BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024
Tamil Nadu, India

Programme : M.Tech., Geological Technology and Geoinformatics

Course Title : Geoinformatics in Disaster Management
Course Code : MTIGT0704

Unit-1: Earthquakes, Plate Tectonics & Neo-Active Seismo Tectonics

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Unit:1. Earthquake Plate Tectonics, Neo-Active Seismotectonics: Introduction to geohazards, classification of natural disasters- Earthquake and its causes, Elastic rebound theory, plate tectonics and earthquakes, earthquake belts of the world, fault associated earthquakes types and nature of seismic waves - intensity and magnitude of earthquake - Warning and prediction of earthquake, Remote Sensing techniques in warning and prediction of earthquakes - Neo-Active Seismotectonics, mapping of Lineament anomalies – Geomorphic anomalies (Tectonic, Denudational, Fluvial, Coastal & Aeolian)-Geophysical anomalies Ground water anomalies - historic seismic data analysis - Micro seismic zonation – GIS integration and risk assessment.

Geoinformatics in Natural Disasters Mitigation and Management

A Disaster or hazards may be defined as an event that generally causes extensive damage in the form of injury, loss of life or damage to property and environment

A potential hazard turns into a disaster when it imparts a significant damage.

The disasters can be classified into two broad categories

- **Natural disasters (hazards)**
- **Man made disasters (hazards)**

Natural Disasters or Geohazards – Such disasters may be of geological or meteorological. Important types of natural disasters are

- Seismcities / Earthquakes
- Landslides
- Tsunami
- Flooding
- Soil erosion and Reservoir siltation
- Saltwater intrusion & Coastal erosion
- Volcanic eruptions
- Forest fires, etc

Man made disasters or hazards:

They may take place because of anthropogenic activities due to human negligence. Important types include

- ❖ **Industrial disasters**
- ❖ **Fire**
- ❖ **Major Accidents, etc.**

- **According to a new UNDP report – "Reducing Disaster Risk: A challenge for Development"**

- **1.5 million people died in earthquakes, cyclones, tropical storms, droughts, volcanic eruptions and other natural disasters over the past two decades and many of these could have been saved with better preparedness**

- **The report also indicates that on an average about 200 deaths per day are caused by natural disasters**

- **India is considered as one of the world’s most disaster prone nations.**
- **India in the past had witnessed several devastating natural disasters like earthquakes, tsunamis, floods, cyclones, droughts and landslides**
- **While floods and droughts are recurrent disasters in few states, tropical cyclones hit most of the eastern coast from West Bengal to Tamil Nadu and part of the western coast of Gujarat and Maharashtra**

Geoinformatics in

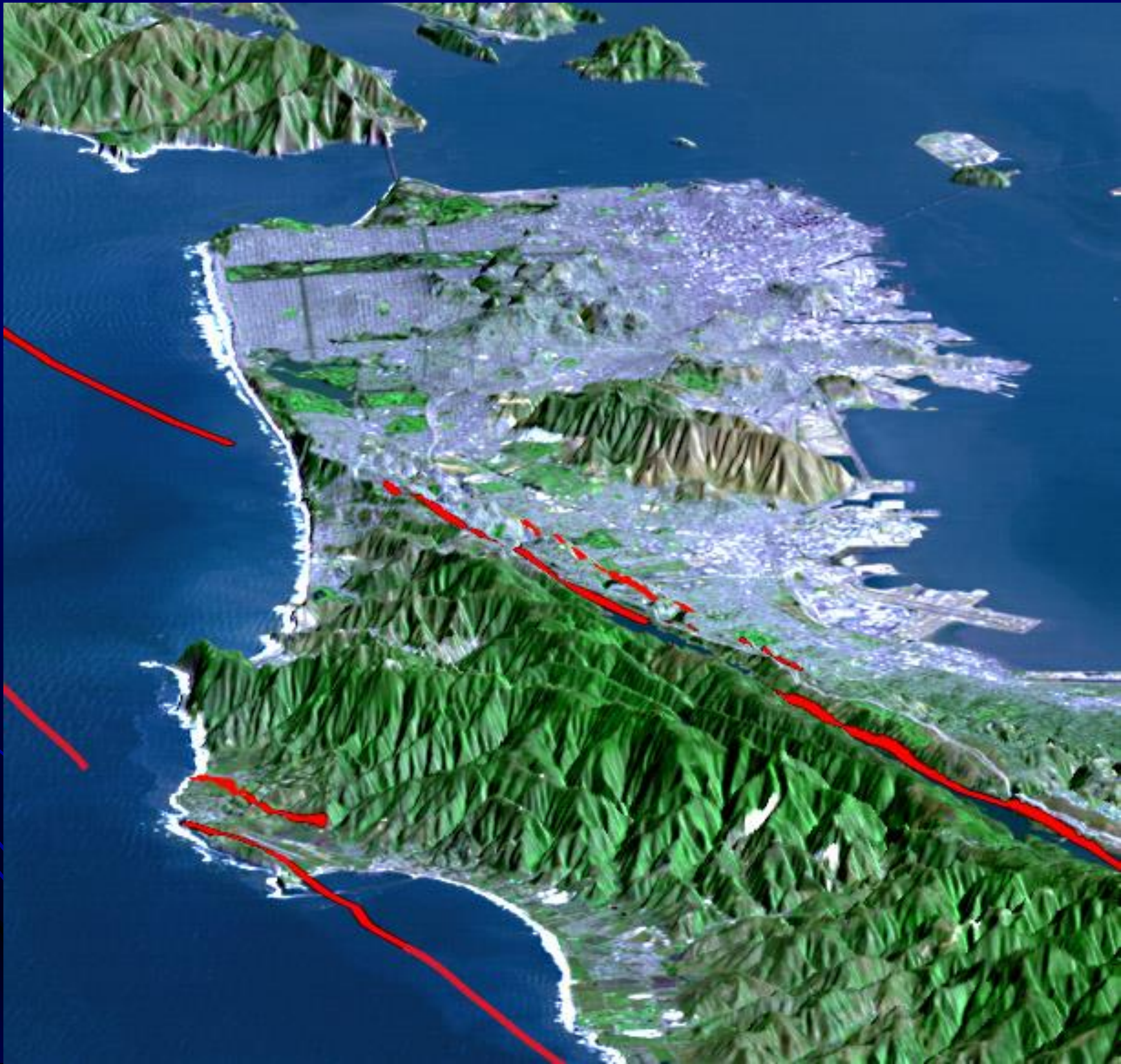
NEO-ACTIVE-SEISMOTECTONICS

What is an earthquake?

- Shaking or vibration of the ground
- rocks undergoing deformation break suddenly along a fault

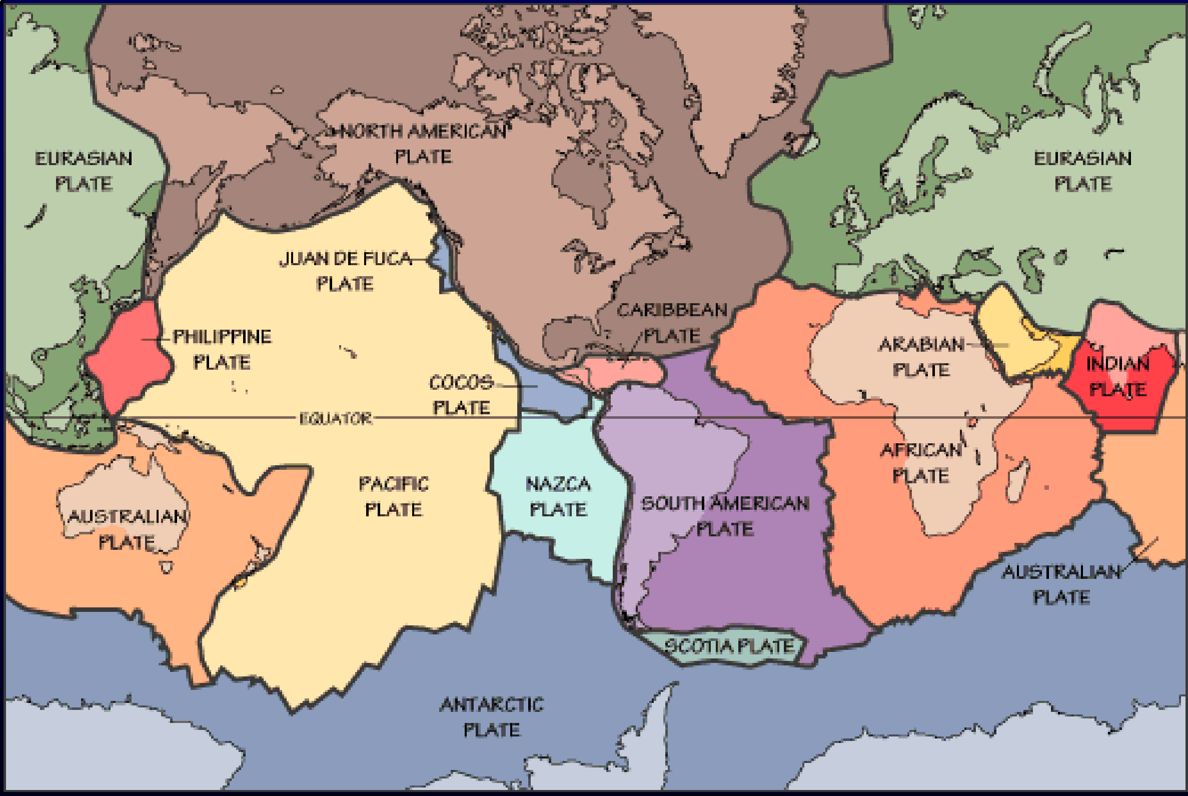
1906 San Francisco earthquake

Oblique view of the San Andreas fault and San Francisco



Where are earthquakes found?

- The Earth's surface is composed of a number of mobile "**tectonic plates**" which are in constant motion



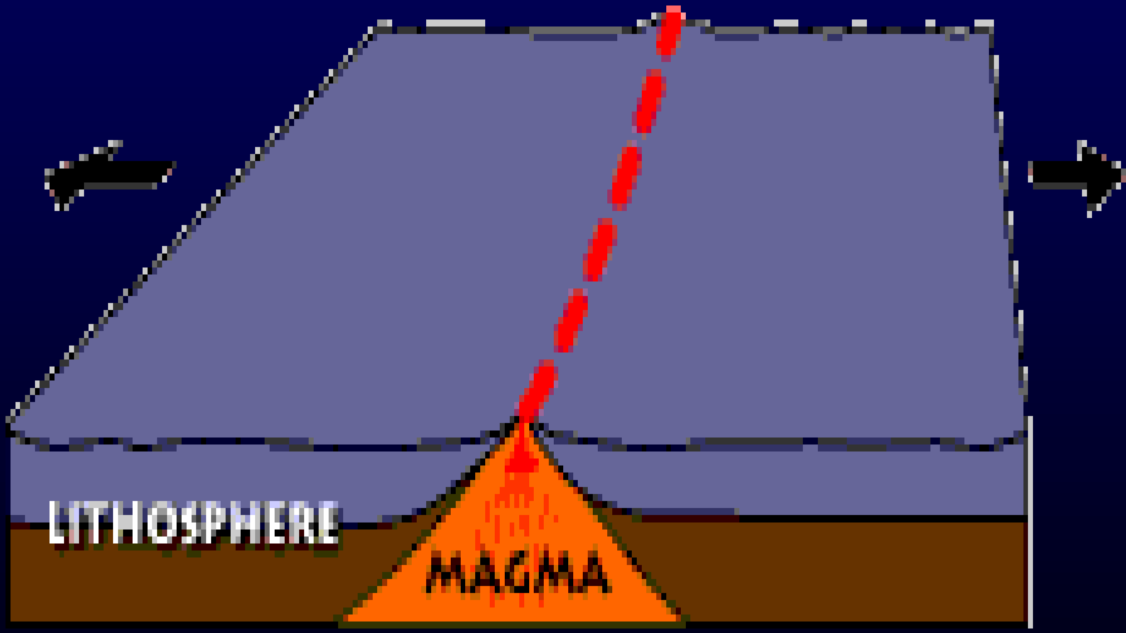
- Most earthquakes are found at plate **margins**

Plate tectonics

- The constant movement of the plates is referred to as **plate tectonics**
- There are three main types of plate boundaries:
  - **divergent**
  - **convergent**
  - **transform**

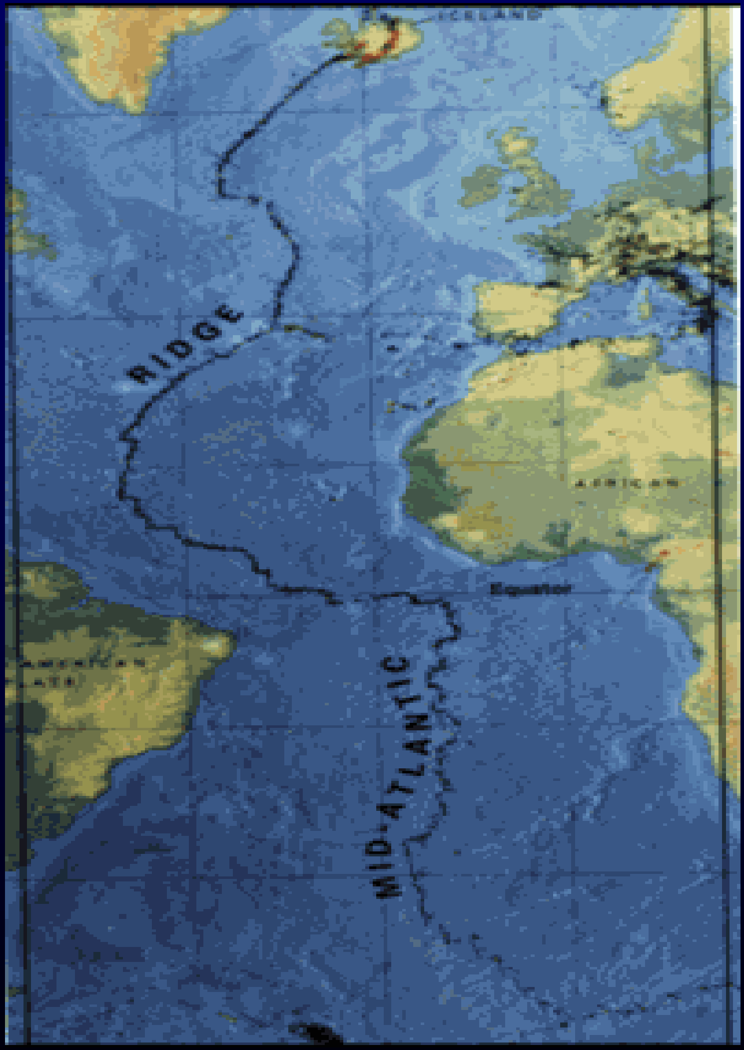
Divergent margins

- Here two tectonic plates are in the process of being created
- Magma is injected into a crack, then cools and becomes new crust



An example of a wide, mature divergent margin

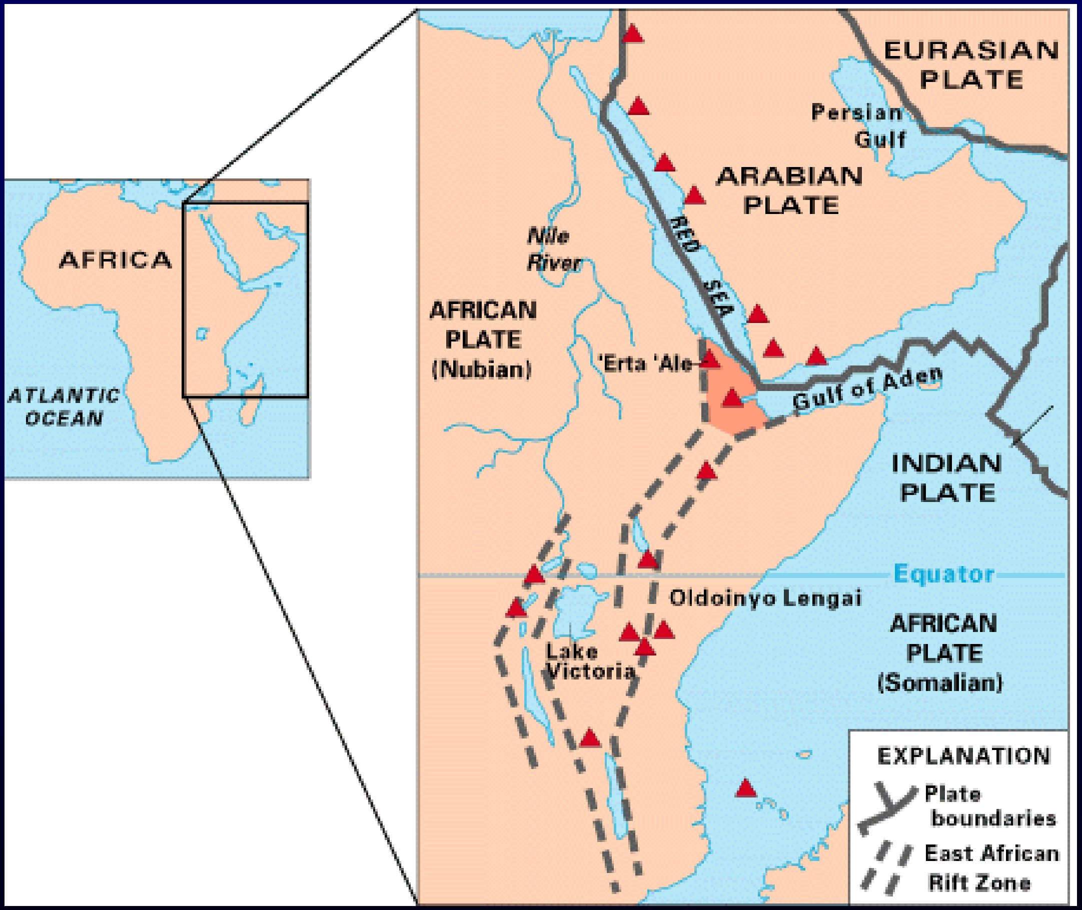
- The middle of the Atlantic Ocean is a divergent margin which is being torn, or rifted, apart…the two plates are separating continuously at a rate of several cm/yr



An immature divergent plate margin

- The Red Sea represents a young rift which is just beginning to separate Arabia from Africa…

- Here, too, volcanism is evident, as a result of rifting

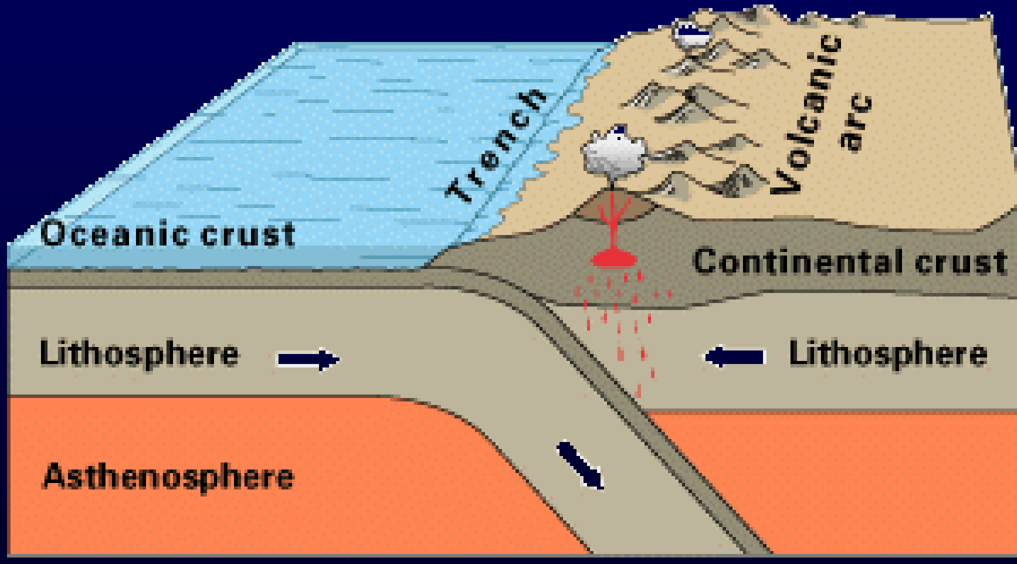


Volcanism in the Afar triangle

- ‘Erta ‘Ale, a volcano slightly west of the Red Sea, represents the **<u>splitting apart and thinning</u>** of the African continent

Convergent margins I

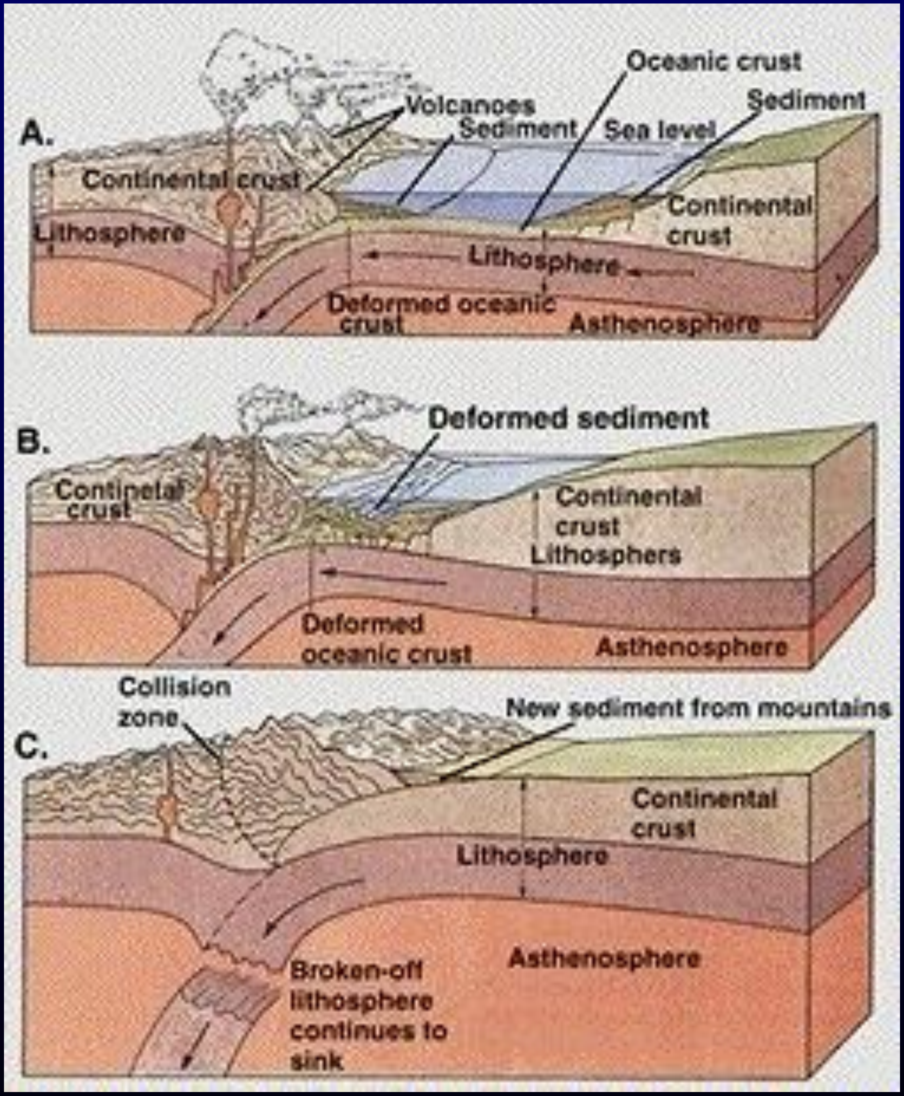
- Instead of two plates being created, they are being consumed…
- Here an oceanic plate slides beneath a continental plate, since the former is denser
- geologists refer to this process as **subduction**
- Large, destructive earthquakes occur here



Oceanic-continental convergence

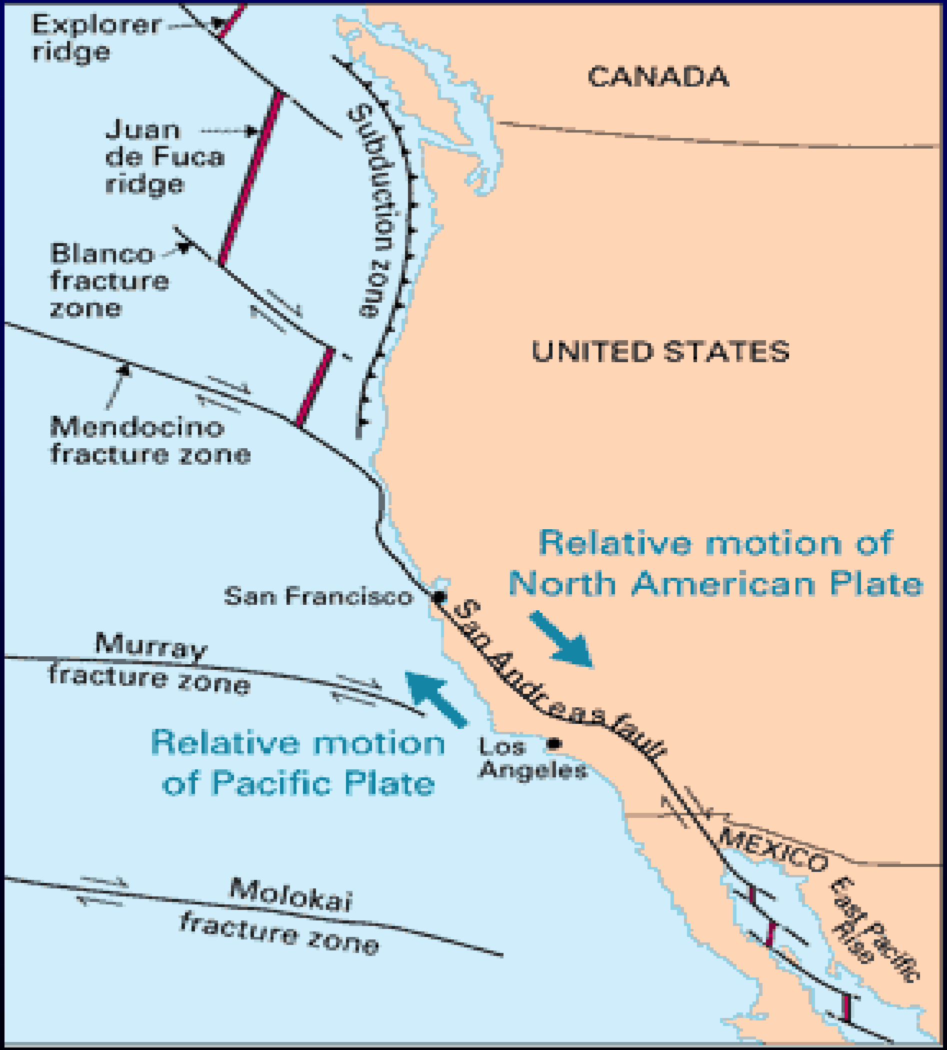
Convergent margins II

- If two continental plates collide, they do not subduct, because they are too **buoyant**
- Instead, intense **compression** with crustal shortening and thickening occur
- Large, destructive earthquakes also are generated in this situation

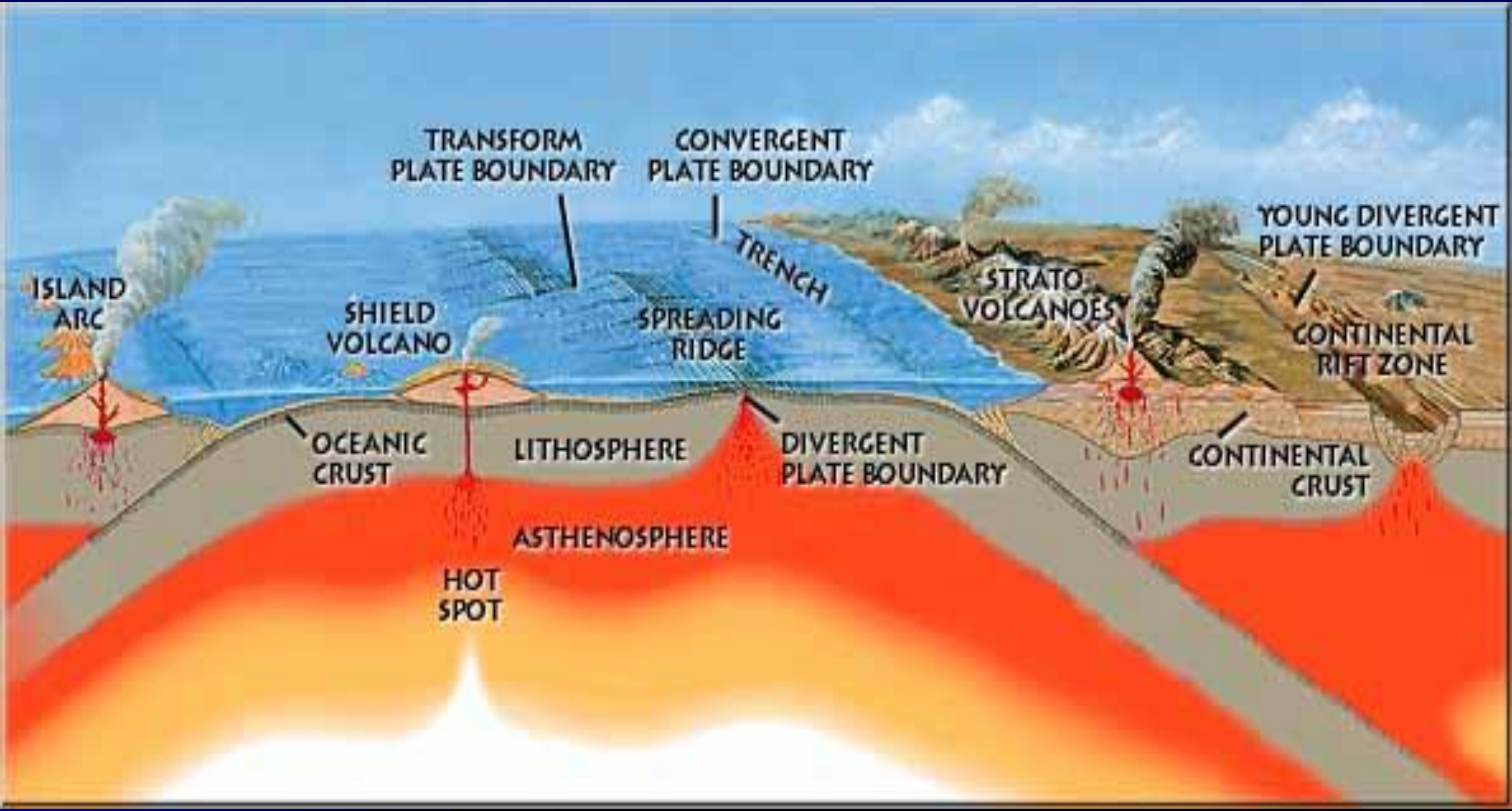


Transform margins

- The third type of plate margin is called a transform boundary
- Here, plates are neither created nor destroyed…
- they simply slide by one another

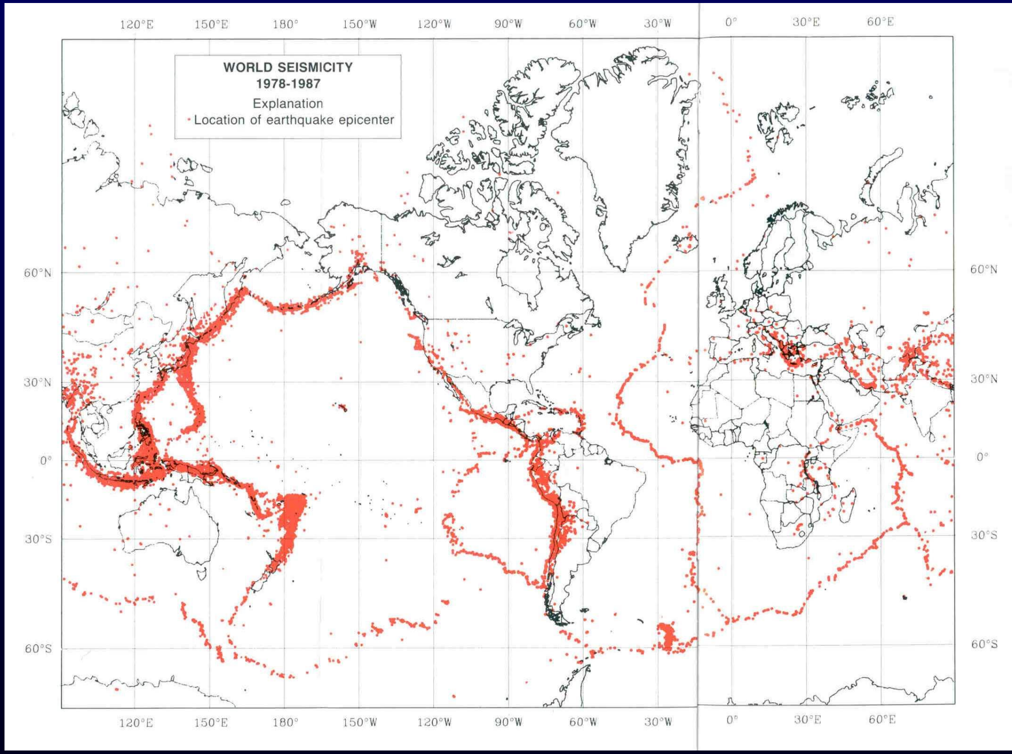


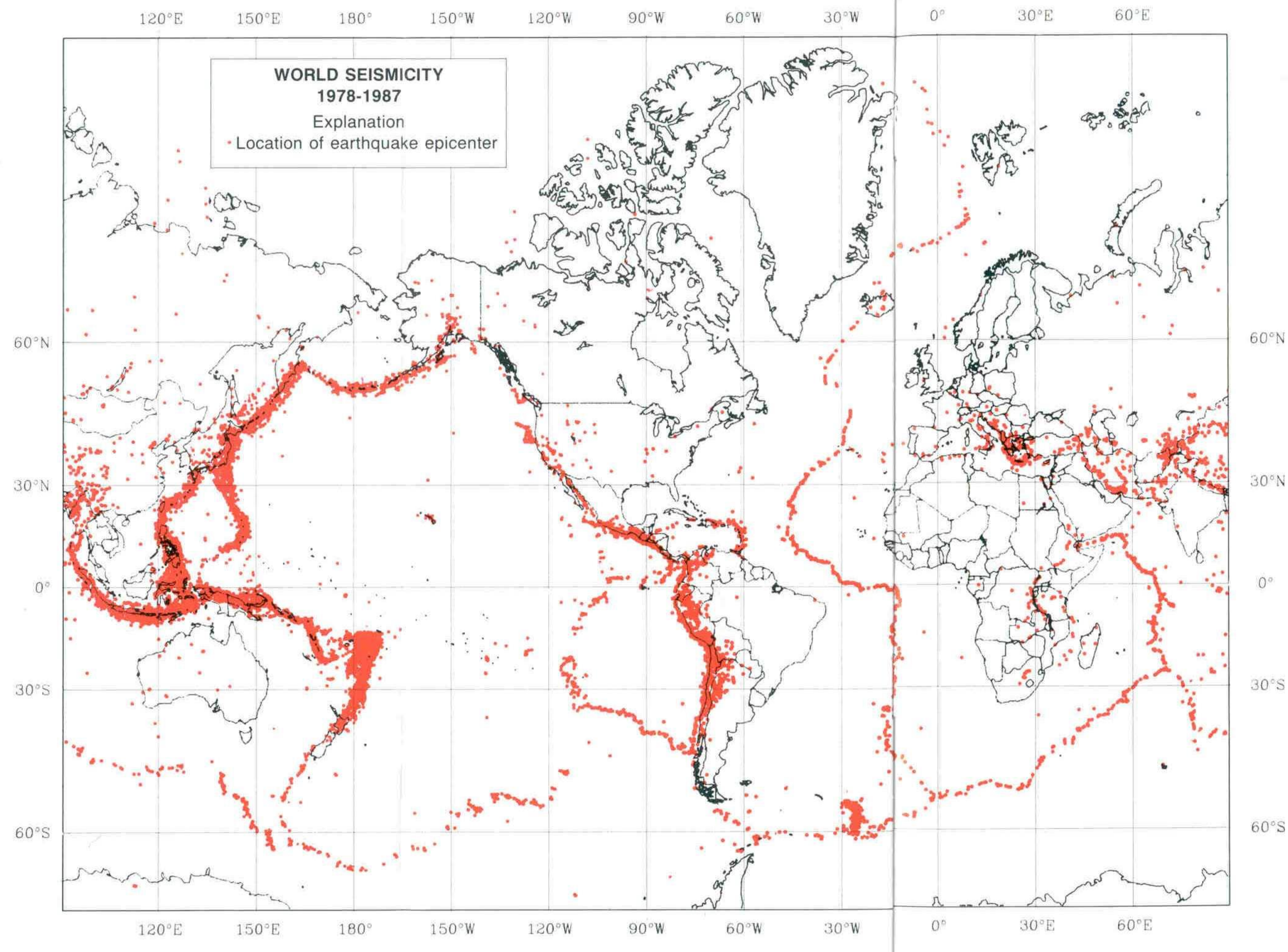
So here's the big picture of what we're living on



Where are the world's earthquakes in terms of plate tectonics?

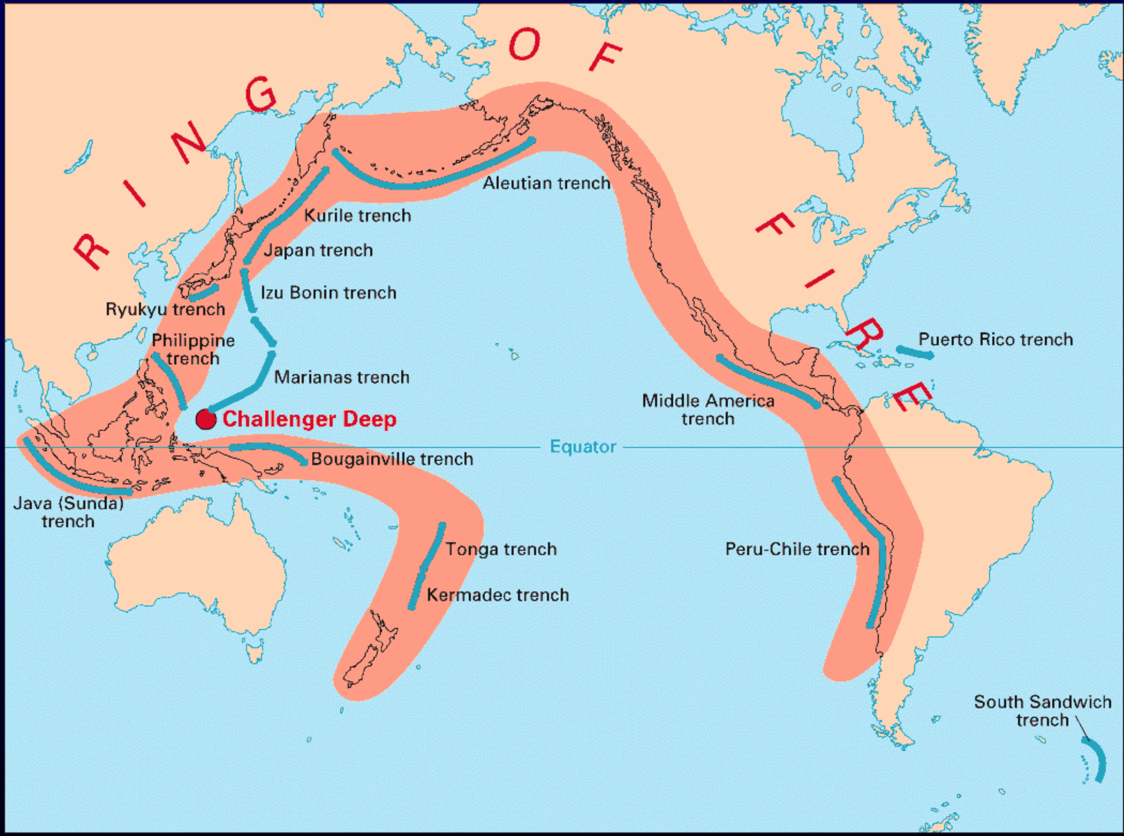
- The great majority of earthquakes are located at <u>**plate margins**</u>
- This where magmatism, friction, faulting, etc., are <u>**most intense**</u>
- Earthquakes in plate interiors are comparatively <u>**less**</u>




WORLD SEISMICITY
1978-1987
Explanation
Location of earthquake epicenter
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
60°N
30°N
0°
30°S
60°S

The Pacific Rim of Fire

- This notorious zone is characterized by **<u>subduction zones</u>**
- Earthquakes and volcanoes here are particularly **<u>violent</u>**
- **<u>friction</u>** from subduction produces large destructive quakes

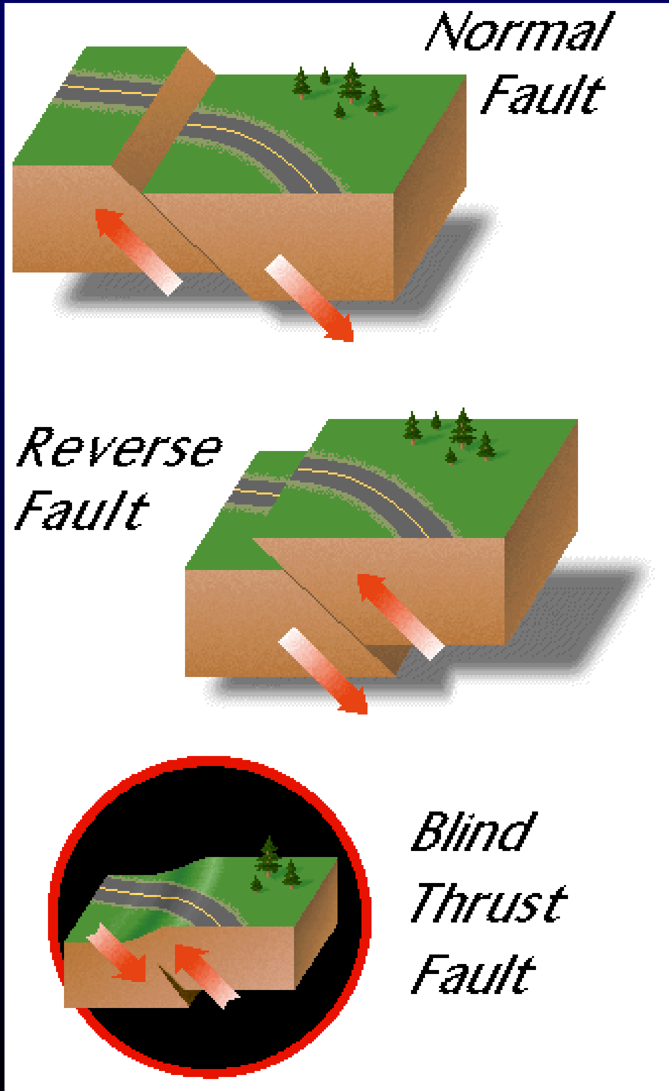


Faults associated with earthquakes

- Faults are planes of weakness along which the Earth has been broken
- Movements on a fault can be either **slow** (ductile deformation) or **fast** (brittle fracture)
- When a fault behaves in a brittle manner and breaks, **earthquakes are generated**

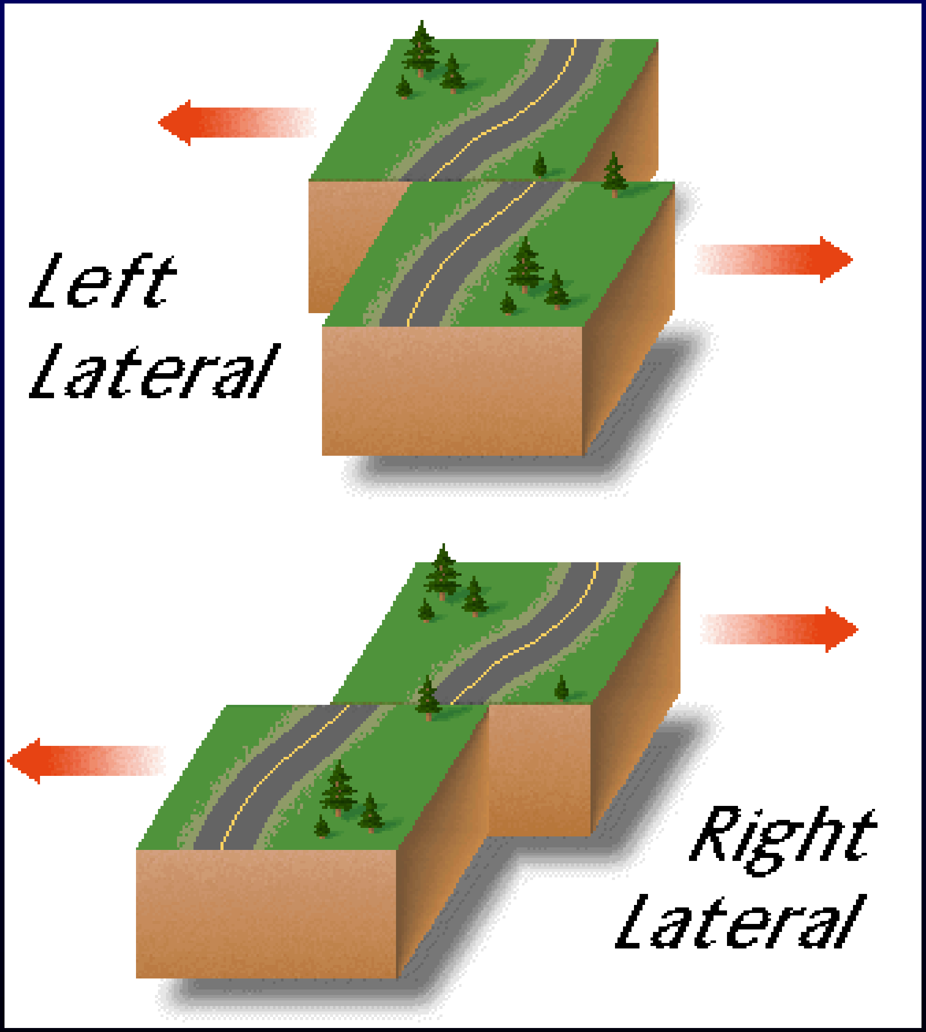
Three types of dominantly vertical faults

- A normal fault is the result of **tensional forces** (e.g., rifting)
- Reverse and thrust faults are the result of **horizontal compression**



Faults whose movement is dominantly **horizontal**

- These faults are termed **strike-slip** faults
- They are a small-scale version of transform plate tectonic margins
- They are termed **left-lateral** (sinistral) or **right-lateral** (dextral) according to their movement

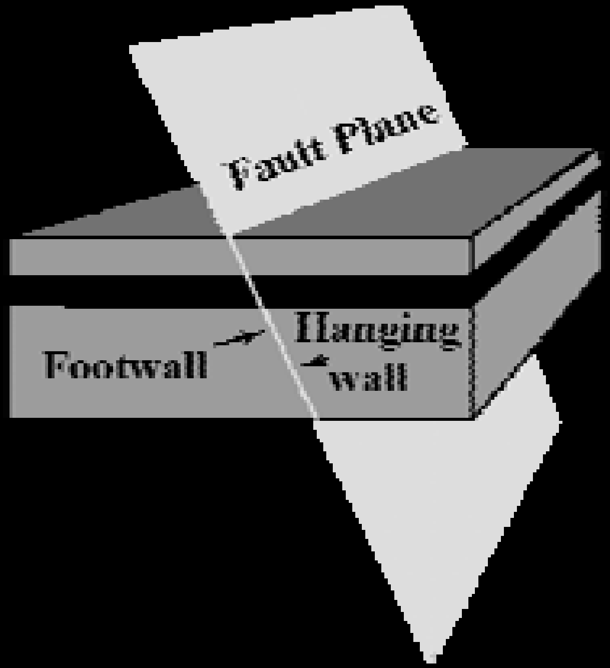


Faults: Planes along which rock bodies are displaced in response to forces acting in opposite directions on either side of the plane

Fault plane: plane along which movement takes place.

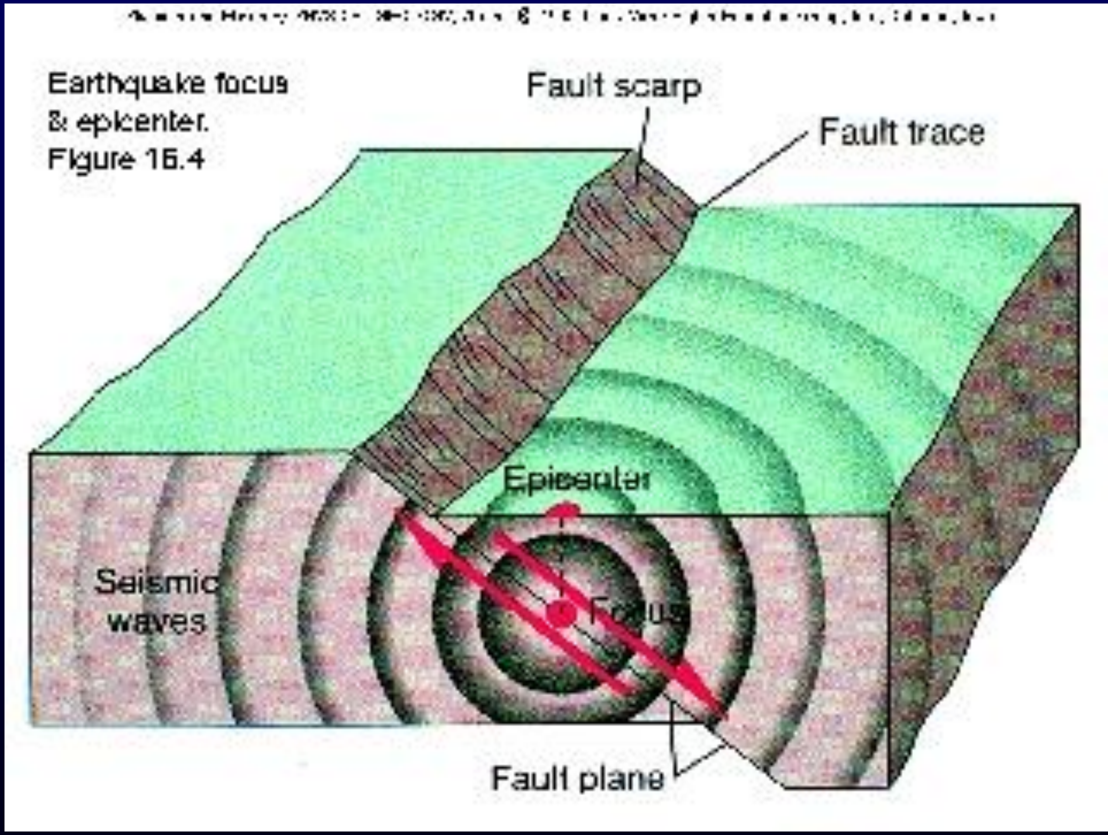
Hanging wall: rock body above the fault plane.

Footwall: rock body below the fault



Earthquake generation along a fault

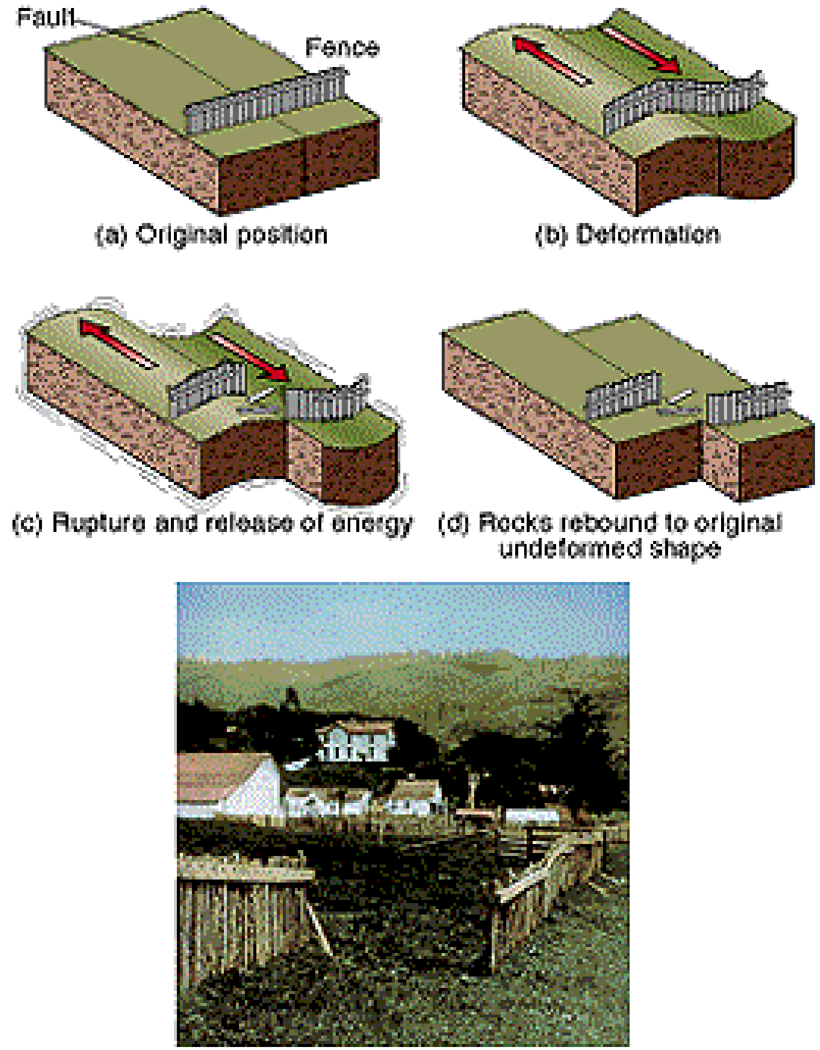
- The earthquake **focus** is its point of origin along a fault plane
- Its **epicenter** is the vertical projection of the focus to the surface



Elastic rebound theory

- Before fault rupture, rock deforms
- after rupture, rocks return to their original shape…
- …maybe[1]

- [1]Pallett Creek shows similar slip amounts after different periods of time; possibly not resetting to zero? See Sieh and Levay, 1998, p. 90



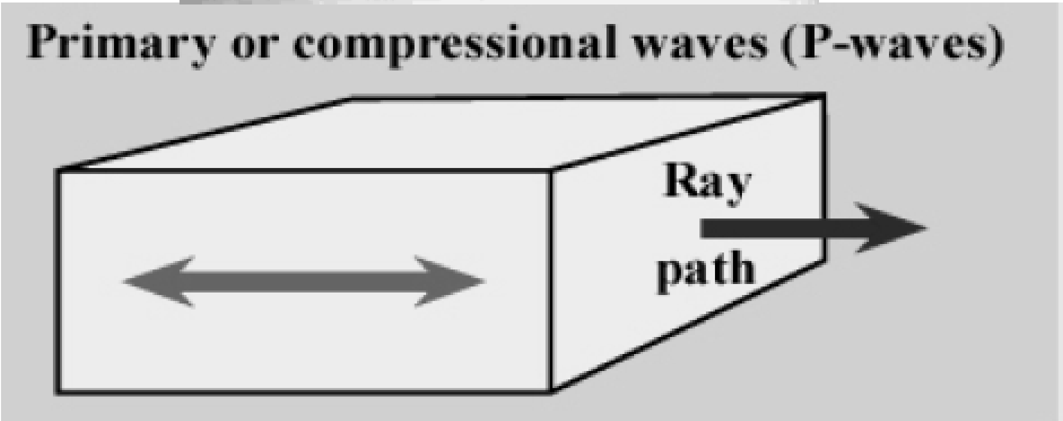
Types of Shockwaves

P-waves (primary waves)

Compress and relax rock through which they pass.

Pass through liquids and solids.

Highest velocity seismic waves.

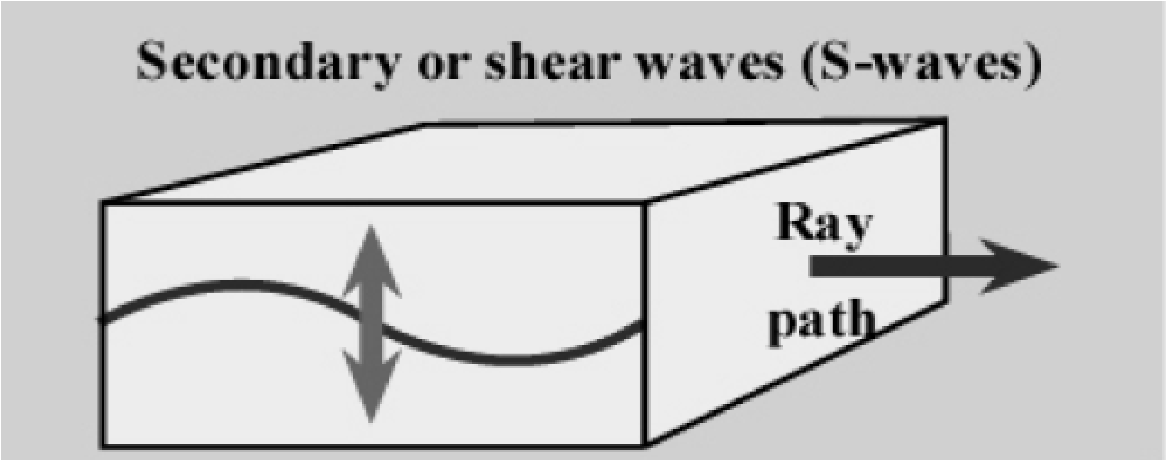


S-waves (secondary or shear waves)

Cause side to side motion of rocks through which they pass.

Velocity slower than P-waves.

Travel through solids, not fluids.



L-waves (surface waves)

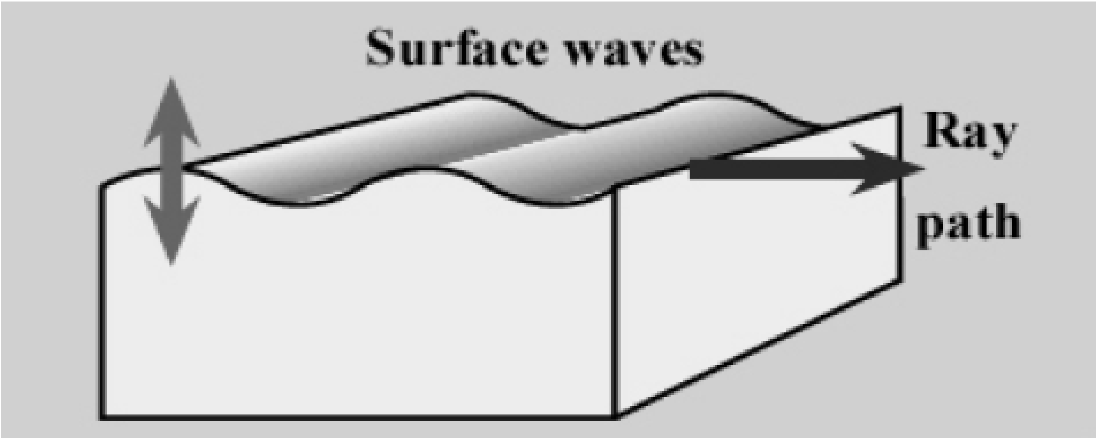
Travel along the surface like a water surface wave.

Slowest waves but most destructive.

Height up to > 0.5 m. Length up to > 8m.

Last for 3 to 4 minutes.

Due to the combination of P-waves and S-waves at the surface.



Seismic Wave Velocities

V_P=primary wave velocity.

$$Vp = \sqrt{\frac{K + \frac{4}{3}n}{d}}$$

K **is the bulk modulus (incompressibility of the medium),** ***n*** **is the rigidity, and** ***d*** **is the density of the medium.**

V_S=secondary wave velocity.

$$Vs = \sqrt{\frac{n}{d}}$$

In a fluid n=0, therefore V_S=0: secondary waves do not pass through fluids.

Typical seismic wave velocities:

Crust	**P-waves**	**<8 km/s**
	S-waves	**<4.5 km/s**
Mantle	**P-waves**	**8-13.6 km/s**
	S-waves	**4.5-7 km/s**

Intensity and Magnitude of Earthquakes

Intensity: a measure of the effect.
Depends on energy released, distance from epicentre, type of bedrock.

Magnitude: measure of the energy released.

Mercalli Intensity Scale

Based on an estimate of the damage caused by an earthquake.

Maximum at the epicentre, decreasing with distance from it.

Modified Mercalli Scale of Earthquake Intensity

I. Instrumental	Detected only by seismographs
II. Feeble	Noticed only by sensitive people.
III. Slight	Resembling vibrations caused by heavy traffic.
IV. Moderate	Felt by people walking; rocking of free standing objects.
V. Rather strong	Sleepers awakened and bells ring.
VI. Strong	Trees sway, some damage from overturning and falling objects.
VII. Very strong	General alarm, cracking of walls.
VIII. Destructive	Chimneys fall and there is some damage to buildings.
IX. Ruinous	Ground begins to crack, houses begin to collapse and pipes break.
X.Disastrous	Ground badly cracked and many buildings are destroyed. There are some landslides.
XI.Very Disastrous	Few buildings remain standing; bridges and railways destroyed; water, gas, electricity and telephones out of action.
XII.Catastrophic	Total destruction; objects are thrown into the air,much heaving, shaking and distortion of the ground.

Richter Scale

Based on the amplitude of seismic waves measured on a seismograph, corrected for distance from the epicentre.

Proportional to the amount of energy released at the focus.

Value does not vary with distance from epicentre.

Logarithmic: a 1 unit increase in the scale represents an increase in energy release by a factor of 31.

Magnitude (Richter Scale)	Approximate Maximum Intensity	Number Per Year	Approx. energy release (Kg of TNT equivalents).
1		2,900,000	20
2	II	360,000	600
3		49,000	20,000
4	III	6,200	600,000
5	VI	800	20,000,000
6	VII	120	600,000,000
7	X	18	20 billion
8	XII	1	60 billion
9		Decades apart	20 trillion

Richter magnitudes

- The Richter magnitude measures the **<u>maximum amplitude</u>** of ground shaking
- It is a logarithmic scale
- 1 Richter unit difference is x 10 for ground motion and x 33 for energy

- Globally, small earthquakes are more frequent than large:
- ~800,000/yr for events of magnitude 2.0-3.4
- while an event of magnitude 8 occurs once every 5-10 years

Richter magnitudes

Earthquake Magnitude Scale

Magnitude	**Earthquake Effects**	**Estimated Number Each Year<B/>**
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years

Destructiveness of an earthquake

- Earthquake magnitude
- Distance to epicenter
- Depth
- Strength of building
- Nature of soil or bedrock on which foundations are built
- Other local conditions

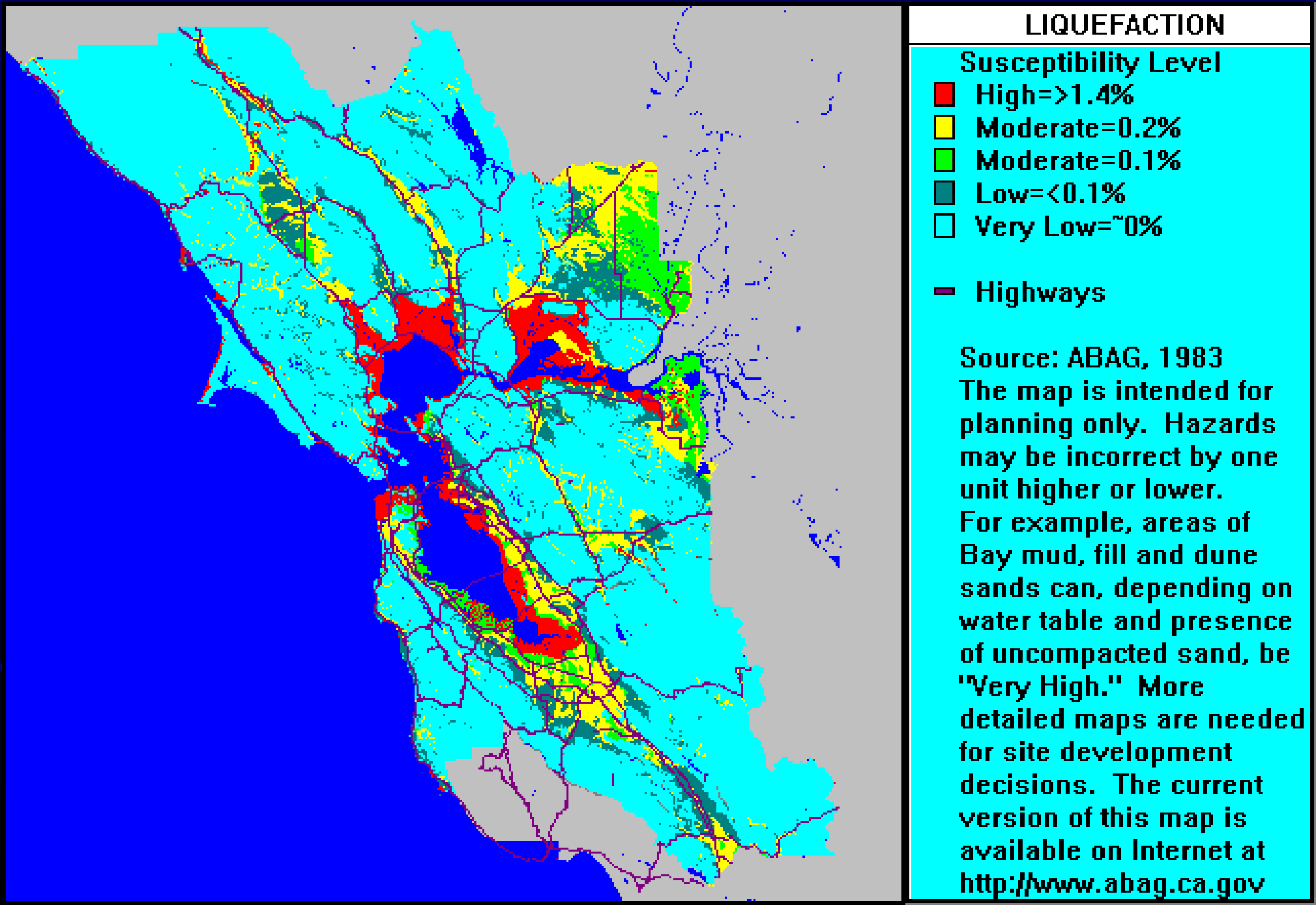
Effects of earthquakes: aftershocks

- **Aftershocks** normally occur after a major earthquake
- There may be many thousands of aftershock events over the space of **months or even years**
- Although their magnitudes generally decrease with time, aftershocks have potential to cause **significant damage to already weakened materials** (e.g., rocks, soils, buildings, power and gas lines)

Effects: liquefaction

- Wet, unsolidated soils and sediments are highly vulnerable
- Under shaking, the ground simply **flows**
- Landfills, harbours, and the like are at risk

Liquefaction hazard in the San Francisco Bay area



Effects: landslides

- The ground vibrations and severe shaking associated with an earthquake can induce **landslides** in mountainous areas

- This example in the Santa Susana Mtns. was caused by the 1994 Northridge event near Los Angeles

Effects: tsunamis

- **<u>Tsunamis</u>** are ocean waves caused by displacements from earthquakes, landslides, etc.
- They can be devastating at great distances from the epicenter

Tsunami damage in Hilo, Hawaii, as a result of the 22 May 1960 Chile earthquake

Effects: building destruction

- Buildings are damaged or destroyed by **ground vibrations and shaking**
- The **magnitude and duration** of shaking are important factors in the extent of damage
- **Liquefaction and aftershocks** increase the damage

Building damage near the epicenter of the 1989 Loma Prieta earthquake

Effects on building materials

- **Masonry** is not capable of withstanding significant bending stresses
- **Wood** is more resistant because it is more yielding
- But wood is vulnerable to **fires**...

Effects: fires

- The ground shaking will **rupture** power and gas lines…
- …and damage to water mains prevents or hinders fire fighting efforts
- the photo shows a broken gas line from the 1994 Northridge earthquake

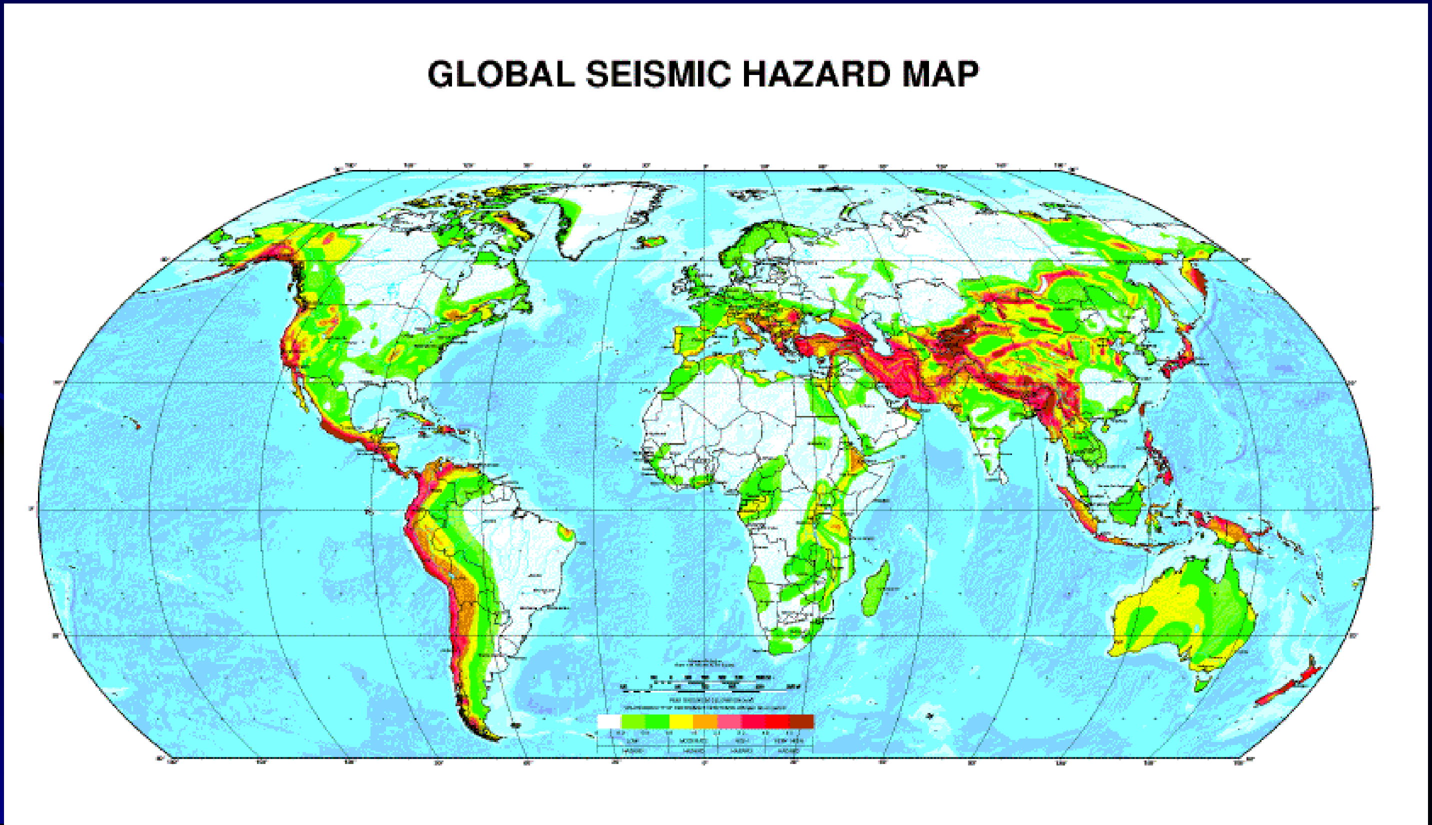
Devastating fires in San Francisco after the 1906 earthquake

Effects: personal loss

- We are examining earthquakes from a scientific perspective…
- …but we must not forget **<u>the human element and the pathos</u>** conveyed by this photograph from the 1994 Northridge earthquake

Mitigating earthquakes

- Seismic hazard maps and risk maps help to properly site and construct buildings



Where to build your dream or trophy house - and where not to build

- Avoid unstable soils and unconsolidated materials...
- avoid mountainous terrain prone to landslides…
- and above all, **<u>avoid active faults !</u>**

Appropriate building codes which can withstand earthquake damage

- Bedrock foundations best
- Avoid asymmetrical buildings
- Bolt house firmly to foundations
- Appliances firmly bolted down
- Gas lines flexible
- Cupboards, shelving attached to walls
- Heavy objects at low levels; anchor heavy furniture
- Beds away from windows to avoid broken glass

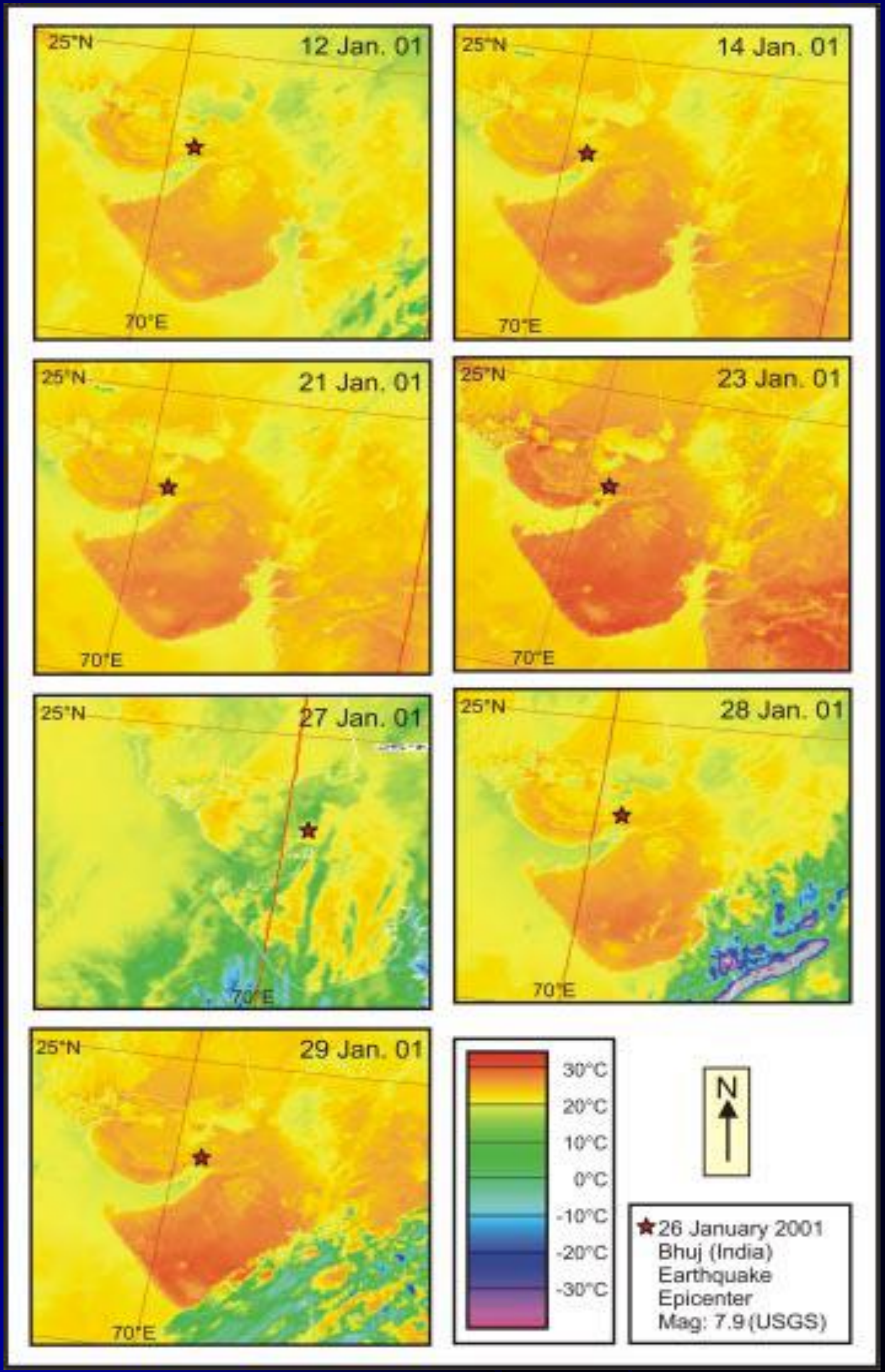
Warning and prediction

- Precursory seismicity
- Precursory deformation
- Changes in physical properties of rocks near a fault
- Changes in water levels, soil gases
- Unusual behaviour of animals

Earthquake prediction

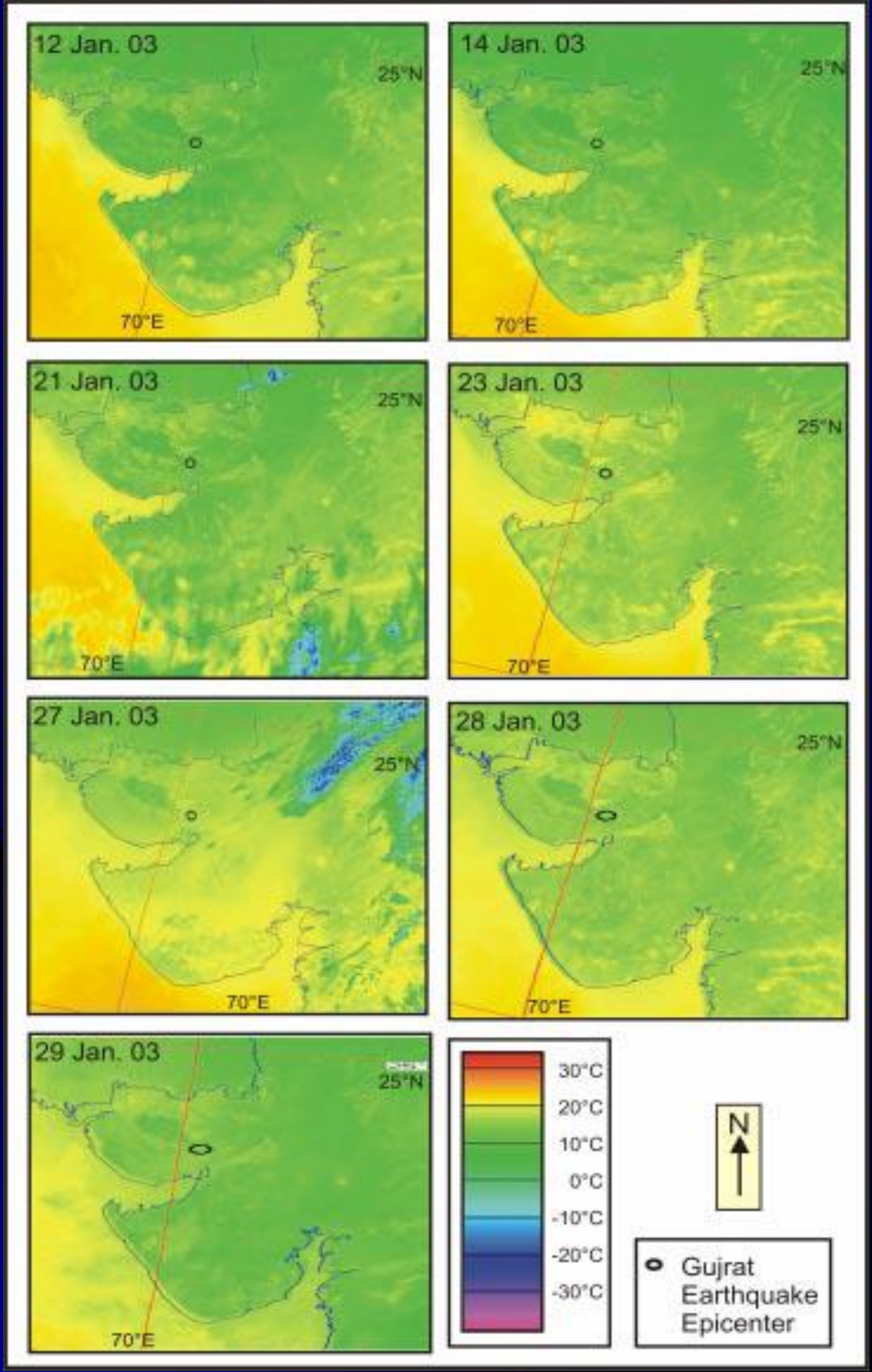
- Important concepts:
- earthquake recurrence interval…seismic gap
- role of paleoseismology

- Yet our predictive ability is **rudimentary**, so we use probabilities
- e.g., 86% probability that a destructive quake of M>7 will hit southern California in the next 30 years (1994 estimate)

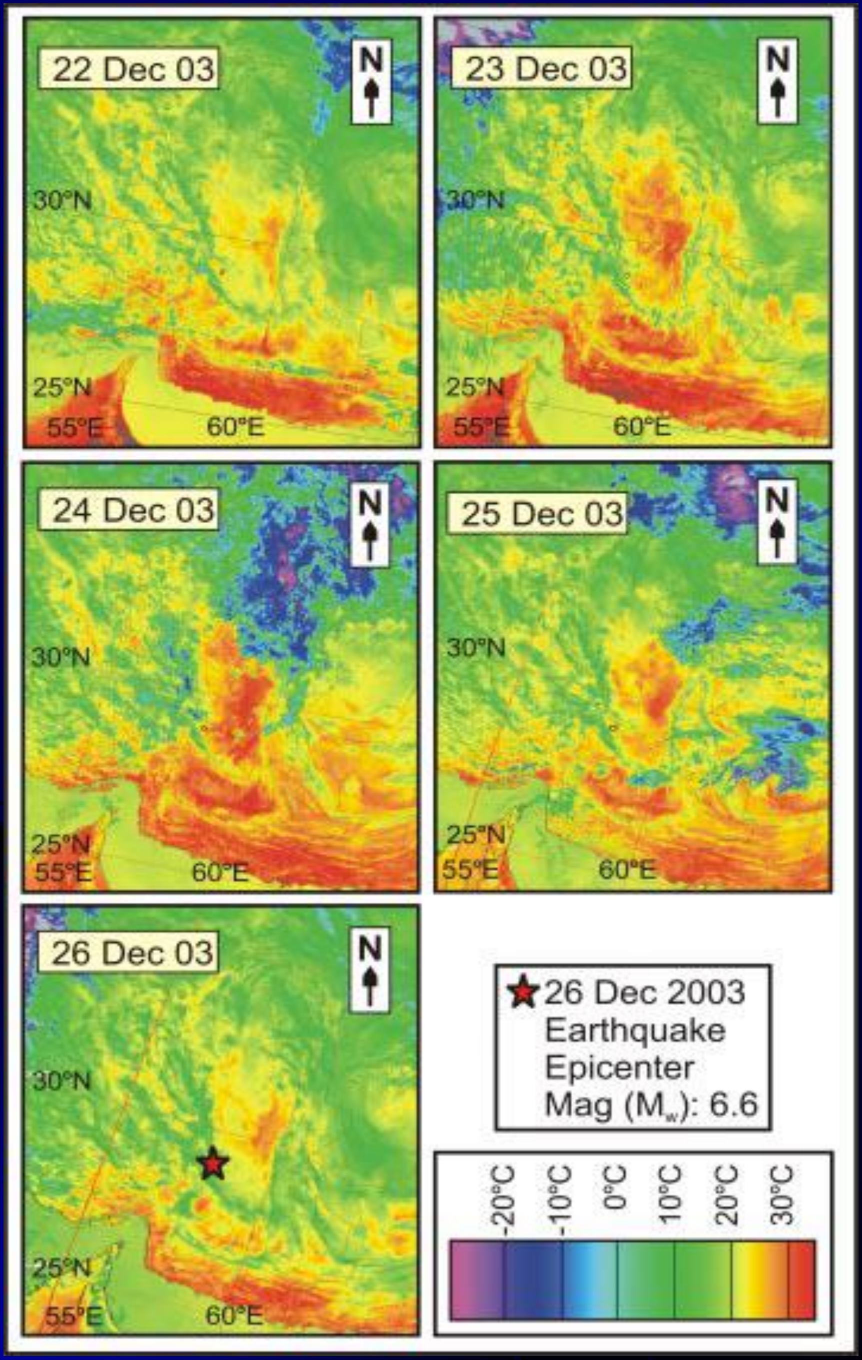


Time series Land Surface Temperature (LST) maps prior to the earthquake of 26 January 2001 in Bhuj, India. Thermal anomaly over the region appeared on 14 January 2001 and was seen to be maximum on 23 January 2001.

Thermal channel 4 of NOAA-AVHRR satellite data was used to calculate the LST of the study area



Land Surface Temperature (LST) maps of the year 2003 over Gujarat shows normal thermal scenario.



AVHRR-NOAA time series data show thermal anomaly before the 26 December 2003 BamEarthquake in
Iran. The maximum anomaly was seen on 24 December 2003, two days before the earthquake.

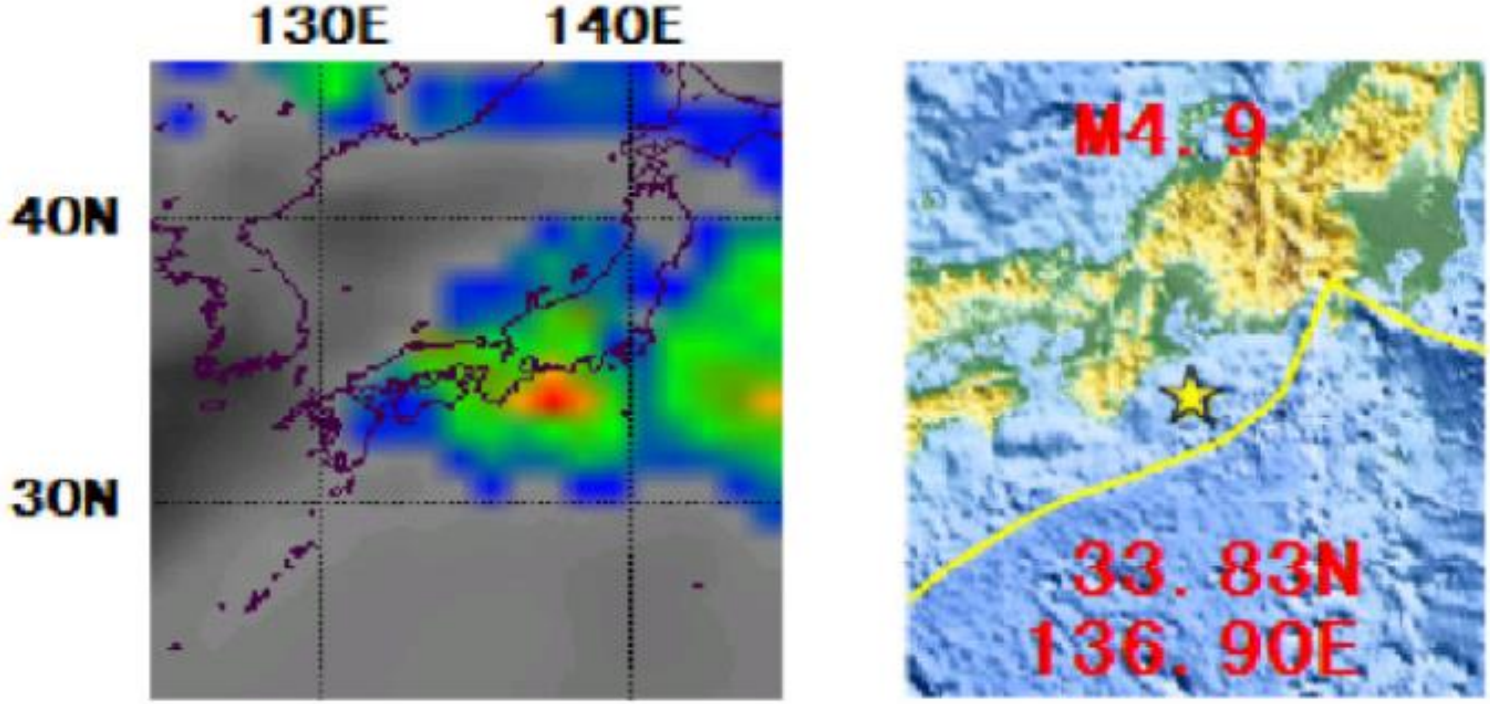


Figure 5. The location of M4.9 earthquake of Japan (USGS) and the temperature anomaly before this quake

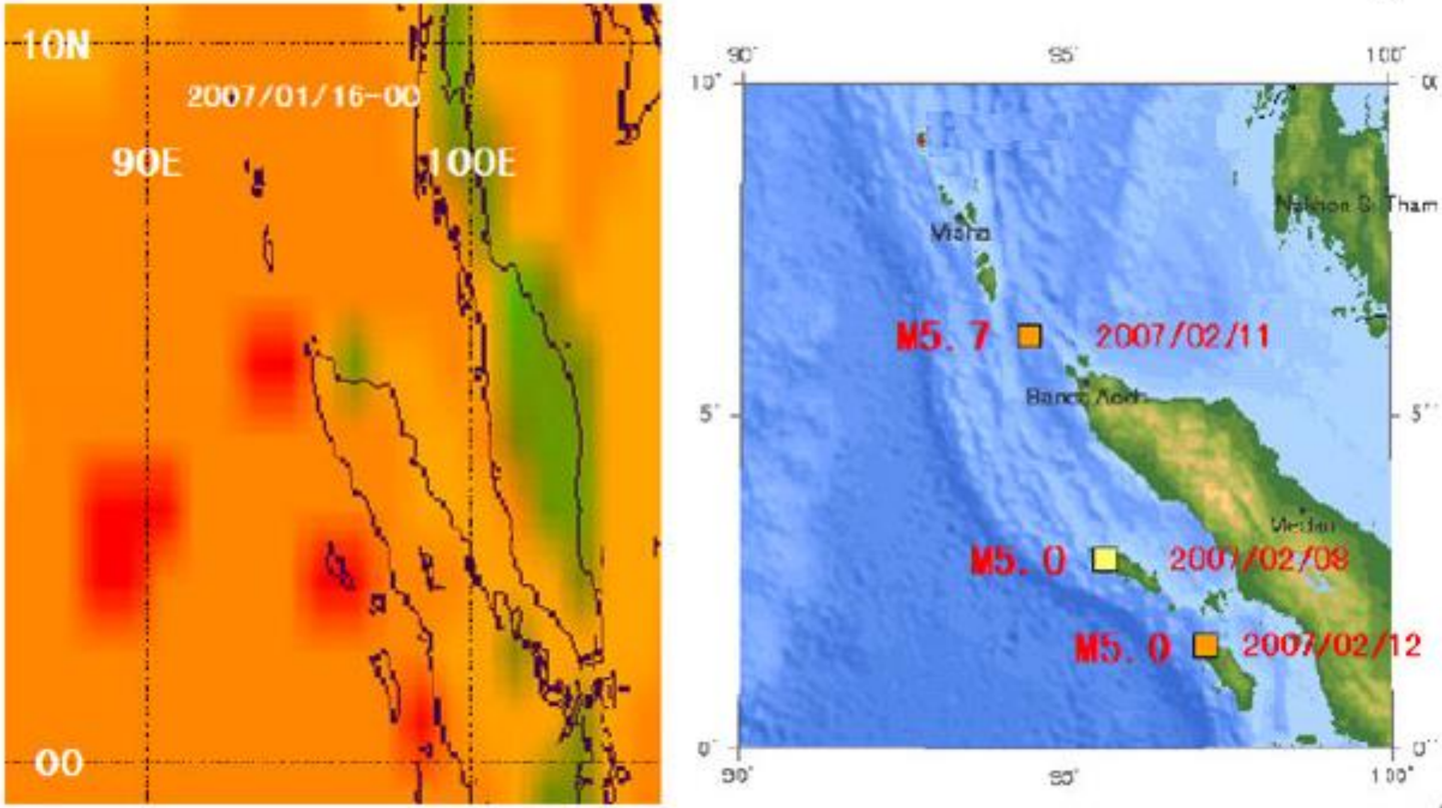


Figure 6. Three earthquakes around Sumantra and three temperature anomalies correspond to their epicenter espectively

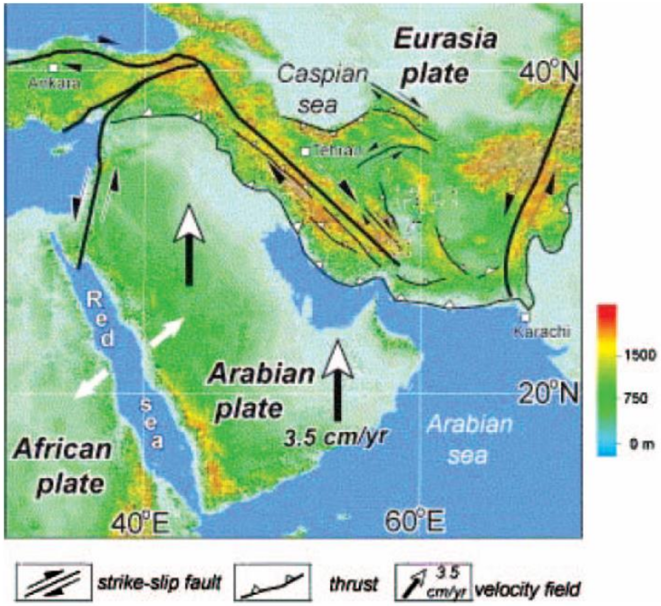


Figure 1. Sketch map of the Iran main fault.

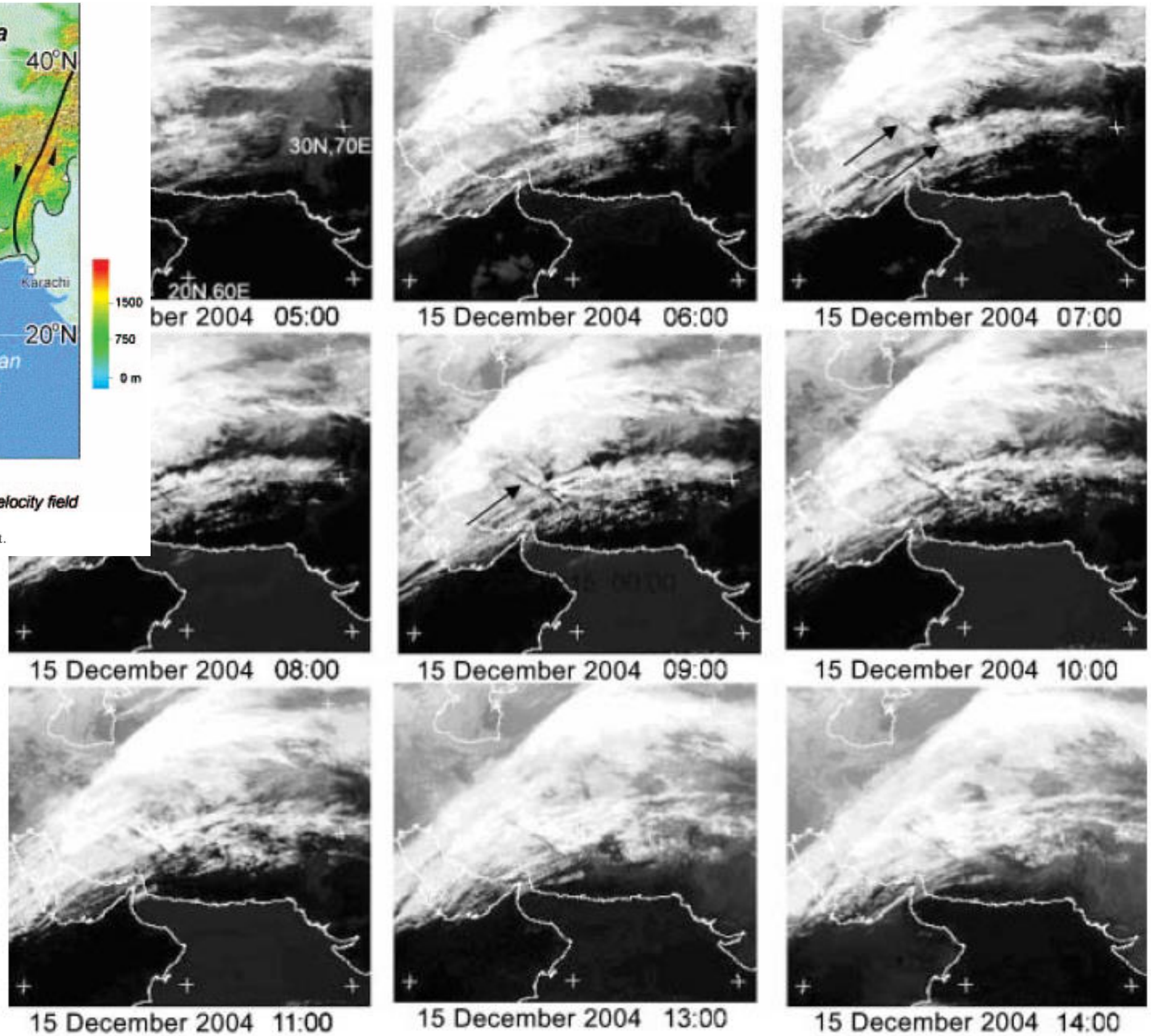


Figure 2. Cloud series images of Iran on 15 December 2004.

Cloud anomaly before Iran earthquake

Geoinformatics in

NEO-ACTIVE-SEISMOTECTONICS

<table>
<tr><th>ERA</th><th colspan="2">PERIOD</th><th>EPOCH</th></tr>
<tr><td rowspan="7"><u>Cenozoic Era</u>

"The Age of Mammals"

65 mya through today</td><td colspan="2" rowspan="2">Quaternary Period
"The Age of Man"
1.8 mya to today</td><td>Holocene
11,000 ya to today</td></tr>
<tr><td><u>Pleistocene</u>
The Last Ice Age
1.8-.011 mya</td></tr>
<tr><td rowspan="5">Tertiary Period
65 to 1.8 mya</td><td rowspan="2">Neogene
24-1.8 mya</td><td>Pliocene
5-1.8 mya</td></tr>
<tr><td>Miocene
24-5 mya</td></tr>
<tr><td rowspan="3">Paleogene
65-24 mya</td><td>Oligocene
38-24 mya</td></tr>
<tr><td>Eocene
54-38 mya</td></tr>
<tr><td>Paleocene
65-54 mya</td></tr>
</table>

Neotectonics, a subdiscipline of tectonics, involves the study of the motions and deformations of the Earth's (geological and geomorphological processes) which are current or recent in geologic time.

Vladimir Obruchev coined the term *neotectonics* in his 1948 article, defining the field as "recent tectonic movements occurred in the upper part of Tertiary (Neogene) and in the Quaternary, which played an essential role in the origin of the contemporary topography".

Since then geologists have disagreed as to how far back to date "geologically recent" time, with the common meaning being that neotectonics is the youngest, not yet finished stage in Earth tectonics.

Some authors consider neotectonics to be basically synonymous with "active tectonics", while others date the start of the neotectonic period from the middle Miocene. A general agreement has started to emerge that the actual time-frame may be individual for each geological environment and it must be set back in time sufficiently far to fully understand the current tectonic activity.

The Center for Neotectonic Studies at the University of Nevada, Reno[5] defines neotectonics as

“The study of geologically recent motions of the Earth's crust, particularly those produced by earthquakes, with the goals of understanding the physics of earthquake recurrence, the growth of mountains, and the seismic hazard embodied in these processes.

Neo - Active tectonic mapping

- Tectonic / Lineament Anomalies
- Tectano-Geomorphic Anomalies
- Fluvial /Riverine Geomorphic Anomalies
- Coastal Geomorphic Anomalies
- Geophysical Anomalies
- Earthquakes occurrences

TECTONIC / LINEAMENT ANOMALIES

- Fracture Swarms
- Radial Lineaments
- Curvilinear Lineaments
- Branch off Lineaments
- Lineament Maxima

Fracture Swarms

Indicating land arching

Fracture swarms are the bundles of closely packed sub parallel lineaments extending for considerable distances

Fracture Swarms

Indicating land arching

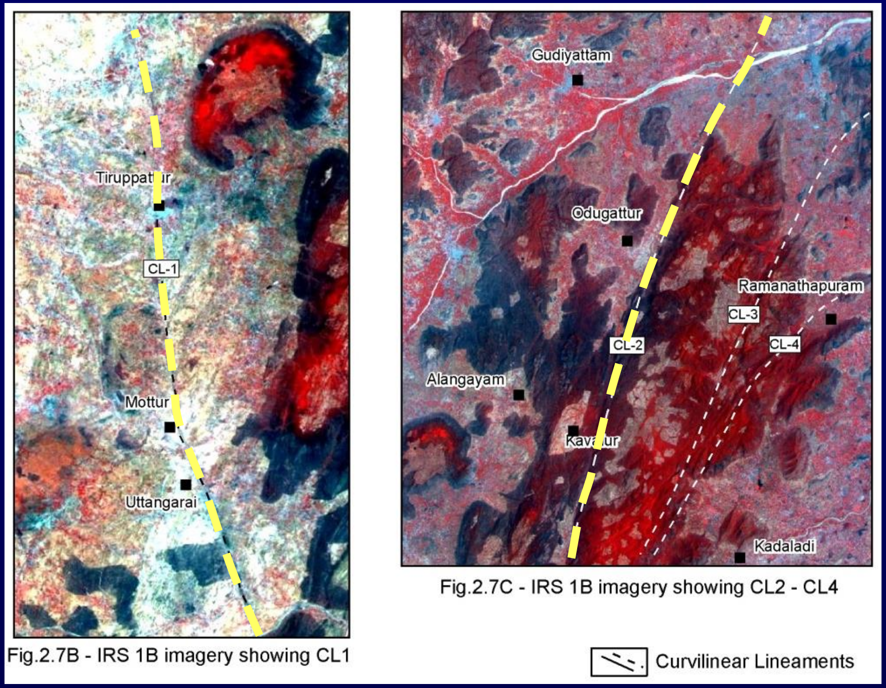


Fig.2.7B - IRS 1B imagery showing CL1

Fig.2.7C - IRS 1B imagery showing CL2 - CL4

Curvilinear Lineaments

Suggesting N-S compression

Lineaments in general will be rectilinear and on certain tectonic conditions they exhibit curvilinear manifestations too.

Curvilinear Lineaments

Suggesting N-S compression

Curvilinear Lineaments
Suggesting E-W Thrust Faults

Branch off Lineaments

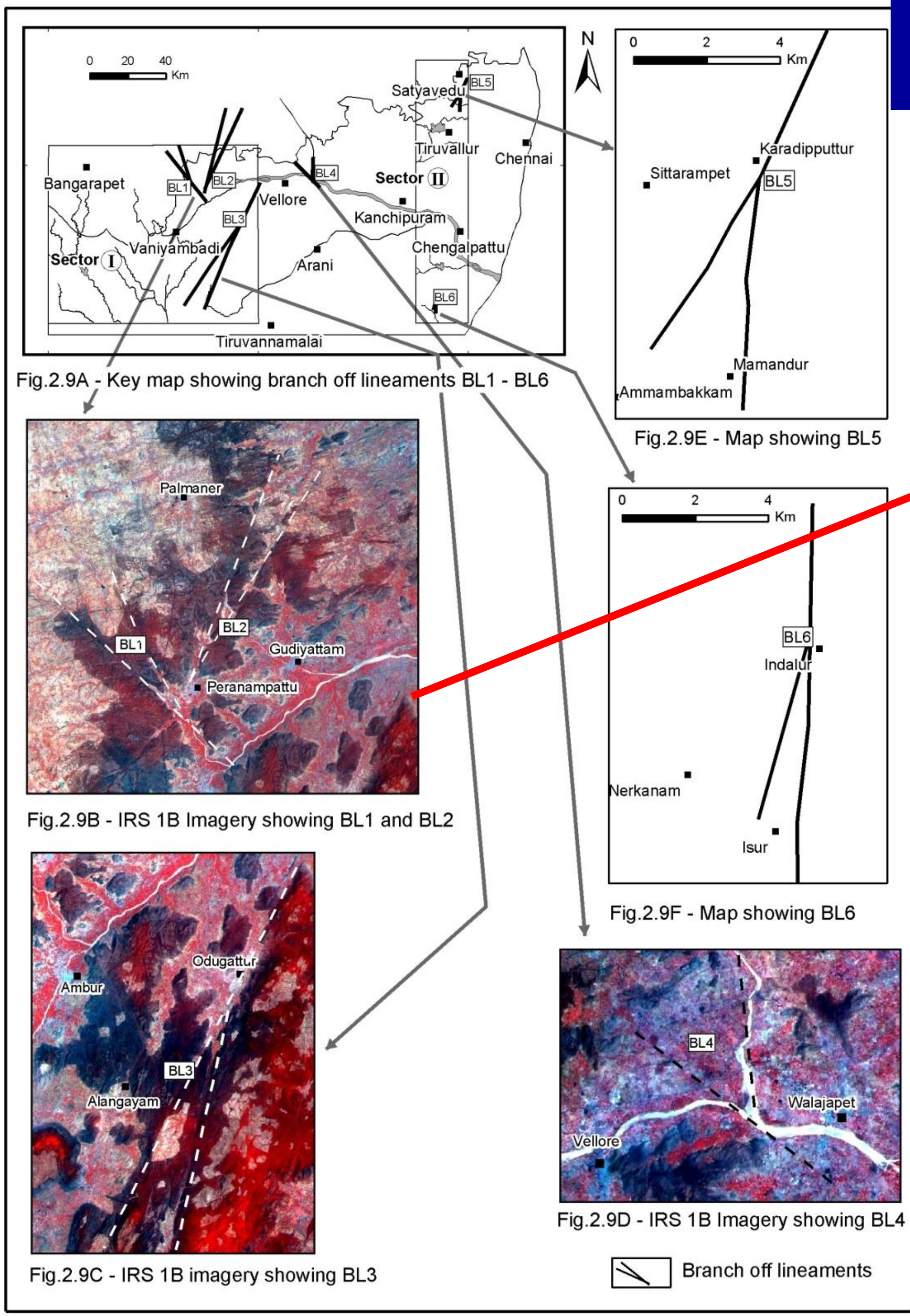
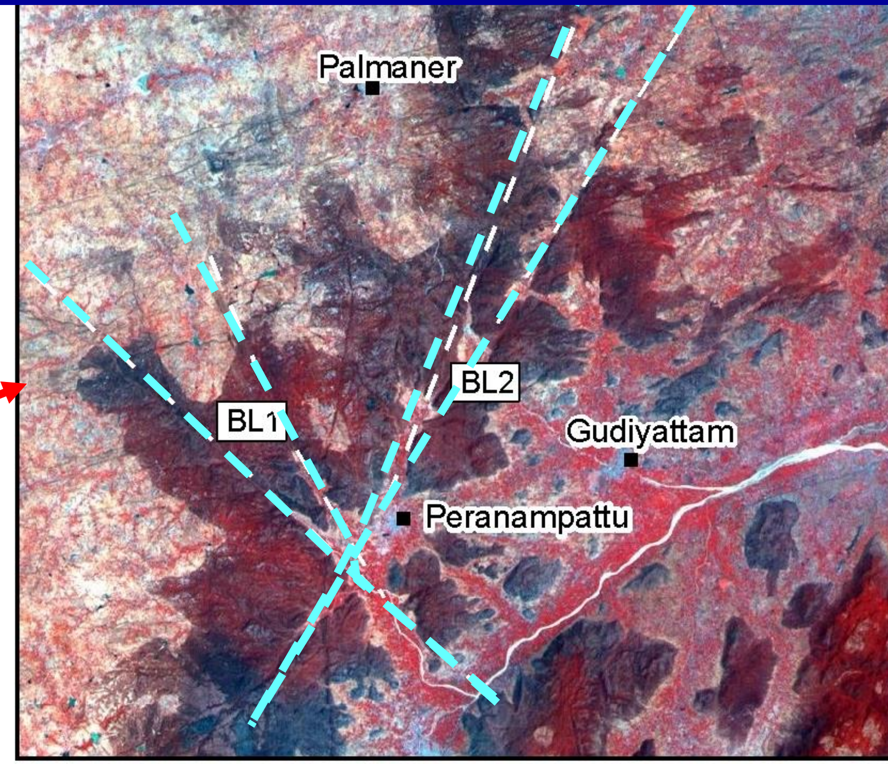


Fig.2.9 - Branch off lineaments



meeting or the branching off of the sub parallel lineaments at acute angles are called Branch off lineaments

Radial Lineaments
(probable diapirism)

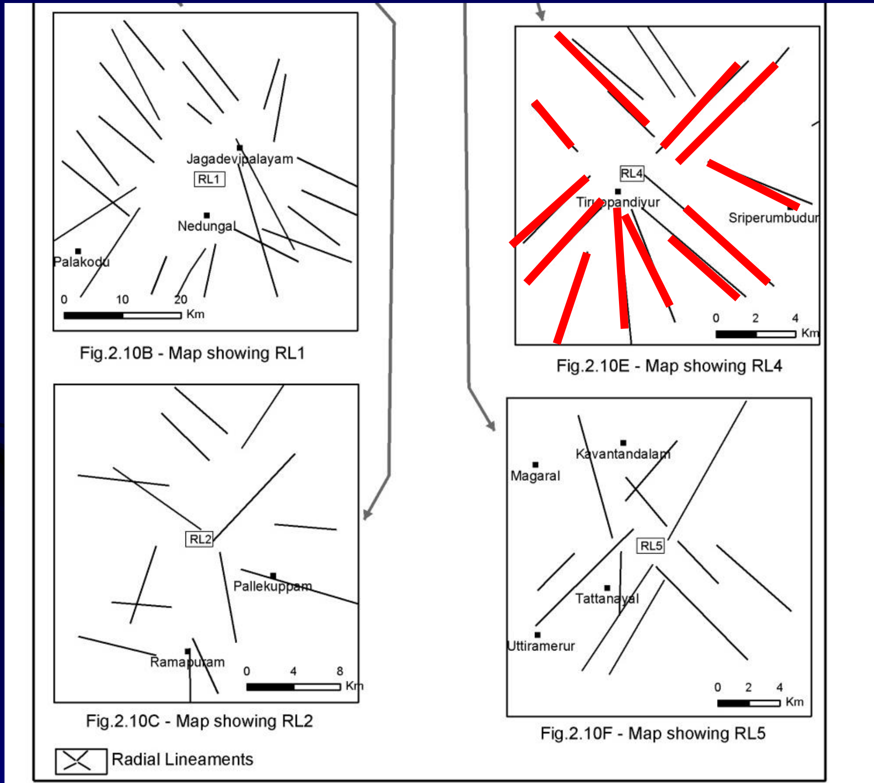


Fig. 2.10 - Radial Lineaments

If the lineaments are arranged in radial pattern is called radial lineaments

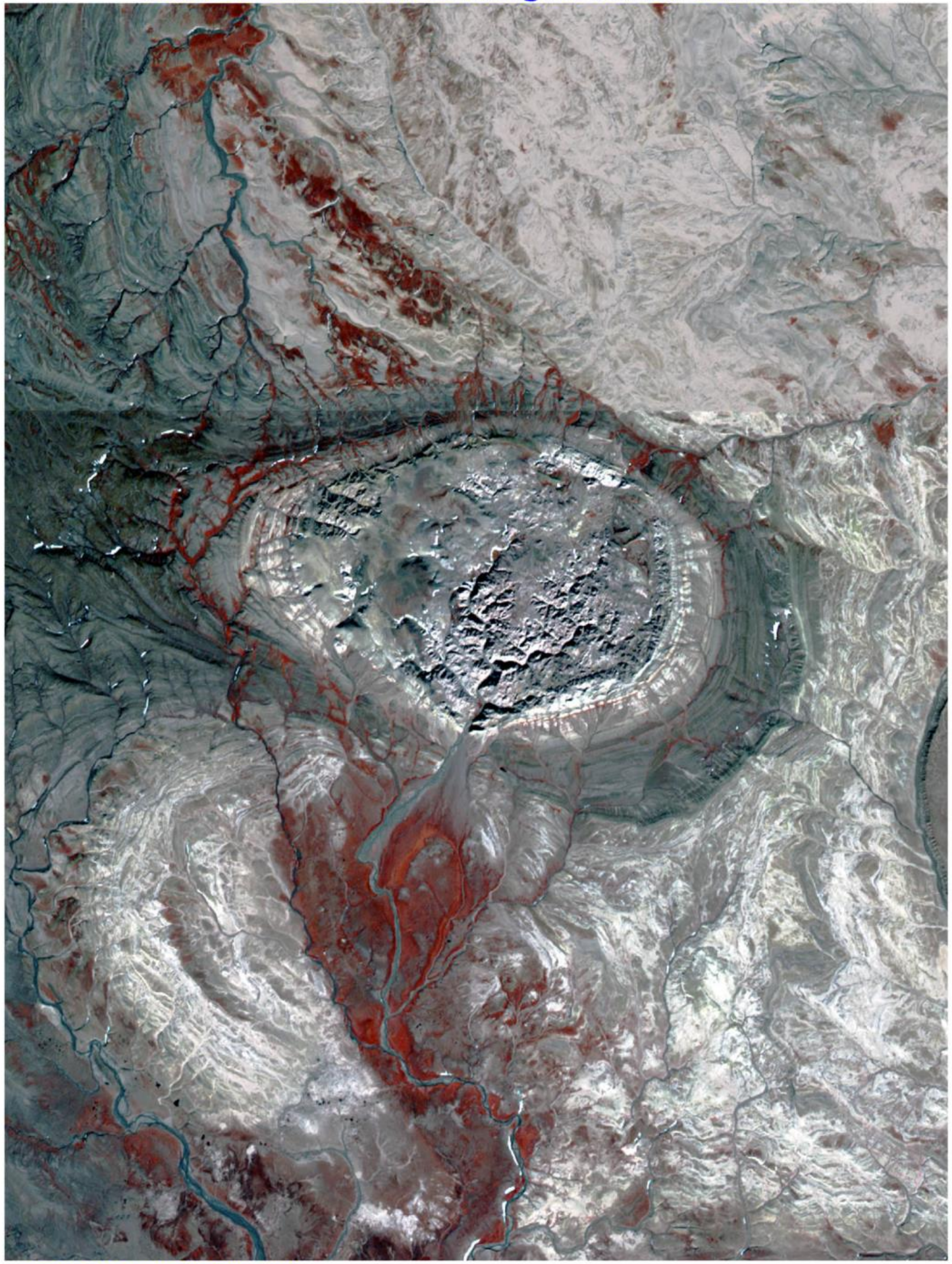
Radial lineaments or radial fractures are normally formed due to impacts of extraterrestrial objects like meteorites, diapheric intrusions (igneous or salt plugs), tectonic phenomena, etc.

Salt Dome

Low density
Buoyant
Diapirs

Surrounding sediments upwarped

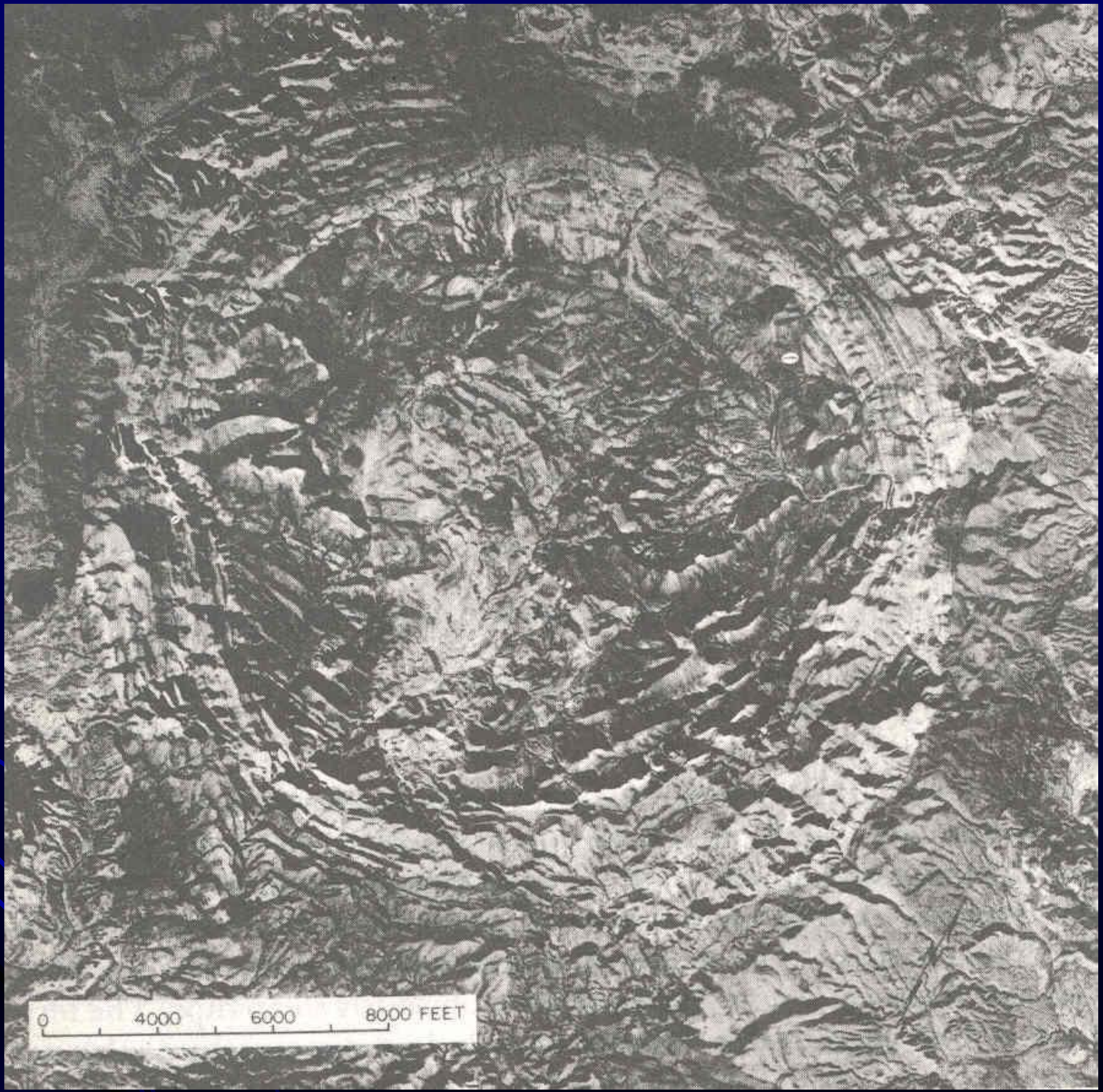
Isachsen Salt Dome, Ellef Ringnes Island, CANADA



ASTER/VNIR, RGB=321 (2000/07/29) METI/ERSDAC

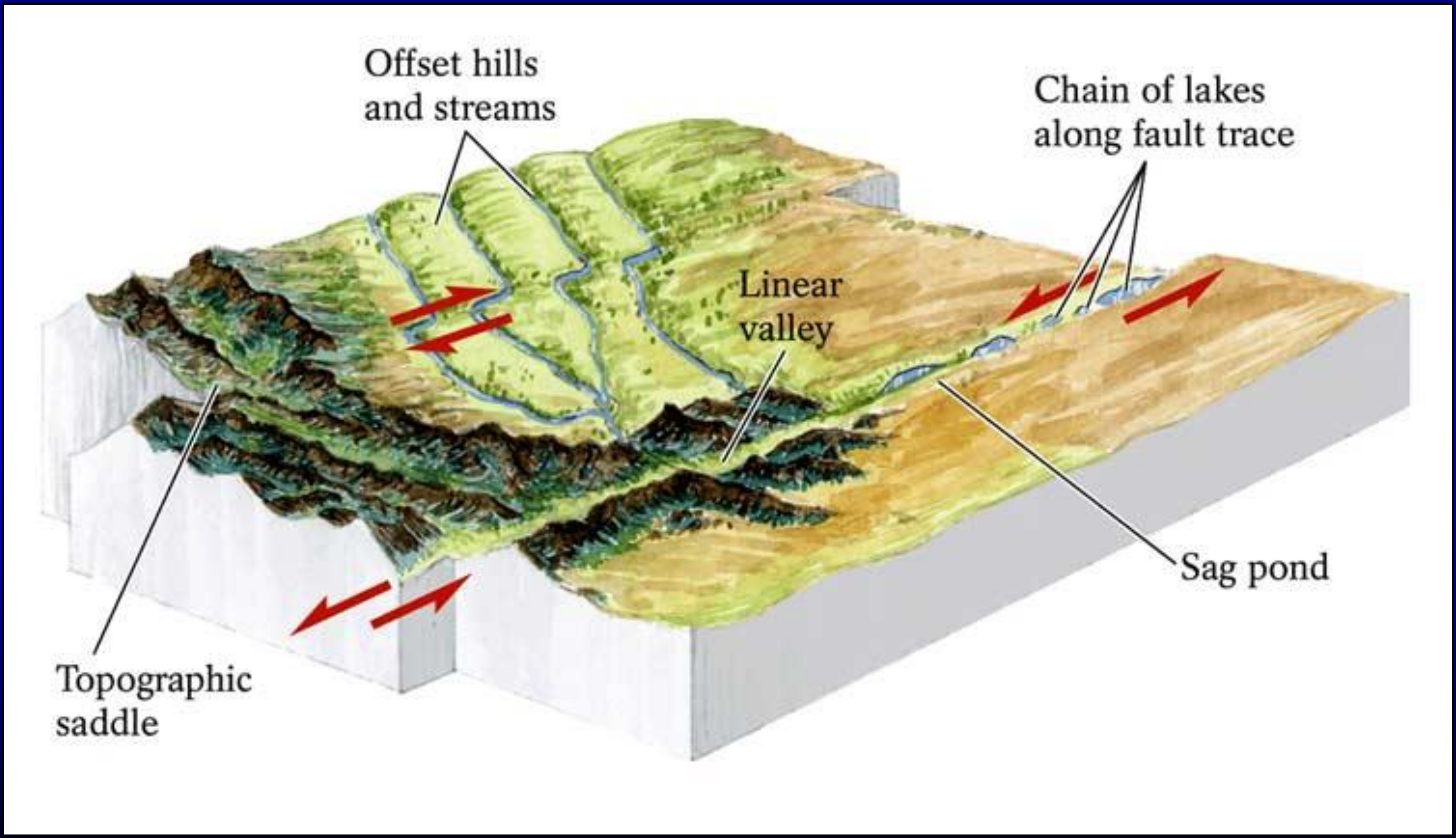
0 1 2 3 4 5 km

TEXAS



TECTANO GEOMORPHIC ANOMALIES

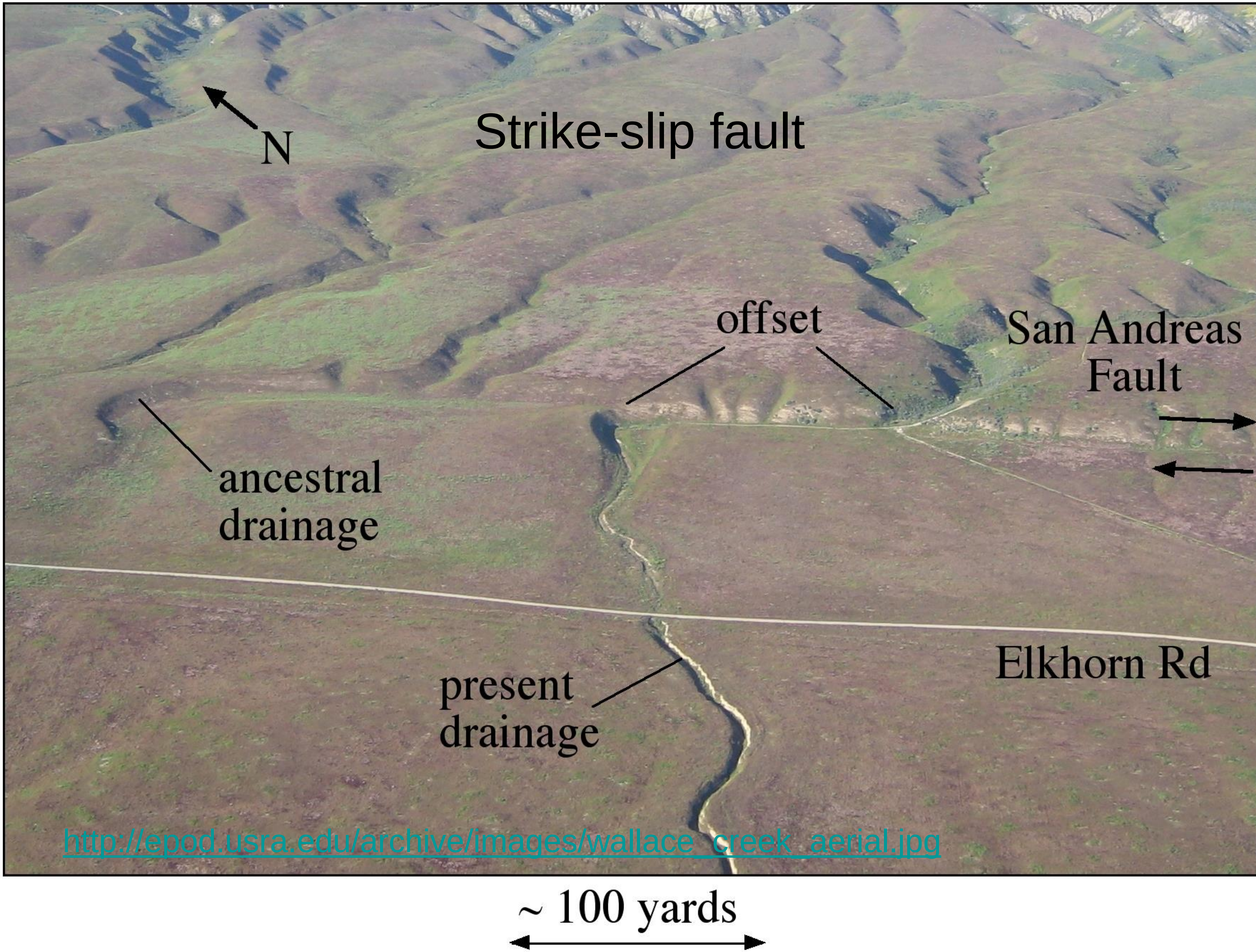
Horizontal Movement Along Strike-Slip Fault



Tectonic Landforms

Faults and Fault Landforms

The East African Rift Valley is a graben


Strike-slip fault
N
offset
San Andreas Fault
ancestral drainage
present drainage
Elkhorn Rd
http://epod.usra.edu/archive/images/wallace_creek_aerial.jpg
~ 100 yards

Landscape Shifting, Wallace Creek

San Andreas Fault

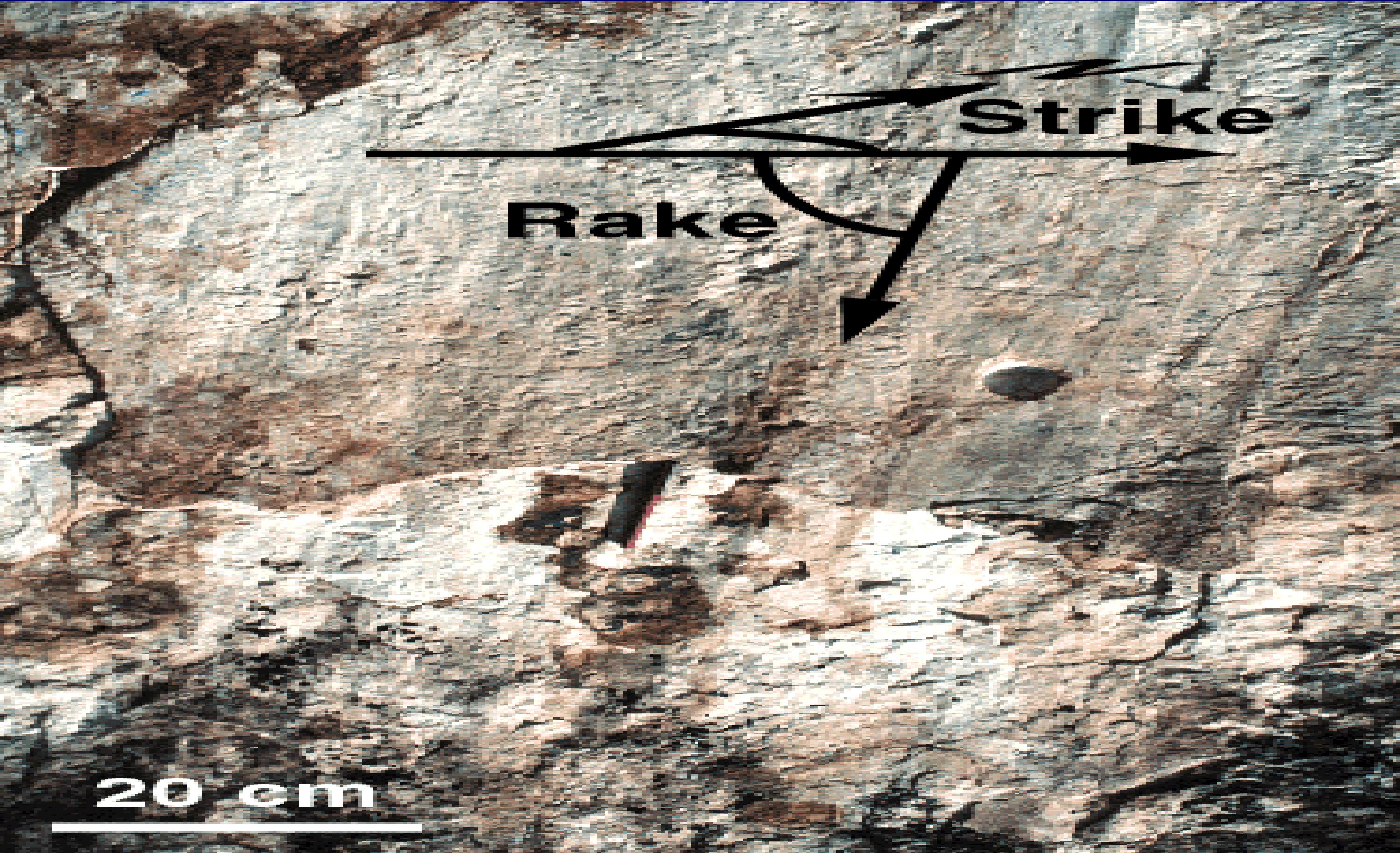
Reverse Fault Quake - Japan

Normal Fault Quake - Nevada

Strike Slip Fault Quake - California

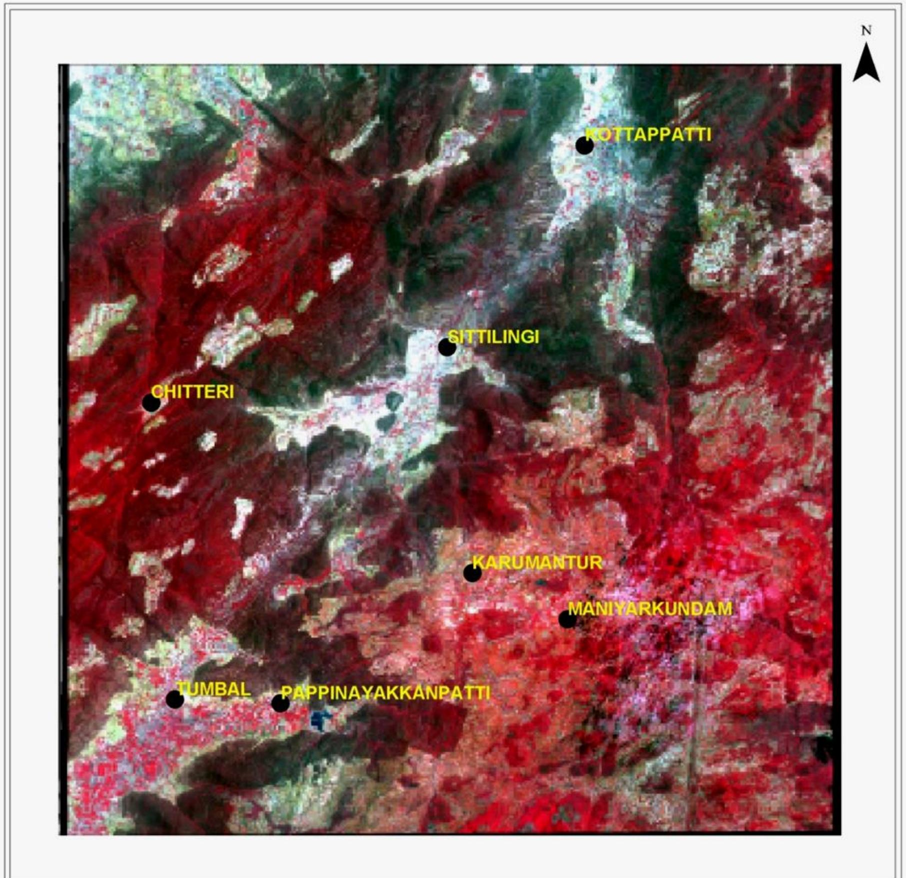
http://pangea.stanford.edu/~laurent/english/research/Slickensides.gif

Fracture Zones and Slickensides



IRS 1D FCC IMAGE (CHITTERI TEST SITE)

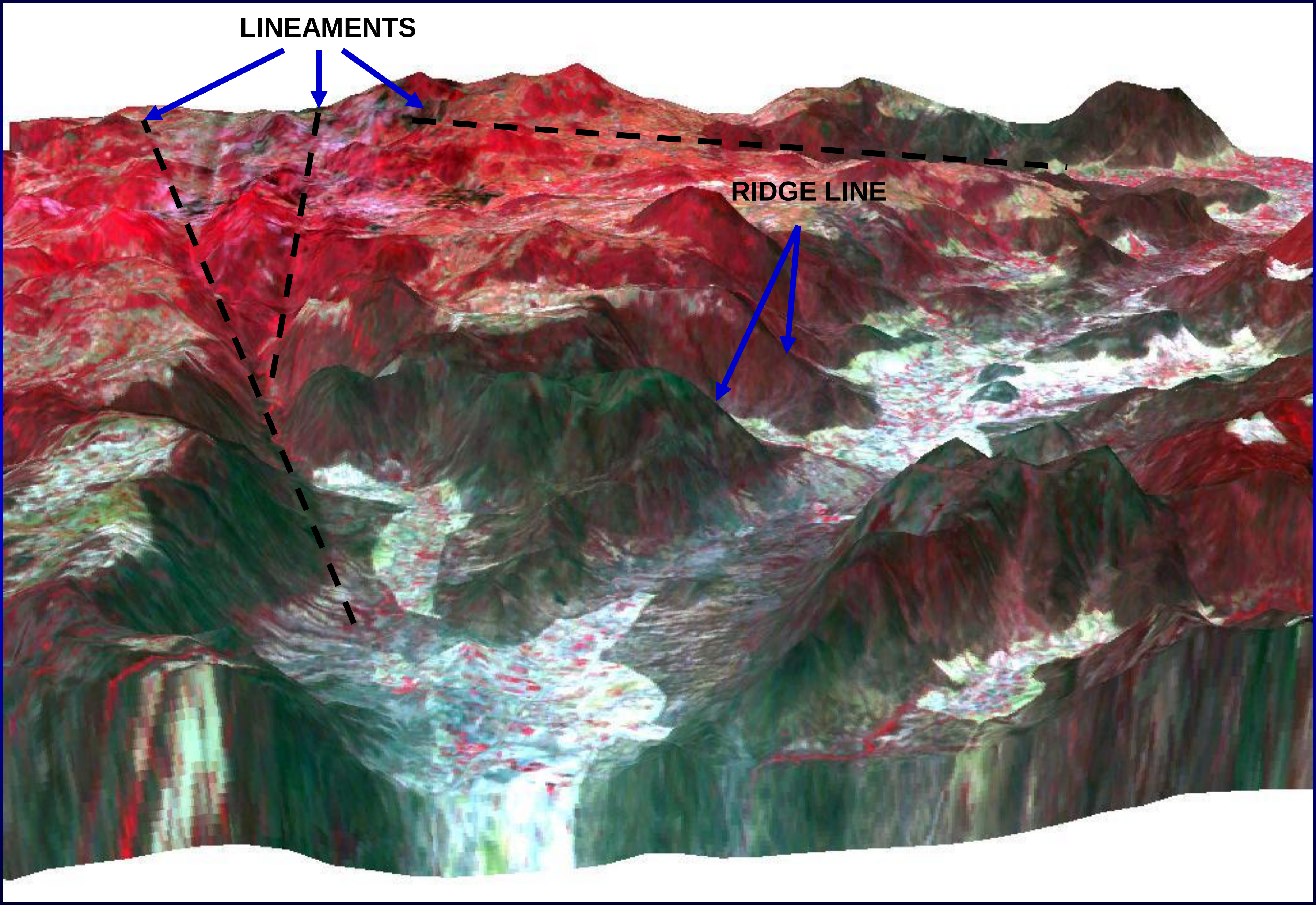
0 5 10 Km

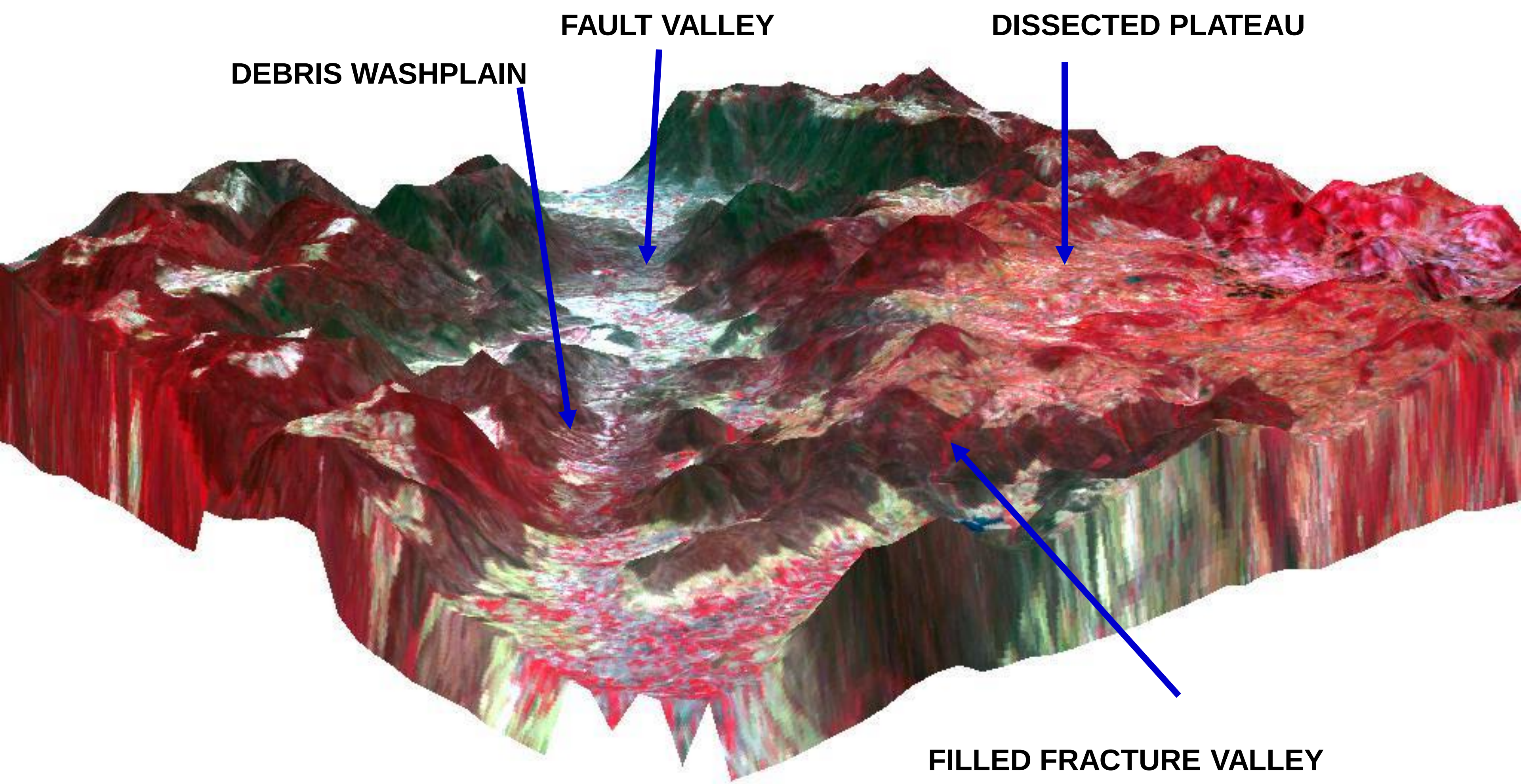


LEGEND

● SETTLEMENTS

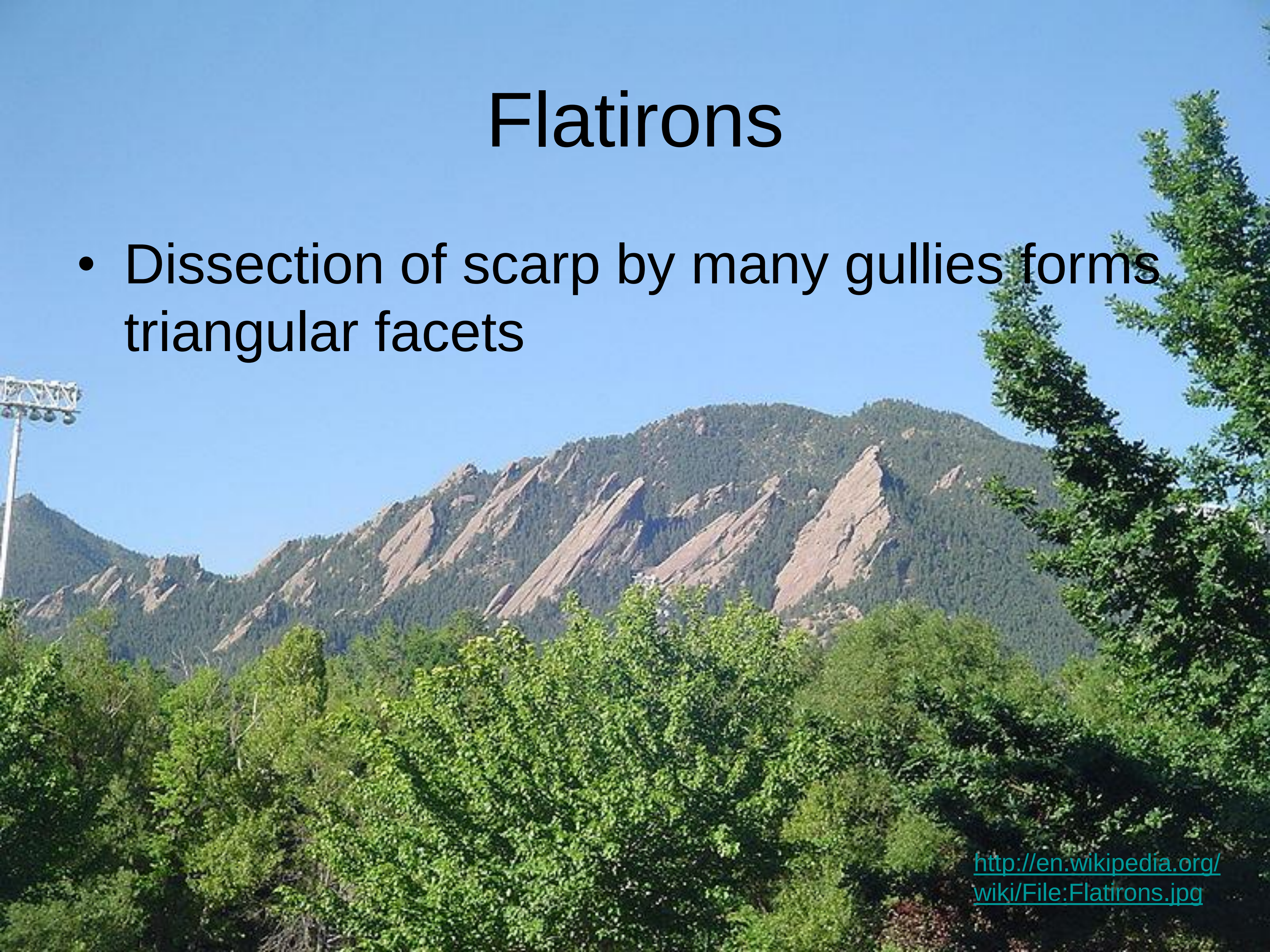
FIG.3


LINEAMENTS
RIDGE LINE


FAULT VALLEY
DISSECTED PLATEAU
DEBRIS WASHPLAIN
FILLED FRACTURE VALLEY

Flatirons

- Dissection of scarp by many gullies forms triangular facets



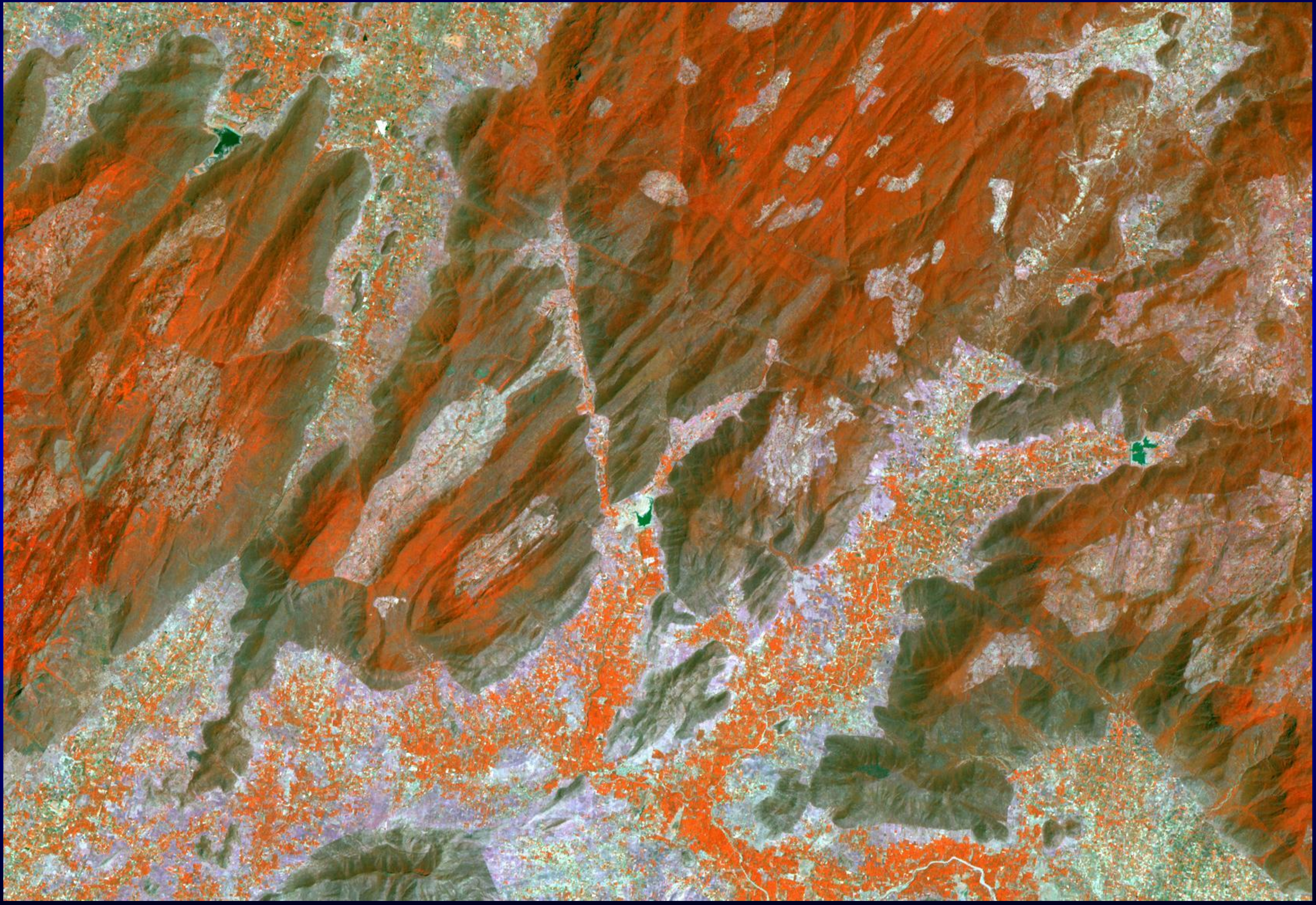
http://en.wikipedia.org/wiki/File:Flatirons.jpg

TRIANGULAR FACETS

(***Jagged, Cappadocia, Turkey***)

Northern Tibet: Triangular facets are fault scarps

BARREN FRACTUTRE VALLEY



DENUDO GEOMORPHIC ANOMALIES

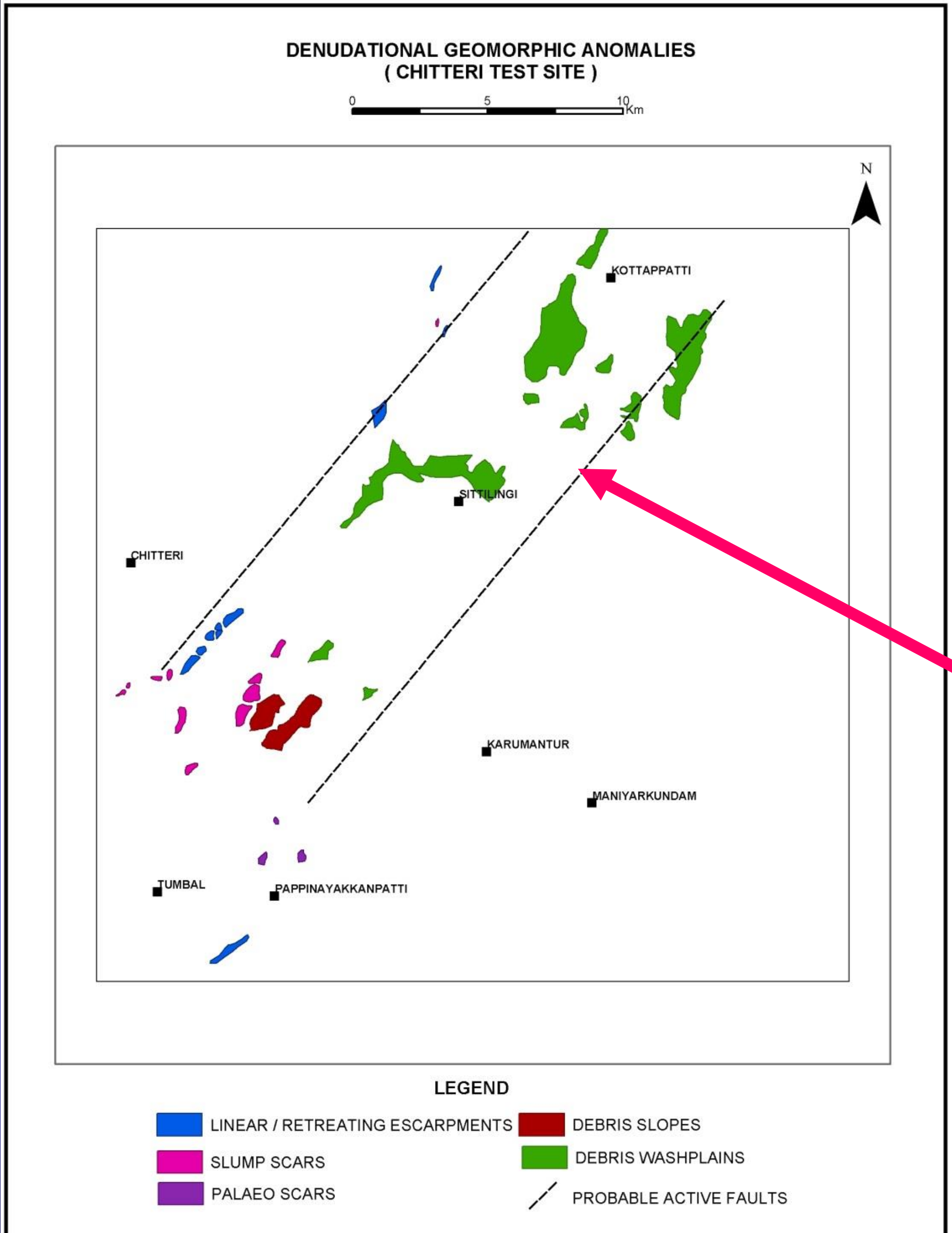
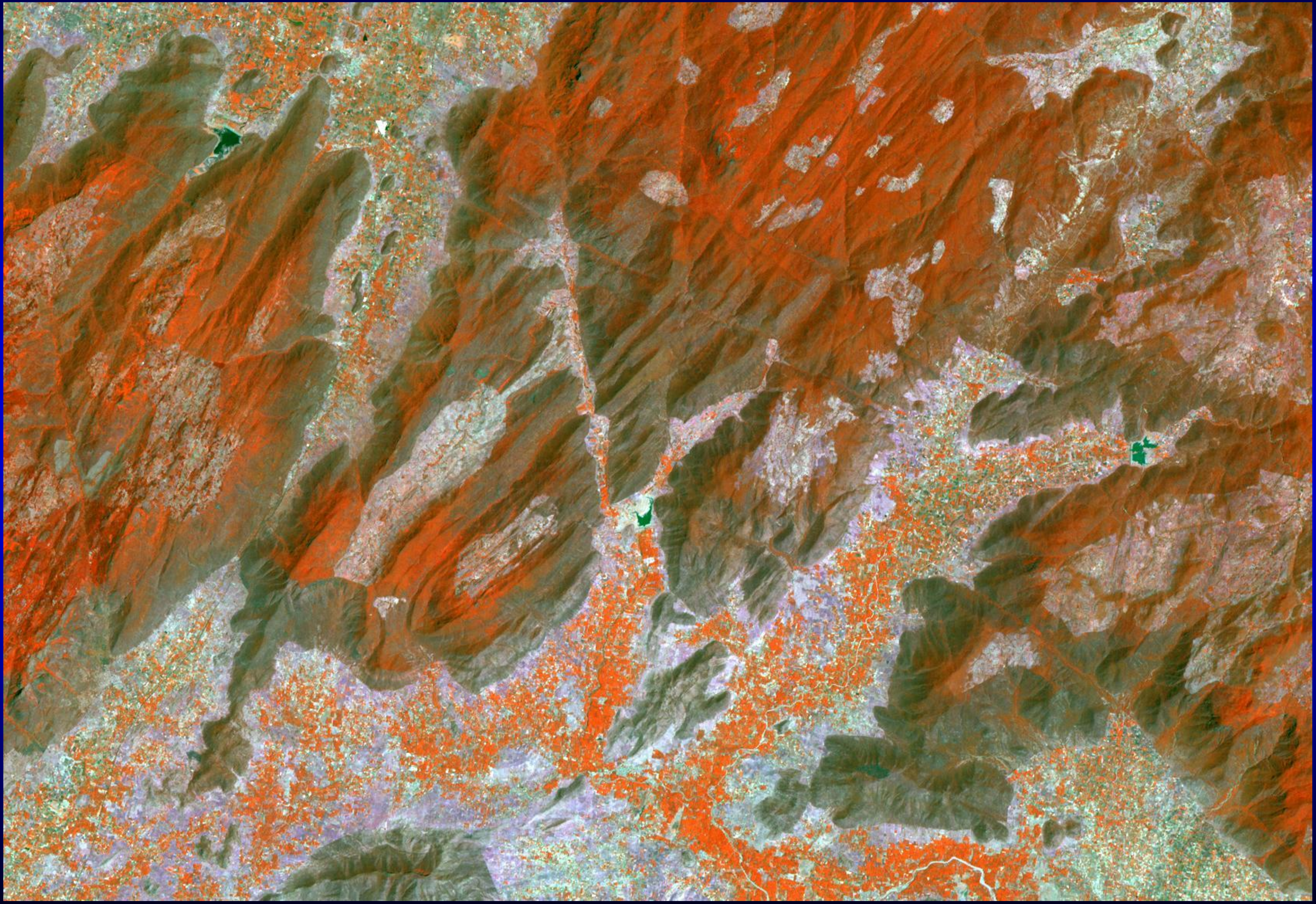


FIG.12

CONCENTRATION OF DENUDATIONAL GEOMORPHIC ANOMALIES IN NE- SW VALLEY

BARREN FRACTUTRE VALLEY



FLUVIAL ANOMALIES

Radial Drainages

- The radial drainages are the drainages that are radiating away in all directions from a central point or drainages converging from the periphery towards a central point.
- The former is called as centrifugal radial drainage and the latter as centripetal radial drainage.
- These have been invariably interpreted to be the indicators of recent tectonic movements unless otherwise these are controlled by the topographic features of erosion or the impact phenomenon.

Radial Drainages

Palaeochannels

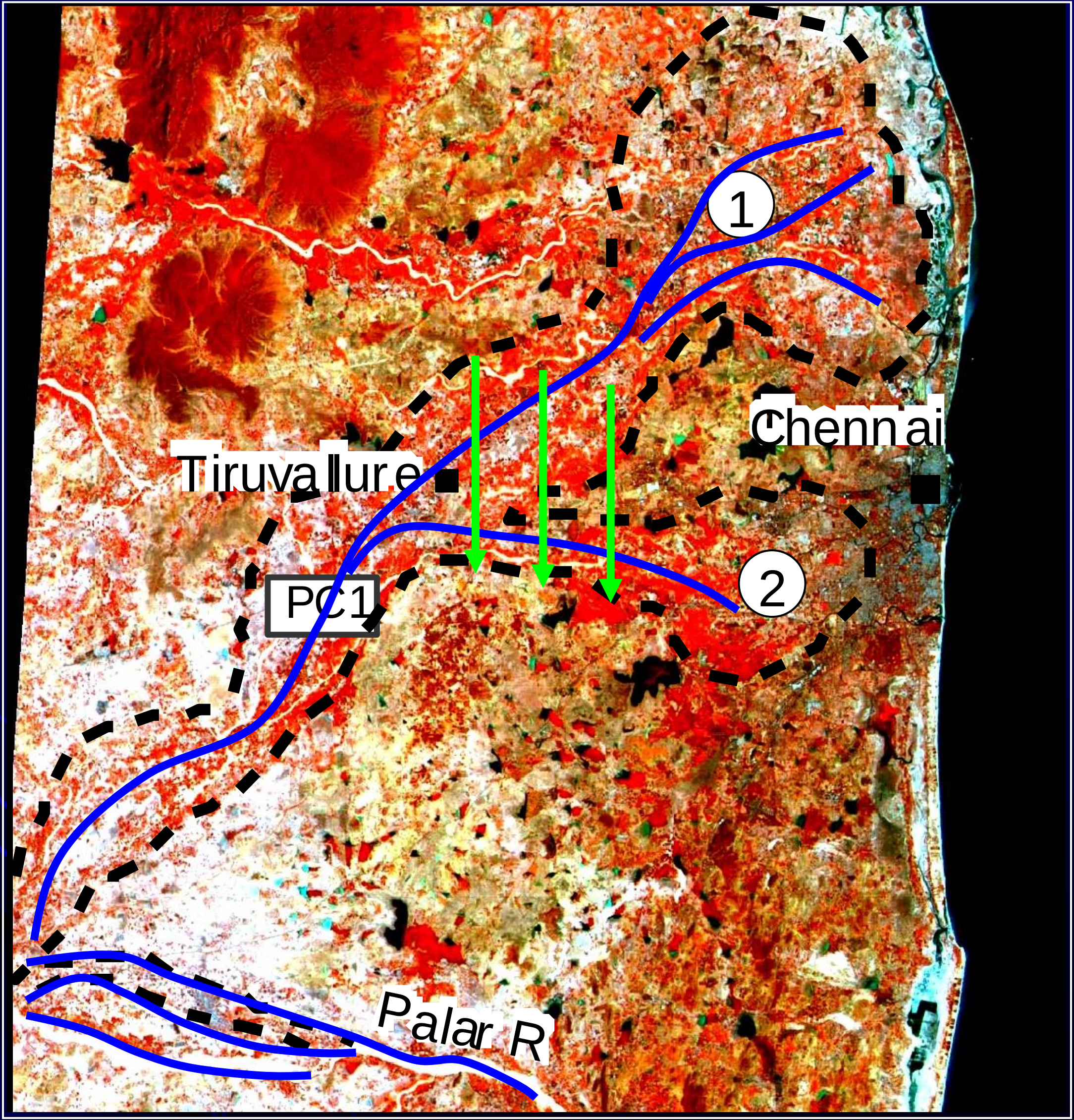
- The palaeochannels are the left out traces of the rivers. The occurrence of palaeochannels indicates that the river has left these traces and migrated away.

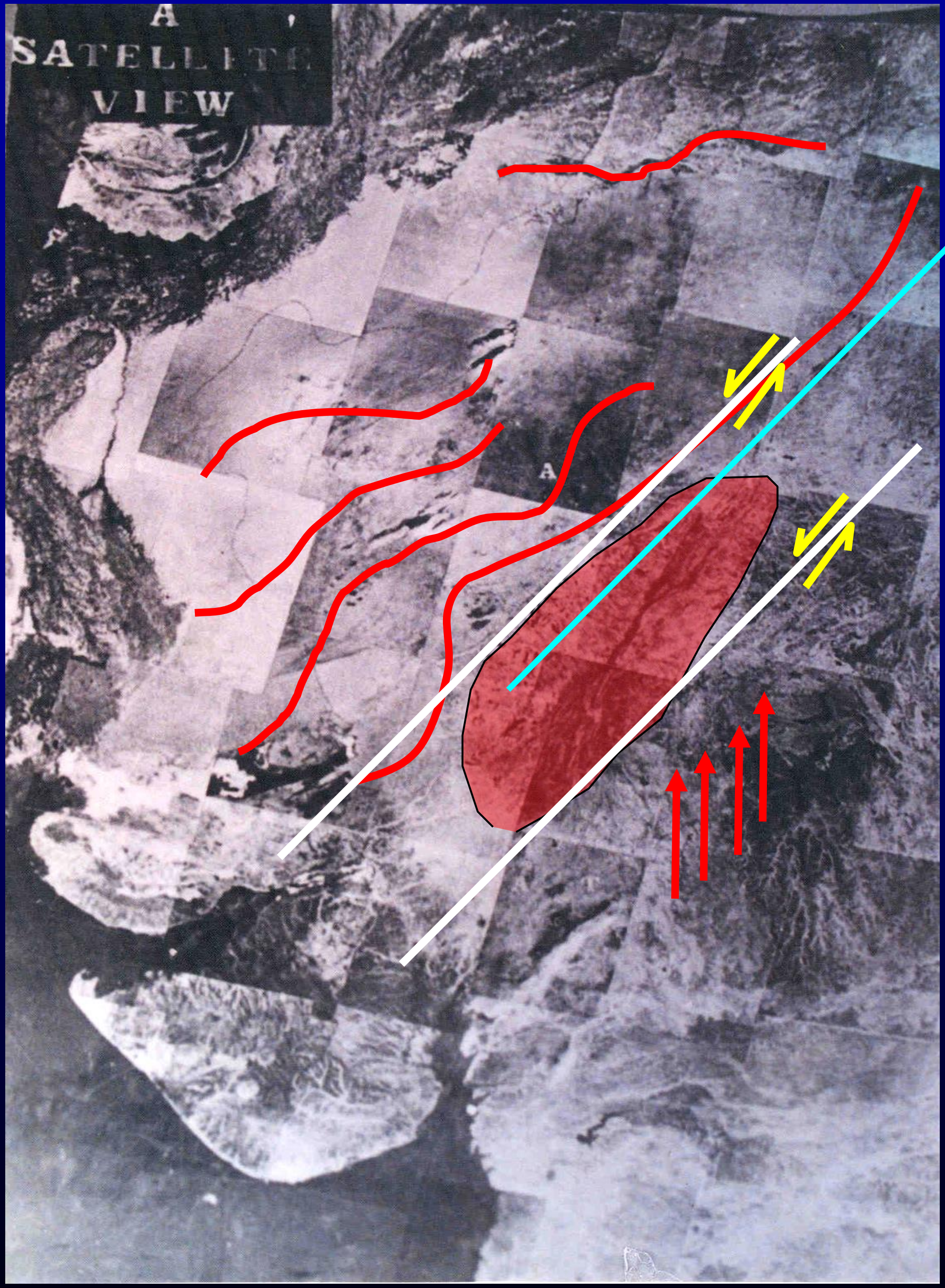
- The palaeochannels mapping and the evaluation of phenomenon of river migration therefrom have been matters of greater interest to the Geoscientists from all over the world, as these give excellent information on the Quaternary geological and climatological events viz:

    - Active tectonic movements
    - Sea level changes
    - Climatic modifications
    - Behavior of the mother channels and the modifications
    - Flood dynamics
    - Littoral currents, etc..

- Which only influences their migration either independently or in conjunction with others

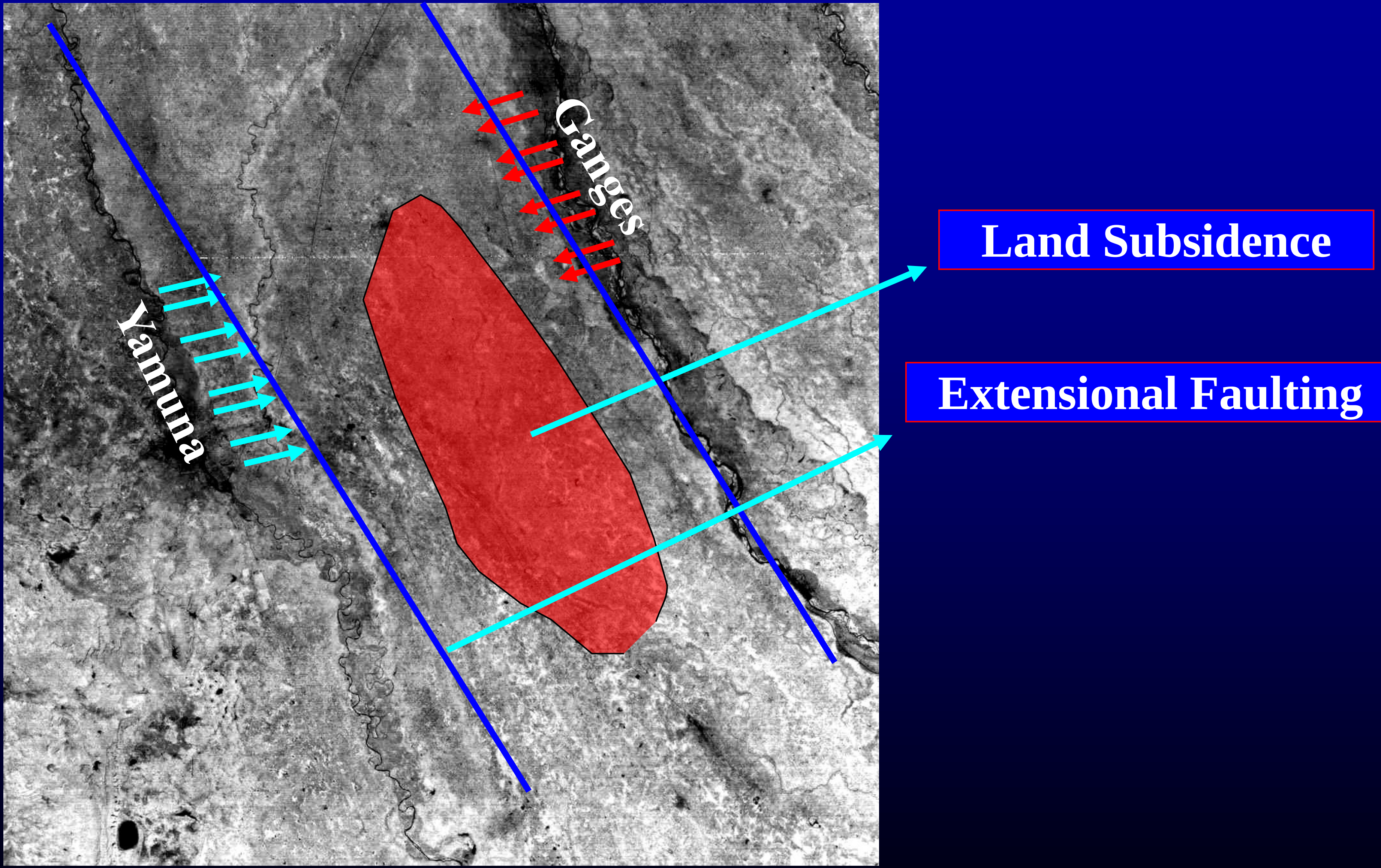
Palaeochannels



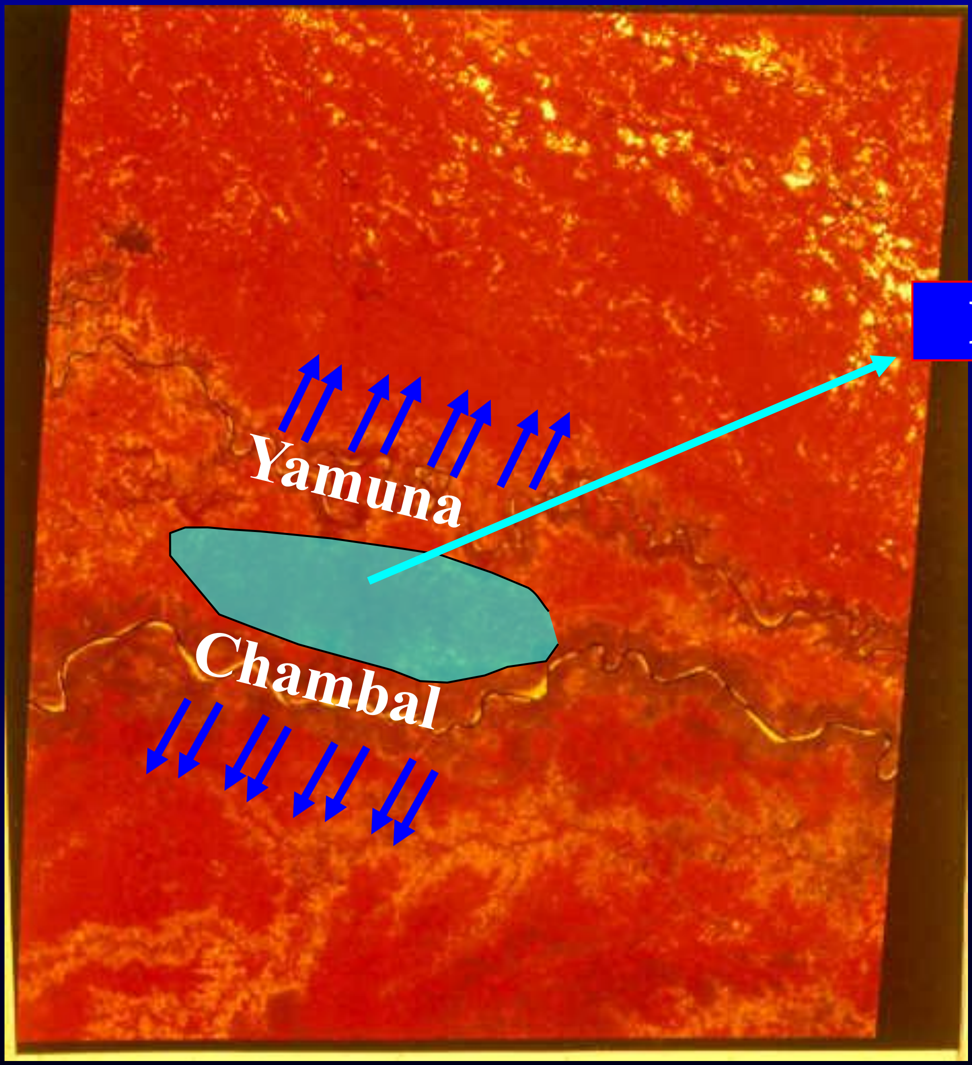


Rise of Aravalli

Easterly Migration & Ganges Westerly Migration



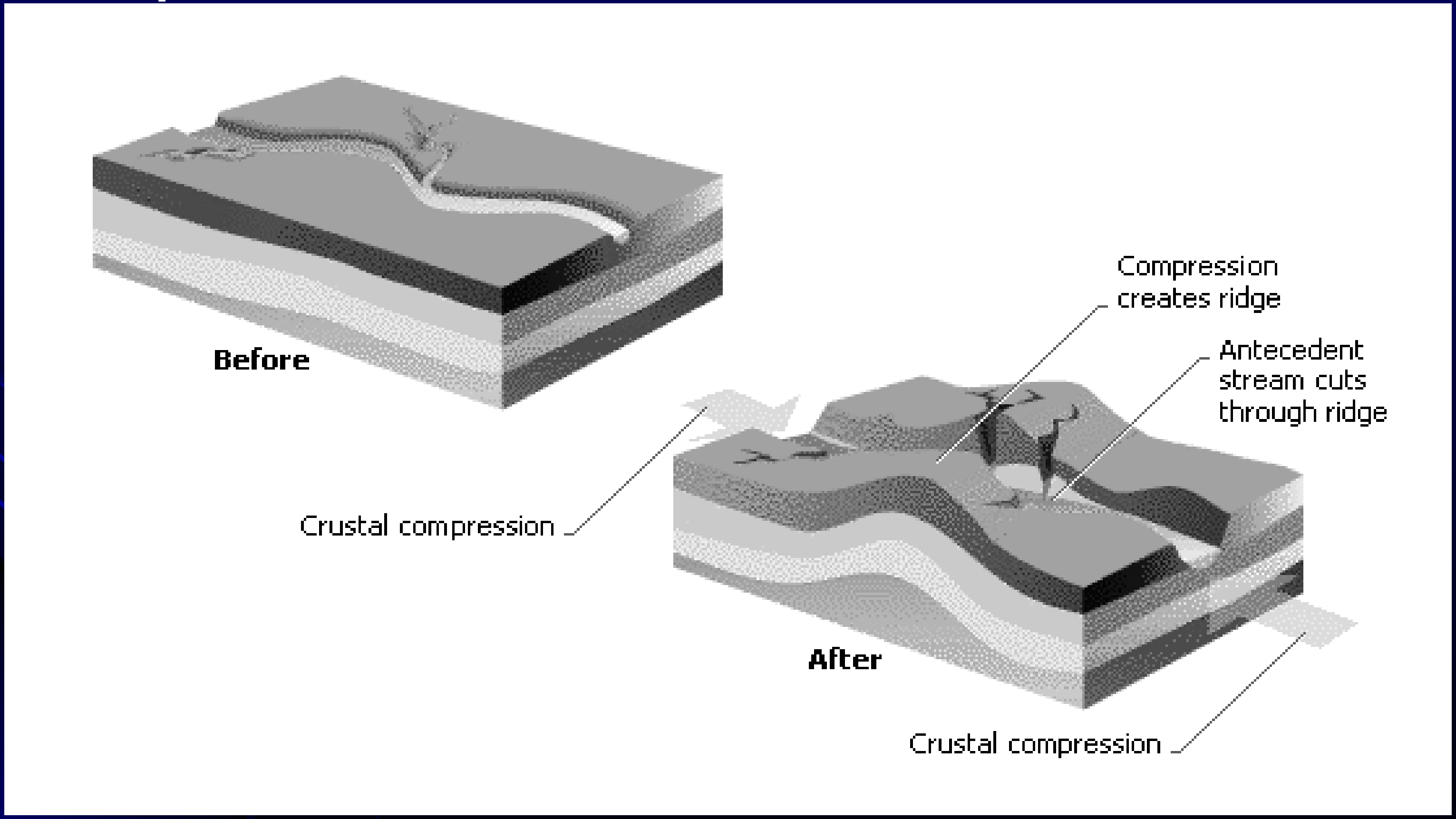
Yamuna & Chambal



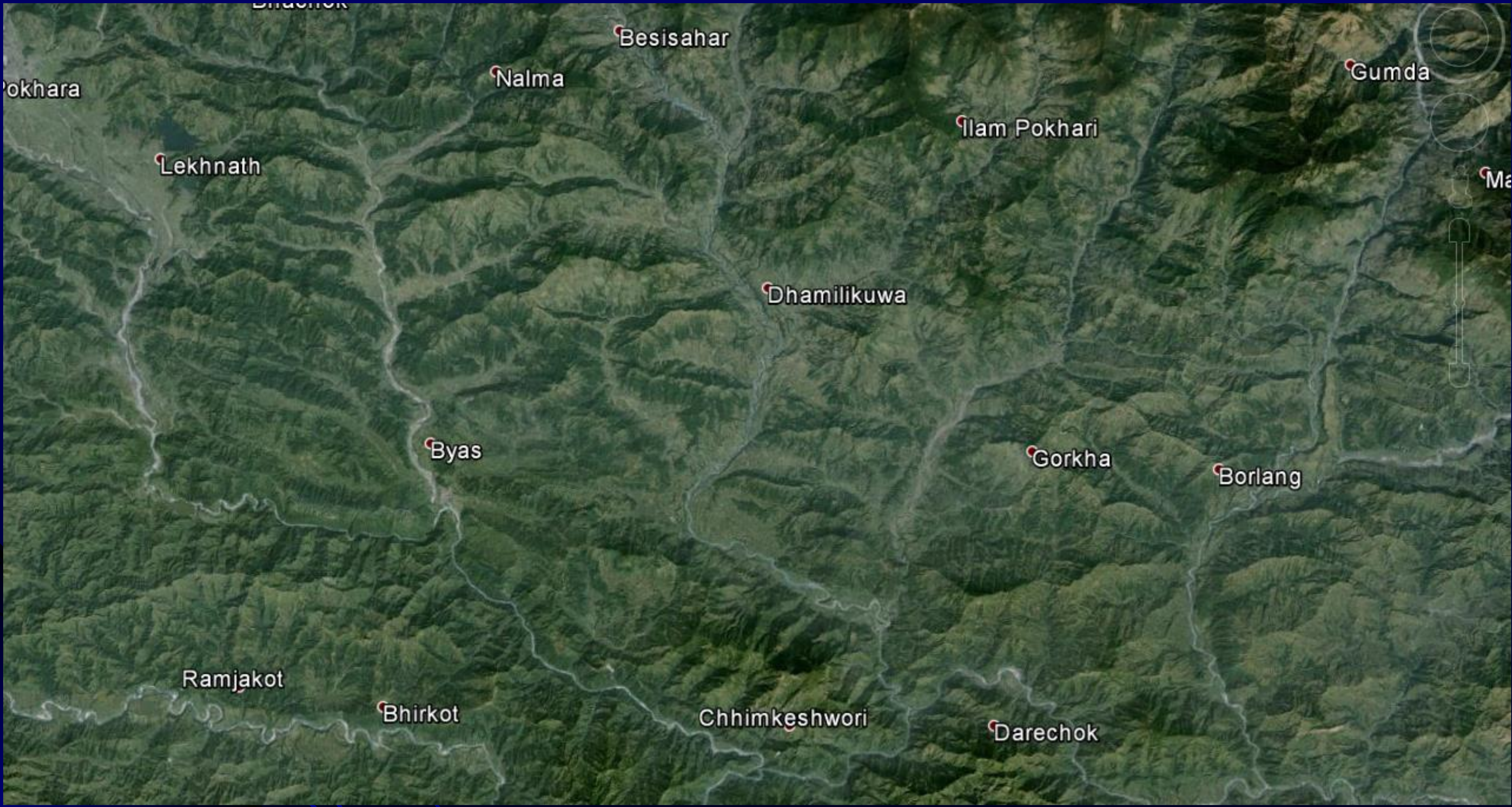
Land Emergence

Antecedent drainage

Antecedent Drainage : An antecedent stream is a stream that was established before the land beneath it was uplifted through geologic processes such as crustal compression. An antecedent stream will maintain its course in spite of crustal compression, and the stream will continue to erode the land at almost the same rate as the crustal compression uplifts it.

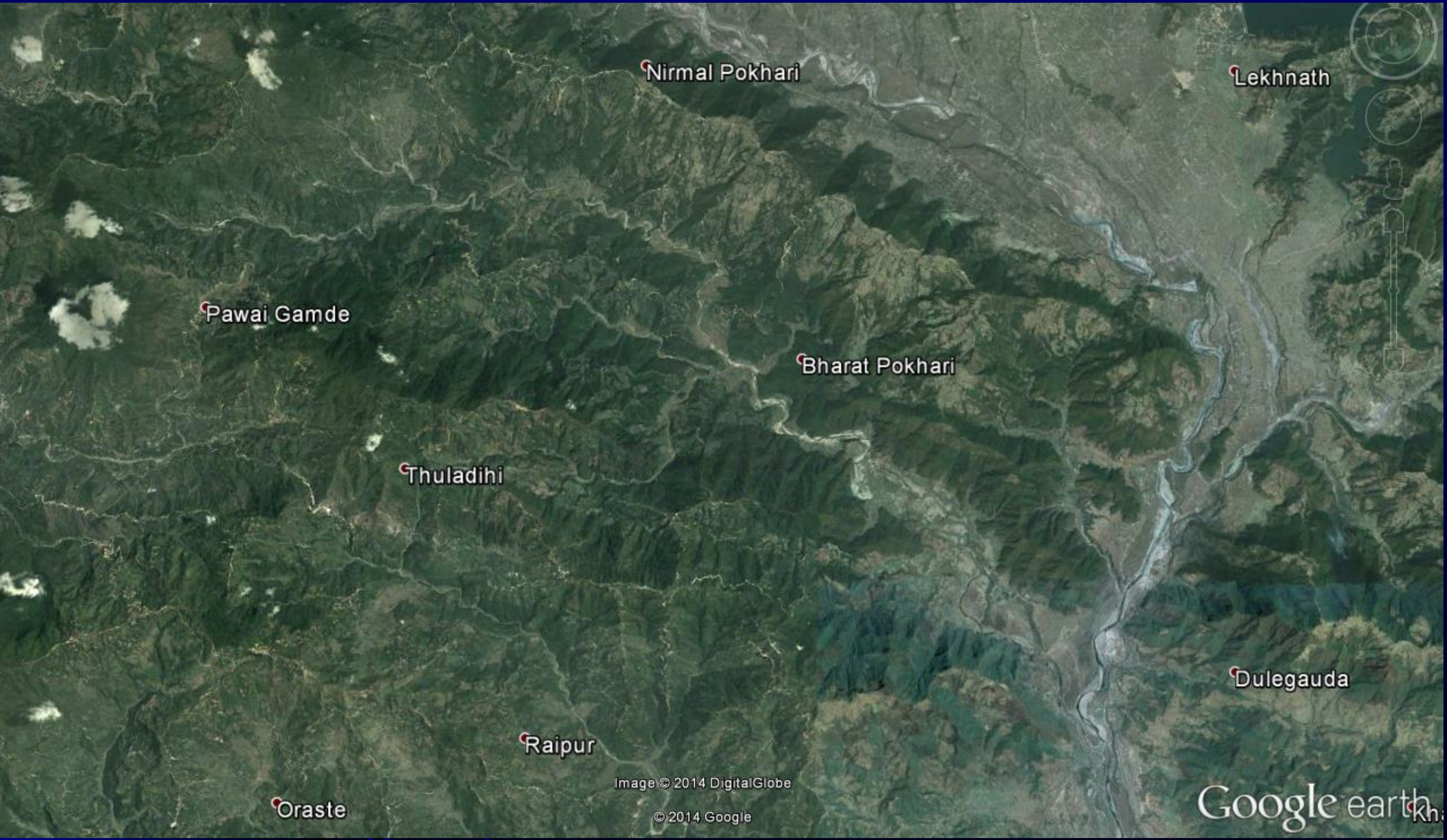


Parallel Drainages

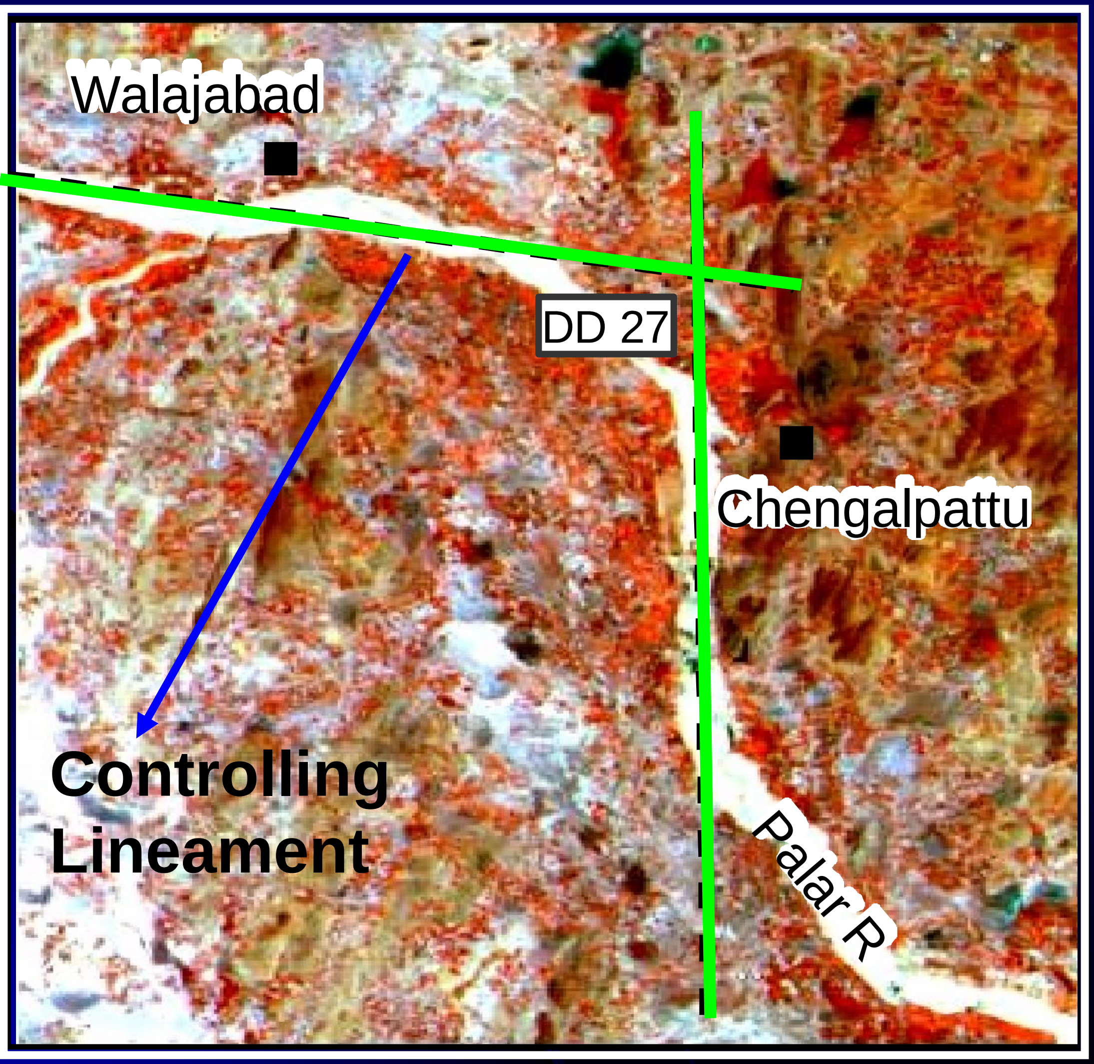


A system of co-linear drainages is called as “parallel drainages”, whereas the long and straight flow paths of the drainages are called as rectilinear drainages.

Parallel Drainages



Deflected Drainages

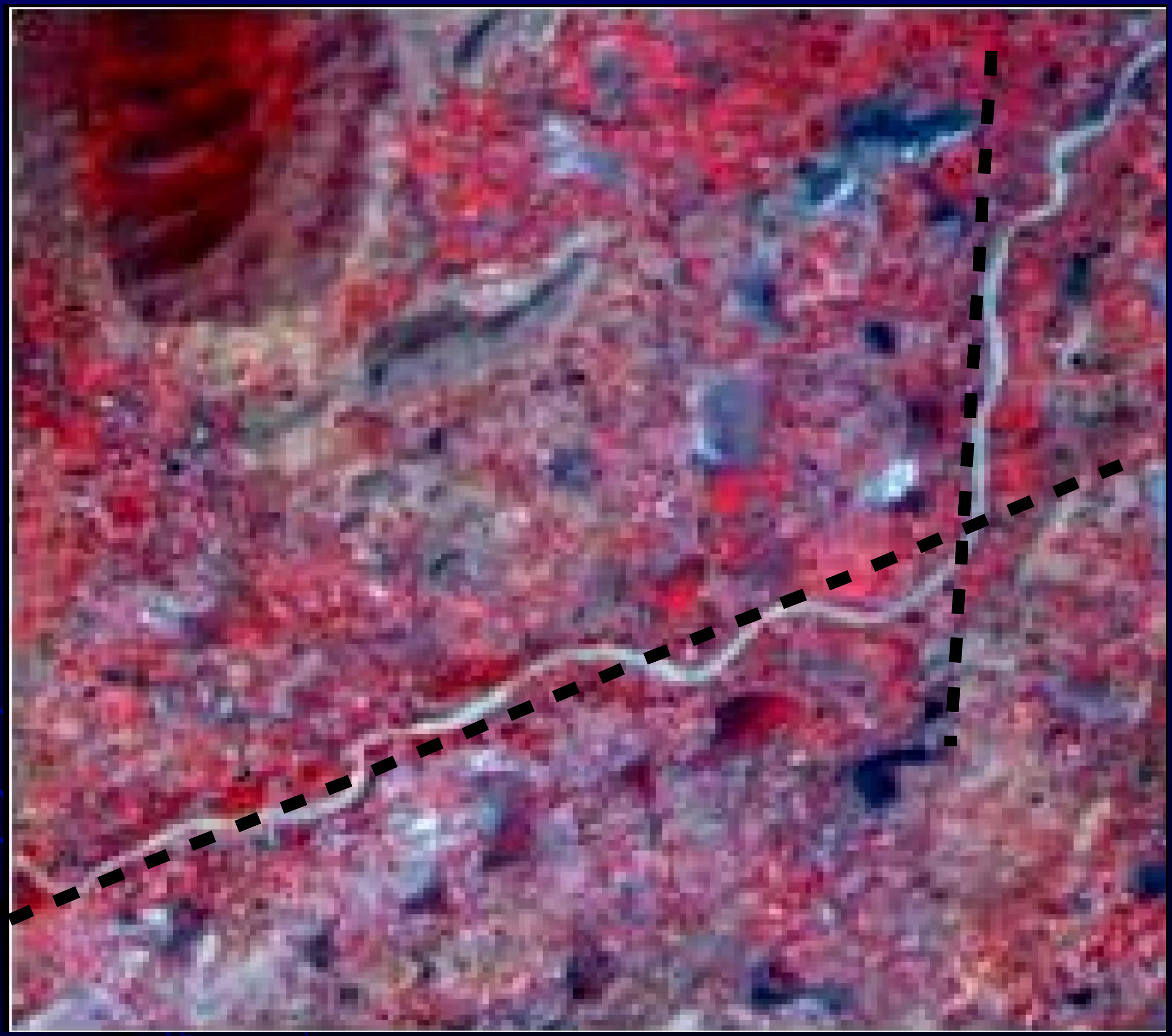


The drainages which are abruptly getting deflected from their normal flow are called as deflected drainages

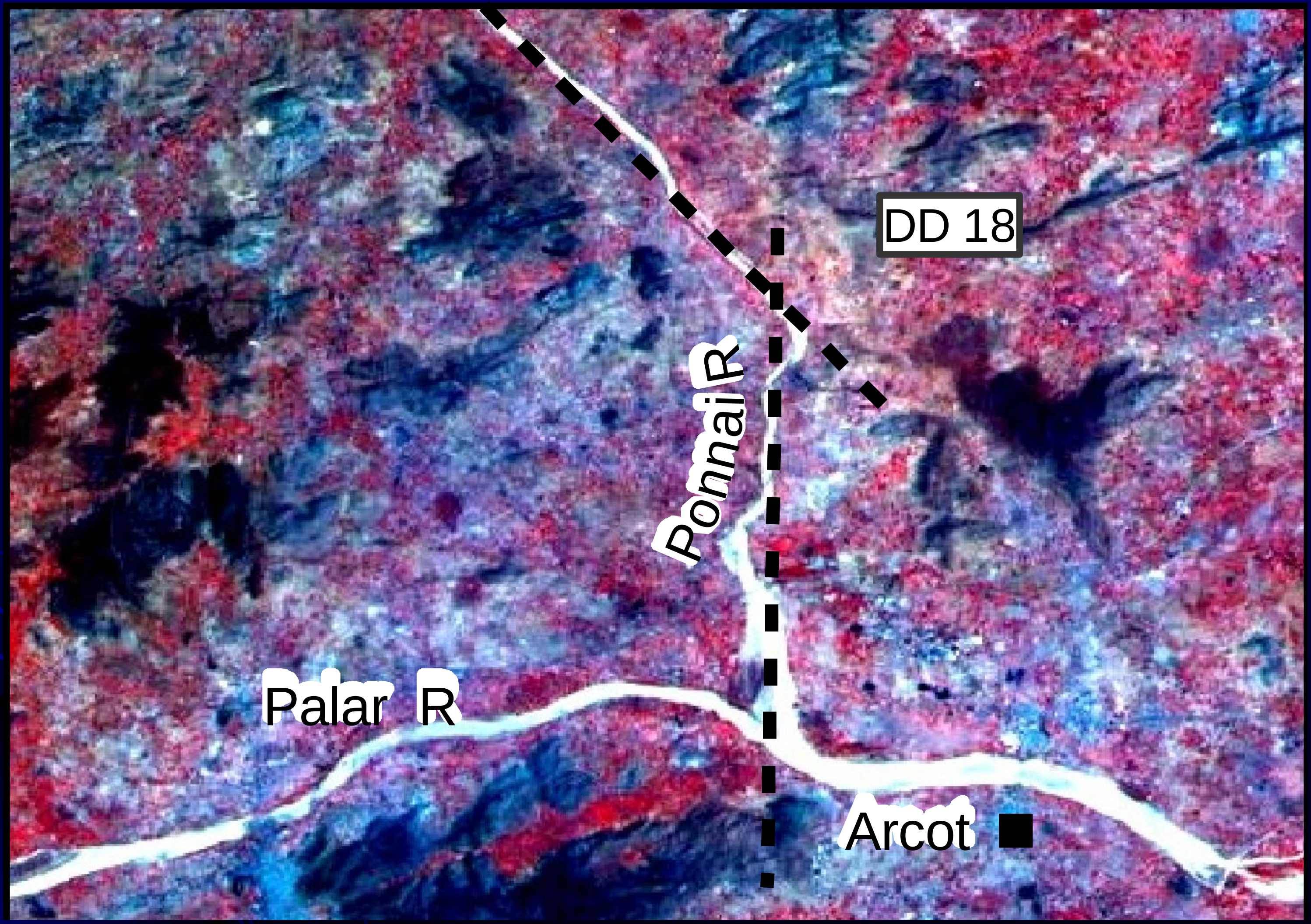
Deflecting Lineament

Deflected Drainages

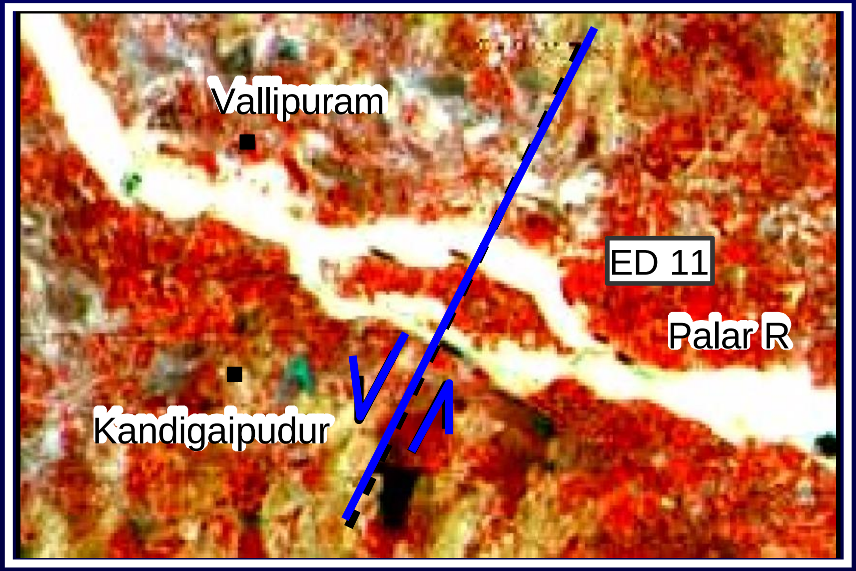
Deflected Drainage in Cheyyar R

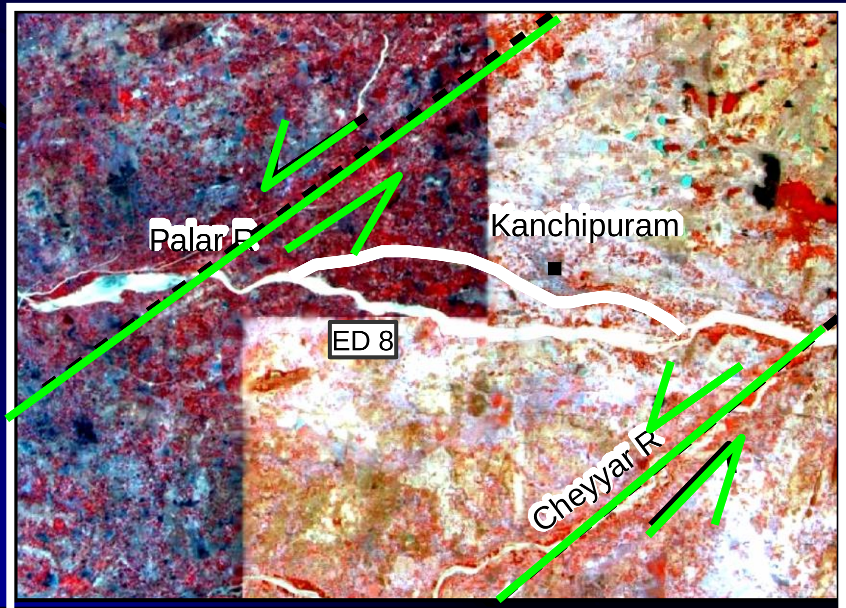


Deflected Drainage



Eyed Drainages

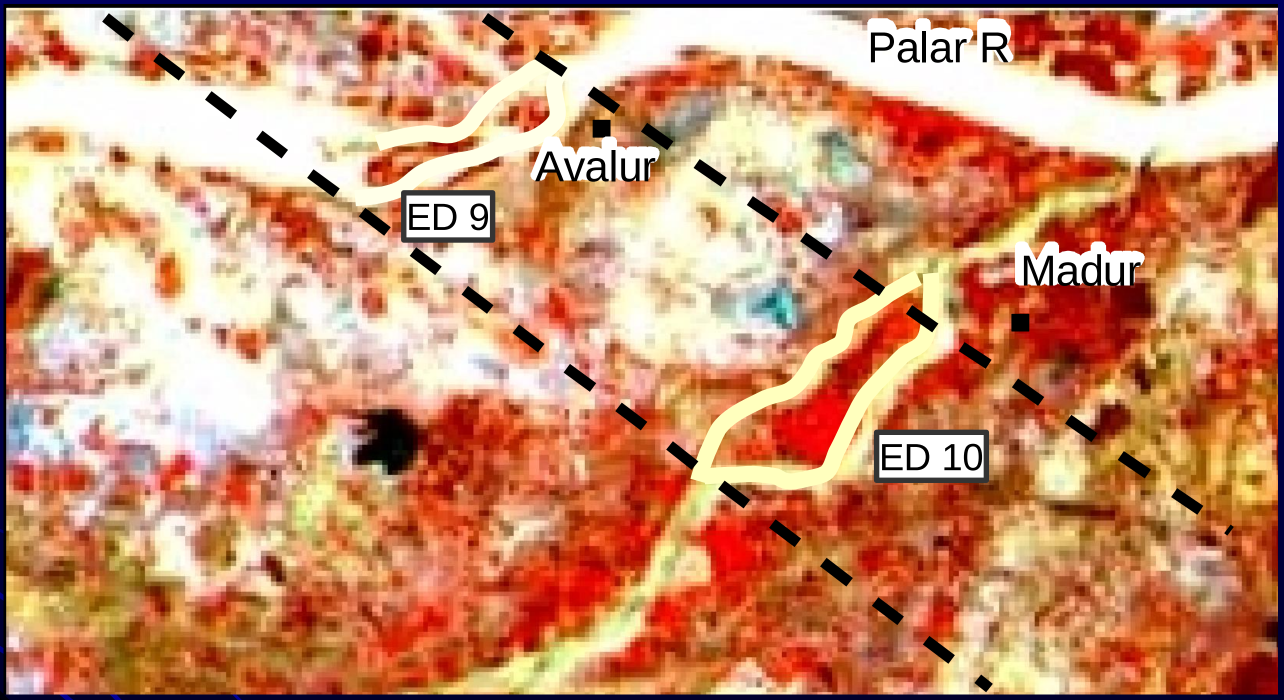




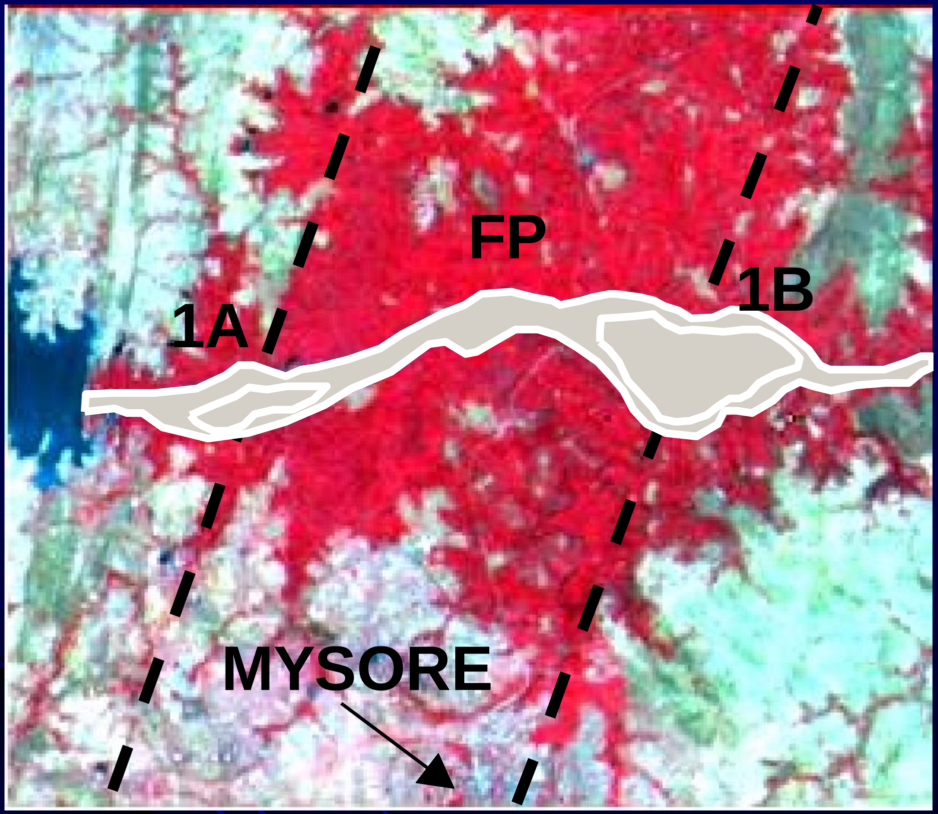
The drainages flow as a single stream, branch off into two and rarely into four or five, run co-linearly or curvilinearly and meet after a few hundred meters or kilometers, thus ultimately giving a shape of an eye or biconvex lens.

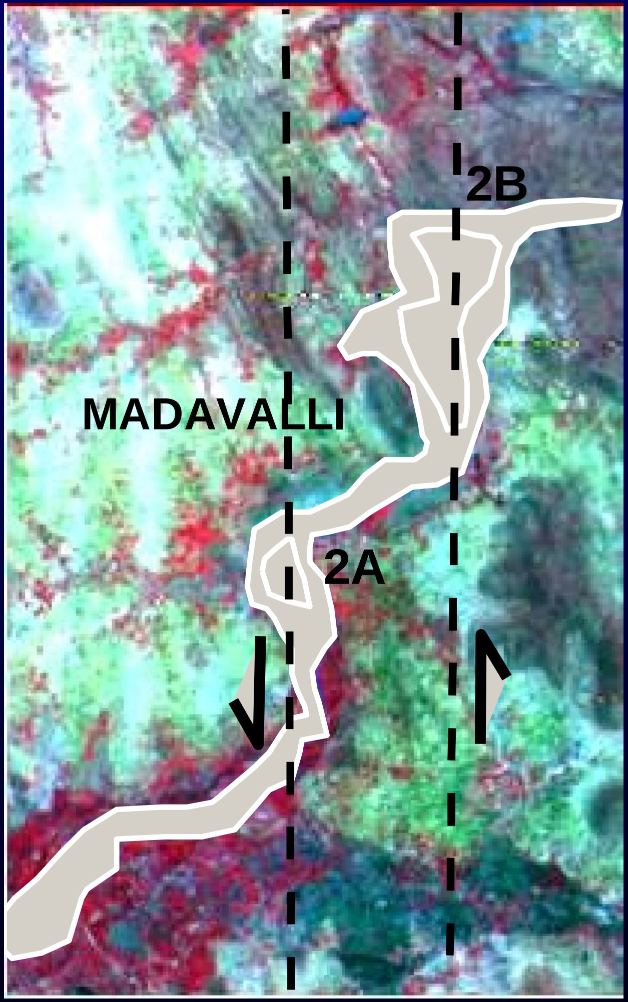
Because of such morphology, such drainage anomalies were interpreted as “eyed drainages”. Smith et al (1997) have called this phenomenon as “Anastomosis”.

Eyed Drainages



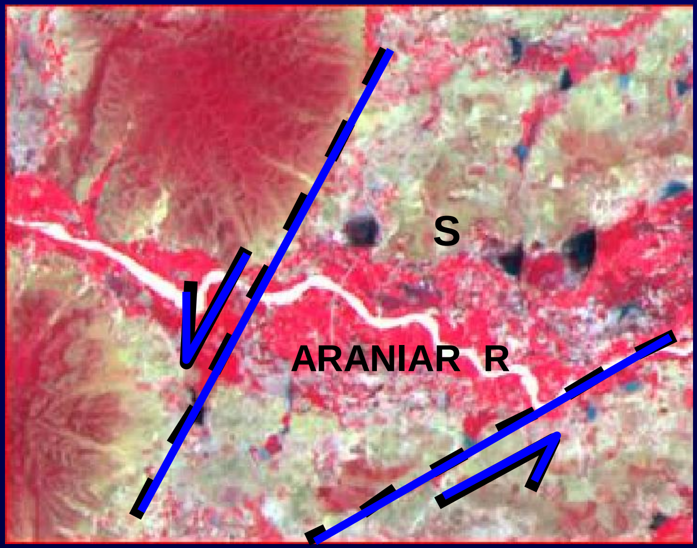
Eyed Drainages





Eyed Drainage in Cauvery in Trichy

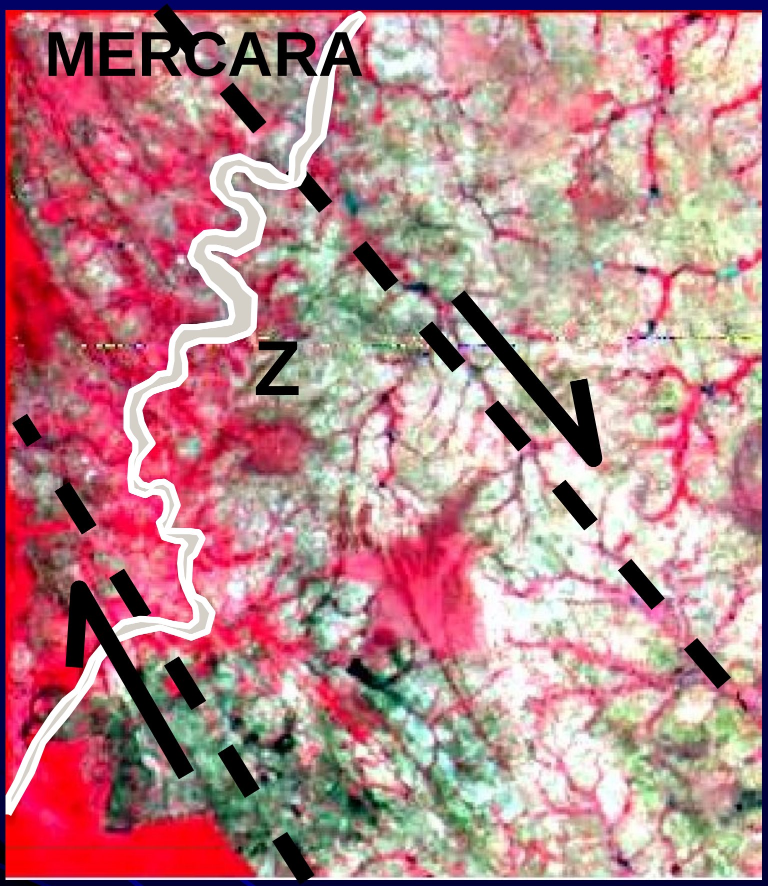
Compressed Meanders

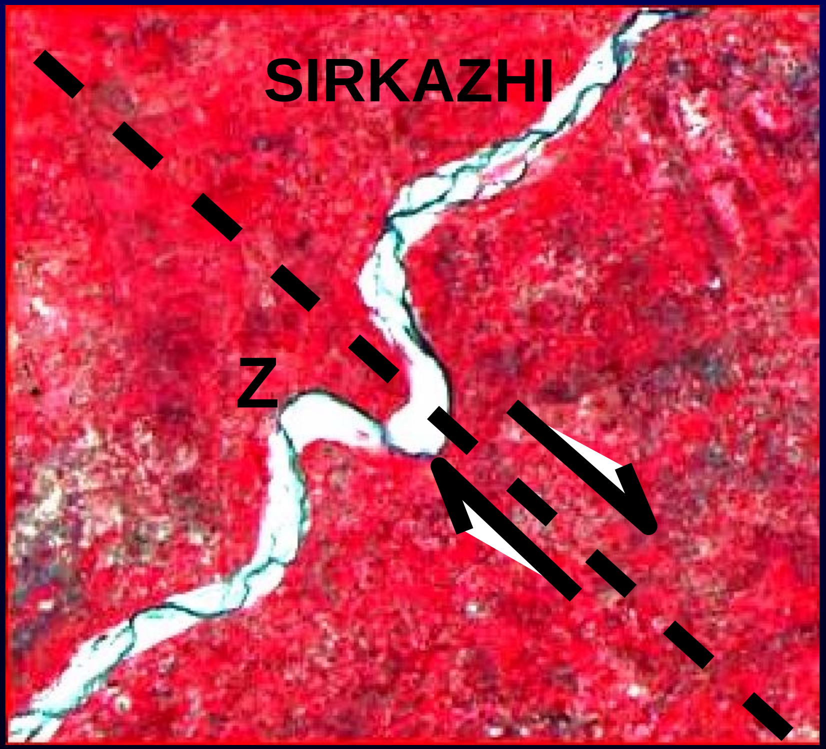


The otherwise normally flowing drainages at some places or some segments exhibiting sinous flow or compressed flow are called as compressed meandering.

These types of anomalous occurrences of compressed meanders in otherwise normally flowing drainage systems have been demonstrated to be indicative of active tectonics in such zones of compressions in many parts of the world

Compressed Meanders


MERCARA
Z


SIRKAZHI
Z

COASTAL GEOMORPHIC ANOMALIES

The coastal zones are arenas where multivariate geologic / geomorphic processes viz: tectonic, fluvial, marine and aeolian processes act in varying degrees and duration, independently and interdependently in varying permutations and combinations and keep on building and destroying landforms during the entire Quaternary period of nearly 1.7 million years.

Hence, the study of these landforms can reveal the above geologic / geomorphic processes and their time transgressive changes

The landforms so generally built by these various processes along the coasts are the deltas of different types, beach ridges, swales and strand plain complexes, wetlands (backwaters, creeks, lagoons, mudflat systems, etc.), beaches, spits, shoals etc.

Their morphology and distribution will be systematic in coastal zones of normal geologic / geomorphic processes and

Wherever and whenever aberrations and disturbances are caused to the above geologic / geomorphic processes, anomalous, ill grown and truncated geomorphic landforms will be created.

One of the major phenomena that is responsible for such coastal geomorphic anomalies are the tectonic activities of the Quaternary period.

Deltas	-	their morphologies
Beach ridges	-	their width, swelling and pinching pattern, if any
Backwater	-	their swelling or shrinking pattern by using multi-dated topographic sheets and remote sensing data
Creeks	-	their time transgressive modifications in the recent period
Beaches	-	their benching pattern, etc.

Lobate Delta

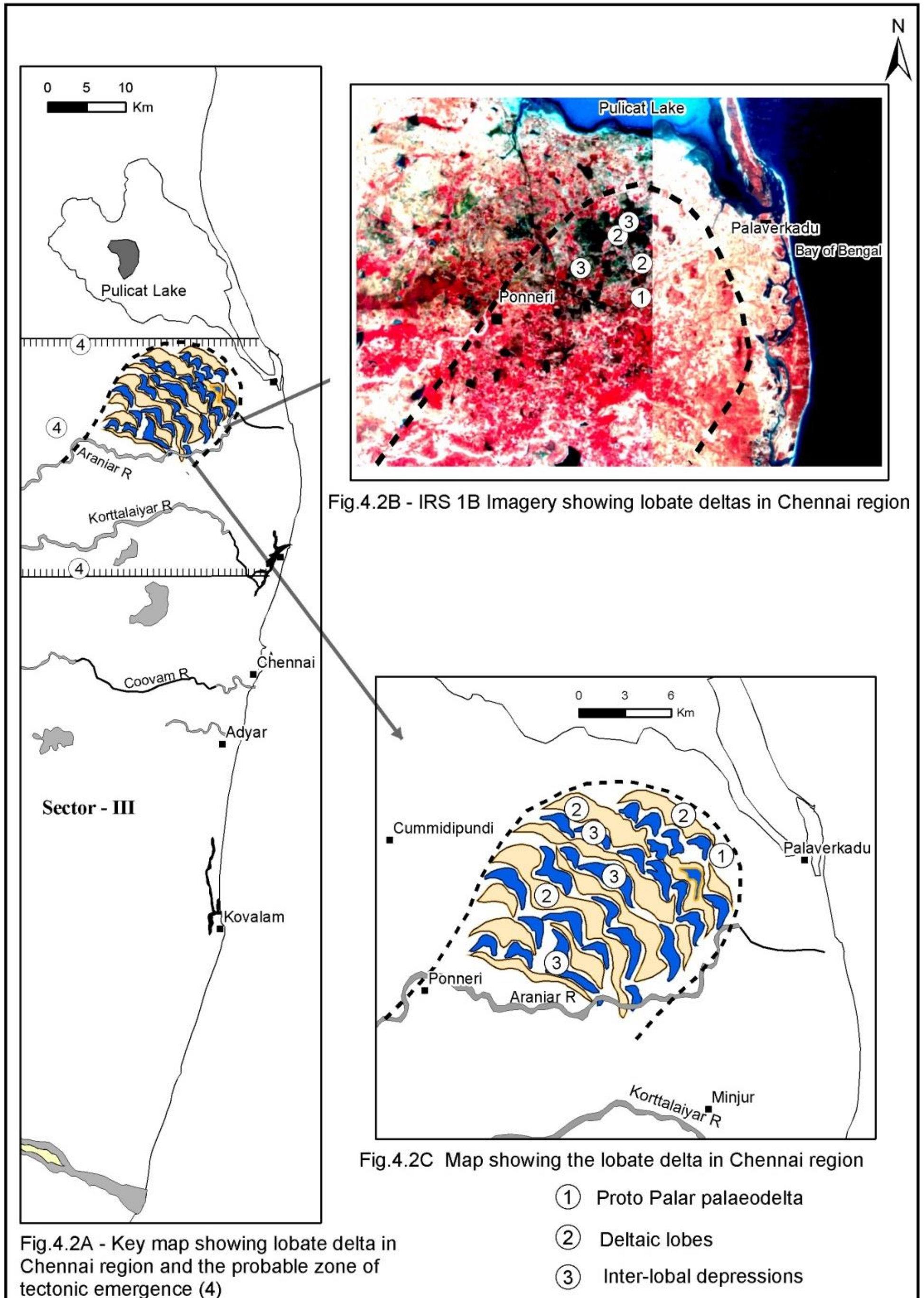
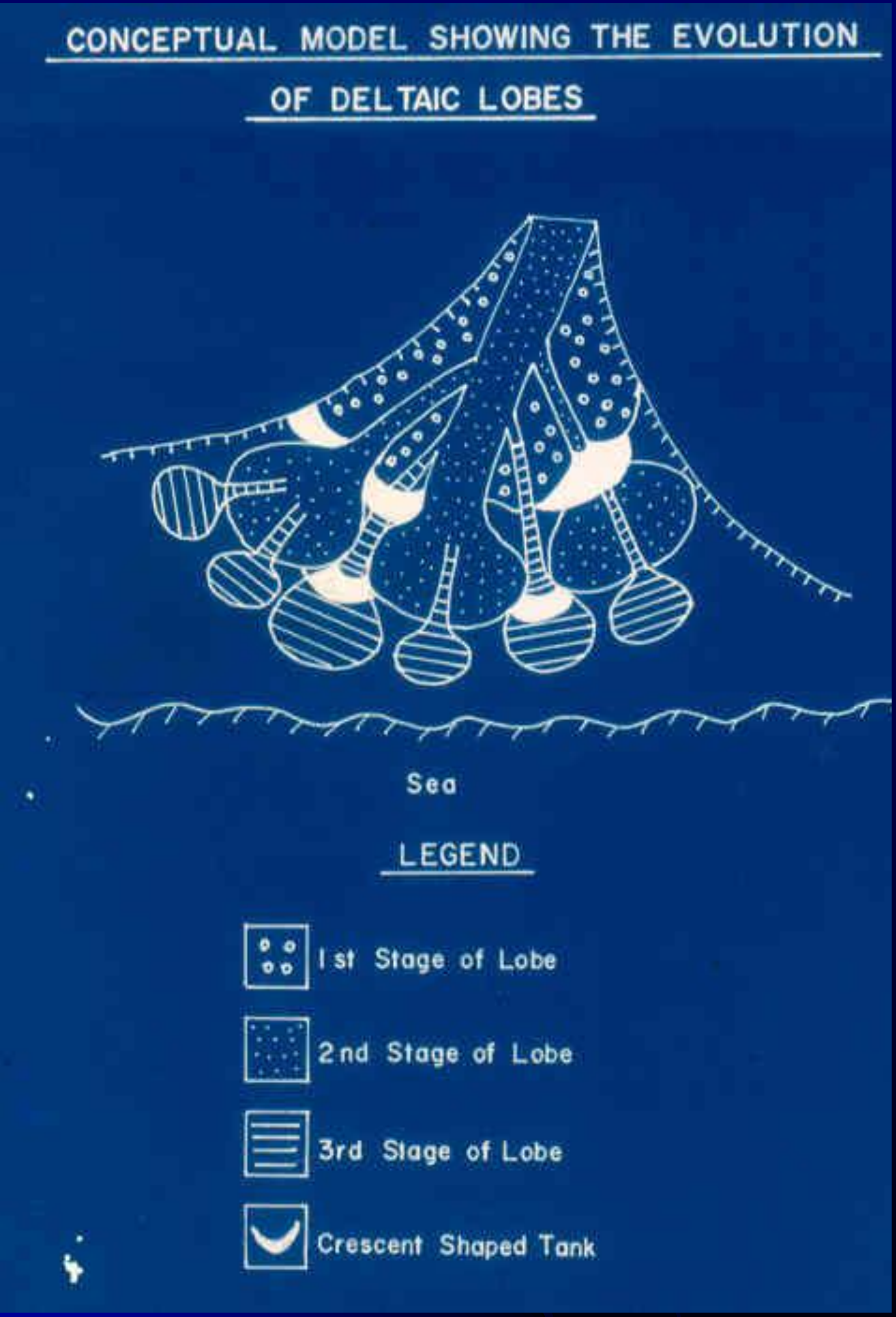


Fig.4.2 - Deltas

Davis and Richard (1987) have demonstrated that the lobate deltas symbolize constant emergence of land or withdrawal of sea and the resultant progradation of deltas by developing lobes after lobes.



when the land emerged and the sea was pushed out, the first order lobes were formed, which were cut and prograded into two or three second order lobes, which in turn were cut and prograded into a large number of third order and fourth order lobes and so on. As a result, the primary or the first order lobes occupy the core and all the other second and further third and fourth order lobes concentrically encircle their predecessors.

Beach Ridges

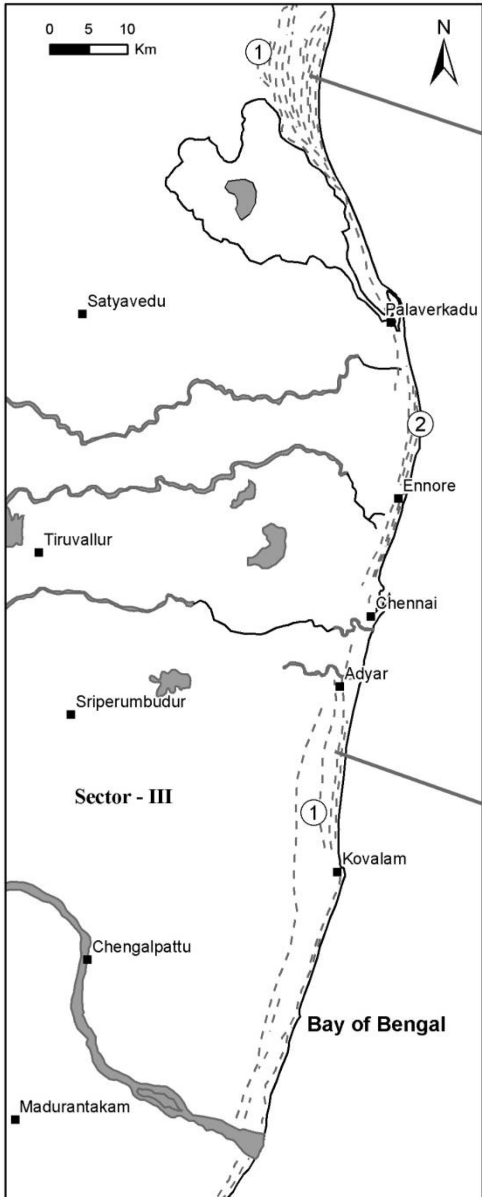


Fig.4.3A - Key map showing beach ridges (1) and convex coast (2) in Chennai region

Fig.4.3B - IRS 1B Imagery showing beach ridges (1) in Pulicat lake region

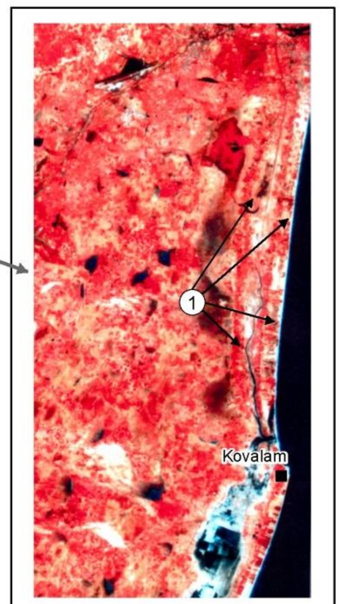


Fig.4.3C - IRS 1B Imagery showing beach ridges (1) in the south of Chennai city

Fig. 4.3 - Beach ridges

Backwater Modification

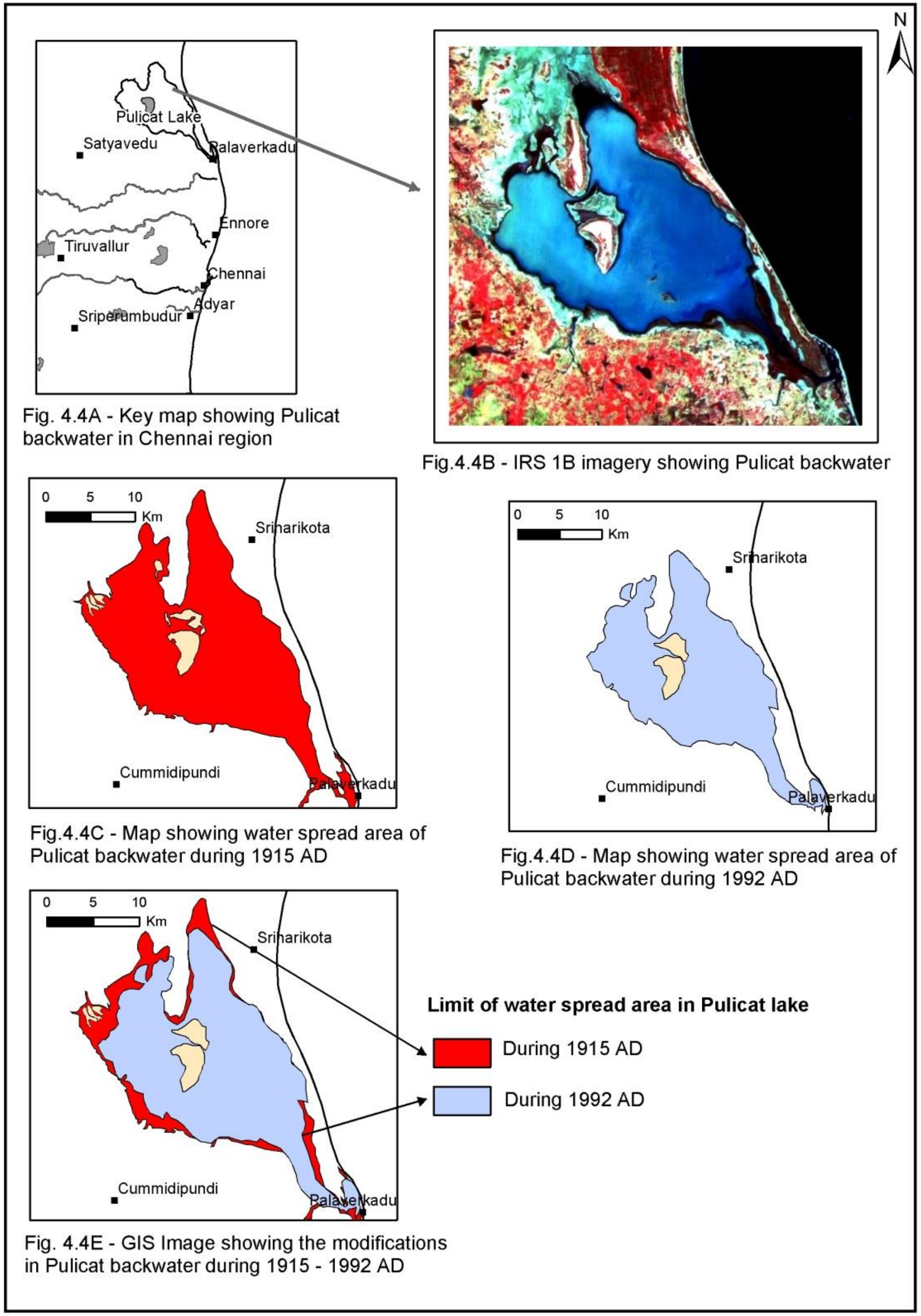


Fig. 4.4 - Backwater modifications

Creek Modification

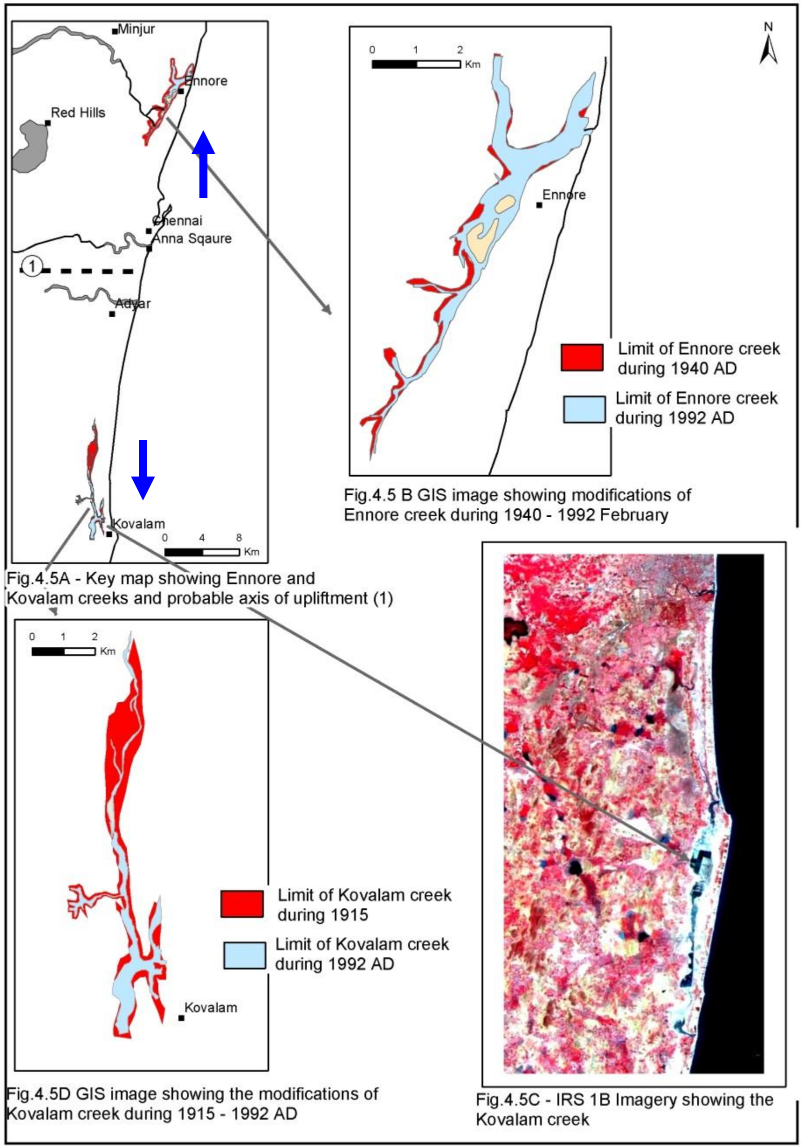


Fig.4.5 - Creek modifications

Raised Beach

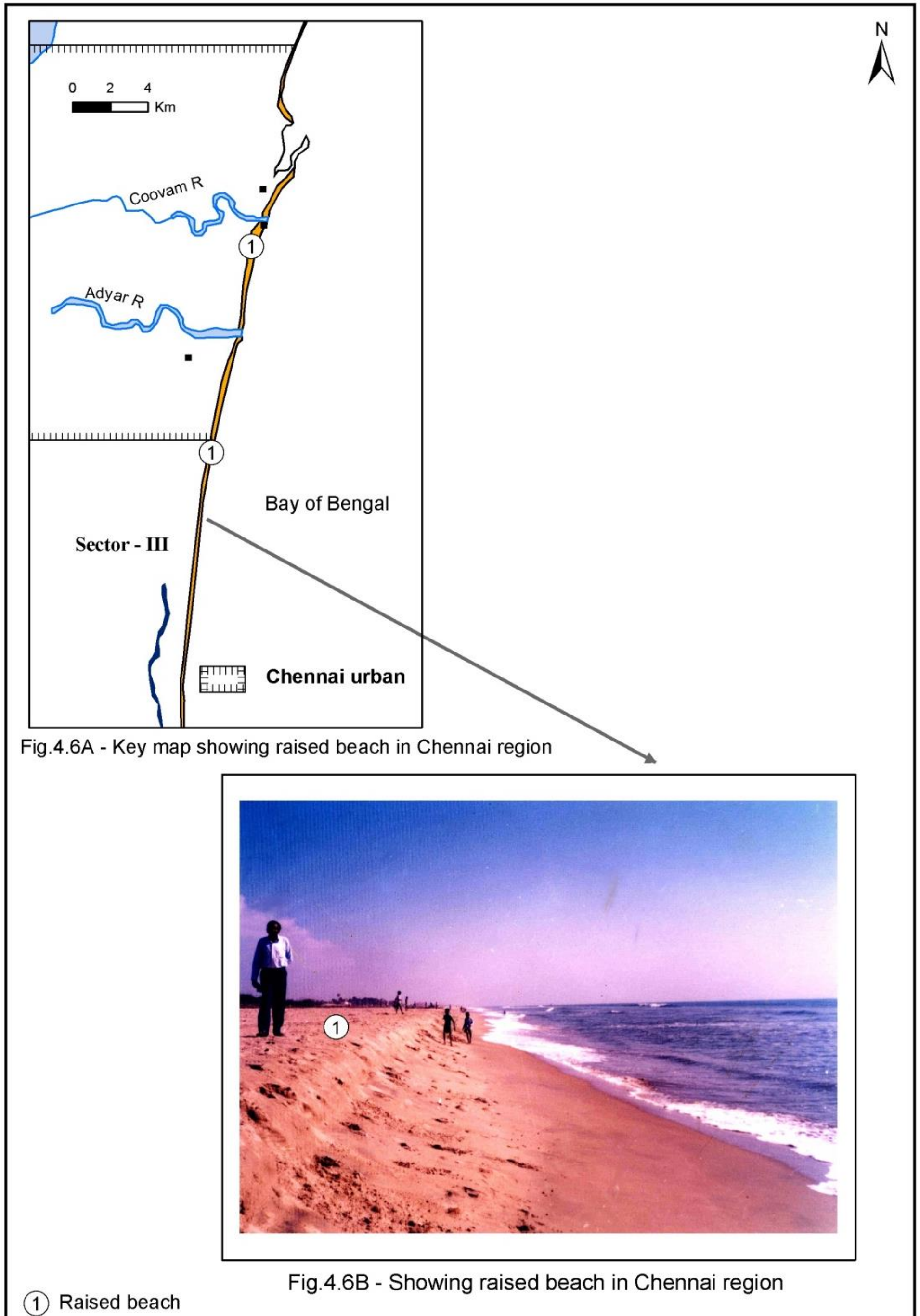


Fig.4.6 - Raised beach

Coastal terraces

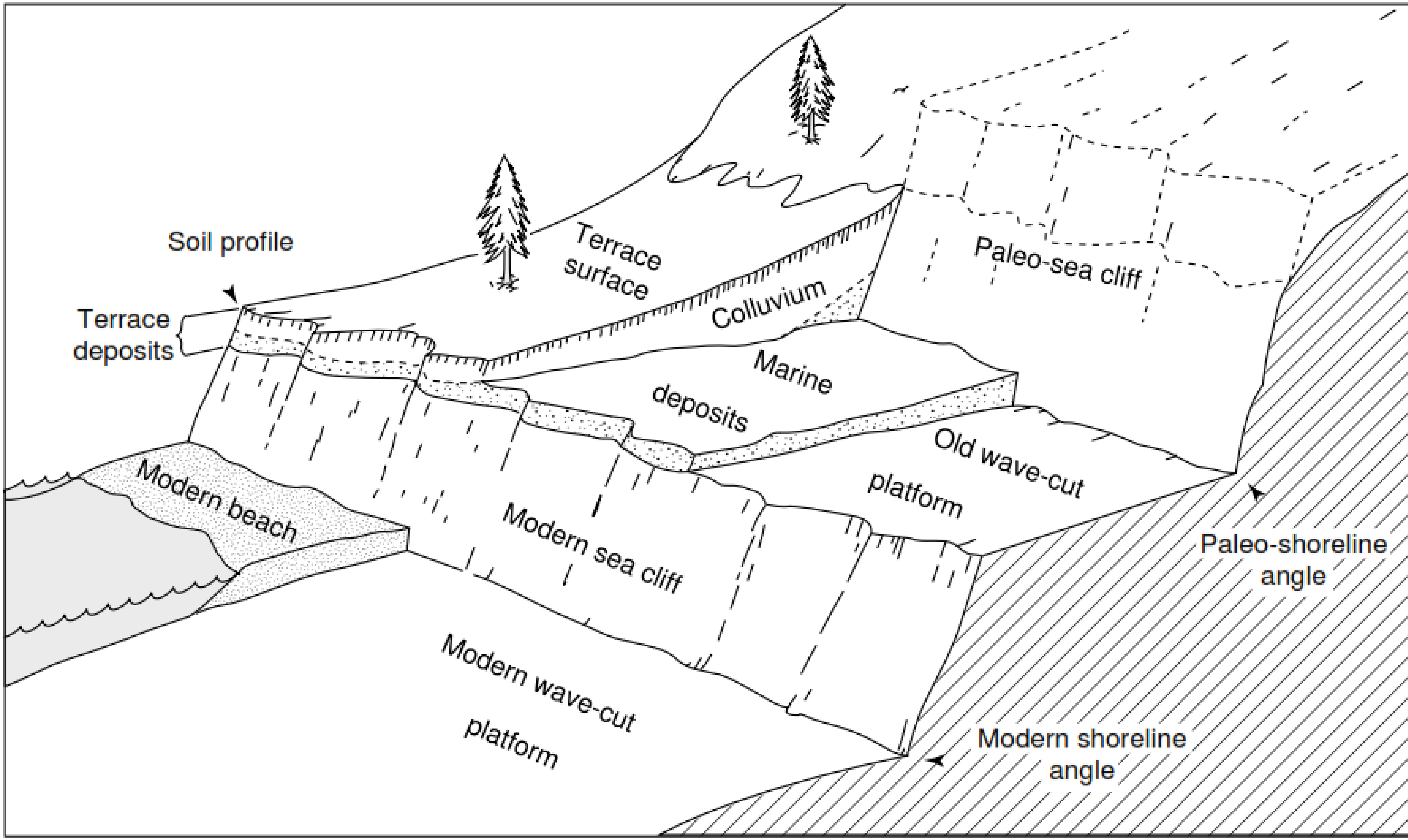


Figure 6.4. An uplifted marine terrace and associated features. (After Weber, 1983)

b)

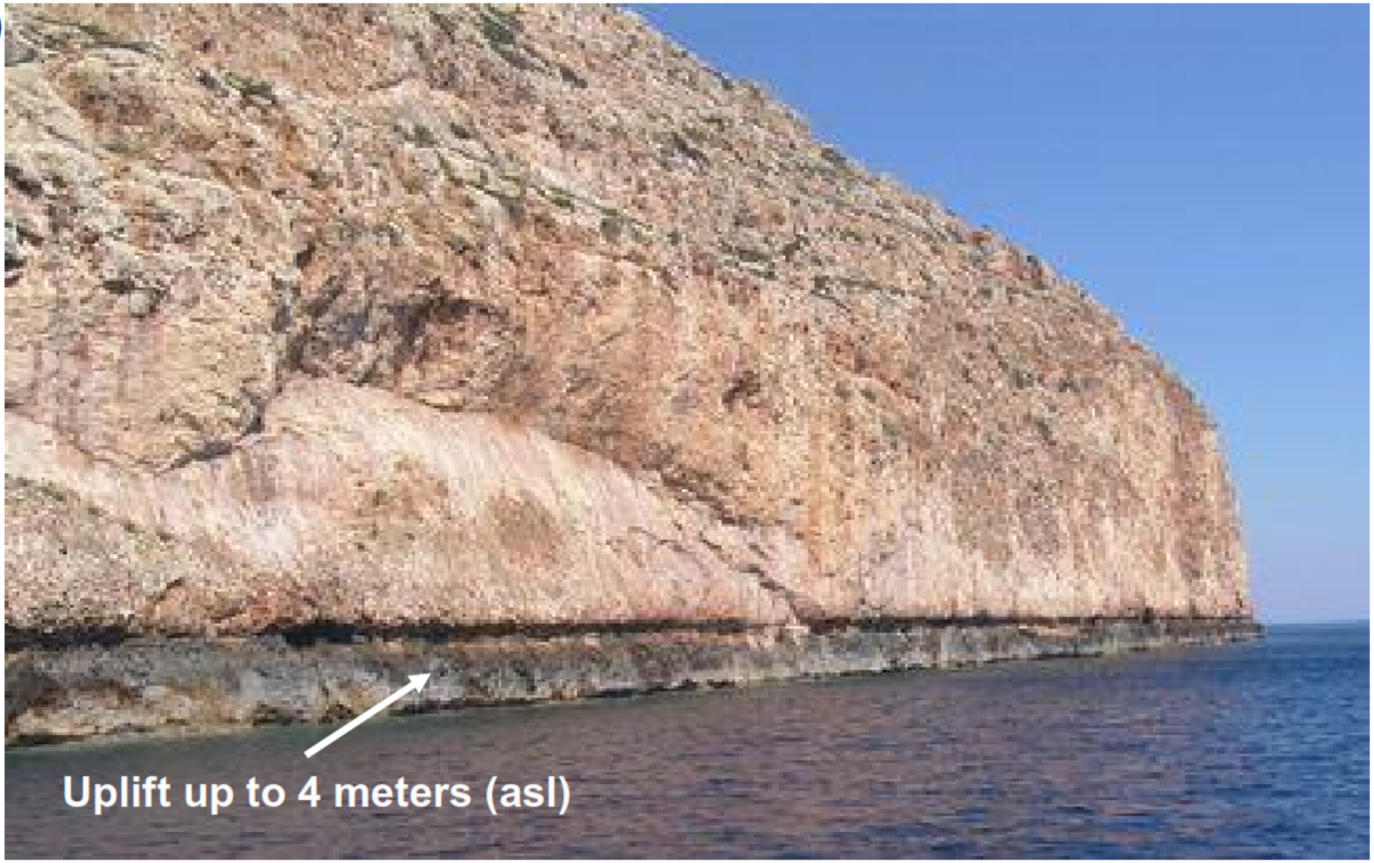


Fig. 2.2: a) Linear feature in Cape Krios, southwestern Crete, with N-S strike, along which the uplifted marine wave-cut bench up to 9 meters can be observed, associated with the 365 AD earthquake. Slickenlines reveal the fault's recent tectonic movement and; **b)** Uplift shoreline in Gramvousa peninsula, northwestern Crete, with uplift up to 4 meters being observed.

Aerial photo of the east coast of Navassa Island

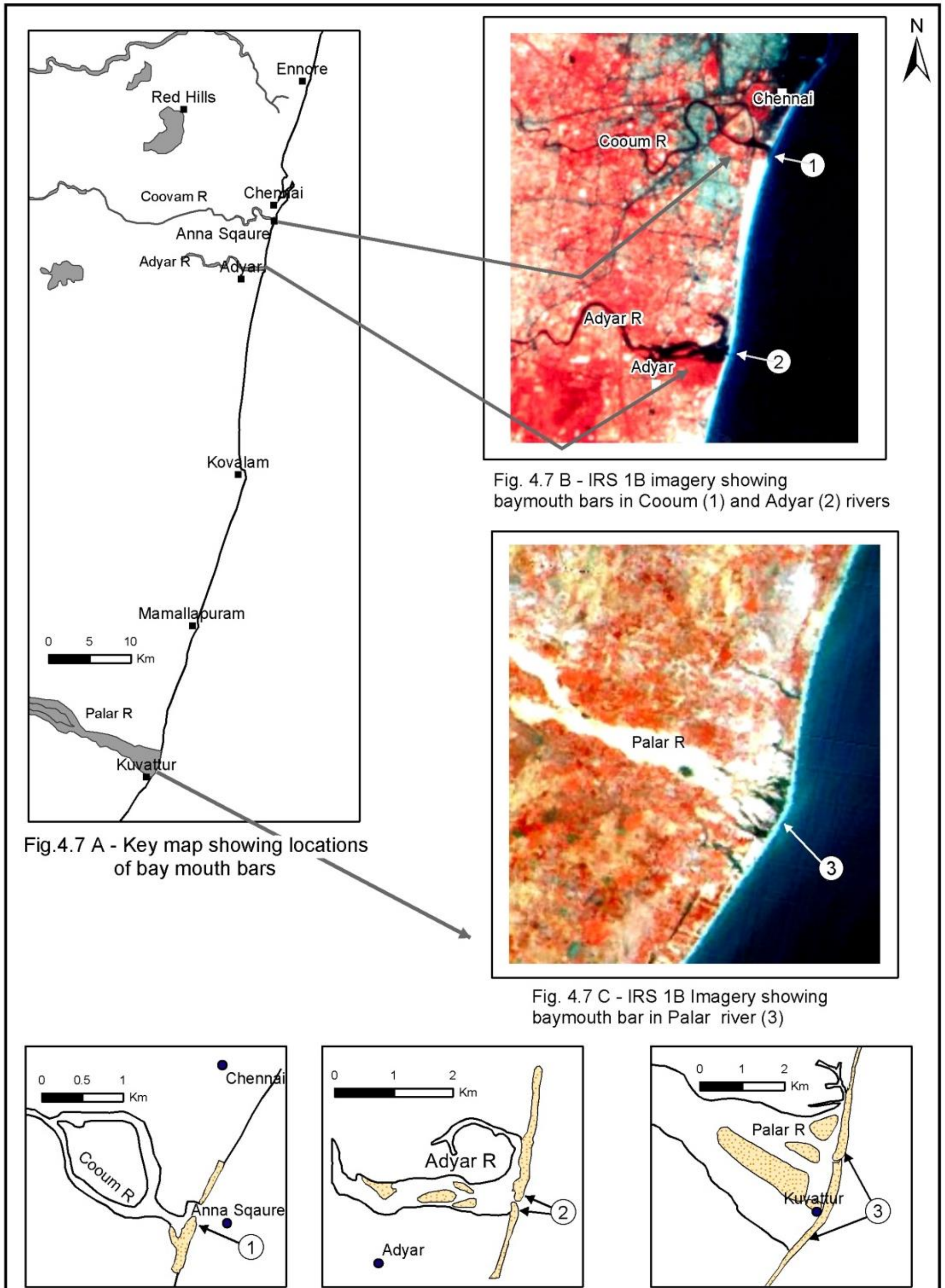


Fig.4.7 A - Key map showing locations of bay mouth bars

Fig. 4.7 B - IRS 1B imagery showing baymouth bars in Cooum (1) and Adyar (2) rivers

Fig. 4.7 C - IRS 1B Imagery showing baymouth bar in Palar river (3)

Fig. 4.7 D - Map showing baymouth bar in Cooum river (1)

Fig. 4.7 E - Map showing baymouth bar in Adyar river (2)

Fig. 4.7 F - Map showing baymouth bar in Palar river (3)

Fig. 4.7 - Bay mouth bars

Bay Mouth bars

- **The interpretations of various coastal geomorphic features like**
  - **Convex coast**
  - **Wide Beach ridges**
  - **Lobate delta**
  - **Backwater Modifications**
  - **Preferential withdrawal of creeks**
  - **Raised / benched beaches**
  - **bay mouth bars**
- **Suggest that tectonic upliftment might be going on right from Middle-Late Holocene period**
- **The selective withdrawal of northern Ennore and southern Kovalam creeks strikingly indicate that land upliftment in inbetween these two creeks along Chennai**

GEOPHYSICAL ANOMALIES

50m Depth

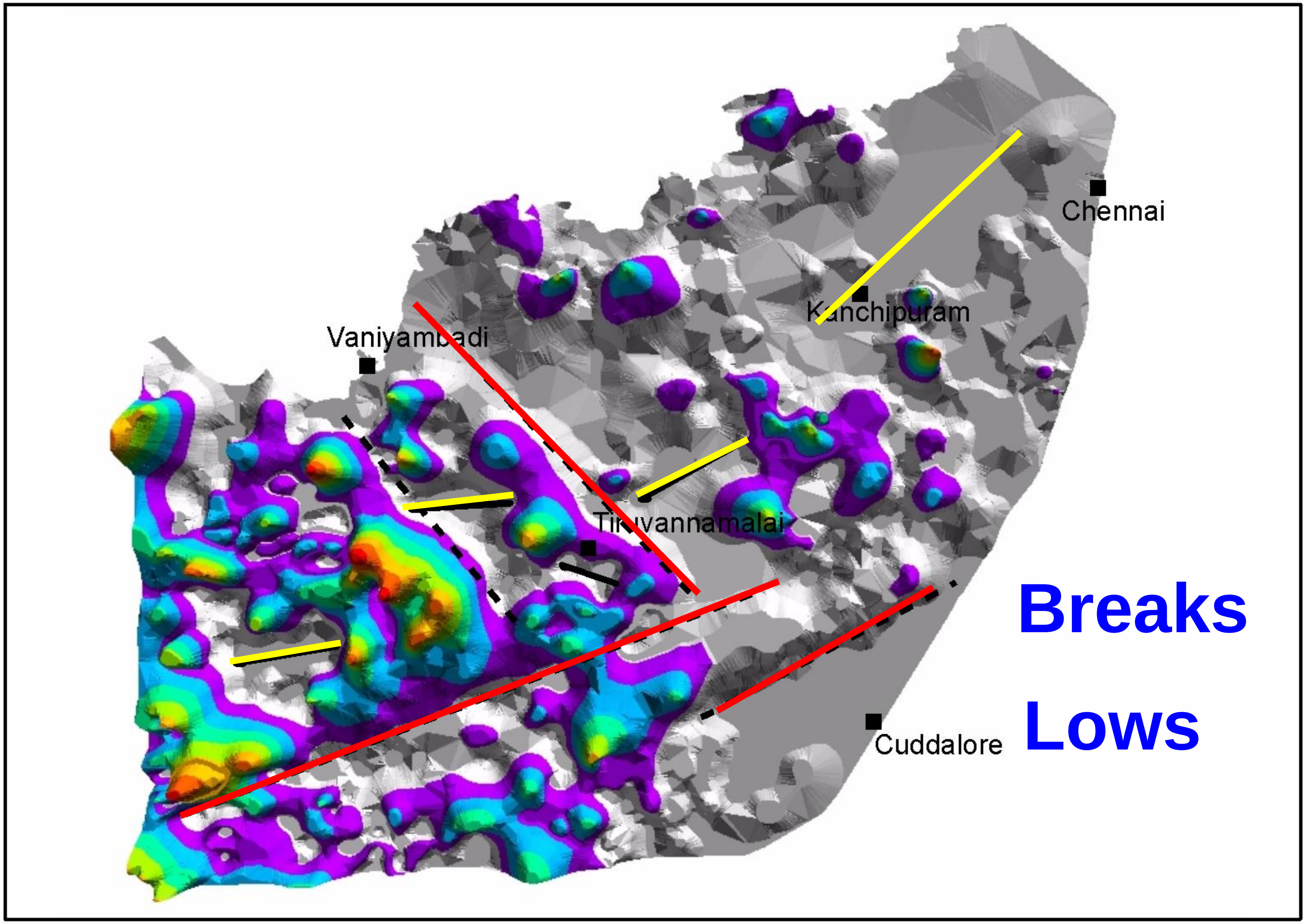


Fig.5.8 - 3D GIS image on Isoresistivity contours of 50m depth

Breaks

Lows

Gravity Anomalies & Seismic Corridors

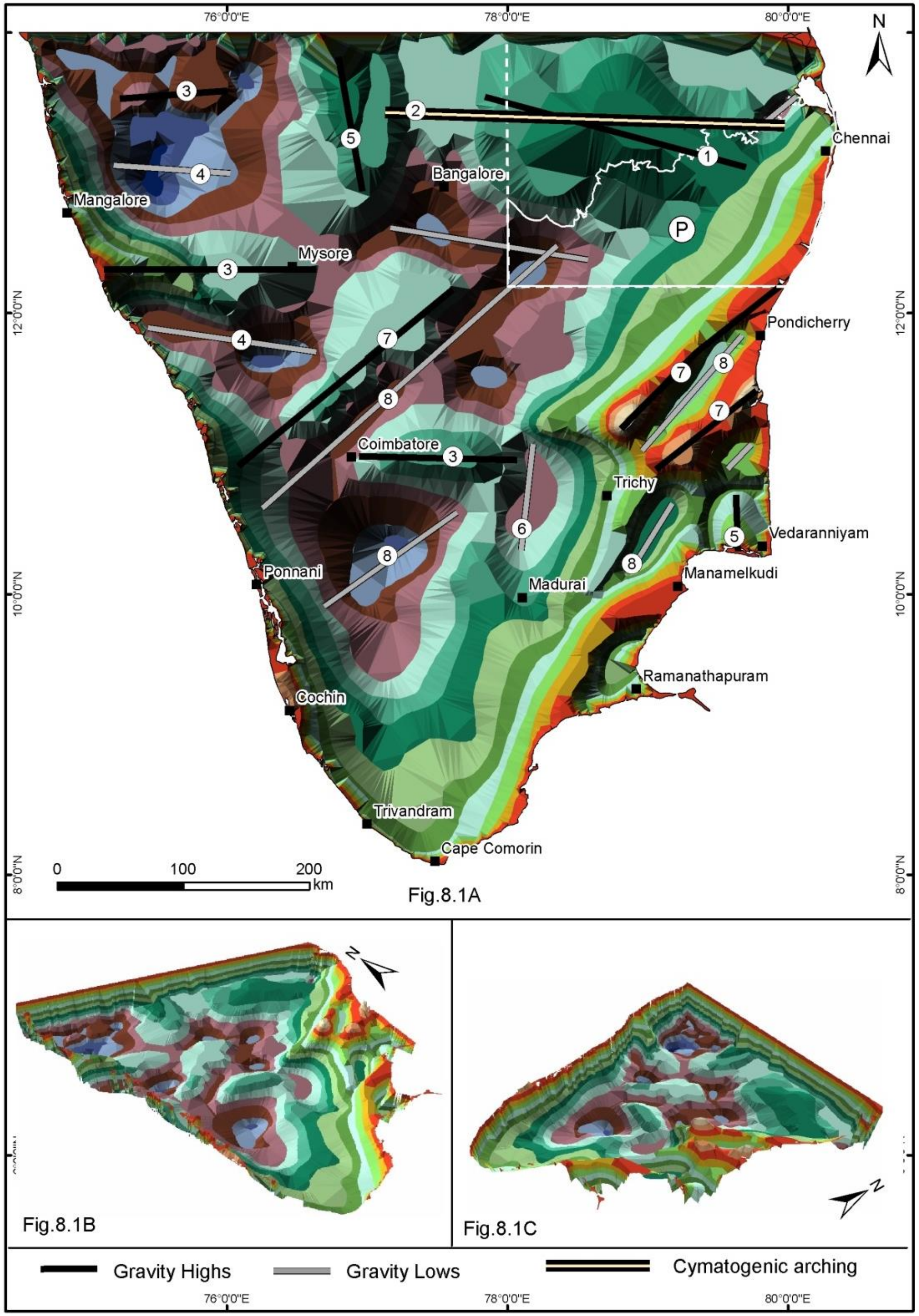


Fig.8.1 - 3D GIS image showing gravity anomalies and Neo - Active Tectonics

TECTONIC WEAK ZONES / ACTIVE FAULTS & HISTORICAL SEISMICITY

Final Lineament / Fault map of South India

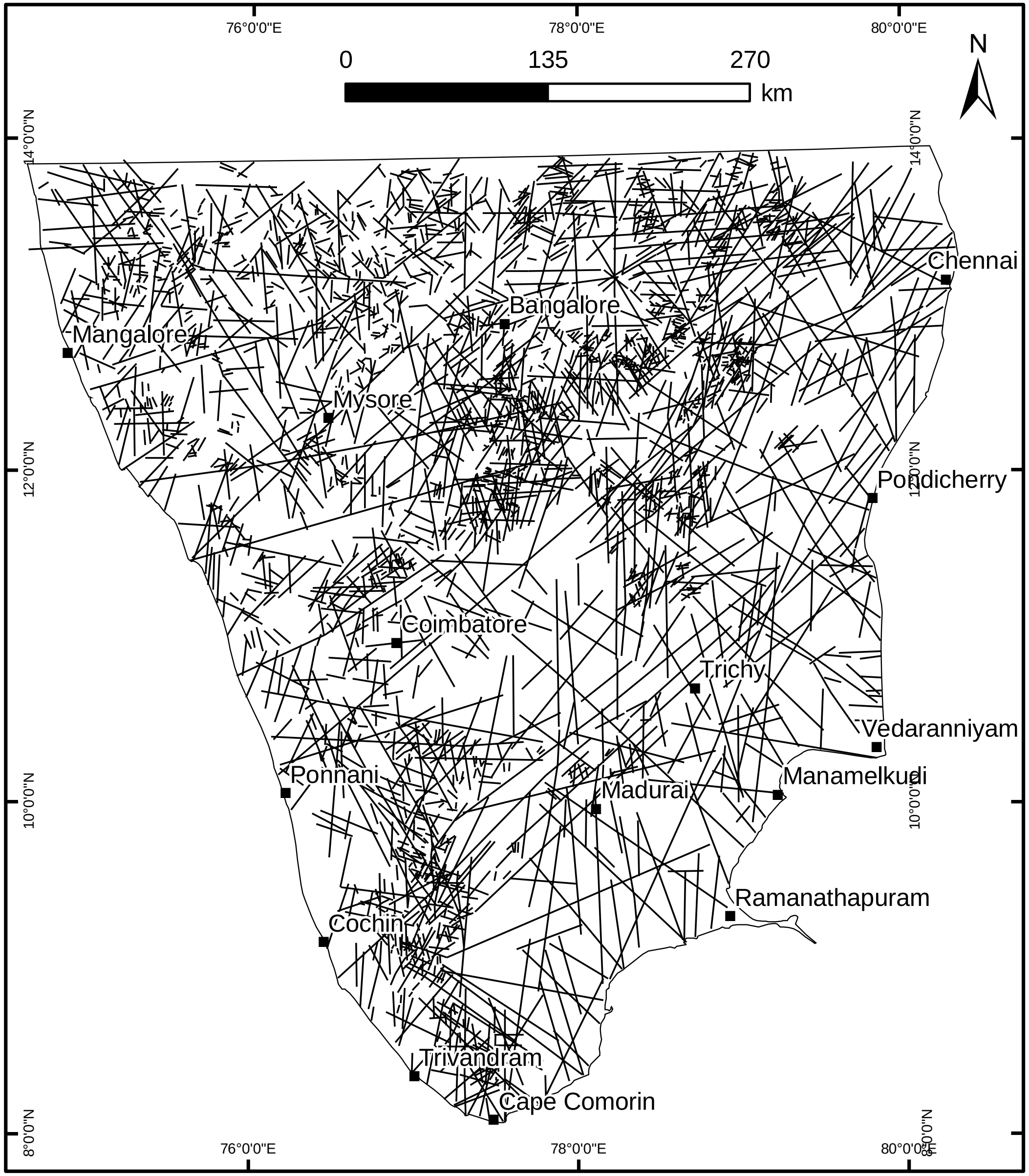


Fig.2: Lineaments of South India

Detection of Seismotectonic Domains

At the next stage,

The relation between the active faults / lineaments and the historical seismicity data were analysed and

Therefrom to domain out the zones of Seismic corridors / Seismic Vulnerable Zones

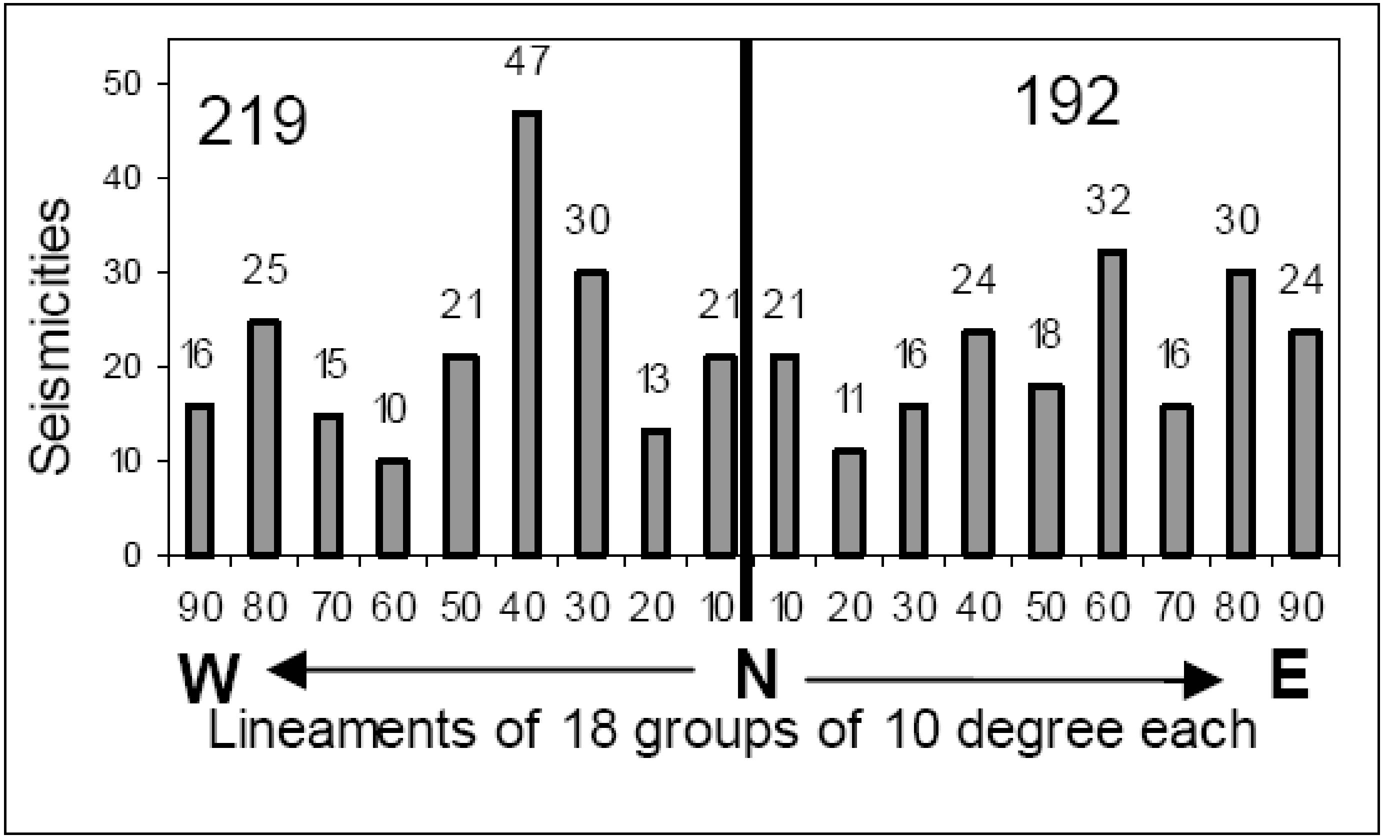


Fig.2: Histogram Showing Number of Seismic counts Falling in 18 Azimuthal Groups of Lineaments of 10^0 each

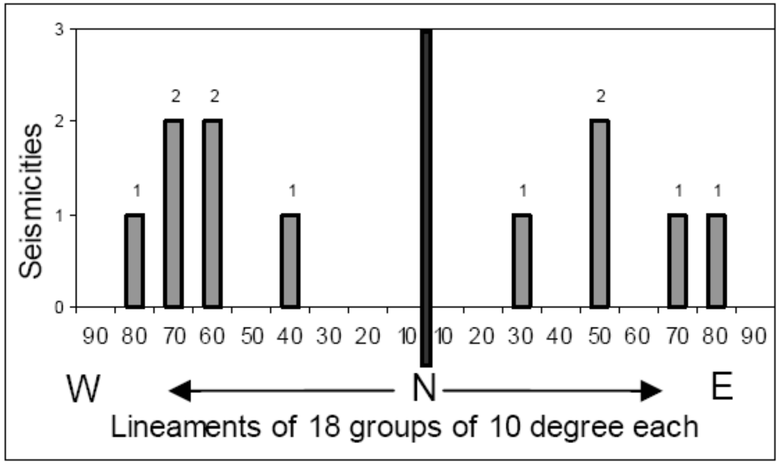


Fig.3: Histogram between Number of Seismic counts during 1807 – 1850 AD and 18 azimuthal Groups of Lineaments

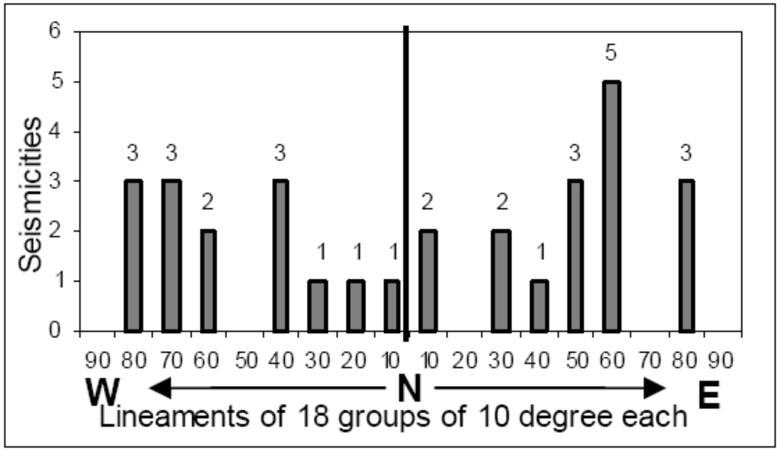


Fig.4: Histogram between Number of Seismic counts during 1850 – 1900 AD and 18 azimuthal Groups of Lineaments

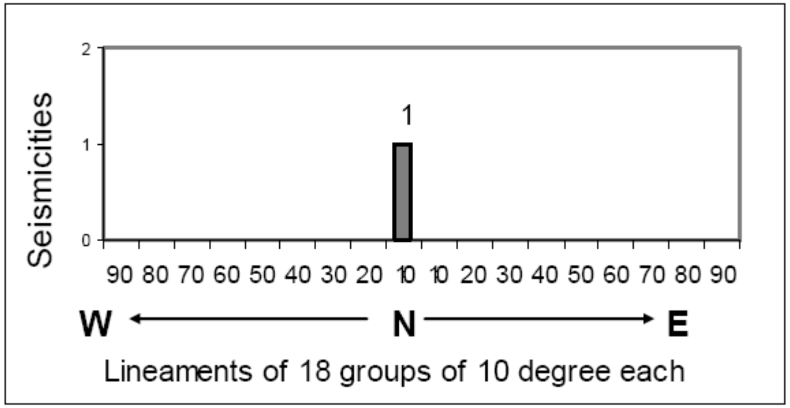


Fig.5: Histogram between Number of Seismic counts during 1901 – 1950 AD and 18 azimuthal Groups of Lineaments

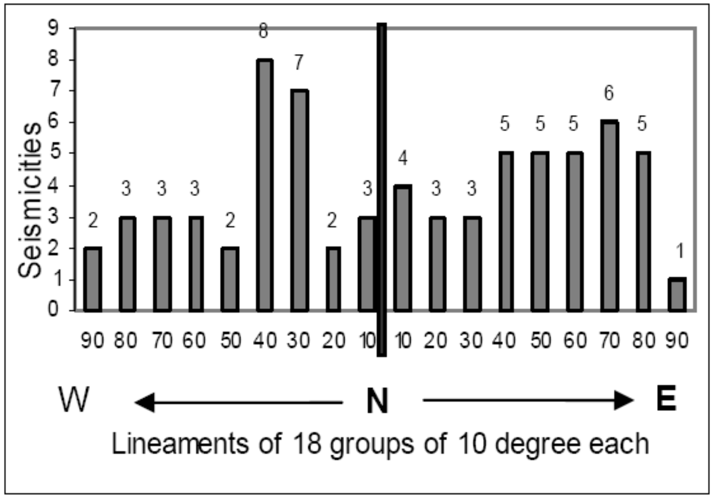


Fig.6: Histogram between Number of Seismic counts during 1951 – 1994 AD and 18 azimuthal Groups of Lineaments

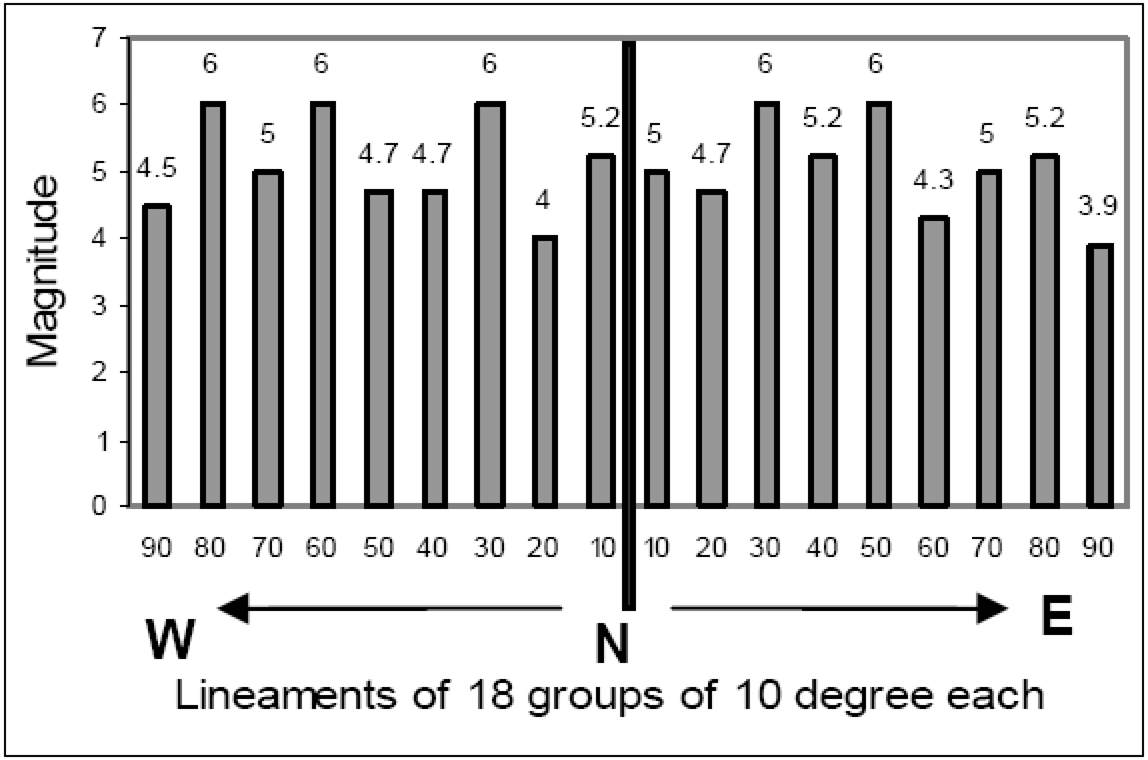


Fig.7: Histogram between the Seismicity of Highest Magnitude and corresponding 18 azimuthal Groups of Lineaments

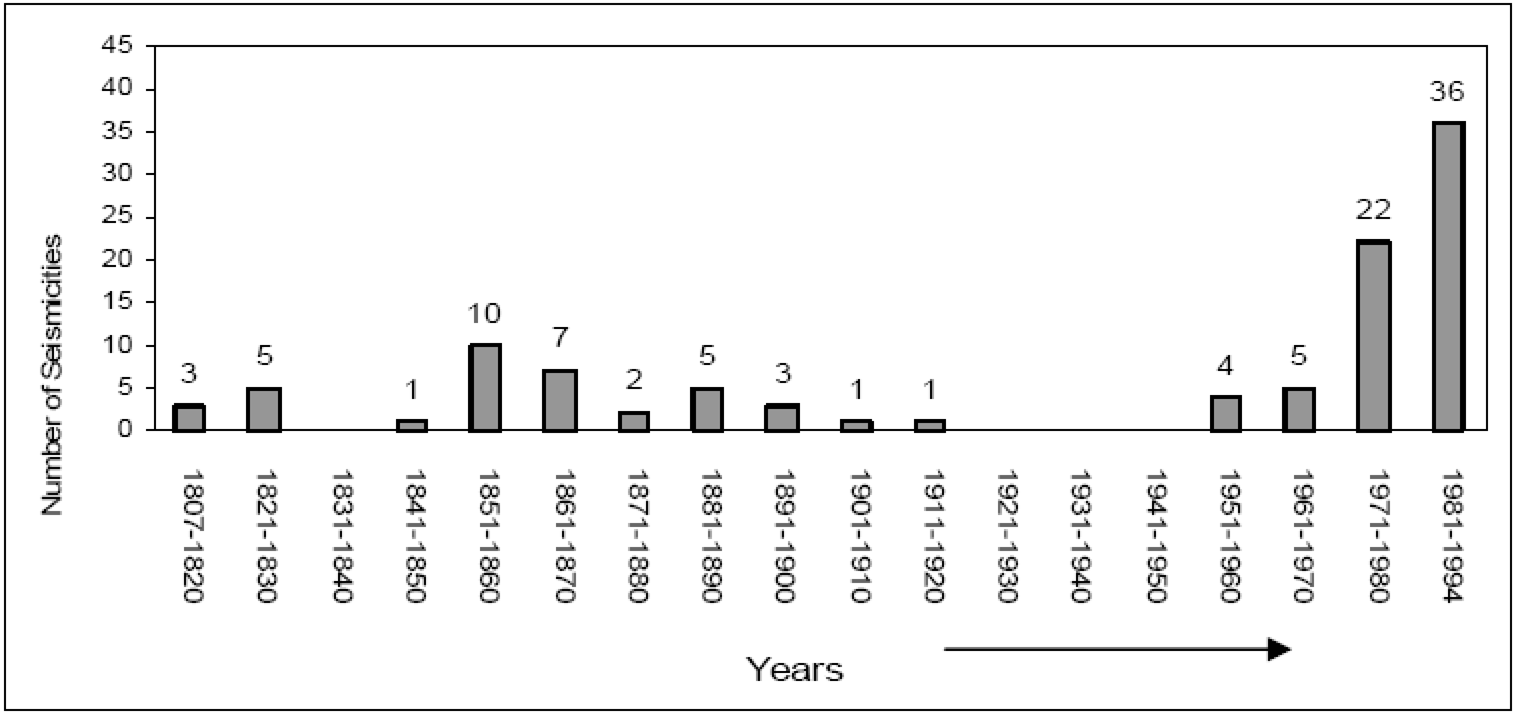


Fig.8: Histogram between e Frequency of Seismicities and the corresponding 18 azimuthal Groups of Lineaments

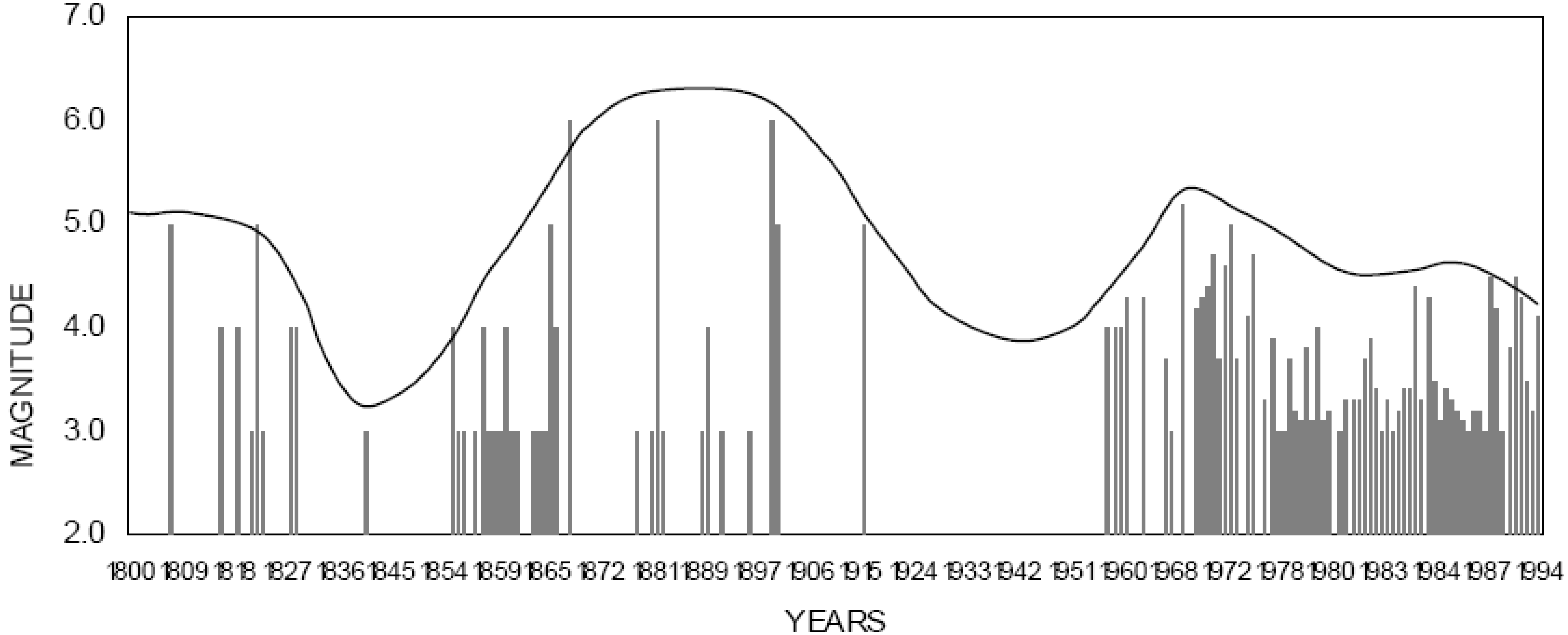


Fig. sr onhe Magnitudes of Seismicities and the years of occurrence (1807 – 1994)

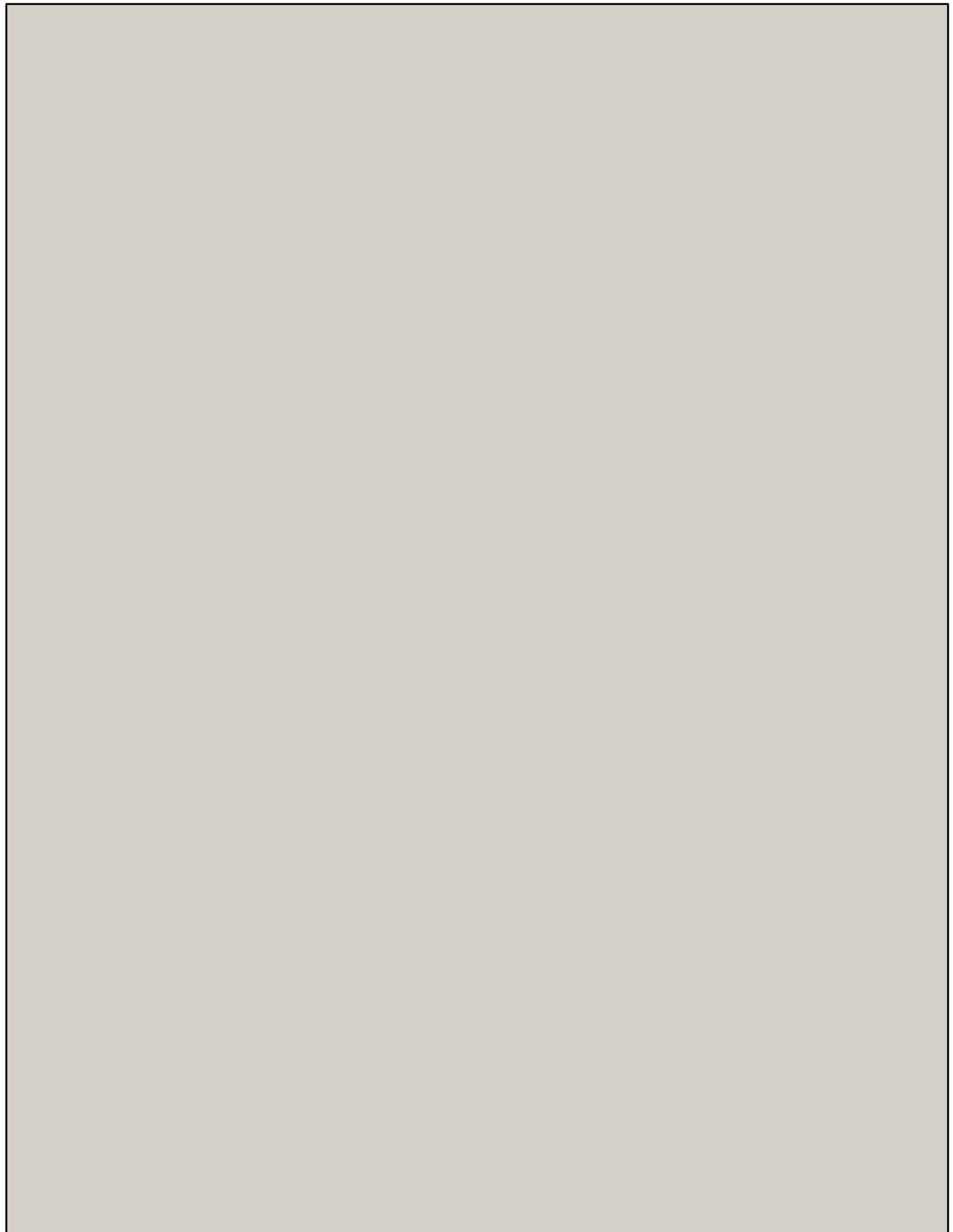


Fig.3: Non Intersecting Lineaments and Epicentres

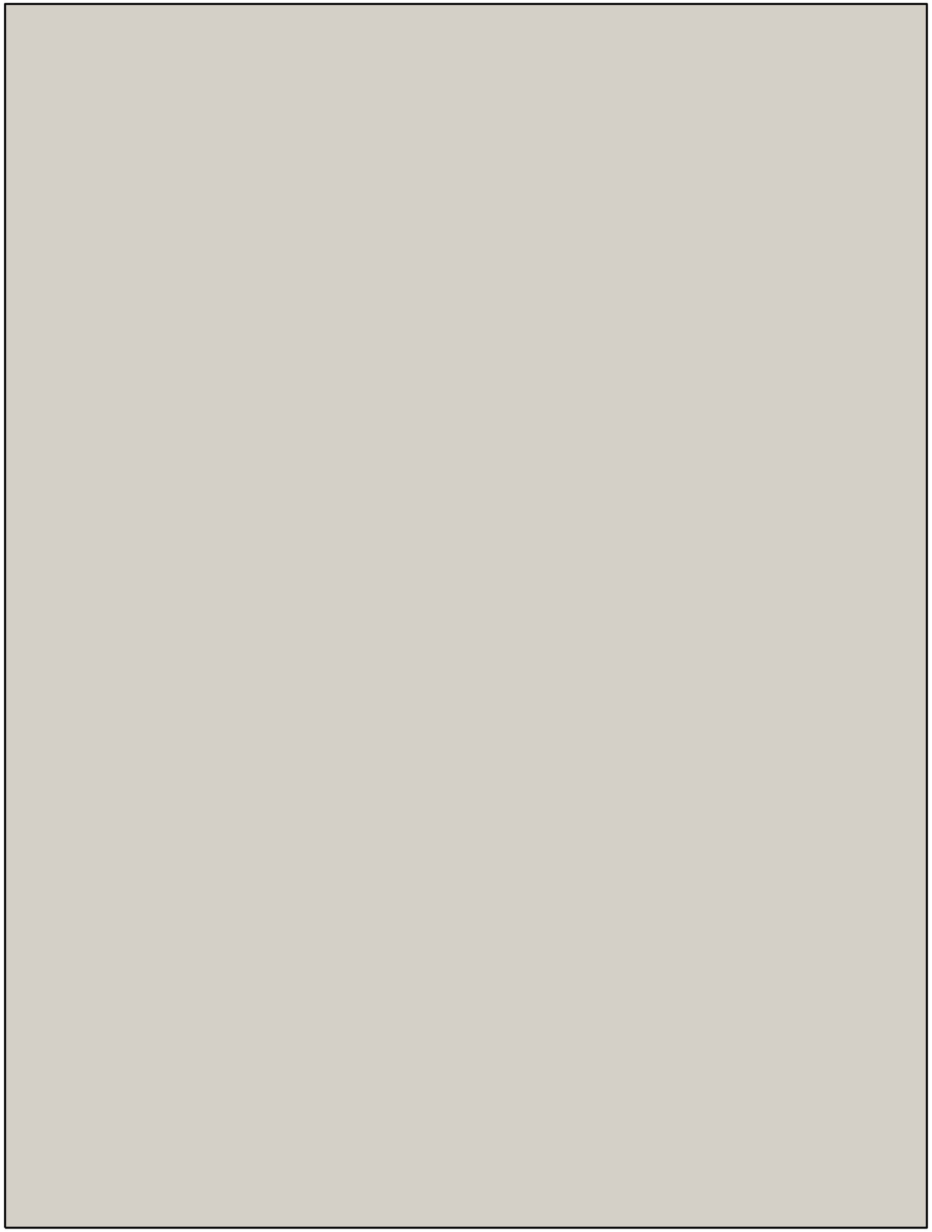


Fig.4: Intersecting Lineaments and Epicentres

Angle of Intersection	No of Epicentres
0-10	0
11-20	3
21-30	3
31-40	6
41-50	8
51-60	7
61-70	5
71-80	7
81-90	6
91-100	4
101-110	5
111-120	1
121-130	3
131-140	2
141-150	0
151-160	0
161-170	0
171-180	0

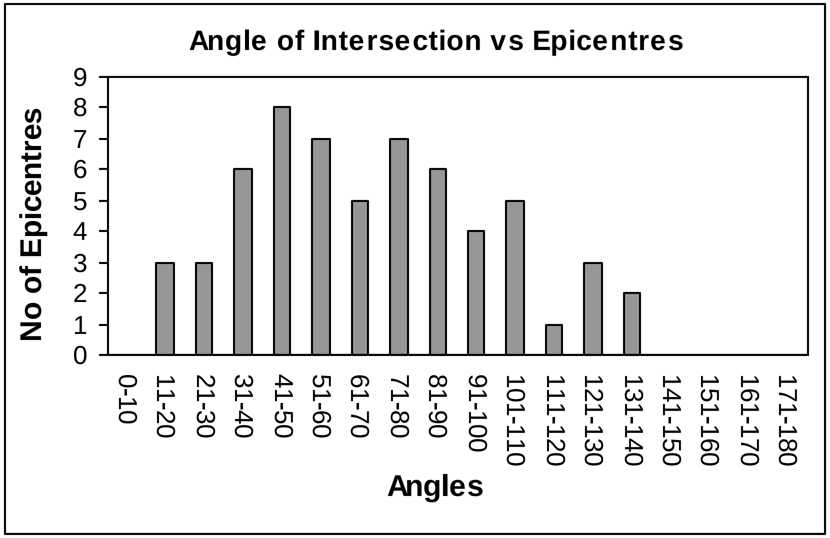
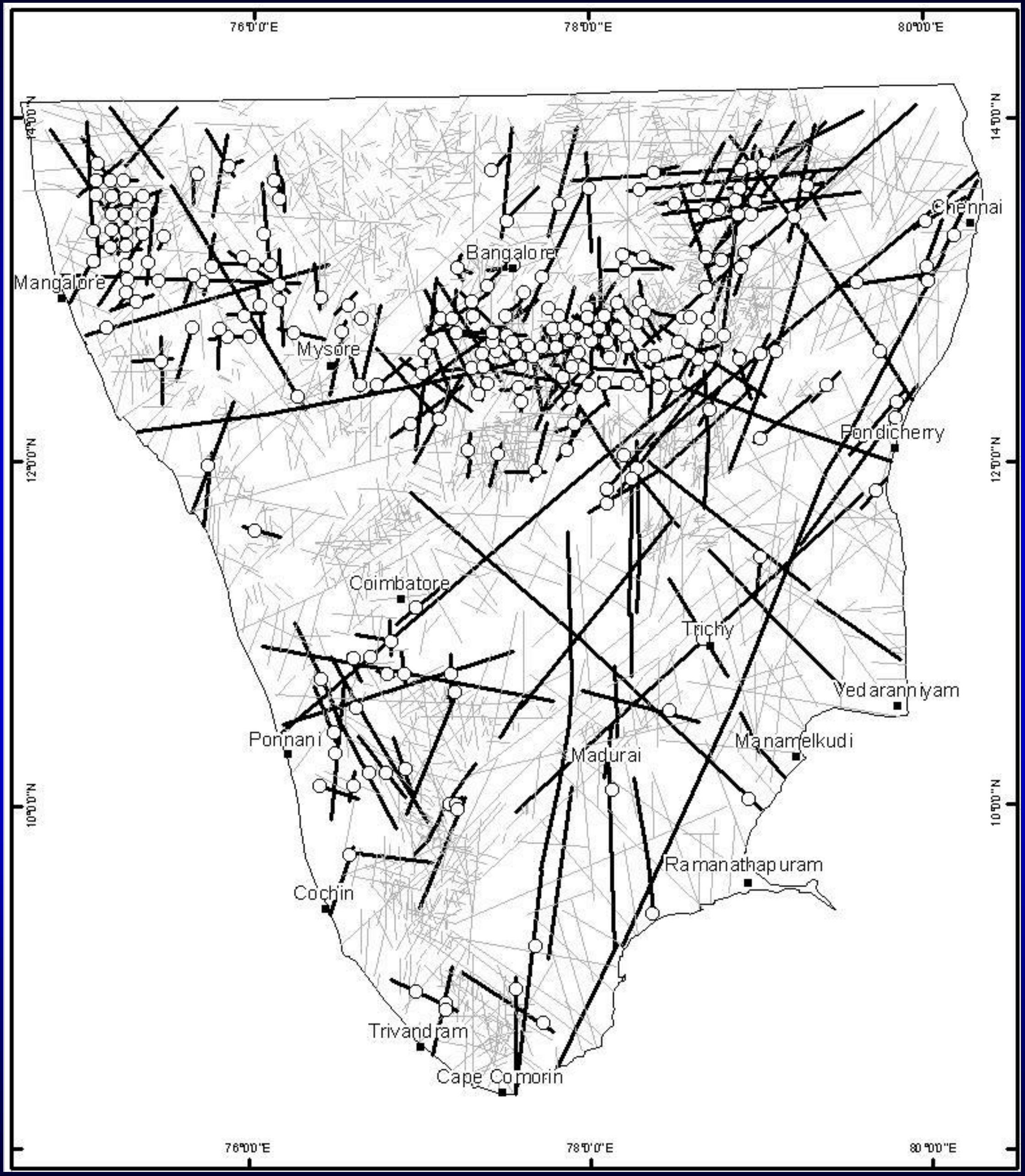


Fig.5: Angle of Intersections vs Epicentres



Seismotectonic Corridors of South India