

STRUCTURAL GEOLOGY

Definition:

“It is the study of the architecture of rocks” – It primarily deals with the geometry of rocks.

Tectonics: It deals with the forces and movement that produced the structures.

Types of forces and their structures:

- **Forces with in the rock – Folds, joints, fractures, faults and foliation.**
- **Forces due to intrusion of magma --- Displacement of solid mass above the Intrusion**
- **Force due to extra terrestrial bodies ---- Impact structures**
- **Force due to collision --- Collision structures.**

Aim of Structural Geology:

Is to determine and explain the architecture of rocks as observed on the out crop in the field.

Objectives of Structural Geology:

What is the structure ?-- Need extensive field study.

When did it develop ? – Field study coupled with Paleontological and radiogenic Dating

Under what physical condition did it form ? --- Dominantly by experimental
Methods supported by field
Data

Structures of rocks:

Primary structure: **Structures developed during the formation of rocks— Eg. Bedding Plane, flow layers etc**

Secondary structures: **Structures developed due to forces.**

Primary structures:

Both in Sedimentary and igneous rocks.

Secondary structures:

Dominantly In metamorphic rocks.

In Sedimentary rocks

- **Bedding plane, laminations**
- **Current bedding and cross bedding**
- **Graded bedding**
- **Load cast, mud cracks, rain prints**
- **Concretionary and nodular**

In Igneous rocks:

- **Flow layers similar to bedding**
- **Flow structures – Laths oriented in the direction of flowage**
- **Pillow, vesicular and amygdular**
- **Spherulitic, orbicular, variolitic and bomb**

Secondary structures: (Deformational structures)

Both Macro and Micro structures.

- **Folds:** Upward and downward bending or wavy nature of rock surface with varying wavelengths and amplitudes perpendicular to the forces.
- **Foliation and Lineation:** Arrangement of flaky, needle like minerals in the direction of least force or oriented in the direction perpendicular to the force.
- **Cleavage / Joints / Fracture :** Discontinuity or break in a solid rock due to force – brittle failure.
- **Fault :** Displacement of rock mass of one block relative to the adjacent block along a joint or fracture.
- **Intrusion/ Diapirs / Salt domes :** Doming up due to vertical force (Diapiric force)
- **Impact structures:** Basinal and Domal structures

Scope of Structural Geology:

It encompasses various components of Geology

Field Mapping

Accumulation or collection of significant facts

Stratigraphy

Formational status to establish the time

Sedimentation

Offer much evidences on the tectonic events.

Paleontology

Establishing the time through fossil assemblages

Petrology

Structural history of igneous, sedimentary and metamorphic rocks.

Mineralogy

It is the integral part of the rock and in turn significant for understanding the forces. (Flaky minerals)

Geomorphology

In regions of recent tectonic activity – even it provides evidences for the older tectonic terrain.

Geophysics

It provides structures of sub surface

Oceanography

Structures of sea floor.

FIELD GEOLOGY

- ❖ When rocks and rock materials are investigated in their natural environment and their natural relation to one another – this study is called **Field Geology**
- ❖ It describes surface features and the underground structures, physiography etc.

Bed rock, Outcrop and Exposure:

- Mantle rock / solid rock ---- Bed Rock
- If it is partially covered and partially seen/ exposed ---- Out crop
- If it is exposed fully without much of cover ---- Exposure

Mantle cover:

- ✓ May be transported or residual
- ✓ Transported does not have any resemblance with the bed / bottom rock
- ✓ Residual will have at least chemical resemblance

Observations and inferences

- The features that are surficial (Out Crop) can be Observed
- The features that are covered need to be inferred
- Indirectly or directly the out crops helps in inferring the covered ones.

Correlations:

- No feature (geologic) exist as isolated phenomena
- They are some way or other dependent upon or associated with other geologic features
- This association has to be established by field geologists – This is **Correlation**

Eg: Outcrop: - Though it is isolated actually they are correlated with the underlying bed rock

Multiple working Hypothesis :

- Geological interpretation is facilitated by what is termed the method of multiple working Hypothesis

Eg: If some feature is seen on the outcrop we need to examine all possible explanations

STUDY OF EXPOSURE :

- Precise location --- With reference to known points
- Nature of exposure ---- Fresh, weathered, coated colour, grain size
- Characters --- Linear, non-linear ; if planar its Strike and dip; only linear – its plunge amount and direction
- Structures  Primary structures
Secondary structures
- Mineralogy -- recognizable mineral content and their relative percentage
- Contact --- contact relation with the adjacent rock
- Field sketch --- special features observed need to be sketched

Organized way of noting down of the data

MAPPING:

Strike Mapping --- to trace the individual litho unit or marker unit to find out any

- **Facies variation**
- **Structural character**

Mapping across the strike

- **to find the contact relation**
- **to map various lithologies**
- **to identify order of superposition**

Looking for -- **Economic minerals**

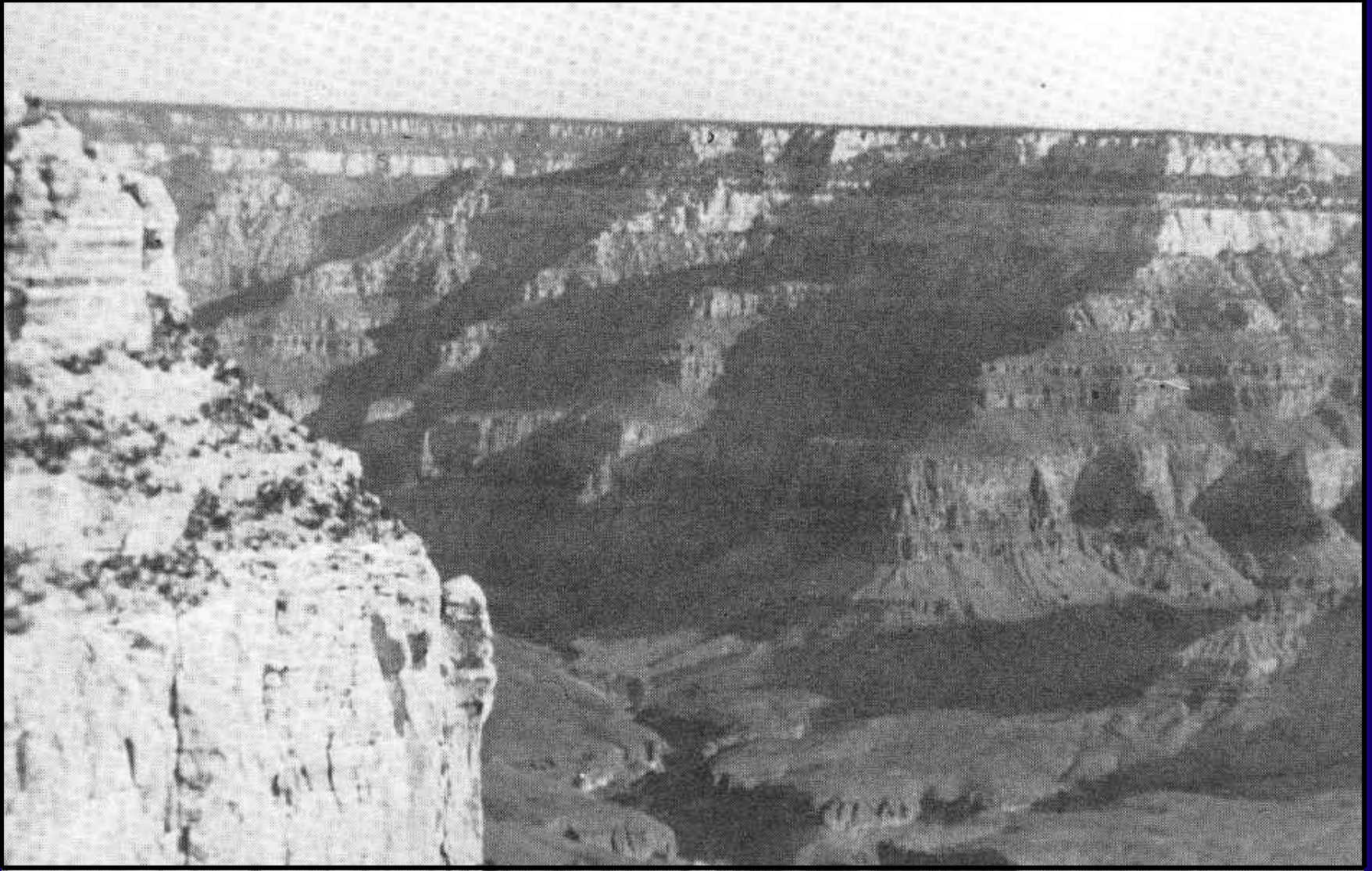
- **as native form**
- **As altered mass (gossan, leaching, etc)**
- **Old working**
- **Mine dump with slag heaps**

PHOTO SIGNATURES OF STRUCTURAL FEATURES

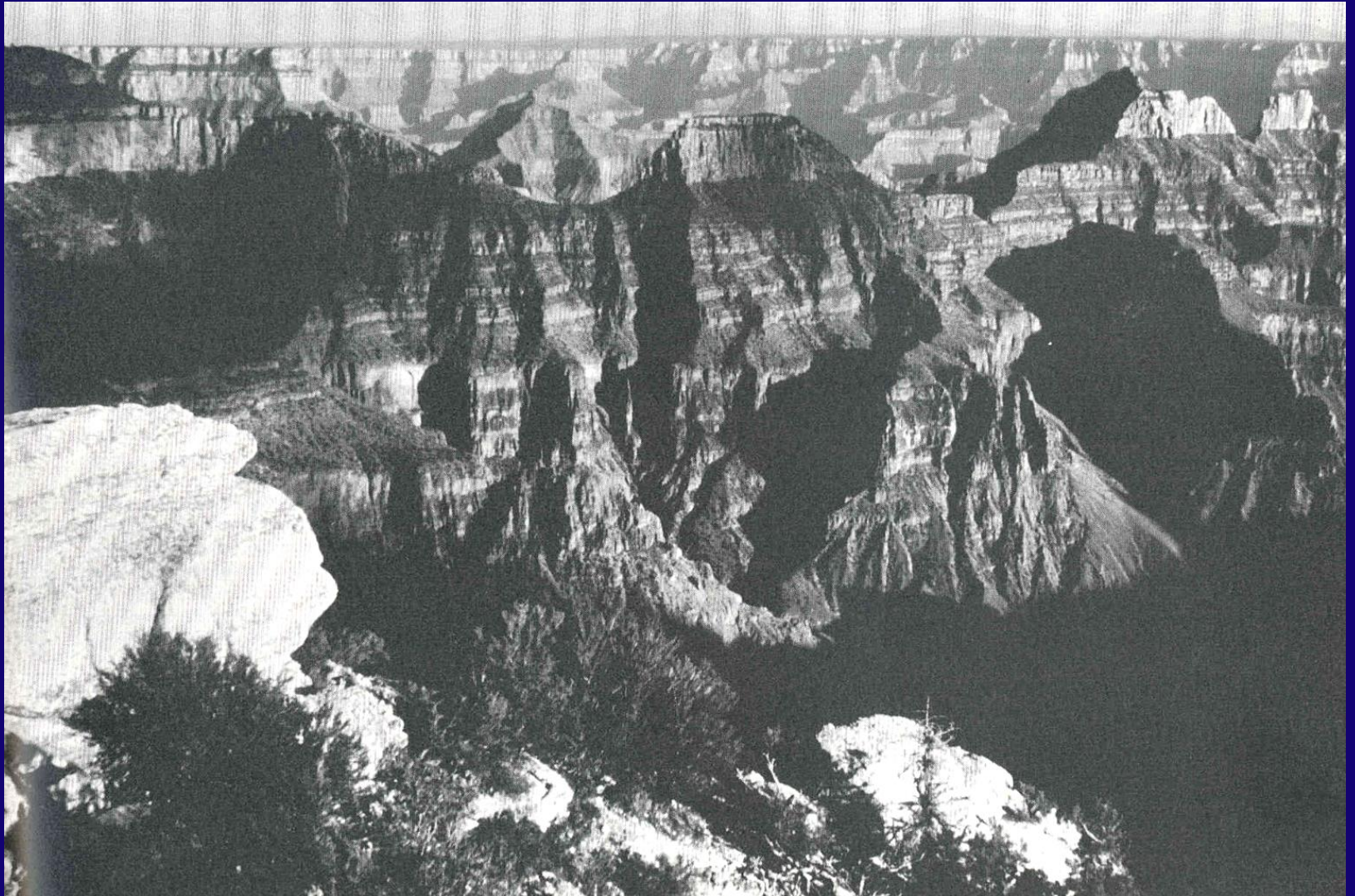
FLAT LYING BEDS:

- Different layer – alternating tonal variation
- Alternate Resistant & Non Resistant units
 - Step cliff for Non resistant
 - Gentle slope for resistant
- Dendritic drainage(if no joints & fractures controls)

GRAND CANYON PLATEAU



GRAND CANYON PLATEAU



IRS – PAN STERIO DECCAN PLATEAU



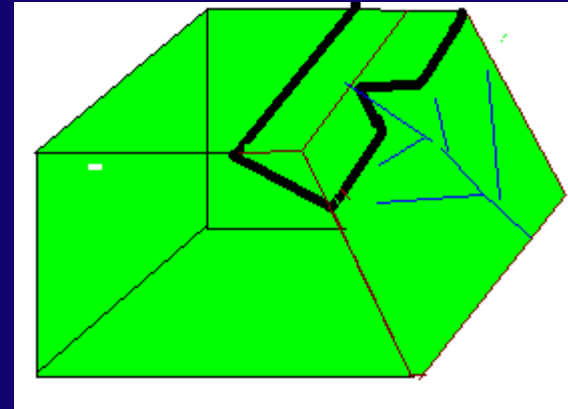
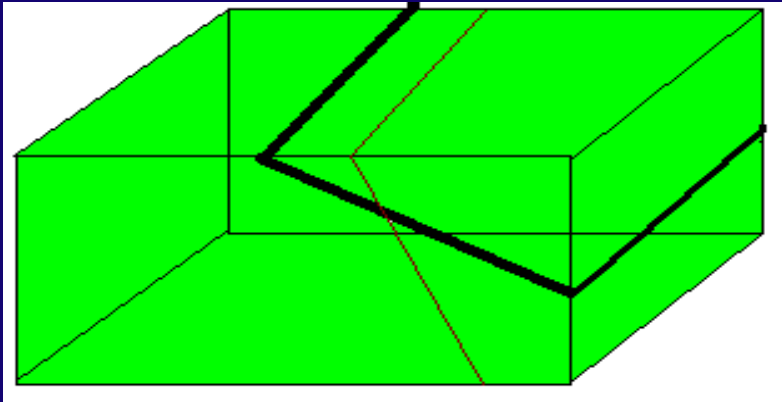
Figure 9. PAN (left) and IRS (right) images of the Deccan Plateau.

DIPPING BEDS:

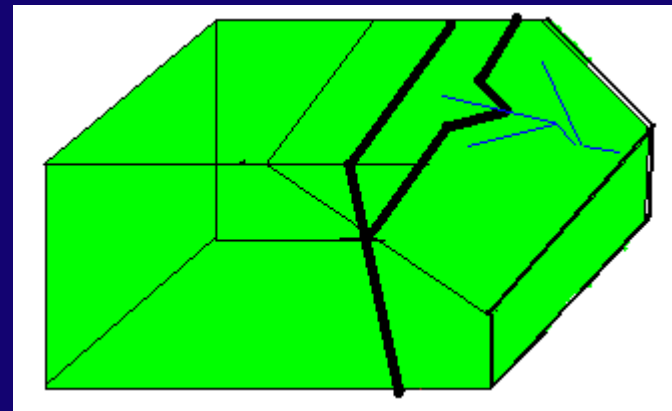
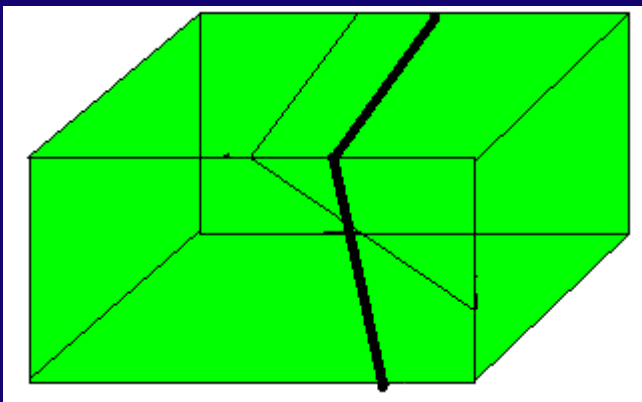
Out crop pattern

- Bed dip & topographic slope coincide-tree crown character
- If bedding by tonal variation is seen then the “V” of the drainage valley with bedding is criteria.
 - ❖ V*point toward dip direction-if the surface gradient is gentler than dip of bed.
 - ❖ V*point opposite to dip direction – if the surface gradient is steeper than dip of bed.

V*point opposite to dip direction – if the surface gradient is steeper than dip of bed.

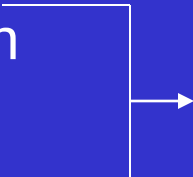


V*point toward dip direction-if the surface gradient is gentler than dip of bed.



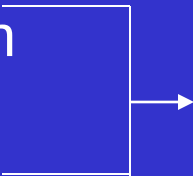
DIPPING BEDS: (Contd.) [Drainage Character]

a (i) Relatively long drainage in the dip direction
(ii) Short drainage opposite to dip



Gentle Slope

b. (i) Relatively short drainage in the dip direction
(ii) Longer drainage opposite to dip



Dips $>45^{\circ}$

c. Long linear beds trends	→	Vertical bed
Initial dip	→	Wavy pattern
Secondary dip	→	Regular pattern

CUESTA – CANADA



APPALACHIAN FOLD



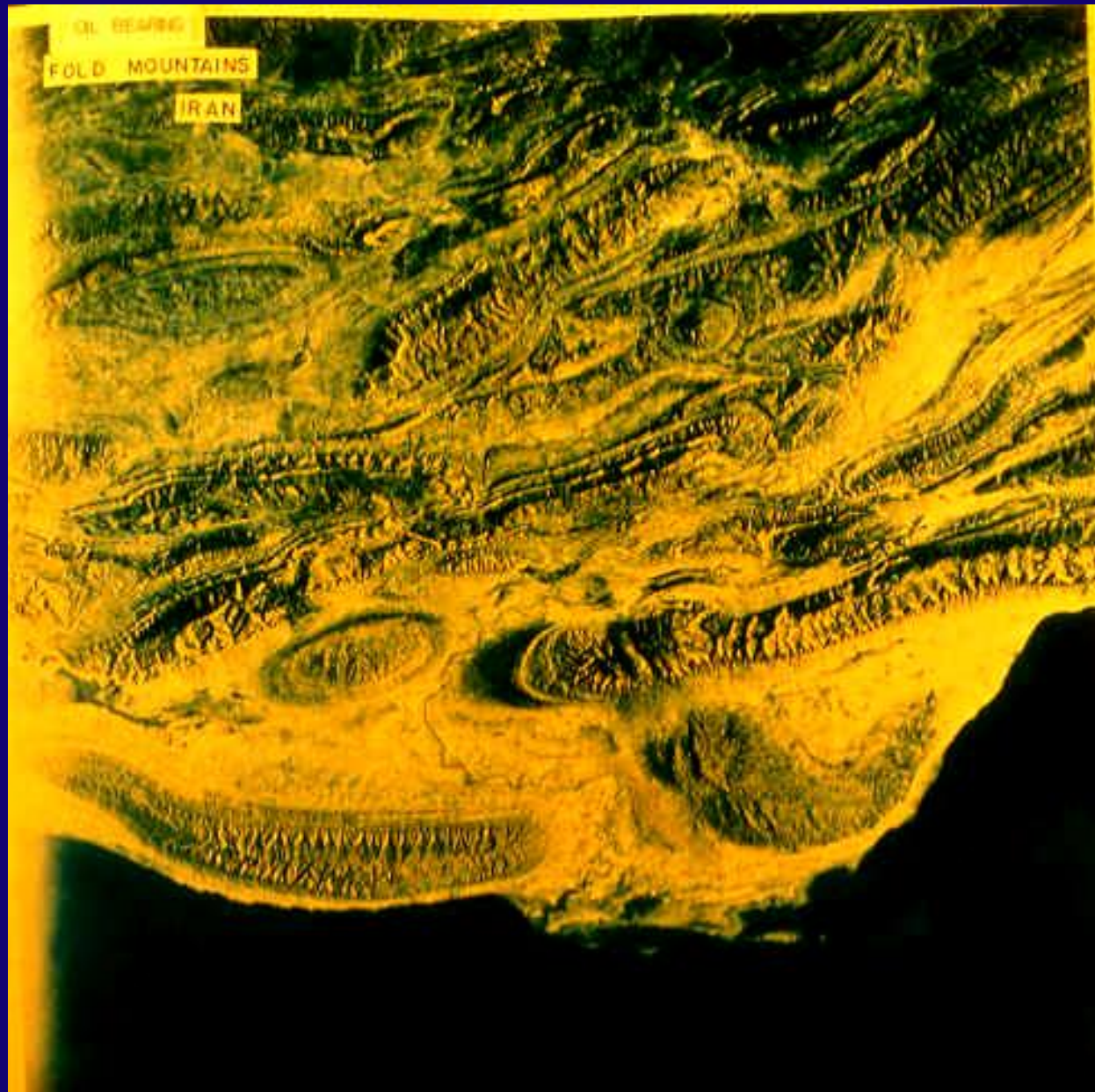
TEXAS



LISS III - BURMA



IRAN FOLD

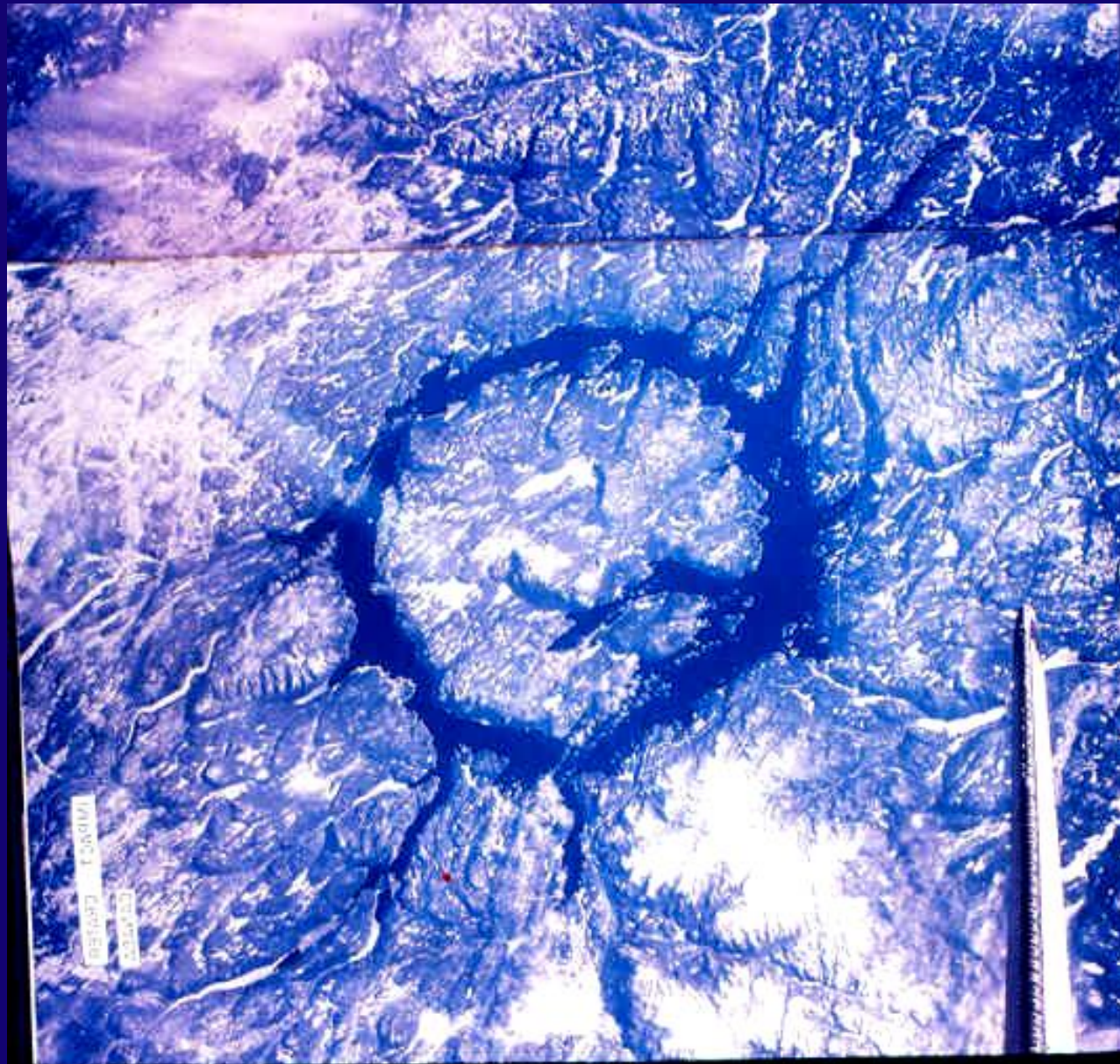




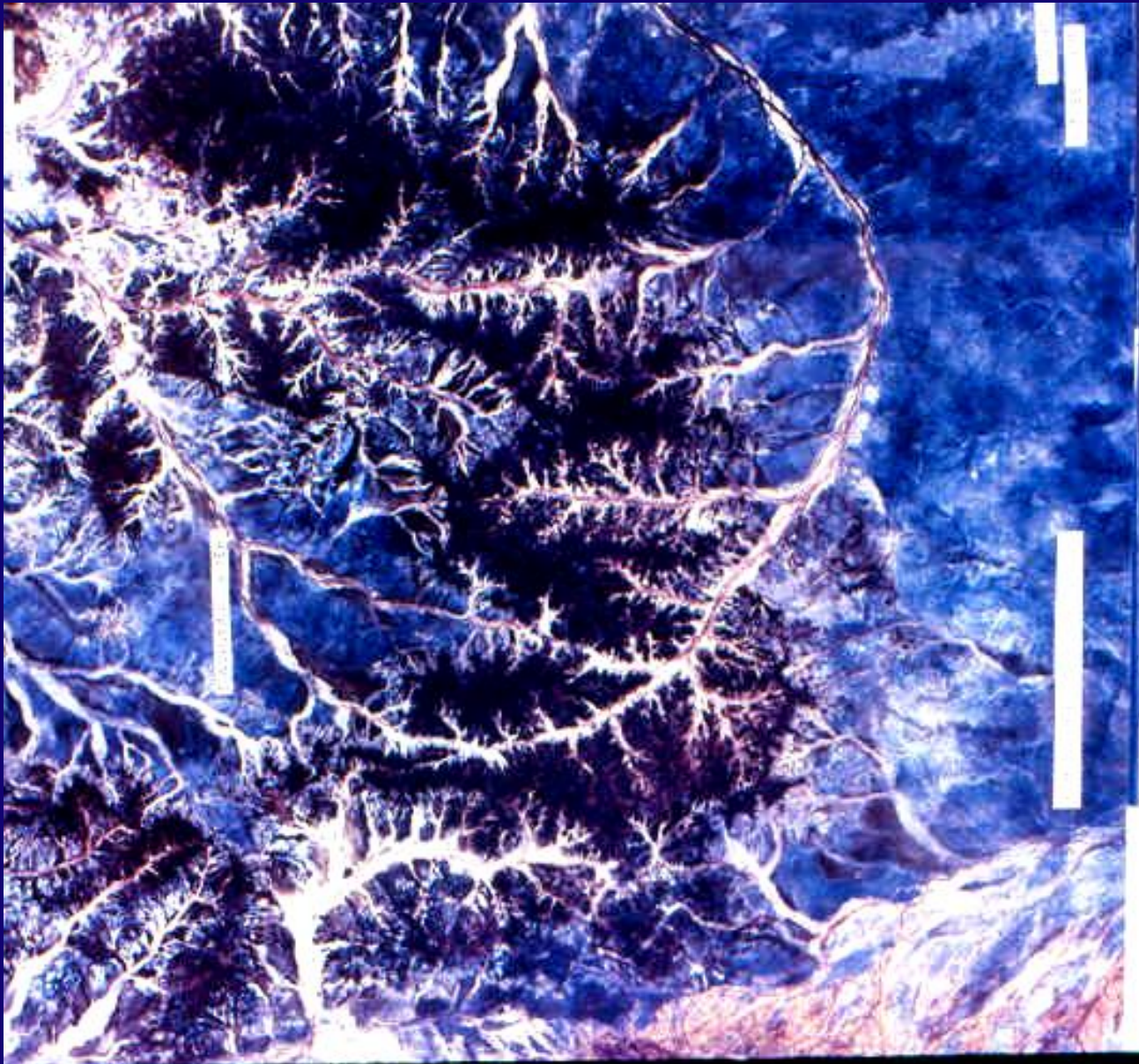
Eastern ghats

**ALWAR
Quartzites**

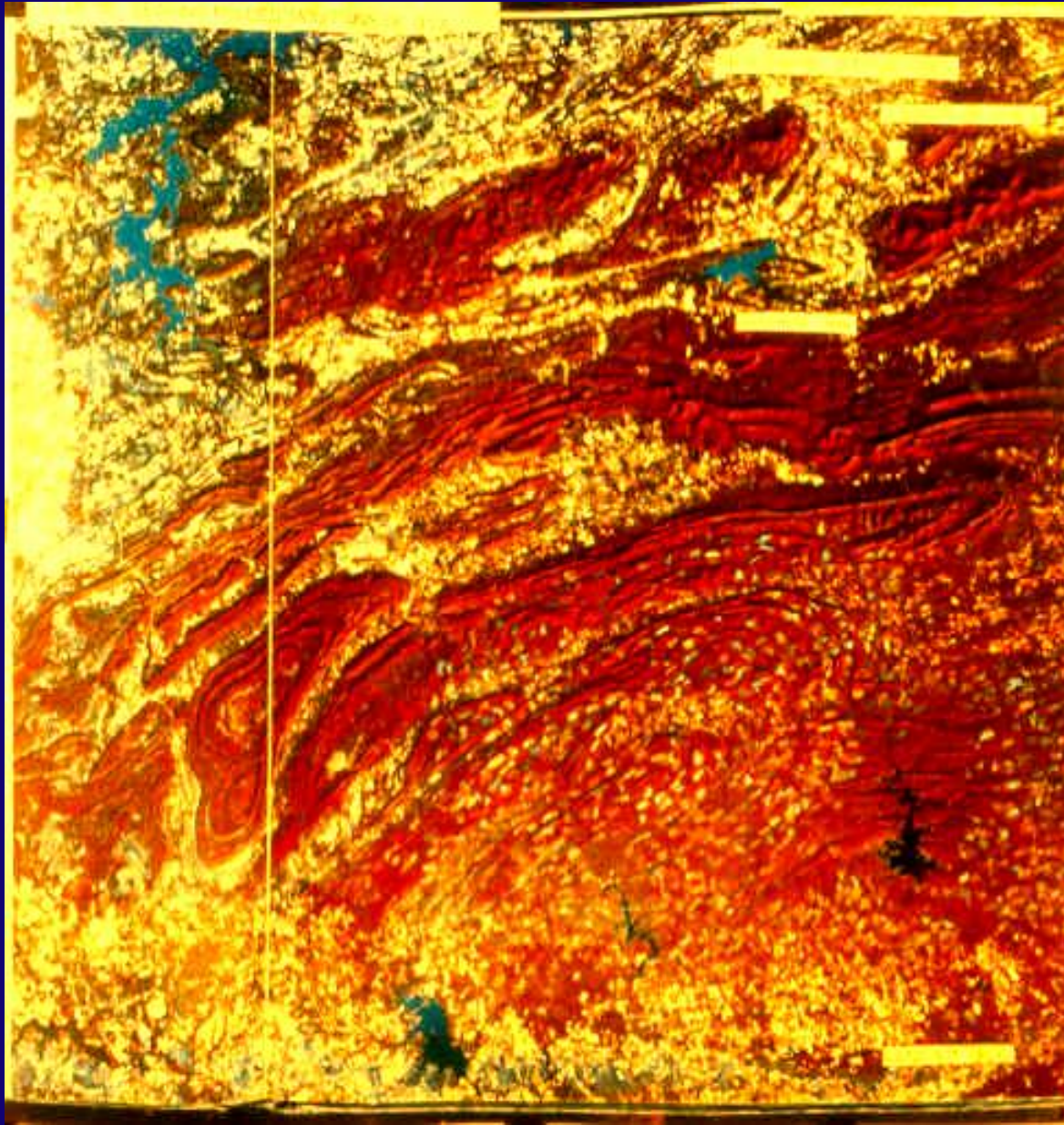
CIRCULAR DRAINAGE



Radial & Annular drainage



FOLDS OF U S A

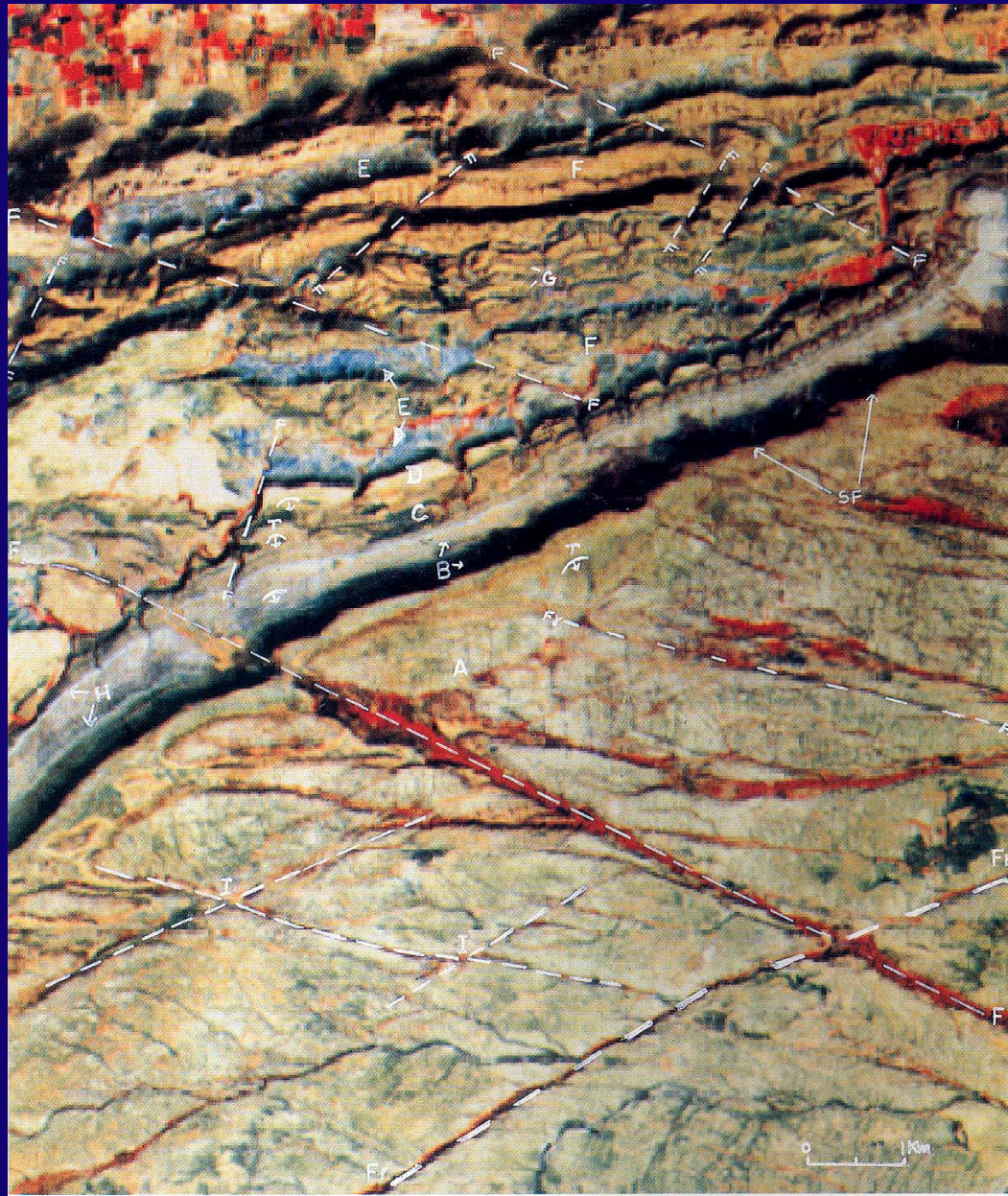


CUESTA





CUDDAPAH BASIN



FOLDS:

EXPOSED ONES - Easy to identify & understand

COVERED / BELOW THE SURFACE - Not easy – take help of drainage pattern

LIMBS : Parallel drainage

Plunging folds : Closure- points the direction of plunge

Antiformal : Two set of parallel drainage flowing in opposite direction.

Synformal : Two set of parallel drainage flowing towards each other

Overtured folds : Difficult – No Photo signatures



Isoclinal folds : Closely spaced parallel structural trends



Open folds : Structural trend lines equally spaced – wide apart.

Closed folds : Unequal disposition and frequent trend line

Parallel folds : Parallel anticline cliffed syncline – at zones of less erosion.

HOMOCLINAL : Parallel drainage

MONOCLINAL : Parallel drainage with offset

SYMMETRICAL FOLDS :

- (i) Two set of drainage flowing opposite or inward
- (ii) Equally spaced structural trends with central gap

ASYMMETRICAL FOLD :

- (i) Two sets of parallel drainage opposite & inward
- (ii) Their lengths are unequal
- (iii) Unequally spaced structural trends

DOMES & BASINS

: Circular outcrop with radial drainage

**FOLDS DUE TO
HORIZ_ COMPRESSIVE
FORCE**

Tight folds with conjugate fractures

**FOLDS DUE TO
TANGENTIAL MANNER**

**“S” or “Z” shaped
folded hills & beds**

**FOLDS DUE TO
IGNEOUS INTRUSION**

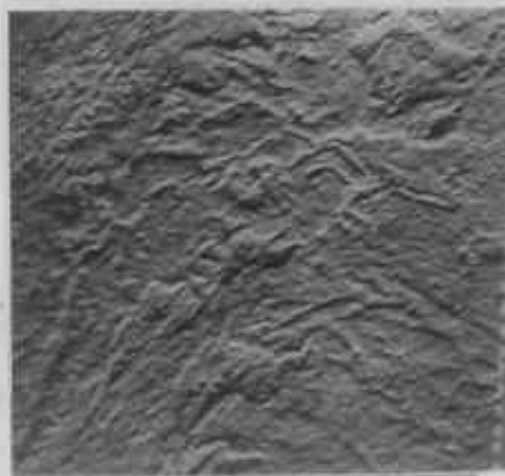
**Structural trends
envelopes Igneous bodies**

Structural mapping Through Remote Sensing:

- Interpretation & tracing of Structural Trend Lines from satellite data
 - ❖ Linear and curvilinear Ridges
 - ❖ Colour or textural linearity
 - ❖ Bedding and foliation
 - ❖ Structural hills
- Possible dip direction of these trend lines
- Constructing fold pattern by connecting trend lines
- Tracing of fold styles
- Marking the axial traces of these fold styles
- Demarcation of domains based on the orientation of axial traces and fold styles
- Constructing entire fold pattern of the area under study
- Constructing the structural history

LANDSAT TM IMAGERY SHOWING STRUCTURAL TRENDS

(NOT TO SCALE)

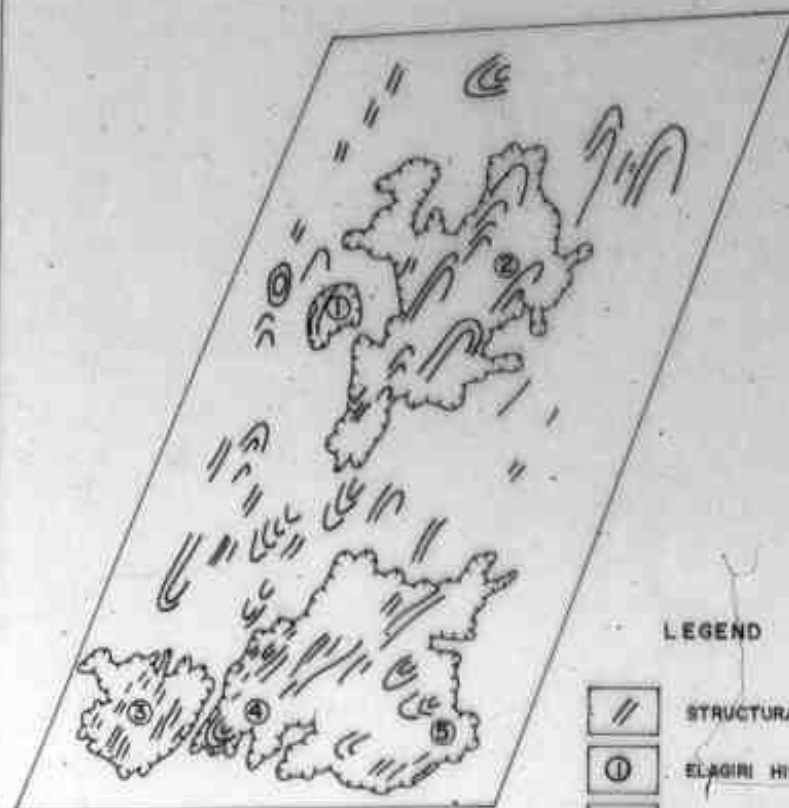


LEGEND



STRUCTURAL TRENDS

STRUCTURAL TRENDLINE MAP OF JAVADI - SHEVROY
CHITTERI - KALRAYAN HILLS



LEGEND

- | | |
|---|-----------------------|
|  | STRUCTURAL TRENDLINES |
|  | ELAGIRI HILLS |
|  | JAVADI HILLS |
|  | SHEVROY HILLS |
|  | CHITTERI HILLS |
|  | KALRAYAN HILLS |

STRUCTURAL TRENDLINE AND RELATED FOLD STYLES

(NOT TO SCALE)



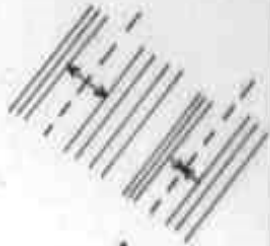
1



2



3



4



5



6

LEGEND



TRENDS OBSERVED IN SATELLITE DATA



AXIS OF FOLDS



DIRECTION OF DIPS



FLAT LYING BEDS



LOW DIPPING BEDS



UPRIGHT SYMMETRICAL ANTICLINES / SYNCLINES



ASYMMETRICAL ANTICLINES / SYNCLINES



VERTICALLY DIPPING BEDS



DOMES BASINS, DOUBLY PLUNGING FOLDS

STRUCTURAL TRENDS, DRAINAGE PATTERN AND FOLDS

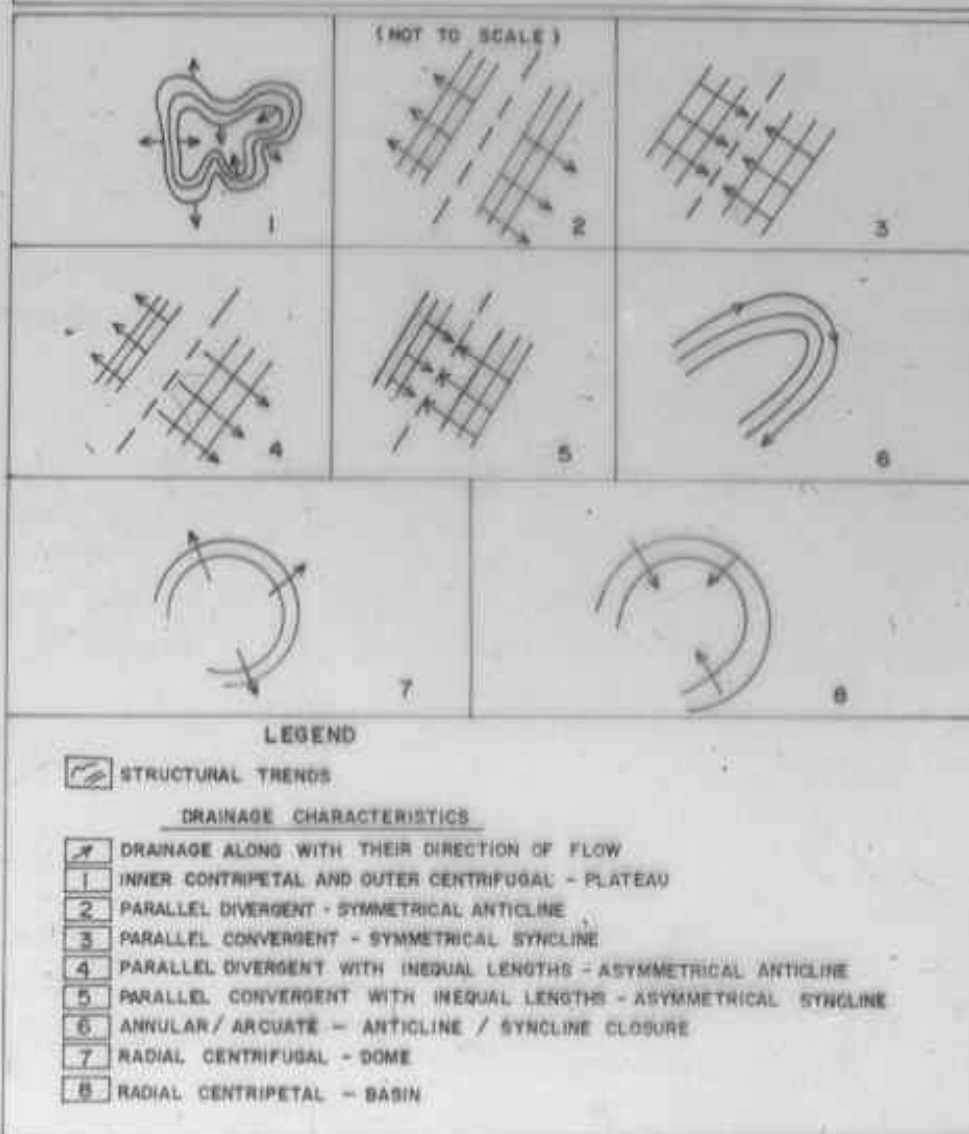


Fig. 1-6

SATELLITE IMAGERY SHOWING STRUCTURAL TRENDLINES
AND SHADOWS

(NOT TO SCALE)

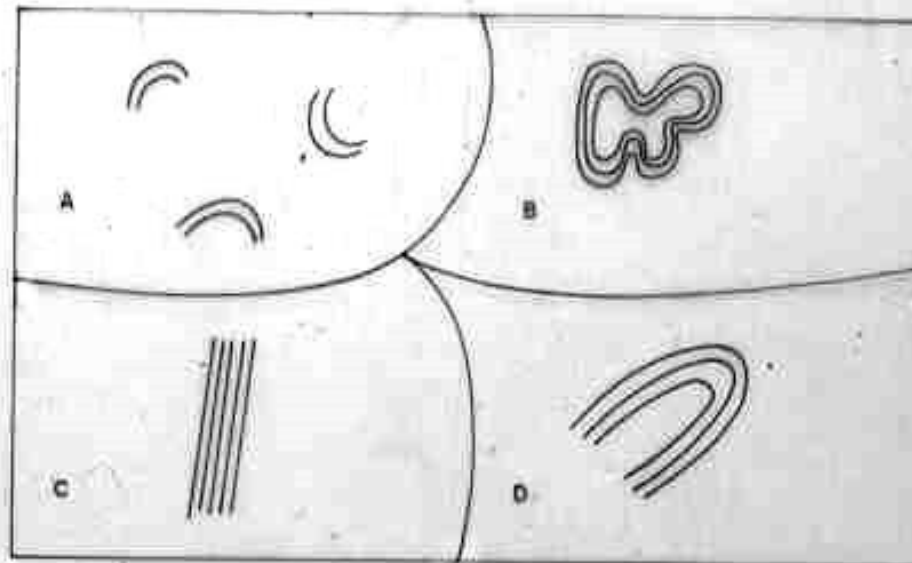


LEGEND

-  STRUCTURAL TRENDLINES
-  DIRECTION OF DIP OF BEDS

DEMARCATON OF STRUCTURAL DOMAINS- CONCEPTUAL MODEL

(NOT TO SCALE)



LEGEND

A-D - DIFFERENT STRUCTURAL DOMAINS

A - DOMAINS OF DOME AND BASINS

B - DOMAINS OF FLAT LYING BEDS

C - DOMAINS OF TIGHT FOLDS

D - DOMAINS OF MARGINAL TIGHT FOLDS

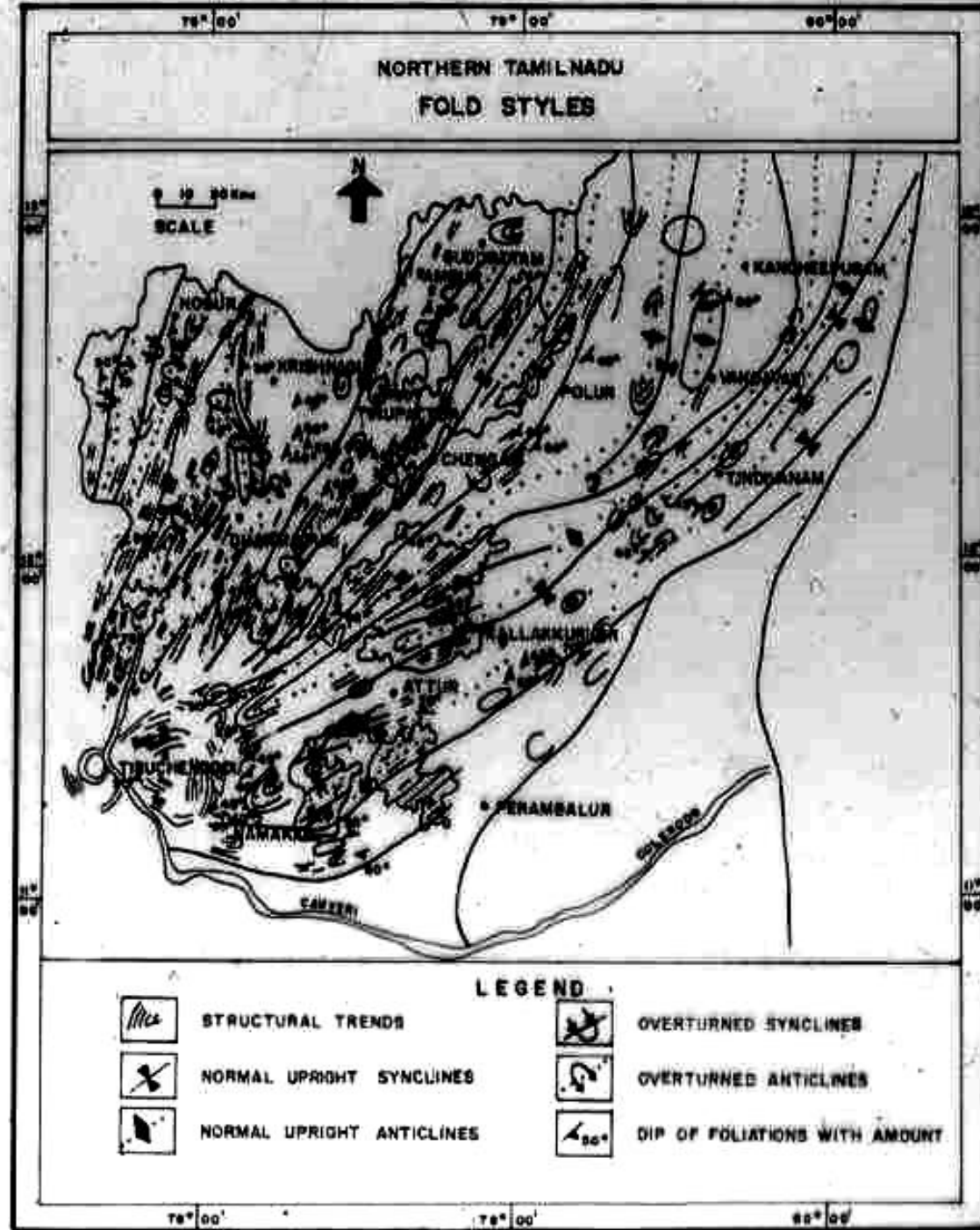
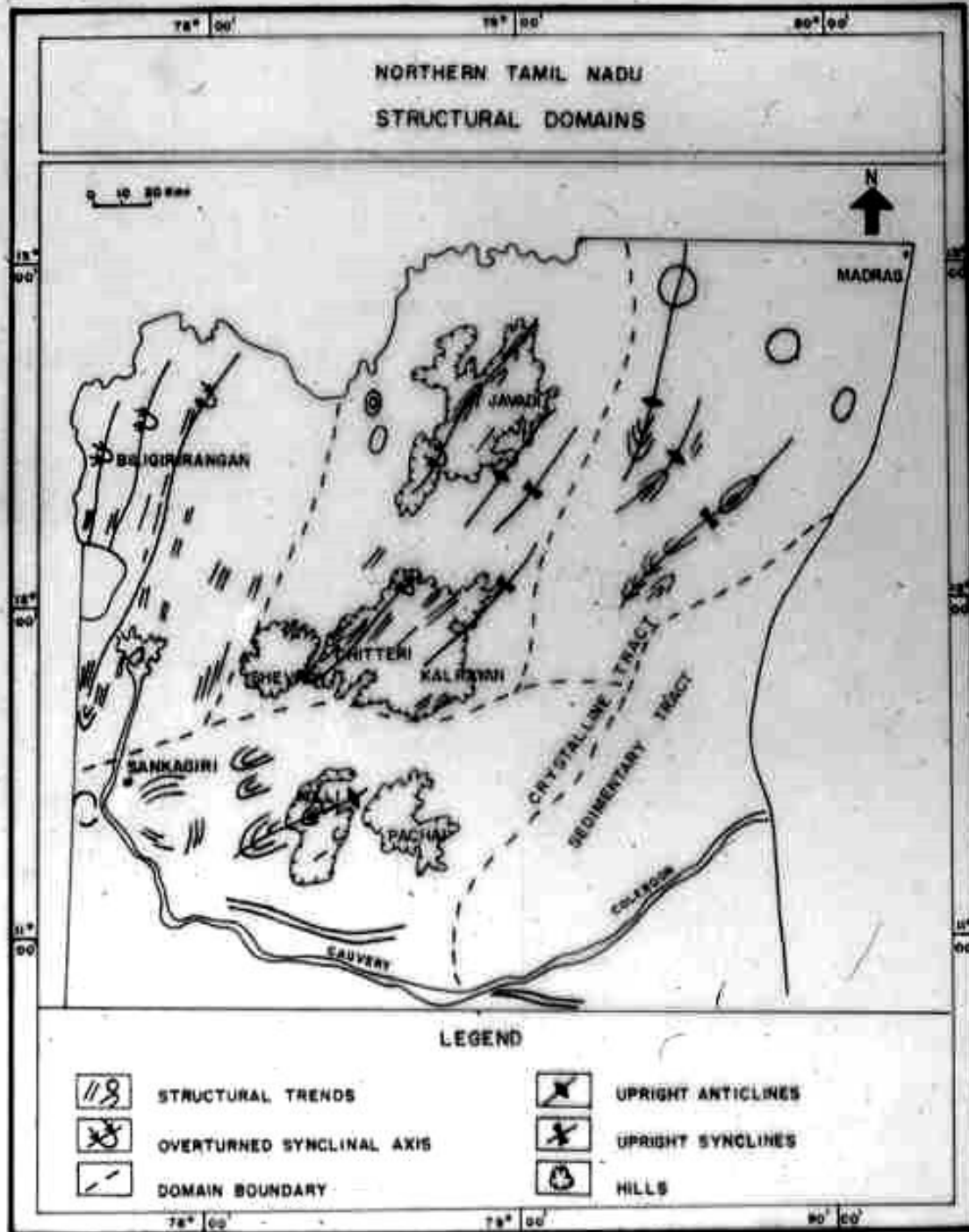


Fig 3.8



LEGEND

	STRUCTURAL TRENDS		UPRIGHT ANTICLINES
	OVERTURNED SYNCLINAL AXIS		UPRIGHT SYNCLINES
	DOMAIN BOUNDARY		HILLS

RECOGNITION OF FAULTS THROUGH REMOTE SENSING

- **Linear feature in terrain**
- **Abrupt end of hills**
- **Juxta position of terrain of contrasting elevation**
- **Abrupt end of lithologies**
- **Abrupt end of folded structures**
- **Striking contrast in the intensity of weathering & degree of denudation**
- **Occurrences of older & younger tectonic land forms on either side of lineaments**
- **Contrast drainage density on either side.**

Drainage anomalies like straightness

Sudden loss or emergence of drainage

Straightness in shore line

Occurrence of mass wasting phenomenon in desert

Occurrence of mineralisation along a lineament

Occurrence of high yield wells along a lineament

Occurrence of hot springs along a lineament

Occurrence of seismic epicenter along a lineament

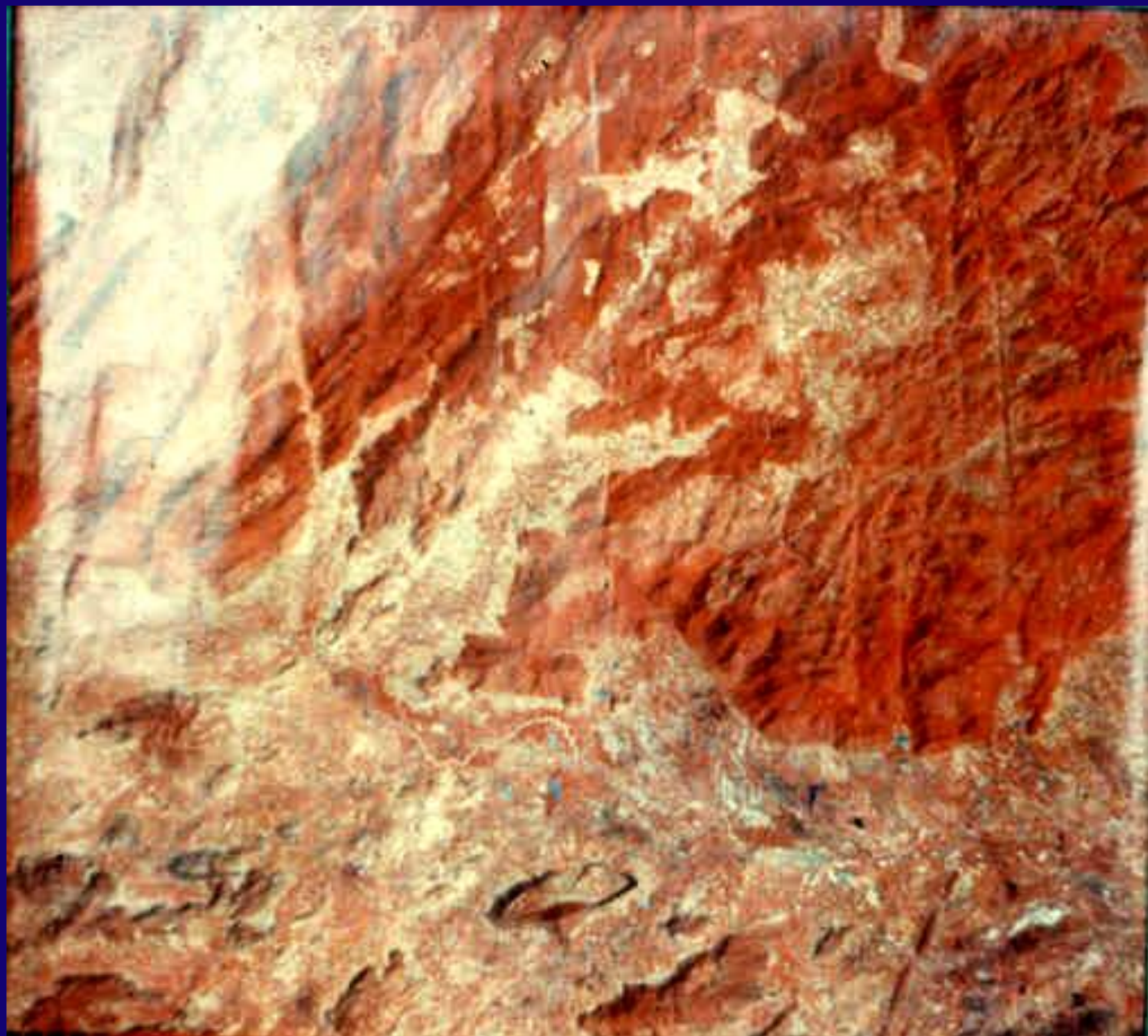
Occurrence of plutonic bodies along a lineament.

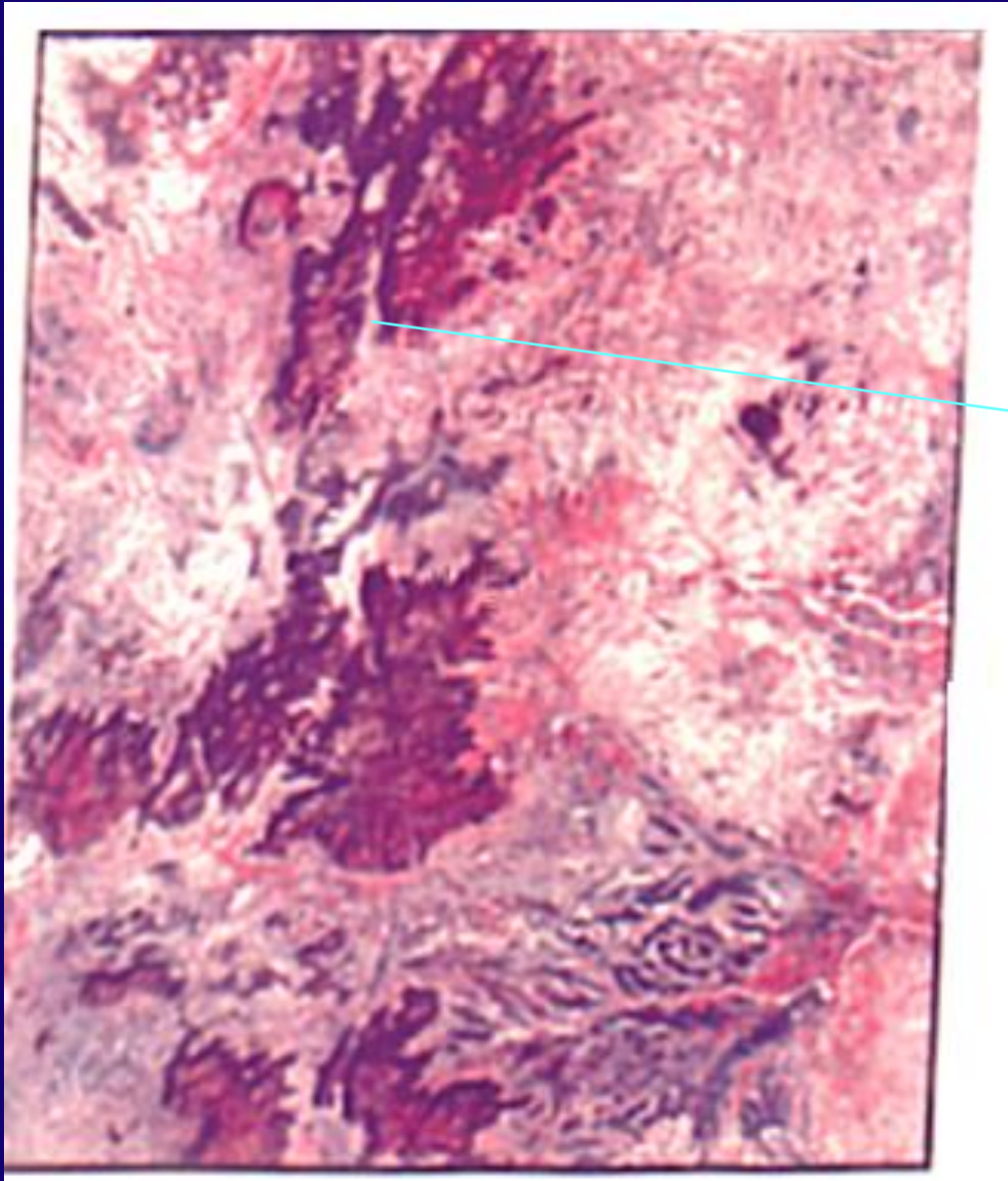




SPOT FCC –LINEAMENTS OF STANLEY RESERVOIR AREA



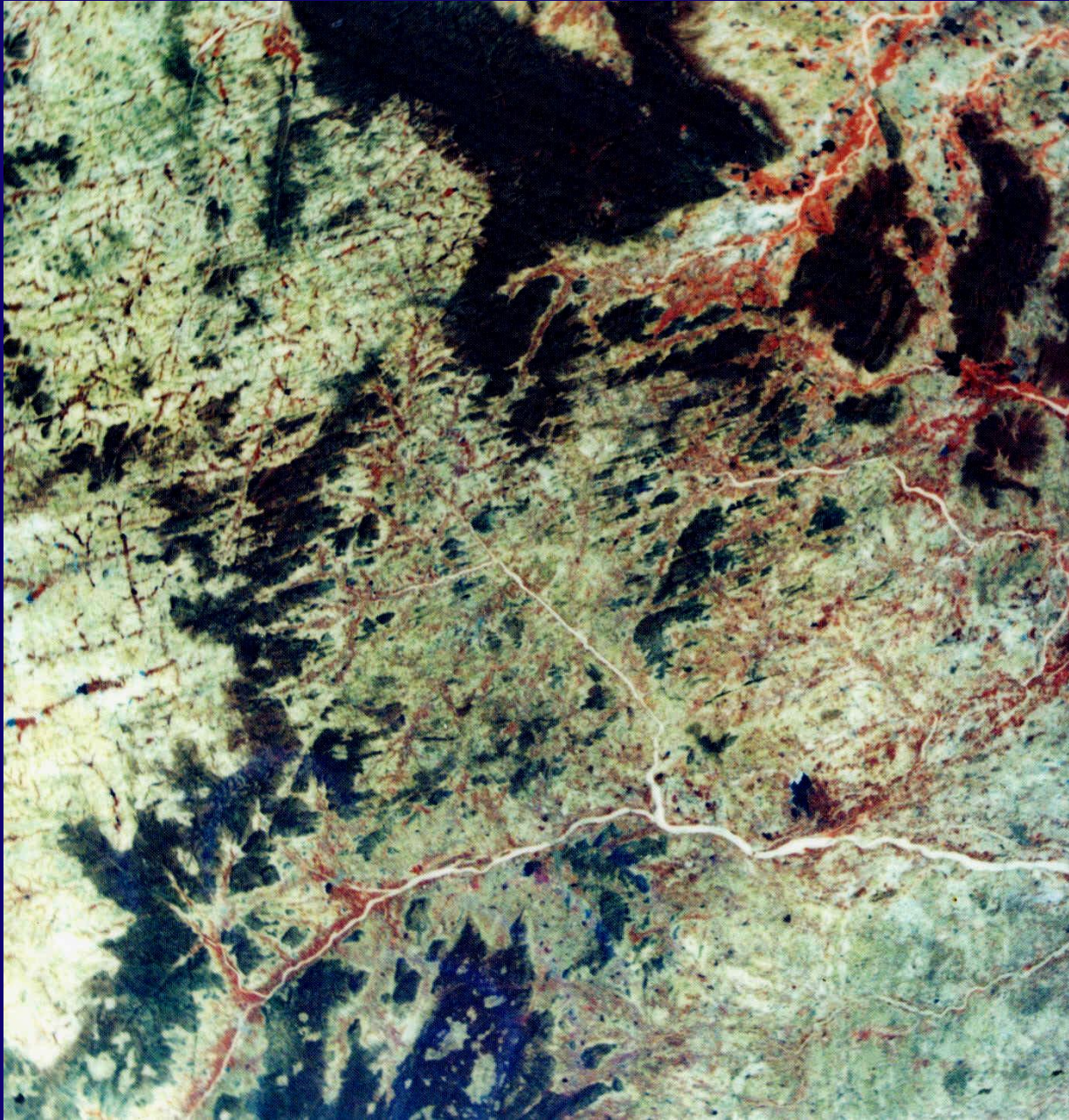




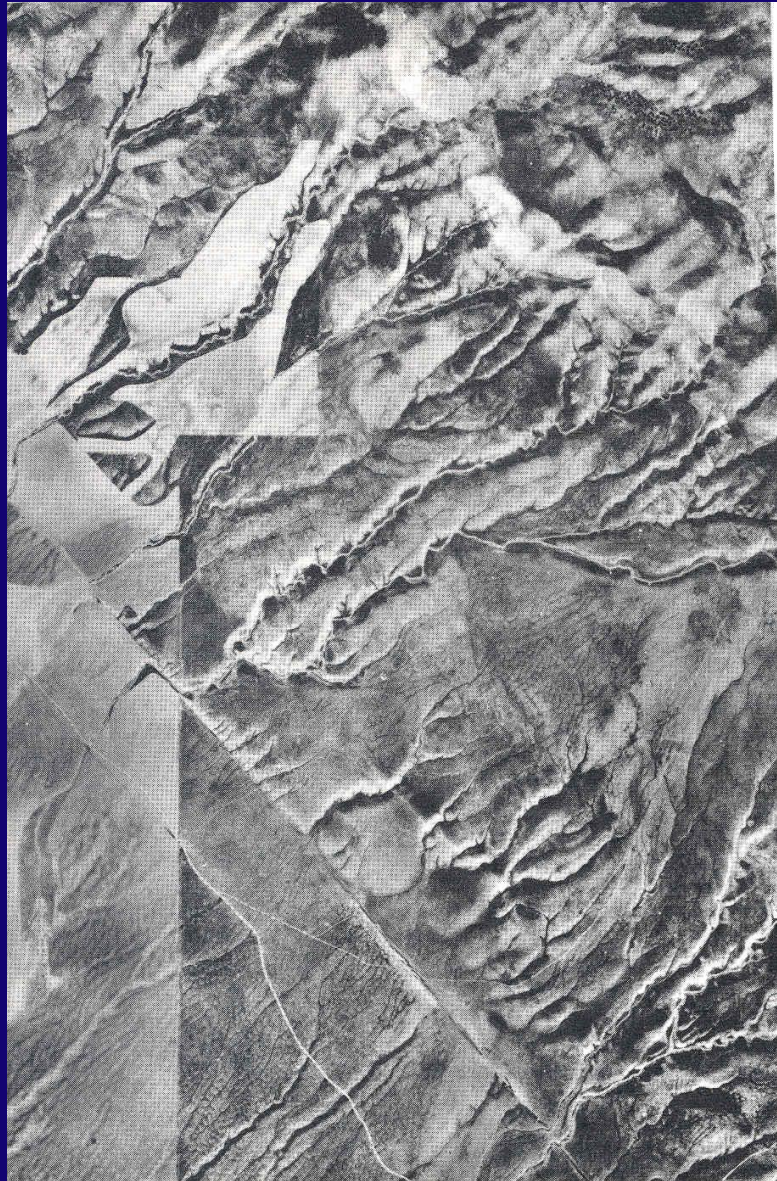
Salem Area

N-S Faults

Tiruthani EW fractures



FAULT SCAR - SAN ANDREAS FAULT



**Regional
Lineament
Studies**

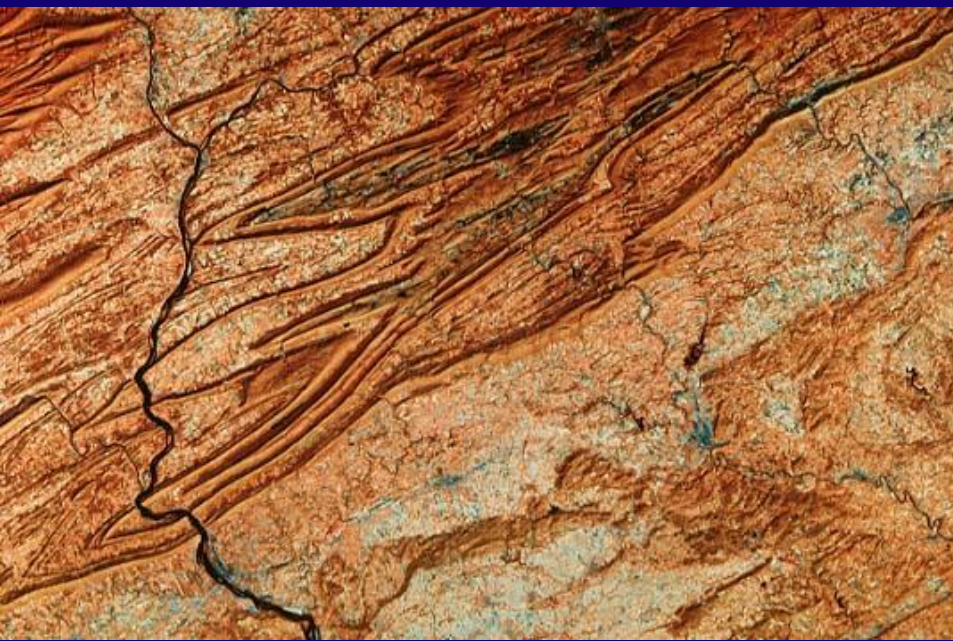
Lineament and Fracture Mapping

Lineament/ fracture are the linear – curvilinear features of tectonic origin seen on the surface of the earth.

Geo scientist have developed number of additional criteria in mapping tectonic linears.

Some of them are discussed here

➤ **Linear Ridges and Valleys**

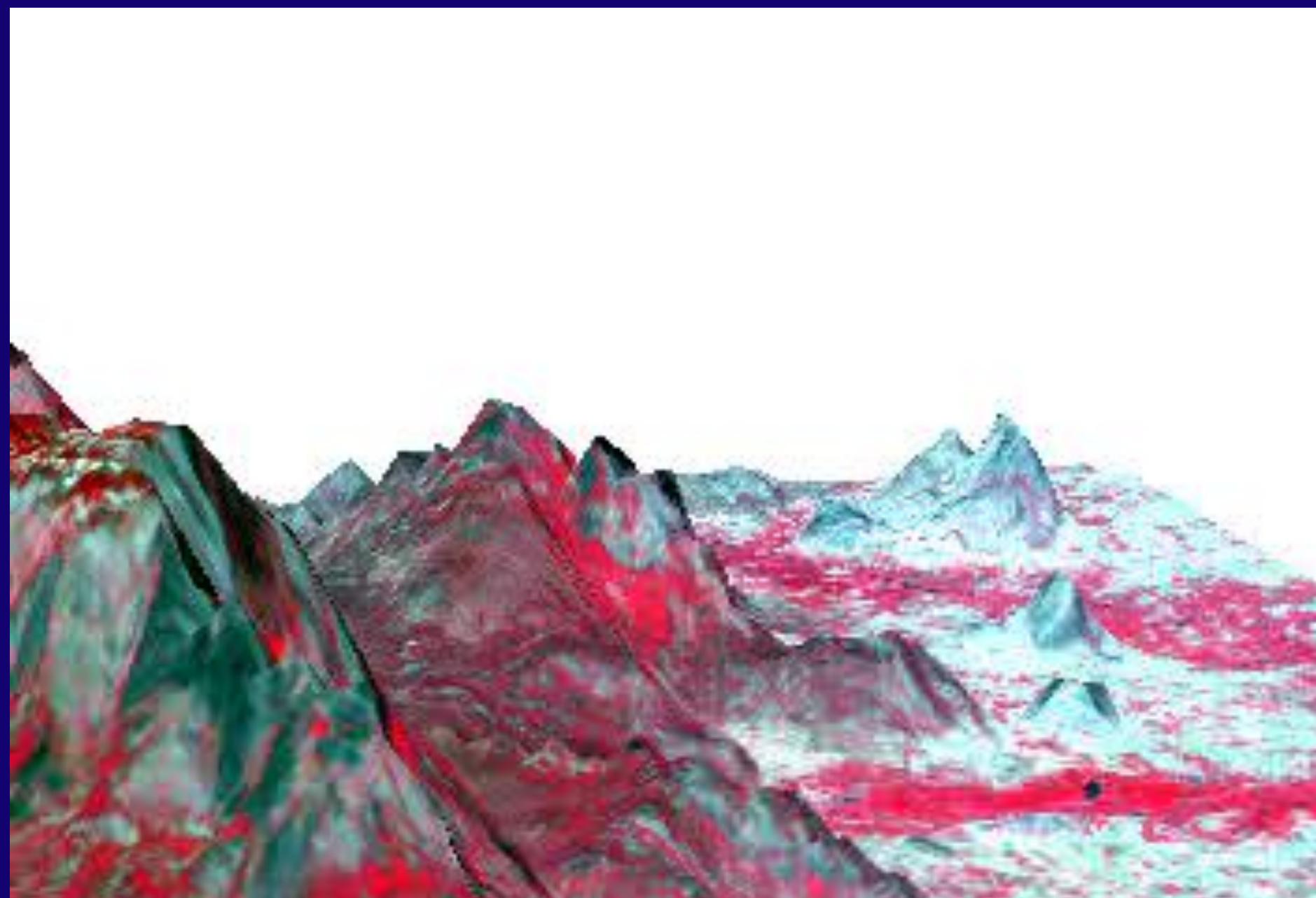


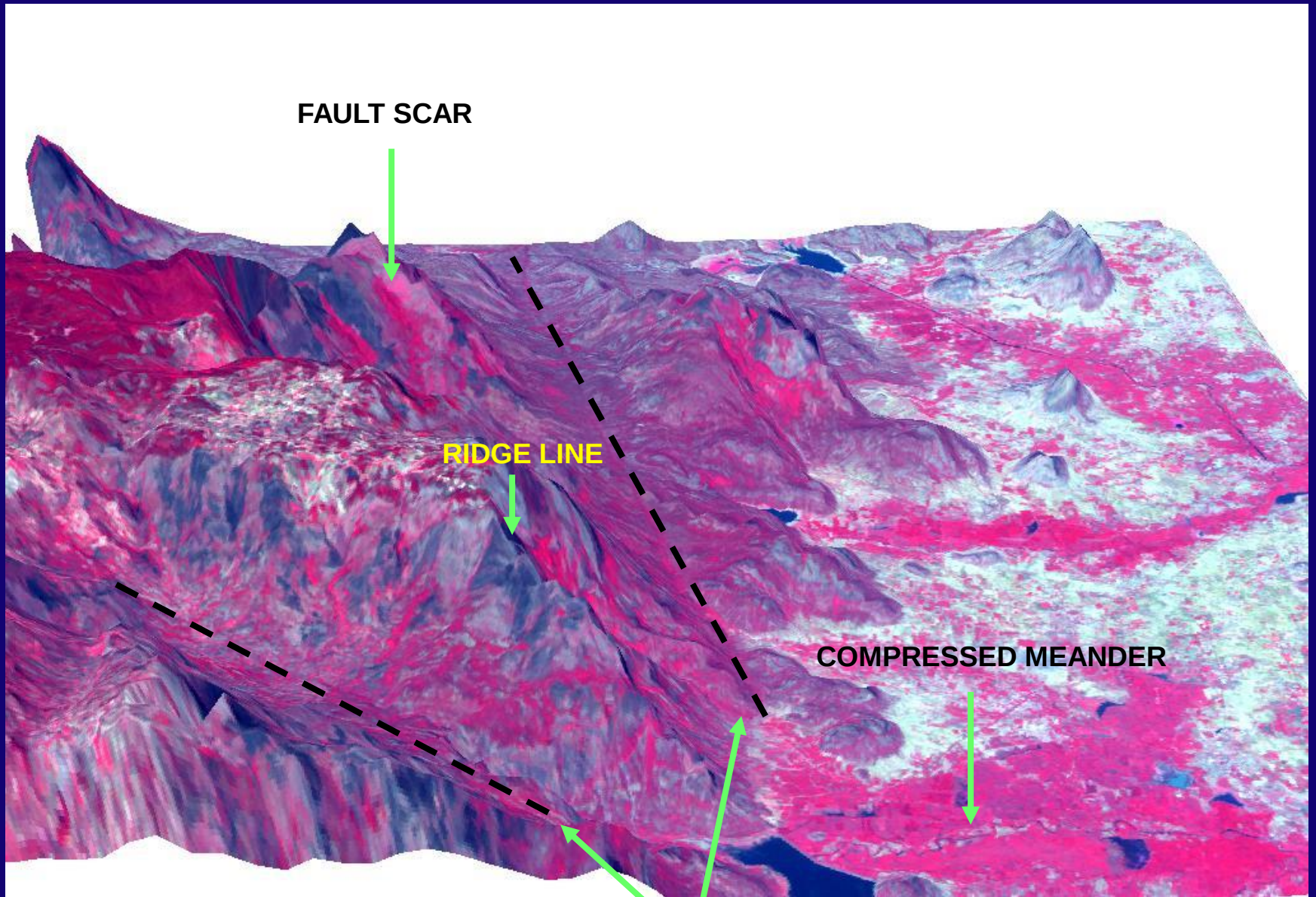
➤ **Rectilinear of the drainage and River**





➤ **Deflected Drainages**



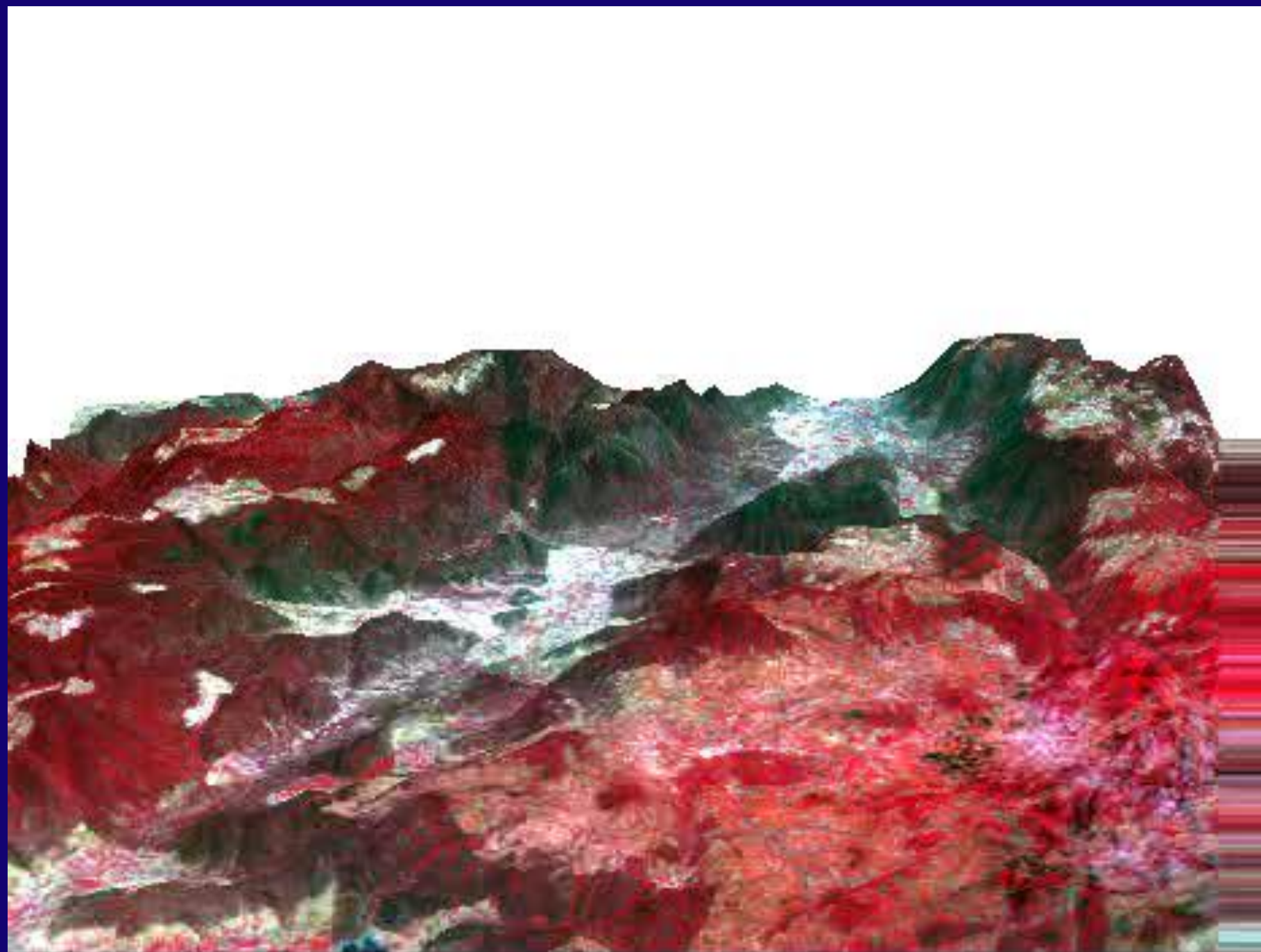


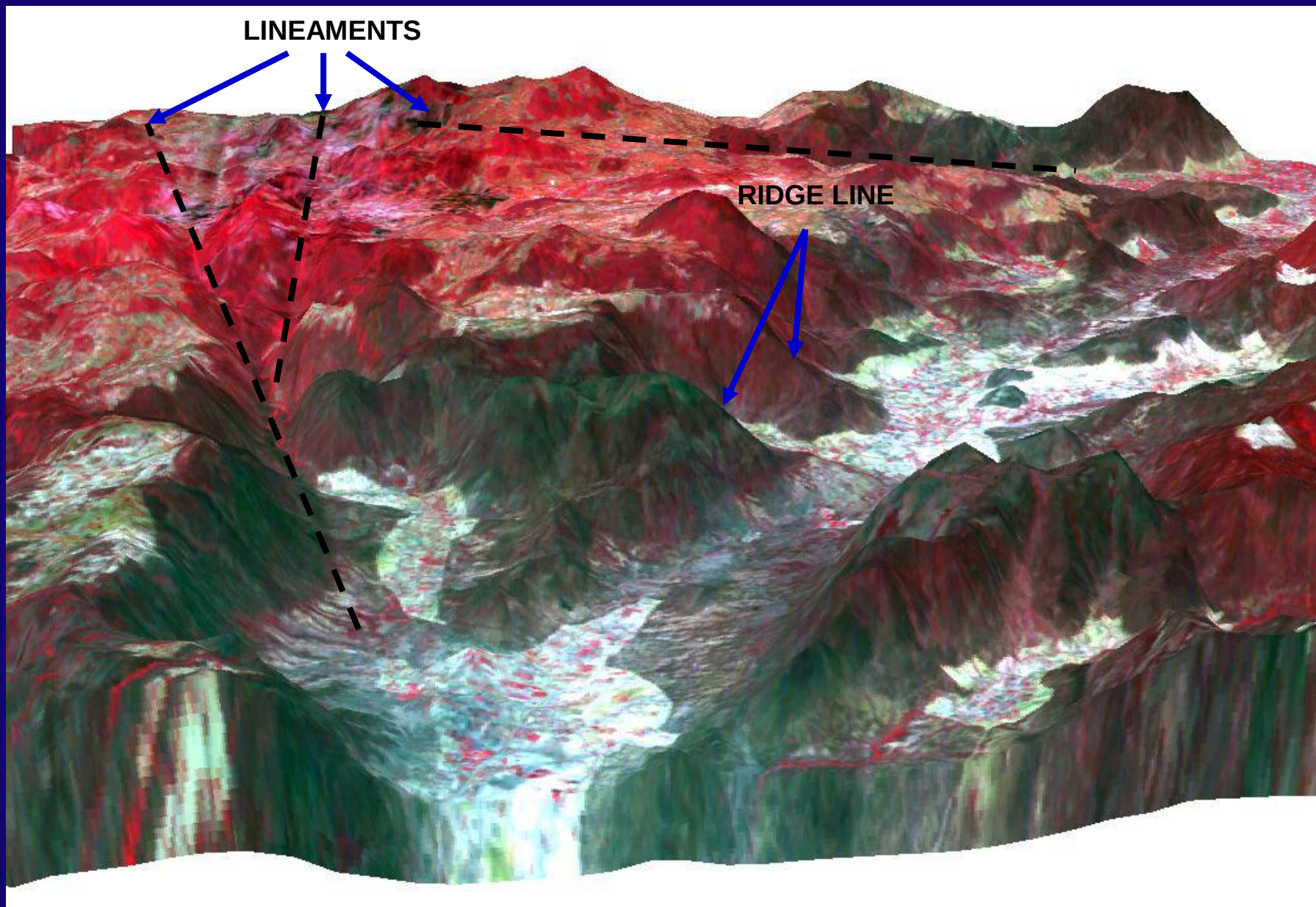
FAULT SCAR

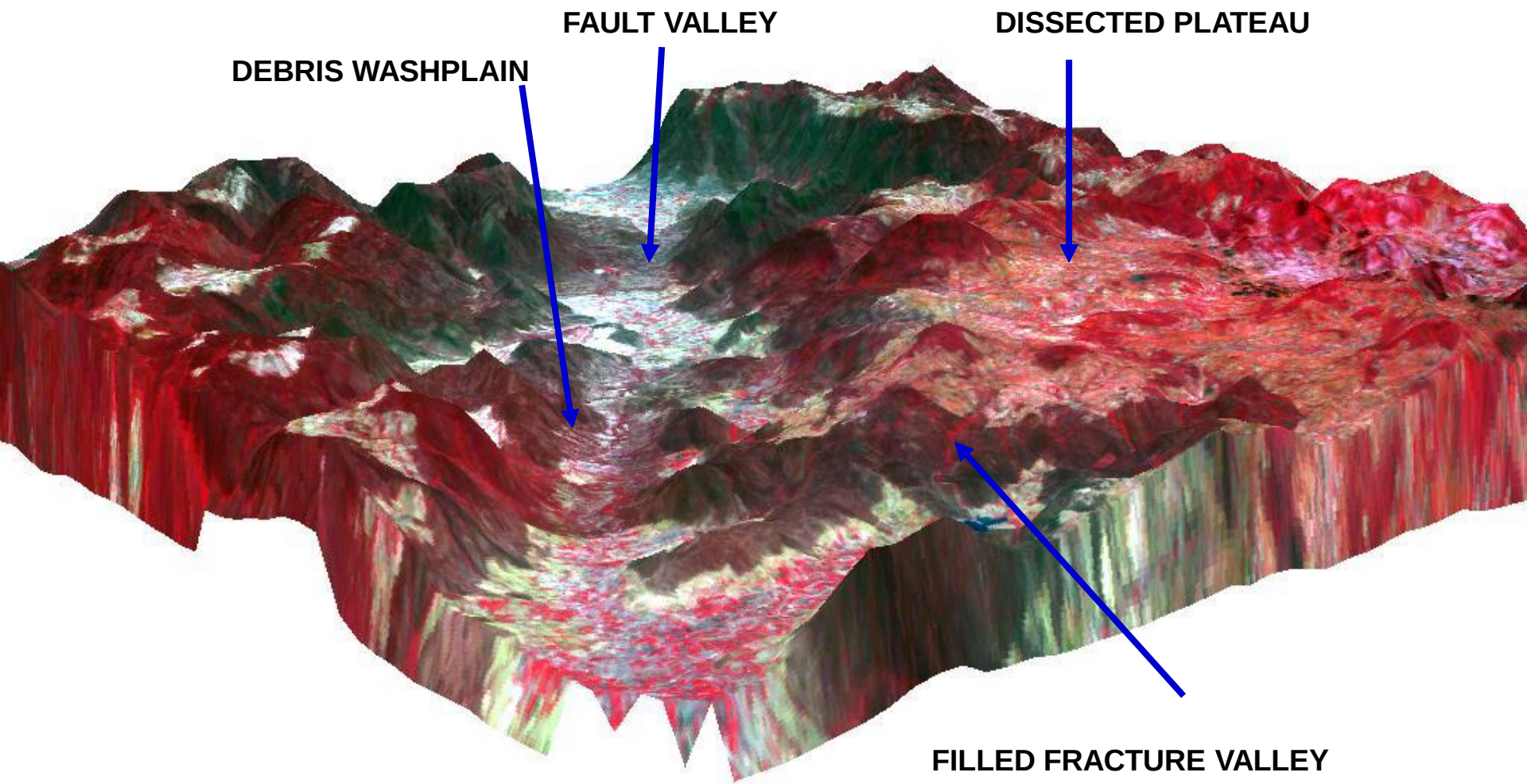
RIDGE LINE

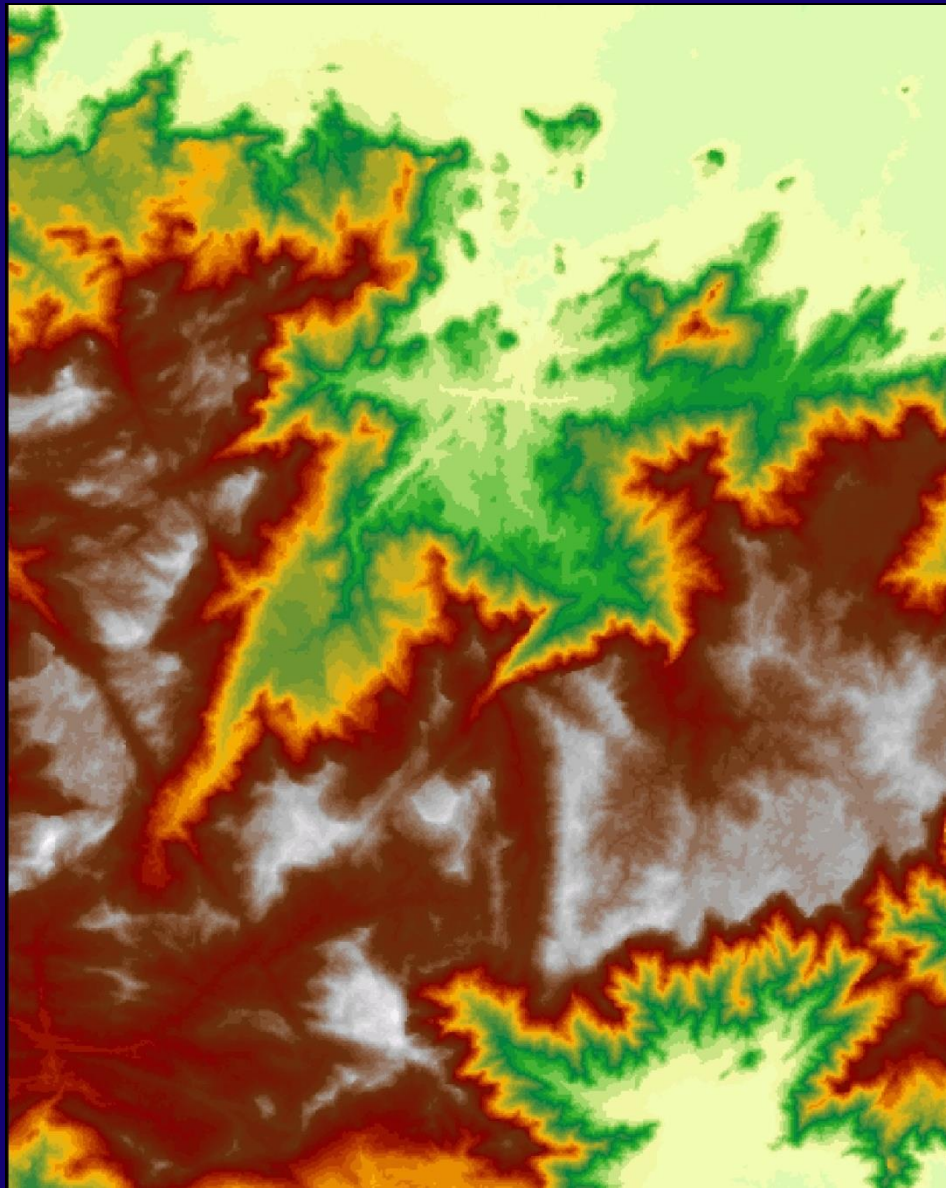
COMPRESSED MEANDER

LINEAMENTS

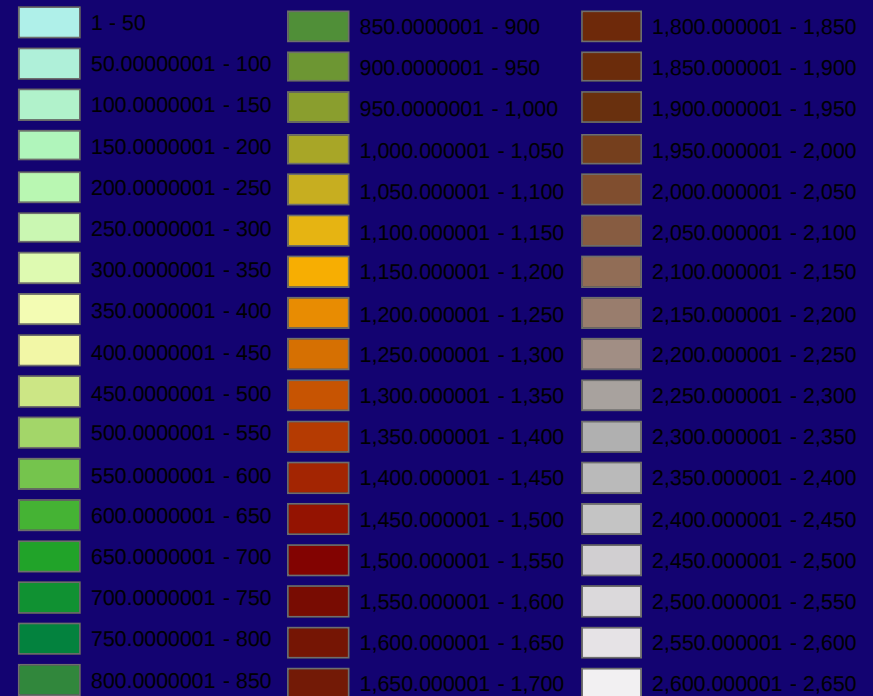


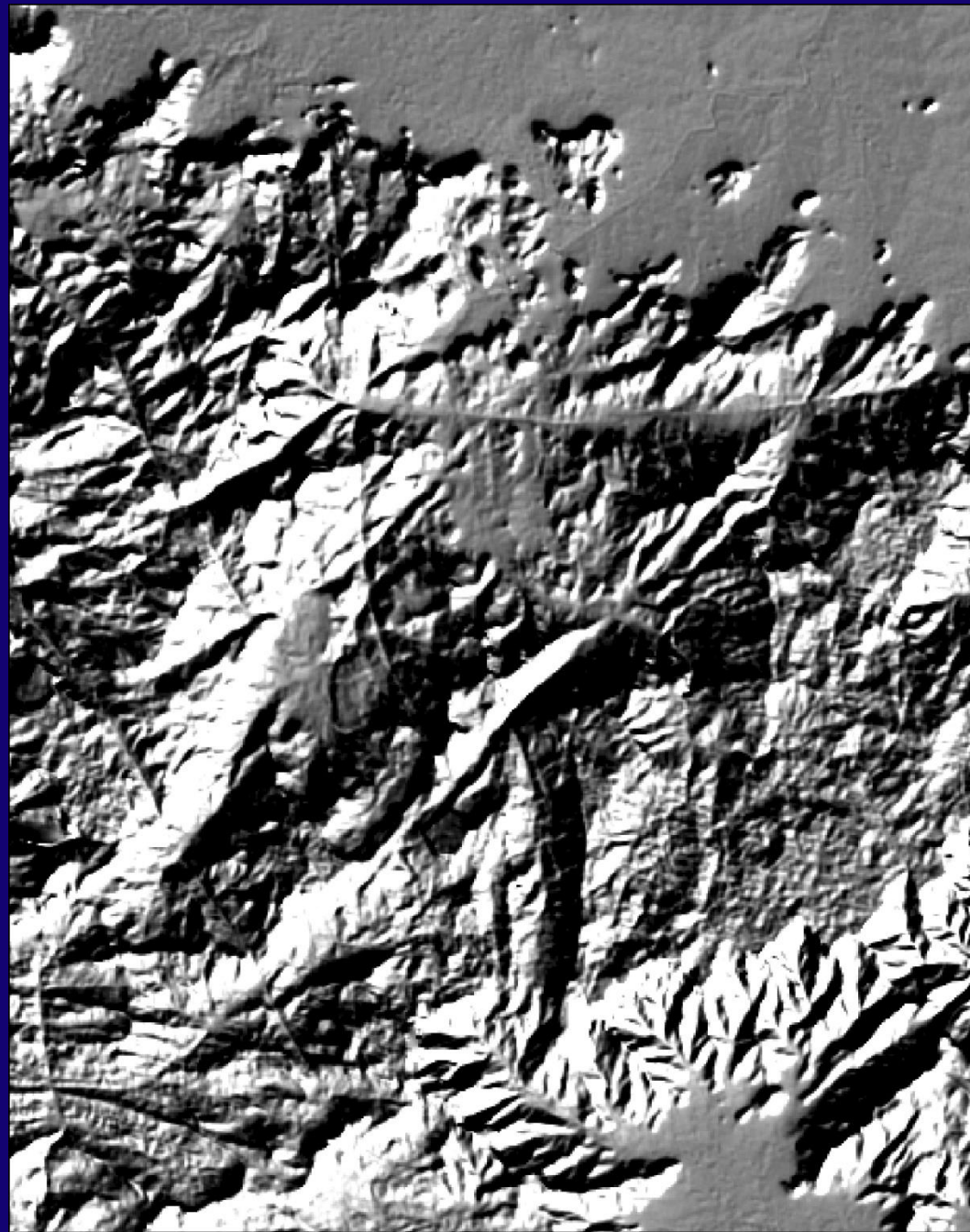




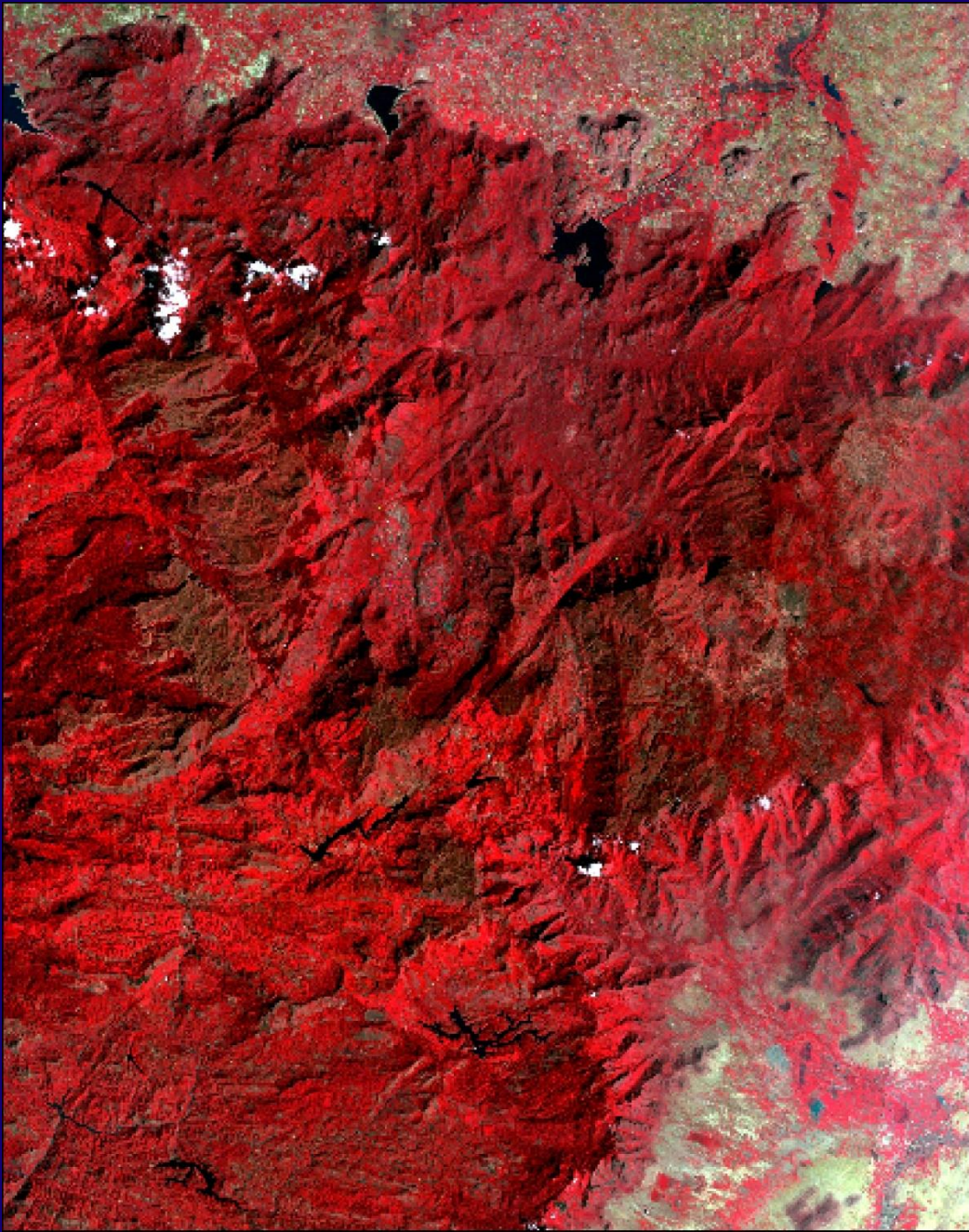


DENSITY SLICED SRTM DATA

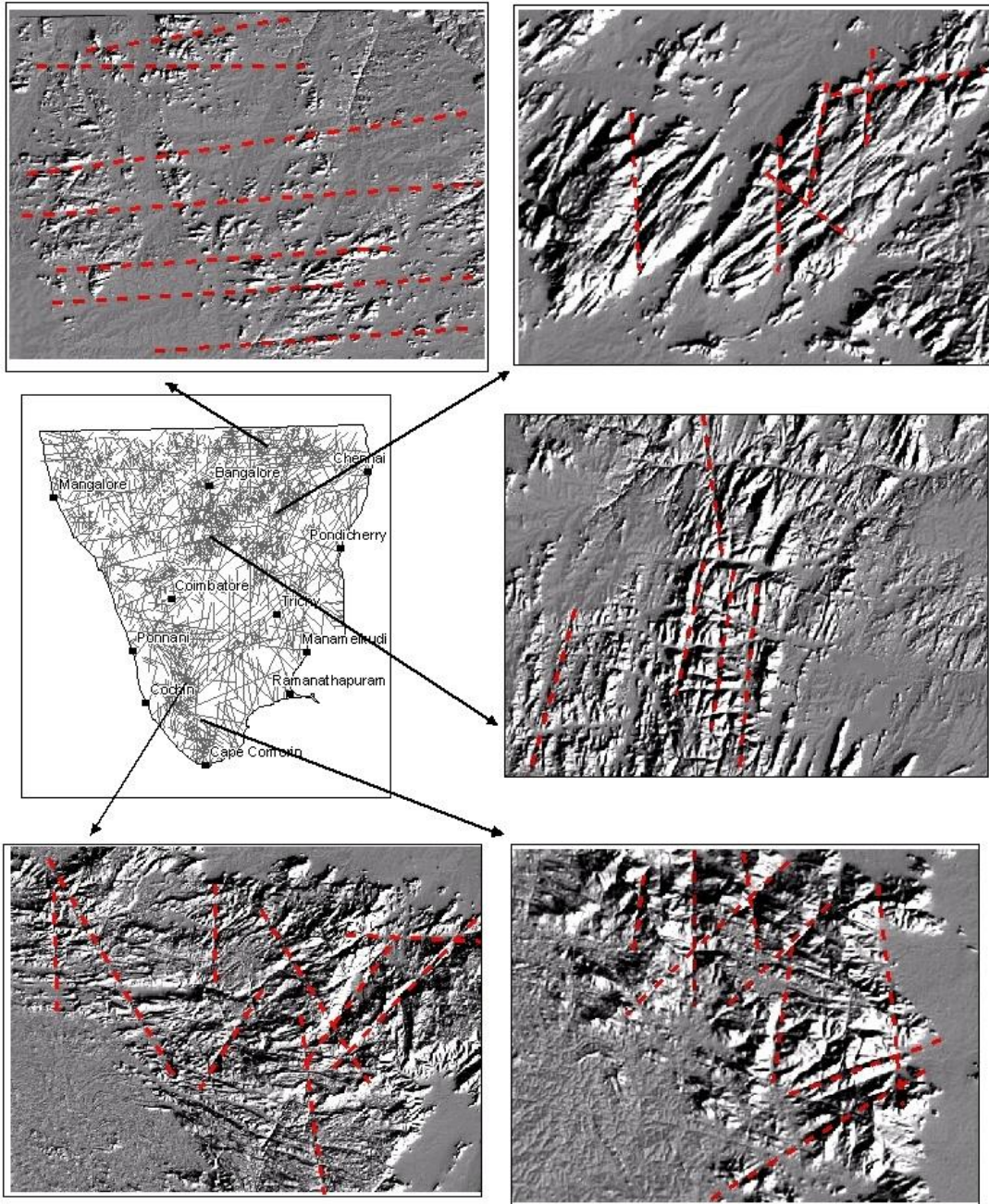




SHADED RELIEF MAP
40 (ALTITUDE) -130 (AZIMUTH)

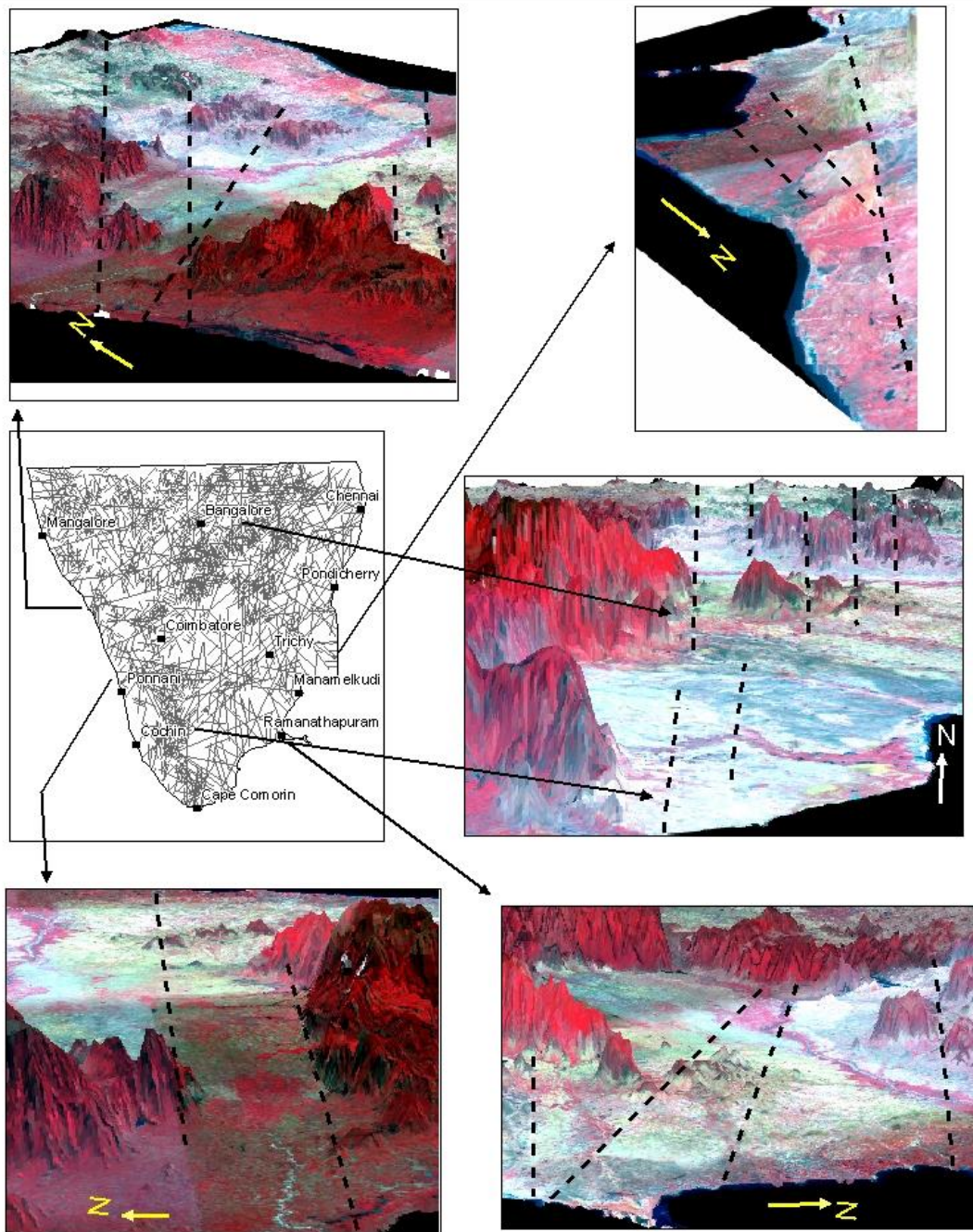


SATELLITE FCC IMAGE



Lineament Mapping from SRTM based Shaded Relief Map

Fig.3 - Lineaments and faults derived from shaded relief map (SRTM)



Lineament Mapping from SRTM based FCC Wrapped DEM

Fig 4 - Lineaments and faults derived from DEM wrapped FCC data

Final Lineament / Fault map of South India

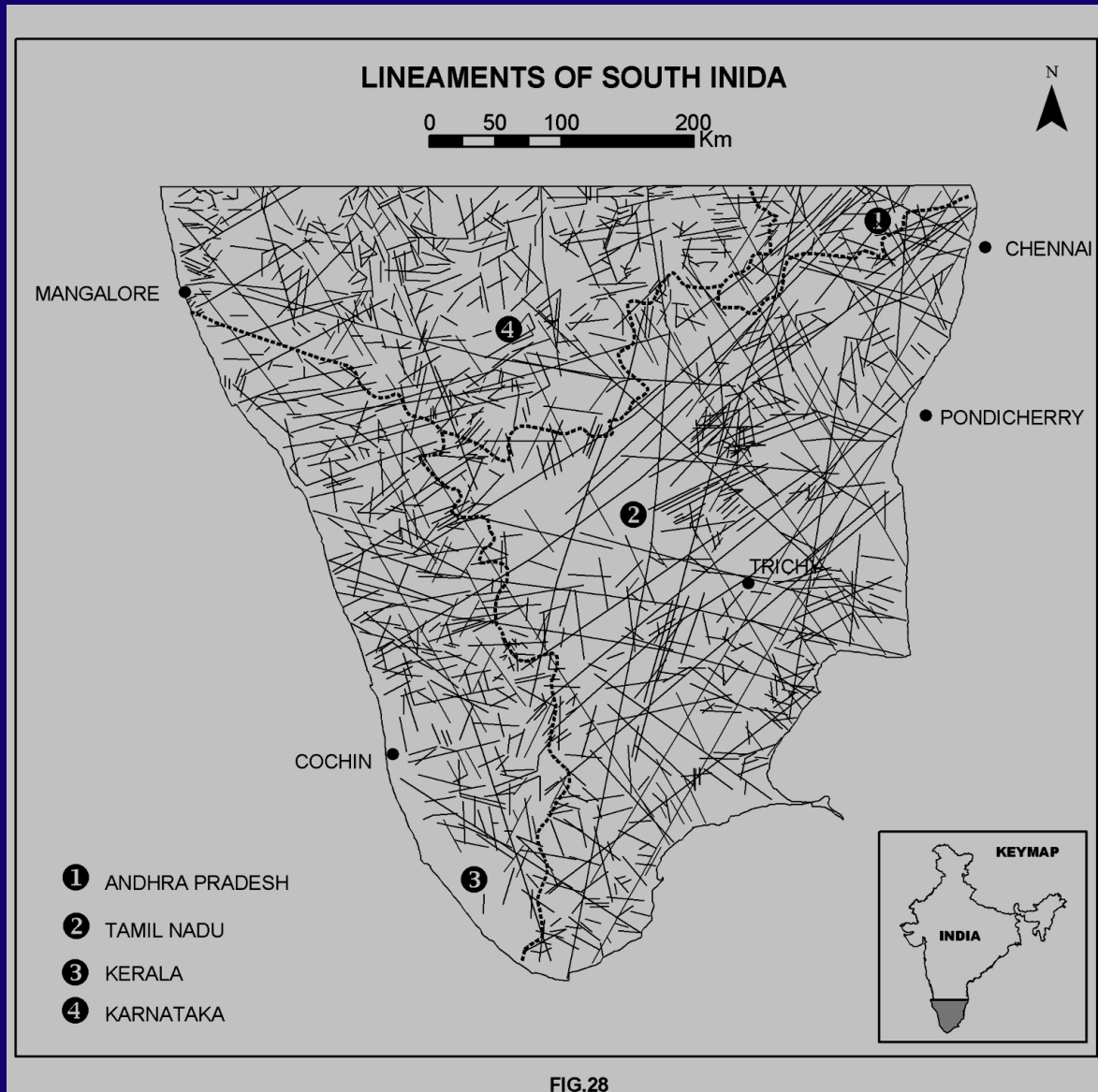


FIG.28

The Representative Neo-Active Tectonic Faults of South India

