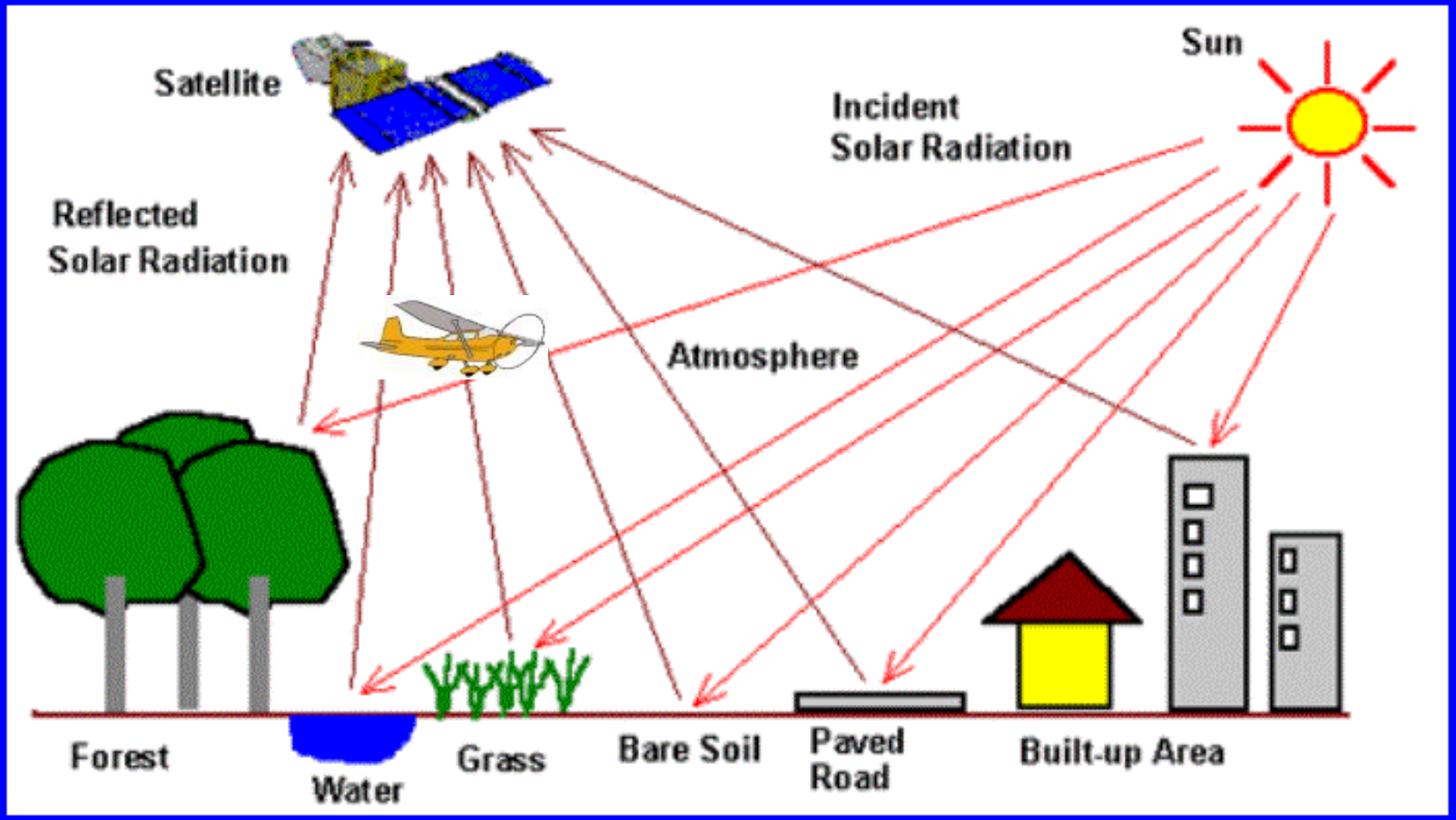
GEOLOGIC REMOTE SENSING FOR EXPLORATION

1. Remote Sensing Primer

2. Geologic Remote Sensing Examples

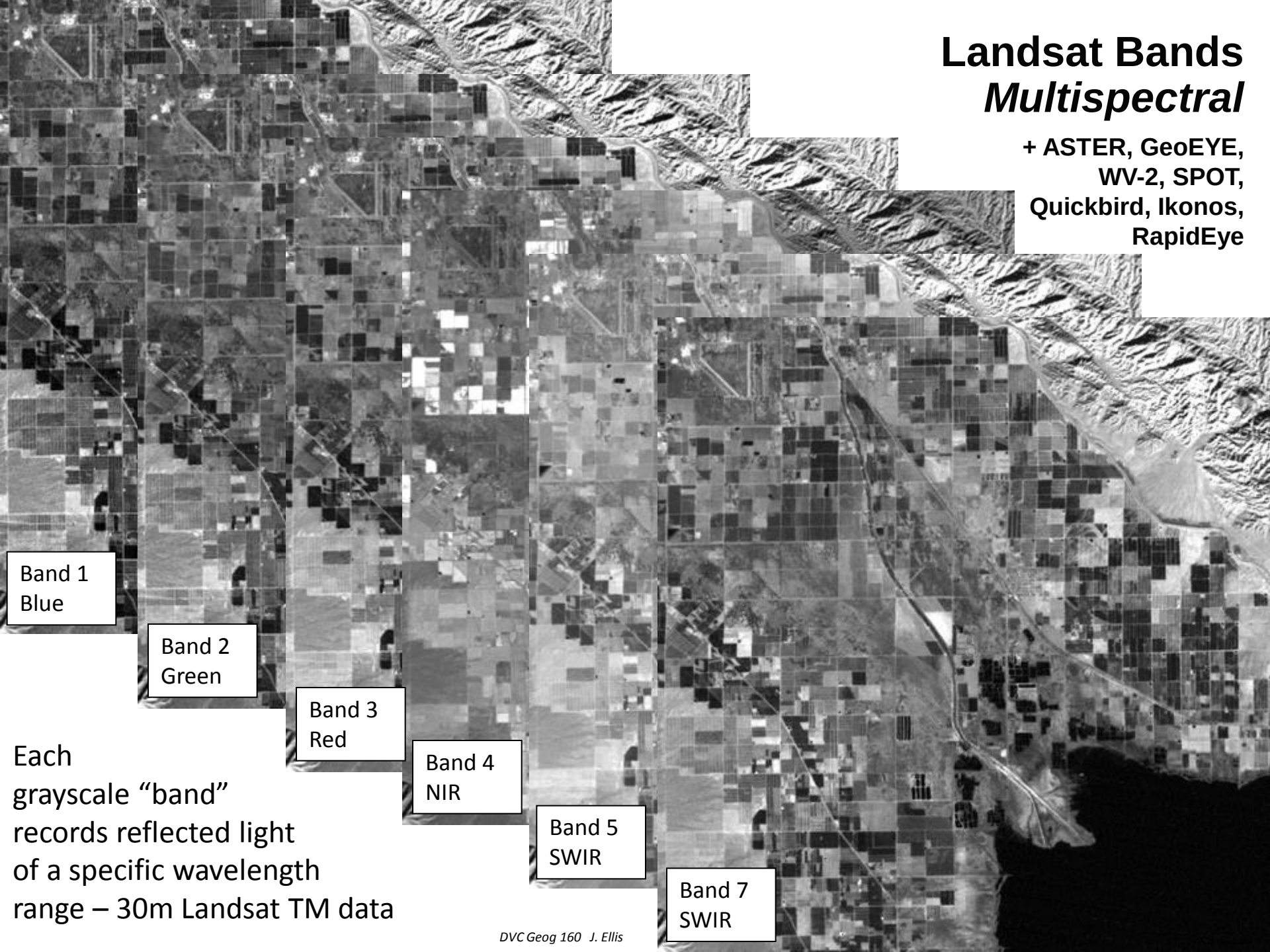
3. Remote Sensing Workflow

REMOTE SENSING PRIMER: Passive Sensors use Reflected Light from the Sun



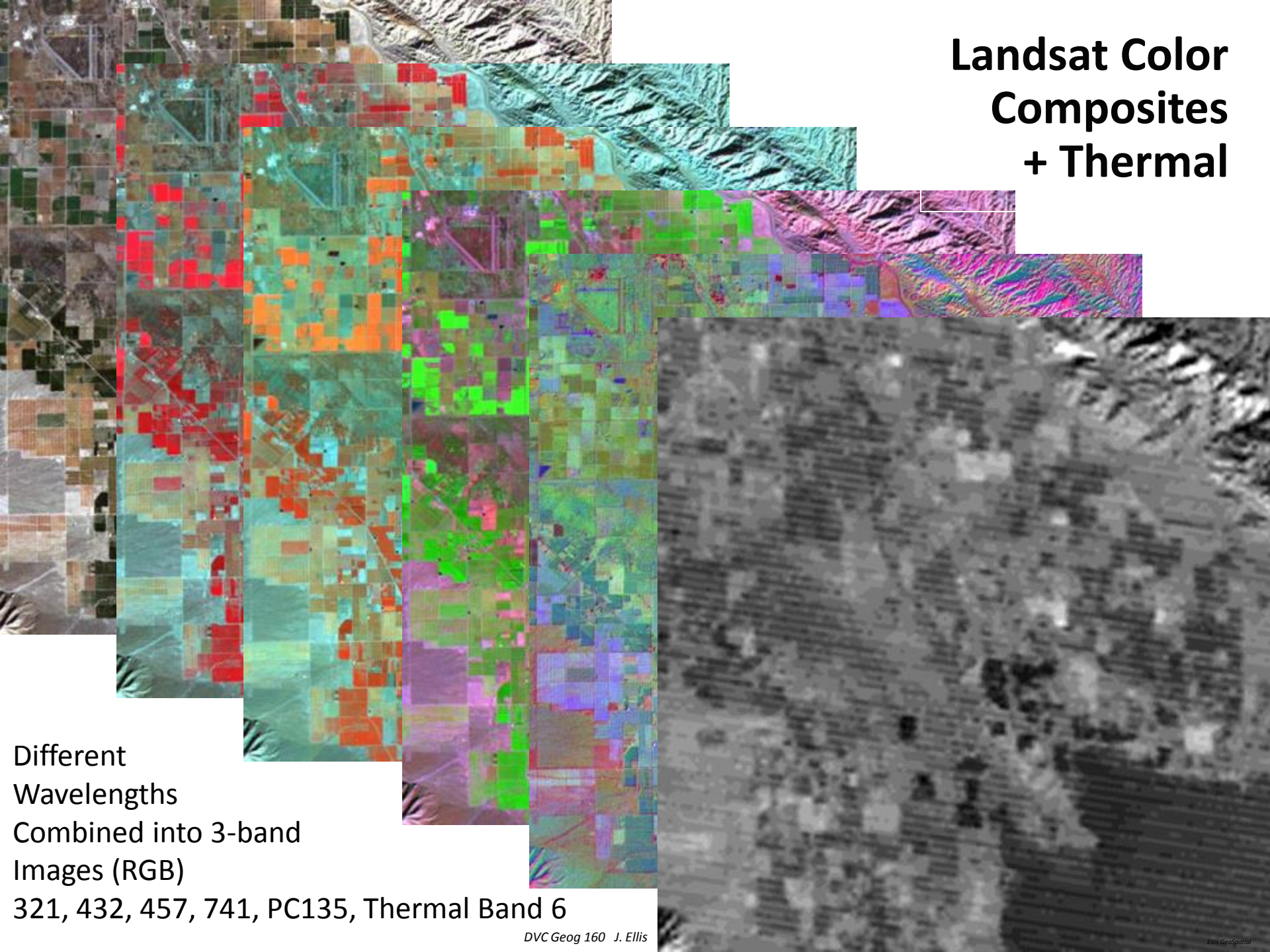
Landsat Bands
Multispectral

+ ASTER, GeoEYE, WV-2, SPOT, Quickbird, Ikonos, RapidEye



Each grayscale "band" records reflected light of a specific wavelength range – 30m Landsat TM data

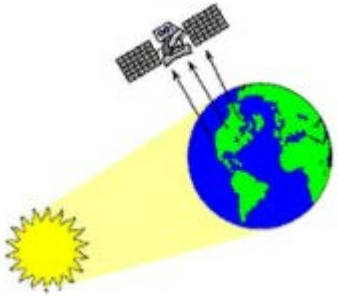
Landsat Color Composites + Thermal

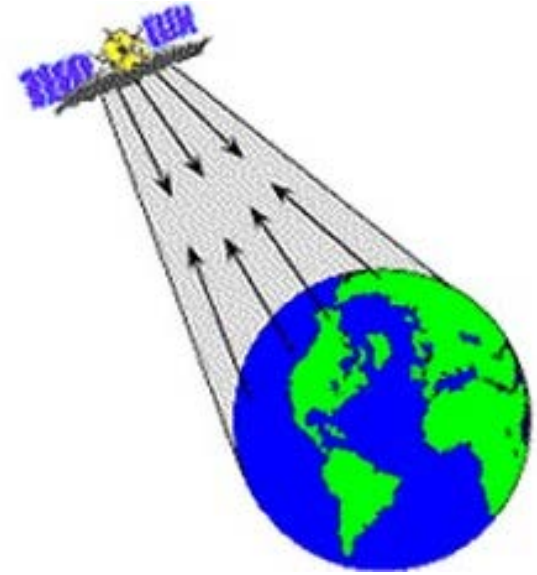


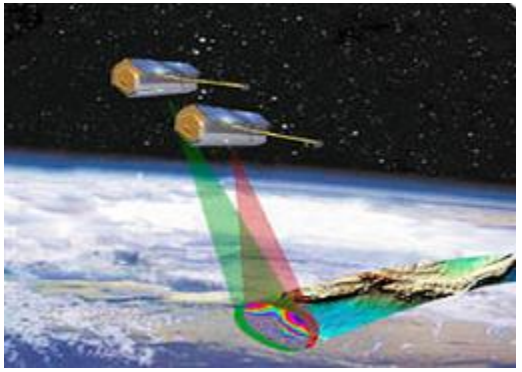
Different
Wavelengths
Combined into 3-band
Images (RGB)
321, 432, 457, 741, PC135, Thermal Band 6

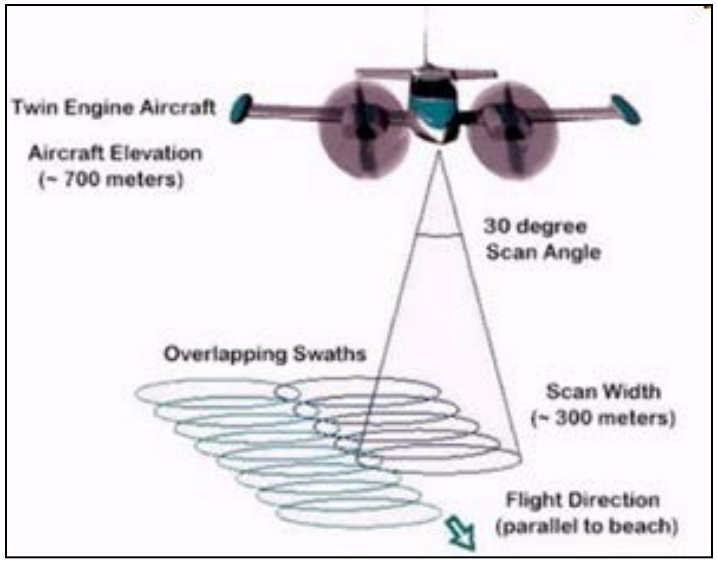
Active Sensors – Radar & LiDAR

Passive





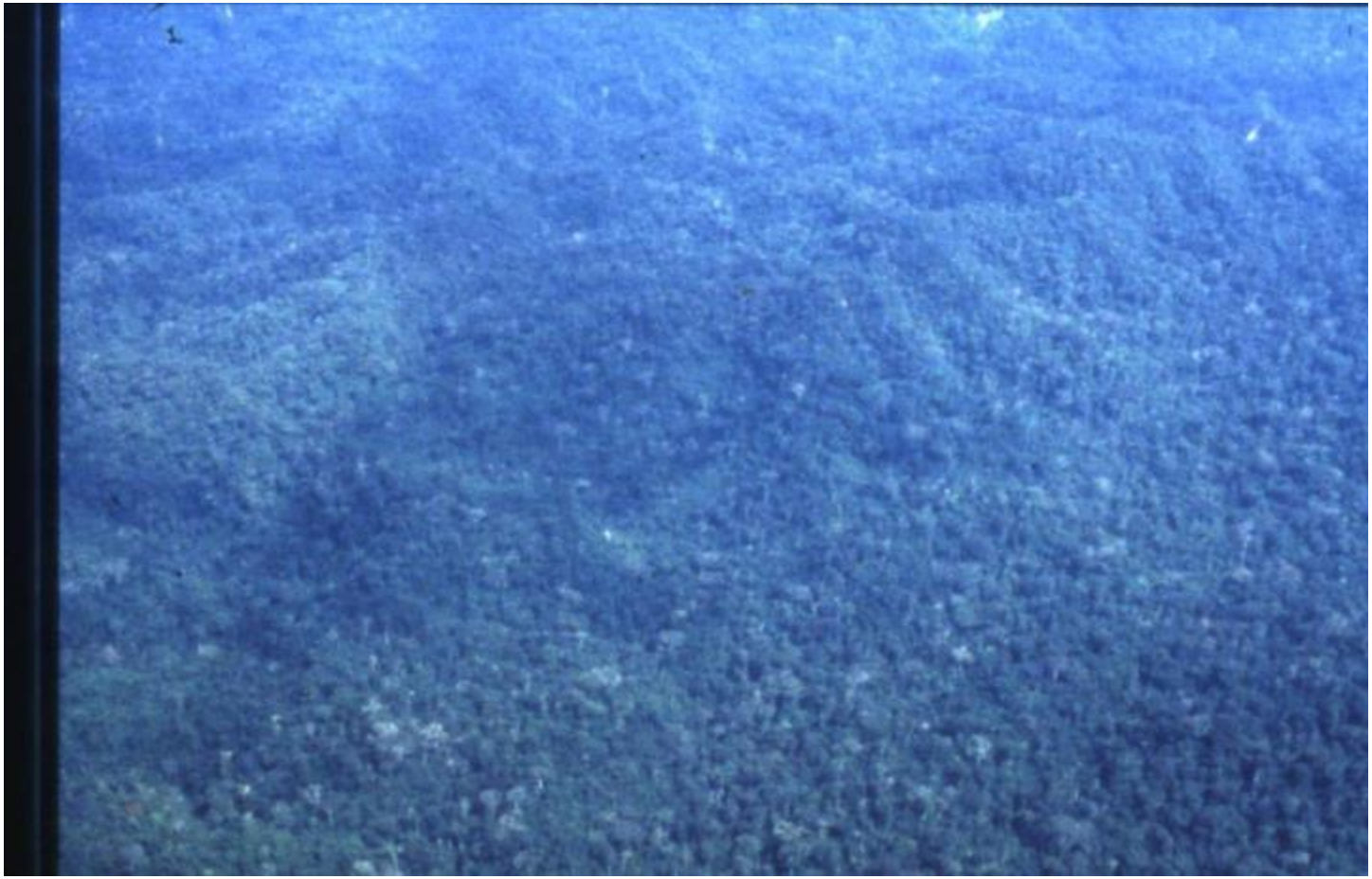




Sources: www.intermap.com; http://babag.net/tag/sensor/ ; http://www.infoterra.de/tandem-x-satellite

Image Processing to Improve Geologic Mapping

Image Processing to Improve Geologic Mapping



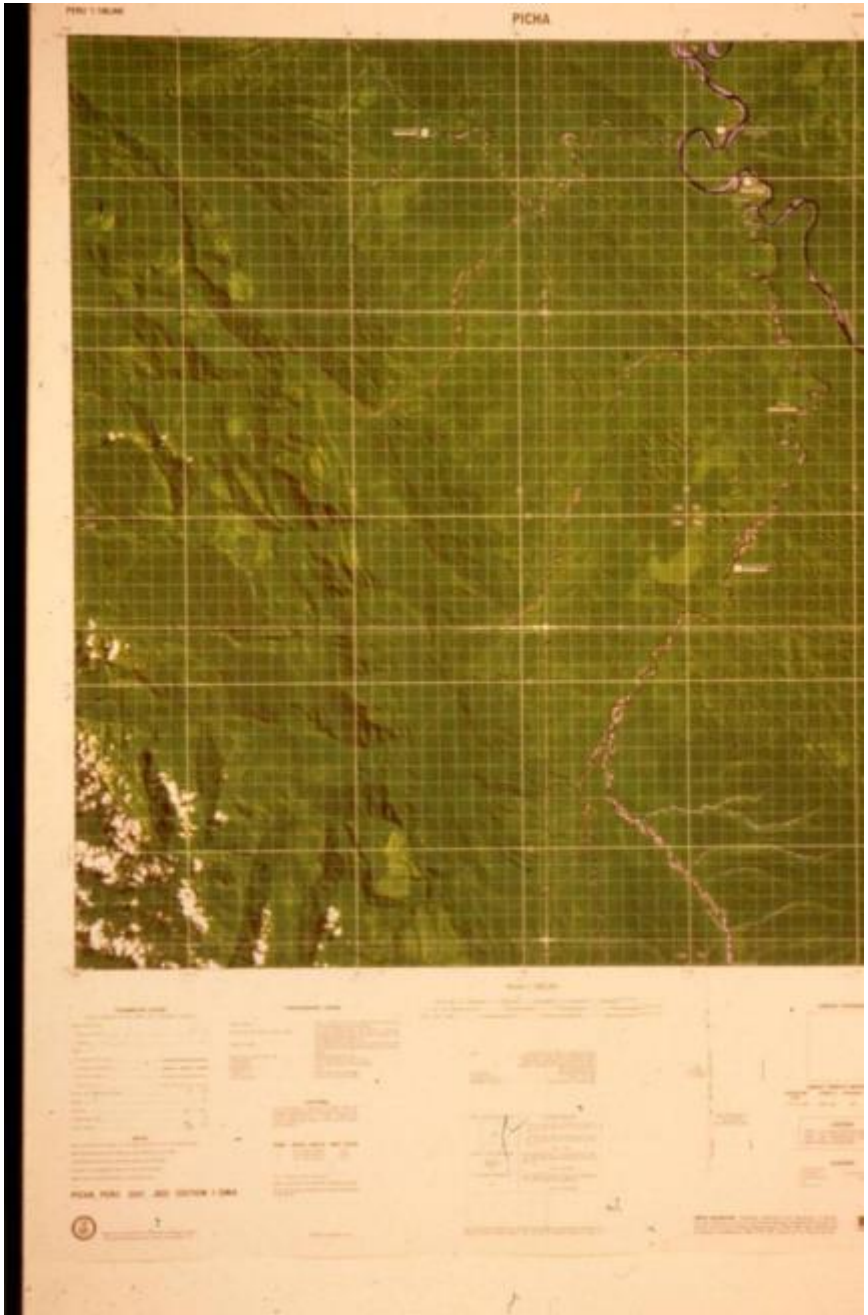
View of vegetation-covered terrain from helicopter

Source: Larry Dekker

Image Processing to Improve Geologic Mapping

Original Published Landsat TM Image Map

Original, Off-The-Shelf Government Processing Emphasized Vegetation Cover, But *Not* Geology



LEGEND
Greens = vegetation
Tan-Brown = open
Dark Blue = water
White = clouds

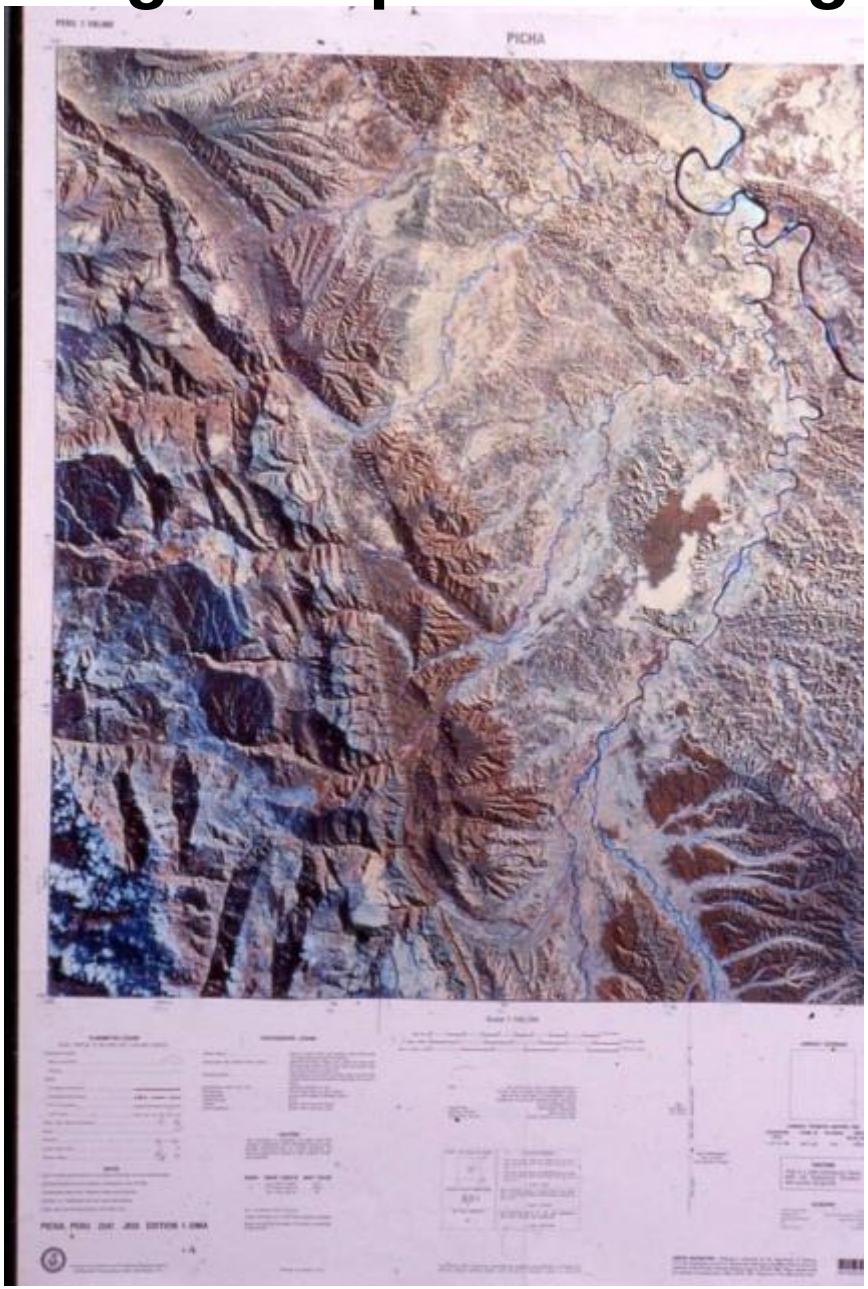
Source: USGS - Landsat TM

Image Processing to Improve Geologic Mapping

Same **Landsat TM Data Processed to Bring Out Geologic Information.**

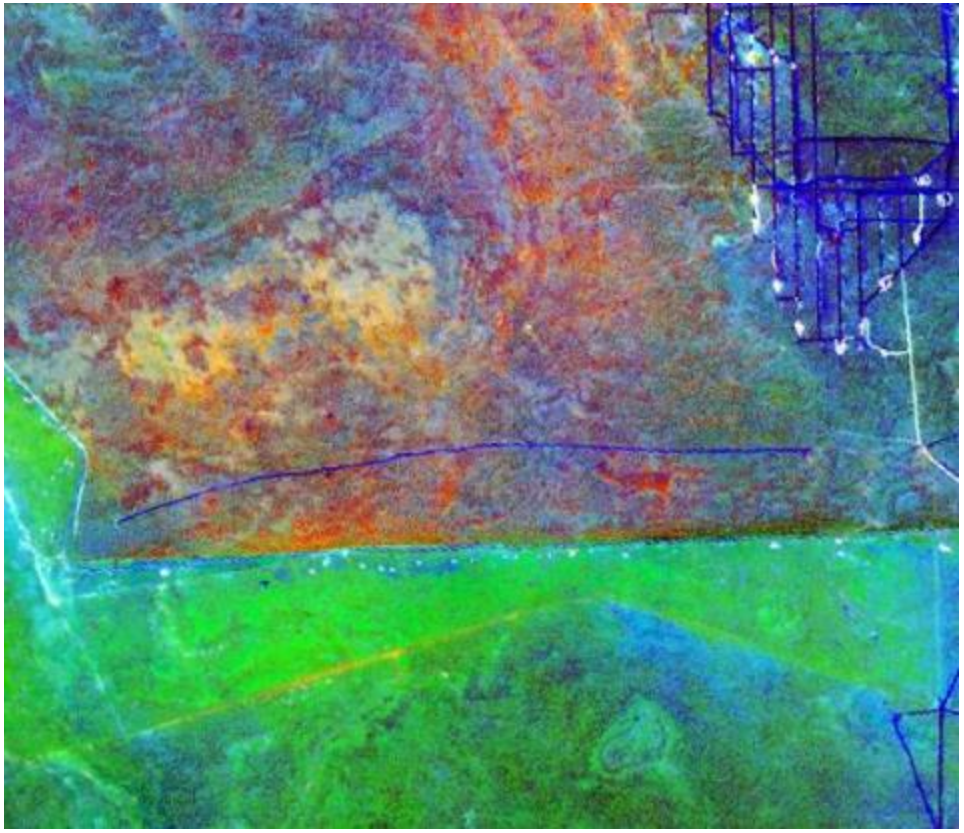
Processing Highlighted Structural & Stratigraphic Patterns.

Processing used Spectral Information in Vegetation Cover To Reveal New Geologic Information



Source: USGS - Landsat TM

Image Processing to Improve Geologic Mapping



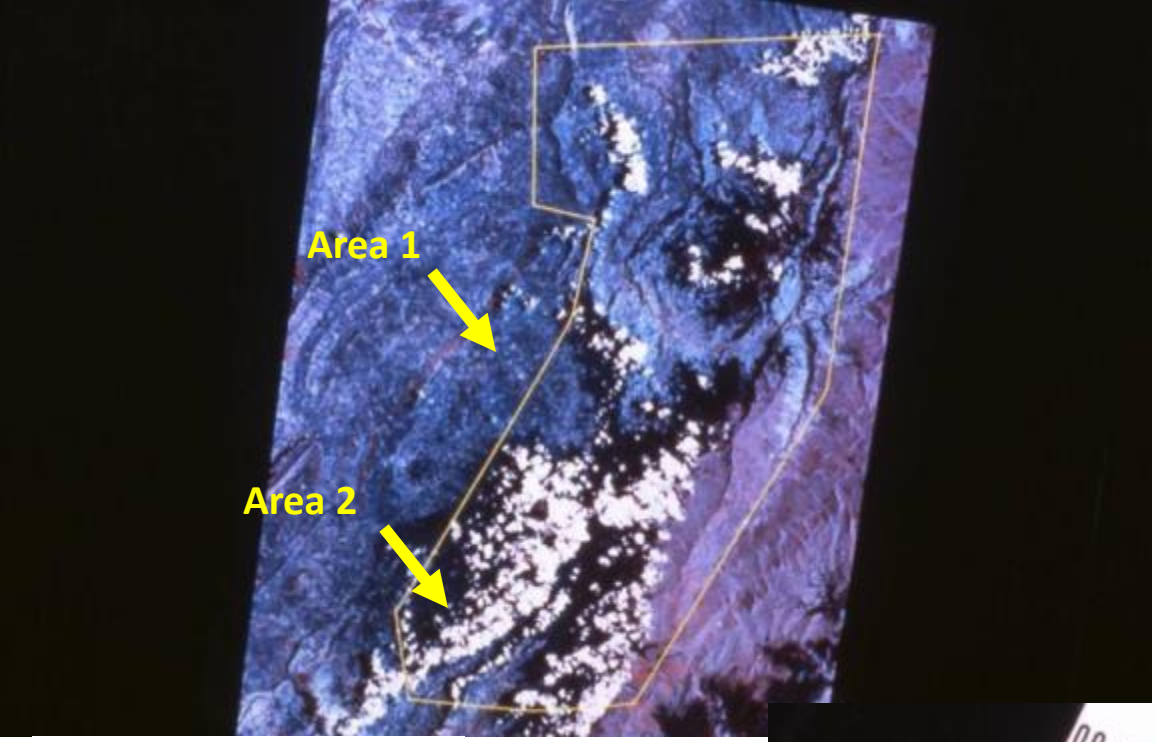
Source: USGS - Landsat TM

Radar in Cloudy Terrain

Chevron Petroleum Company of Colombia

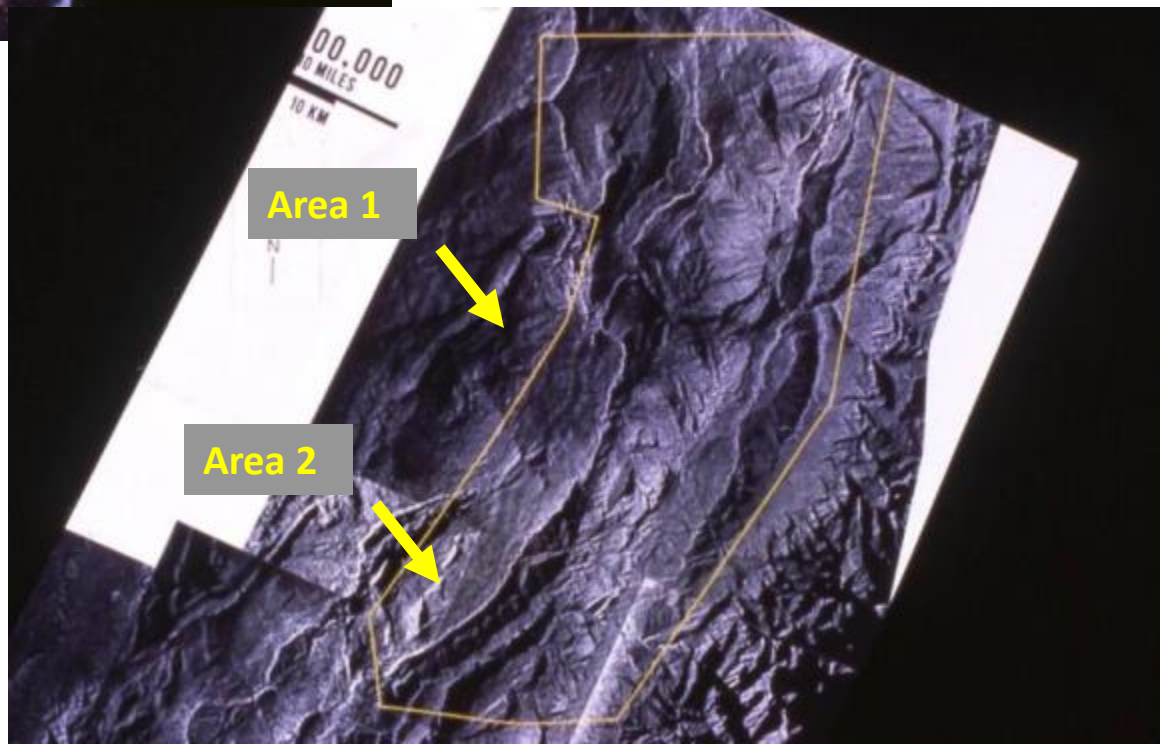
J.M. Ellis, W. Narr, P.B.Goodwin And G. Pérez

From:
-AAPG Distinguished Lecture, Dr. J. Ellis
-Earth Observation Magazine
Feb 1995



Landsat TM image

Blues = agriculture
Darks = Forest
White = Clouds
Purples = High Mountains

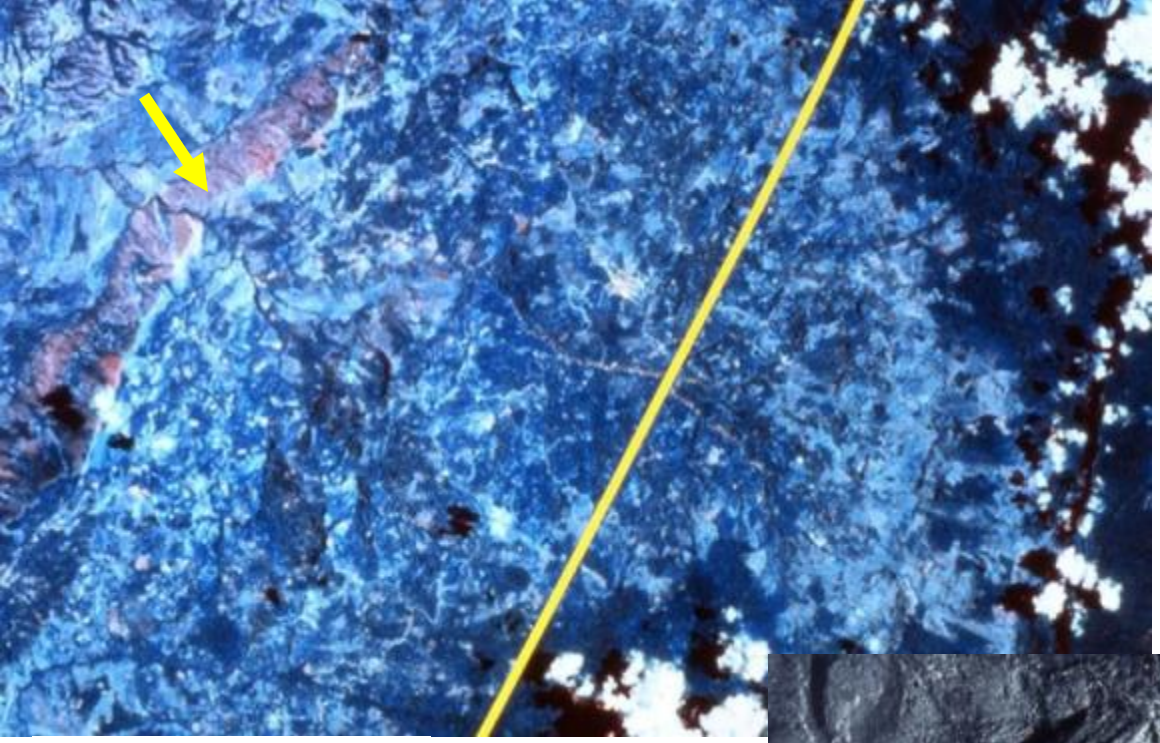


Airborne Radar Mosaic

Illuminated from the West

Source: Chevron & Intera Technologies (now Intermap)

Radar in Cloudy Terrain



Landsat TM image

Blues = agriculture

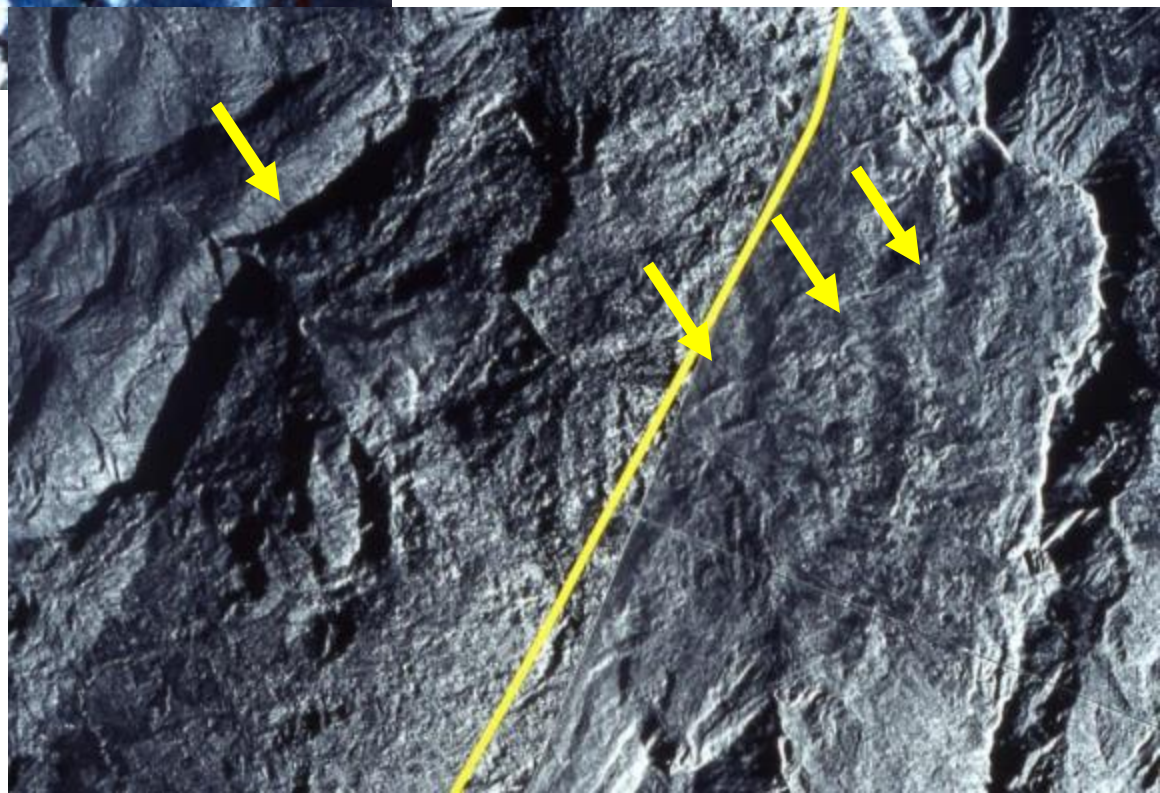
Darks = Forest

White = Clouds

Pinks-Whites = Open

Airborne Radar Mosaic

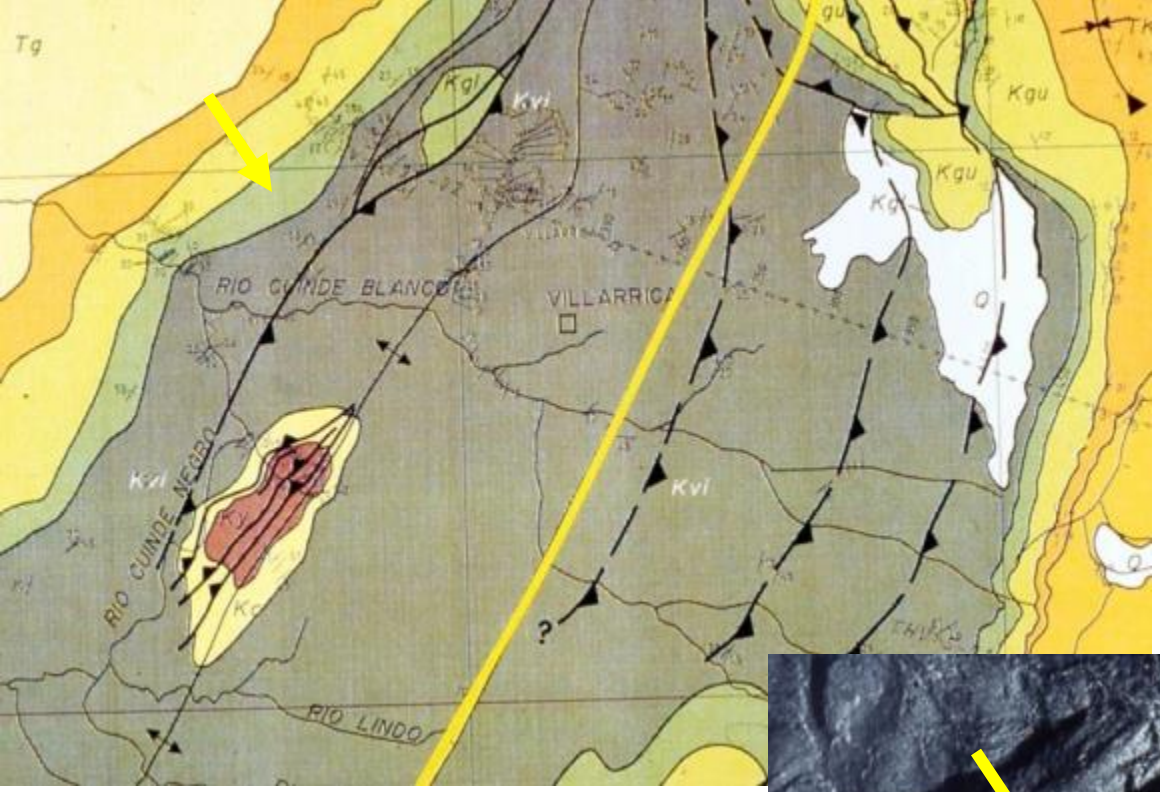
Illuminated from the West



AREA 1

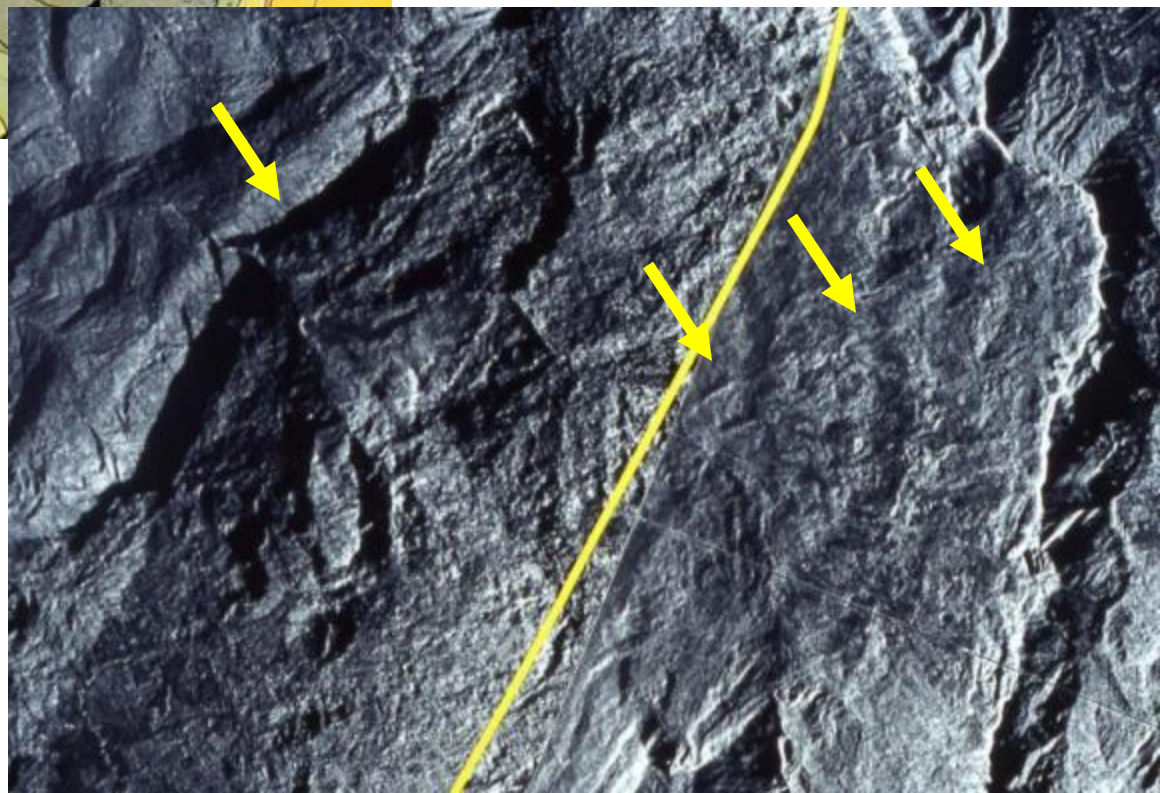
Source: Chevron & Intera Technologies (now Intermap)

Radar in Cloudy Terrain



New Geologic Map Interpreted from Radar and Field Mapping – note new thrust faults

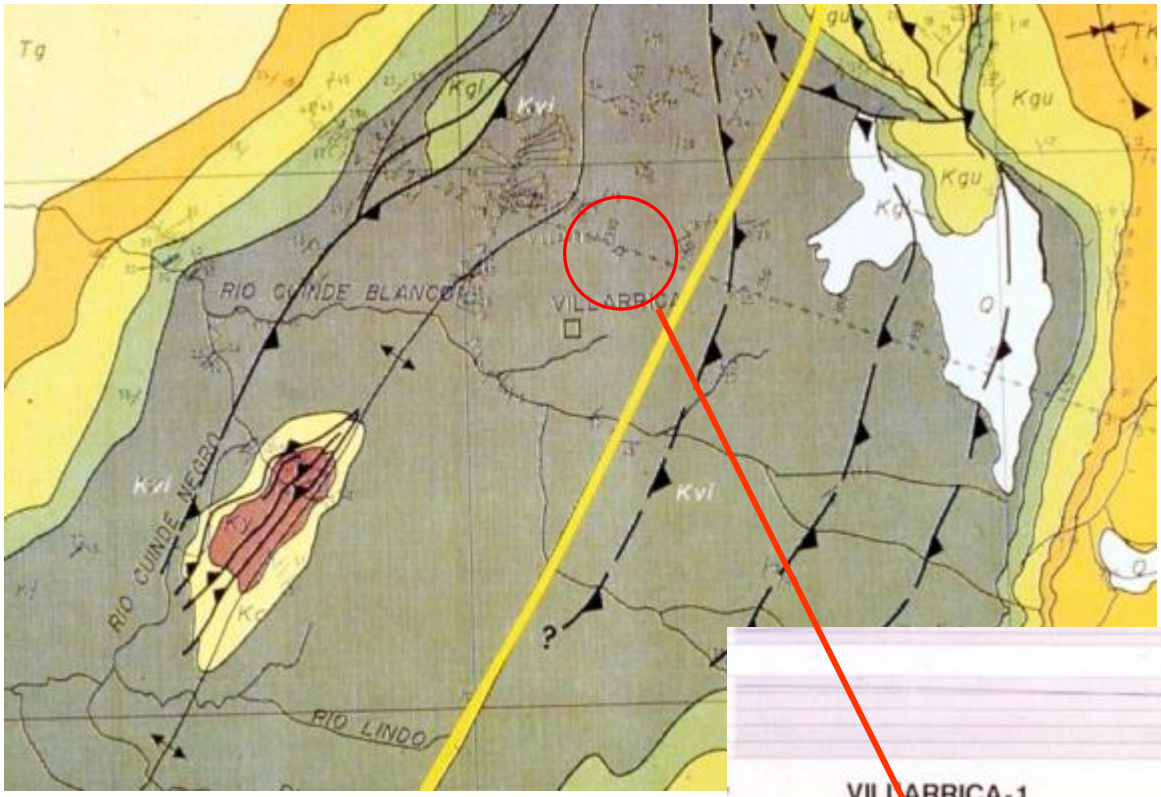
Airborne Radar Mosaic
Illuminated from the West



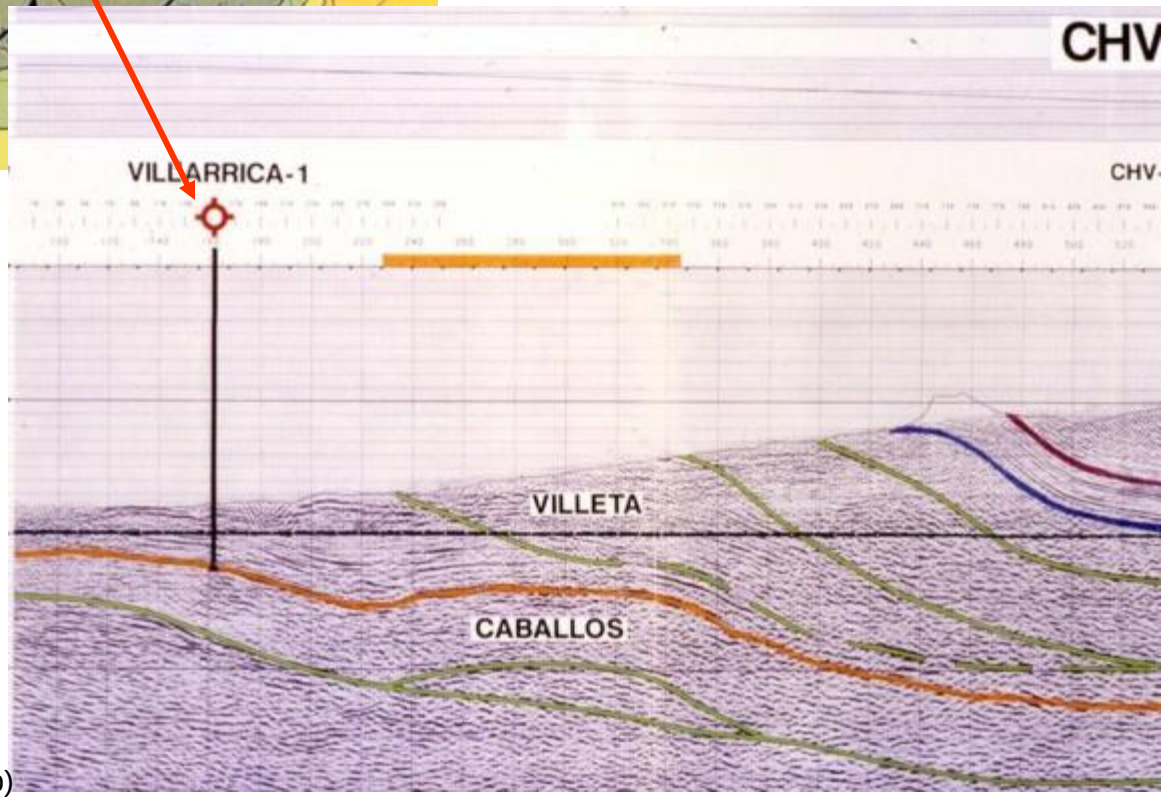
Source: Chevron & Intera Technologies (now Intermap)

Radar in Cloudy Terrain

Thrusts mapped on Radar used to Interpret Seismic
Dry hole makes sense

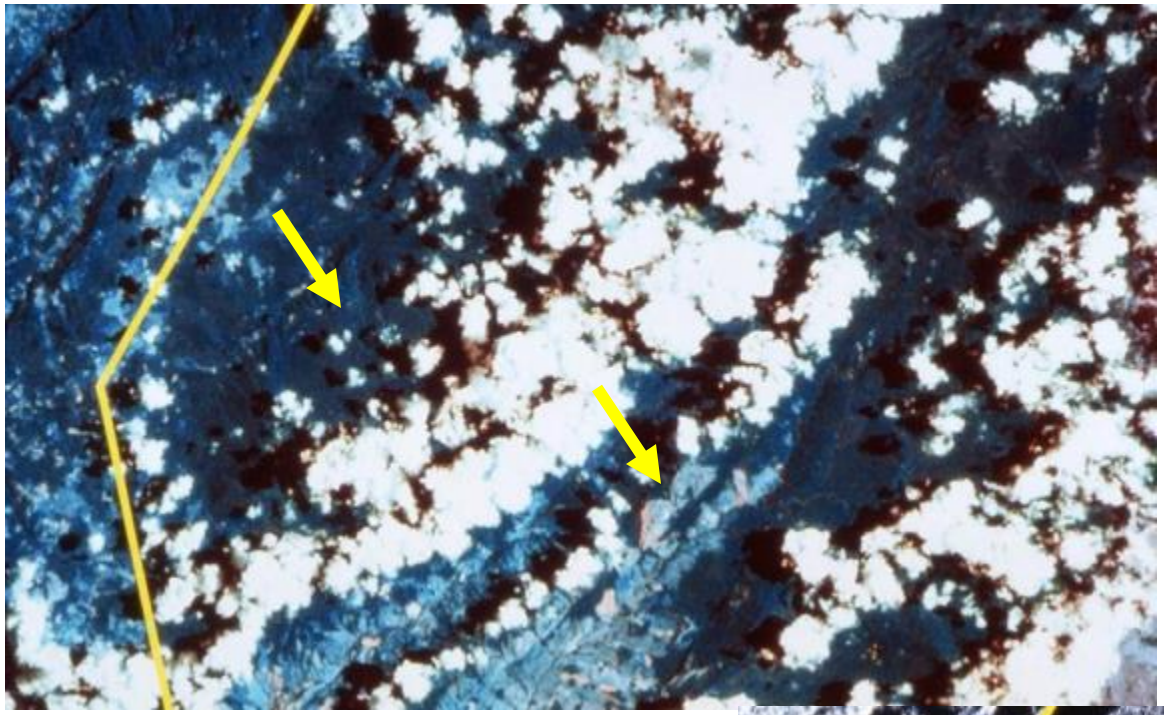


New Geologic Map Showing Old Well and Seismic Line



Source: Chevron & Intera Technologies (now Intermap)

Radar in Cloudy Terrain



Airborne Radar Mosaic

Illuminated from the West

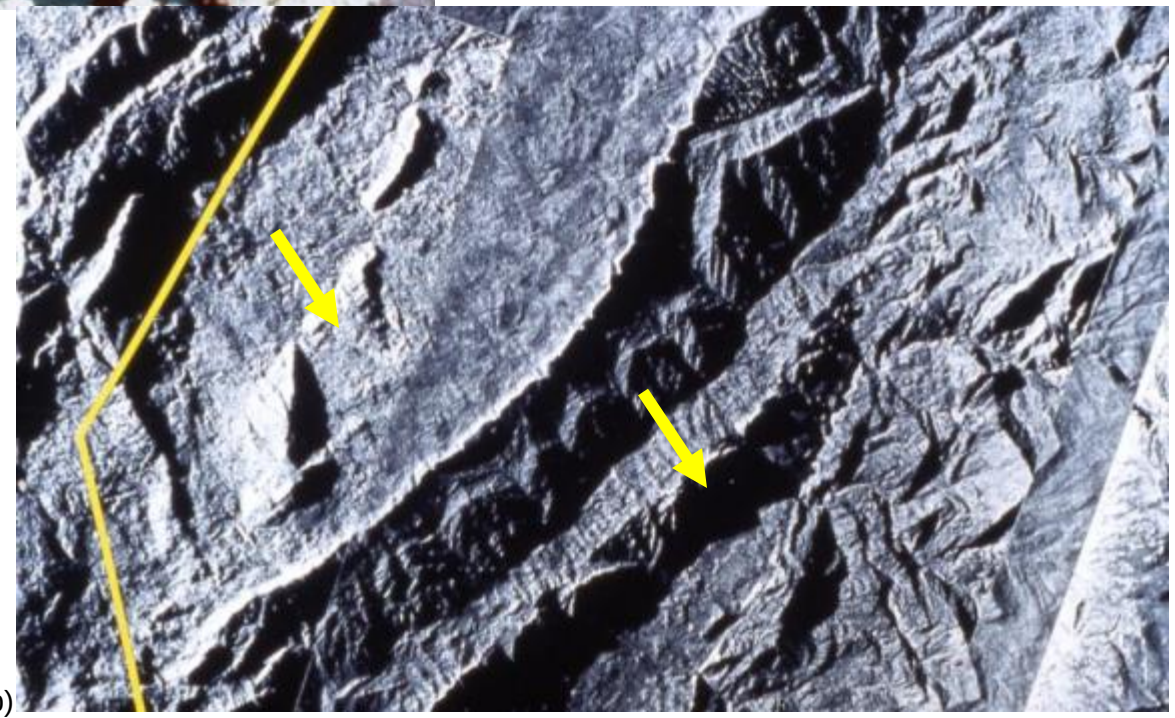
Landsat TM image

Blues = agriculture

Darks = Forest

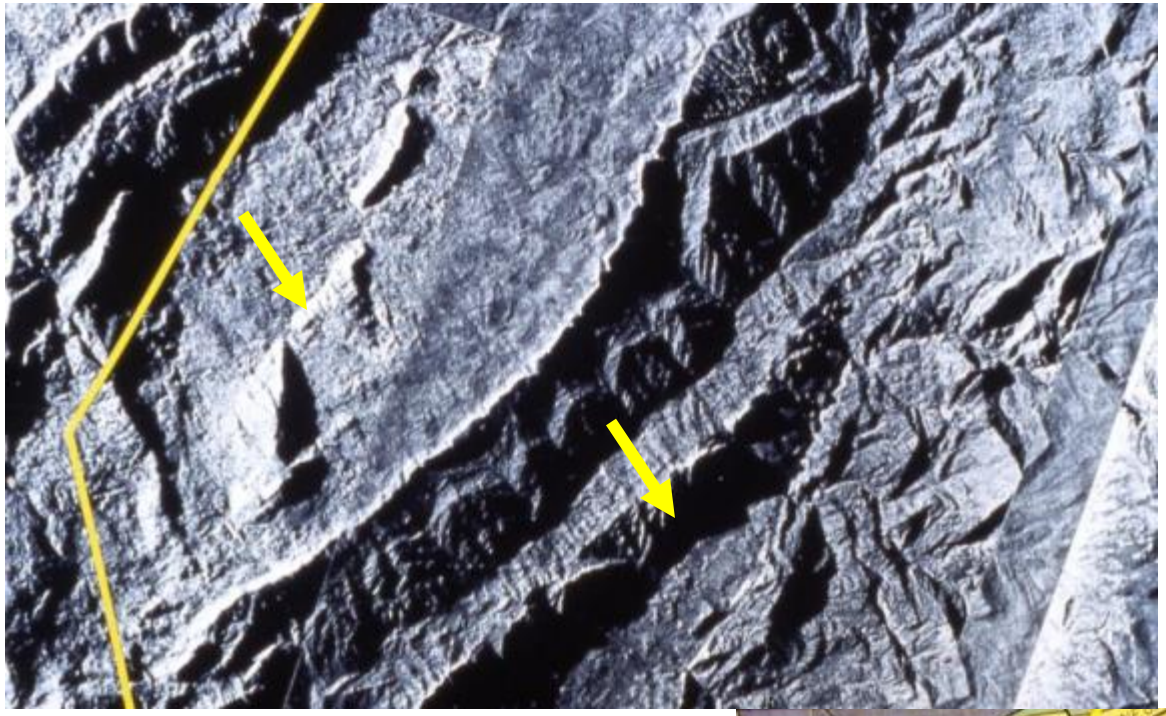
White = Clouds

AREA 2



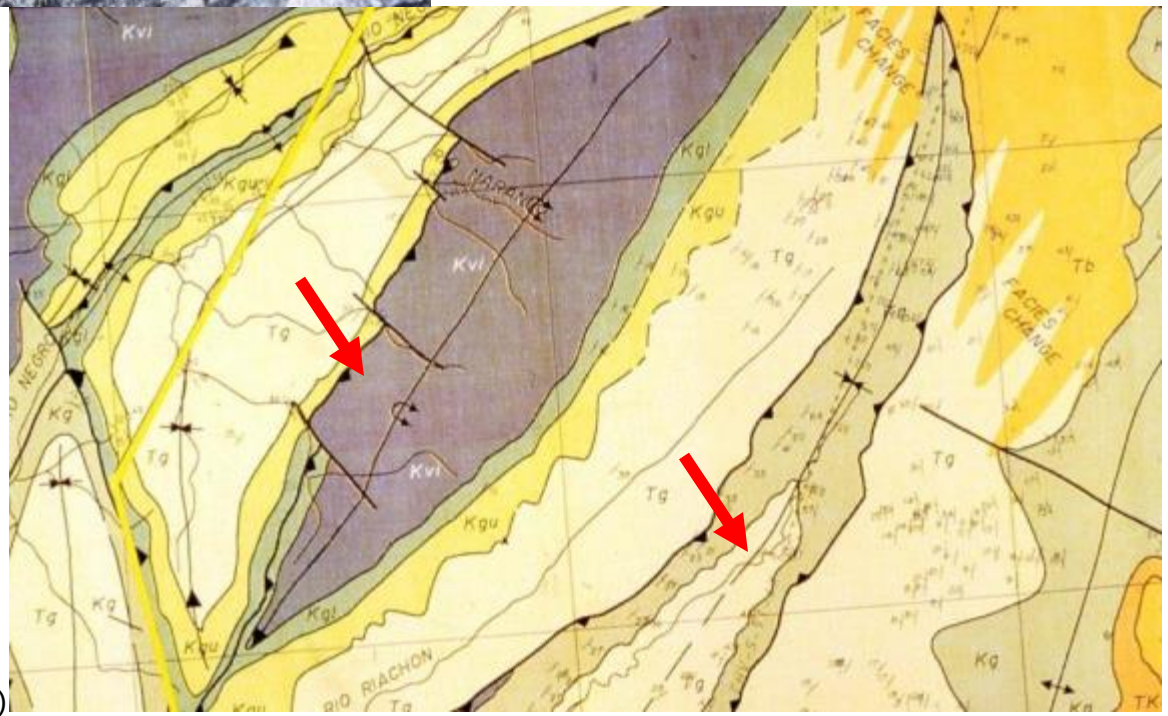
Source: Chevron & Intera Technologies (now Intermap)

Radar in Cloudy Terrain



Airborne Radar Mosaic
Illuminated from the West

New Geologic Map
Interpreted from Radar
And Fieldwork

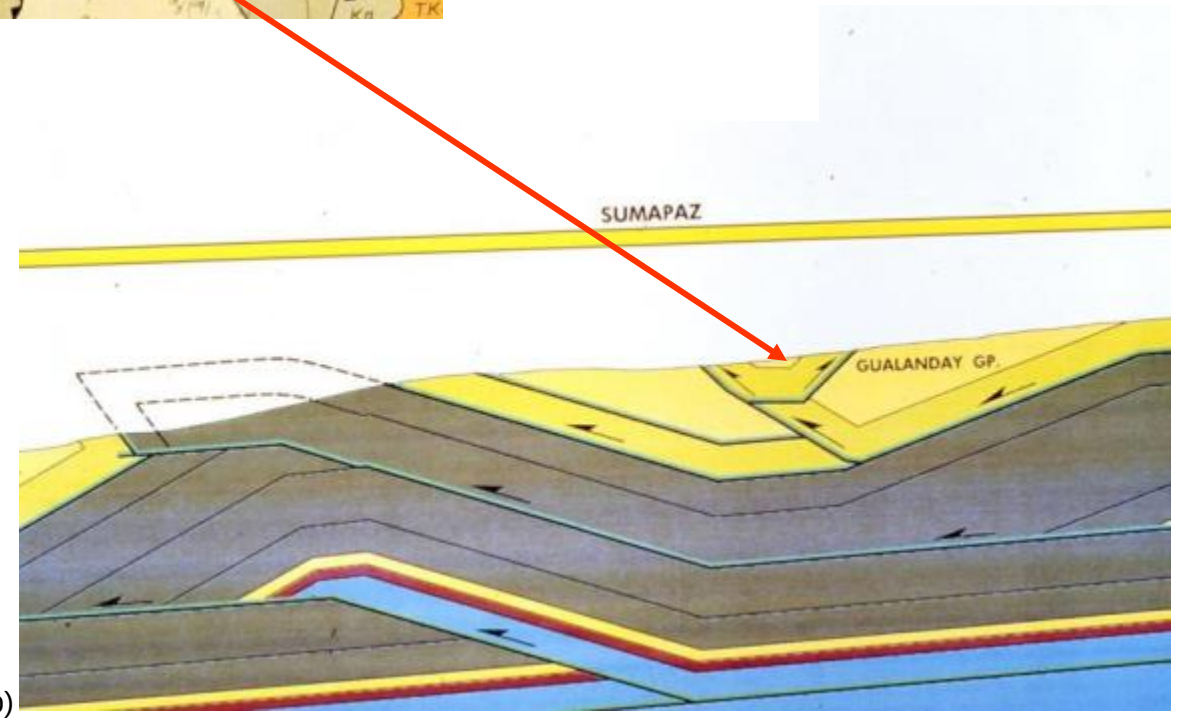


Source: Chevron & Intera Technologies (now Intermap)

Radar in Cloudy Terrain

Geologic Map Showing New Structural Feature Interpreted from Radar

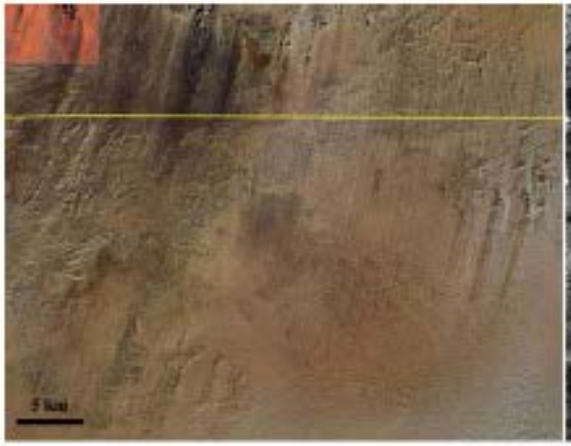
Balanced Cross Section Constrained By Radar Interpretation



Source: Chevron & Intera Technologies (now Intermap)

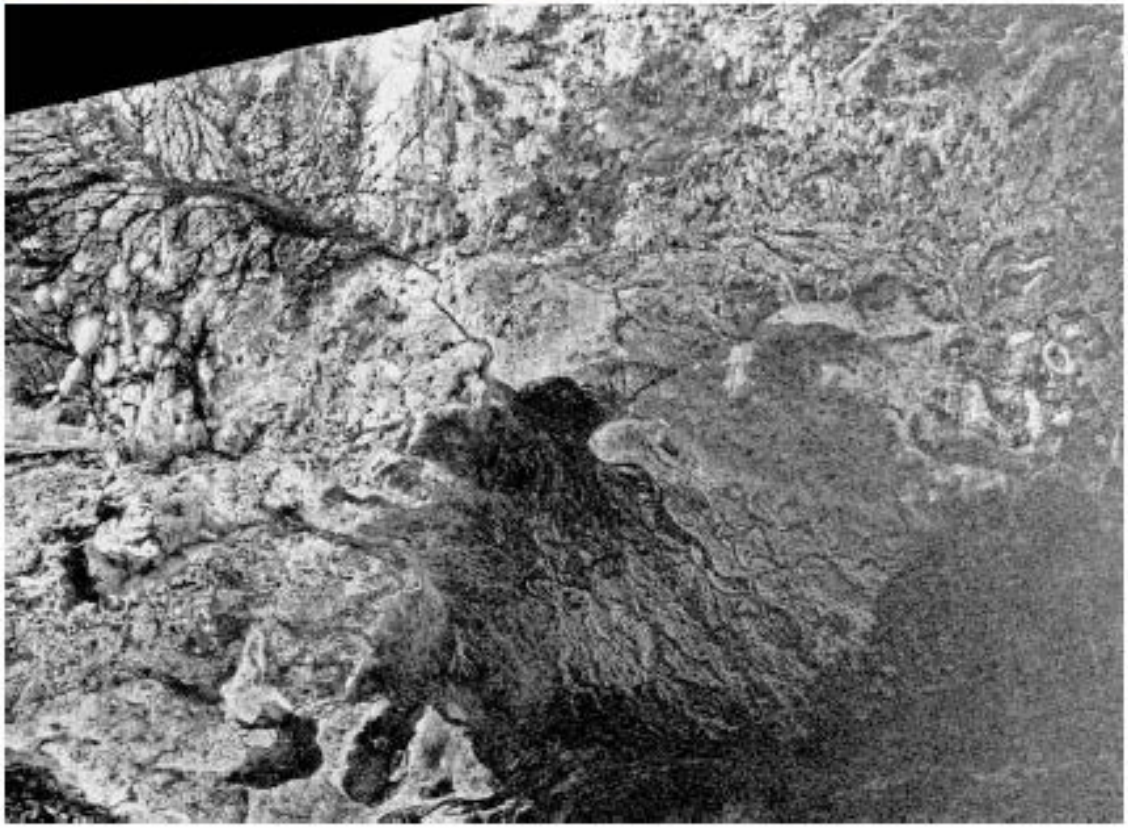
Long Wavelength Radar in Arid Regions

Landsat



Short Wavelength Radar (JERS-1)

Long Wavelength Radar (PALSAR)

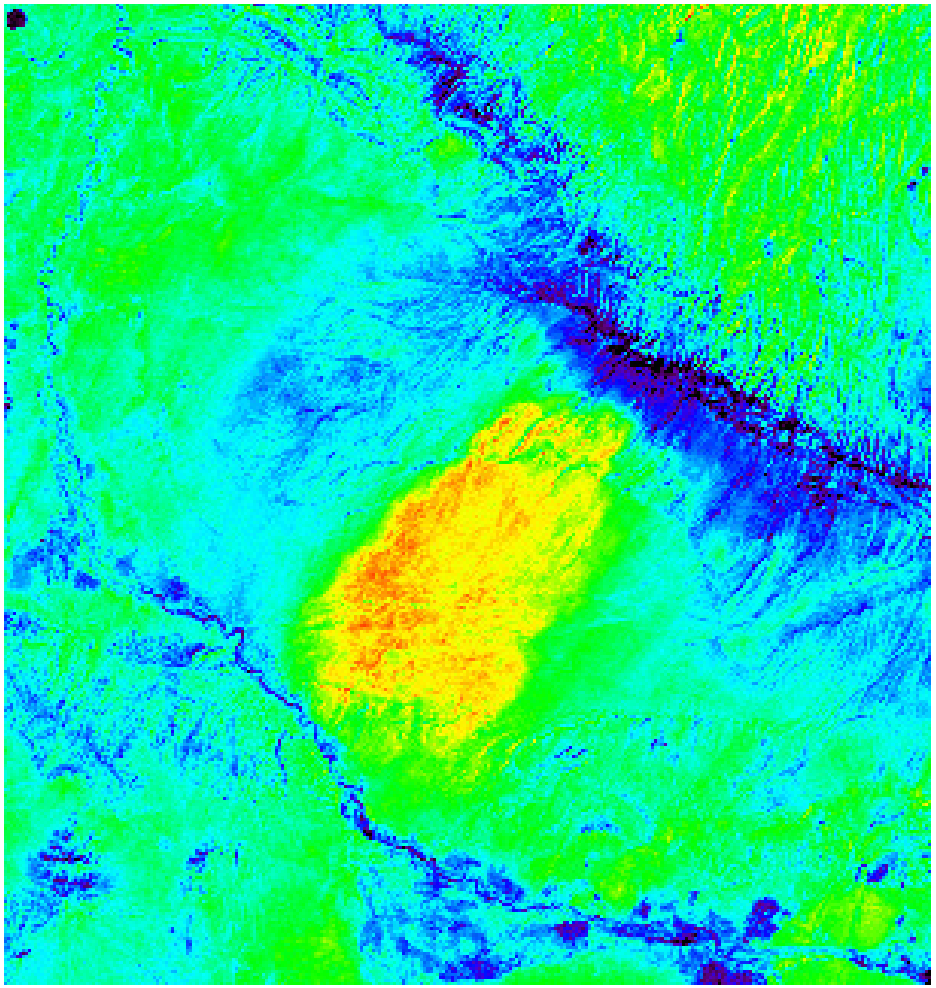


Palou, 2009? CNES

EORC JERS-1
PALSAR

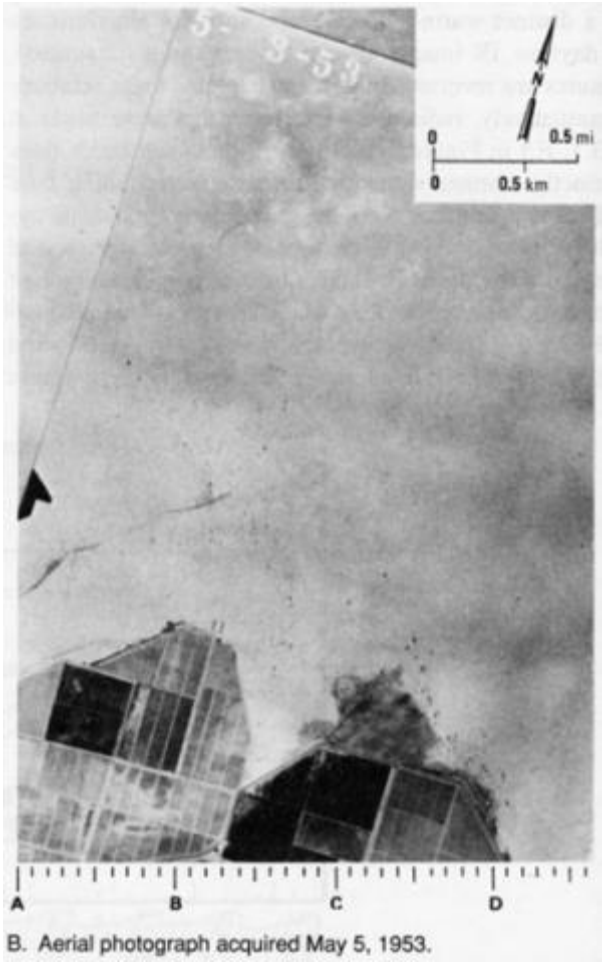
Figure 3. Landsat (top left), JERS-1 (top right) and PALSAR image (bottom) of a region located around 21°55'N, 26°36'E. PALSAR much better reveals paleodrainage channels in the lower part of the scene (JAXA/METI).

Daytime Thermal – Landsat Band 6



Source: USGS - Landsat TM

Airborne Nighttime Thermal



B. Aerial photograph acquired May 5, 1953.

A. Nighttime thermal IR image (8 to 14 μm) acquired August 1961.

Figure 5-23 Images of the Imler Road area, Imperial County, California. From Sabins (1969, Plate 1).

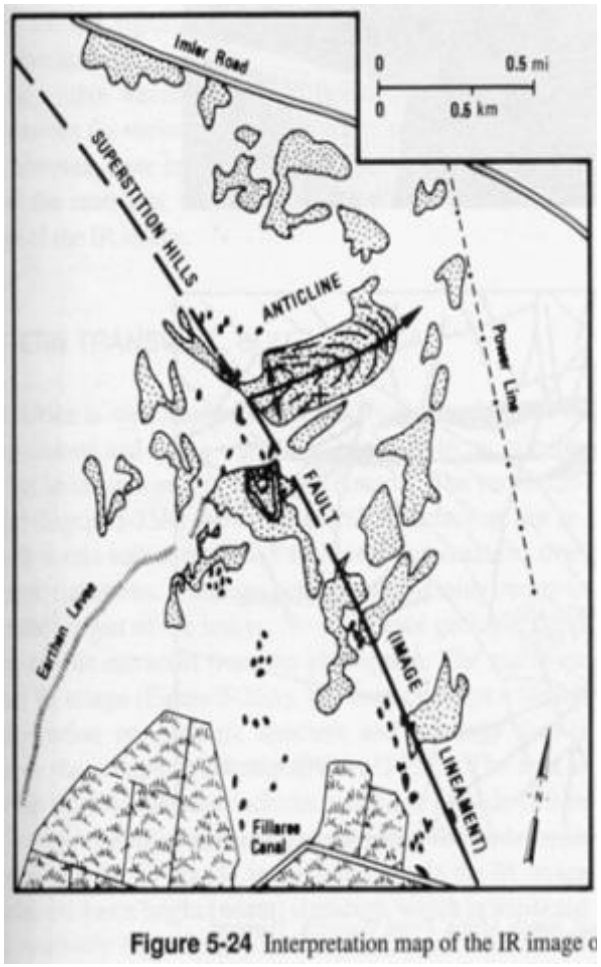
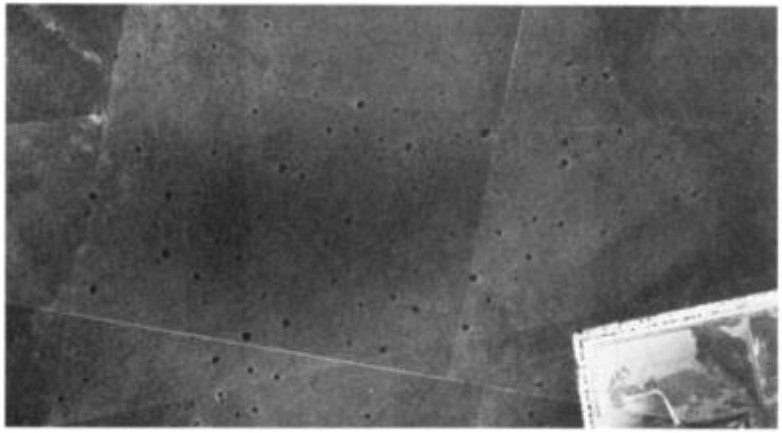


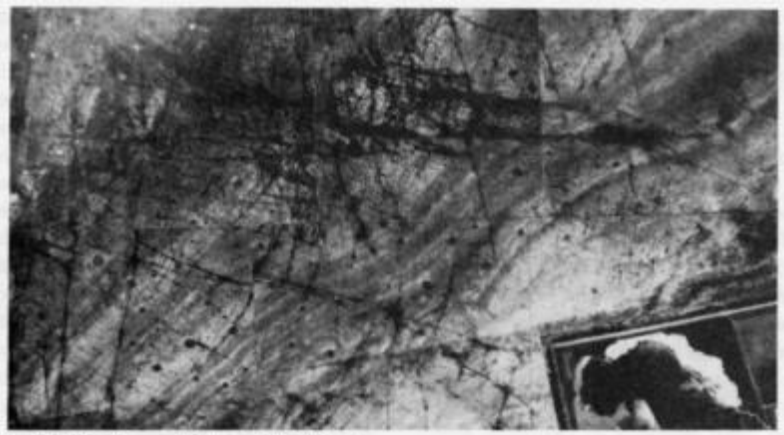
Figure 5-24 Interpretation map of the IR image

From: Floyd F. Sabins, 1997, Remote Sensing Principles and Interpretation: 3rd edition, Waveland Press, Inc., 494 p.
(Dr. Sabins former Senior Research Scientist at Chevron (COFRC, La Habra, CA))

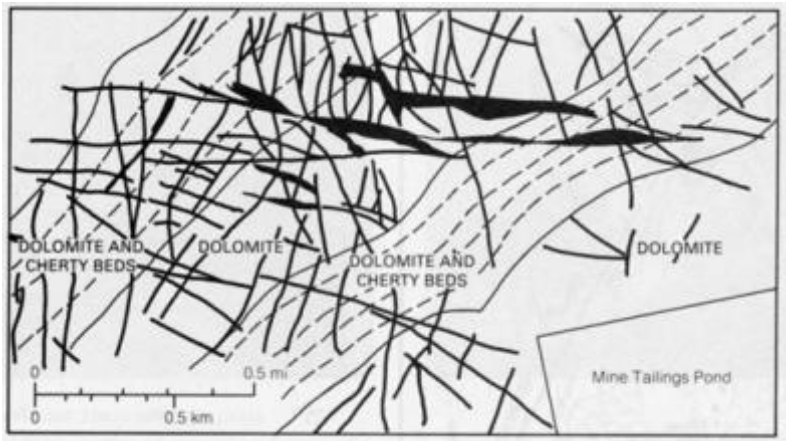
Airborne Nighttime Thermal



B. Aerial photograph.



A. Nighttime thermal IR image (8 to 14 μm).

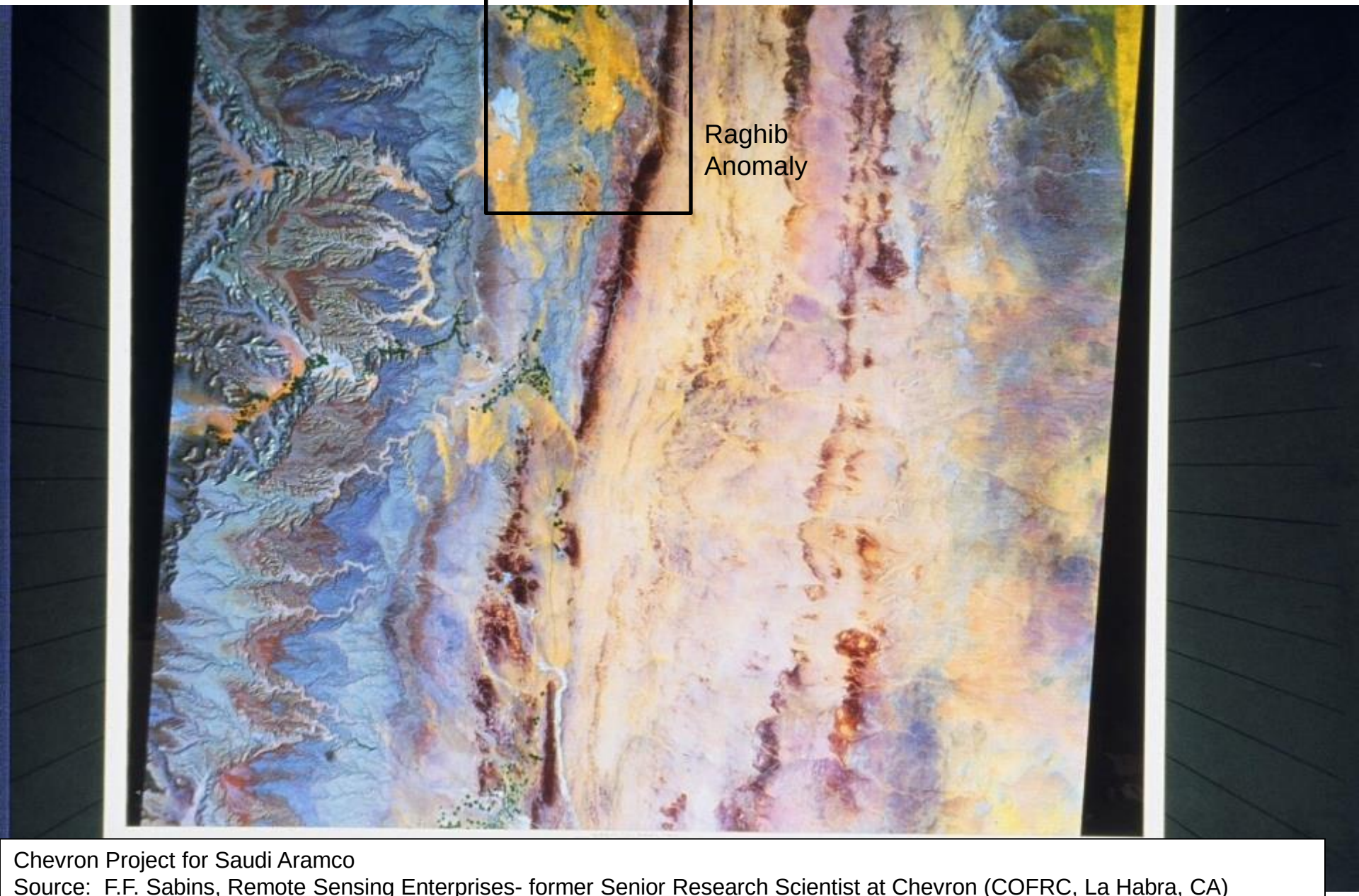


C. Interpretation map of thermal IR image.

From: Floyd F. Sabins, 1997, Remote Sensing Principles and Interpretation: 3rd edition, Waveland Press, Inc. NY, 494 p. (Dr. Sabins former Senior Research Scientist at Chevron (COFRC, La Habra, CA))

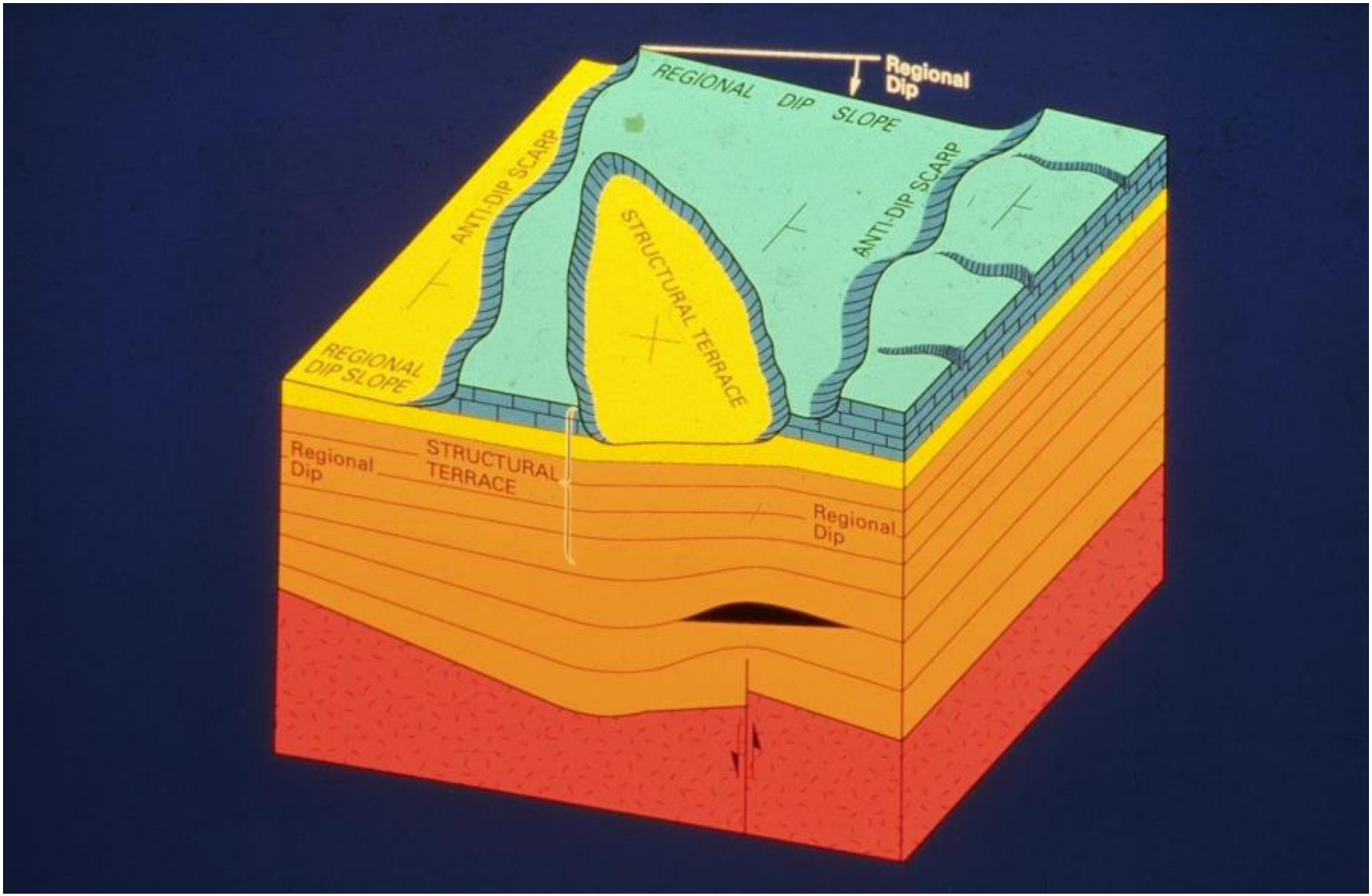
Stilfontein area, western Transvaal, South Africa. From Warwick, Hartopp, and Viljoen (1979, Figures 8 and 9)

Landsat Interpretation



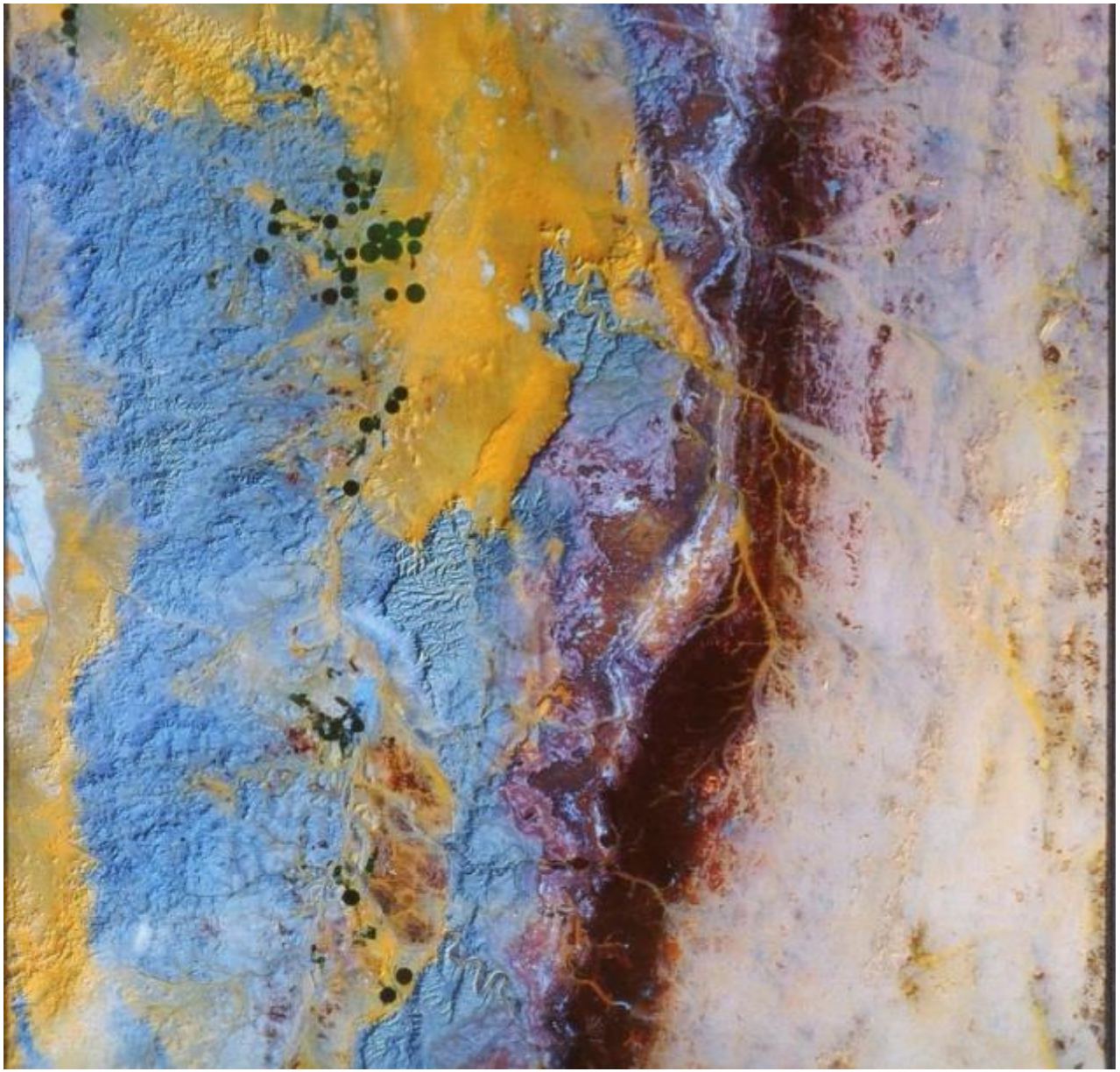
Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises- former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

Play Concept

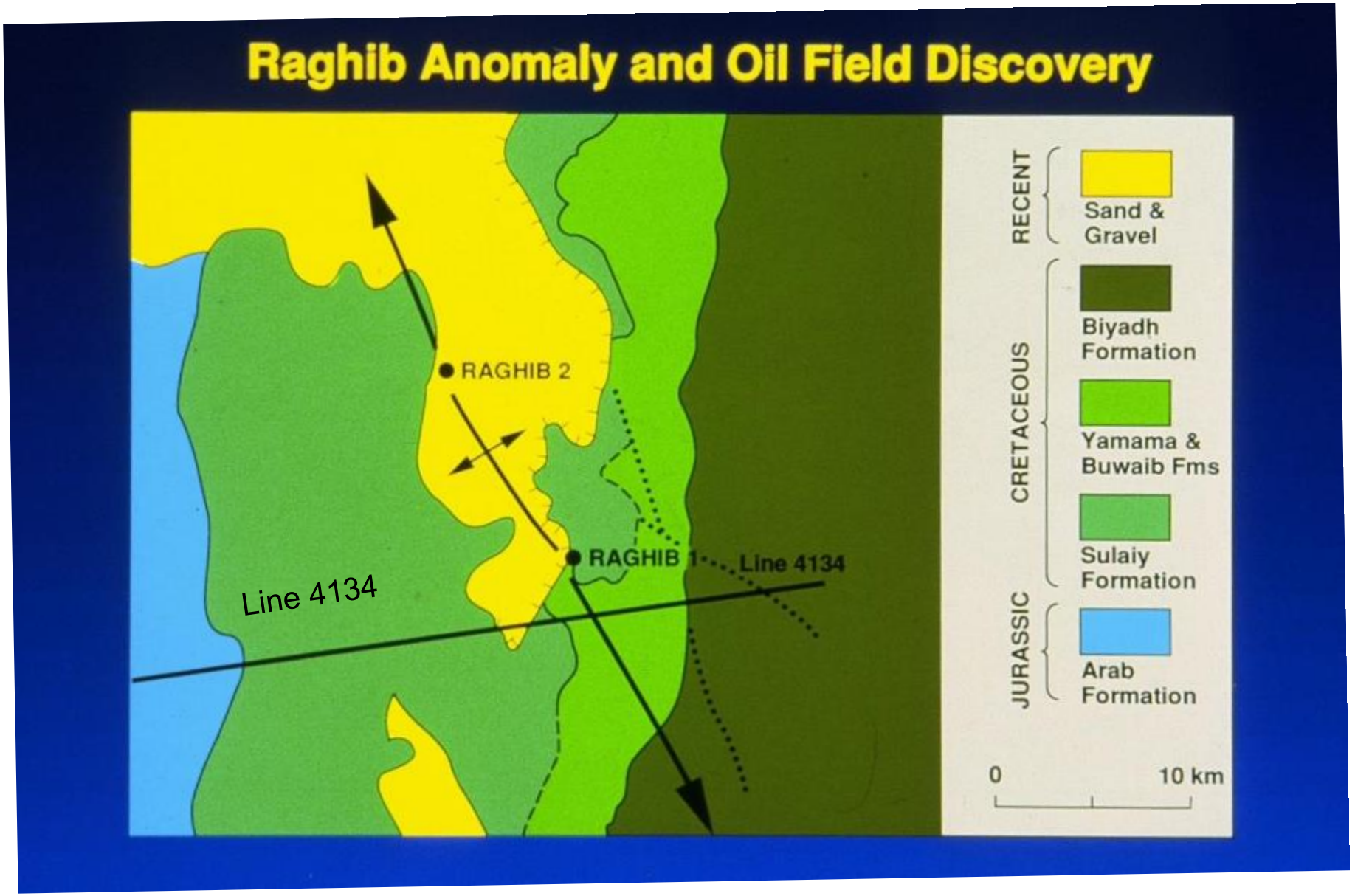


Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

Raghib Anomaly - Landsat 742 as RGB

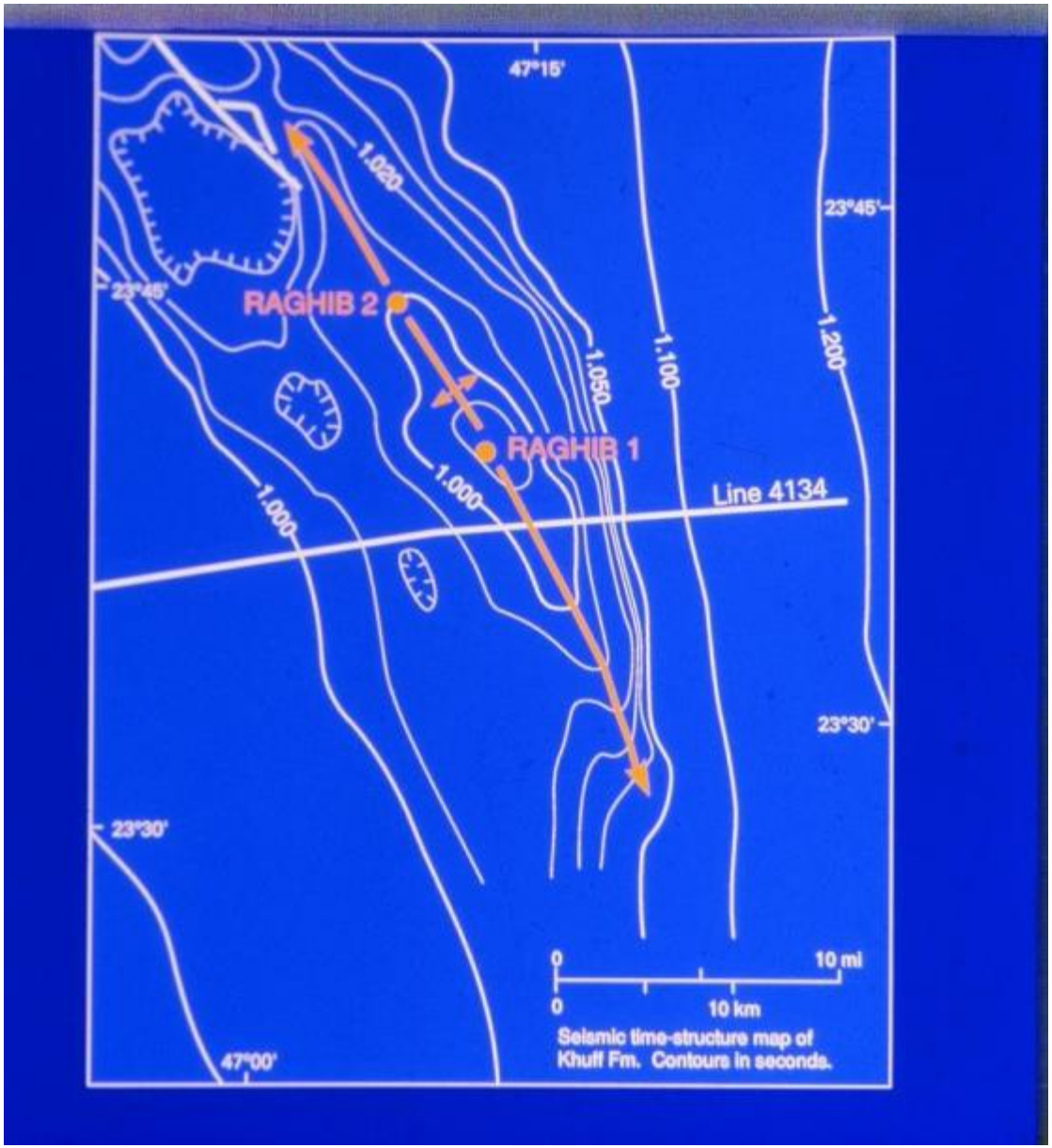


Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)



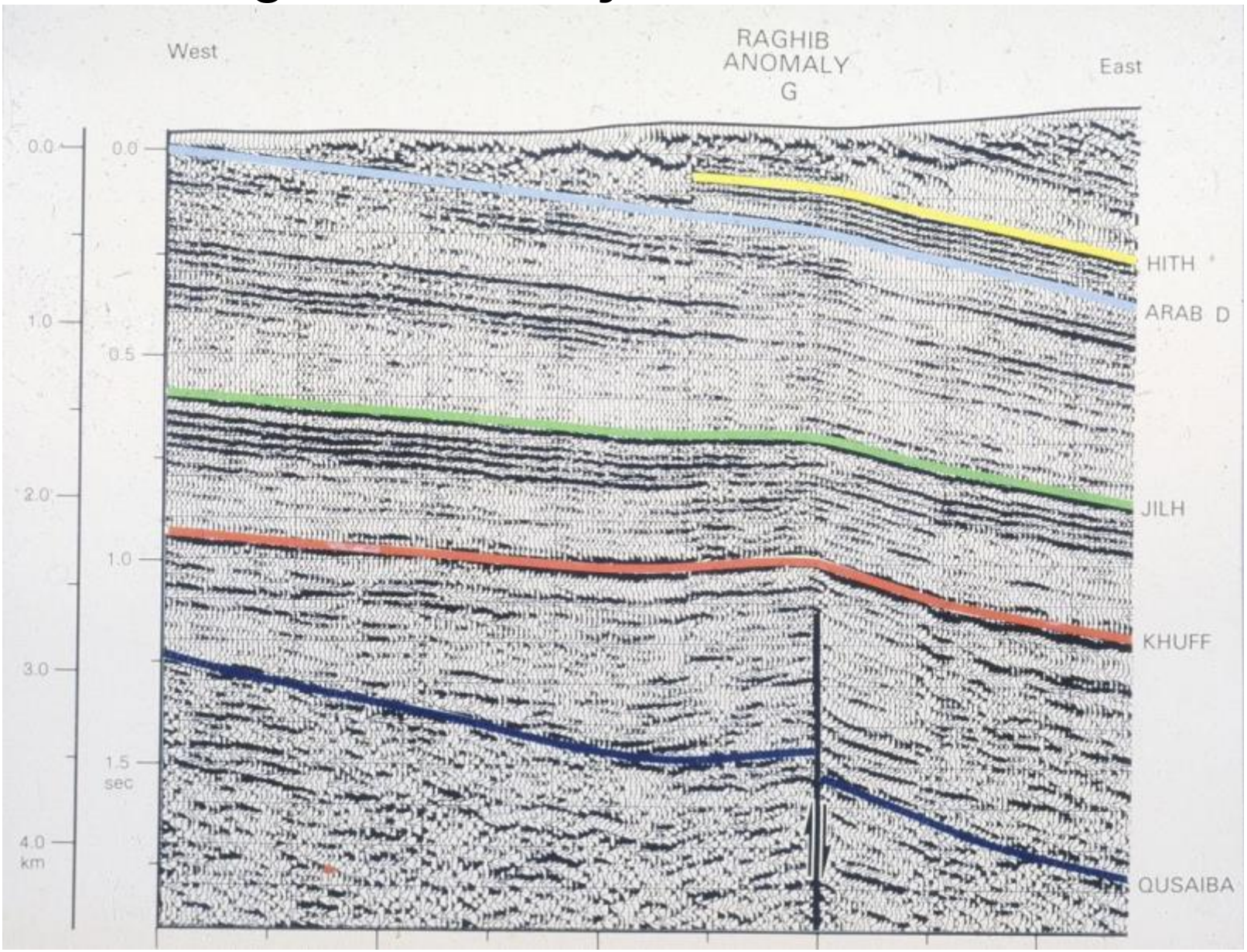
Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

Raghib Anomaly - Seismic Structure Map



Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

Raghib Anomaly - Seismic Line



Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

Raghib Anomaly Cliff Facing Dip Direction

Chevron Project for Saudi Aramco
Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

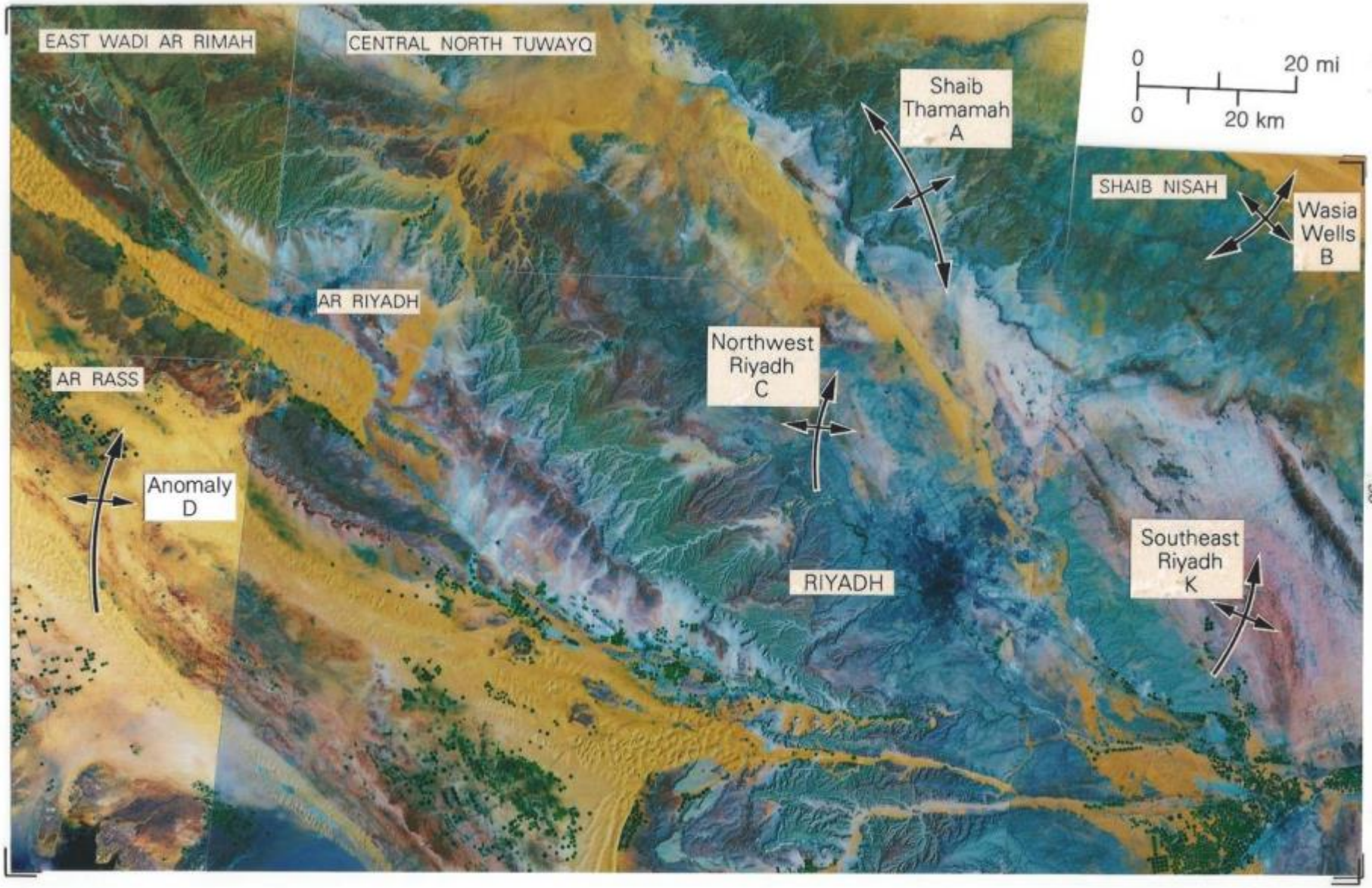


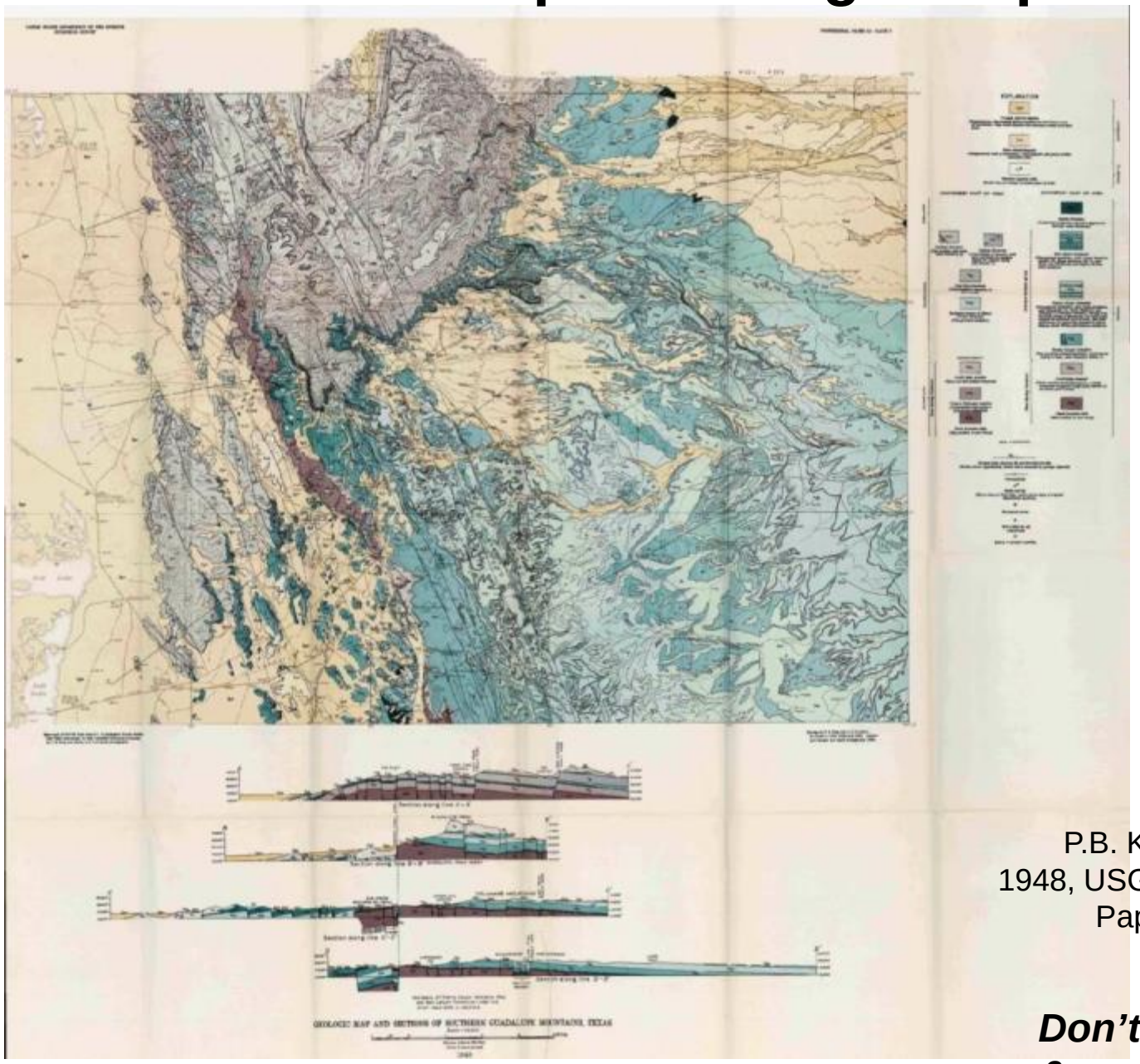
Figure 31

Landsat mosaic of Riyadh region showing location of images and major Landsat anomalies.

Chevron Project for Saudi Aramco

Source: F.F. Sabins, Remote Sensing Enterprises - former Senior Research Scientist at Chevron (COFRC, La Habra, CA)

Convert those Paper Geologic Maps!

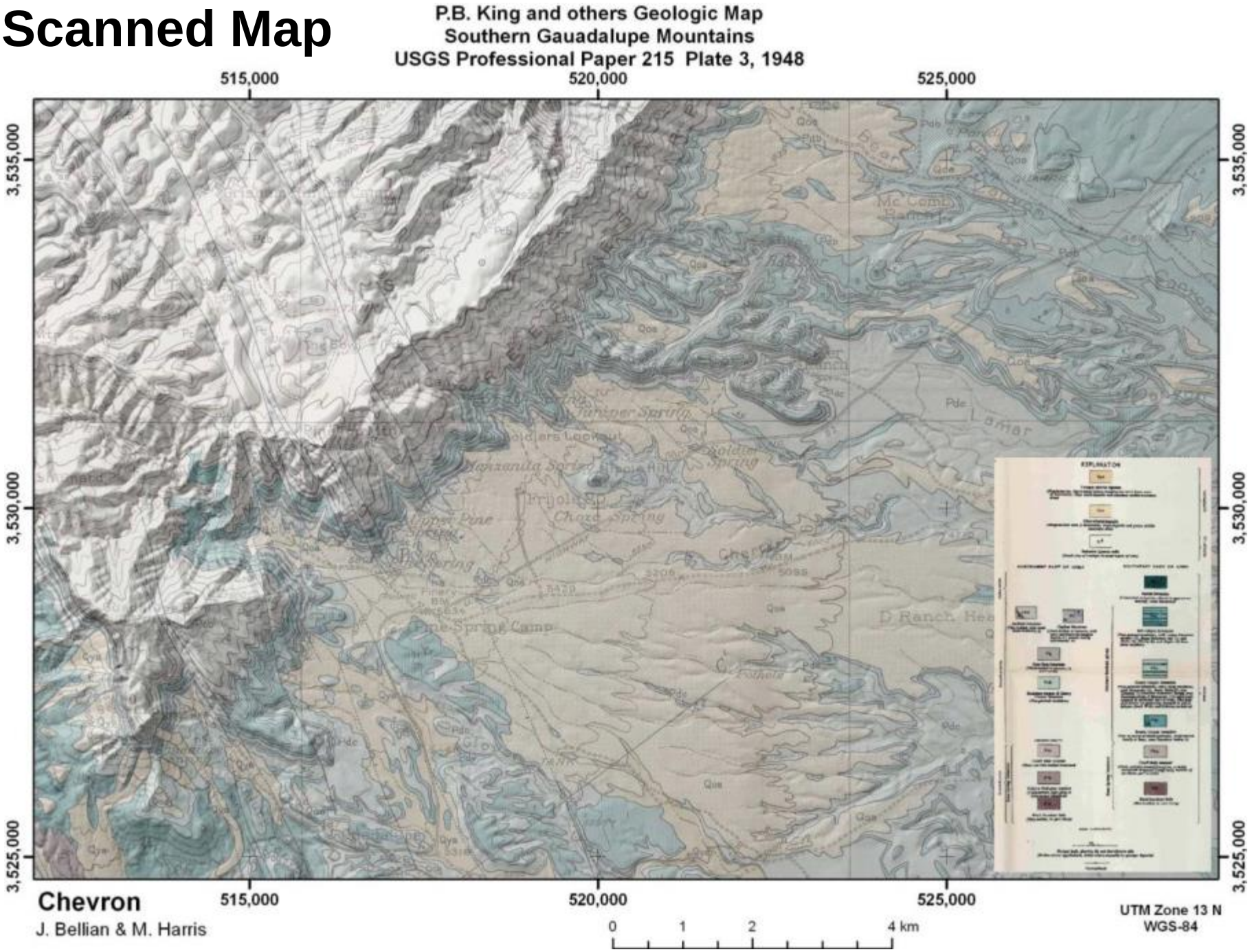


P.B. King and others, 1948, USGS Professional Paper 215, Plate 3

Don't just scan & georeference!

Source: USGS

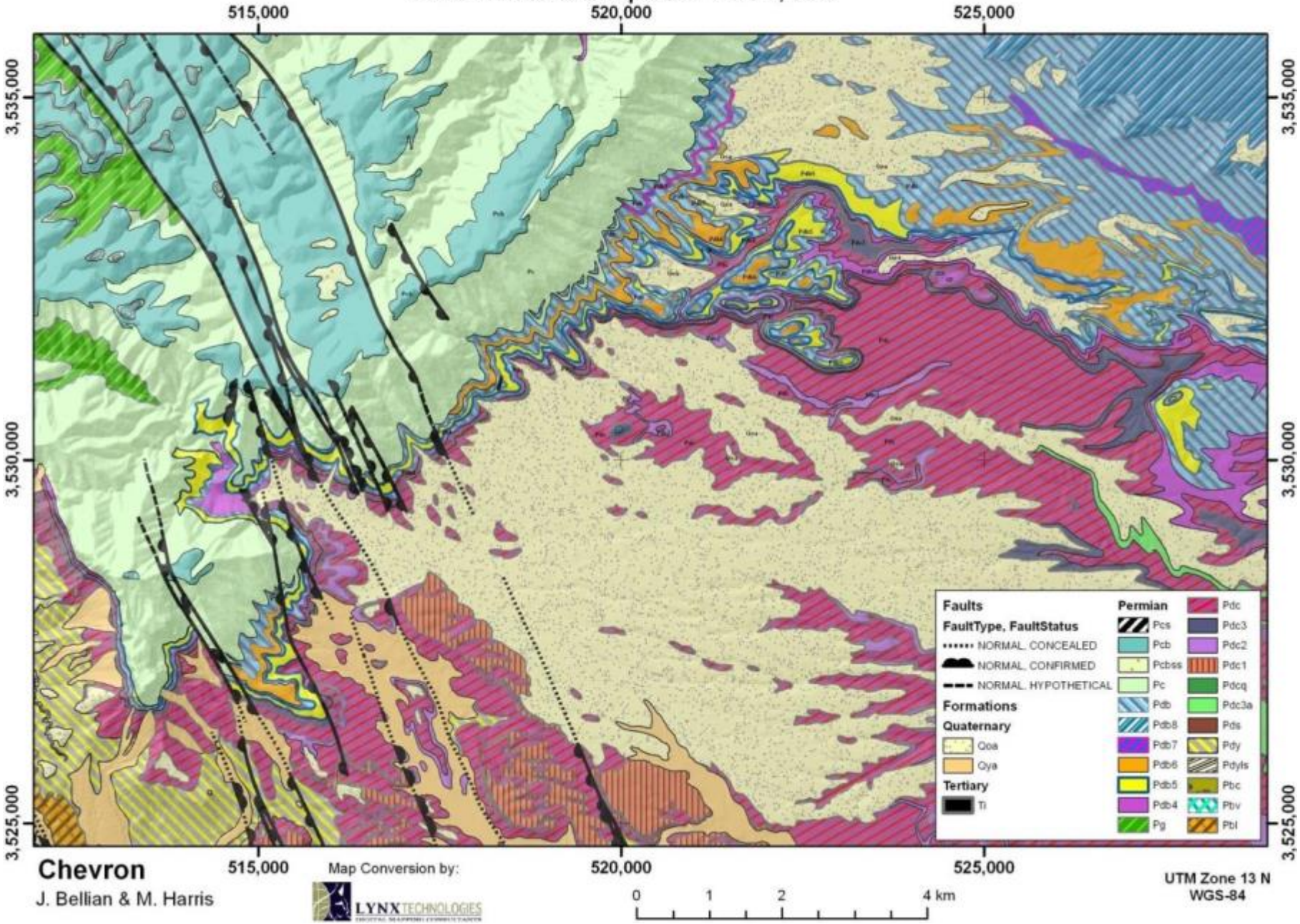
Scanned Map


P.B. King and others Geologic Map
Southern Gauadalupe Mountains
USGS Professional Paper 215 Plate 3, 1948
515,000
520,000
525,000
3,535,000
3,530,000
3,525,000
Chevron
J. Bellian & M. Harris
0
1
2
4 km
UTM Zone 13 N
WGS-84

Converted Map

P.B. King and others Geologic Map
Southern Gauadalupe Mountains
USGS Professional Paper 215 Plate 3, 1948

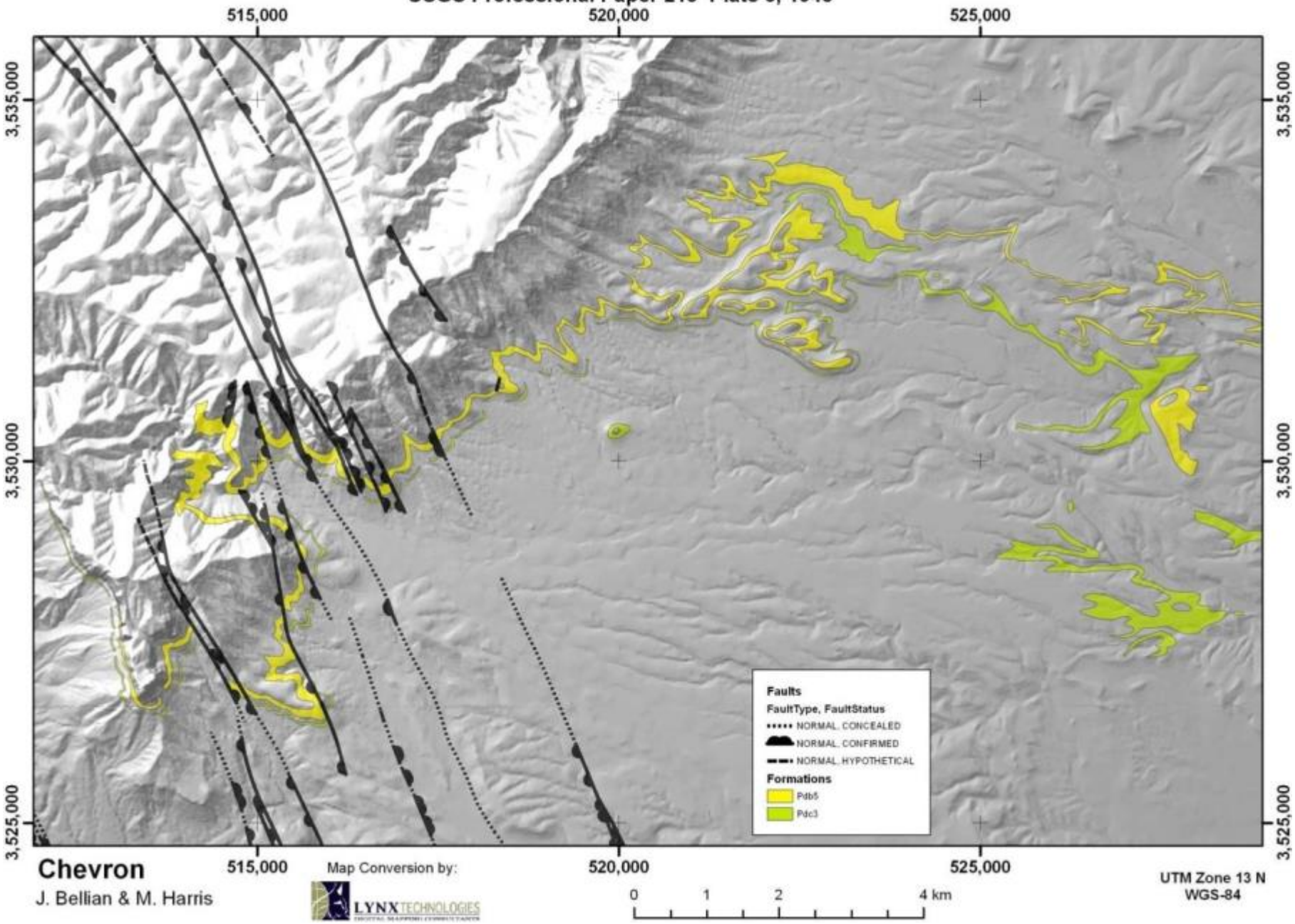
GIS Map with Attributes



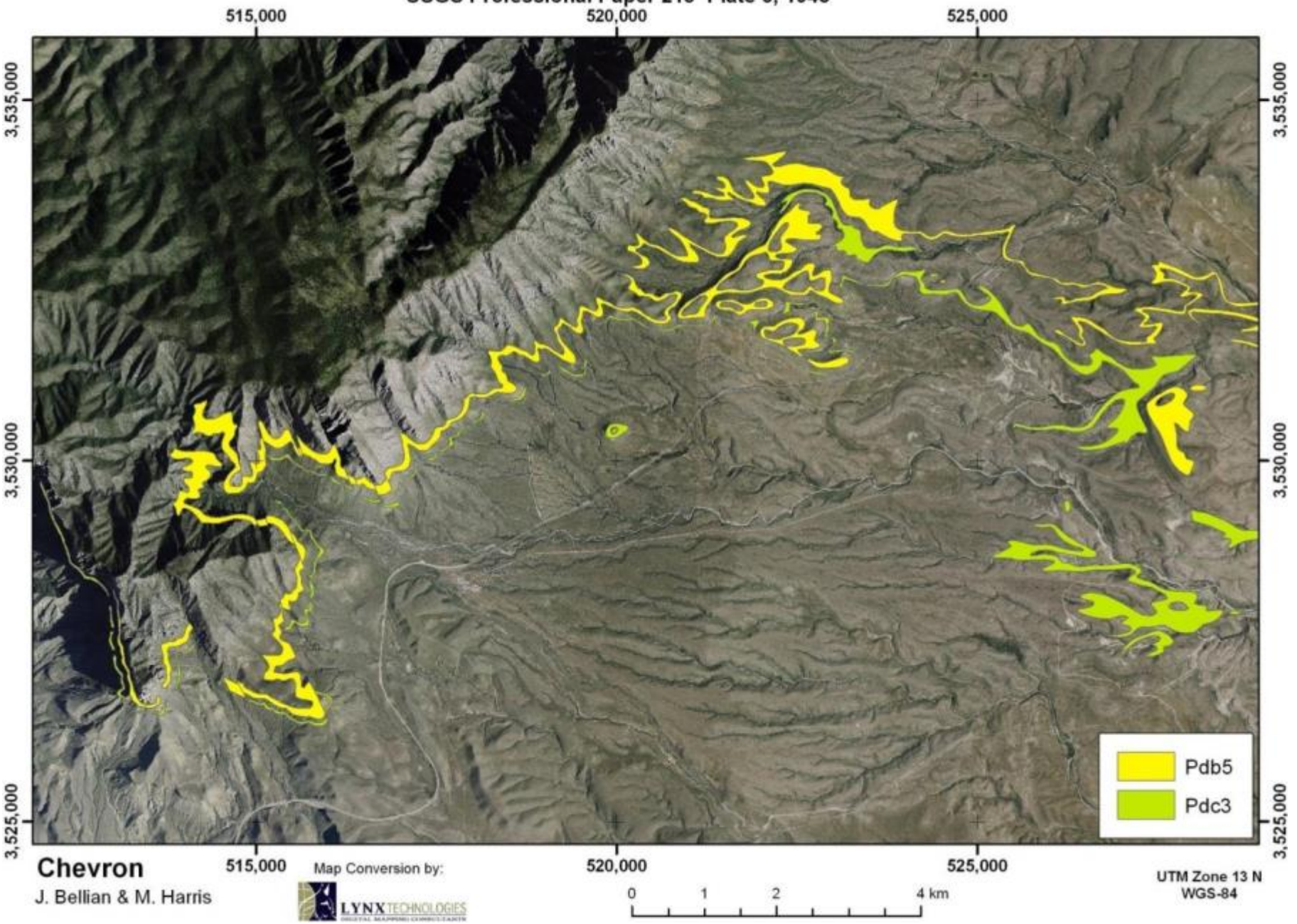
Extract Key Beds

P.B. King and others Geologic Map
Southern Gauadalupe Mountains
USGS Professional Paper 215 Plate 3, 1948

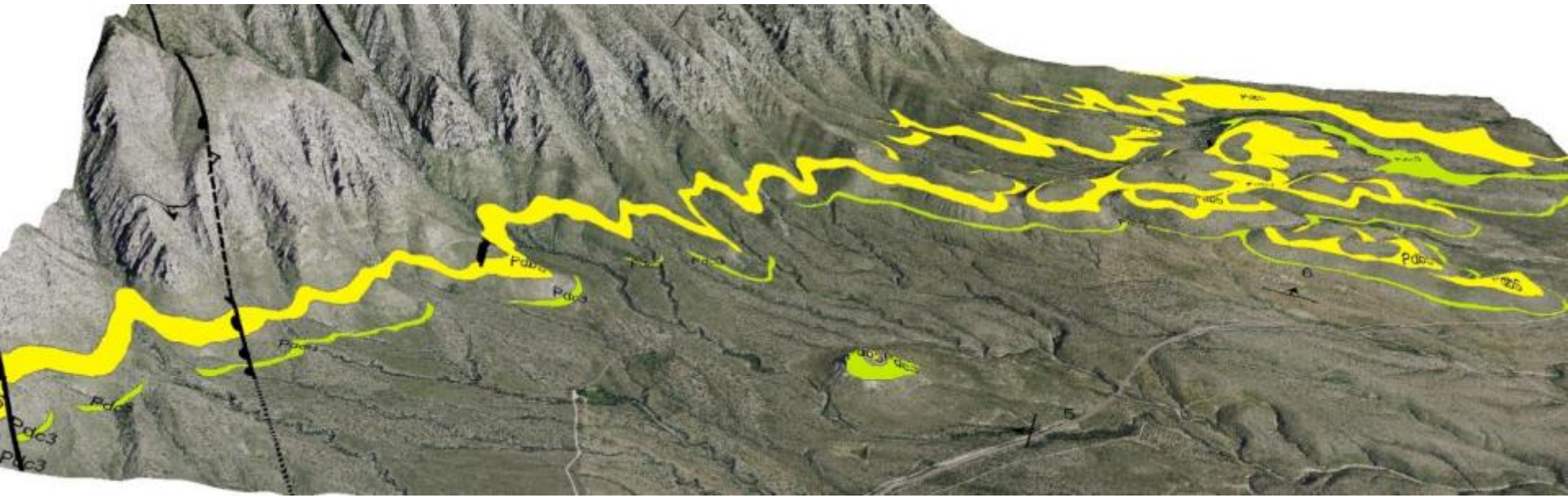
Used GIS Attributes



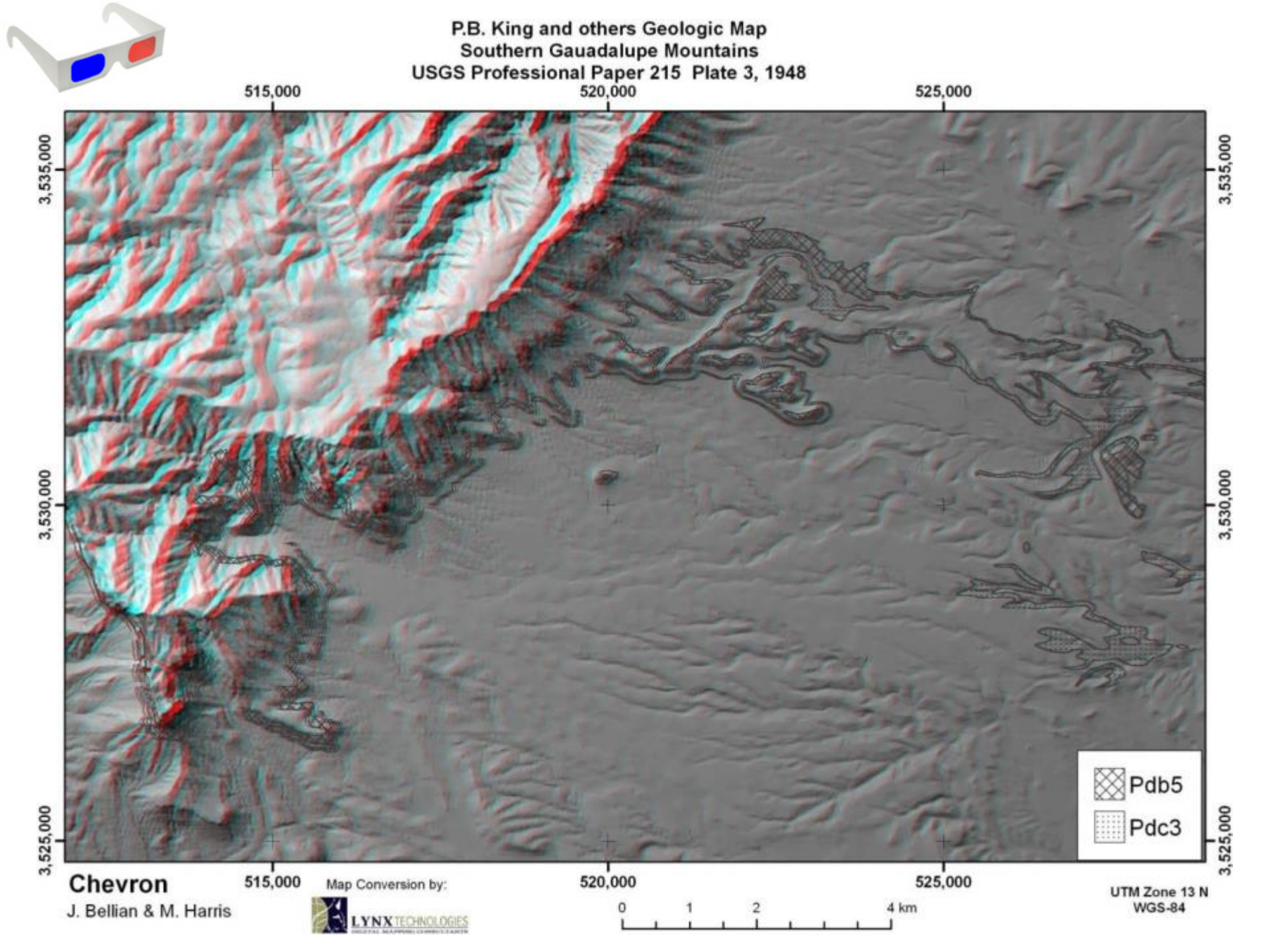
Aerial Image



Key Beds Draped on DEM & Aerial Image



Source: Chevron Carbonate Research Group, M. Harris & J. Bellian


P.B. King and others Geologic Map
Southern Gauadalupe Mountains
USGS Professional Paper 215 Plate 3, 1948
515,000
520,000
525,000
3,535,000
3,530,000
3,525,000
Pdb5
Pdc3
Chevron
J. Bellian & M. Harris
Map Conversion by:
LYNX TECHNOLOGIES
0 1 2 4 km
UTM Zone 13 N
WGS-84

P.B. King and others Geologic Map
Southern Gauadalupe Mountains
USGS Professional Paper 215 Plate 3, 1948

520,000 525,000

-9 5 5 20 6

Pdb5
Pdc3

520,000 525,000

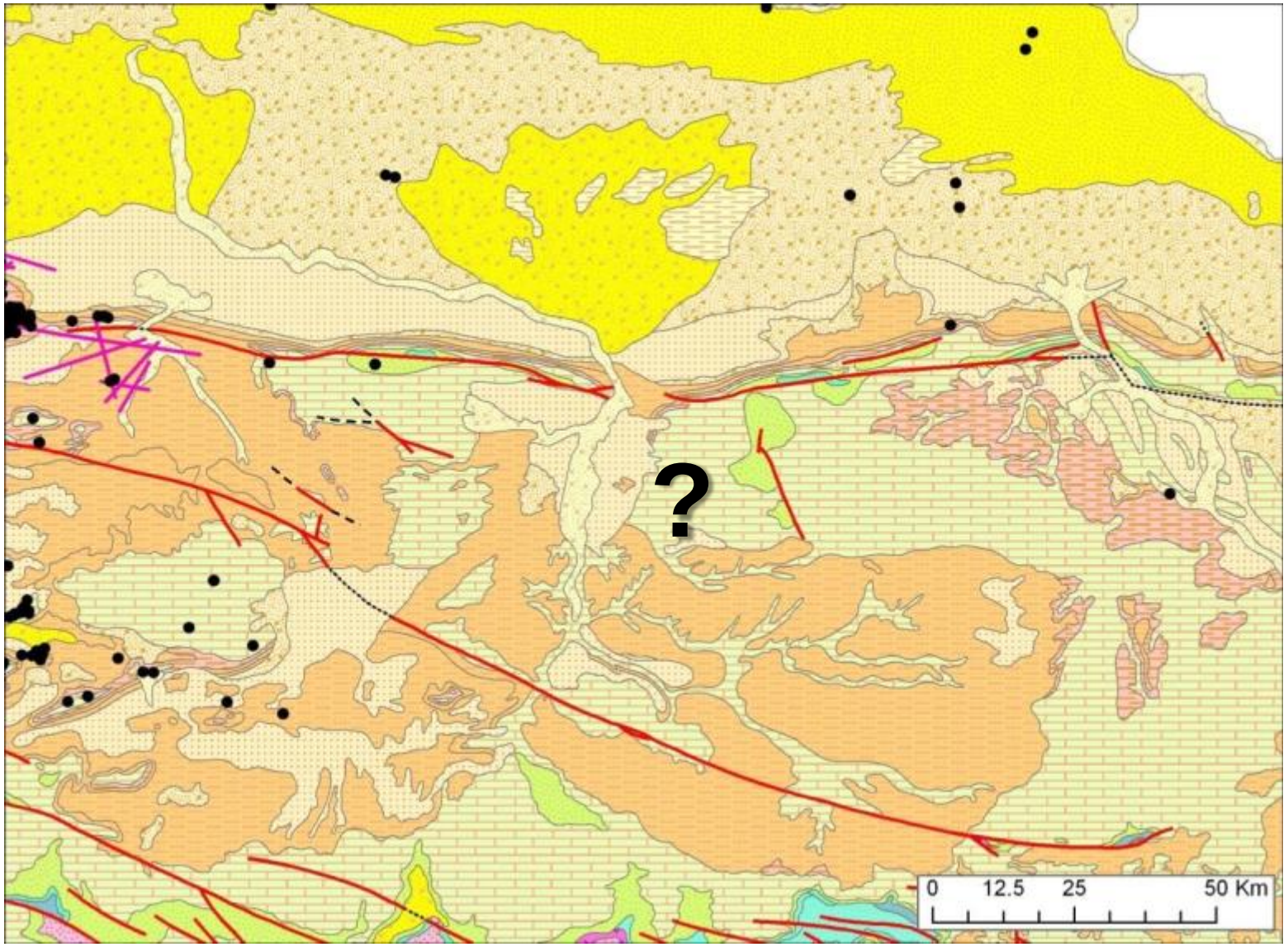
Chevron
J. Bellian & M. Harris

Map Conversion by:
LYNX TECHNOLOGIES

0 0.5 1 2 km

UTM Zone 13 N
WGS-84

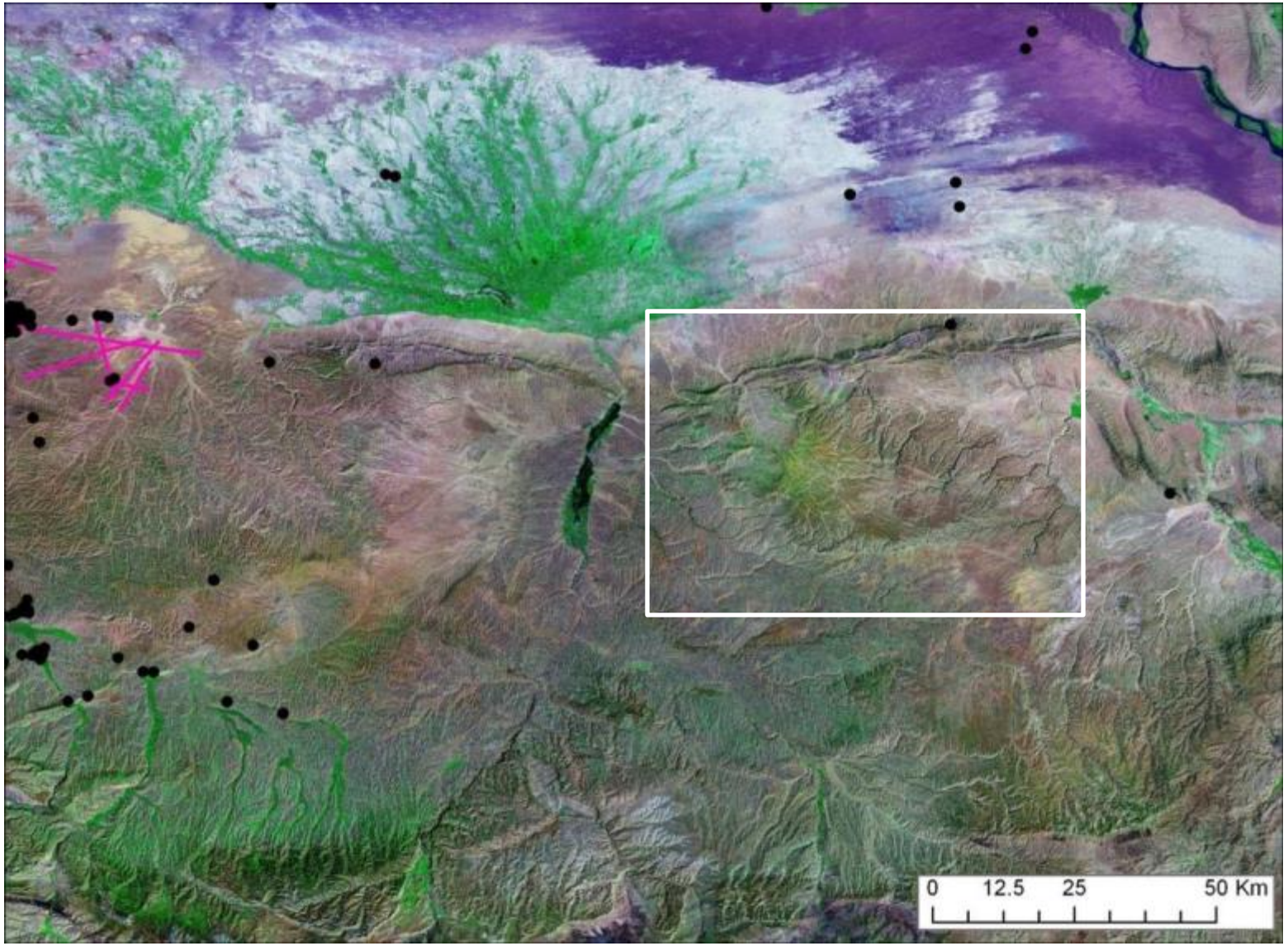
Scoping an Area of Interest



Source: USGS

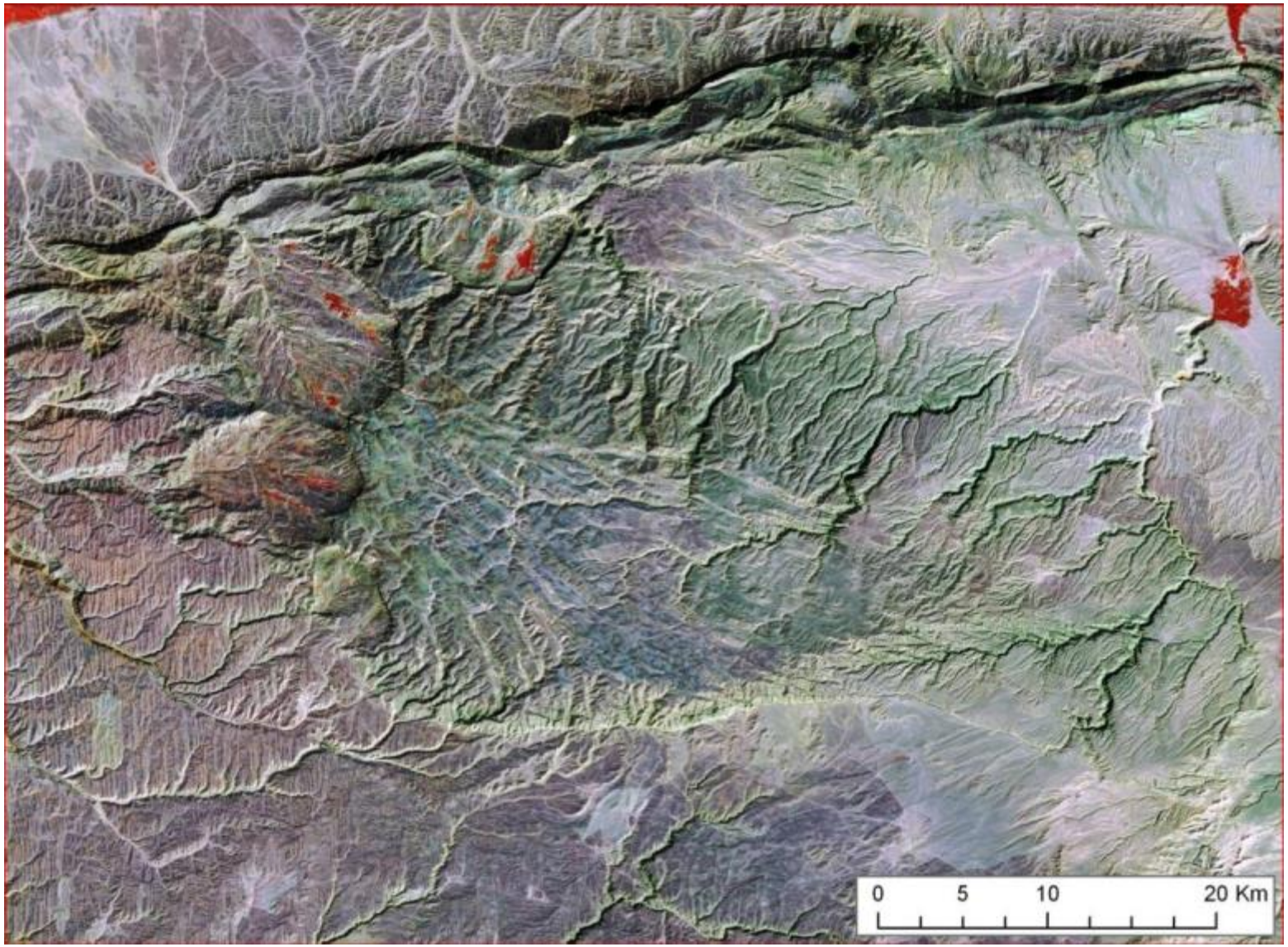
Google Earth

Enhanced Landsat TM Image



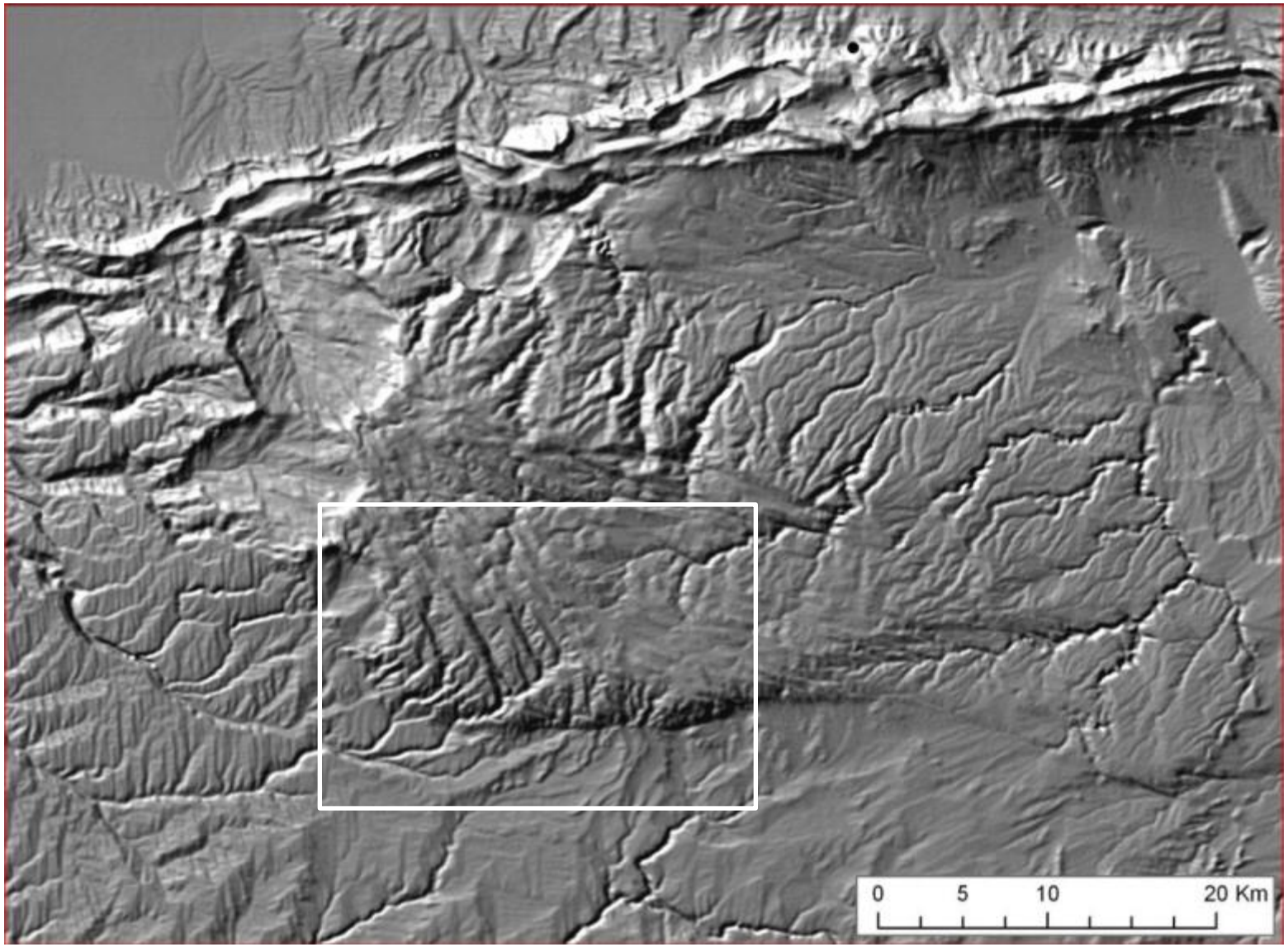
Source: USGS - Landsat TM

Enhanced Landsat TM Image



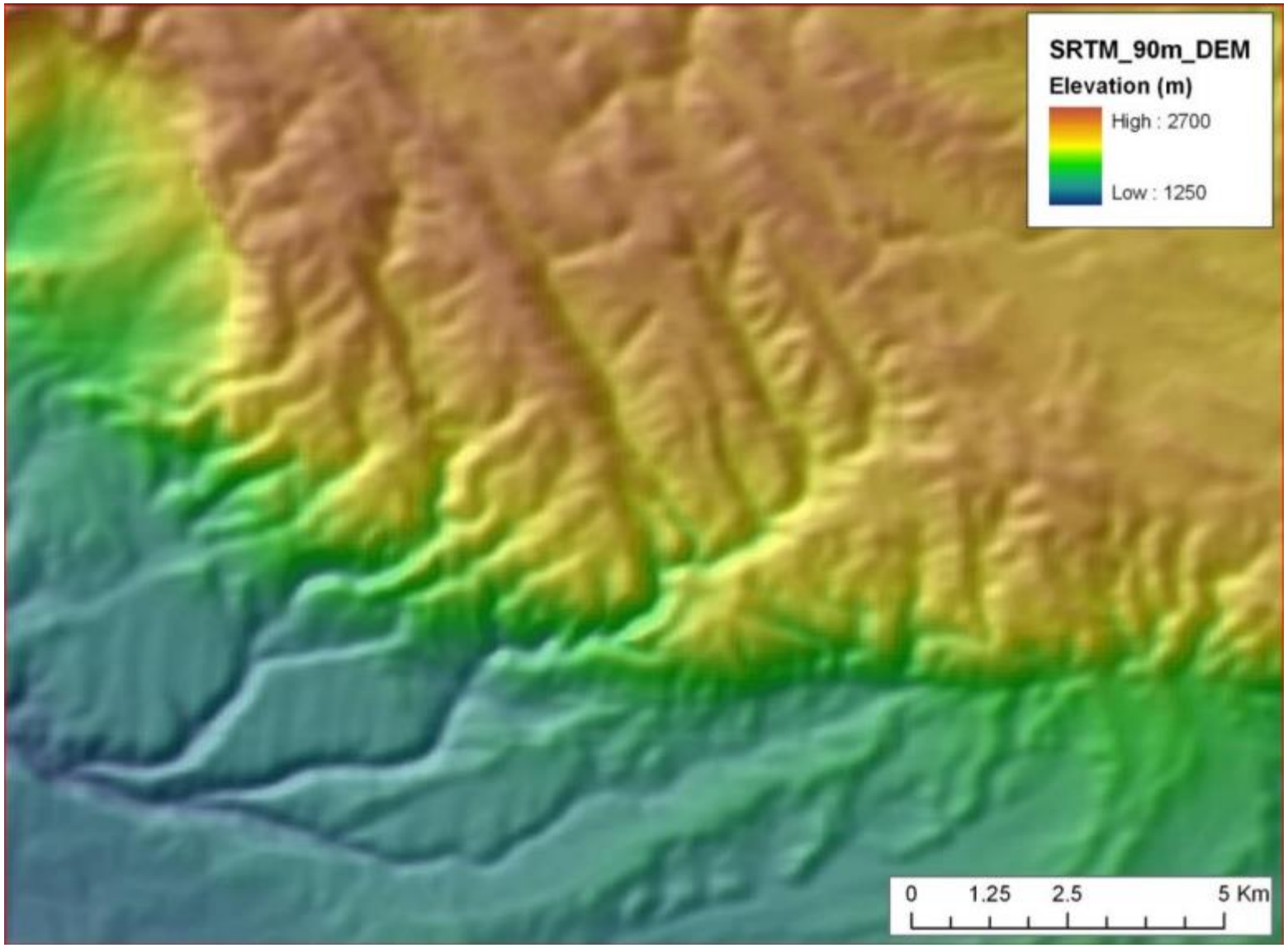
Source: USGS - Landsat TM

SRTM (90m) DEM – illuminated from NW



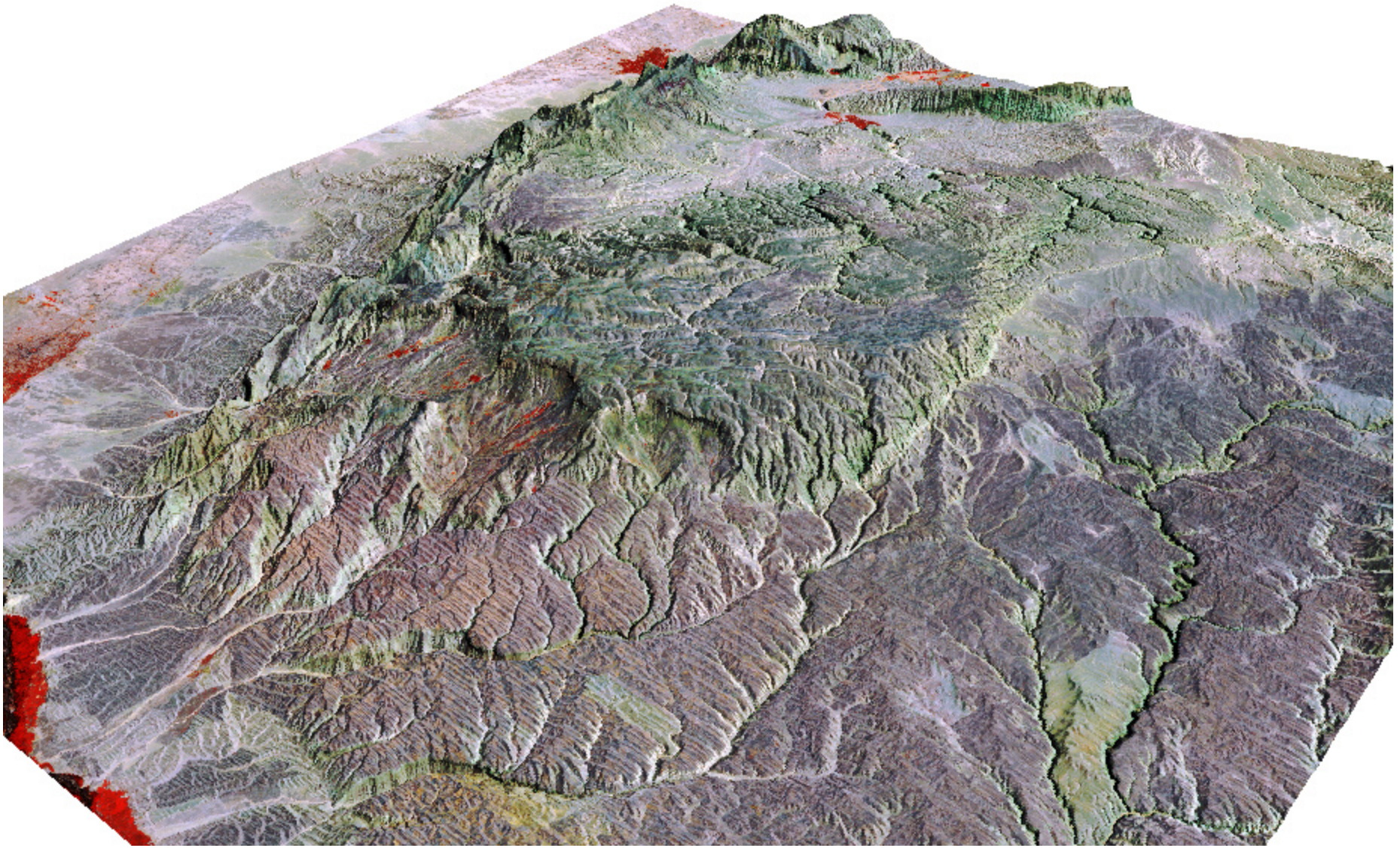
USGS/GLFC SRTM DEM

SRTM (90m) DEM with Color-Coded Elevation



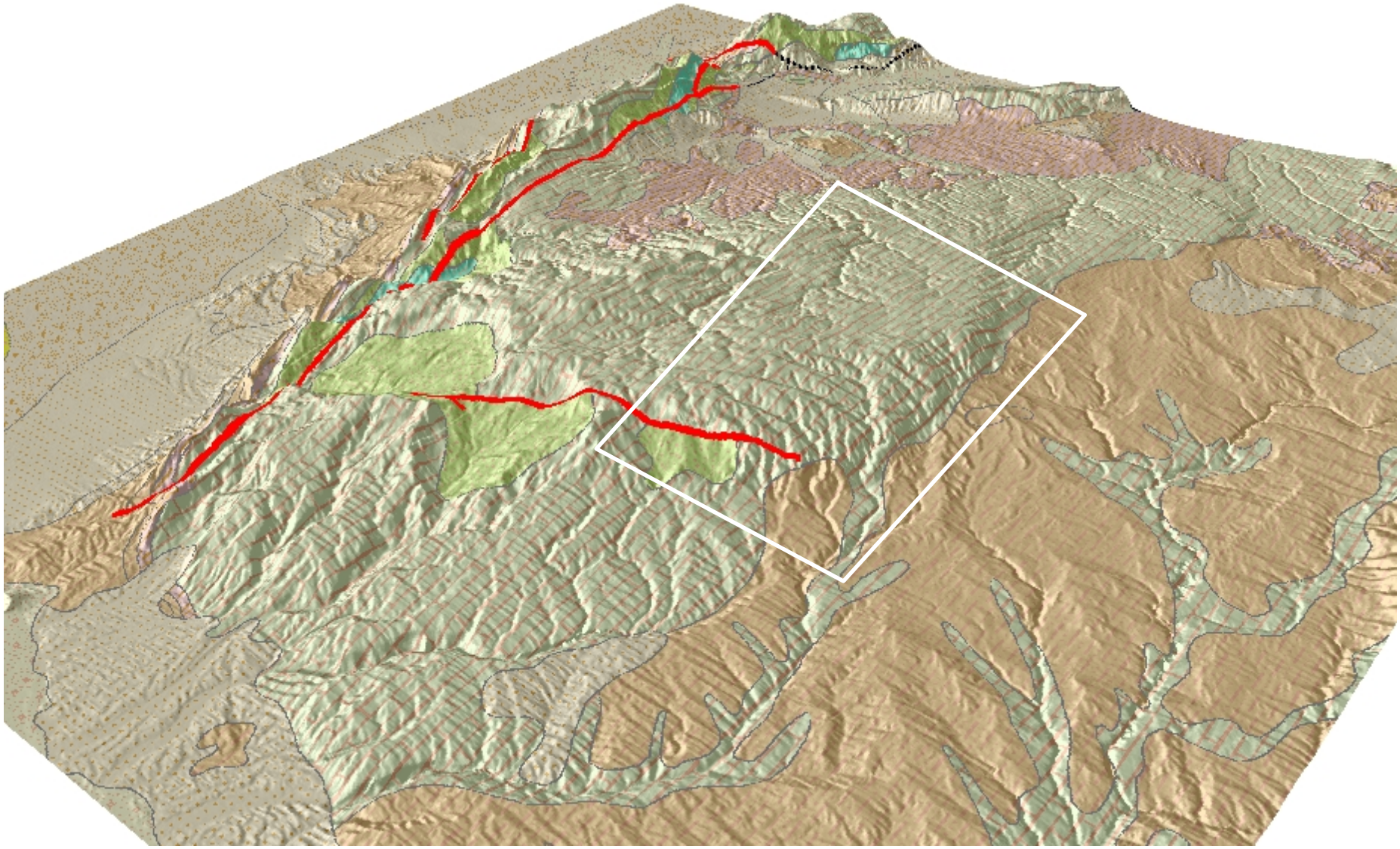
USGS/GLFC SRTM DEM

Draping Color Landsat on DEM – 2X V.E.

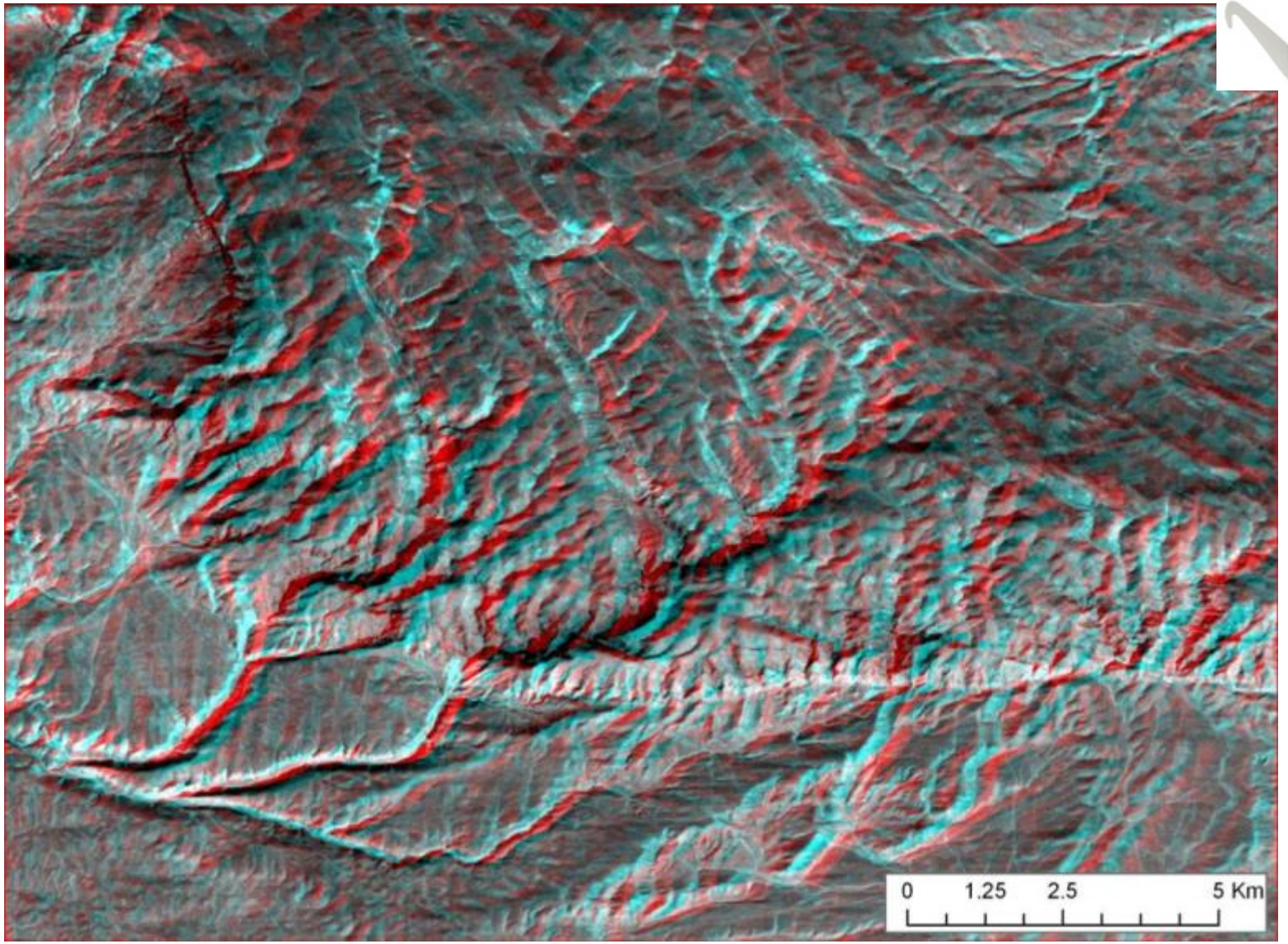


Source: USGS - Landsat TM

Draping Geology Map on DEM – 2X V.E.

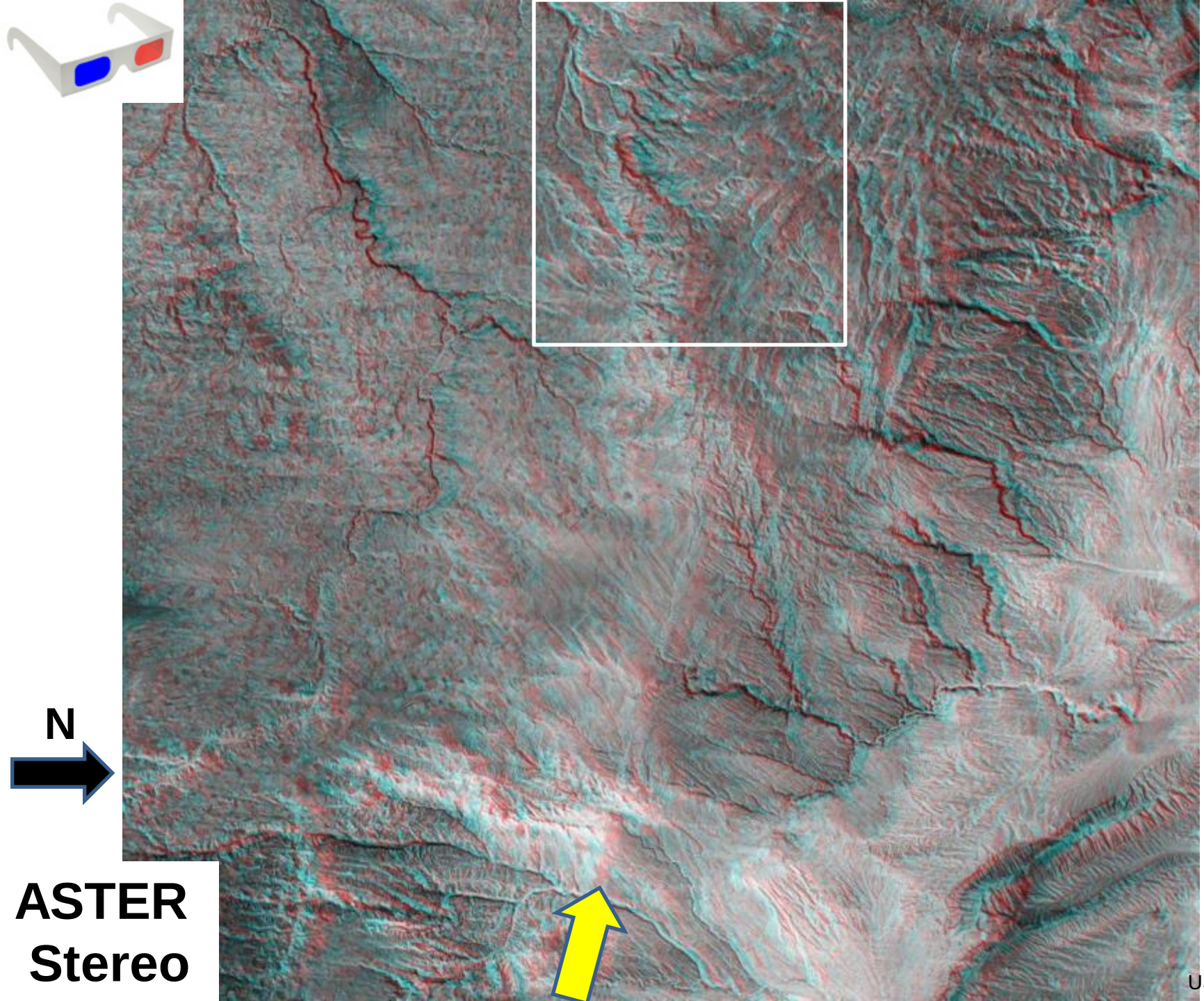


Anaglyph of SRTM DEM with Landsat Image



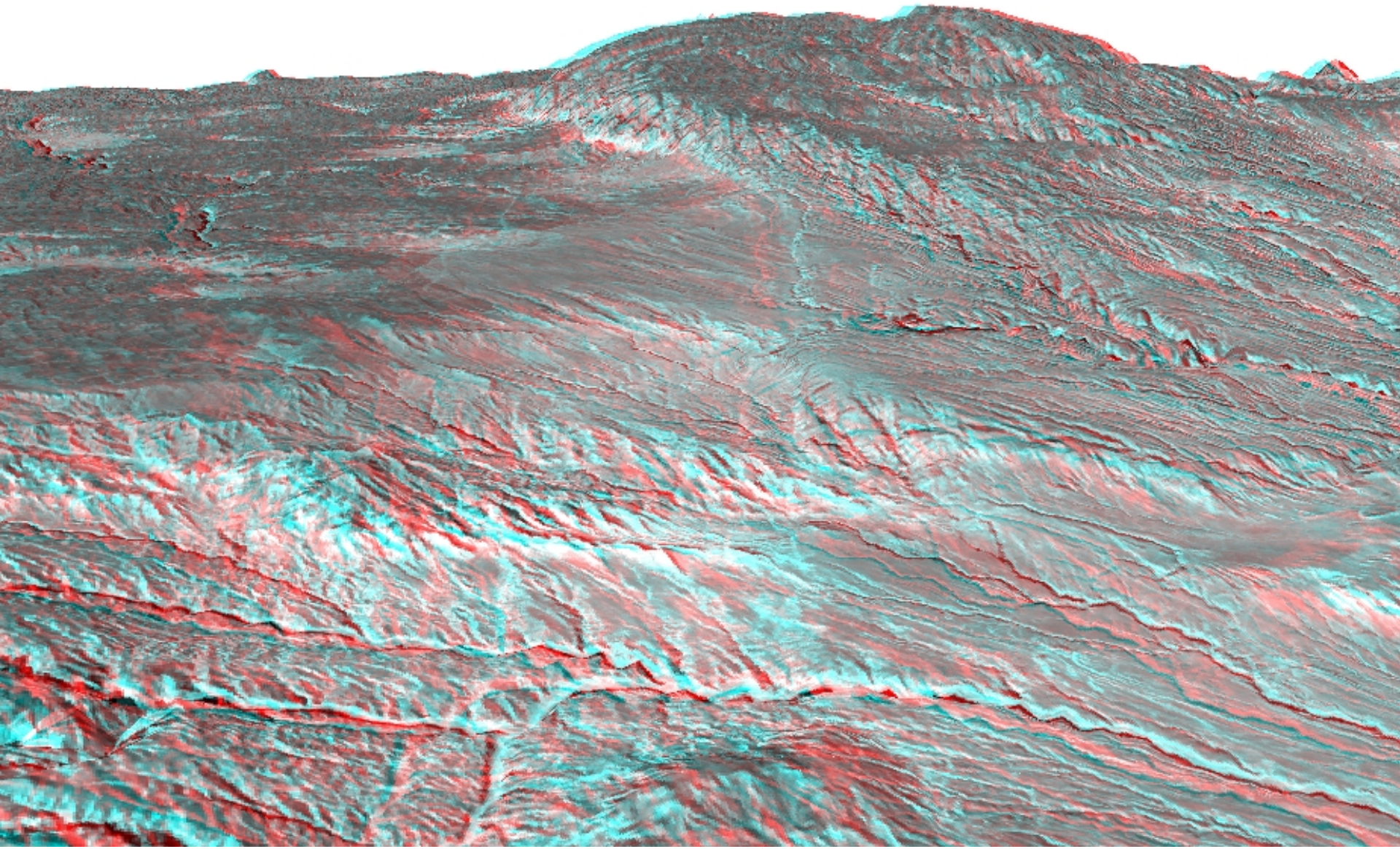
N

USGS/GLFC SRTM DEM



USGS ASTER

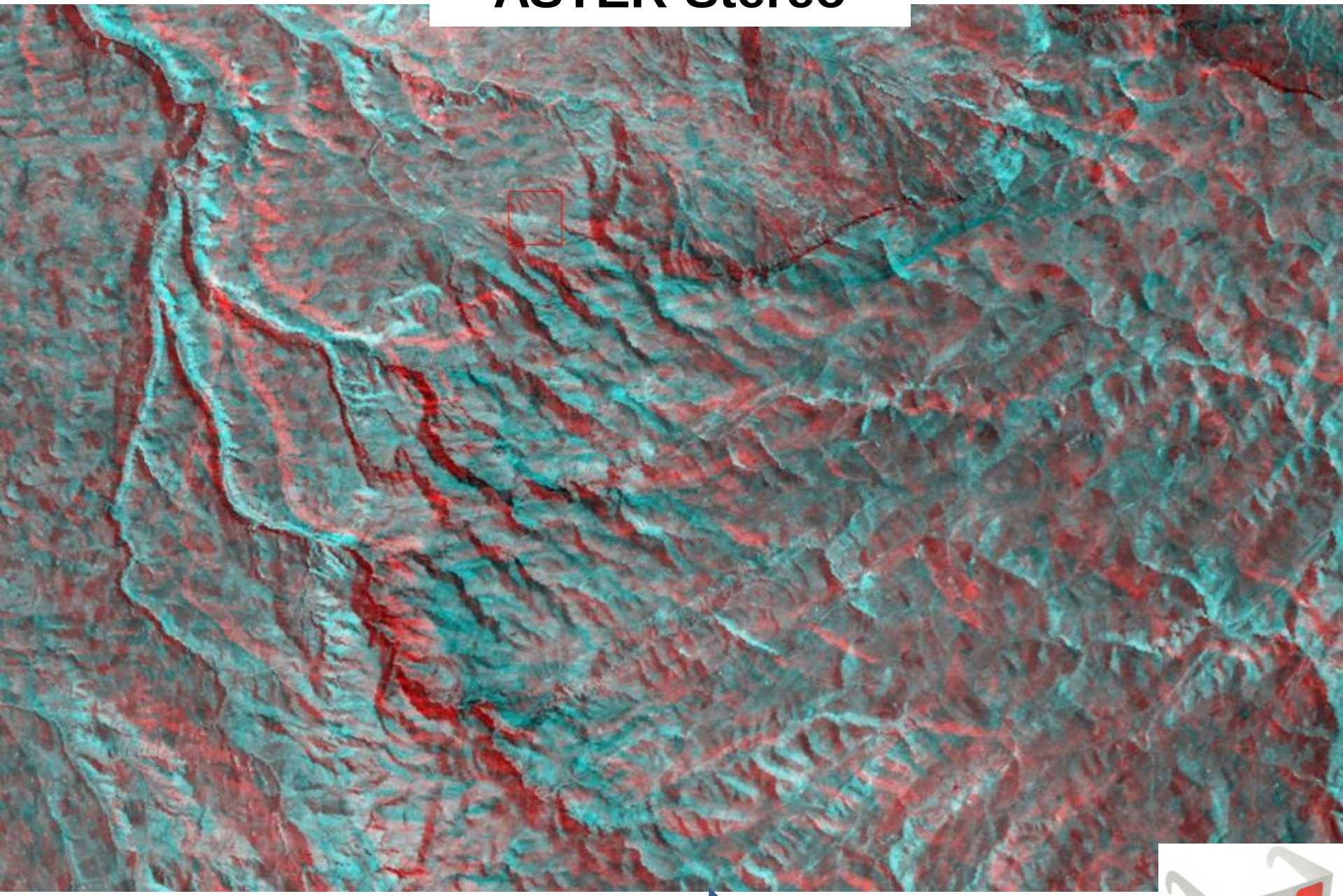
ASTER Stereo – Looking West



N

USGS ASTER

ASTER Stereo



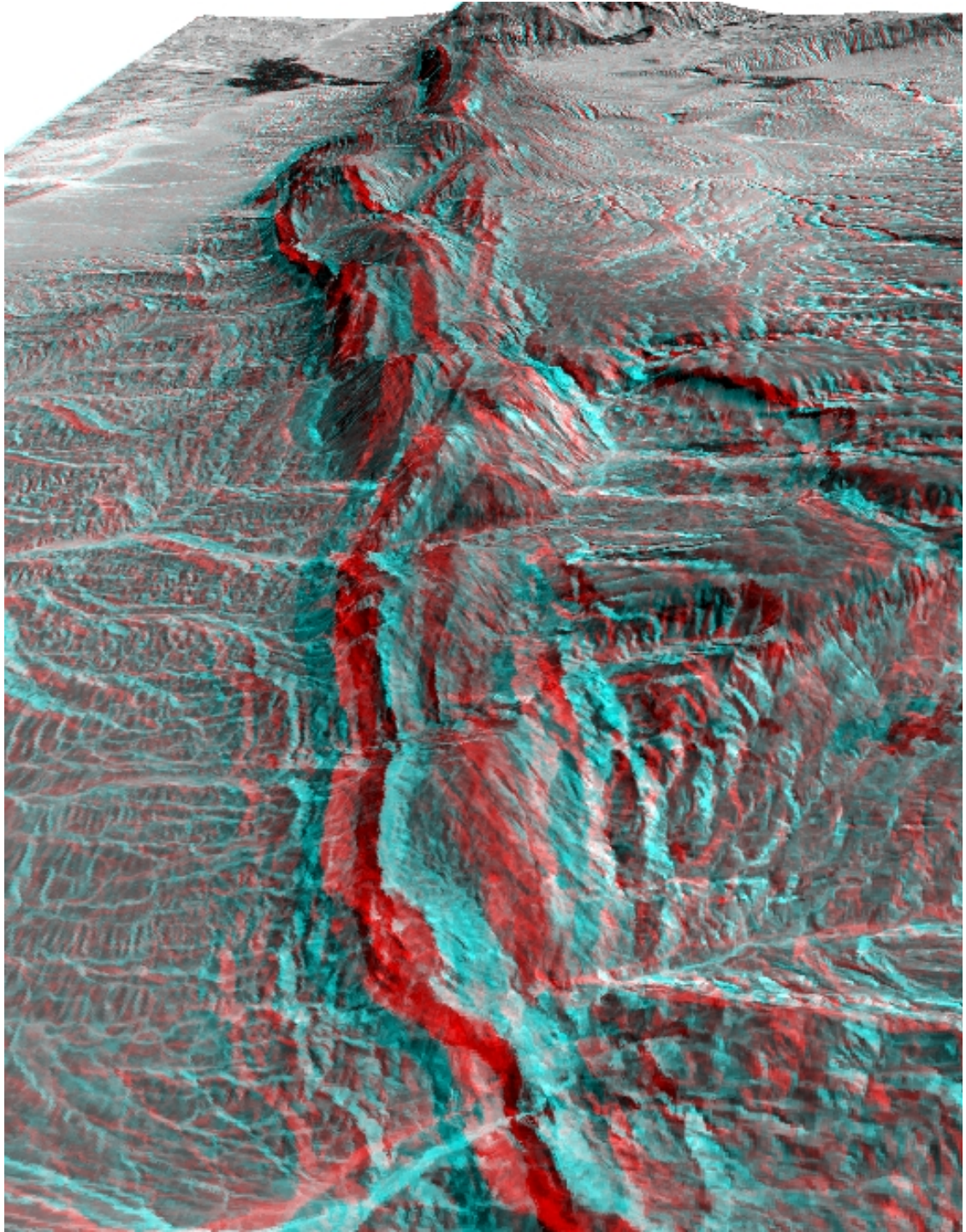
N

USGS ASTER

ASTER Stereo

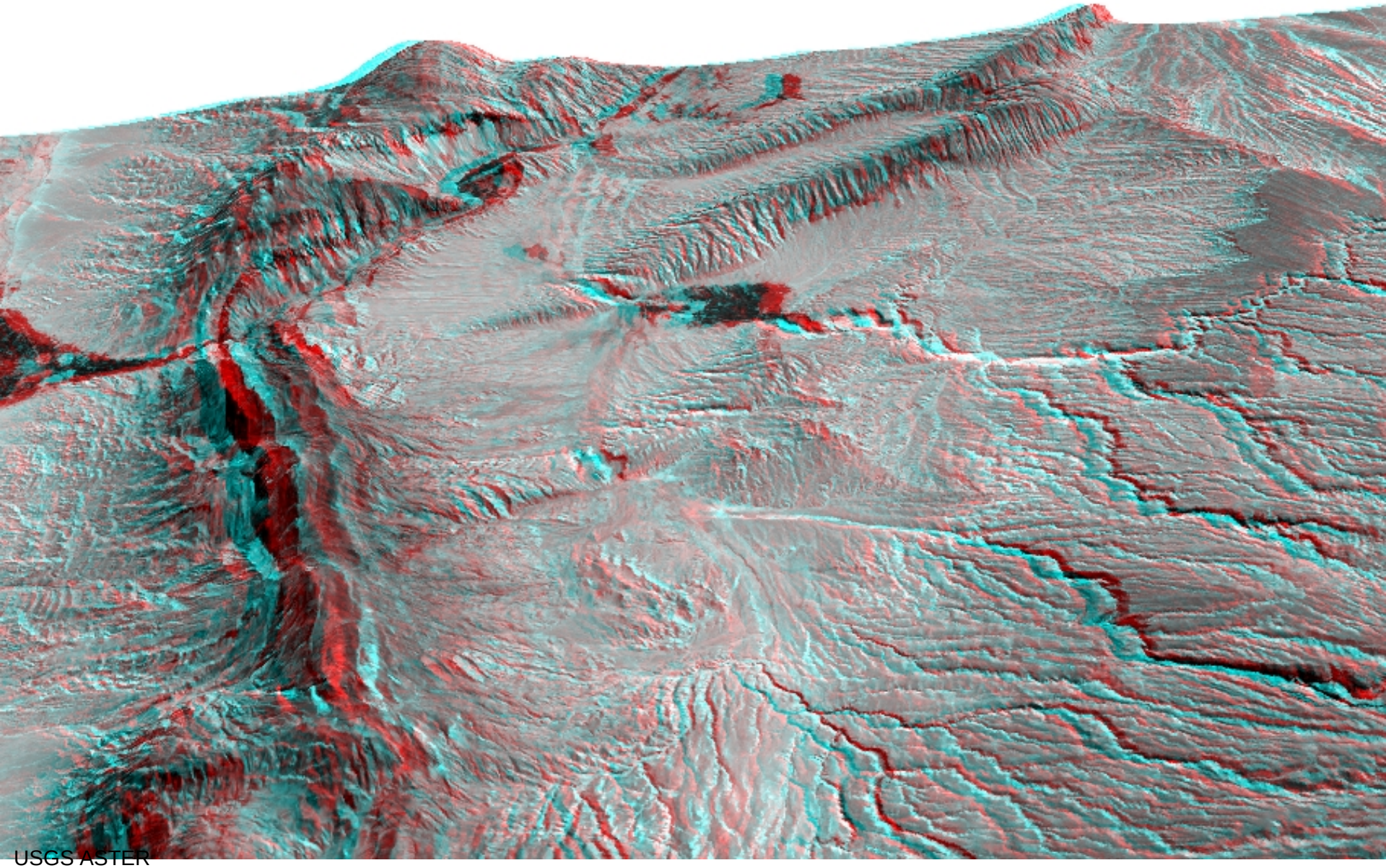
USGS ASTER

ASTER Stereo Looking East

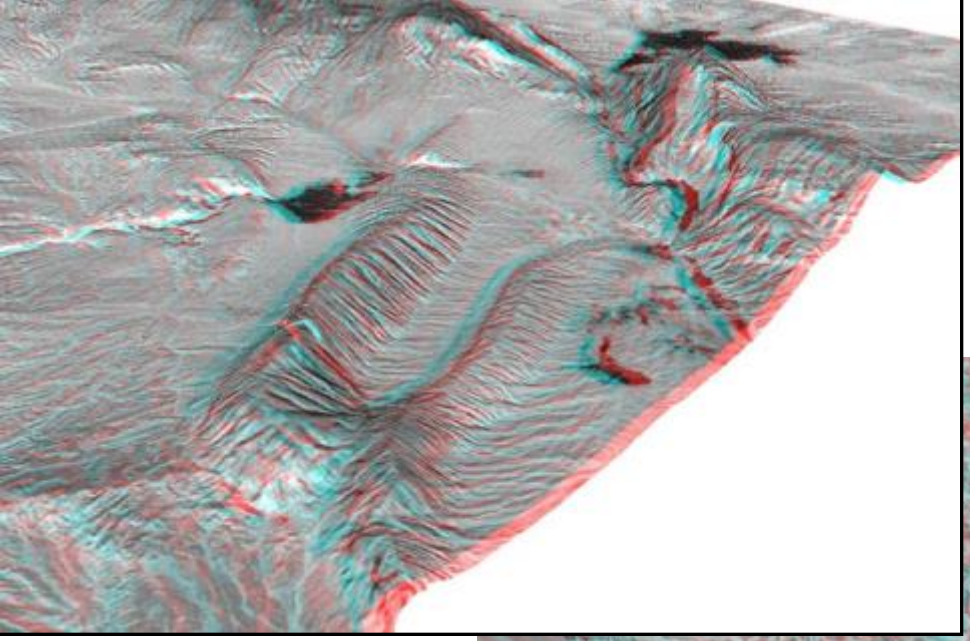


USGS ASTER

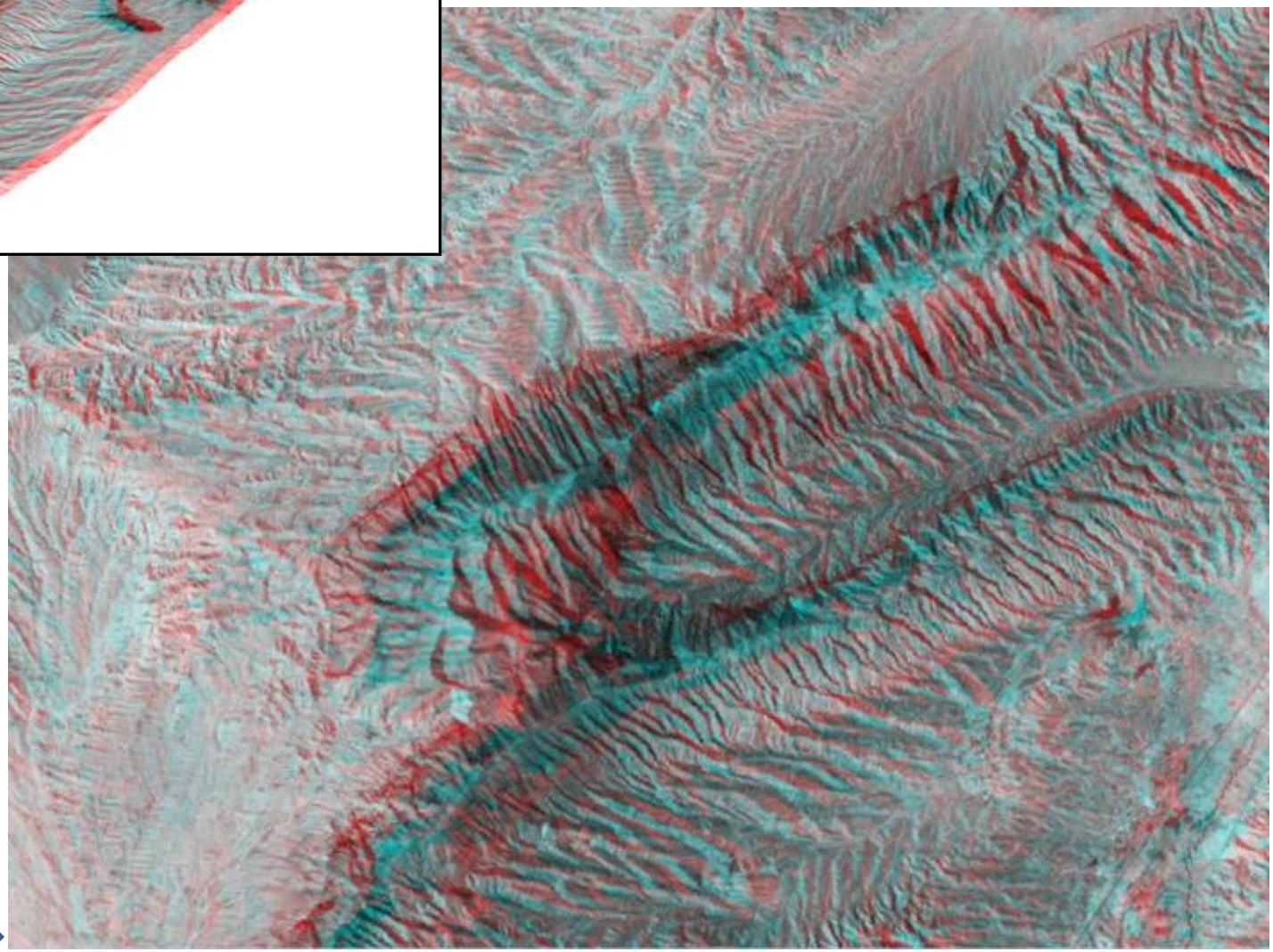
ASTER Stereo – Looking East



USGS ASTER



ASTER Stereo

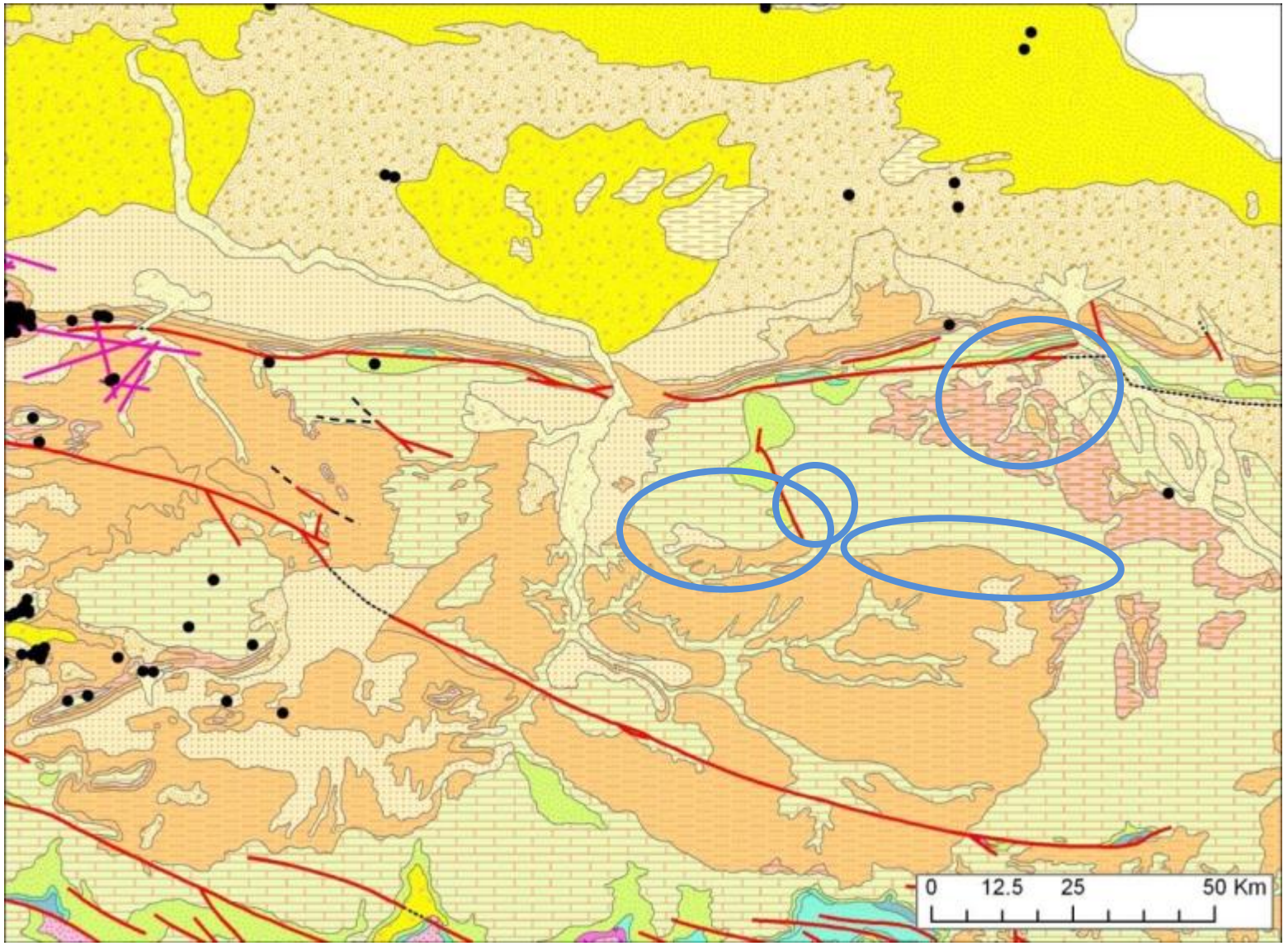


SRTM DEM

N

USGS ASTER
USGS/GLFC SRTM

Do We Have Some New Areas of Interest??



A Remote Sensing Workflow

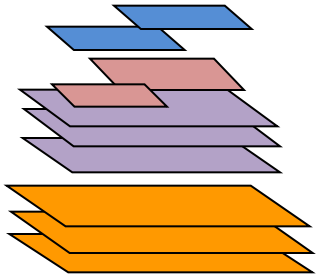
View Online Data

Acquire Additional Data
Images, Maps, DEMs

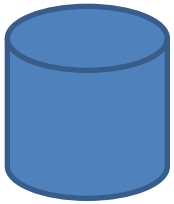
Process Additional Data

Interpret

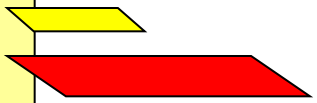
Integrate with GIS



Manage



Convert to WMS



Ellis GeoSpatial

The End

Think Remote Sensing!

Thanks to:

Floyd Sabins, Remote Sensing Enterprises
Ward Kilby, CalData
John Diggens, Consultant
Mitch Harris & Jerome Bellian, Chevron