BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024
Tamil Nadu, India

Programme : M.Tech., Geological Technology and Geoinformatics

Course Title : Geomorphology and Geodynamics
Course Code : MTIGT0506

Unit-2: Tectonic Geomorphology & Fluvial Geomorphology

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TECTONIC GEOMORPHOLOGY

(TECTONIC LANDFORMS)

DEFINITION: Land forms formed or produced by denudational processes or physico- chemical breaking down processes but retained their original tectonic fabric.

***Tectonic geomorphology*: how tectonic activity affects process and morphology in geomorphic systems and how landforms can be used to assess tectonic activity.**

Landform of structural origin is related to structural aspect of the area.

Most of the landform under this class has genesis related to underlying structure.

Structure plays an important role for reducing the resistance of rock which manifests itself in different geomorphic forms.

- **Surface features of the land**
  - Tectonic and volcanic forces attempt to raise land
    - create **initial landforms**
  - … weathering and erosion attempt to reduce land surface (denudation)
    - create **sequential landforms**
- Agents of denudation are… running water, waves, wind, ice, gravity

REASONS FOR STUDYING TECTONIC LANDFORMS

(i) Mineral targetting (structurally controlled deposits)

- Bauxites in plateau
- Copper in escarpments (Vindhyans)
- Minerals in Strain maxima zones in folds
- Remobilised deposits in fractures / maximas

(ii) Groundwater in younger fractures

(iii) Hotwater springs in younger fractures

(iv) Detection of zones of Active tectonics

(v) Landslides mapping etc.,

(vi) Earthquake vulnerability mapping

CLIMATE FAVOURABLE FOR TECTONIC LANDFORMS

i) Temperate
ii) Humid
iii) Subhumid
iv) Arid - rarely

PARENT ROCKS

i) Sedimentary
ii) Meta sedimentary
iii) Volcanic

AGENTS

i) Atmosphere
ii) Wind
iii) Water

LANDFORMS

<u>Structural Hills</u>

- Highly Dissected
- Moderately dissected
- Poorly dissected

<u>Tors complexes</u>

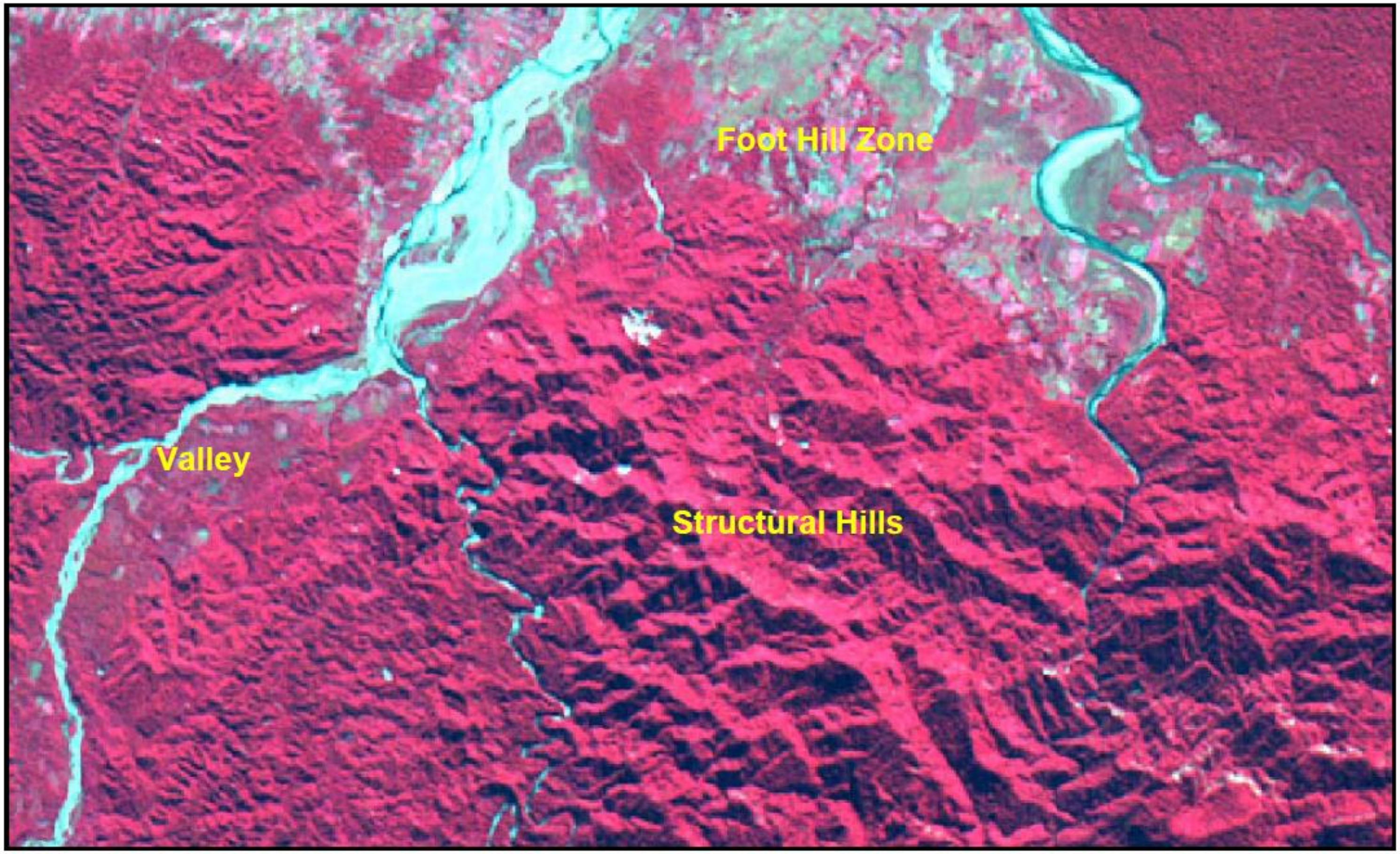
<u>Horizontal Landforms</u>

- Tectonic Plateau
  - Highly Dissected
  - Moderately dissected
  - Poorly dissected
- Tectonic Mesa / Butte
  - Highly Dissected
  - Moderately dissected
  - Poorly dissected

LANDFORMS IN UNDEFORMED ROCKS

Structural Hills: **Hills are originated due to tectonic process and If are highly dissected by the drainage lines, then can be further classified as highly, moderately and low dissection depending on the density of joints and drainage.**

Fig. 4.24: Satellite image of Himalayan region showing the structural landforms.



Pre-Cordillera: Patagonian Andes, Argentina

Structural Hills:

Aerial view,
Himalayan Foothills,
northern Pakistan

Plunging folds

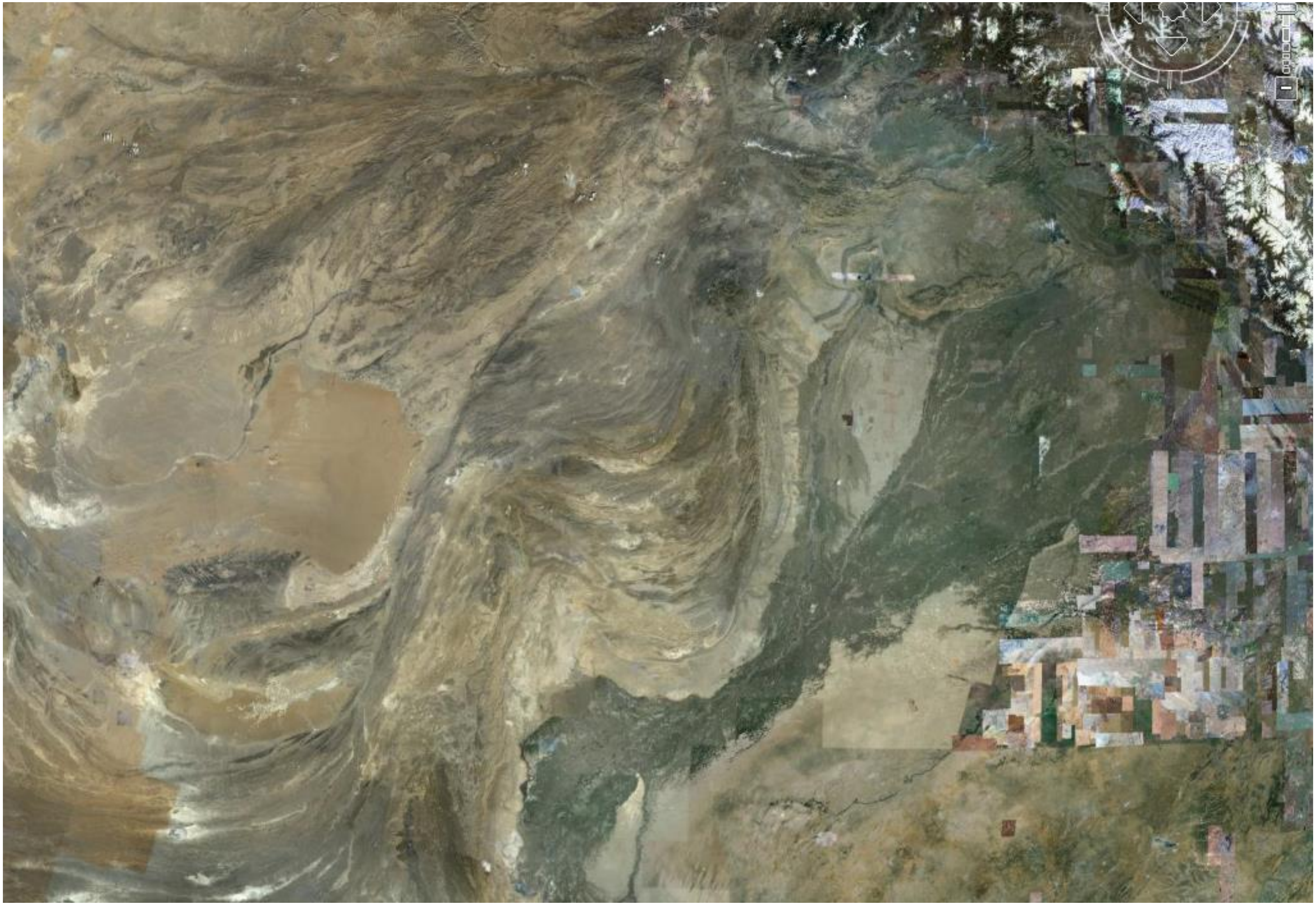
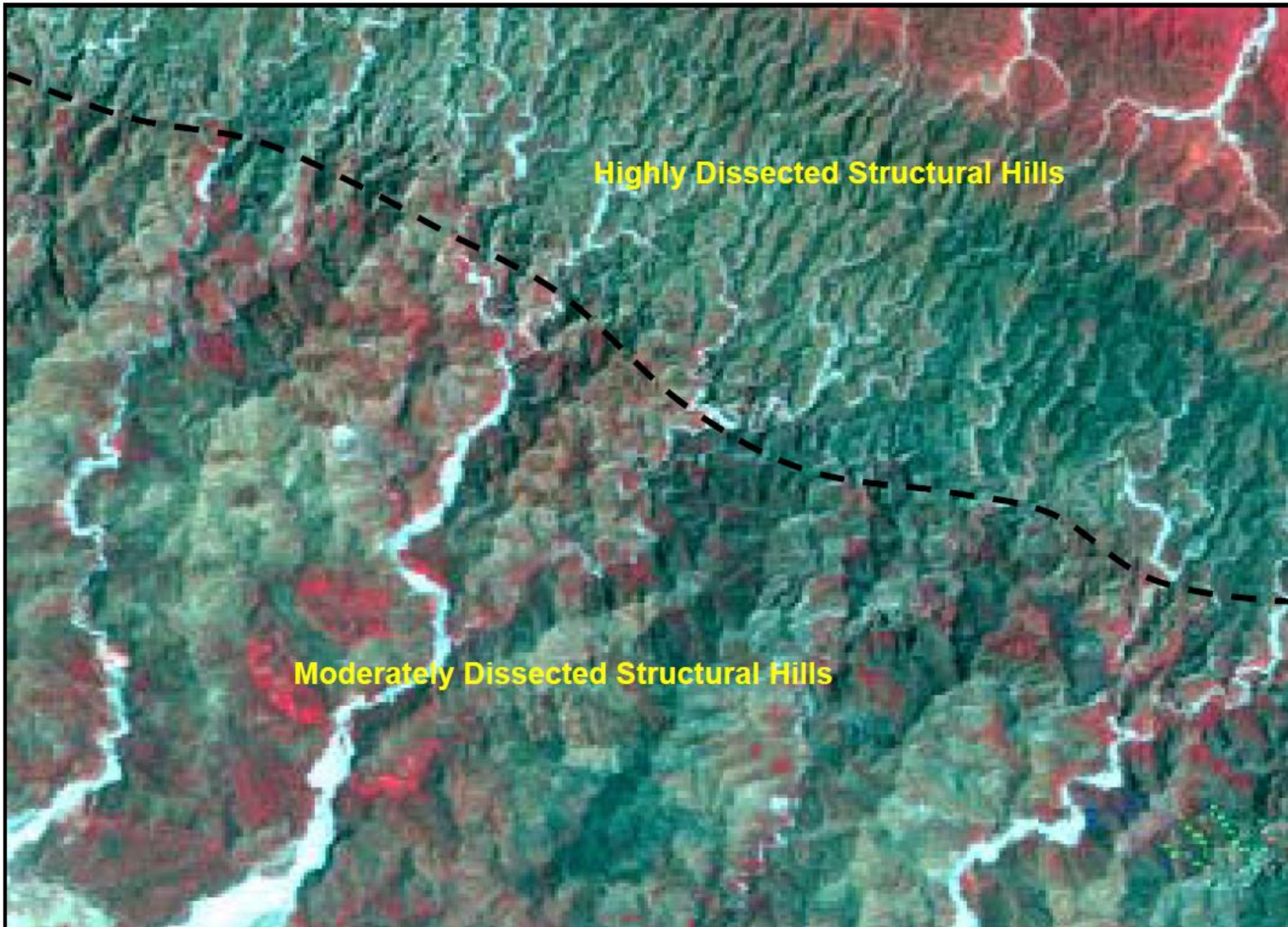


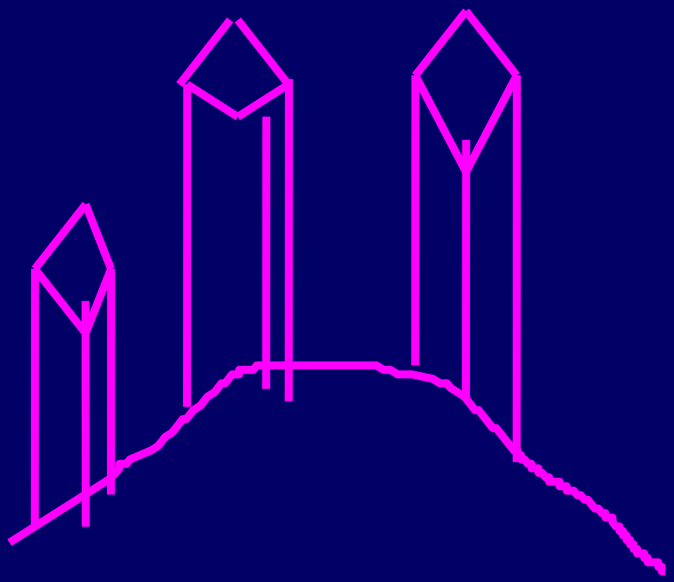
Fig. 4.26: Satellite image of Himalayan region showing dissected structural hills.



TORS

Tor is a complexly jointed blocked hills

(a) Tor complex

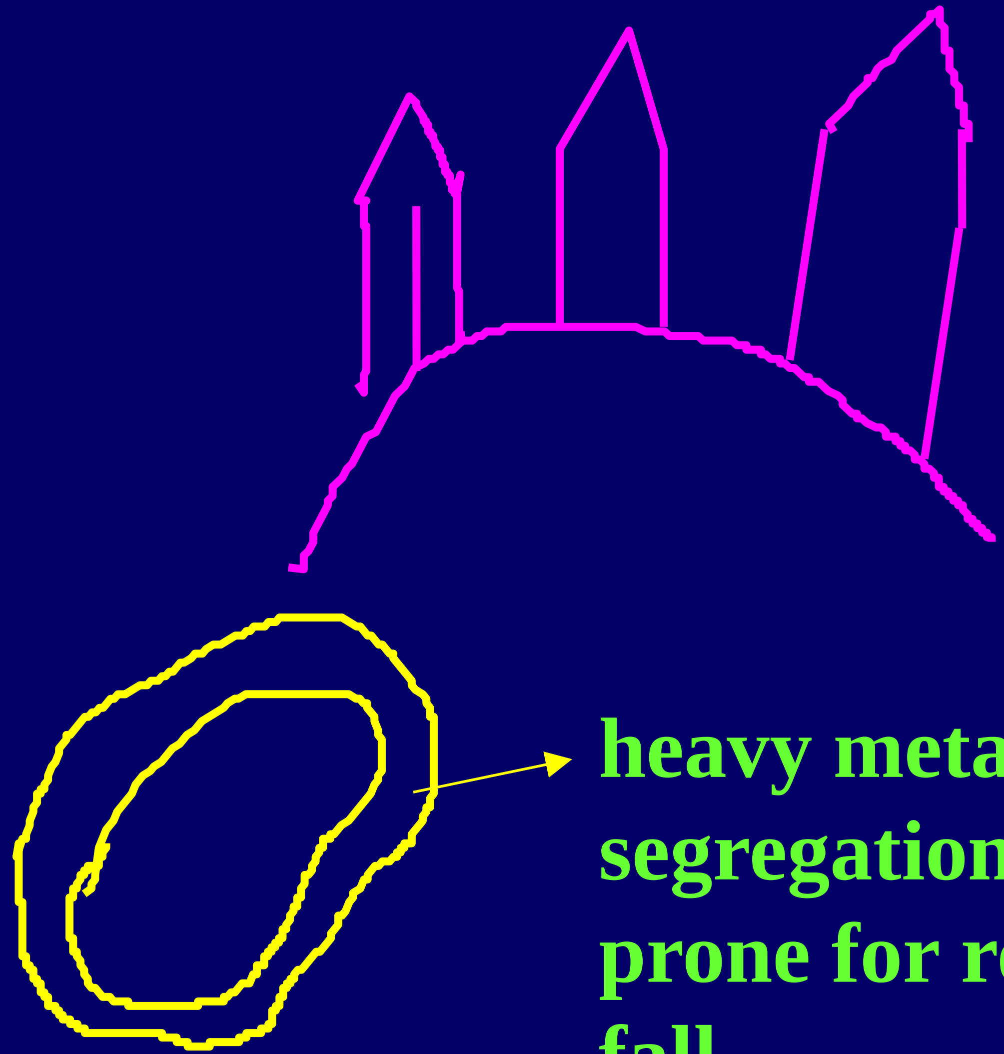


Tor: A high, isolated, craggy hill, pinnacle, or rocky peak; or a pile of rocks, much-jointed and usually granitic, exposed to considerable weathering, and often assuming peculiar or fantastic shapes.

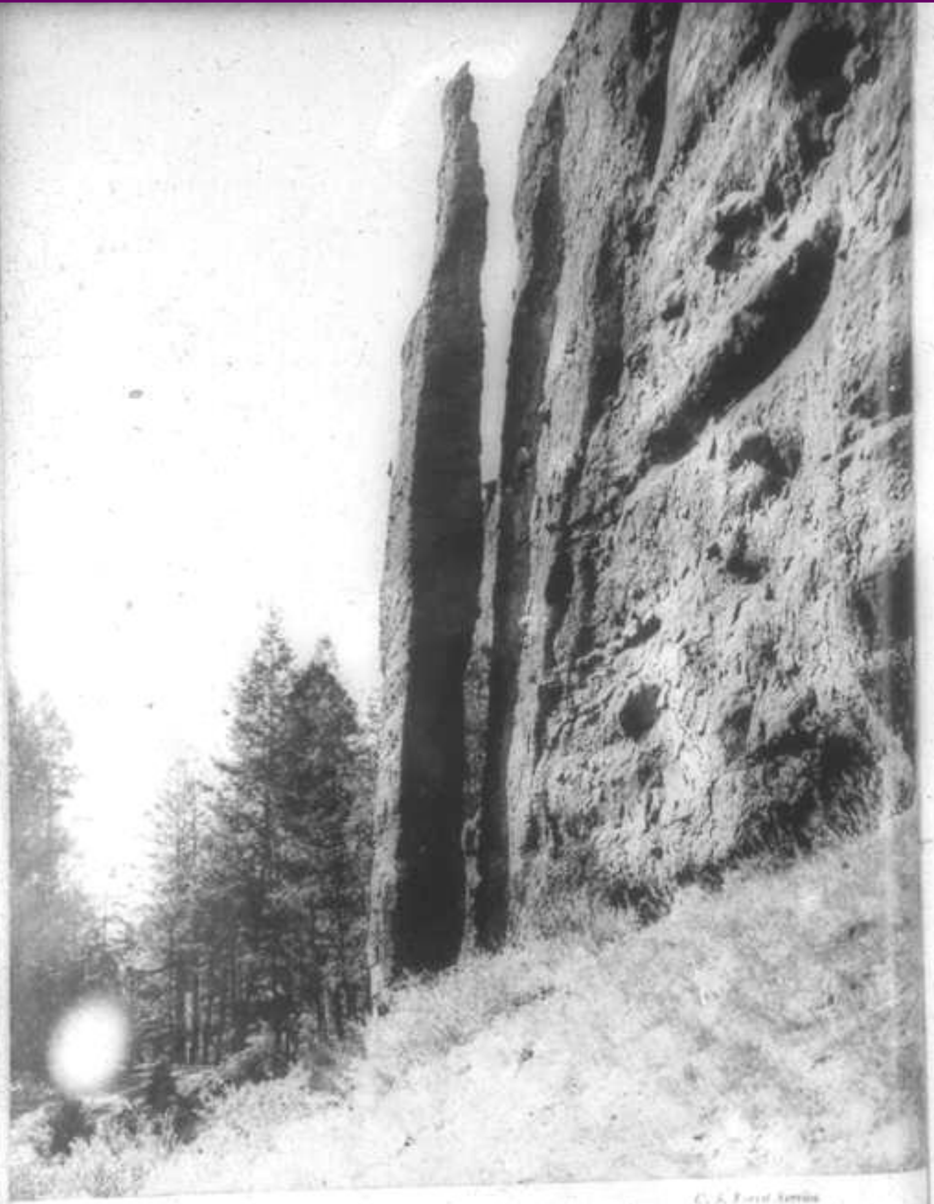
- **No heavy metal seggregate in the foot.**
- **Less reservoir siltation in the foot hill reservoirs**


William Allen
HEAD, FORT

(b) Tor cliffs



heavy metal segregation and prone for rock fall



U. S. Forest Service

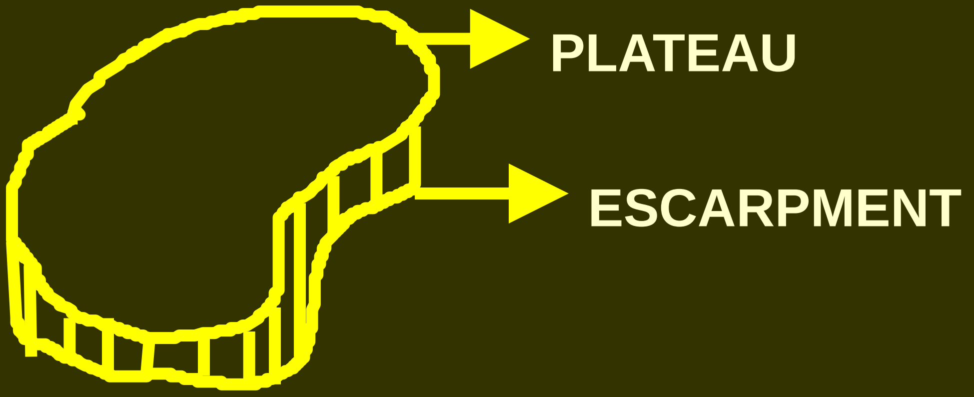
CHIMNEY ROCK ALONG THE HIGHWAY BETWEEN CODY AND YELLOWSTONE PARK

Vertical joints in horizontal beds of volcanic tuff and agglomerate.

RELICT TOR CLIFF (TORRES DEL PAINE, PANTAGONIA)

(3.6.1.1) Plateau: Vast horizontal plate like landforms covering several hundred sq km Surrounded by vertical wall like escarpments are developed due to tectonic processes

E-g
- *i) Plateau in Sst - Vindhyans*
- *ii) Plateau in Cuddapah*
- *iii) All Deccan trap plateau*
- *iv) Plateau in metamorphites (charnockite)*



b) Signatures

- normally boat like
- rims / slopes prolific with vegetation

Landforms and Rock Structure

Landforms of Horizontal Strata and Coastal Plains

Arid climate landforms: horizontal strata in an arid climate often produce plateaus, mesas, and buttes

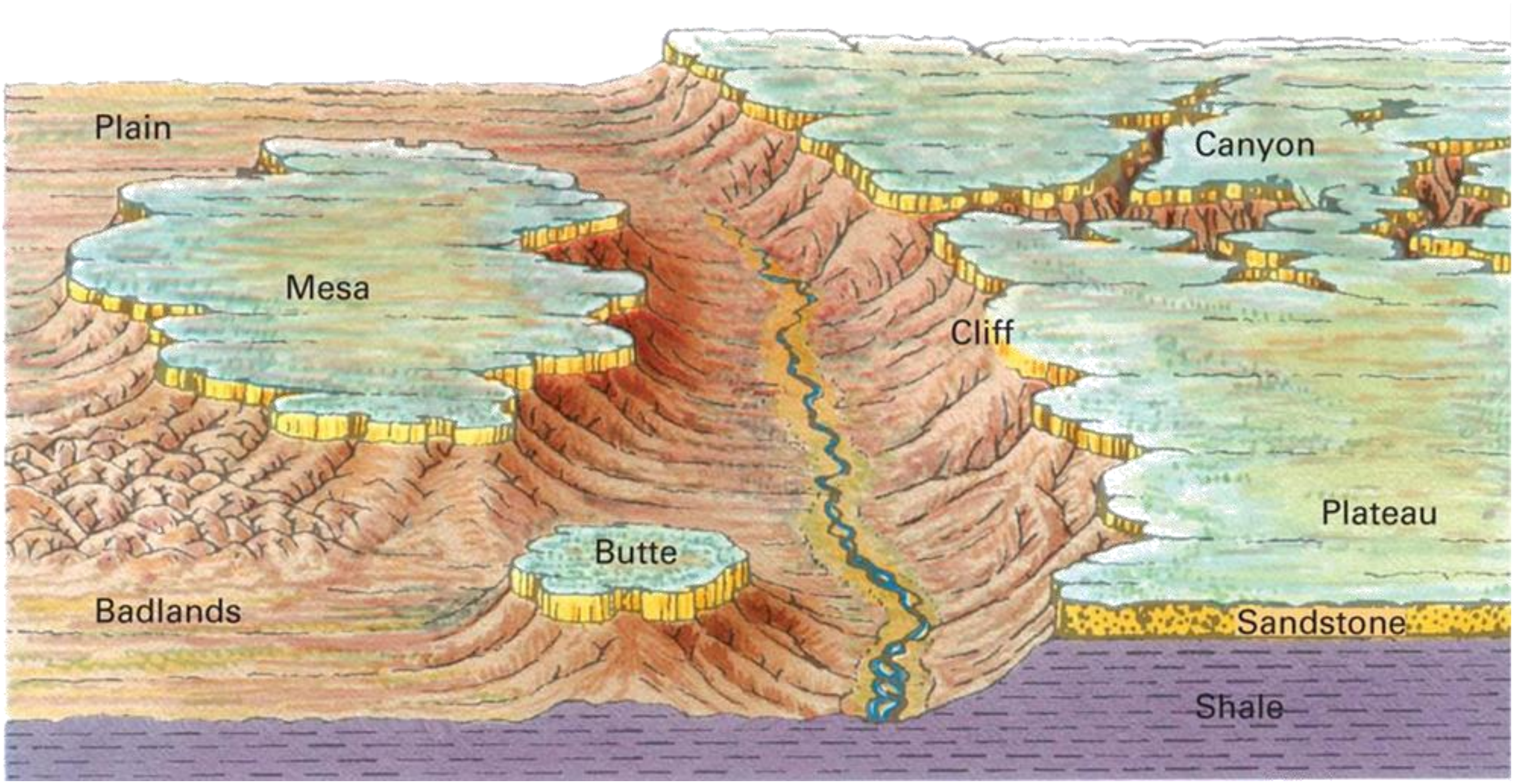
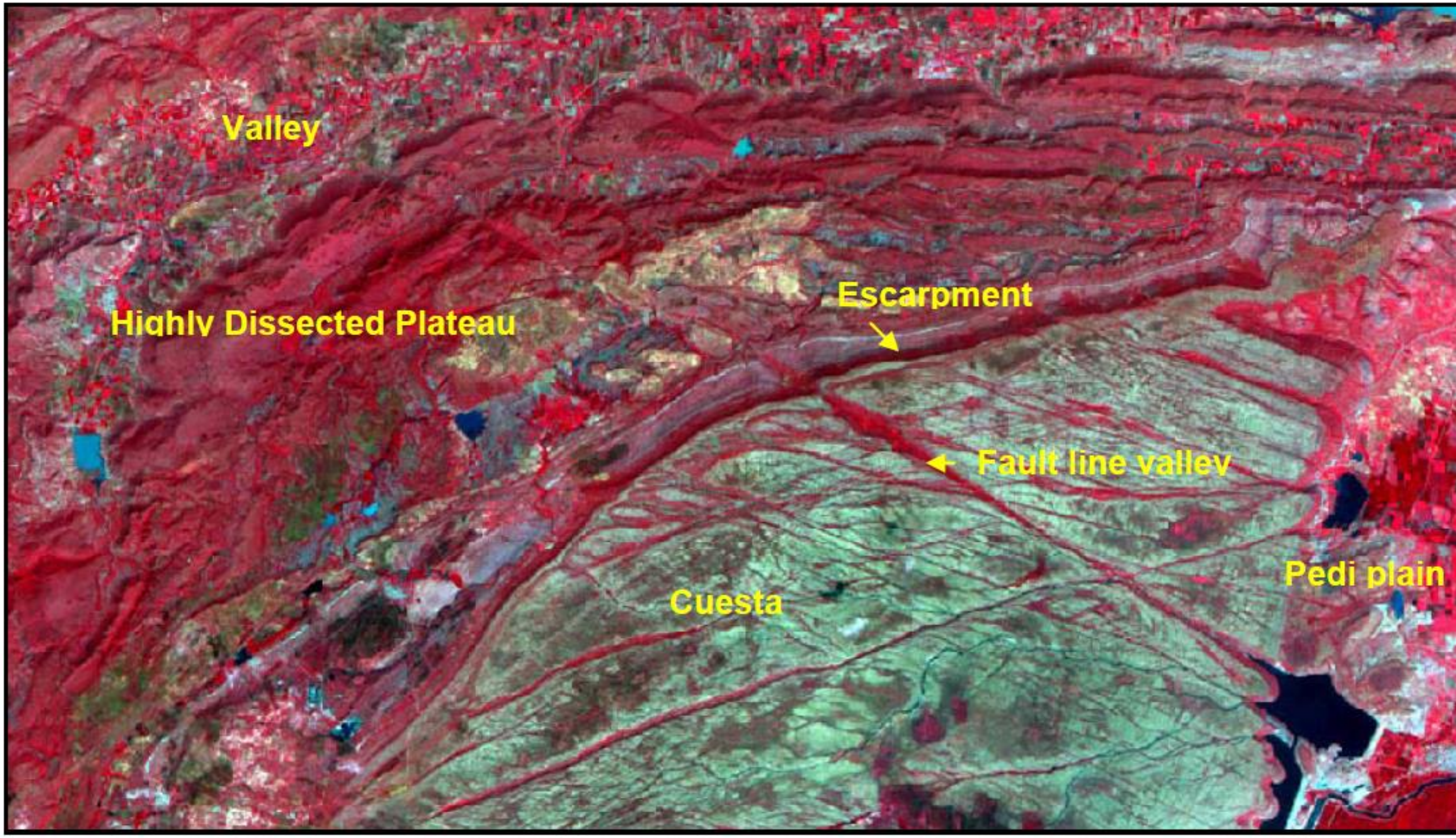
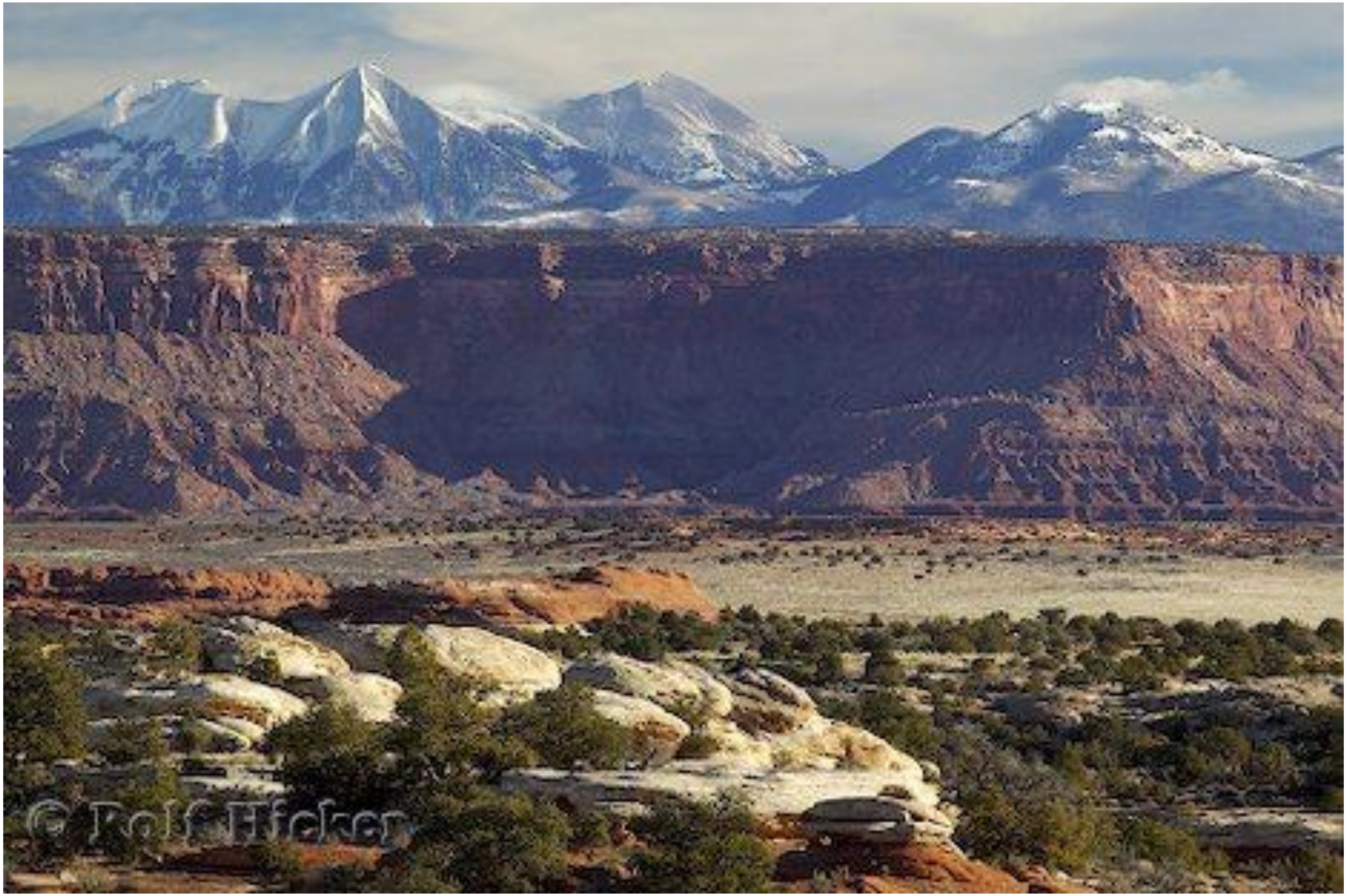
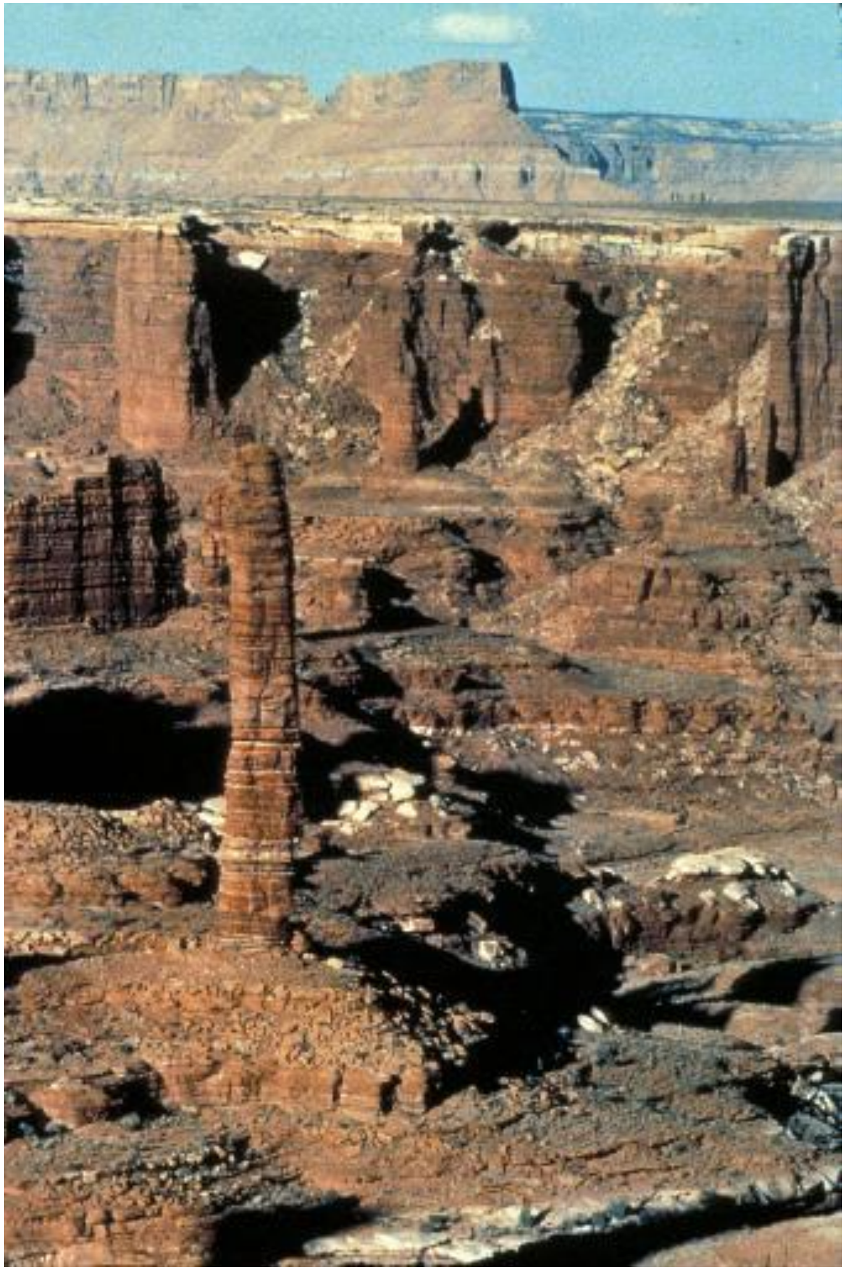


Fig. 4.21: Satellite image of Cuddapah basin showing the Structural landforms.




© Rolf Hicker



Cedar Mesa Sandstone;
Colorado Plateau;
Erosional Features;
Geomorphology

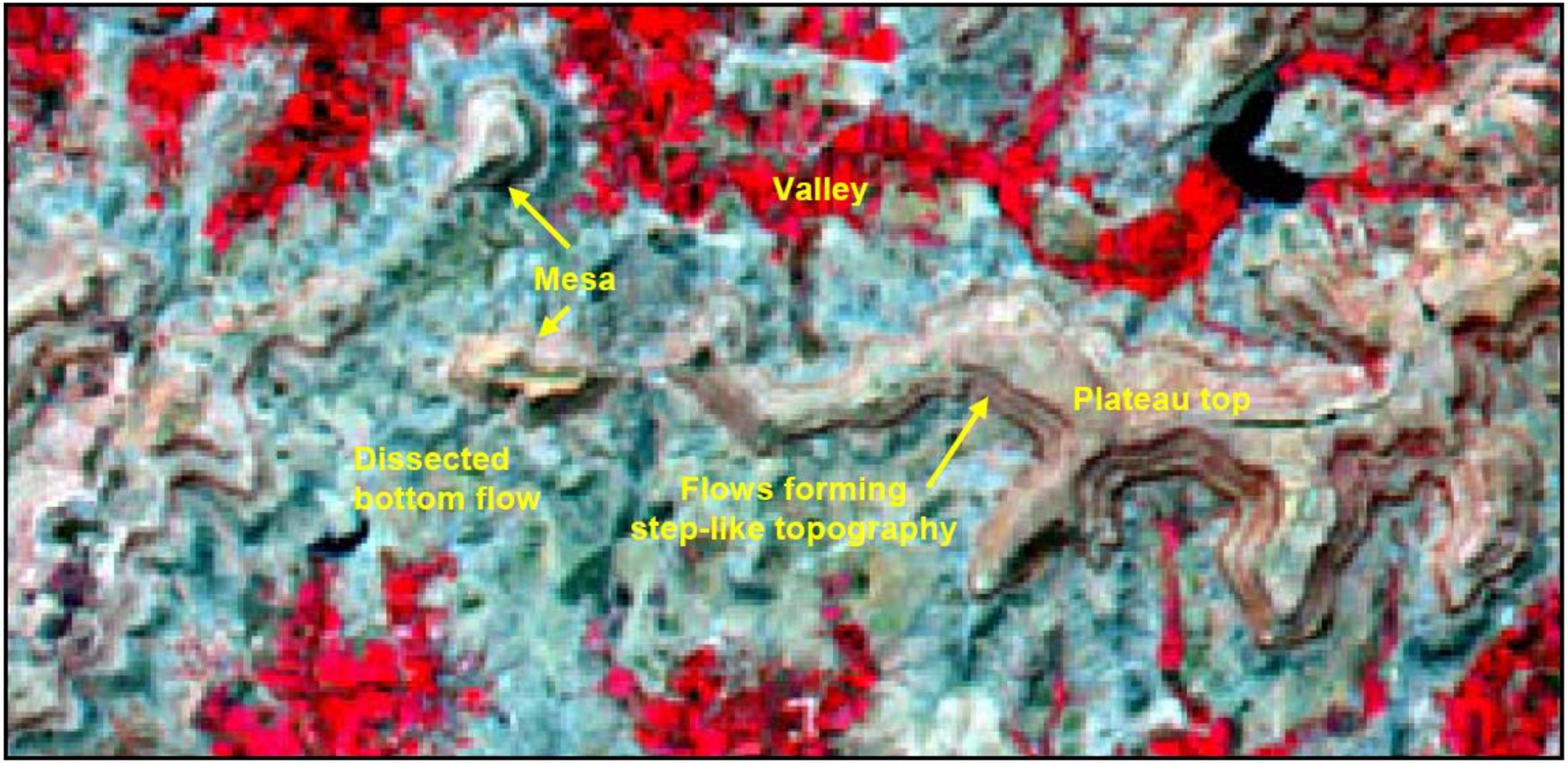
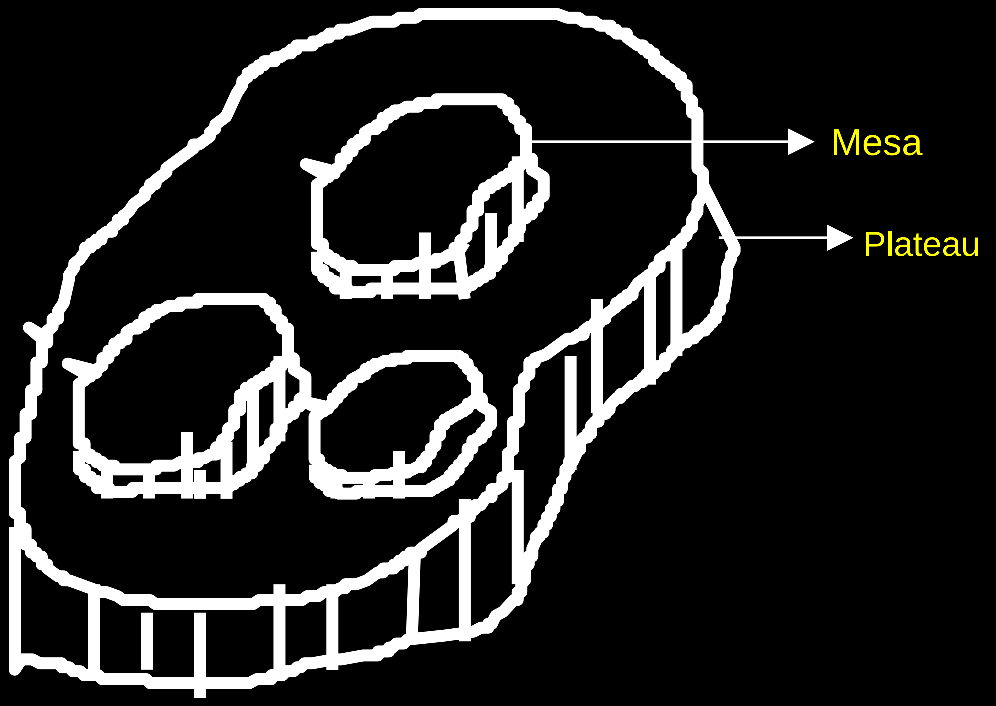


Fig. 4.7: Satellite image of Deccan trap area
showing a pile of basalt flows forming step like topography

(3.6.1.2) Mesa: *Plateau of small aerial extent*

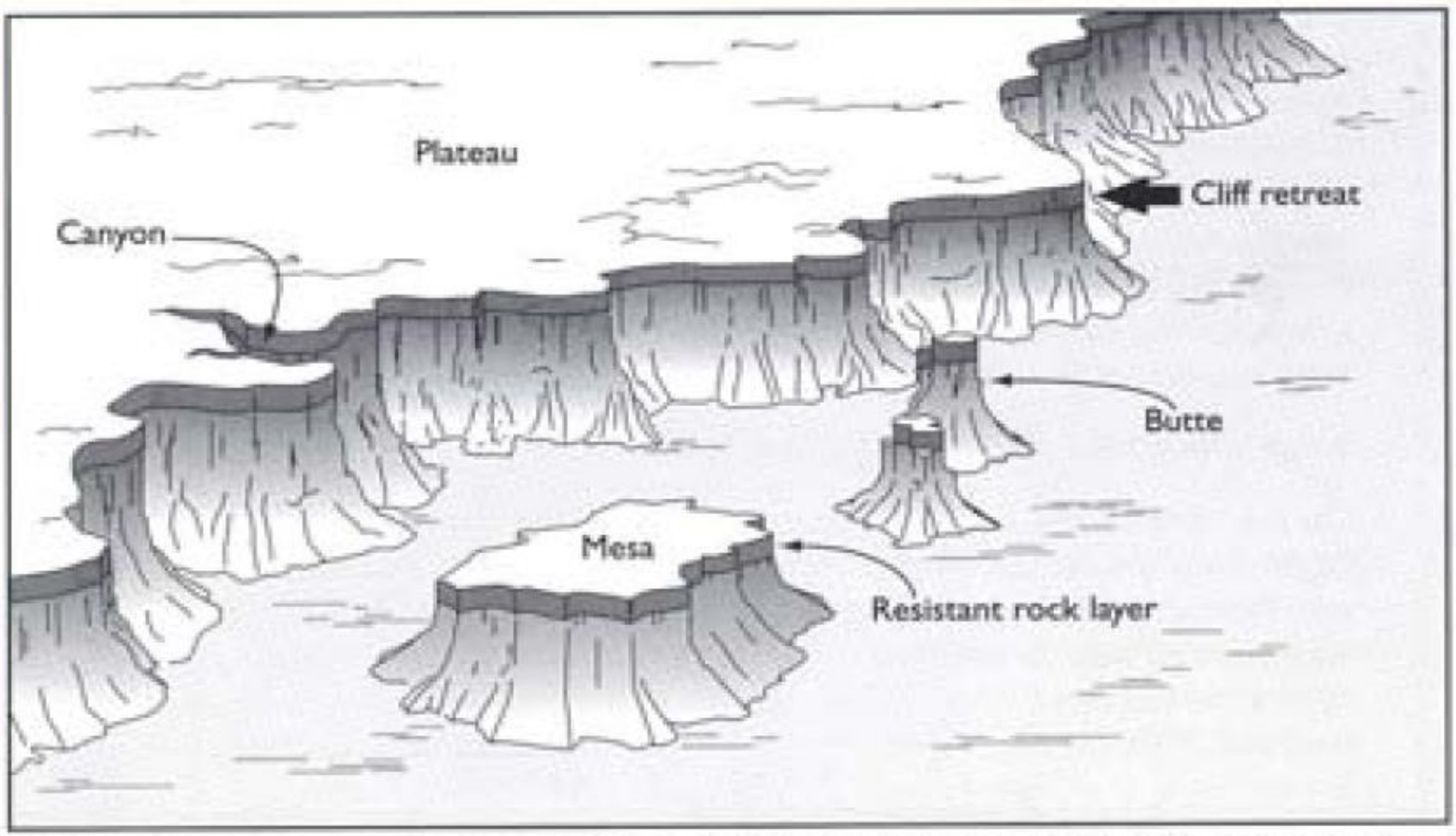
An isolated flat-topped hill with steep sides found in landscapes with horizontal strata.



Mesas and buttes

- **Mesa: an aerially-extensive, flat-topped hill with upper layer more resistant to erosion than lower layer**
- **Butte: an eroded remnant of a mesa**
- **Both are formed by mass wasting and slope and tectonic upliftment of strata in arid to semi-arid environments**

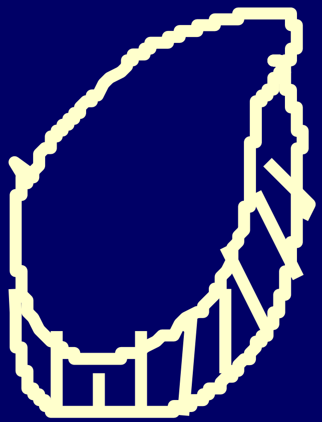
Mesas and Buttes



Buttes and mesas form as canyons cut into a cliff of soft sediments capped by more resistant rock.

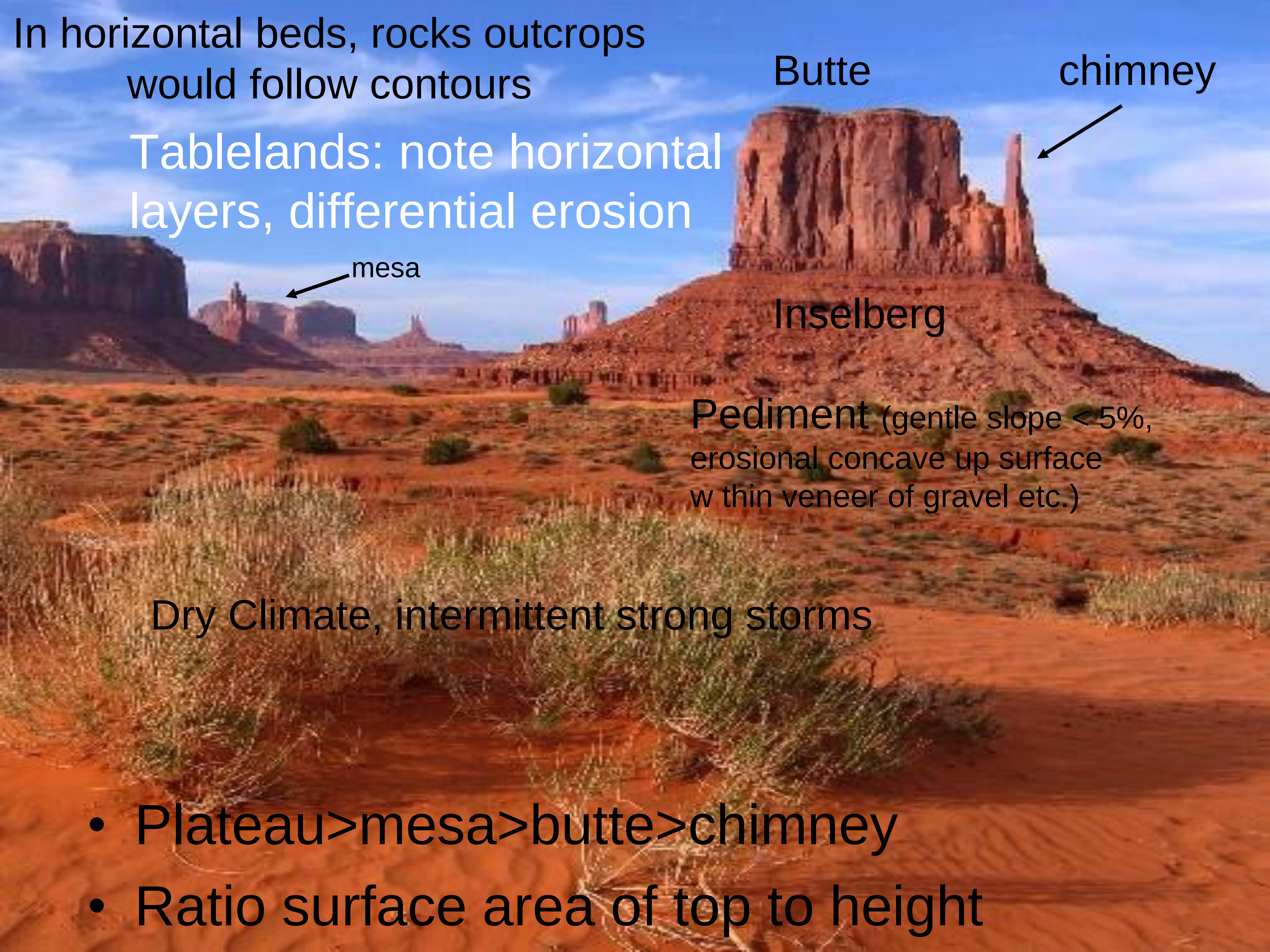
Mesas

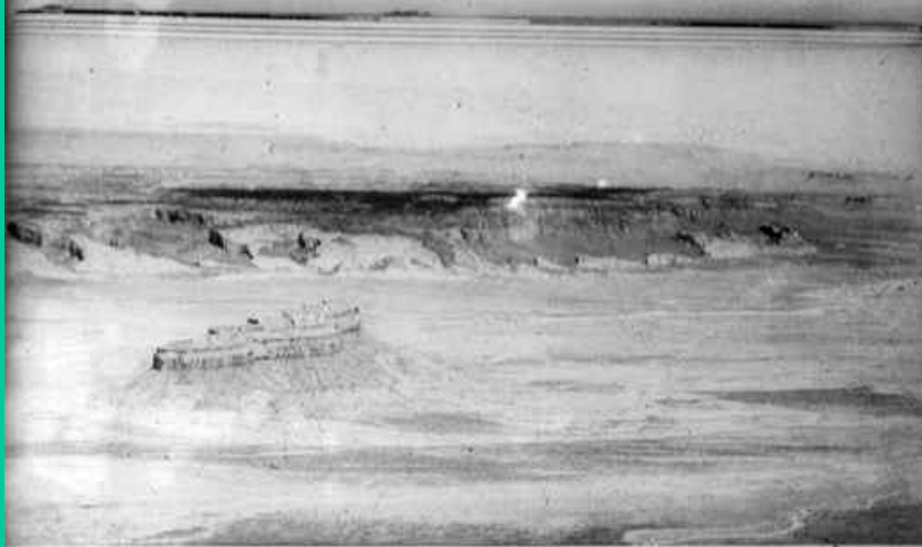
(3.6.1.3) <u>Butte</u>



- **Mesa: an aerially-extensive, flat-topped hill with upper layer more resistant to erosion than lower layer**
- **Butte: an eroded remnant of a mesa**
- **Both are formed by mass wasting and slope and tectonic upliftment of strata in arid to semi-arid environments**

- relict isolated Mesas of small magnitudes
- suggest advance stage of denudation
- indicate maturity in denudation


In horizontal beds, rocks outcrops would follow contours
Butte
chimney
Tablelands: note horizontal layers, differential erosion
mesa
Inselberg
Pediment (gentle slope < 5%, erosional concave up surface w thin veneer of gravel etc.)
Dry Climate, intermittent strong storms
• Plateau>mesa>butte>chimney
• Ratio surface area of top to height



American Museum of Natural History

BORDER OF TYENDE MESA NEAR AGATHLA PEAK, COLORADO PLATEAU, NORTHERN ARIZONA

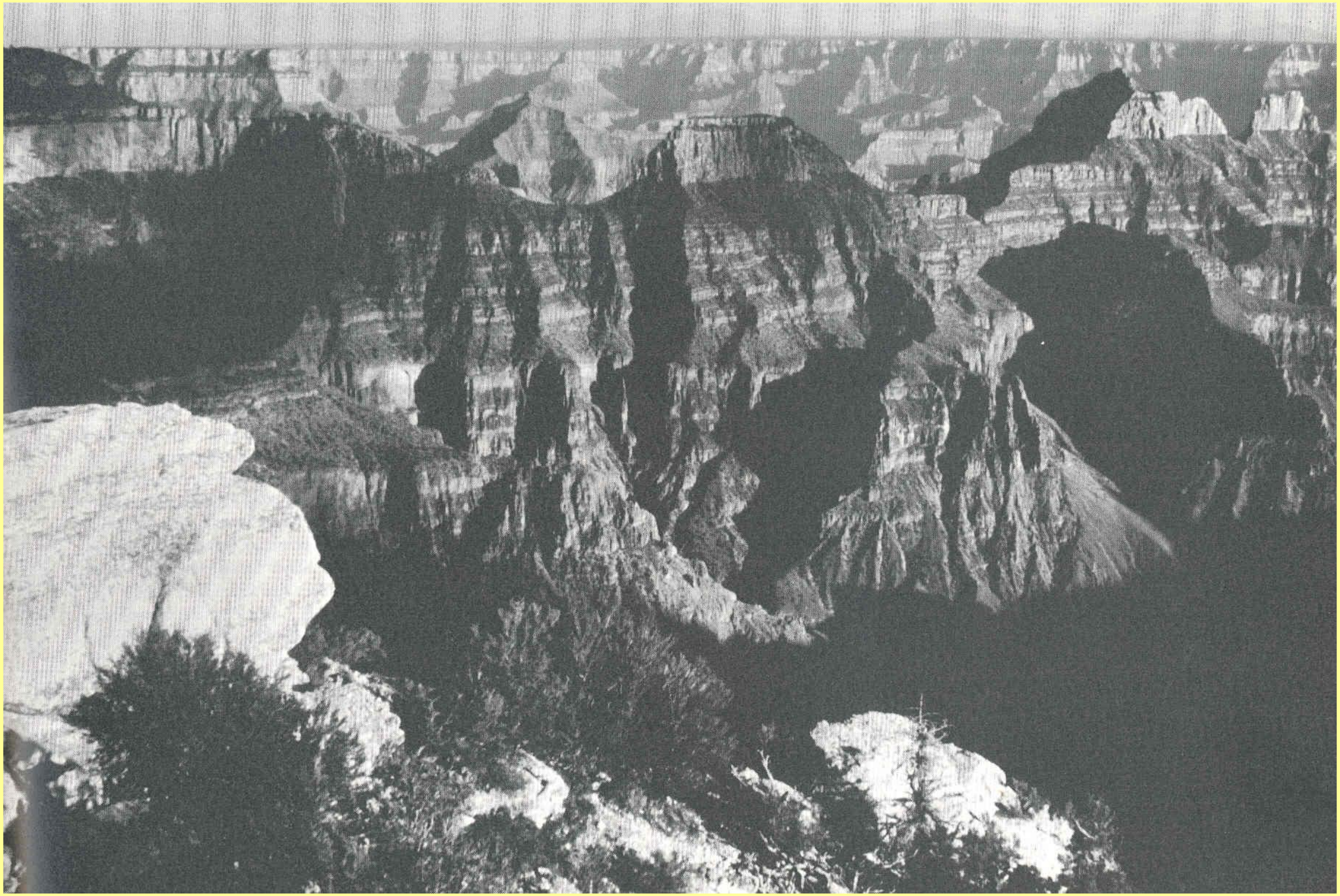
An old plateau with sandstone-capped mesa monadnocks.

THE TOTEM POLE, MONUMENT VALLEY, ARIZ.

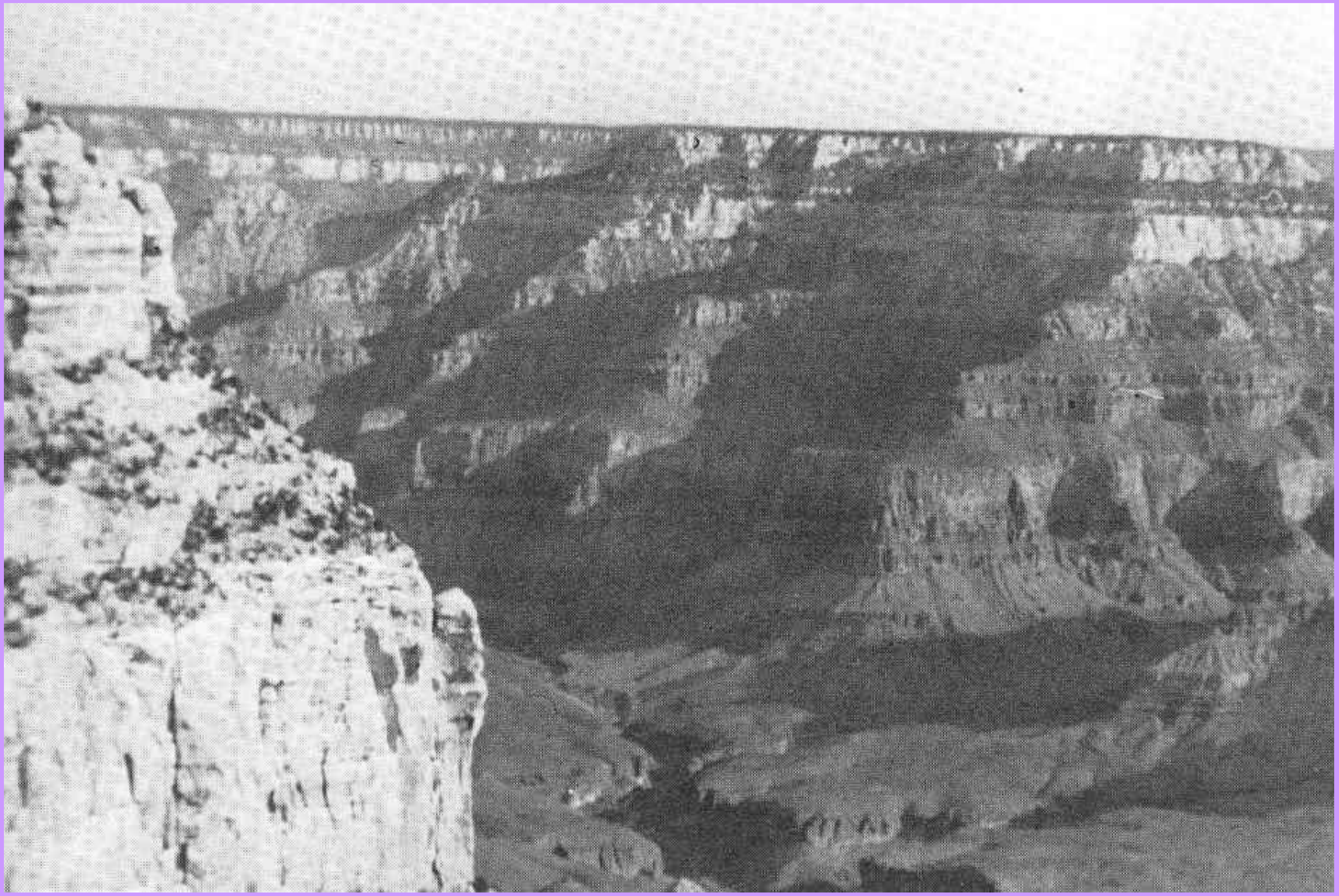
An old plateau with monadnocks of sandstone, forming pinnacles and buttes.

Moore

GRAND CANYON PLATEAU

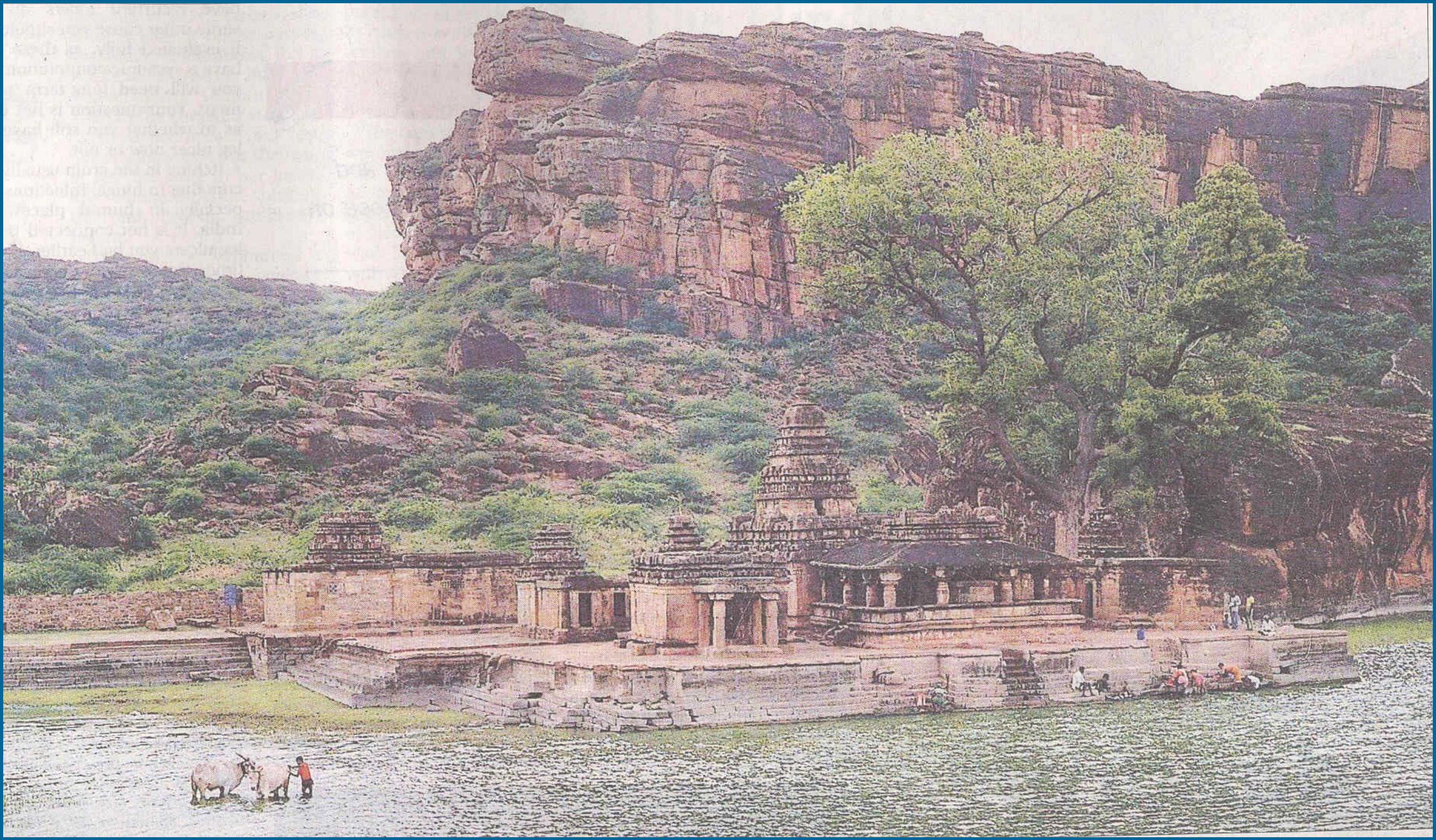


GRAND CANYON PLATEAU




Dry Climate, intermittent strong storms

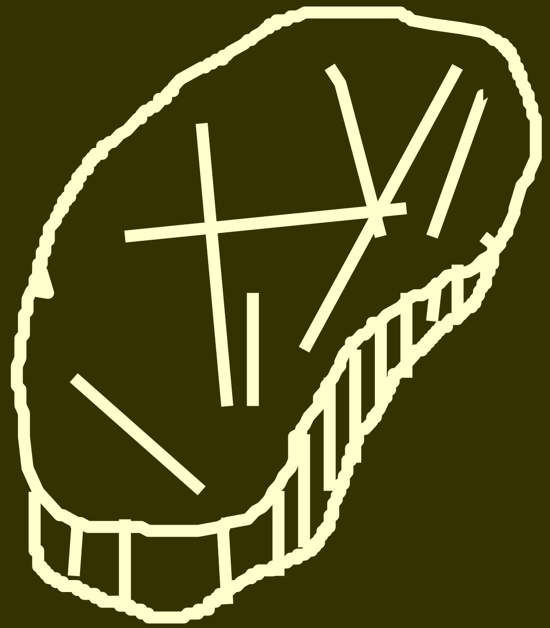
BHUTANATHA TEMPLE - BADAMI



STEP LIKE ESCARPMENTS

(*Iguassu Falls, Brazil*)

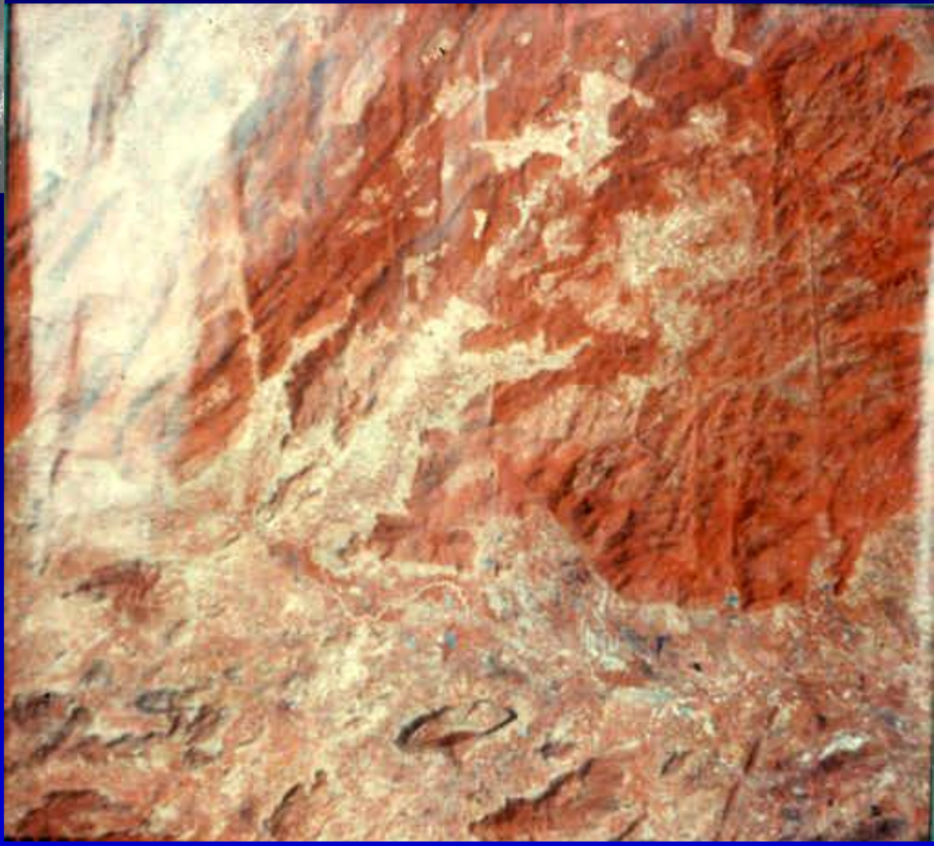
(3.6.1.4) <u>Dissected plateau, Mesa and Butte</u>



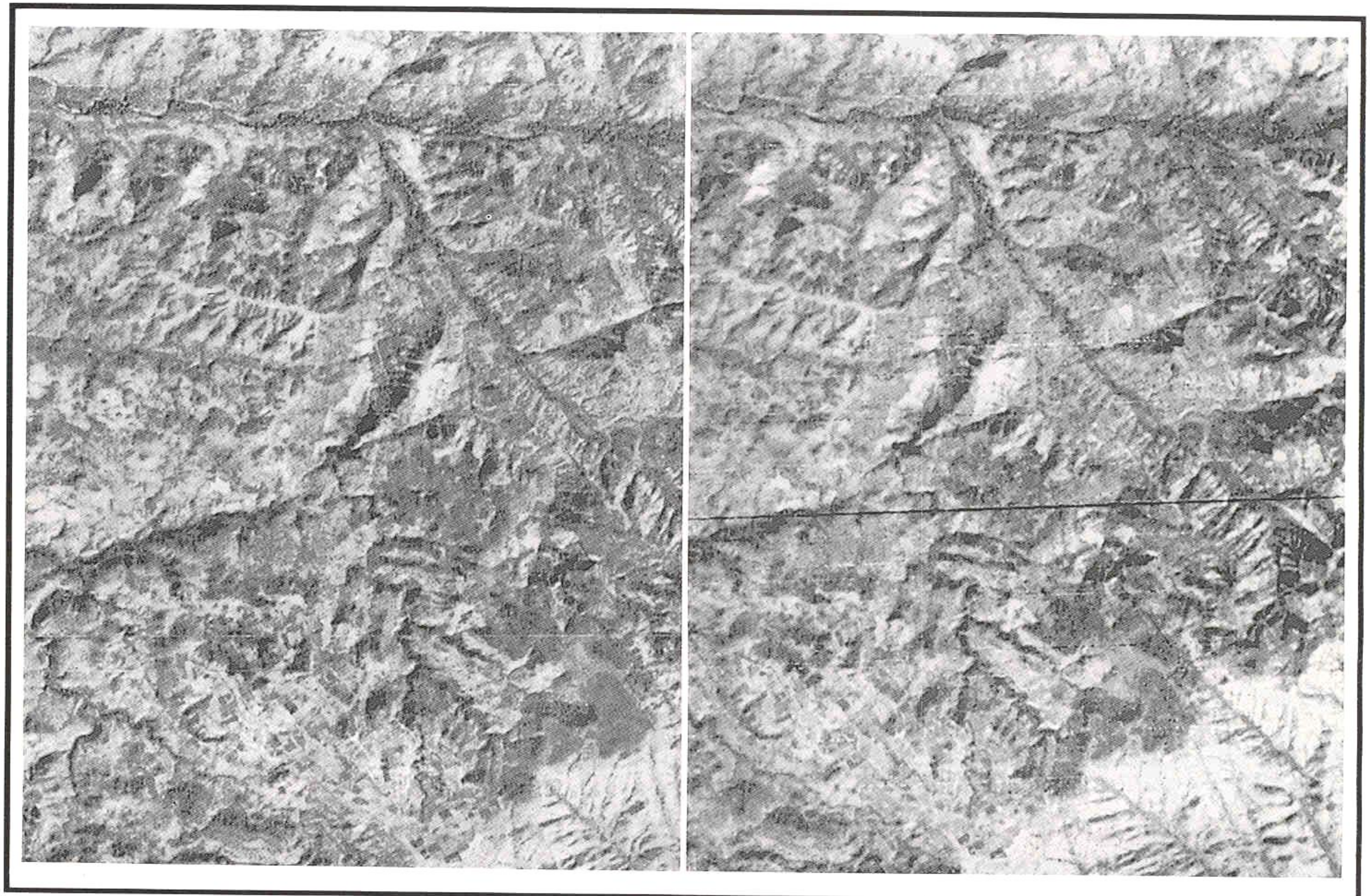
- better groundwater prospects
- erosion prone

(E-g) Vindhyans, Shevroy, Chitteri, Kalrayan

PLATEAU - HIGHLY DISSECTED (1.1.1.1)



IRS – PAN STEREO DECCAN PLATEAU



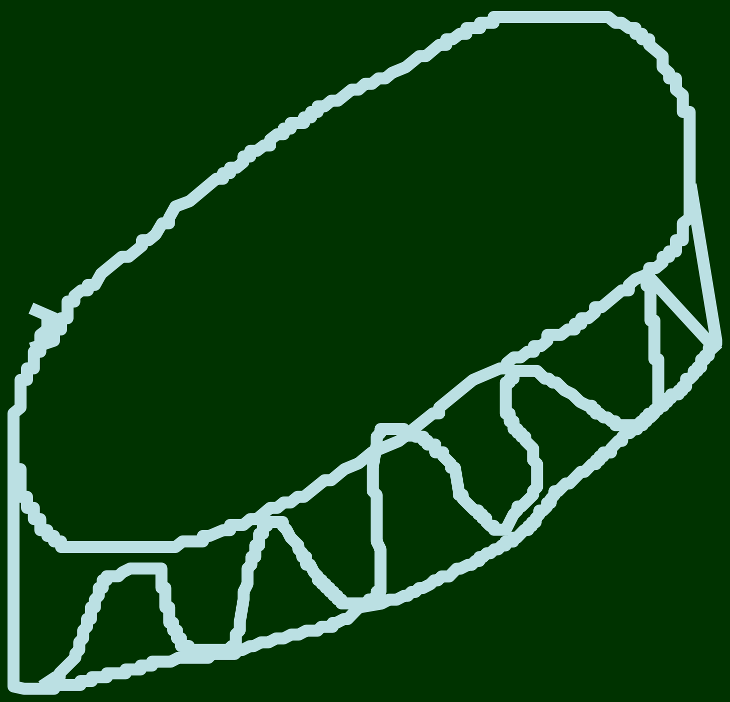
HIGHLY DISSECTED PLATEAU

(*Tower View, Bryce, Canyon*)

INTENSELY DISSECTED PLATEAU

(*Bryce Canyon, National Park, Utah*)

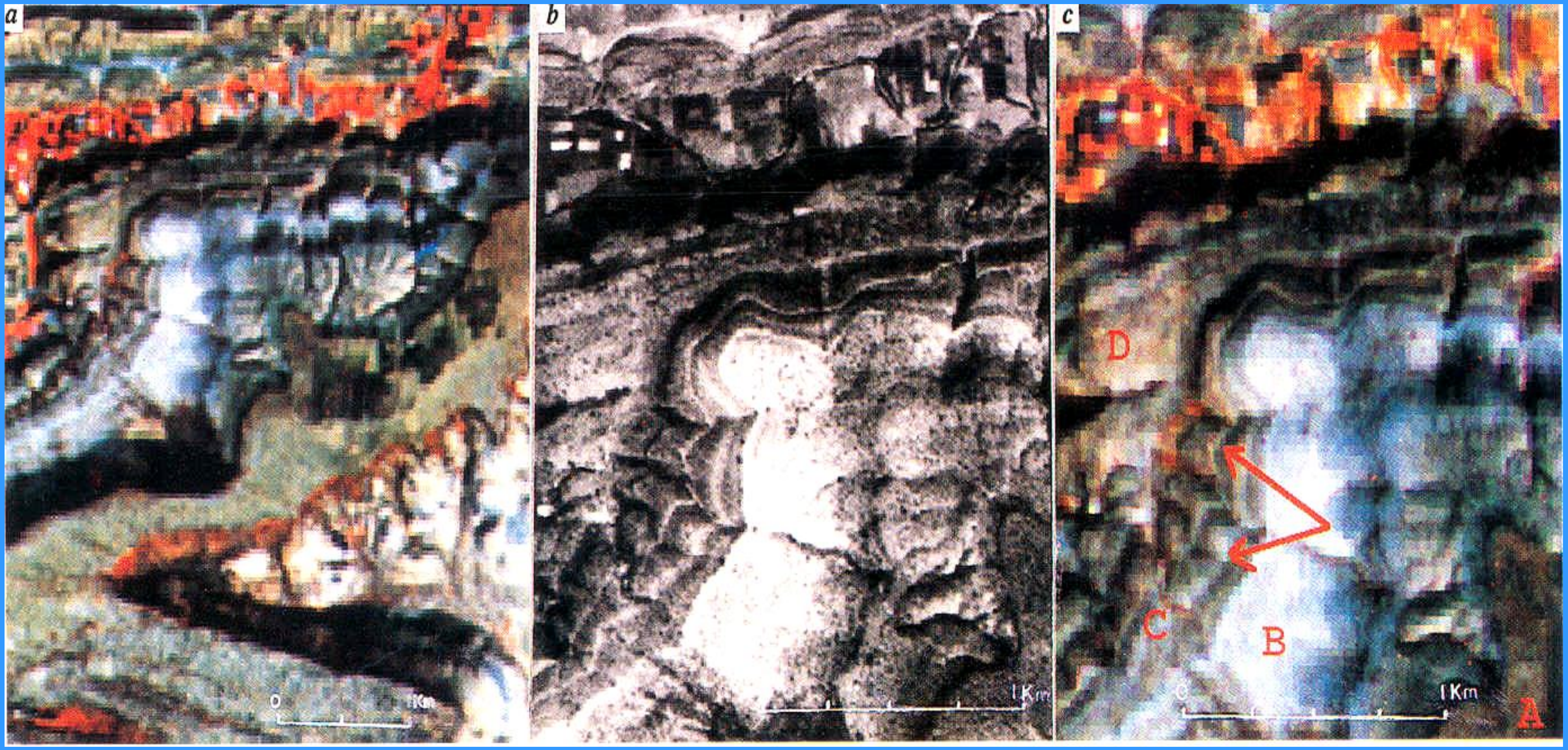
Plateaus in the folded basement



- better groundwater prospects in axis
- groundwater heterogenous in metamorphic plateau
- sheet flow in volcanic plateau
- erosion generally less, except in metamorphic plateau

Plateaus in the folded basement

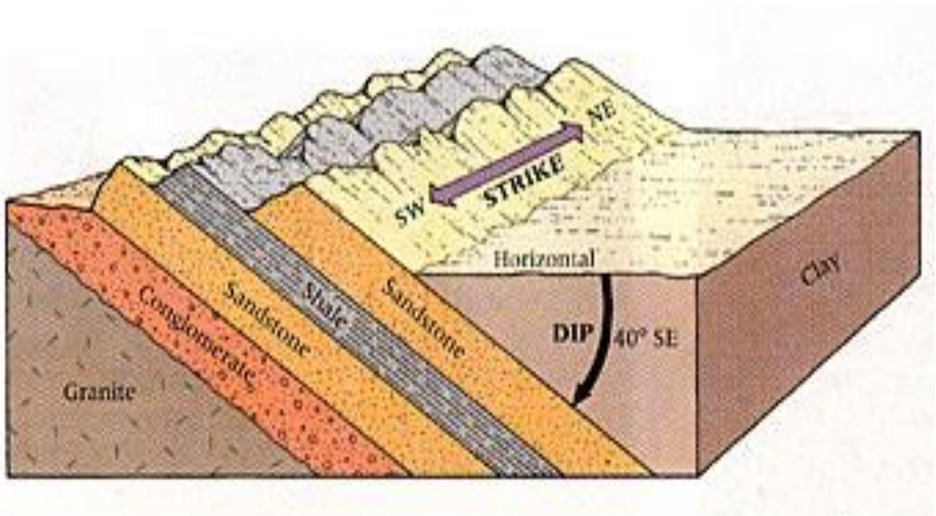
CUDDAPAH BASIN

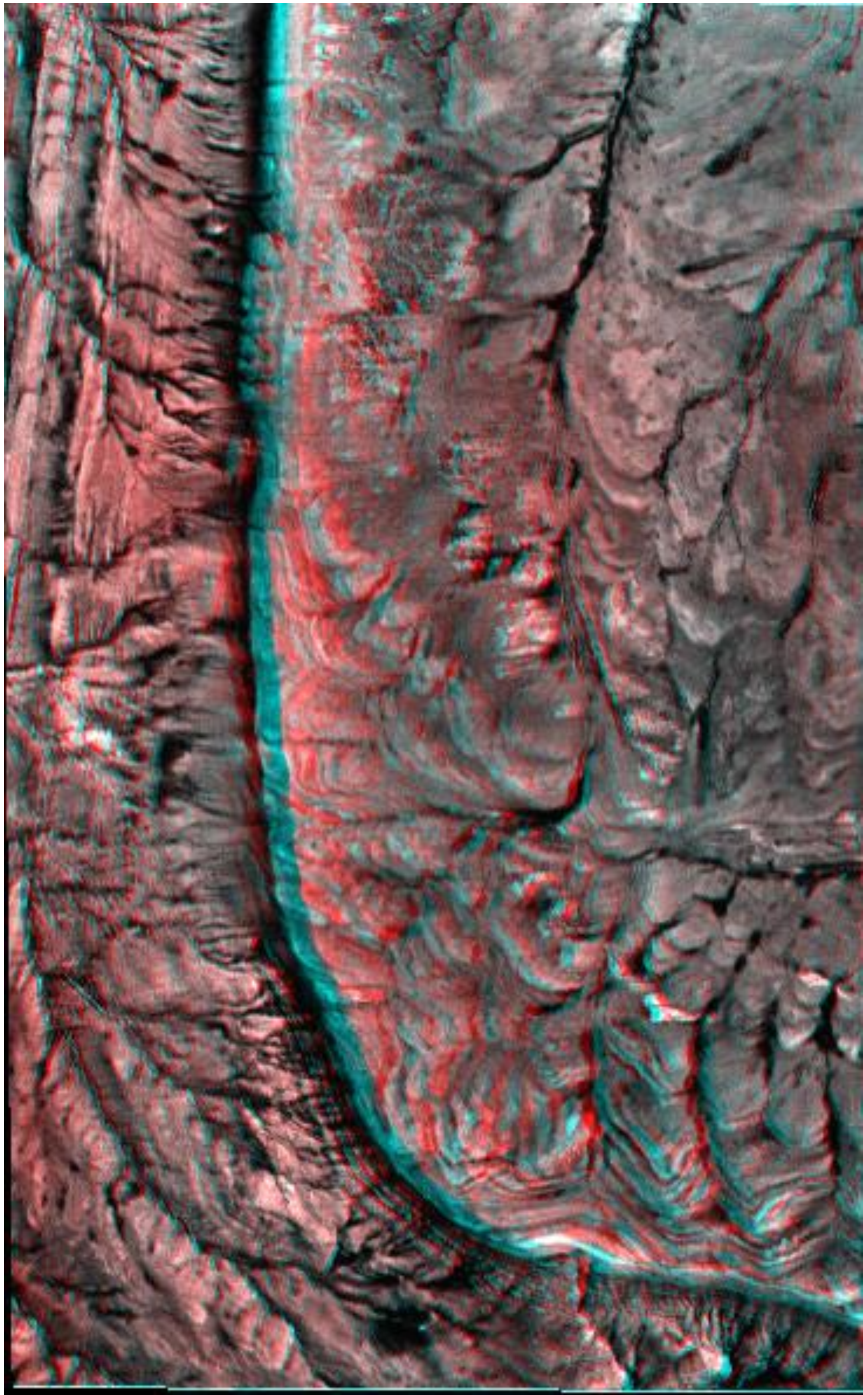


LANDFORMS IN MARGINALLY DEFORMED ROCKS

Tilted Strata

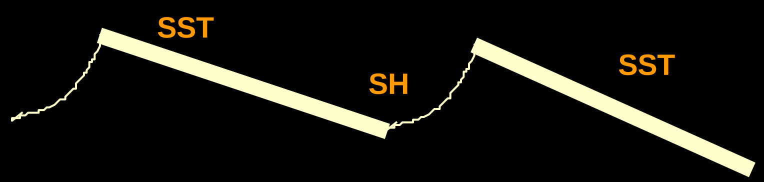
- Monoclinal folds, or one side (limb) of a fold
- Name = f(dip angle)
  - Cuesta (gentle)
  - Hogback (steep)
  - Flatiron remnant of dissected Hogback w triangular face





(3.6.2) DIPPING LANDFORMS

(3.6.2.1) ***Cuesta***



- **dip less than 25º**
- **cap or sheet rock at top**
- **obsequent slope by shale**
- **runoff area**
- **valleys better for reservoirs / storage**

Cuesta: A hill or ridge with a gentle slope on one side and a steep slope on the other; specifically an asymmetric ridge with one face (dip slope) long and gentle and conforming with the dip of the resistant bed or beds that form it, and the opposite face (scarp slope) steep or even cliff-like and formed by the out crop of the resistant rocks, the formation of the ridge being controlled by the differential erosion of the gently inclined strata.

Cuestas - <30° dip
Hogbacks - >30° dip

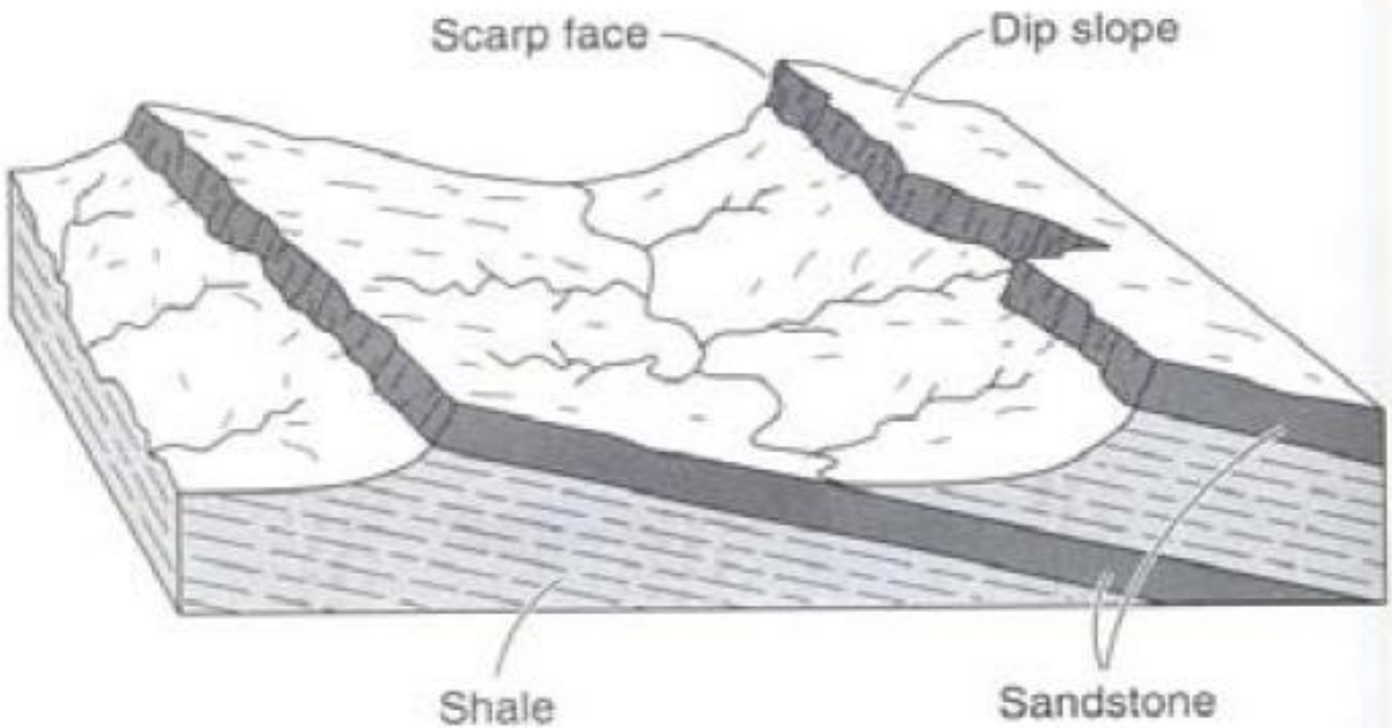


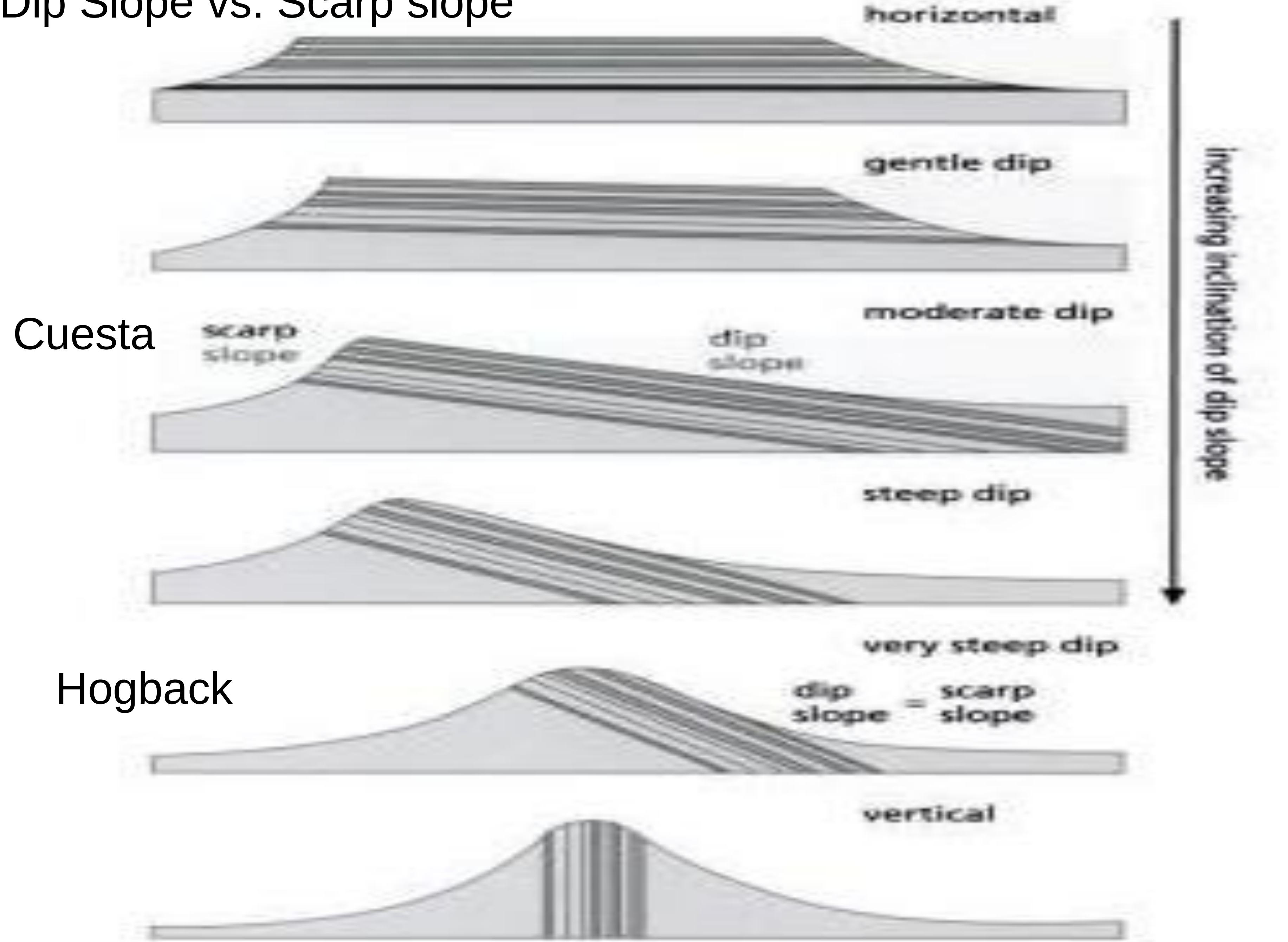
FIGURE 9–6
Adjustment of topography to geologic structure.

TECTONIC CUESTA

PASSIVE DIP SLOPE

CUESTA SCRAP PASSIVE
OBSEQUENT SLOPE

Dip Slope vs. Scarp slope



Topography of dipping layers

- Homoclinal Shifting
  - deflection of streams along weaker layers
  - Form homoclinal valleys
- Dip slope and Scarp Face
  - Scarp face is steeper, erodes more rapidly
  - Scarp face (and drainage divides) will retreat in direction of dip

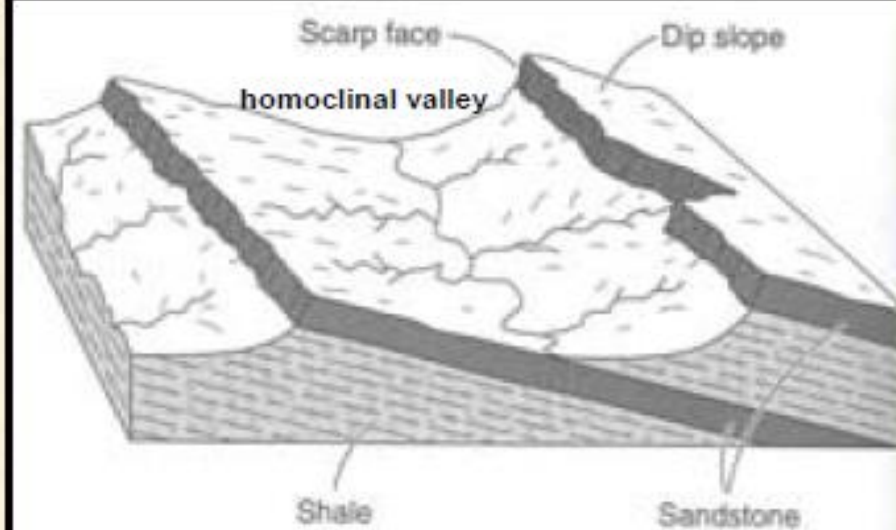


FIGURE 9–6
Adjustment of topography to geologic structure.

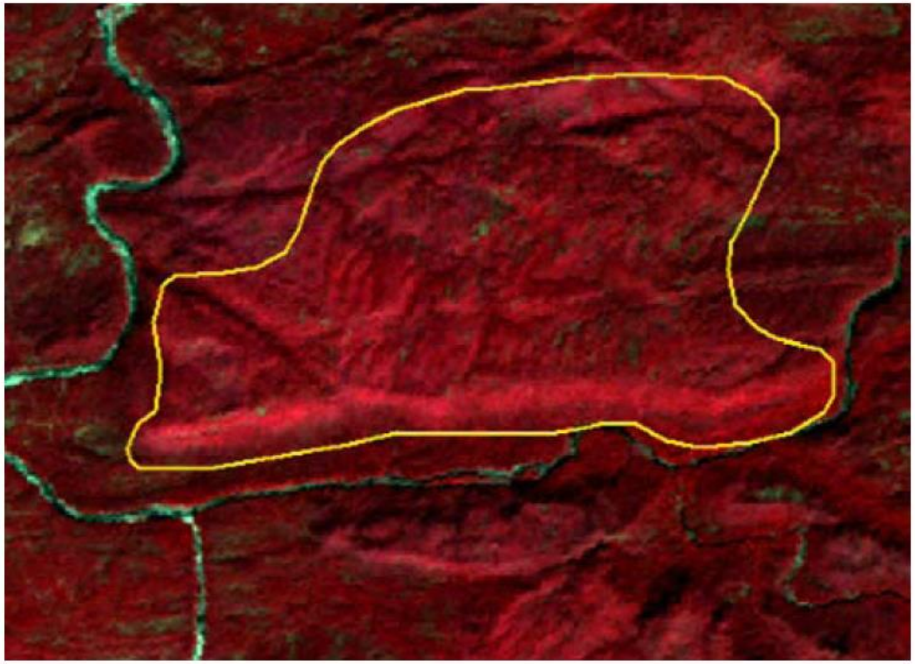
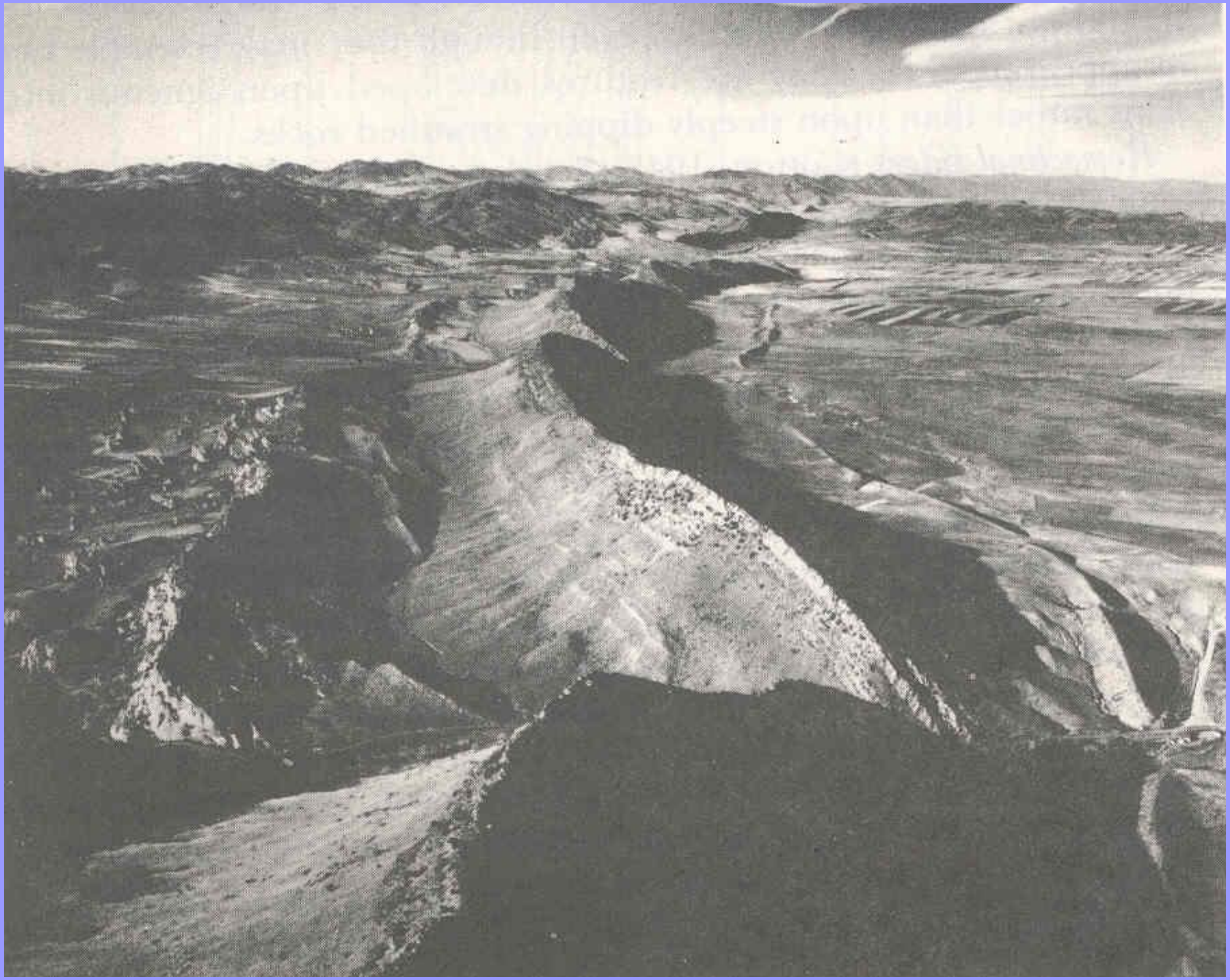


Fig. 2.2 Cuesta in the Moderately dissected structural hills and valleys in Hoshangabad district, Madhya Pradesh state. It is seen as a hill or a ridge with a gentle slope on one side and a steep slope on the other.

CUESTA

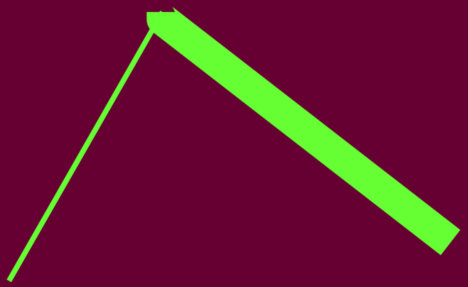
CUESTA – CANADA

CUESTA



(3.6.2.2) <u>Hogbacks</u>

- *dip more than 25^o*
- *dip and obsequent slope will look almost similar in expression*
- *dip and obsequent slopes are equal*



Hogback

Dakota Hogback, Morrison, Colorado

–Flatiron remnant of dissected Hogback with triangular face

Anti-dip Side of Hogbacks, Flinders Range, Australia

Short, N. M., and Blair, R. W., 1986, Geomorphology from Space, NASA
daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/

Dip Slope of Flatirons, Flinders Range, Australia

Delete Slide in 2008

Ridges

- Dip of Cuesta < Hogback

http://ww

http://www.aureo.org/conference/boulderconference.html

HOG BACKS

(***Rainbow Heaven, Himalayas, Pakistan***)

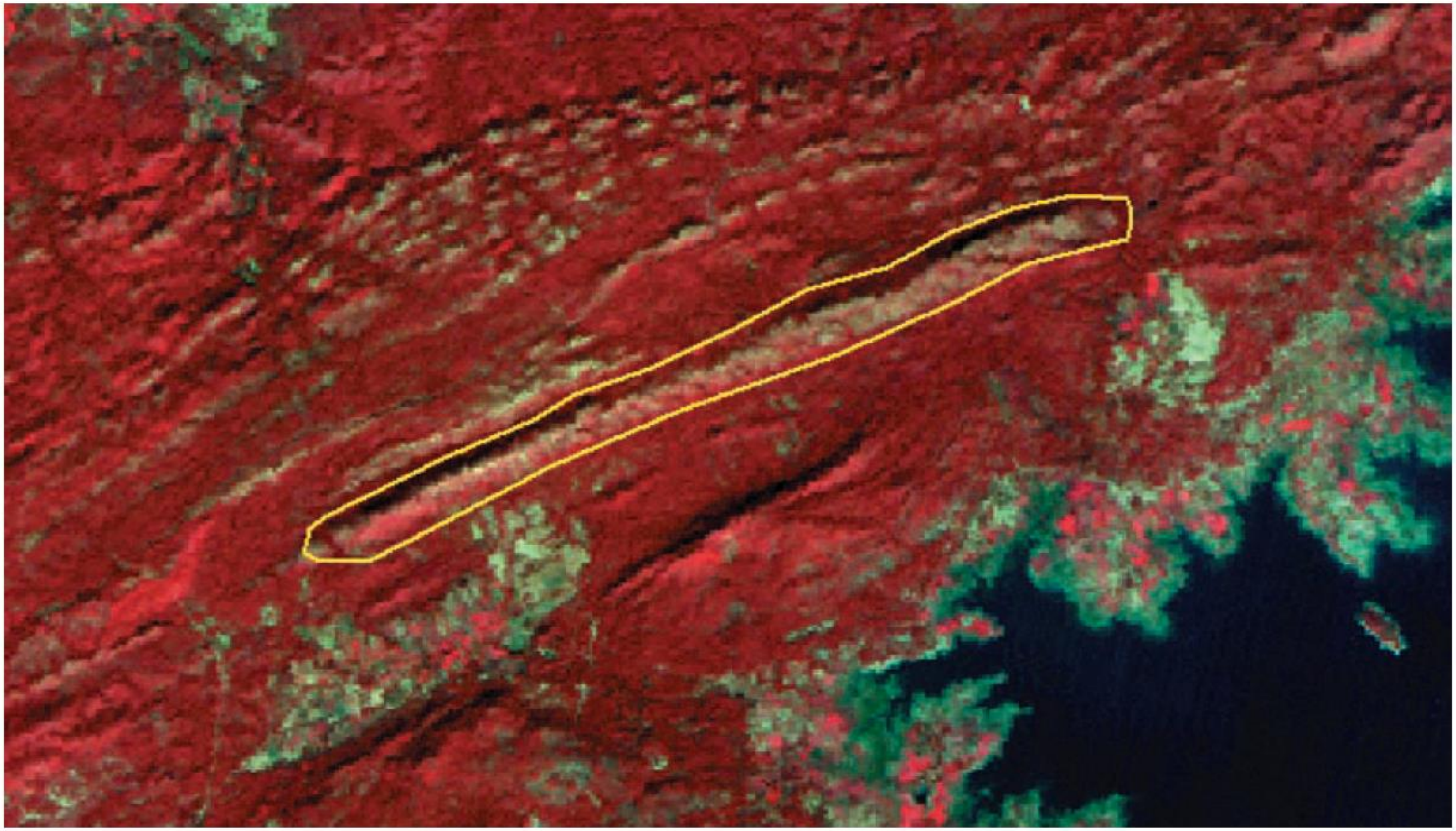


Fig. 2.1 Hogback in the Low dissected structural hills and valleys in Hoshangabad district, Madhya Pradesh state. Ridge with a sharp summit and steep slopes of nearly equal inclination on both flanks, and resembling in outline the back of a hog.

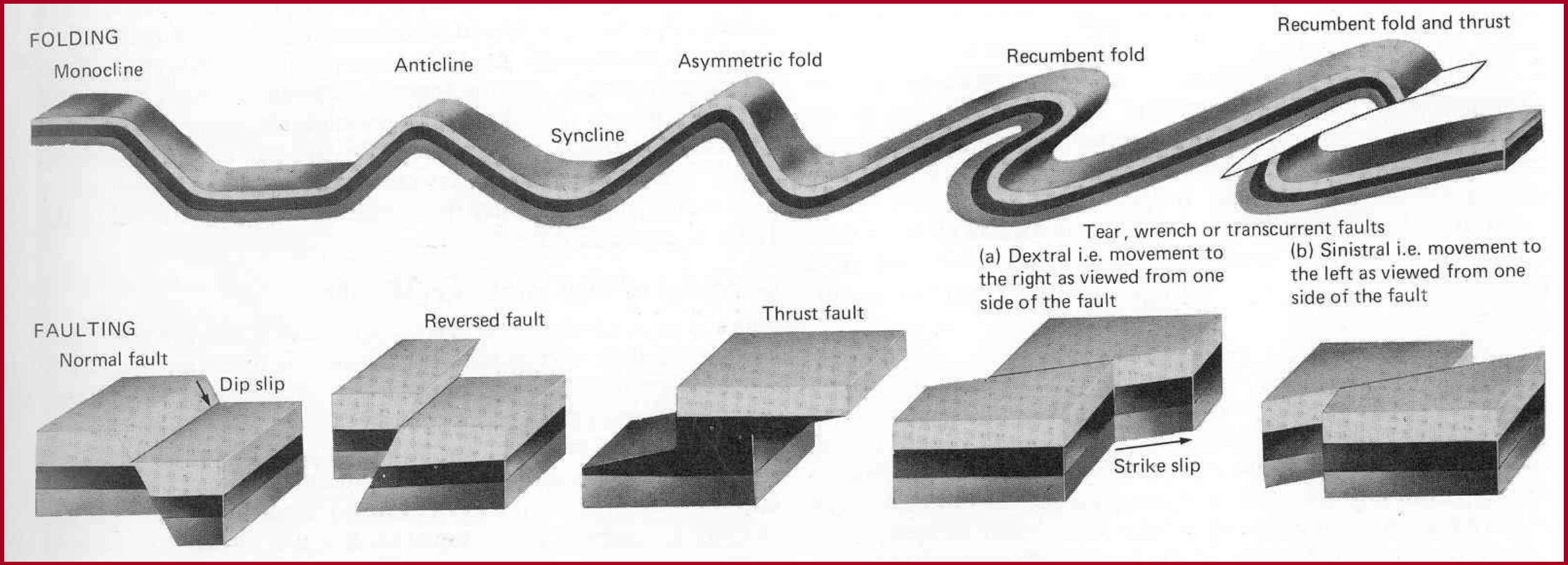
(3.6.3)LANDFORMS IN FOLDED ROCKS

LANDFORMS IN FOLDED ROCKS

FOLDS

- Bends or wave-like features in layered rocks
  - –Plastic strain, compressive stress
- Geometry of folds:
  - –**Anticline vs. syncline**
    - ***Hinge line, limb, axial plane***
  - –Plunging fold (hinge lines dip)
  - –Structural dome
  - –Structural basin

FOLDING



FOLDING
Monocline
Anticline
Syncline
Asymmetric fold
Recumbent fold
Recumbent fold and thrust
Tear, wrench or transcurrent faults
(a) Dextral i.e. movement to the right as viewed from one side of the fault
(b) Sinistral i.e. movement to the left as viewed from one side of the fault
FAULTING
Normal fault
Dip slip
Reversed fault
Thrust fault
Strike slip

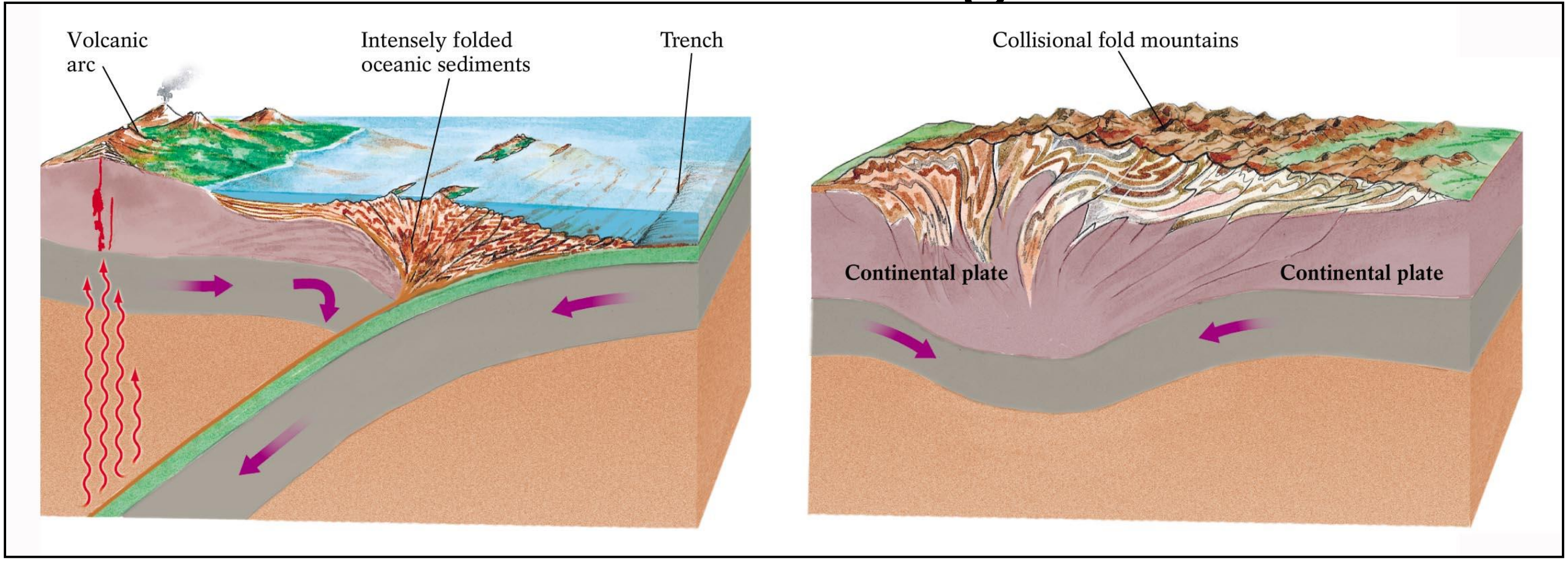
Folds Related Landforms

Folded Mountains
Anticline
Syncline
Domes
Salt dome
Basins
Annular Hills
Linear Ridges & Linear valleys
- **Anticlinal ridge**
- **Synclinal valley**
- **Homoclinal ridge**
- **Anticlinal Valley**
- **Homoclinal valley**
- **Synclinal Ridges**

Folded mountains

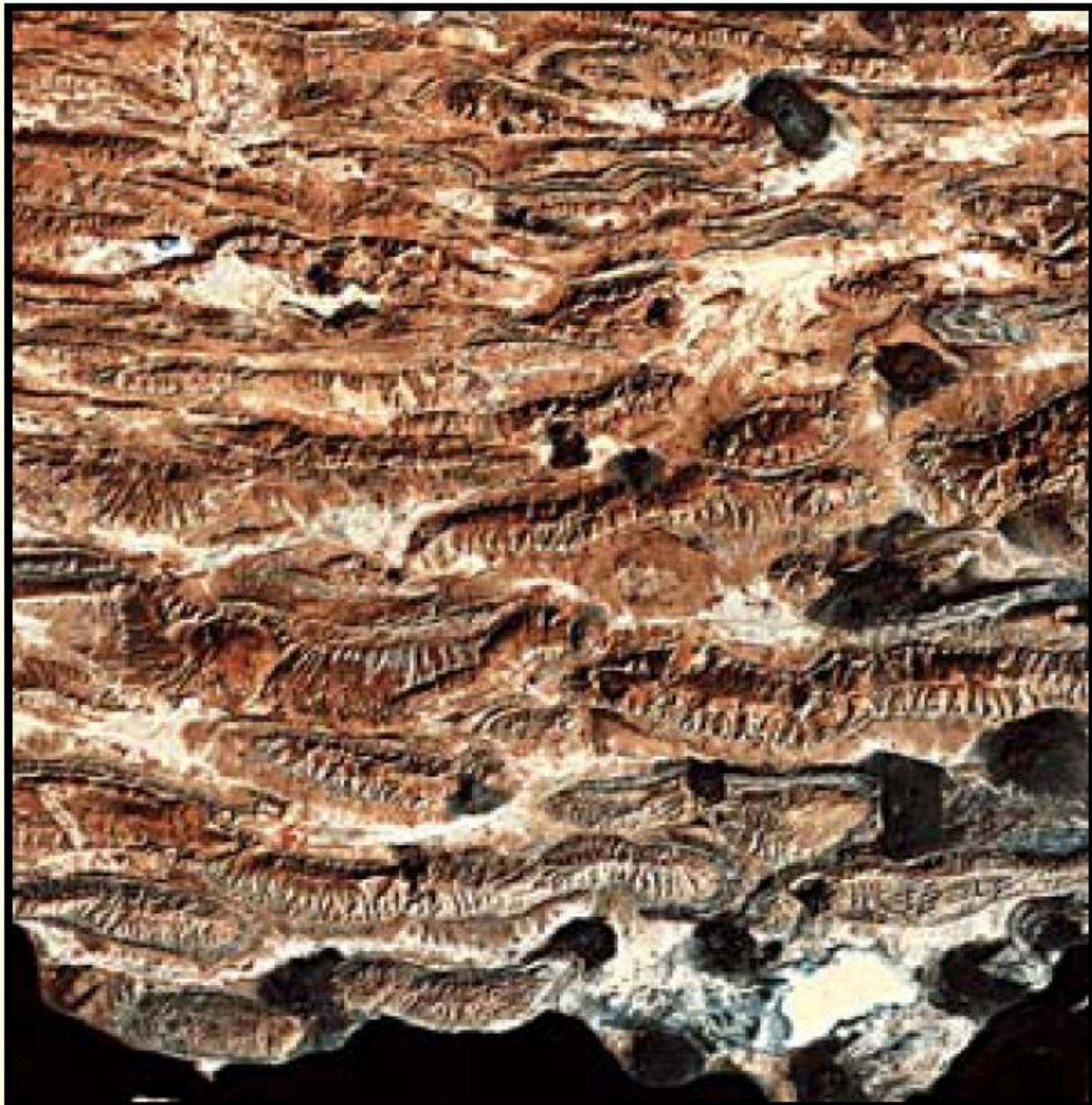
- **mountains with tight folding** (E-g) **Aravalli, Delhi, Bhimas, Cuddapah, himalayas**
- **contour in curved pattern**
- **curved ridges and valleys**
- **images, show curvilinear and contoured & vegetation banding radial, annular, drainage anomalies**

Convergent Plate Boundaries and Folding



Subduction causes Arc: Under Ocean Lithosphere Japan, Aleutians, Cent. Am.; under continent Andes, Cascades

Continent-Continent collision forms
Fold and Thrust Mountains: Alps, Himalayans, Appalachians

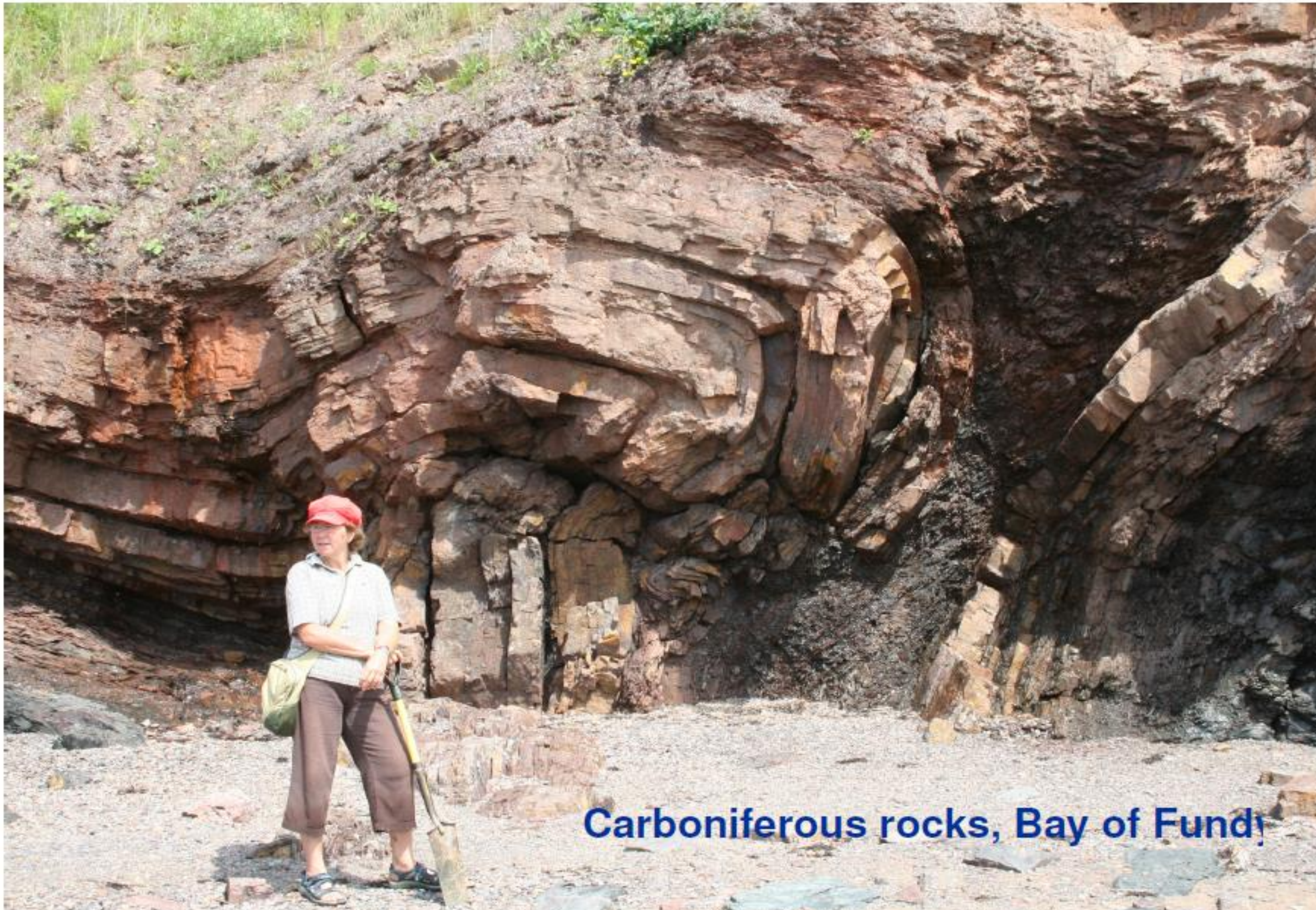


Zagros Mountains

Short, N. M., and Blair, R. W., 1986, Geomorphology from Space, NASA

daac.gsfc.nasa.gov/ DAAC_DOCS/ geomorphology/ GEO_2/GEO_PLATE_T-42.HTML


SH
DEBRIS
SLOPE
SH


Carboniferous rocks, Bay of Fundy

Panchromatic Stereopair of a Folded Landscape Near Maverick Spring, WY

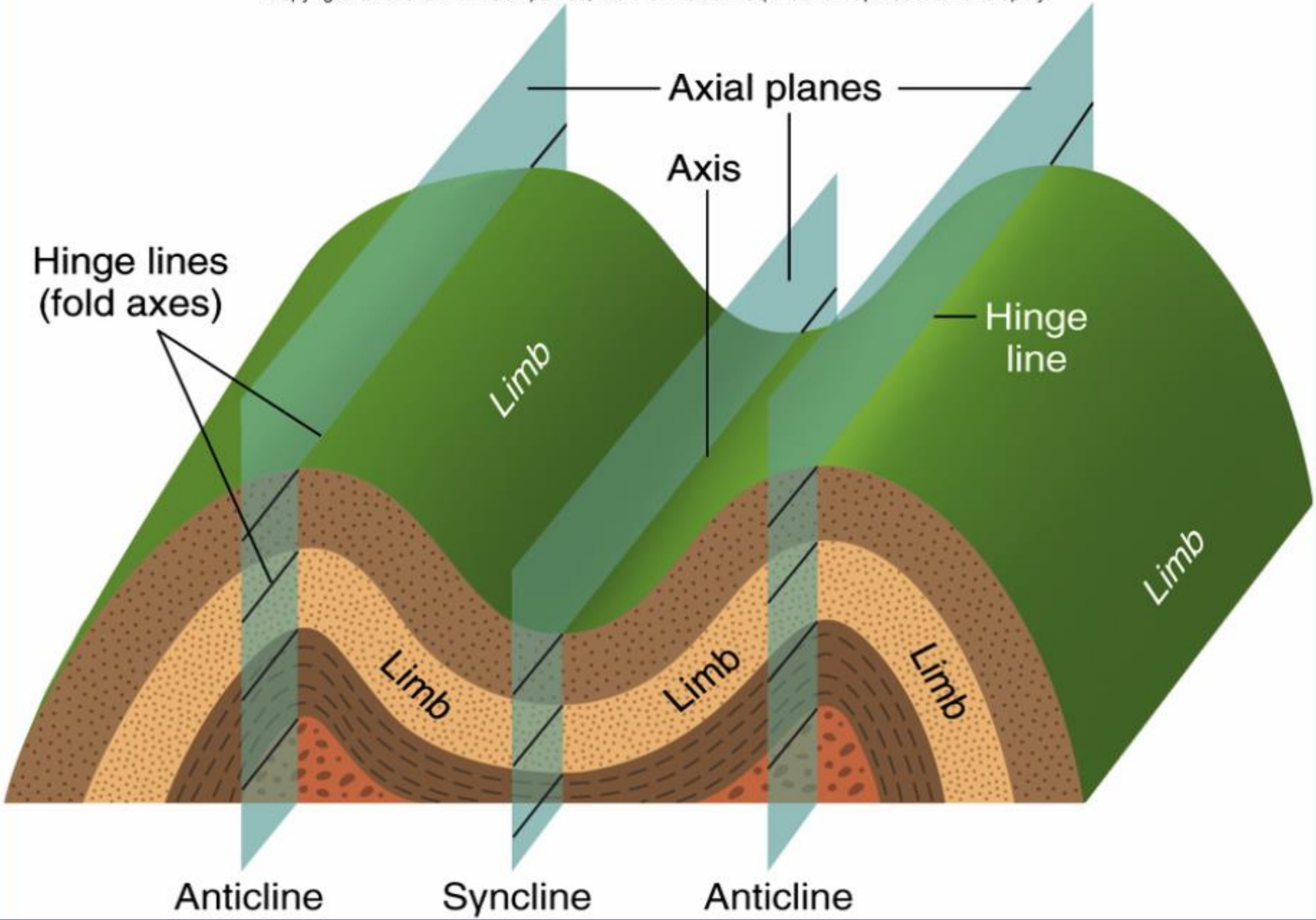
This dissected asymmetric dome is an erosional remnant of a lunging anticline. Note the fine-textured topography, the strike of the ridges and valleys, the radial and trellis drainage controlled by the anticlinal structure, and the prominent hogback ridges.

Landforms : Anticline and Syncline

Anticline ridge: **A fold, the core of which contains the stratigraphically older rocks.**

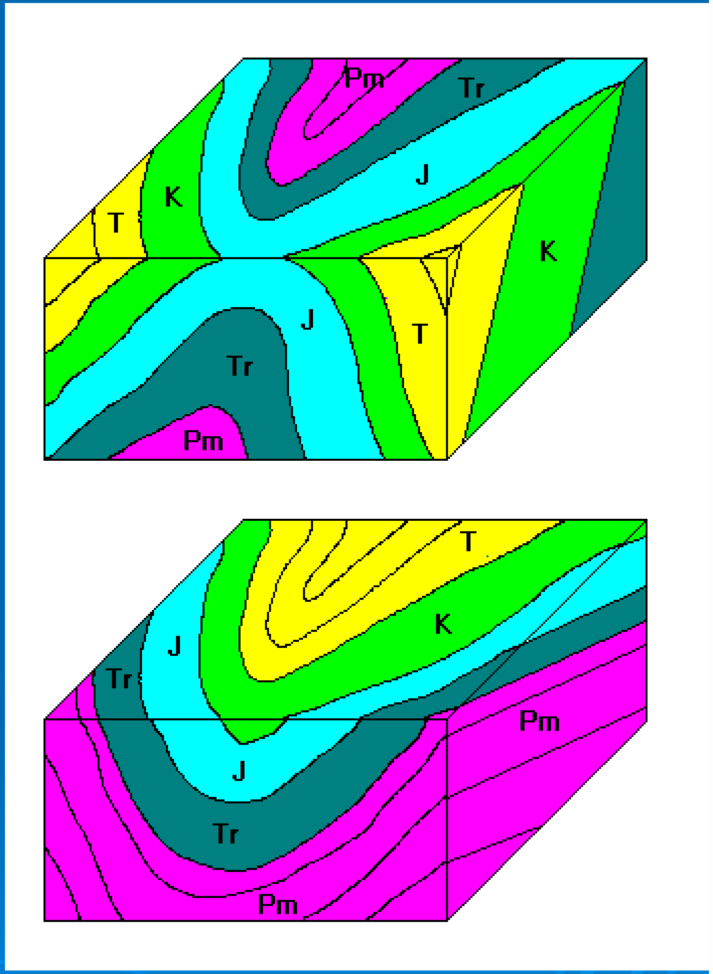
Antiform/Anticlinal ridge : **A breached/unbreached uplift, where the structure is shown directly in the topography and perhaps by drainage pattern. In case of the presence of older rock in the core of the uplift the antiform is called as anticline.**

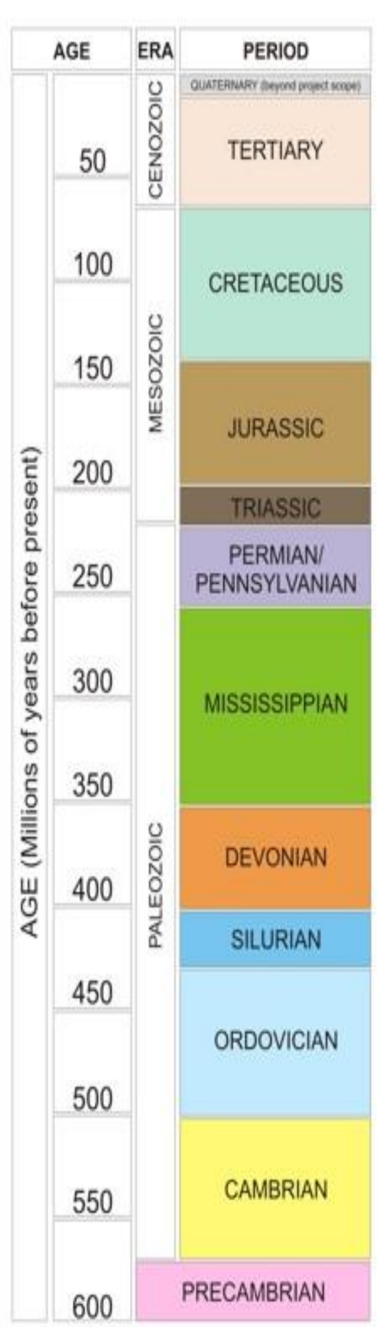
Synform / Synclinal valley: **A breached/unbreached depression, where the structure is shown directly in the topography and perhaps by drainage pattern. In case of the presence of younger rock in the core of the depression the synform is called as syncline**


Axial planes
Axis
Hinge lines
(fold axes)
Limb
Hinge
line
Limb
Limb
Limb
Limb
Anticline
Syncline
Anticline

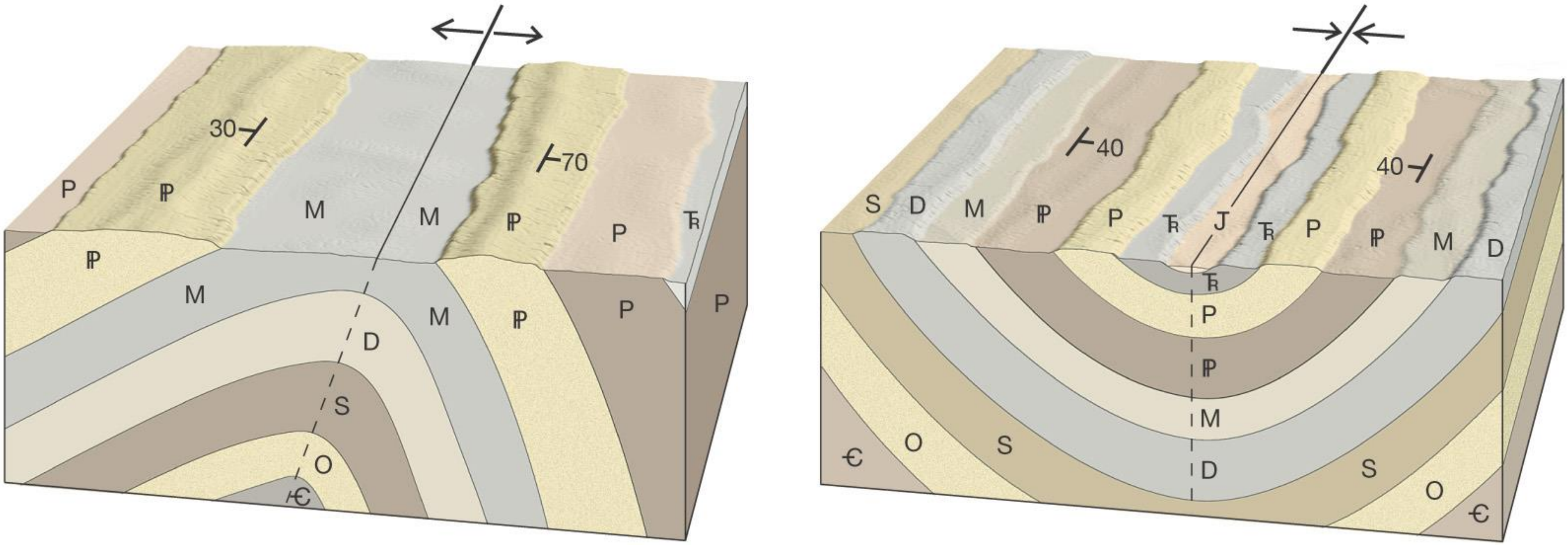
Folds and Block Diagrams

- Anticline = oldest rocks exposed in the center.
- Syncline = youngest rocks exposed in the center





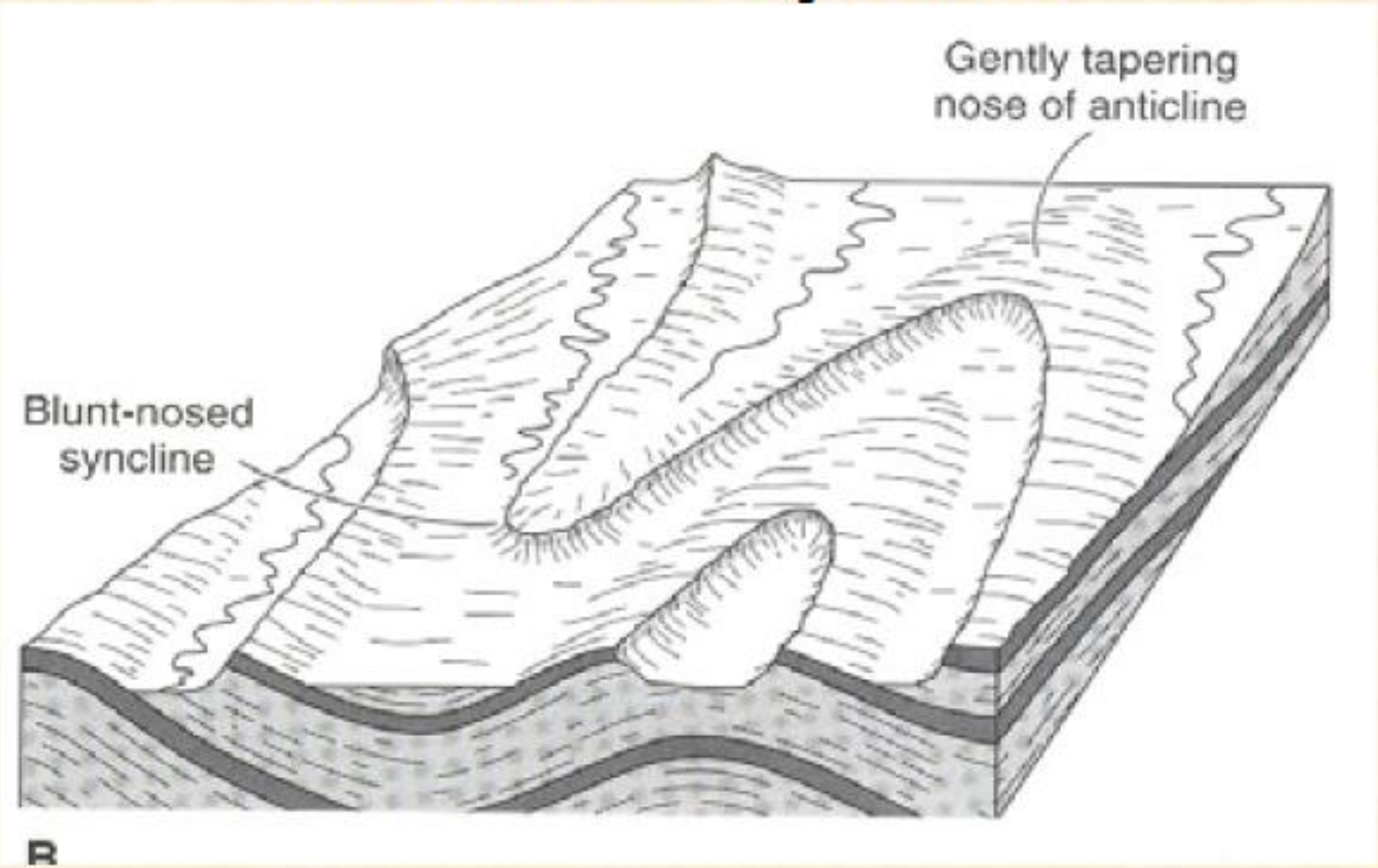
Which directions are these beds dipping?
What are the relations of older and younger beds?
What are the names of the landforms?



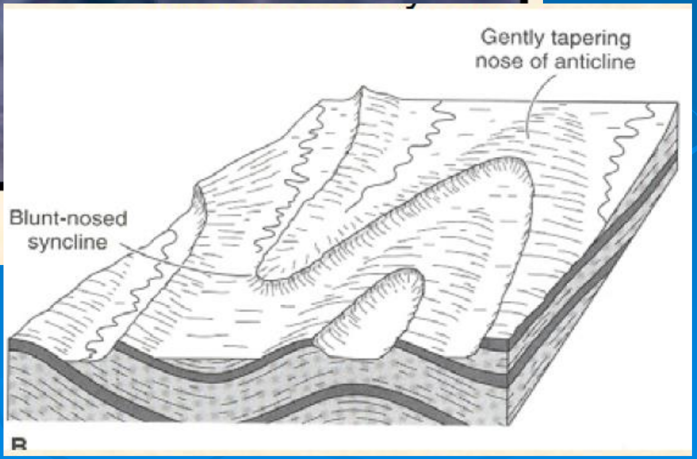
A. Anticline (asymmetrical): oldest rocks (€) occur in the center of the fold

B. Syncline (symmetrical): youngest rocks (J) occur in the center of the fold

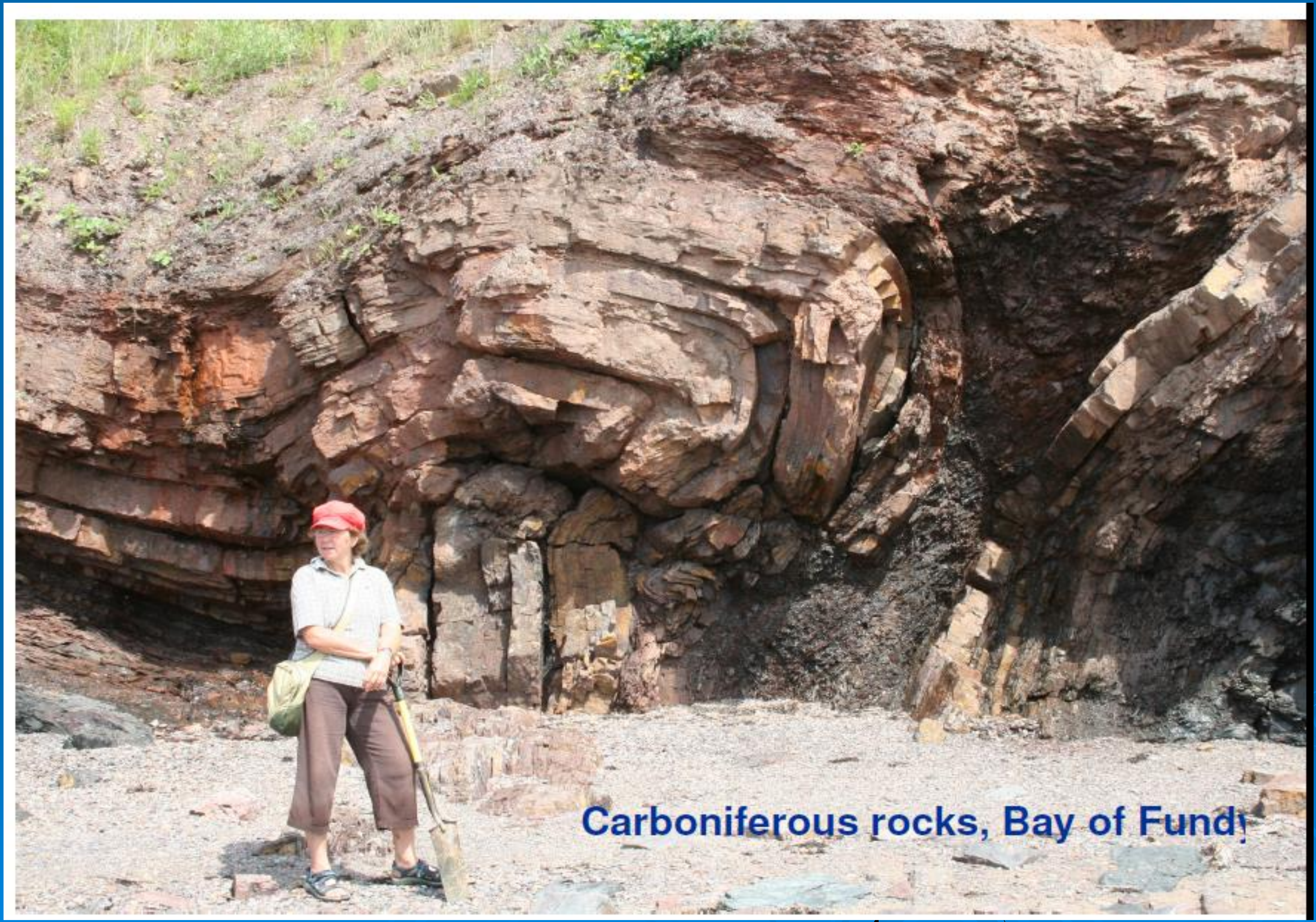
Apex of the outcrop pattern: Anticline or syncline?



Sheep Mountain, Wyoming.

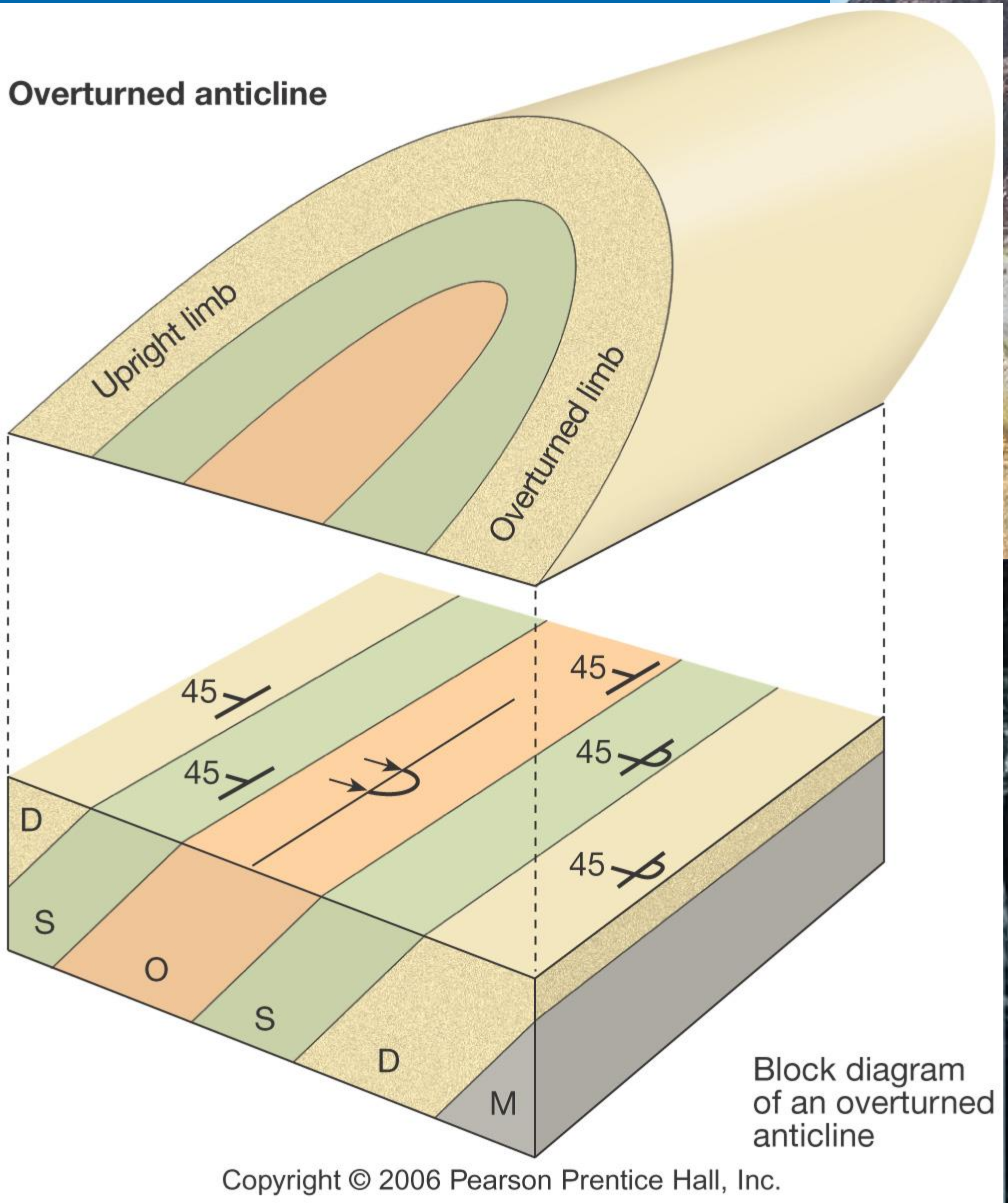


Virgin Anticline, SW UT


Carboniferous rocks, Bay of Fundy


www.geology.wisc.edu/courses/g112

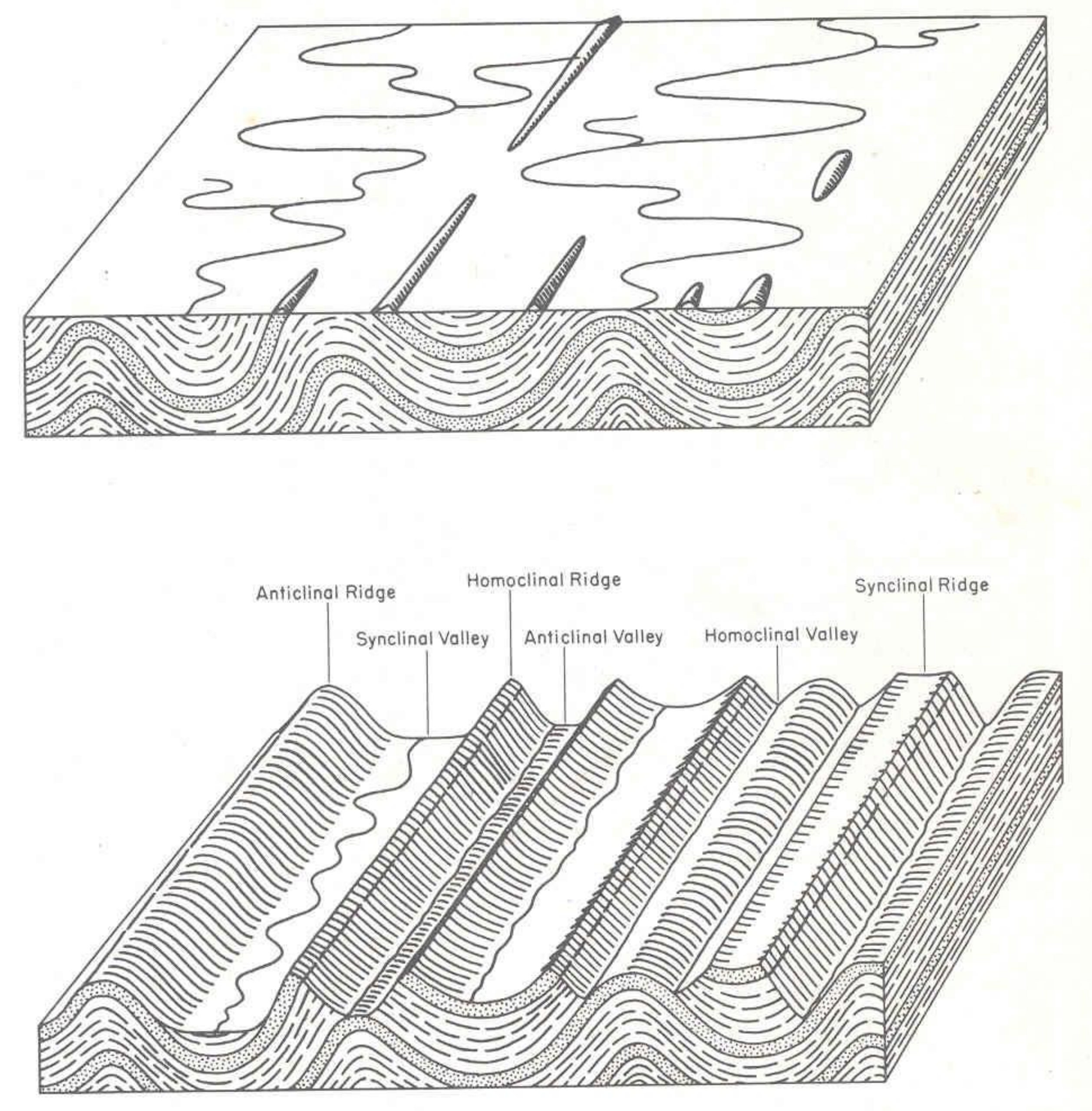

CFW '07


Overturned anticline
Upright limb
Overturned limb
45
45
45
45
45
D
S
O
S
D
M
Block diagram of an overturned anticline
Copyright © 2006 Pearson Prentice Hall, Inc.

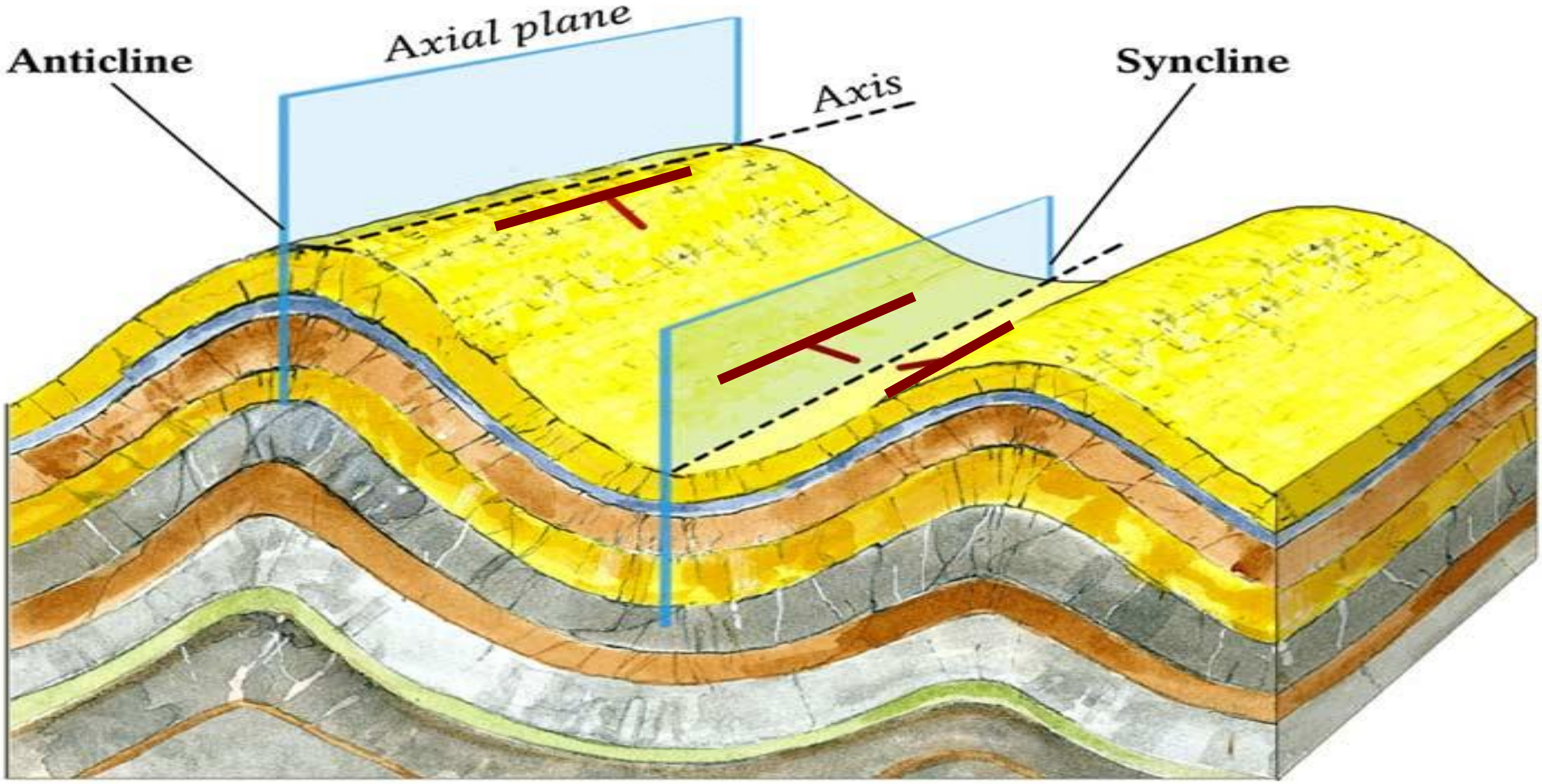

web.uct.ac.za/depts/geolsci/dlr/laingsburg


www.geology.wisc.edu/courses/g112

ERODED ANTICLINES AND SYNCLINE

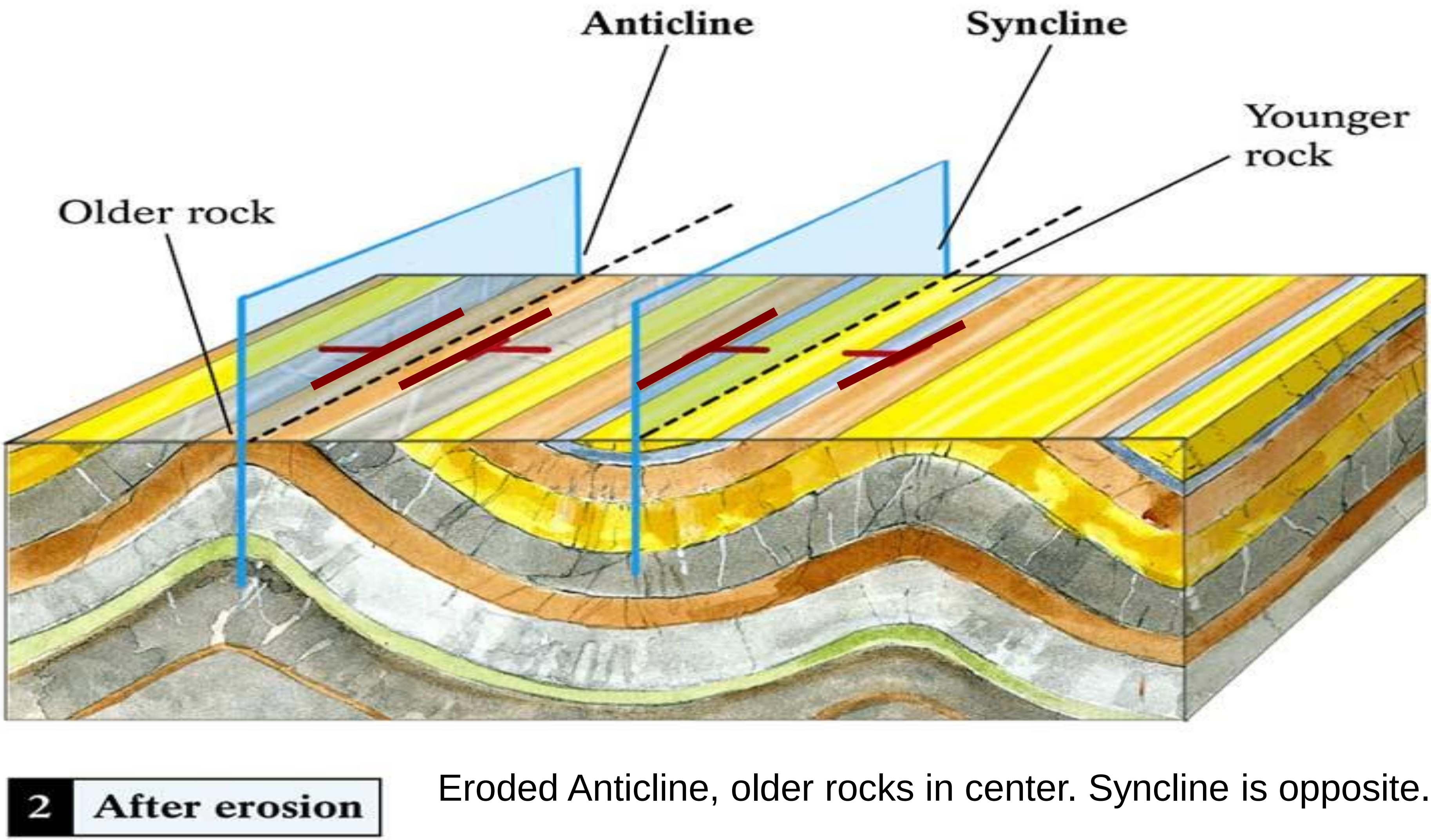


Folds are typical of convergence
Folded Rock Before Erosion

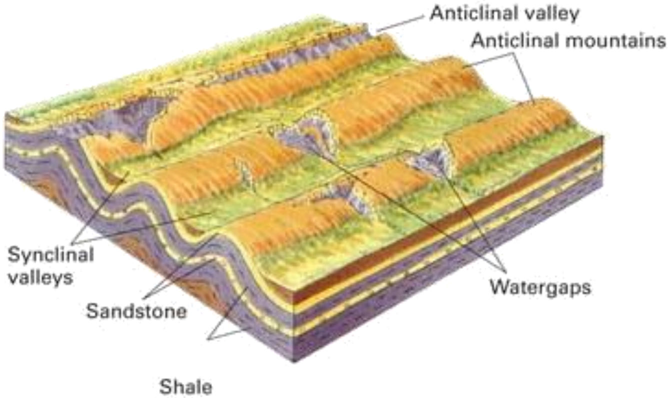


1 Folded rocks before erosion

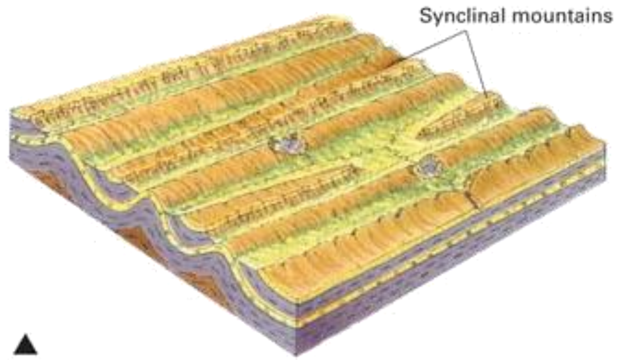
Folded Rock After Erosion



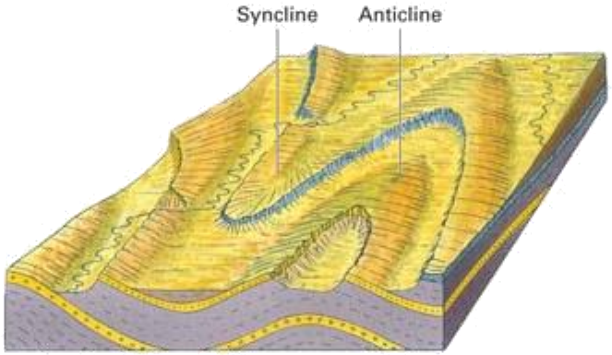
Eroded Anticline, older rocks in center. Syncline is opposite.



A First, weaker formations such as shale and limestone are eroded away, leaving long, narrow ridges of hard strata, such as sandstone or quartzite. Sometimes, the resistant rock at the center of the anticline is eroded through to reveal softer rocks underneath, creating an anticlinal valley.



B Synclinal mountains can also be formed after continued erosion, when resistant rock at the center of a syncline is exposed, standing up as a ridge.



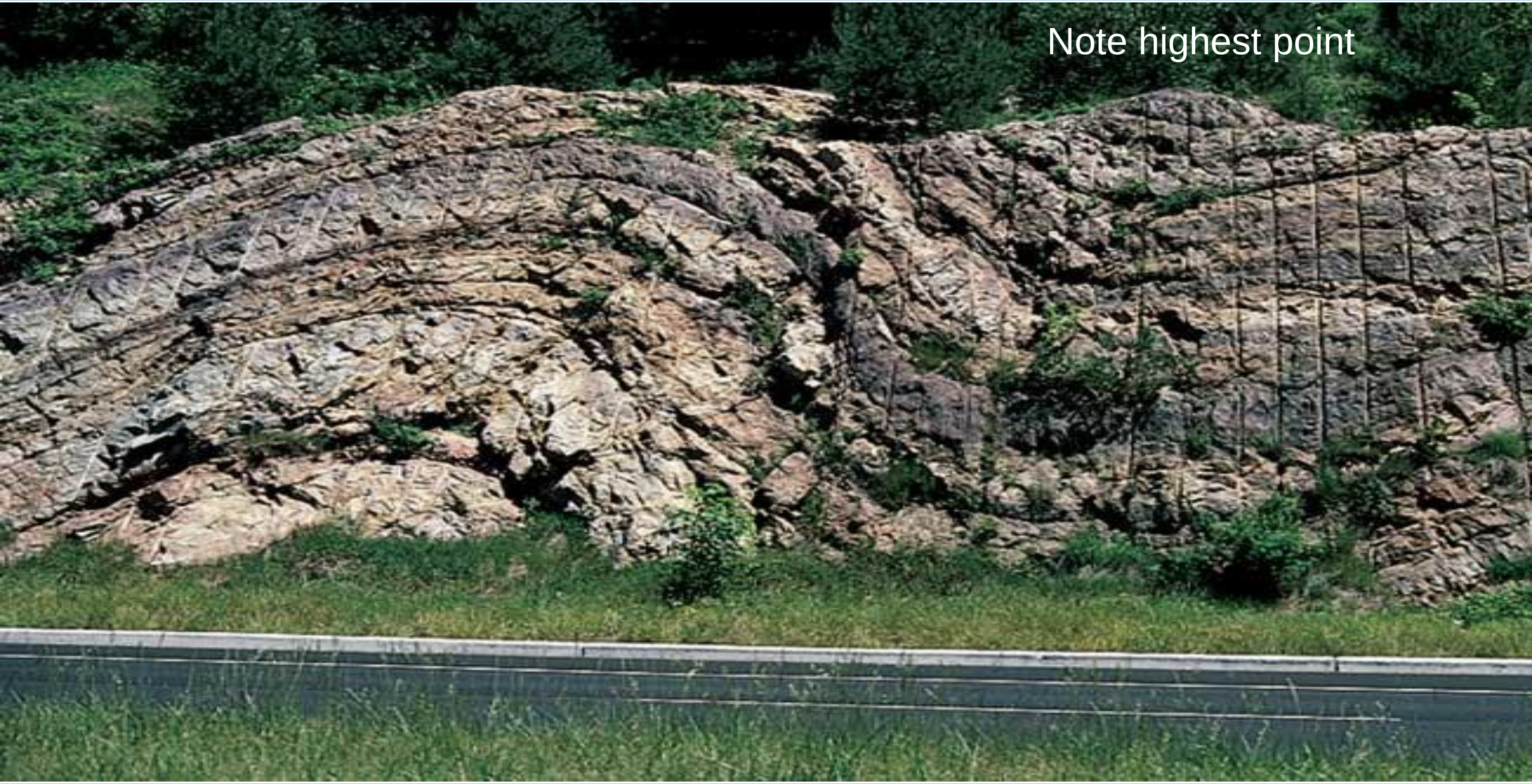
C Plunging folds that have been eroded lead to zigzag ridges.

D **Ridge-and-valley landscape** This Landsat image shows the ridge-and-valley country of south-central Pennsylvania in color-infrared. The land surface shows zigzag ridges formed by bands of hard quartzite. The strata were crumpled during a continental collision that took place over 200 million years ago.

Live Folds - Anticline, Zagros Mtns

Short, N. M., and Blair, R. W., 1986, Geomorphology from Space, NASA
daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/
GEO_2/GEO_PLATE_T-42.HTML

Folded Rocks, Hwy 23 Newfoundland, New Jersey

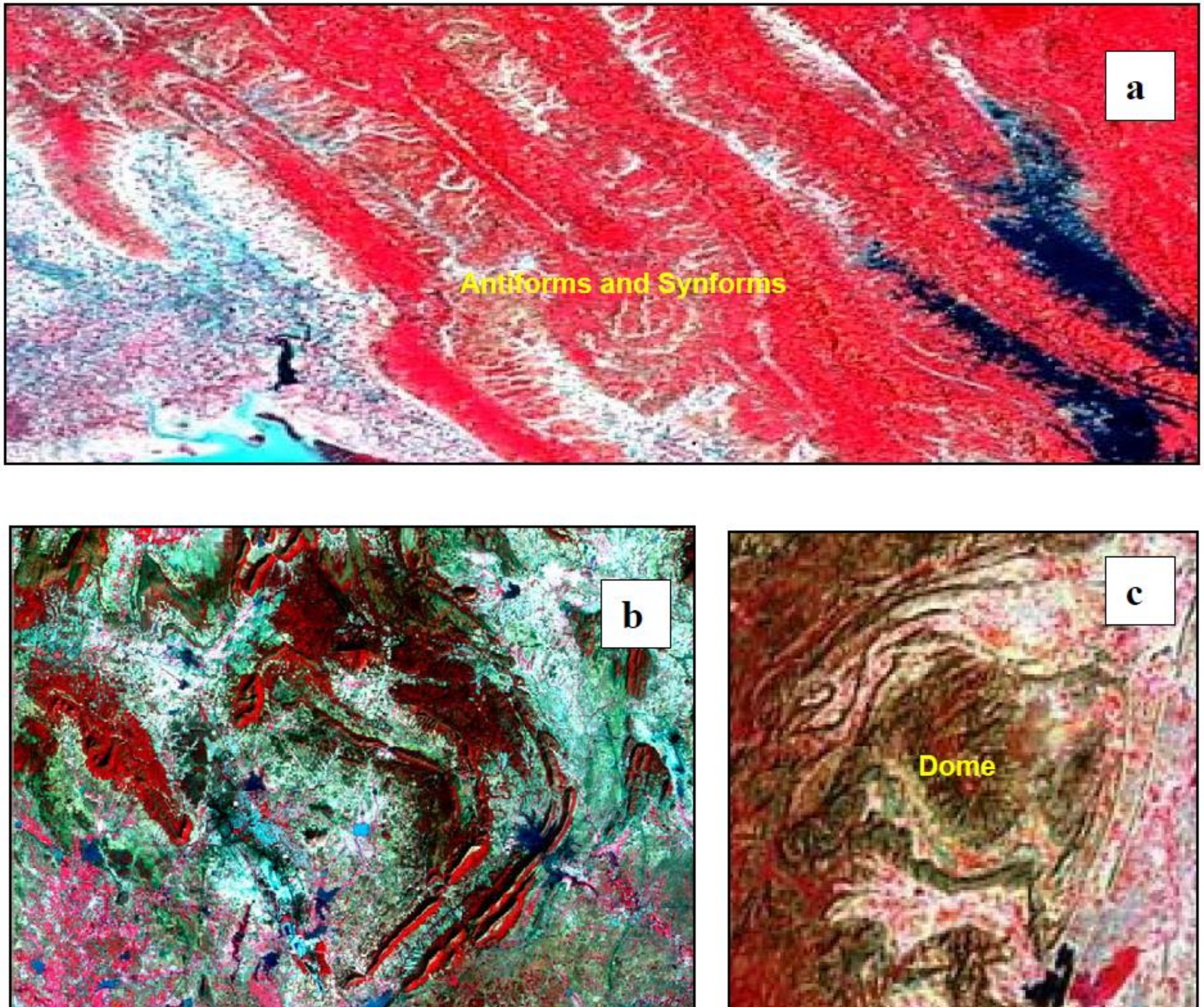


Source: Breck P. Kent

Adjacent Anticline and Syncline

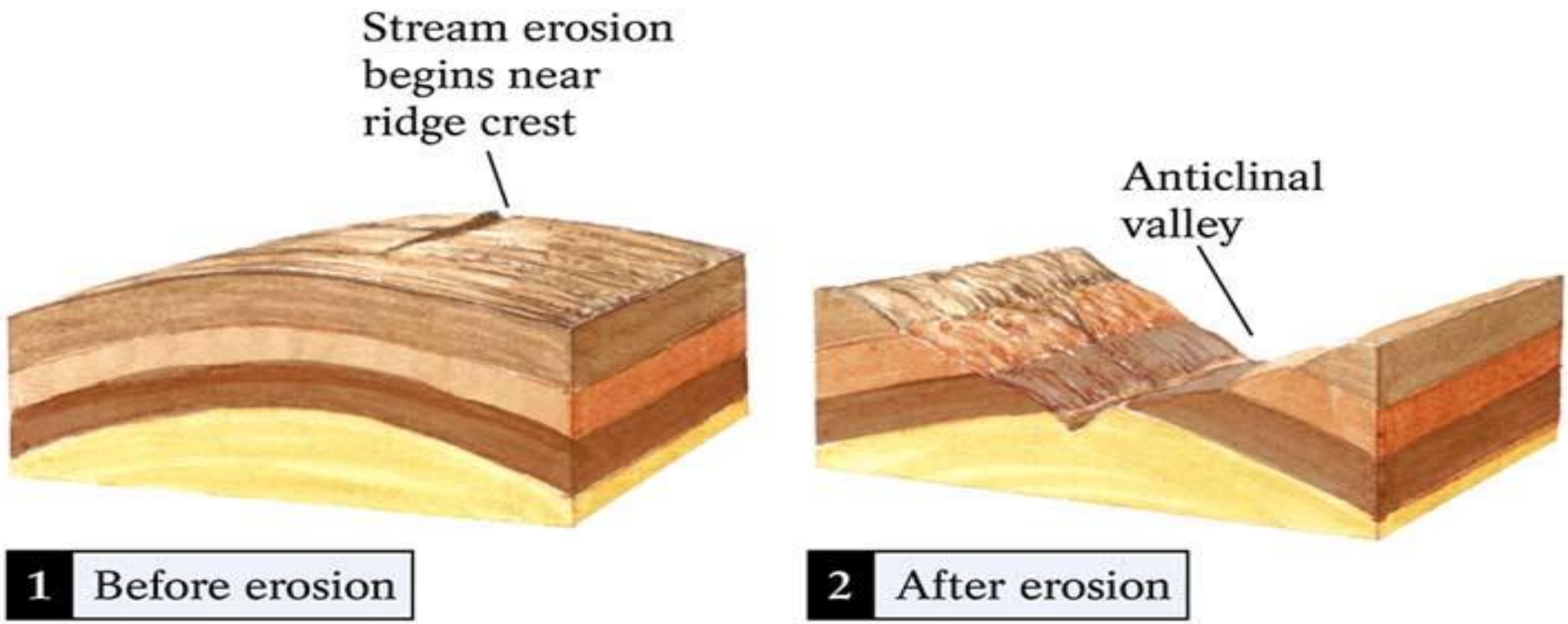
ANTICLINAL RIDGE – ZAGROS MOUNTAINS

Fig. 4.15: Satellite image of a) Northeastern region b) part of Madhya Pradesh and b) Cuddapah basin showing folds



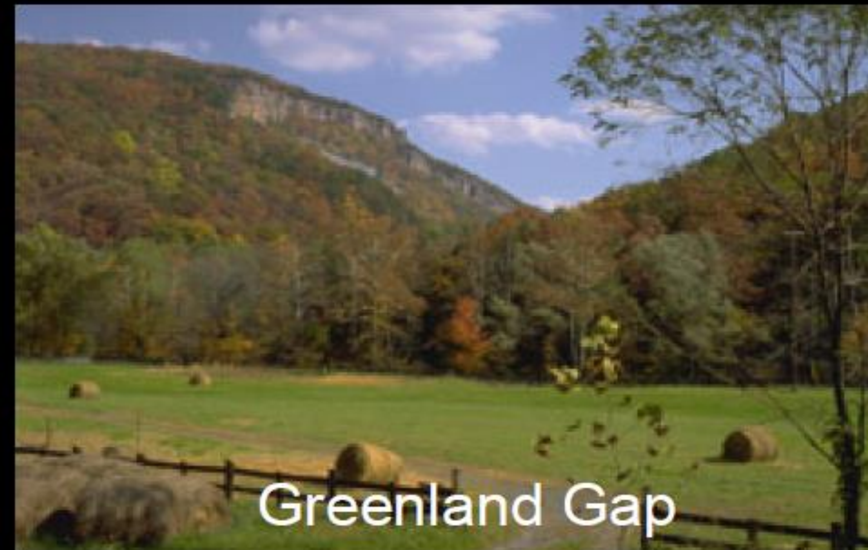
ANTICLINAL VALLEY

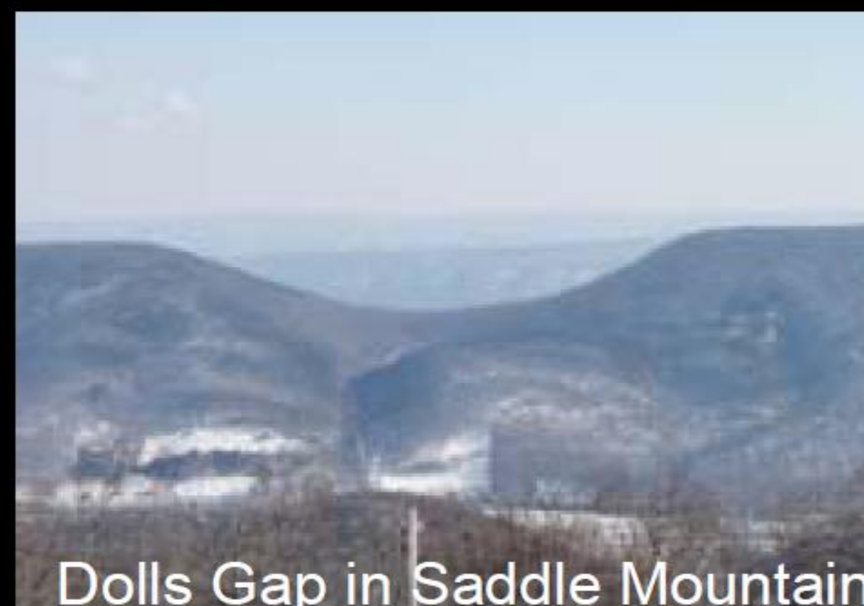
Topography may be opposite of Structure
Anticline Before/After Erosion



(a) Anticline with highly erodible surface **Notice center rock oldest**

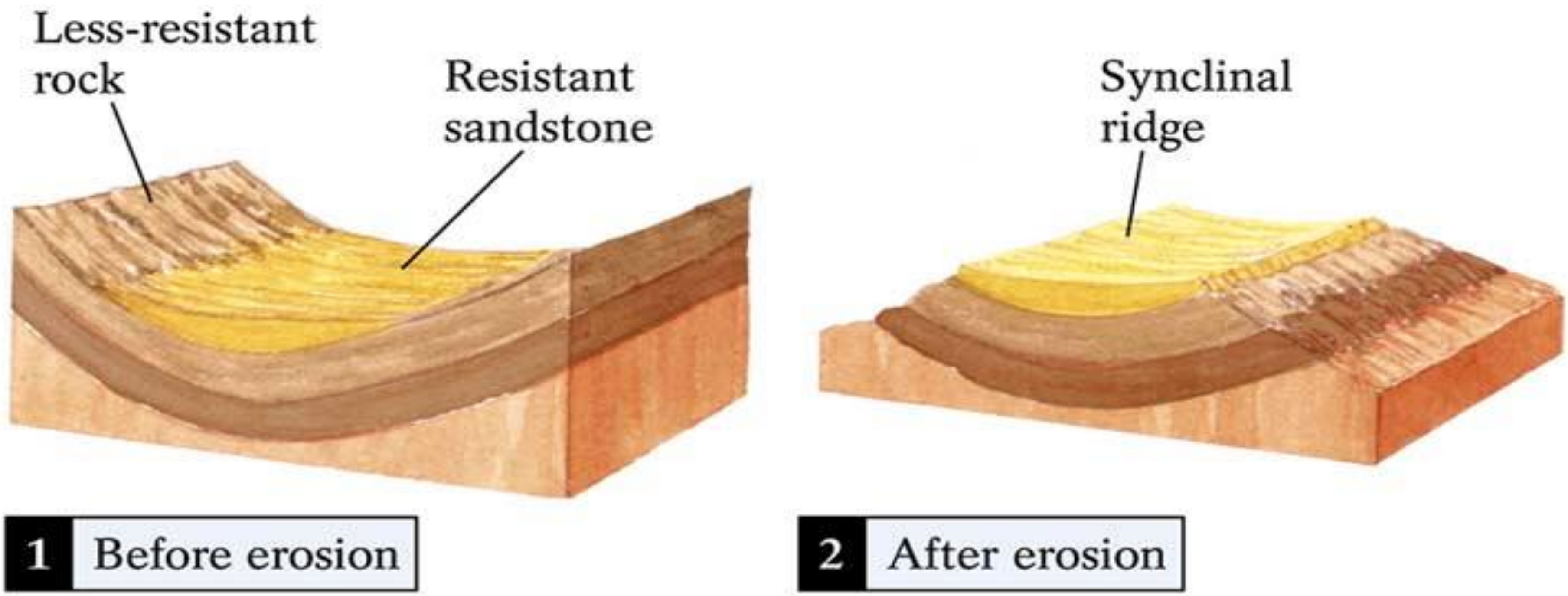
Wills Mountain (Breached) Anticline





Topography may be opposite of Structure

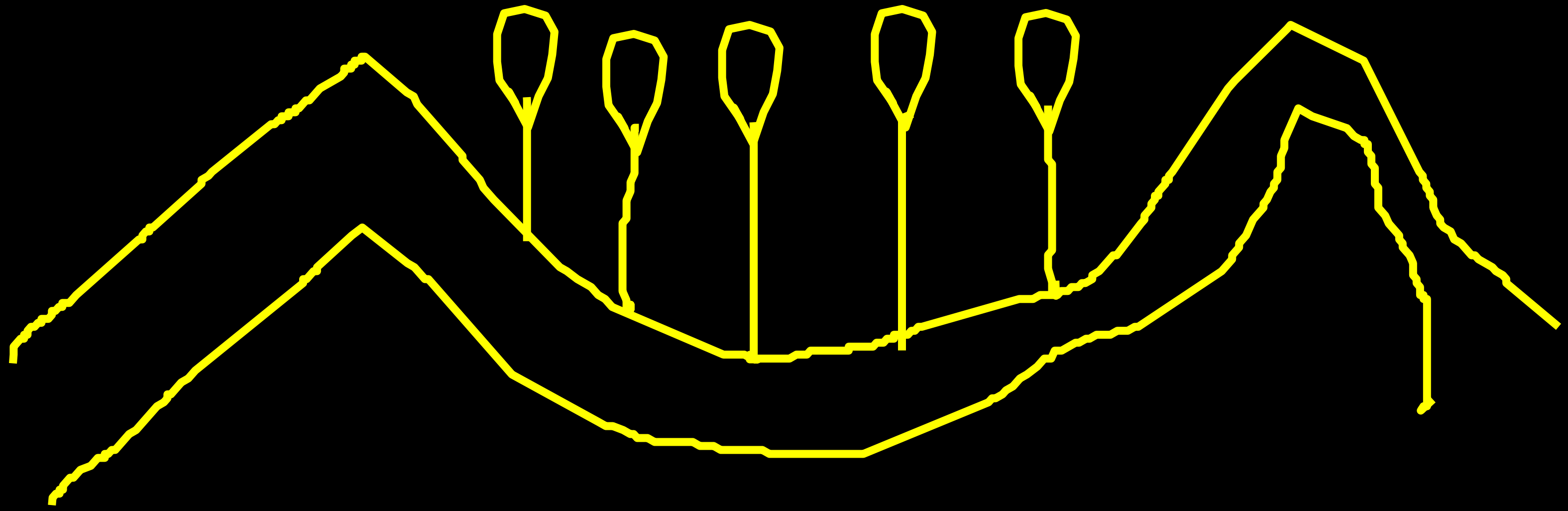
Syncline Before/After Erosion



(b) Syncline with resistant rock at axis

Notice center rock youngest

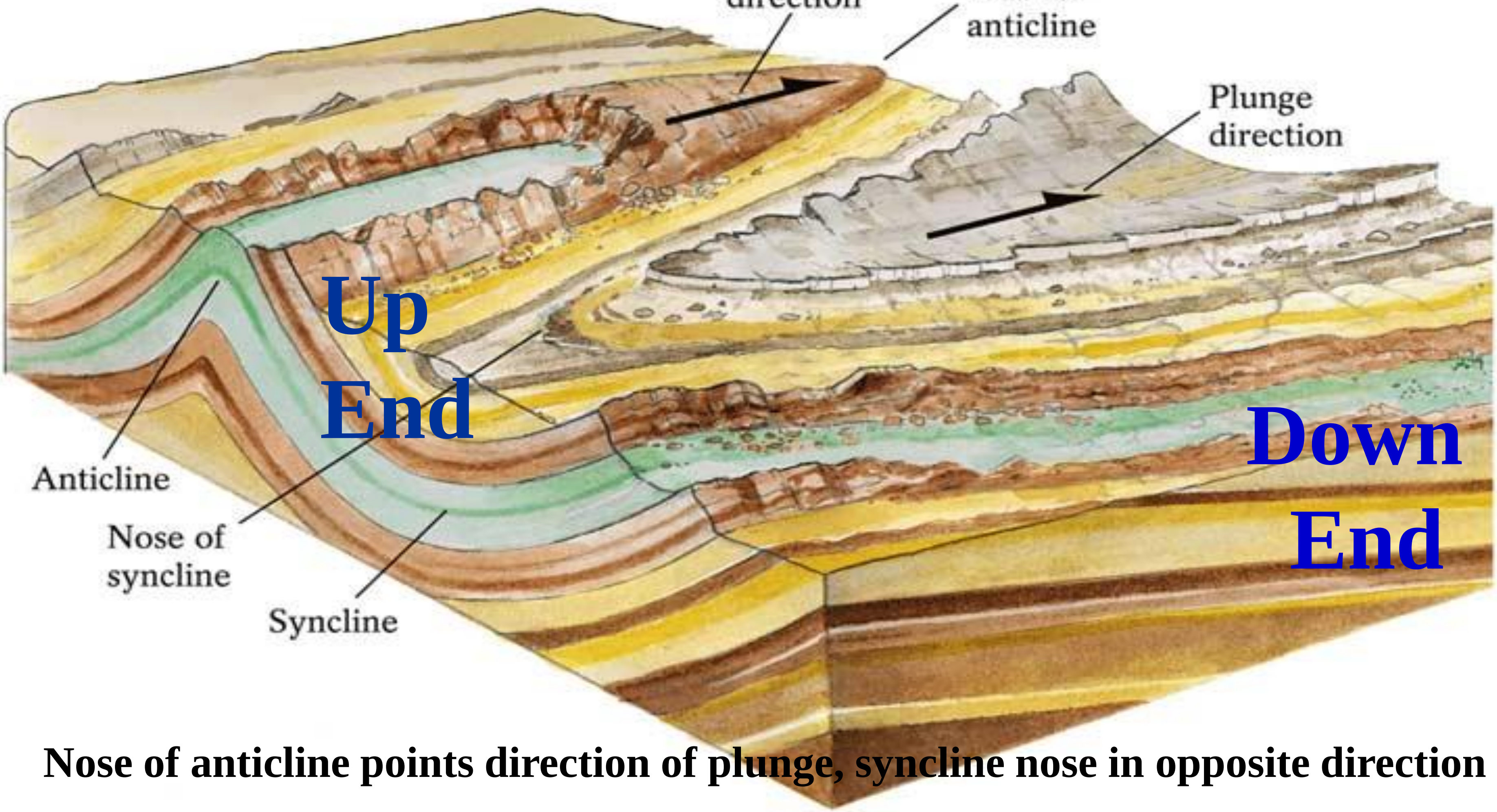
Synclinal valleys



Sideling Hill, MD-WV-PA, Synclinal Ridge

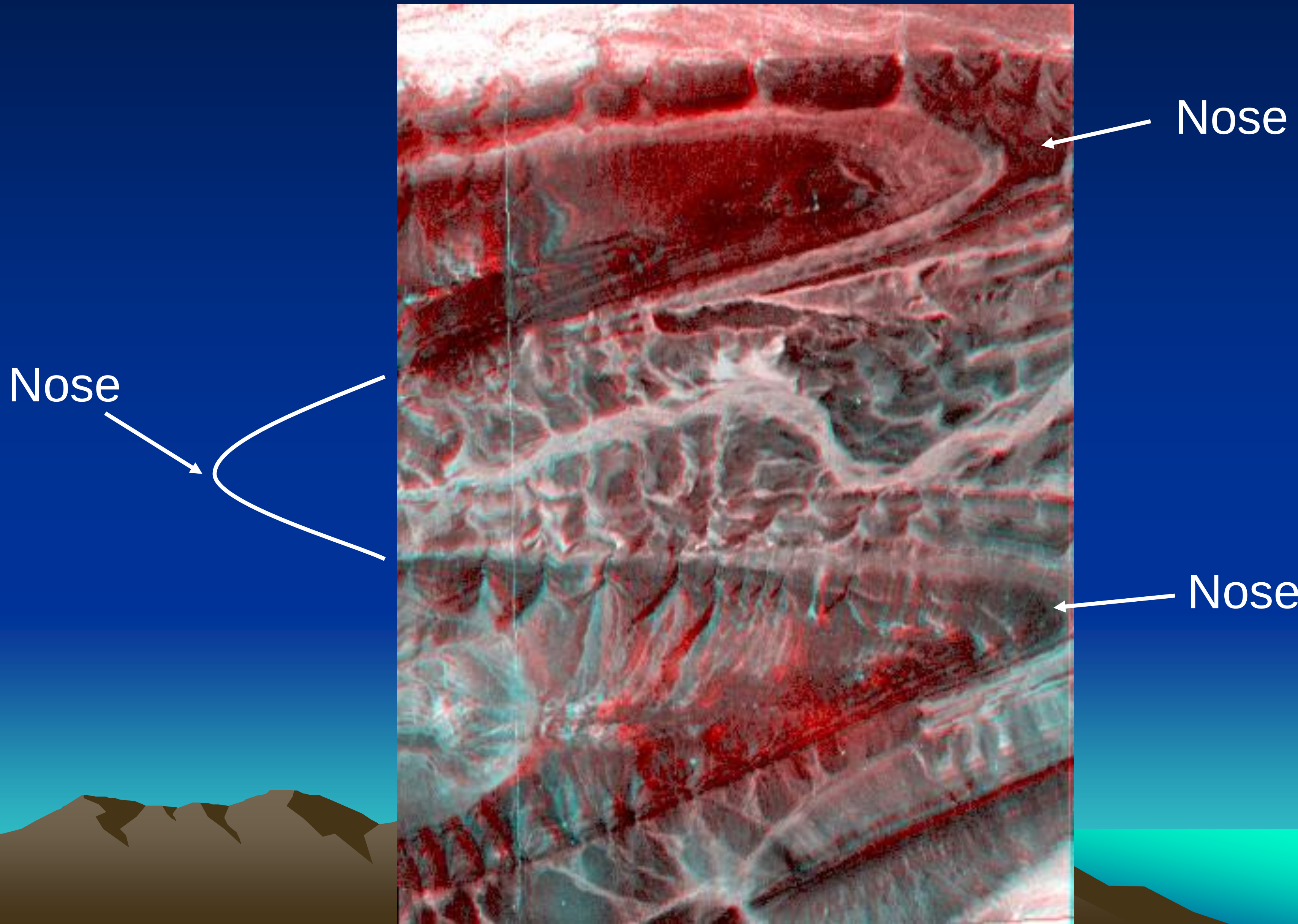
Plunging Folds and Nose Rules

Demo: Plastic box, water, paper folds

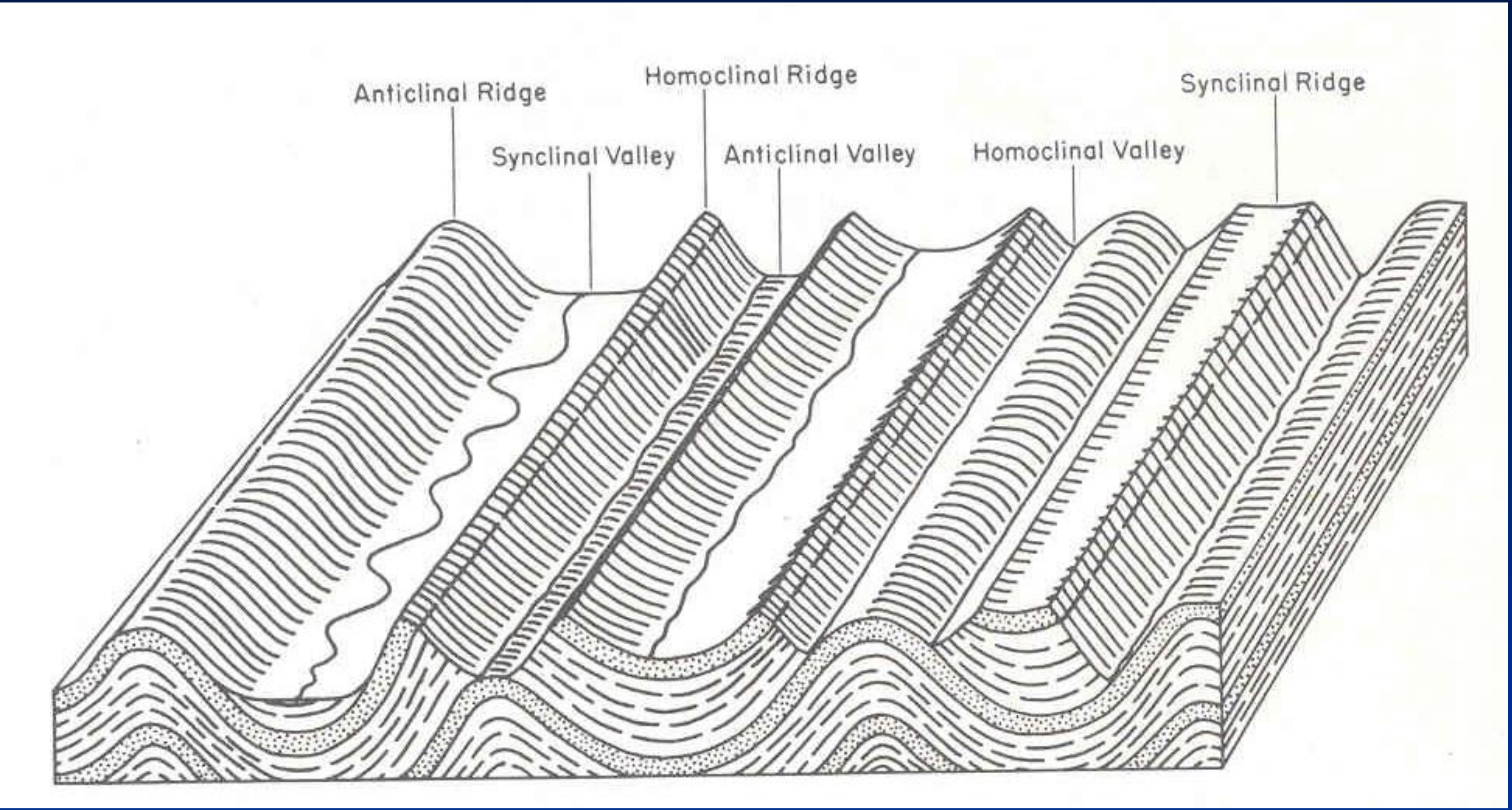


Nose of anticline points direction of plunge, syncline nose in opposite direction

Plunging Folds



HOMOCLINAL RIDGES AND HOMOCLINAL VALLEY



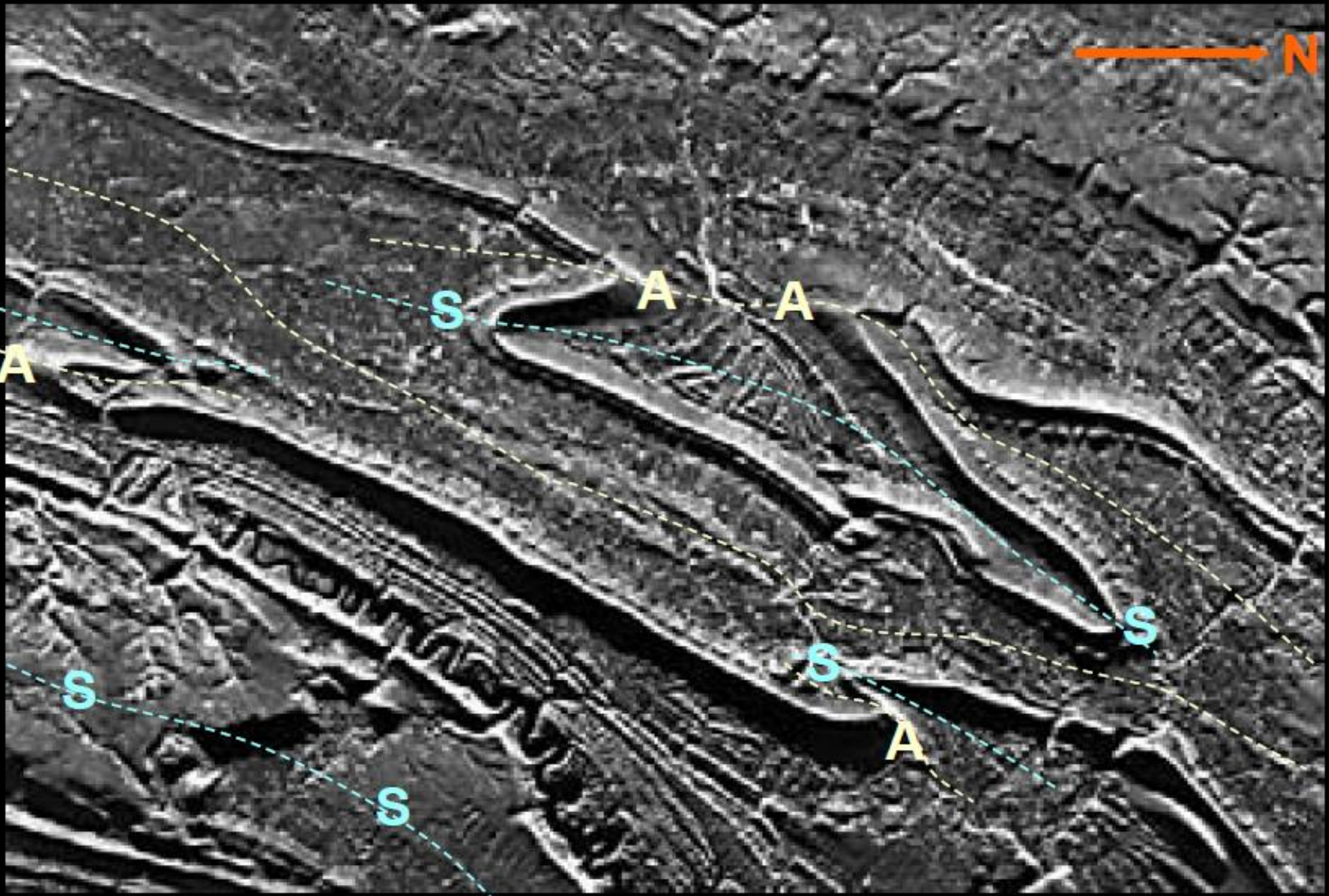
Differential weathering weak and strong beds causes the Homoclinal ridges and valleys

Short, N. M., and Blair, R. W., 1986, Geomorphology from Space, NASA
daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/
GEO_2/GEO_PLATE_T-42.HTML

Homoclinal, Anticlinal & Synclinal Ridges, near Altoona, Pennsylvania

A =
Anticline

S =
Syncline

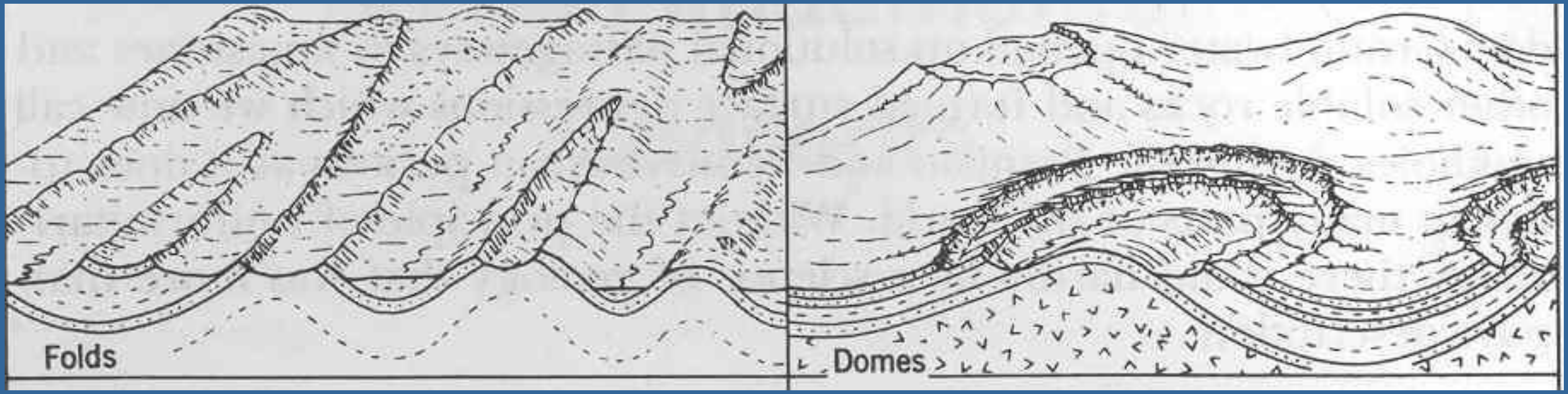


Short, N. M., and Blair, R. W., 1986, Geomorphology from Space, NASA
daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/

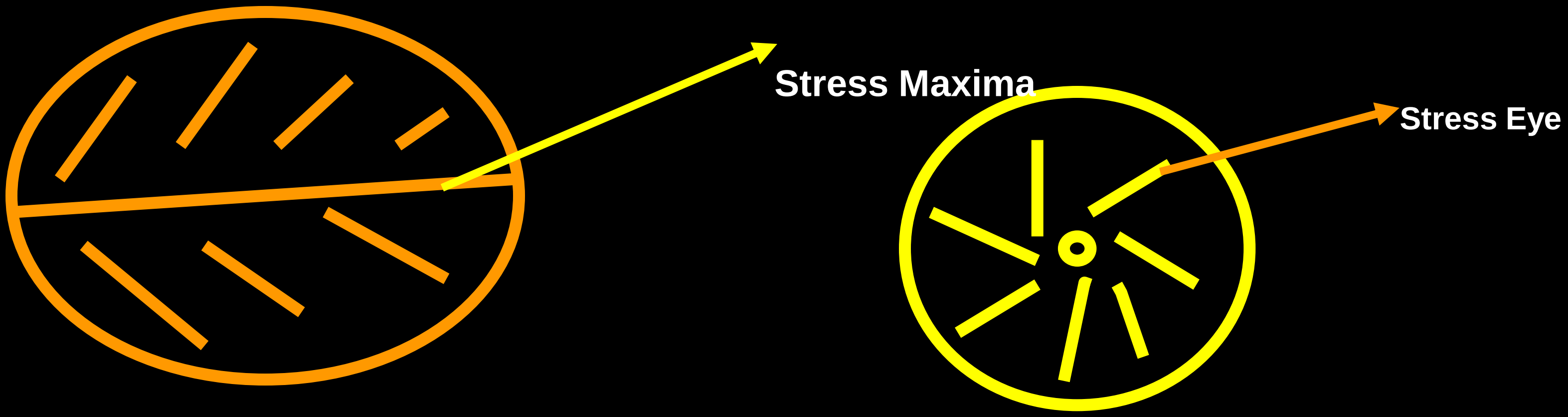
Homoclinal Ridges, near Rawlings, Wyoming

Short, N. M., and Blair, R. W., 1986, Geomorphology from Space, NASA
daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/

FOLDS DOMES



(3.6.3.3) DOMED MOUNTAINS / BASINAL MOUNTAINS



- qua-quaversal dips
- radial centripetal / centrifugal drainage

Domes

unstable, seismic prone, crest stress accumulated domain, erosion prone, unsafe for dams

Basins

- Aseismic, suitable for dams - better groundwater prospects.
- suitable for waste disposals
- suitable for water storage

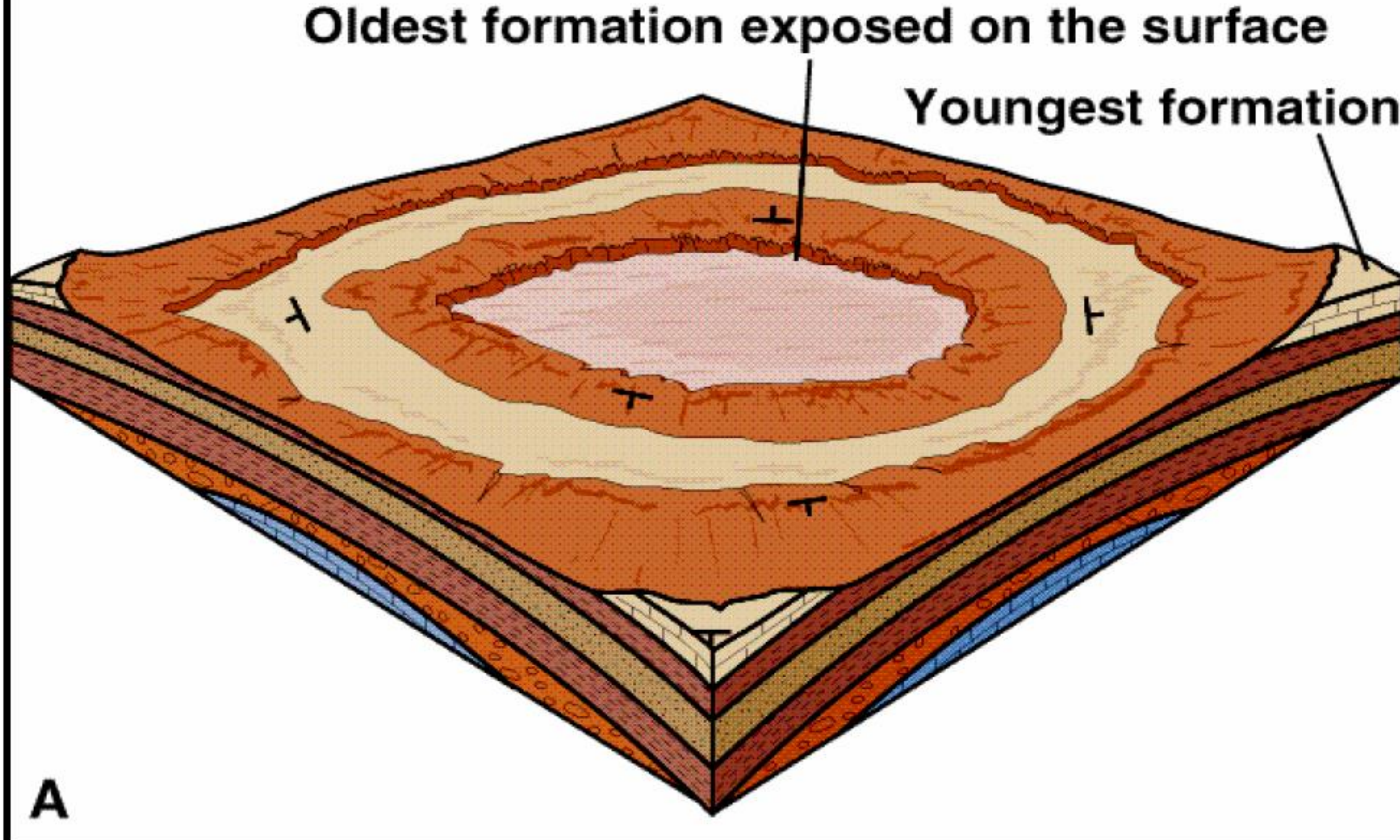
Domes

- **Domes** are a broad upwarping in the rock underlying an area may deform the overlying sedimentary layers. The Black Hills of South Dakota.

Sedimentary Basins

- **Basins** are downwarped structures that have a roughly circular shape. An example of a basin is the bowl-shaped Michigan basin.

Structural Dome



Richât Structure, Mauritania
Surface Expression of a Dome

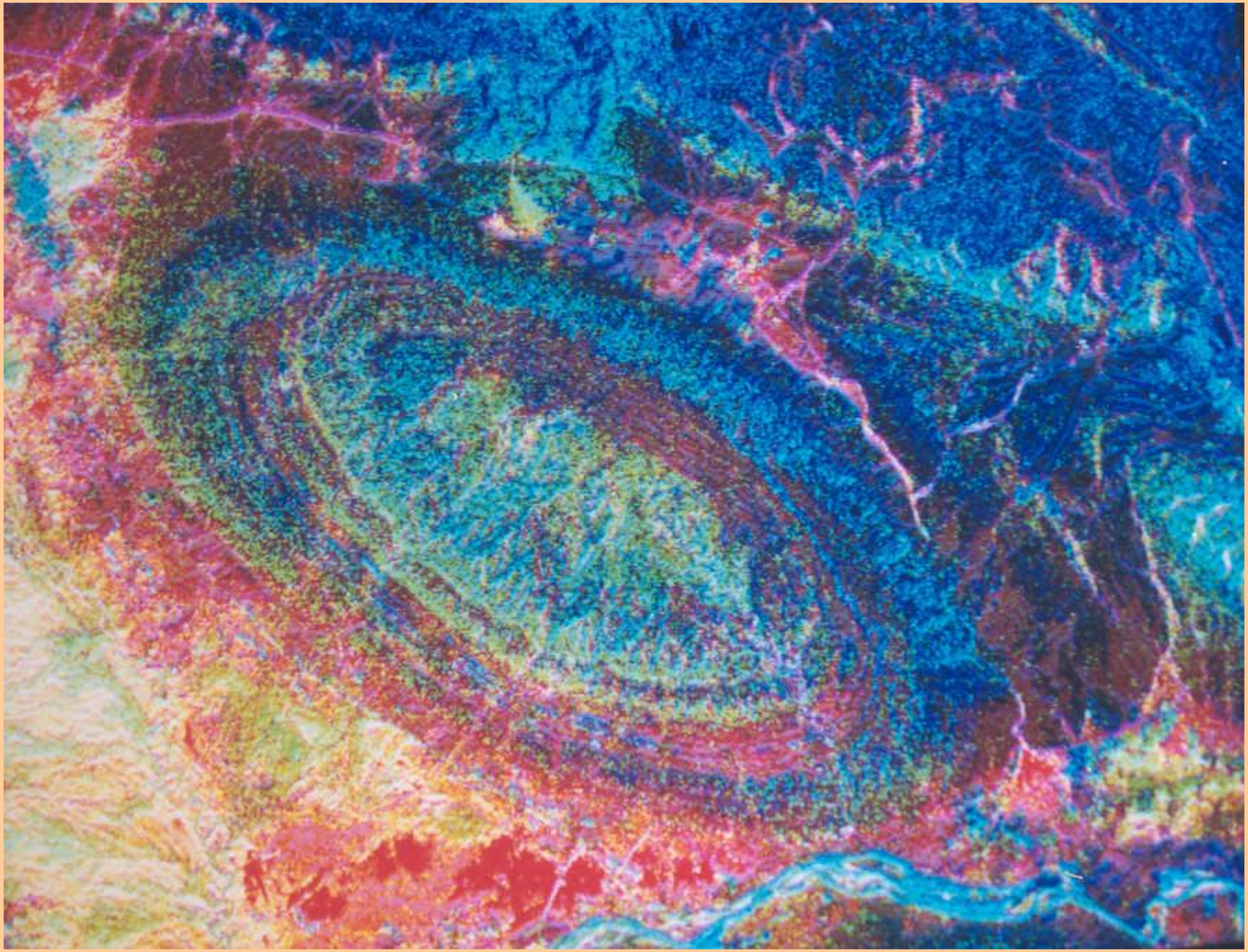
Beds dip away from center.

Note Fractures.

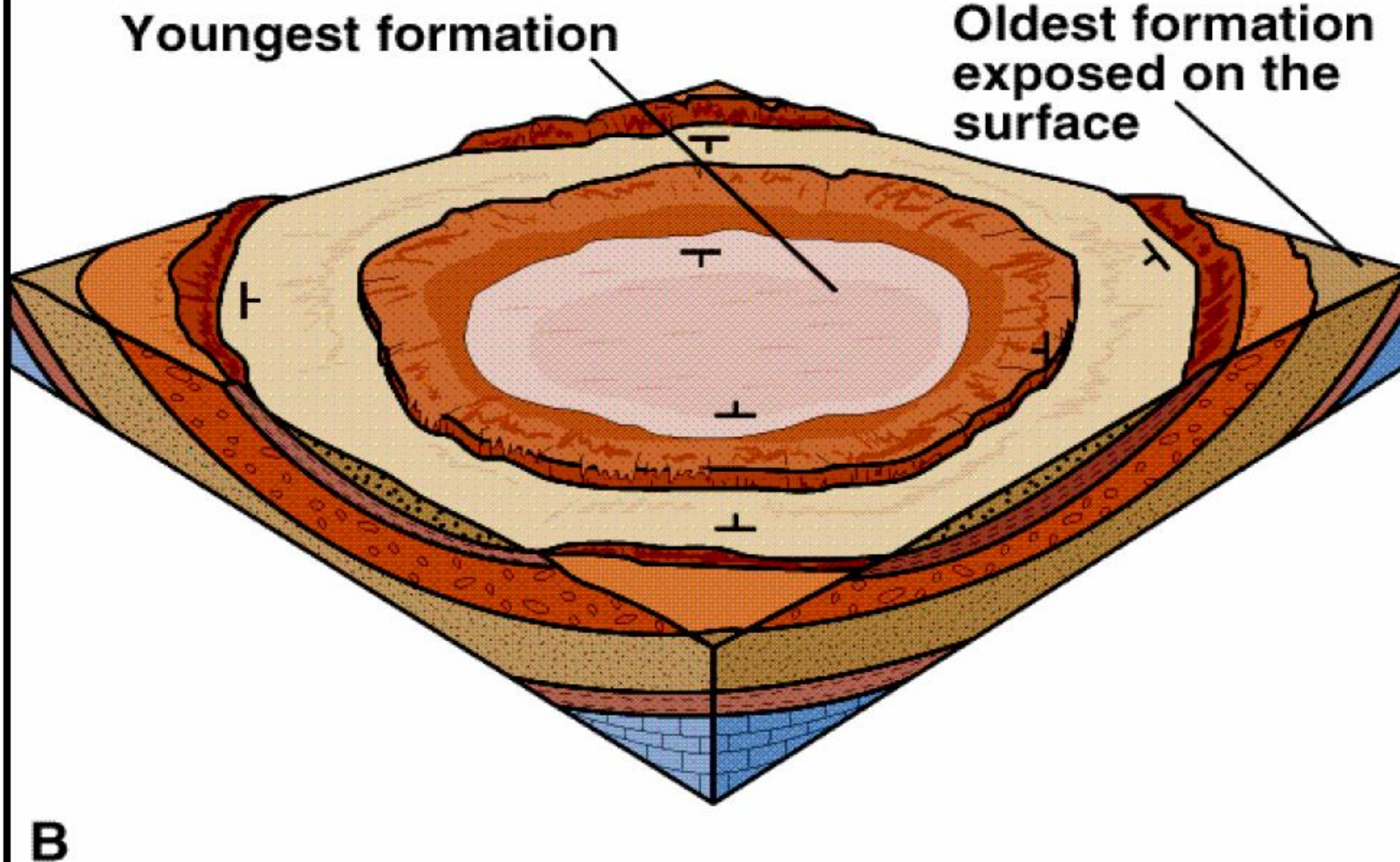
http://daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/GEO_2/GEO_PLATE_T-31.HTML

Grenville Dome, Wyoming

DOMES - IRAN



Structural Basin



BASINAL HILLS or Synclinal Mountains

Synclinal mountains may vary from elongate narrow ridges to broad plateau like expanses, but typically they are broader than aticlinal mountains

Isachsen Salt Dome, Ellef Ringnes Island, CANADA

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

0 1 2 3 4 5 km

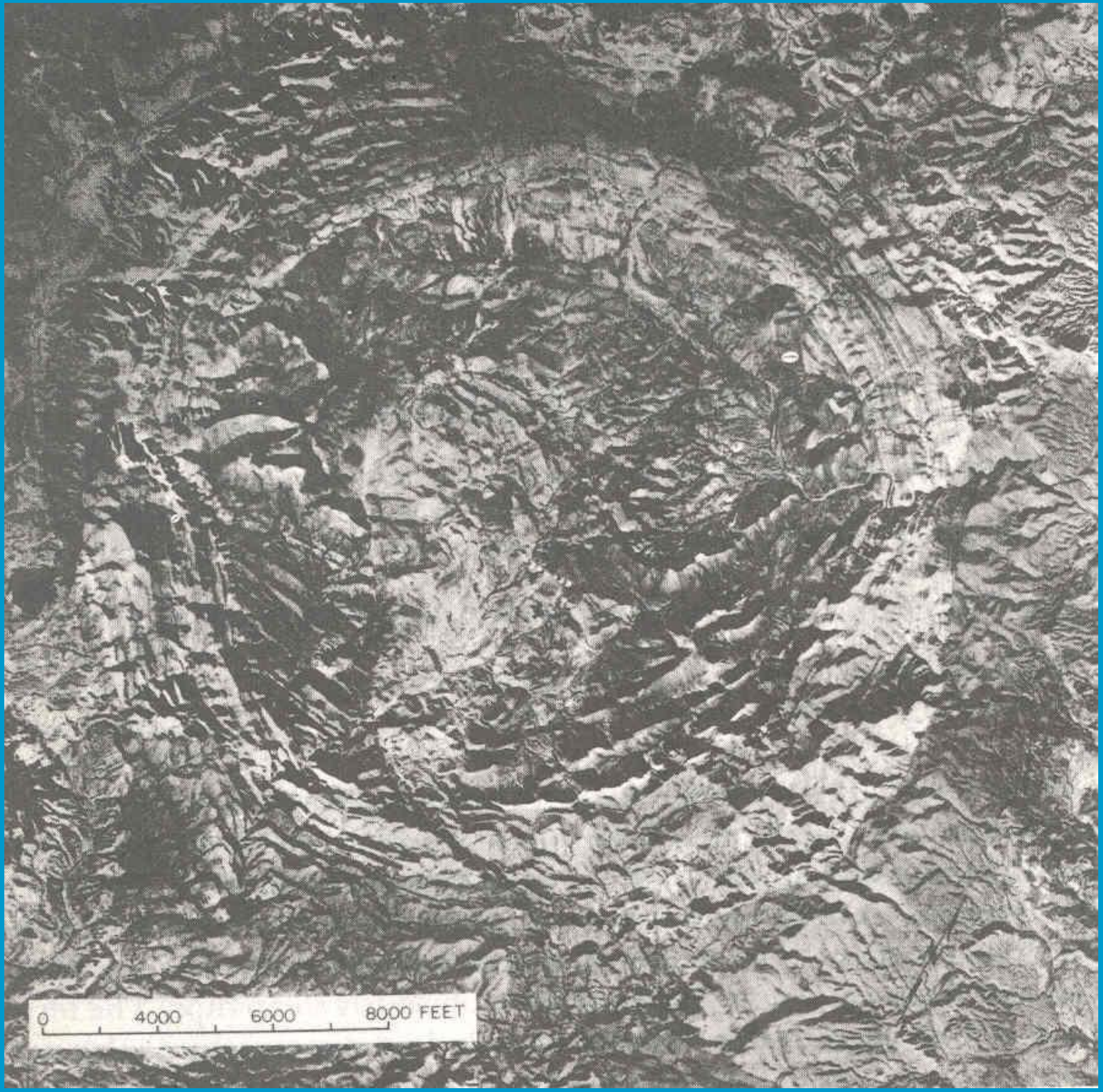
Salt Dome

Low density
Buoyant
Diapirs

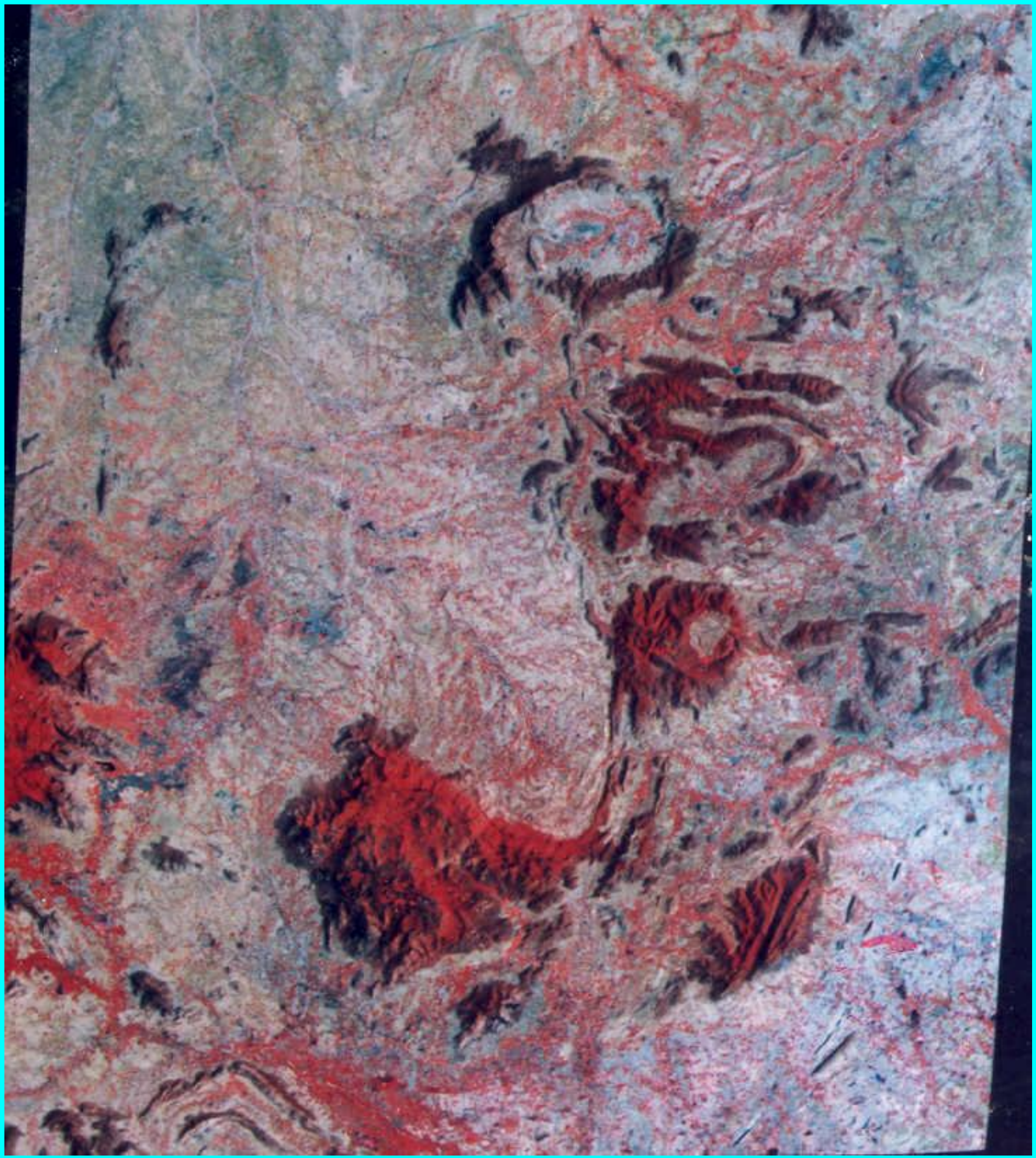
Surrounding sediments upwarped

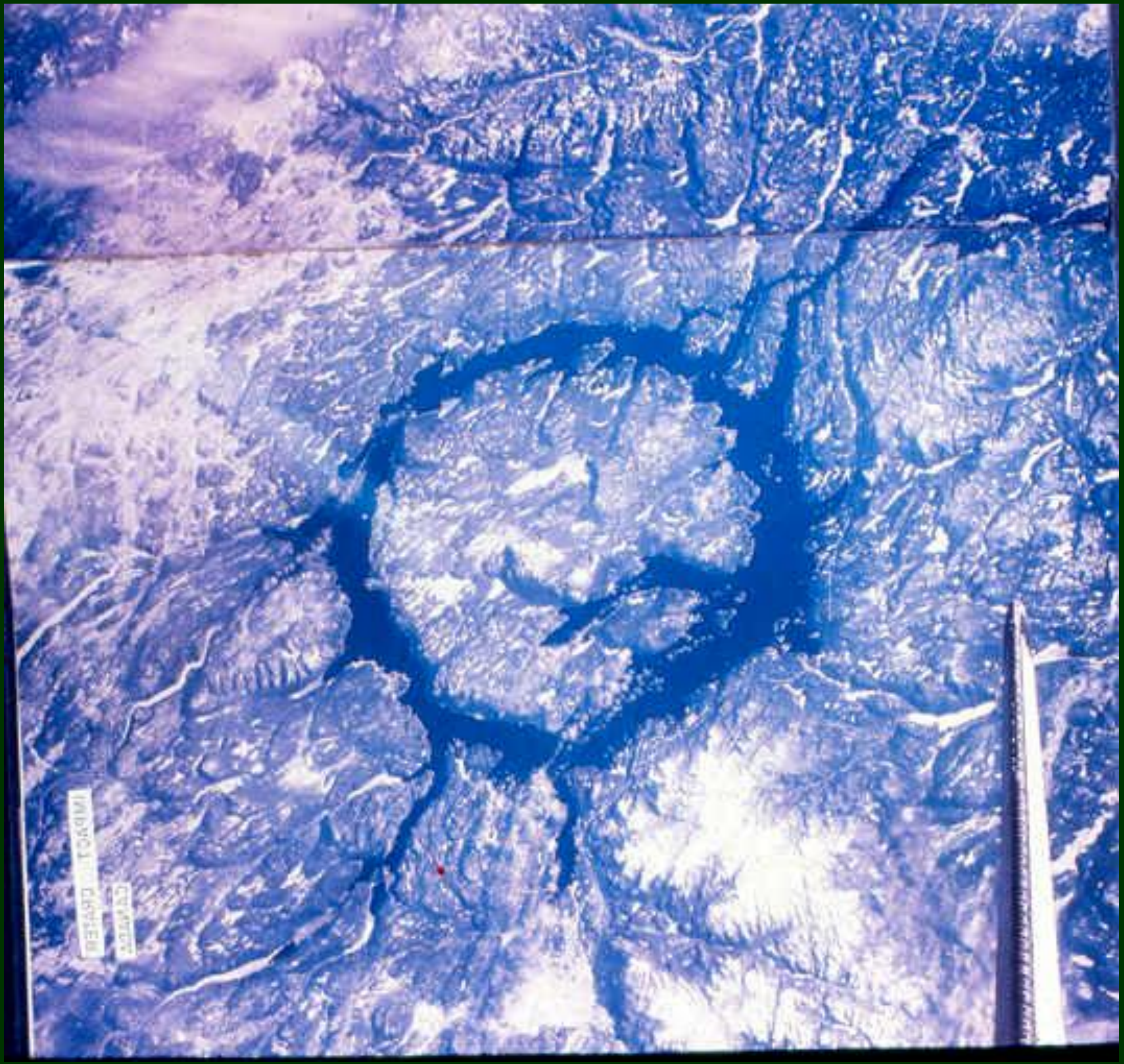
Petroleum exploration

TEXAS

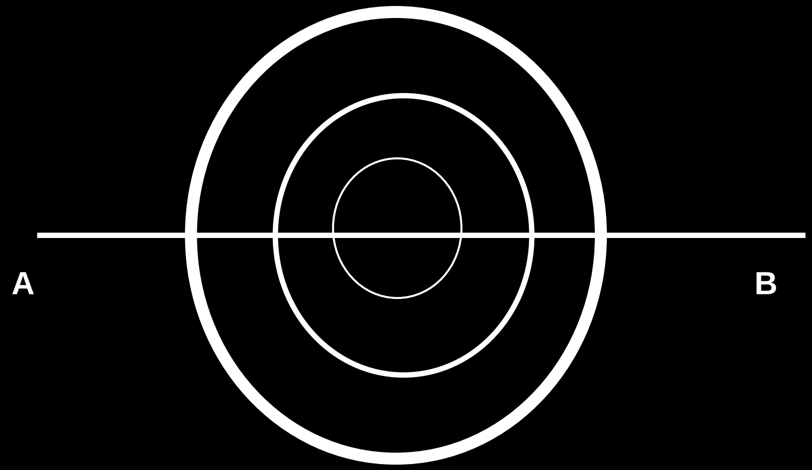


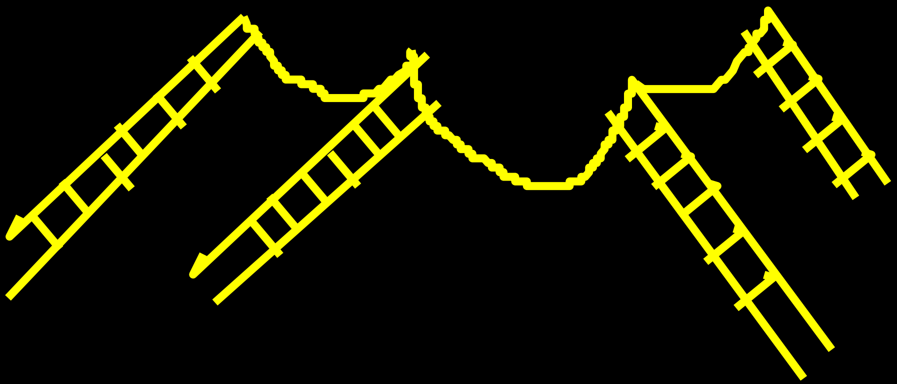
KADAVUR





(3.6.3.4) Annular Hills

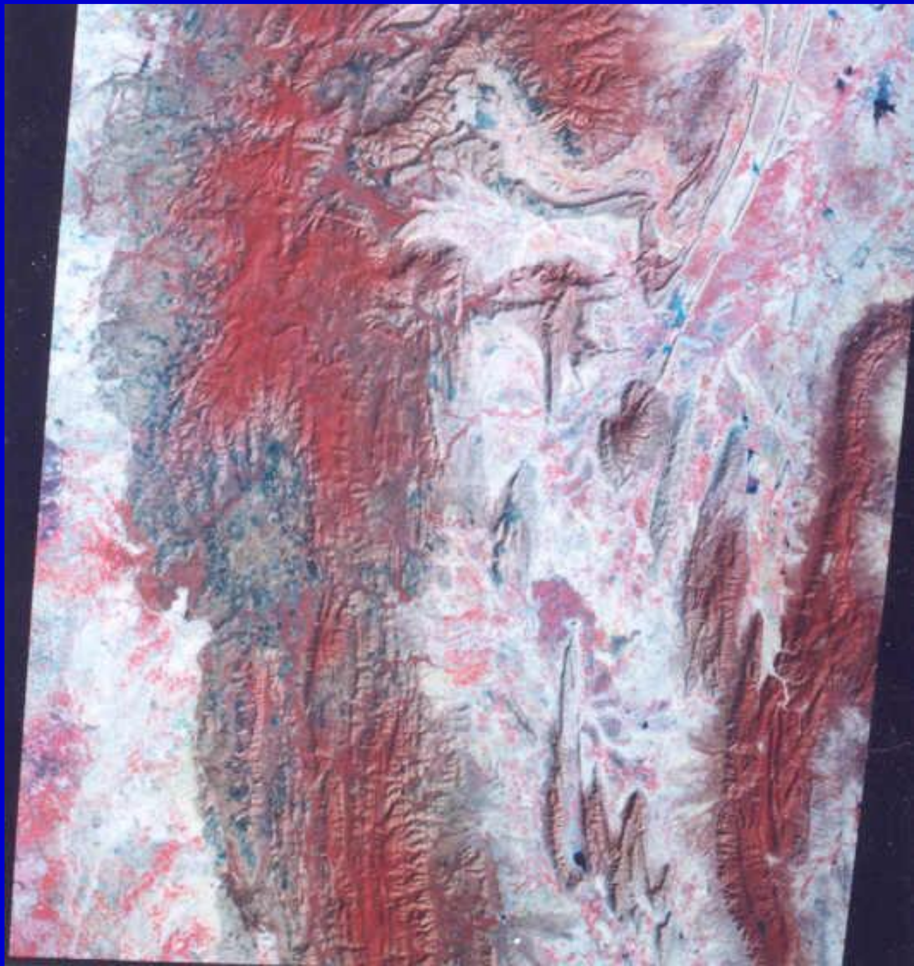




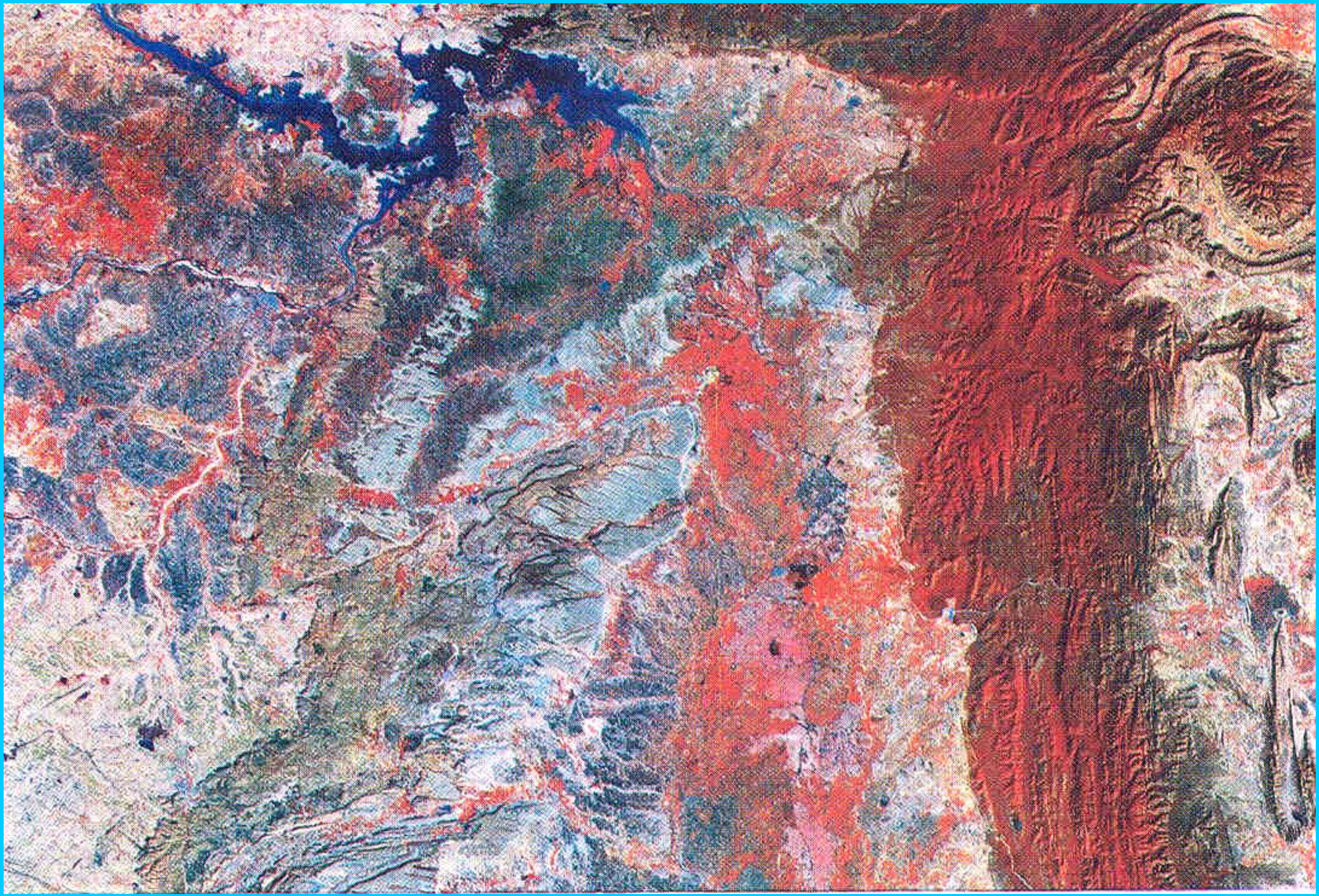
- circular ridges & valleys
- radial annual centrifugal / centripetal drainage

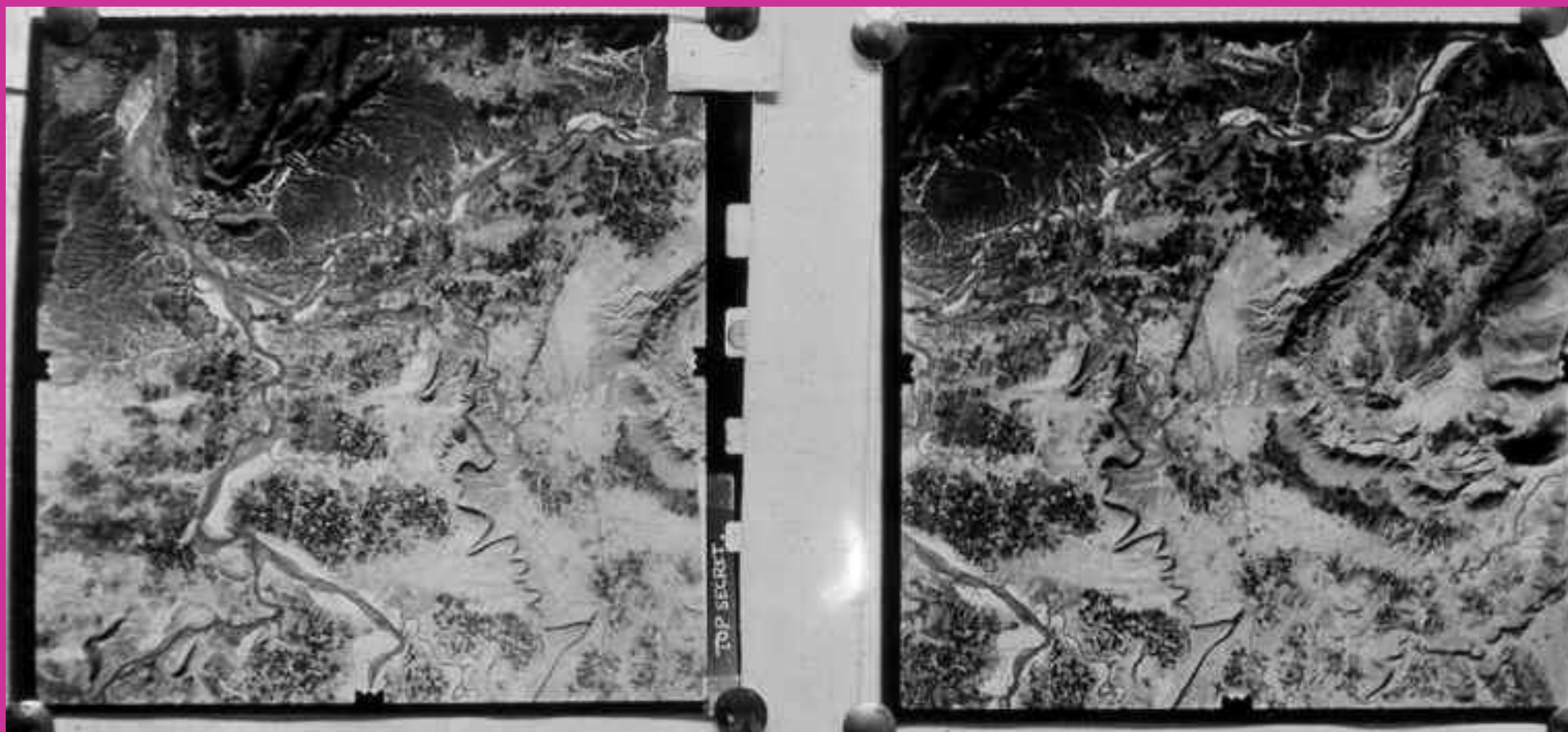
(E-g) Ramgarh dome, Ishwarakuppam dome

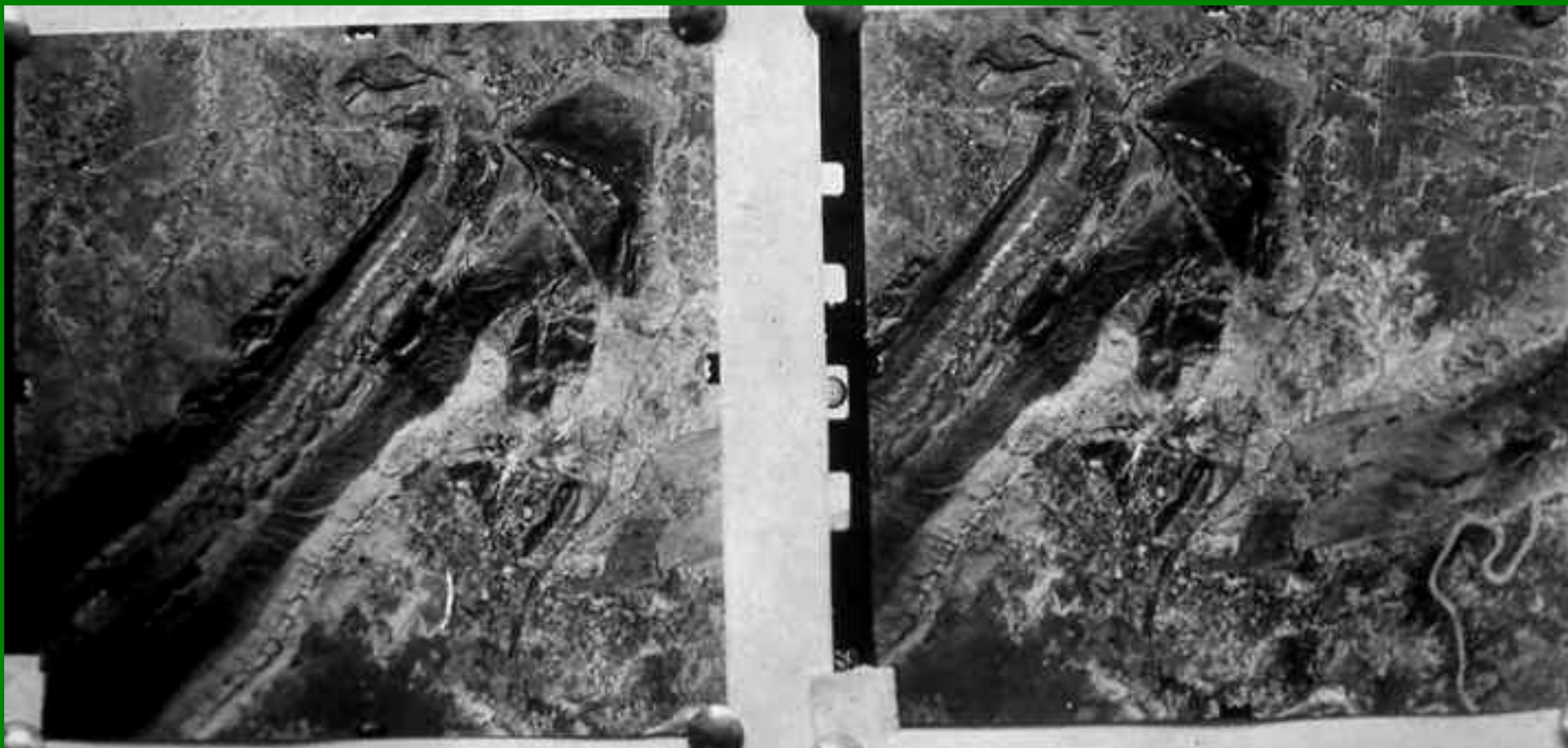
ANNULAR HILLS & VALLEYS



LISS III – CUDDAPAH BASIN



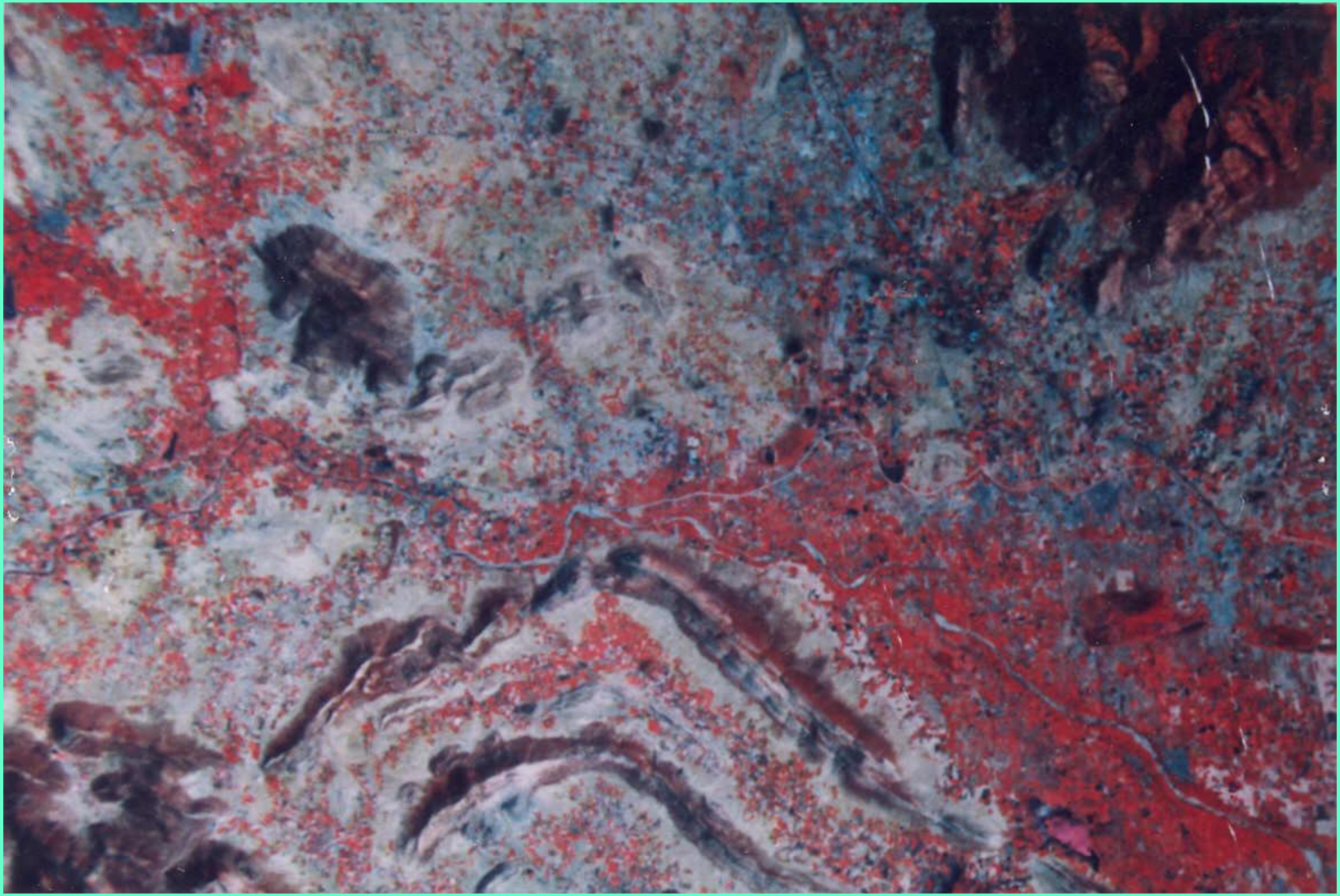

TOP SECRET.



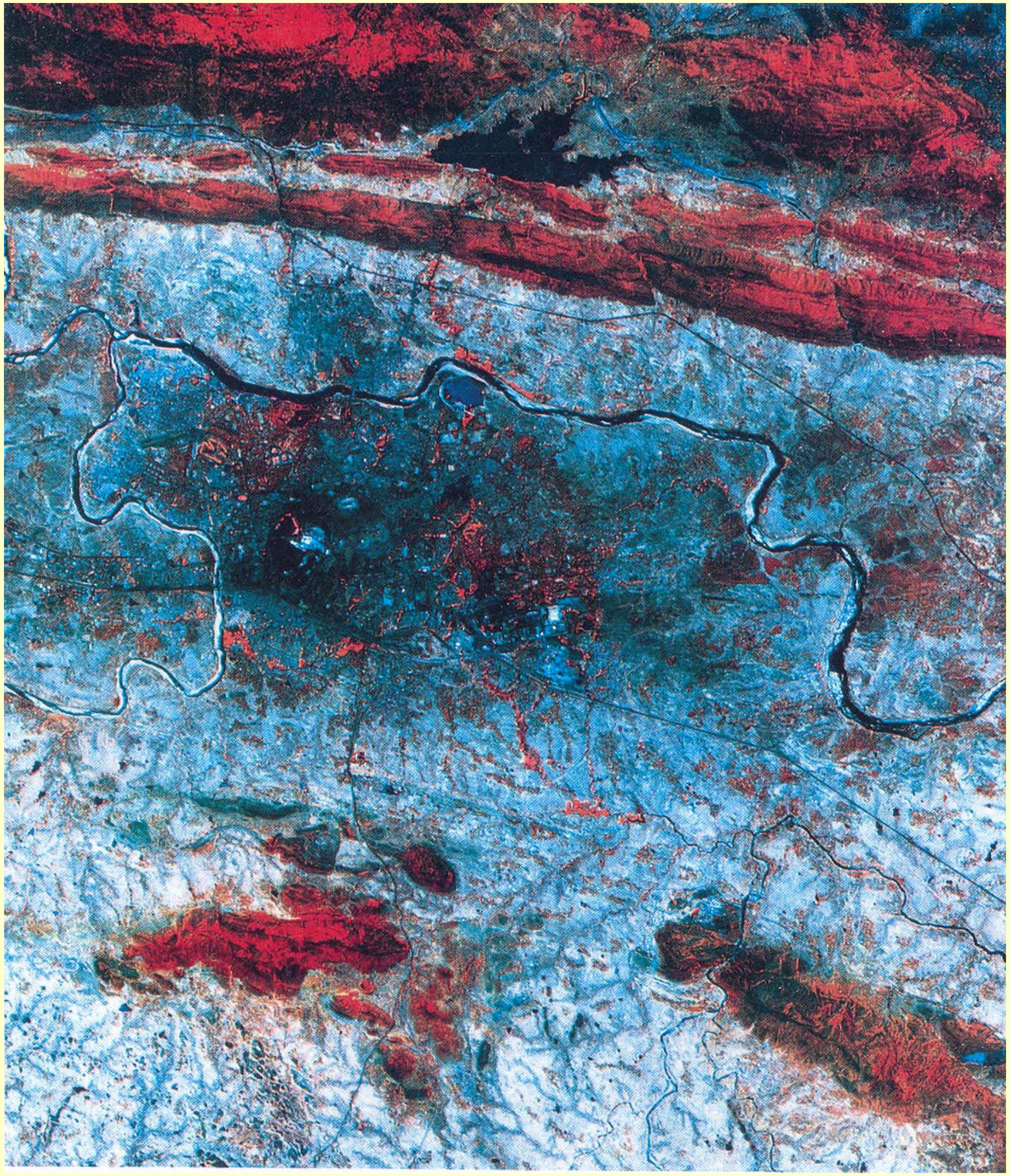
(3.6.3.2) Linear Ridges

- ➔ steep dipping hills form ridges
- ➔ no debris slope
- ➔ least erosion

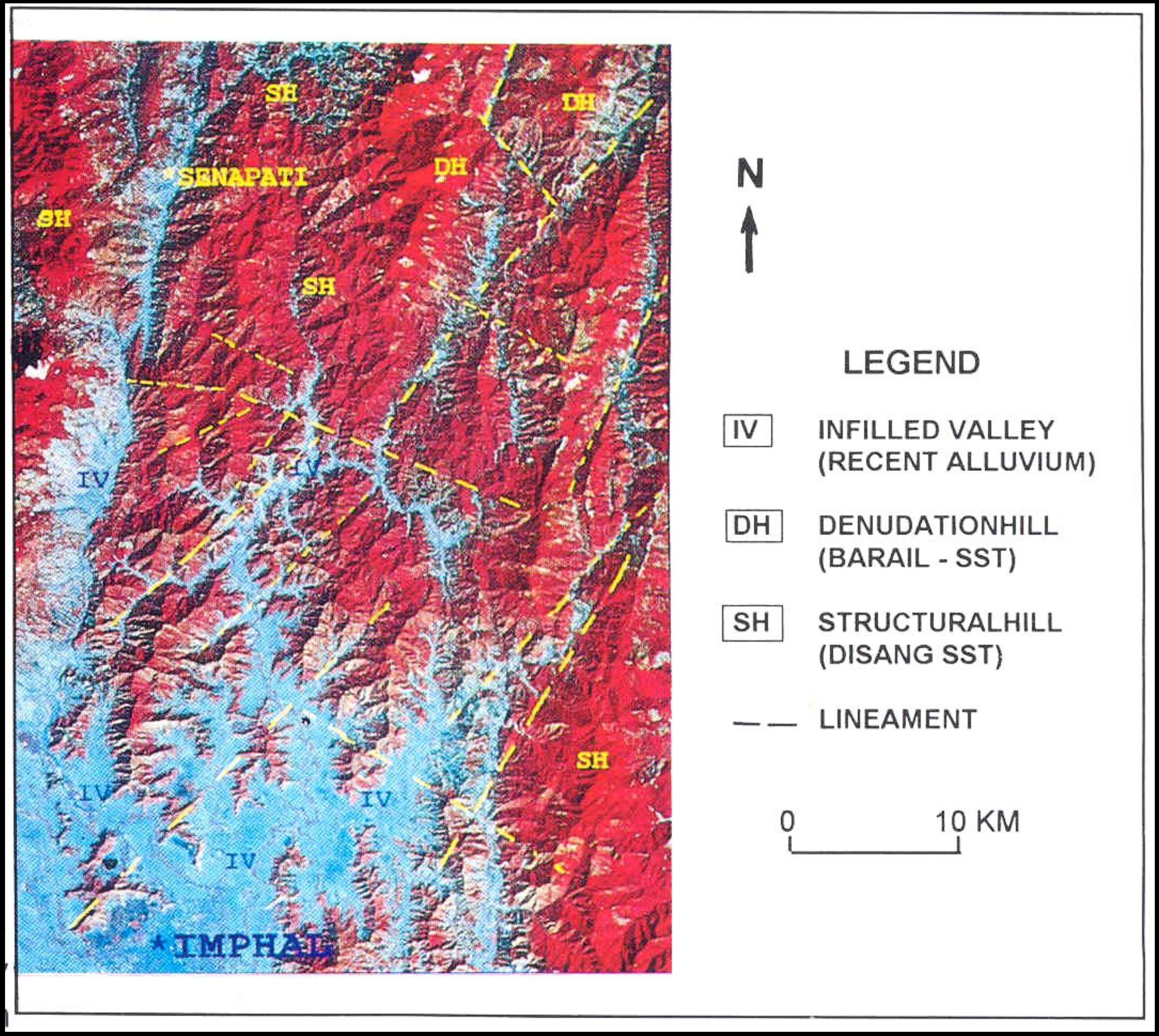
RIDGES - MADURAI



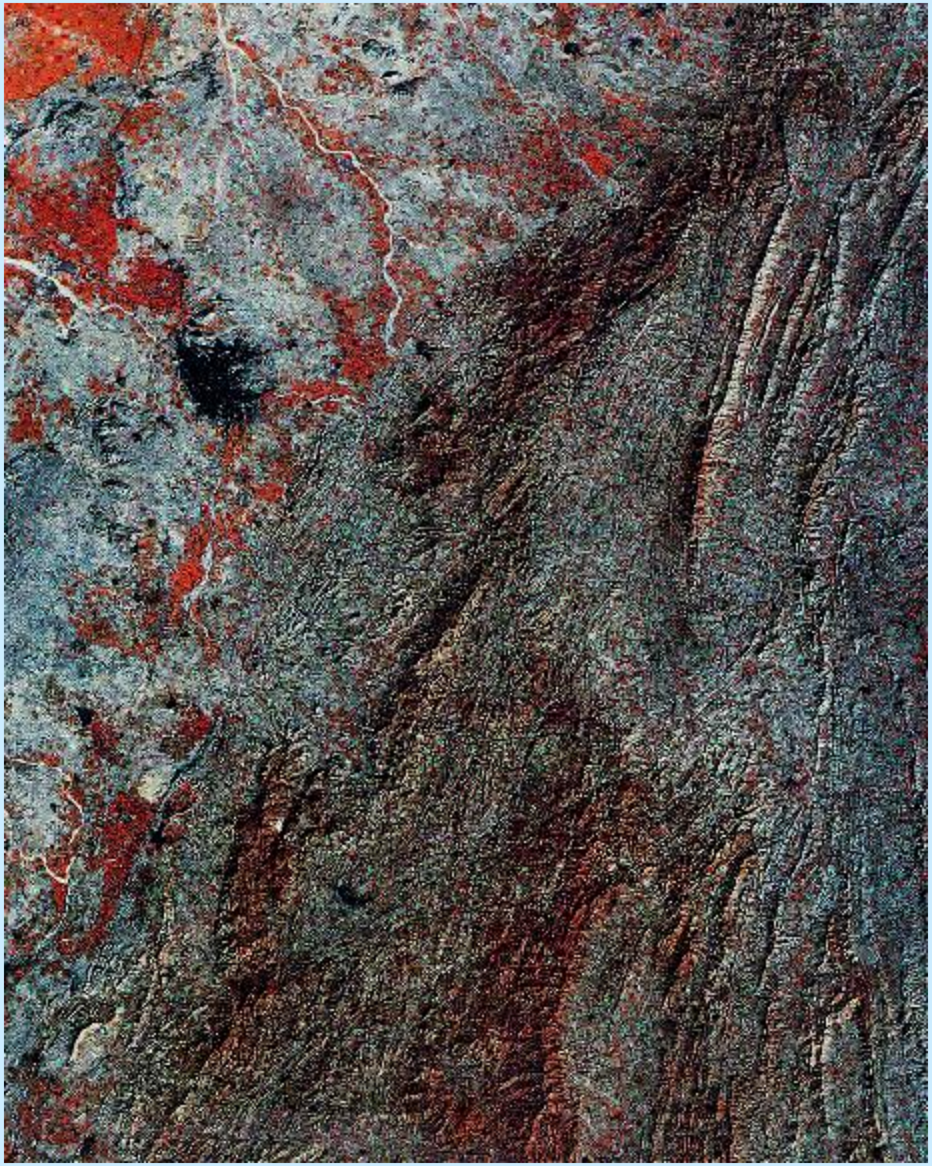
LISS III – JAMSHEDPUR



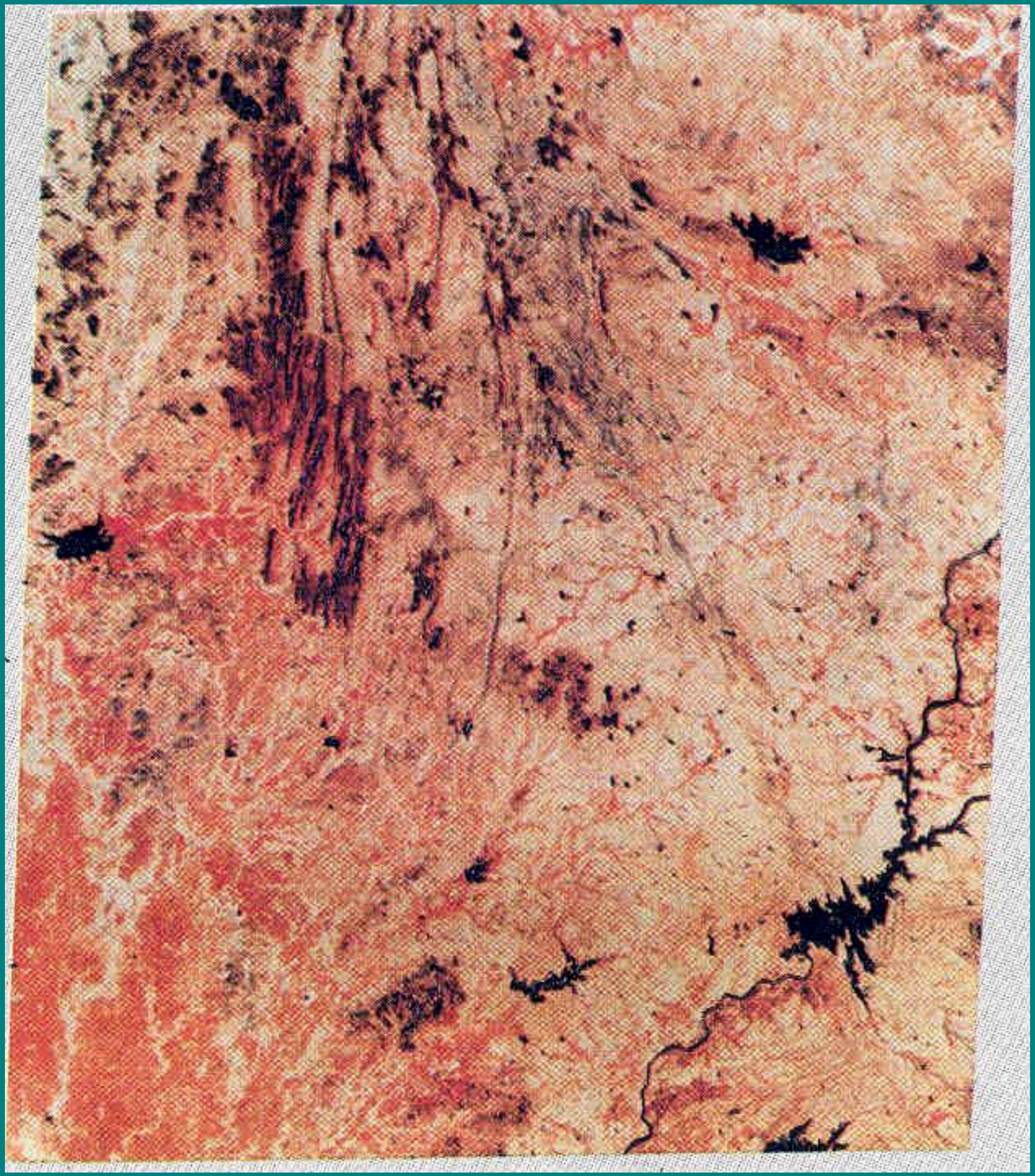
LISS III – MANIPAL



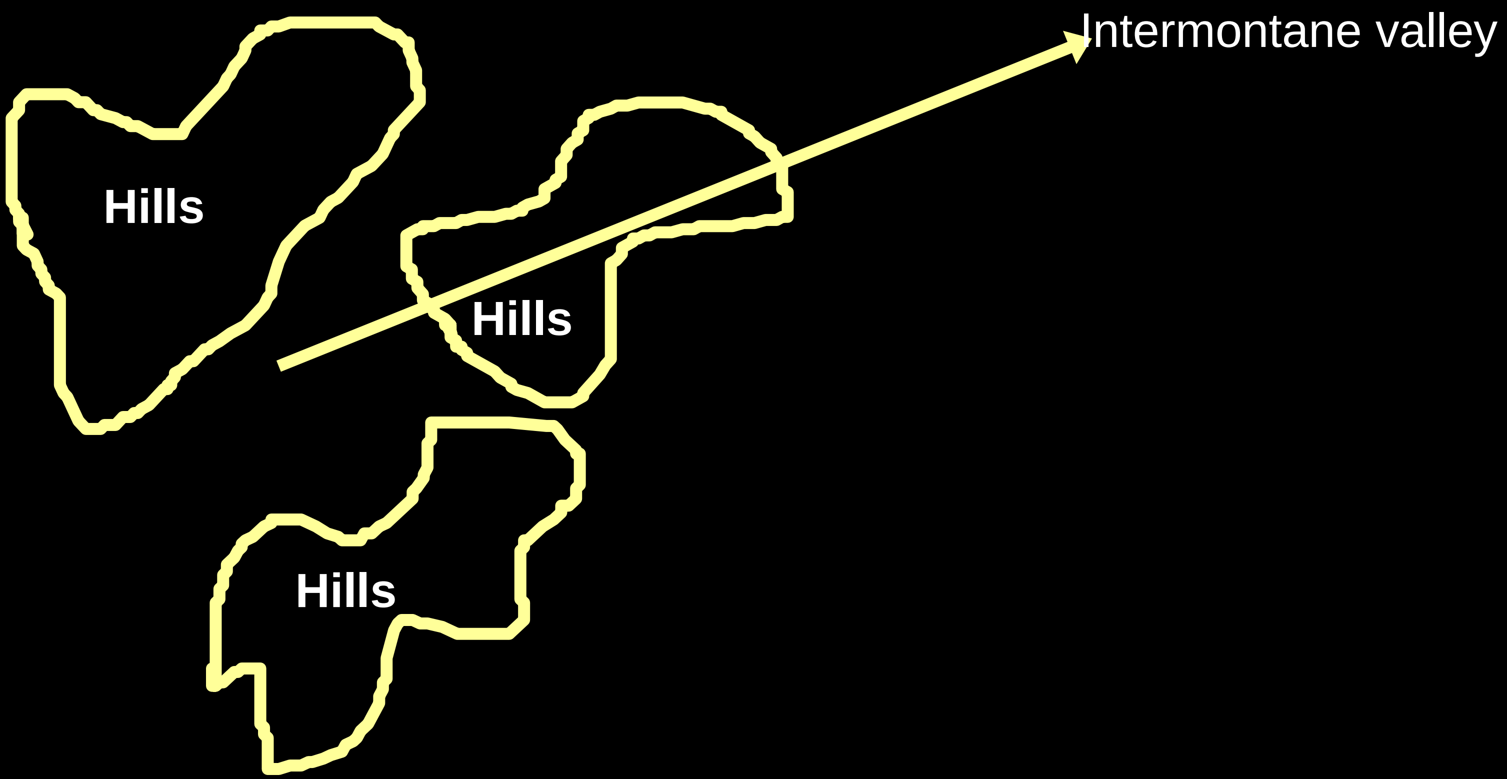
IRS 1C – ARAVALLI



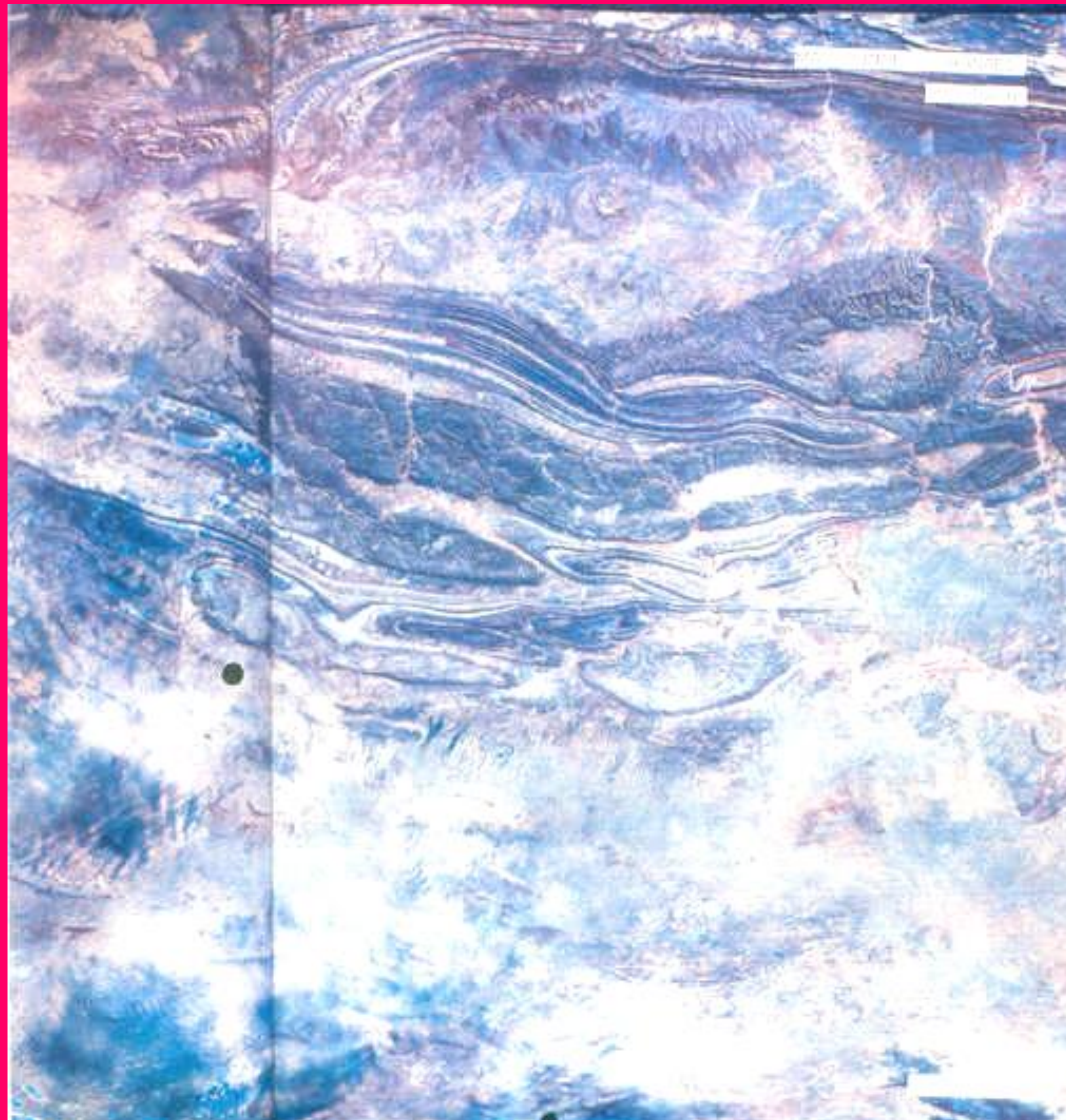
IRS 1C – ARAVALLI MOUNTAIN

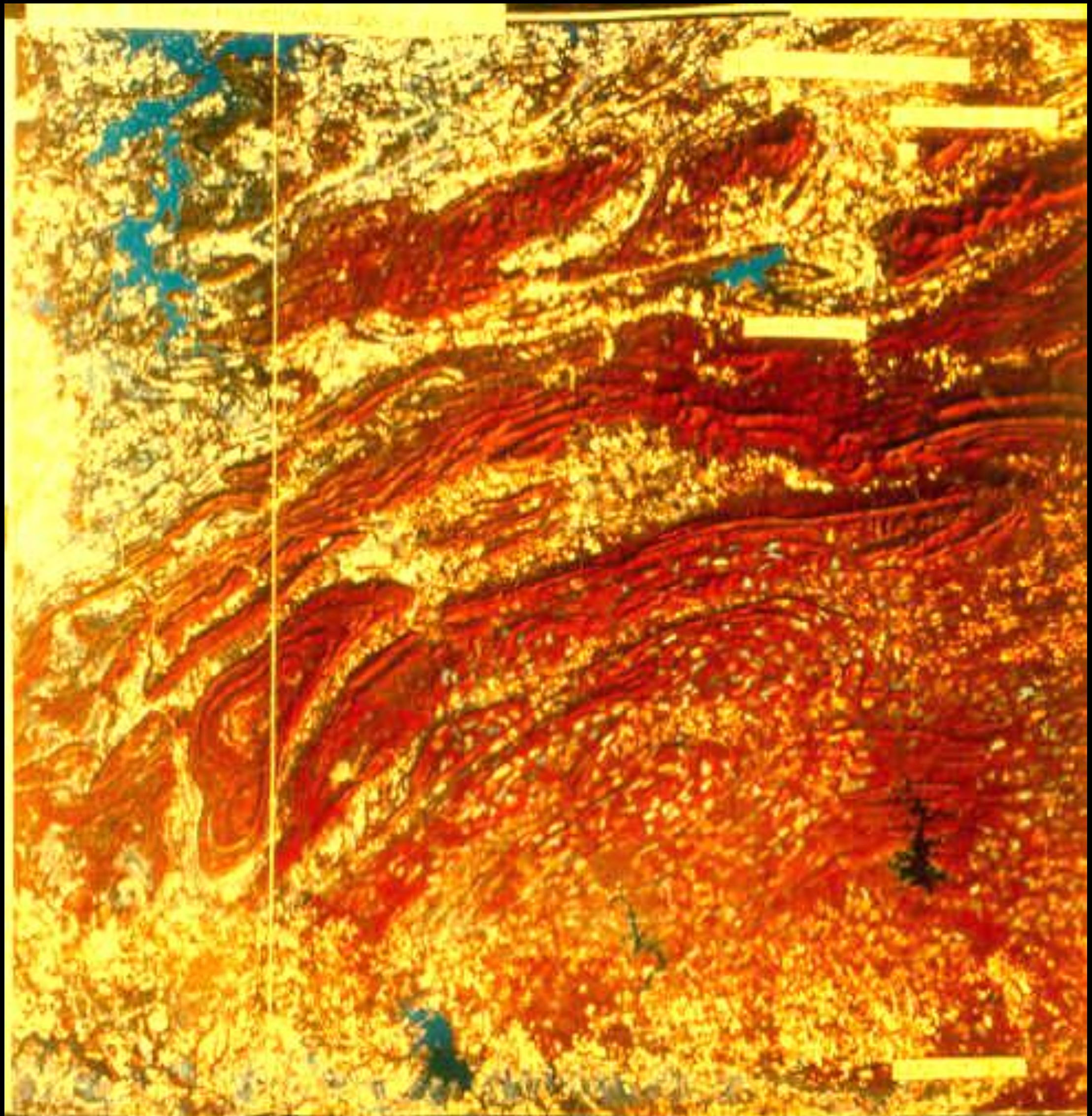


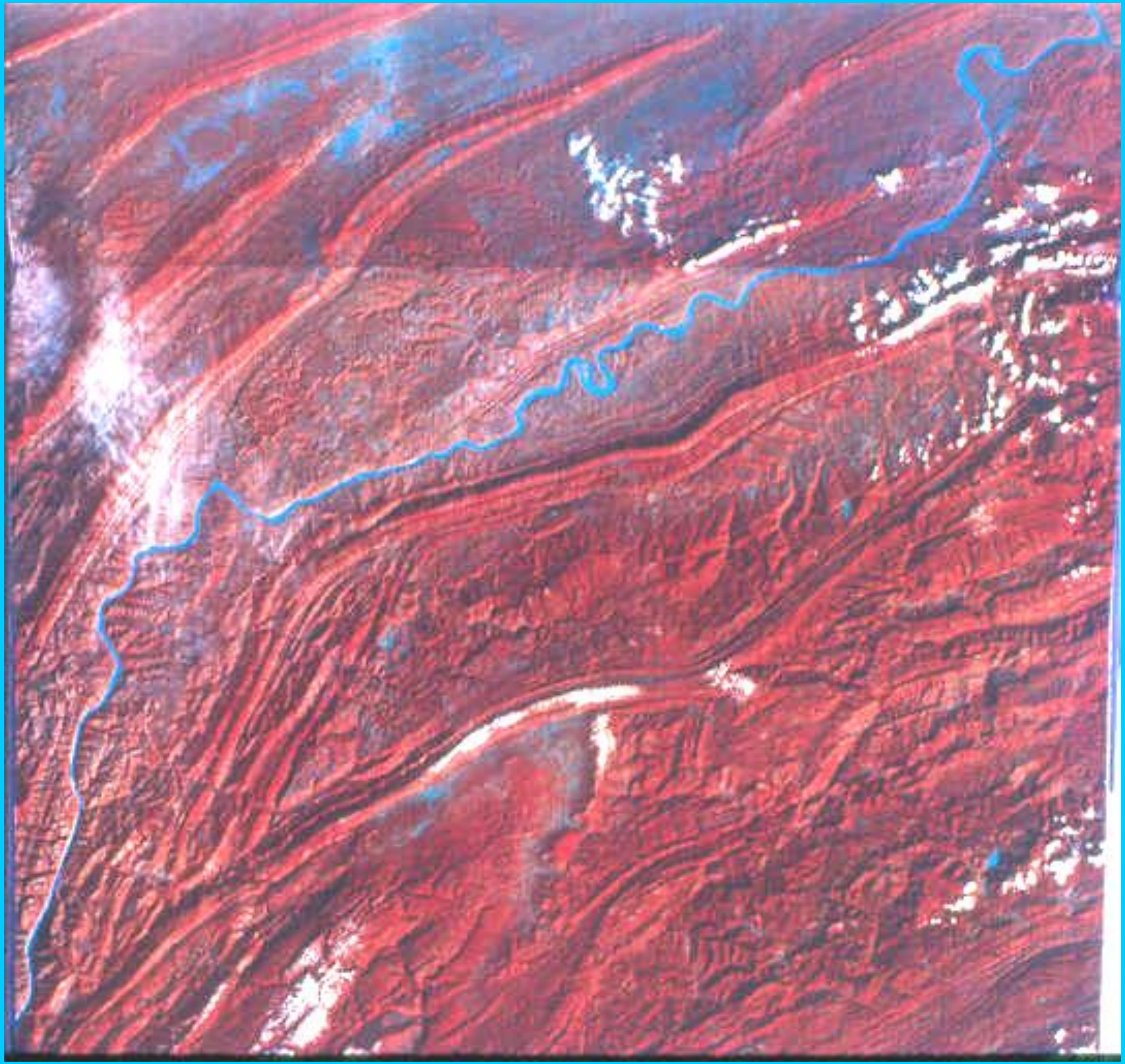
(3.6.3.7) Intermontane valleys




SUN EL
HDG
REV 304
LANDSAT
1219-0440
154-053
27-2-73
FILES
MERGED
PRODUCED
ON NRSA
SAFS
14-FEB-85







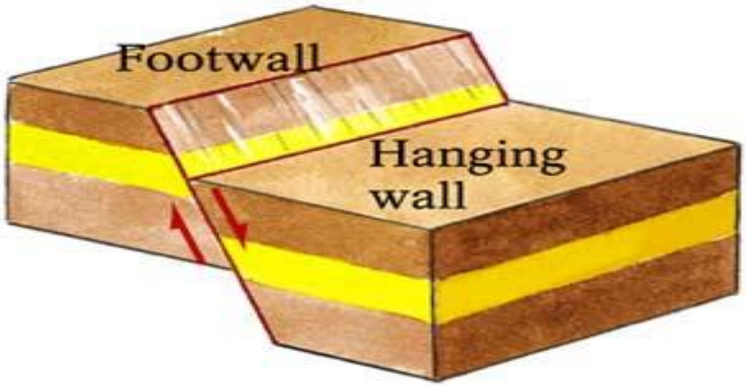
CUDAPPAH BASIN

LANDFORMS IN FAULTED ROCKS

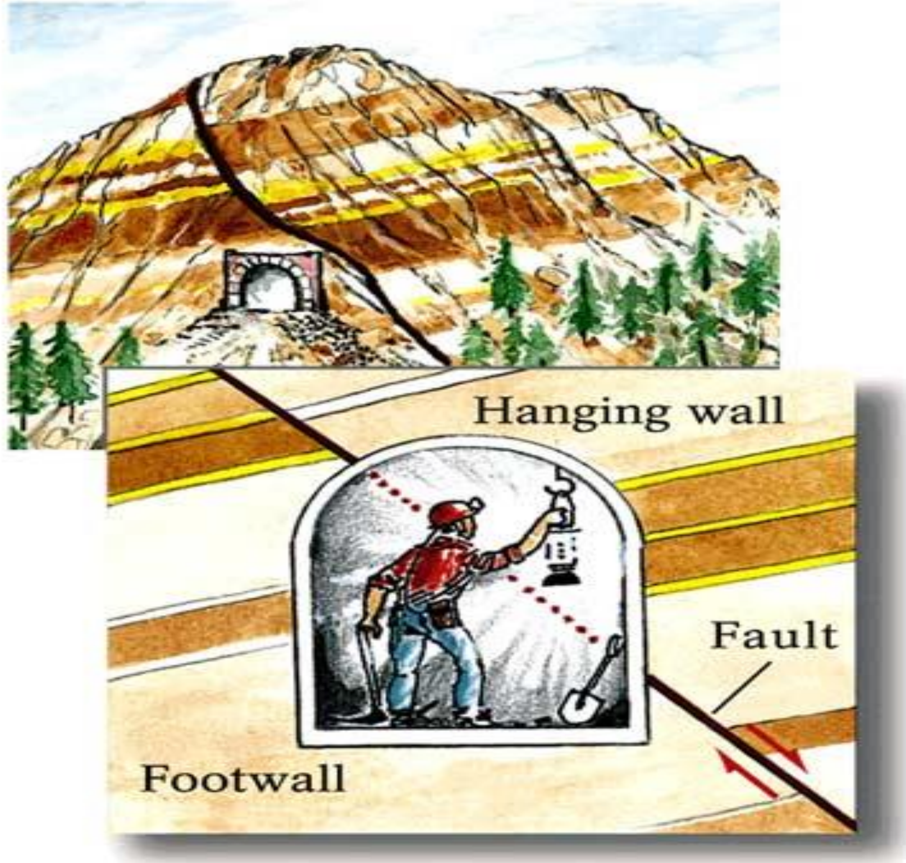
3.6.4 LANDFORMS RELATED TO FAULTING

Demo: Cardboard Models

Dip-Slip Faults



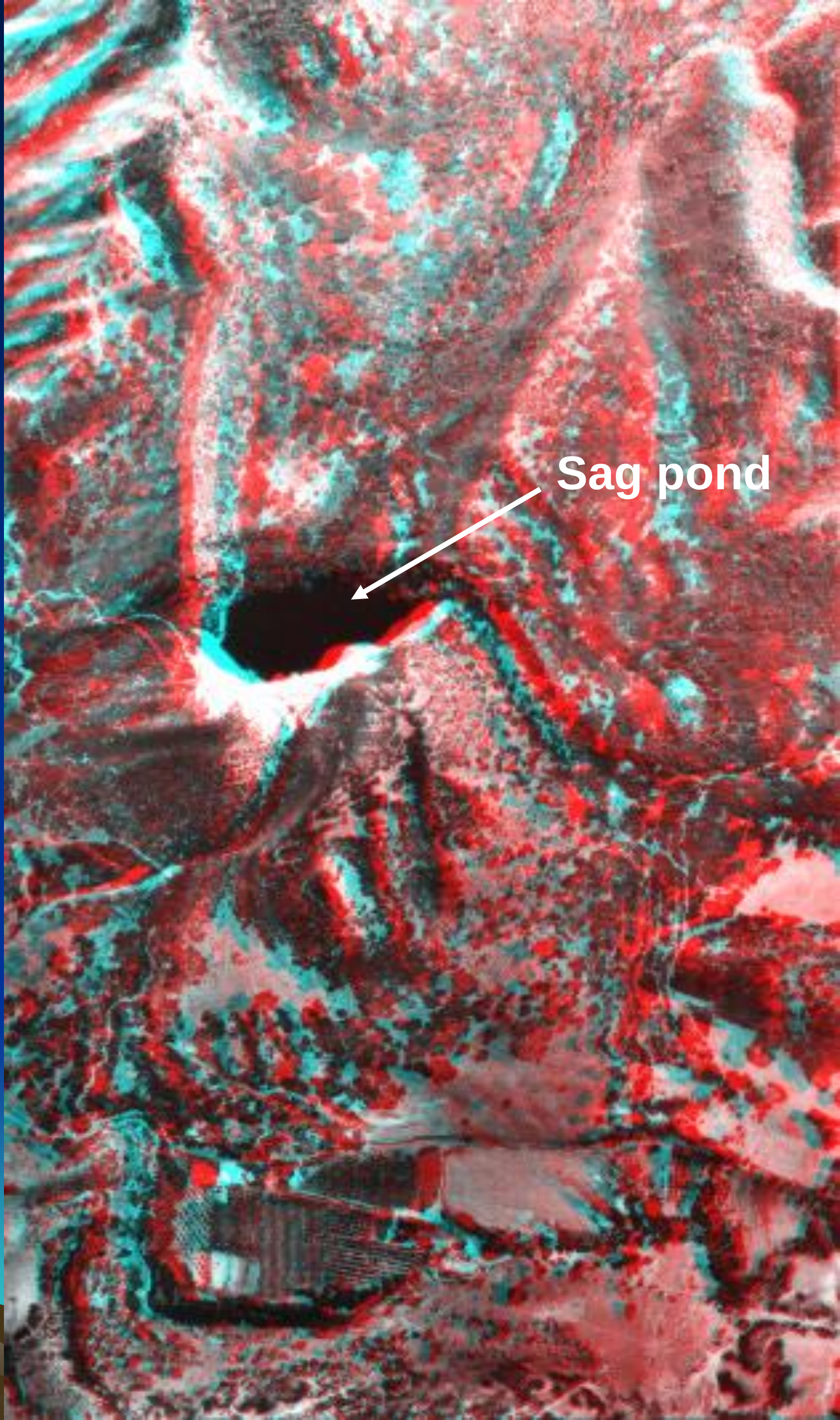
Normal Fault



Reverse Fault

Faults 1: Normal Faults

- Typical of Divergent Margins
- Rift Valleys and Mid-Ocean Ridges
- High-angle and Listric
- Horst and Graben Structure
- Hanging wall is down



A typical sag pond caused by fault-induced tilting.

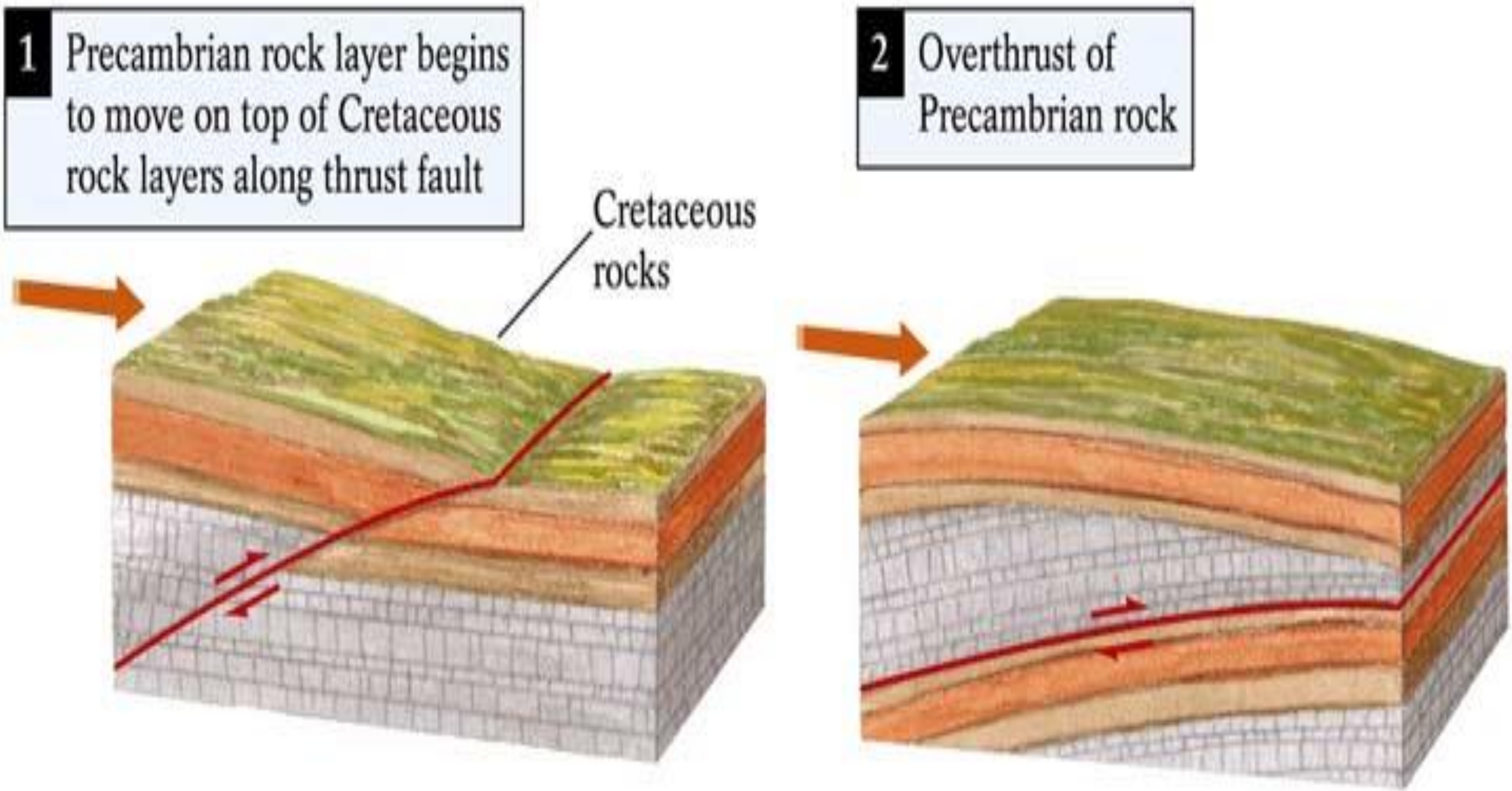
From Drury, Ch 4

Faults 2: Reverse Fault Structures

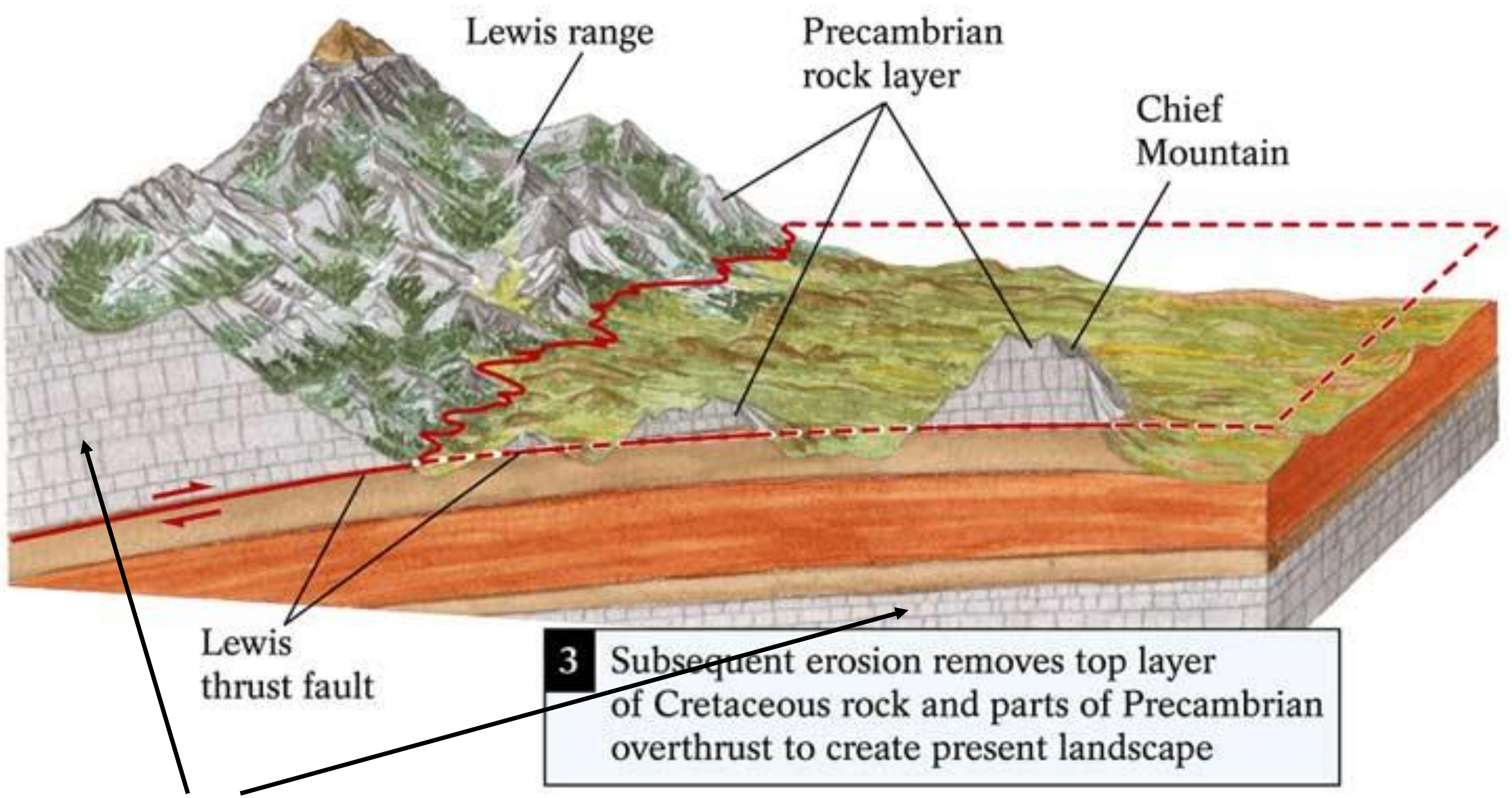
- Typical of Convergent Margins
- E.g. Accretionary Wedges (Santa Catalina Island) and Fold and Thrust Mountains (Himalayas, Alps, Appalachians)
- Often low-angle thrusts
- Hanging wall is up

http://rst.gsfc.nasa.gov/Sect2/05-01_reverse_fault-jyougashima_DSC8766.jpg

Shallow Reverse Fault = Thrust Fault



Lewis Thrust Fault (cont'd)



Same layer

Klippe - Thrust Fault Remnant

A feature of thrust fault terranes. The klippe is the remnant portion of a nappe after erosion.

http://www.pbase.com/dougsherman/image/93469147

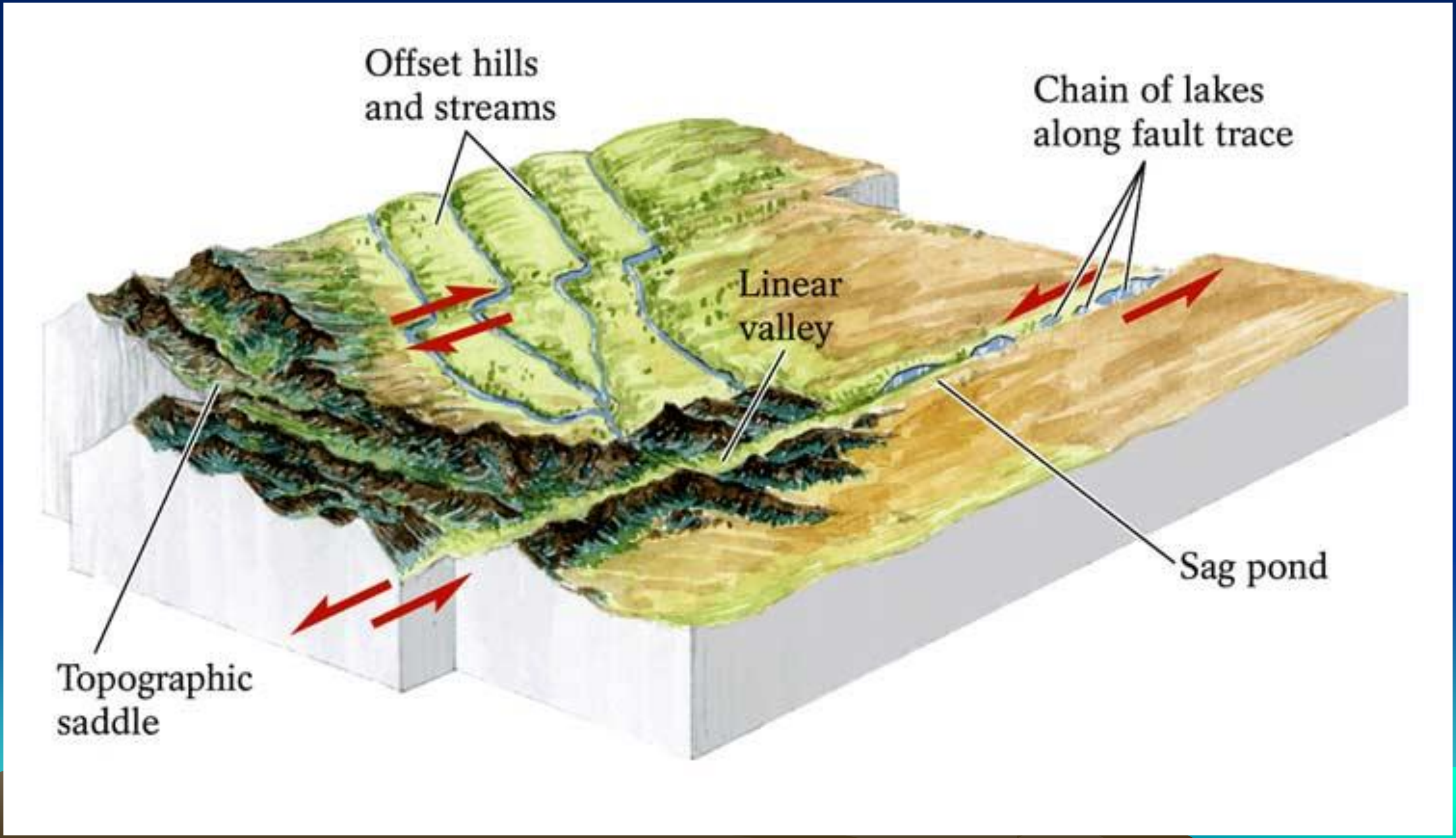
Chief Mountain, a klippe outlier of the Lewis Thrust, Glacier National Park, MT

Lewis Thrust Fault (cont'd)

Source: Breck P. Kent

PreCambrian Limestone over Cretaceous Shales

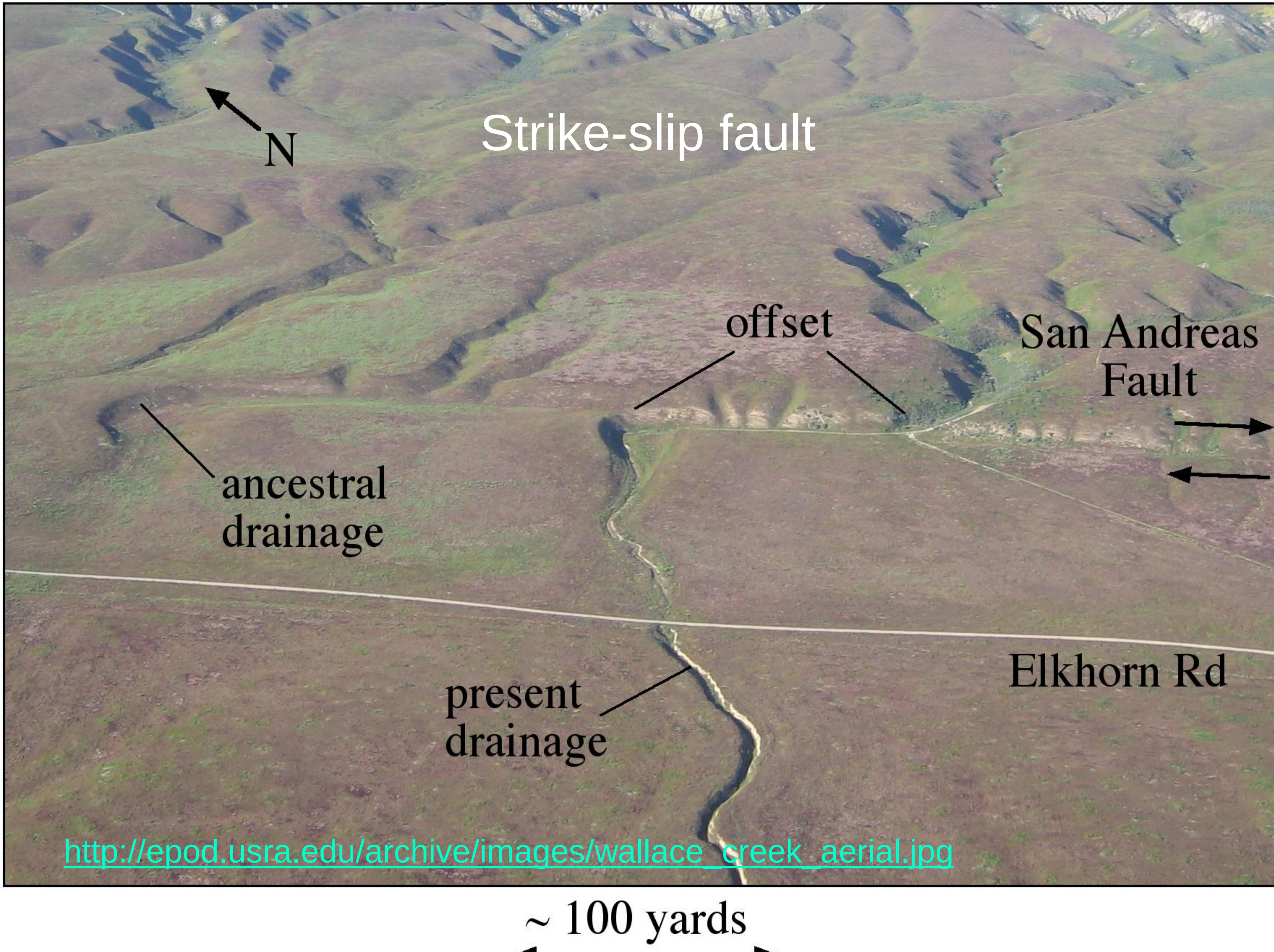
Horizontal Movement Along Strike-Slip Fault



Tectonic Landforms

Faults and Fault Landforms

The East African Rift Valley is a graben

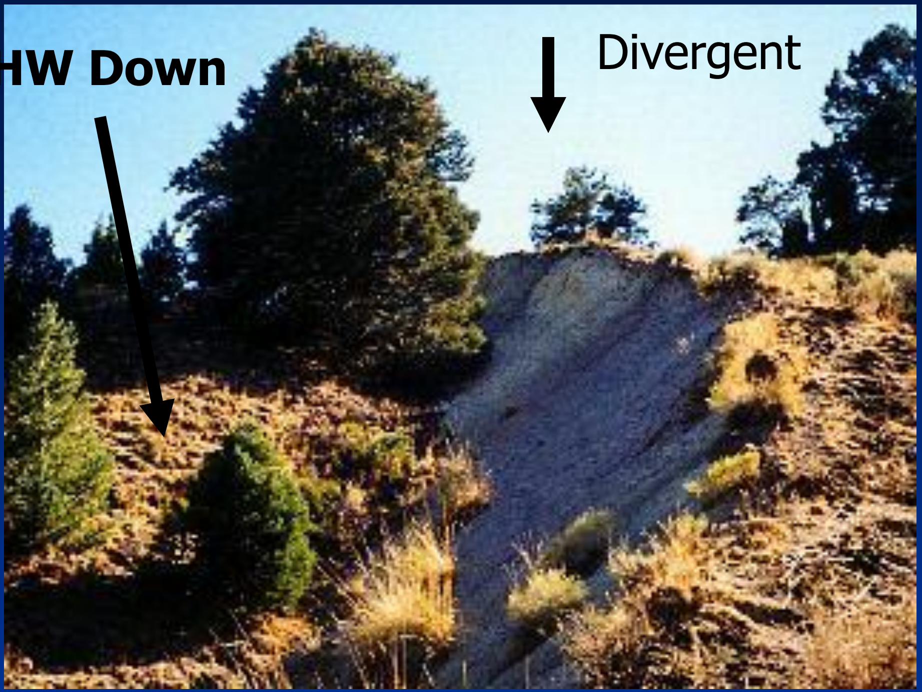

Strike-slip fault
N
offset
San Andreas Fault
ancestral drainage
present drainage
Elkhorn Rd
http://epod.usra.edu/archive/images/wallace_creek_aerial.jpg
~ 100 yards

Landscape Shifting, Wallace Creek

San Andreas Fault

Reverse Fault Quake - Japan

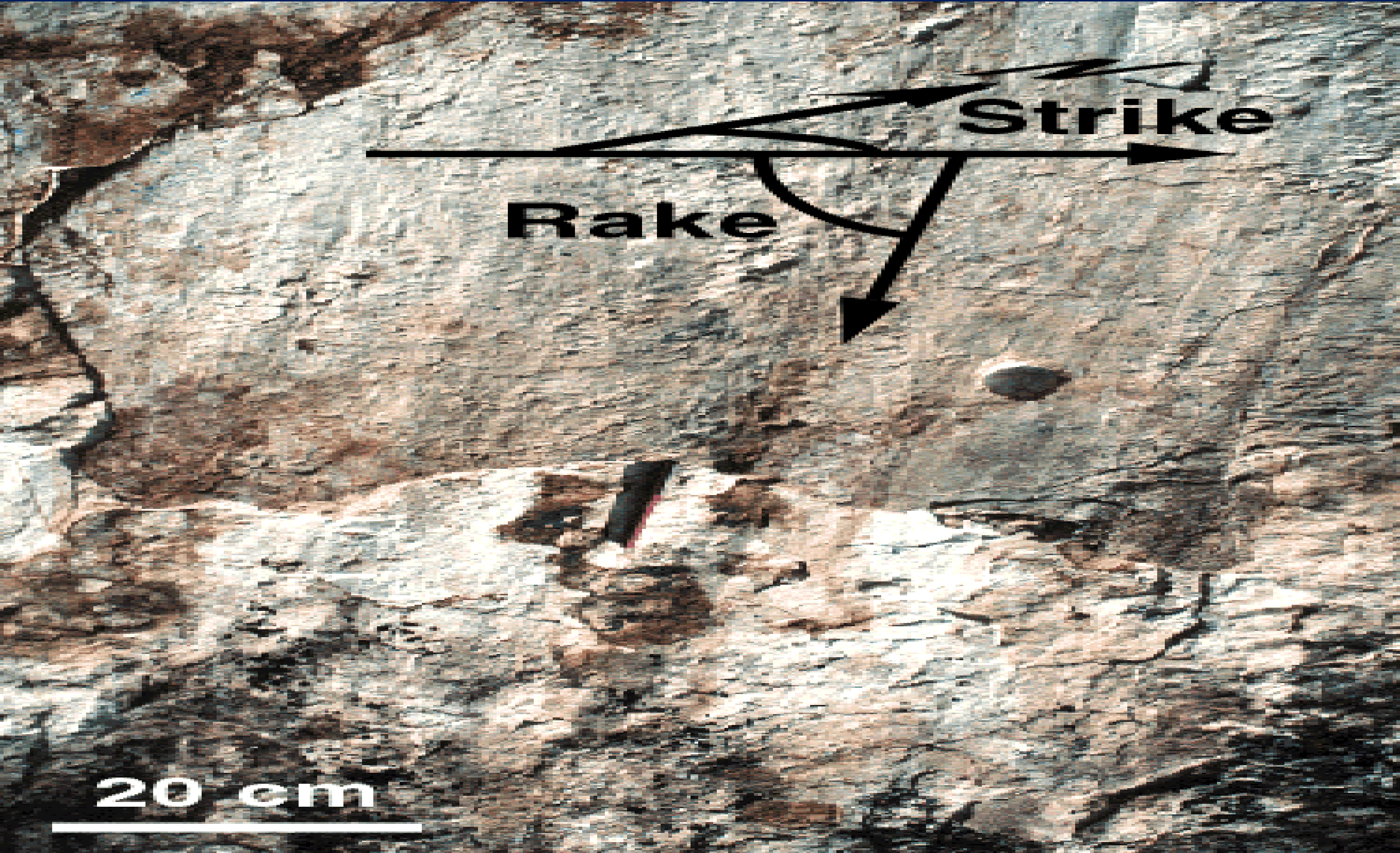
Normal Fault Quake - Nevada



Strike Slip Fault Quake - California

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

Fracture Zones and Slickensides



Geomorphic features

- Fault scarp
- Fault-line scarps
- triangular facets
- alignment of facets
- increase of stream gradients at the fault line
- hanging valleys
- aligned springs and vegetation
- landslides
- displaced stream courses

Fault Related Landforms

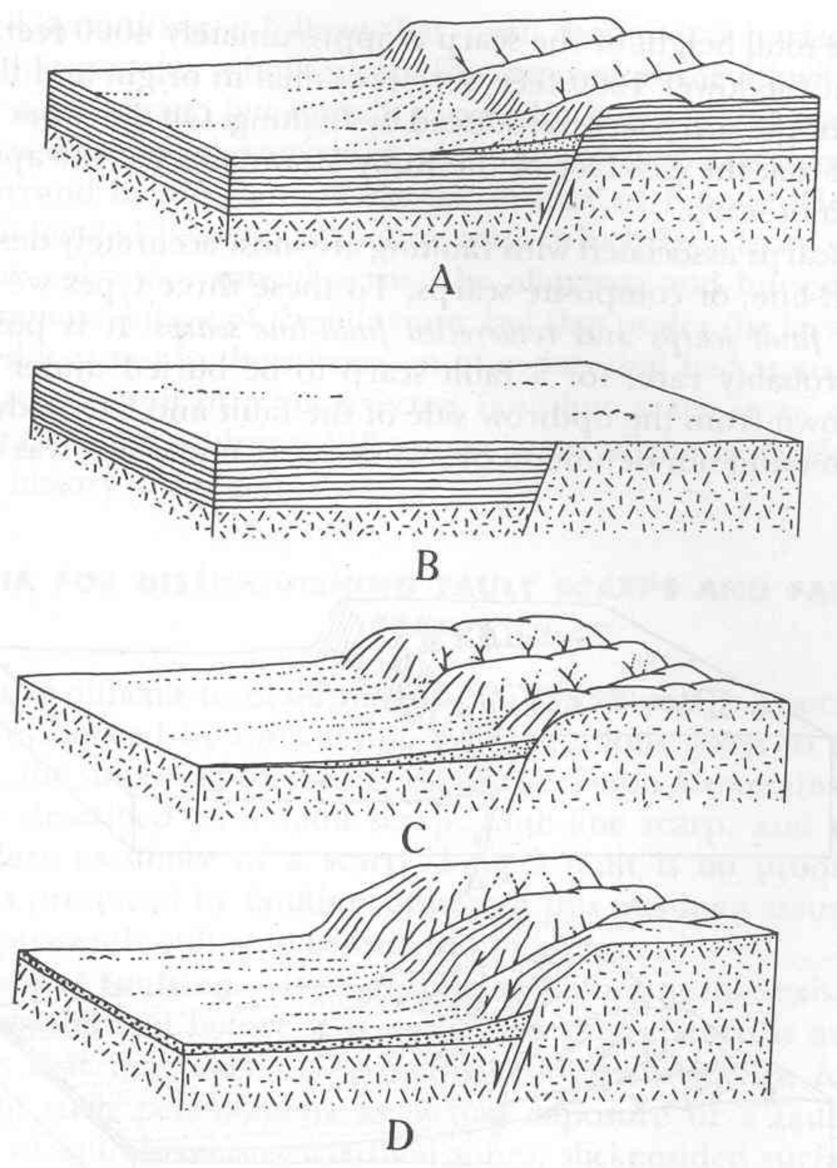
Fault scarp
Fault-line scarps
Triangular facets
<u>Horst and Graben</u>

<u>Fracture valleys</u>
- **Filled**
- **Barren**

<u>Fault valleys</u>

<u>Rift valleys</u>

FAULT SCARP: The scarp produced directly by the faulting is called fault scarp

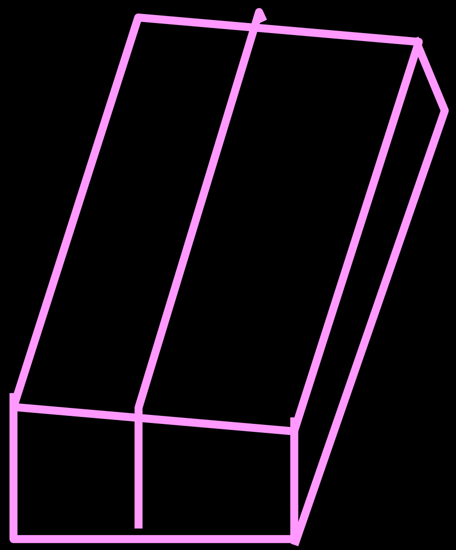


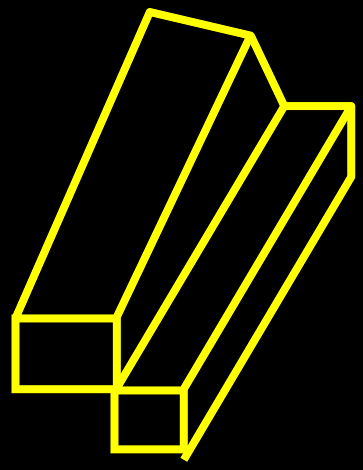
Different stages in the formation of the scarps

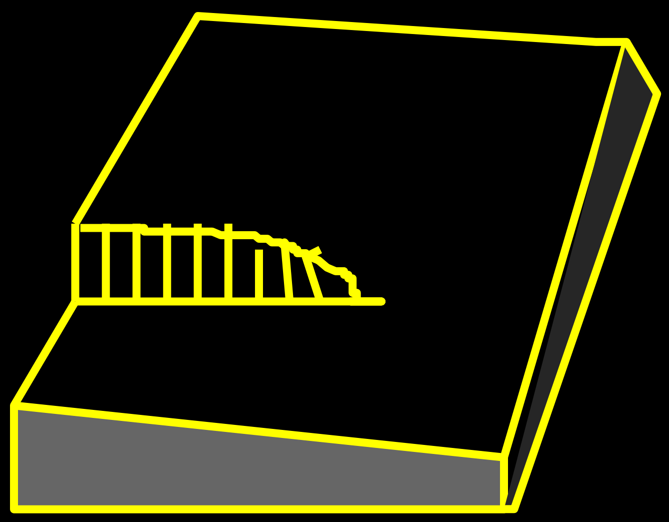
A) Formation of Fault Scarp
B) Destruction of fault scarp by erosion
C) Renewal of erosion, following upliftment, with development of fault line scarp
D) Renewal of faulting with composite scarp, whose upper part is of erosional and lower part of fault origin

Northern Tibet: Triangular facets are fault scarps

Fault Escarpment

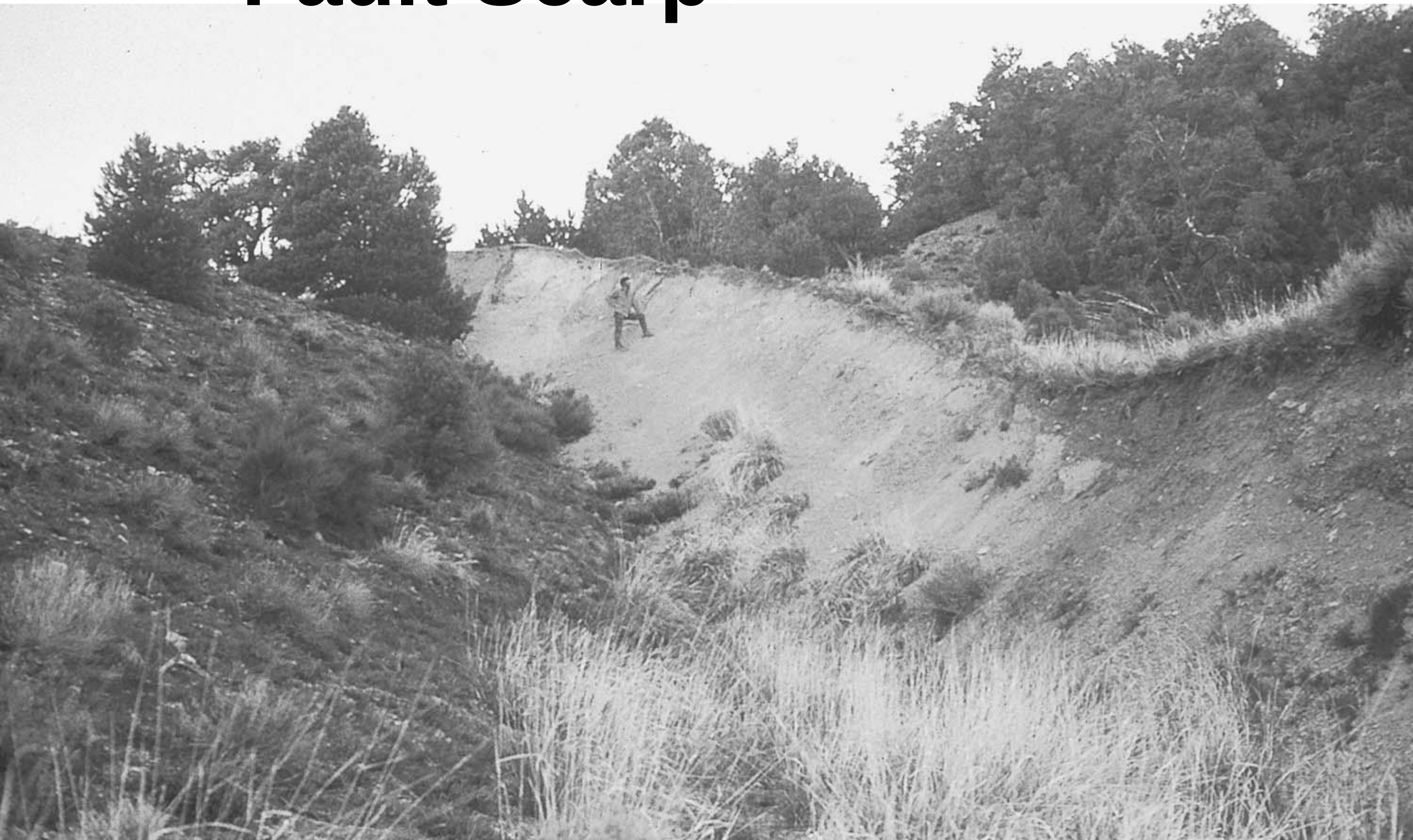






- straight escarpments / active faults / seismic prone
  (E-G) Bangalore - Cape Comorin fault

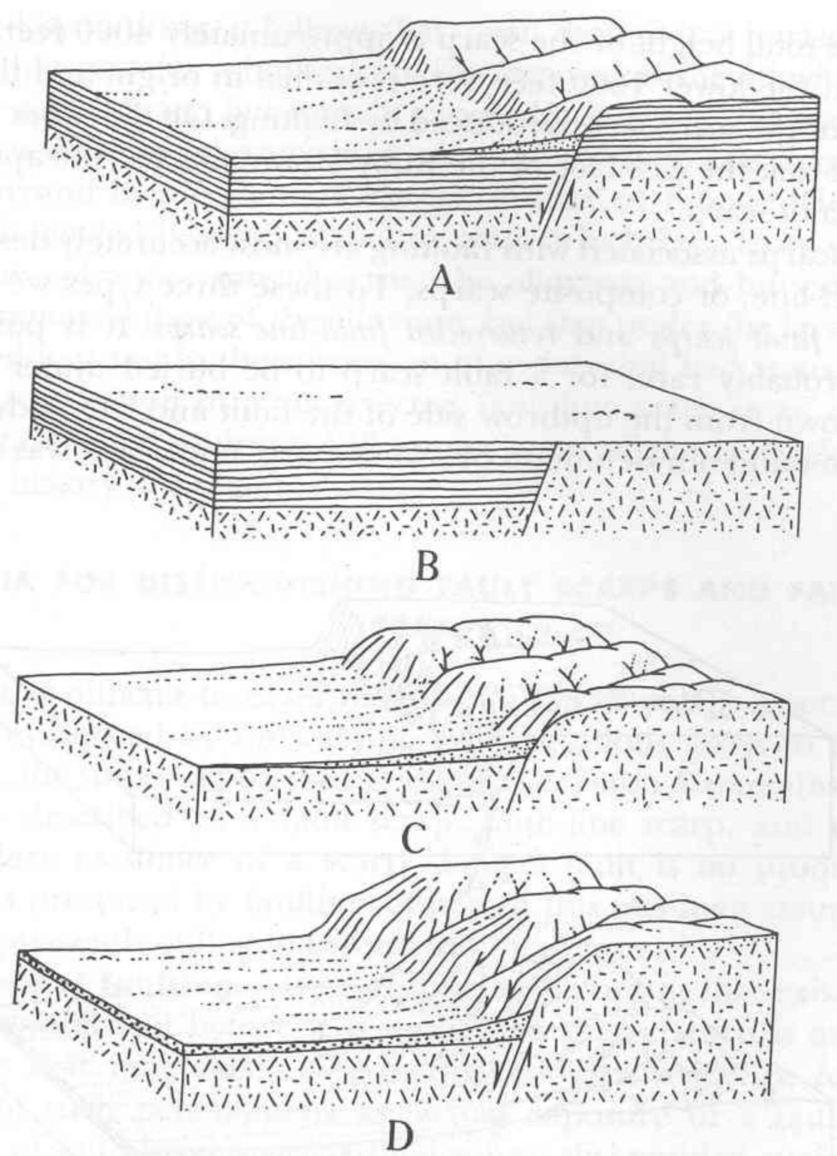
Fault Scarp



FAULT SCARP - NEVEDA

ESCARPMENT – KOLLAR

FAULT LINE SCARP: Fault line scarp produced by the differential erosion along the fault line



Different stages in the formation of the scarps

A) Formation of Fault Scarp
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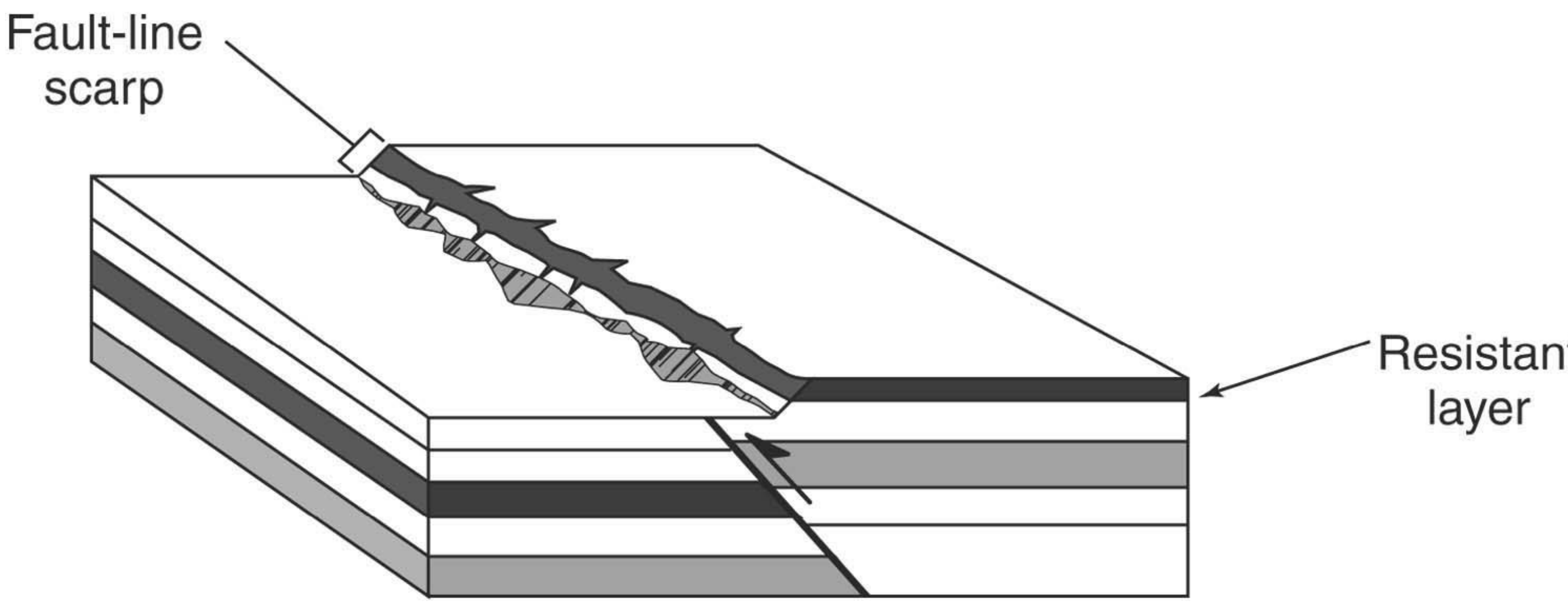
D) Renewal of faulting with composite scarp, whose upper part is of erosional and lower part of fault origin

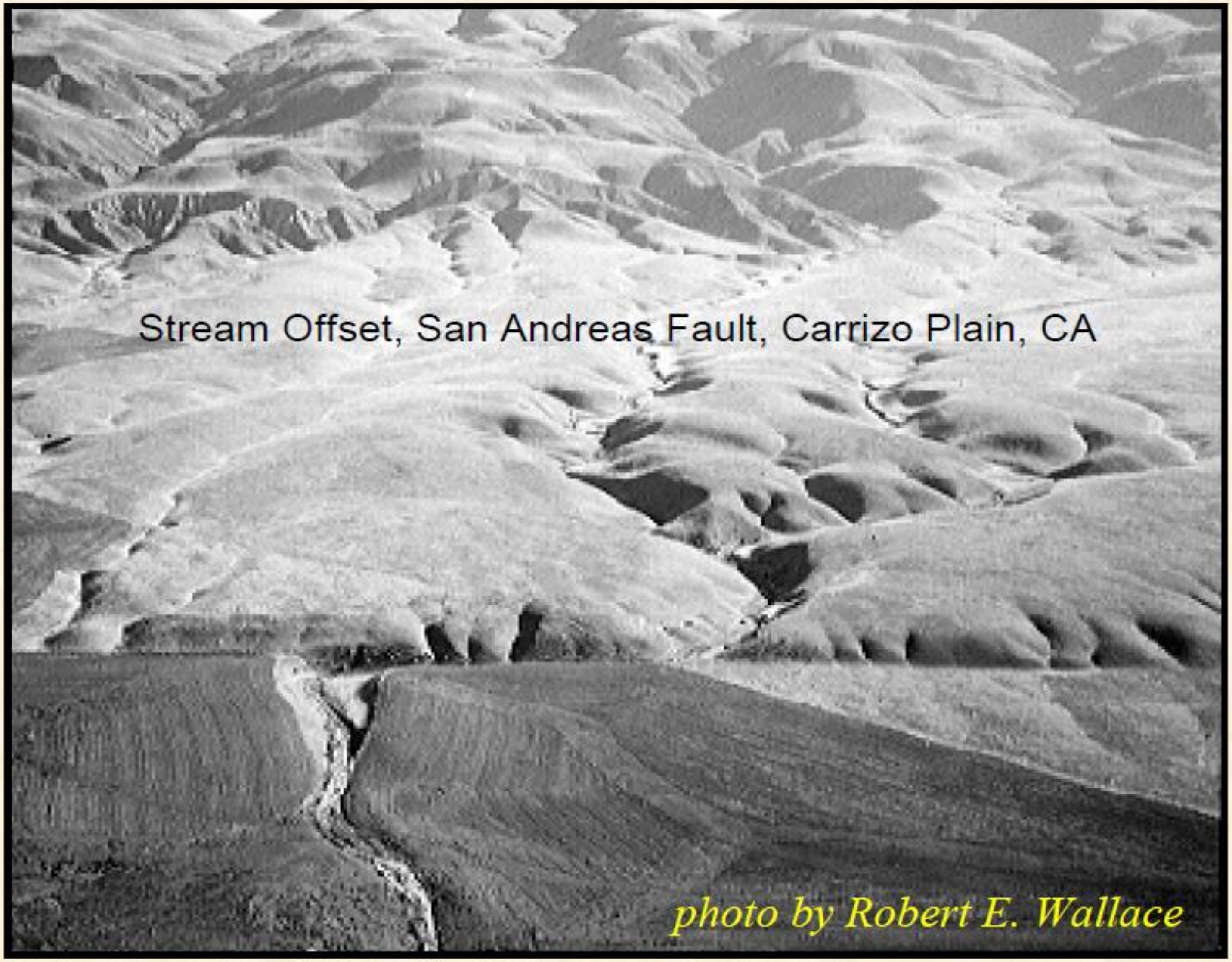
Fault-line scarp caused by faulting of a resistant layer




Fault Line scarp
(High-angle
Normal Fault)

Fault Line scarp

San Andreas Fault



Fault scarps

California

Fault scarps

Grand Canyon

Fault line scarps

California

Fault scarps

California

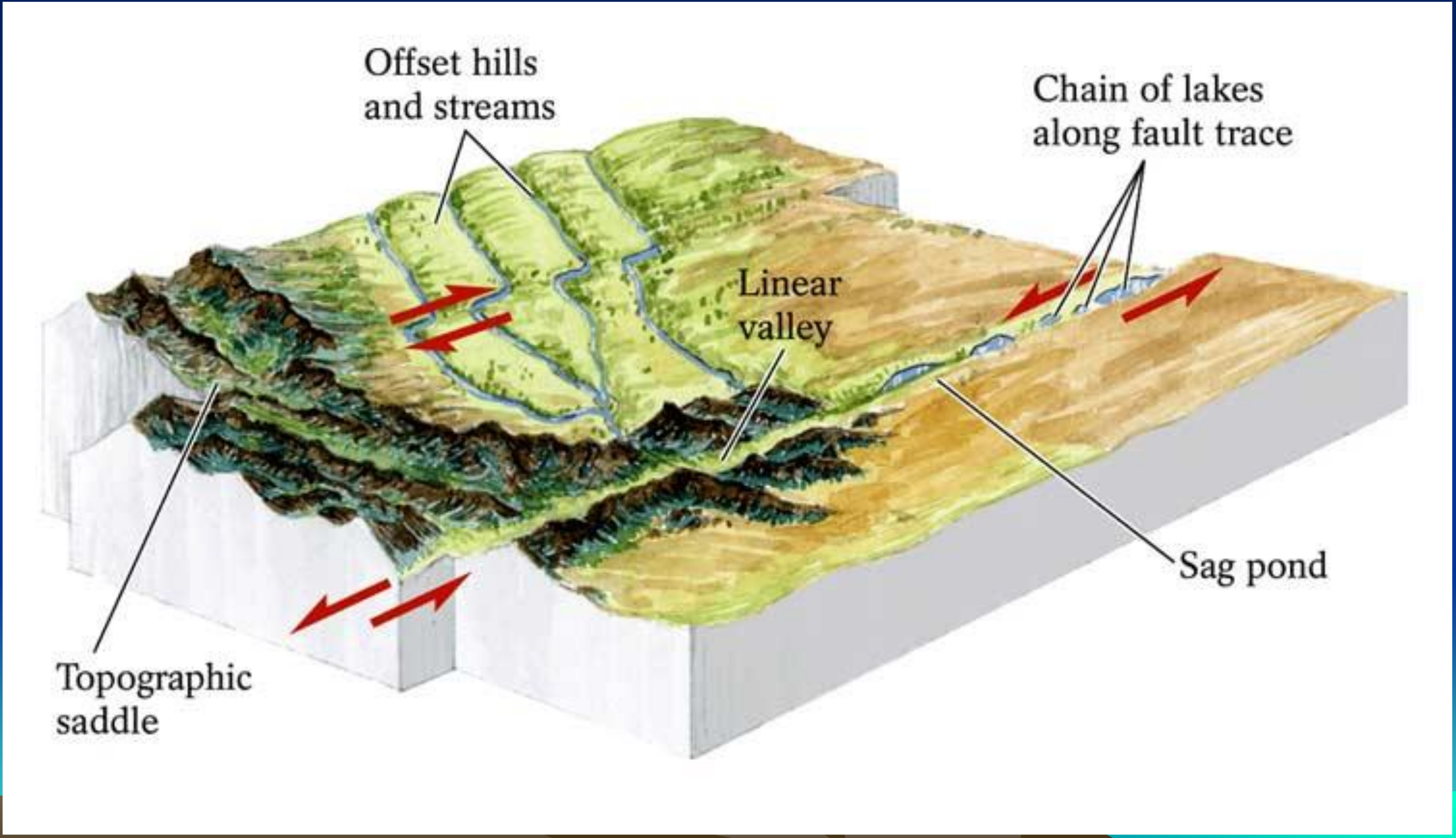
Fault scarps

Taiwan

Fault scarps

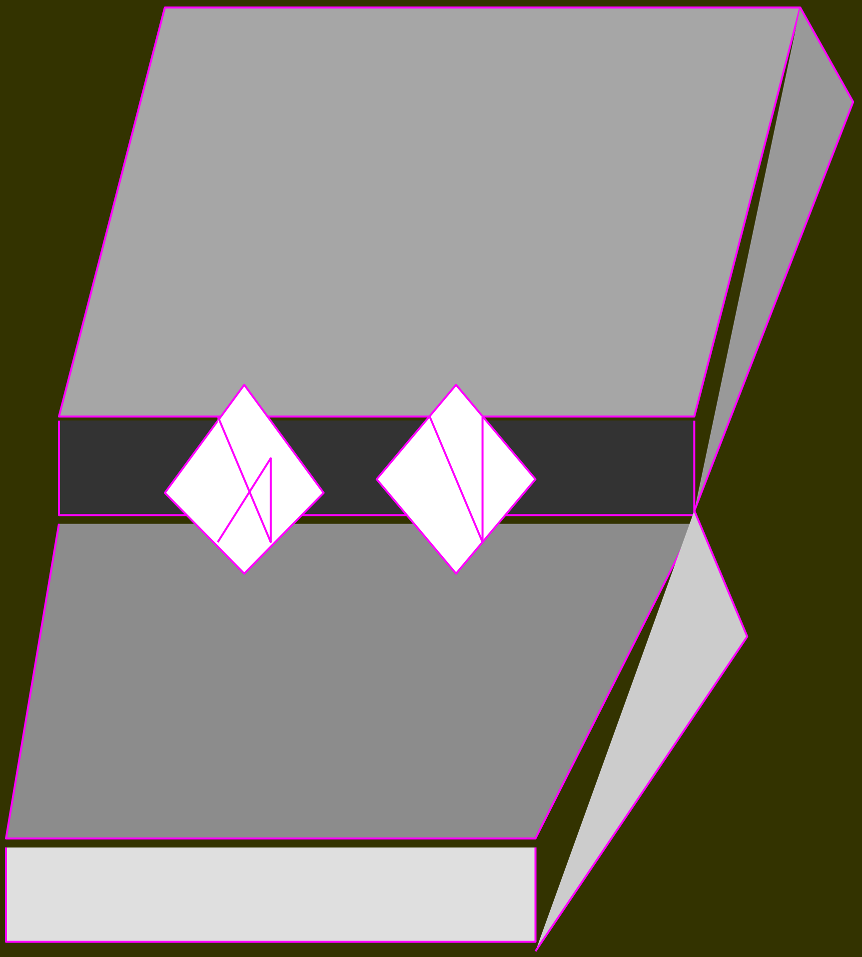
Taiwan

Sag Pond: Chain of lakes formed in fault line is called Sag pond



Sag pond on trace of 1906 break along San Andreas fault. California

Triangular facets : Due to erosion along the Fault scarp and Fault line scarp develop the Triangular facet



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

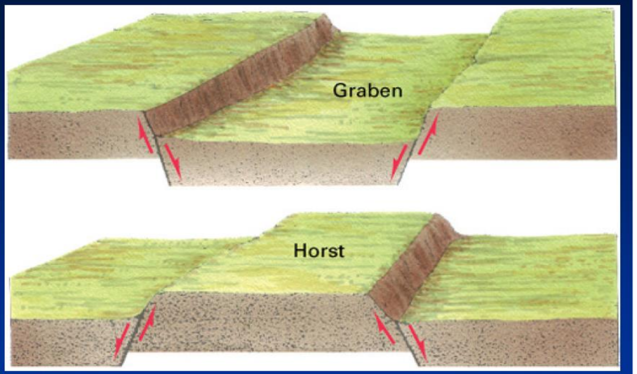
Horst and Graben

Blocks of the earth's crust may be relatively raised or lowered between more or less parallel faults without pronounced tilting.

The relatively raised blocks are commonly called horst and the lowered blocks are called as graben

The Jordan-Dead sea depression, Death valley, the Rhine graben, the rift valleys of east Africa - GRABEN

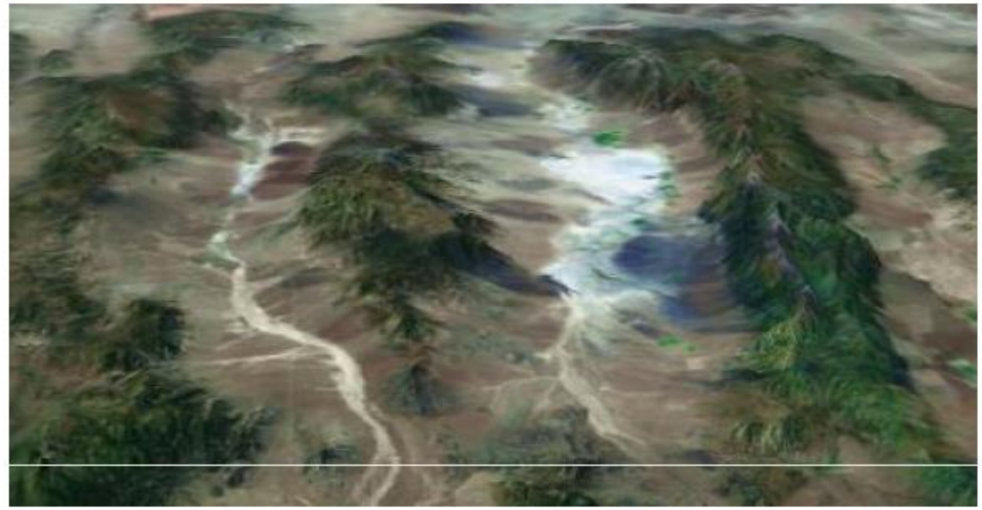
The Vosgas Mountains to the west of Rhine graben and Block forest plateau to the east of it, the Palaestine plateau to the west of dead sea



–May form **horst and graben topography** (p.323 and on)

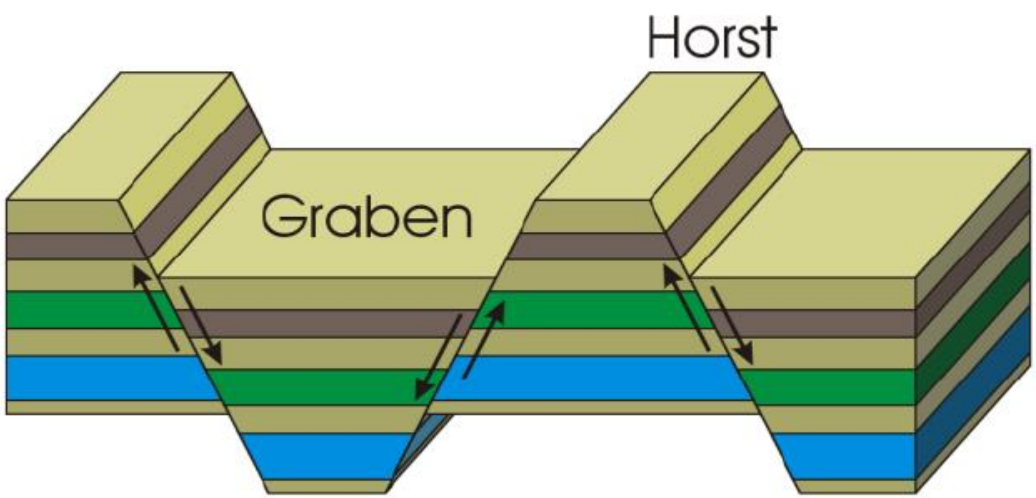
Graben

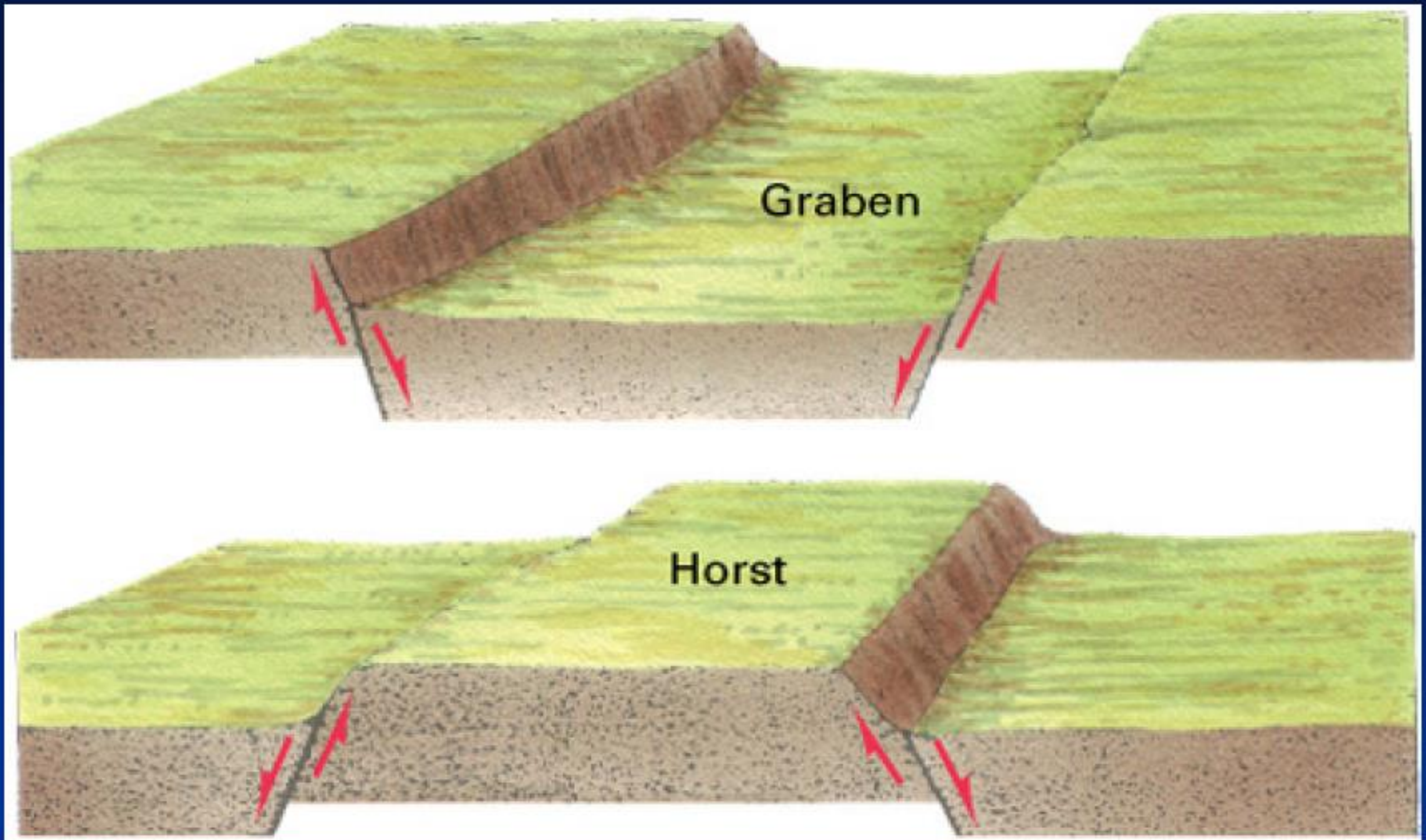
- As the crust is stretched, a block called a **graben**, which is bounded by normal faults, drops down. Graben is a German word for ditch or trench.



Horsts

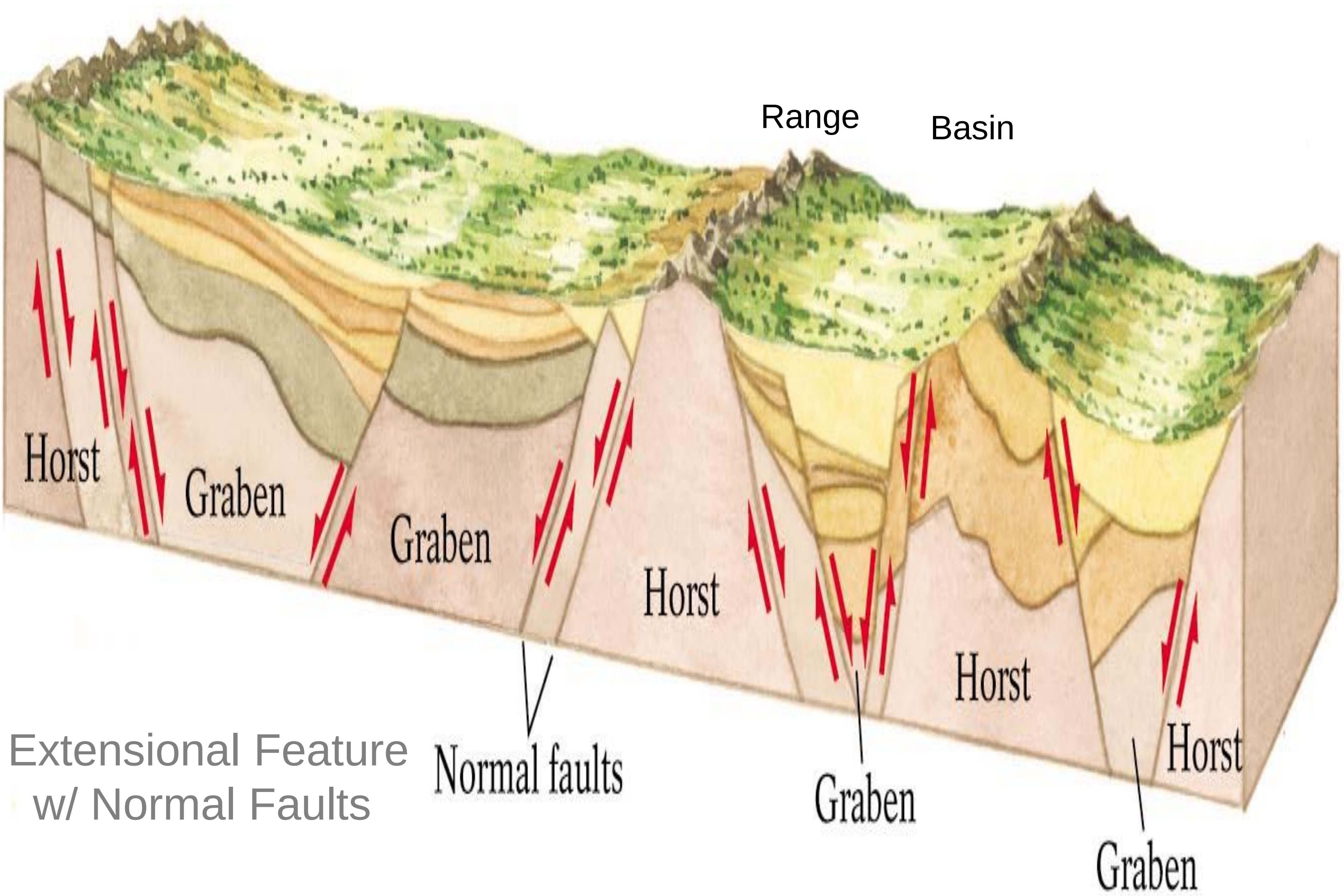
- Grabens produce an elongated valley bordered by relatively uplifted structures called **horsts**.





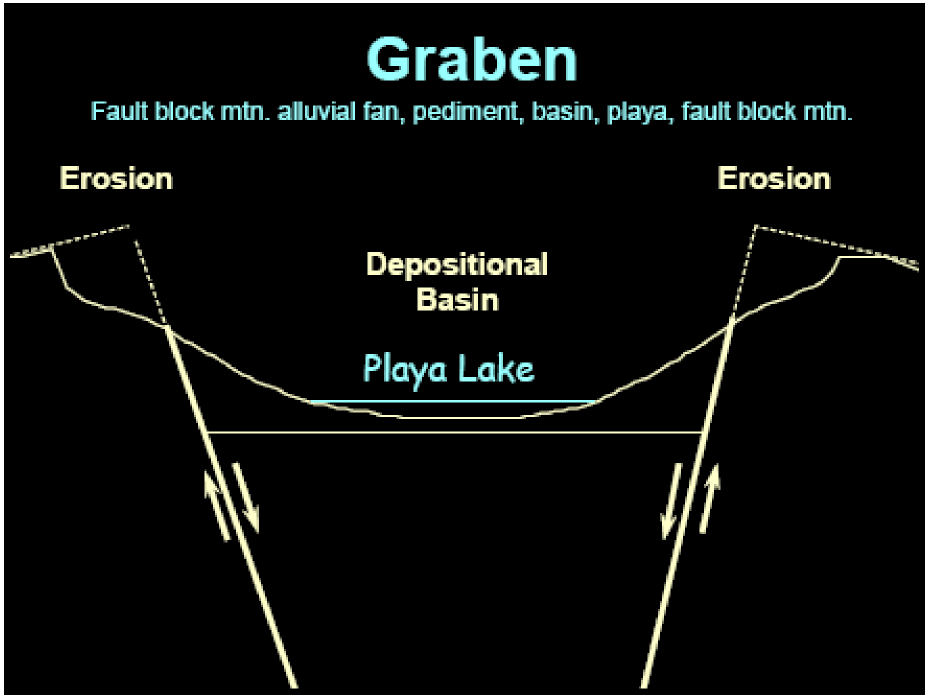
–May form **horst and graben topography** (p.323 and on)

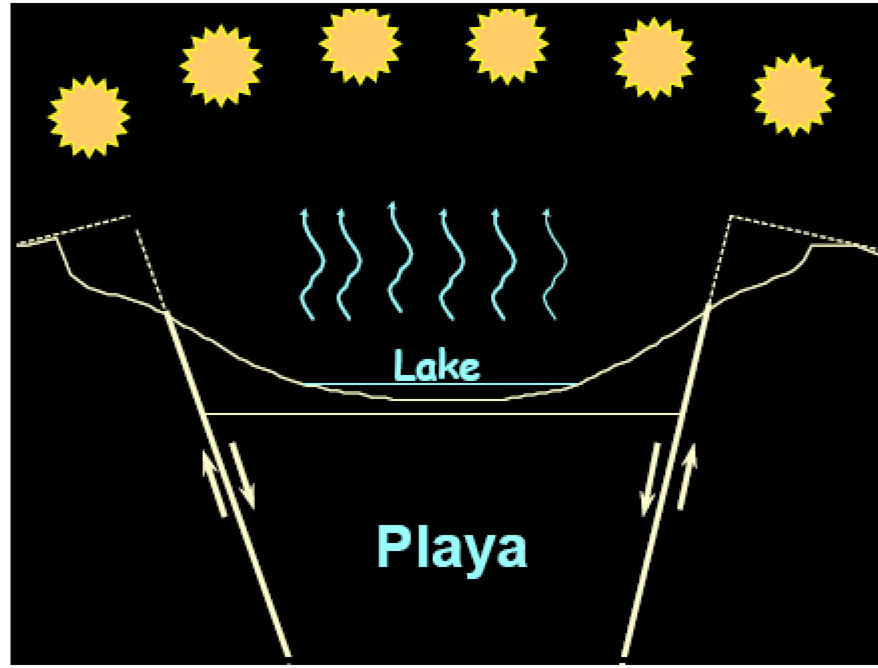
Horst and Graben

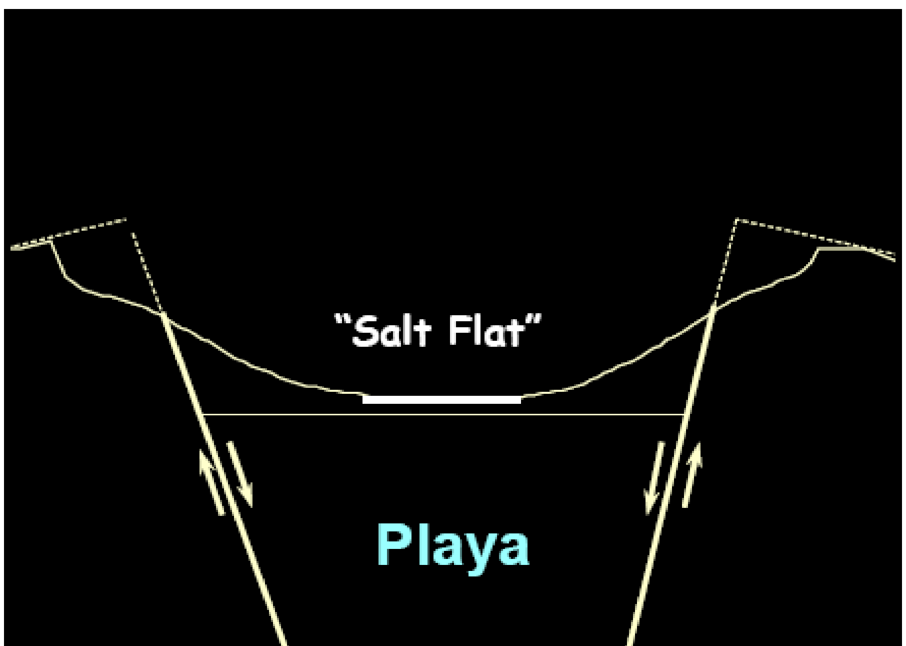


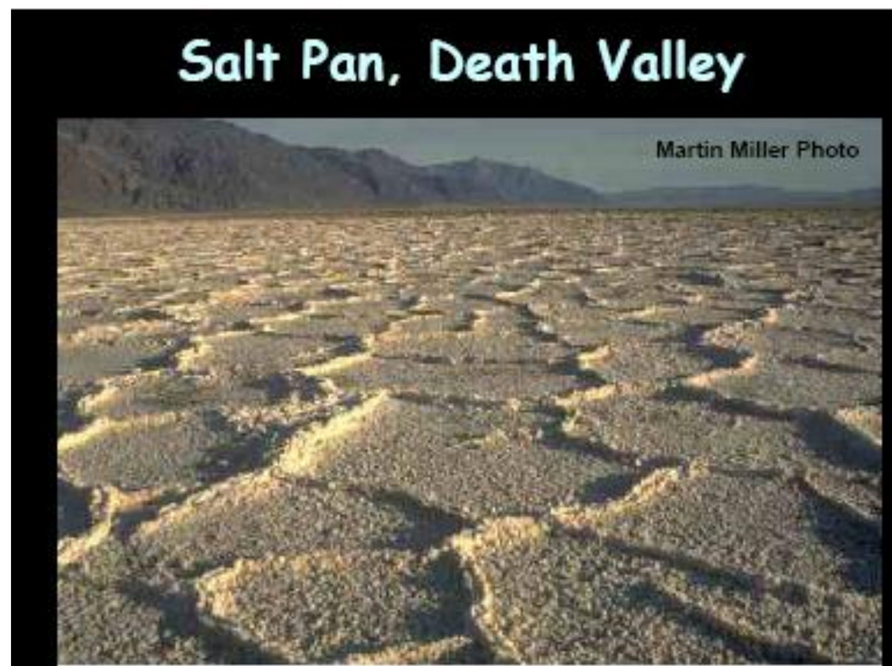
Extensional Feature
w/ Normal Faults


Fault scarp, Death Valley

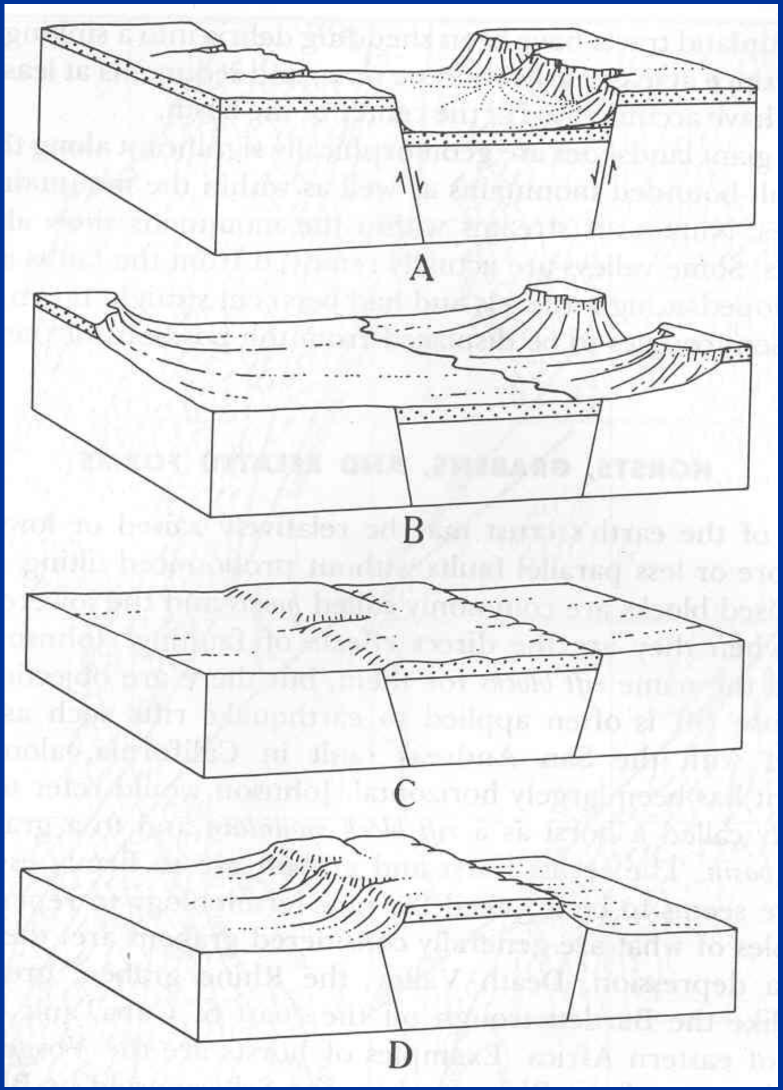

Graben
Fault block mtn. alluvial fan, pediment, basin, playa, fault block mtn.
Erosion
Erosion
Depositional Basin
Playa Lake


Lake
Playa


"Salt Flat"
Playa


Salt Pan, Death Valley
Martin Miller Photo

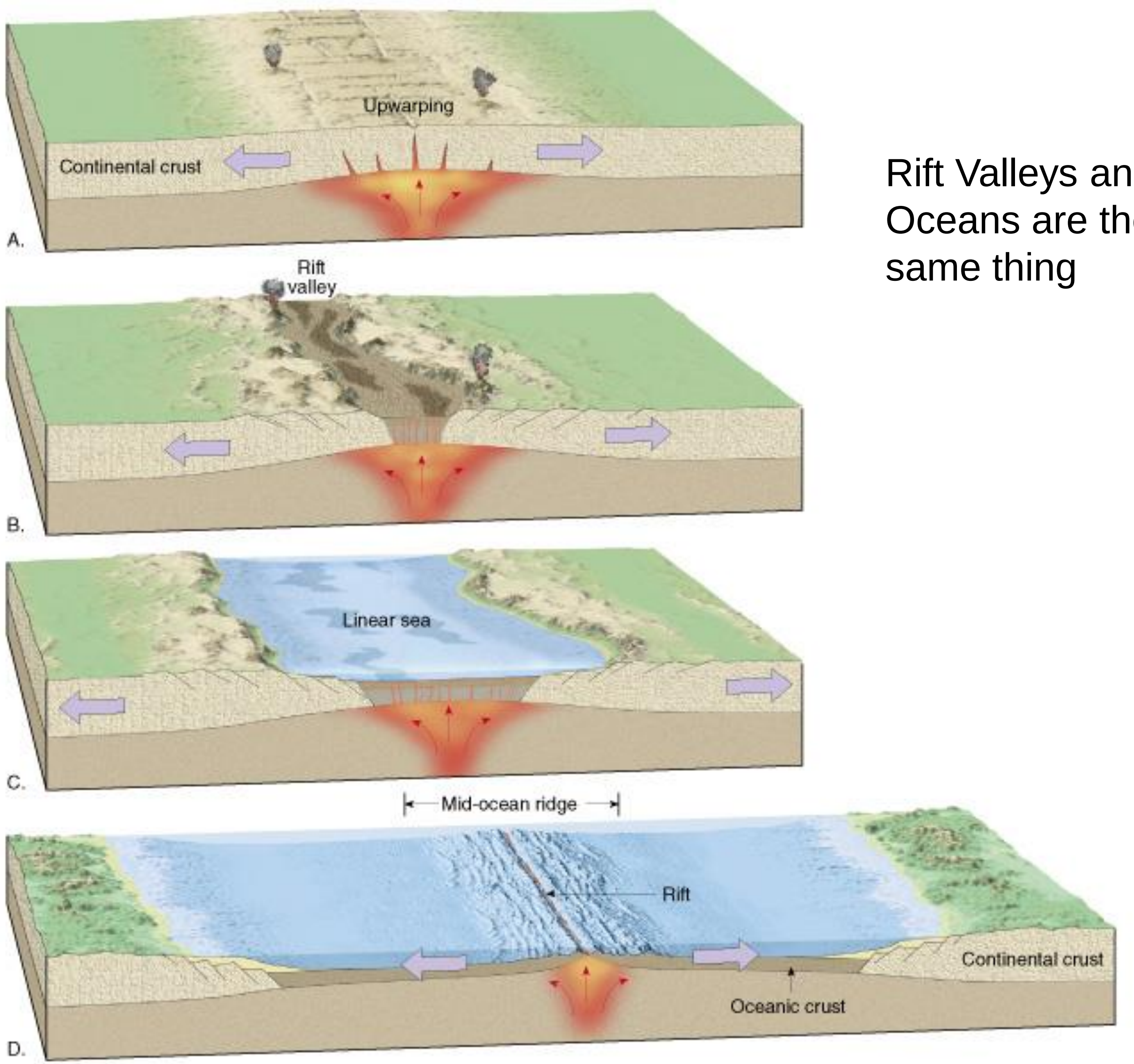
INVERSION OF TOPOGRAPHY



Stages of development of inversion topography upon a graben

A) Formation of graben by fauting
B) Destruction by erosion of the fault produced topography
C) Renewal of erosion accompanying uplift
D) Development of an obsequent rift block mountains where the originally graben exits

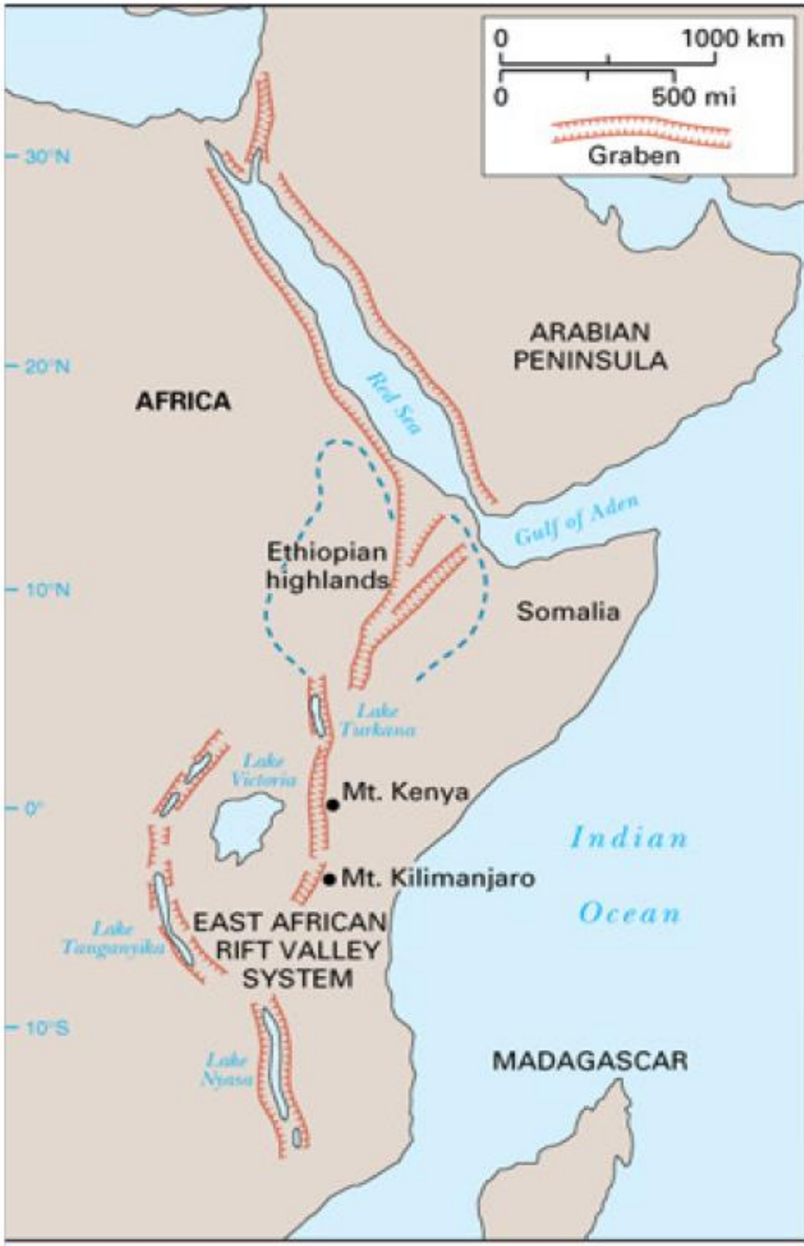
Continental Rift into Ocean Basin - Tension => Divergence

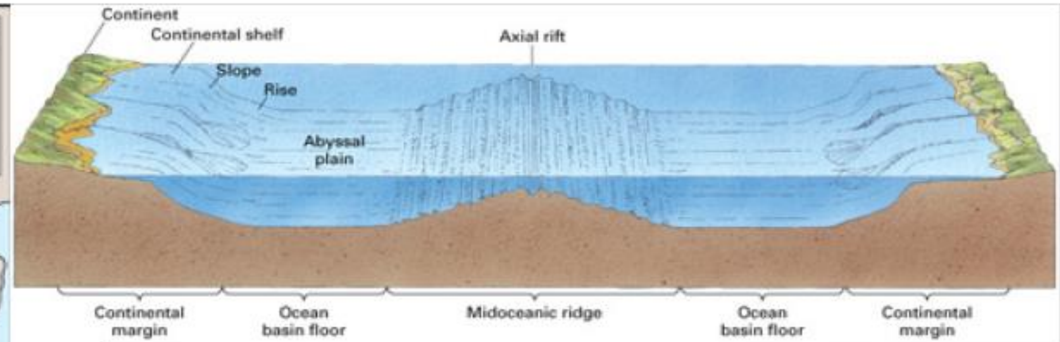


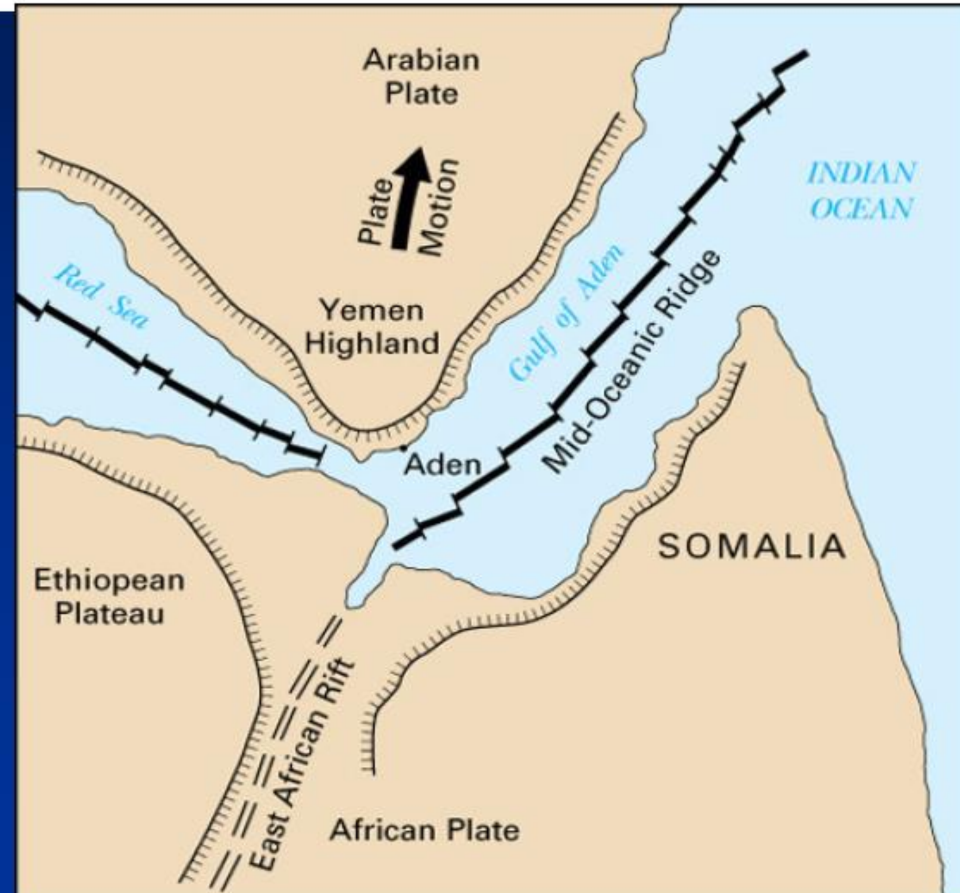
Rift Valleys and Oceans are the same thing

Rift valleys: The term rift valley applied to the great trough or great grabens of East Africa and elsewhere. Rift valley may develop on a block of weak rock bounded by parallel faults. Such feature is called as rift block valley

- seismic prone
- hot water / geothermal

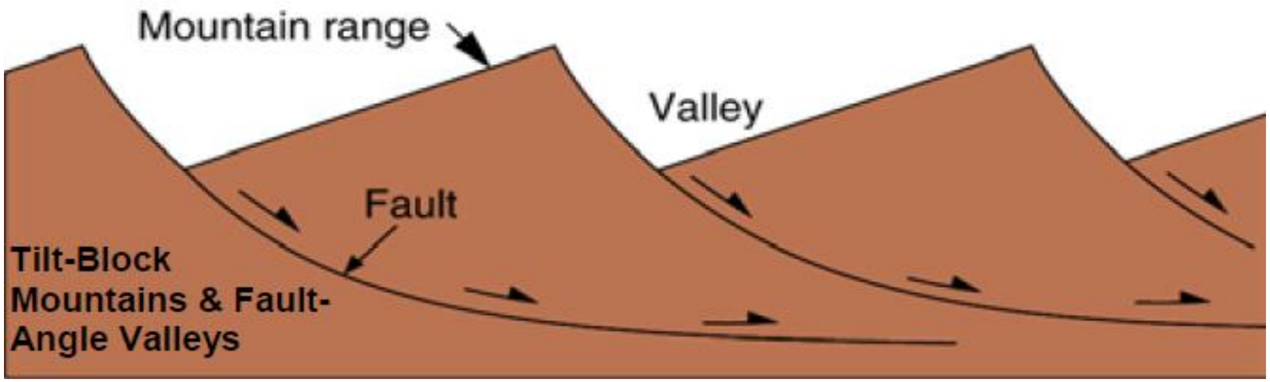

0
1000 km
0
500 mi
Graben
30°N
20°N
10°N
0°
10°S
ARABIAN
PENINSULA
AFRICA
Red Sea
Gulf of Aden
Ethiopian
highlands
Somalia
Lake
Turkana
Lake
Victoria
Mt. Kenya
Indian
Ocean
Mt. Kilimanjaro
Lake
Tanganyika
EAST AFRICAN
RIFT VALLEY
SYSTEM
Lake
Nyasa
MADAGASCAR


Continent
Continental shelf
Slope
Rise
Abyssal
plain
Axial rift
Continental
margin
Ocean
basin floor
Midoceanic ridge
Ocean
basin floor
Continental
margin


Arabian
Plate
Plate
Motion
INDIAN
OCEAN
Red Sea
Yemen
Highland
Gulf of Aden
Mid-Oceanic Ridge
Aden
SOMALIA
Ethiopean
Plateau
East African Rift
African Plate

Rift Valley development

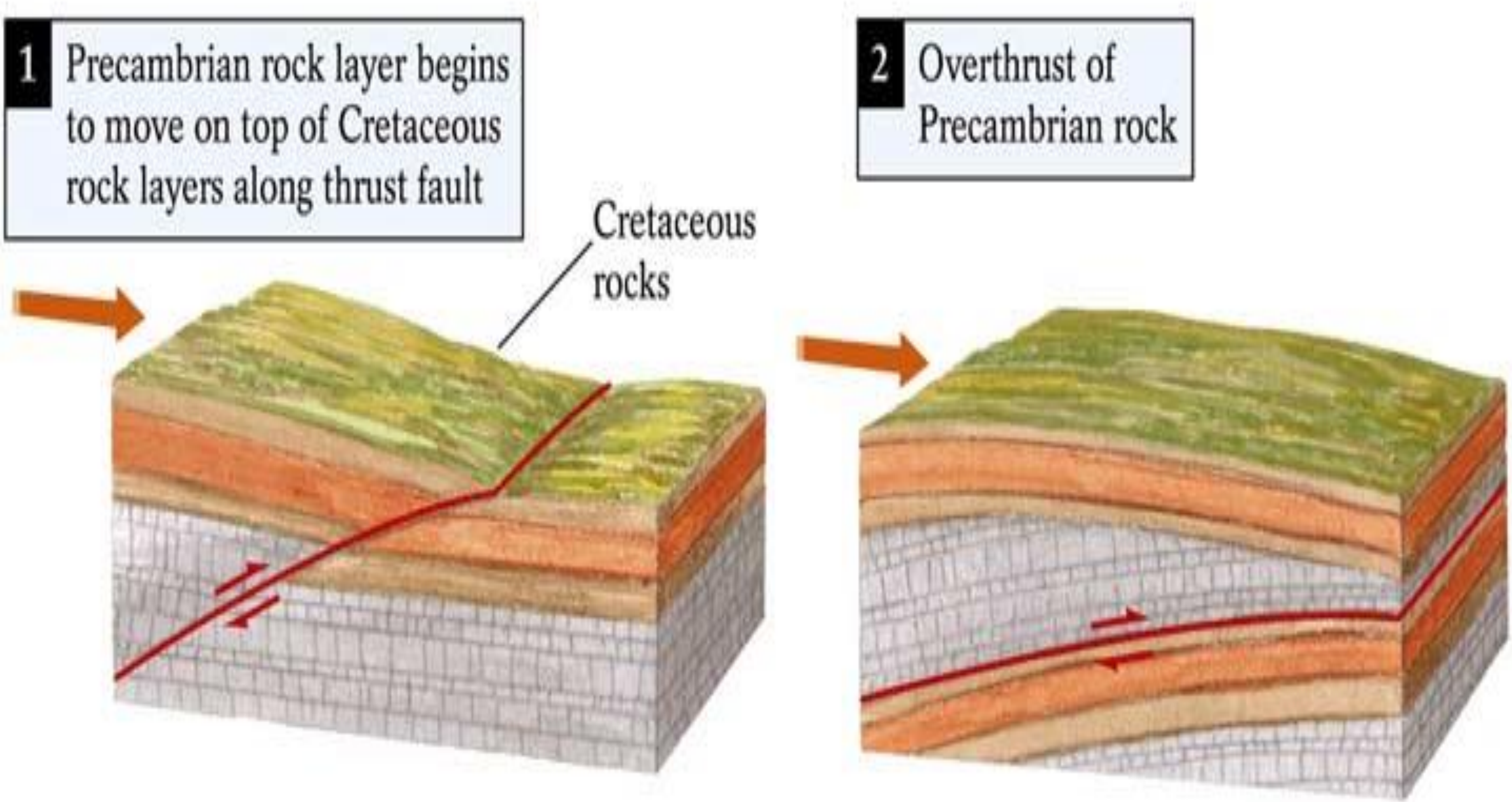
Basins and Range Topography



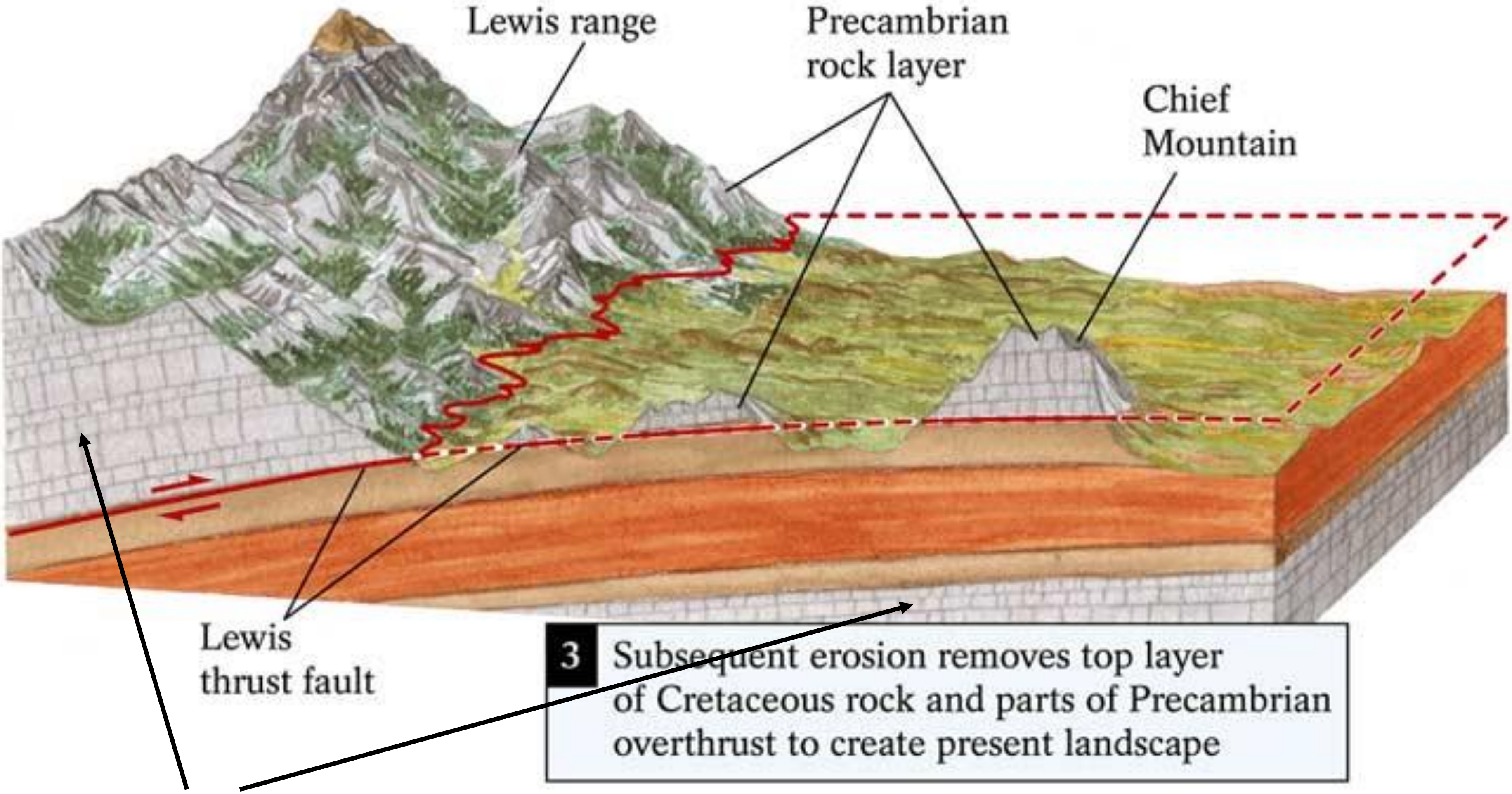
Faulted and tilted monoclinal blocks that had been raised above the adjacent basins along range-front fault

Basins and Range Topography – Western United state

Shallow Reverse Fault = Thrust Fault



Lewis Thrust Fault (cont'd)



Same layer

Klippe - Thrust Fault Remnant

A feature of thrust fault terranes. The klippe is the remnant portion of a nappe after erosion.

http://www.pbase.com/dougsherman/image/93469147

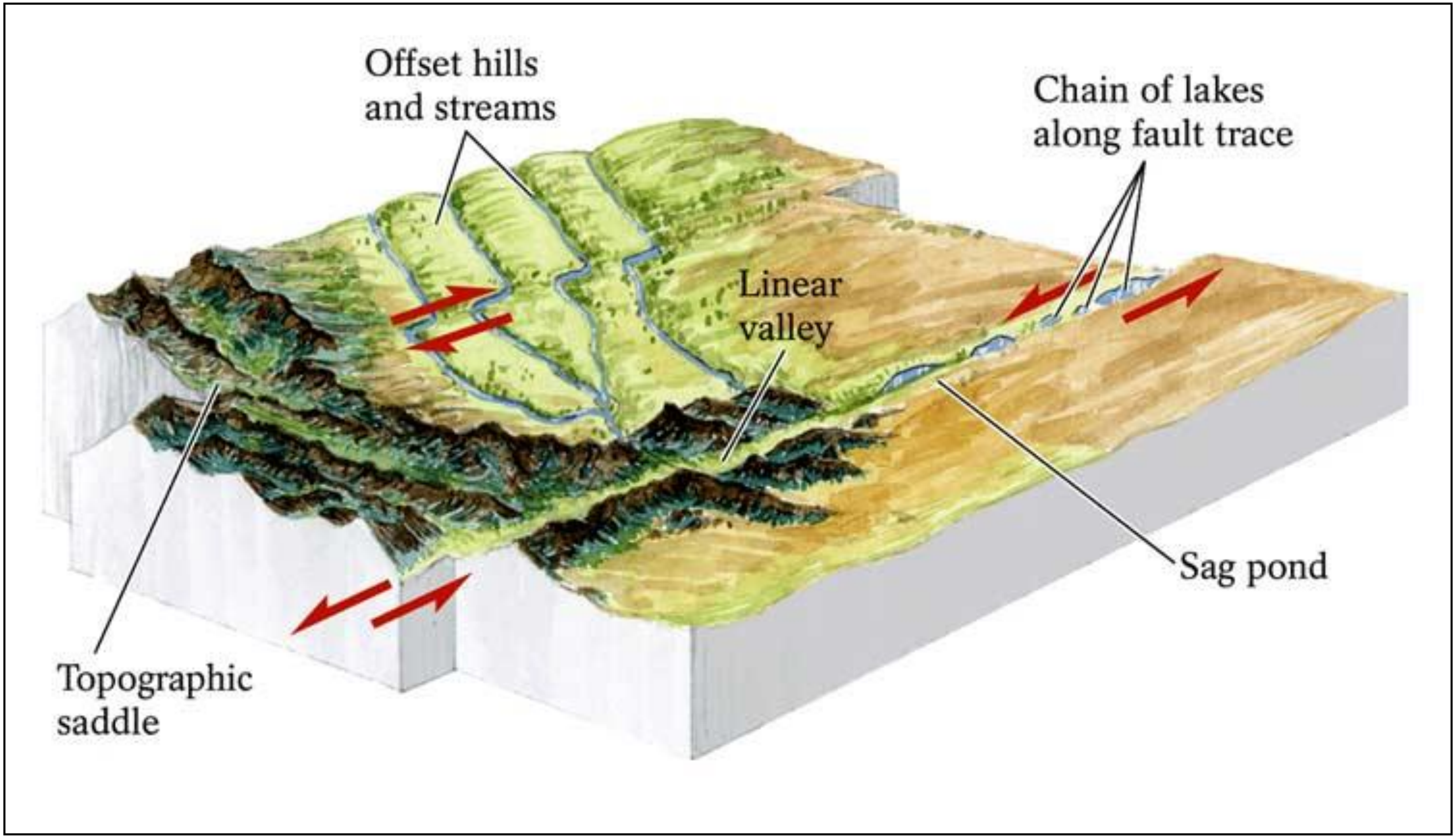
Chief Mountain, a klippe outlier of the Lewis Thrust, Glacier National Park, MT

Lewis Thrust Fault (cont'd)

Source: Breck P. Kent

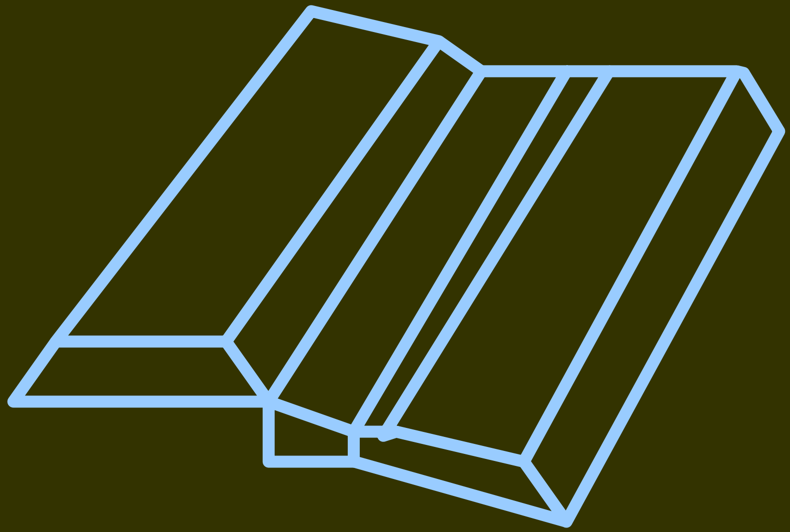
PreCambrian Limestone over Cretaceous Shales

Horizontal Movement Along Strike-Slip Fault

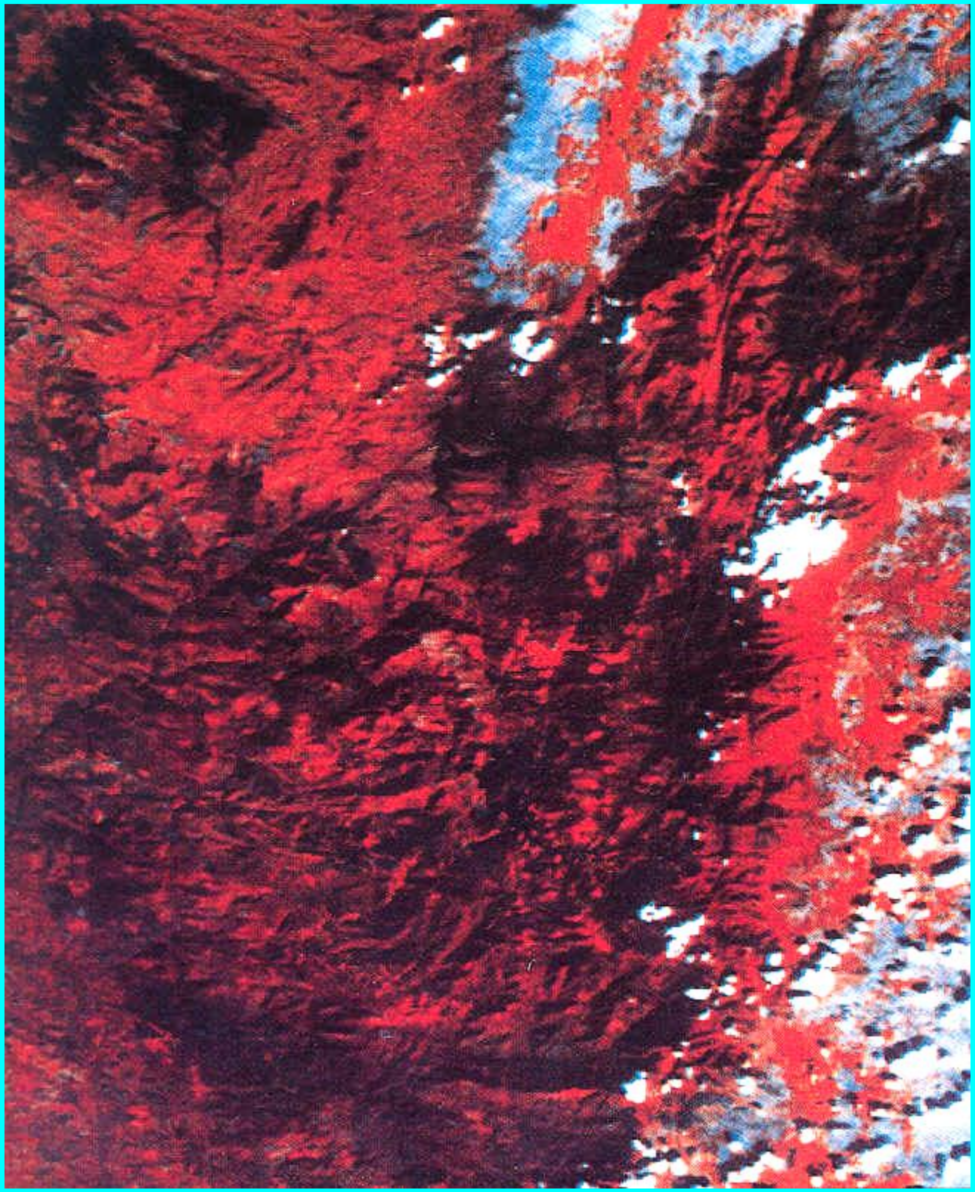


(3.6.4.2) **Fault valleys**

➡ *seismic prone*

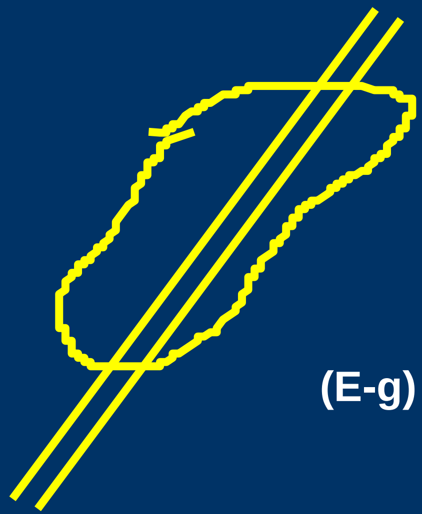


CUMBUM TECTONIC VALLEY



Fracture valleys: Valley developed by the erosion along the faults, fracture, lineaments is called fracture valleys

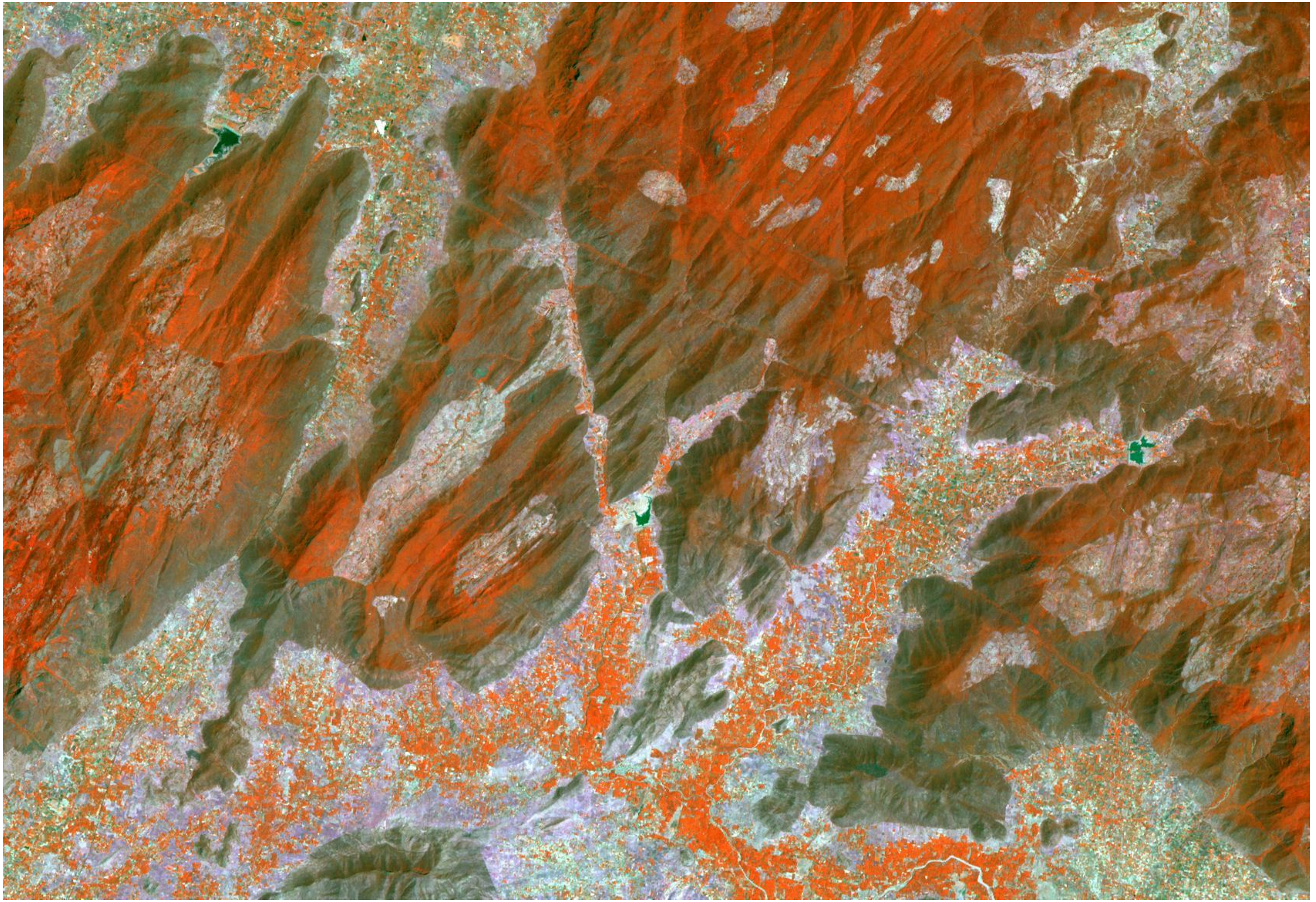
Further, may classified into filled fracture valleys or barren fracture vallys



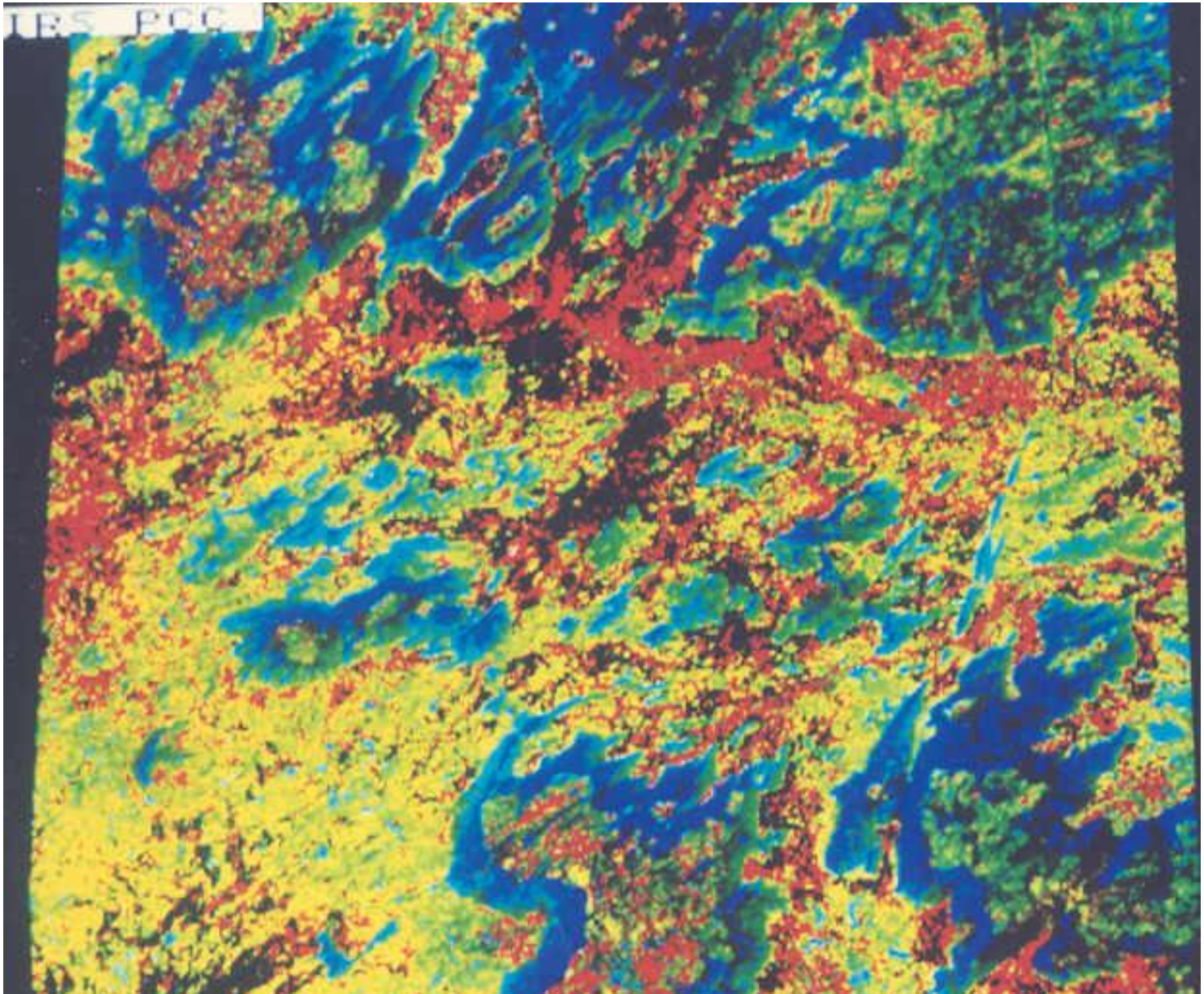
(E-g) Javadi, Shevroy, Chitteri hills

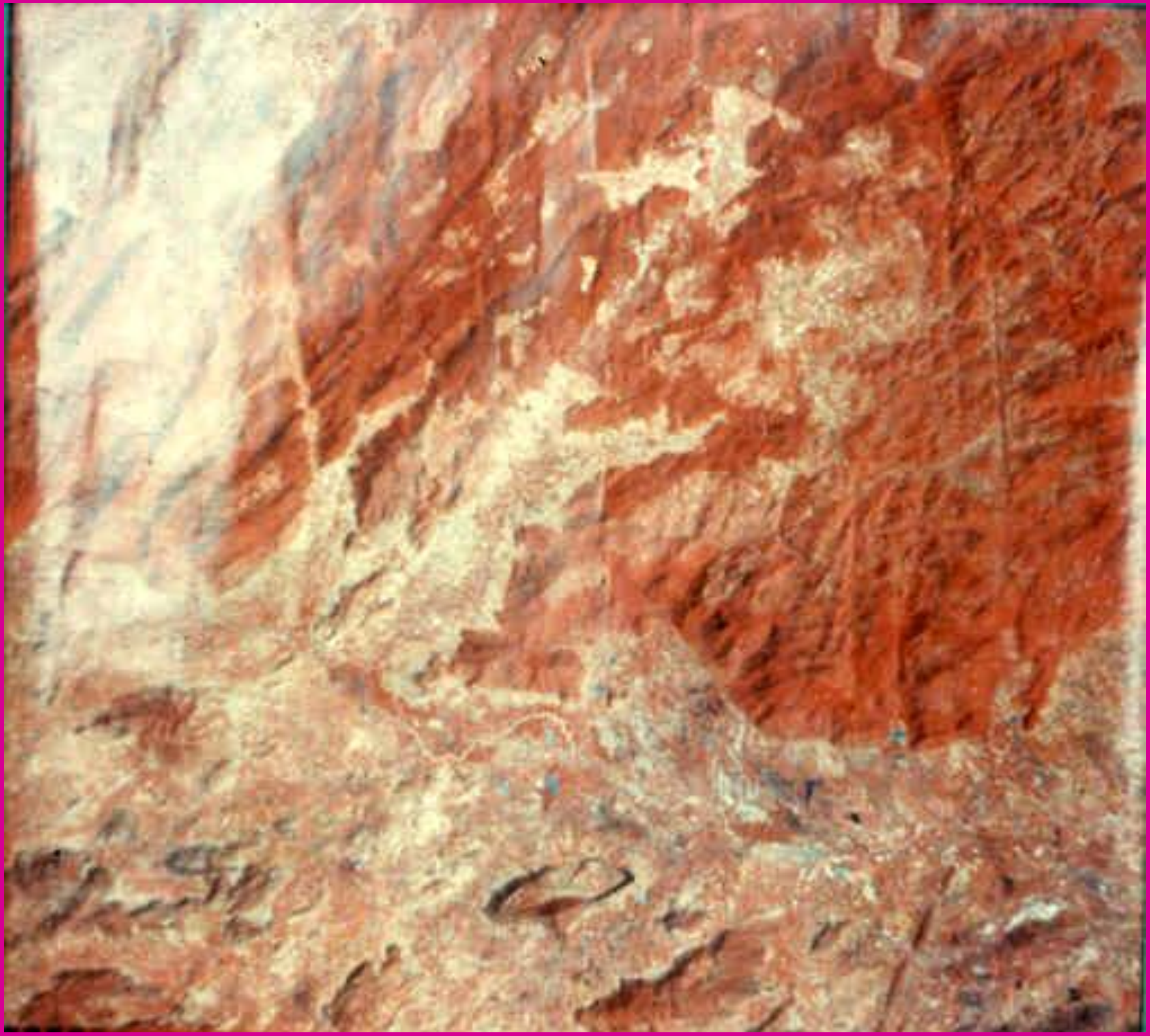
- *metallogeny*
- *erosion prone*
- *groundwater flow*
- *pollutant migration*

BARREN FRACTUTRE VALLEY

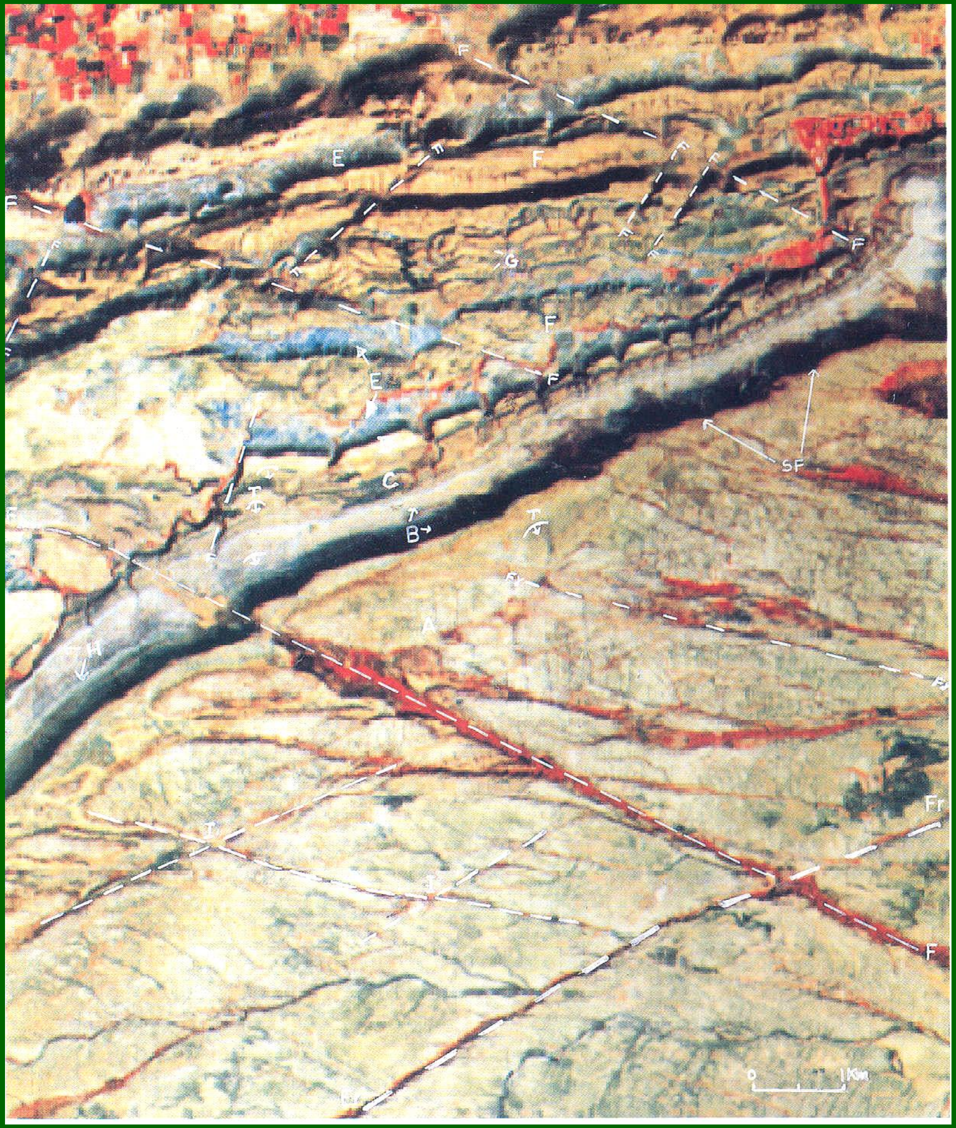


FILLED FRATURE VALLEY





CUDDAPAH BASIN



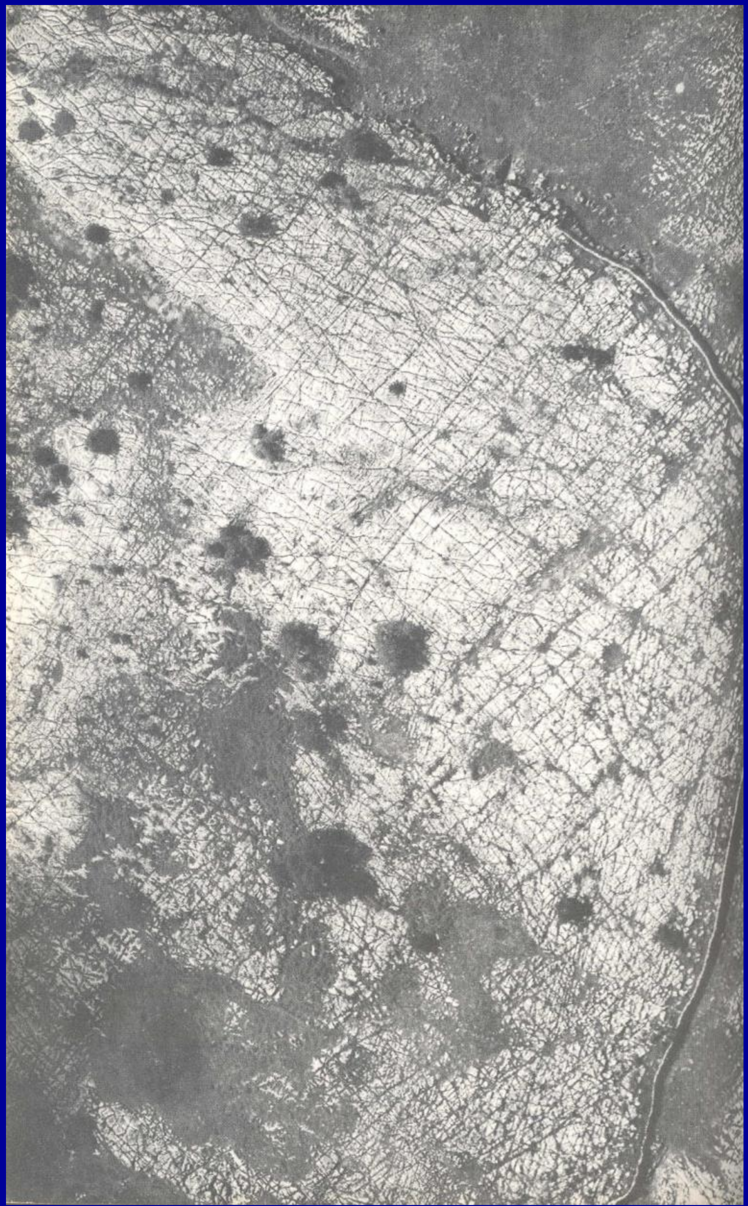
Tectonic Pediments

If pediments dissected by the fractures are called tectonic pediments

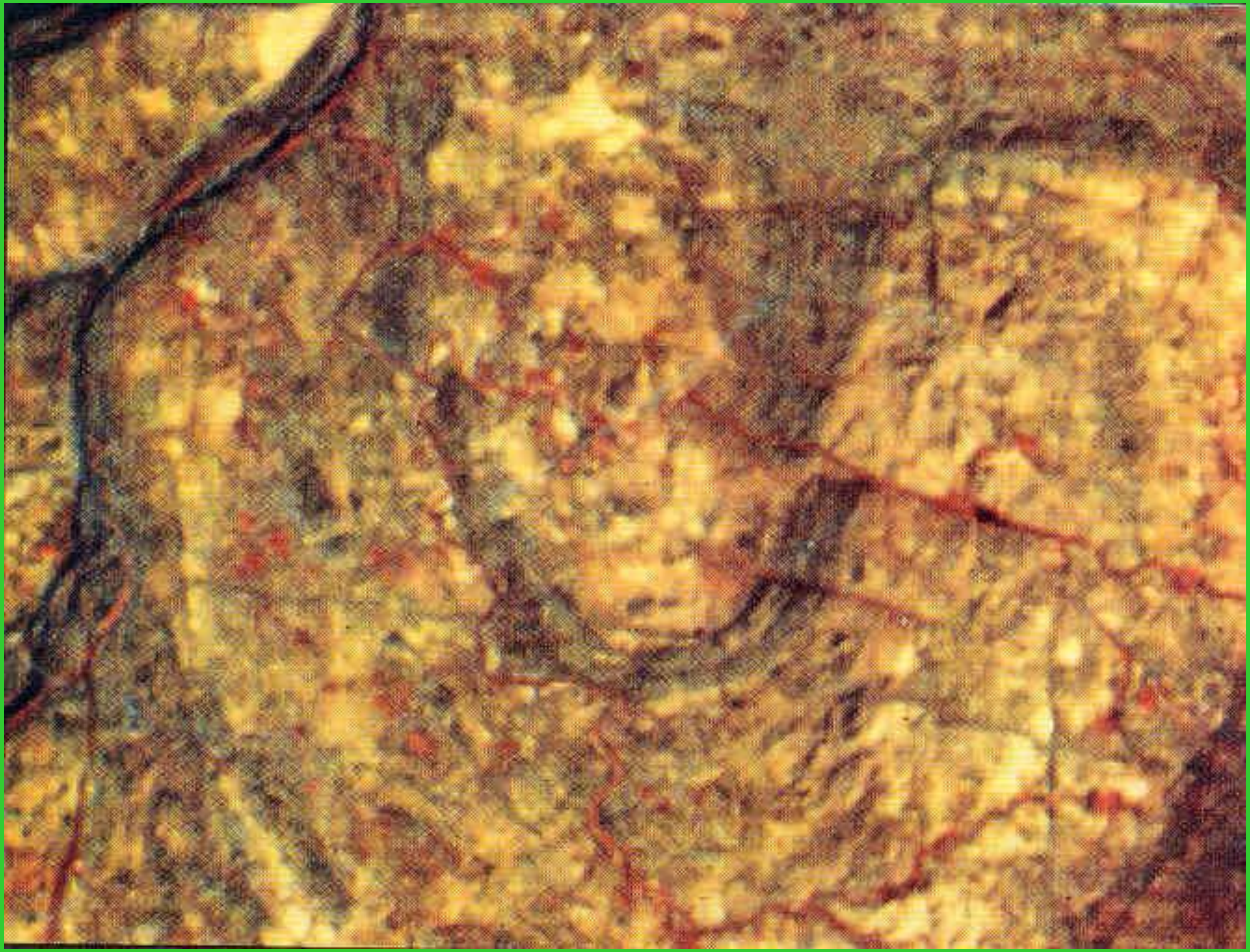
Joints: Fractures – with no movement

PEDIMENTS

PEDIMENT IN LIMESTONE - YORKSHIRE



IRS 1A - KARNATAKA




BUTTERFLY®

(3.7) TECTONIC LANDFORMS IN VOLCANICS

(3.7.1) Plateau, Mesa, Butte

(3.7.2) Batholiths

(3.7.3) Sills

(3.7.4) Dykes

(3.7.5) Volcanic craters / Cynder cones

LISS III - BURMA

RETREATING ESCARPMENT

(***Mt. Robson, Canadian Rockies***)

FLUVIAL GEOMORPHOLOGY

Definition:

Study of river actions and the landforms formed due to such river actions

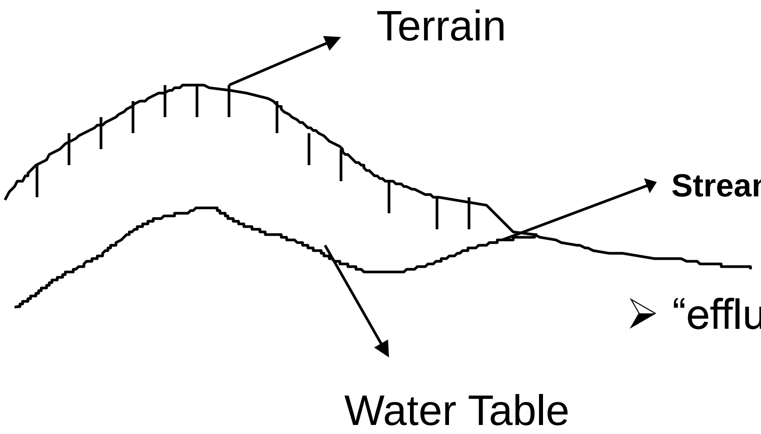
The study of erosional and depositional processes from running water or river that forms the landscape.

WHY TO STUDY FLUVIAL GEOMORPHOLOGY/ ECOSYSTEM ?

- To understand the ongoing erosional and depositional dynamics of the river systems
- To fabricate the past fluvial activities of the various geological basins so as to understand the basin dynamics and the resources.
- To fabricate the palaeo flood cycle.
- To understand the areas prone for erosion and reservoir siltation.
- To locate placer deposits.
- To detect Groundwater locales
- To identify zones of natural and artificial recharge
- To identify vulnerable areas for pollution
- To select suitable sites for dams , reservoirs and bridges
- To locate deltas and palaeo shores
- To locate locales of hydrocarbon
- Inter linking of Rivers

SOURCES OF RIVER

- Rainfall
- Snow melt
- Water Table



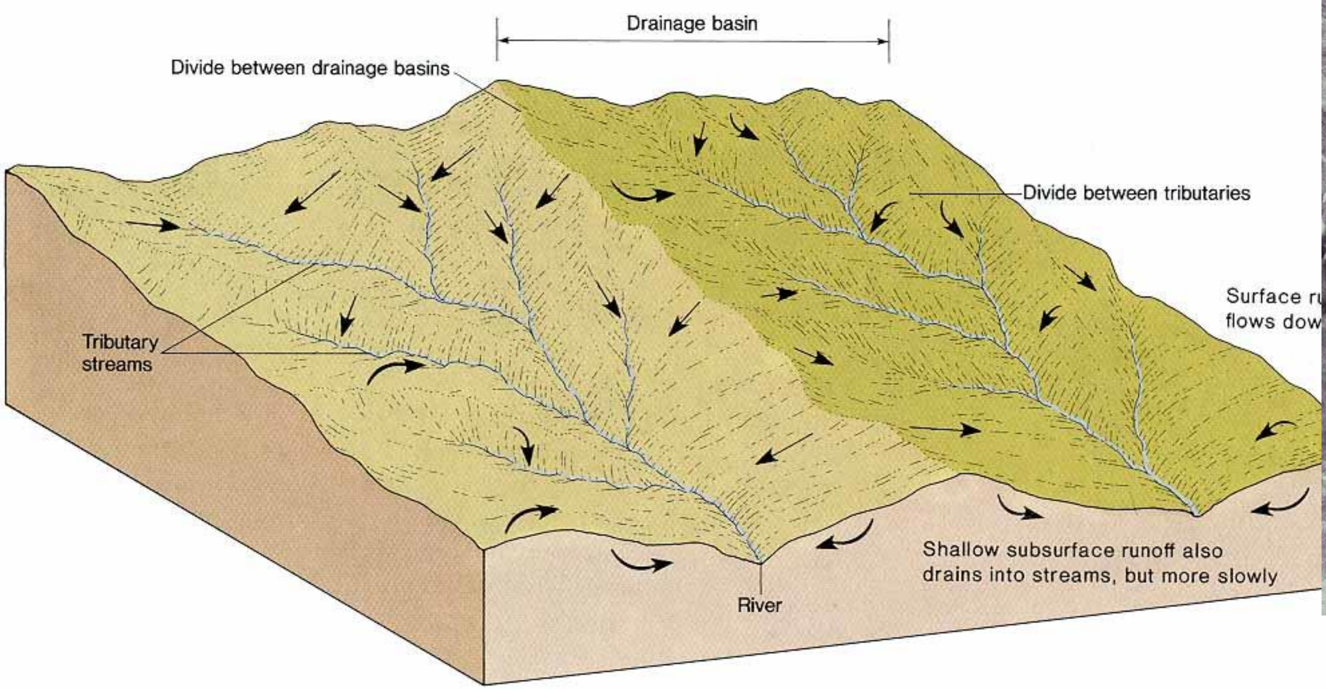
- "effluent streams"

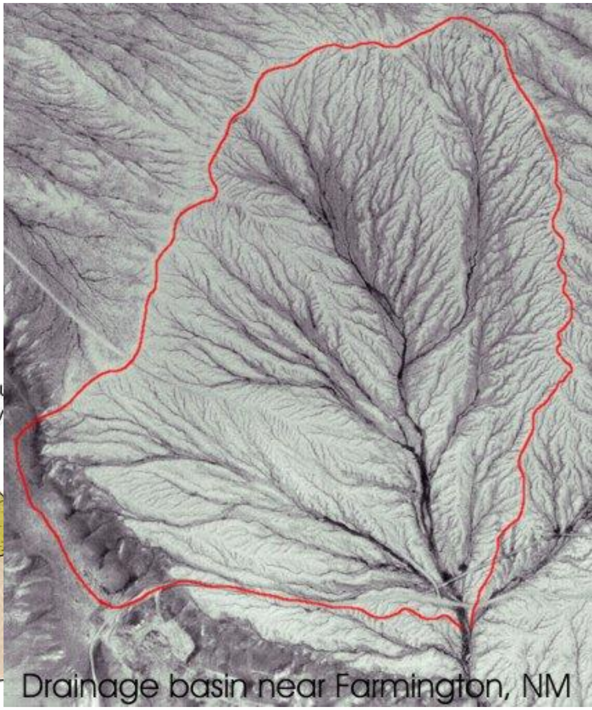
PARTS OF RIVER

- **Stream:** A flow of water
- **River :** Big flow of water through a channel
- **Tributary** : a stream flowing into or joining a larger stream
- **Distributaries :** River branch off into multiple stream where it reaches its delta
- **Upstream** : moves toward headwater (up the regional slope of erosion)
- **Downstream :** moves toward mouth of river (delta)
- **Drainage basin:** Area or catchments whose rainfall being drained into a river

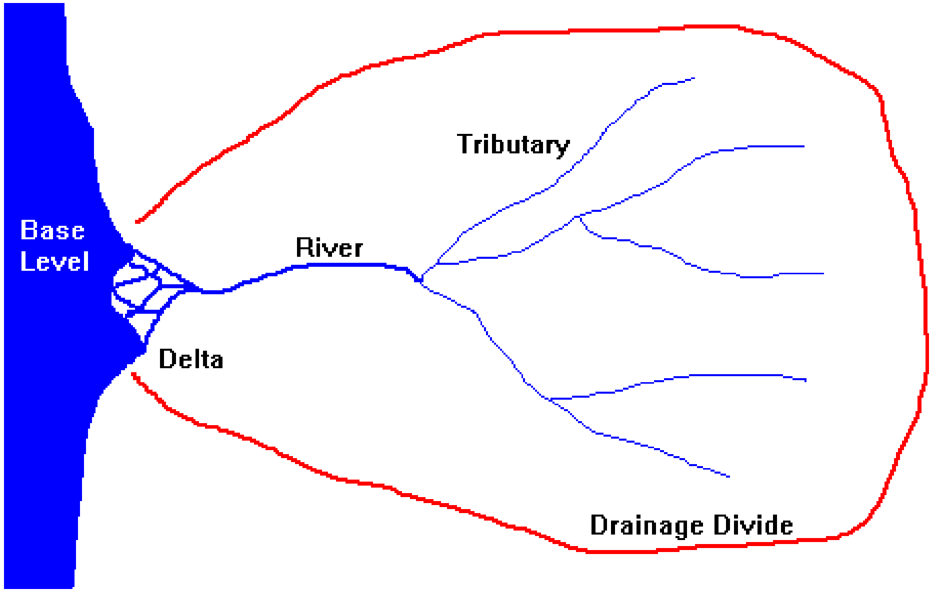
Stream Systems

- Each stream drains a specific portion of the landmass, this is called the watershed or drainage basin
- Drainage basins are separated by drainage divides
- Drainage divides may be distinct (mountain ridges) or much more subtle





Stream Systems



Anatomy of a Drainage Basin

River Basin Processes

- **Erosion**
- **Transportation**
- **Deposition**

Erosion

- **Attrition:** As the rocks and pebbles are being swept along they bang against each other and they slit up or little bits get knocked off, making them smaller and smaller. This also has the effect of smoothing and rounding the particles too.

- **Corrasion:** The bits of rock and sand in the river rub along the banks, wearing it down and knocking more particles into the water flow.

- **Hydraulic action:** This is when the water simply hits part of the river bank so hard it sweeps it away.

- **Corrosion:** The rainwater that flows into the river all along its length is very slightly acid. This acid very slowly dissolves minerals such as calcium carbonate in limestone. These minerals are then carried in the water, and eventually come out in our water systems as limescale.

Transportation

- **Traction:** This is when the force of the water simply rolls large rocks along the riverbed. The river usually only has this much force in times of flood.

- **Saltation:** Little pieces of gravel and sand bounce along the riverbed in a series of short hops as the river picks them up then drops them again because they are not light enough to be kept afloat.

- **Suspension:** Tiny grains of sand are light enough to actually be kept in midflow and washed along with the water.

- **Solution:** When limestone is dissolved by the weak acid in the water it is mixed with the water and called a solution.

Deposition

In sections of the river where the water velocity slows down, such as wider sections towards the mouth of a river, or on the inside of meanders, the flow of the water is not strong enough to hold up the particles it is carrying. It drops them on the riverbed and this is called deposition.

CHARACTERISTICS OF STREAMS

Permanent streams

- Contain water through out the year
- Snow fed river

Intermittent Streams

Streams contain water intermittently
due to changes in snow melt
due to changes in rainfall
due to fluctuating water table

Epimeral Streams

purely rainfed

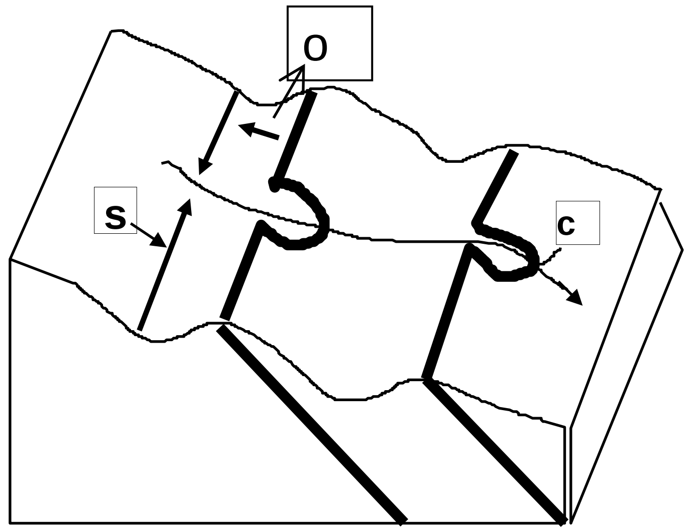
- A river system consists of a main channel (trunk stream) and all of the tributaries that flow into it or joining the trunk stream.

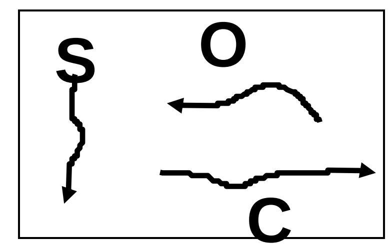
- **A RIVER SYSTEM CAN BE DIVIDED INTO THREE SUBSYSTEMS:**

- ***collecting system*** (branches) -- consisting of a network of tributaries in the headwater region, collects and funnels water and sediment to the main stream
- ***transporting system*** (trunk) -- the main trunk stream, which functions as a channelway through which water and sediment move from the collecting area toward the ocean. (Erosion and deposition also occur in a river's transporting system)
- ***dispersing system*** (roots) -- consists of a network of distributaries at the mouth of a river (delta), where sediment and water are dispersed into an ocean, a lake, or a dry basin

Terrain controlled drainage

Consequent Streams





Streams following the dip slope

➔**drainages following in the dip slopes are called consequent drainage**

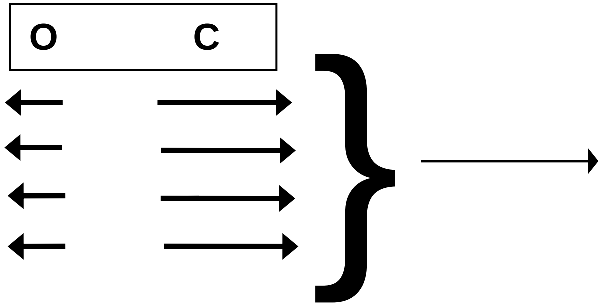
➔**Indicate low dipping formations underneath** generally the main stream

Obsequent drainage

Dainages flowing against or in opposite direction to the dip slope

drainages following the obsequent slope

➔Helps in understanding the basement structure
➔Highly useful in engineering geology projects



indicates cuesta or asymmetrical anticline

➔If such consequent and subsequent drainages are sharp, vertically cutting and straight then it will indicate recent tectonic movements.

Subsequent drainage

Drainages orthogonal to consequent drainage (or) drainages parallel to strike (or) drainages perpendicular to dip.

Subsequent Stream generally a tributary, it adjusts its course by differential erosion through softer rocks

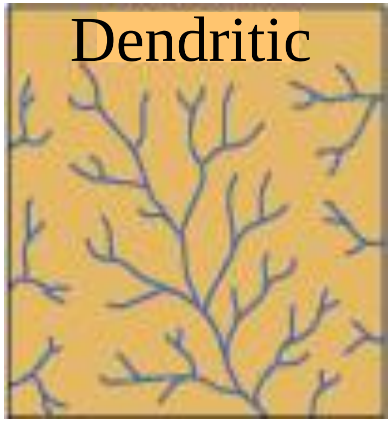
Insequent stream those developed by random headward erosion.

Resequent Stream follows the same direction as consequent stream, but it is a tributary.

Subsequent drainage

Drainages orthogonal to consequent drainage (or) drainages parallel to strike (or) drainages perpendicular to dip.

Subsequent Stream generally a tributary, it adjusts its course by differential erosion through softer rocks

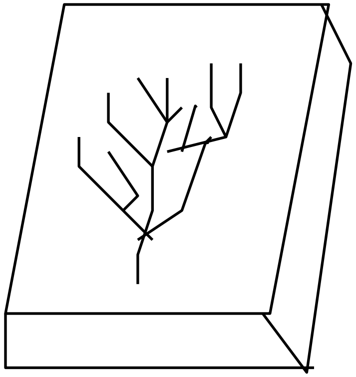


Dendritic drainage

Hapzardly flowing drainages without any strong tectonic control

➔ ***indicate flat lying beds underneath or granite or Shale.***

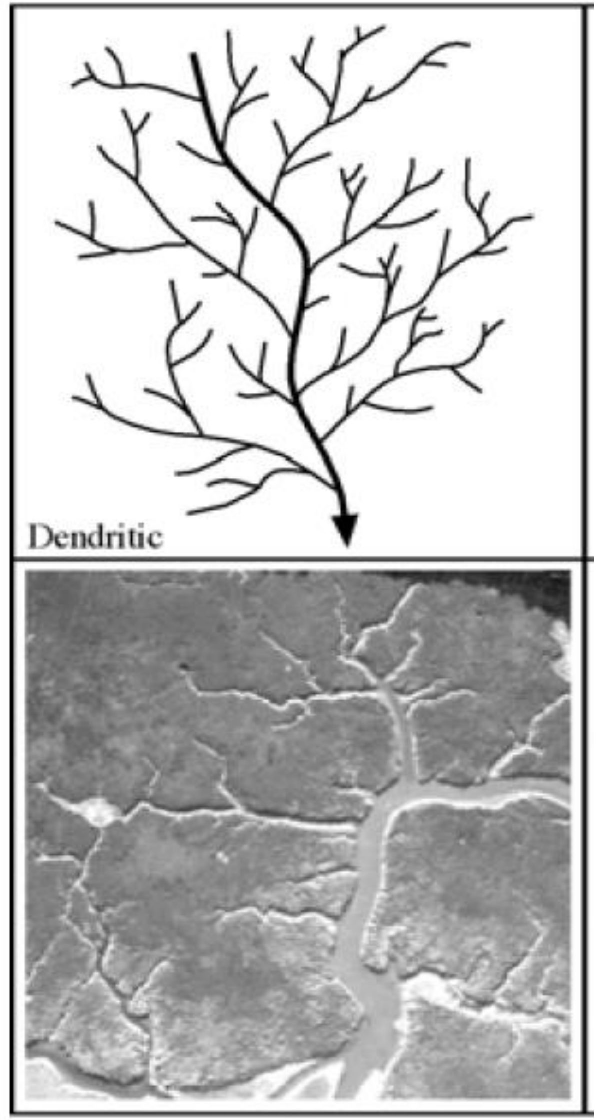
➔ **(e.g) All dendritic drainages in sedimentary and granitic terrains.**



Dendritic drainage

Dendritic: Irregular pattern of channels that branch like a tree. Developes on flat lying or homogeneous rock.

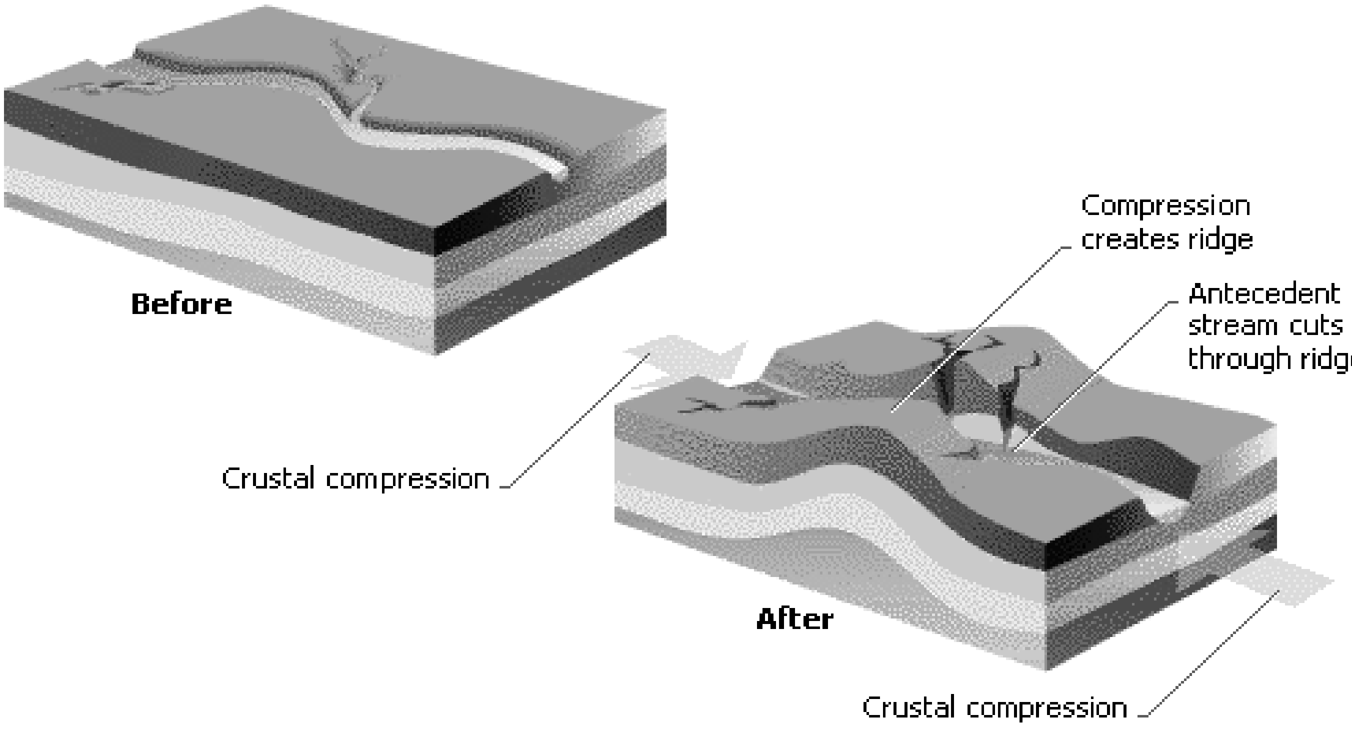
- Flat-lying
- Horizontal rock or sediments
- Bevelled crystalline rocks
- Incising floodplains or lakes
- Very common



a.

Antecedent drainage

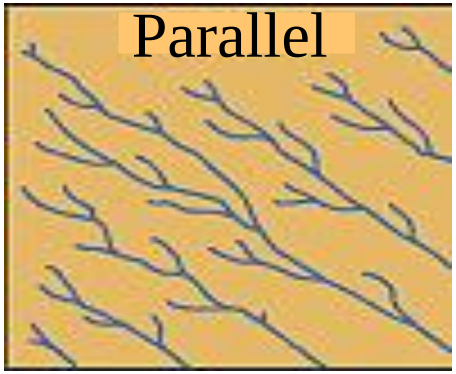
<u>Antecedent Drainage</u> : An antecedent stream is a stream that was established before the land beneath it was uplifted through geologic processes such as crustal compression. An antecedent stream will maintain its course in spite of crustal compression, and the stream will continue to erode the land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

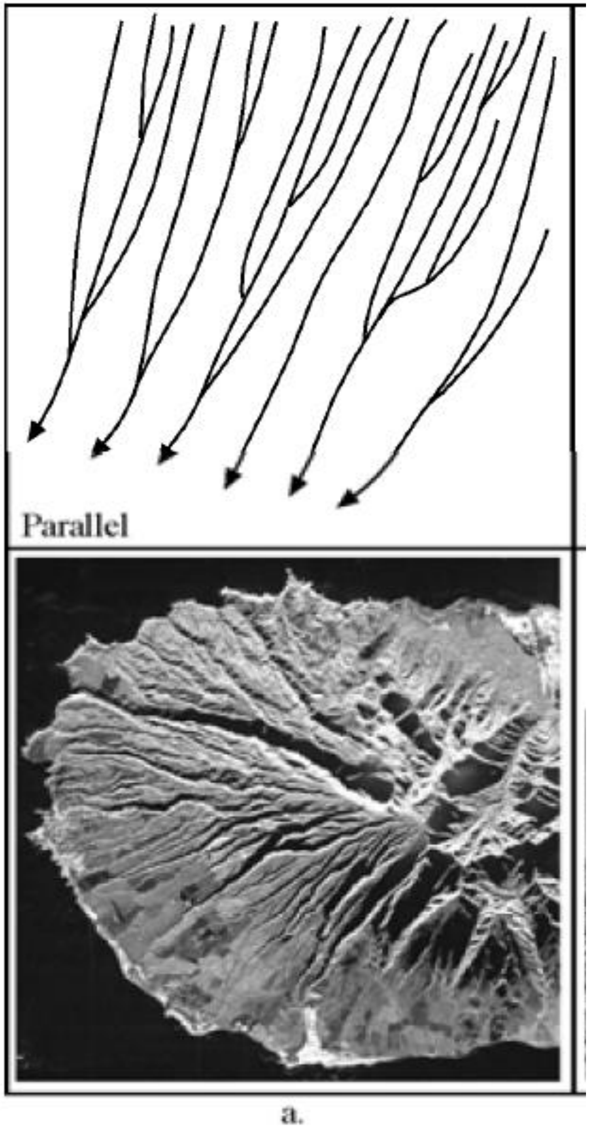


Parallel Drainage

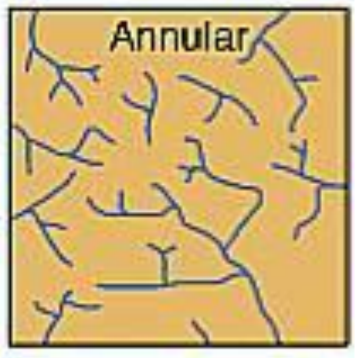
- **Parallel or sub-parallel drainage formed on uniformly sloping surface.**
  - **dune**
  - **dip slope**

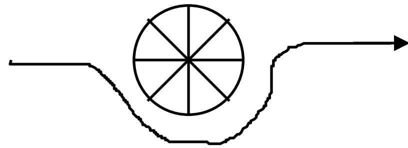
Example: rivers of lesser Himalayas.

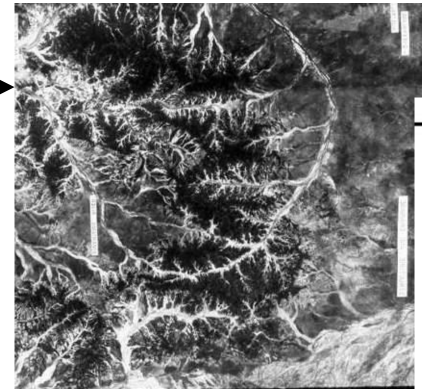




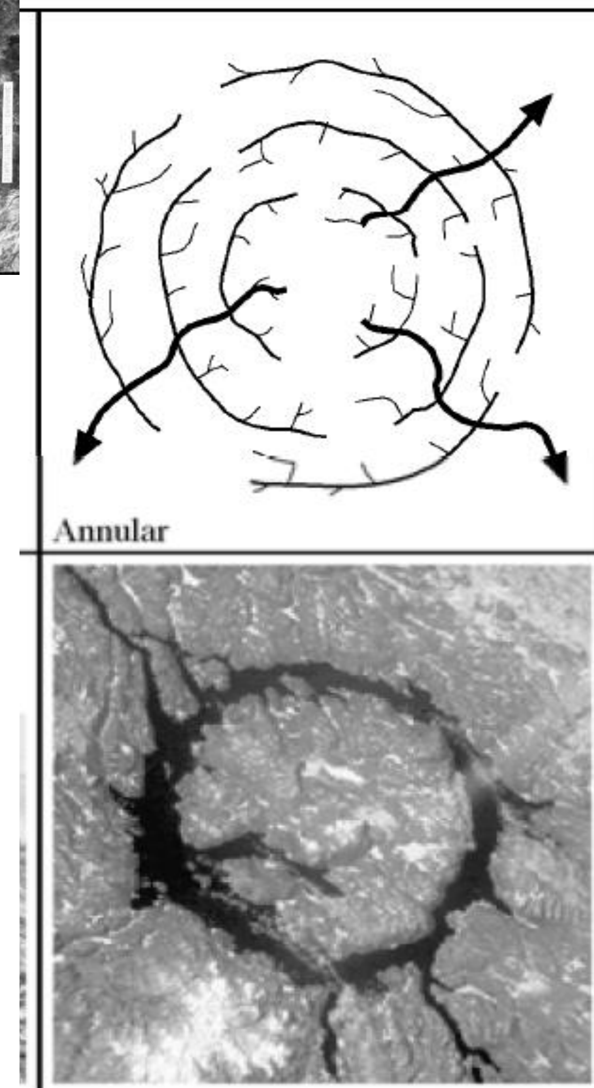
Curvilinear / Annular Drainage







- **Streams flow nearly circular or concentric paths**



ANNULAR When the upland has an outer soft stratum, the radial streams develop subsequent tributaries which try to follow a circular drainage around the summit. Example: Black Hill streams of South Dakota.

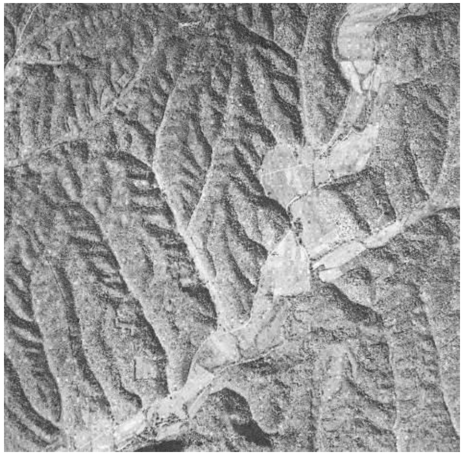
Anomalous annularity in drainages

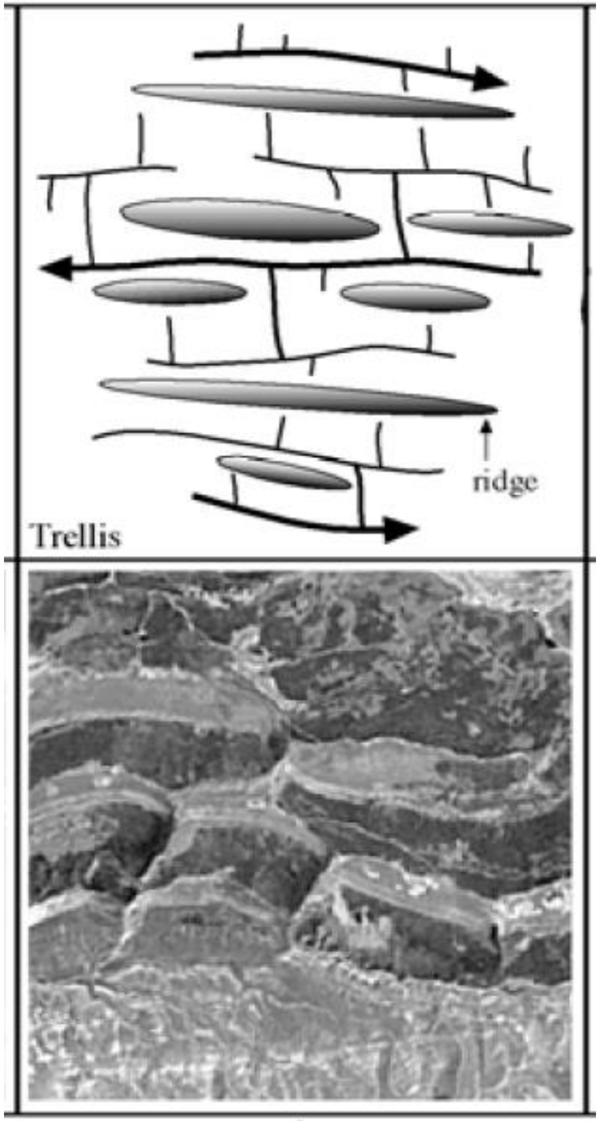
➔indicates surficial and subsurface domes and basins

➔if deep vertical cutting is observed in such annular areas the same will indicate recent and ongoing doming

(e-g) Southern Saurastra, Iswara kuppam dome, Kadavur area

Trellis





- Rectangular arrangement of channels in which main tributaries are parallel and very long

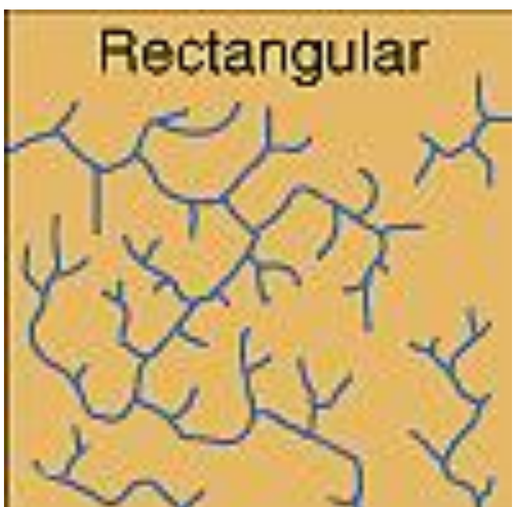
TRELLIS: The short subsequent streams meet the main stream at right angles, and differential erosion through soft rocks paves the way for tributaries.

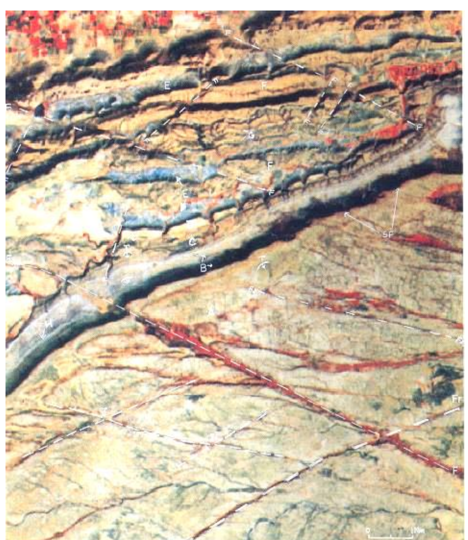
Rectangular drainage

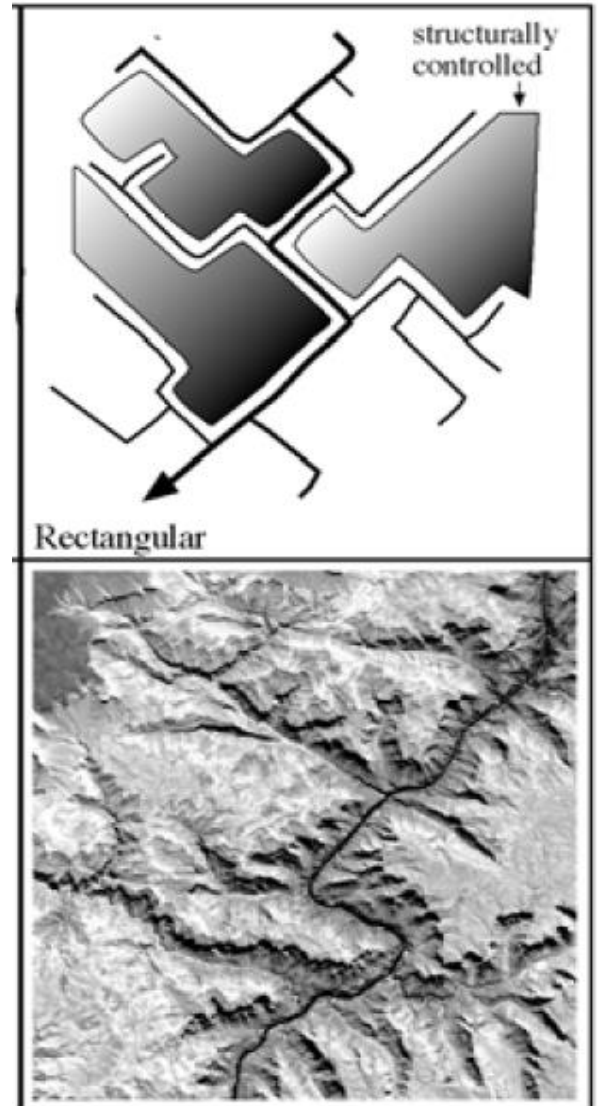
RECTANGULAR The main stream bends at right angles and the tributaries join at right angles creating rectangular patterns. This pattern has a subsequent origin.

➔**Rectangular drainages are seen in zones of mutually perpendicular Joints**

➔**Channels marked by right-angle bends**

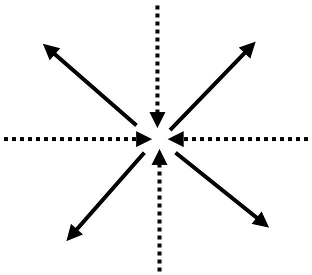




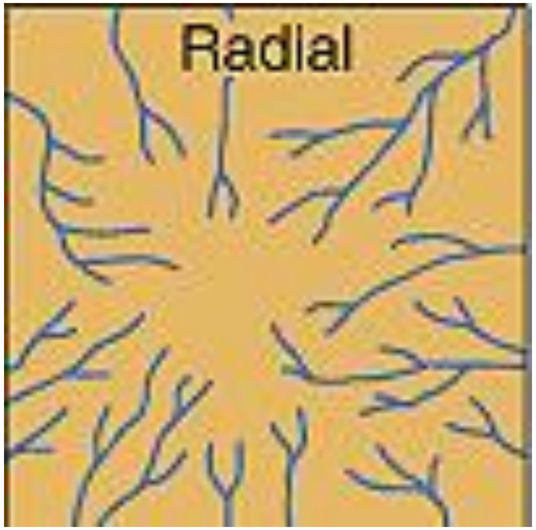


c.

Radial drainages

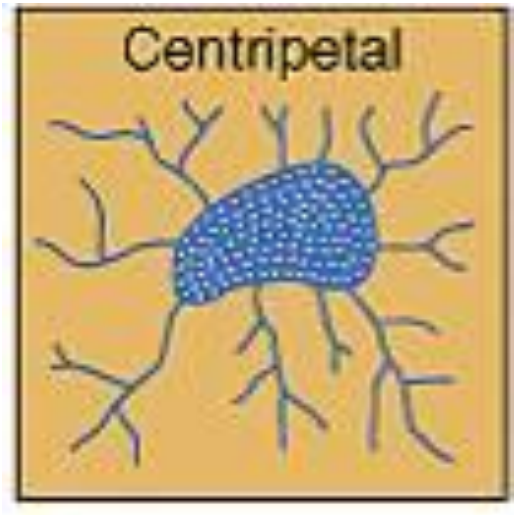


(a) Radial centrifugal - domes
(b) Radial centripetal - basin
(c) Annular and radial - domes/ basins with alternating hills and valleys



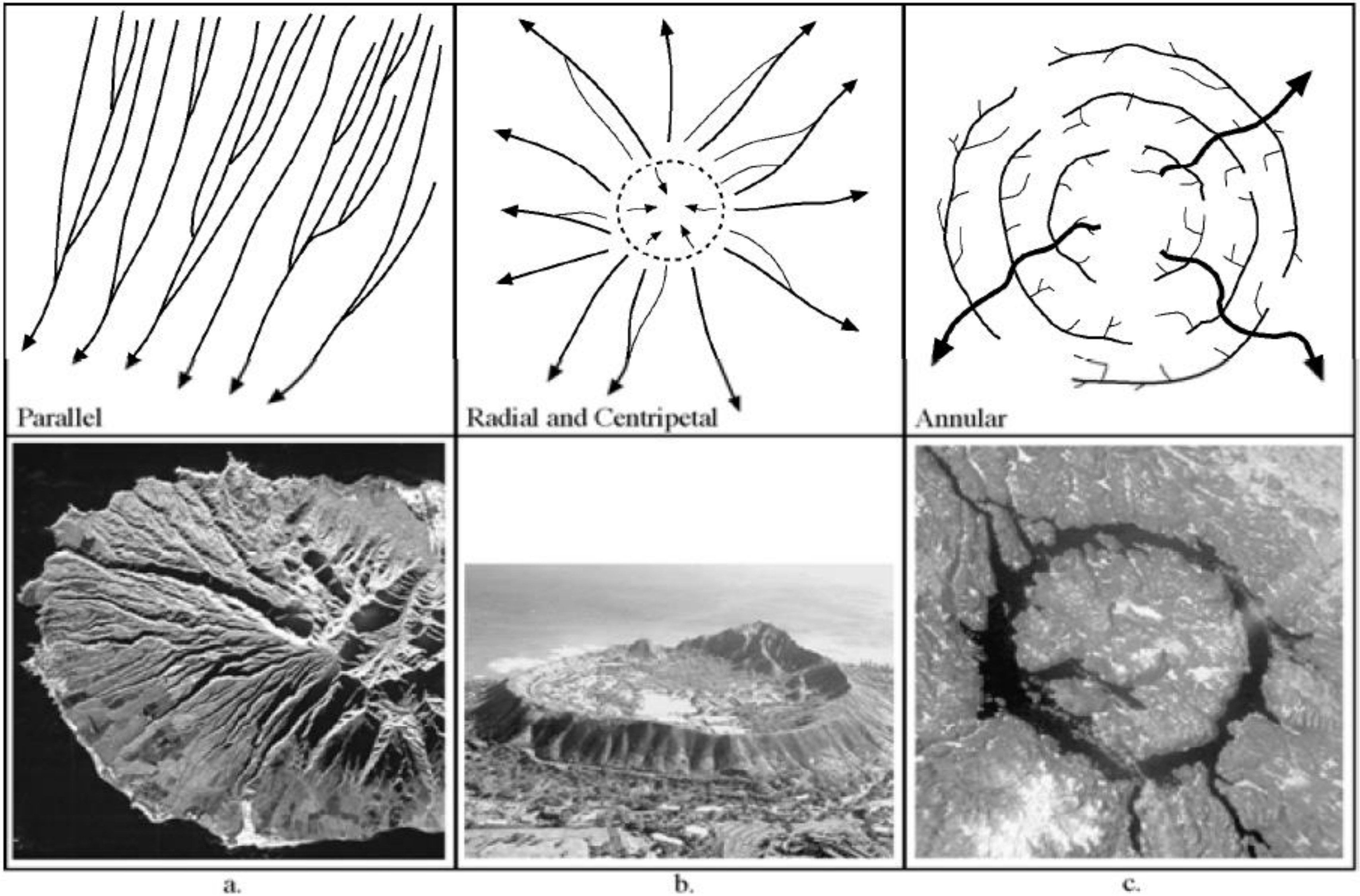
Streams radiates out from the center of the topographic high

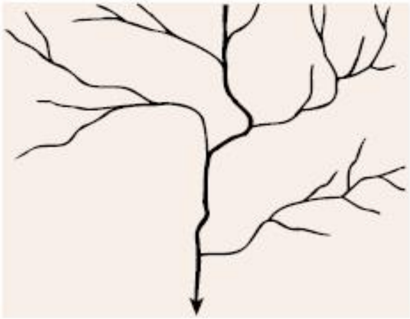
common in Volcanic terrain



- Streams converge toward a central depression

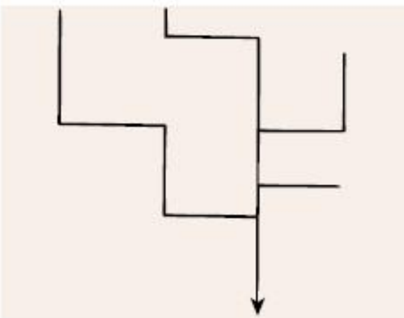
Different Drainage Patterns





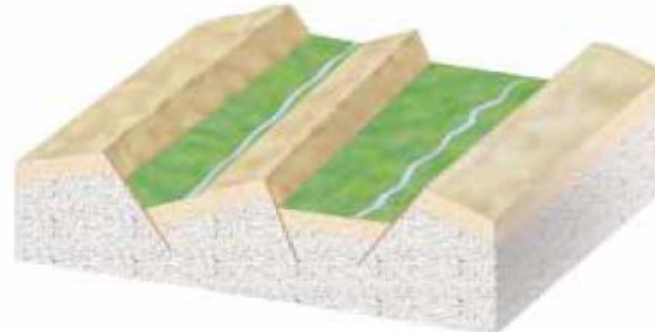
(a)

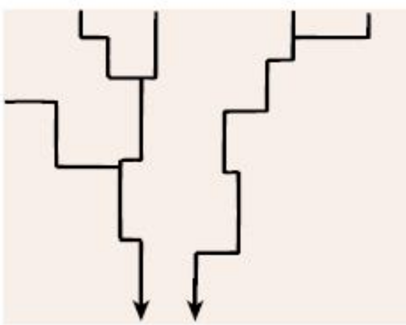
Dendritic drainage pattern.
Bedrock is relatively uniform.



(b)

Trellis drainage pattern.
Streams develop along faults, joints, or other parallel structures in the rock.





(c)

Rectangular drainage pattern.
Streams follow joints that intersect at right angles.

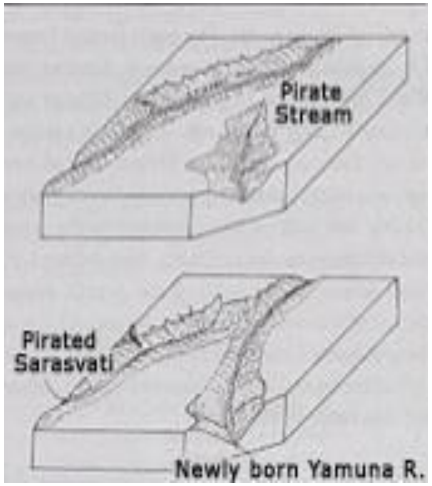
(d)

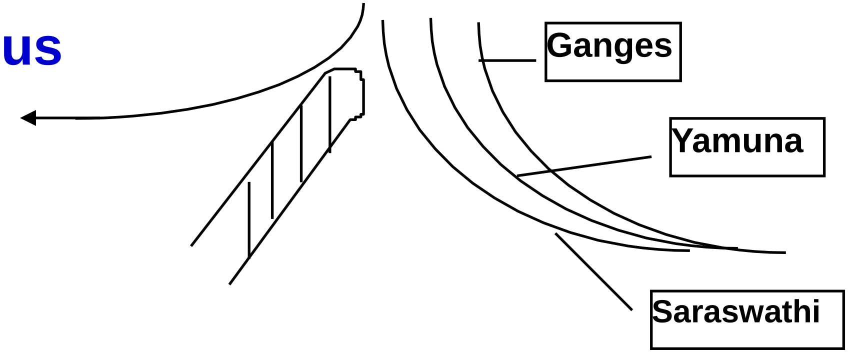
Radial drainage pattern.
Stream channels flow from mountain peak.

PIRATED DRAINAGES

Drainage of one water shed being captured by the drainage of other watershed is called Pirated drainages for e.g.

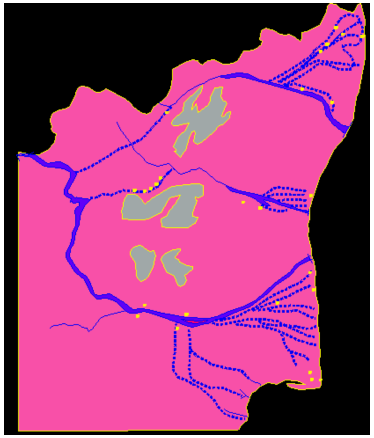
➔Capturing of Saraswathi by Indus



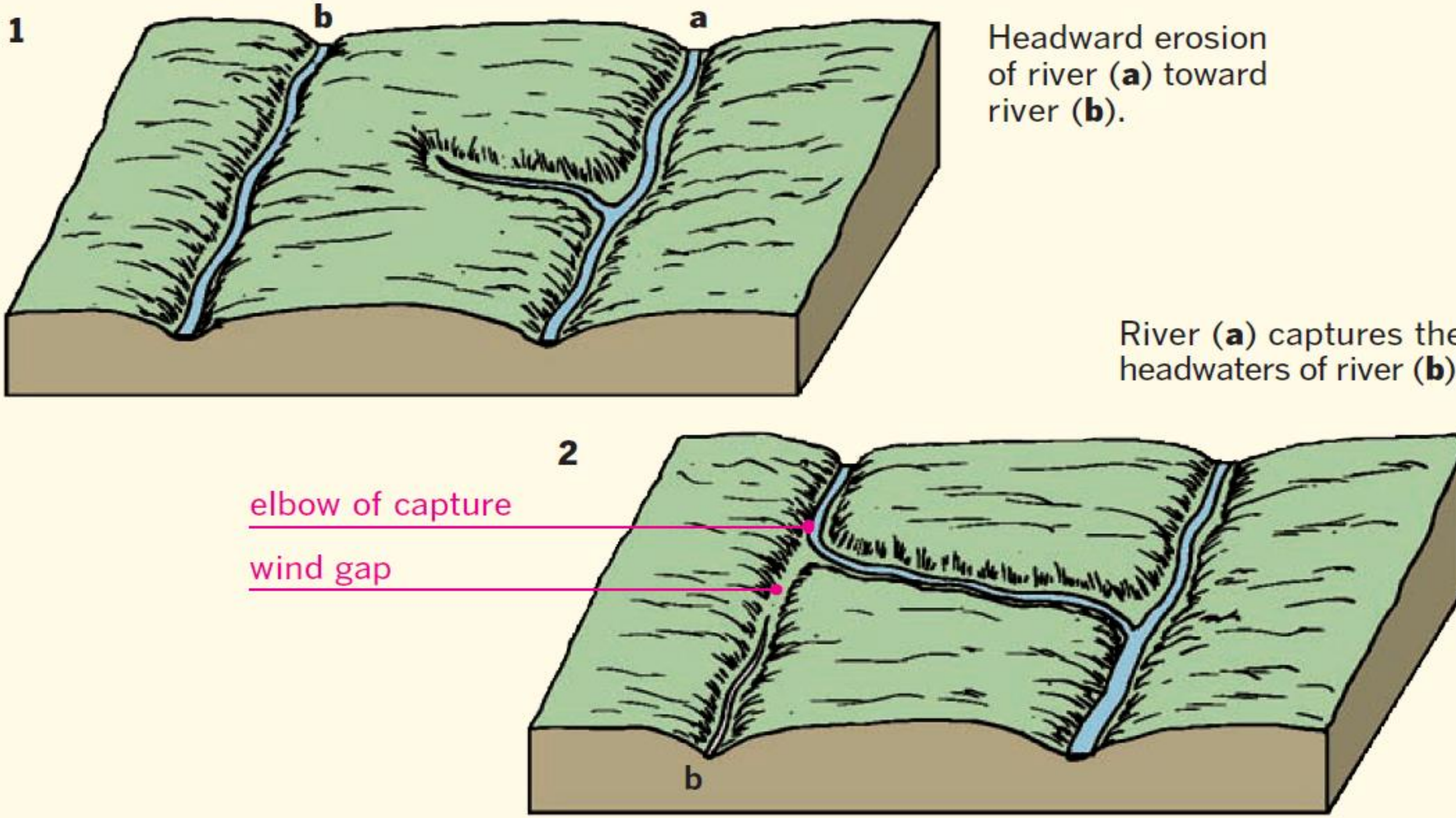


➔Capturing of Cauvery by Ponnaiyar

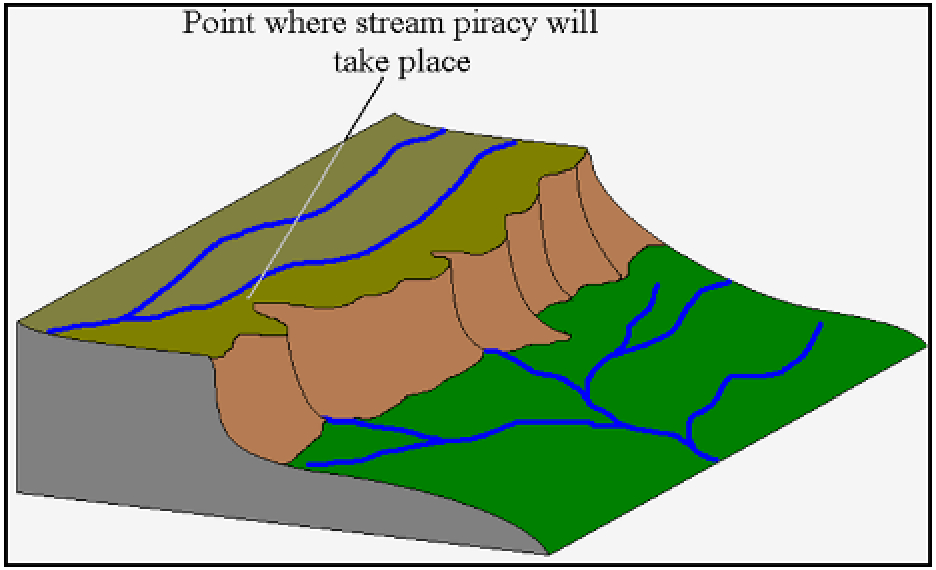
➔Capturing of Cauvery by Proto Amaravati

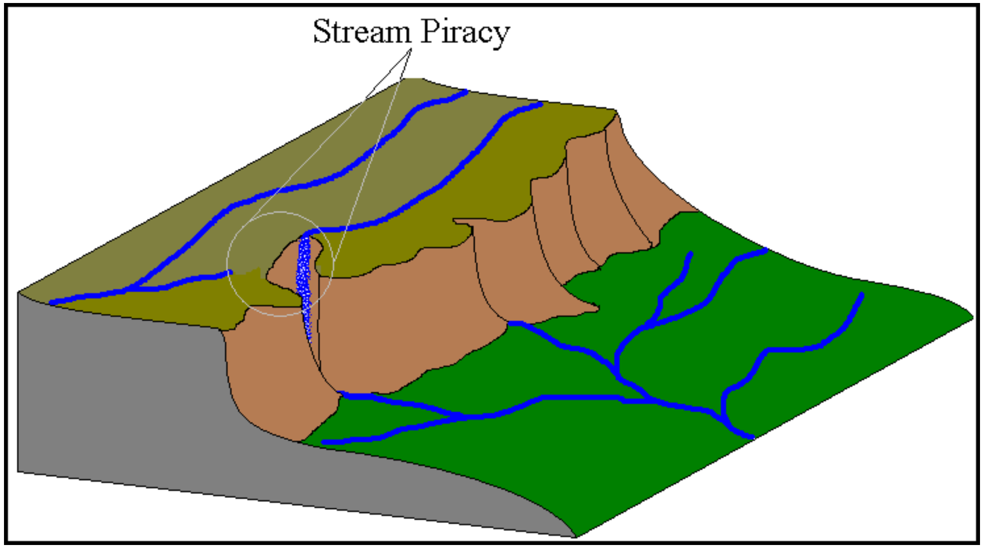


River capture



Stream piracy

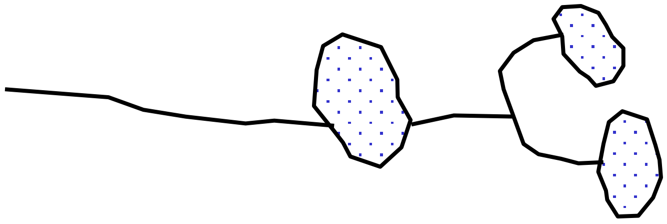




Drowned stream

➔Sometimes due to sudden rise of sea level the deltas & rivers will get drowned. (e.g.) **Mississippi**

Ponded Streams



Man Made Streams

All irrigation canal, there will not be fluvial activity

Life History of Rivers

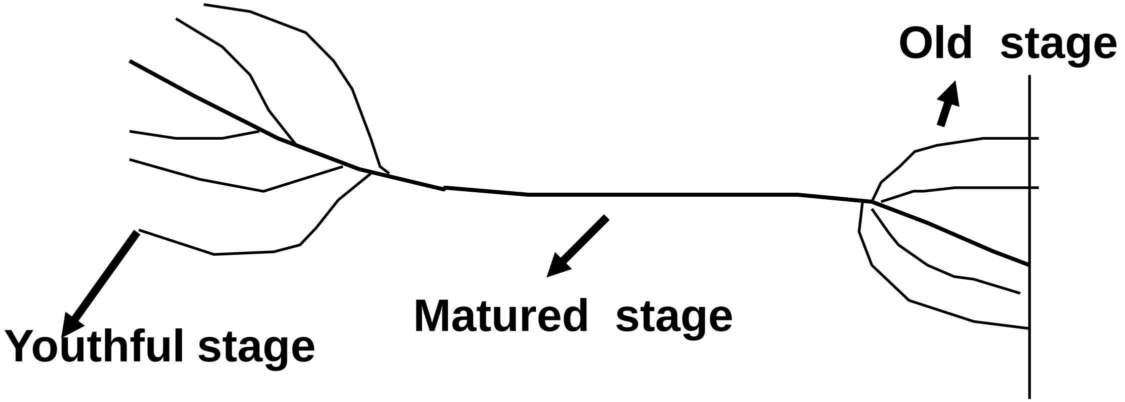
- Youthful stage – Hilly area- much above MSL / base level of erosion – Extensive erosion
- Mature stage – Claimed down the hill – Lost considerable elevation – Watch and Walk phase – both erosion and deposition
- Old stage – at coastal zone – at base level of erosion – loosing of all energy – Deposition / delta building is the only process
  - Idealistic life cycle of the rivers
  - But in mature stage , the river flow get abberated by palaeo geological structures and ongoing tectonics
  - In old stage sea level variations abberate the river flow dynamics

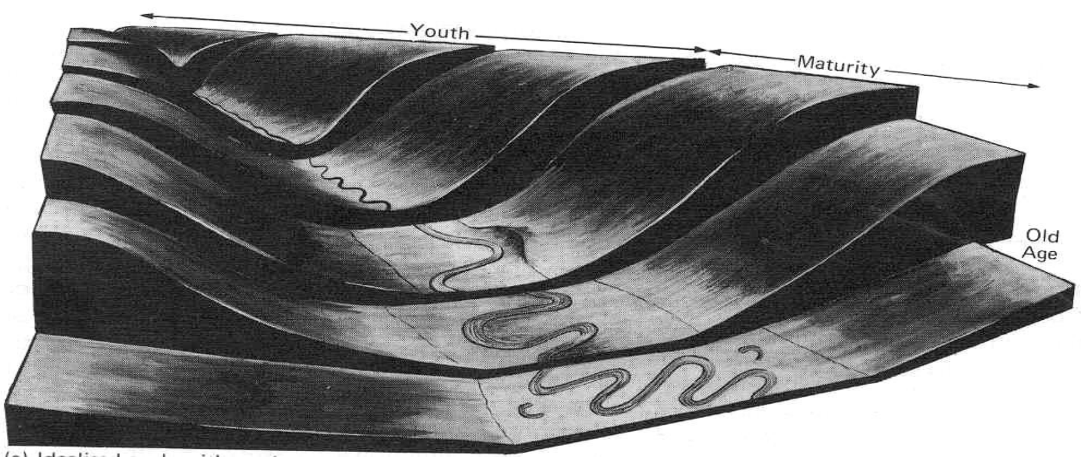
- **Due to this, the type and assemblages of Land forms will be unique and self styled in each stage**

- **And these need to be mapped critically and models to be built**
  - **for natural resources**
  - **environmental modelling**
  - **disaster mapping and mitigation**

LIFE HISTORY OF RIVERS

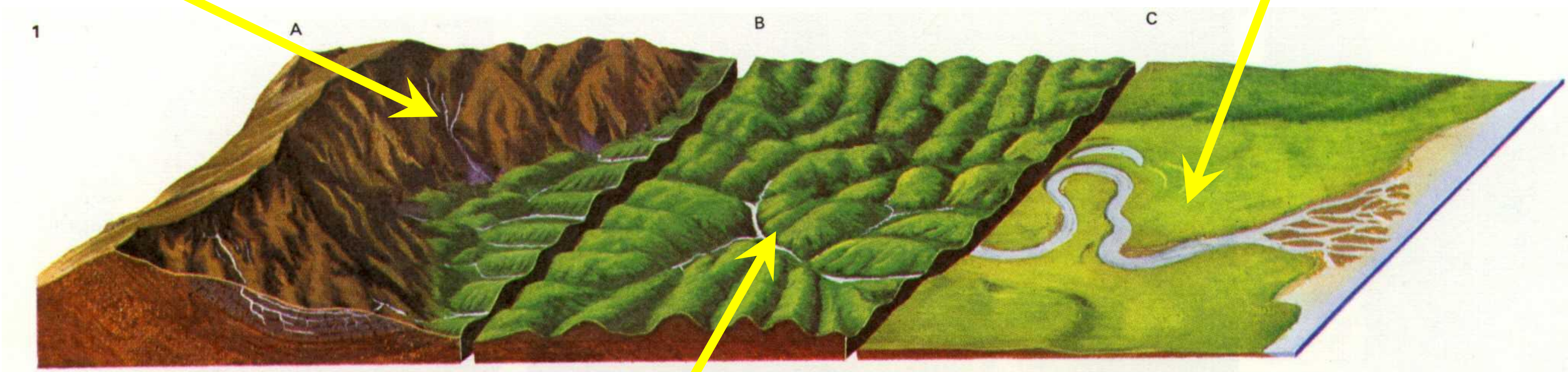
STREAMS SHOW THREE STAGES OF GRADATION FROM MOUNTAINS TO THE SEA:





C: old age or lower stage

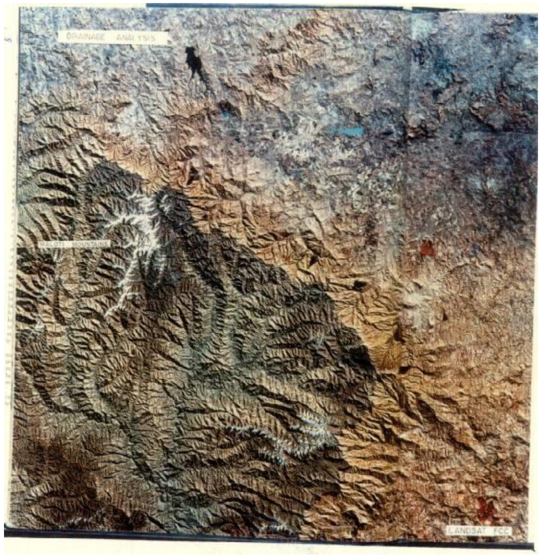
A: youthful or upper stage



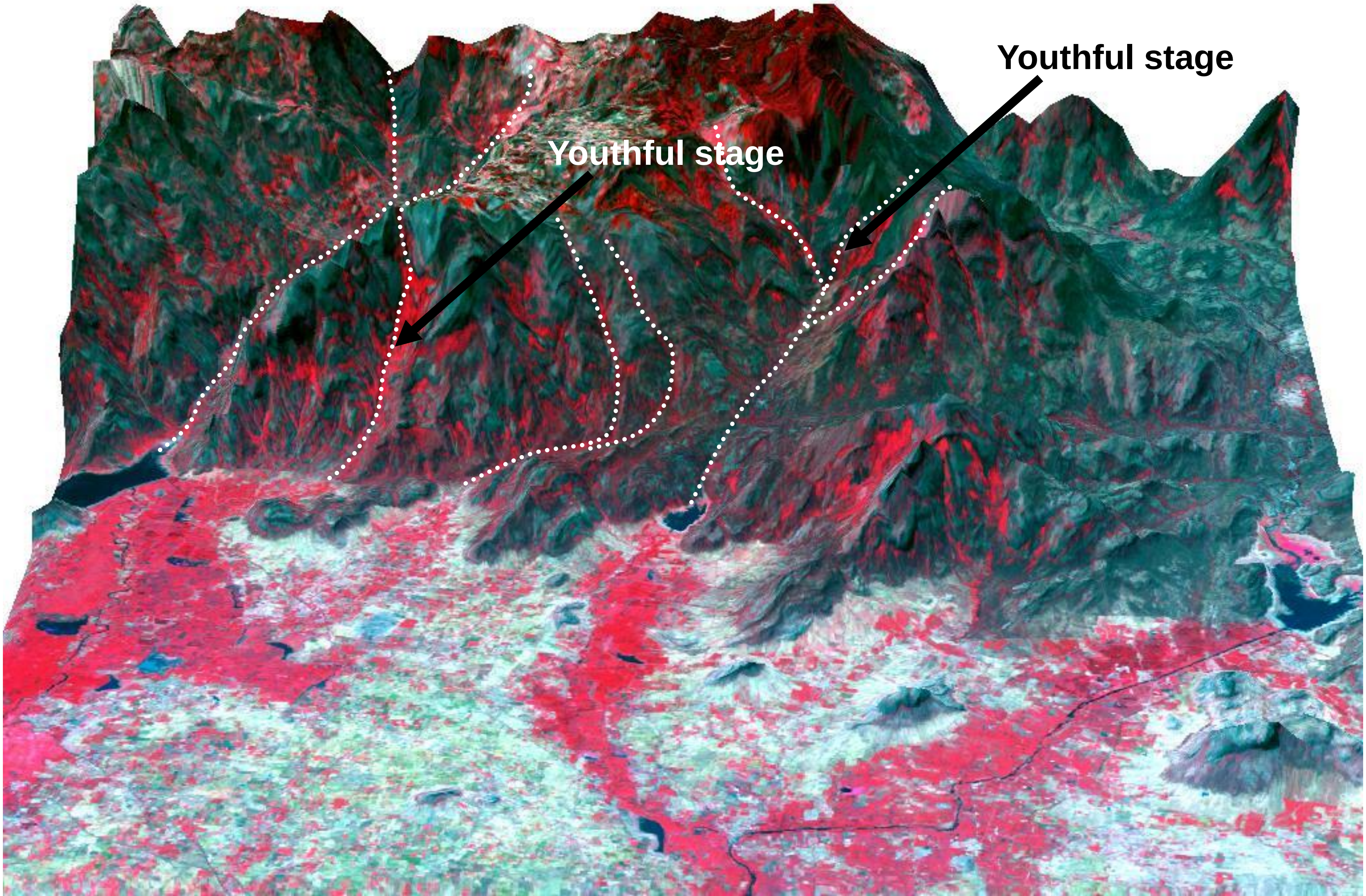
B: mature or middle stage

Youthful Stage

- **River is in catchment area**
- **Terrain gradient high**
- **River has more energy**
- **Much above sea level**
- **Hence erosion is the dominant process**
-
- ***Called Torrential phase***

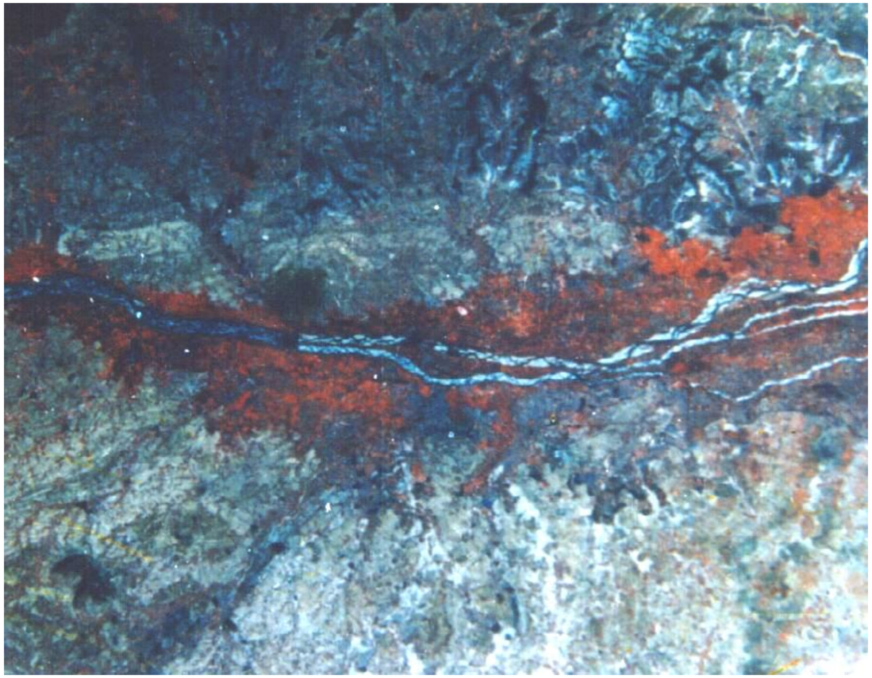


Youthful stage of River

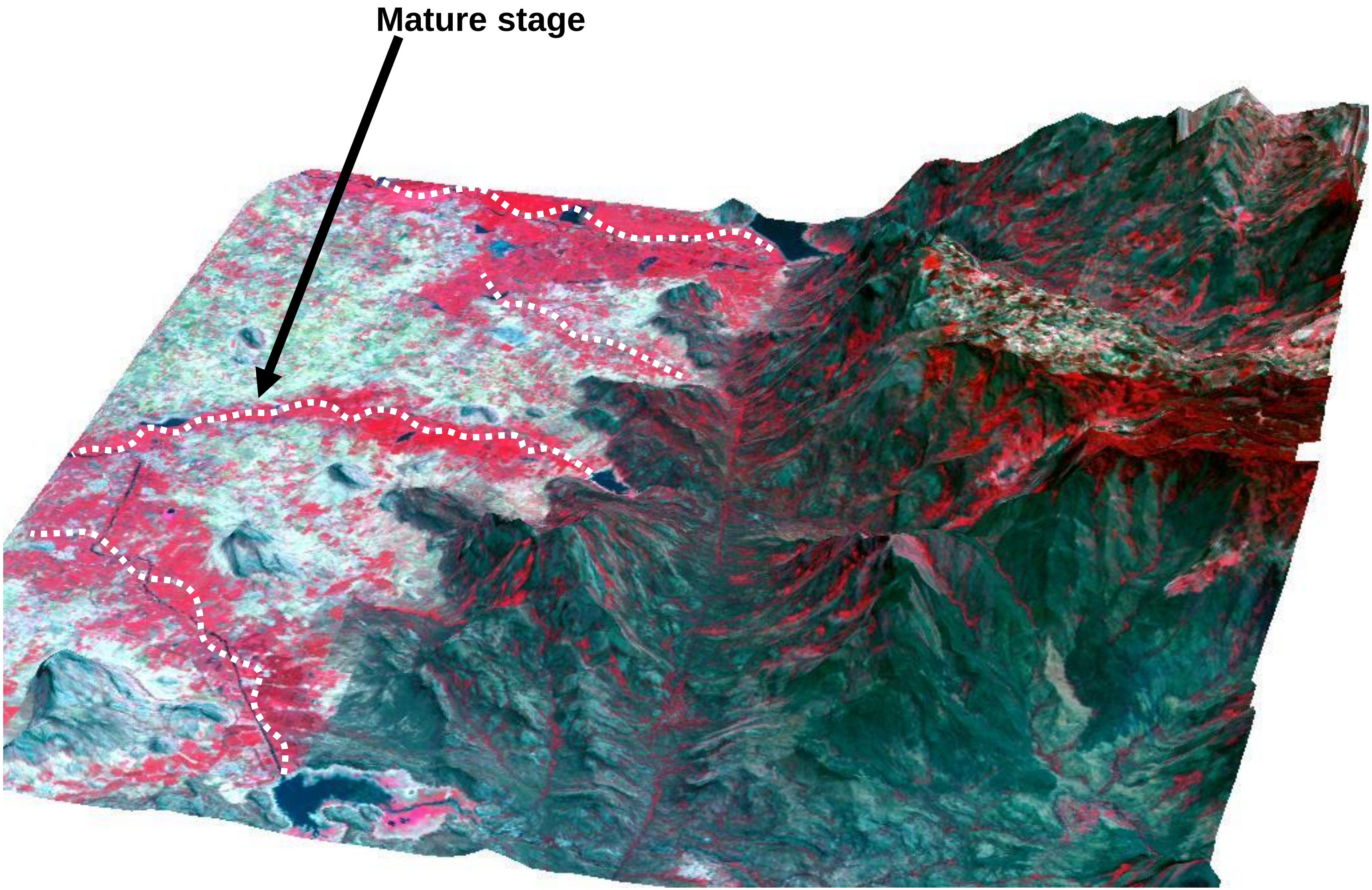


MATURE STAGE

- ➔**River runs in the plains**
- ➔**Little above MSL**
- ➔**Hence both erode and deposit**
- ➔**Mostly controlled by geological structures**
- ➔***called as "watch & walk phase"***

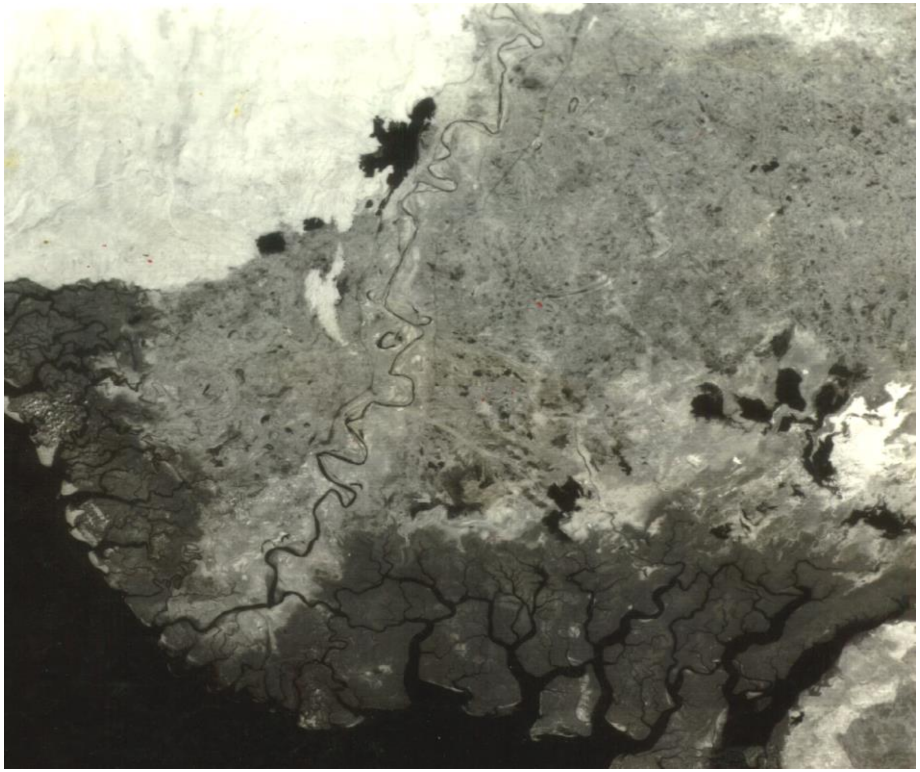


Mature stage of the River

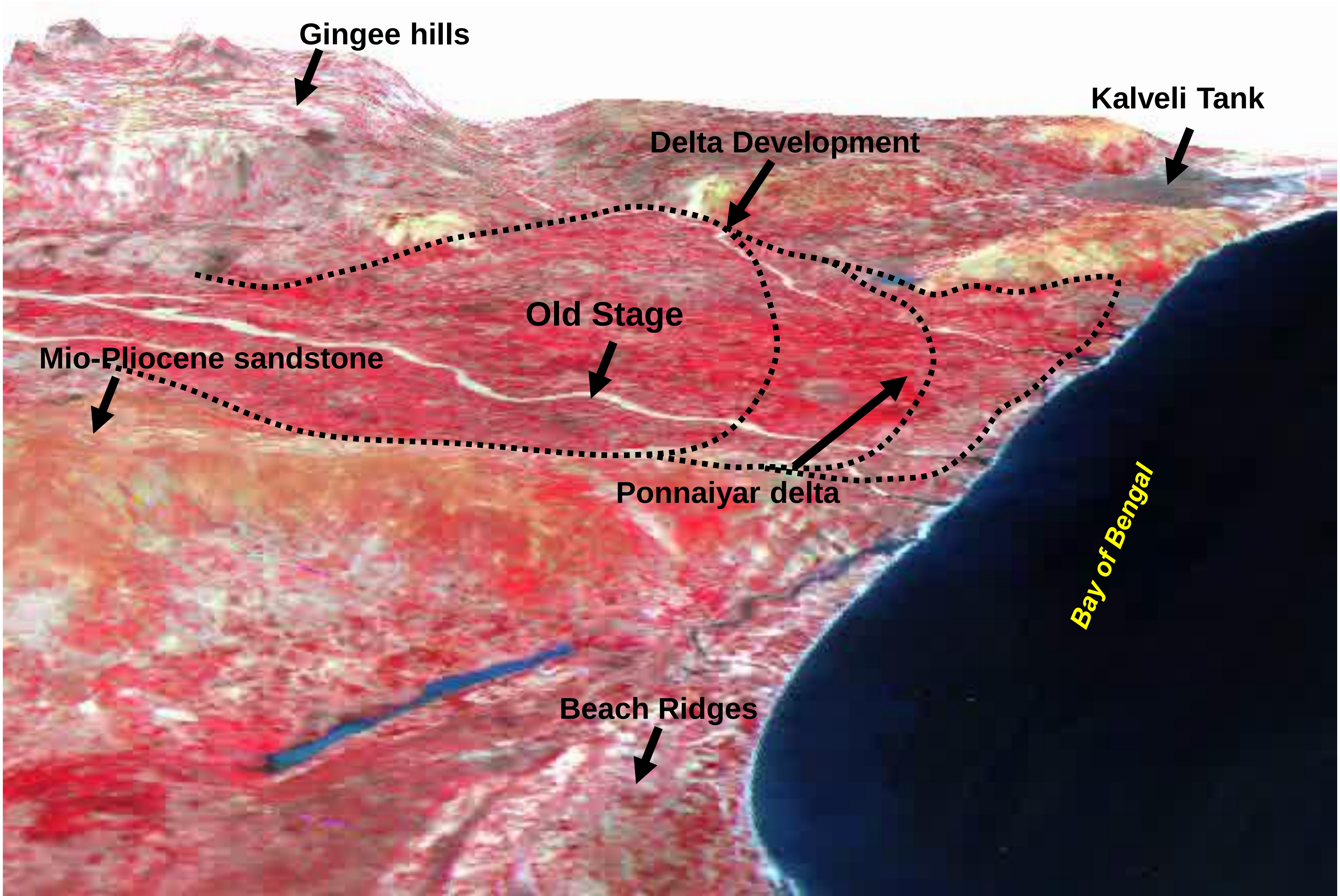


OLD STAGE

- ➔**Coastal zone**
- ➔**Sluggish movement**
- ➔**Terrain is flat**
- ➔**Only deposition will take place**
- ➔***called “brownian phase or movement***



Old stage of the River



LANDFORMS OF FLUVIAL ORIGIN

- ➔ Landforms of Youthful stage
- ➔ Landforms of Mature stage
- ➔ Landforms of Old stage

Landforms of Youthful stage

(A) Destructional Landforms

(B) Constructional landforms

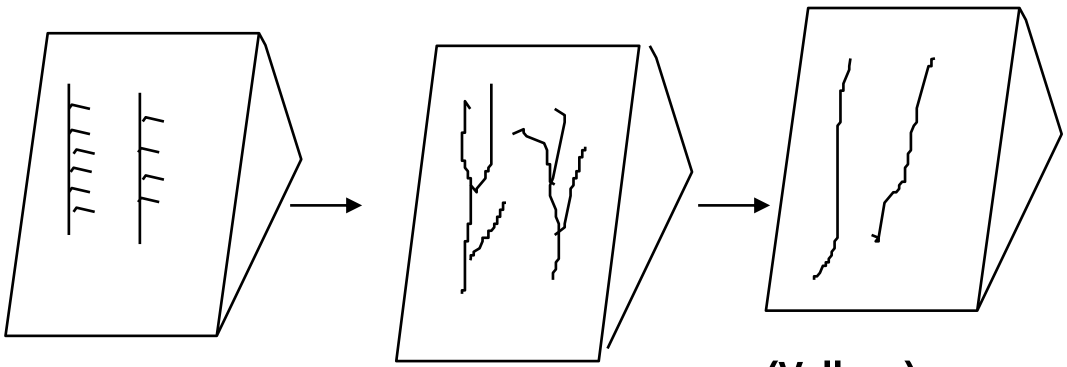
(A) Destructional Landfroms

Valleys

A valley is a longitudinal depression whose cross section is V shaped
Three processes in valley developments such as 1.valley deepening, 2. valley widening and 3. valley lengthening

Valley deepening due to the bedrock erosion

a) Origin of valleys



(Gullies) (Ravines) (Valleys)

RIVER VALLEYS The extended depression on ground through which a stream flows throughout its course is called a river valley at different stages of the erosinal cycle

the valley acquires different profiles. At a young stage, the valley is deep, narrow with steep wall-like sides and a convex slope. The erosional action here is characterised by predominantly vertical downcutting nature. The profile of valley here is typically 'V' shaped.

As the cycle attains maturity, the lateral erosion becomes prominent and the valley floor flattens out. The valley profile now becomes typically 'U' shaped with a broad base and a concave slope.

A deep and narrow 'V' shaped valley is also referred to as gorge and may result due to downcutting erosion and because of recession of a waterfall. Most Himalayan rivers pass through deep gores (at times more than 500 metres deep) before they descend to the plains.

An extended from of gorge is called a canyon. The Grand Canyon of the Colorado river in Arizona (USA) runs for 483 km and has a depth of 2.88 km

b) Classification of valleys

i) **Glacial valleys**

ii) **Tectonic valleys**

iii) **River valleys**

c) Limit of valleys

i) Depth of valleys

Height of valleys above base level of erosion

ii) Length of valleys

Valley can't grow in the tail, it can grow only in the head It is called as length of valleys or 'head ward' erosion

iii) Width of valleys

IG4e_16_05

Features of erosion

a) Rill erosion

- Deep cuttings
- Closely spaced, almost parallel
- Due to softer lithologies and loose soil

b) Gully erosion

- Rills get widened into **‘V’** shaped valleys called gully erosion

c) Sheet erosion

- Gullies widened into sheets
- *removal blanket after blanket*

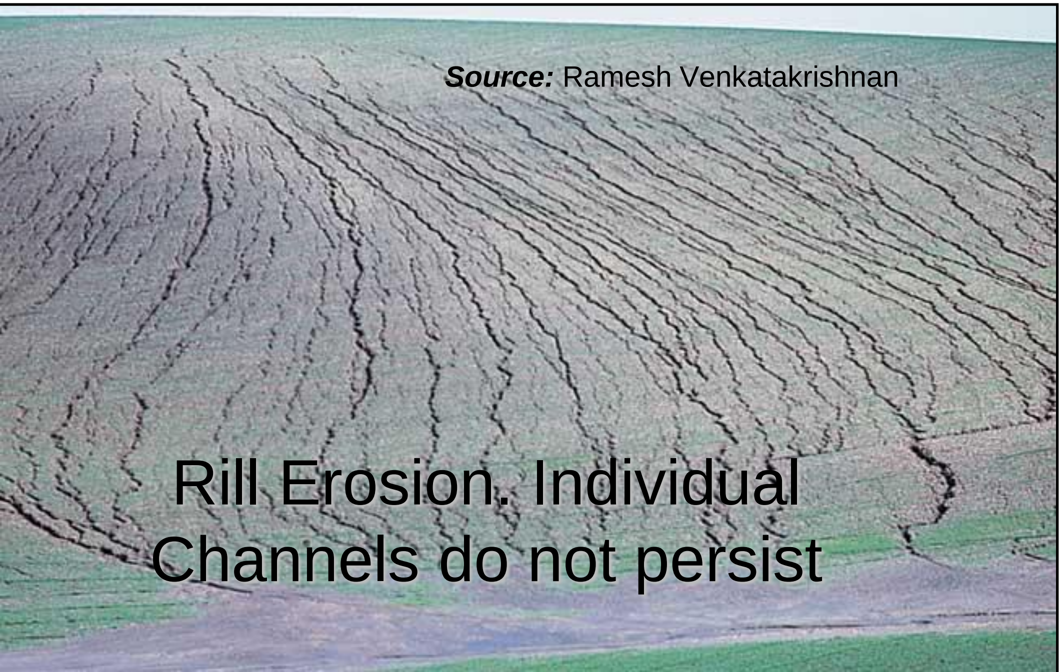
d) Gorges and Canyons

- Undercutting is more when compared to lateral cutting

Rill Erosion, Gully formation

Rill: a trickle of water, a very small stream

Gully: a small watercourse with steep sides, usually cut into soil

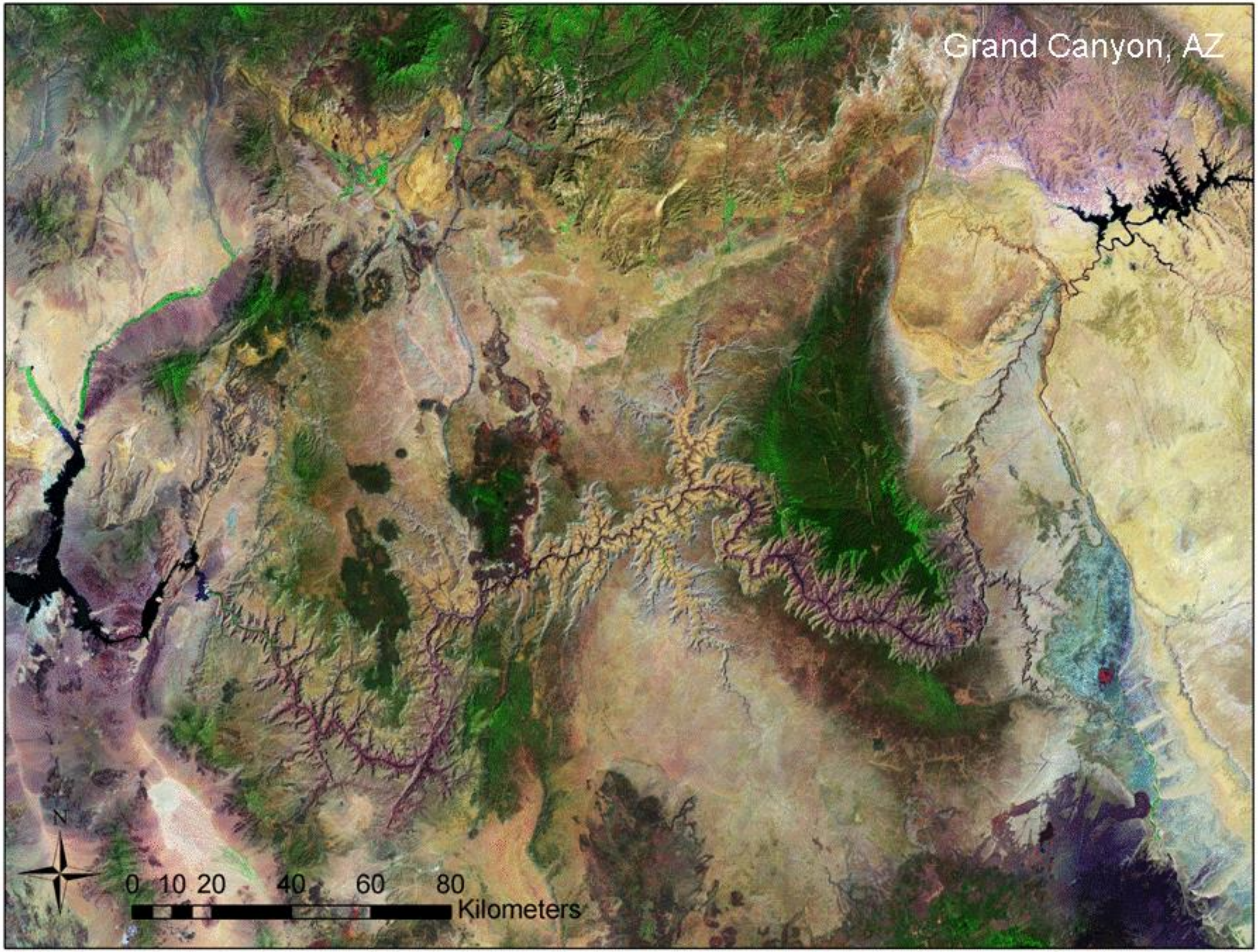


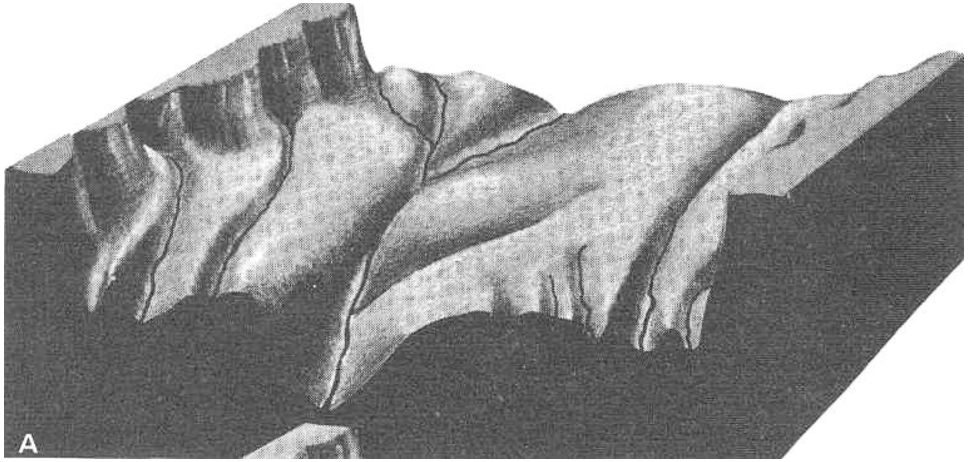
Rill Erosion: **concentrated flow pattern in numerous parallel seams flowing downslope, rills may coalesce into larger features known as gullies**

Gully Erosion **is larger, channelize flows carrying the potential for large amount of sediment.**

Rill and Gullies common in semi-arid areas with sparse vegetative cover and high erosion potential.

Deforestation and devegetation can result in greatly accelerating the erosion process.


Grand Canyon, AZ
N
0 10 20 40 60 80
Kilometers

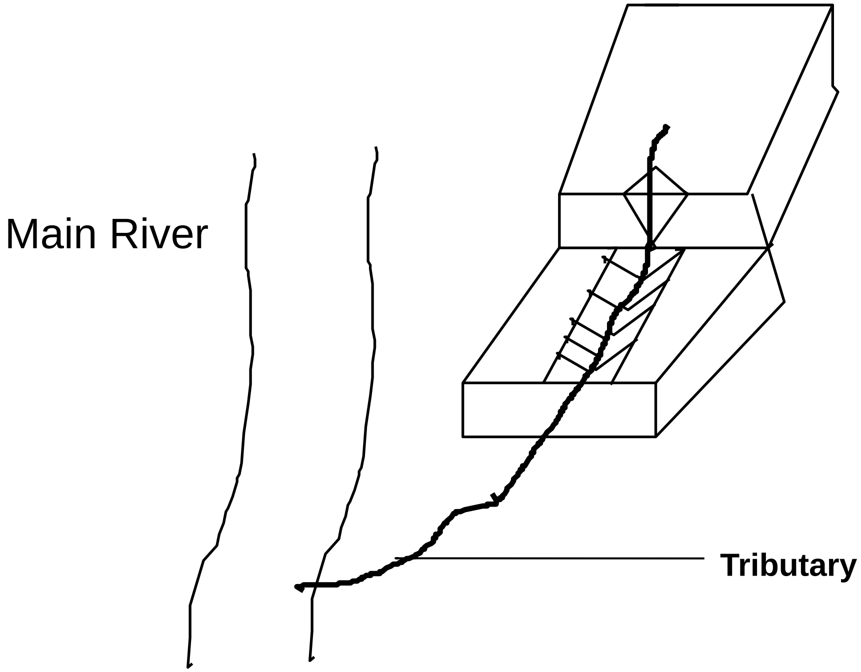


Gullies

Gullied Plateau

iv) Hanging valleys

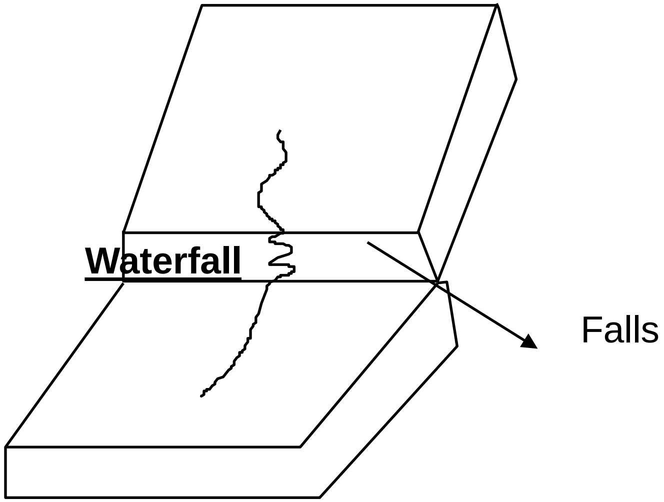
Valley of tributary lying above the main river



Water falls

WATERFALLS A waterfall is simply the fall of an enormous volume of water from a great height, because of a variety of factors such as variation in the relative resistance of rocks, relative difference in topographic reliefs, fall in the sea level and related rejuvenation, earth movements etc. For example, jog or Gersoppa falls on Sharavati (a tributary of Cauveri) has a fall of 260 metres.

➔ **a) due to faulting**

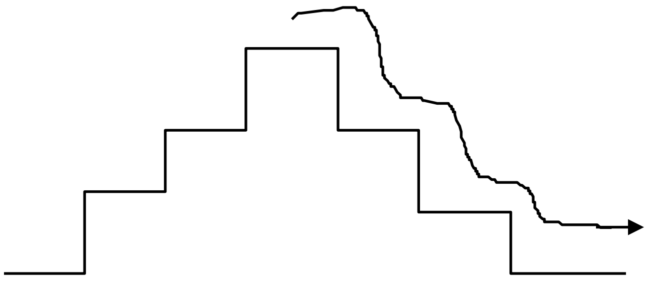


➔ **b) due to hanging valleys**

Due to difference in heights of valley of the tributary and valley of the main streams, the tributary will meet the main river through a water fall

Niagara Falls due to faulting

c) **<u>Due to plateau land forms</u>**



WATERFALL: Plunging down of water over a cliff is termed as water fall

RAPID: is one on which water flows along a steep slope

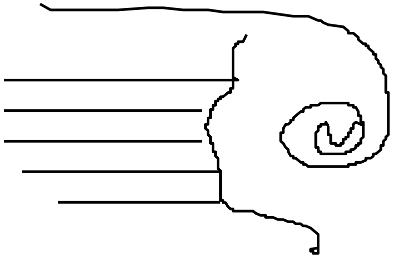
CASCADE: If water flows over step like terraces are known as cascades

Waterfalls

Rapids

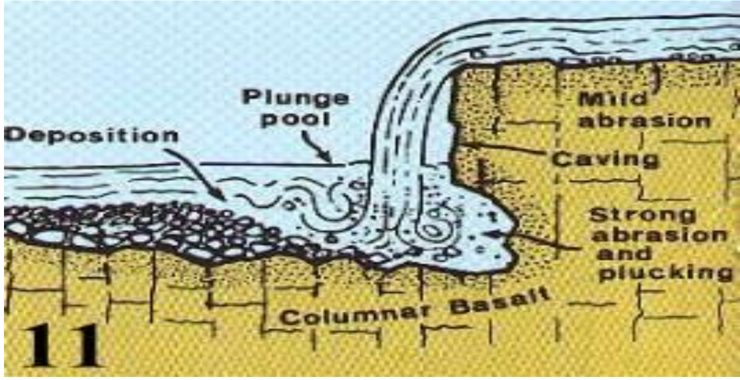
Cascade

Pot holes



POT HOLES The kettle-like small depressions in the rockly beds of the river valleys are called pot holes which are usually cylindrical in shape. Pot holes are generally formed in coarse-gained rocks such as sandstone and granites.

- **Pot holes are smaller depression found on bed rock of stream**
- **Plunge pools are larger pot holes usually found on the bottom of the water falls**



The Work of Streams

streams erode their beds and banks by hydraulic action, abrasion, and corrosion

abrasion by stones on a bedrock riverbed can create deep depressions known as potholes

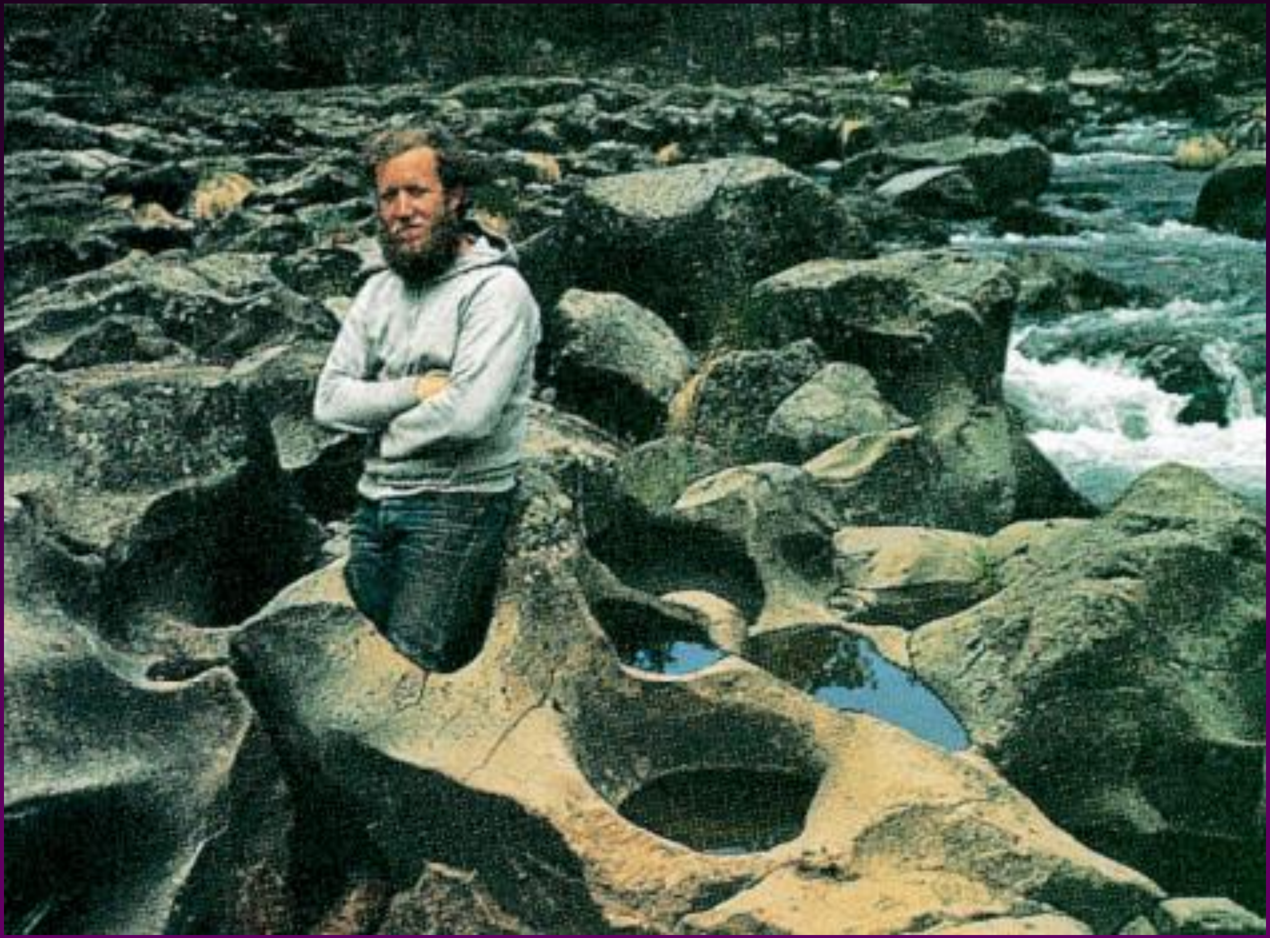
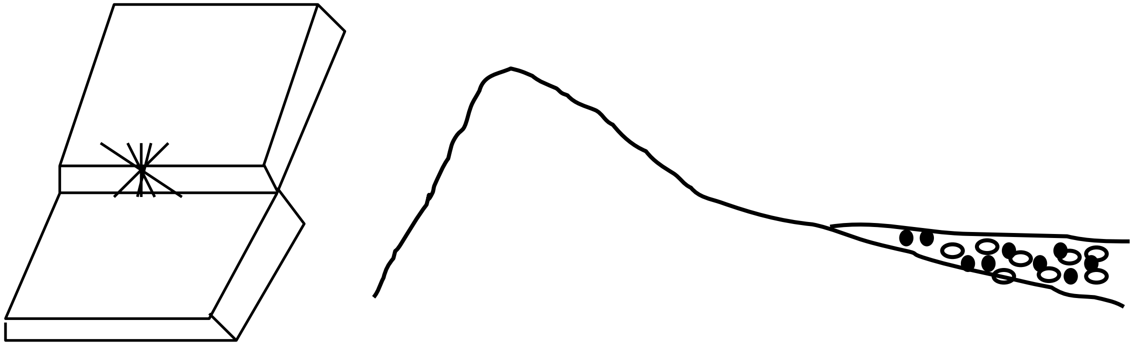


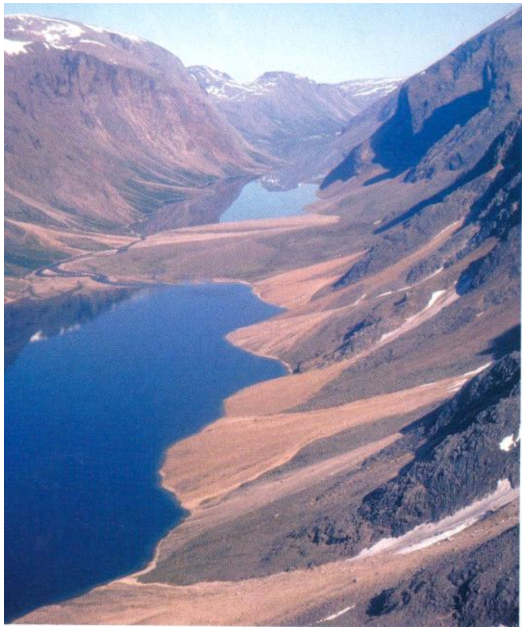
Figure 16.6, p. 551

(B) Constructional landforms

Alluvial cone/Fan



Finer material on top coarser in the bottom



➔ Bottom better for heavies

➔ Bottom better for GW / natural spring

➔

➔ < 25 degree Alluvial fan

Fluvial Landscapes

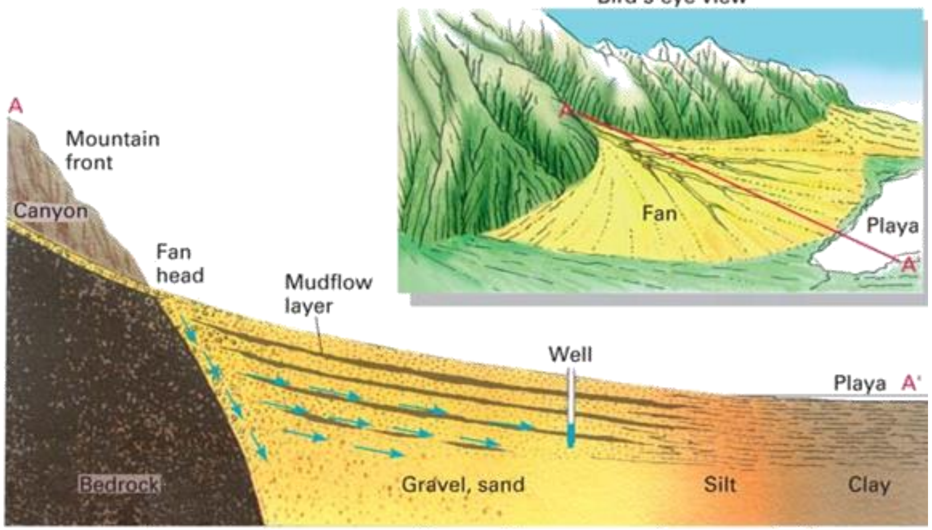
Alluvial Fans

Alluvial fan: gently sloping, conical accumulation of coarse alluvium deposited by a braided stream

Alluvial fans

- Long, low, triangular-shaped accumulated sediment apron
- Found at drainage mouths
- Morphology is dependent on:

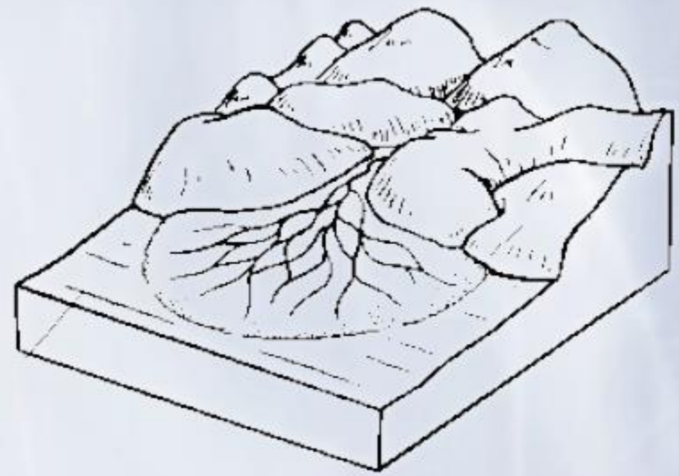
•Area of drainage basin,
•Lithology,
•Tectonism
•Climate
•Available space

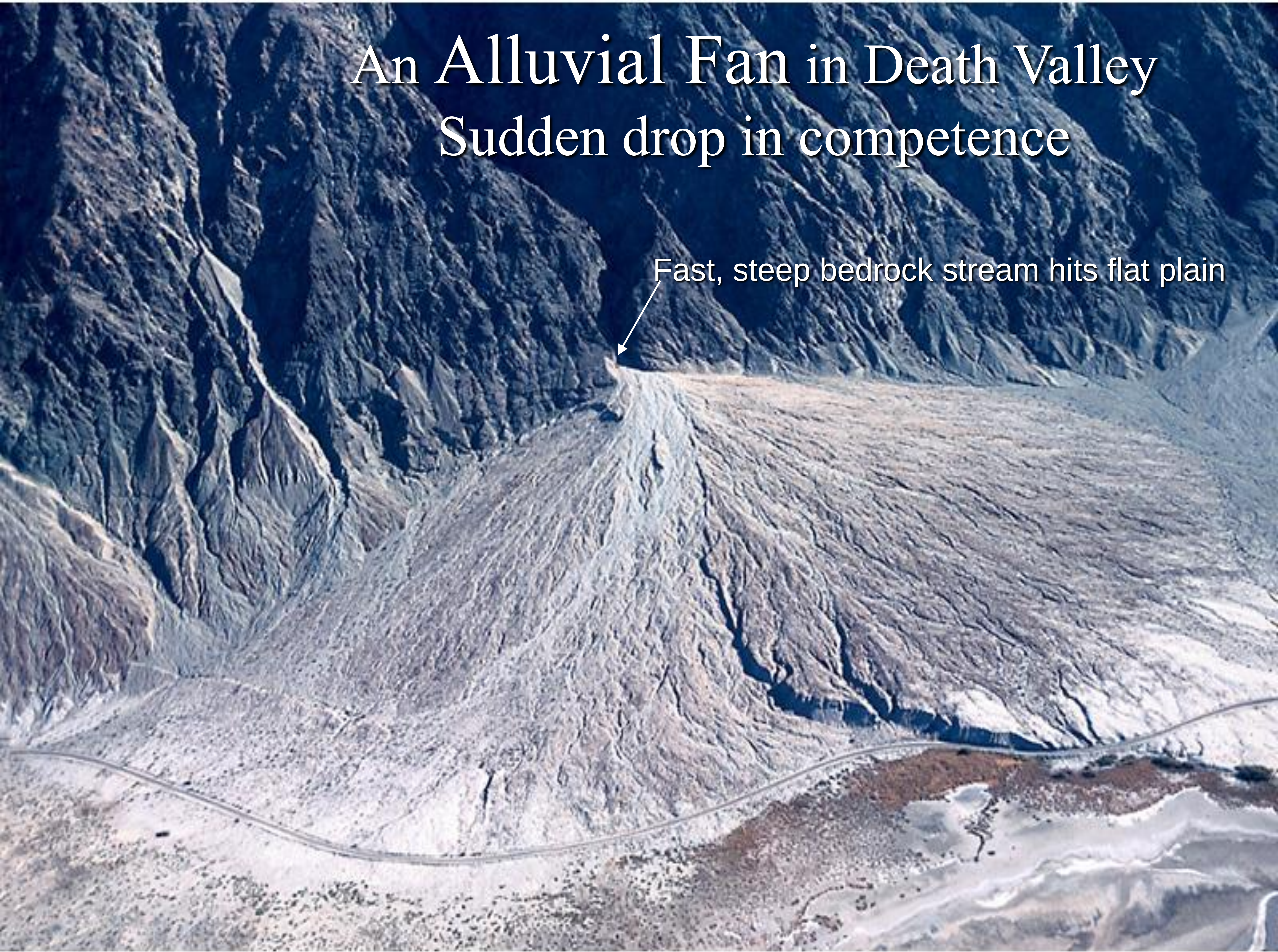


Cross section

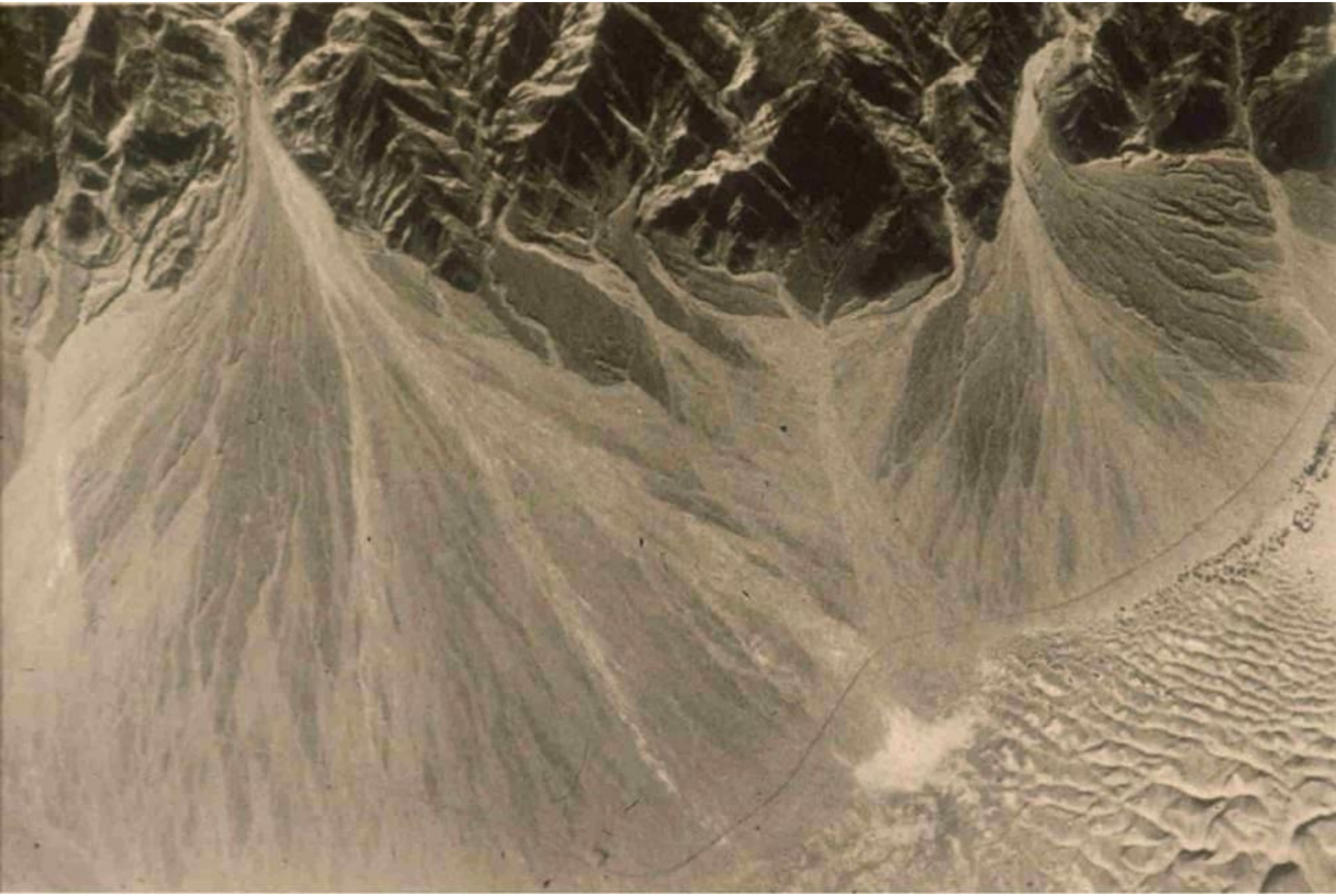
Alluvial Fans

- Fan-shaped deposit where a fast flowing stream flattens, slows, and spreads, typically at the exit of a canyon onto a flatter plain.
- Sediment introduced at the apex will tend to a state that minimizes the transport energy plus the gravitational potential of the material.
- This leads to *distributary channels* and deposition of sediment in a characteristic cone shape.




An Alluvial Fan in Death Valley
Sudden drop in competence
Fast, steep bedrock stream hits flat plain

Alluvial Fans



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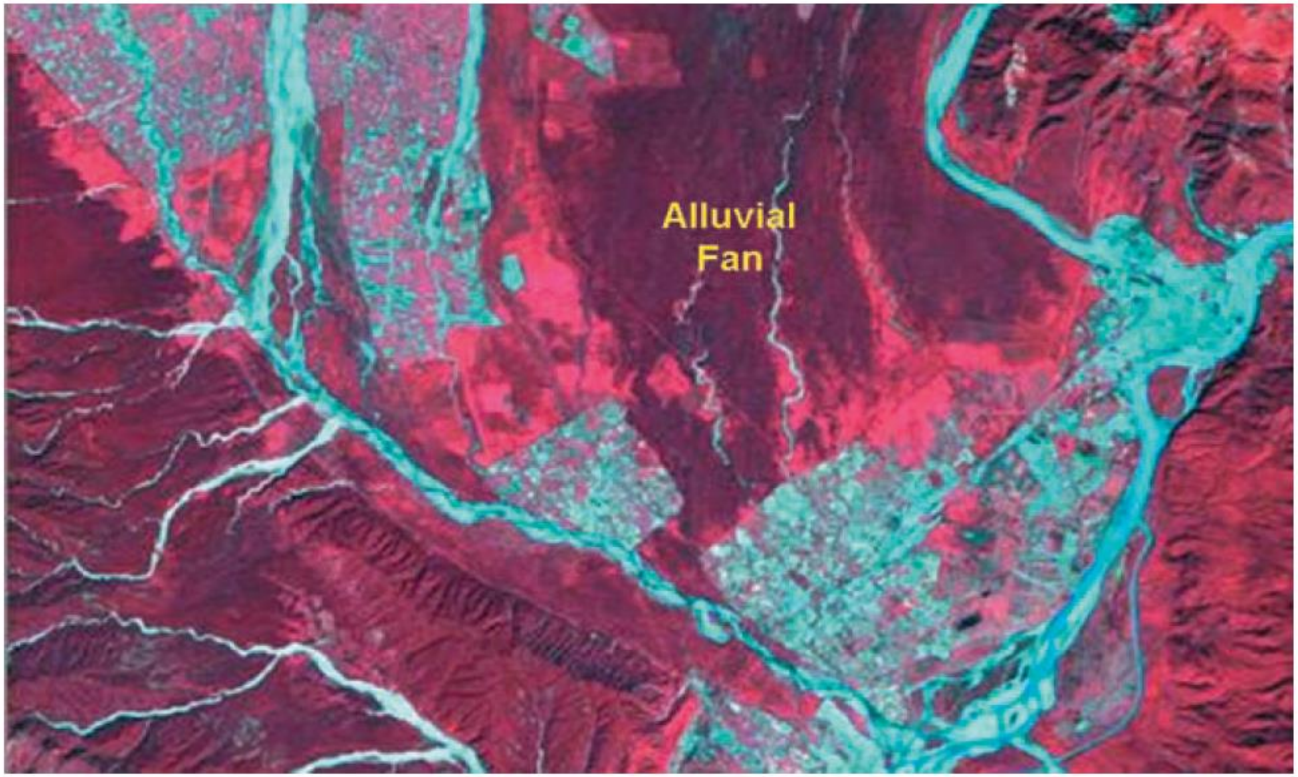
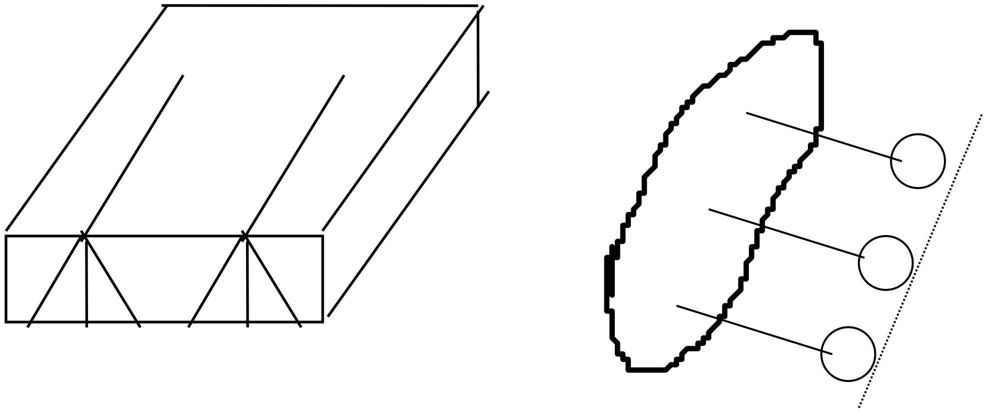


Fig. 2.38 Alluvial fan seen in the foot hills of the Himalayas. The bifurcating drainage from the foot hill is clearly seen. The Yamuna river is seen in the extreme east.

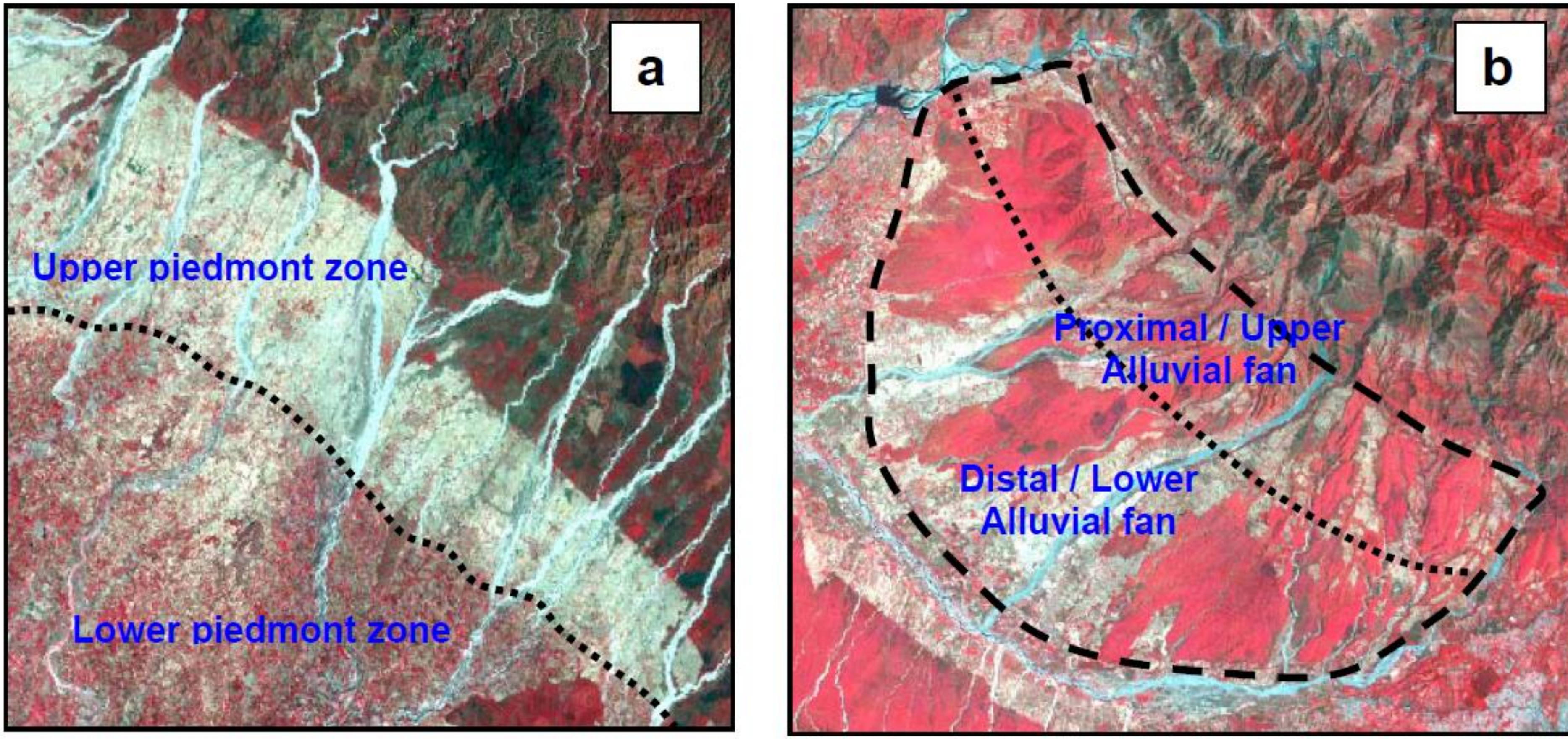
Piedmont zone



➔Due to coalescence of number of alluvial fans a narrow strip of loose sediments are formed fringing the hills called piedmont zone (e.g. (Western rime of Aravallis)

- ✦ Potential Ground water
- ✦ Lower zone for heavy Minerals
- ✦ Lower Zone Better Groundwater

Fig. 4.25: Satellite image of a) Siwalik foothills,   and b) a part of Doon valley.



Coalescing Alluvial Fans

Bazada: **A broad, continuous alluvial slope or gently inclined detrital surface extending along and from the base of the mountain range out into and around an inland basin, formed by the lateral coalescence of a series of separate but confluent alluvial fans, and having an undulating character due to the convexities of the component fans; it occurs most commonly in semiarid or desert region.**

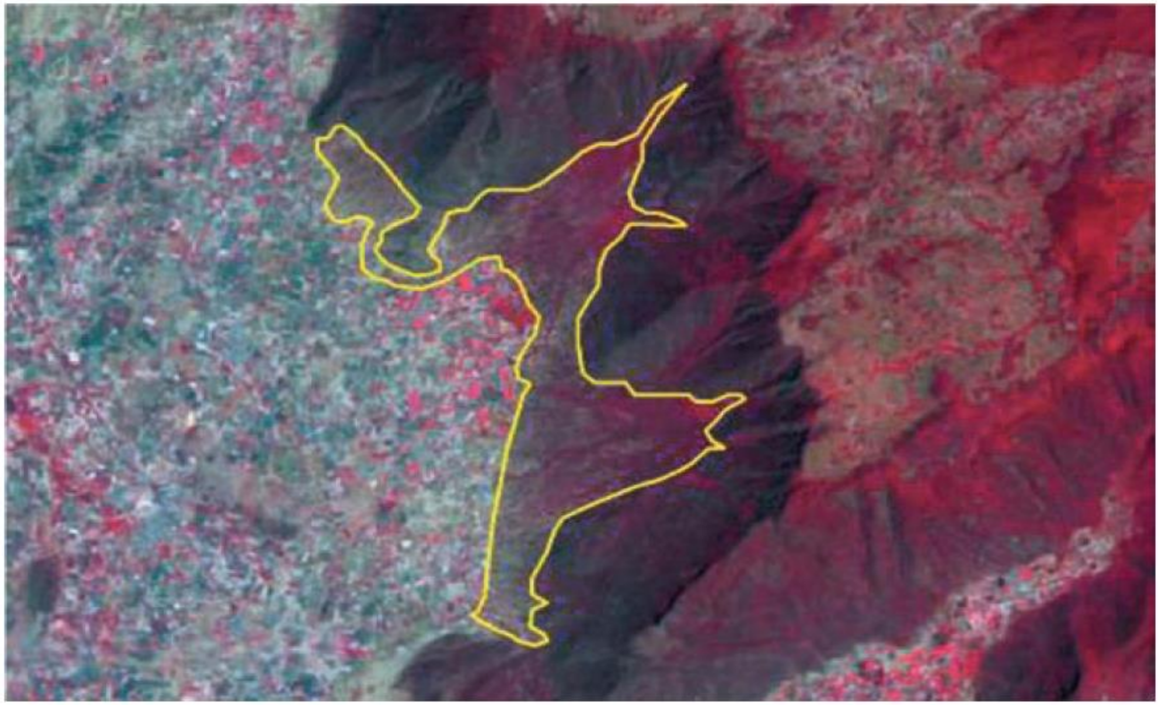
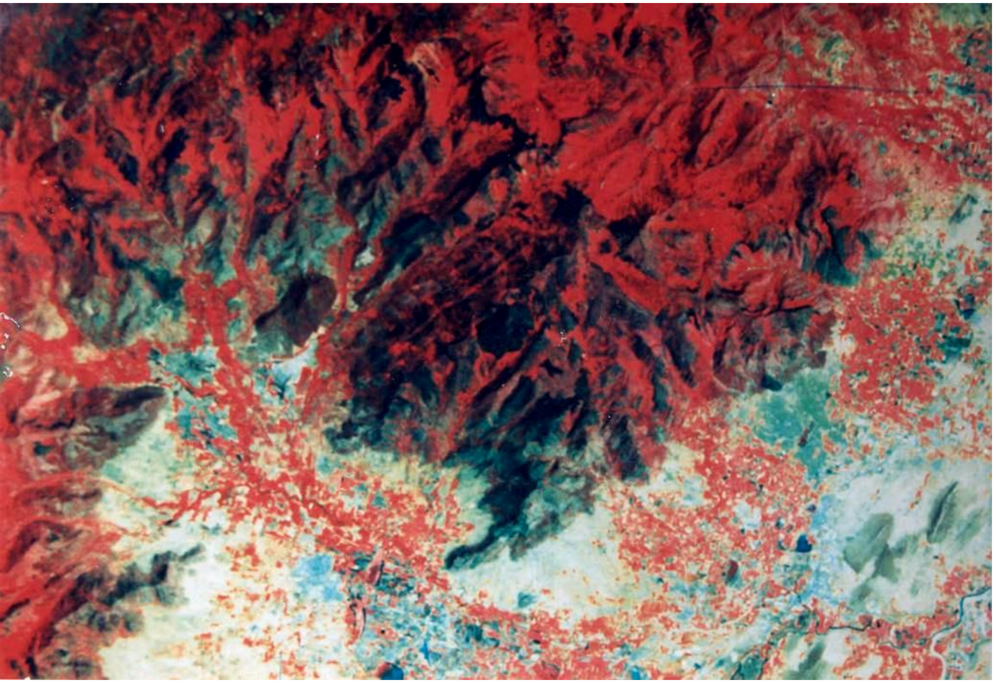


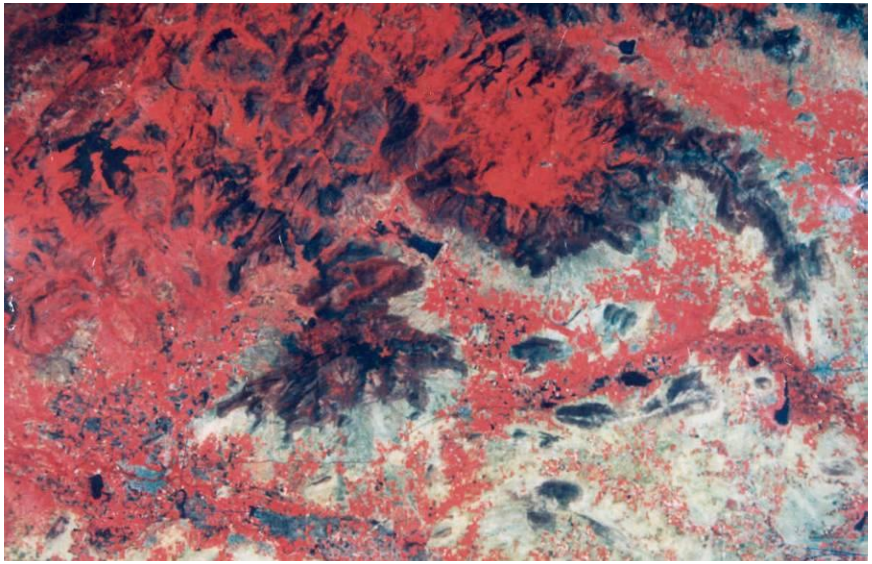
Fig. 2.26 Bajada in the foot hill of Pachamalai hills in Tiruchirappalli district, Tamil Nadu. It is a coalescence of alluvial fans. Diverging drainage lines on the top of the alluvial fans are visible.

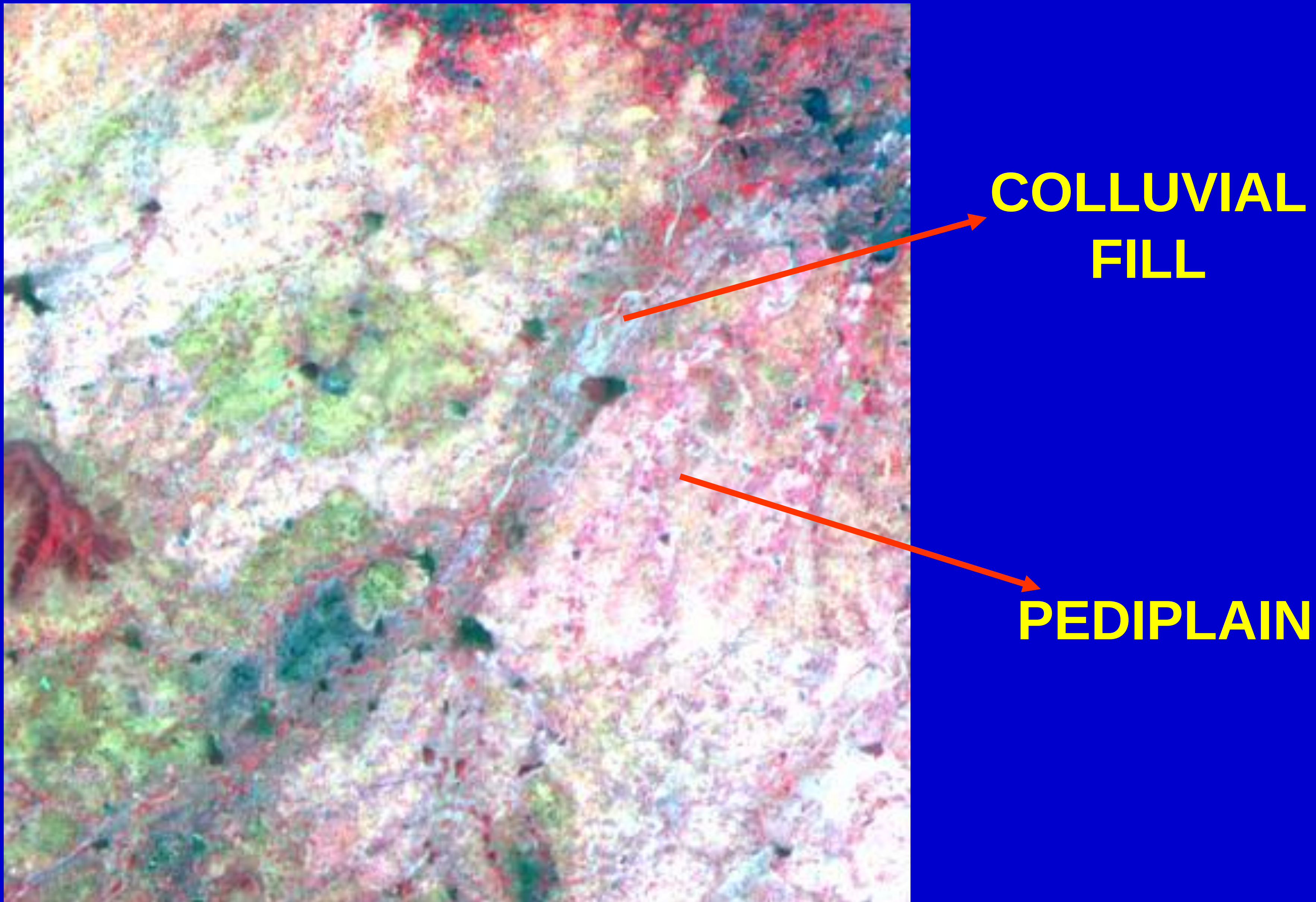
Valley fills

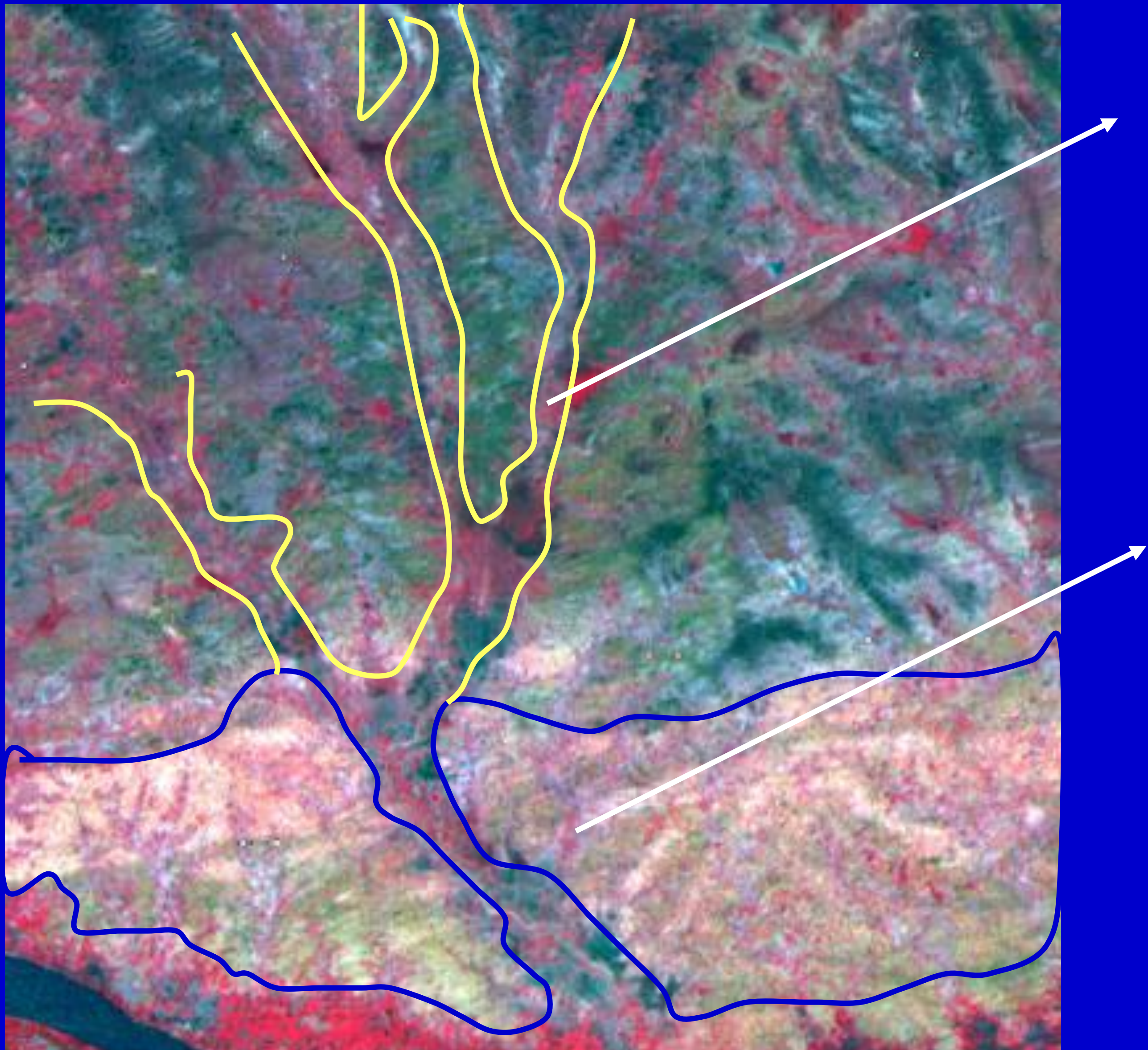
Valley fill: The unconsolidated sediment deposited by any agent so as to fill or partly fill a valley.

Colluvial fills






COLLUVIAL FILL
PEDIPLAIN


COLLUVIAL FILL
MODERATE
ROCKY
PEDIMENTS

LANDFORMS OF MATURE STAGE

- **Signature of mature stage**

  (i) Hills with diminished relief

  (ii) Flat topped hills, wide valleys

  (iii) Well developed dendritic drainages

  (iv) Absence of water falls, rapids

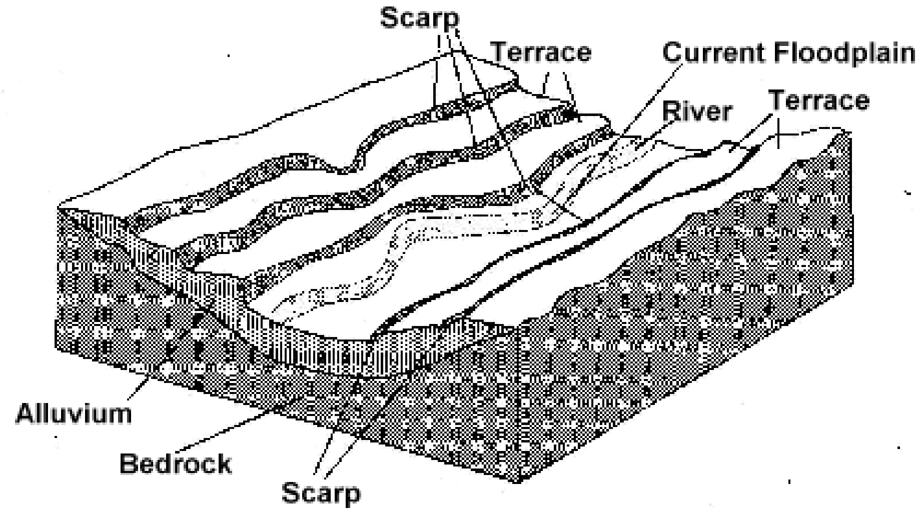
Stream cut terraces

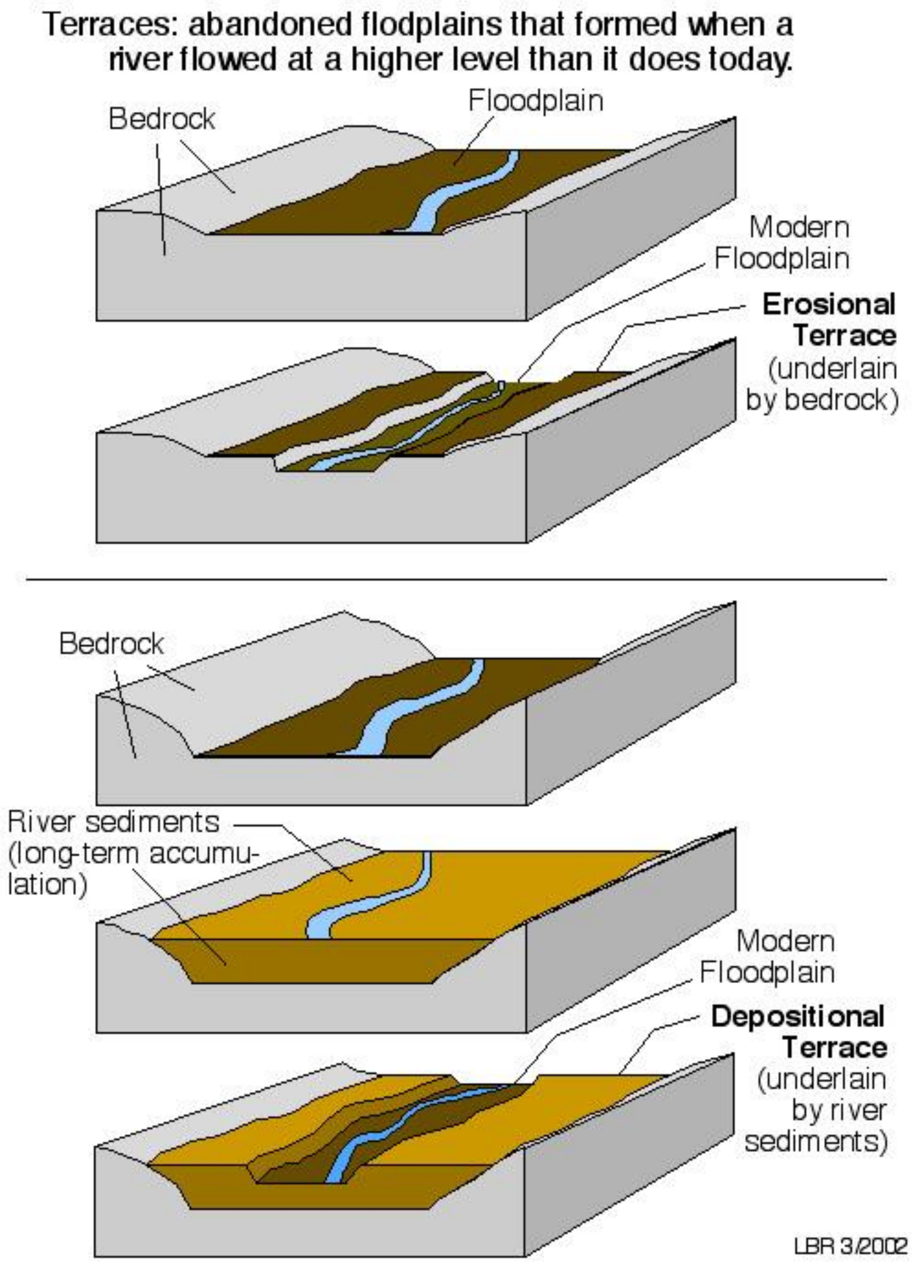
- Step like flat level surfaces cut by stream erosion
  - Paired: are the terraces equal in number and level carved on both banks of the river
  - Unpaired: number and level of the terraces are unequal on both the banks of the river.

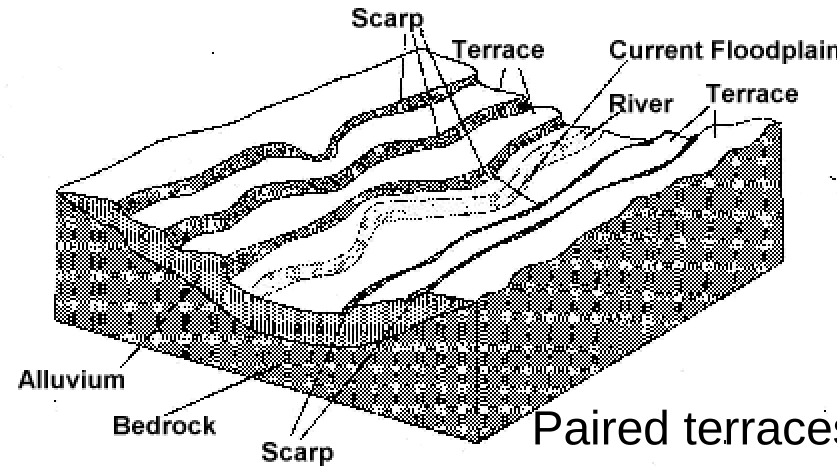
➔Due to fall of Flow rate

➔Rise of land

➔Fall of sea level







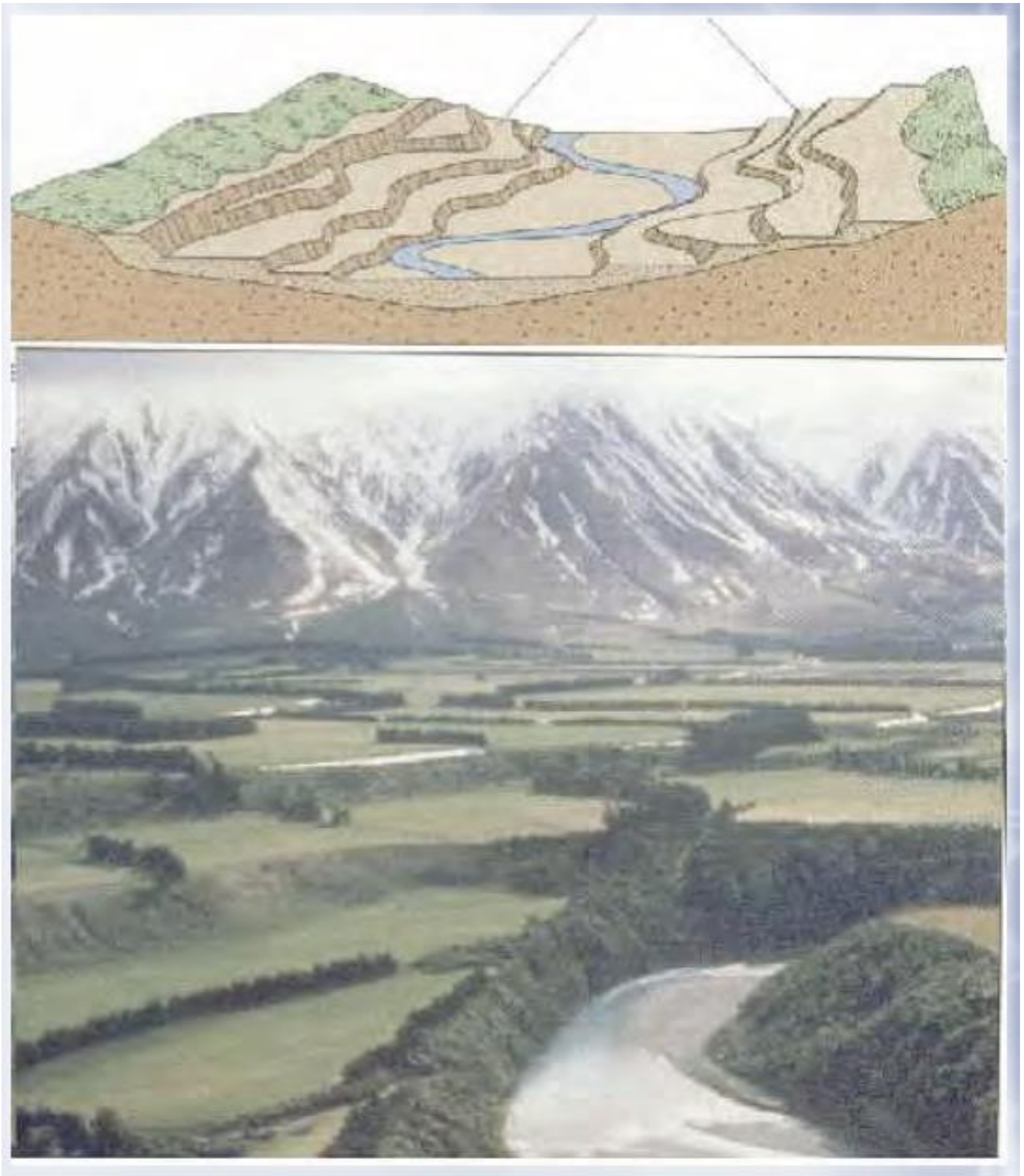
Paired terraces

Unpaired Terraces

Stream Terraces

Terraces are benches on the valley side formed when a stream cuts into a former floodplain. Most result from aggradation (deposition) followed by incision (erosion).

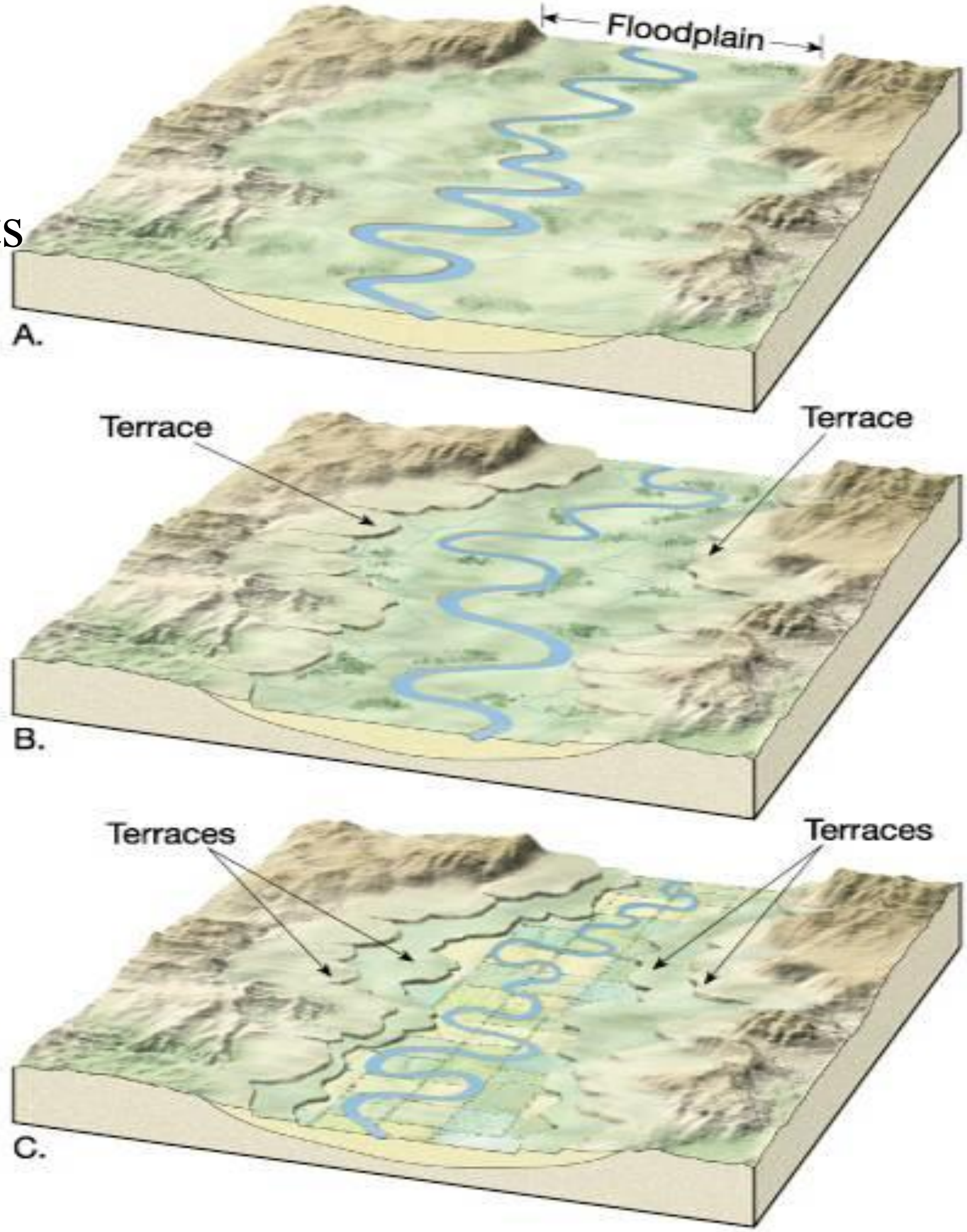
They occur when the balance between sediment supply and river discharge changes. This can happen because of climate change, or tectonic changes, including base level change.



Base level drops,
or region uplifts.
Water goes faster, stream cuts down into channel, straightens, new lower floodplain narrower.

Old, unused floodplain a terrace

Further incision cuts a new terrace



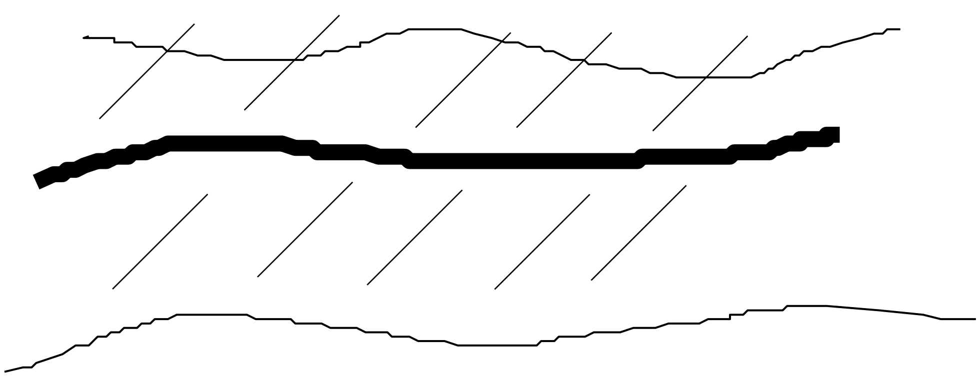
RIVER TERRACES - CHINA

Flood plains

➔when the river floods, the river deposits the loose sediments on either banks called Flood plains

➔Flood plains are the broad flat plains parallel to the river channel found by the lateral deposition of the stream during flood times.

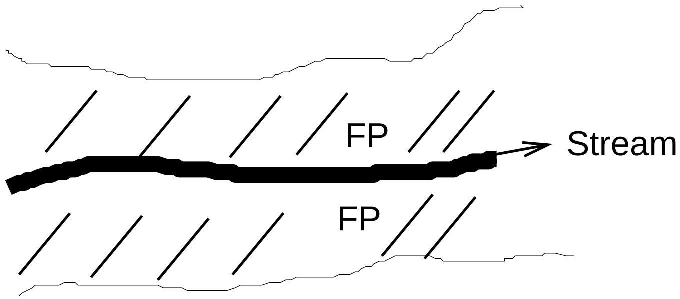
- It will have loose un consolidated sediments
- Retain more moisture
- Accumulate better Ground water
- Better recharge zone from river

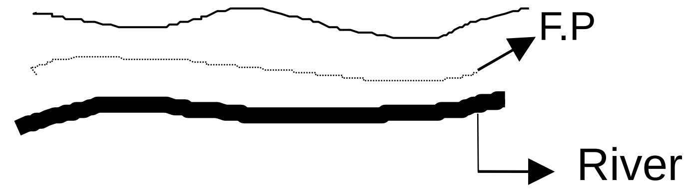


A **floodplain** is the flat land immediately surrounding a stream channel and innundated at times of high flow.

Floodplains can form either by deposition of overbank suspended sediment or by deposition of bedload as the channel migrates across its valley.

Paired Flood plain

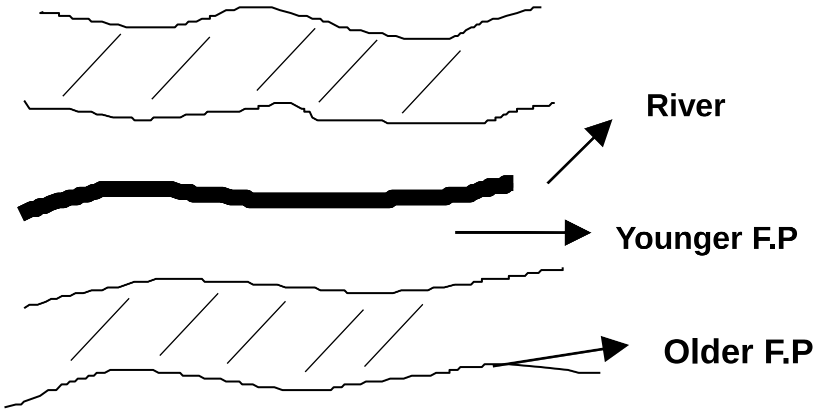




Unpaired Flood Plain

- ➔**Shifting river**
- ➔**Northern bank prone for erosion**
- ➔**Northern bank prone for flooding**
- ➔**Southern half have poor Ground water**
- ➔**Southern bank is emerging**

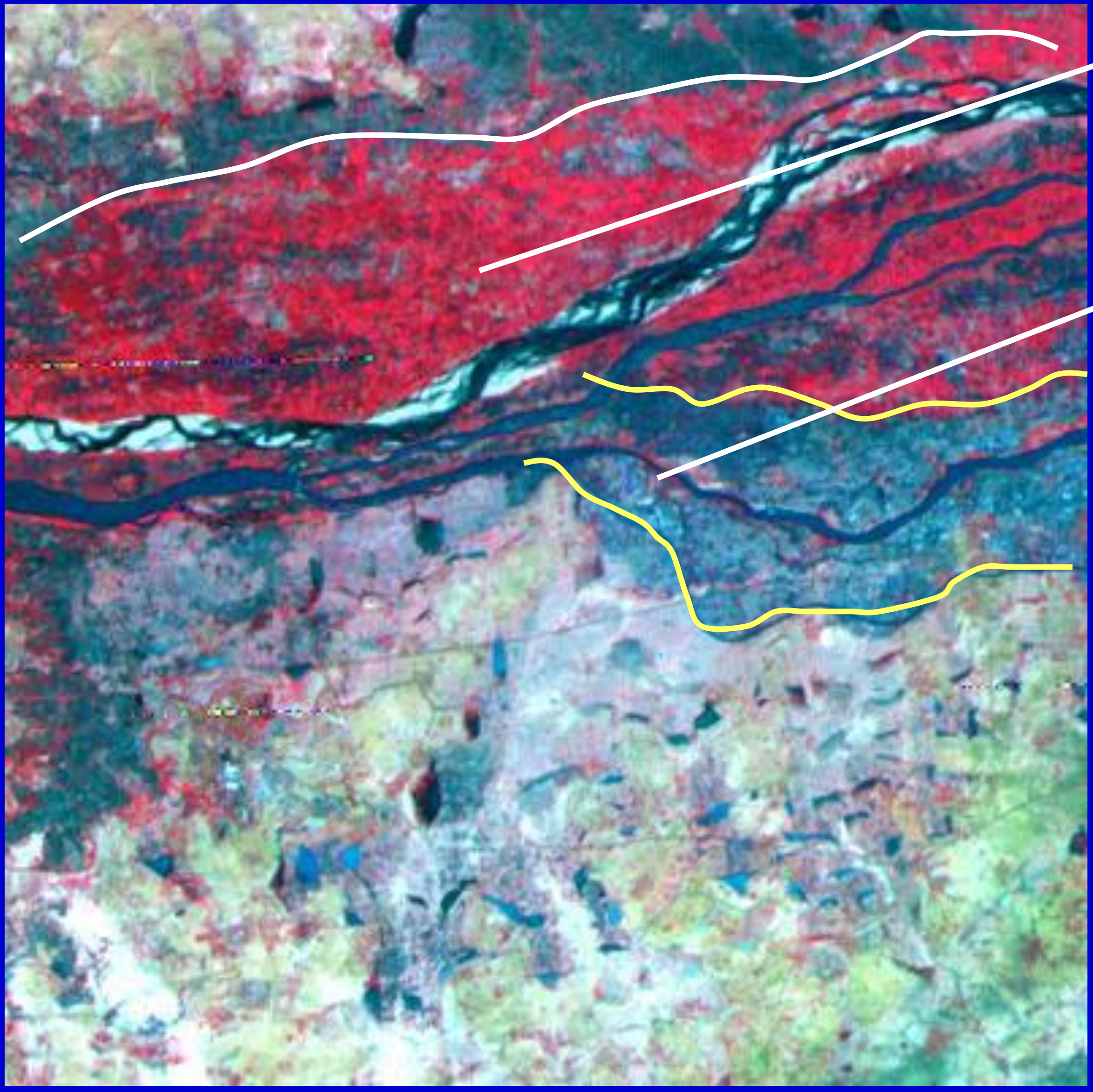
Older Flood plain and Younger Flood plain



- ➔ Show distinct two levels with contrasting tone
  - Reasons,
    - (i) Rise of land
    - (ii) Fall of sea level
    - (iii) Excessive daming

- ➔ Resources / Environment
    - (i) Younger Flood plain - better Ground water
    - (ii) Younger Flood plain - prone for flooding
    - (iii) Younger Flood plain - better recharge zone.

FLOOD PLAIN

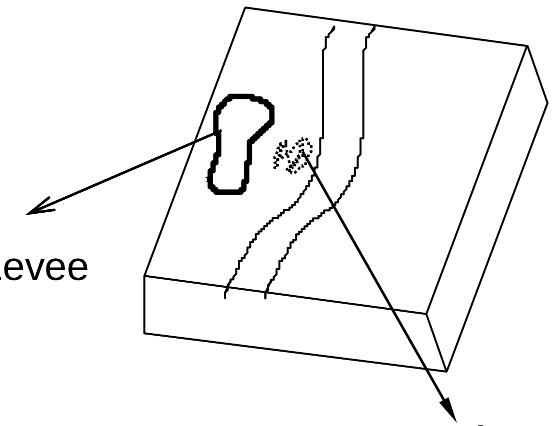


LOWER FLOODPLAIN

UPPER FLOODPLAIN

Paired Flood Plain

Natural Levees



➔ **Long lens shaped sand bodies at the bank of rivers**

- **Better Groundwater pockets**
- **Heavy Minerals**

Back swamp

➔ **Narrow depression between river bed and Levees**

- **Poor quality in Ground water**
- **Zone prone for flooding**
- **Poor area for bridges**
- **Black clay**

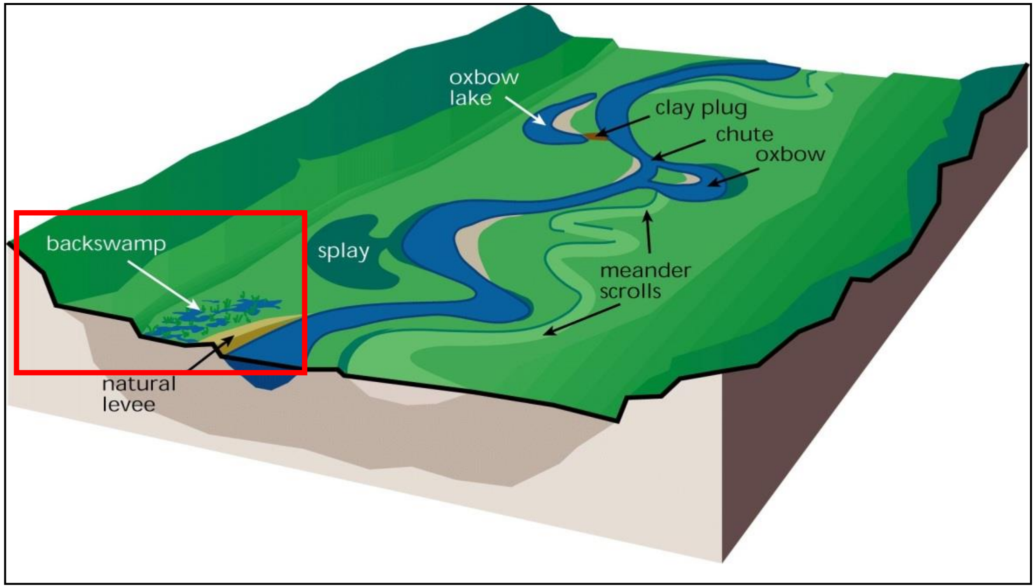
Levees

The boundary between channel and floodplain may be the site of a **natural levee** (a broad, low ridge of alluvium built along the side of a channel by debris-laden floodwater).

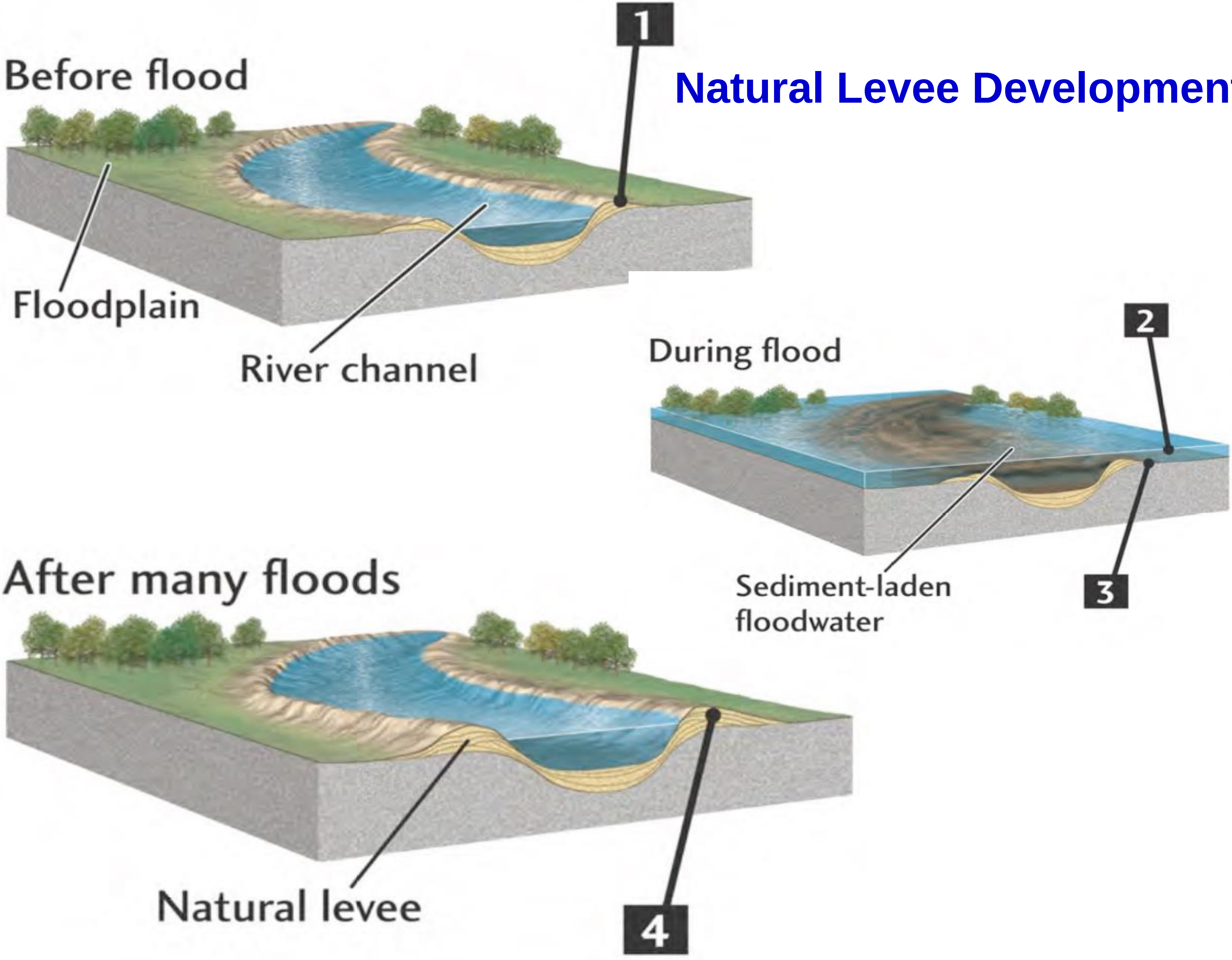
Levees form when debris-laden floodwater overflows the channel and slows as it moves onto the floodplain.

Backswamp

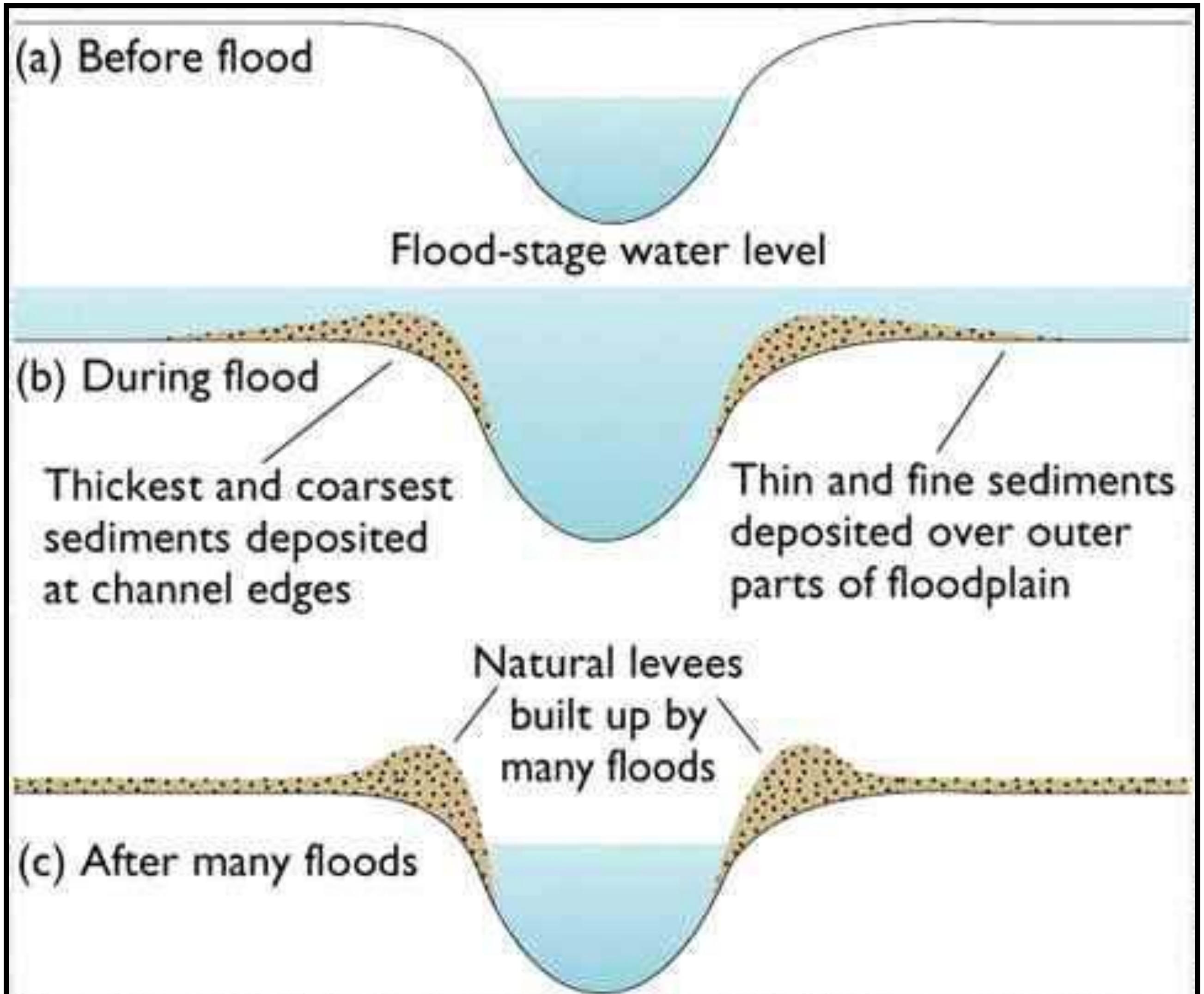
A low area of swampy ground beyond a river's natural levees.

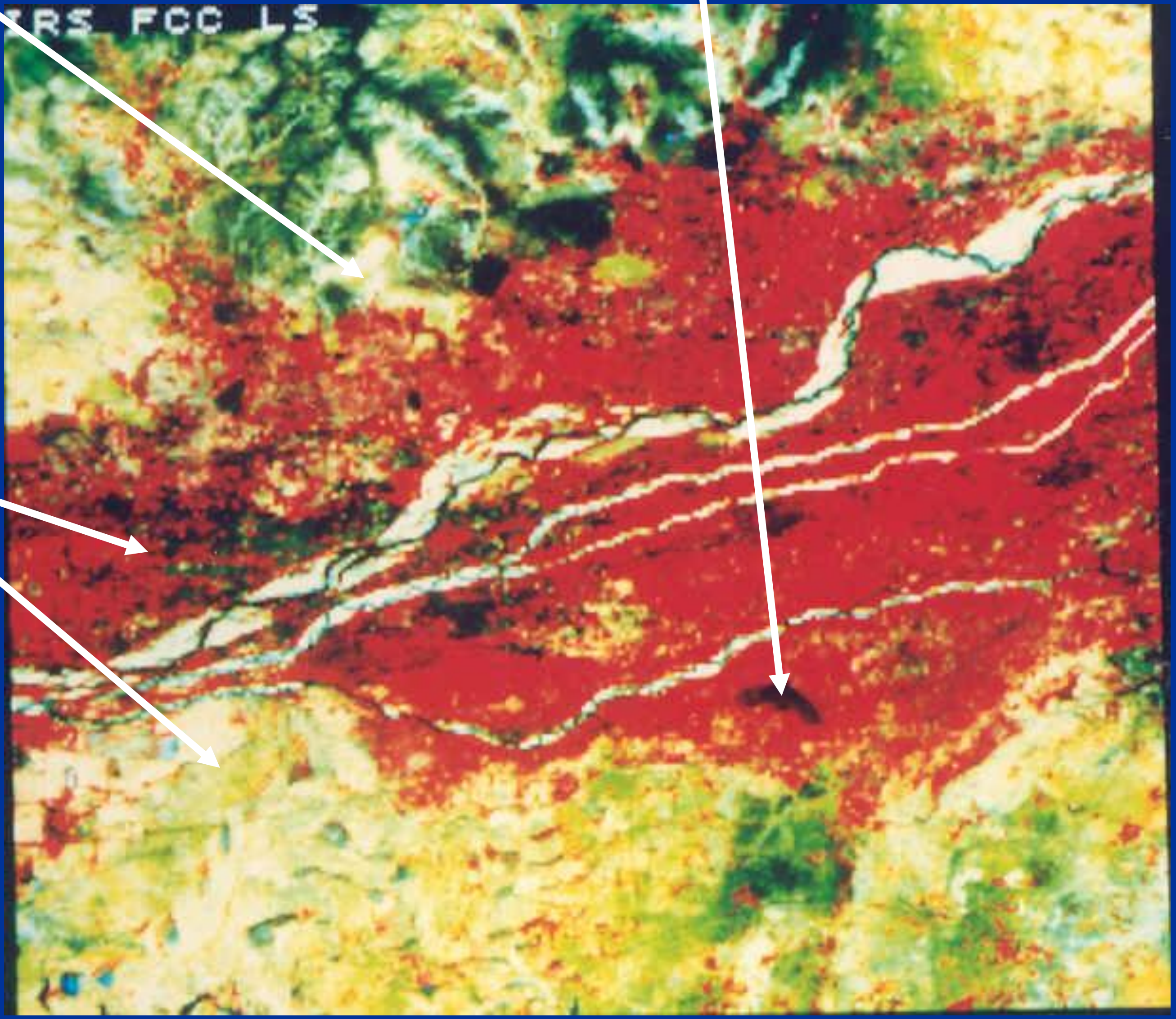


Natural Levee Development



Flooding & Sedimentation




Levee
Back Swamp
Unpaired Flood Plain

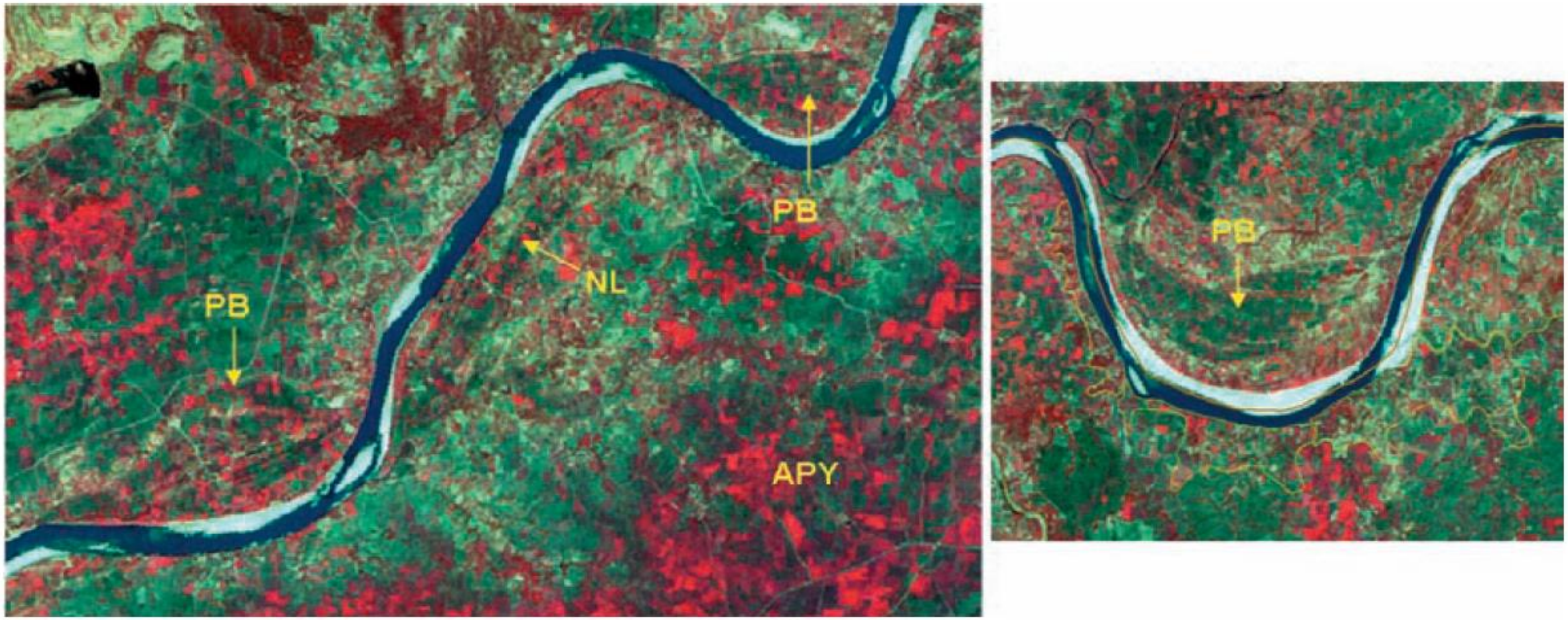
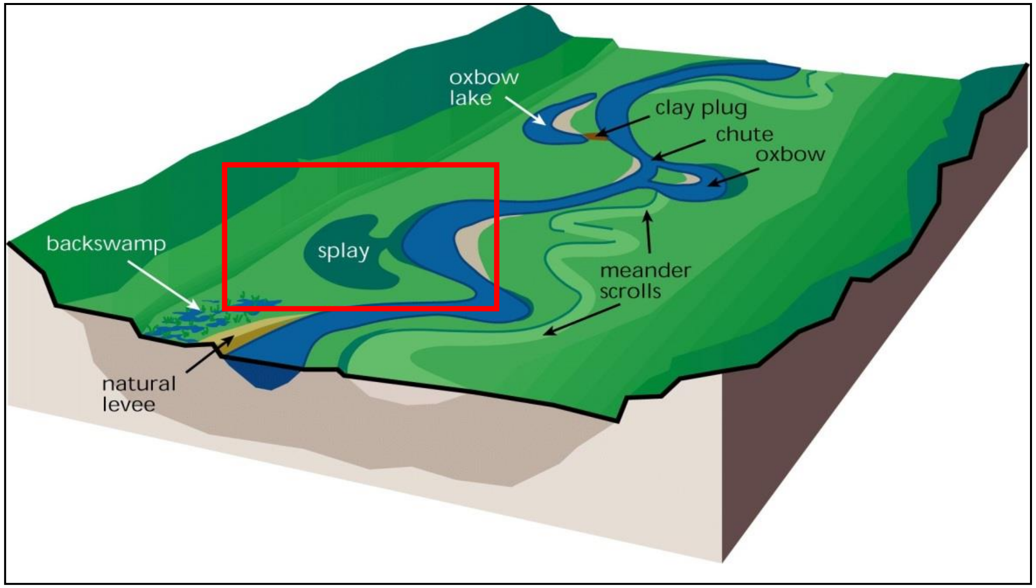


Fig. 2.41 Landforms associated with flood plains along Narmada river. Point bar (PB) and Natural levee (NL), Point bar can be identified as low actuate ridges of sand/gravel developed on the inside of a growing meander of a stream.

Splay

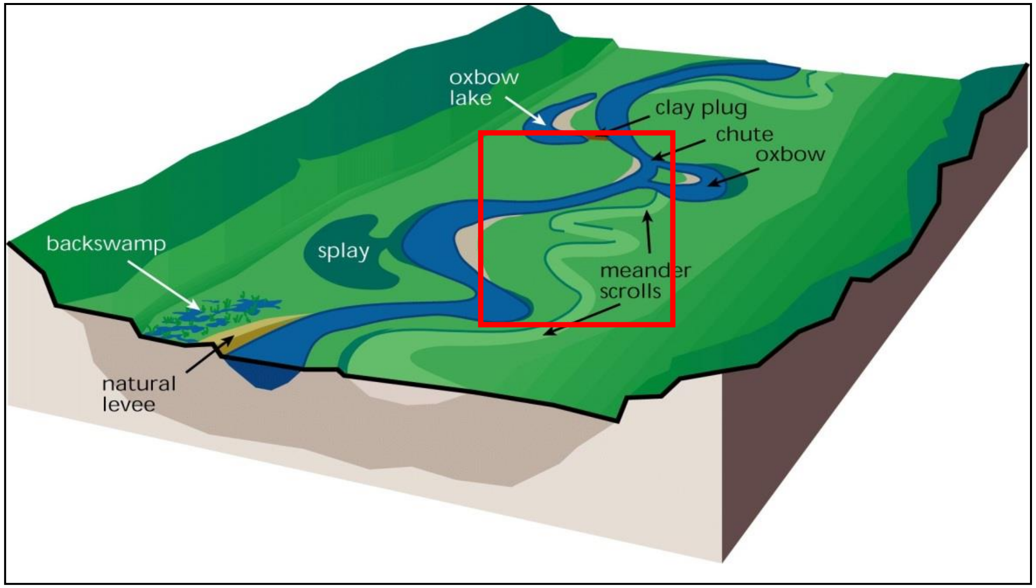
A deposit of coarse material resulting from a levee breach during a flood.



Meander scroll or Scar

A meander scroll consists of long, curving, parallel ridges (scrolls) that during stages of high water have been aggraded against the inner bank of the meandering channel, while the opposite bank experienced erosion.

Meander scar: A crescentic, concave mark on the face of a bluff or valley wall, produced by the lateral plaination of a meandering stream which undercut the lateral plaination of a meandering stream which undercut the bluff, and indicating the abandoned root of the stream. An abandoned meander often filled in by deposition and vegetation, but still discernible (esp. from the air).



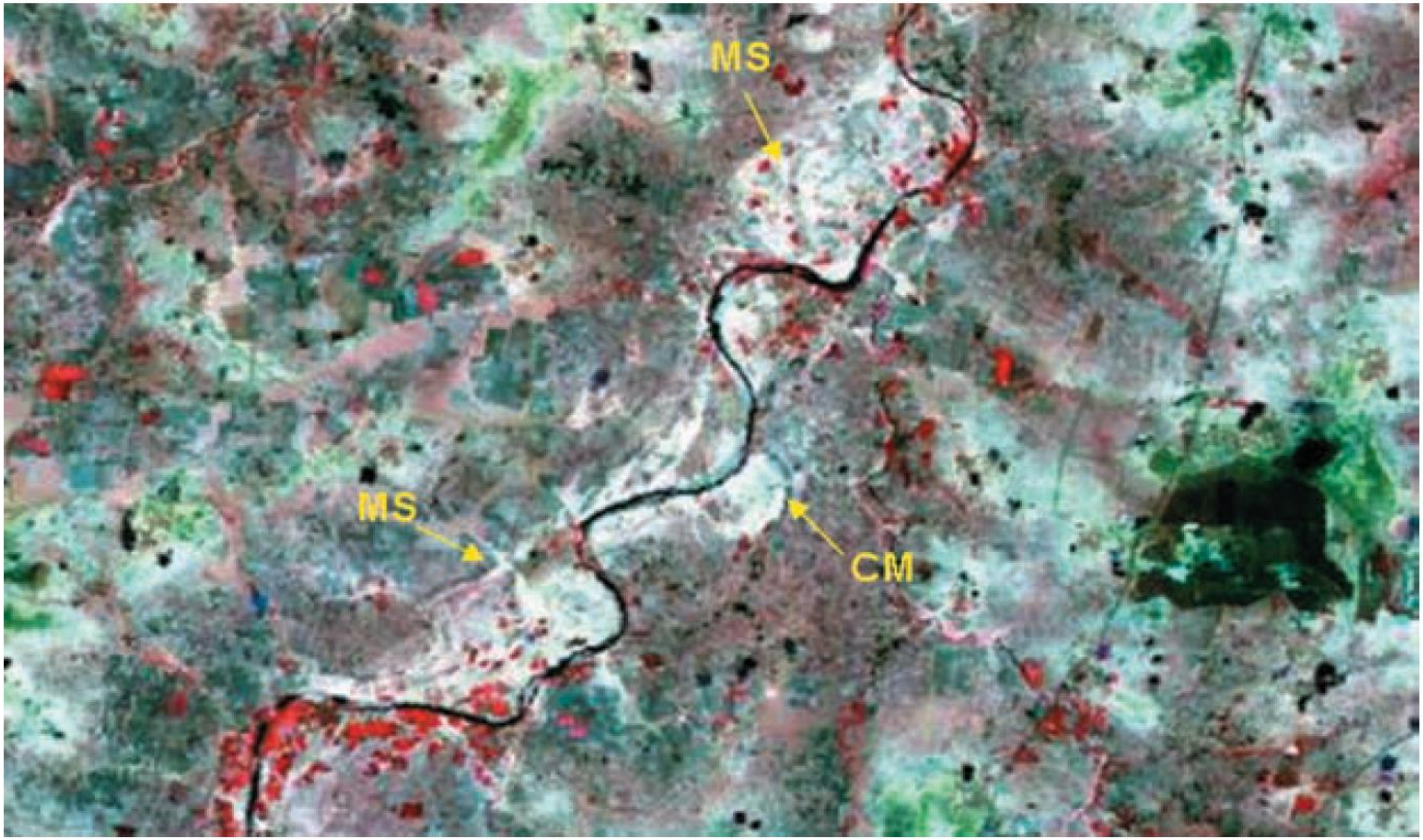
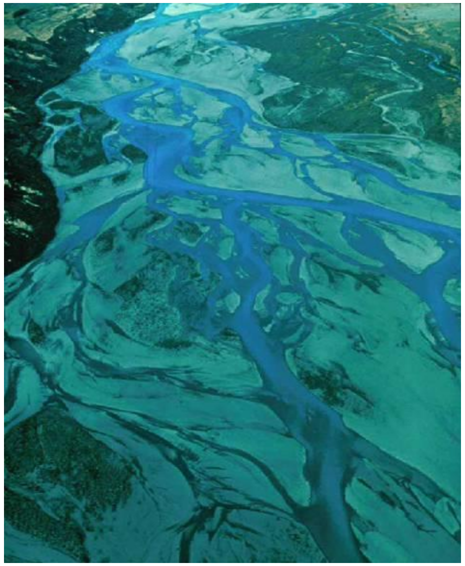


Fig. 2.46 Meander scrolls (MS) and cut-off Meander (CM) formed along Kharun River at the border of Durg and Raipur districts as seen from the IRS LISS-III summer season satellite image. These landforms are indicators for good groundwater prospects.

Braided streams

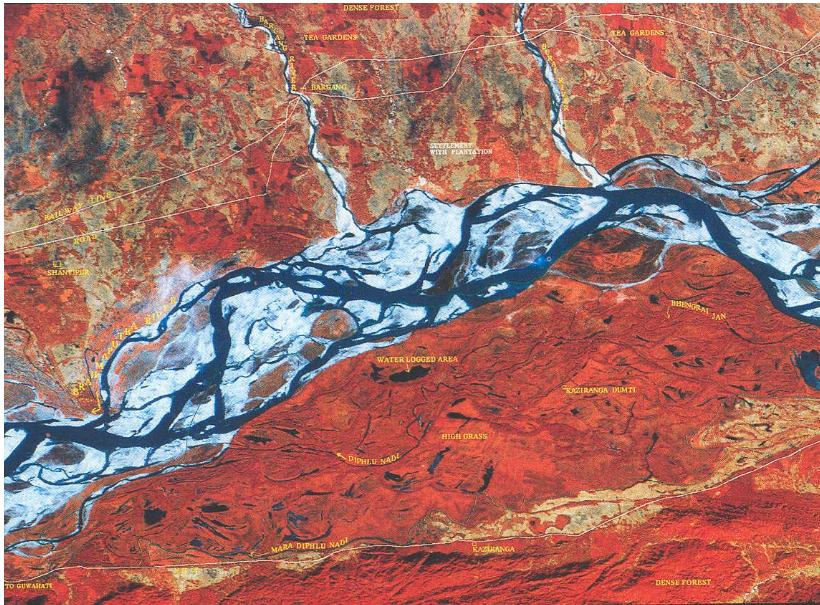
A network of converging and diverging *streams* separated from each other by narrow strips of sand and gravel.



Rivers split up within mother channels

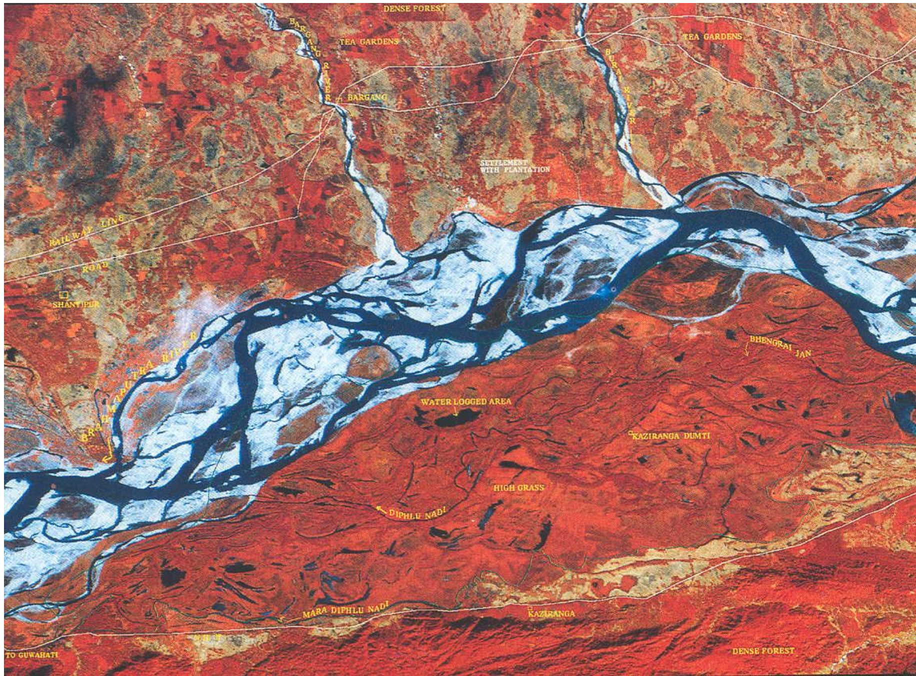
- ❖**Indicate dams in up stream**
- ❖**Land emergence and seismicity**

BRAHMAPUTRA R showing Braided streams



Braided stream: A stream that divides into or follows an interlacing or tangled network of several, small, branching and reuniting shallow channels separated from each other by branch islands or channel bars, resembling in plan the strands of a complex braid.

Such a system is generally believed to indicate the inability to carry its entire load such as an overloaded and aggrading stream flowing in a wide channel on a flood plain.



BRAHMAPUTRA R showing Braided streams

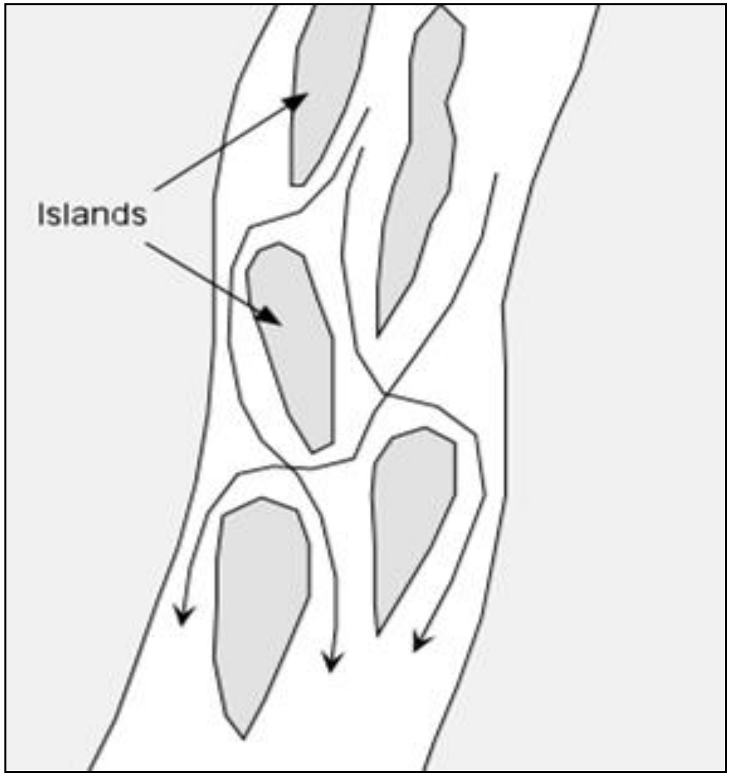
Figure 14.4

Source: Photo courtesy of Dominic Habron

Braided Channels

BRAIDED CHANNELS

Many converging and diverging streams separated by gravel bars (or sand bars).



Braided Streams

- High sediment load
- Anastamosing channels
- Constantly changing course
- Floodplain completely occupied by channels
- Many small islands called mid-channel bars
- Usually coarse sand and gravel deposits.

Braided Channels

- If a stream is unable to move all the available load, it tends to deposit the coarsest sediment as a bar that locally divides the flow.
- Braided channels tends to form in streams having highly variable discharge, easily erodible banks, and/or a high sediment load.

Braided Channels

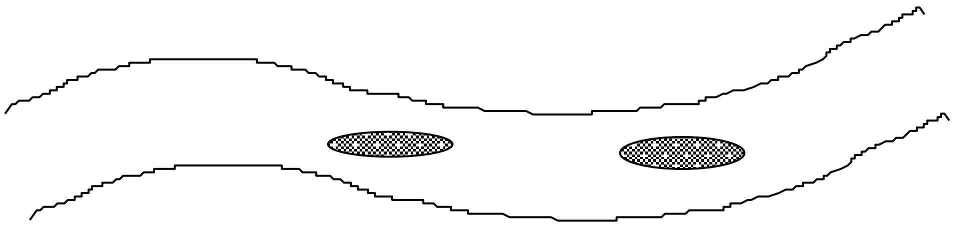
- Glacial streams generally are braided because:
  - The discharge varies both daily and seasonally.
  - The glacier supplies the stream with large quantities of sediment.

- Braided channels clog themselves with sediment, so channels always shifting

- Generally in streams near mountain fronts

Braided Streams

Sand bars or Channel bar



◆**Lens shaped sand bodies within the river**

✸ **Due to loss of bed load**
✸ **Nearing of coastal zone**

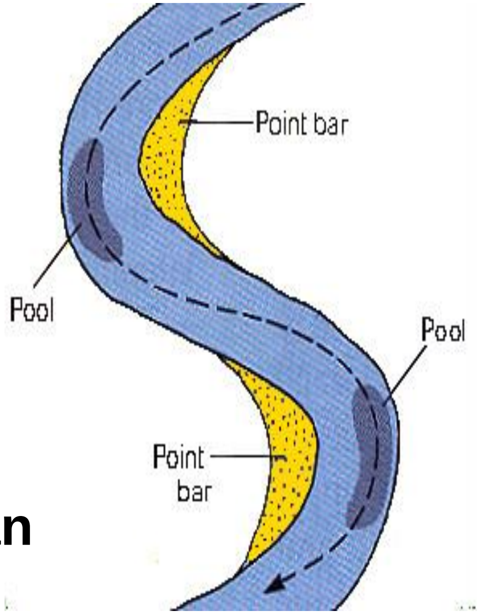
Channel bar: An elongate deposit of sand and gravel located in the course of a stream, especially of a braided stream.

1.6.2.10 Point Bar

- **Point bar : these are deposits formed inside a meander curve or at the river's mouth**

  a) **Nosing indicate flow direction**

  b) **Point bar with opposite nosing can indicate drainage reversal**



Stream Gradation

as a flood plain develops it widens over time creating a flat valley floor where the river meanders back and forth (ALLUVIAL MEANDERS)

(on the inside of each bend – point bar deposition, on the outside of each bend – erosion)

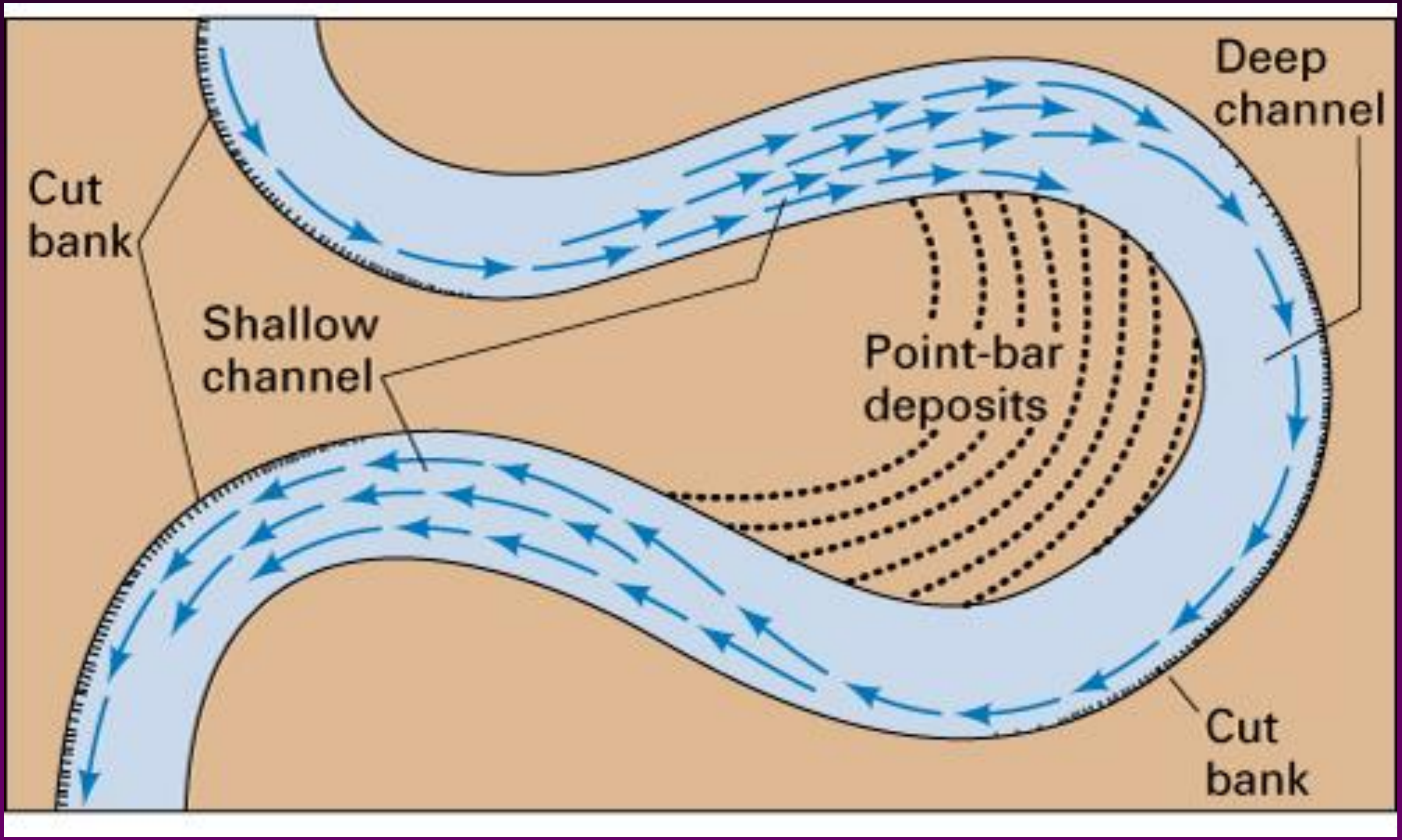


Figure 16.12, p. 555

Fig. 2.42 Point bar deposits (PB) and meander scars (MS) within the older flood plains along Dudhi river, Hoshangabad district.

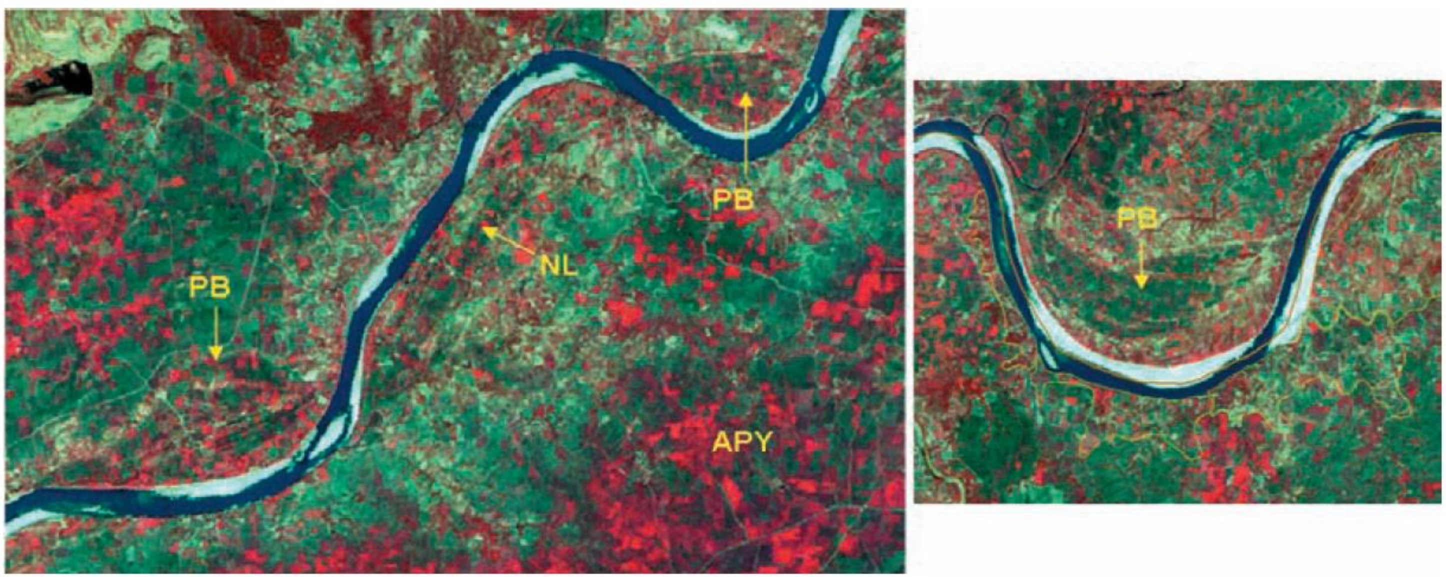


Fig. 2.41 Landforms associated with flood plains along Narmada river. Point bar (PB) and Natural levee (NL), Point bar can be identified as low actuate ridges of sand/gravel developed on the inside of a growing meander of a stream.

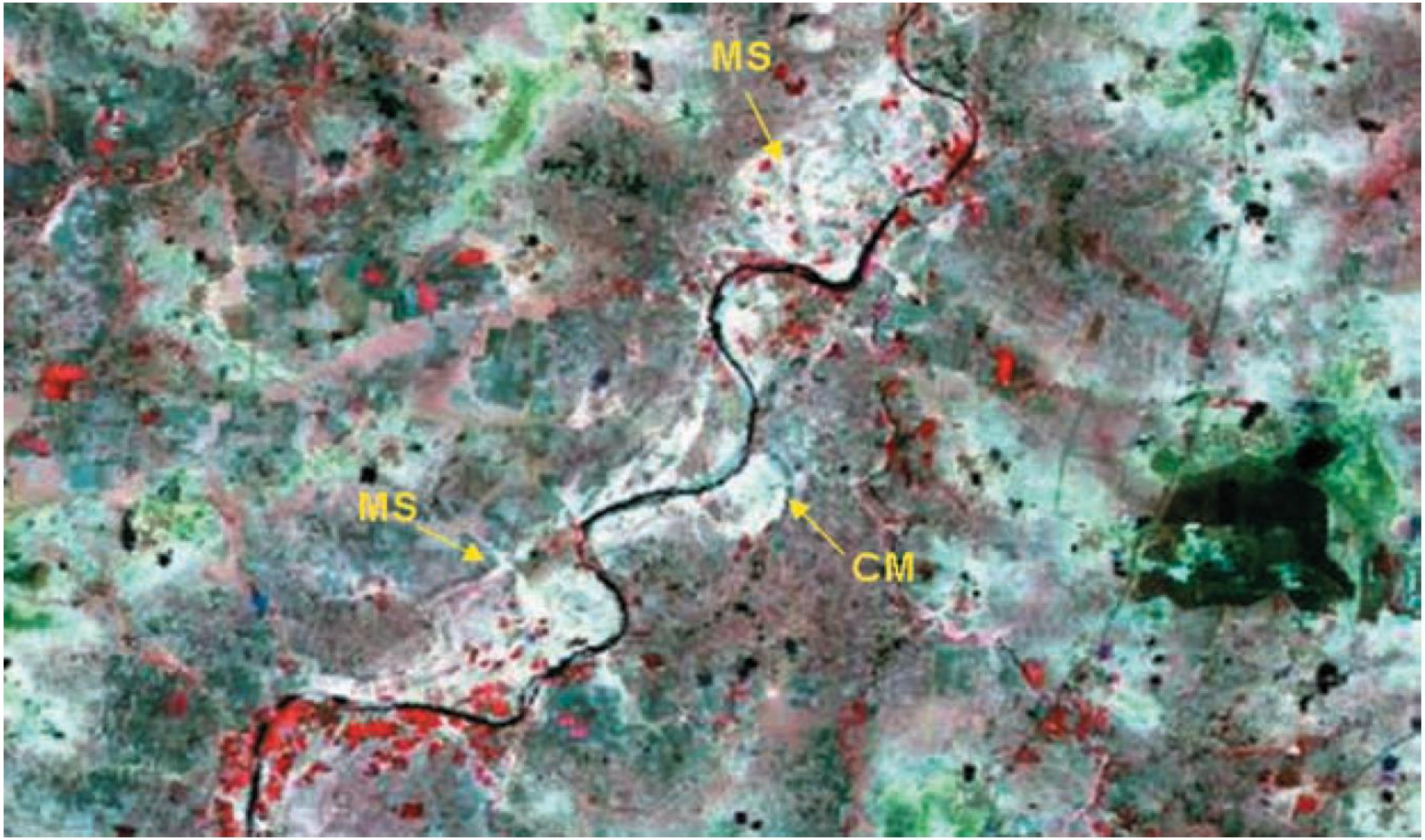
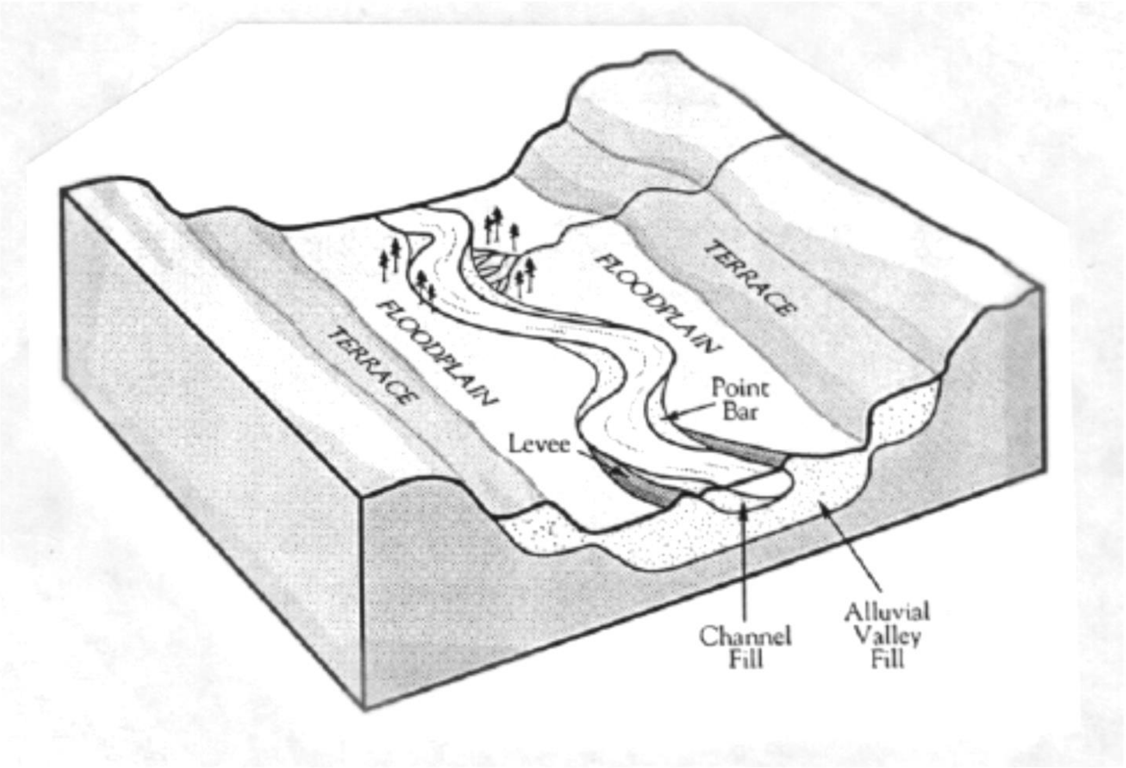


Fig. 2.46 Meander scrolls (MS) and cut-off Meander (CM) formed along Kharun River at the border of Durg and Raipur districts as seen from the IRS LISS-III summer season satellite image. These landforms are indicators for good groundwater

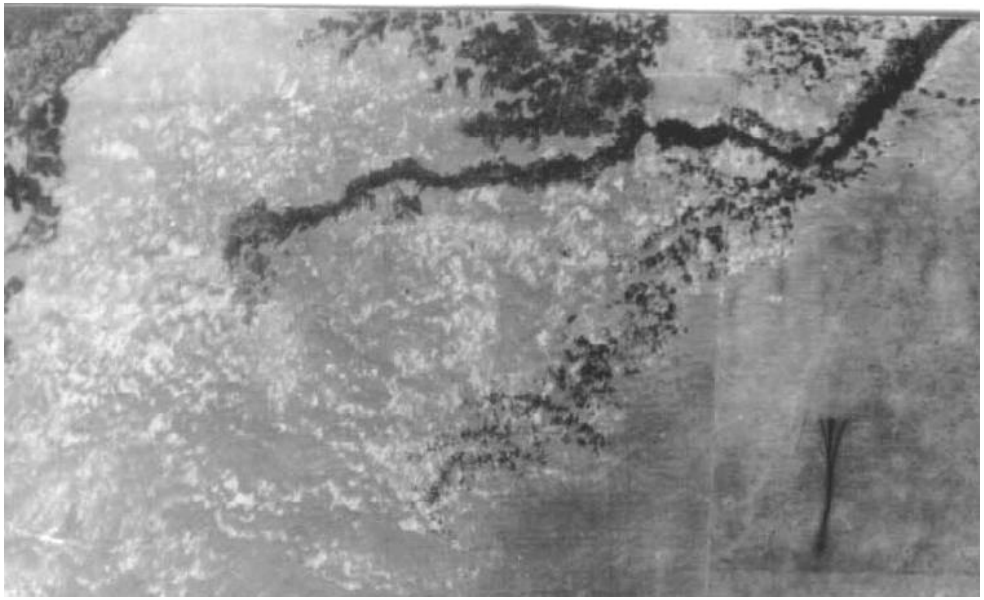
Depositional terraces

✦ When the river reaches maturity it deposits terrace after terrace

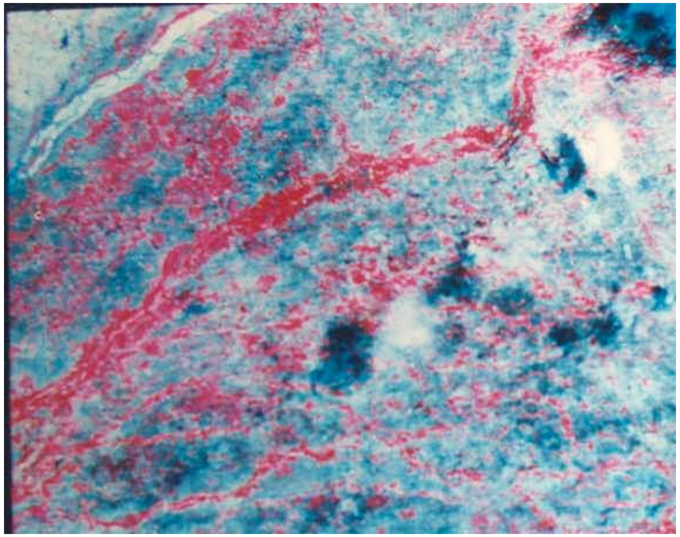
✦ Himalayan rivers



Palaeo Channels / Buried Channels / Migration of Rivers



SARASWATI RIVER MIGRATION



PALAEO CHANNEL – PALAMCAUVERY

(a) Reasons for Migration

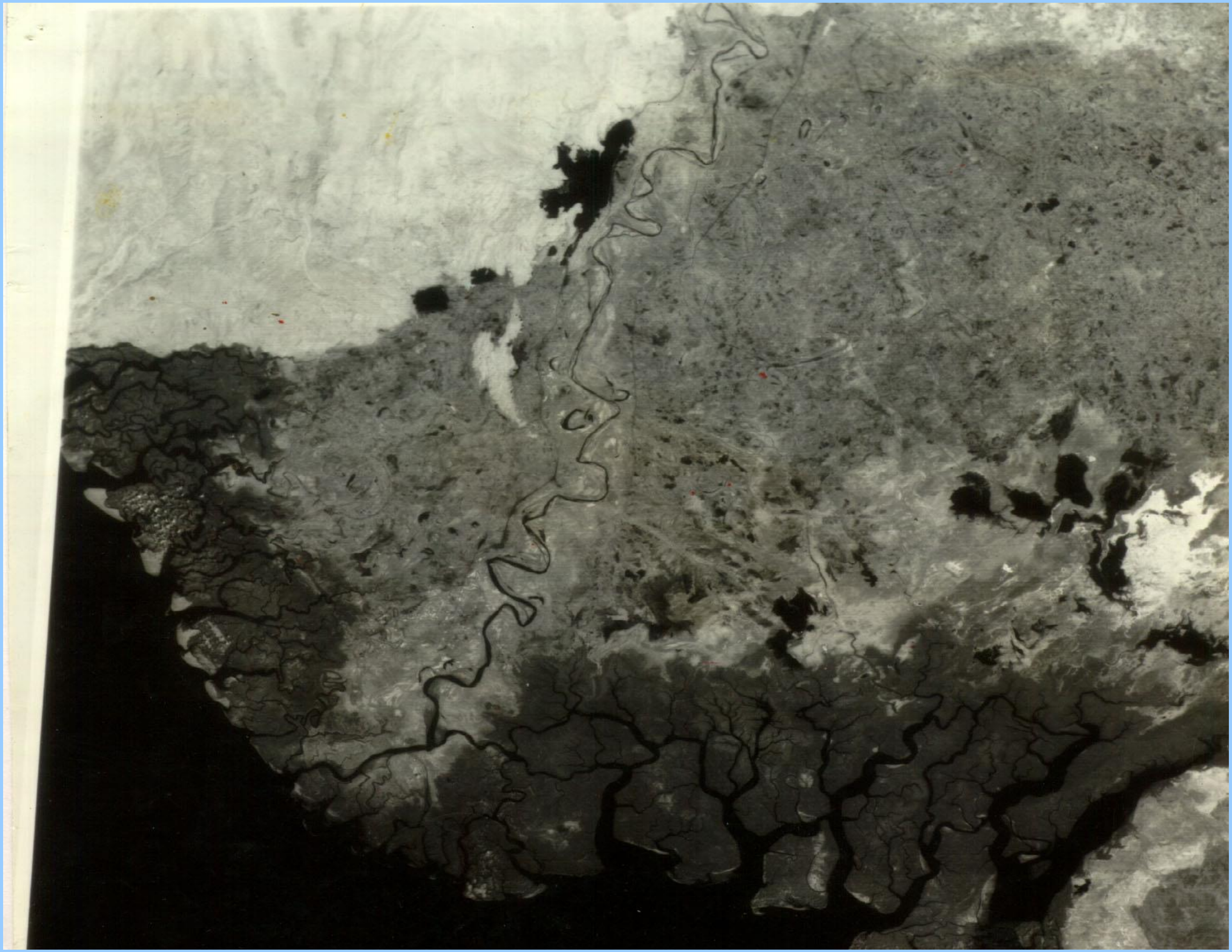
- ❖Spinning of the Earth
- ❖Isostatic Movements
- ❖Eustatic Changes
- ❖Frequent Flooding
- ❖Climatic Changes
- ❖Behaviour of Mother Channel
- ❖Littoral Currents etc.,

LAND FORMS OF OLD STAGE

Characteristics of Old Age Streams

- **River changes its works from erosion to deposition**
- **The valley floor is very broad and flat**
- **Slope are greatly gentle**

OLD STAGE



Delta

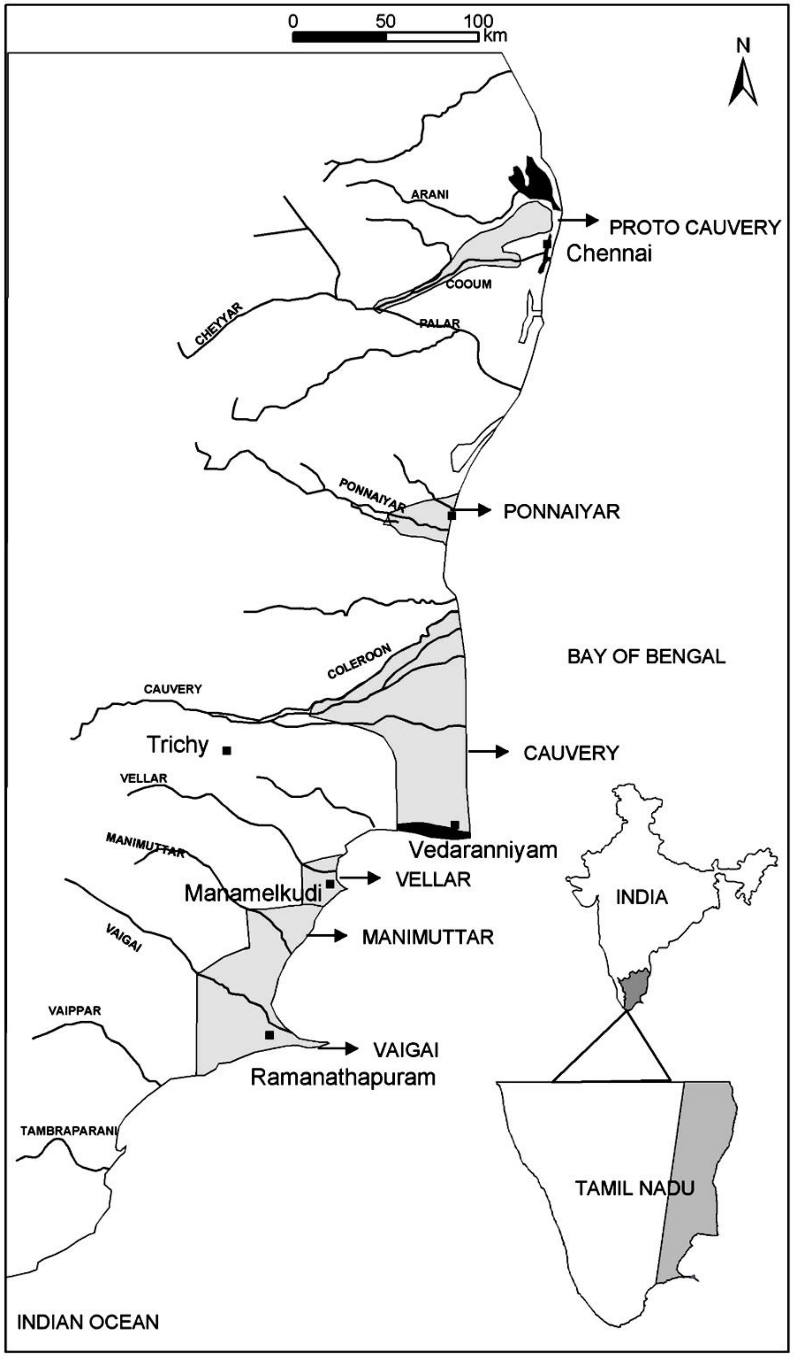
A body of alluvium, nearly flat and fan-shaped, deposited at or near the mouth of a river or stream where it enters a body of relatively quiet water, usually a sea or lake is called delta

Where a river empties into a large body of water, such as a: sea, ocean, or lake, it loses speed

It loses energy and **deposits** suspended material

Since it is no longer constrained by riverbanks as it gradually loses speed as it reaches further into the sea

Thus, the sediments carried by river has been deposited as triangular body is called DELTA.

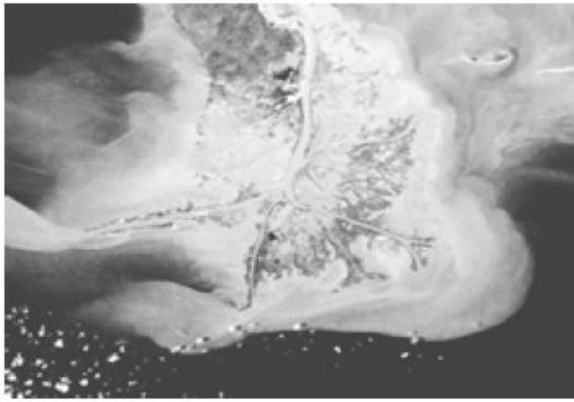


Delta Development

- Term delta comes from the Δ shape of the Nile delta - a shape shared by other deltas.
- Deltas develop because two things happen when a river reaches a lake or the sea:
  - Gradient drops to 0, therefore velocity drops, suspended load is deposited.
  - There is no longer any confining topography, so the river spreads out.
  - This latter leads to the development of *distributary channels*.

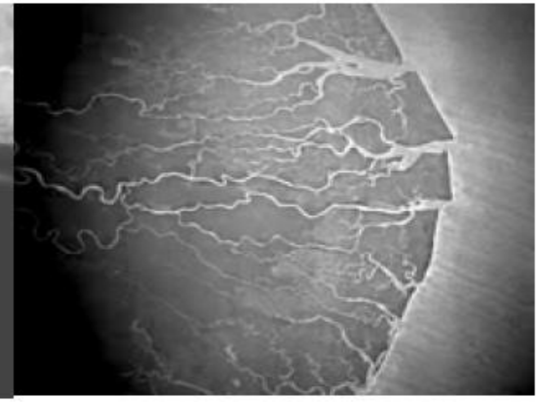
Deltas

Mississippi River Delta, U.S.



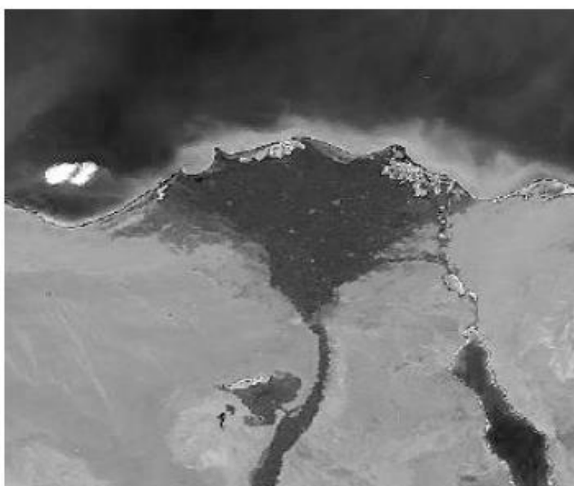
bird's foot delta

Niger River Delta, Africa



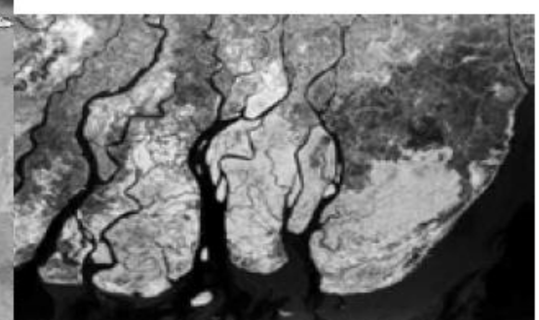
lobate delta

Nile River Delta, Egypt



lobate delta

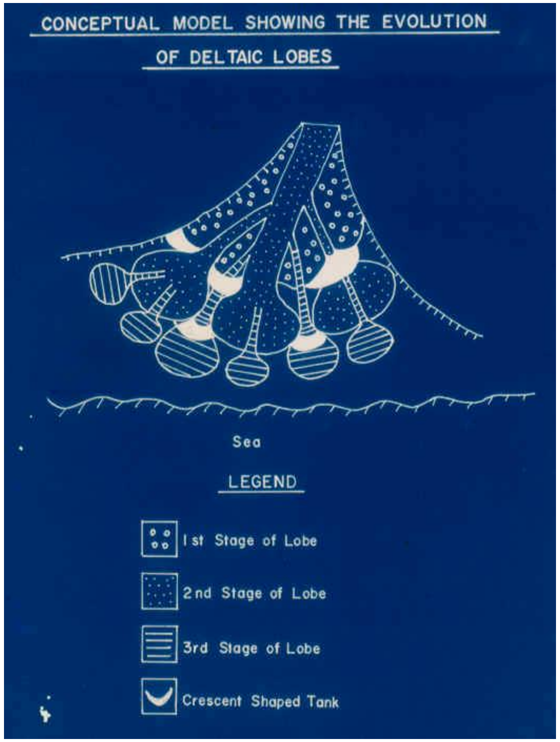
Irrawaddy River Delta, Burmah



crenulate delta

Deltas signify the land-ocean interactive dynamics and the related geological processes

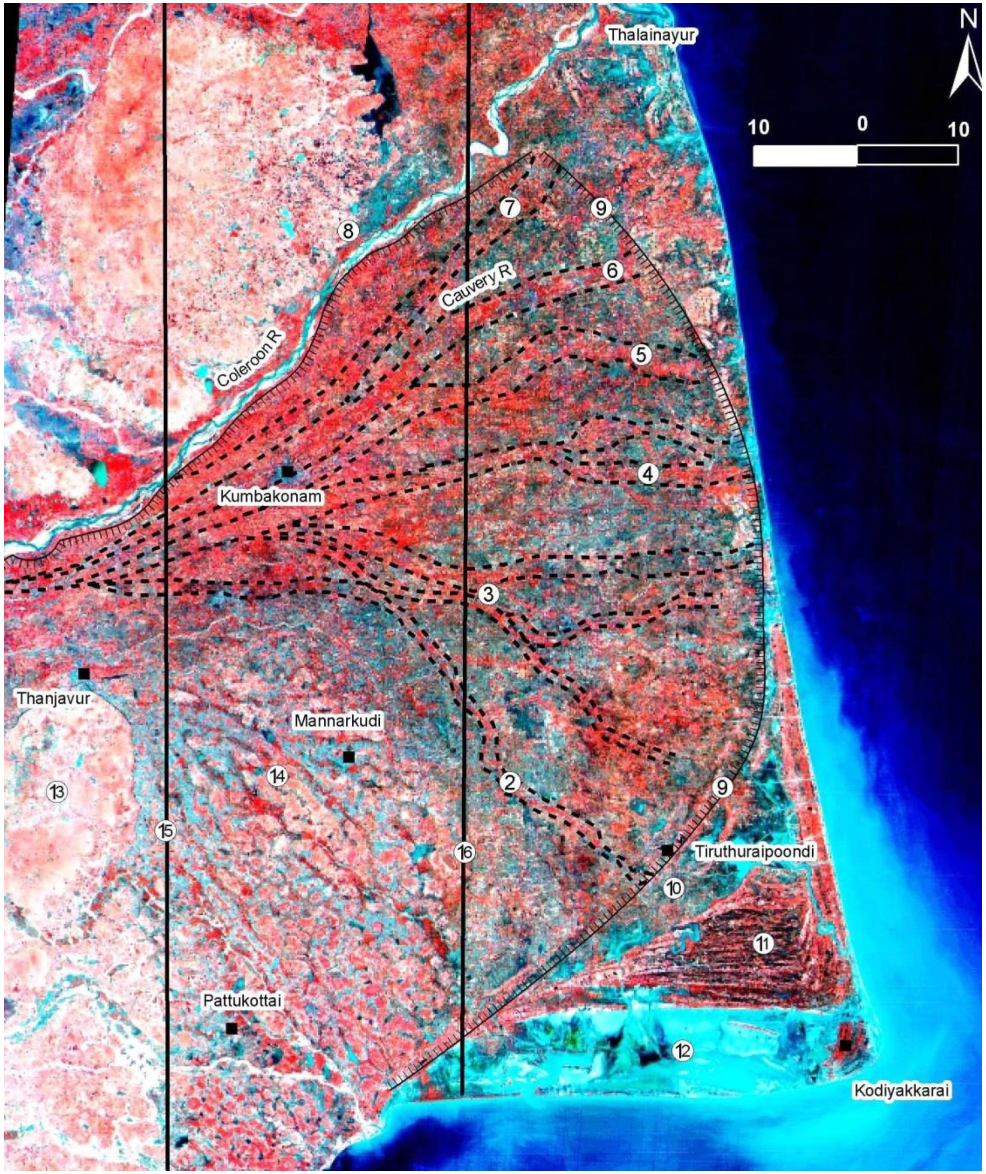
Lobate delta



Lobate delta covers the river derived sediments (e.g. ancient Mississippi river delta)

lobate deltas symbolize constant emergence of land or withdrawal of sea and the resultant progradation of deltas by developing lobes after lobes.

Arcuate Delta



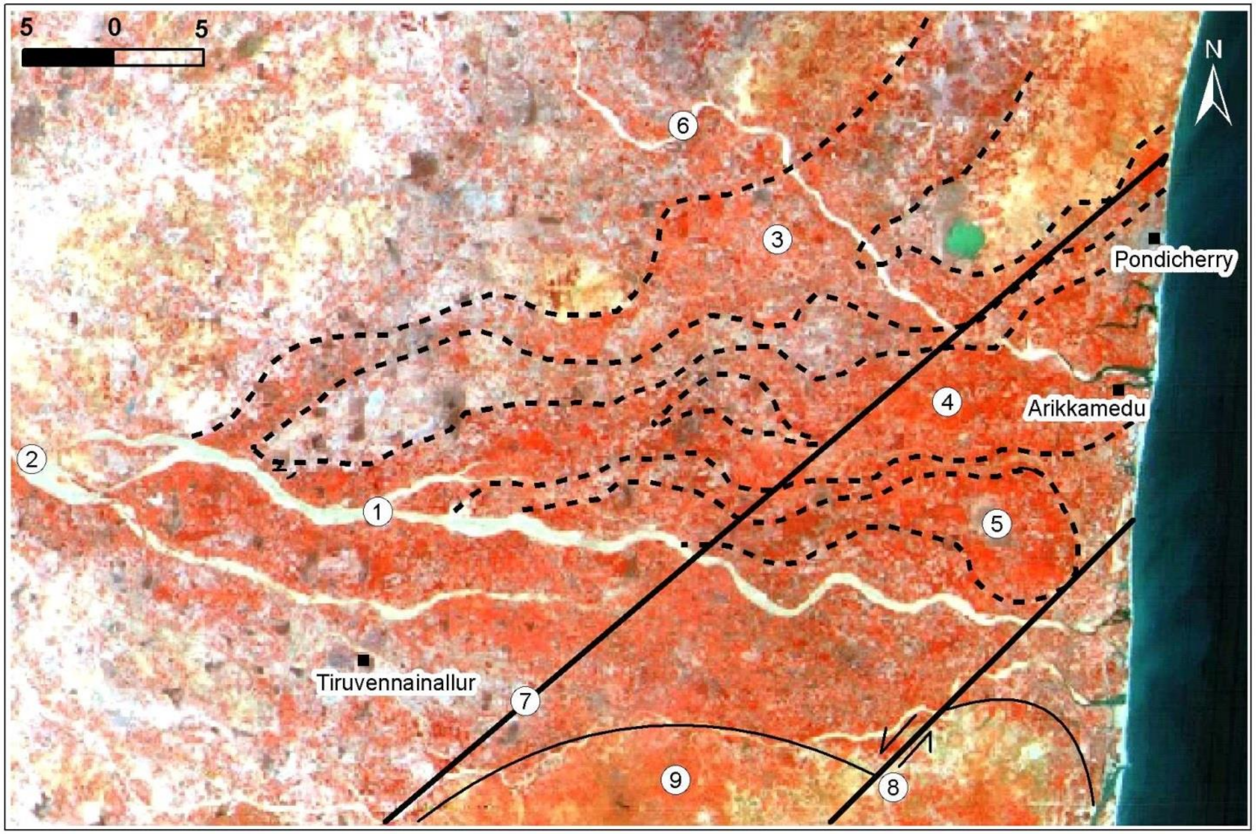
An arcuate delta has three sided outline with seaward margin convex or arcuate

The Nile and the Cauvery delta has this morphology

Cuspate Delta

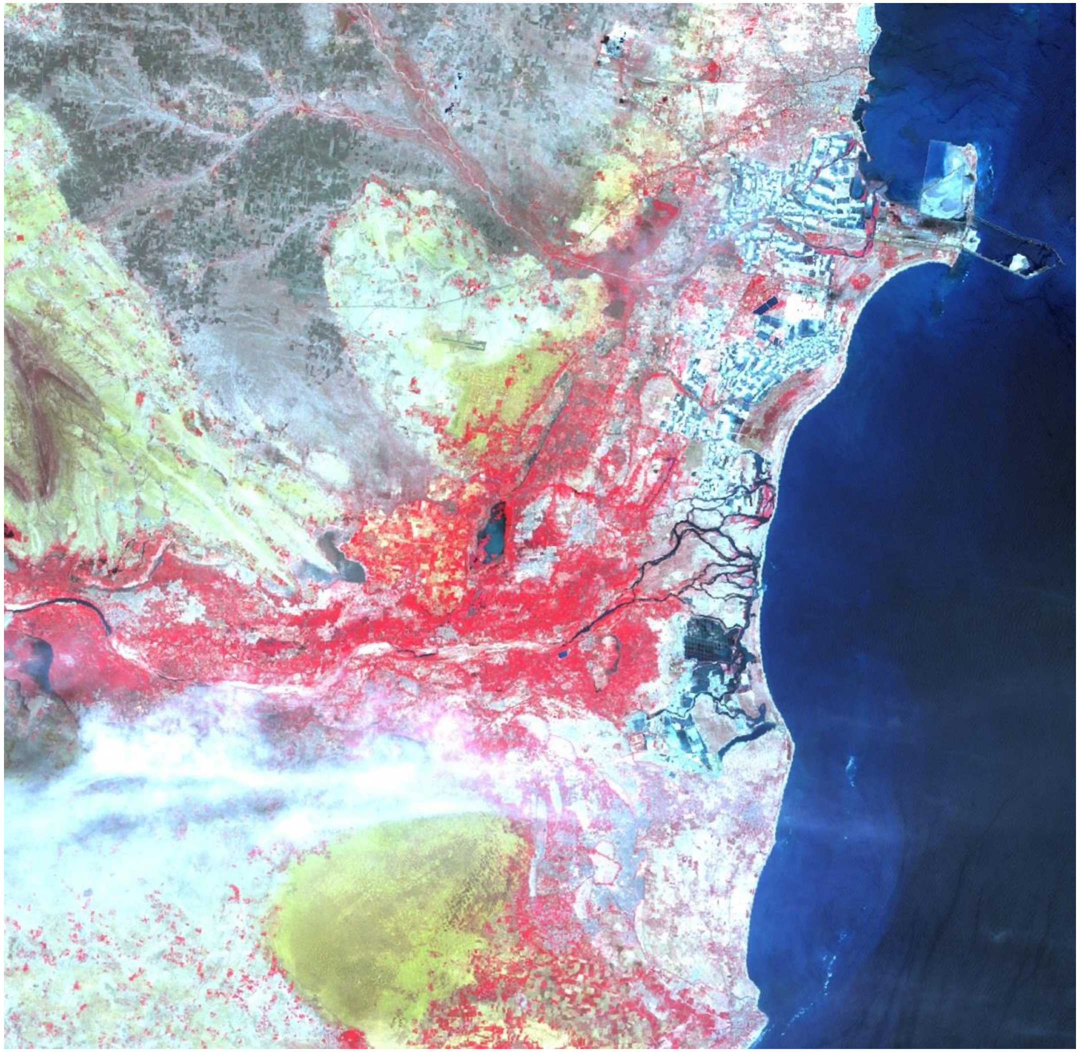
Triangle shaped deposits accumulate on either side of the main channel. (e.g. Brazos river delta, Texas, Tiber river delta

Digitate Delta



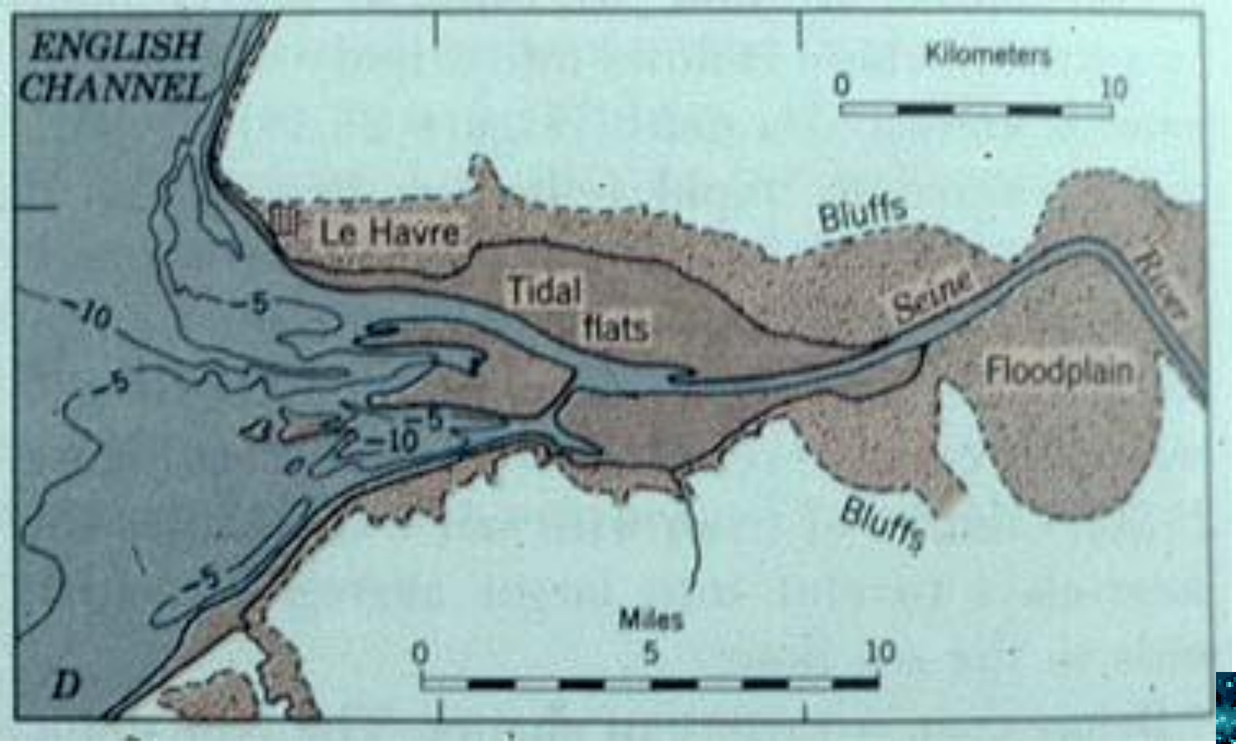
Digitate delta indicates that the delta might have been in the process of subsidence inviting the tidal waters since its inception

Estuarine Delta



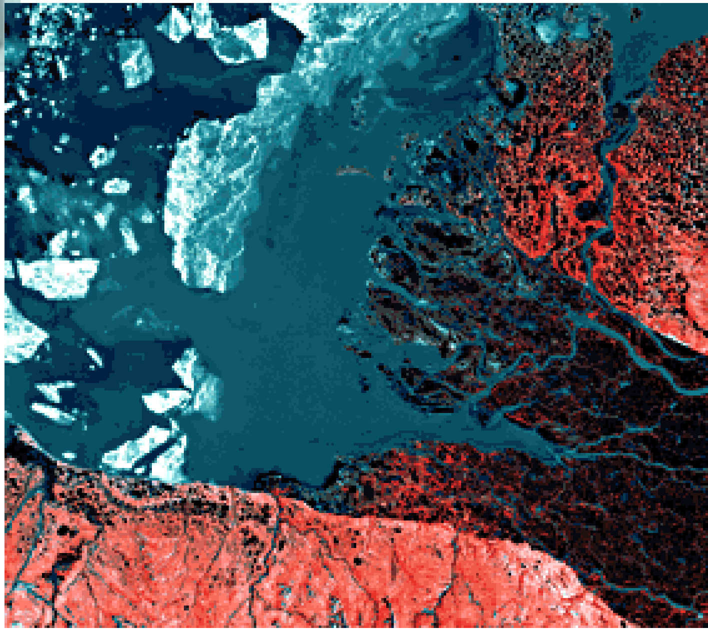
This delta is funnel shaped has the length several times greater than maximum width

The distributaries are braided and are separated by sandbars or islands



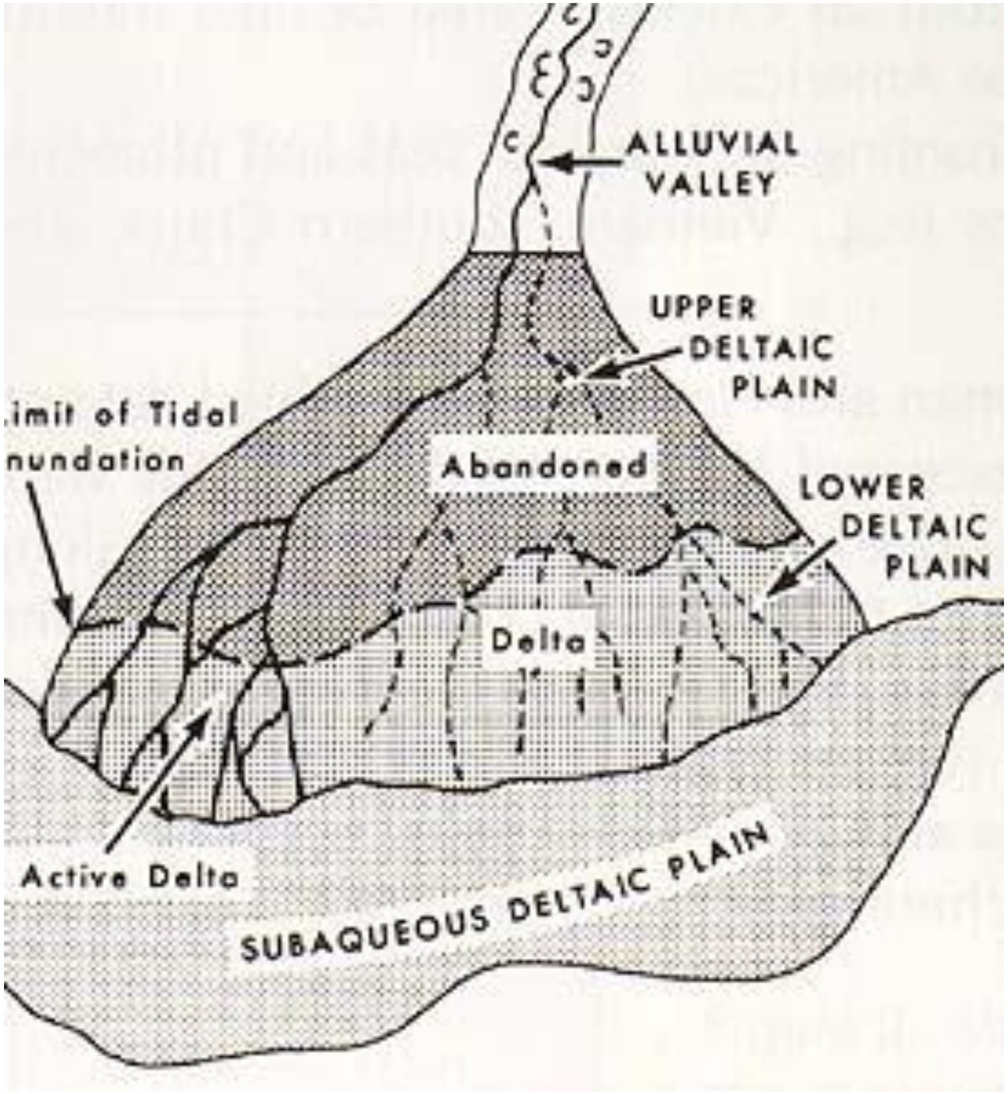
Estuarine Delta

Mackenzie



MICRO DELTA – UPPER ANICUT

Deltaic Plain (Upper / Older)
Deltaic Plain (Lower / Younger)



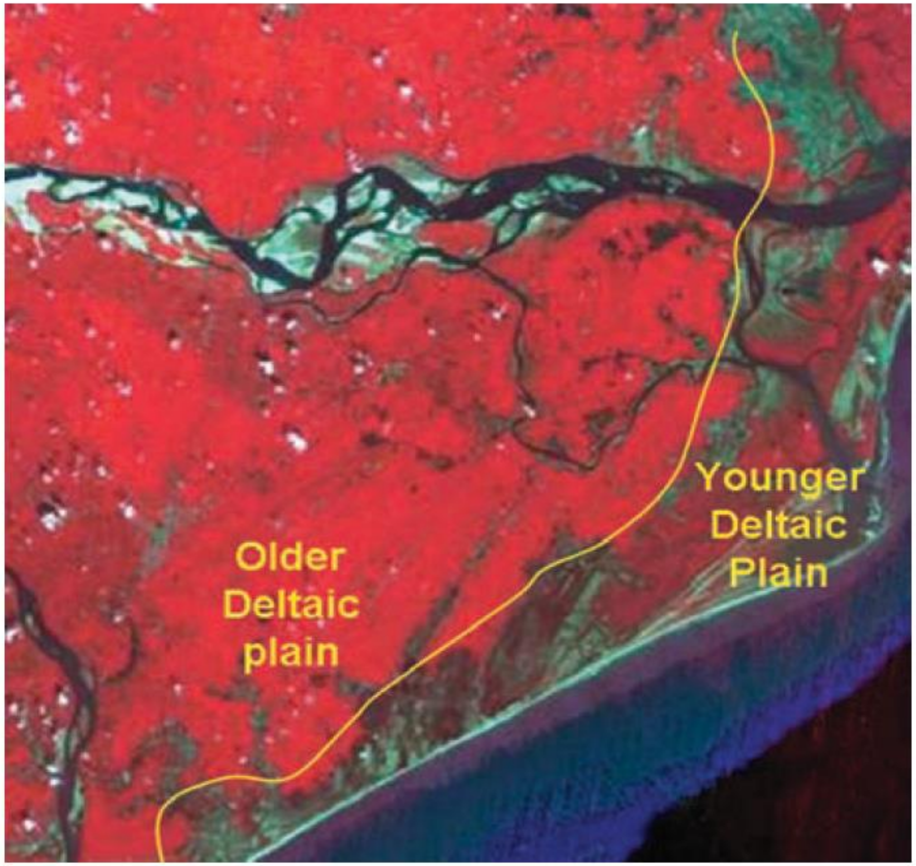
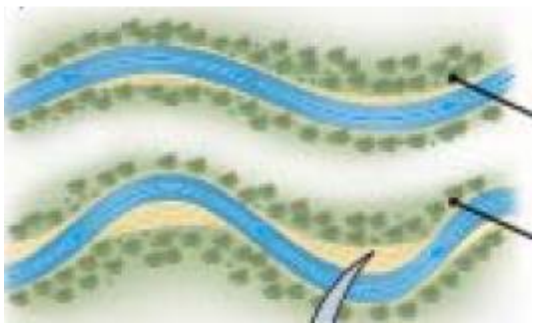


Fig. 2.47 The boundary between older and younger deltaic plain can be clearly seen in the Godavari Delta. The Younger deltatic plain are characterized by some of coastal landforms like beach ridge, swale etc. The river has broaden after entering this plain. Such features are not seen in the older deltaic plain. Fluvial landform dominates and some of old traces of palaeo-beach ridge can be traced in this plain. Salinity problems are relatively less as compared to the younger deltaic plain. The older deltaic plains are intensively cultivated as compared to younger deltaic plain as seen in this false colour composite.

Meander loop

➔Low velocity, low sediment streams flowing on nearly flat floodplain form meanders. Meanders shift from side to side by snaking motion



Meandering channels

Loops or meanders form as stream erodes its banks.

Erosion takes place on the cut bank, which is the outside loop of the meander.

Deposition takes place on the point bar, which is on the inside loop of the meander.

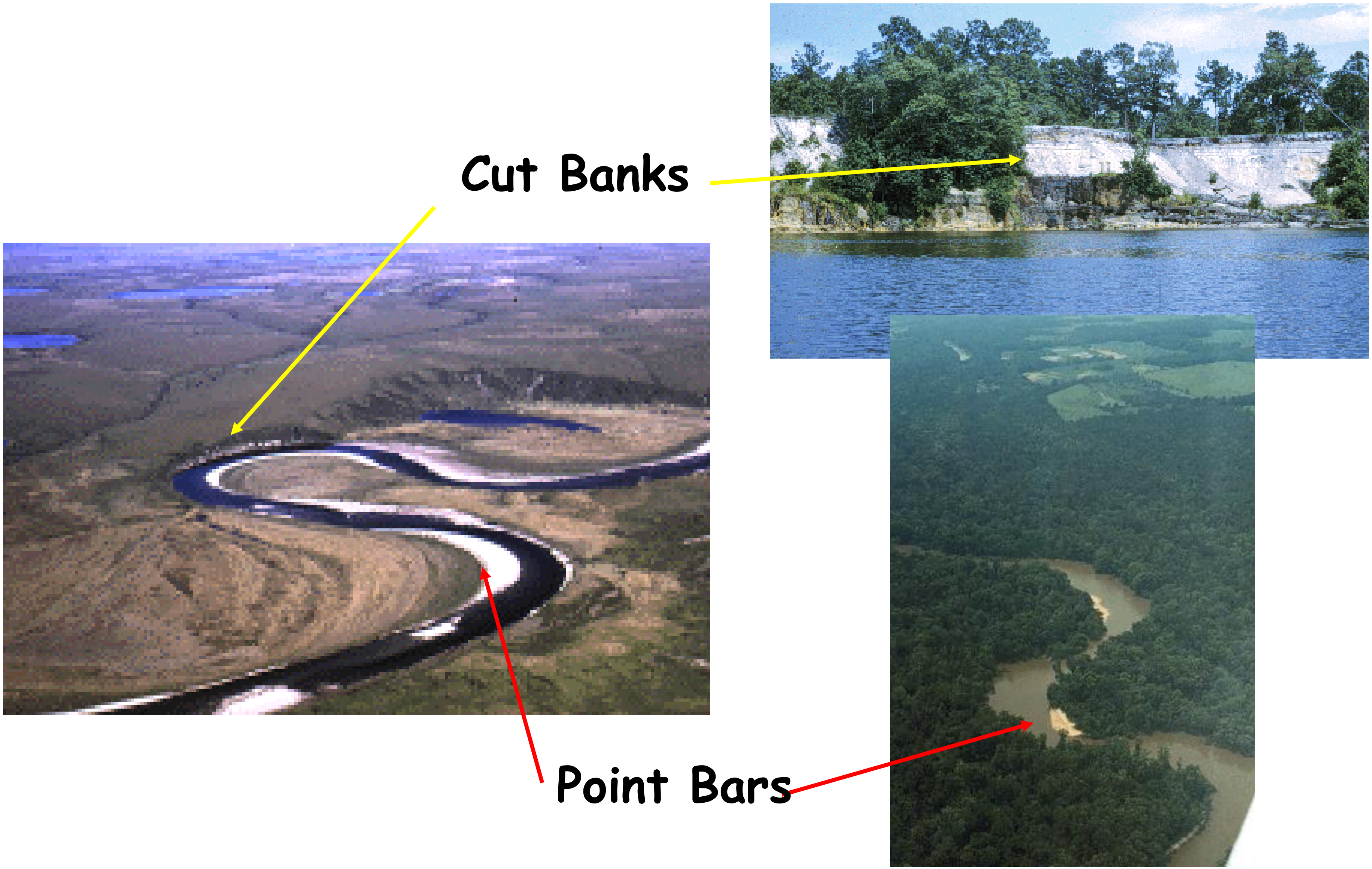
Meandering channels

Change their channel course gradually

Create floodplains wider than the channel

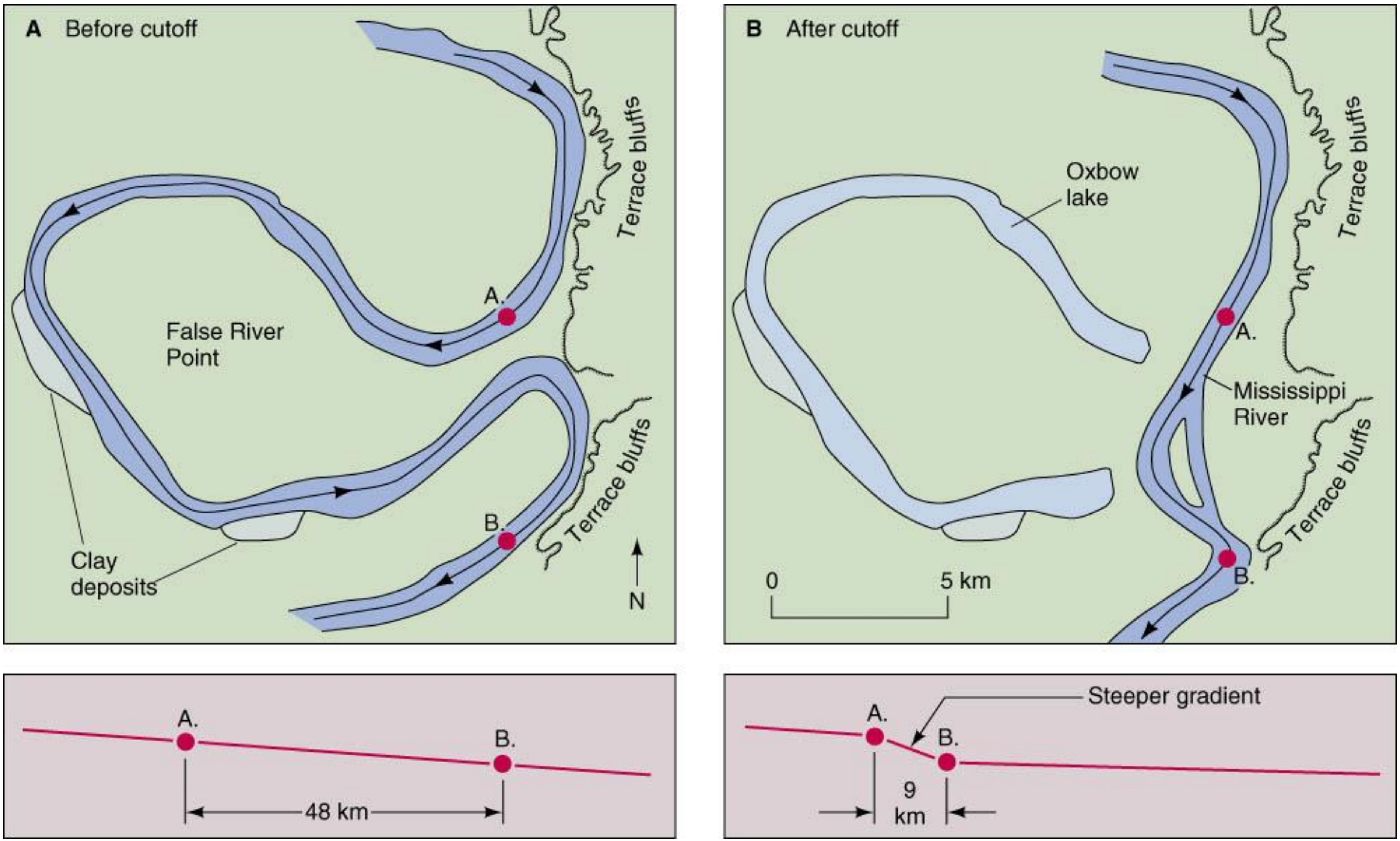
- Very Fertile soil
- Subjected to seasonal flooding

Meandering channels



- Meandering streams often characterized by large loopy bends across their floodplains.
- Meanders occur most commonly in channels that lie in fine-grained stream sediments and have gentle gradients.

Growing meanders can intersect each other and cut off a meander loop, forming an oxbow lake.



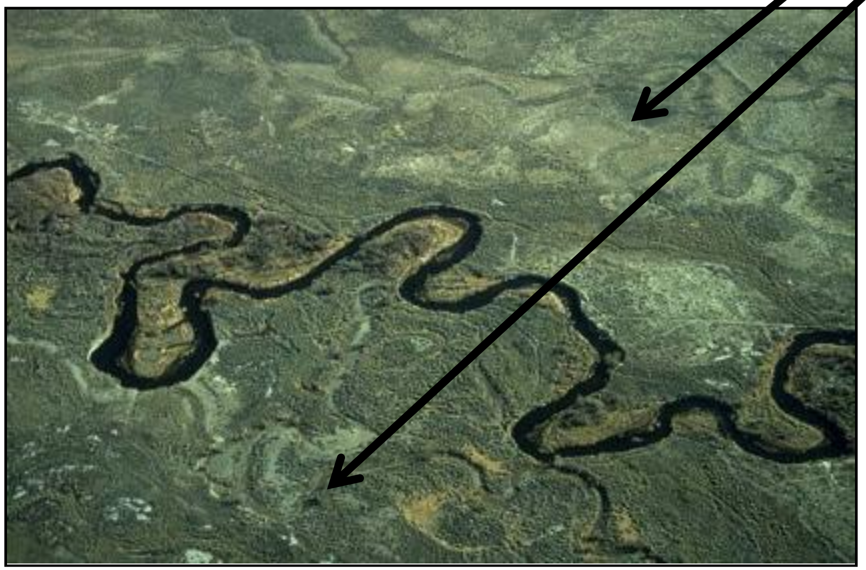
Old channels abandoned as a river meanders across its floodplain form oxbows.

Meander "train" = belt of meandering

Owens River, CA

Sacramento River, CA

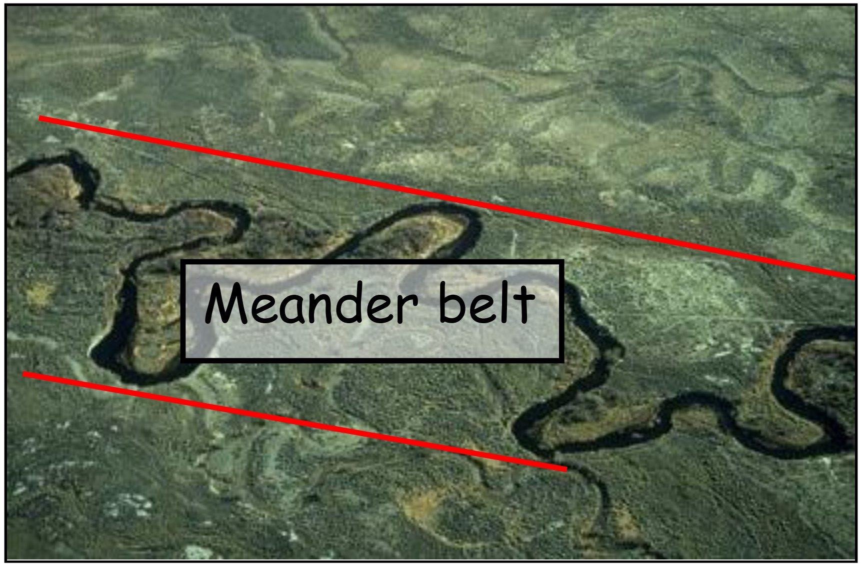
Note old meanders

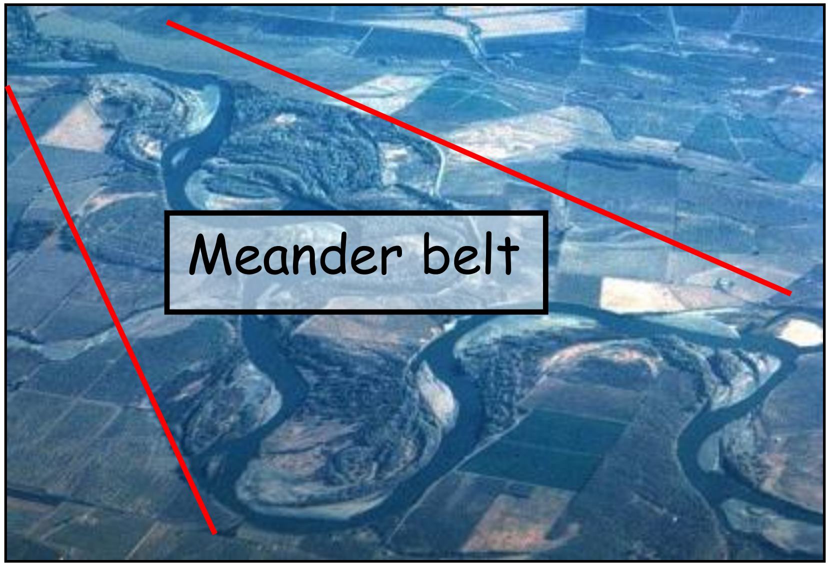


Owens River, CA

Sacramento River, CA

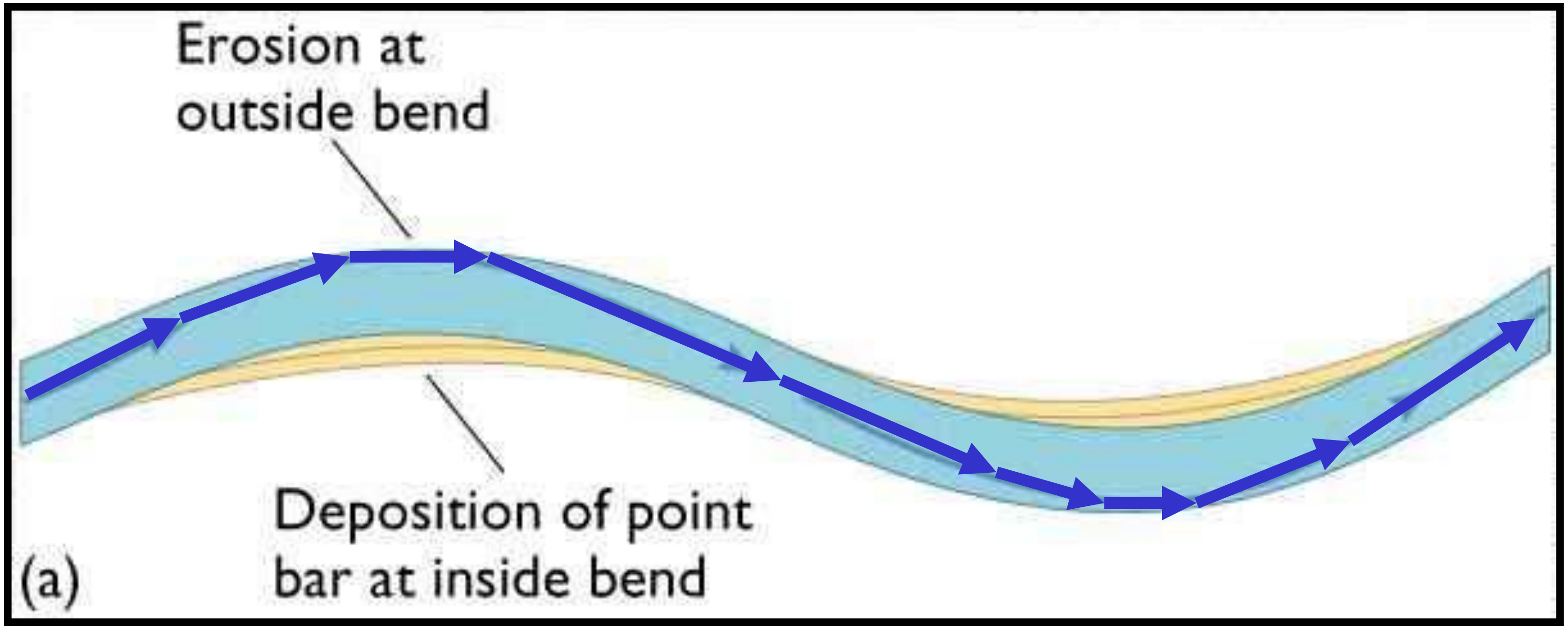
Meander "train" = belt of meandering

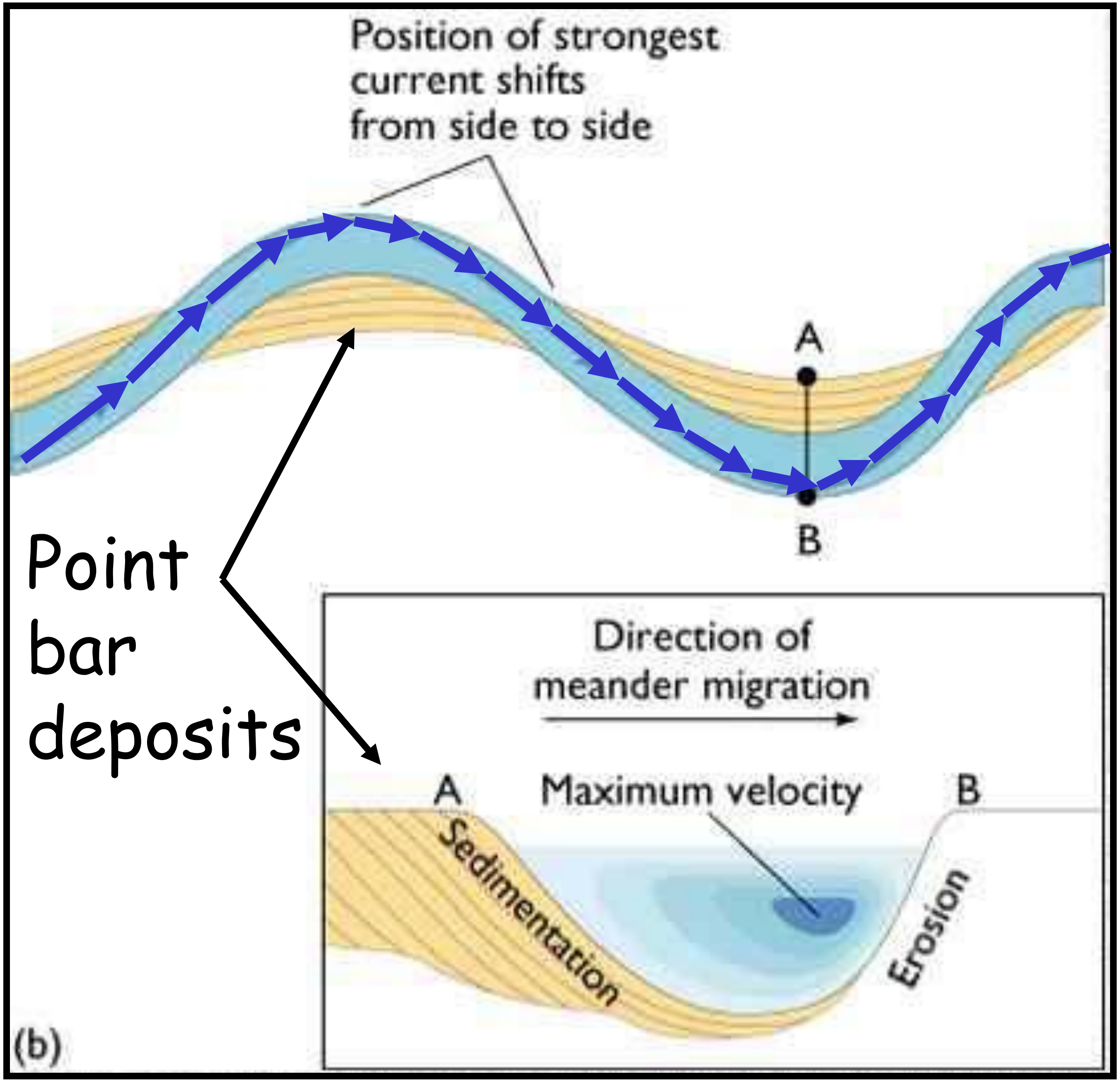




Channel migration zone = area across which the river is prone to move.

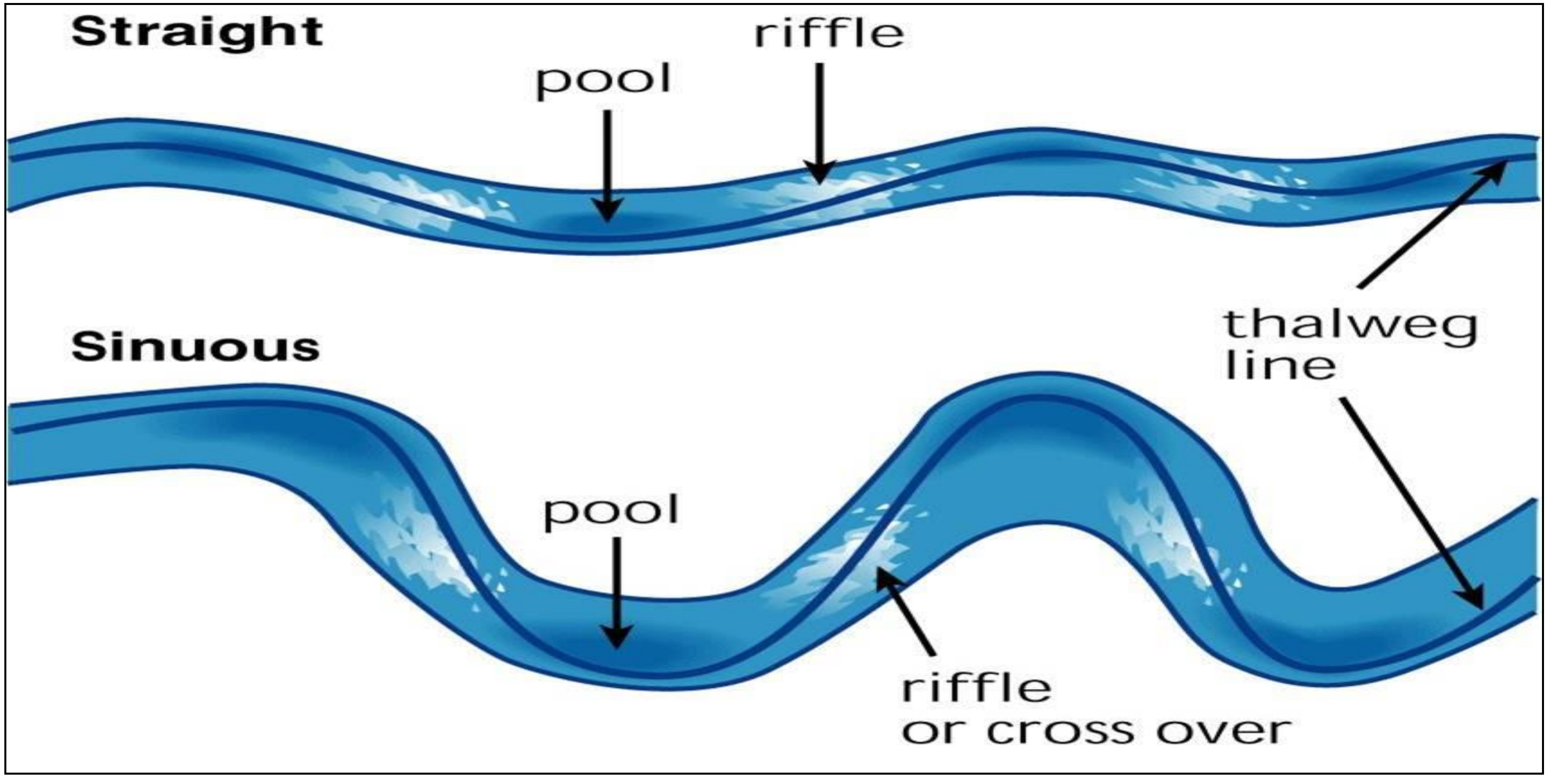
Formation of Meanders




Position of strongest
current shifts
from side to side
A
B
Point
bar
deposits
Direction of
meander migration
A
Maximum velocity
B
Sedimentation
Erosion
(b)

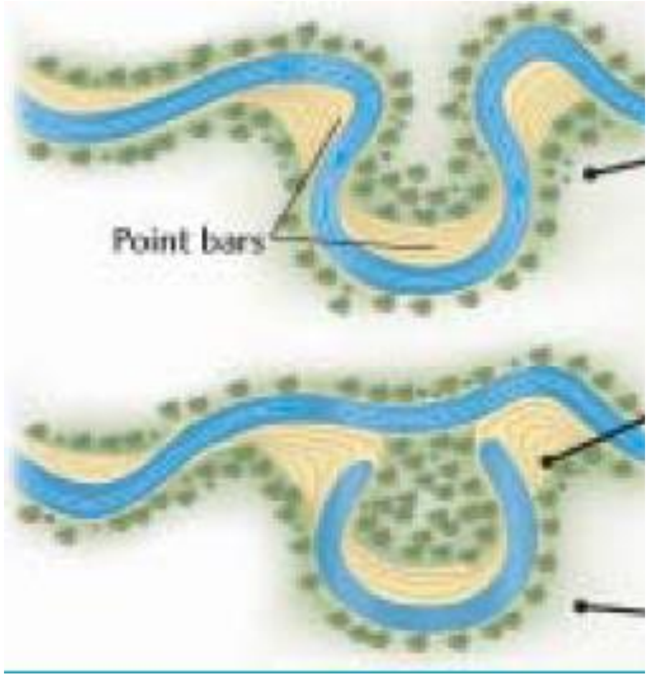
Pool - riffle sequence

Riffle to riffle = 5 - 7 channel widths

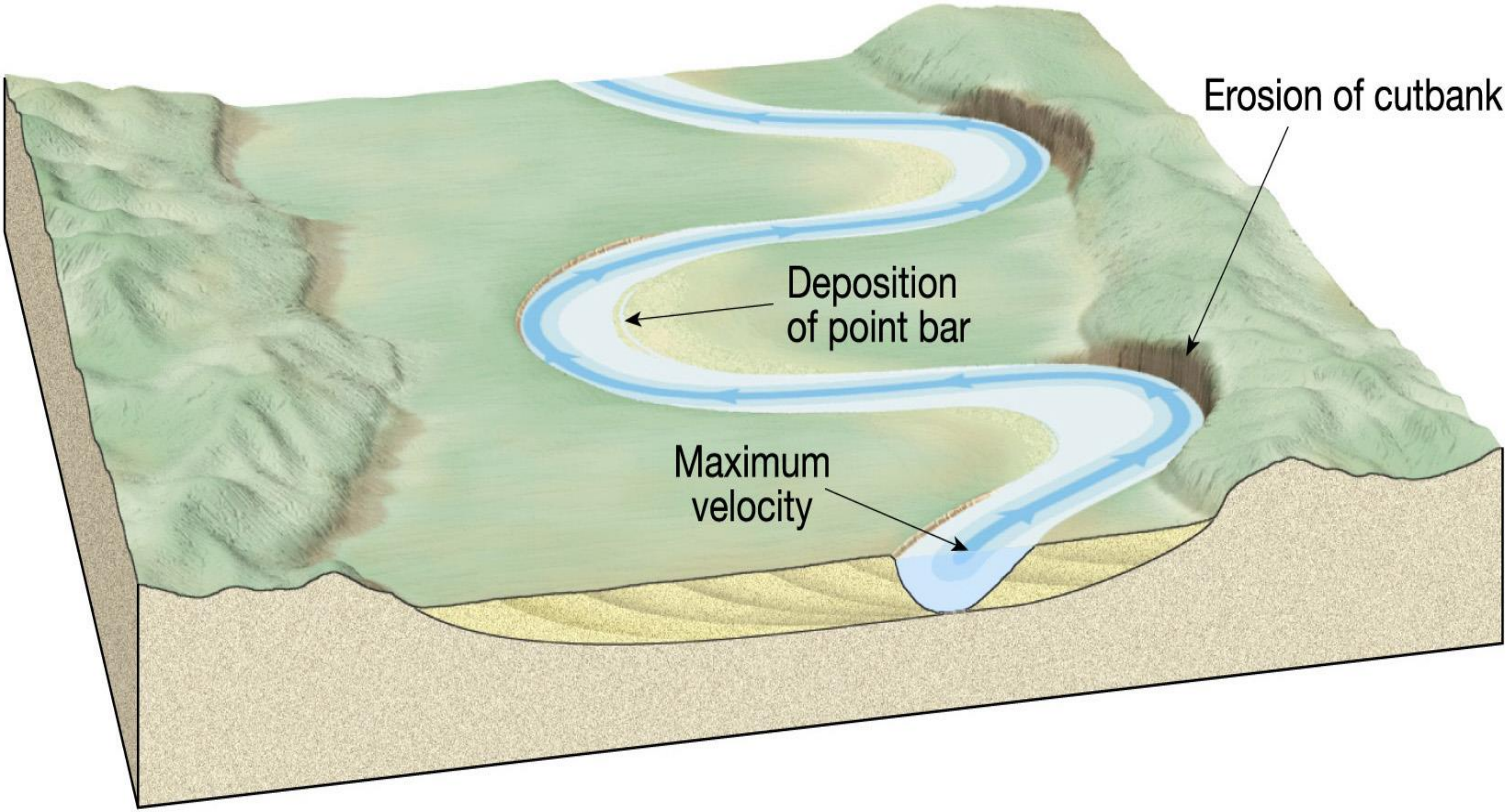


Cut Off Meanders / Oxbow Lakes

- ➔As the erosion and deposition processes continues, the heads grow closer and the point bar bigger. During a major flood when velocity and water volume increase, the river takes a new shorter course cutting across the loop
- ➔The abandoned loop remains as an oxbow lake

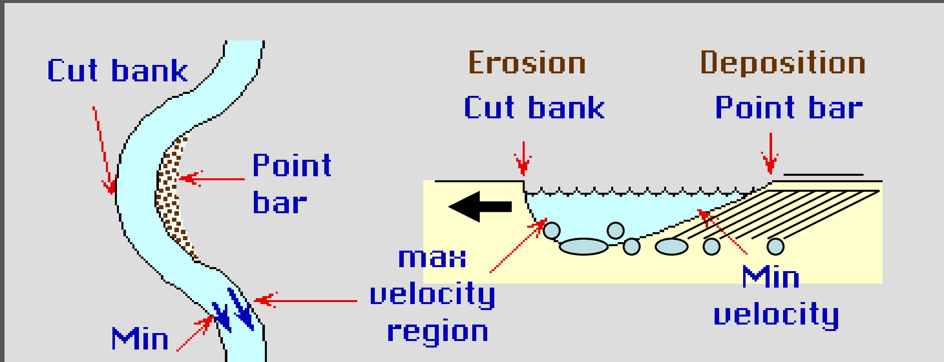


Erosion and deposition along a meandering stream

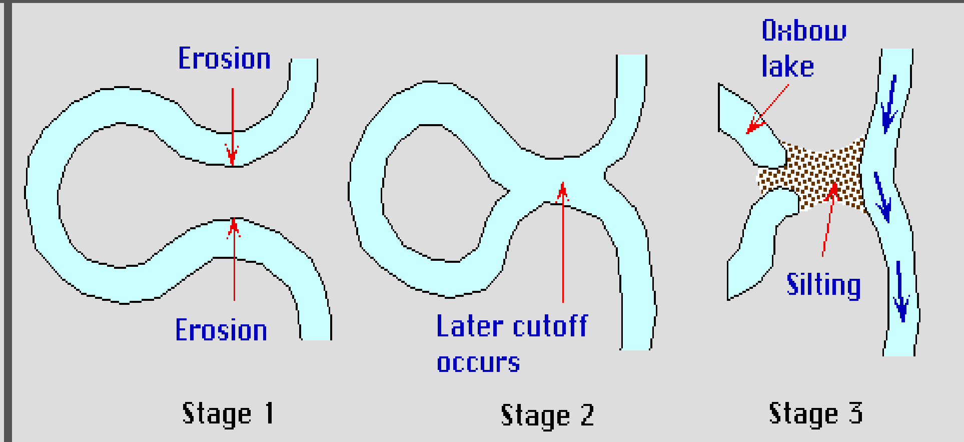


Meanders get more extreme with time. Note the THALWEG (blue arrows)

Meandering Stream



Channel moves in direction of cutbank
Pointbar advances as crossbed drapes

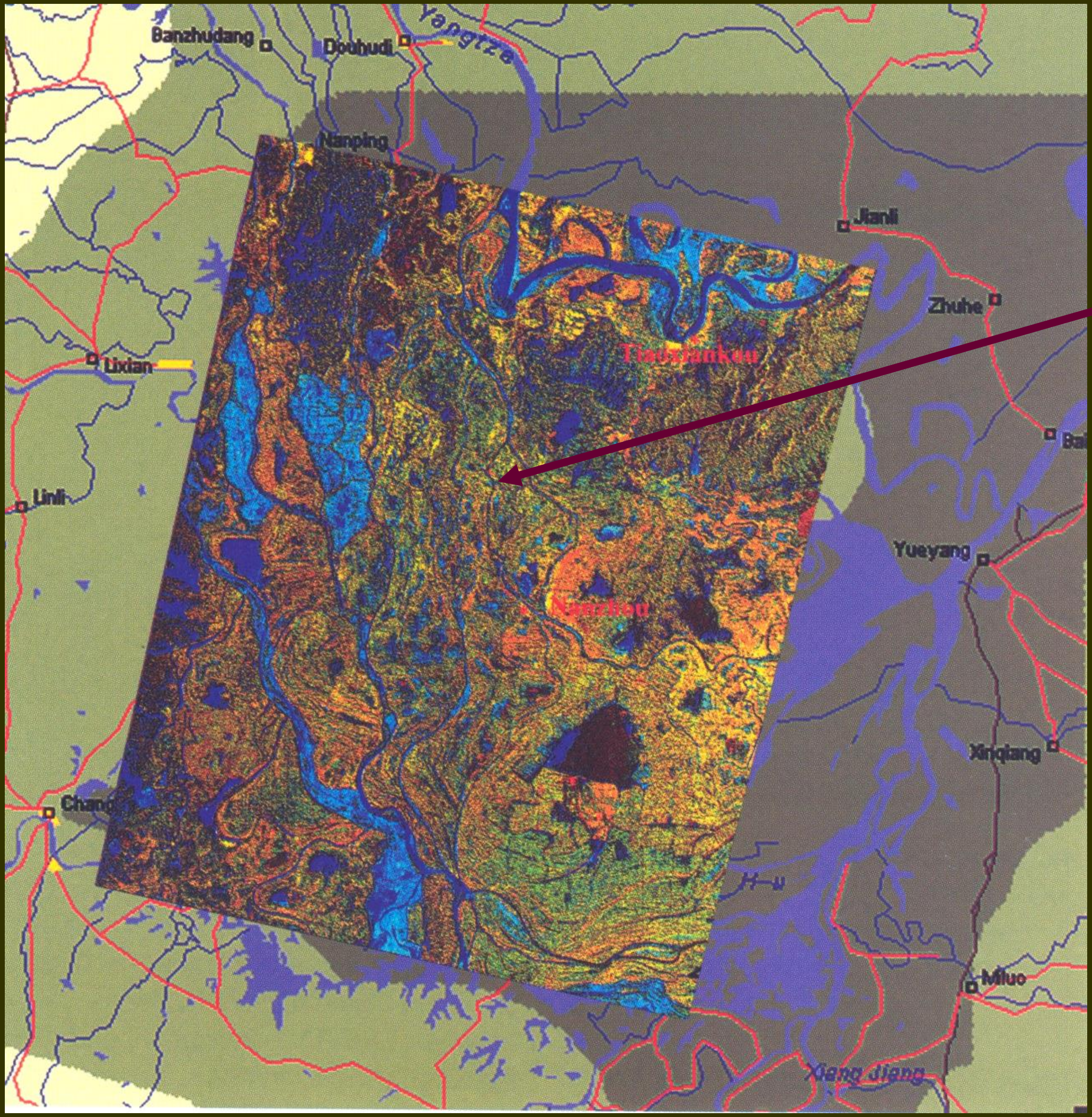


http://hays.outcrop.org/gallery/rivers/arid_meander?full=1

Meander plain:

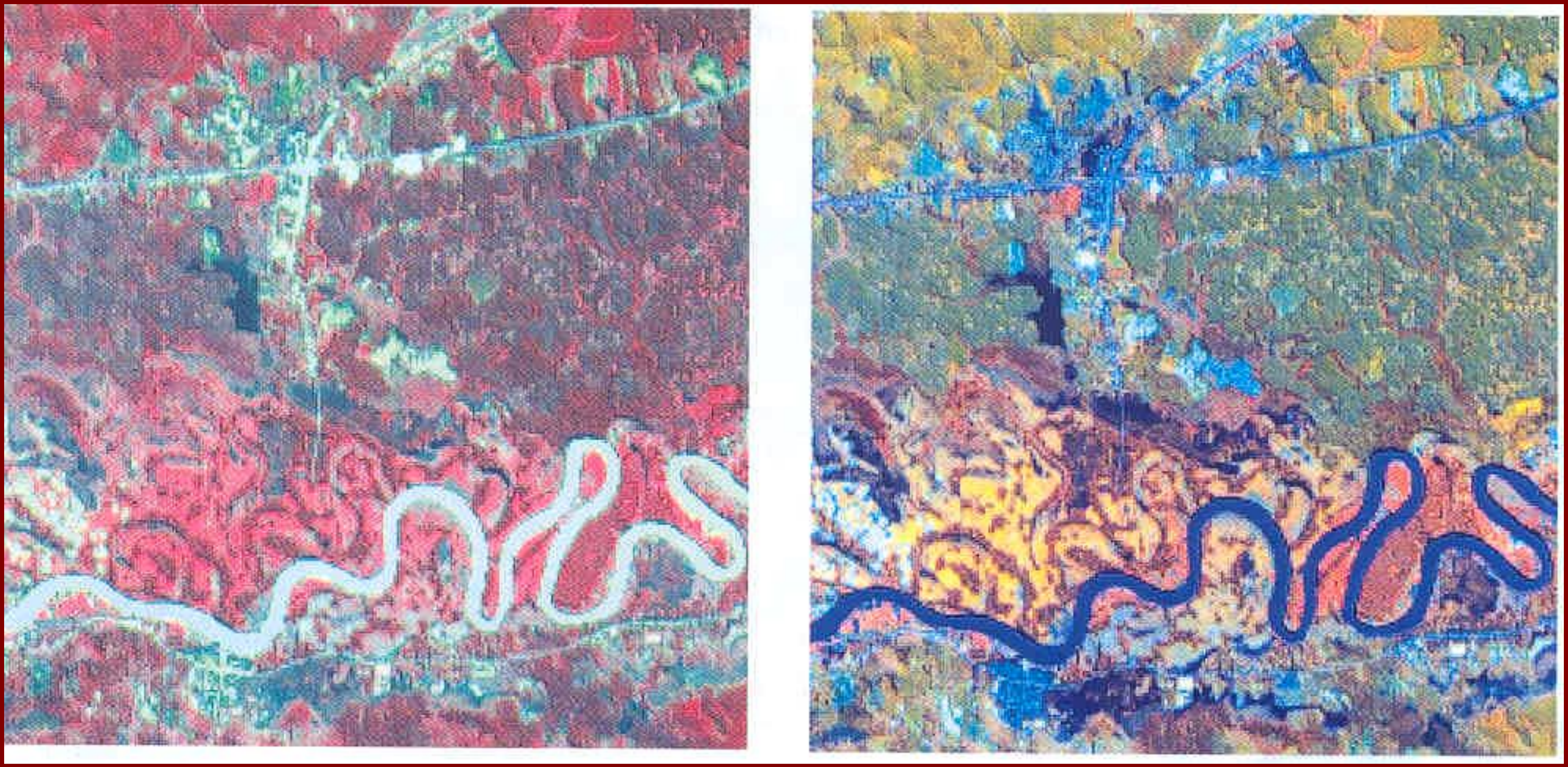
- Plain developed in between the meanders called meander plain

YANZGE – RIVER – SAR - ERS



Meander Plain

SWIR



- Yazoo river: are tributaries flowing parallel to the main stream.

LAND FORMS OF REJUVENATION

Definition:

Landforms formed due to rejuvenation of rivers

inducing processes

➔Younger or mature stage landforms may be subsided due to tectonic activity (Flood Plain in youthful stage)

➔Old or mature stage landforms may be uplifted due to tectonic activity (Entrenched meanders)

➔Sea level Changes

Land forms

Incised or entrenched meanders

➔A deep valley cut by a meandering stream

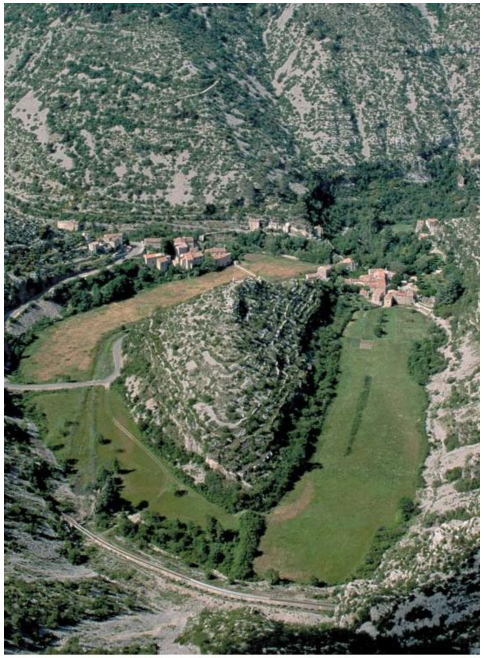
2. River cut terraces in old stage.

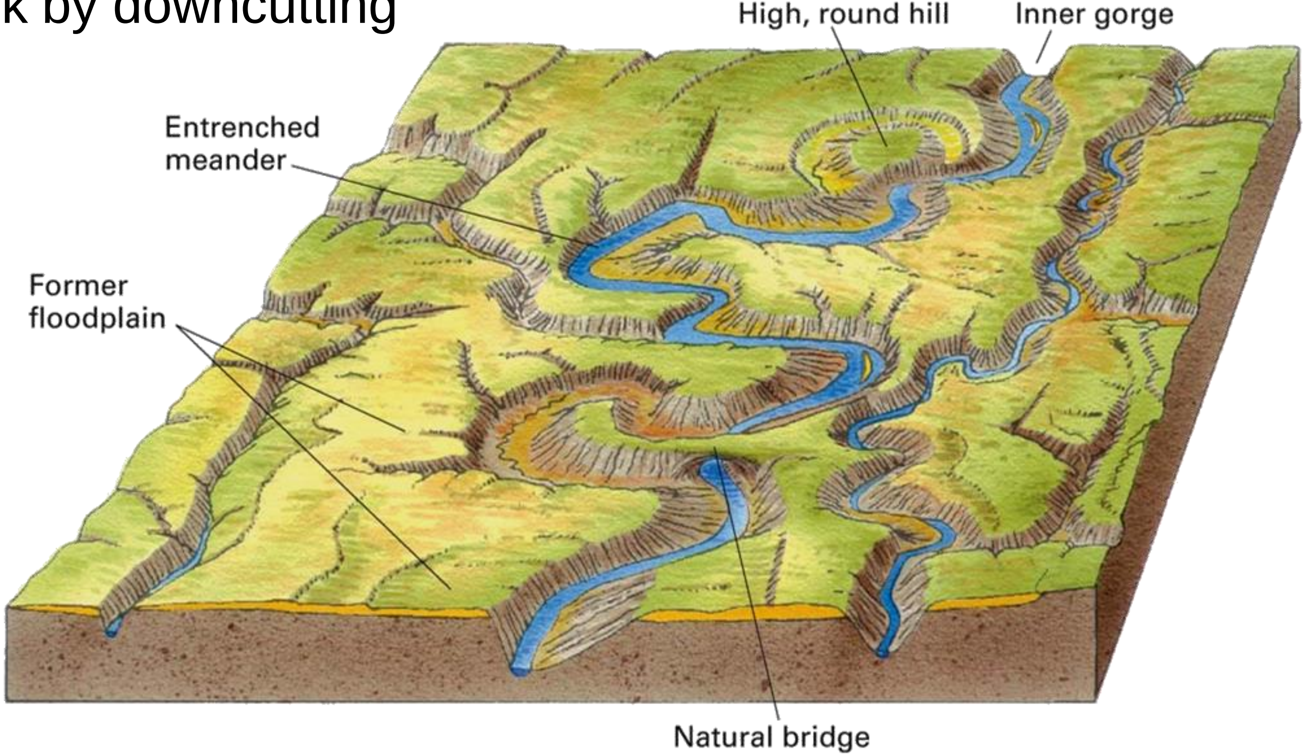
Fluvial Landscapes

Entrenched Meanders

Rapid tectonic uplift increases the river's gradient and velocity, so it cuts down into the bedrock

Entrenched meanders: winding, sinuous valley produced by degradation of a stream with trenching into the bedrock by downcutting





Flood plain in youthful stage