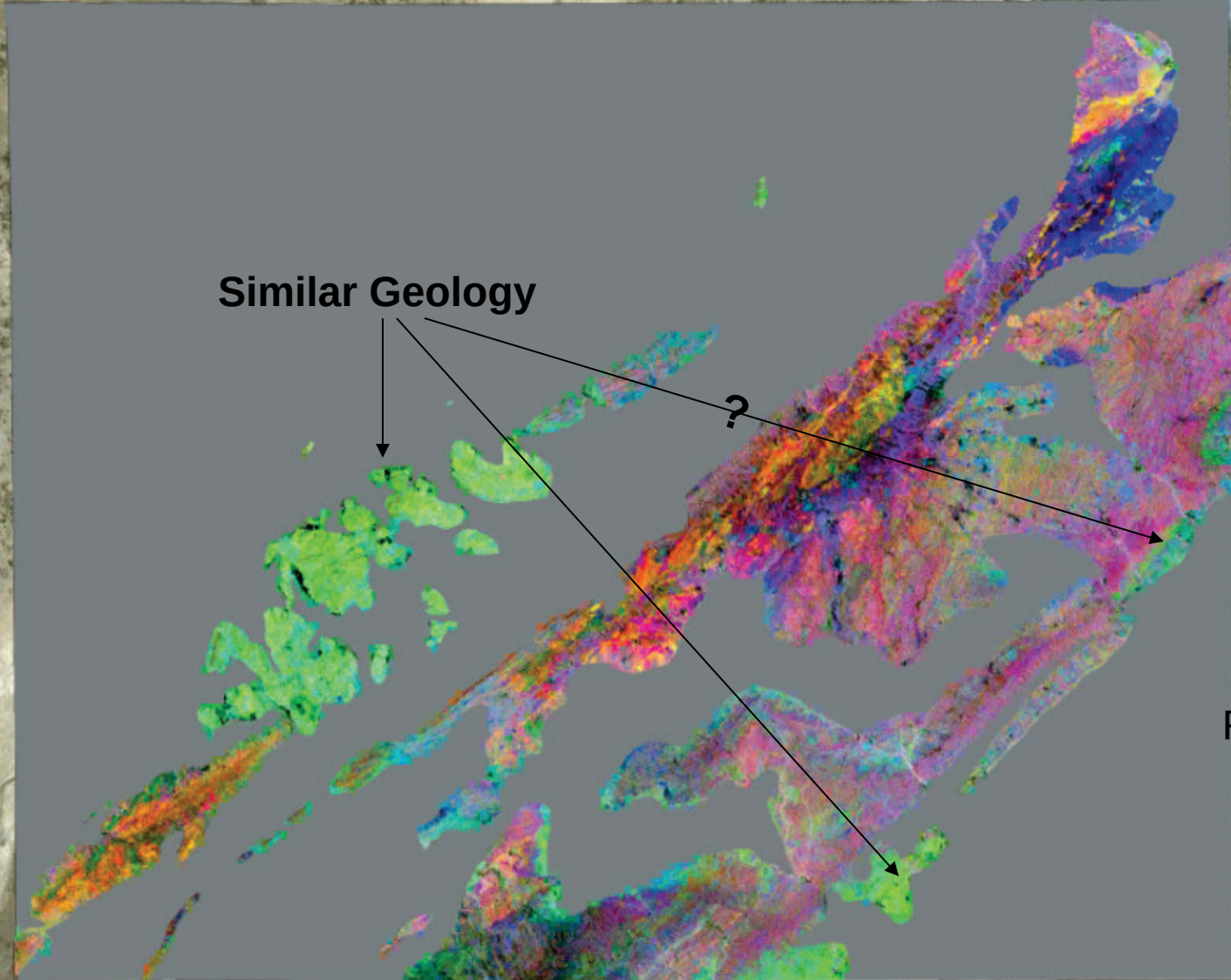


14.9 km

© 2013 Cnes/Spot Image

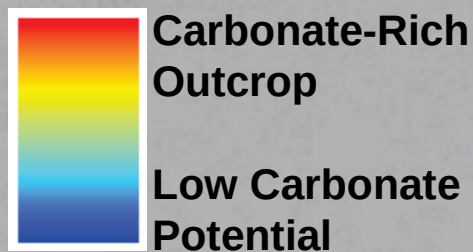
Google earth

Arid Region Outcrop Example – Landsat Data Processed for Spectral Patterns



Thermal

Arid Region Outcrop Example – ASTER



Bernard Hubbard
USGS
Ward Kilby
CalData

ASTER band
ratio 13/14

Emitted
Energy

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

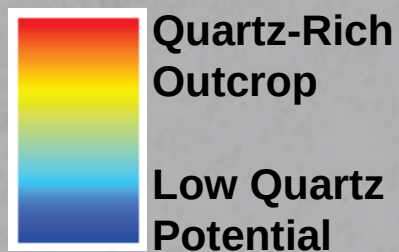
14.9 km

© 2013 Cnes/Spot Image

Google earth

Thermal

Arid Region Outcrop Example – ASTER



ASTER band
ratio 14/12

Emitted
Energy

14.9 km

© 2013 Cnes/Spot Image

Google earth

Thermal

Arid Region Outcrop Example – ASTER



ASTER band
ratio
 $12+13/14$

Emitted
Energy

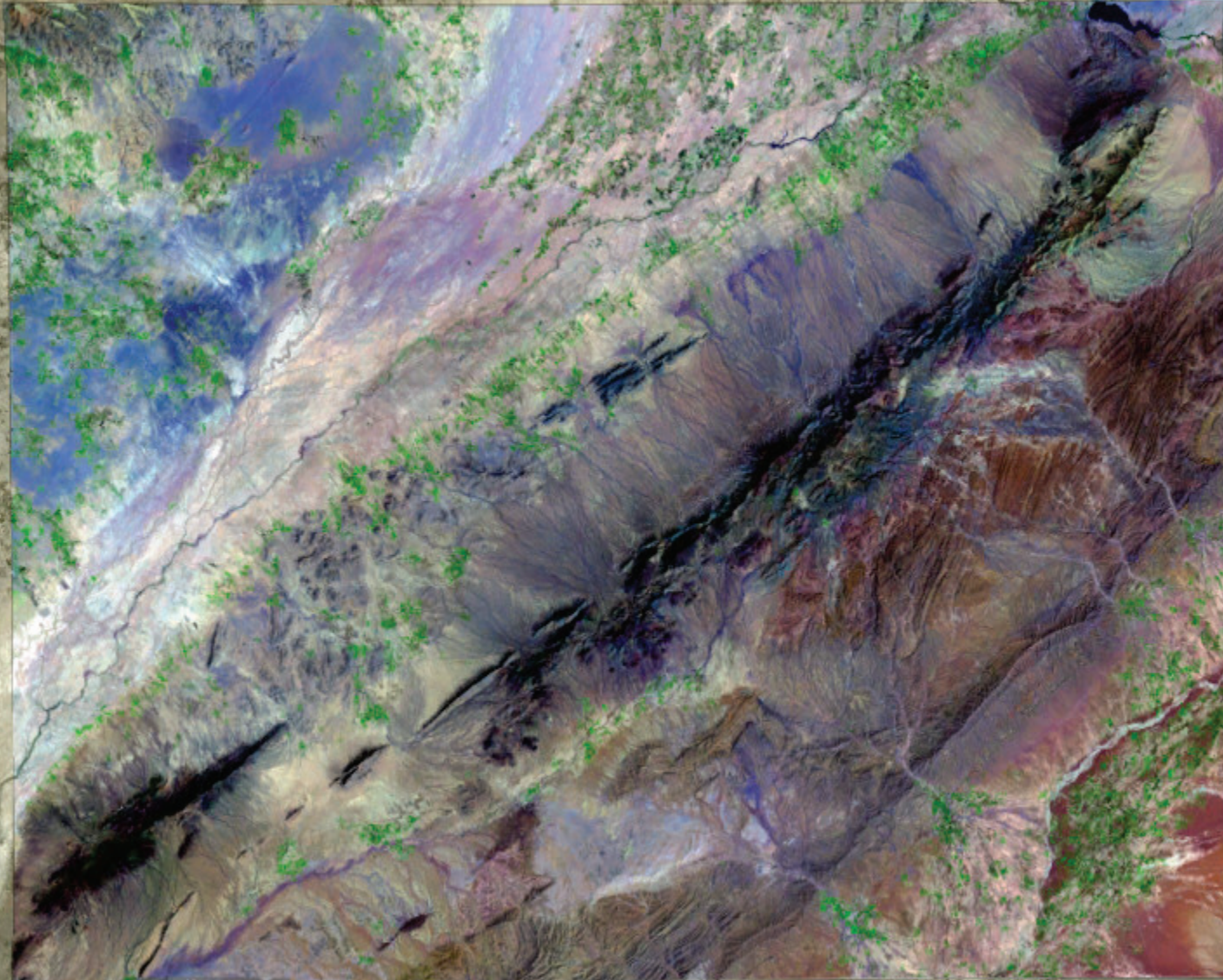
Rich in Mg & Fe
olivine, pyroxene, amphibole,
biotite mica, plag feldspars

14.9 km

© 2013 Cnes/Spot Image

Google earth

Arid Region Example – Enhanced Landsat Color Image



14.9 km

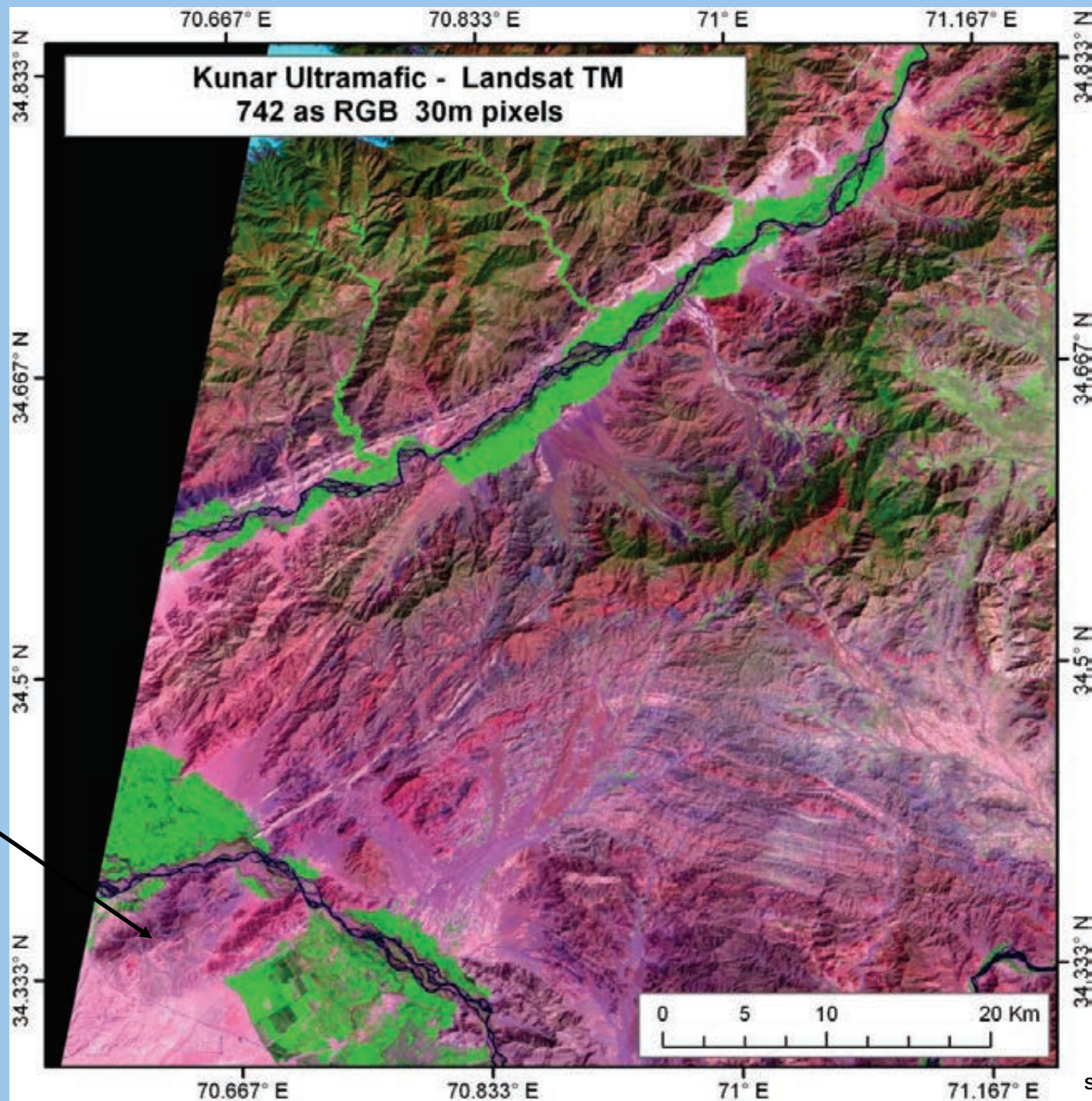
© 2013 Cnes/Spot Image

Google earth

Thermal

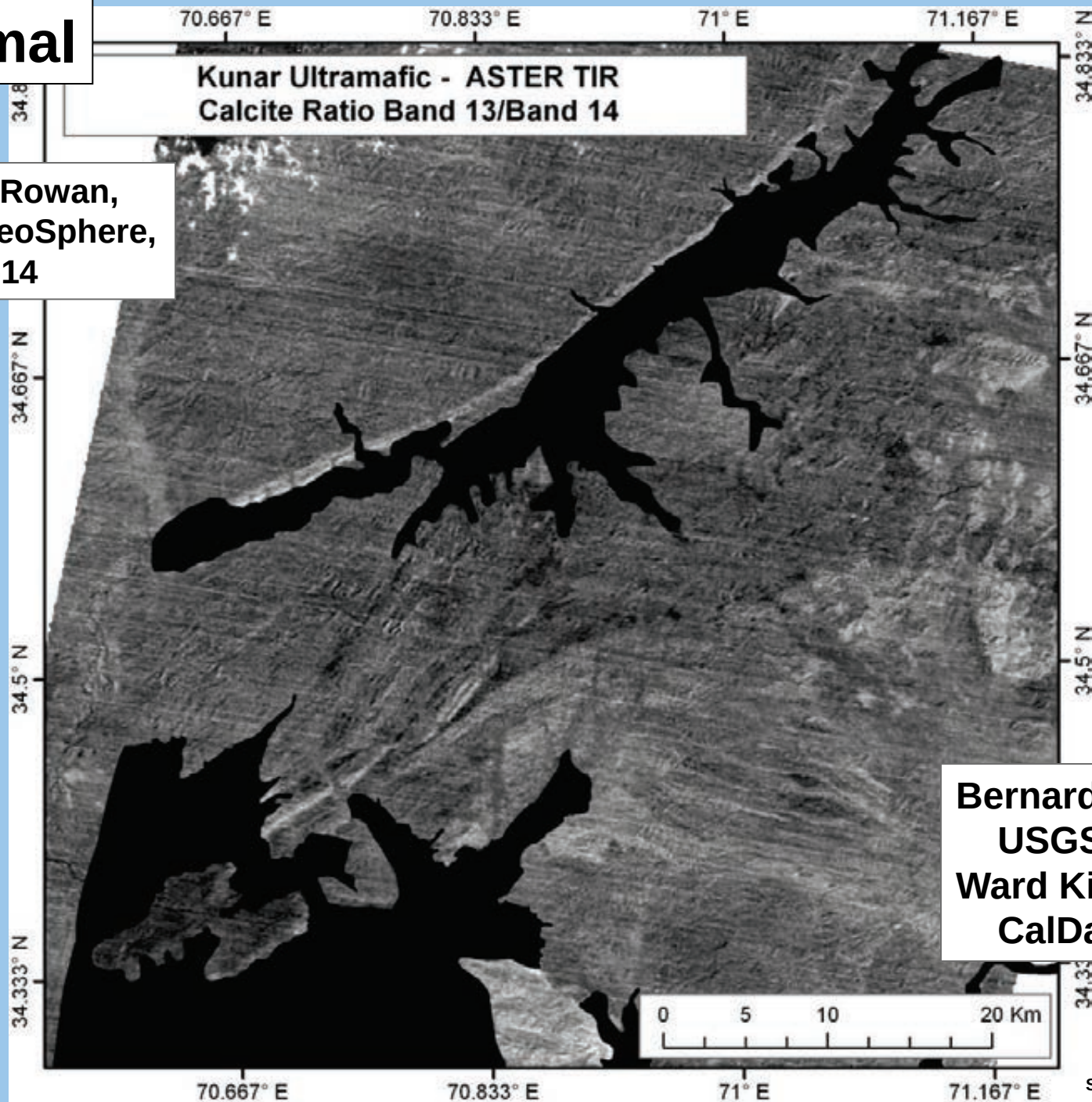
Chromite in Ultramafics



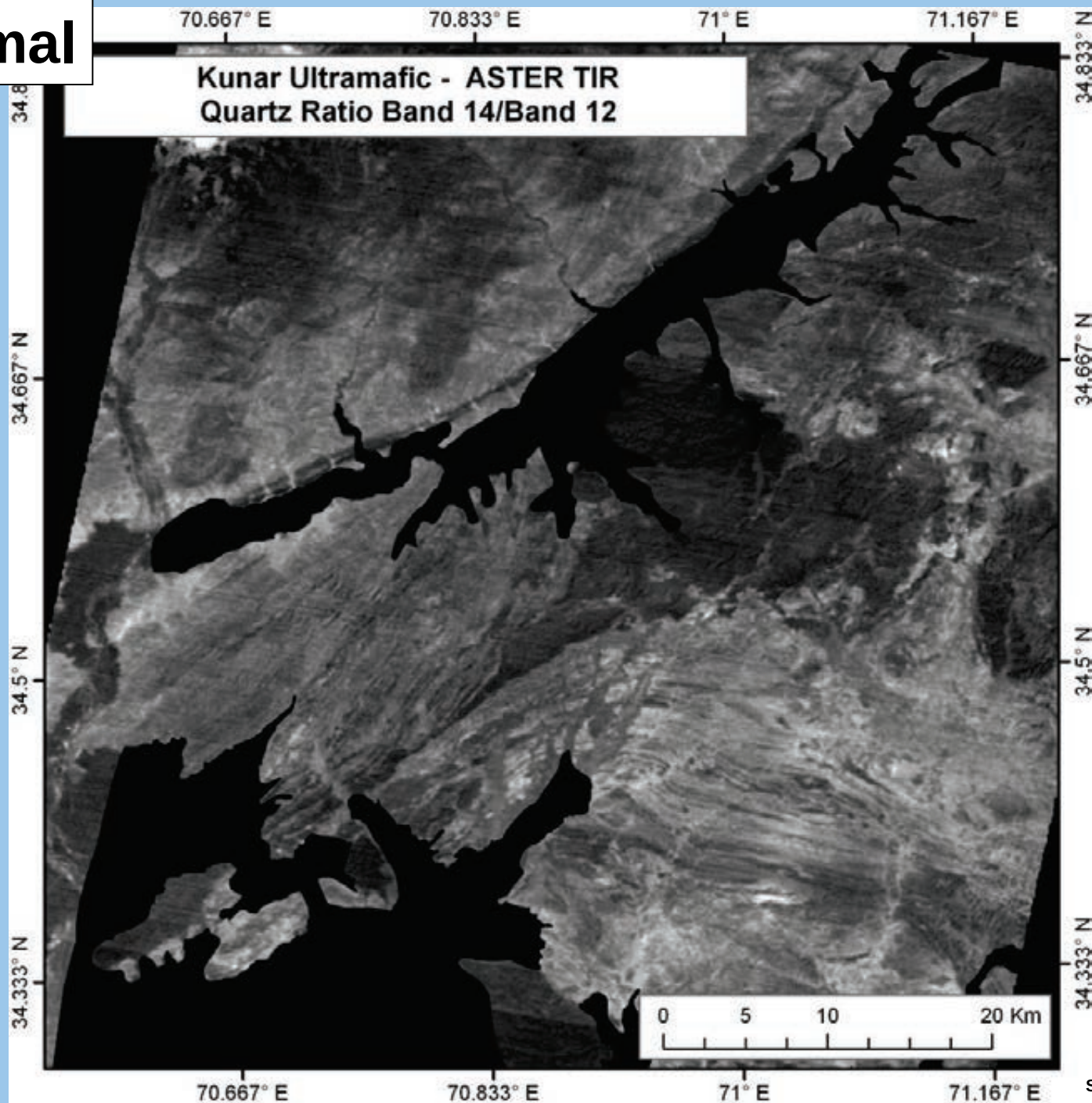


Thermal

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



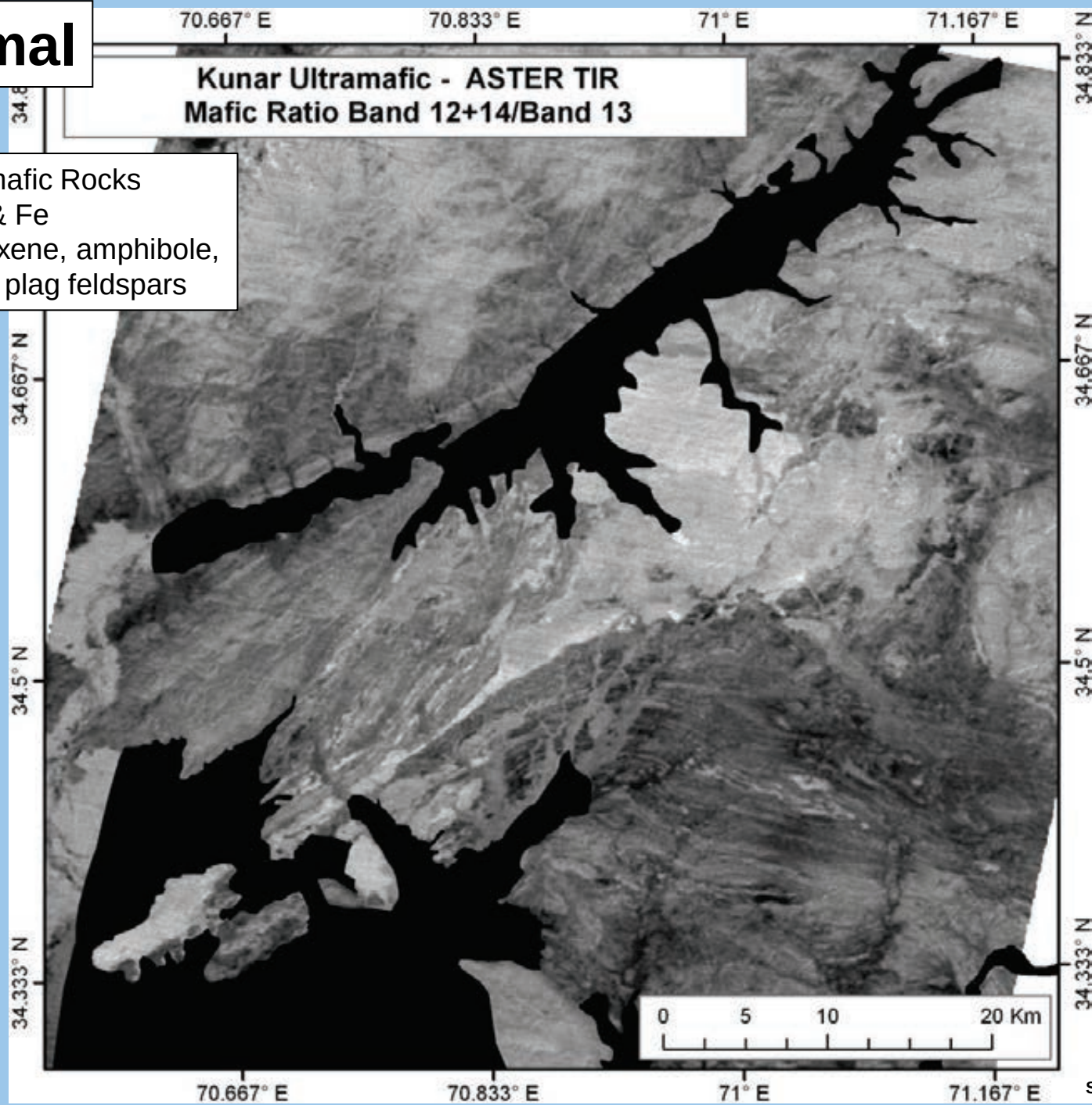
Thermal



Emitted
Energy

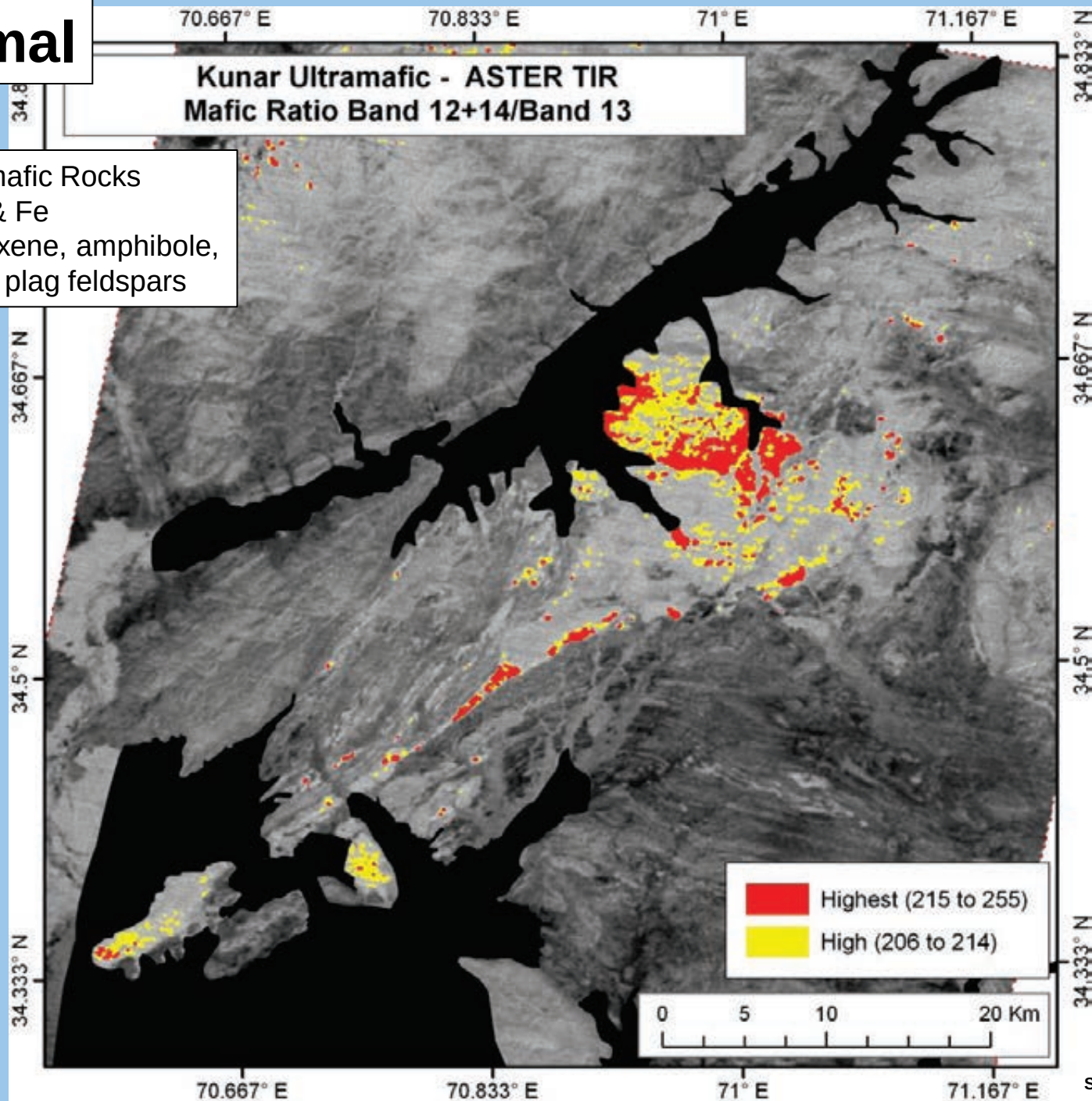
Thermal

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



Thermal

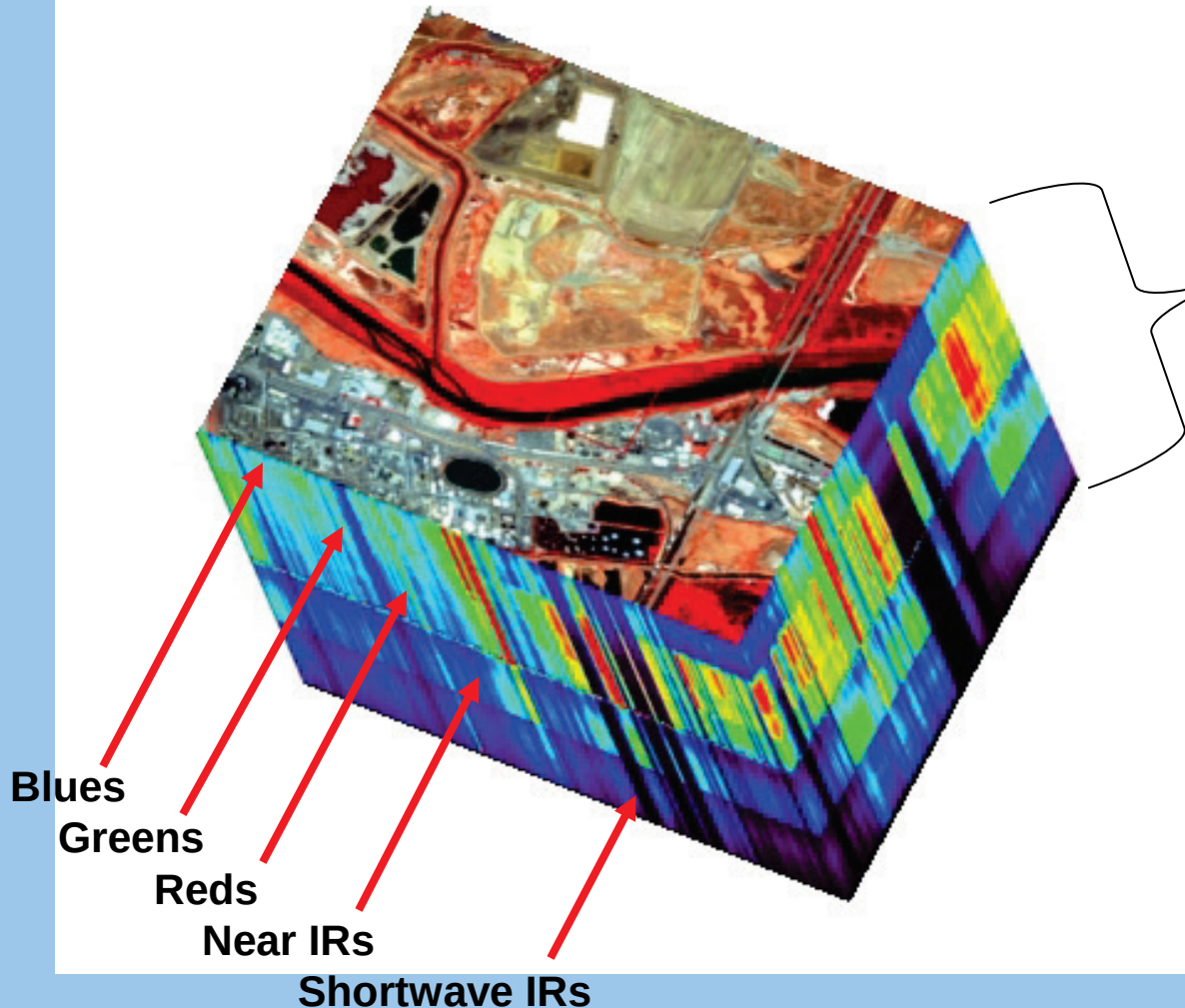
Mafic-Ultramafic Rocks
Rich in Mg & Fe
olivine, pyroxene, amphibole,
biotite mica, plag feldspars



**MAPPING OIL
SPILLS & SEEPS
WITH HYPERSPECTRAL**

HYPERSPPECTRAL DATACUBE

Continuous spectrum collected



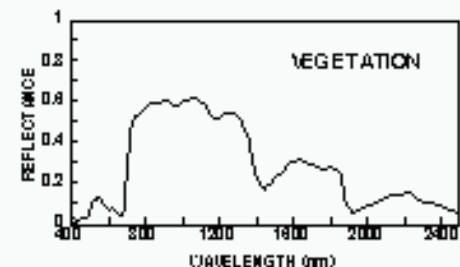
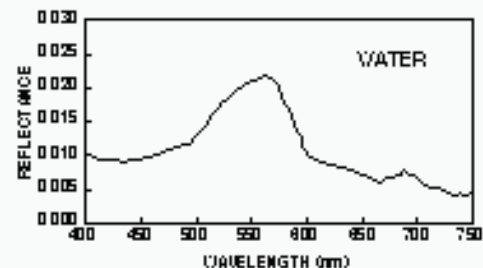
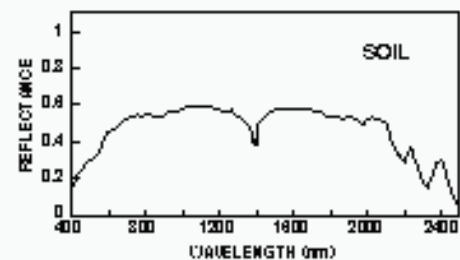
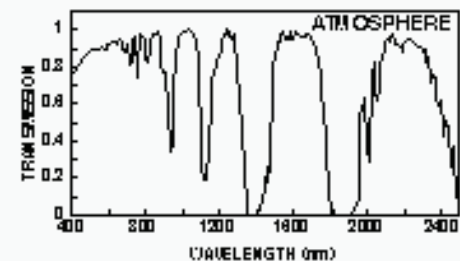
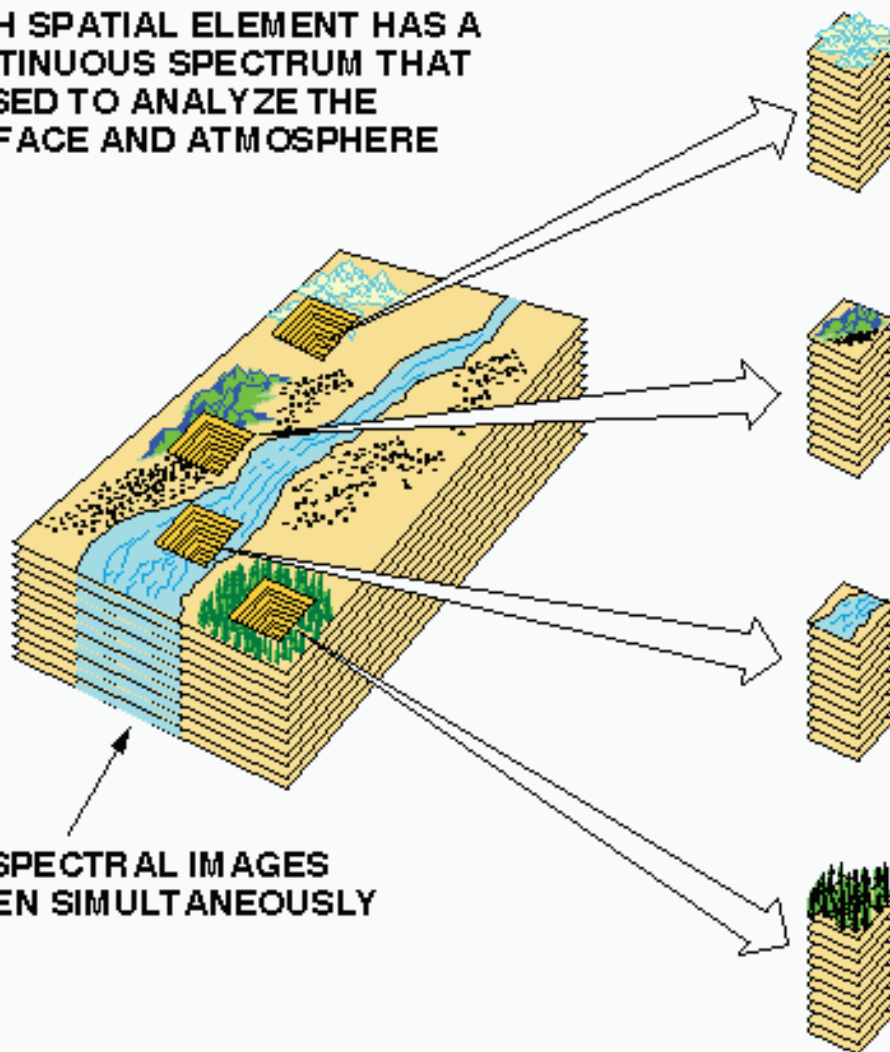
**Stack of B&W
images, each
a narrow
wavelength
band - from
reflected
visible Blue to
shortwave IR**

~ 50 - 300 bands

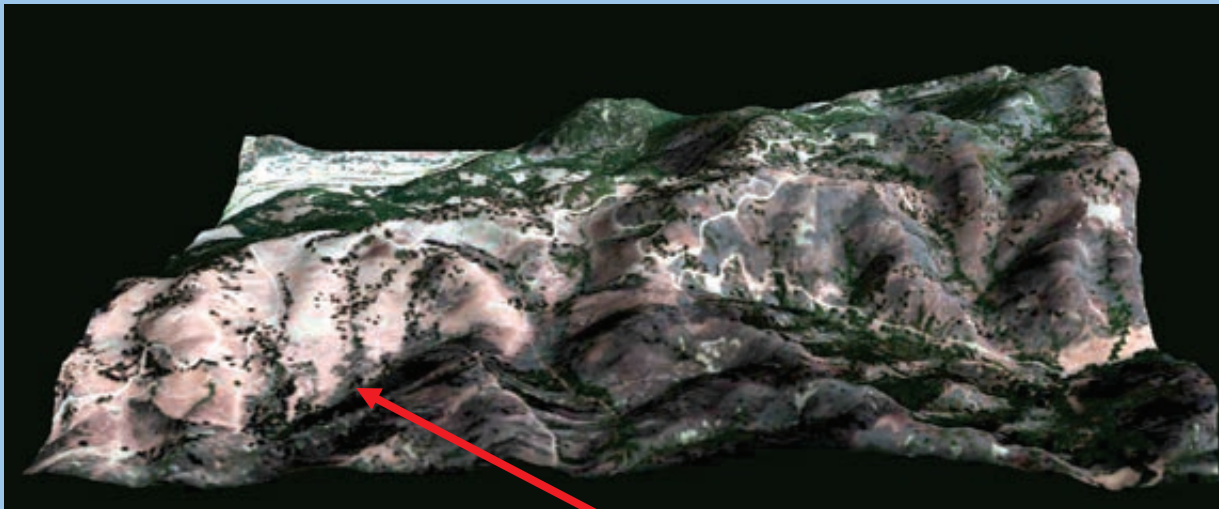
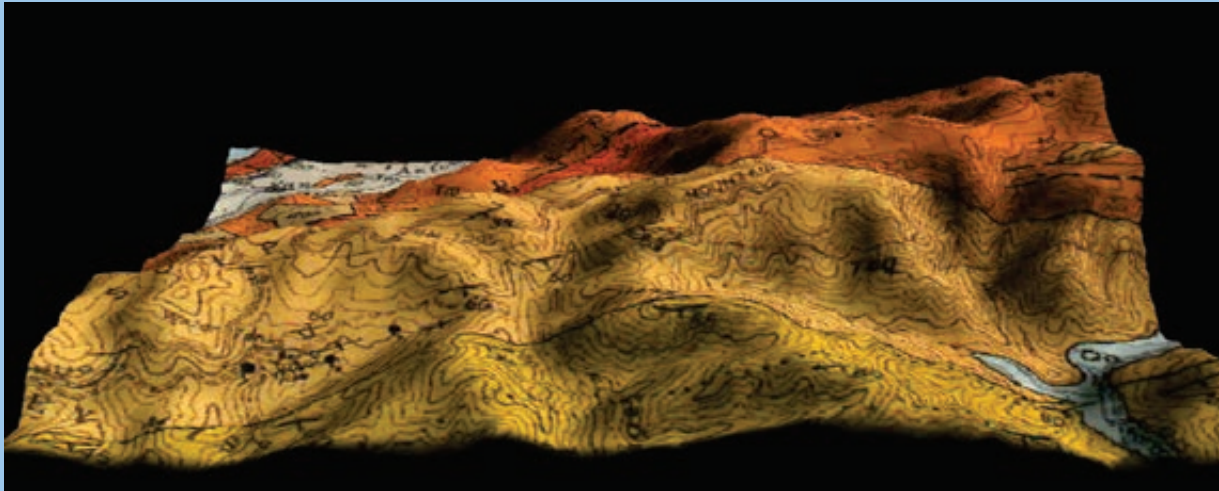
HYPERSENSPECTRAL

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"

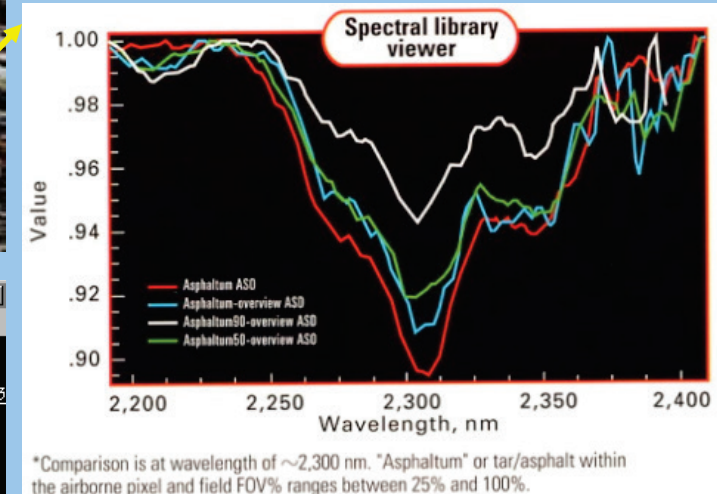
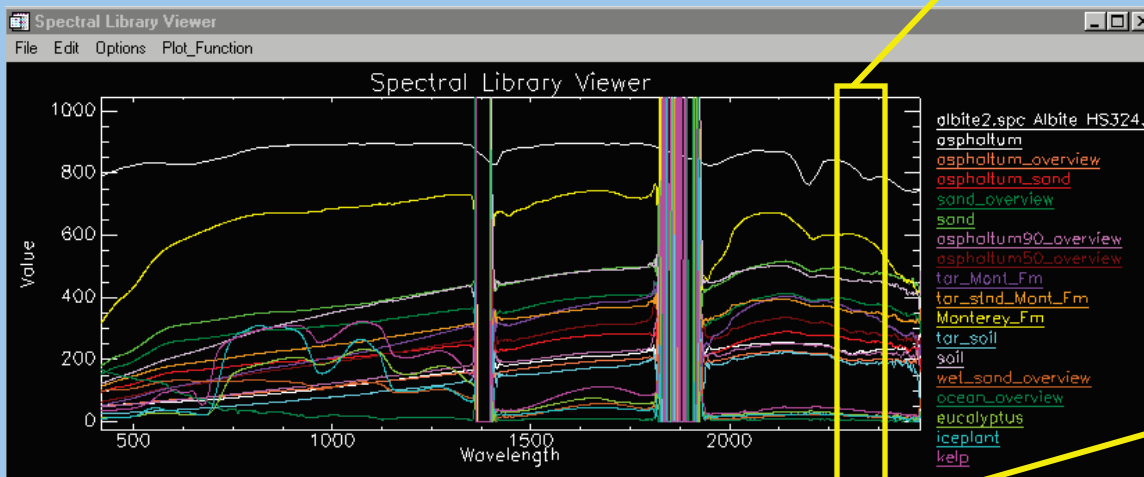
OIL SEEP IN AREA



DIBBLEE OIL SEEP



BUILDING AN OIL SPECTRAL LIBRARY BASED ON FIELD MEASUREMENTS



*Comparison is at wavelength of ~2,300 nm. *Asphaltum* or tar/asphalt within the airborne pixel and field FOV% ranges between 25% and 100%.

PROVING AIRBORNE SENSING MATCHES GROUND MEASUREMENT



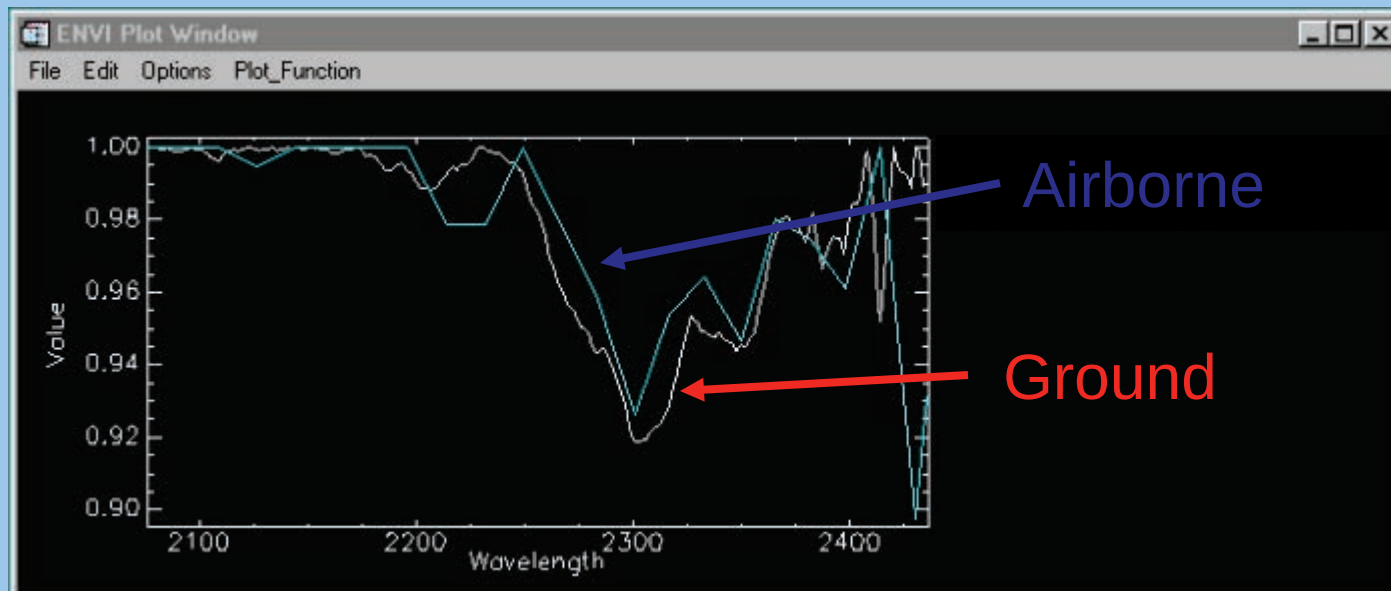
Geologic Map



Hyperspectral Image



Zoom-in to pixel



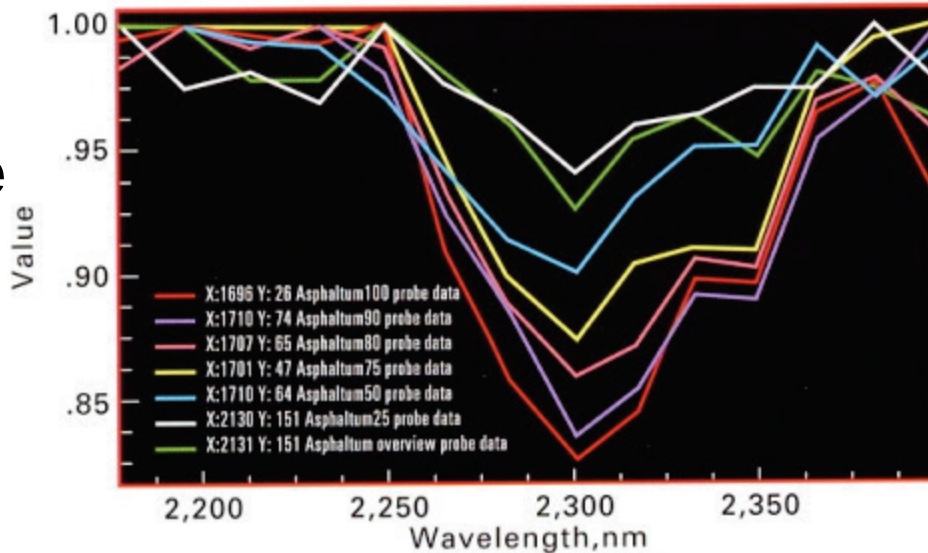
Airborne

Ground

Airborne

BITUMEN ABSORPTION SIGNATURES COMPARED*

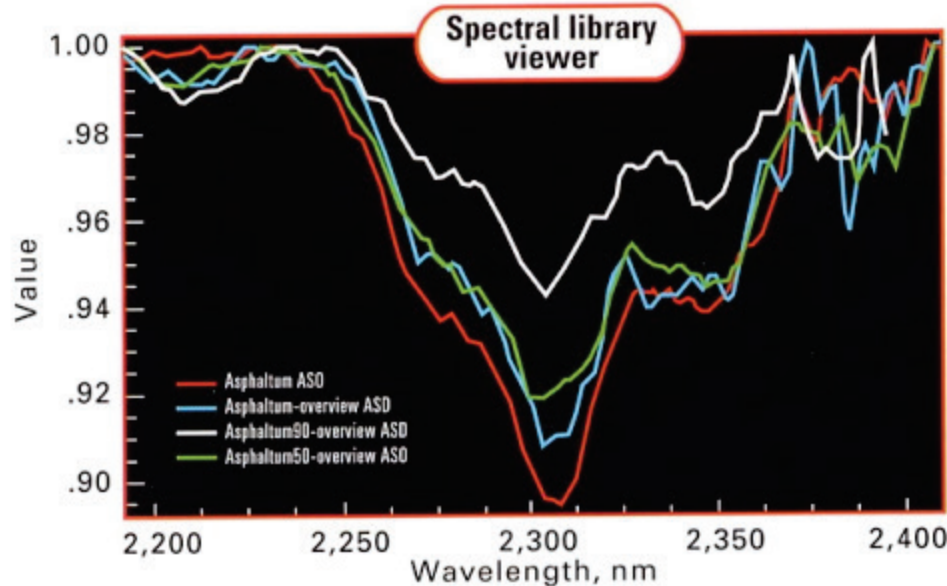
Fig. 5



Increasing distance
from pure tar site

Increasing mixture of
non-tar with tar
in airborne pixels

Ground

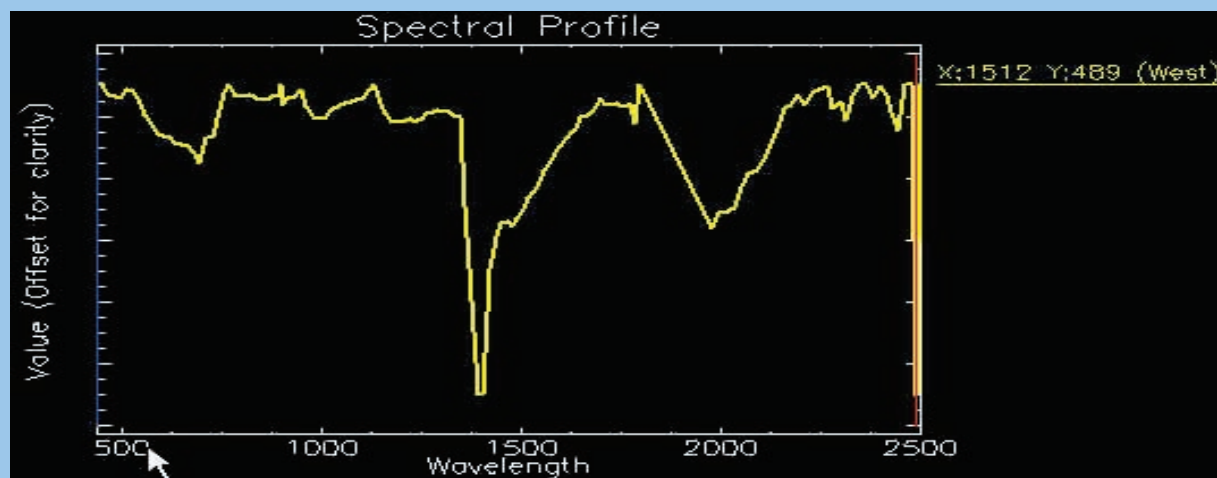
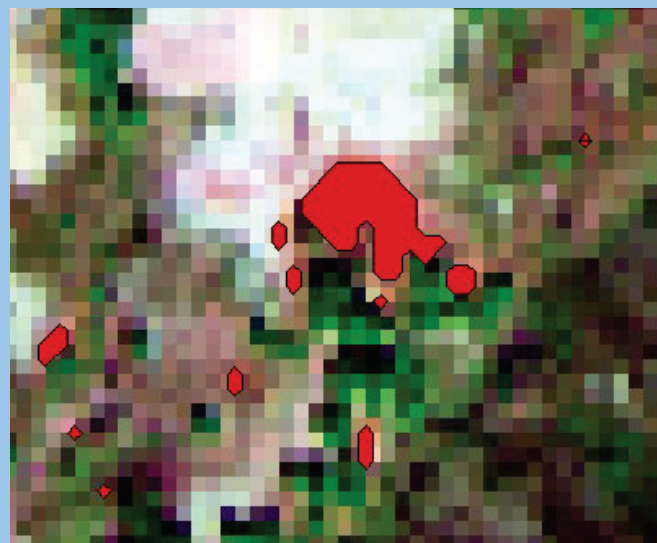
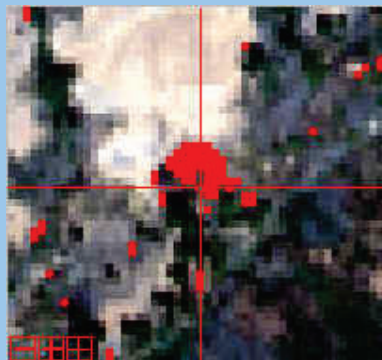
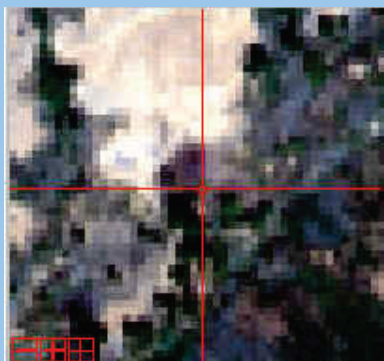


Increasing distance
from pure tar site

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

*Comparison is at wavelength of $\sim 2,300$ nm. "Asphaltum" or tar/asphalt within the airborne pixel and field FOV% ranges between 25% and 100%.

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

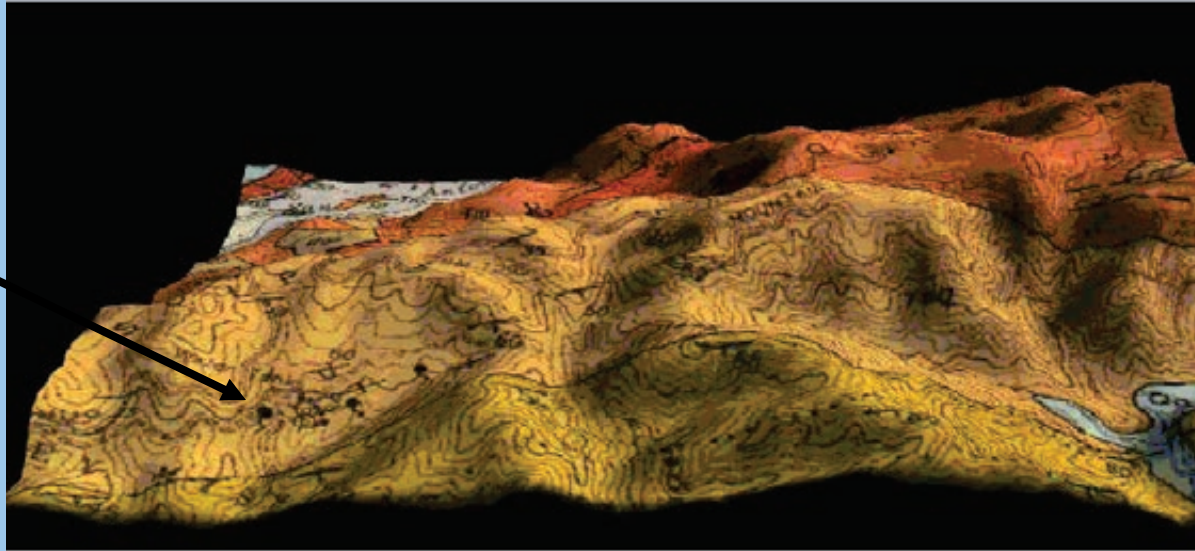


Hydrocarbon Spectral Signature

**Extrapolation of
Dibblee oil seep.**

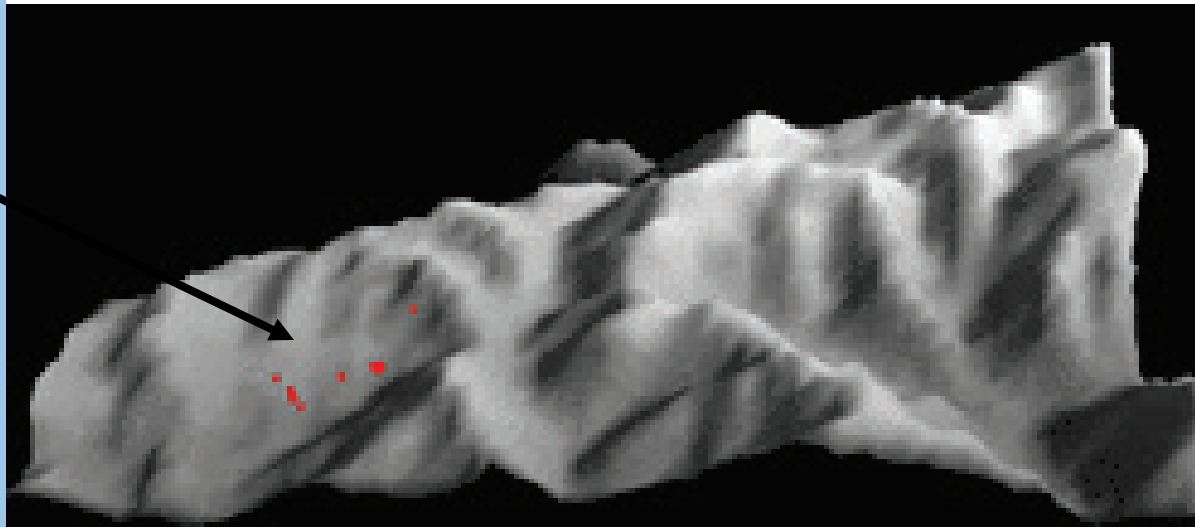
**Spectral signature
from training site
pixel extrapolated to
surrounding area.**

OIL SEEP DETECTION & MAPPING



**Original
Map**

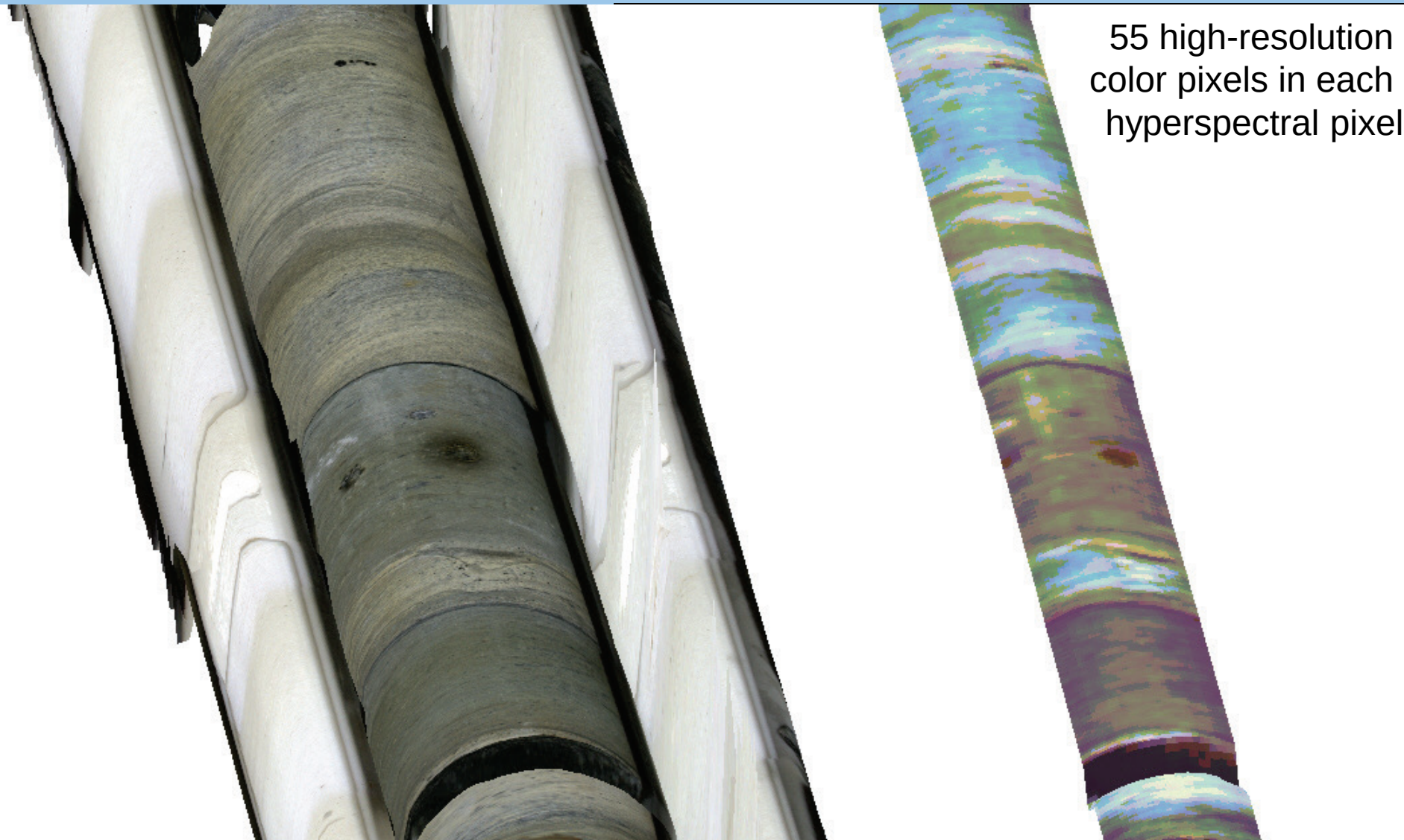
*Red Dots
Mapped
As Oil
Seeps*



**Actual
Locations
Of Oil
Seeps**

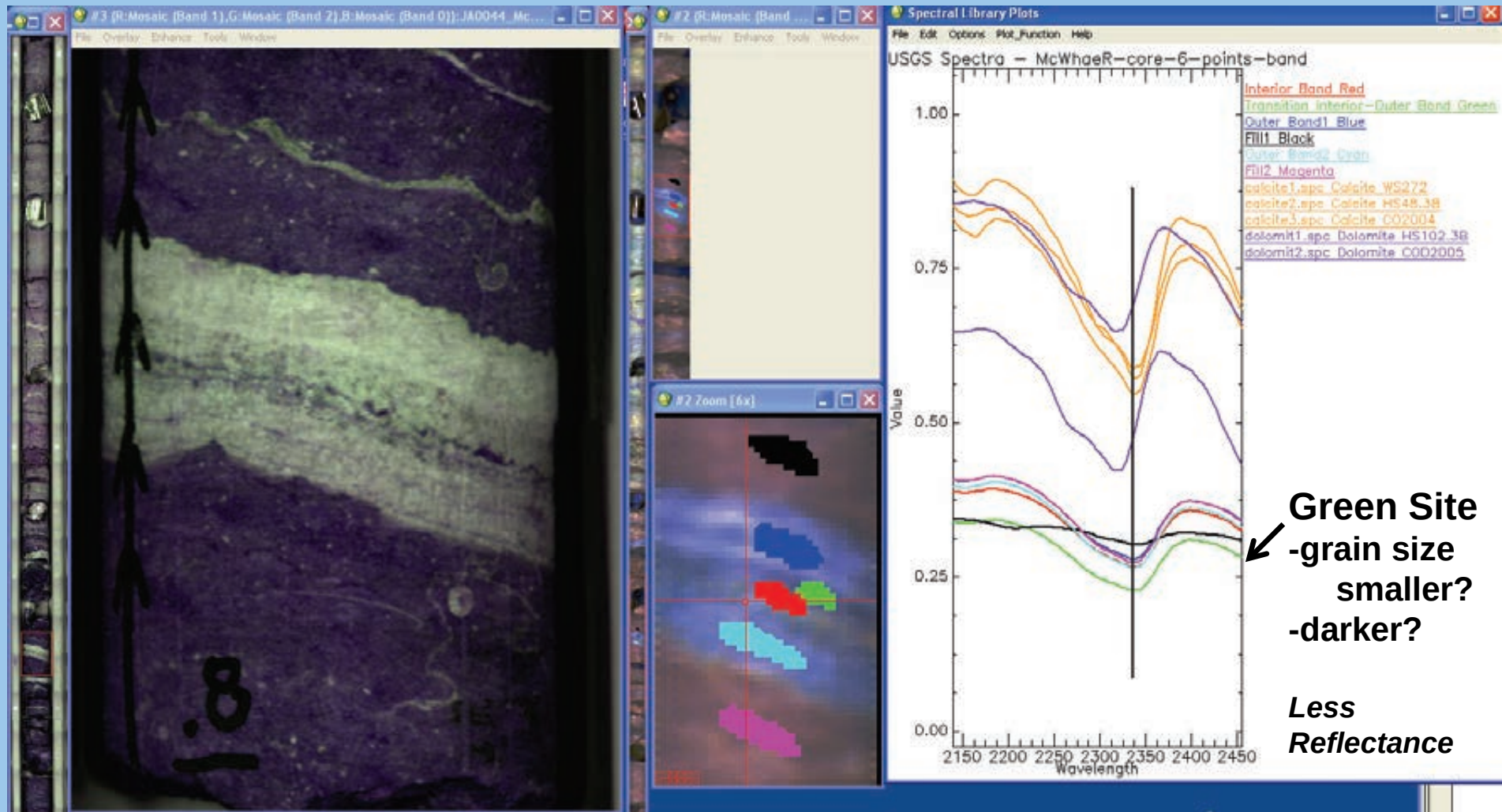
MAPPING CORE WITH HYPERSPECTRAL

Core Scanning for Mineralogy



Each pixel = 0.5 x 0.5 mm

Core Section with Training Sites



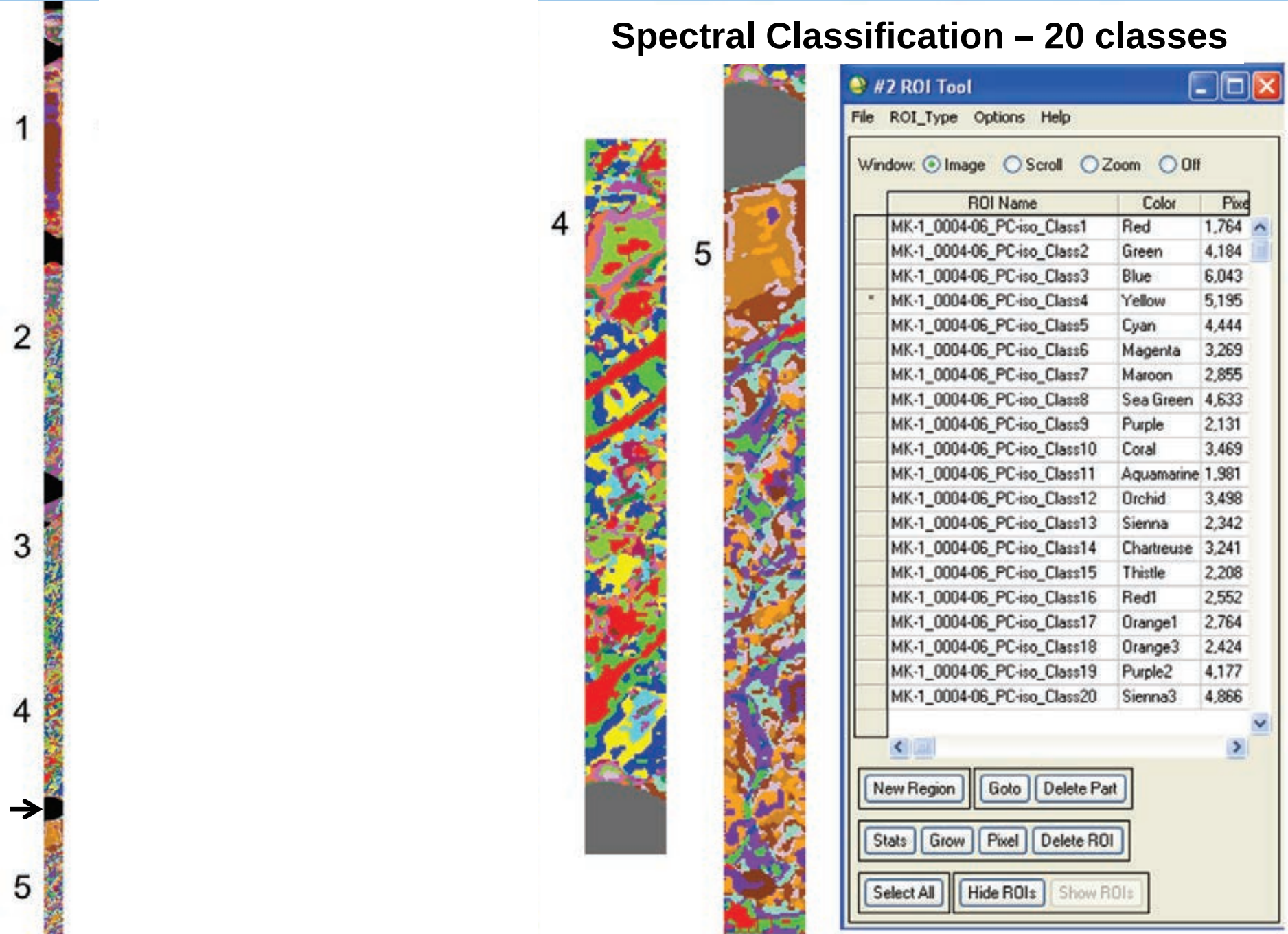
**MR-1
0004-06
Analyzed**

**MK-1 Core Color Change - Gaps Masked (BLACK)
Ready for Hyperspectral Mapping**

0004 - 06 Core
Color Image Hyperspectral



Spectral Classification – 20 classes

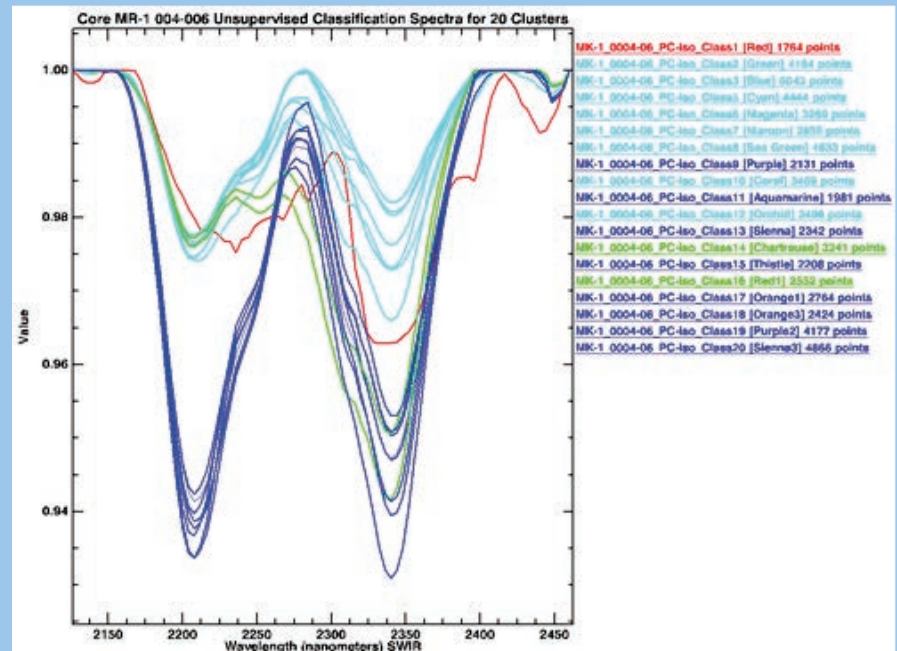


Each pixel = 0.5 x 0.5 mm

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-*

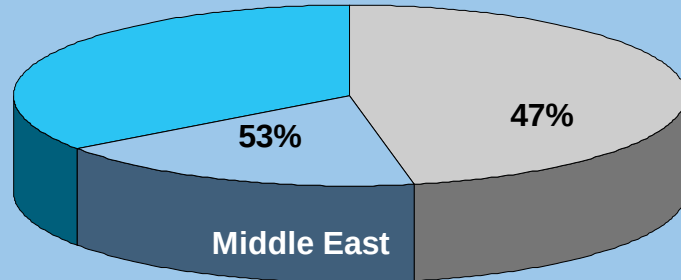
Paul (Mitch) Harris, Chevron

Sam Purkis, National Coral Reef Institute

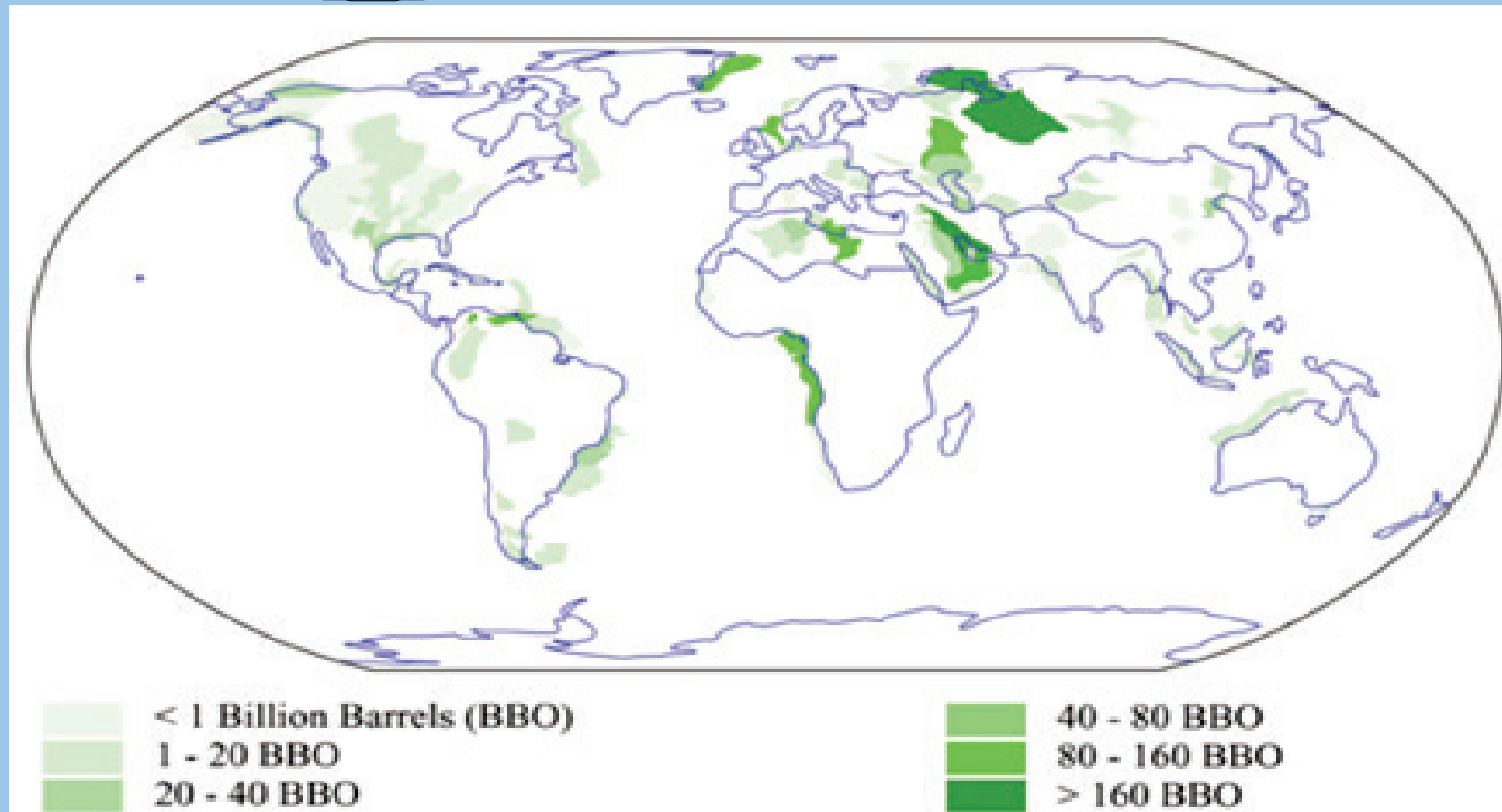
Jim Ellis, Ellis GeoSpatial



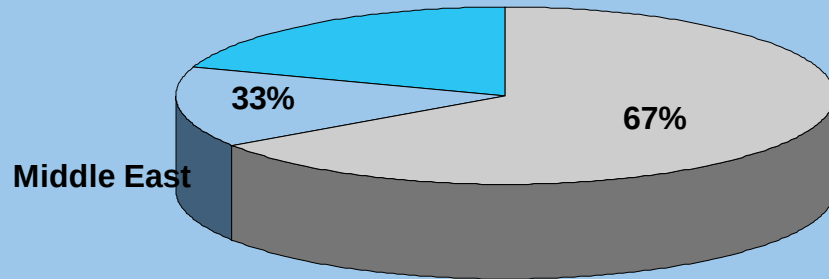
Over Half of the World's Oil Comes from Carbonate Reservoirs



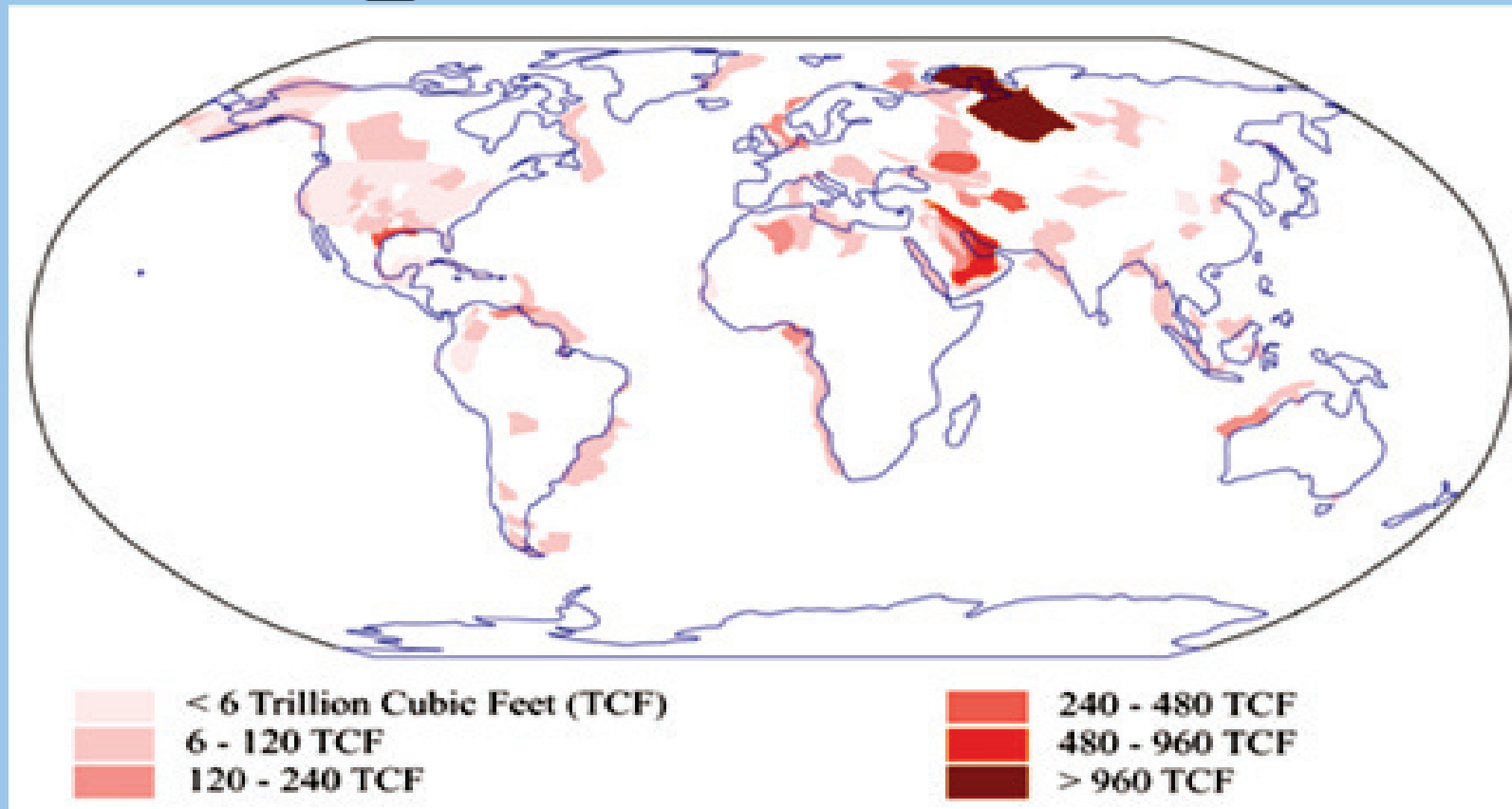
Based on Data from 17 Giant Provinces Accounting for 80% of World Oil Reserves



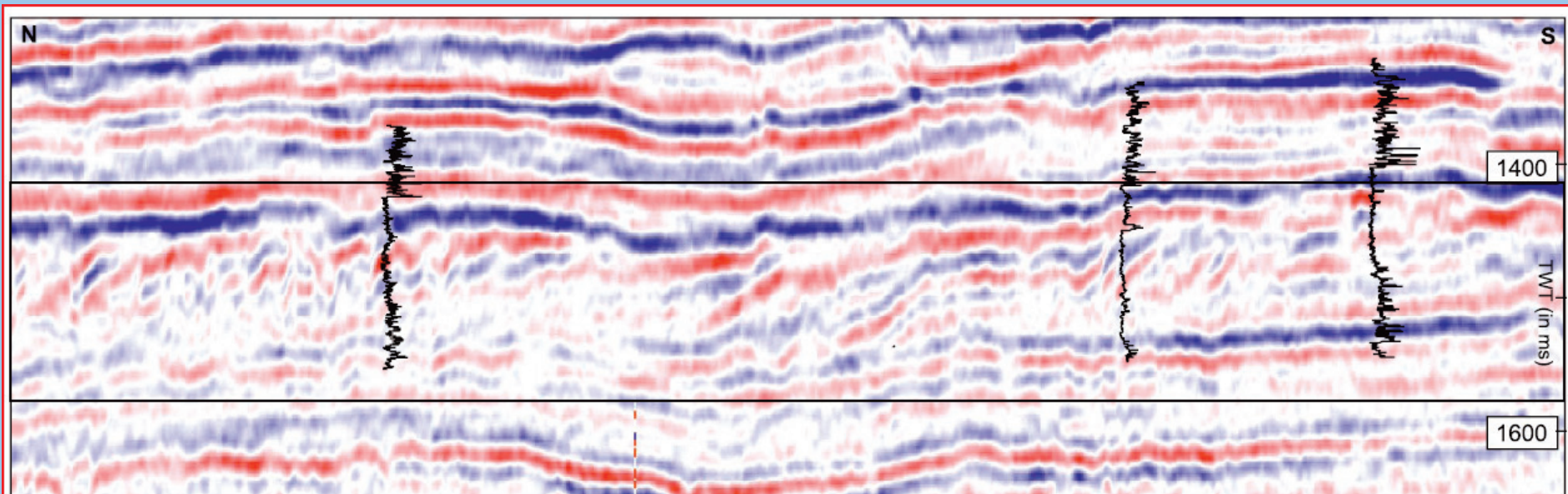
One Third of the World's Gas Comes from Carbonate Reservoirs



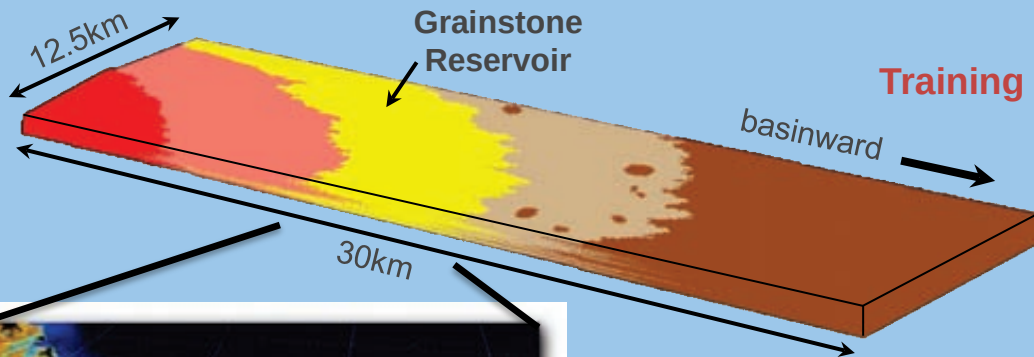
Based on Data from 16 Giant Provinces Accounting for 80% of World Gas Reserves



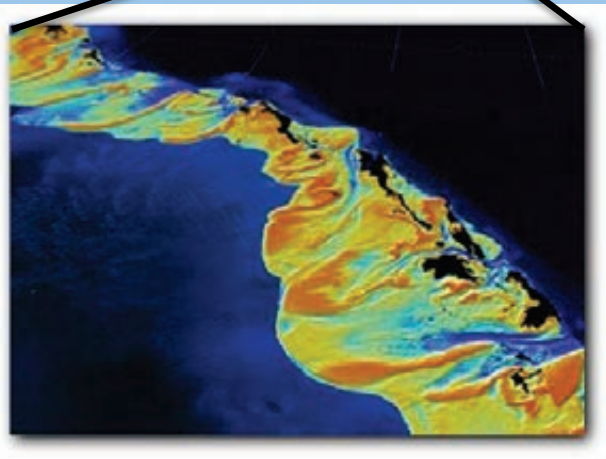
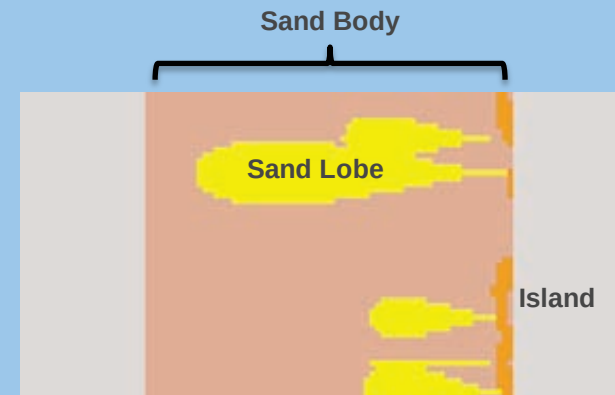
Modern Analogs Help Refine Subsurface Interpretations



Modern Analogs Can Provide Key Inputs for Reservoir Modeling

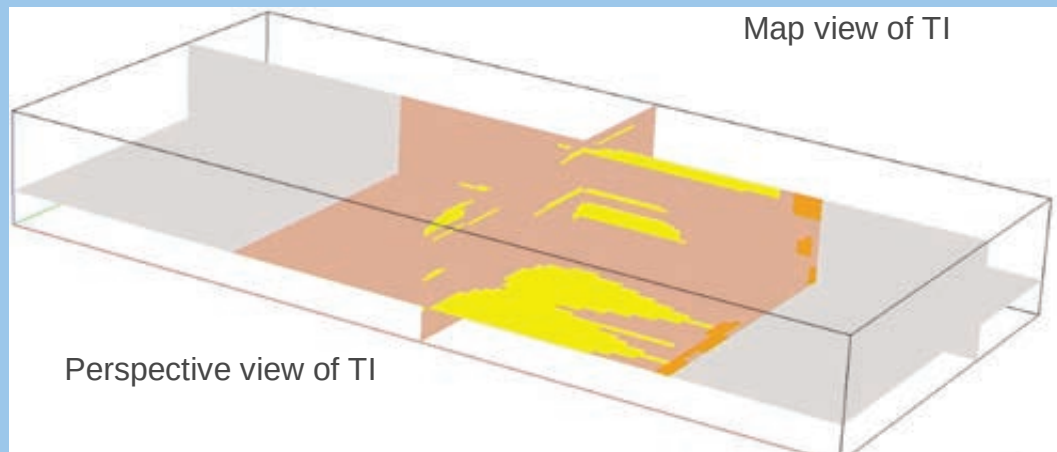


Training Images Based on Modern Analogs



Exumas, GBB

**architectural
property**



MODERN CARBONATE ENVIRONMENTS

ATLANTIC OCEAN

FLORIDA

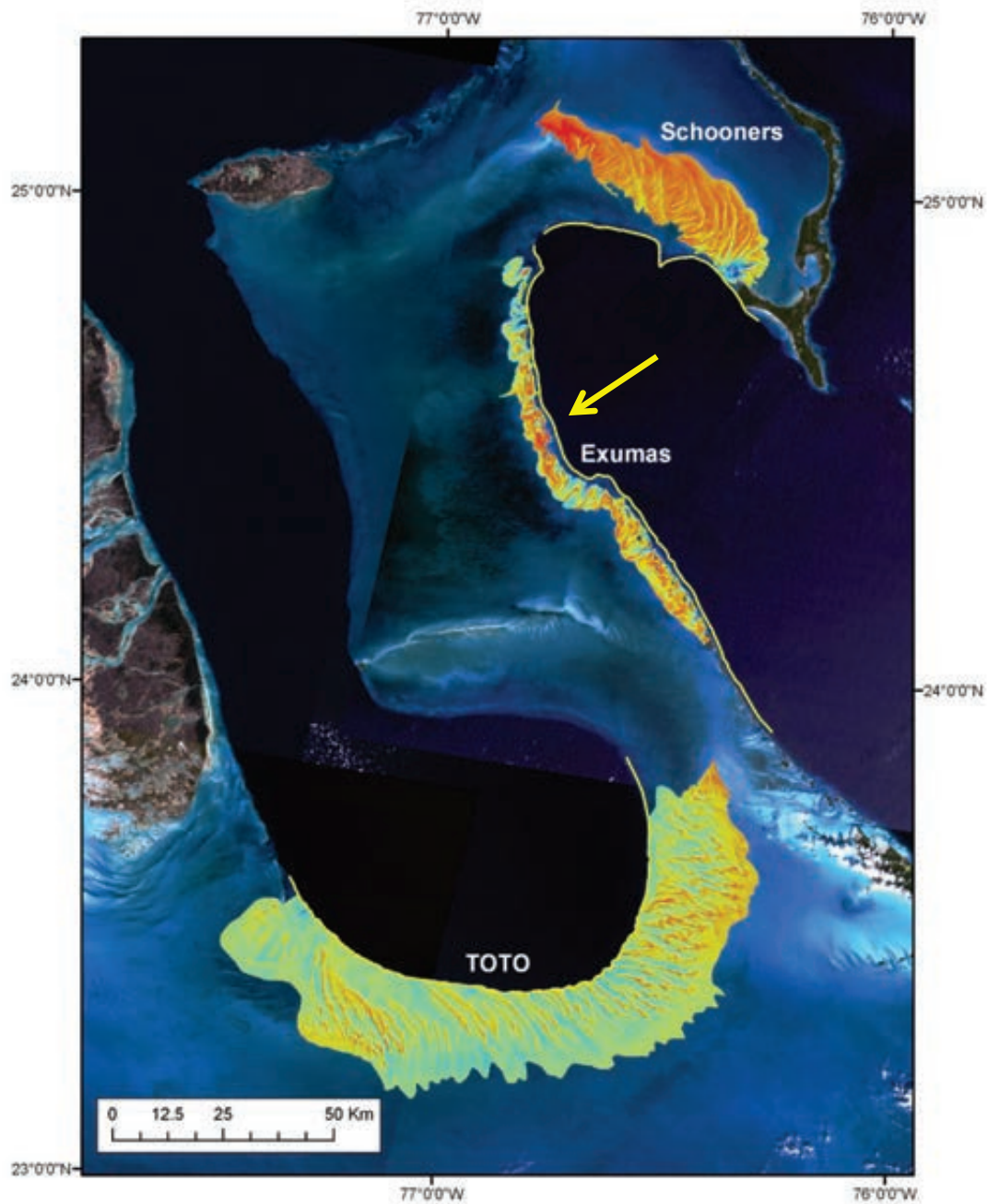
Miami

*THE
EXUMAS*

GREAT BAHAMA BANK

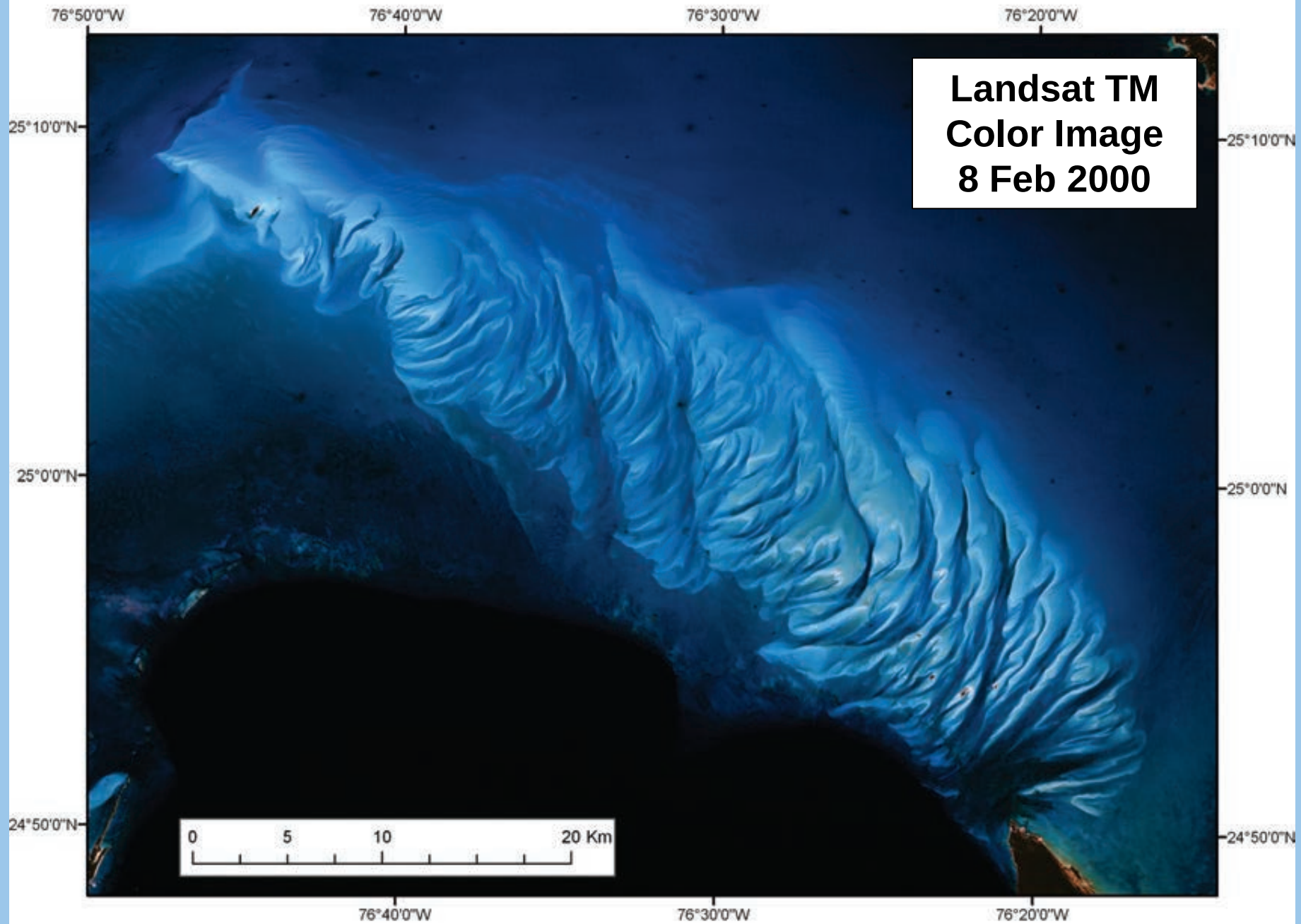
CUBA

What can be
done with
multispectral
images?

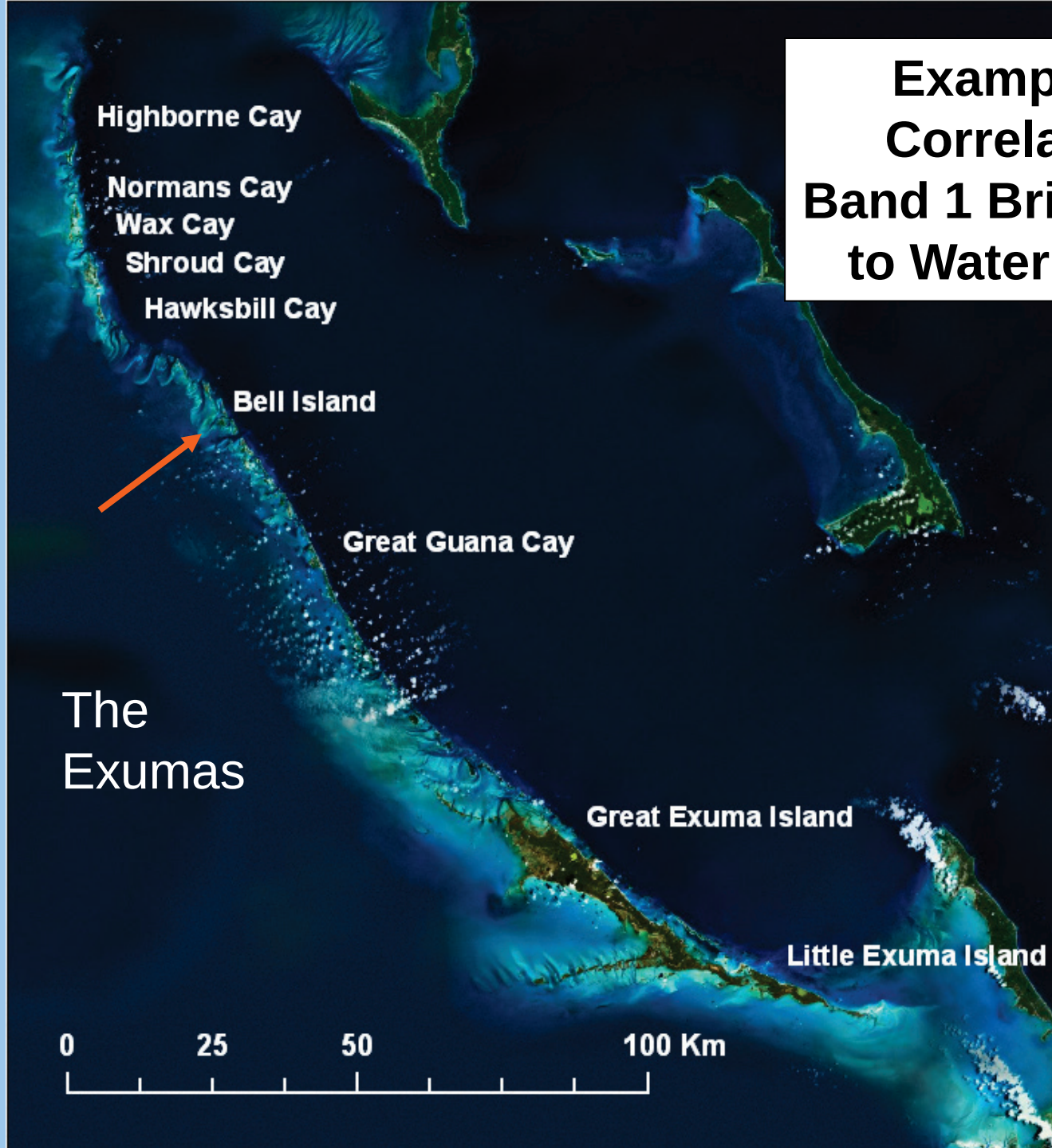


Navigation Chart





**Example of
Correlating
Band 1 Brightness
to Water Depth**



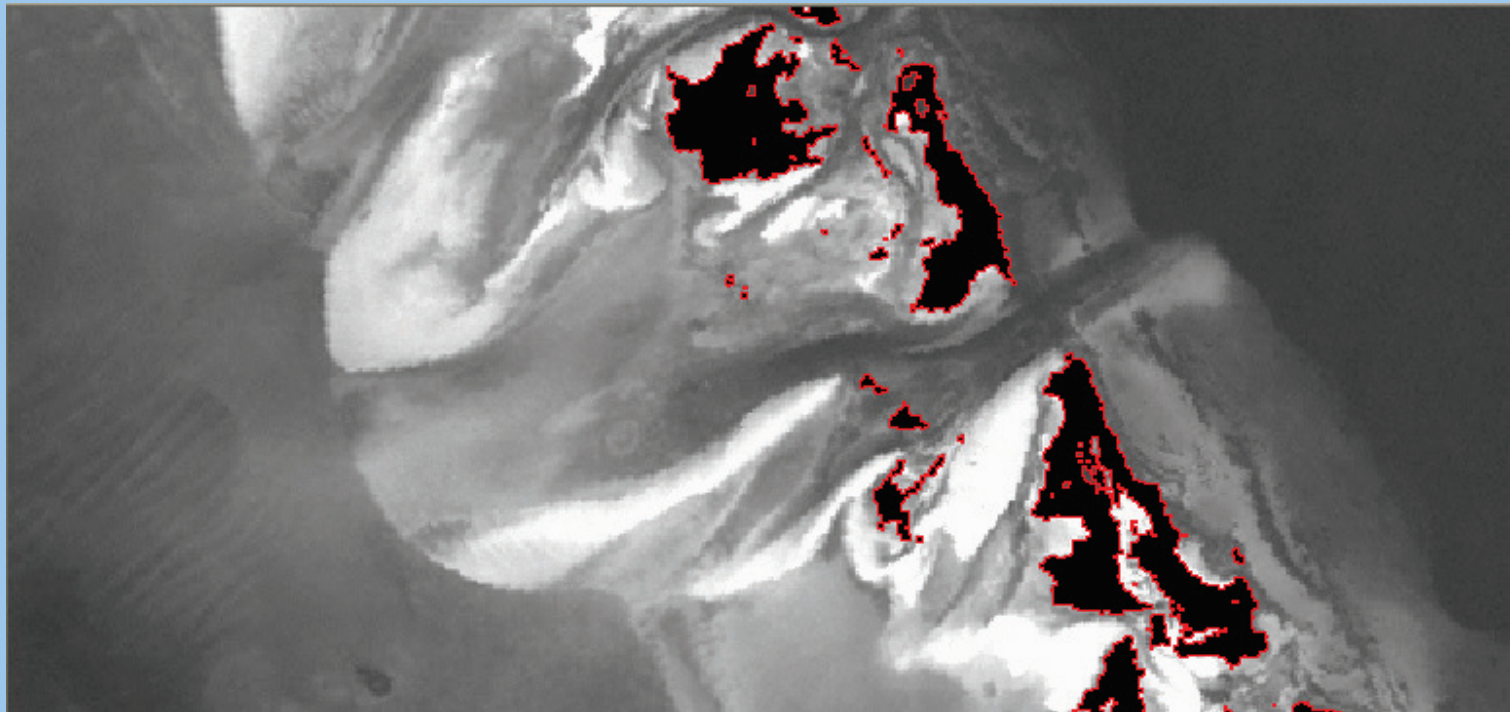
**Some Areas had
Navigation Charts**

**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**

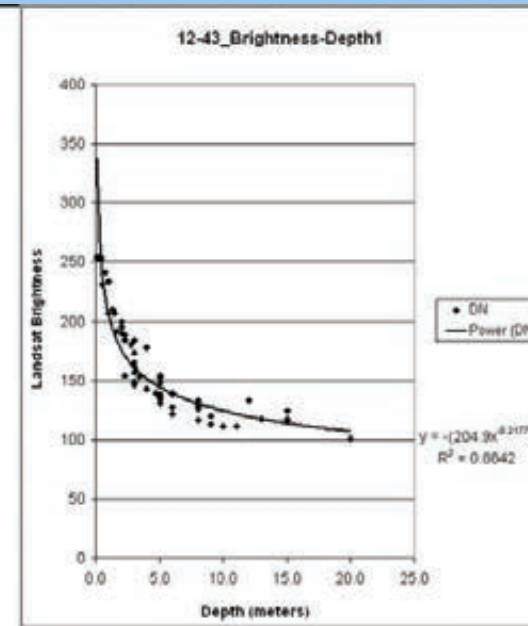


Using Imagery and Soundings to make an Offshore DEM

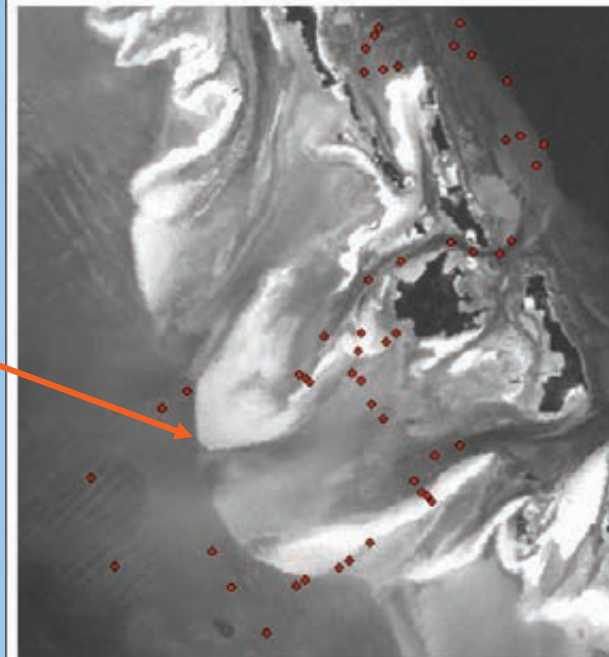


Navigation Chart with Soundings
(1:32,000) ©Lewis Offshore Ltd

ENVI Band Math

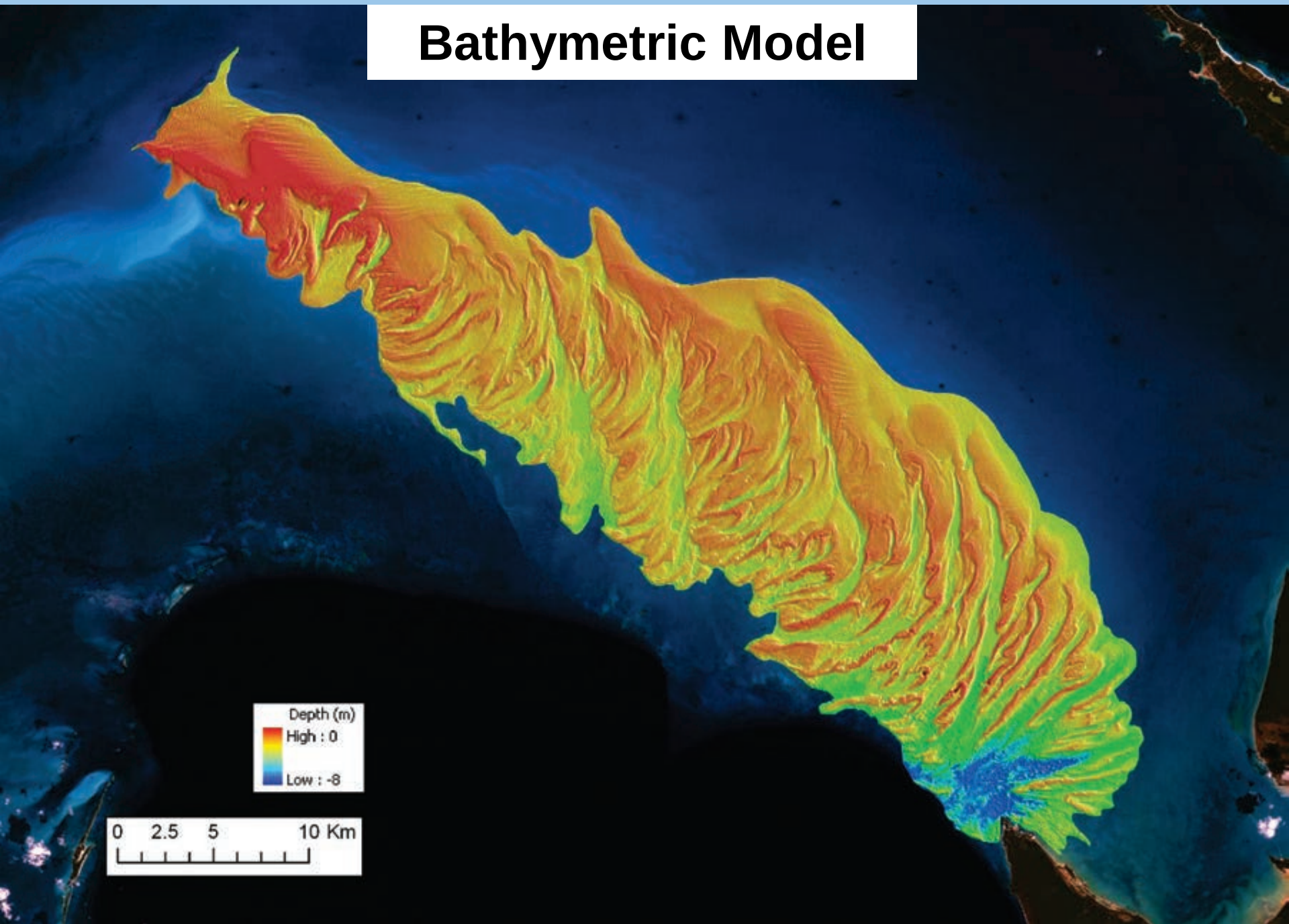


Depth	Brightness
0.1	254
0.2	254
0.4	252
0.4	254
0.5	231
0.7	242
1.0	207
1.0	233
1.0	234
1.3	210
1.4	209
1.5	207
1.6	192
2.0	195
2.0	190
2.0	200
2.3	154
2.3	184
2.3	188
2.8	180
3.0	184
3.0	165
3.0	157
3.0	162
3.0	149
3.0	173
3.0	146
3.4	153
4.0	178
4.0	143
4.7	139
4.8	138
5.0	152
5.0	130
5.0	138
5.0	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

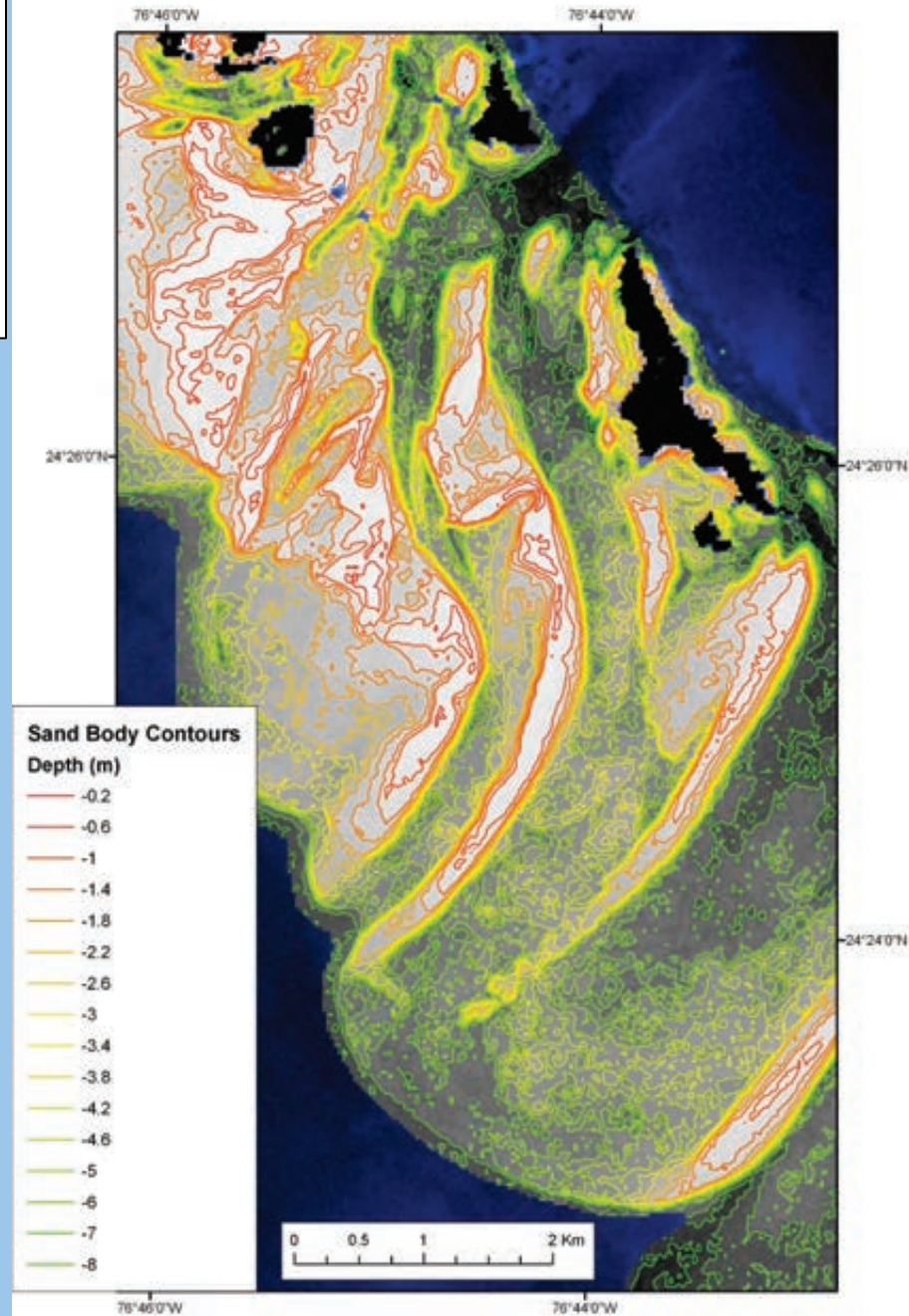


Landsat Band 1 (reflected blue light)

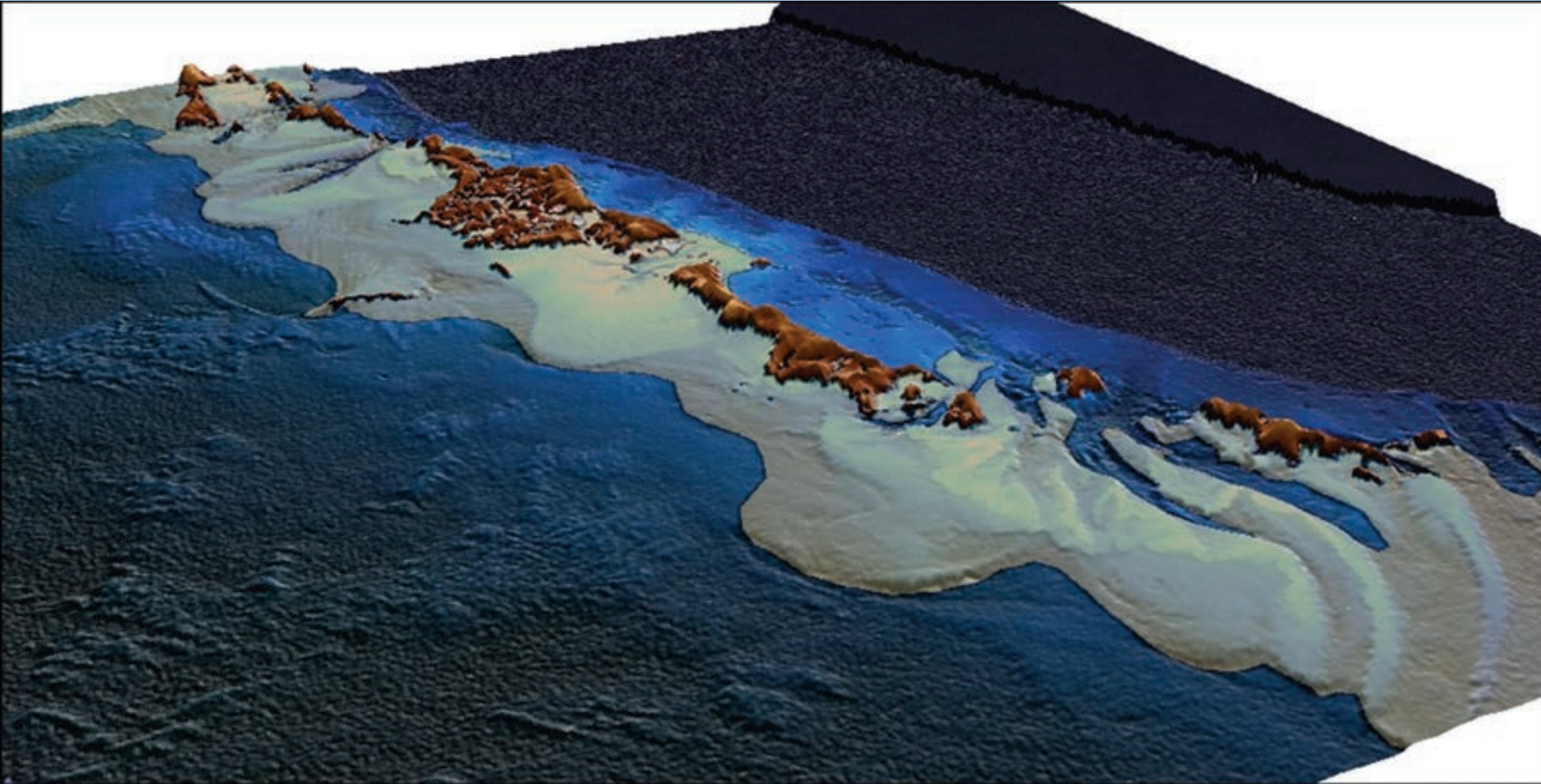
Bathymetric Model

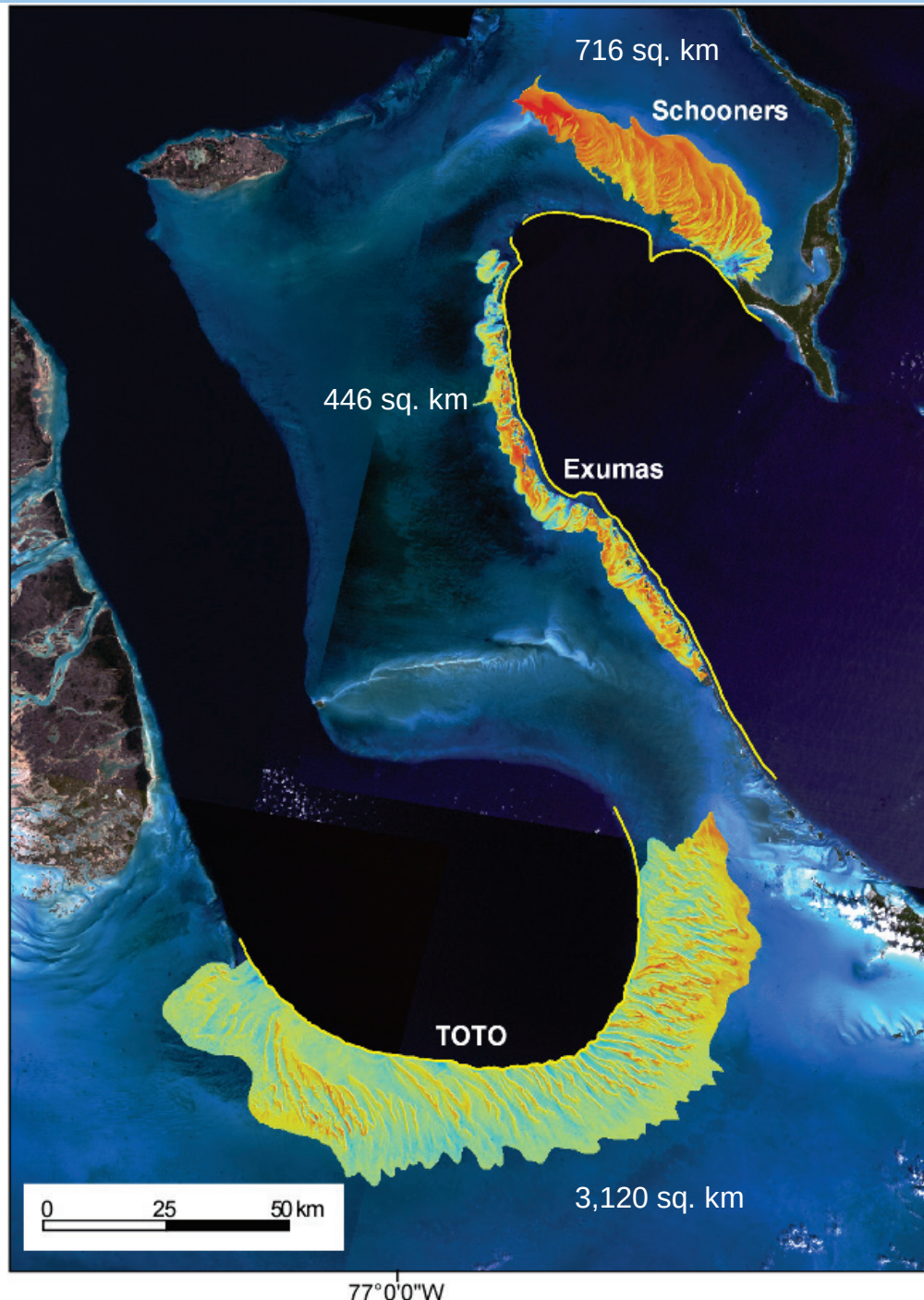


**Bathymetric
Contours
(Selected Contours
from 0.2 meter
interval)**



DEMs Enable Perspective Views - Visualization



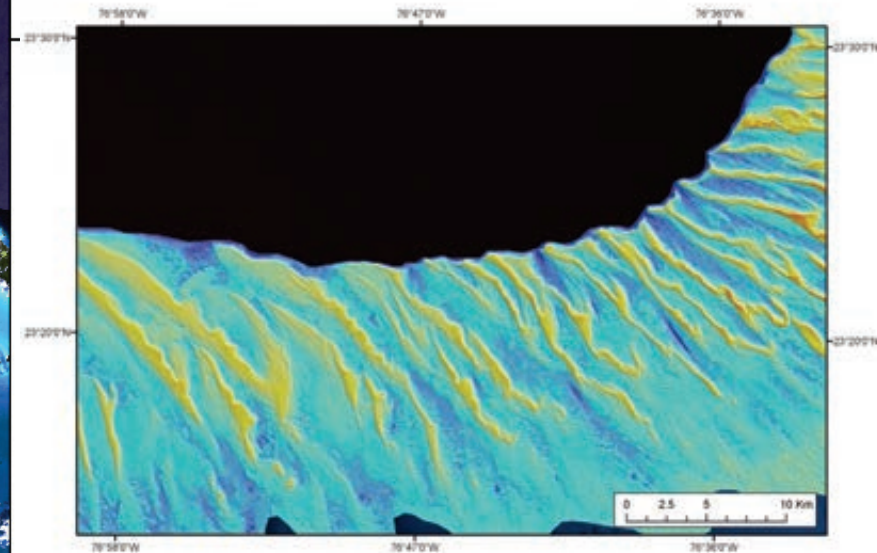


Sand Bars

3 sites

4,282 sq. km

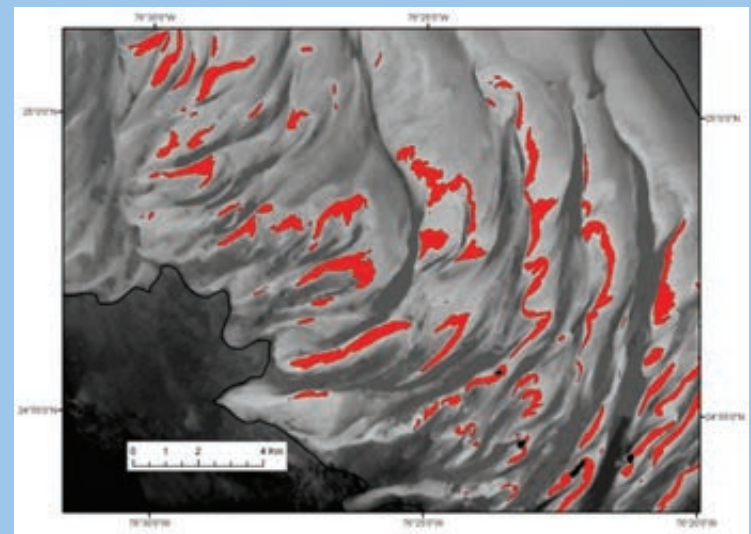
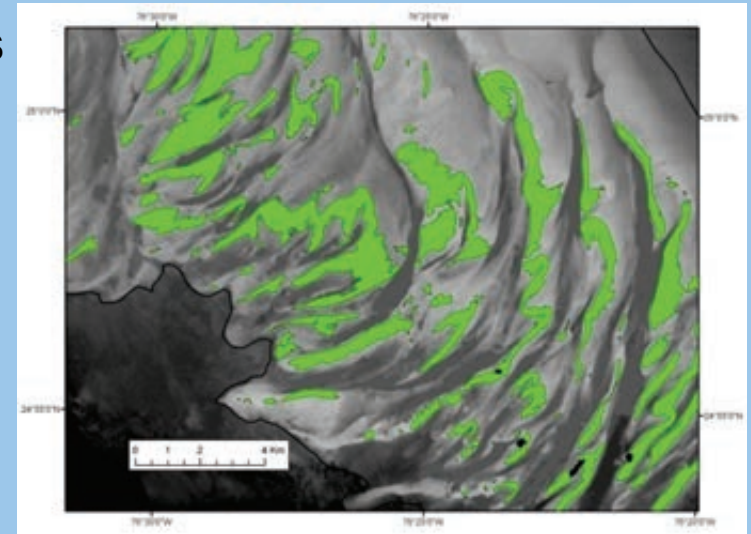
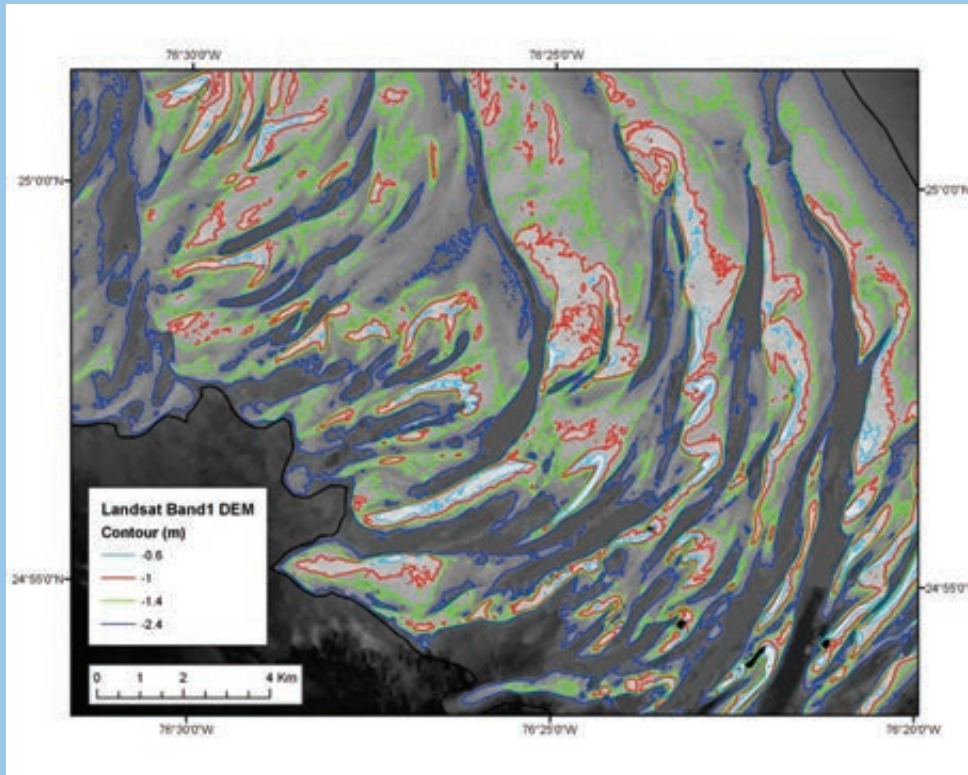
1,175 GIS polygons
partitioned to:
Sandbars (547) and
Bar-crests (628)



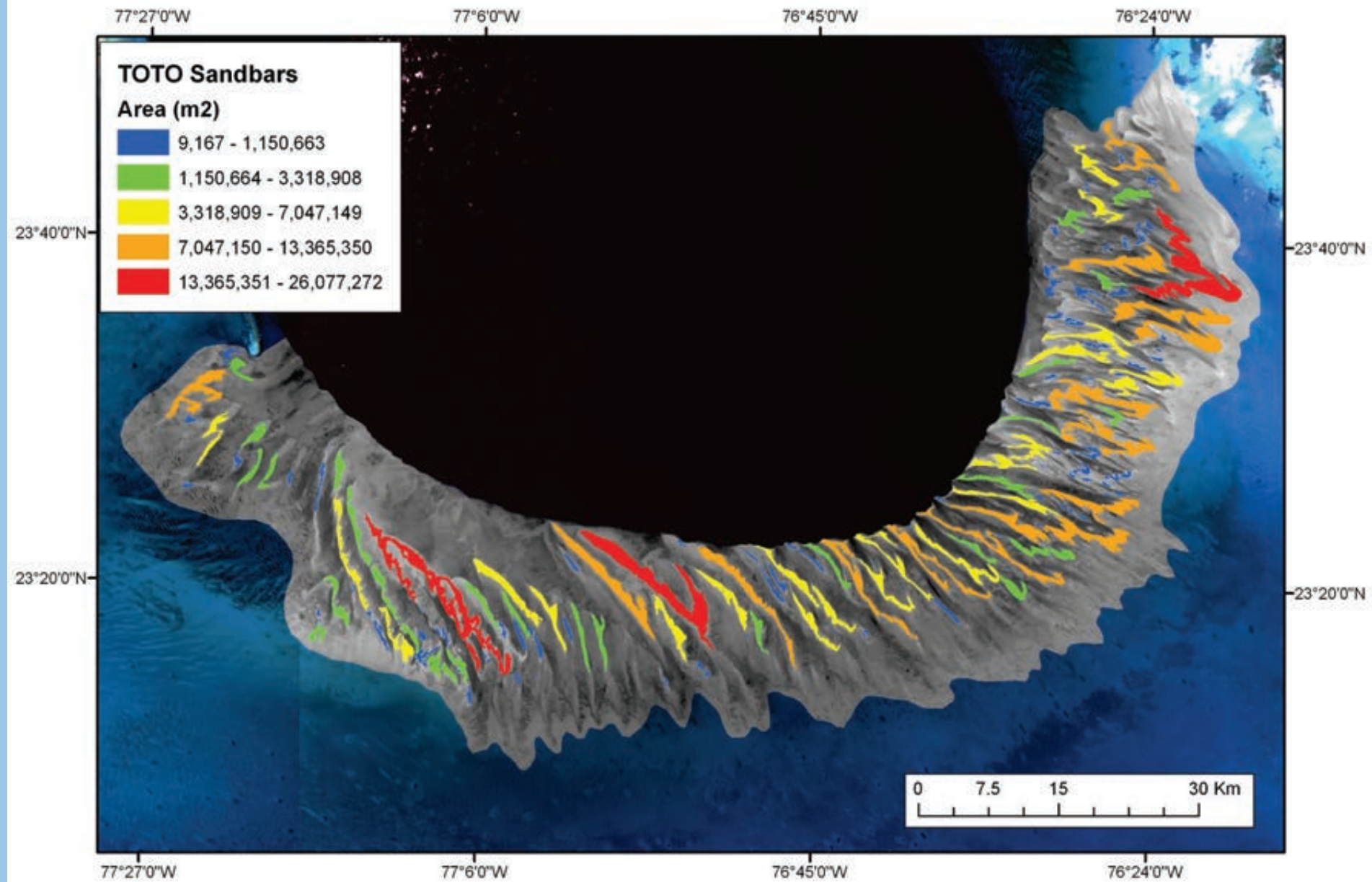
Sandbars and Bar Crests

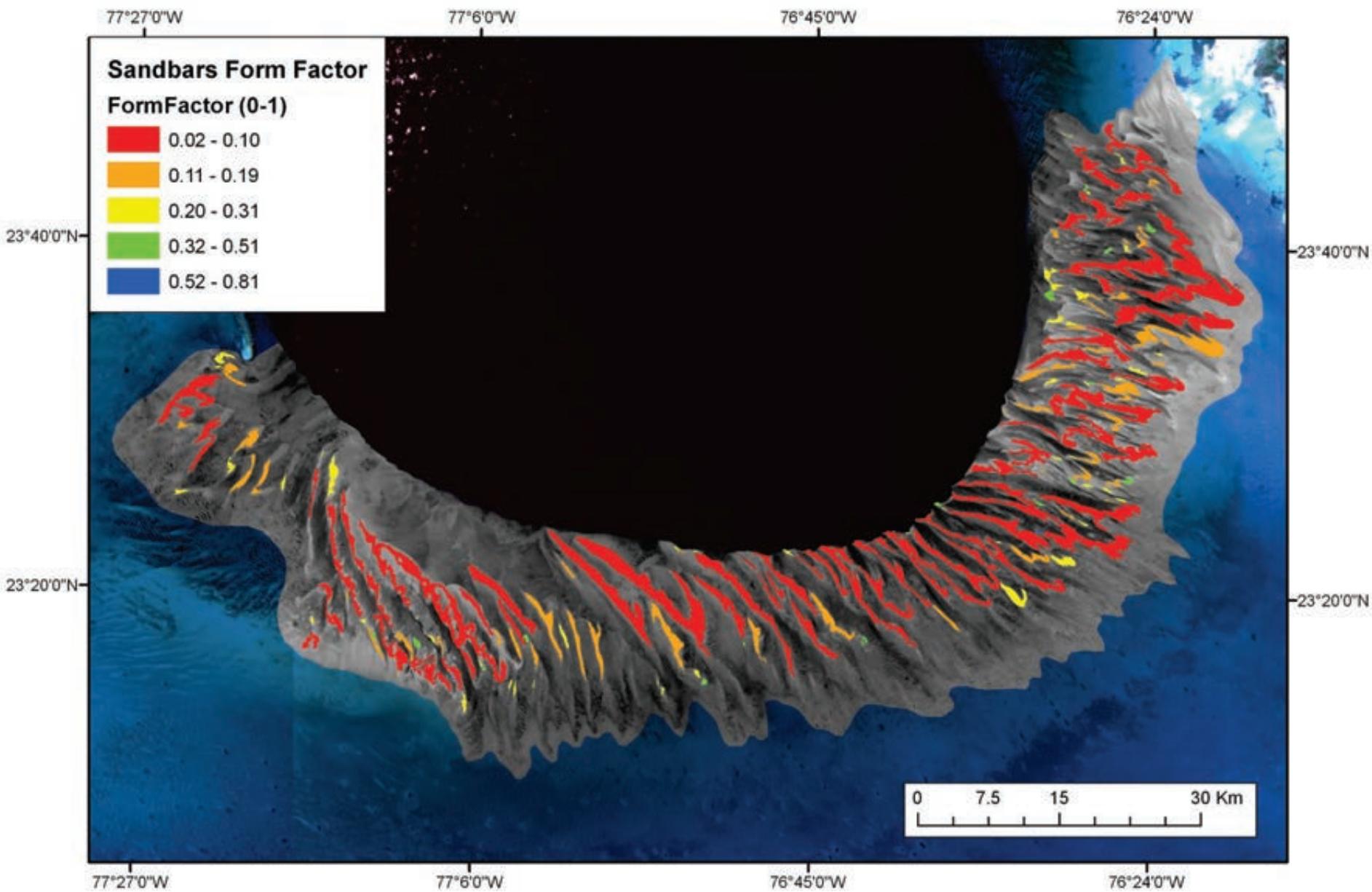
Sandbars

Select Contours of DEM

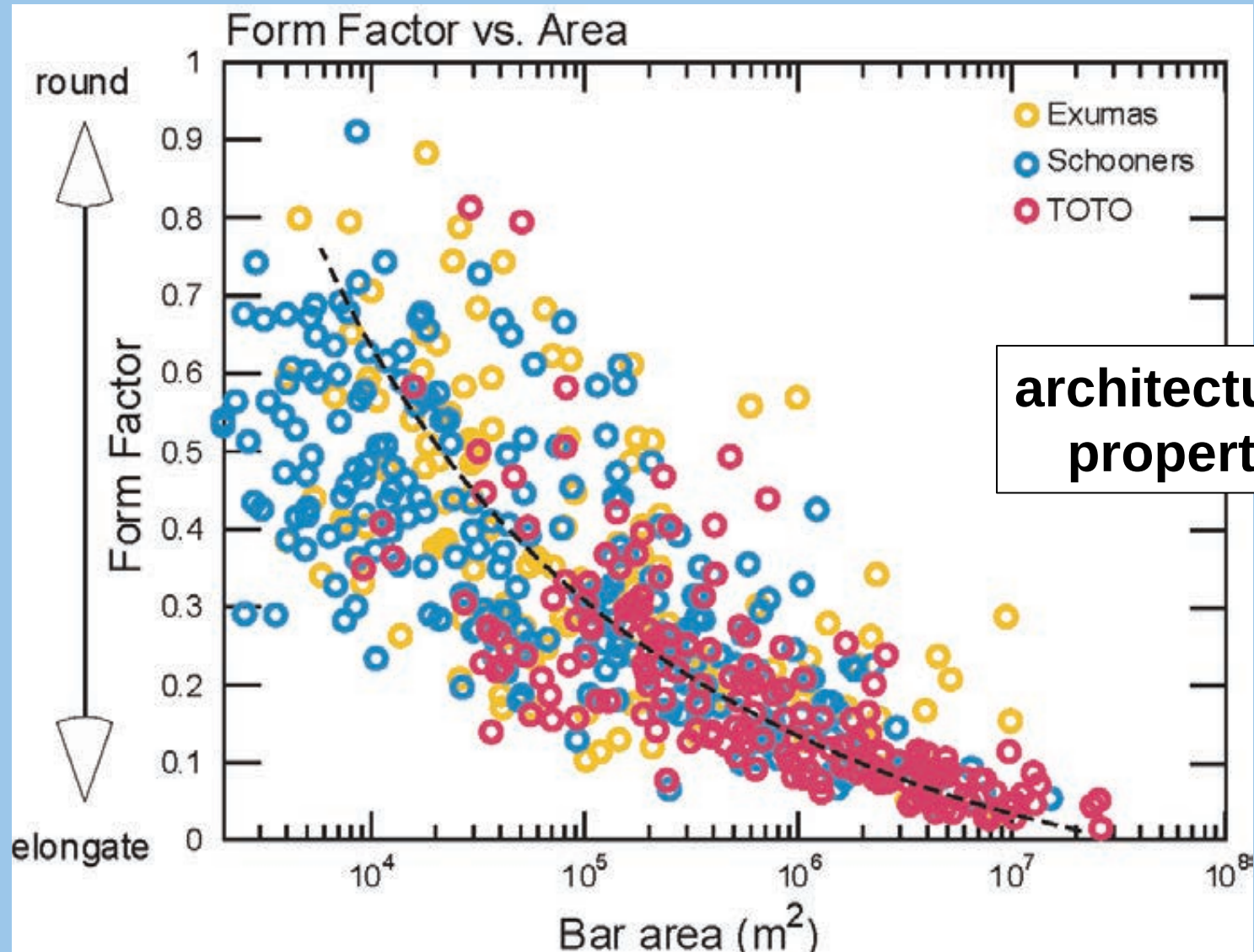


Bar Crests

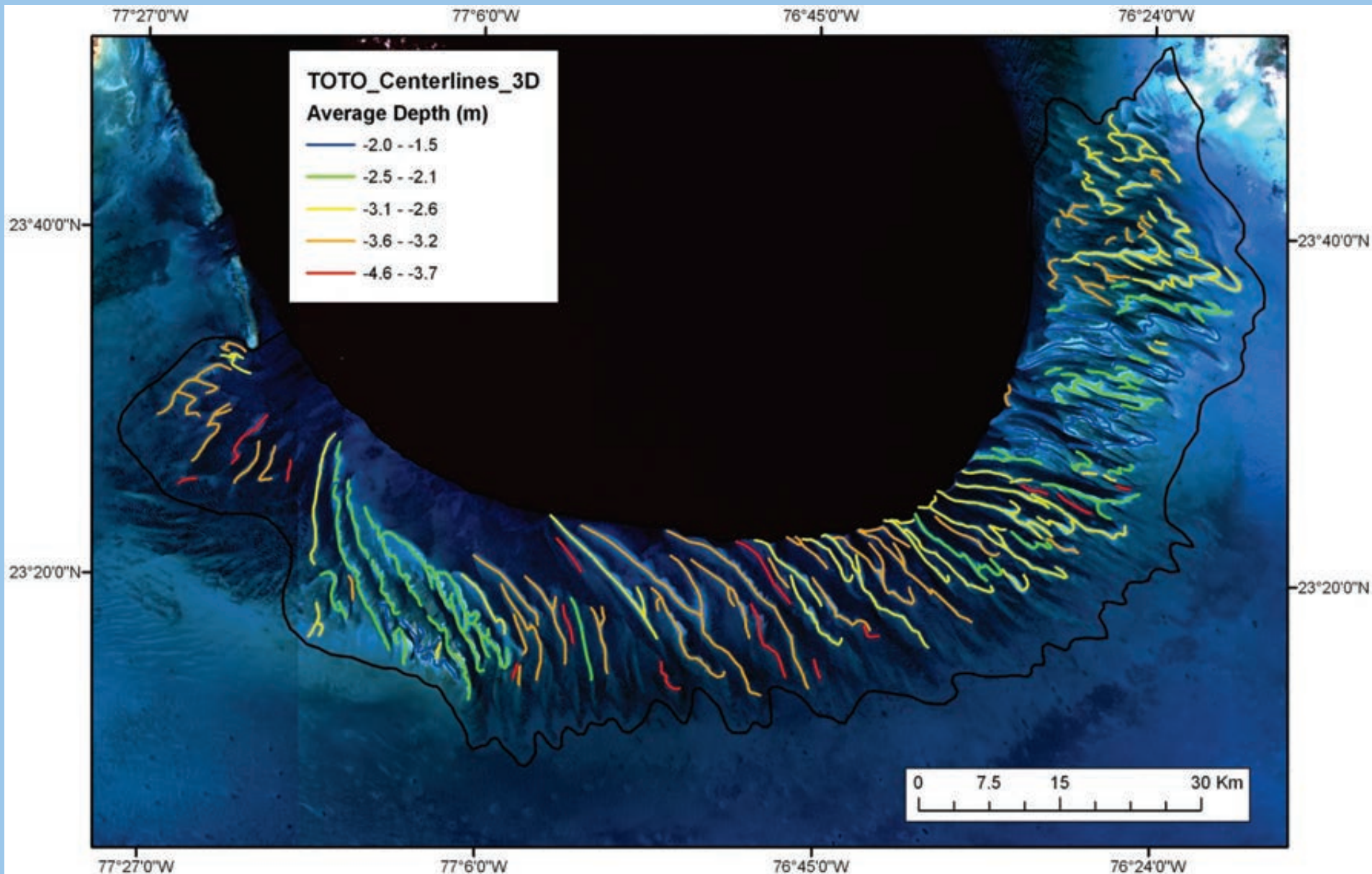




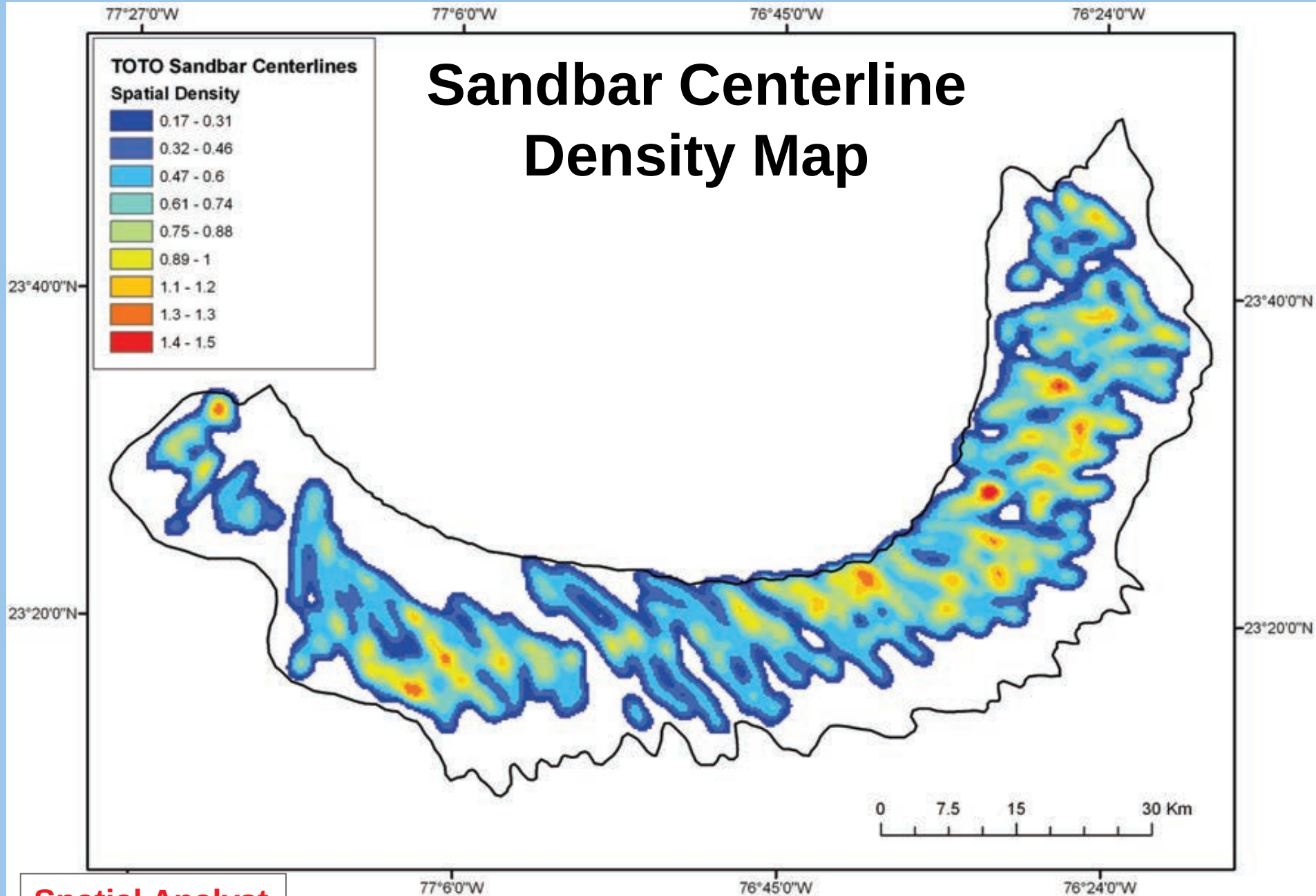
Form Factor – Sand Bar Area Distribution



Sandbar Centerline Density Map



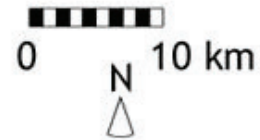
Sandbar Centerline Density Map



Exumas

Seismic View

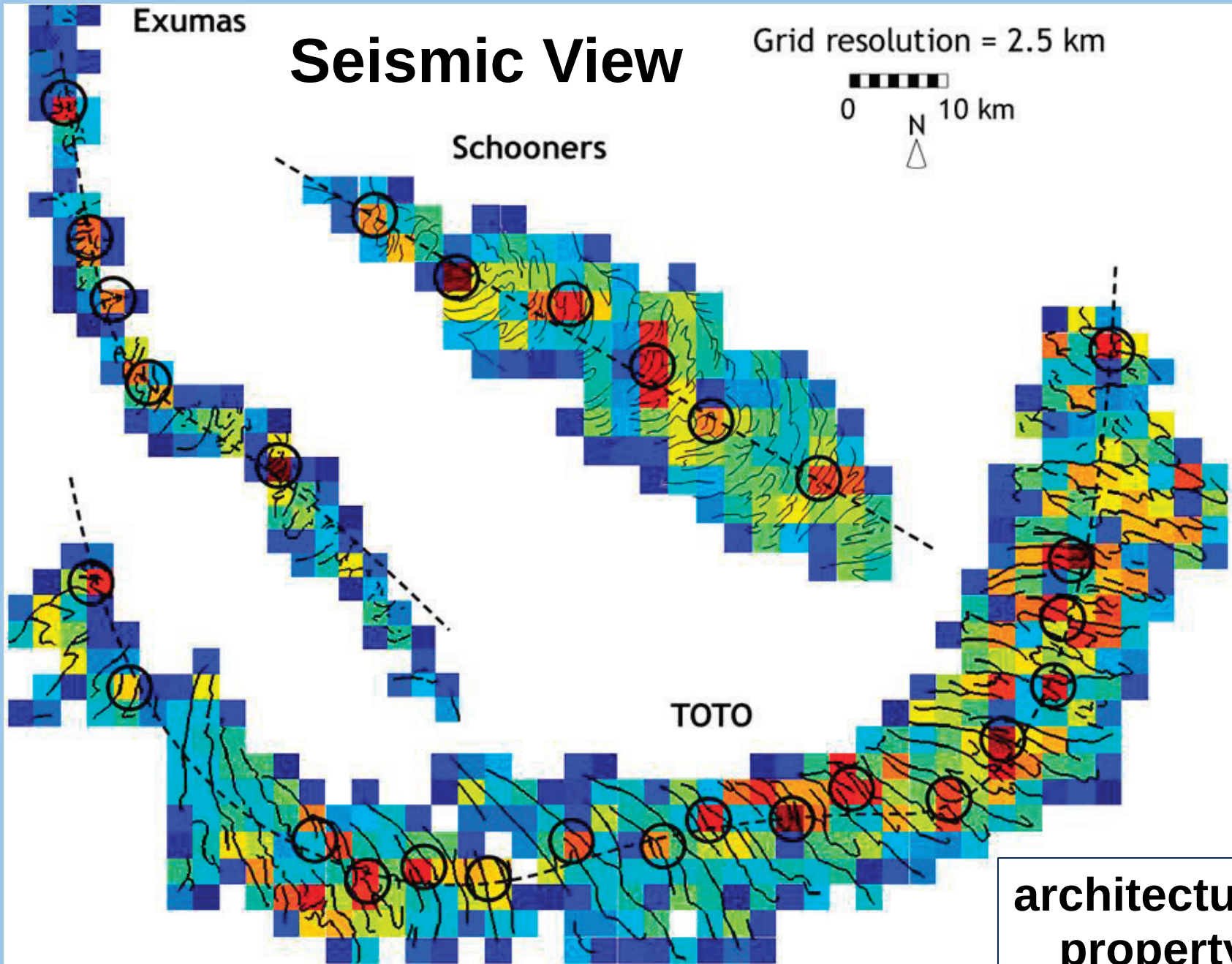
Grid resolution = 2.5 km



Schooners

TOTO

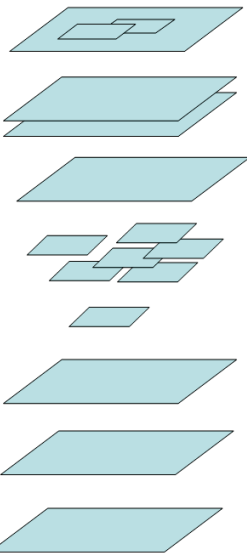
architectural
property



Information Distribution

ArcGIS Explorer
& Online

GIS Stack of Images & Maps for Exumas



New Geologic Maps

Regional
Local

Bathymetric/Topographic Contours

Derived from DEMs

GIS Hyperlinked References

Descriptions of specific sites

Integrated Images & Maps

For visualization of select areas

Bathymetry Control

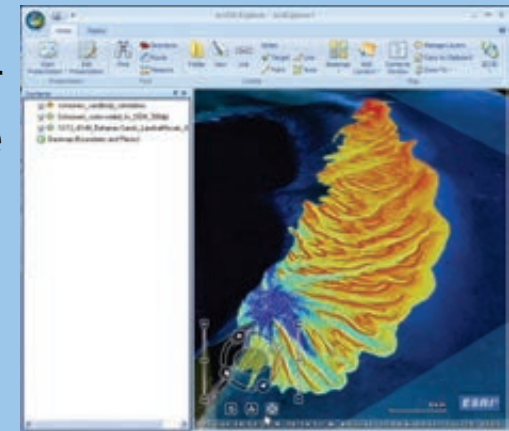
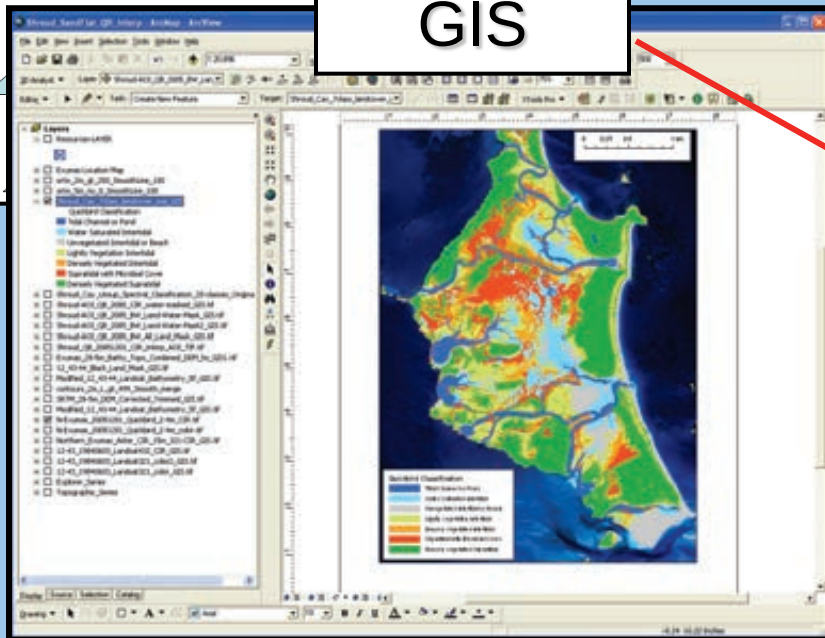
Depths from Nautical Charts

Land-Water Boundary

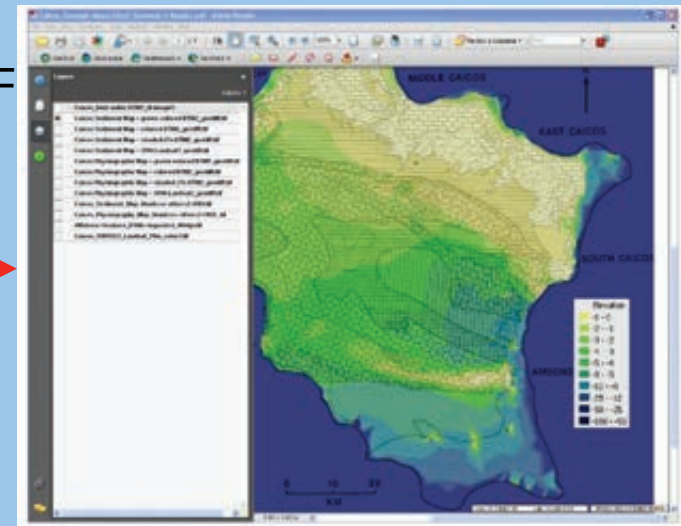
30 m - derived from Landsat

Onshore DEM

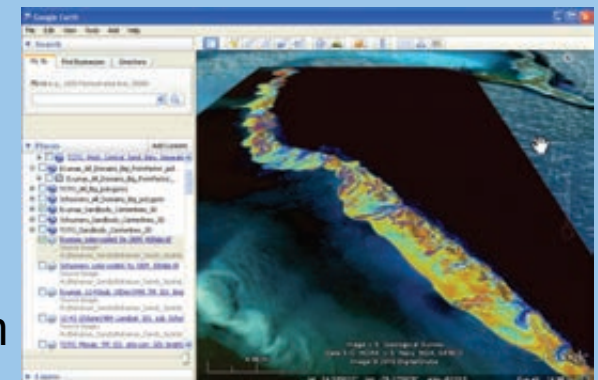
Complex
GIS



GeoPDF



.kmz's for
GoogleEarth



For the past 30 some years, the Caicos Platform has been an important area for studies of Holocene and Pleistocene carbonate successions and a destination for numerous geoscientists interested in learning about modern carbonate sedimentary systems. During the past few years there has been a renewed interest in understanding the geology of the platform, stemming in large part from recognition in the petroleum industry that more refined reservoir models of carbonate systems are needed both in exploration and development. The impetus for this workshop and this volume was a desire to bring together both present and past Caicos Platform workers with those not familiar with the Platform to share knowledge on the Holocene to Pleistocene sedimentology, diagenesis, platform evolution, and the applicability of the platform as an analogue for ancient isolated carbonate platforms.

This volume includes a broad array of papers and is divided into five sections:

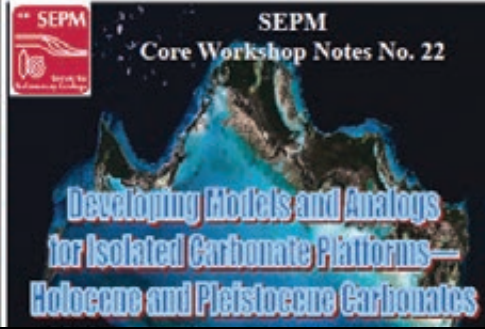
- Introduction
- Holocene, Platform-Scale Surficial Sediment and Facies Distribution
- Holocene Subsurface Studies
- Holocene Sedimentology, Reservoir and Source-Rock
- Pre-Holocene Platform Evolution Sedimentology, and

William Morgan and Paul (Mitch) Harris

The DVD contains an extensive program. If the DVD does not automatically run when inserted into your computer, please refer to the enclosed instructions for more information. If there are any questions contact SEPM.

Developing Models and Analogs for Isolated Carbonate Platforms and Pleistocene Carbonates of Caicos Platform, BIR
SEPM Core Workshop 22, Copyright © 2008
SEPM (Society for Sedimentary Geology), Digital Version, ISBN

Caicos Carbonates



The Exuma Islands and surrounding carbonate sand bodies of Great Bahama Bank are an important training venue, an area of interest to researchers of modern carbonates, and a valuable modern analog for understanding carbonate sand bodies in the subsurface. We hope to promote this interest by making readily available a set of processed satellite images, offshore/onshore digital elevation model (DEM), and interpretation maps organized into a GIS, along with several examples of how this data can be visualized and used for geological interpretation.

Our application of spatial analysis techniques to the Exumas and its carbonate sand bodies provides new insights into this modern carbonate setting and potentially provides data that can have value as an analog in reservoir characterization and modeling. To increase accessibility, improve learning, and promote spatially accurate feedback, the stack of images, color-coded DEM, and geologic maps were exported out of GIS into easier and more flexible viewing programs such as GeoPDFs, GoogleEarth, and Animations.

PAUL M. (MITCH) HARRIS and JAMES ELLIS

DVD #1 contains an extensive program. If the DVD does not automatically run when inserted into your computer, please refer to the enclosed instructions for more information. If there are any questions contact SEPM.

Satellite Imagery, Visualization, and Geological Interpretation of the Exumas, Great Bahama Bank: An Analog for Carbonate Sand Reservoirs
SEPM Short Course Notes 53, Copyright © 2009
SEPM (Society for Sedimentary Geology), ISBN 978-1-6676-198-0



SEPM Short Course Notes No. 53

Satellite Image Processing and Geospatial Interpretation of Modern Carbonate Sand Deposits on Great Bahama Bank

Processed satellite images, derived bathymetry (Digital Elevation Models), and sand body interpretation maps of three key areas of modern carbonate sand deposition on Great Bahama Bank (GBB) are organized into a GIS to develop morphometric data. The results of the sand body and sandbar interrogation imply that certain architectural properties of high-energy sand deposits are generic. We think such results broaden our perspective of the types of information that can be derived from studies of the modern and hopefully will stimulate further studies.

Collectively, the sand deposits show a range of depositional facies patterns. Running the southern end of Tongue of the Ocean (TOTO) is the broadest expanse of "high-energy" sands found in the Bahamas characterized by narrow sandbars separated by wide, deep channels and a lack of islands. A variation of the tidal bar motif with broader and more irregular sandbars, relatively narrow channels, and few small islands occurs at the northern end of Exuma Sound (Schooners). Sands associated with tidal channels and the numerous islands of the Exumas chain along the western edge of Exuma Sound occur primarily as flood tidal deltas.

An objective of this study is to move the geospatial data from a high-end GIS (GBB DVD 2) into lower cost and more readily available viewers, i.e., GeoPDF, Google Earth, animation, and ArcExplorer, to support training and improve communication. Examples of these types of files, as well as a detailed and well-illustrated summary paper and appendix, are included on GBB DVD 1.

PAUL M. (MITCH) HARRIS, JAMES ELLIS, and SAMUEL J. PURKIS

Note:
GBB DVD-1 contains an extensive program. If your computer security does not allow it to run, please open the GBB DVD 1 folder and then file "GBB Paper.pdf". GBB DVD-2 contains high-end GIS files for those that want to access them and are described in the paper and appendix on DVD-1. To access the files open the appropriate folders on DVD-2.

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

SEPM SC NOTES # 54 - DELINEATING AND QUANTIFYING DEPOSITIONAL FACIES PATTERNS OF MODERN CARBONATE SAND DEPOSITS ON GREAT BAHAMA BANK

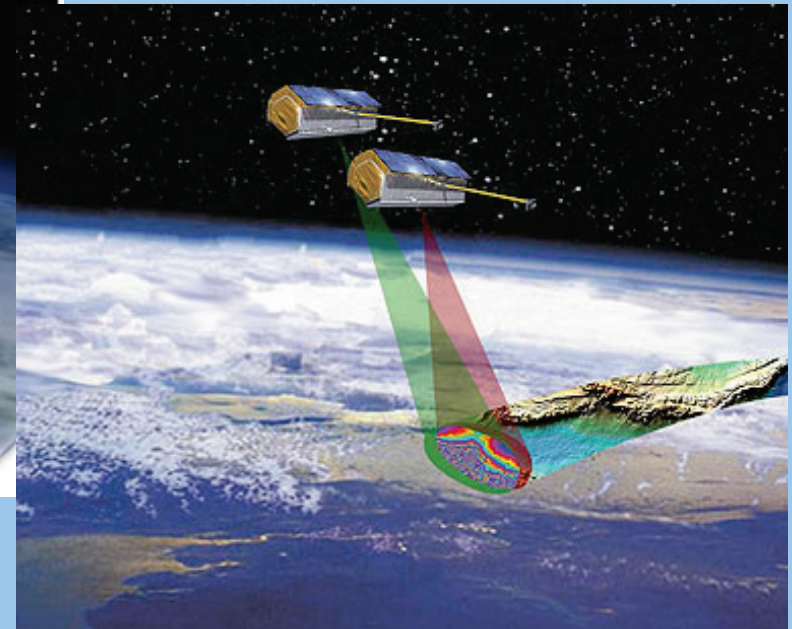
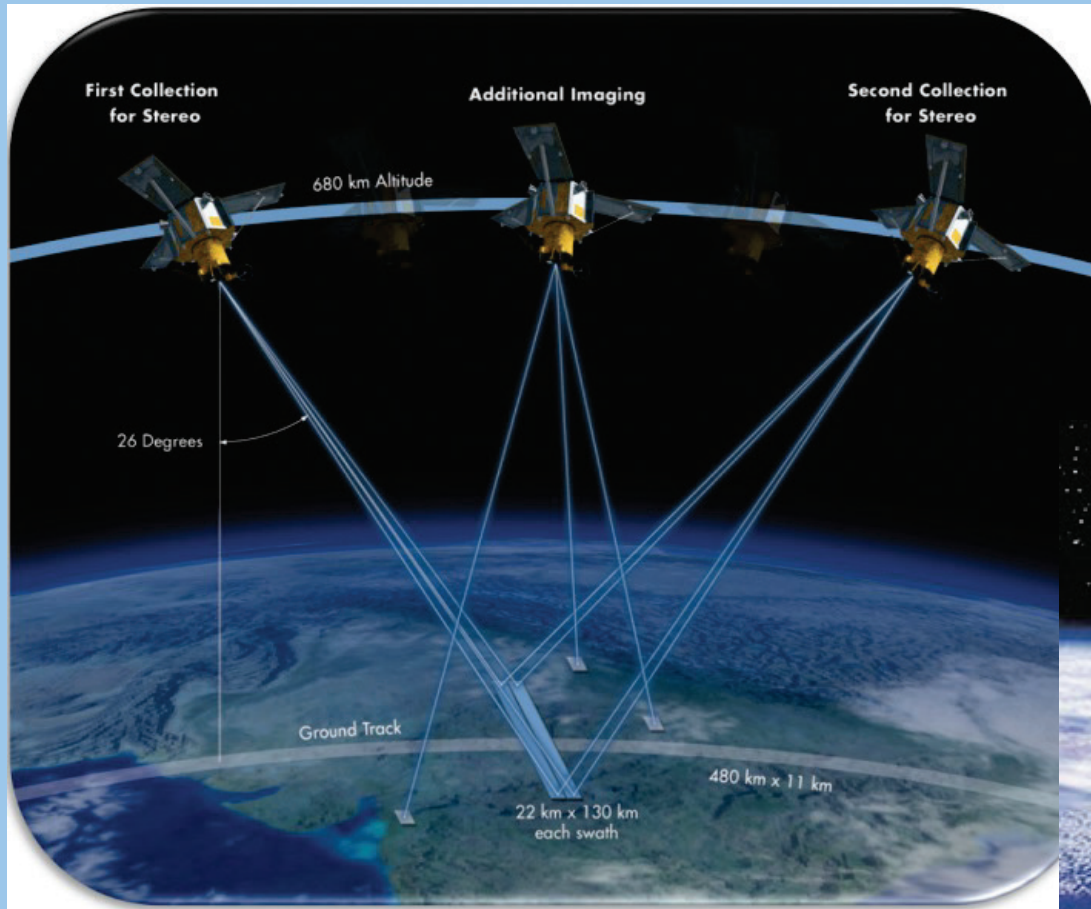


Digital Elevation Models DEMs



Acquiring Images with Off-Nadir and Fore & Aft Viewing

Enables stereoscopic 3D viewing & building surface elevation models

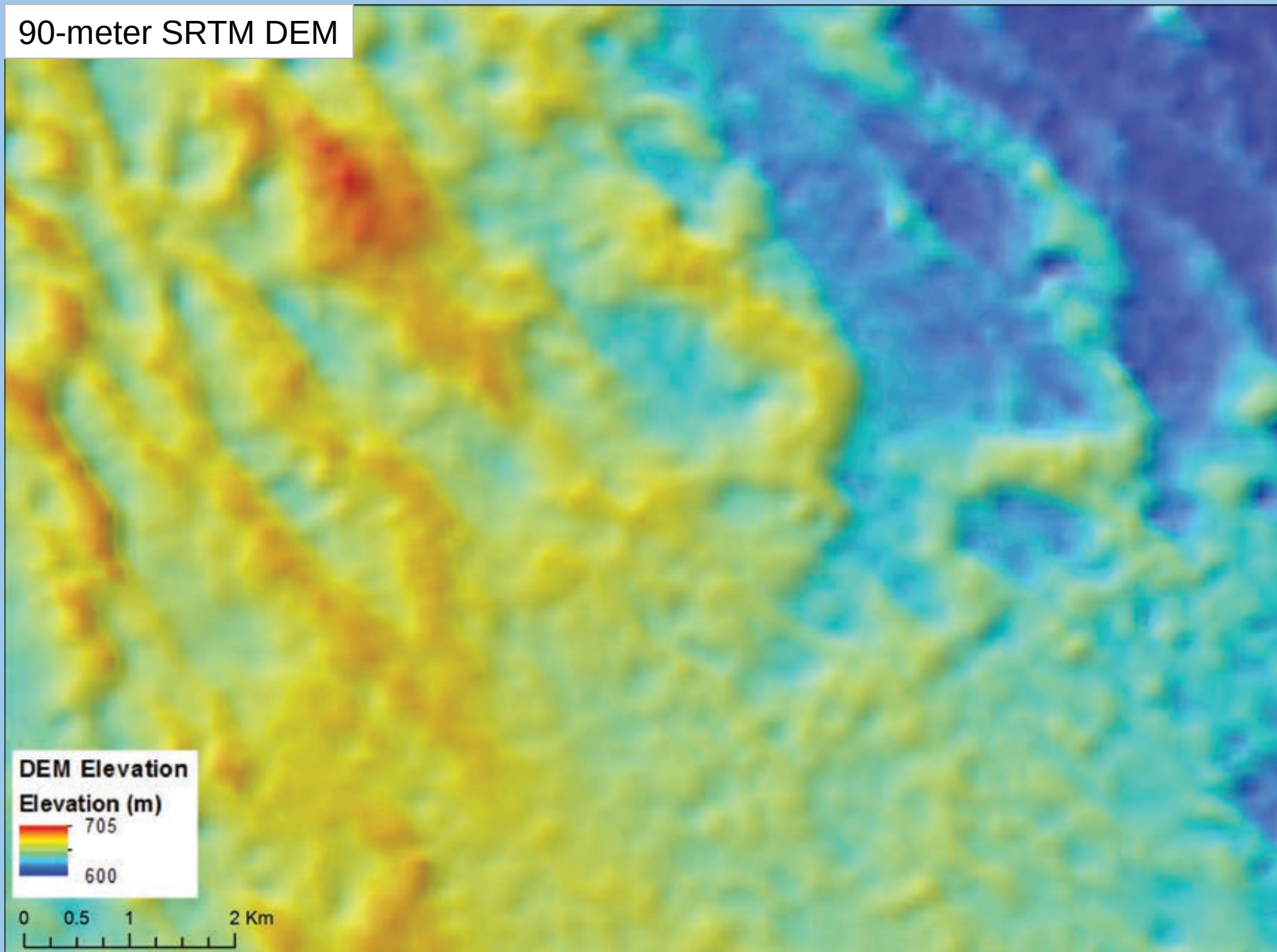


Satellite Image

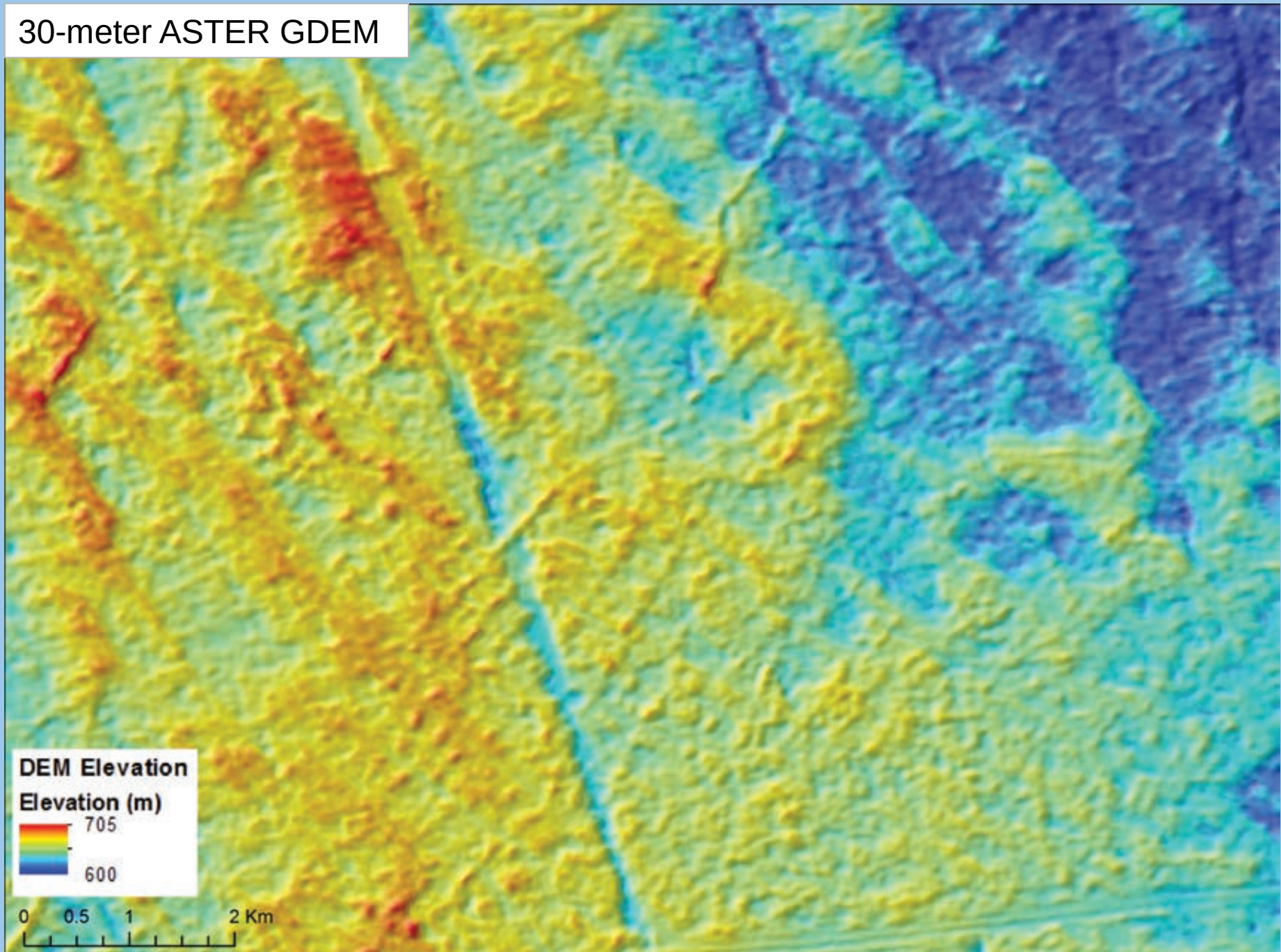


Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

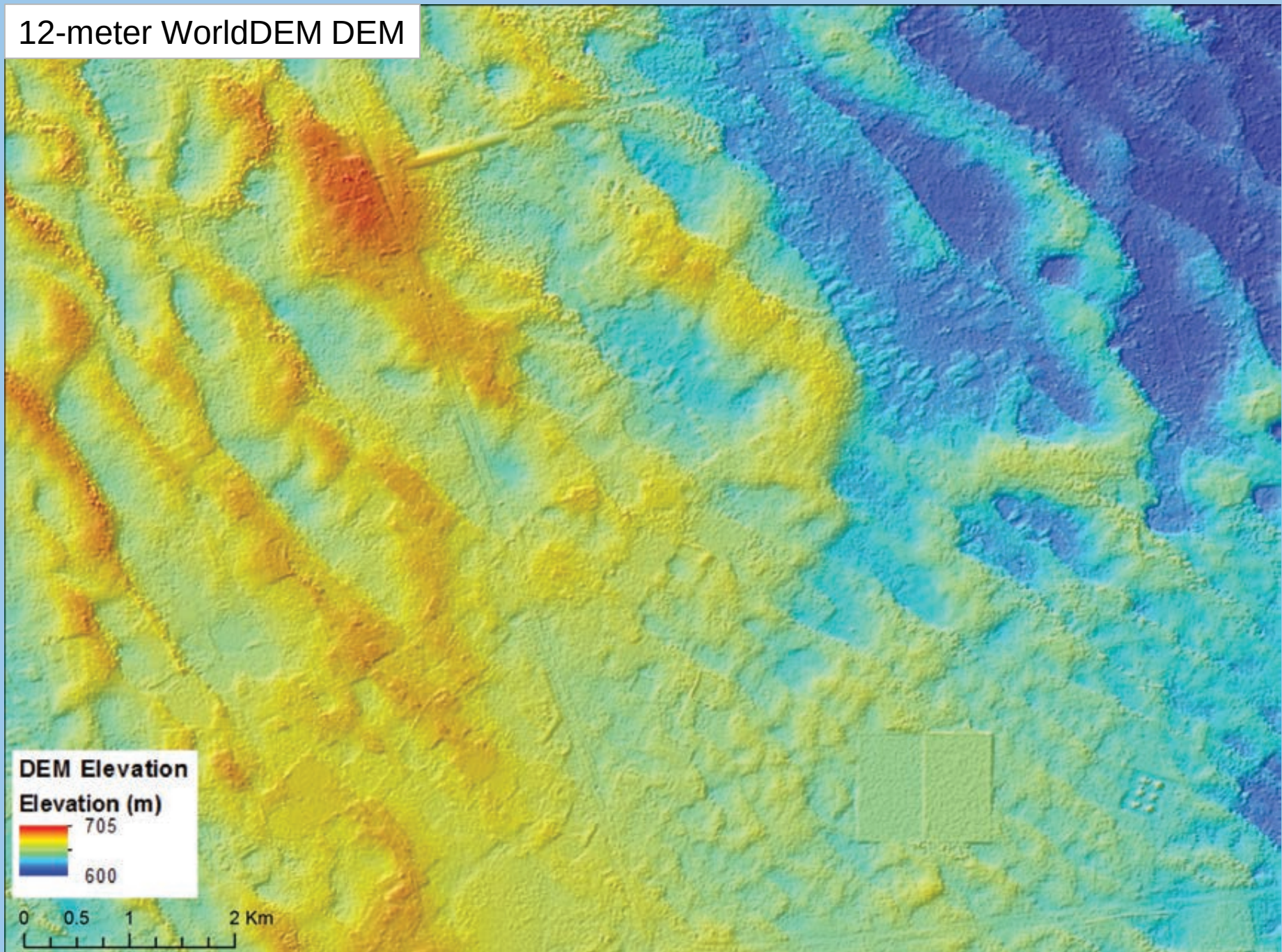
90-meter SRTM DEM



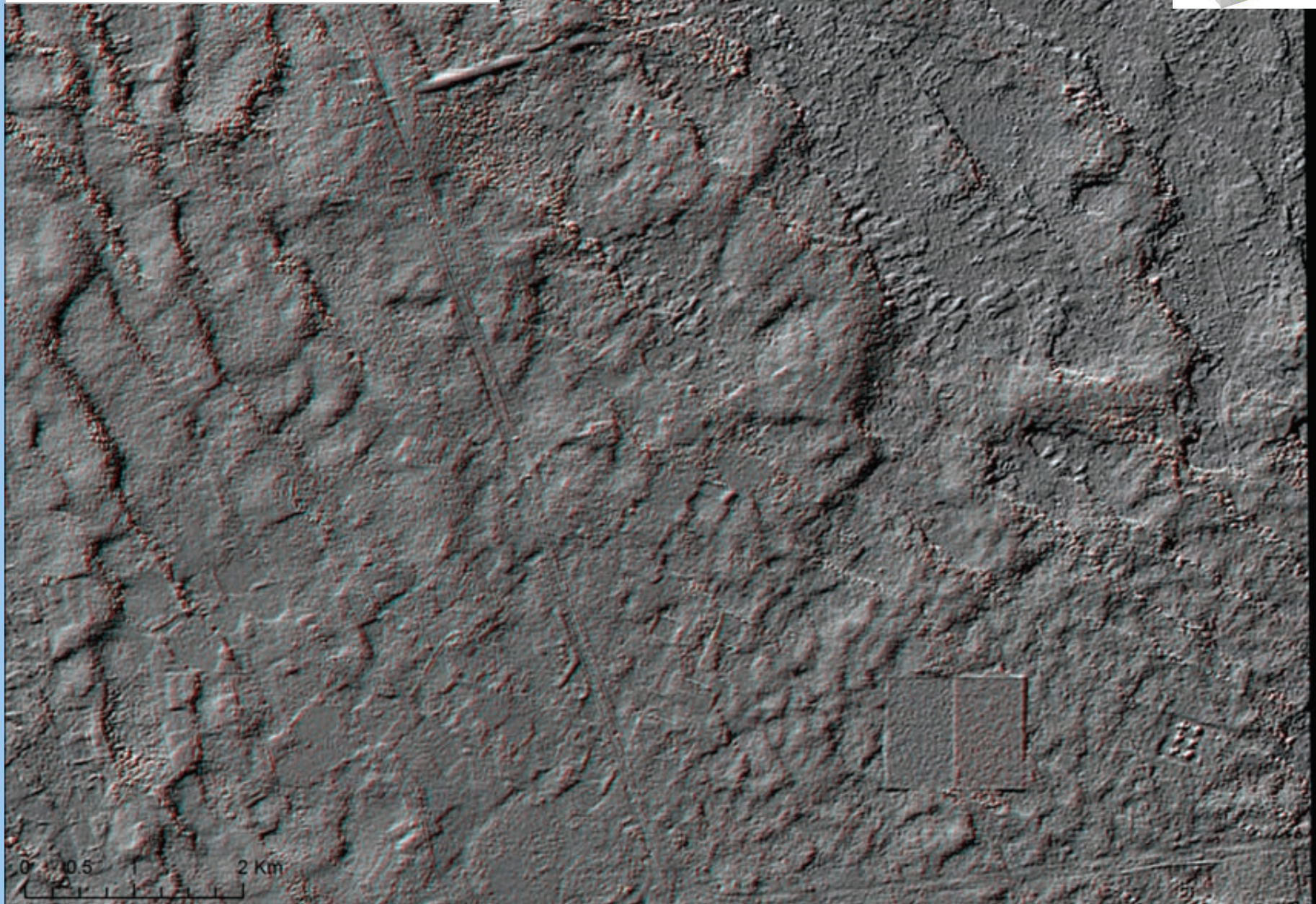
30-meter ASTER GDEM



12-meter WorldDEM DEM



12-meter WorldDEM DEM – Red-blue anaglyph with 10x vertical exaggeration



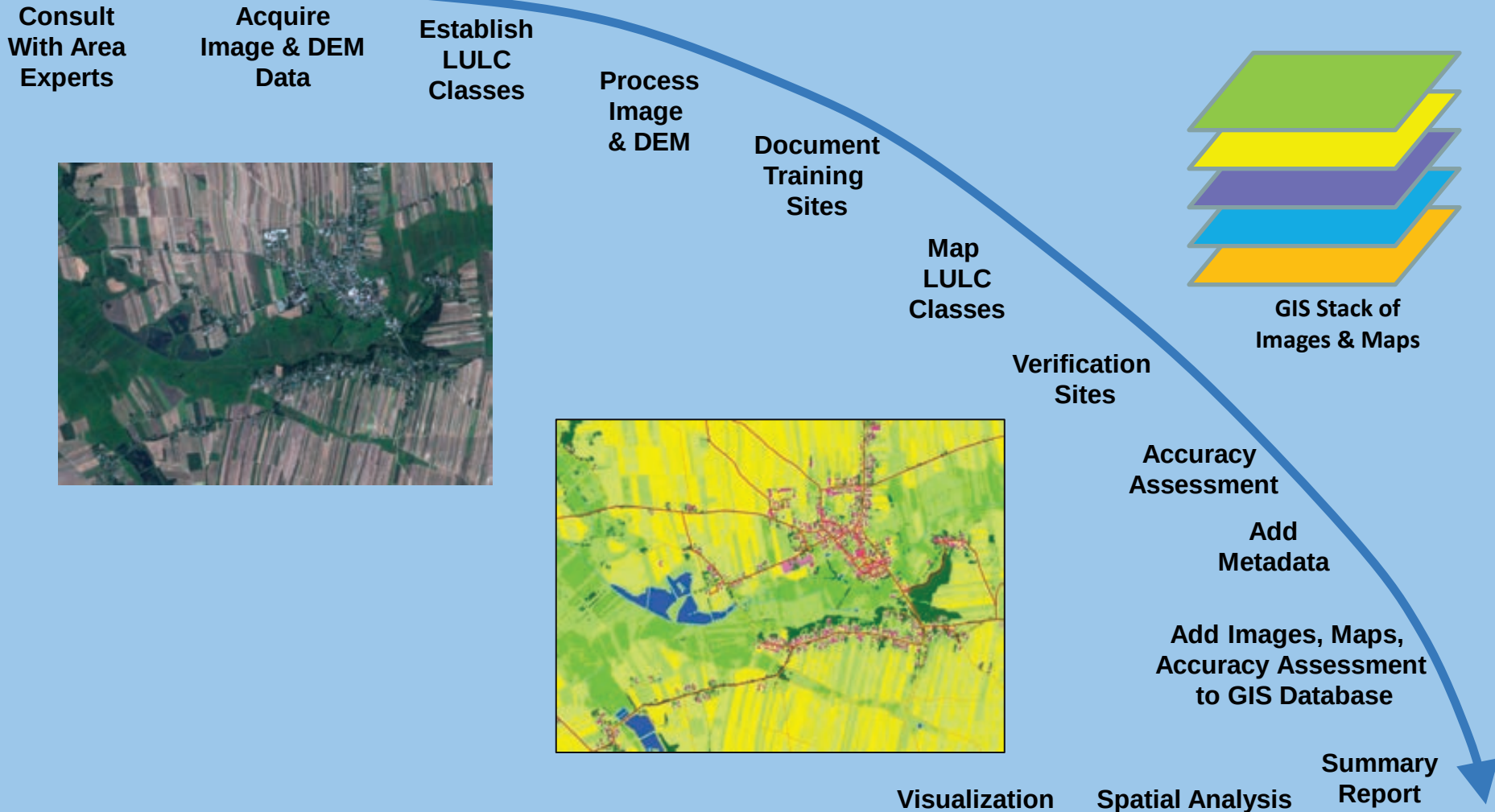
ENVIRONMENTAL MAPPING LAND COVER Using Multispectral Satellite Data

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





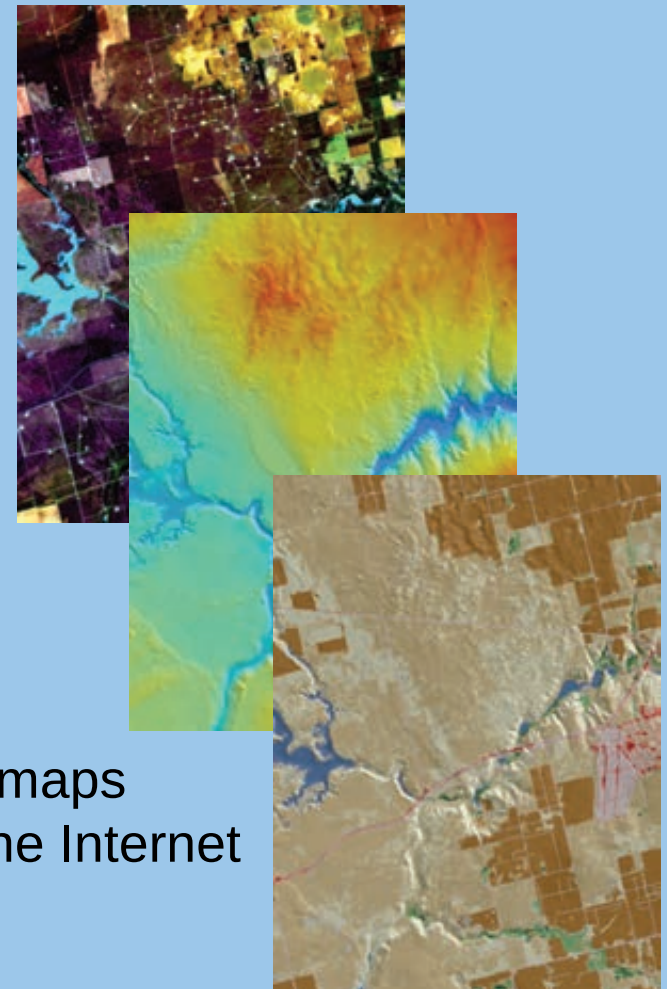
Building Knowledge of Company Footprints

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

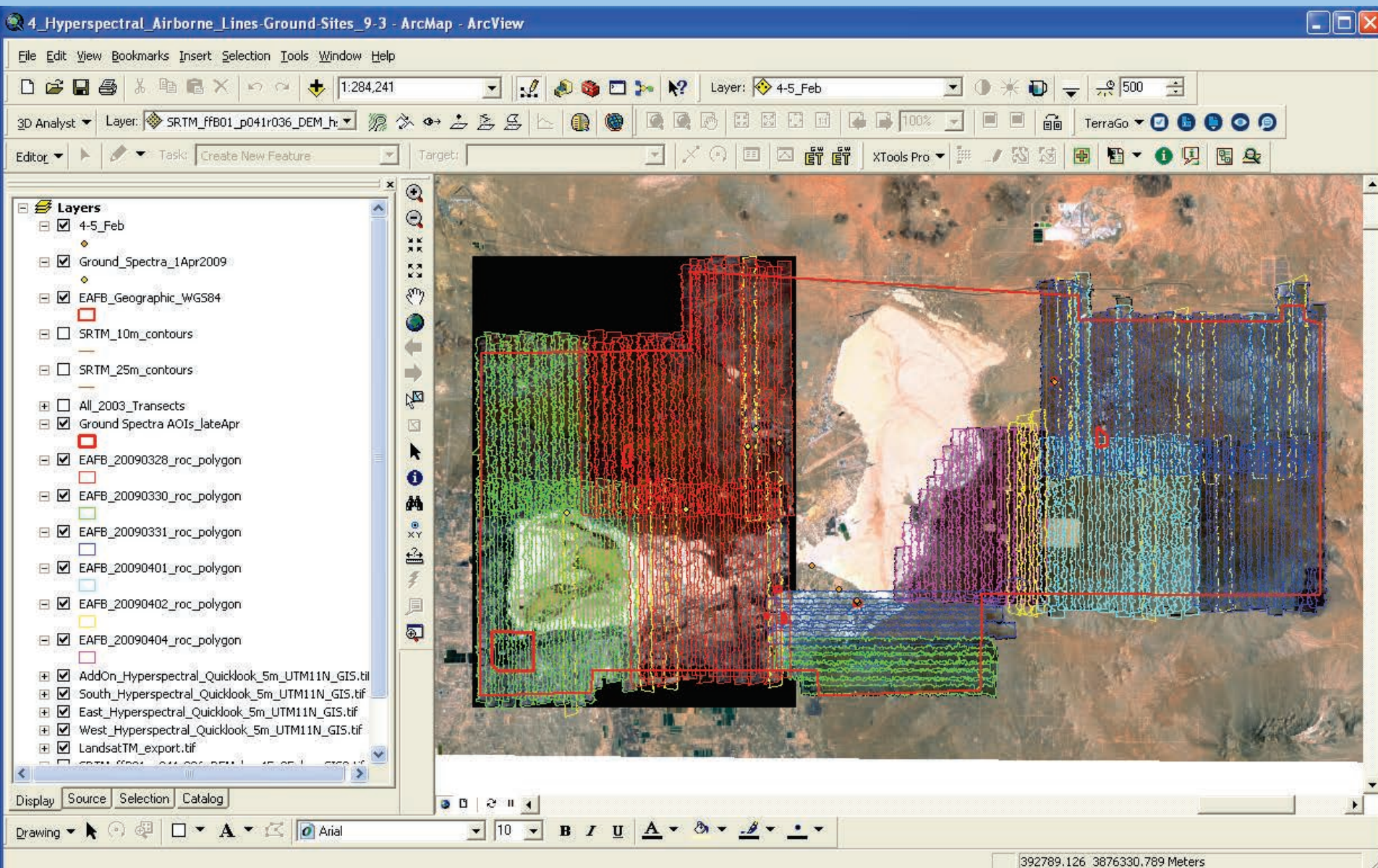


ENVIRONMENTAL MAPPING LAND COVER Using Hyperspectral Airborne Data

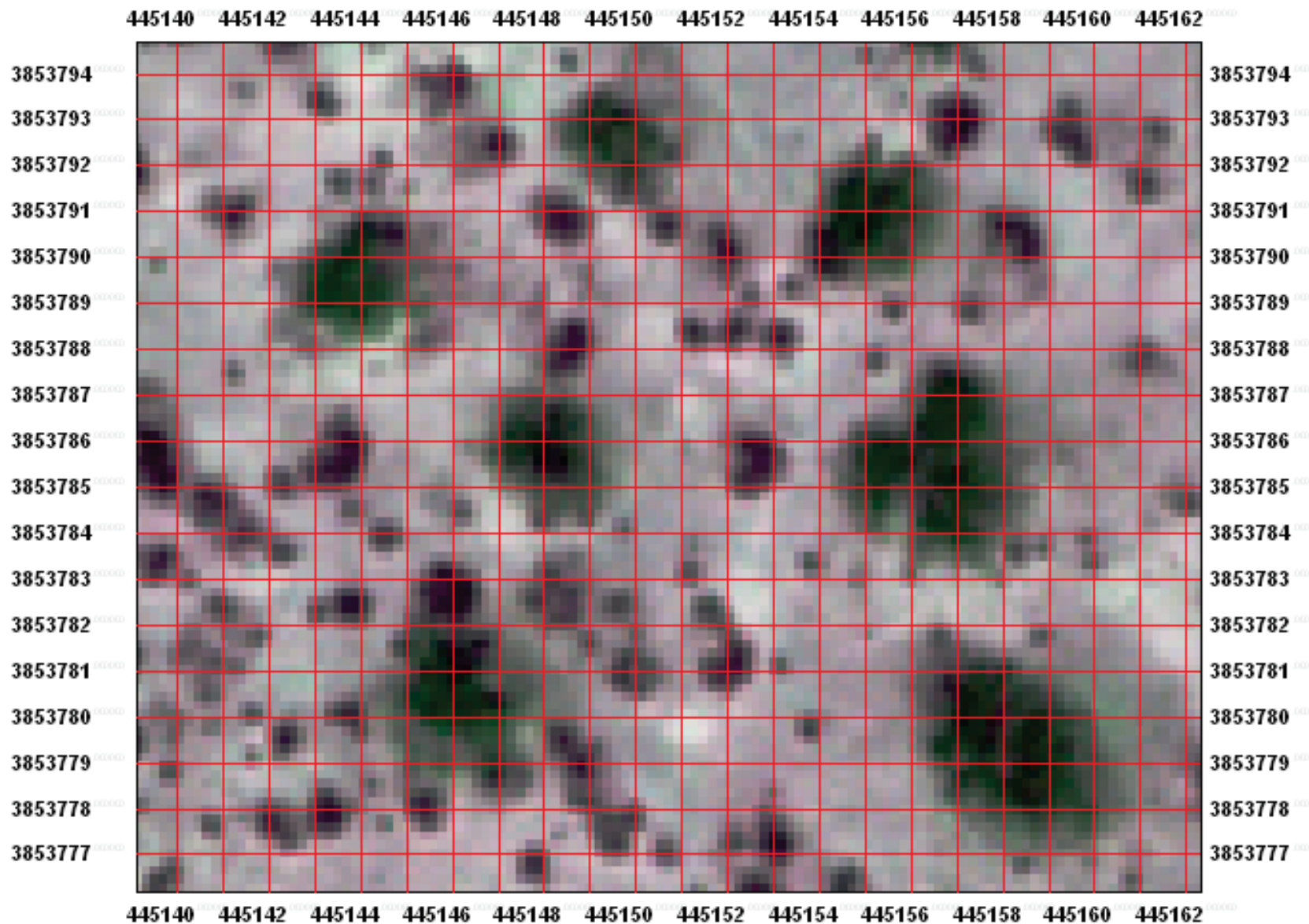
Edwards Air Force Base

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

Airborne Hyperspectral Flight Lines in GIS



1 meter Grid on Vegetation in SE Area of Edwards Air Force Base



~0.2m Ultra Cam backdrop image

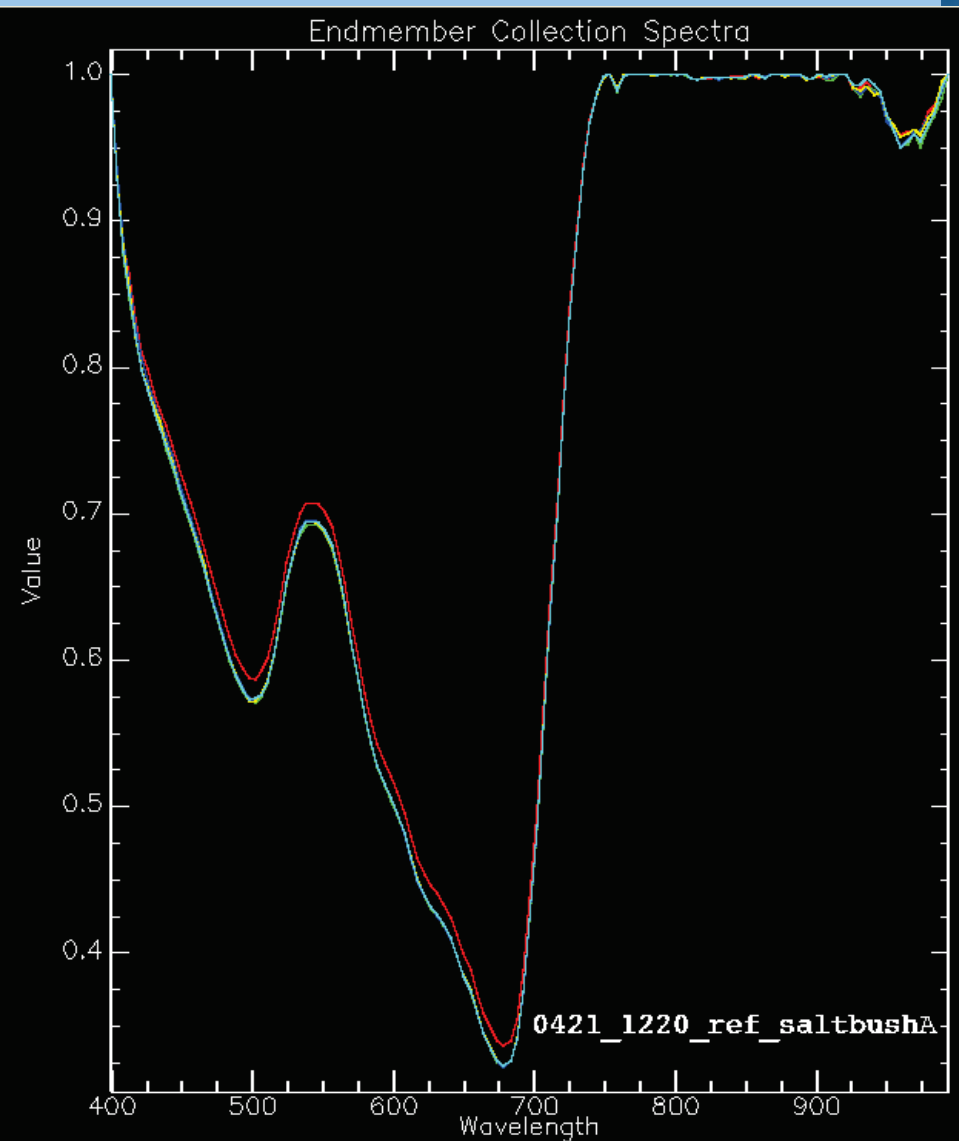
Pixels with Mixtures of Materials & Some Pure

Calibrating Ground Spectrometer

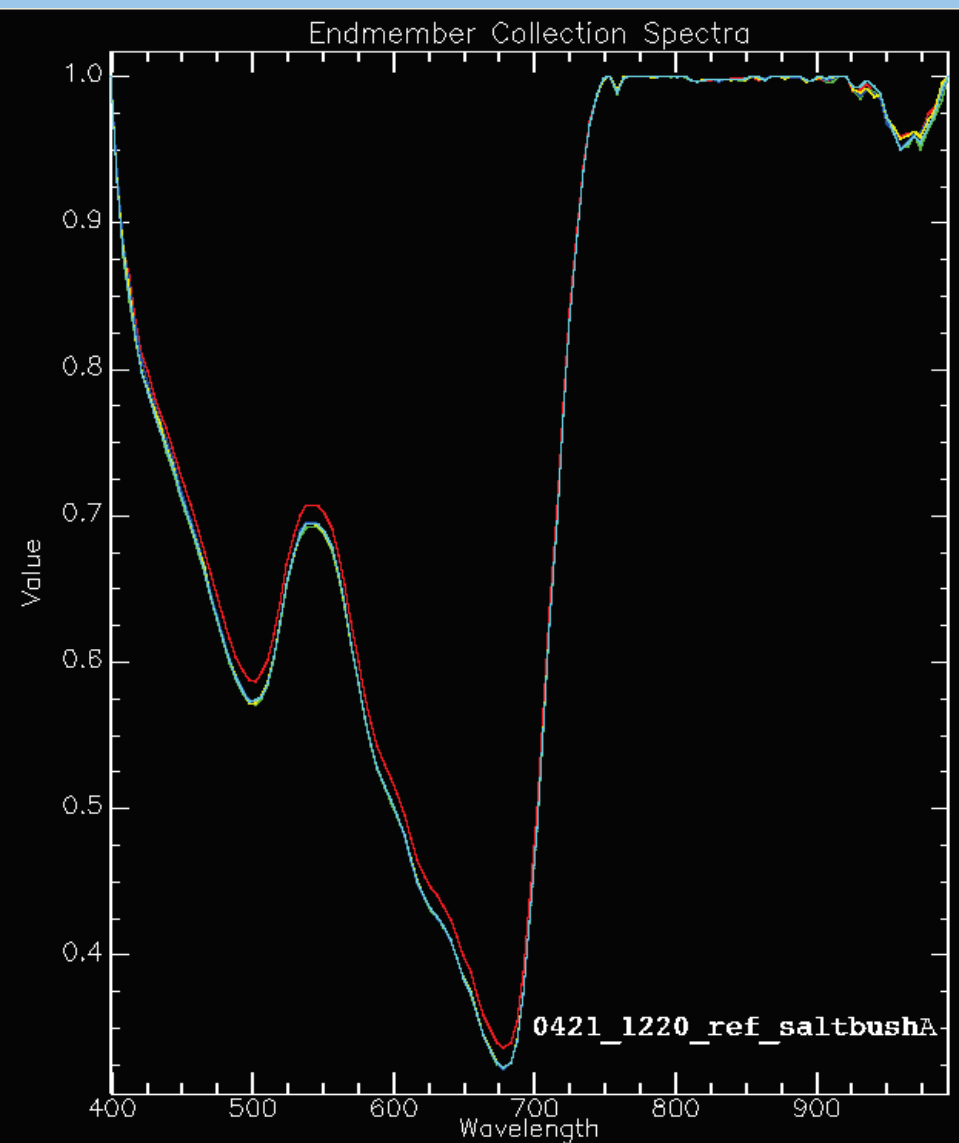


VNIR Sensor

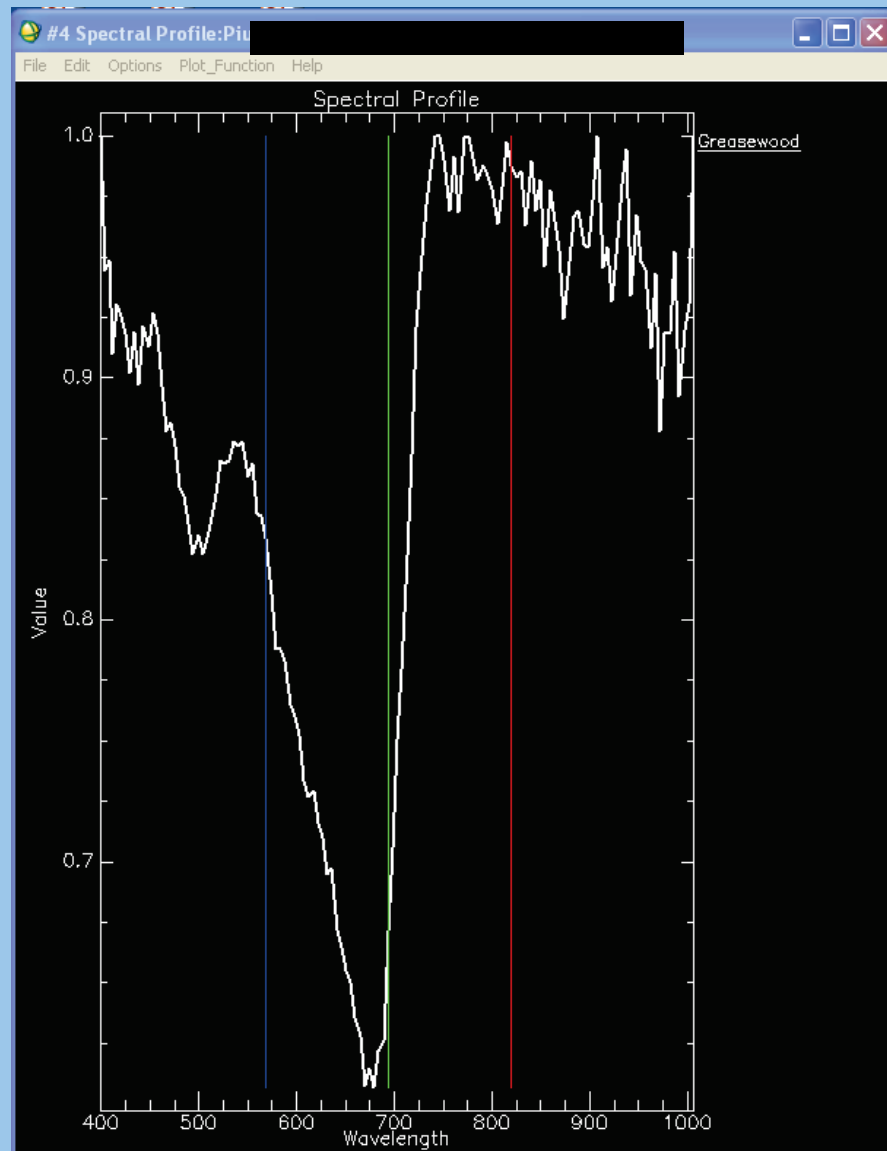
Ground Spectra for Saltbush



Ground Spectra for Saltbush



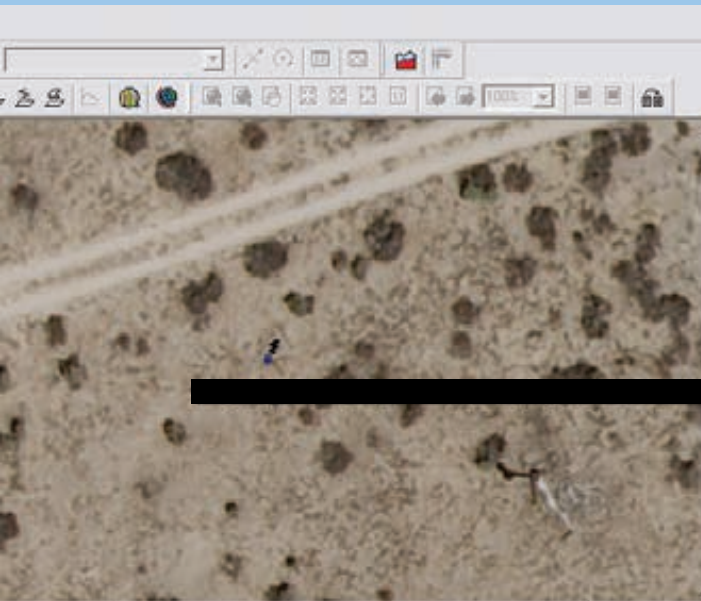
Airborne Spectra for Saltbush



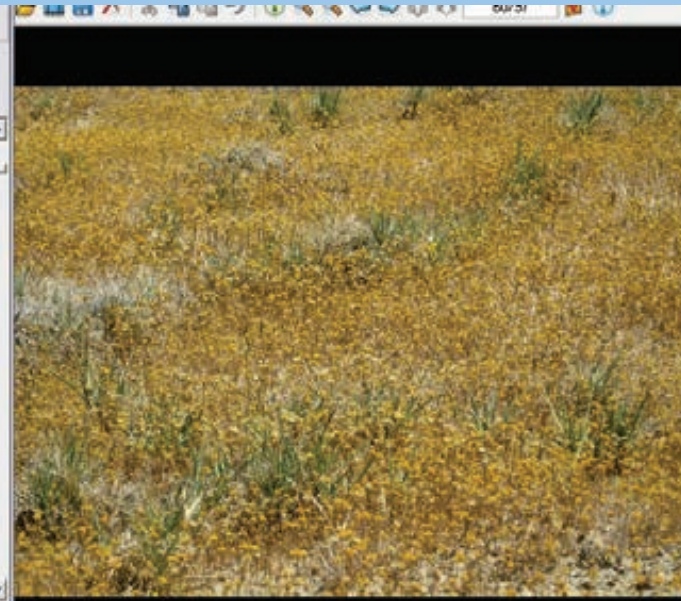
VNIR Sensor

Gold Fields

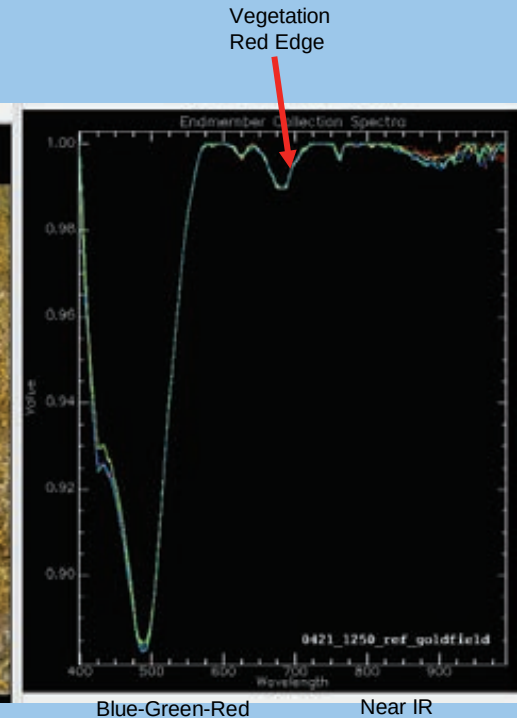
Sampling site, ground photo, and ground spectra in GIS



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

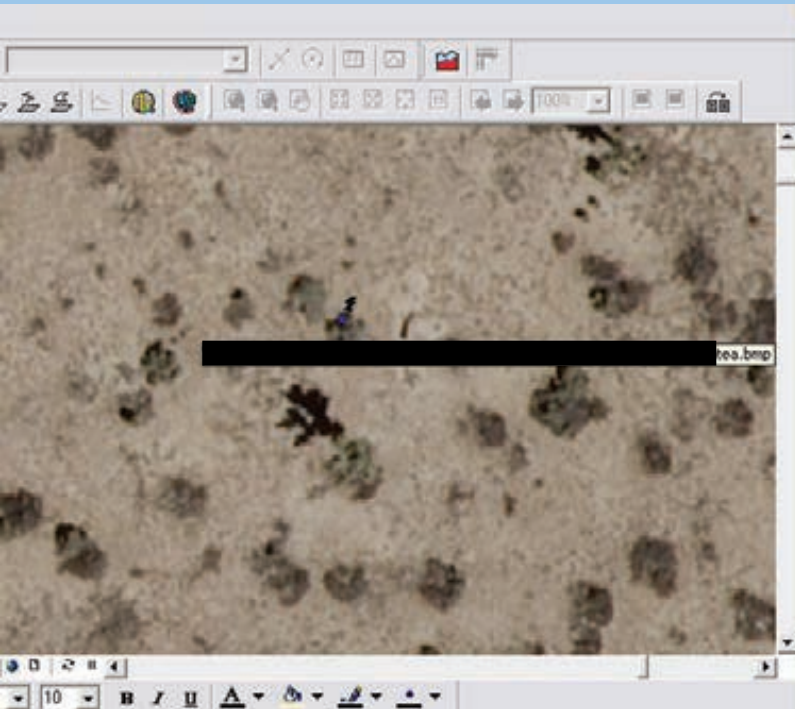


Visible-Near IR spectral
signature of feature
shown on left

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

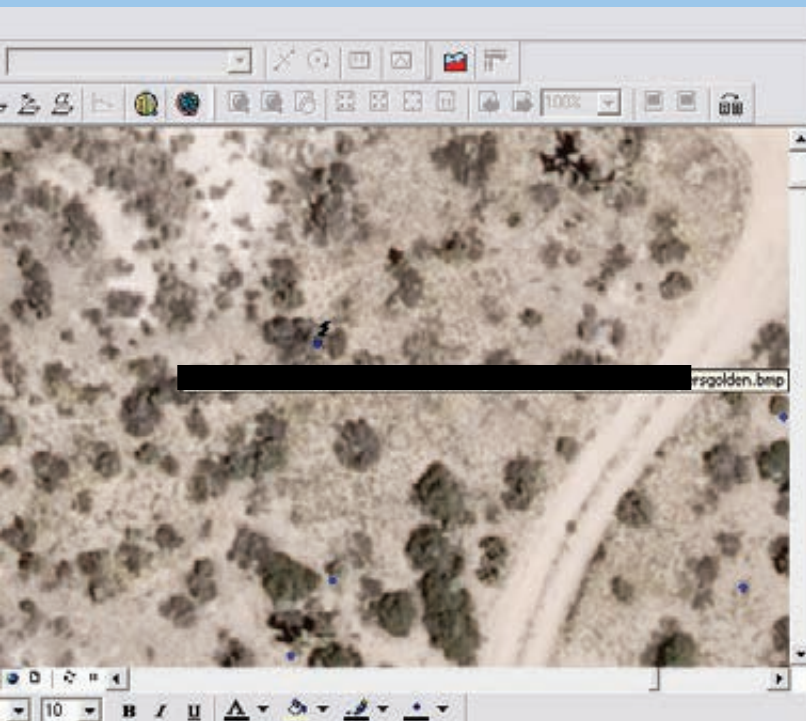


Visible-Near IR spectral
signature of feature
shown on left

VNIR Sensor

Coopers Goldenbush

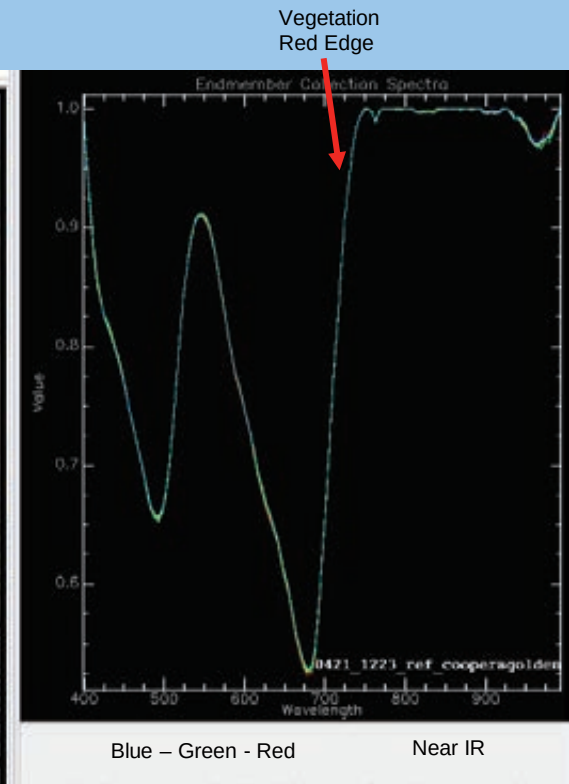
Sampling site, ground photo, and ground spectra in GIS



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

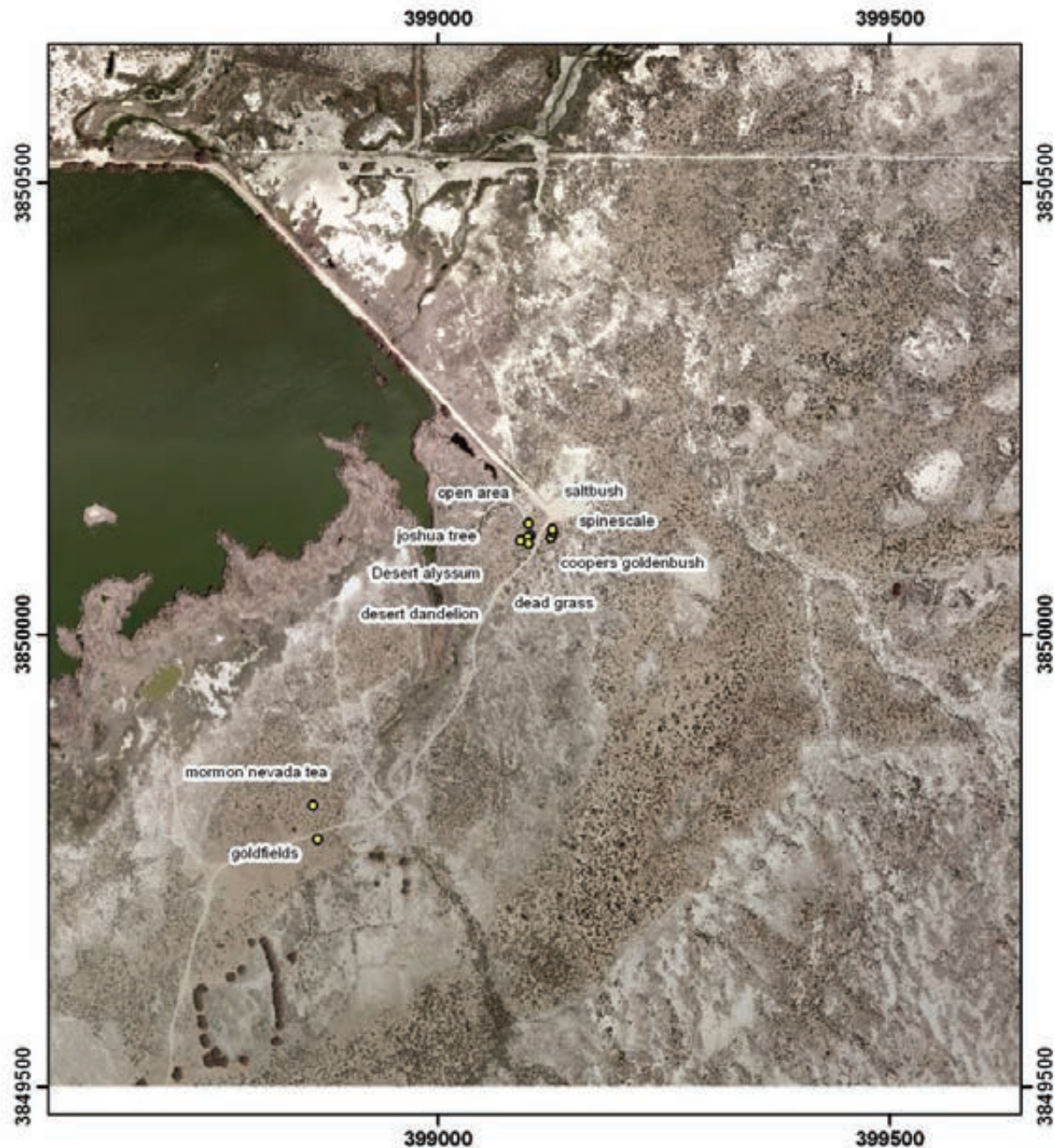
East Piute Ponds - Spectra Evaluation
Natural Color UltraCAM
Apr-Jun 2008

Ground spectra sites shown.

Ground Sample
Locations on
Airborne
Orthorectified
Base Image
4" pixels



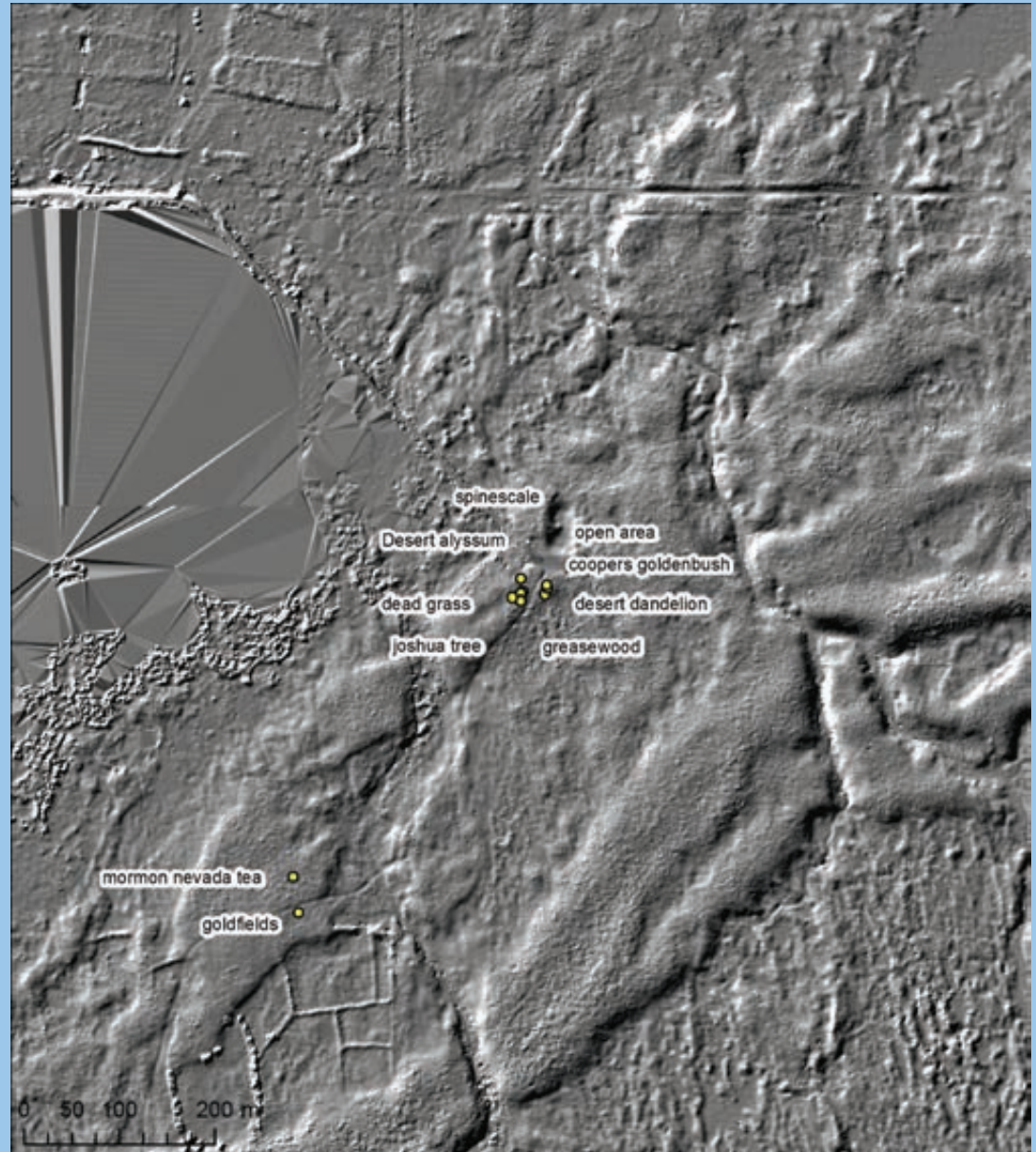
0 0.5 1 Km



0 125 250 Meters

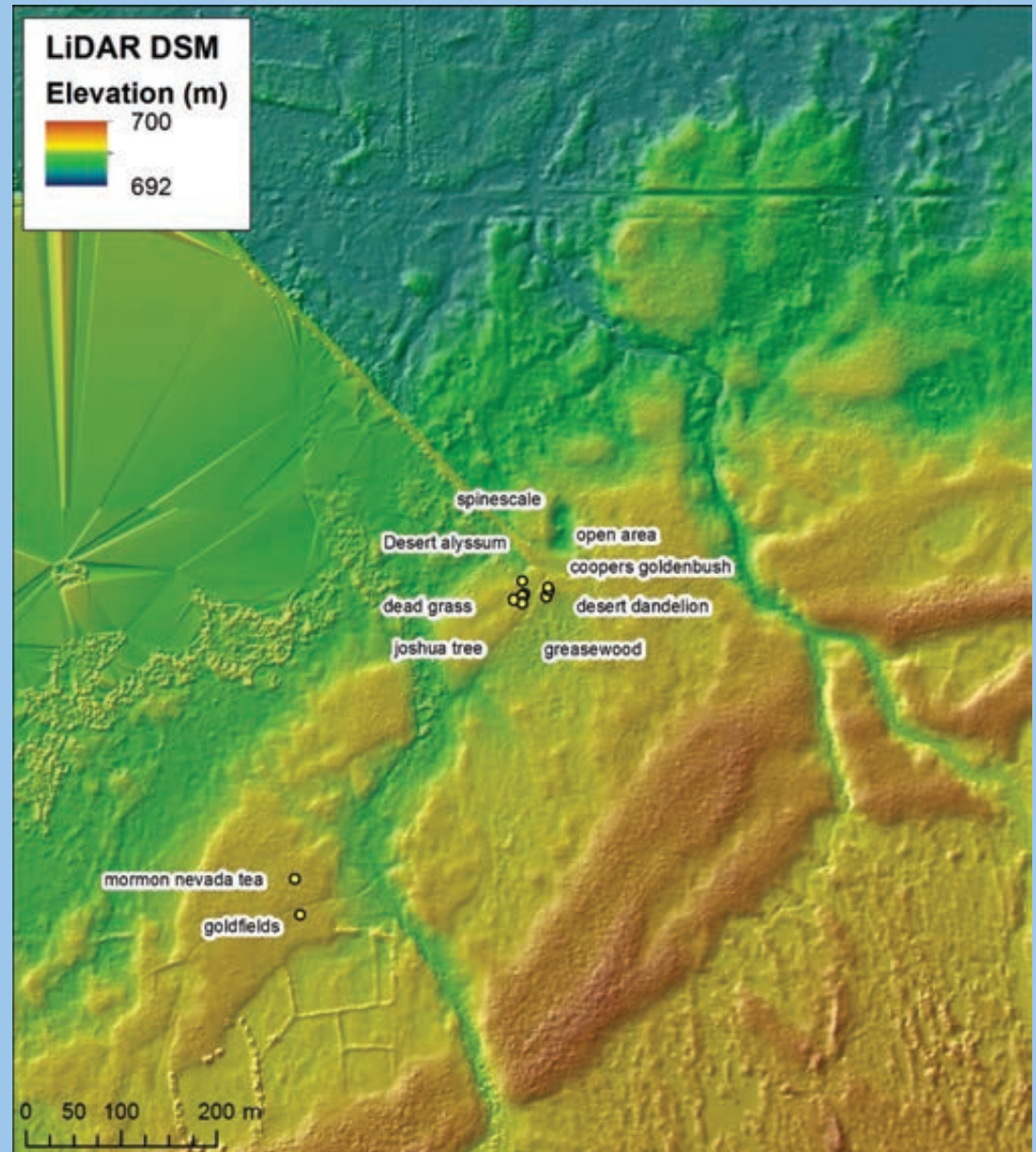
Airborne LiDAR DEM

Illuminated from NW
10° above horizon

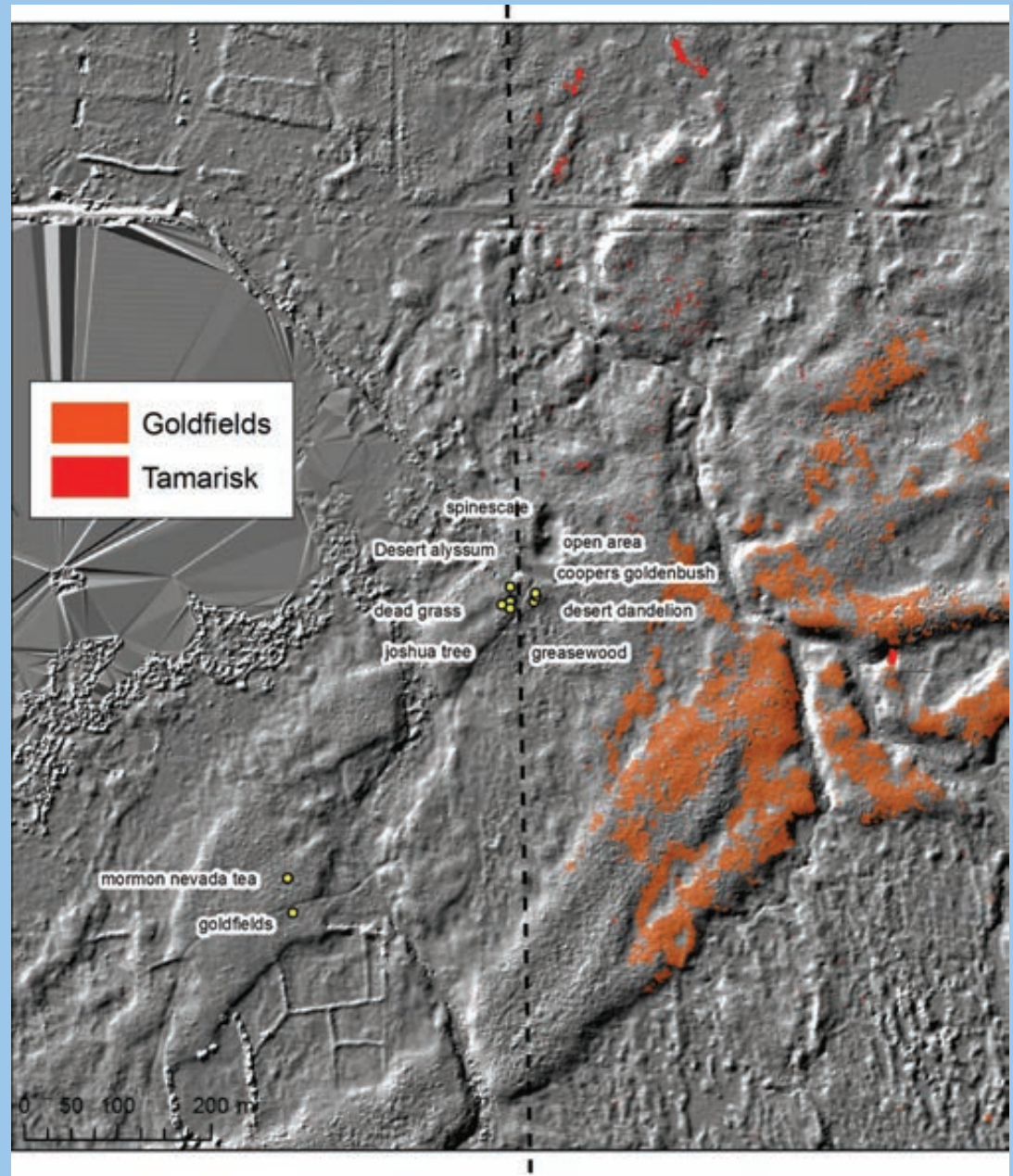
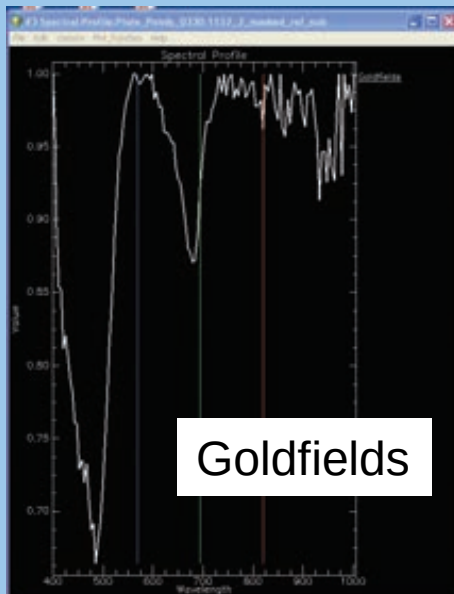
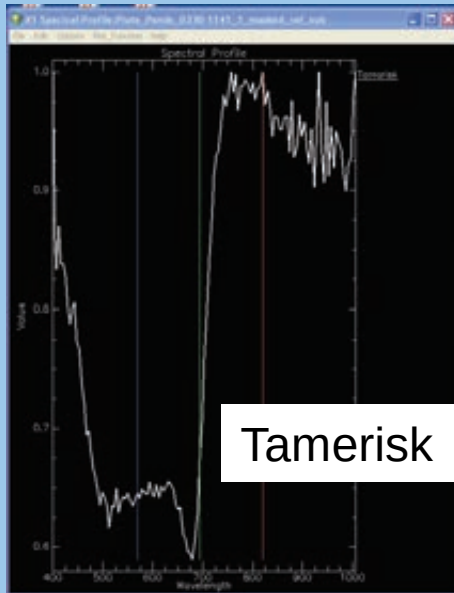


Airborne LiDAR DEM

Illuminated from NW
10° above horizon



Species Map



Habitat - replicate

MAPPING in the USA

LiDAR from NOAA

Cambria, WNY

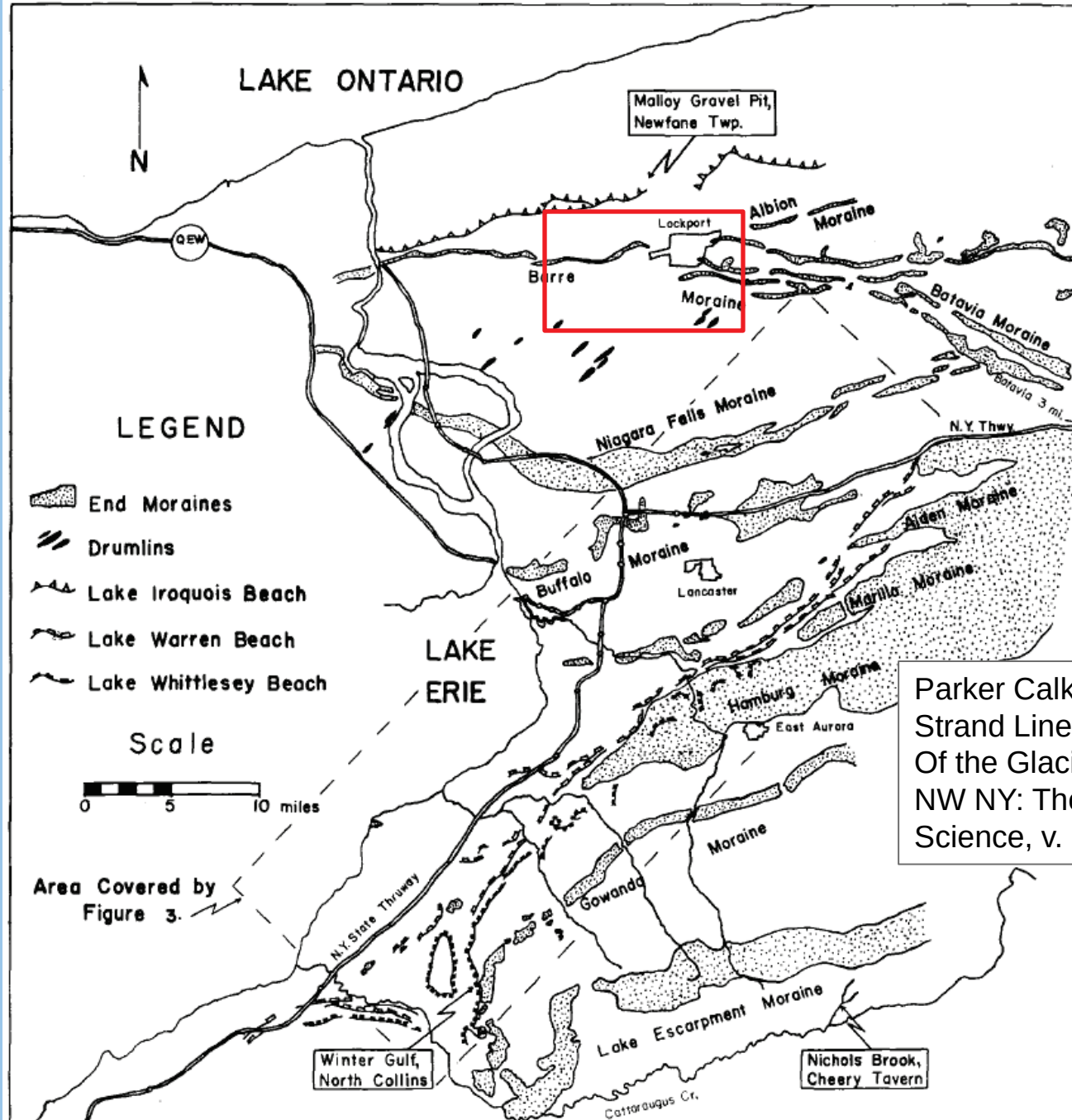
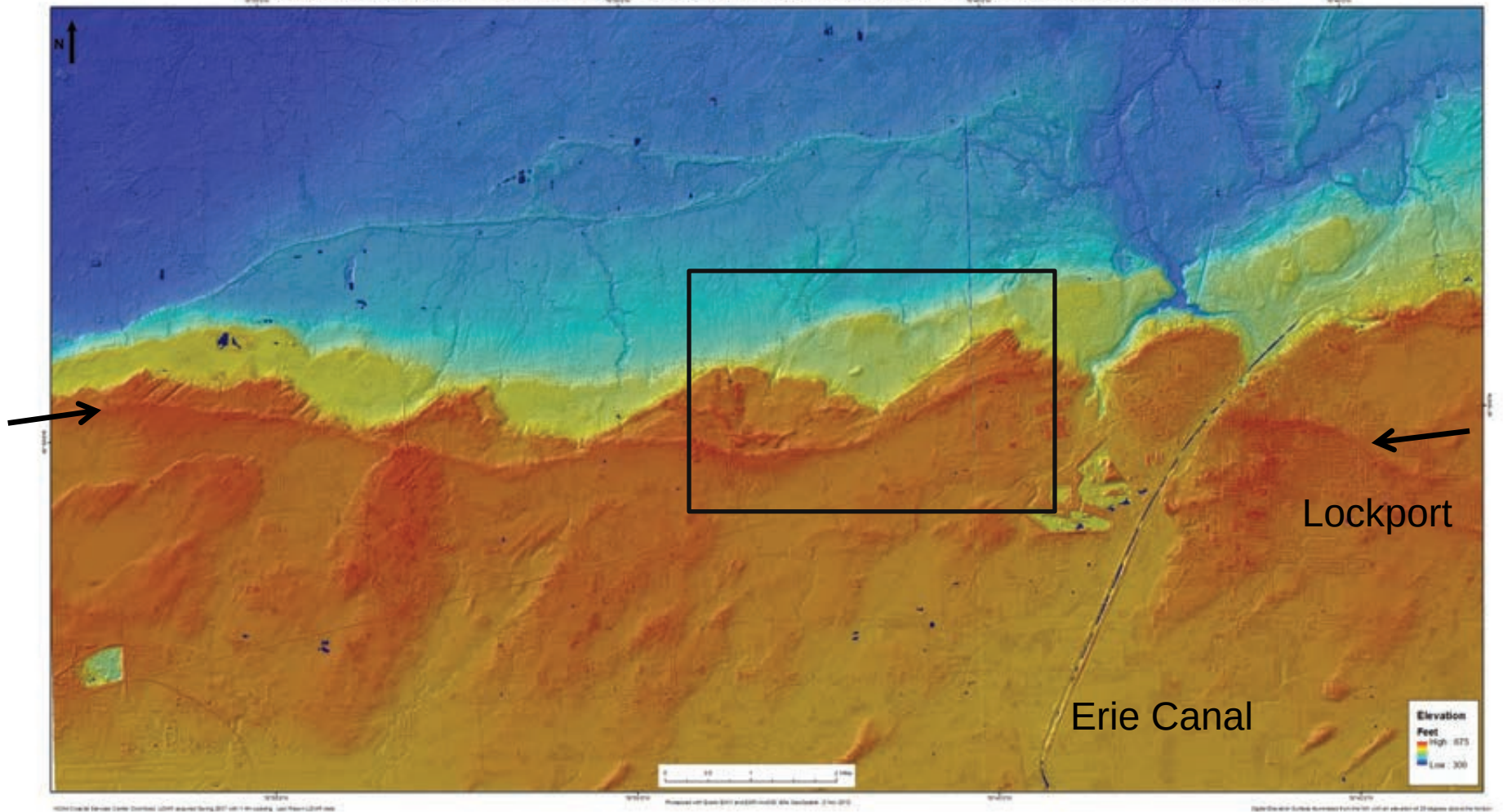


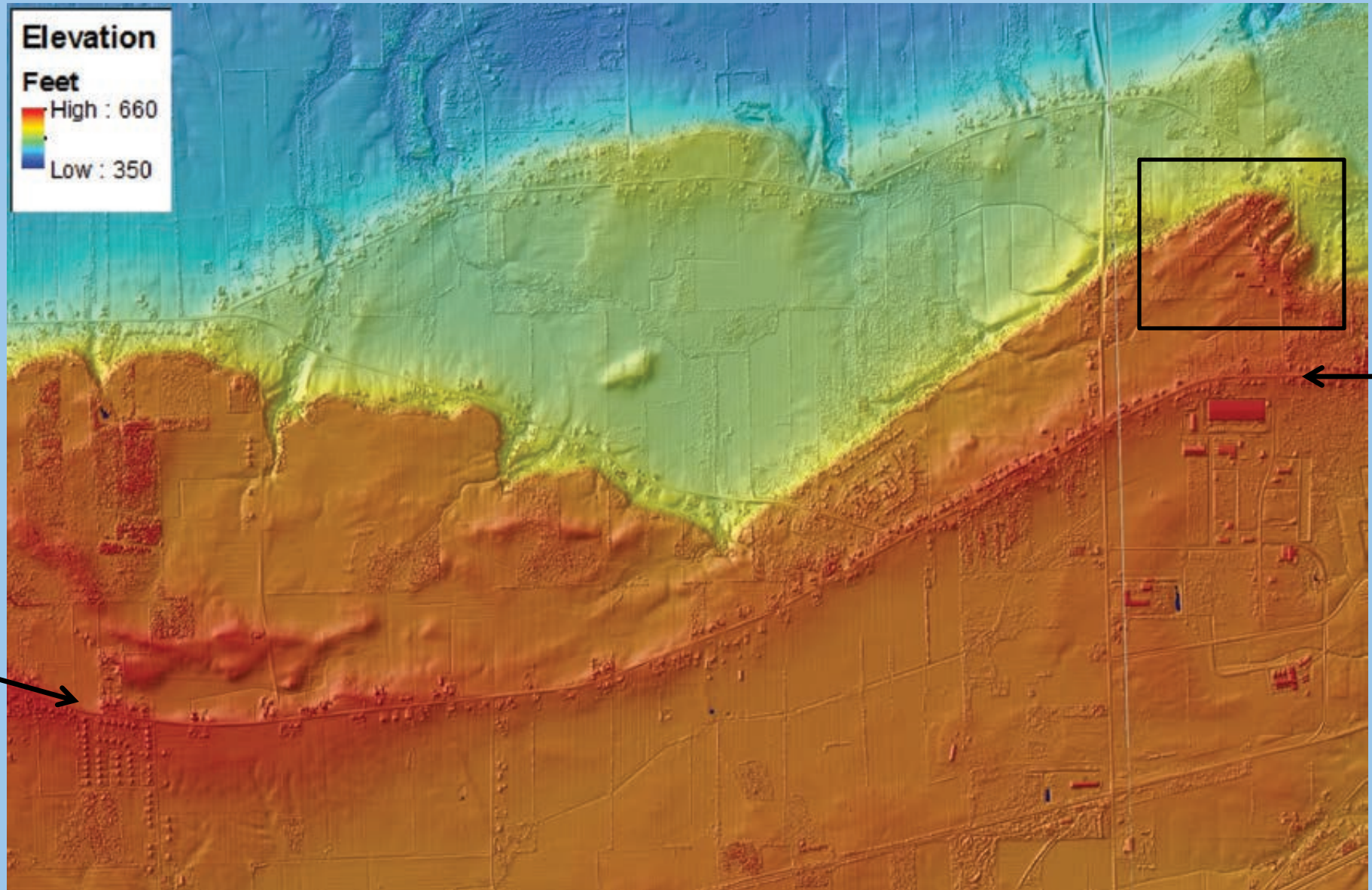
FIGURE 1. Location map of study area showing end moraines and major strand lines of northwestern New York.

Awesome Geomorphology – Barre Moraine!

NOAA LiDAR Digital Surface Model of Cambria and Surrounding Area - Surface Illuminated from Northwest

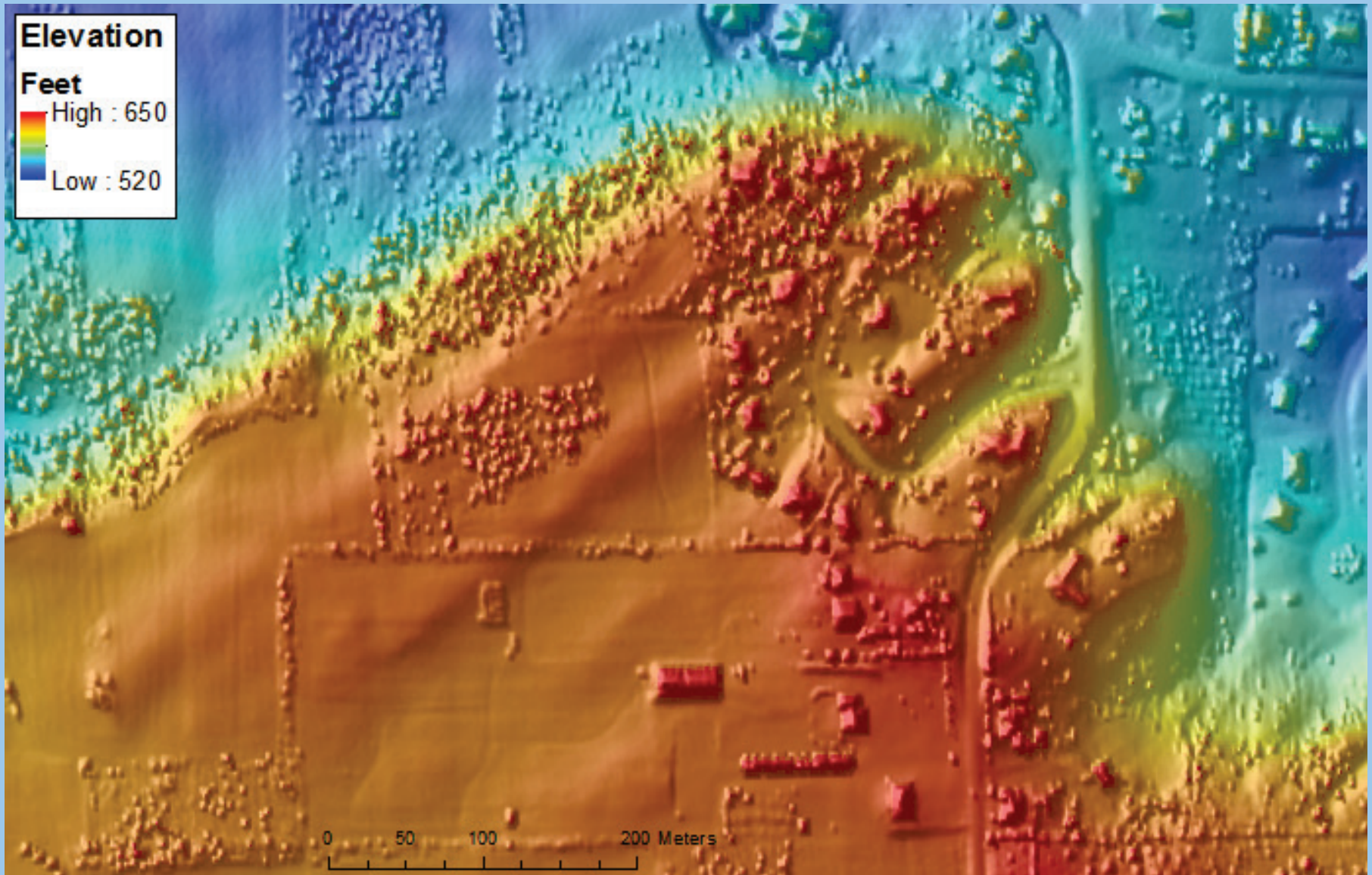


Niagara Escarpment with Glacial Deposits



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

James Ellis
jellis@ellis-geospatial.com

