Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course Code : MTIGT1003 4 Credits

GIS BASED 3D VISUALIZATION IN GEOLOGICAL TECHNOLOGY

Unit-2: 3D Visualisation of Topographic Data

Dr. K.PALANIVEL

Professor, Department of Remote Sensing

Course Objectives

- To learn the fundamentals of 3D visualization in GIS
- To study the possible methods of visualizing various Geological data
- To understand the ways and means of representing topographic relief in a 3 dimensional pattern
- To learn the methods of generating 3D images and interpretation of important geological structures using Geophysical data
- To learn the application of Geoinformatics in natural disaster mitigation.

MTIGT1003: GIS BASED 3D VISUALIZATION IN GEOLOGICAL TECHNOLOGY 4 Credits

Unit-1: Principles of 3D Visualization: Data Input (x, y, z) – Monoscopic and Stereoscopic 3D visualization; TIN – Vertical Exaggeration – DEM based visualization – Concepts of Shaded Relief mapping. **12 Hrs.**

Unit-2: 3D Visualisation of Topographic Data: Generation of x, y, z data – 3D visualization of topography – DEM based topographic analysis – shaded relief – applications. **12 Hrs.**

Unit-3: 3D Visualisation of Geophysical Data: X, Y, Z data from different sources – Generation of DEM, Different processed outputs of DEM, Shaded relief maps of Gravity, Magnetic and Resistivity data – Its applications. **16 Hrs.**

Unit-4: 3D Visualisation of Subsurface Lithology: Collection of borehole data – working out lithology and lithotop of various horizons – DEM of shaded relief of thickness of various formations, Depth of various formations and litho top of various formation – their interpretations. **12 Hrs.**

Unit-5: 3D Visualisation of Groundwater: Collection of water level and other aquifer variables (Transmissivity, Permeability, Storage co-efficient, etc.) – Generation of x, y, z – Generation of DEM and shaded relief of groundwater systems and interpretation. **12 Hrs.**

Unit:6. Current Contours: (Not for Final Exam only for Discussion): Step-by-step procedures for generation of high resolution DEM using CARTOSAT Stereo data; Derivation DEM products like Anaglyph and 3D Fence Diagram. Use of DEM for automated mapping of Geological Structures in GIS.

Course outcomes

After the successful completion of this course, the students are able to:

- Understand the concepts, develop GIS database and generate 3D visualization of Geological and other terrain features
- Know the fundamentals pertaining to volume estimation, drainage mapping, watershed delineation, slope classification using 3D visualization techniques
- Learn the method of 3D visualization of topographic data
- Understand the method of visualization of Geophysical data and their application
- Learn the method 3D visualization of subsurface lithology and its applications
- Understand the method of 3D visualization of groundwater and its applications.

References

- Burrough, PA., Principles of Geographical Information Systems, Oxford University Press, 1997.
- DeMers, Michael N, Fundamentals of Geographic Information Systems, John Wiley and Sons, 1999.
- David J., Bringing Geographical Information Systems into Business, Second Edition Grimshaw, John Wiley and Sons, 1999.
- Christian, Serving Maps on the Internet: Geographic Information on the World Wide Web Harder, ESRI Press, 1998.
- Graeme F. Bonham-Carter, Geographic Information Systems for Geoscientists: Modelling with GIS, Pergamon Publications, 1994.
- Sabins, F.F.Jr., Remote Sensing Principles and Interpretation, Freeman, Sanfrancisco. 1978.
- Lillisand, T.M. and P.W. Kiefer, Remote Sensing and Image Interpretation, John Wiley & Sons, New York, 1986.

UNIT-2:
3D Visualisation of Topographic Data

Unit-2: 3D Visualisation of Topographic Data: Generation of x, y, z data – 3D visualization of topography – DEM based topographic analysis – shaded relief – applications. **12 Hrs.**

Generation of x, y, z data

1. Topographic Data can be collected from **SOI toposheets**
   - Spot heights – as Point information in plains, Lake beds, River beds, etc.
   - Bench Marks – As points, with accurate height value in decimal places, e.g., BM69.459
   - Triangulated point height - ▲547.75
   - Relative Heights – As lines, along tank bunds, river bunds, etc., e.g. R4
   - Open Contours – As lines
   - Broken Contours – As lines – Approximated
   - Closed Contours – As polygons.

Generation of x, y, z data … contd …

2. Elevation data from Aerial Photographs – using Parallax bar with Stereo-pair and Stereo-triplet

– Stereoplotters can be used

- Digital Stereoplotters – with computers
- Digital Photogrammetric Softwares with special equipments like, Anaglyph and dual monitors, etc.

Generation of x, y, z data … contd …

3. Satellite data with different viewing angles
    - SPOT
    - CARTOSAT
    - ASTER

4. Shuttle / Aerial Data – E.g. SRTM, RADAR, etc.

5. GPS survey data – from field survey
    - DGPS surveys- Static mode
    - Kinetic mode
    - Semi-kinetic mode = Stop and Go.

Generation of x, y, z data ... contd ...

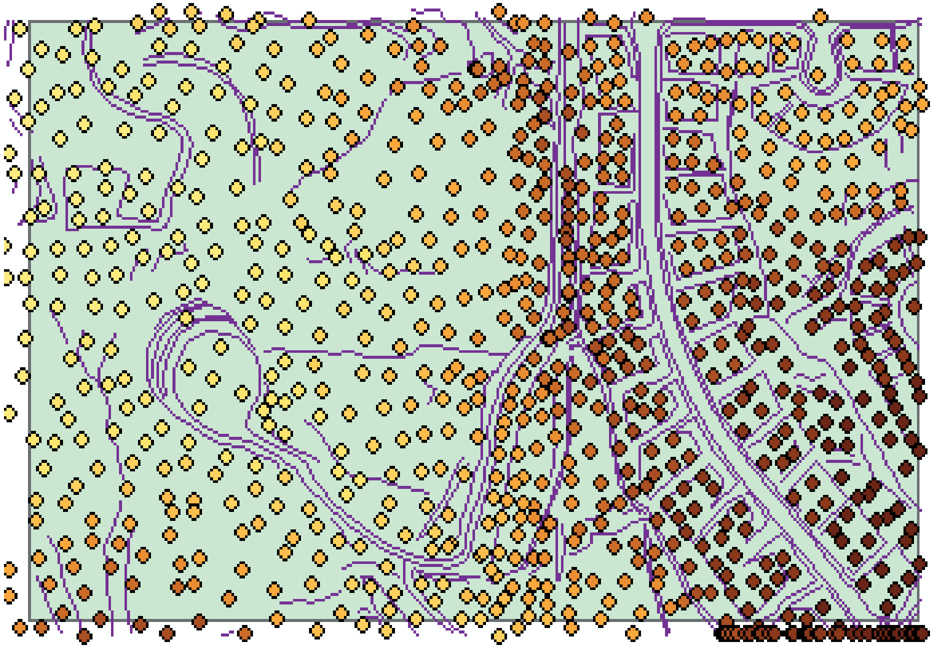
- Conventional method of converting Elevation data from SOI toposheet to Computer
  - Superimpose grid map over toposheet
  - Calculate average height value for each and every grid
  - Note x, y and z values as a table to enter into computer
- Directly note down the available height information from toposheet discussed previously.
- Additional data collected through GPS survey in gap areas can be included in the data table.
- X,Y,Z-table can be used as direct input for generating manipulated data – For e.g., rasterization with grids.

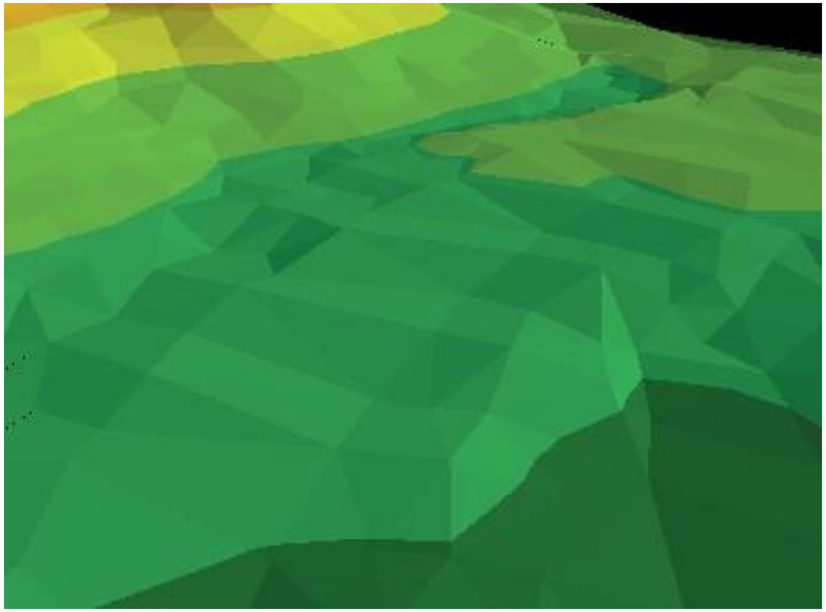
Generation of x, y, z data … contd …

- Alternate way to generate digital data using GIS is
  - Digitize all the point data and enter z value – height in PAT
  - Digitize Relative heights as lines with elevation detail in LAT by adding adjacent terrain height
  - Digitize open and dashed contours as lines with height data in LAT
  - Digitize closed contours as polygons with height values in PAT
  - Digitize the field surveyed points with elevation detail in PAT
  - Then, convert all line and polygon files into point feature files and
  - Finally integrate them all and use this Integrated Point Output (IPO file) as input for the generation of Raster DEM using Krigging method of interpolation.

Use of Break lines

- Digitize Escarpments, Ridges, Stream line in Valley, Edges, Pits, Cols and Borders of angular features
- This file containing all the above line features can be used as Breaklines
- It is an additional input for the generation of DEM with visual clarity and improved accuracy.

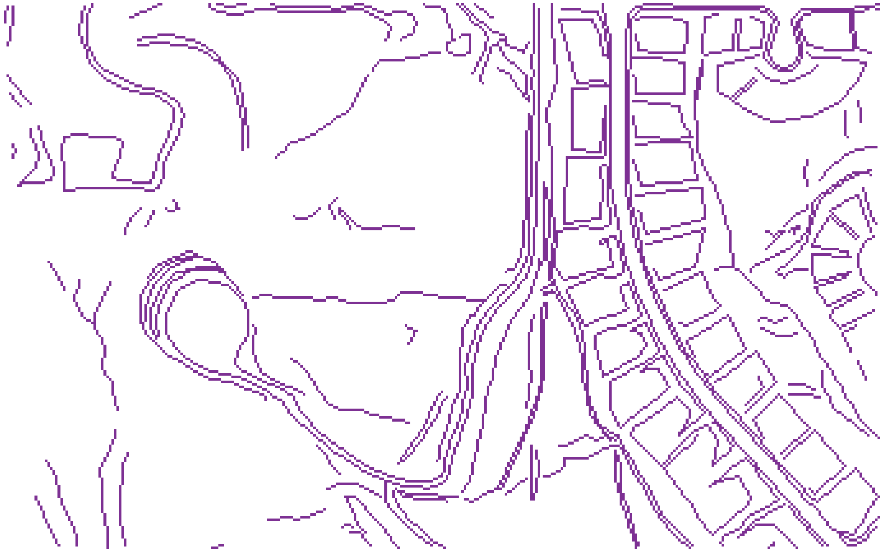


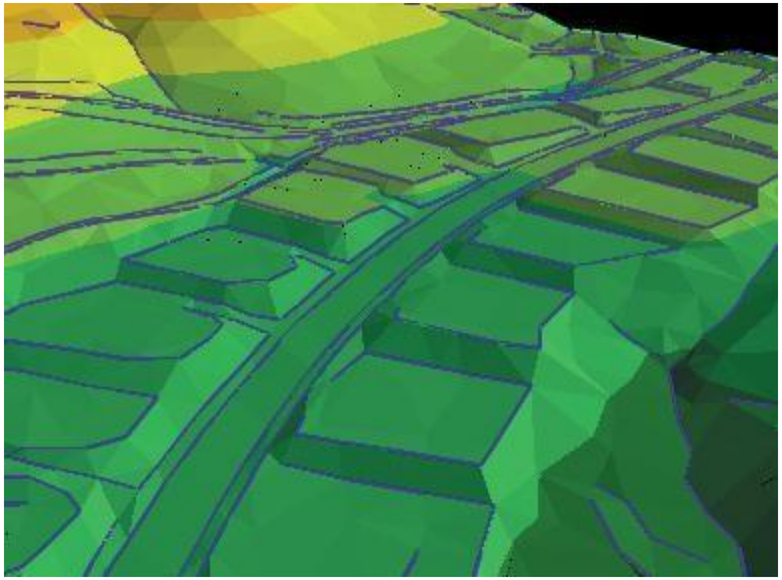


TIN created from mass points

Breaklines are lines with or without height measurements.

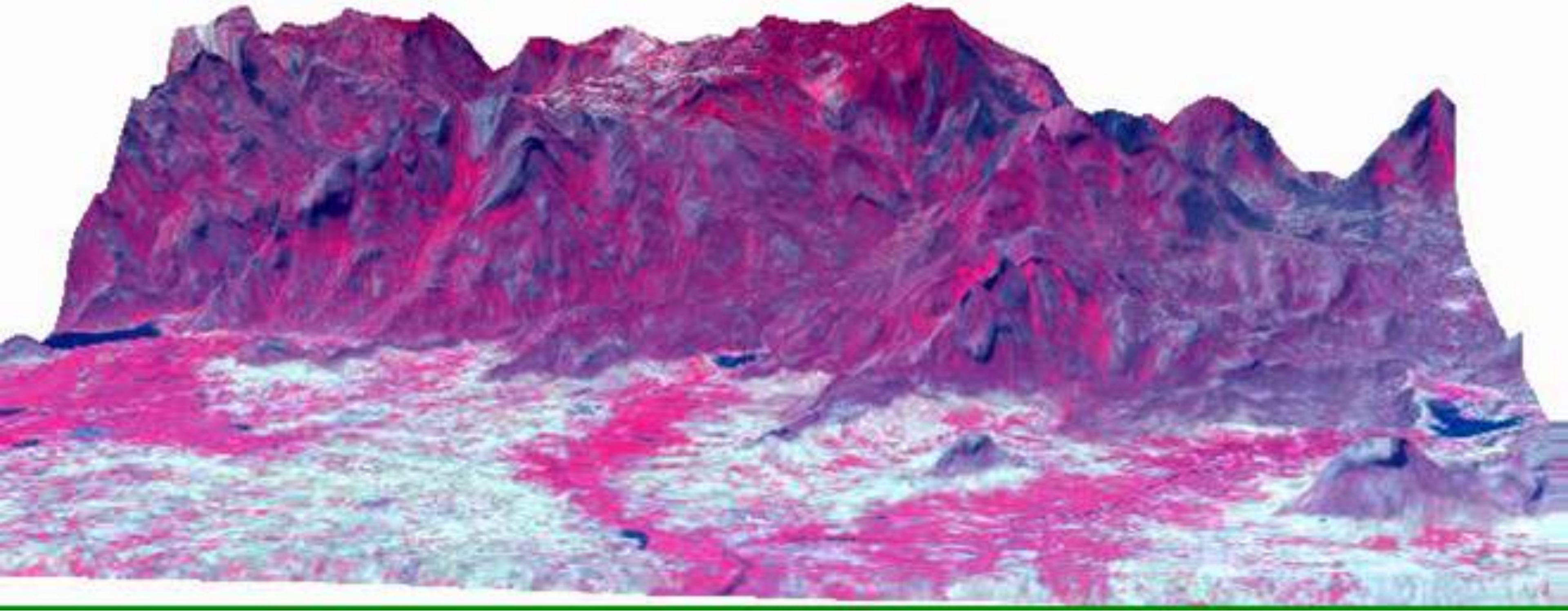
TIN created from mass points and breaklines



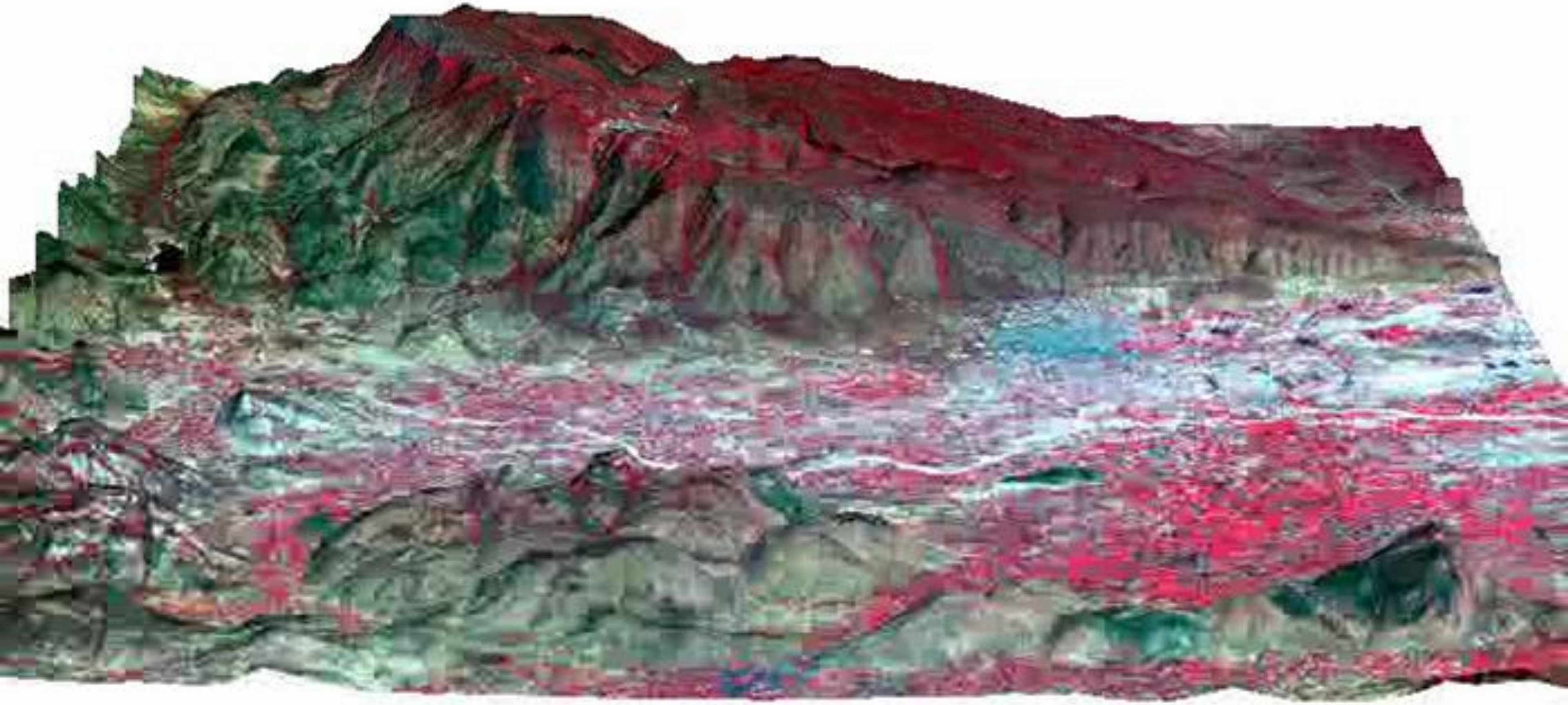


3D visualization of topography

- Density sliced DEM
- Shaded Relief Map
- Profiles
- FCC Wrapped DEM
- Aerial Photograph Wrapped DEM
- Fly through models.



3D Fly-thru showing Geomorphic landforms and Structural features of Palani hills



3D Fly-thru showing Geomorphic landforms and Structural features of Tirumala hills

DEM based topographic analysis

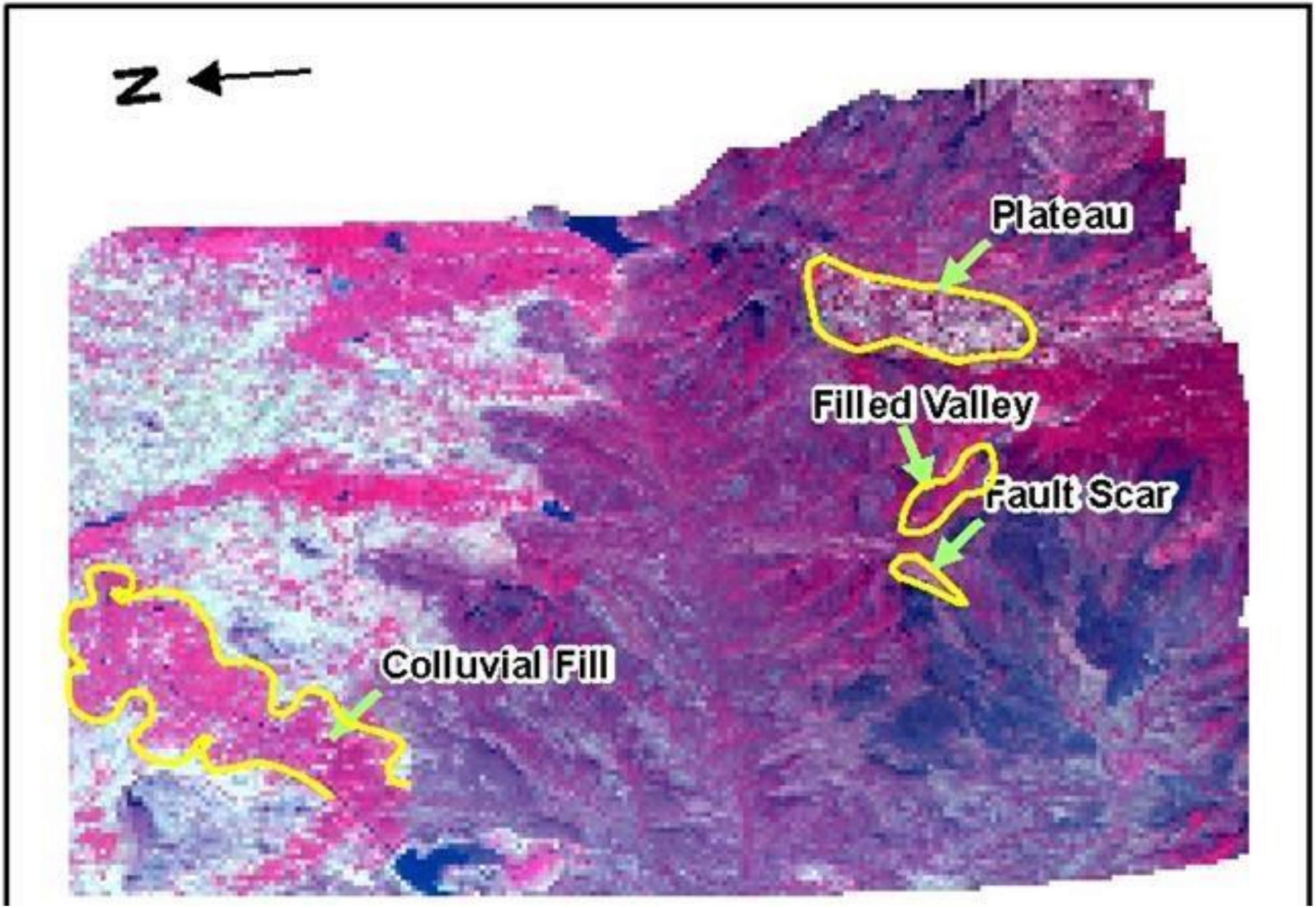
1. Volume estimation by numerical integration Using,
   - Block diagrams, profiles and horizons
   - Contour maps
2. Establishing viewsheds for applications such as microwave transmission tower setup, hide point in defence ministry, etc., using
   - Line of sight maps
   - Maps of slope, convexity, concavity and aspect
   - Shaded relief maps
3. Integrated Watershed Management through drainage morphometric analysis in GIS using DEM
   - Drainage network and drainage basin delineation using DEM
   - Drainage / stream orders, flow length, flow direction and accumulation, etc.

Shaded Relief Mapping and Analysis

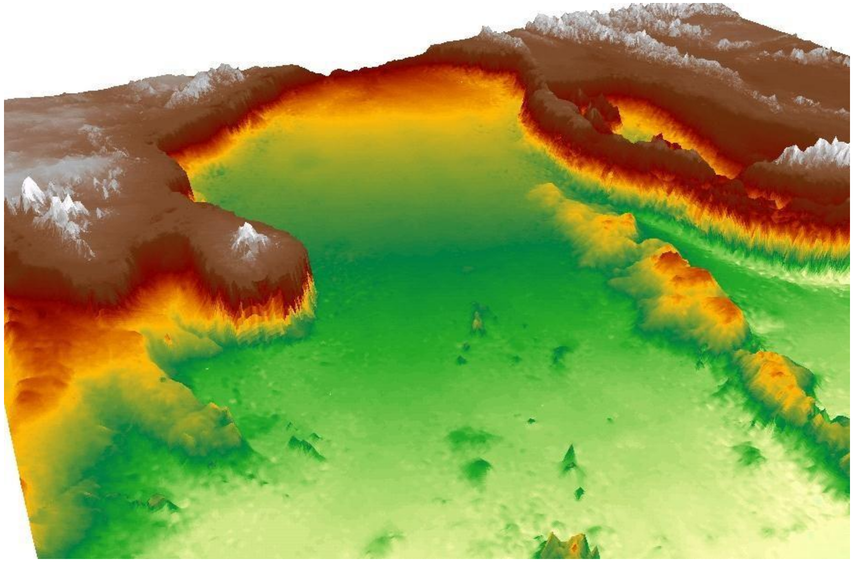
- Lineament / Fracture swarms / Fault mapping
- Classification of lineament based on their length and direction
- Calculation of Lineament Frequency, Lineament Intersection density, Lineament Length density
- Drainage mapping and density calculations
- Hiding / shadow region estimation

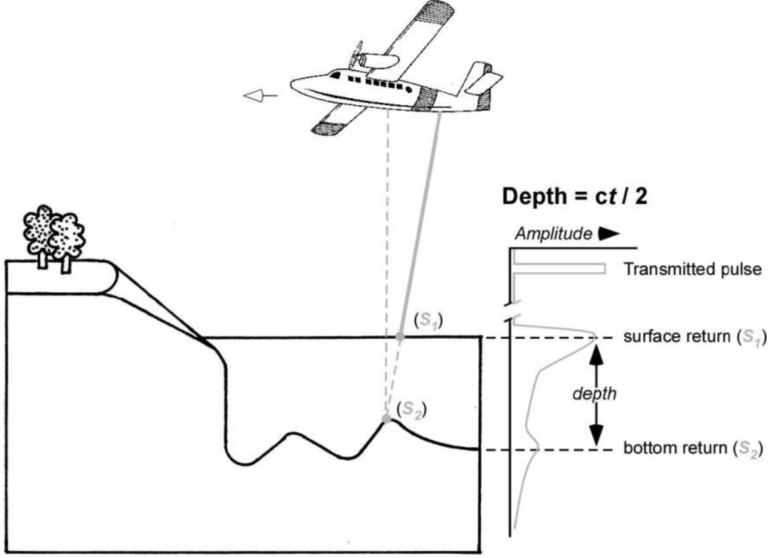
Other Applications

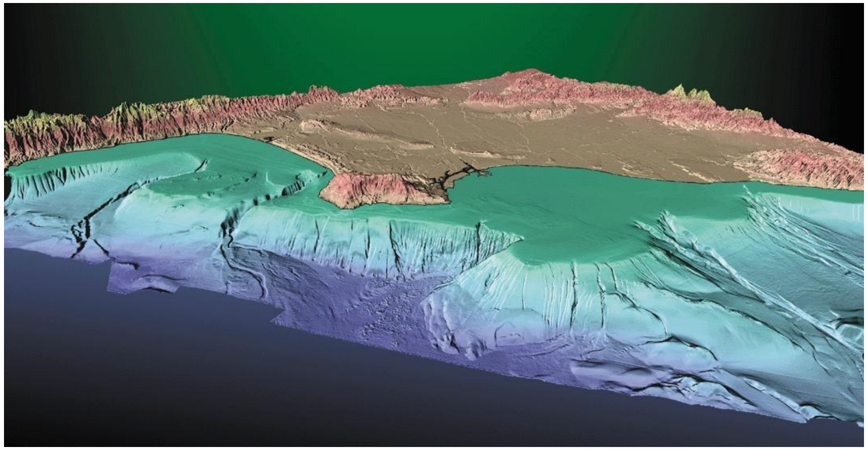
- Structure mapping – Trend lines, Fold styles
- Lithology mapping
- Geomorphology mapping
- Site selection for Dam construction,
- Bathymetry mapping, etc.


N
Plateau
Filled Valley
Fault Scar
Colluvial Fill

BATHYMETRY:

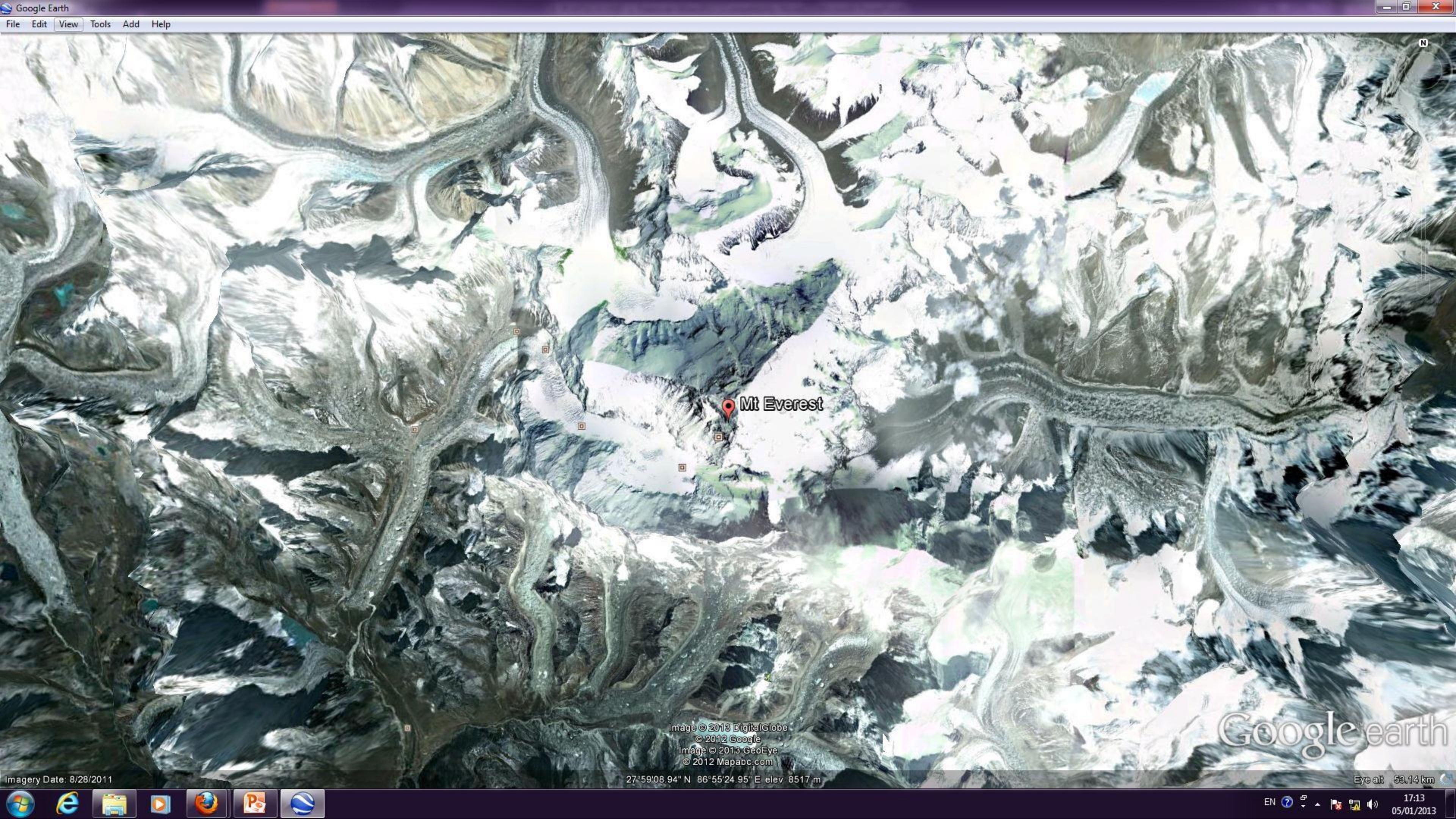






For any offshore structures including harbor development

Pipeline etc.,



Ice desert – Ice rivers – Mt. Everest from Google earth

Terrain view – 3D view - Ice desert – Ice rivers – Morains and ‘U’–shaped valleys are visible - Mt. Everest from Google earth

V-Rule

Exhibits the RELATIONSHIP BETWEEN

OUTCROP PATTERN

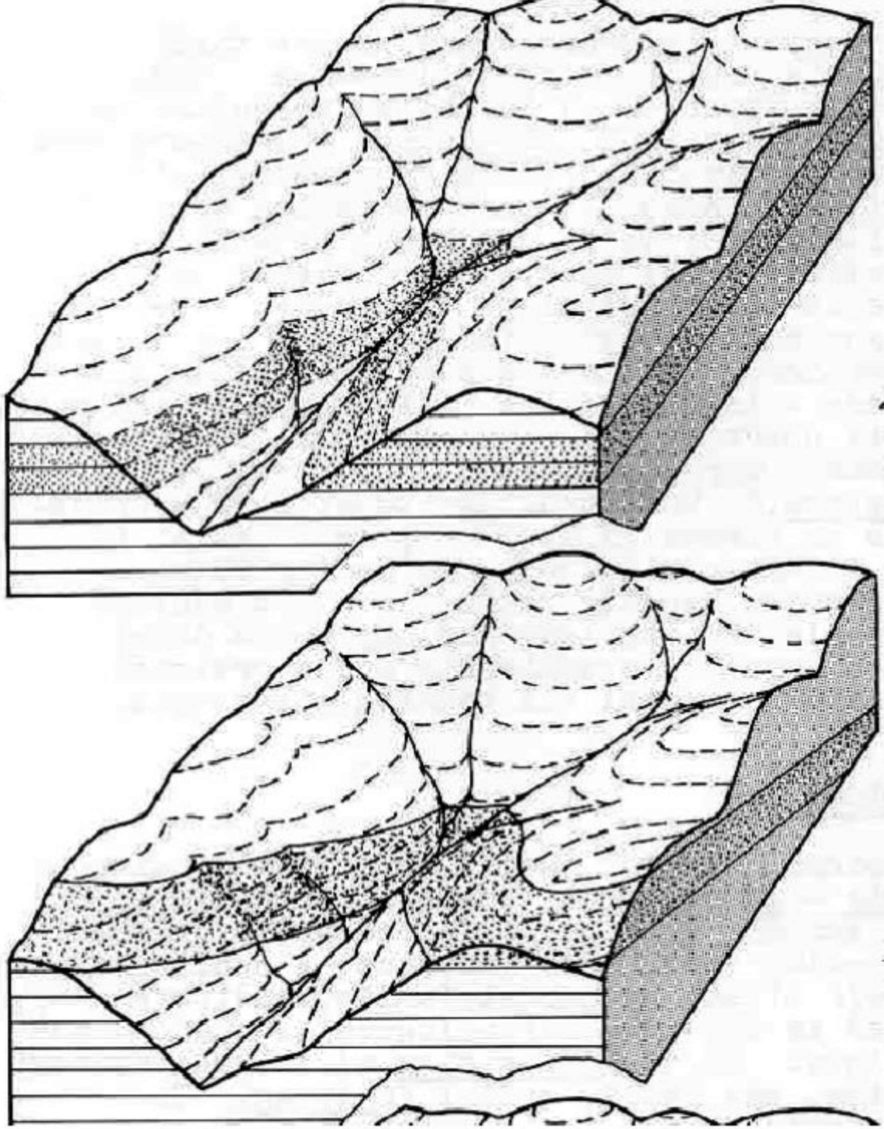
AND

ATTITUDE

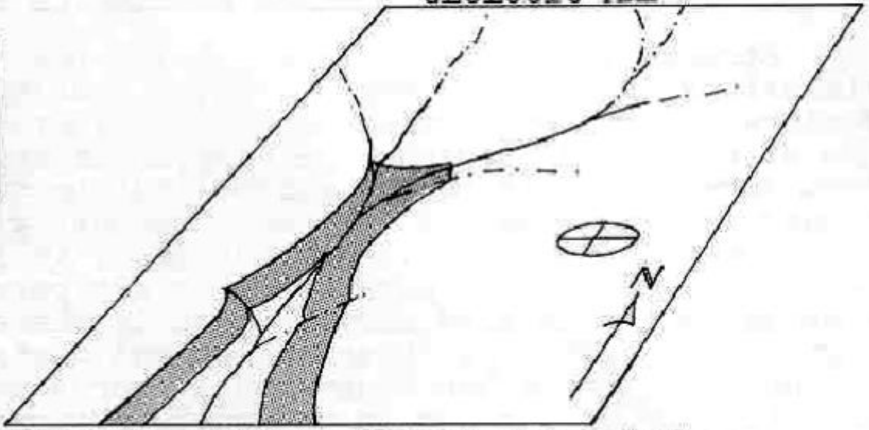
OF THE FORMATION / BED / ROCK LAYERS

This relationship is very well used in STRUCTURAL GEOLOGICAL MAPPING of terrains using satellite data wrapped DEM

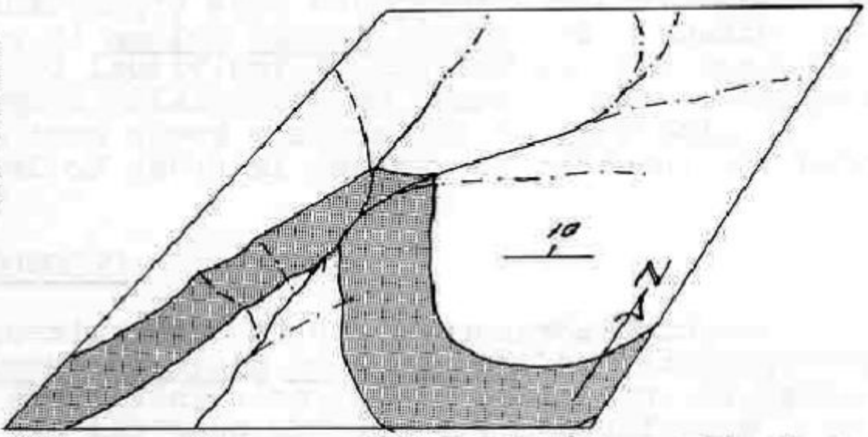
BLOCK DIAGRAM



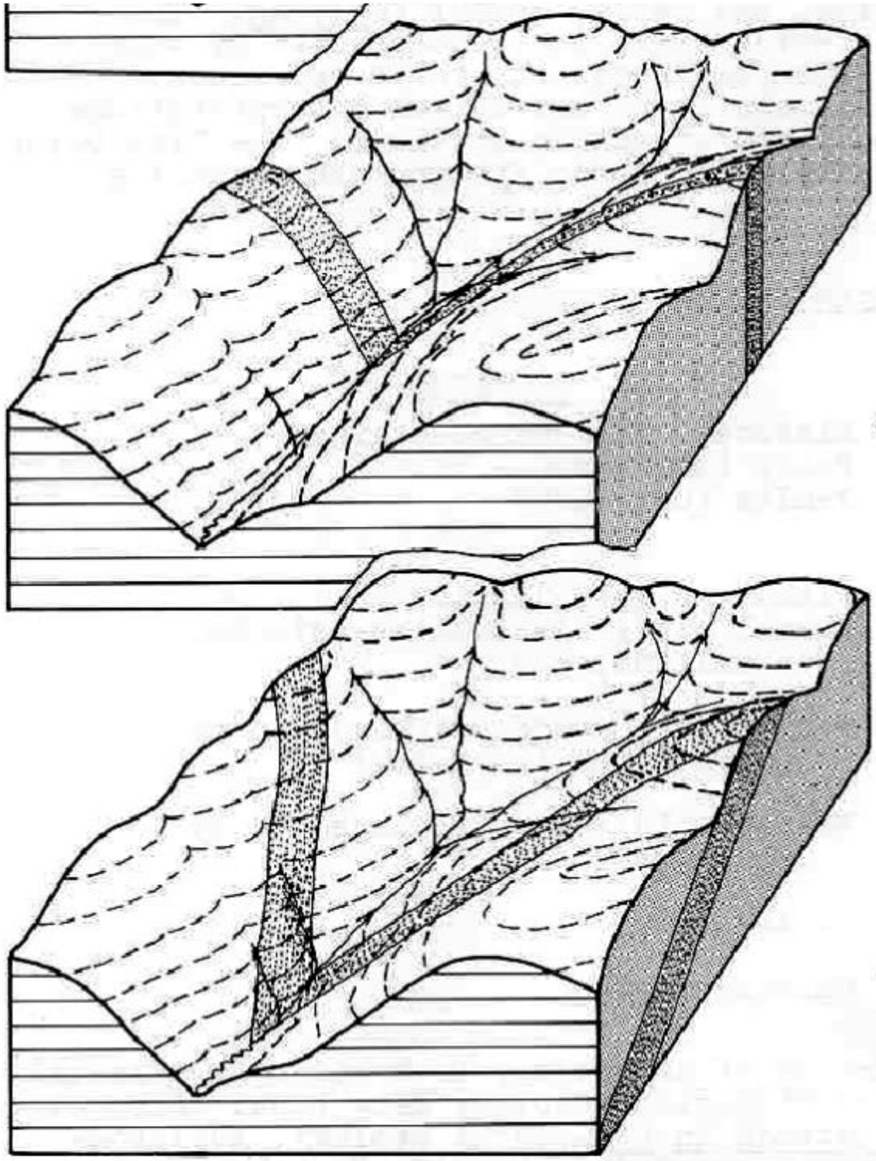
GEOLOGIC MAP

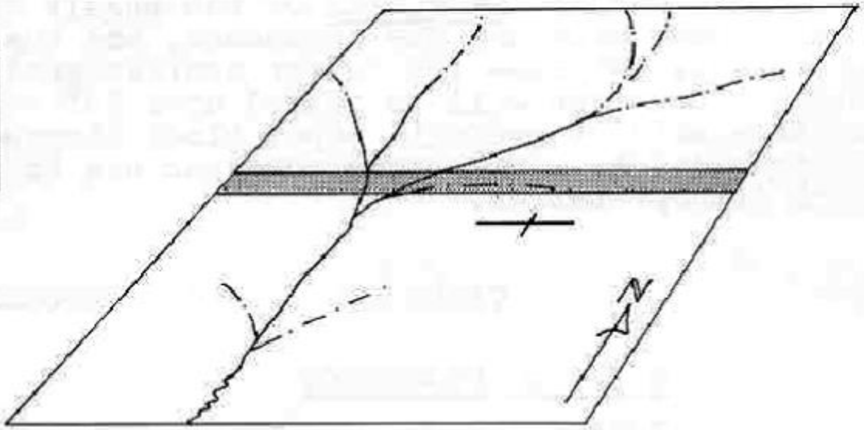


Outcrop pattern of horizontal bed.
Contours are shown as dashed lines.

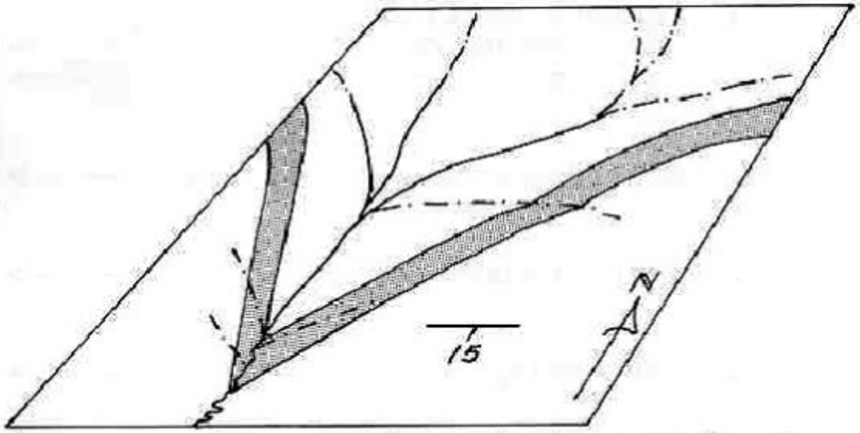


Outcrop pattern of bed dipping north at a low angle. "V" upstream.





Outcrop pattern of vertical bed.

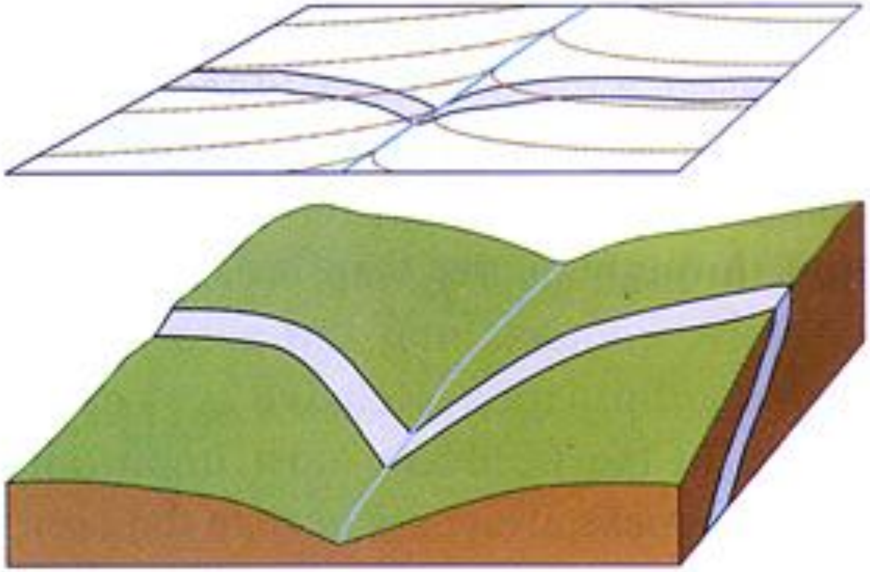


Outcrop pattern of bed dipping south at low angle. "V" downstream.

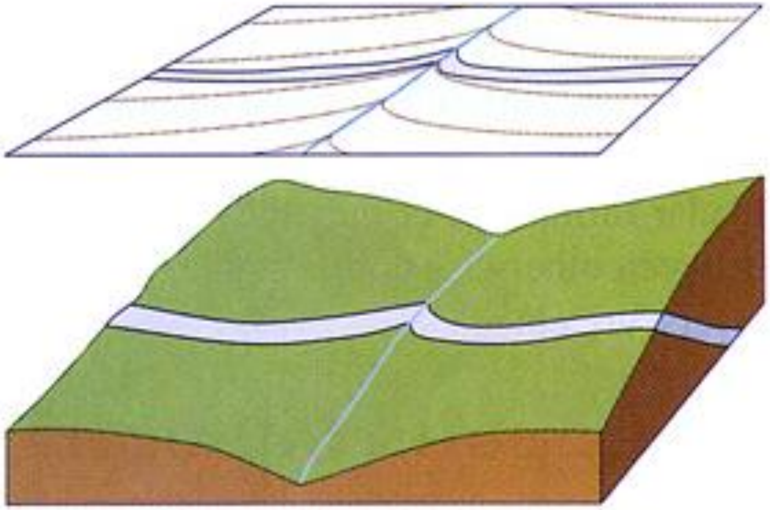
Rule of ‘V’s

- “Where a contact crosses a valley, it forms a “V”, the apex of which points in the direction of dip of the contact”
- Three Exceptions to the rule are:

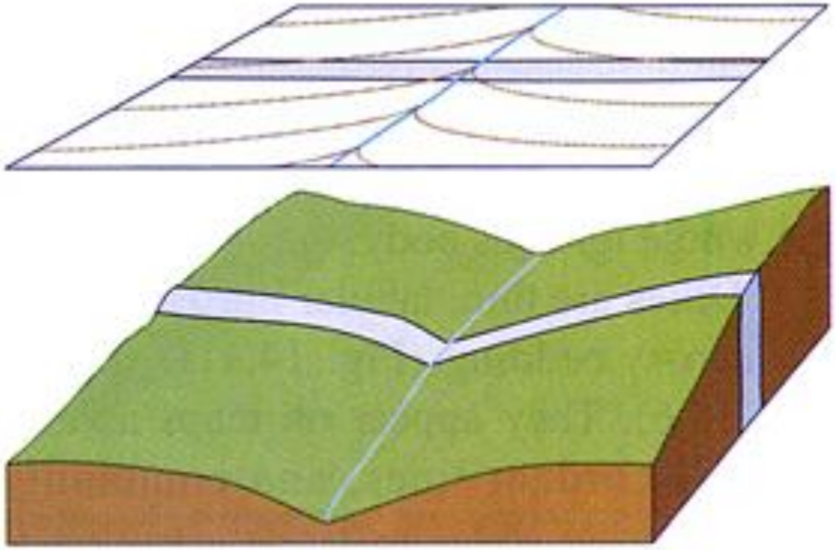
1) If beds are vertical, the contact is NOT deflected on crossing a valley and no V is formed
2) If the beds are horizontal, the V points up-valley and is parallel to the contour lines
3) If the bed dips down the valley, but at an angle less than the amount of the slope of the valley, the V points up-valley.



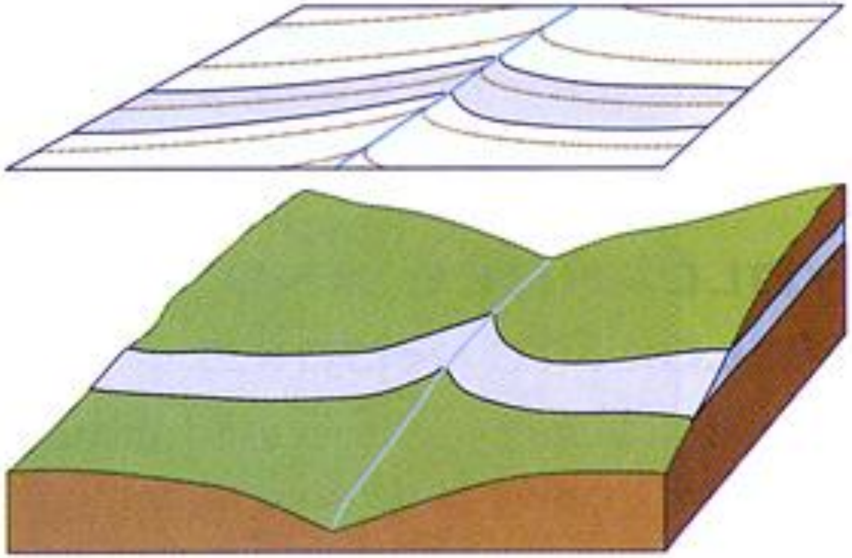
A. V points opposite to contours.



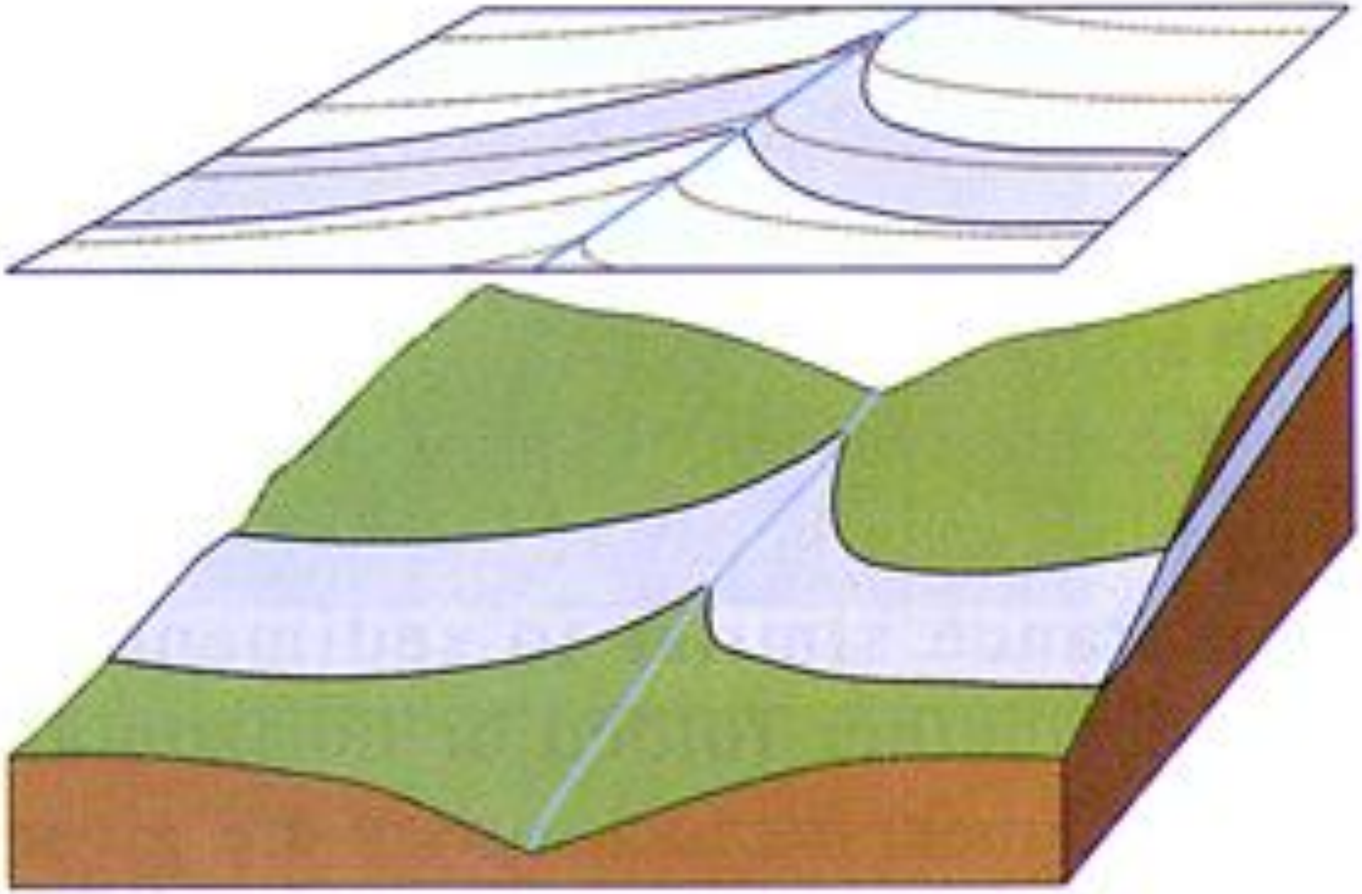
B. V is not parallel to contours; its point
is at a **lower** elevation than its sides.



C. Contacts cut straight across contours.



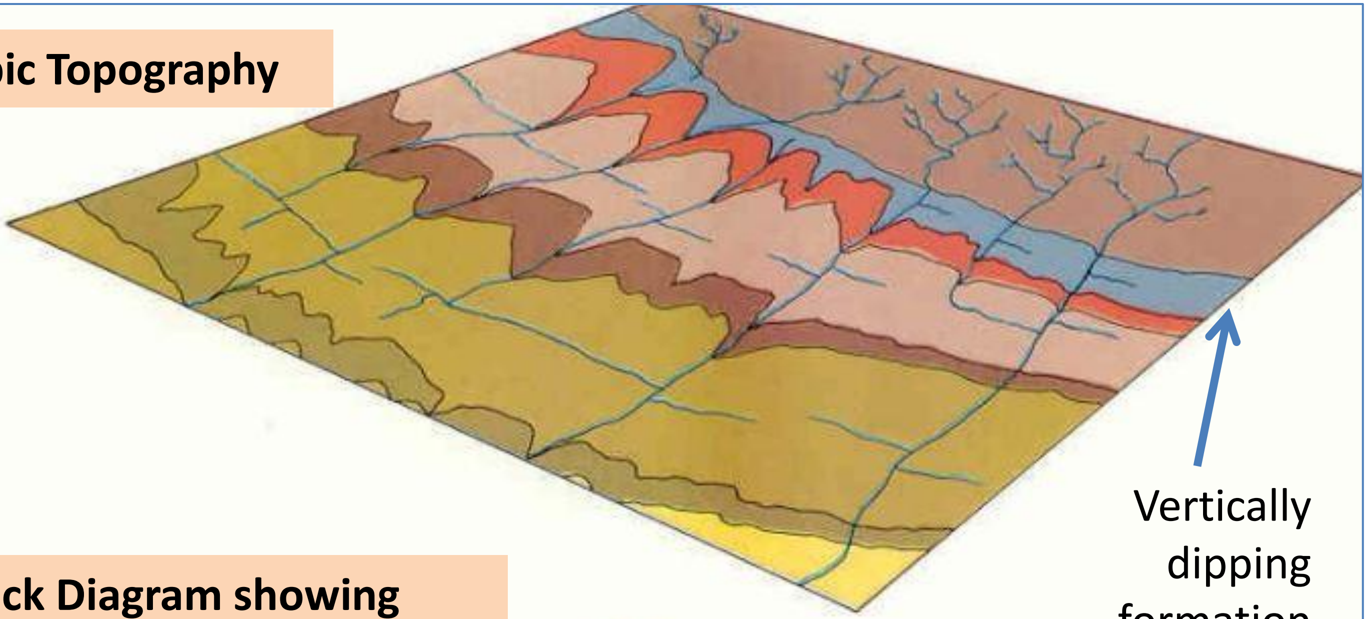
D. Contacts parallel contours.



E. V is not parallel to contours; its point is at a **higher** elevation than its sides.

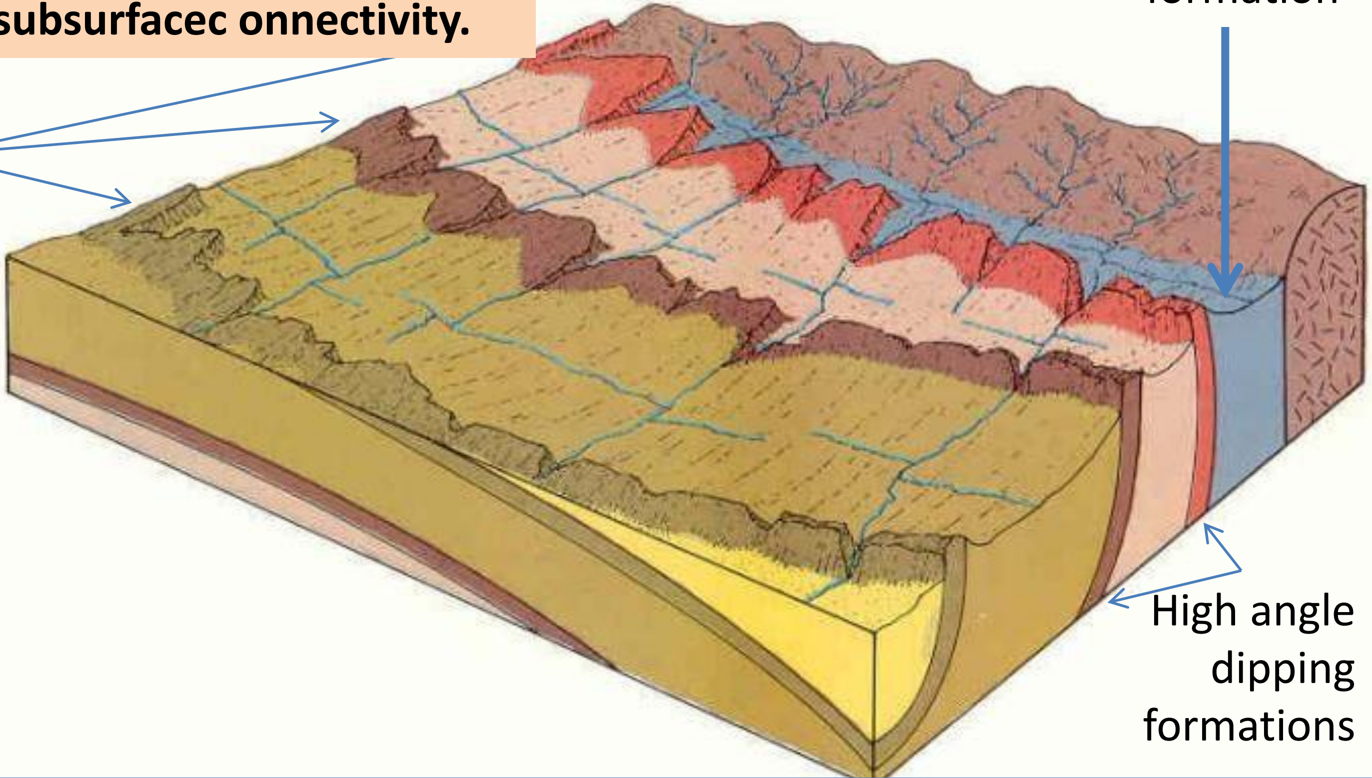
3D Monoscopic Topography

Ref. Fig. 6.6



Vertically dipping formation

3D Monoscopic Block Diagram showing Topography and its subsurfacec onnectivity.



Low angle dipping formations

High angle dipping formations

Figure 6.6. When a sequence of rocks is tilted and truncated by erosion, the outcrop patterns will appear as bands which, on a regional basis, are roughly parallel. Important variations in details of the basic pattern are developed in areas dissected by erosion and should be carefully analyzed, for they provide important information concerning the subsurface structure.

When dipping strata are traced across a valley, a V-shaped outcrop pattern is produced which points in the direction of dip. Exception to the rule is possible if the degree of bedding dip is less than the gradient of the valley, but such conditions are seldom encountered. The size of the outcrop pattern V is inversely proportional to the magnitude of dip:

1. low angle dip -large V (front part of Figure)

2. high angle dip - small V

3. vertical dip - V is absent (back part of Figure)

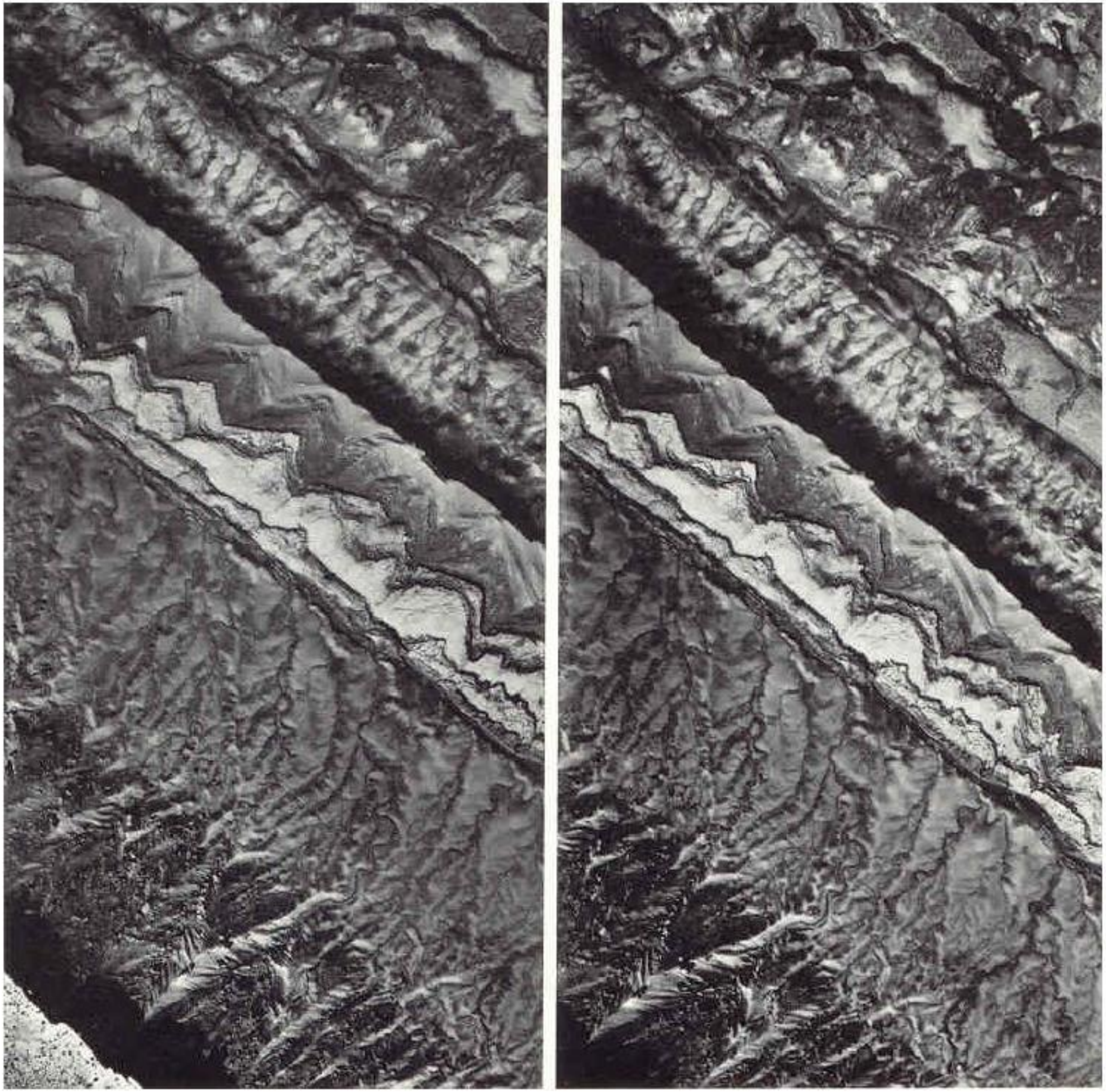
Careful examination of Figure will reveal several additional relationships basic to geologic maps:

1. Older beds dip toward younger beds unless the sequence is overturned. 2. Outcrop width depends on a. thickness of the beds

b. dip of the beds (low dip maximum width)

c. slope of the topography (steep slope minimum width)

Stereo satellite PAN image – depicting several tilted geological formations and their outcrops with drainages along several valley cuts.



QUESTA.

3. Where bedding is expressed by bands of differing photographic tone or by topographic breaks in slope due to the resistance of beds, the rule of V's may be applied to determine the direction of dip; that is, where the trace of a bed intersects a stream valley a V in the outcrop pattern will point the direction of dip (Figure 6.5, 6.6).

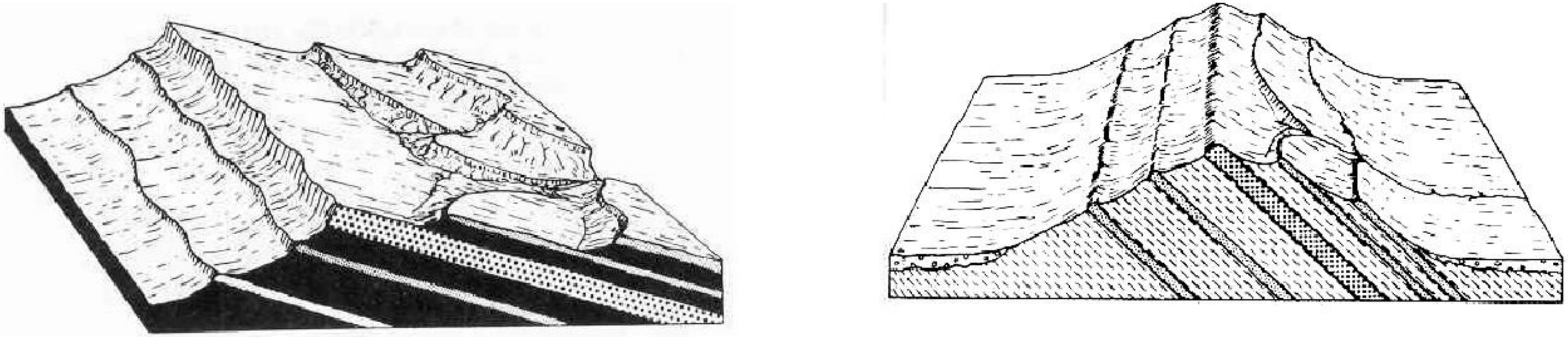
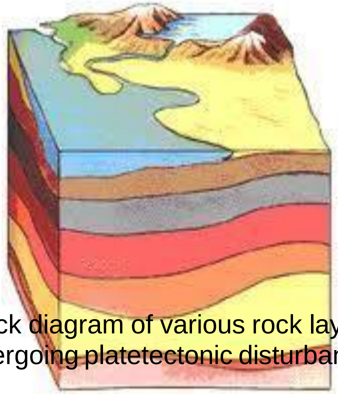


Figure 6.5

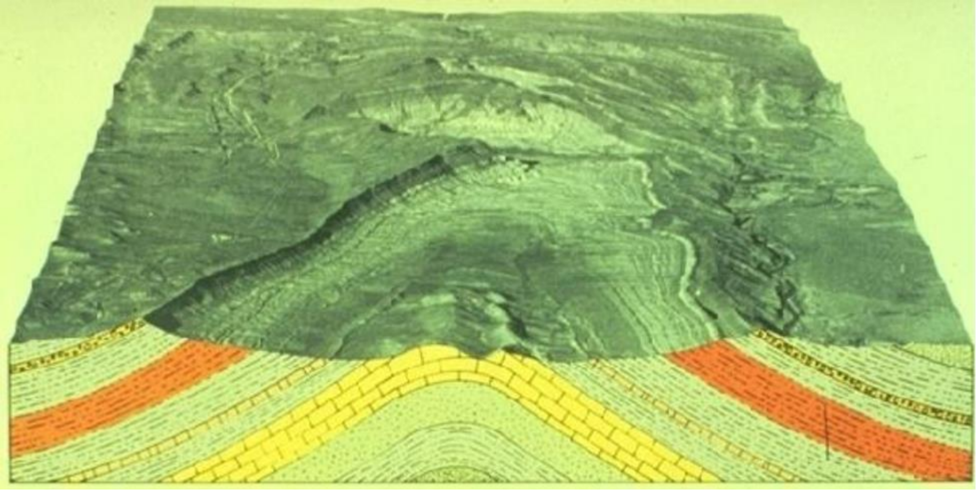
But if the direction of dip and direction of stream flow are the same and the stream has a gradient greater than the amount of dip, the case will be reverse.

Satellite Image of Structural Features



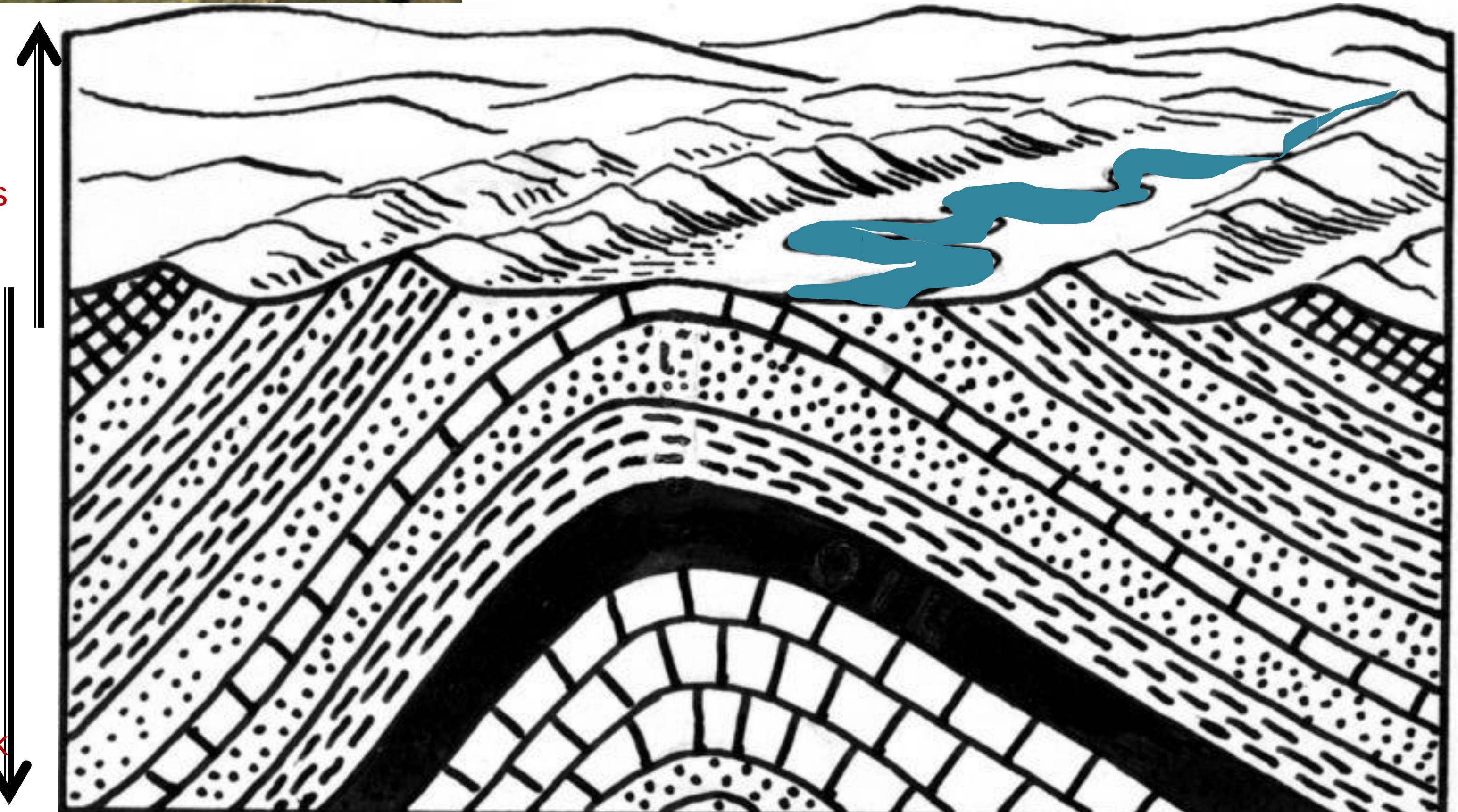
Block diagram of various rock layers undergoing platetectonic disturbances

We will see a different view of the similar such structural hill area viewed by another satellite called GeoEye in the forth coming slides



Plunging fold interpreted into the subsurface.

Above:Aerial photograph of Sheep Mountain - a **doubly plunging** anticline (NW WY). "V" s are pointing the direction of the plunges. Erosion due to the Gros Ventre River along the south flank resulted in a spectacular landslide in 1925.

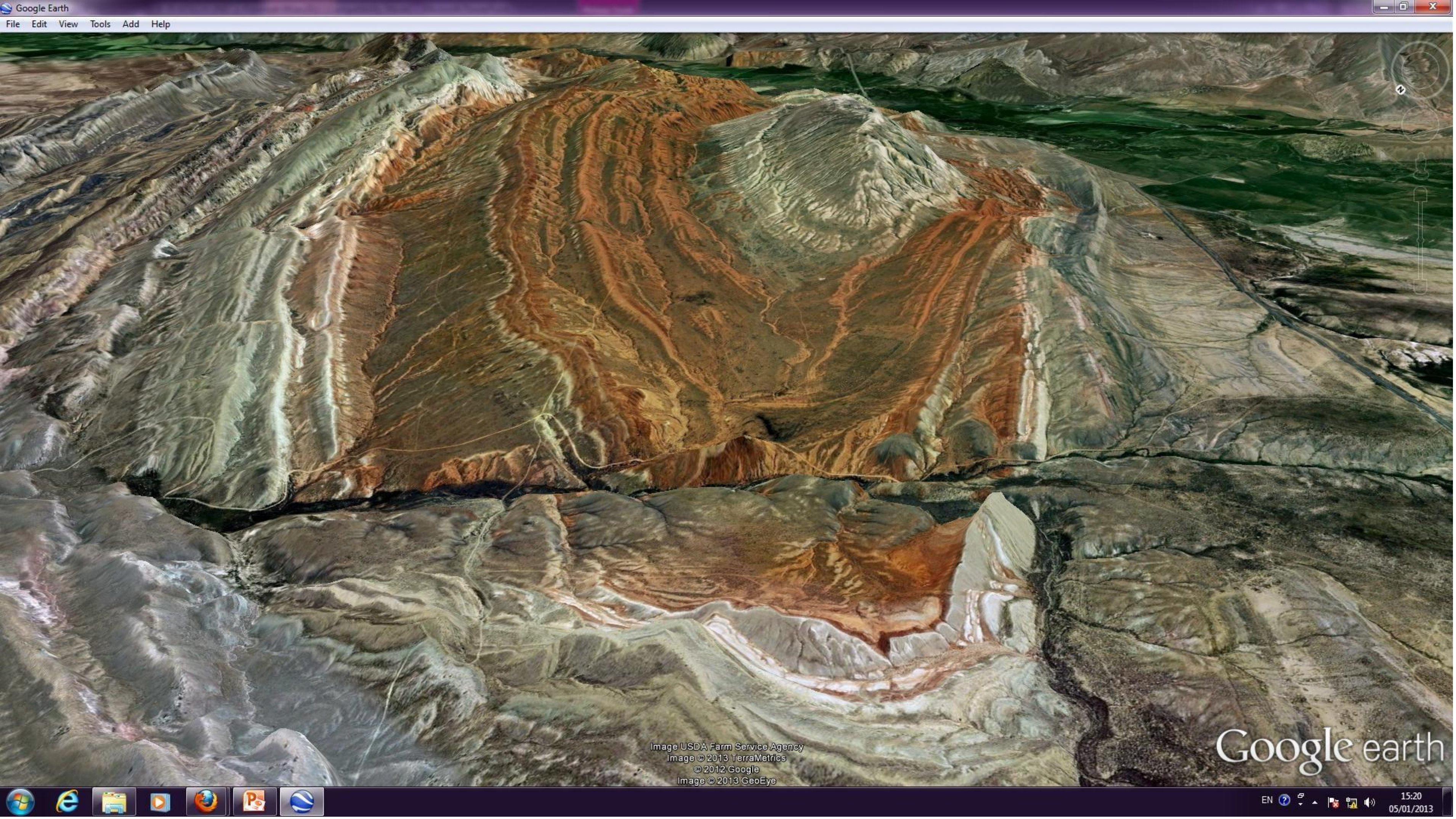


Oblique Surface view showing landscapes above anticlinal structure

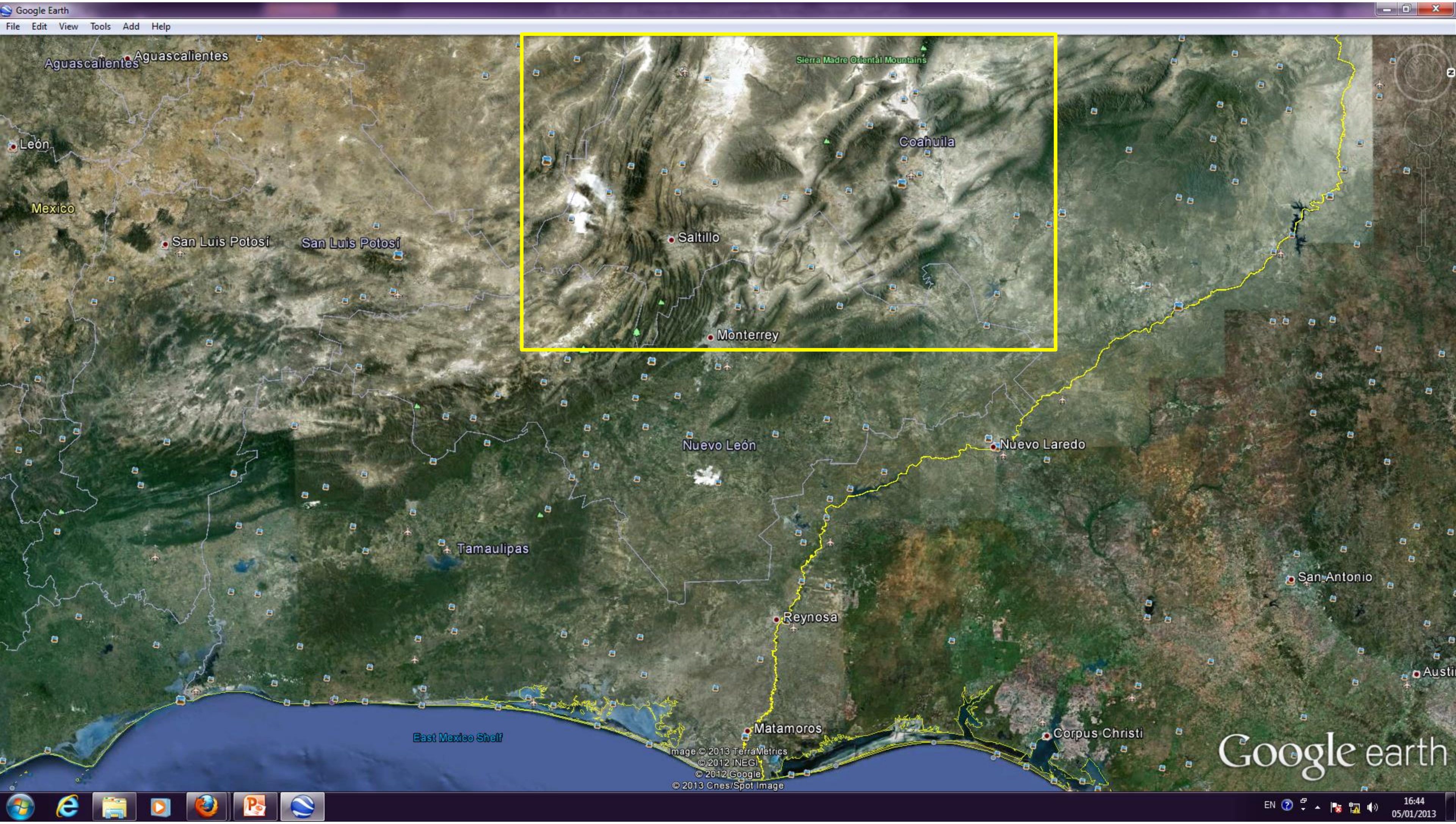
Vertical Cross Section of Block diagram showing the subsurface folded rock stratum


4.41 mi

Sheep Mountain, Albany, Wyoming WY, United States –
GeoEye satellite data viewed using Google earth

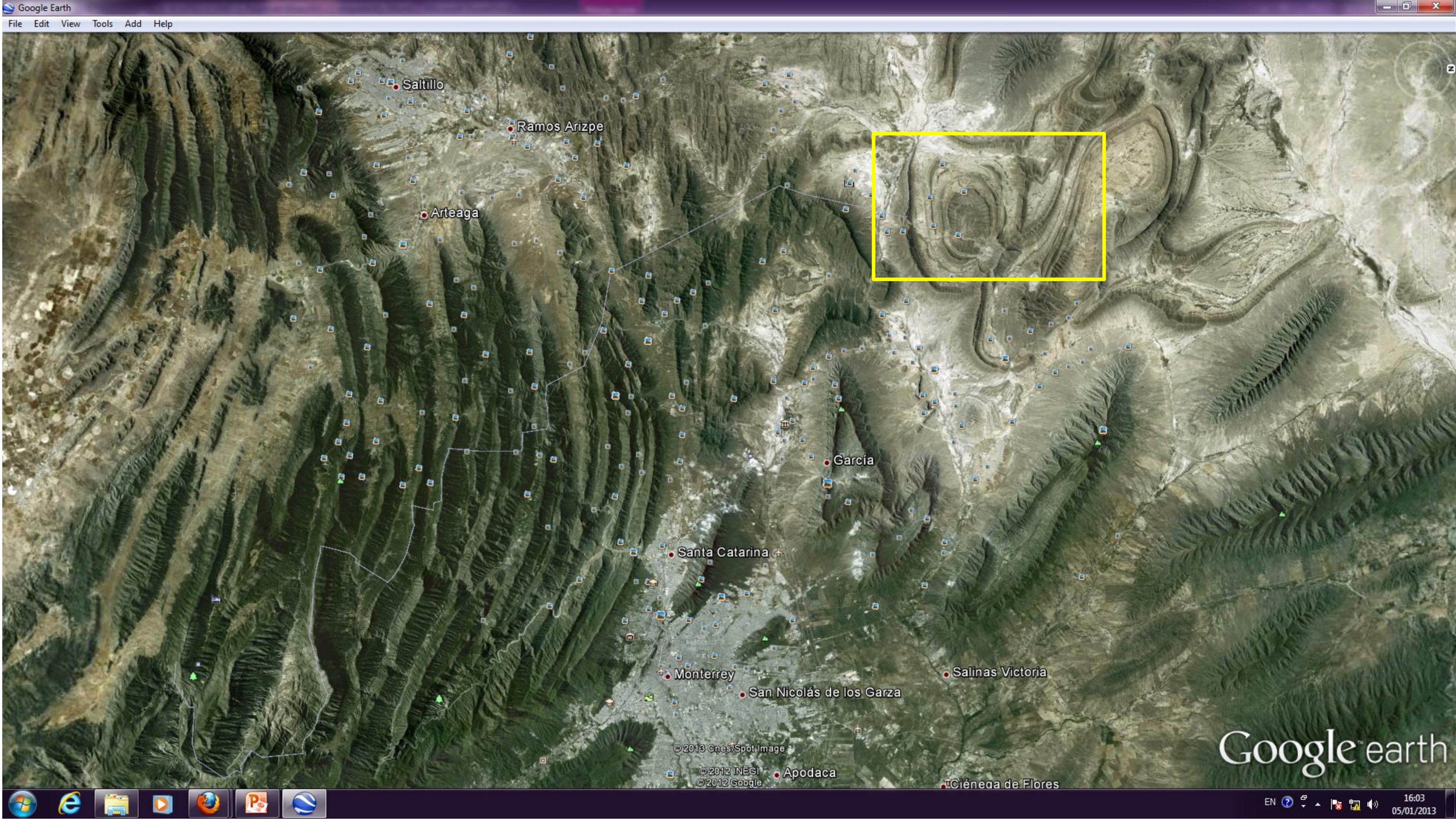


Sheep Mountain, Albany, Wyoming WY, United States
– viewed using 3D terrain option of Google earth



Carricitos - Sierra Mountain, Monterry, United States – viewed using Google earth – Let us zoom a small portion (yellow rectangle area) of this image

Carricitos - Sierra Mountain, Monterry, United States – viewed using Google earth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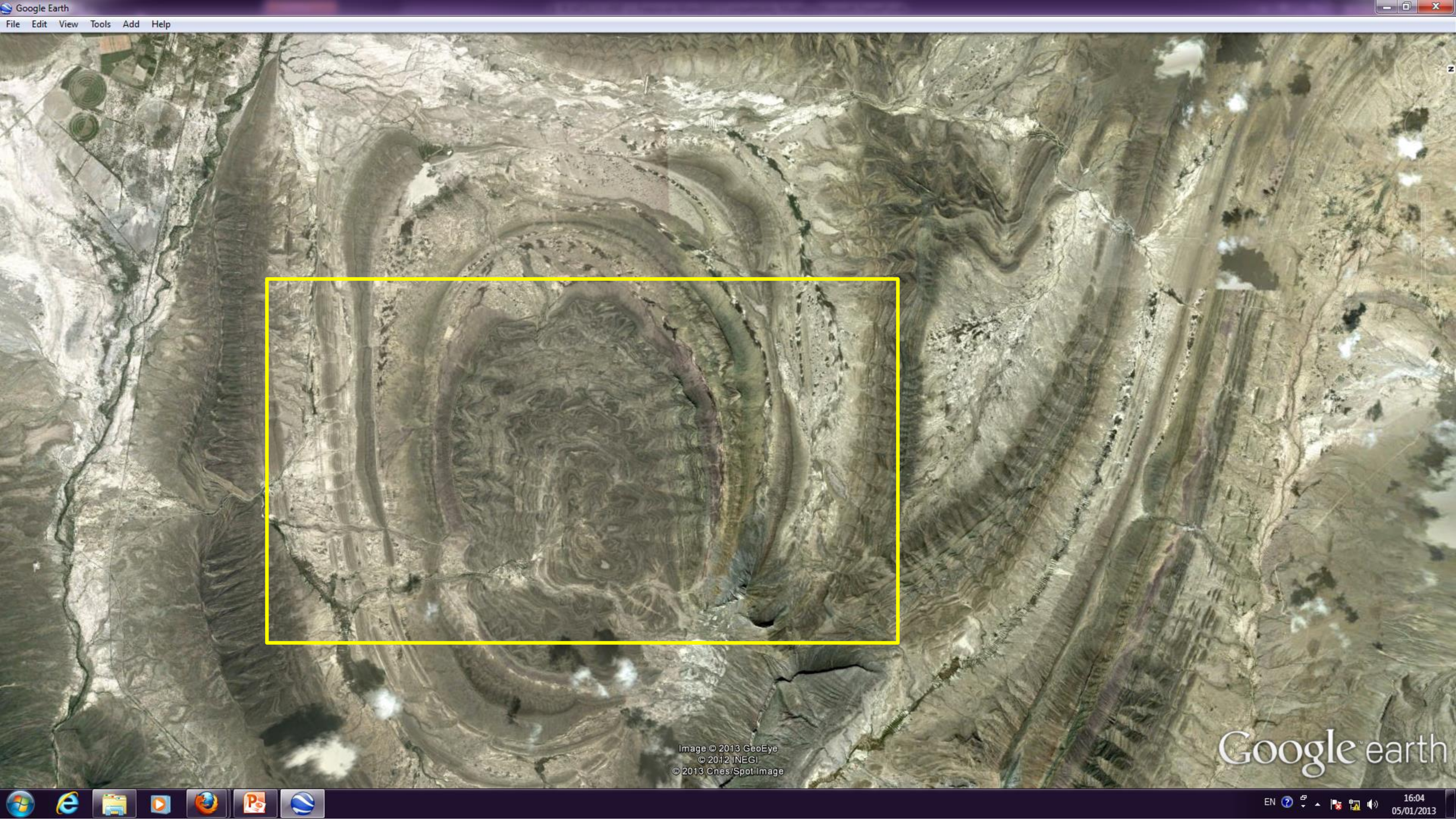
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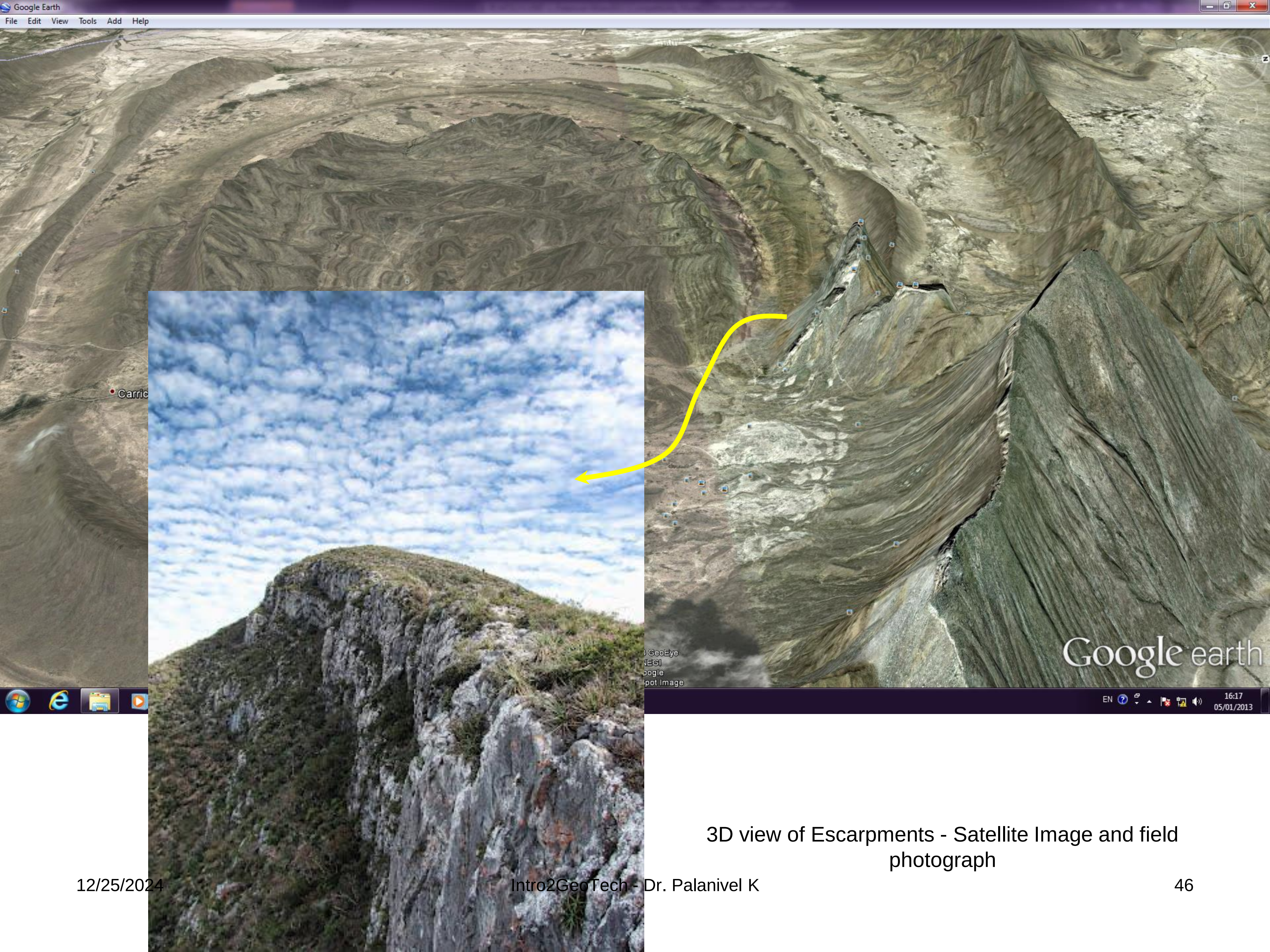
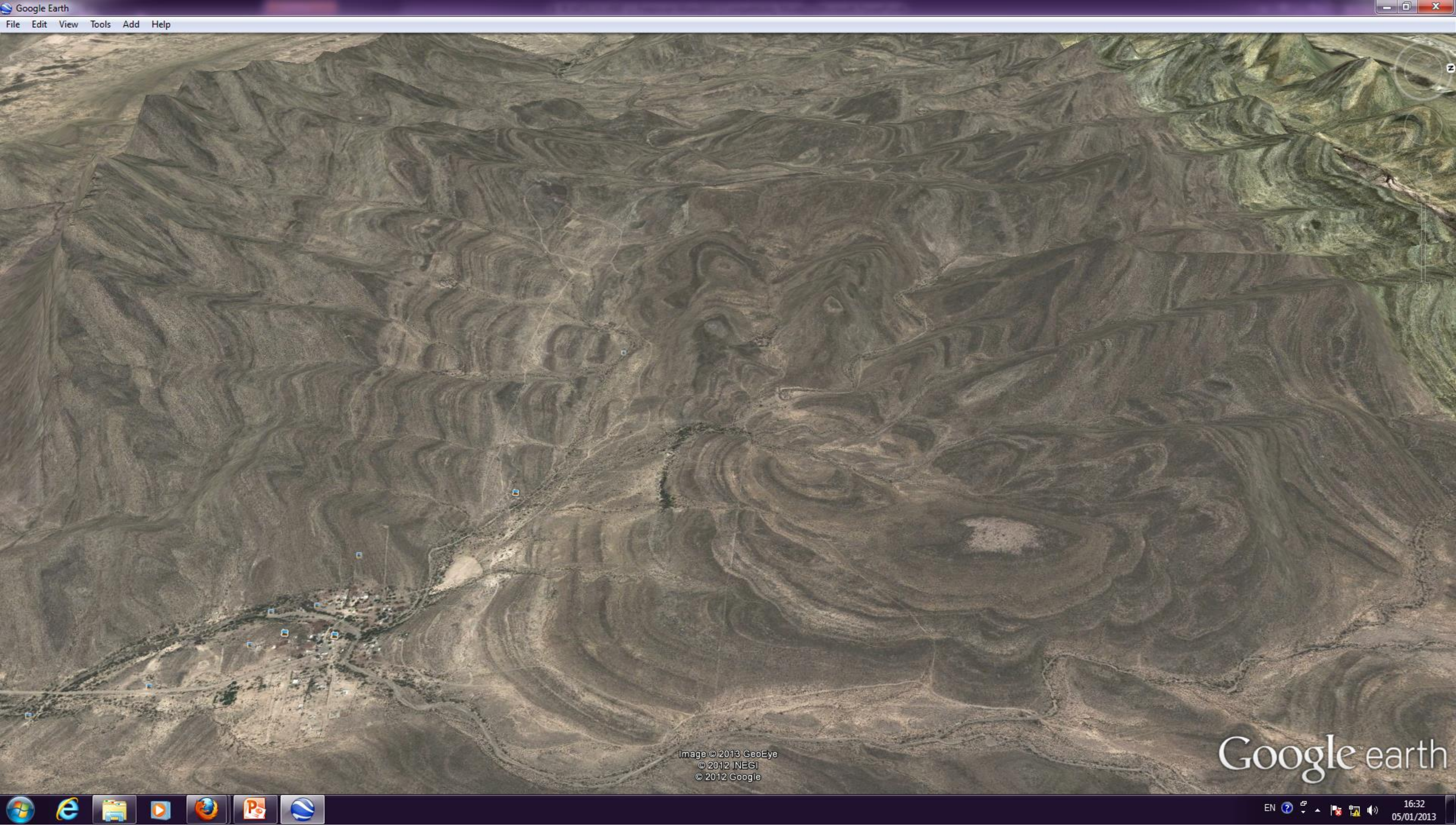
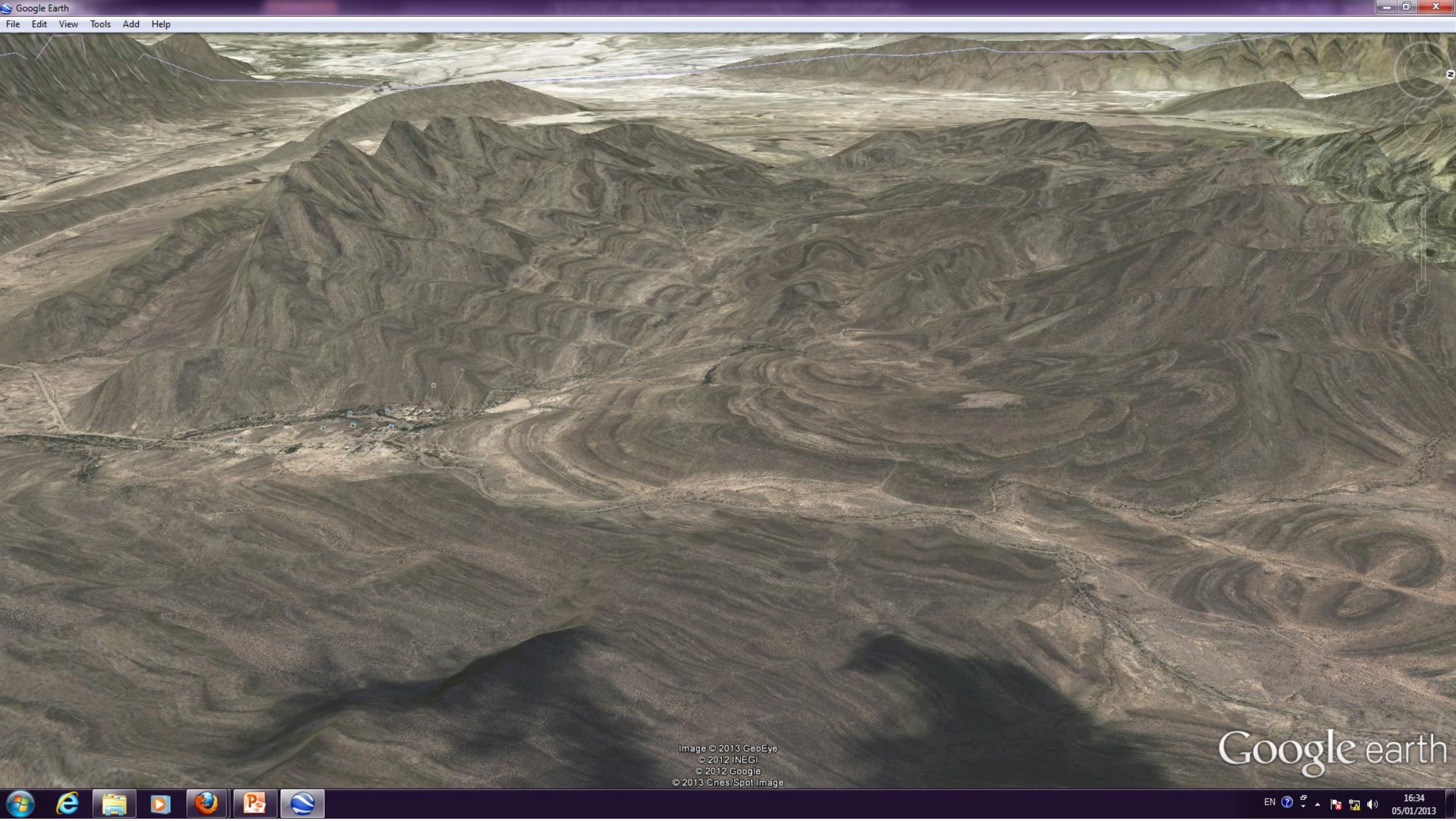
Escarpments, i.e., Steep sided portion of hills Structural Features shown both in satellite image, terrestrial photograph (right) and a high oblique aerial photograph (left)

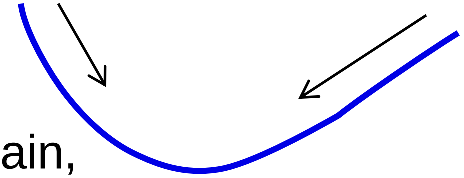


3D view of Escarpments - Satellite Image and field photograph



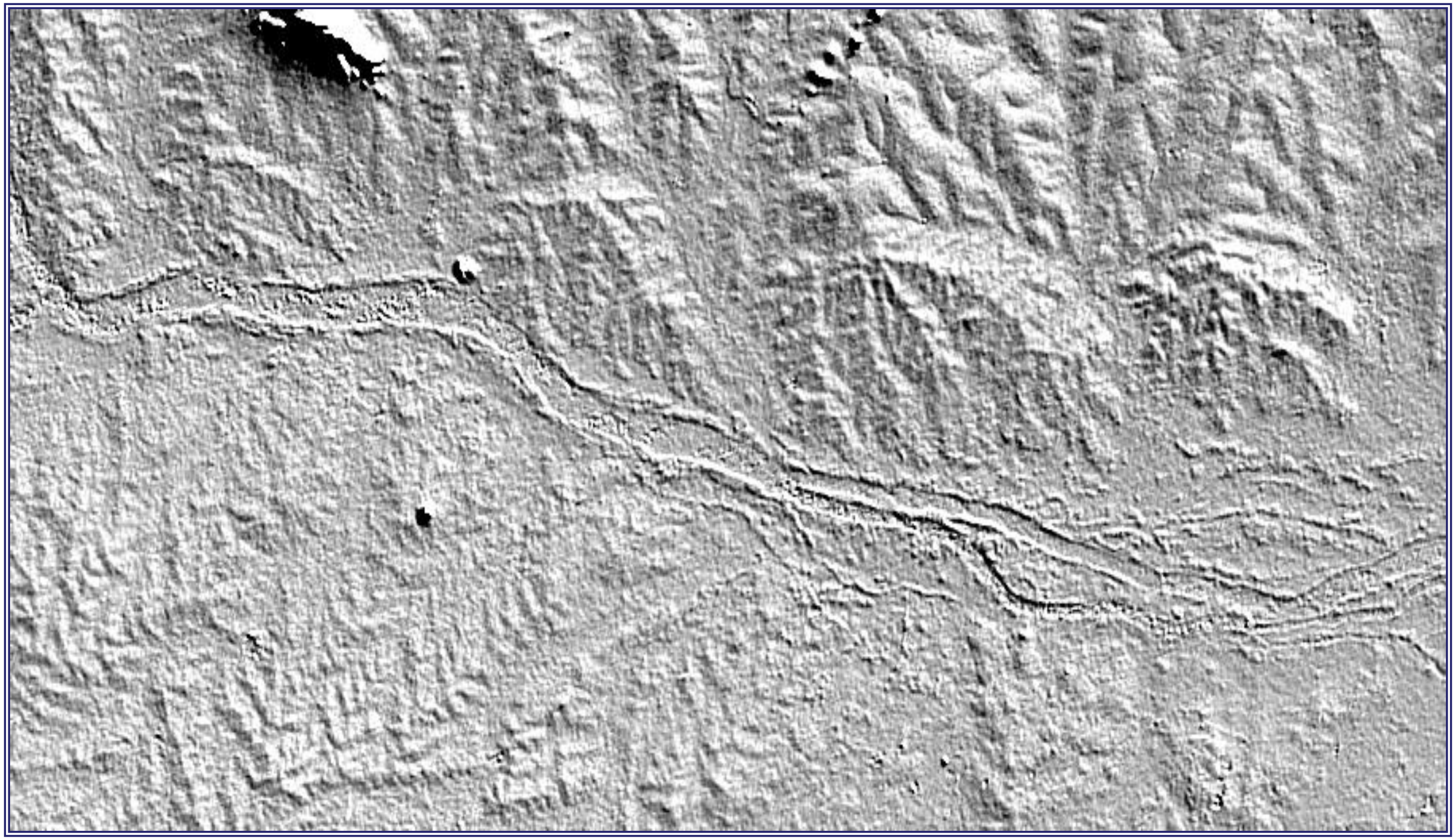
Note the multiple rock layers which are visible with alternating light and dark colours – each rock layer can be traced very well – Have a look on Western and Eastern side rock layers of this 3D image – Note the direction of 'V' point seen along either sides of drainages. If you are not clear, see the next slide showing a 3D image viewed west with lower elevation and high oblique angle (in which the distant hills are also appearing….)

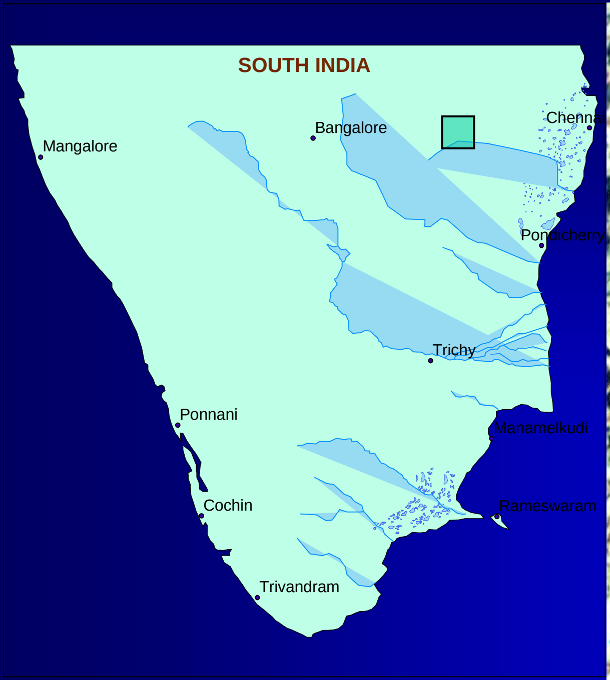


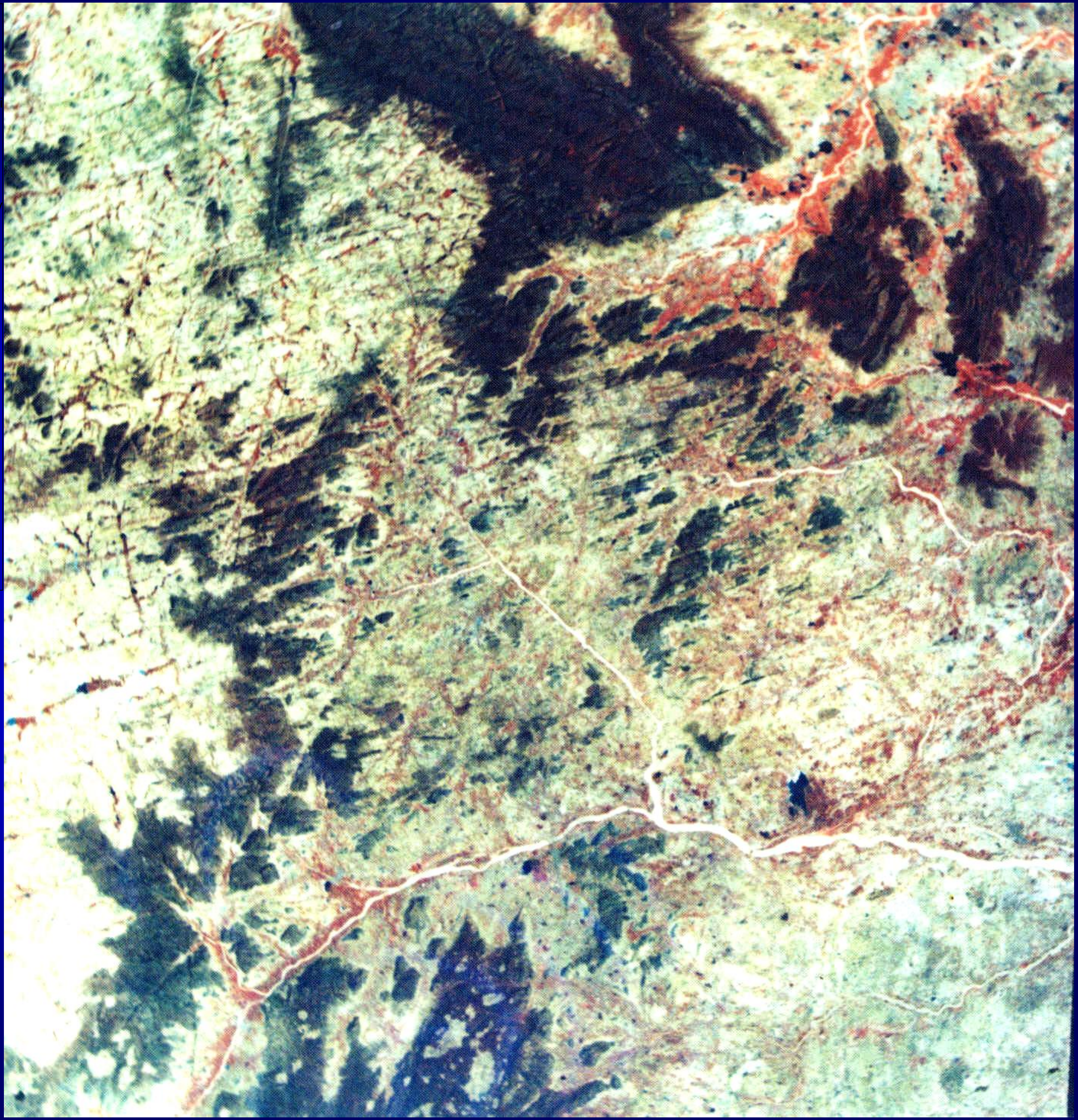


Doubly Plunging Syncline structure (i.e. inclined towards the center) of Carricitos - Sierra Mountain, Monterry, United States – viewed using Google earth

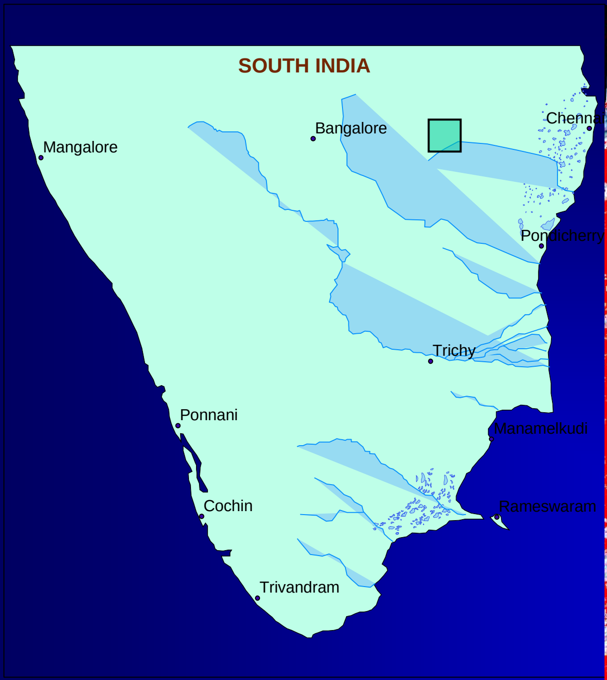
SHADED RELIEF MAP

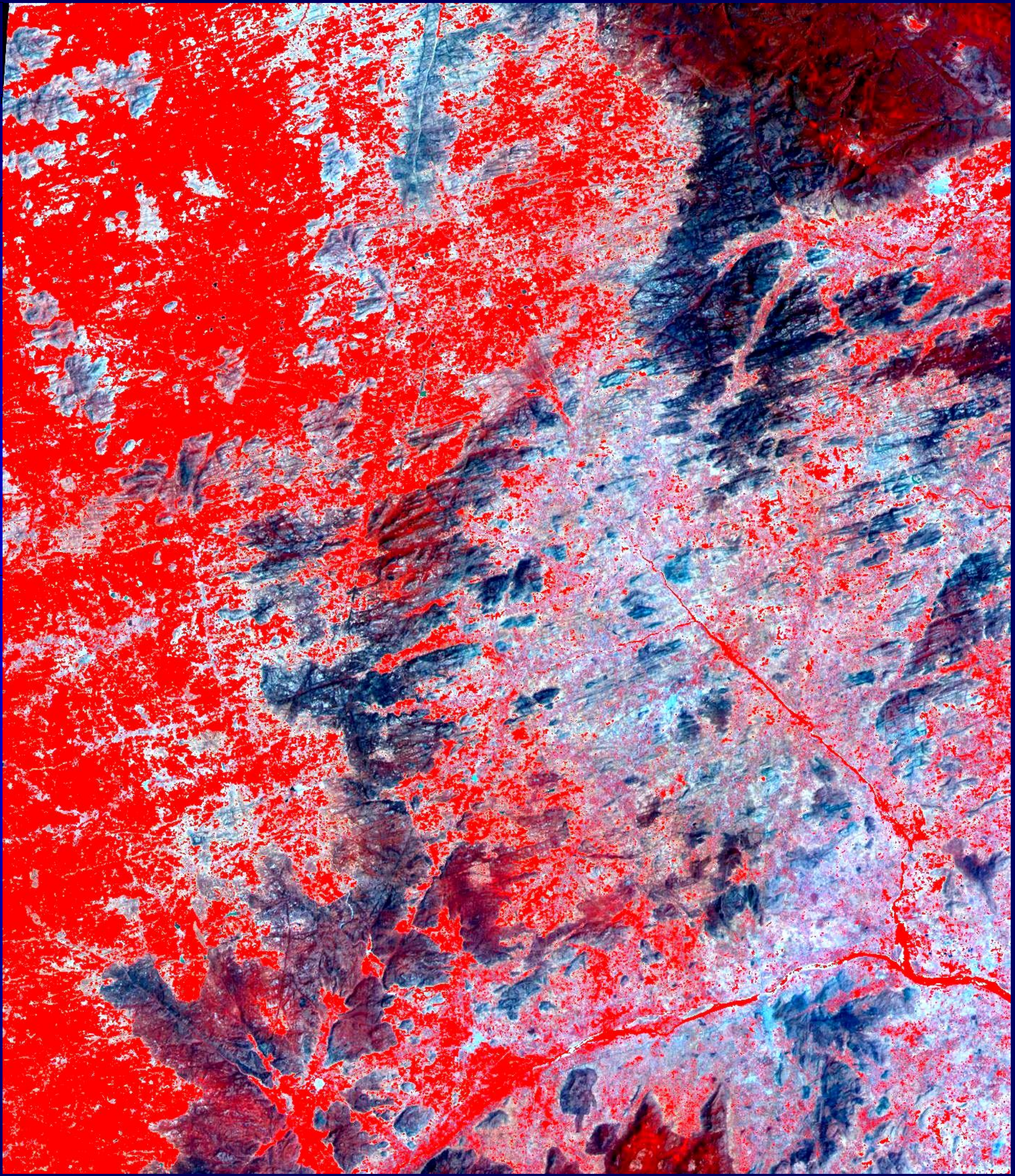






SOIL EROSION – TIRUTTANI & TIRUMALA REGION

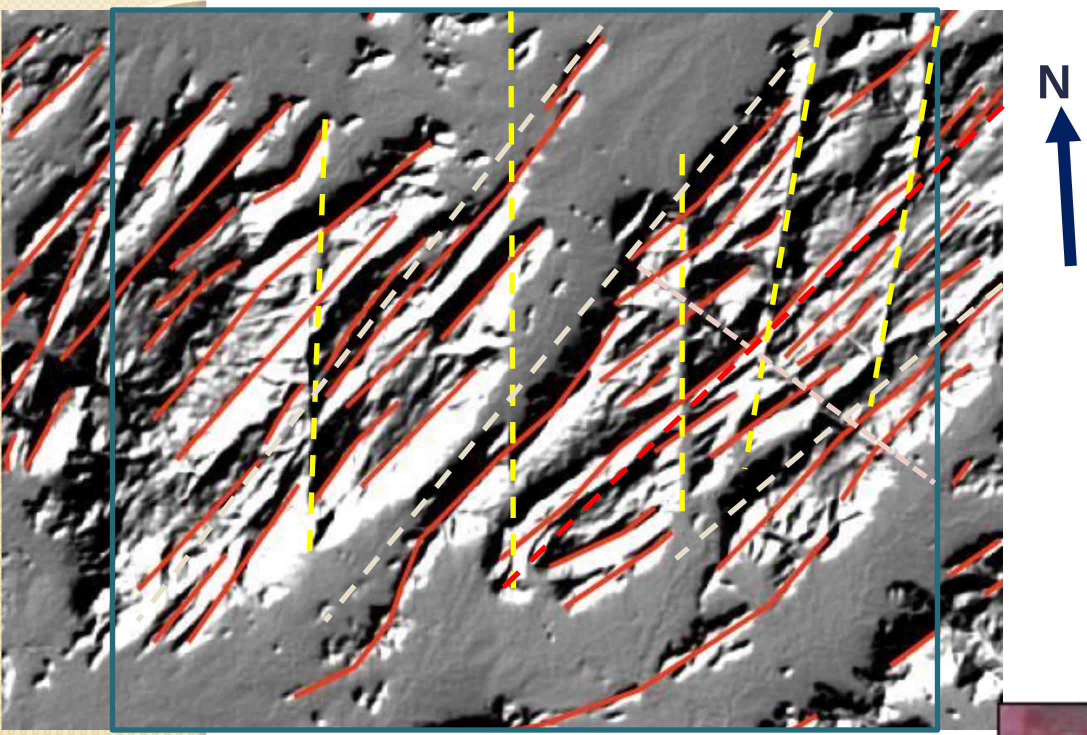




SOIL EROSION – TIRUTTANI & TIRUMALA REGION

PROCESSED IMAGE

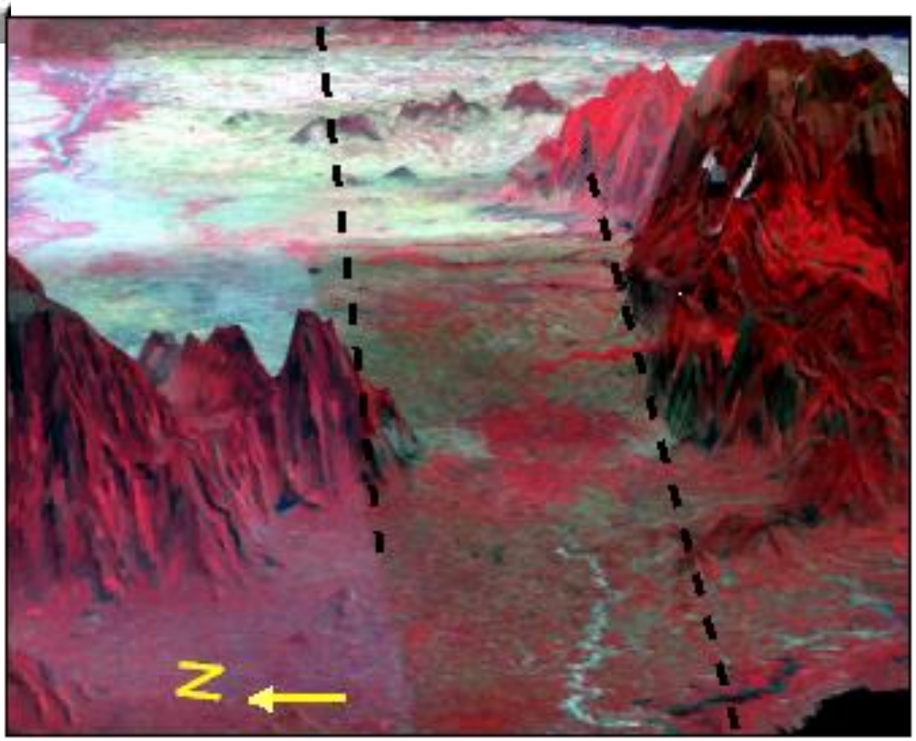
Mapping of Terrain Parameters



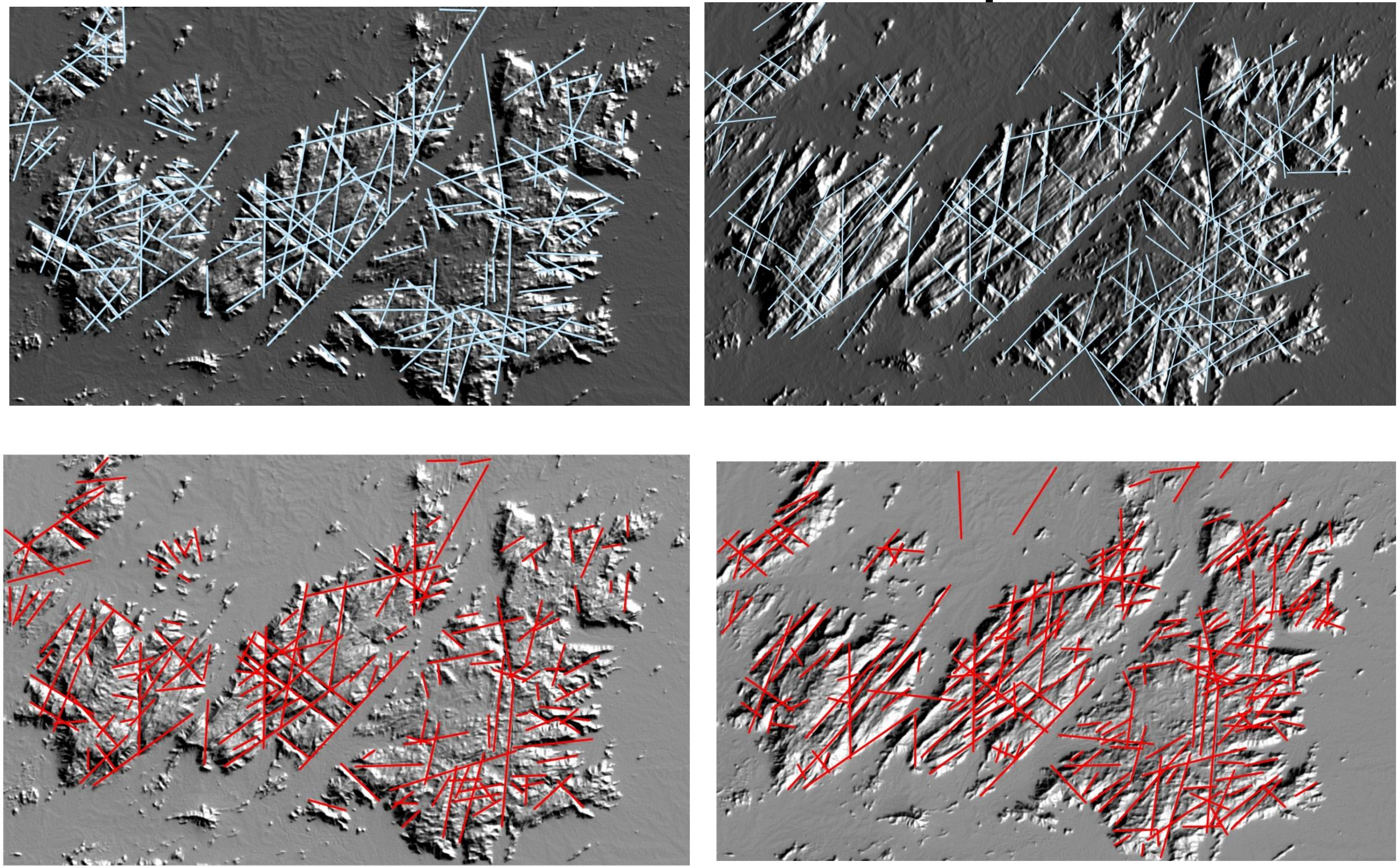
SRTM based shaded relief image shows the faults / fractures in Chitteri and Kalrayan hills

Lineaments / Faults

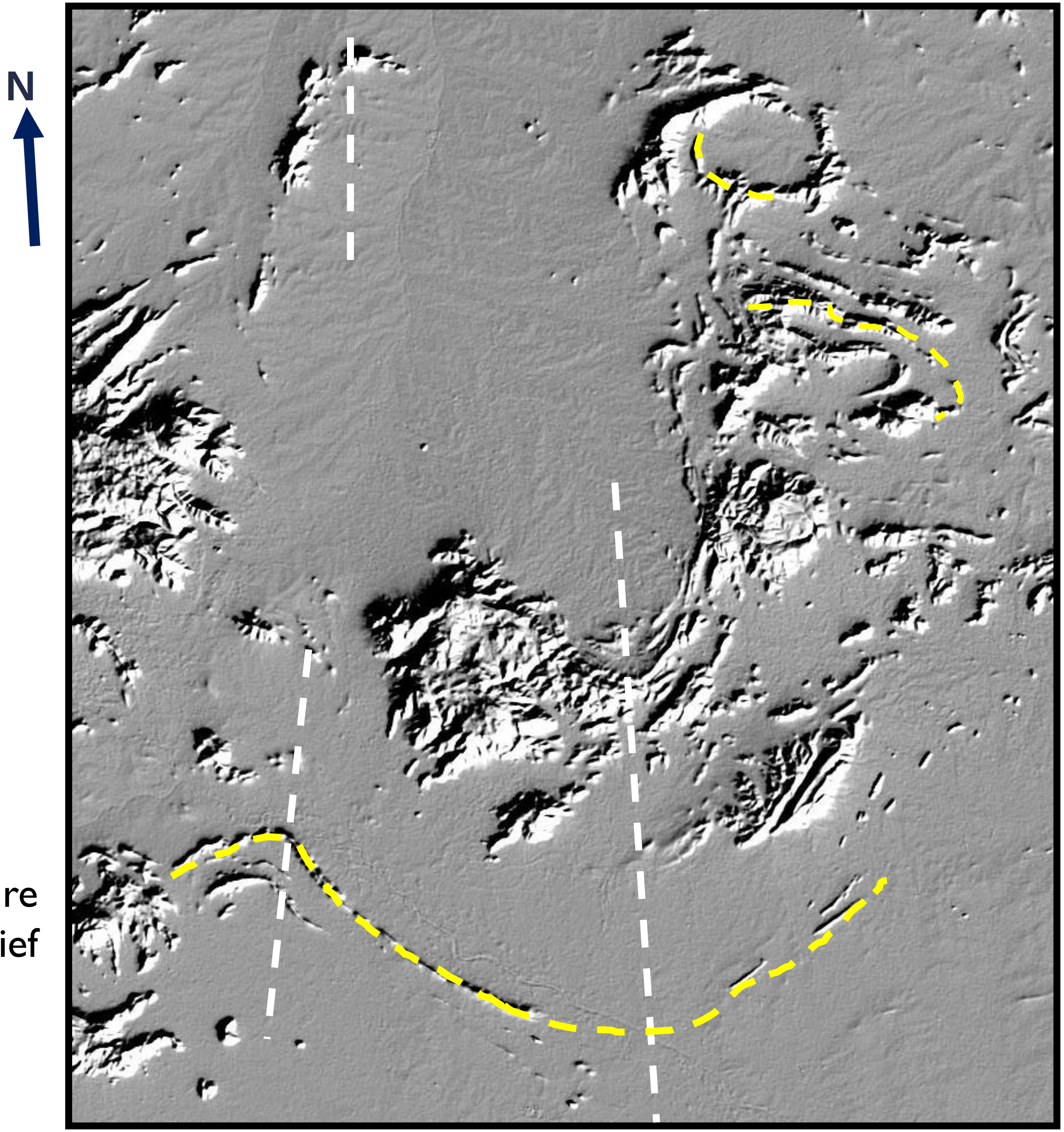
FCC wrapped over SRTM DEM shows the Palaghat Graben



Shaded Relief Map

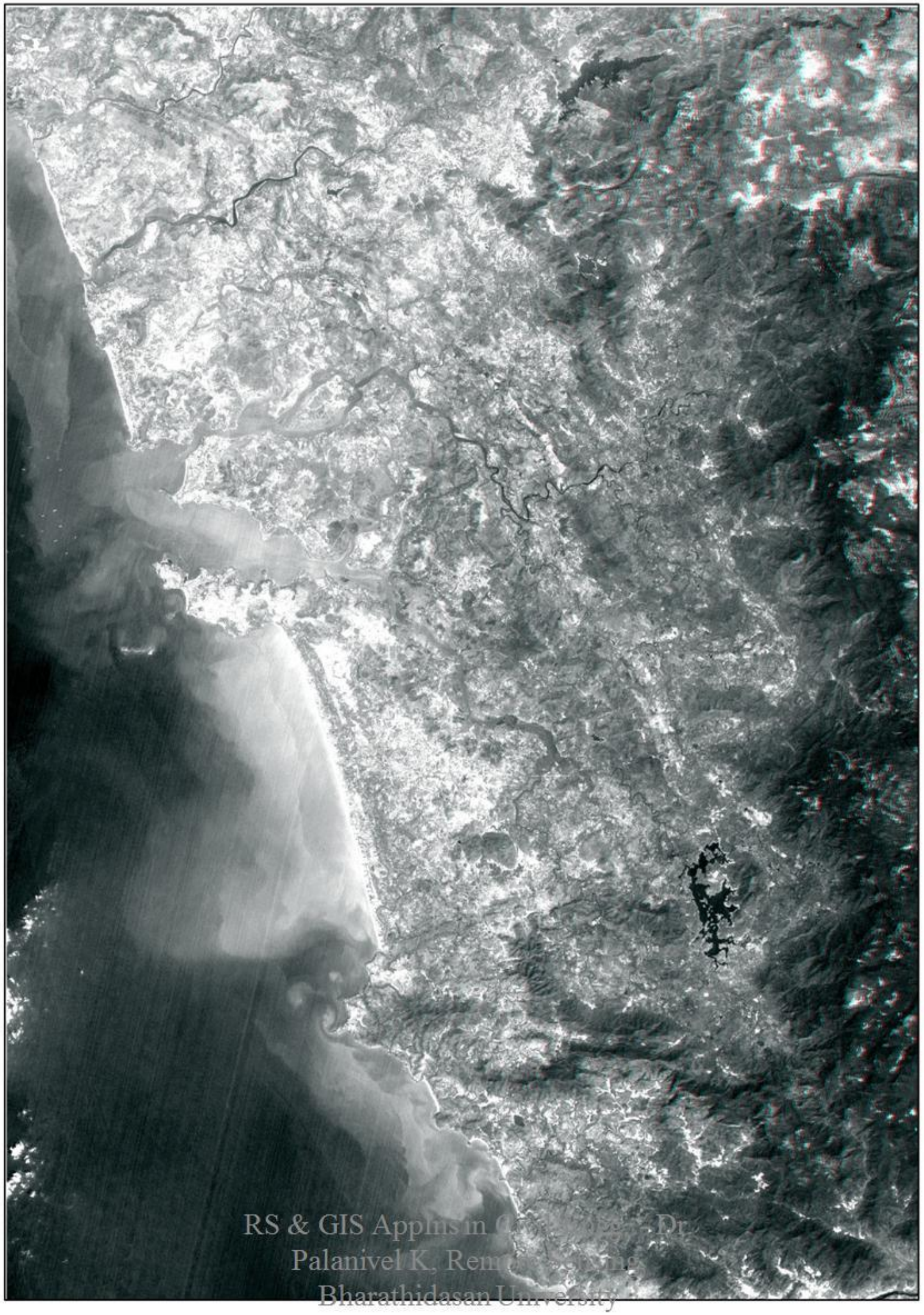


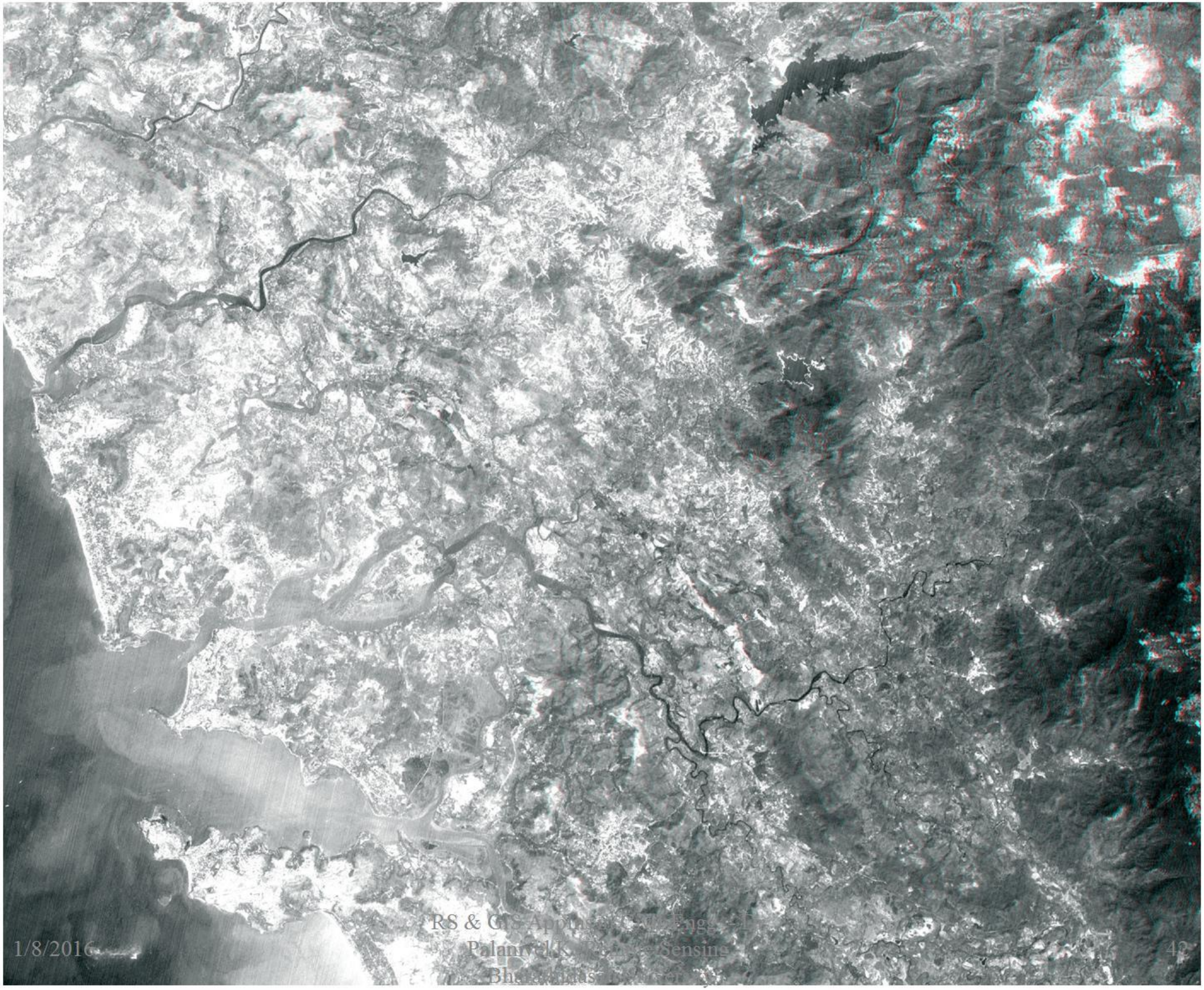
Mapping of Folded structures – Fold Axes, Structural Trends

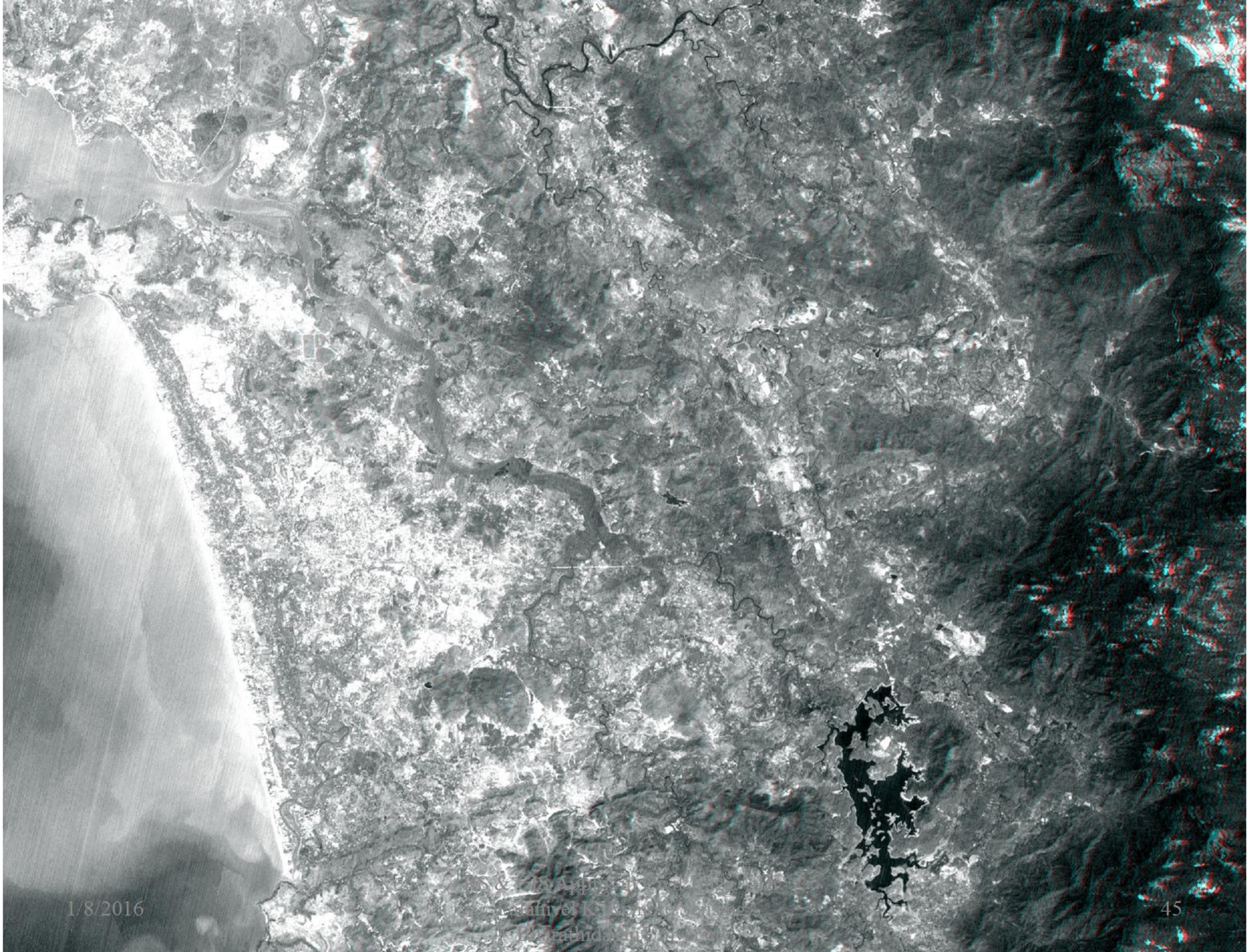


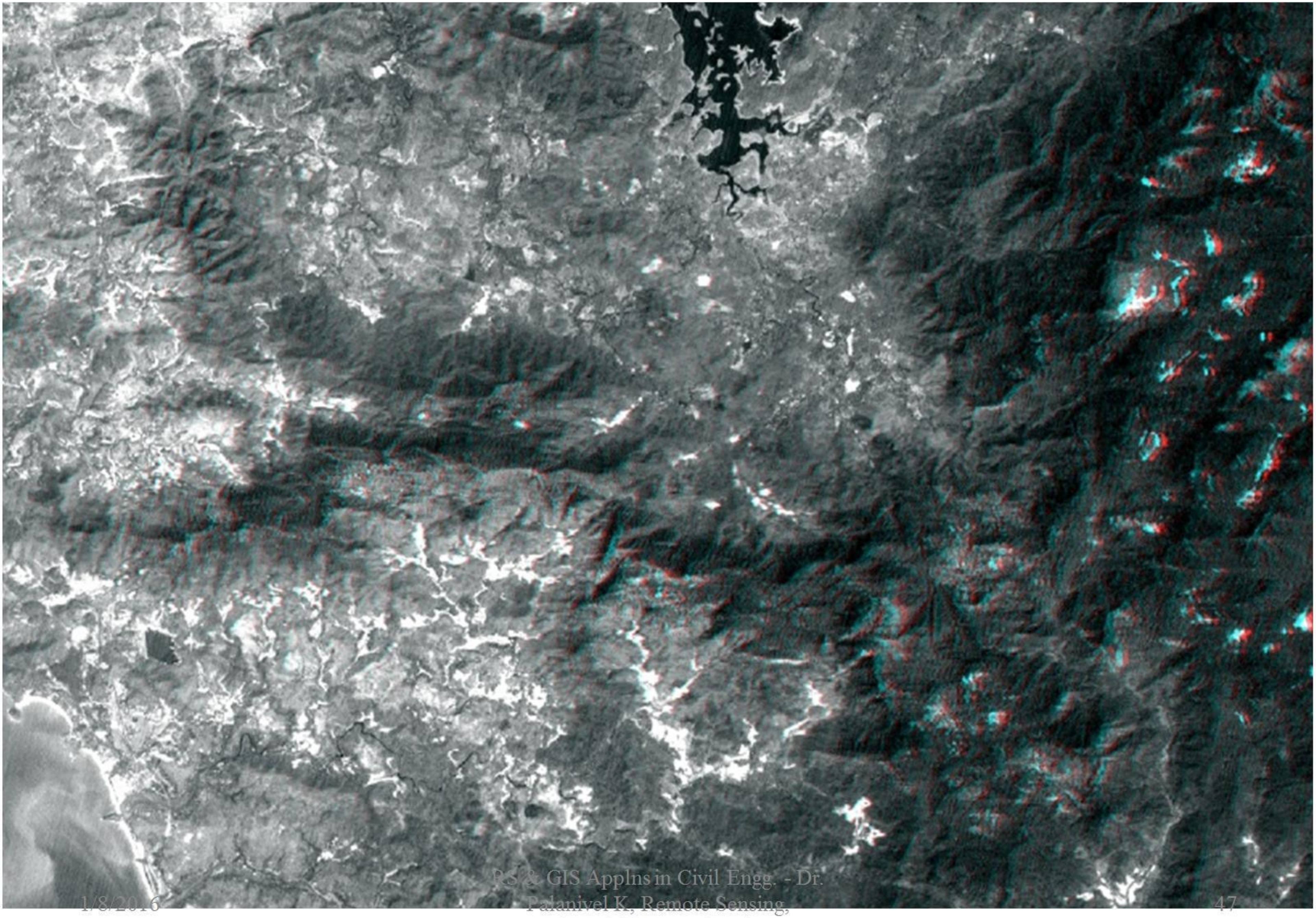
Mapping of Kadavur structure using SRTM based shaded relief image

Cartosat DEM based Anaglyph of Goa state, Western India

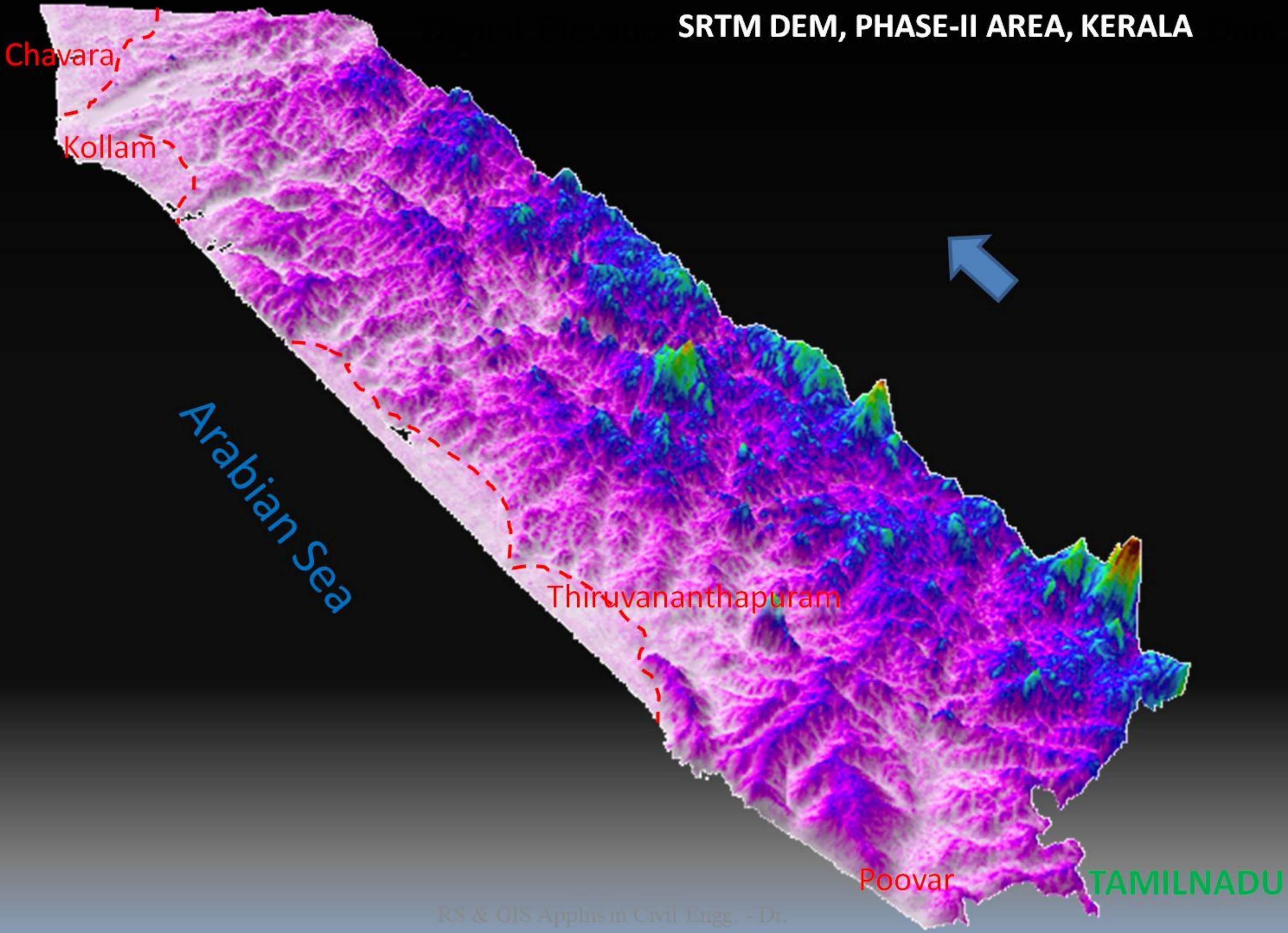




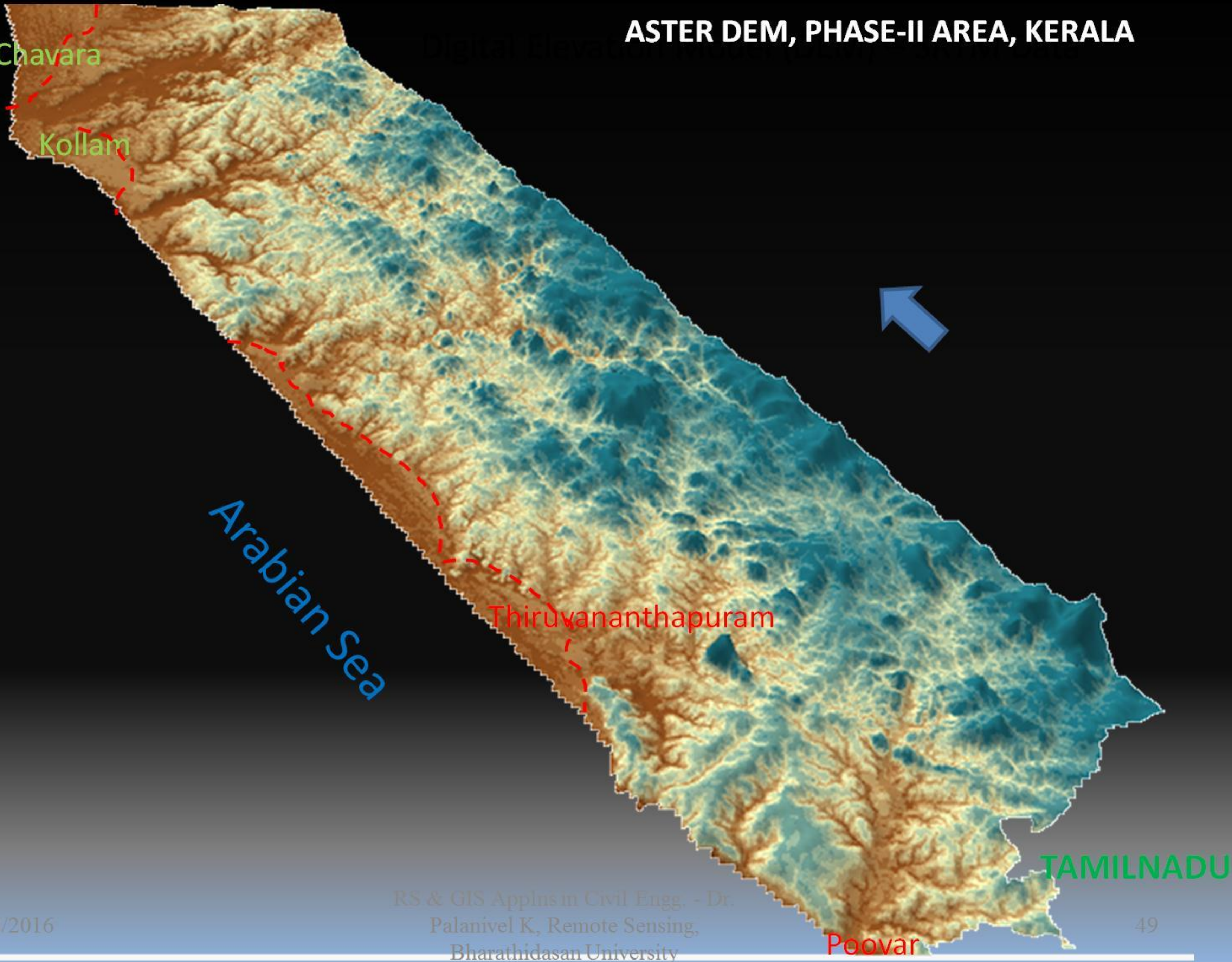




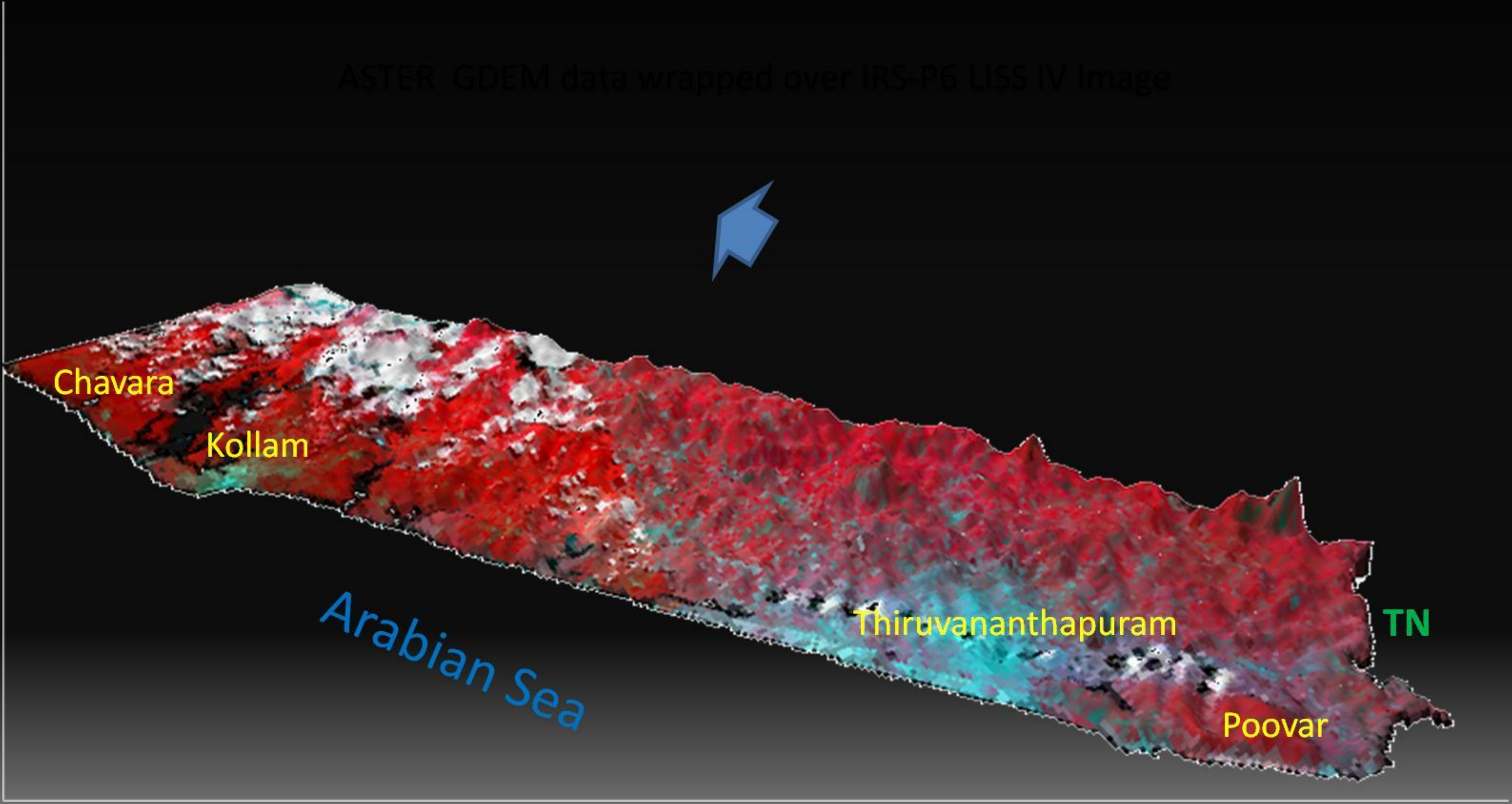
SRTM DEM, PHASE-II AREA, KERALA



ASTER DEM, PHASE-II AREA, KERALA

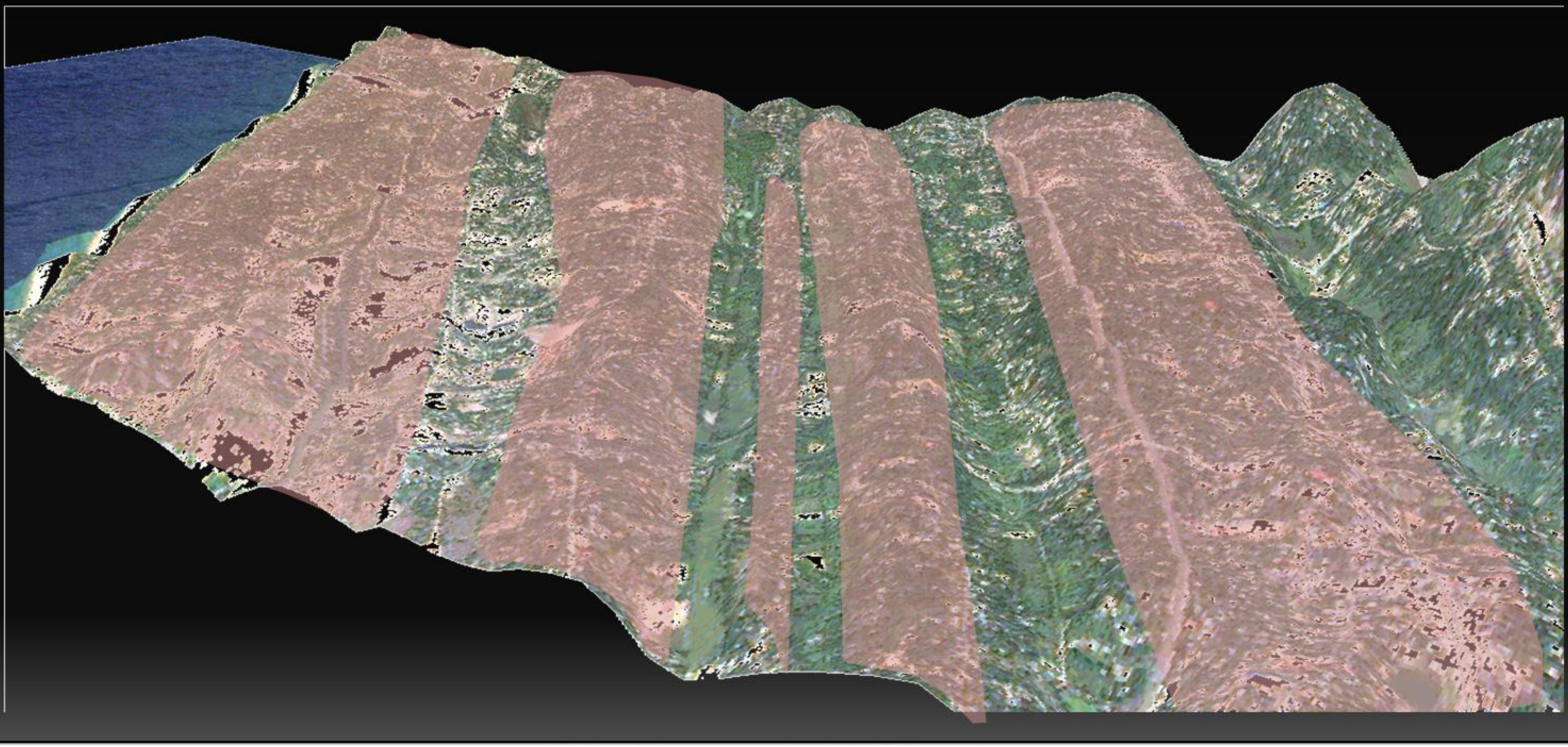


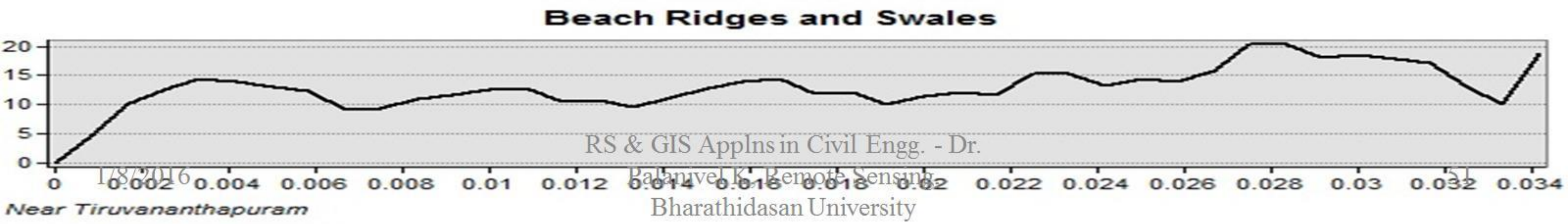
FCC WRAPPED DEM, PHASE-II AREA, KERALA


ASTER GDEM data wrapped over IRS-P6 LISS IV Image

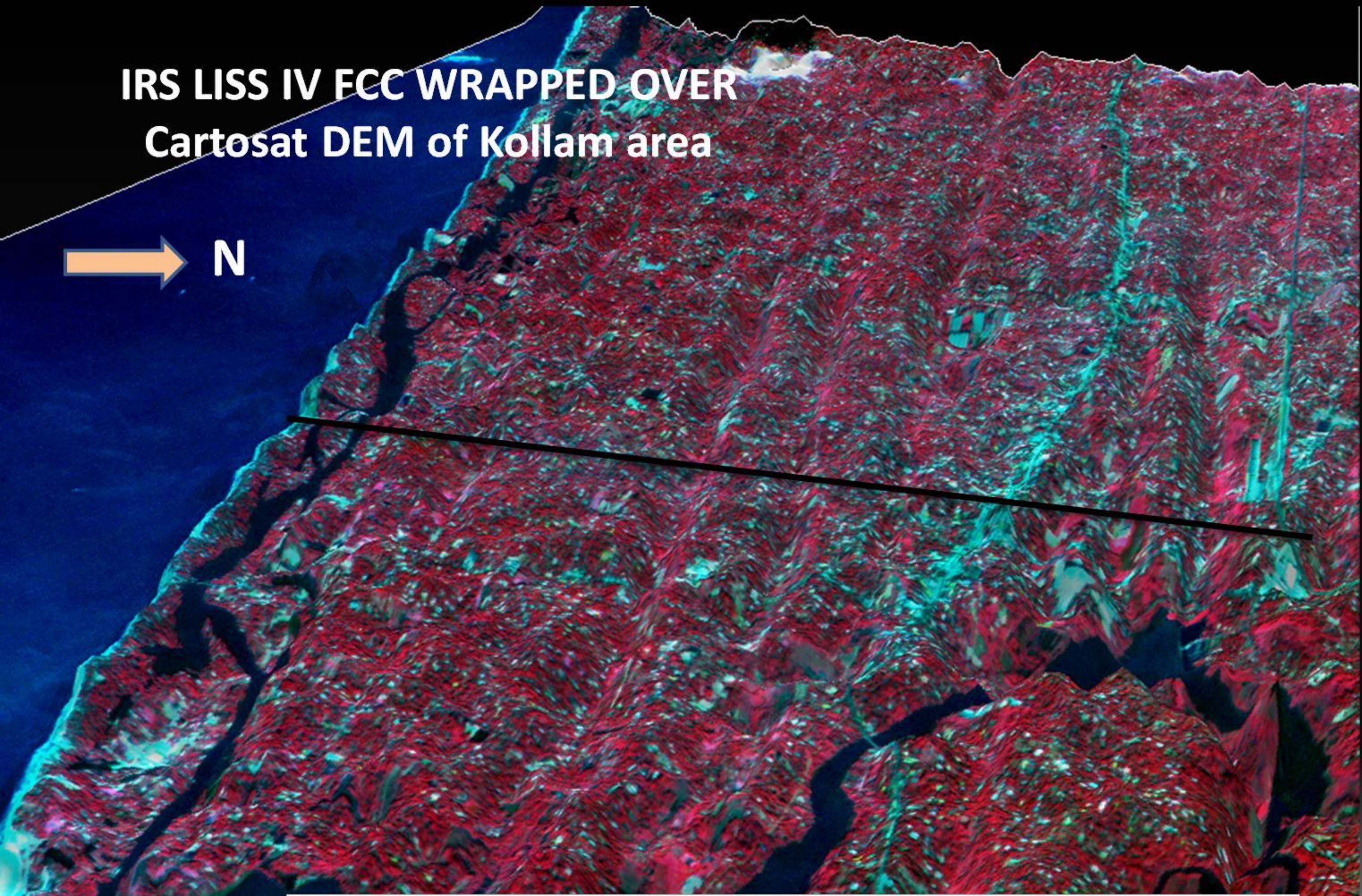
Cartosat DEM of part of Kollam area

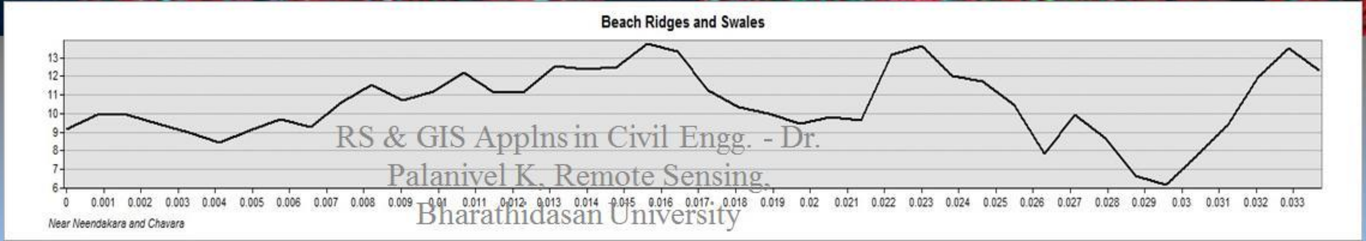
→ N



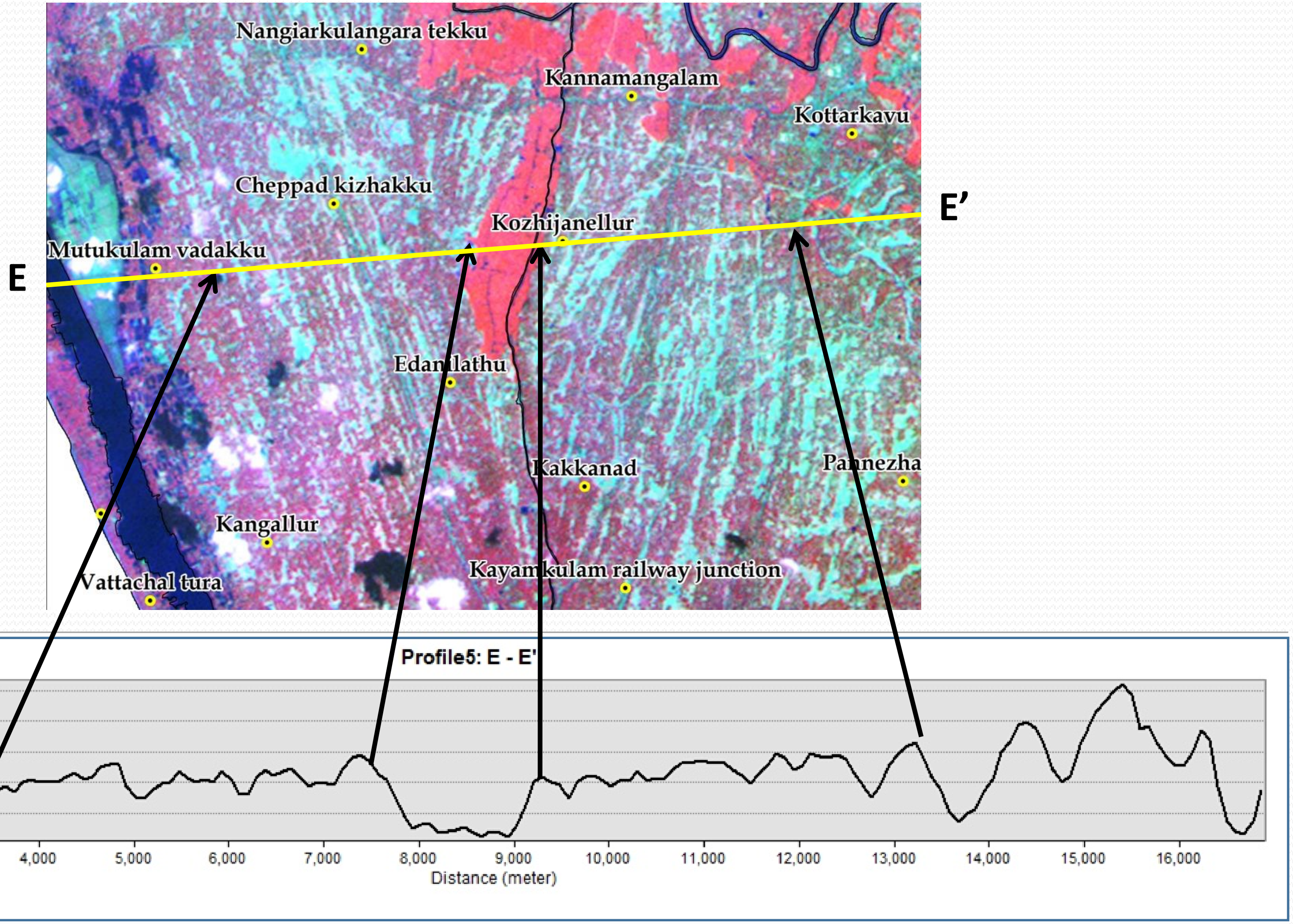


IRS LISS IV FCC WRAPPED OVER Cartosat DEM of Kollam area

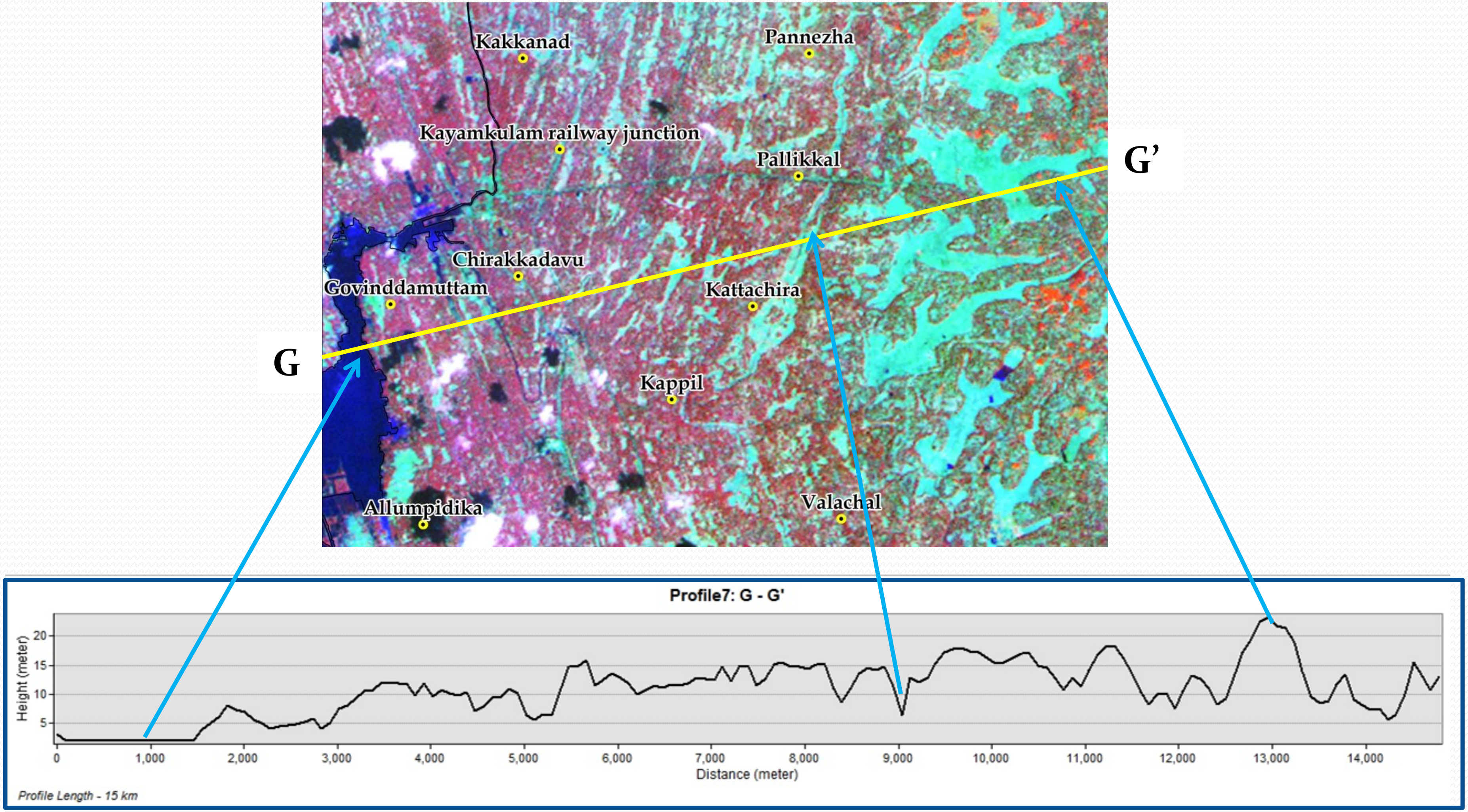



Beach Ridges and Swales

Vertical profiles using DEM, part of coastal Kerala



Vertical profile of part of coastal Kerala showing Lagoon, Beach Ridge and Swale Complex, Dissected Hill and Valley



Case Study - 1

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 14 (2009) 71-82

DEM-based analysis of morphometric features in humid and hyper-arid environments using artificial neural network

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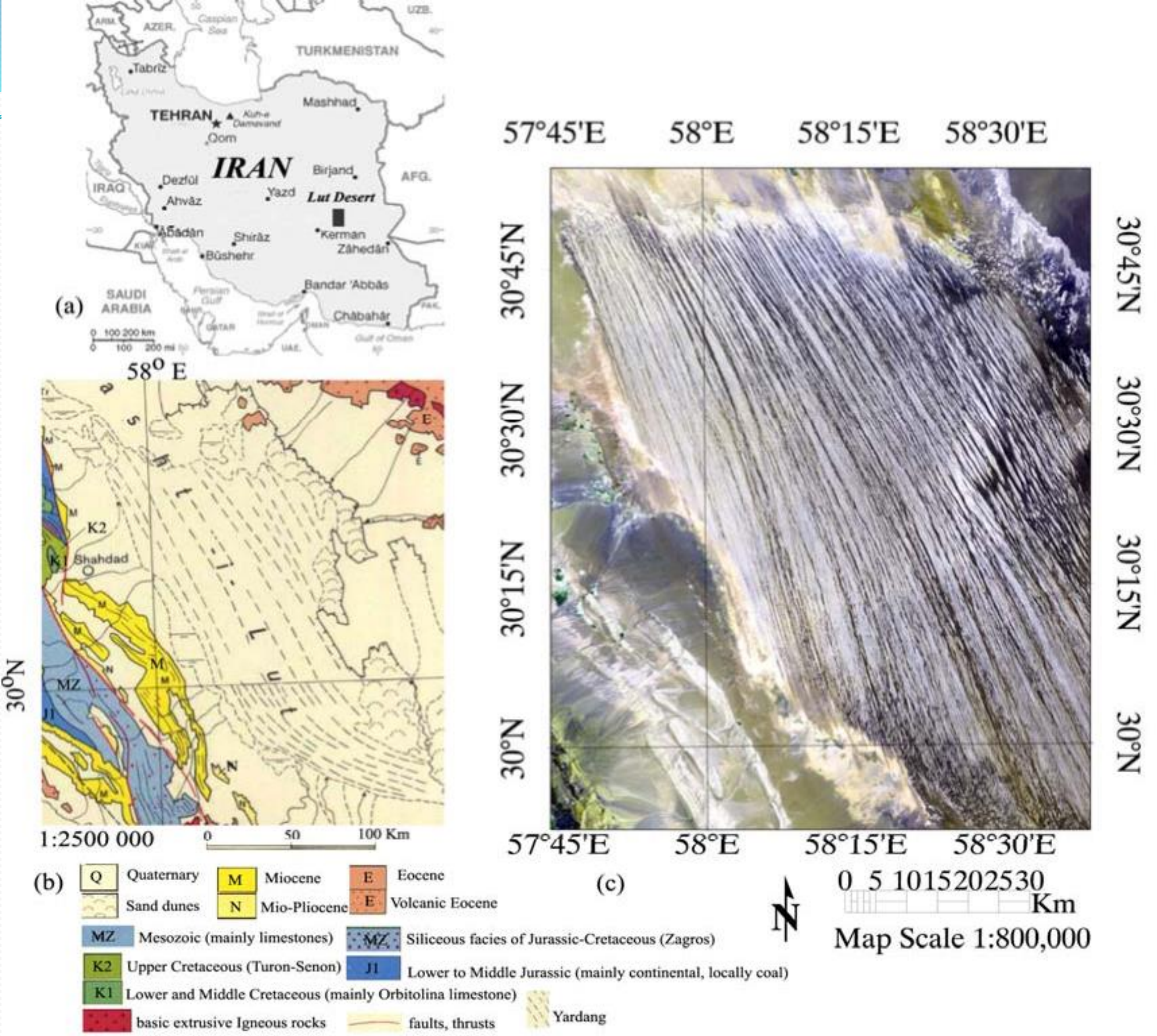
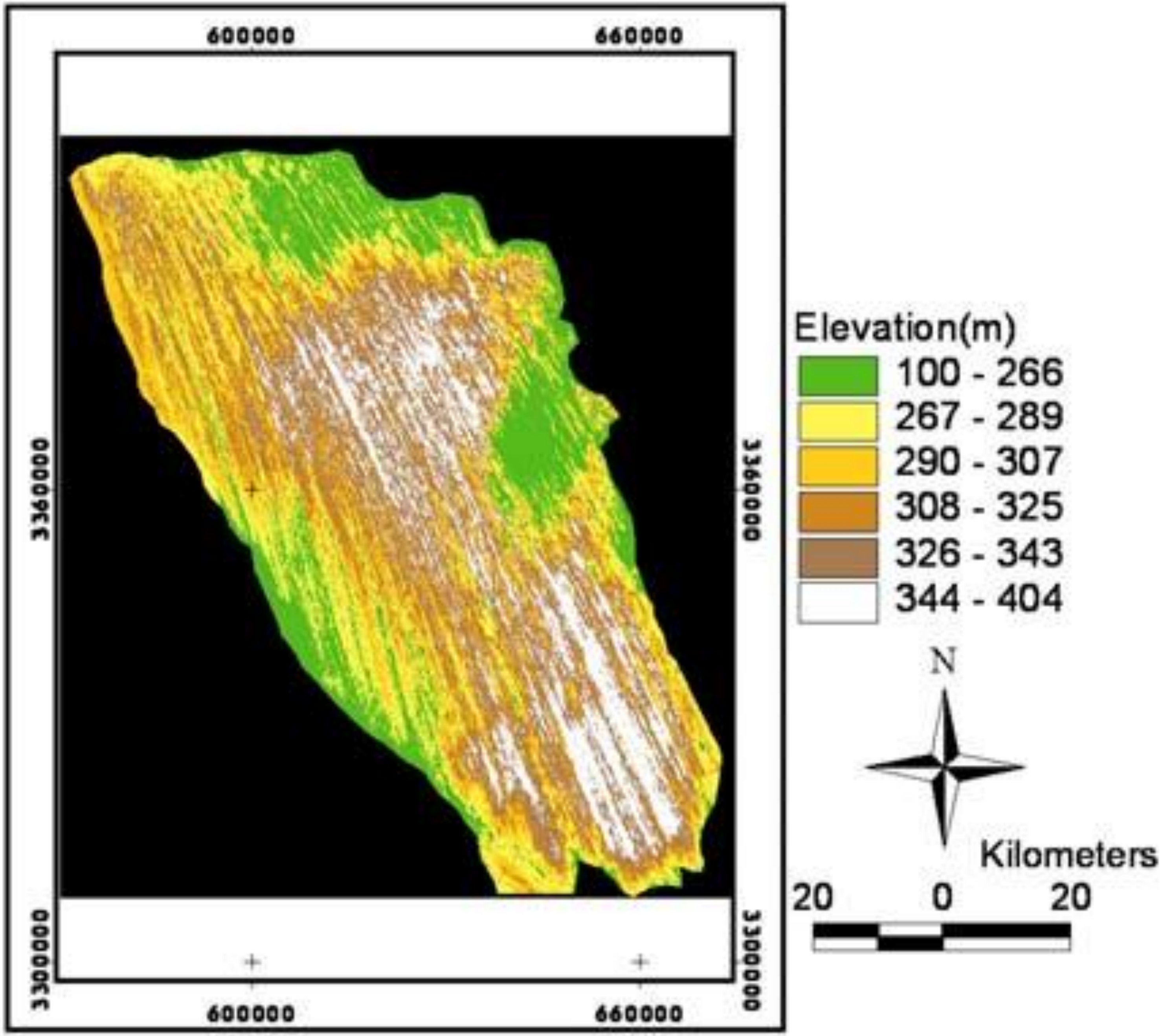
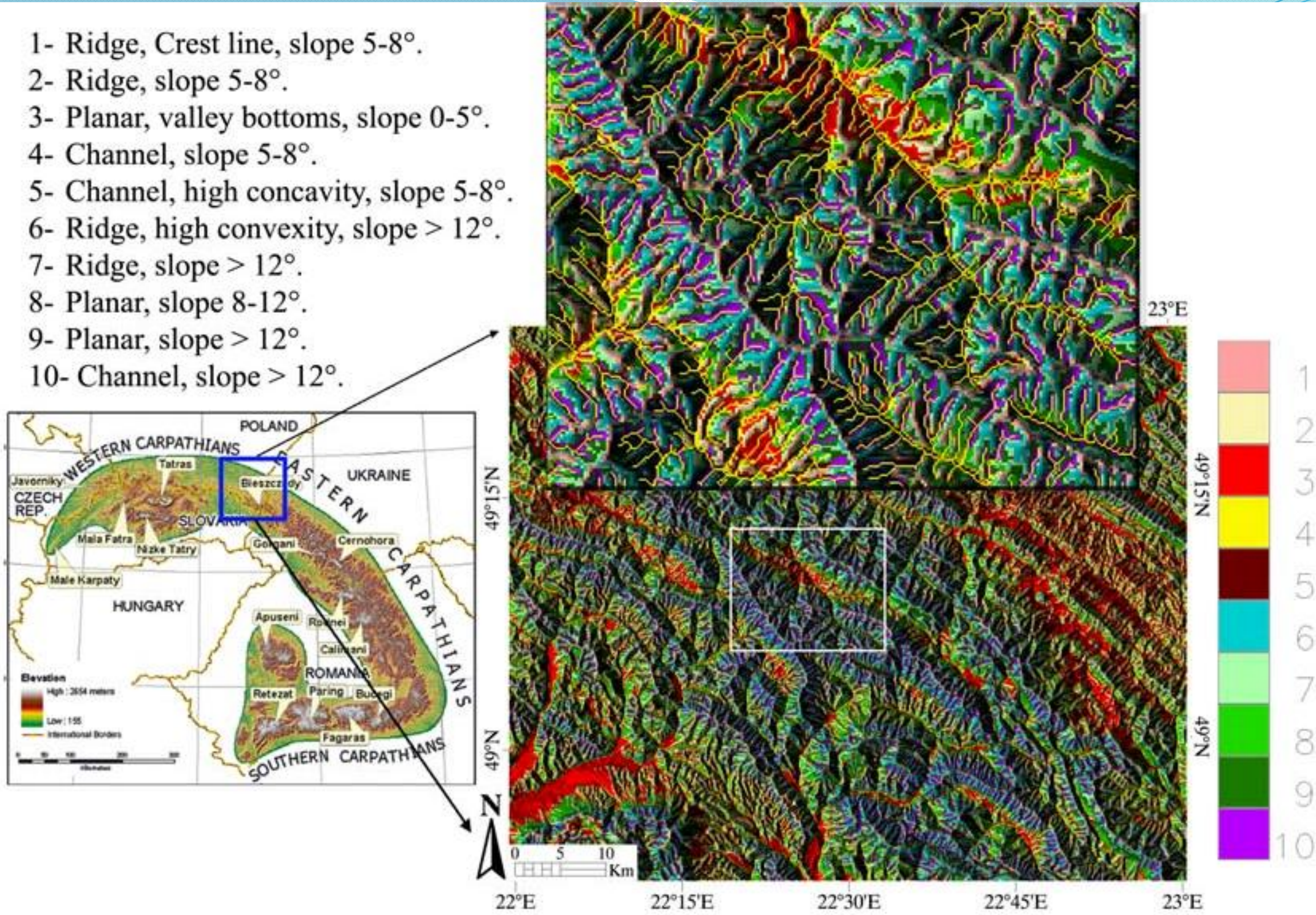
- A robust approach was tried using artificial neural networks
- in the form of a Self Organizing Map (SOM) as a semi-automatic method for analysis and identification of morphometric features
- in two completely different environments, the Man and Biosphere Reserve “Eastern Carpathians” (Central Europe) in a complex mountainous humid area and Yardangs in Lut Desert, Iran.


(a)
TEHRAN
IRAN
Lut Desert
Tabriz
Mashhad
Qom
Birjand
Dezful
Yazd
Ahvaz
Abadan
Shiraz
Kerman
Zahedan
Bushehr
Bandar 'Abbas
Chabahar
TURKMENISTAN
AZER.
UZB.
IRAQ
AFG.
SAUDI ARABIA
QATAR
UAE
PAK.
0 100 200 km
0 100 200 mi
58° E
30°N
K2
K1
Shahdad
MZ
J1
M
N
E
1:2500 000
0 50 100 Km
(b)
Q Quaternary
Sand dunes
M Miocene
N Mio-Pliocene
E Eocene
E Volcanic Eocene
MZ Mesozoic (mainly limestones)
MZ Siliceous facies of Jurassic-Cretaceous (Zagros)
K2 Upper Cretaceous (Turon-Senon)
J1 Lower to Middle Jurassic (mainly continental, locally coal)
K1 Lower and Middle Cretaceous (mainly Orbitolina limestone)
basic extrusive Igneous rocks
faults, thrusts
Yardang
57°45'E
58°E
58°15'E
58°30'E
30°45'N
30°30'N
30°15'N
30°N
(c)
N
0 5 10 15 20 25 30 Km
Map Scale 1:800,000

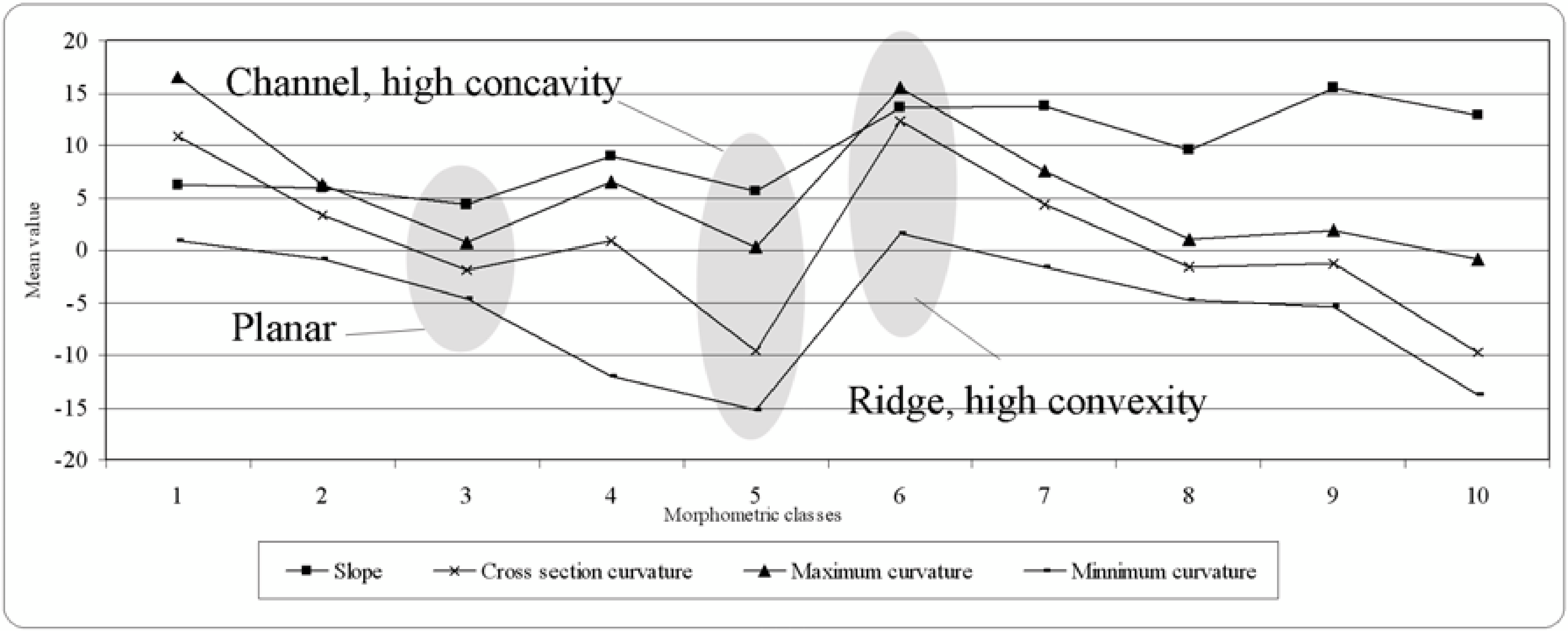


Elevation ranges for Lut Desert, Iran produced from SRTM DEM with 90 m resolution, UTM projection and WGS84 datum

1- Ridge, Crest line, slope 5-8°.
2- Ridge, slope 5-8°.
3- Planar, valley bottoms, slope 0-5°.
4- Channel, slope 5-8°.
5- Channel, high concavity, slope 5-8°.
6- Ridge, high convexity, slope > 12°.
7- Ridge, slope > 12°.
8- Planar, slope 8-12°.
9- Planar, slope > 12°.
10- Channel, slope > 12°.



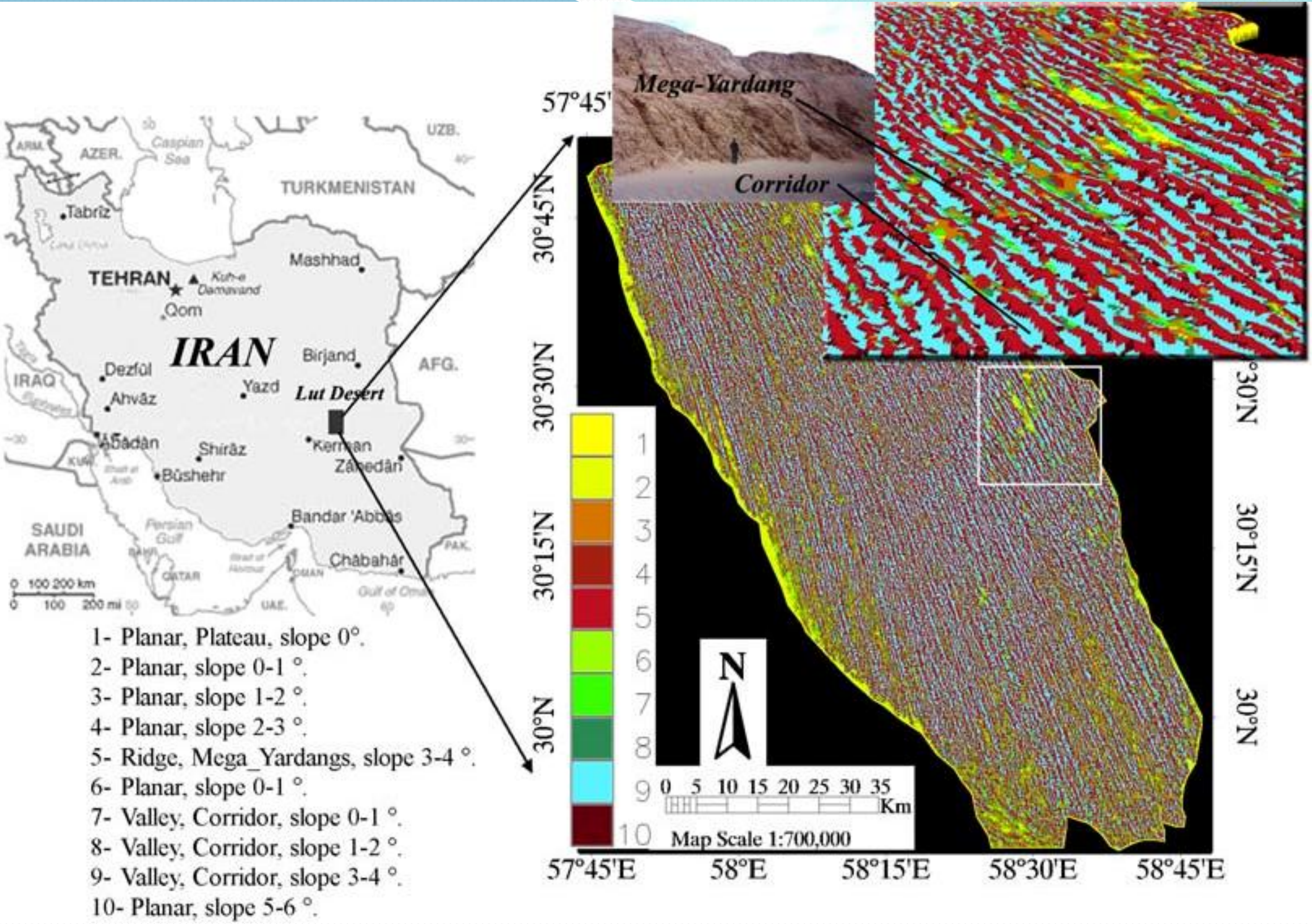
Morphometric features map using SOM with DEM-90 in Eastern Carpathians with dropped drainage network over zoom



Channel, high concavity

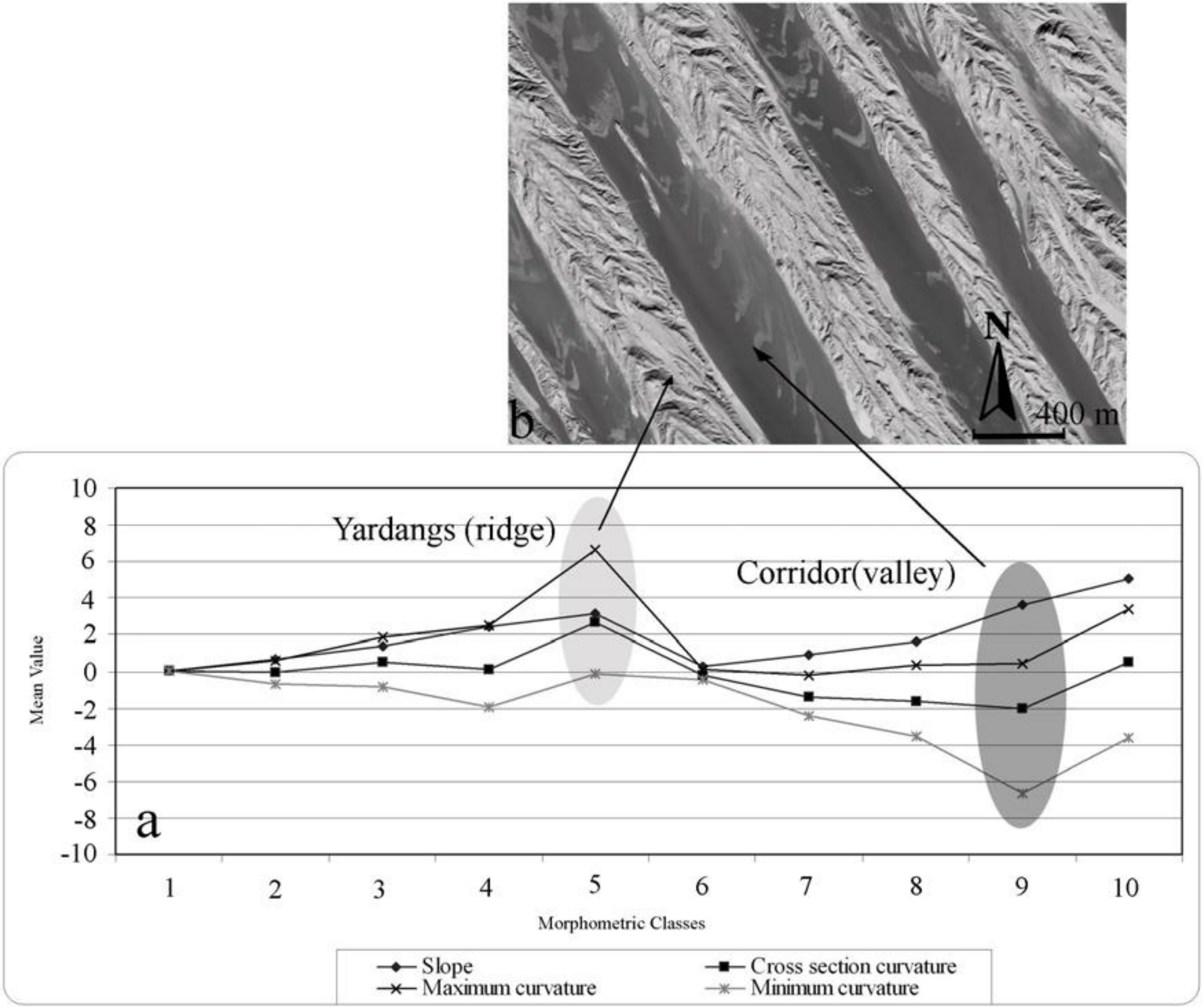
Planar

Ridge, high convexity



1- Planar, Plateau, slope 0°.
2- Planar, slope 0-1 °.
3- Planar, slope 1-2 °.
4- Planar, slope 2-3 °.
5- Ridge, Mega_Yardangs, slope 3-4 °.
6- Planar, slope 0-1 °.
7- Valley, Corridor, slope 0-1 °.
8- Valley, Corridor, slope 1-2 °.
9- Valley, Corridor, slope 3-4 °.
10- Planar, slope 5-6 °.

Morphometric features map using SOM with DEM-90 in Lut desert with 3D zoom sample and field image. Mega yardangs and corridors between them are represented by red and cyan color



Morphometric signatures of yardangs and corridors. (b) The 60-centimeter QuickBirde image showing the mega yardangs and corridors.. Yardangs oriented to the prevailing wind direction, 330° and corridors in some places are covered by sand sheets

Mega-Yardangs, an aeolian landform due to intensive formative processes cover a large area in the hyper-arid Lut desert. They form elongated basins and ridges with a width ranging from a few meters to hundreds of meters. These features can clearly be recognized and classified when their width is significantly larger than the DEM resolution but become unrecognizable if their width is less than the grid resolution. Morphometric signatures, three-dimensional inspection, auxiliary data such as 30 m resolution Landsat ETM+ and 60 cm resolution QuickBird data facilitated the evaluation of the output SOM in terms of geomorphometric features.

SOM provide a valuable method to extract information on morphological features in a wide range of landscapes that can be used in geosciences, environmental and geo-ecosystem modeling. This procedure is promising and offers new possibilities to study both types of terrain features, general landforms and landform elements.

Thank you