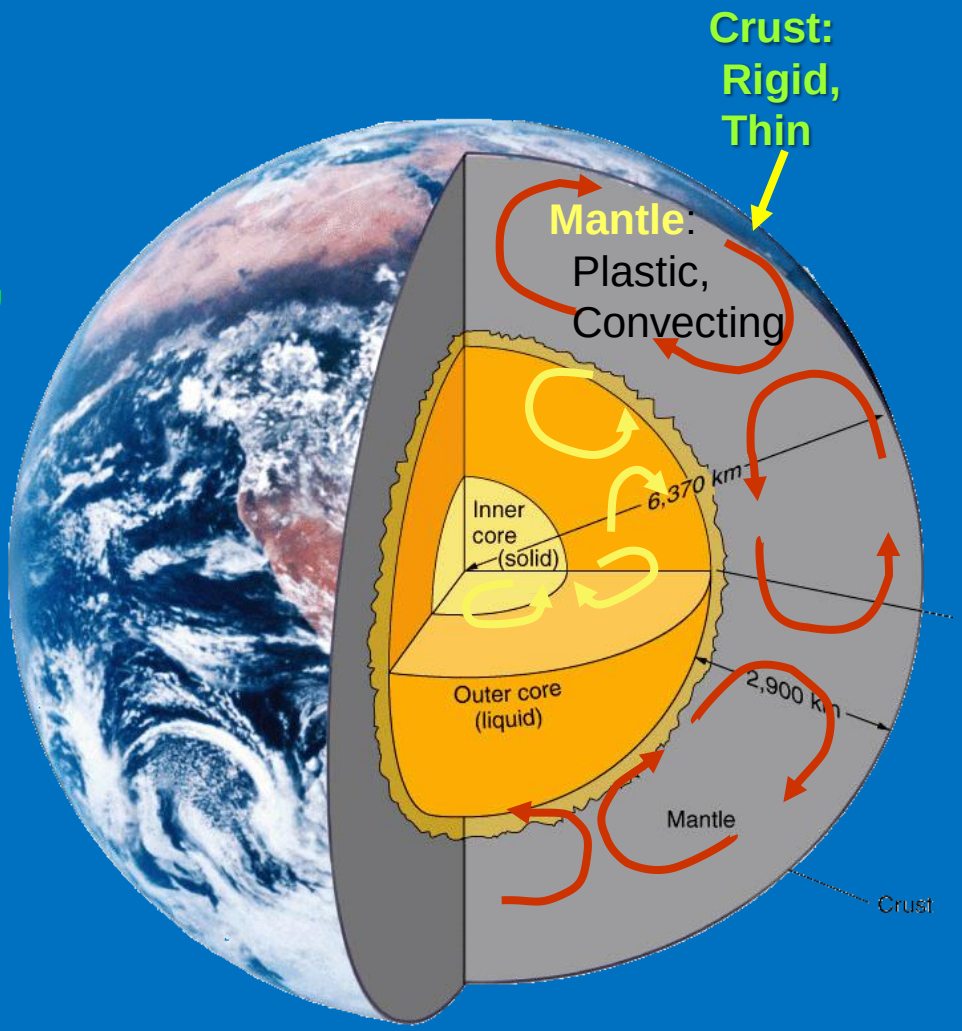
Tectonic Stresses ⇒ Large Scale Strain of the Crust i.e., Geologic Structures

- Inner core: Solid iron
- Outer core: Liquid iron, convecting (magnetic field)
- Mantle (Asthenosphere) : Solid iron-magnesium silicate, plastic, convecting
- Crust (Lithosphere): Rigid, thin 5-30km



Tectonics and Structural Geology

Tectonic Stresses

resulting from

Internal Energy

(heat driving convection

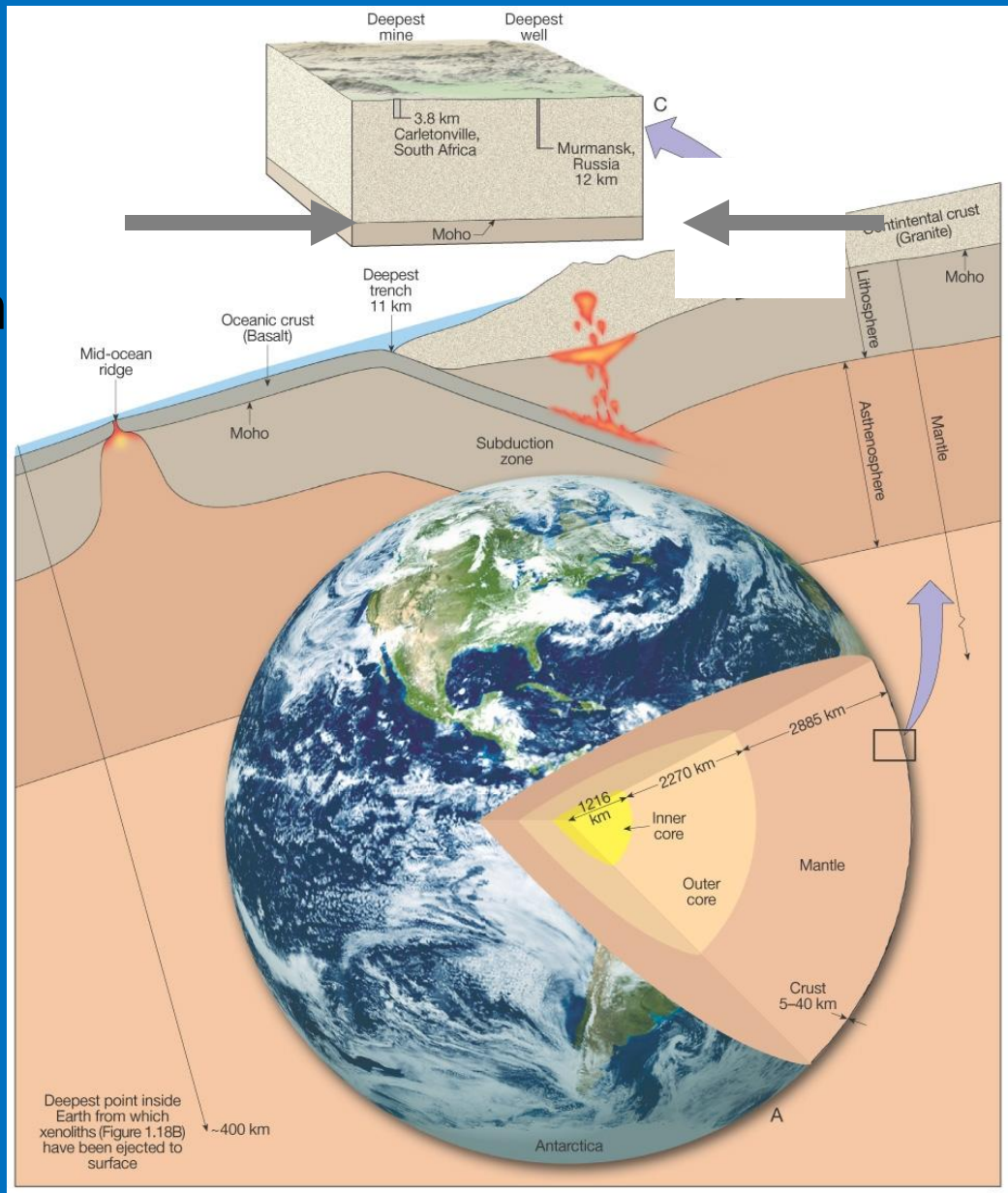
Strains (deforms) the Mantle and Crust

–Bends Rocks, i.e., ductile strain (**Folds**)

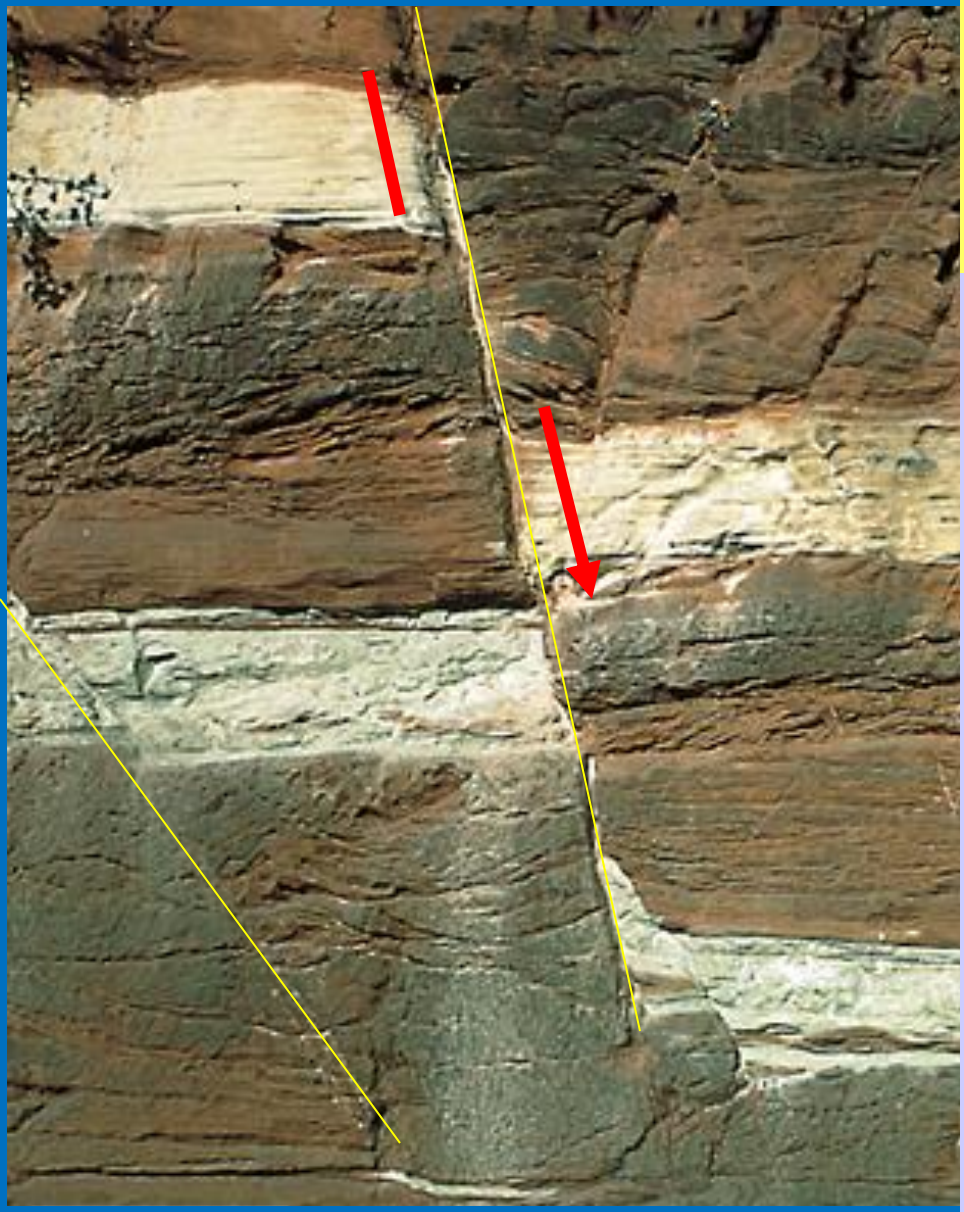
–Breaks Rock, i.e., brittle strain (**Joints**) and

–Moves large blocks along **Faults** and

–Releases energy → **Earthquakes**



What is a Fault?



- **A fault is a break or fracture between two blocks of rocks in response to stress.**

- **Three types of stresses produce faults**
  1) **Tension**
  2) **Compression**
  3) **Shear**

➢One block has moved relative to the other block.

➢The surface along which the blocks move is called a ***fault plane.***

Fractures

- **Joints:** fractures with no relative movement
- **Faults:** fractures with relative movement

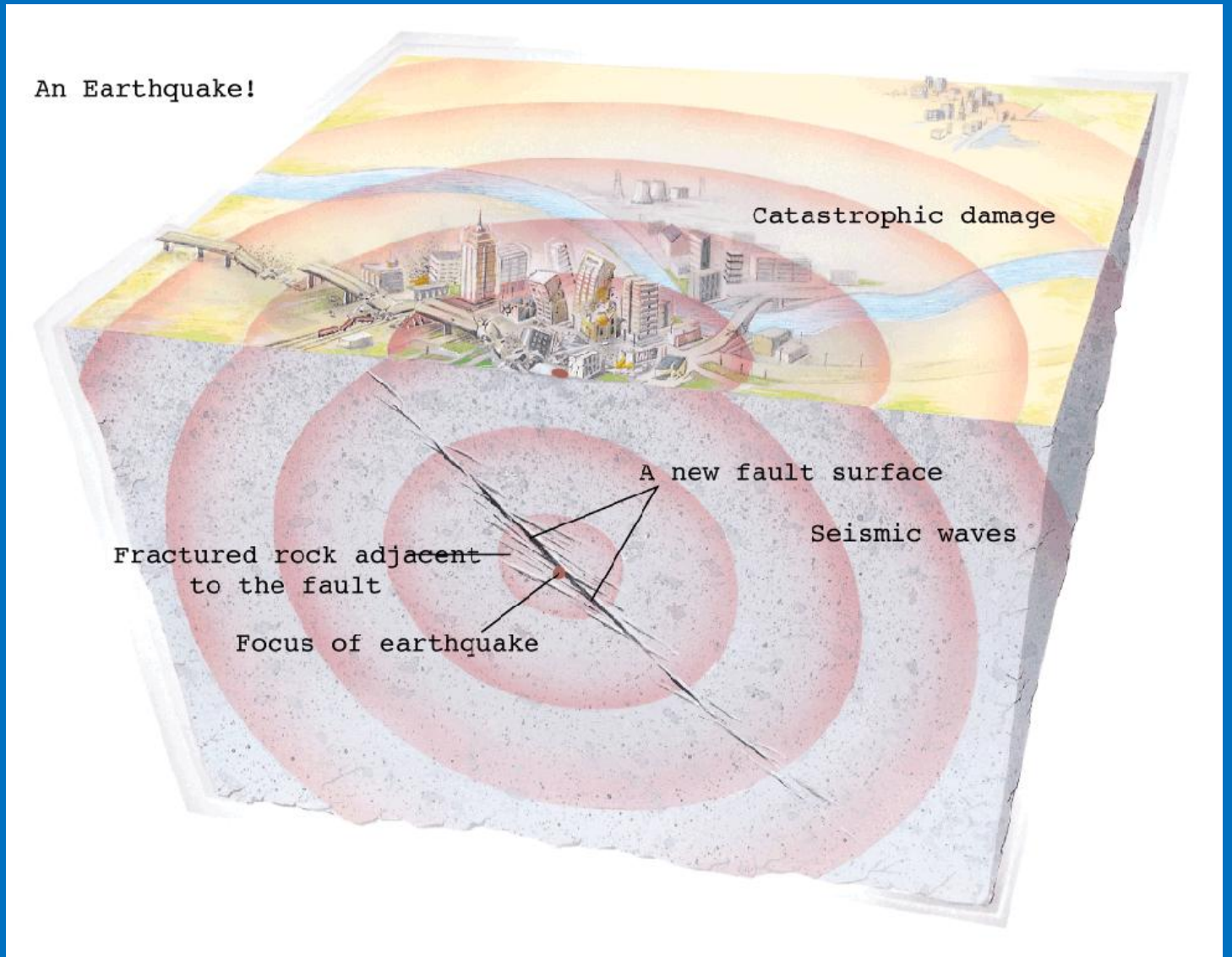
1) Hanging wall vs. footwall

2) Fault names: based on geometry & kinematics

3) Characteristics and terminology

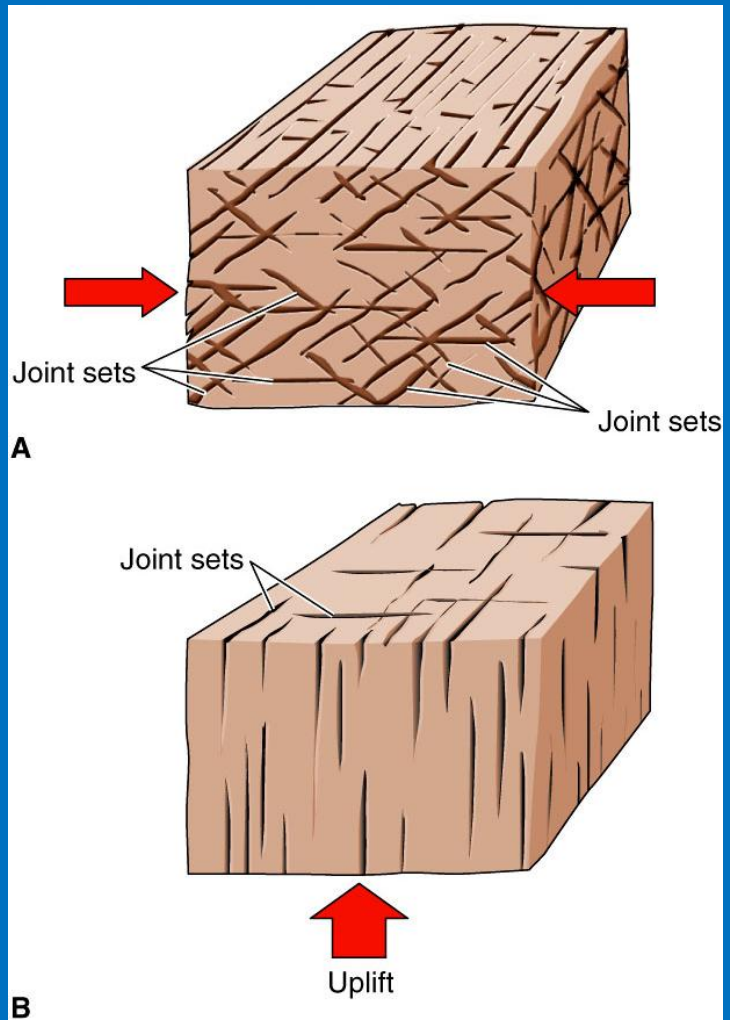
- Strike-slip faults
- Normal faults
- Thrust faults

In addition, though many faults break the Earth's surface, others do not. These latter structures are called blind faults.



Brittle Strain → Joints

- When shallow crust is strained rocks tend to exhibit brittle strain



FAULT AND TERMINALOGY

Faults: **are fractures that have appreciable movement parallel to their plane. They produced usually be seismic activity.**

- **Understanding faults is useful in design for long-term stability of dams, bridges, buildings and power plants. The study of fault helps understand mountain building.**

- **Faults may be hundred of meters or a few centimeters in length. Their outcrop may have as knife-sharp edges or fault shear zone.**

Fault: Fractures along which **there is visible offset** by shear displacement; generally ***planar or curviplanar***

Hanging wall: The block toward which the fault dips.
Footwall: The block on the underside of the fault.

There is a chicken and egg relationship between faults and earthquakes-

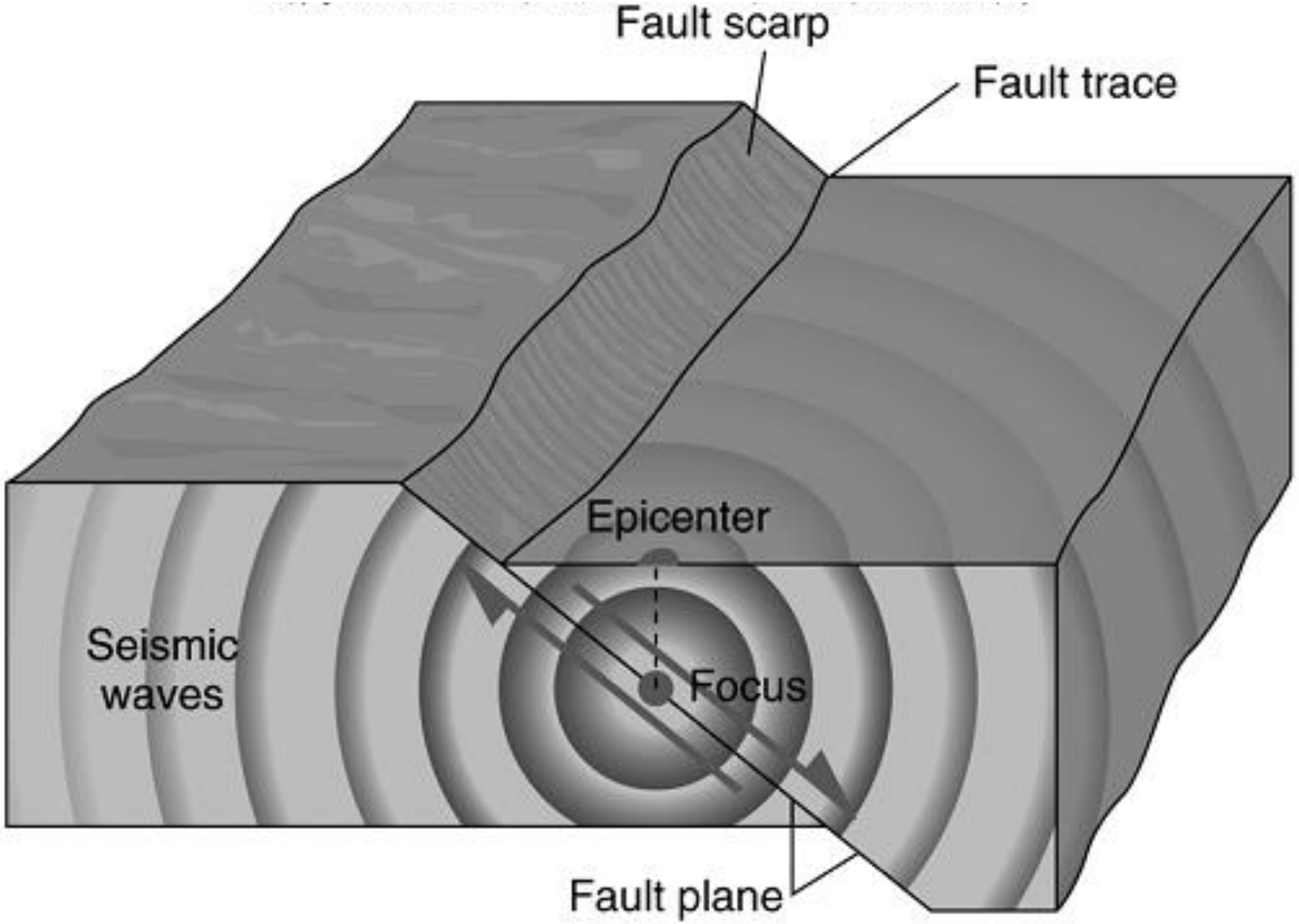
1) It was initially thought that earthquakes caused faulting (but then what caused the earthquake?)

2) It was later realized that faulting produced the earthquakes.

Thus earthquakes may occur because:-

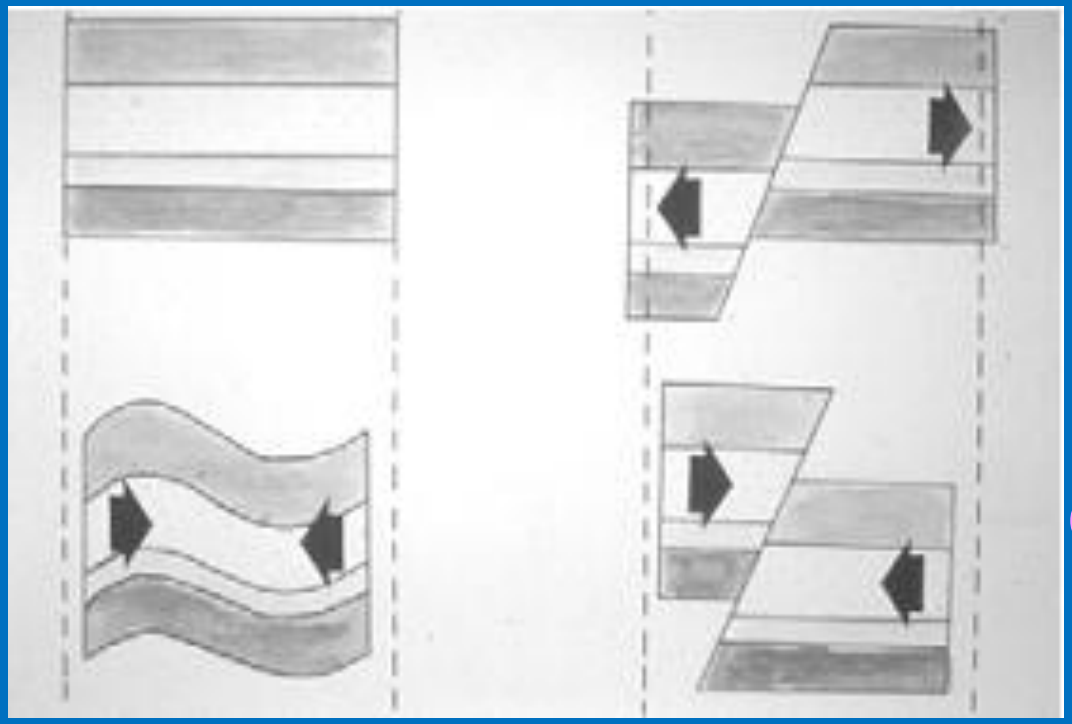
a) Rocks are initially broken to produce a fault.

b) Movement or re-activation of an already existing fault.
[Faults may therefore be thought of as "fossil" relicts of previous earthquakes]



Relationship between faulting and an earthquake

Folding and Faulting



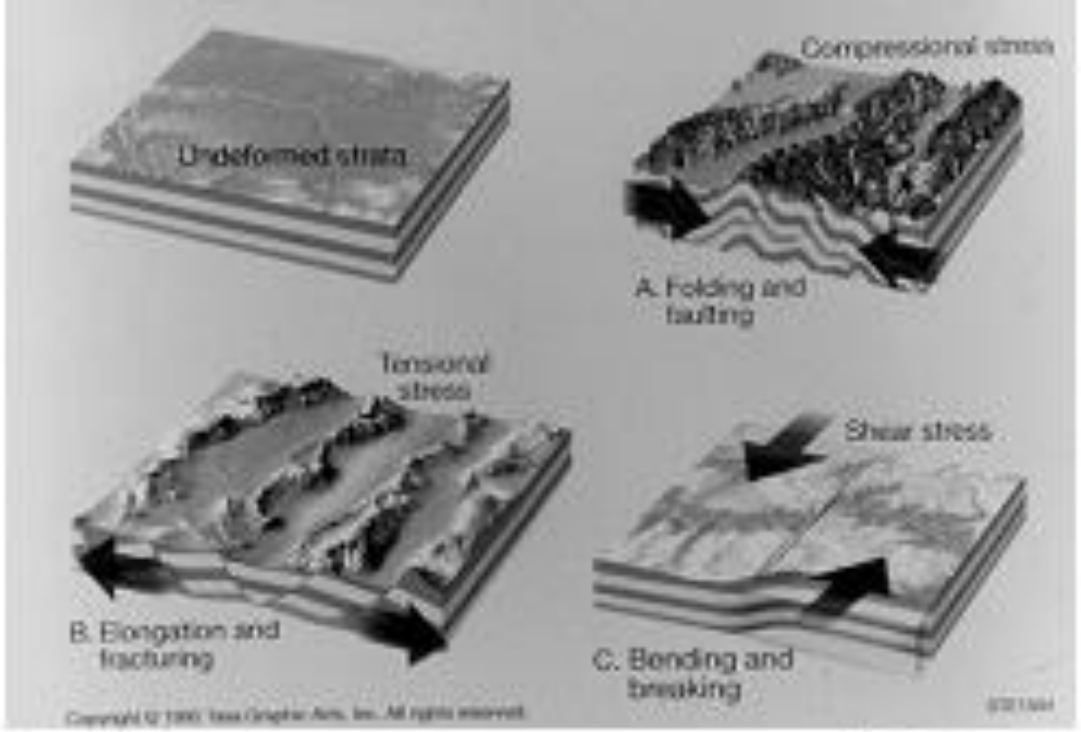
TENSION

COMPRESSION

COMPRESSION – causes rocks to fold and ultimately break to produce a fault.

TENSION – causes rocks to stretch and also break to produce a fault.

****Faulting also occurs in response to shearing stresses**

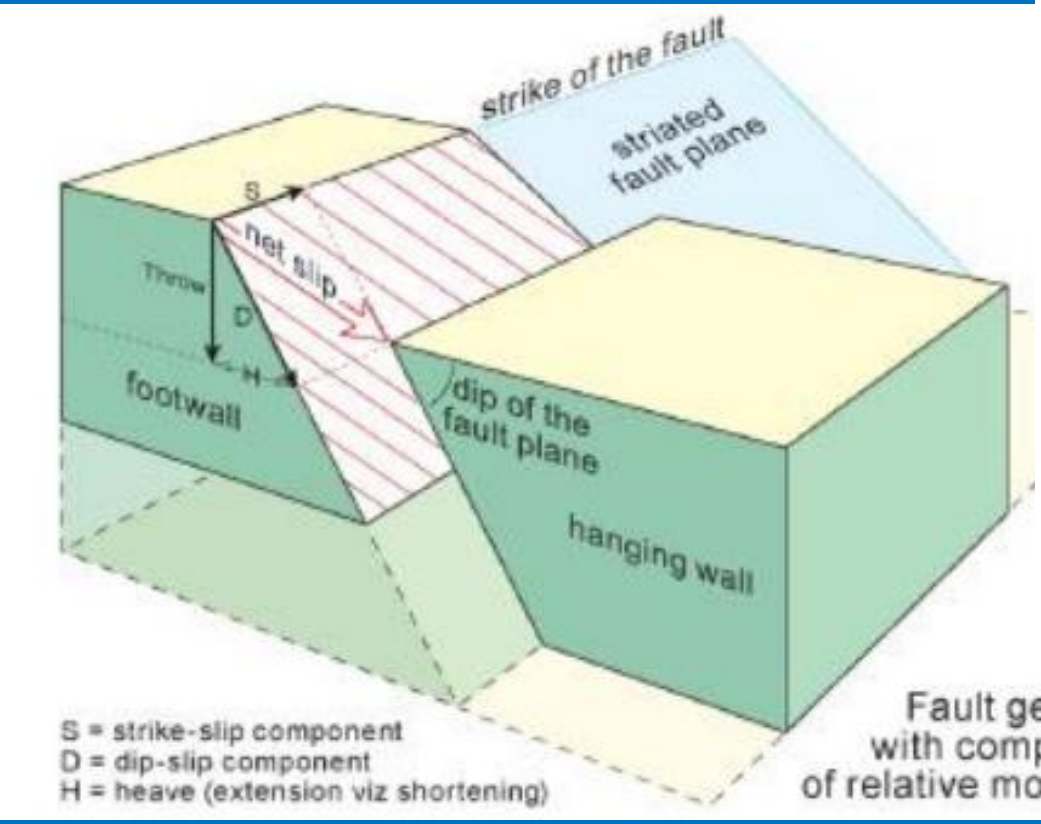


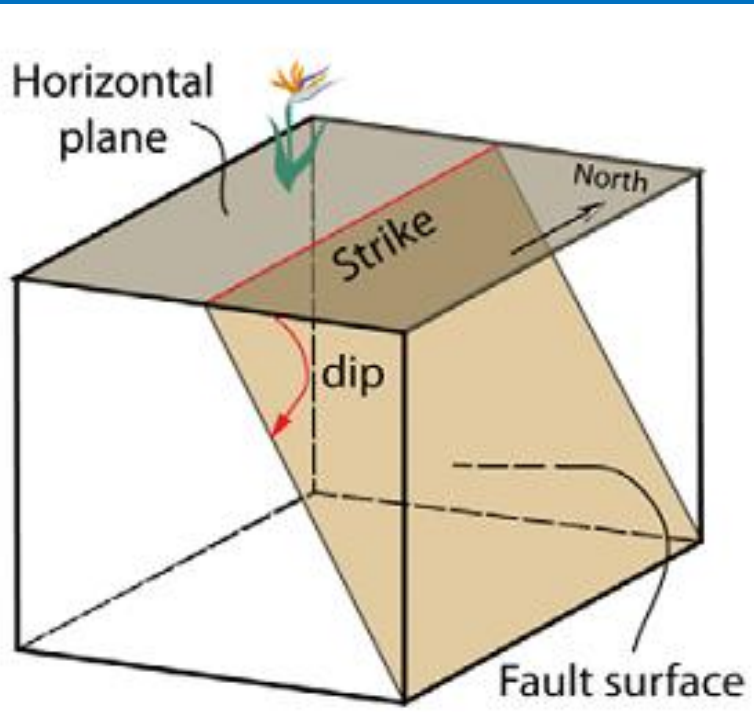
Relationship of stresses to types of faulting

Example of folded rocks that have broken to produce a fault

Fault plane: it is the planer surface along which relative displacement of blocks takes place during the process of faulting.

Stikes and Dips are used to identify geologic structures





Slip vs. Separation

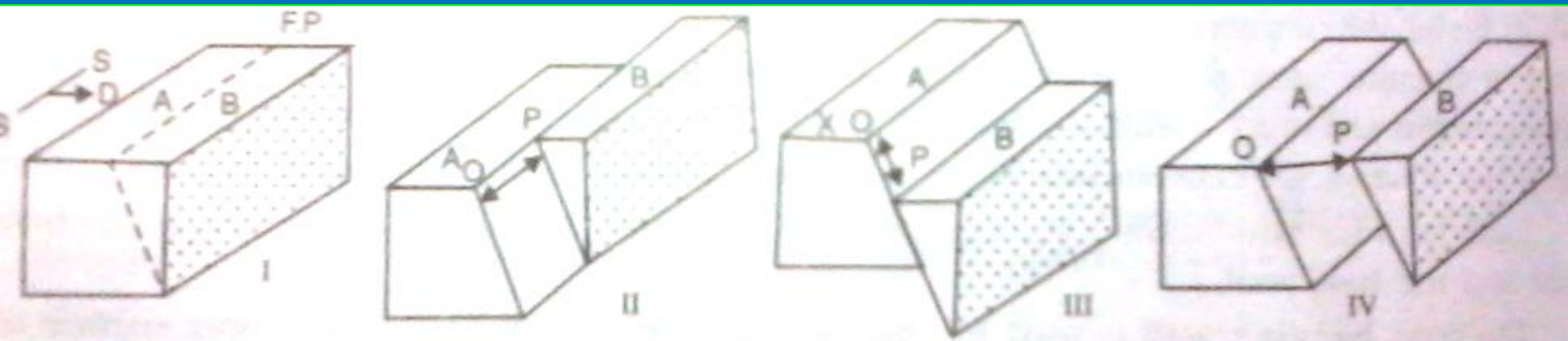
Slip: actual relative displacement /3D
Separation: apparent relative displacement/ 2D

Slip may be defined as the relative motion of rock blocks along fault planes.

1. Strike slip: the slip that occurs along the direction of the strike of fault plane.

2. Dip slip : the slip that occurs along the direction of the dip of the fault plane.

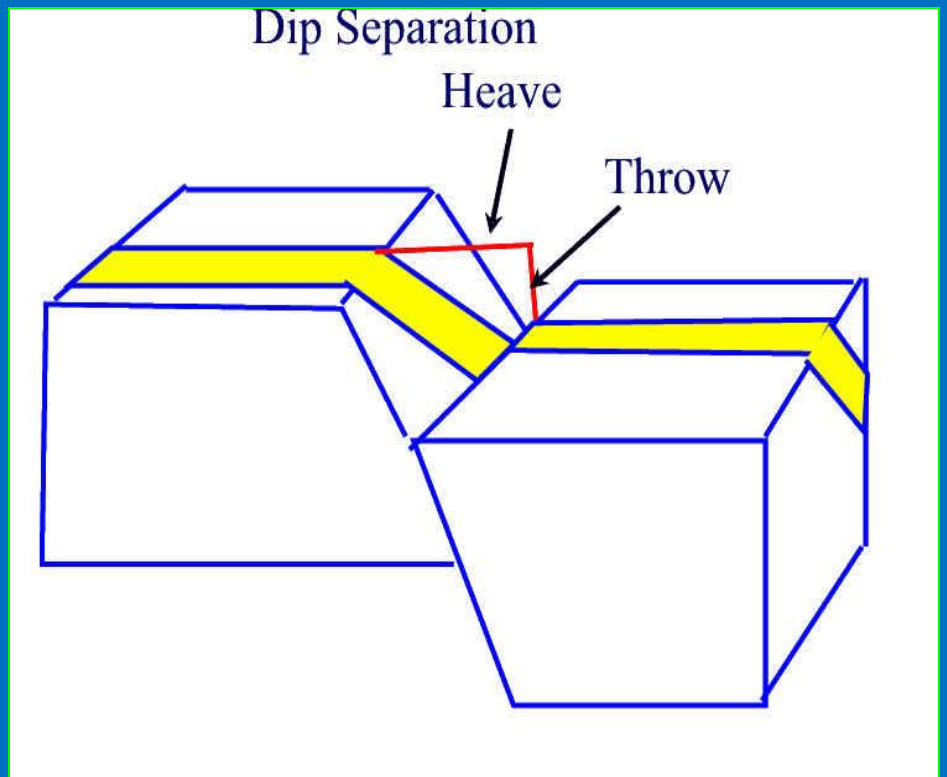
3.Oblique slip: the slip that occurs both in dip and strike direction i.e. it is combination of strike and dip direction.



Slip and Separation
I–Before faulting; II–Strike slip; III–Dip slip; IV–Oblique slip

Separation: The amount of ***apparent offset*** of a faulted surface, measured ***in specified direction***

1. Heave: The horizontal component of dip separation measured perpendicular to strike of the fault



2. Throw: The vertical component measured in vertical plane containing the dip.

Following are the factors commonly considered important :

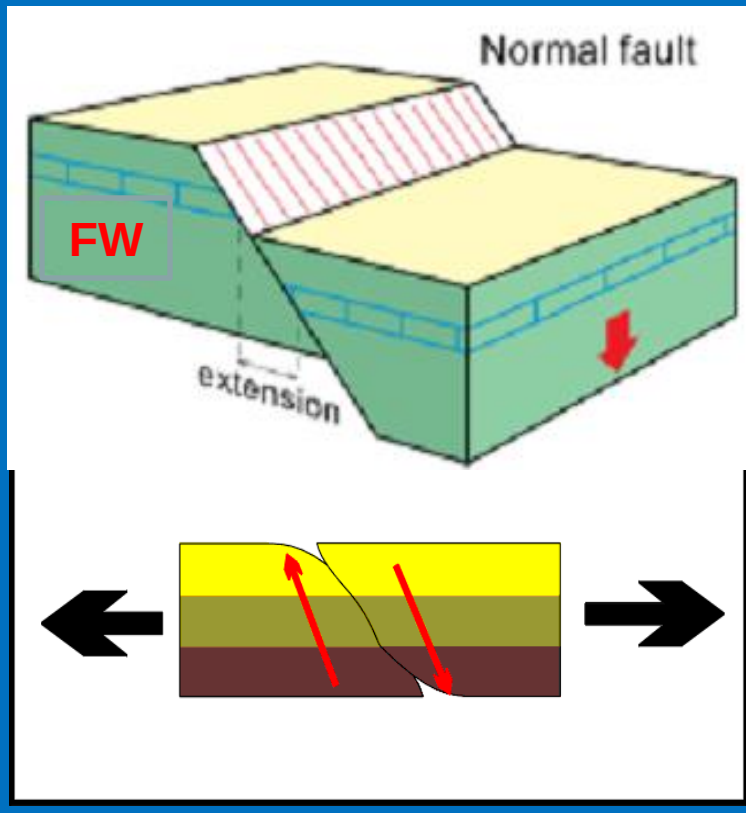
1. The apparent movement of the rock blocks along the fault plane.
2. The direction of the slip.
3. The relation of the fault altitude with the altitude of the displaced bed

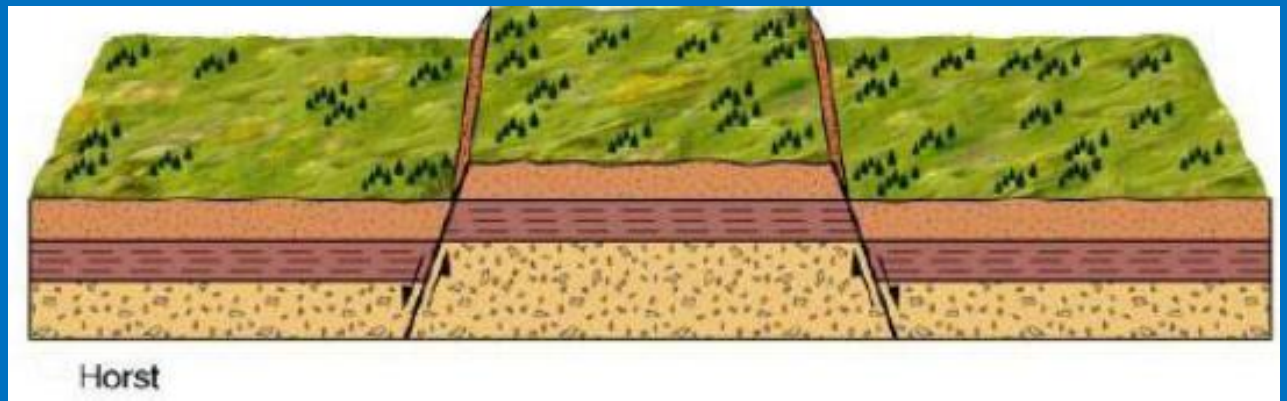
**The *attitude of a fault* describes its orientation in 3D space, and consists of its strike and its dip.

Apparent movement as basis

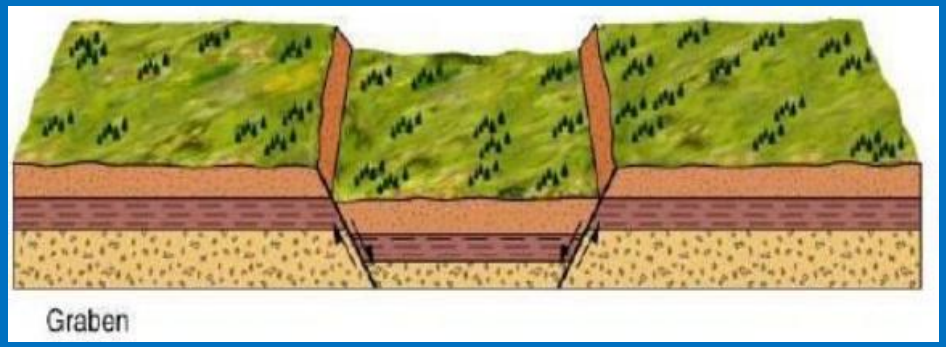
a. Normal faults: faults in which the hanging wall is moved down with respect to the foot wall.

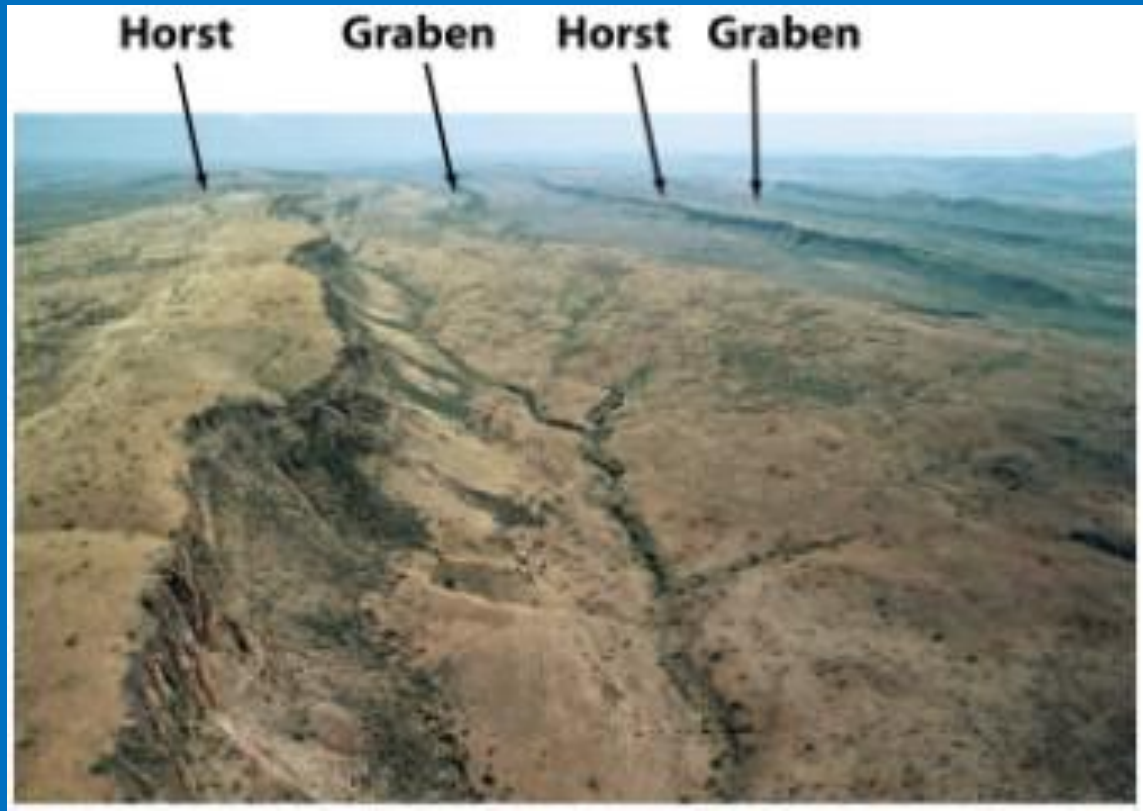
Horst : when two normal faults are on the either side of a central wedge shaped block such that it appears high up with respect to either blocks.



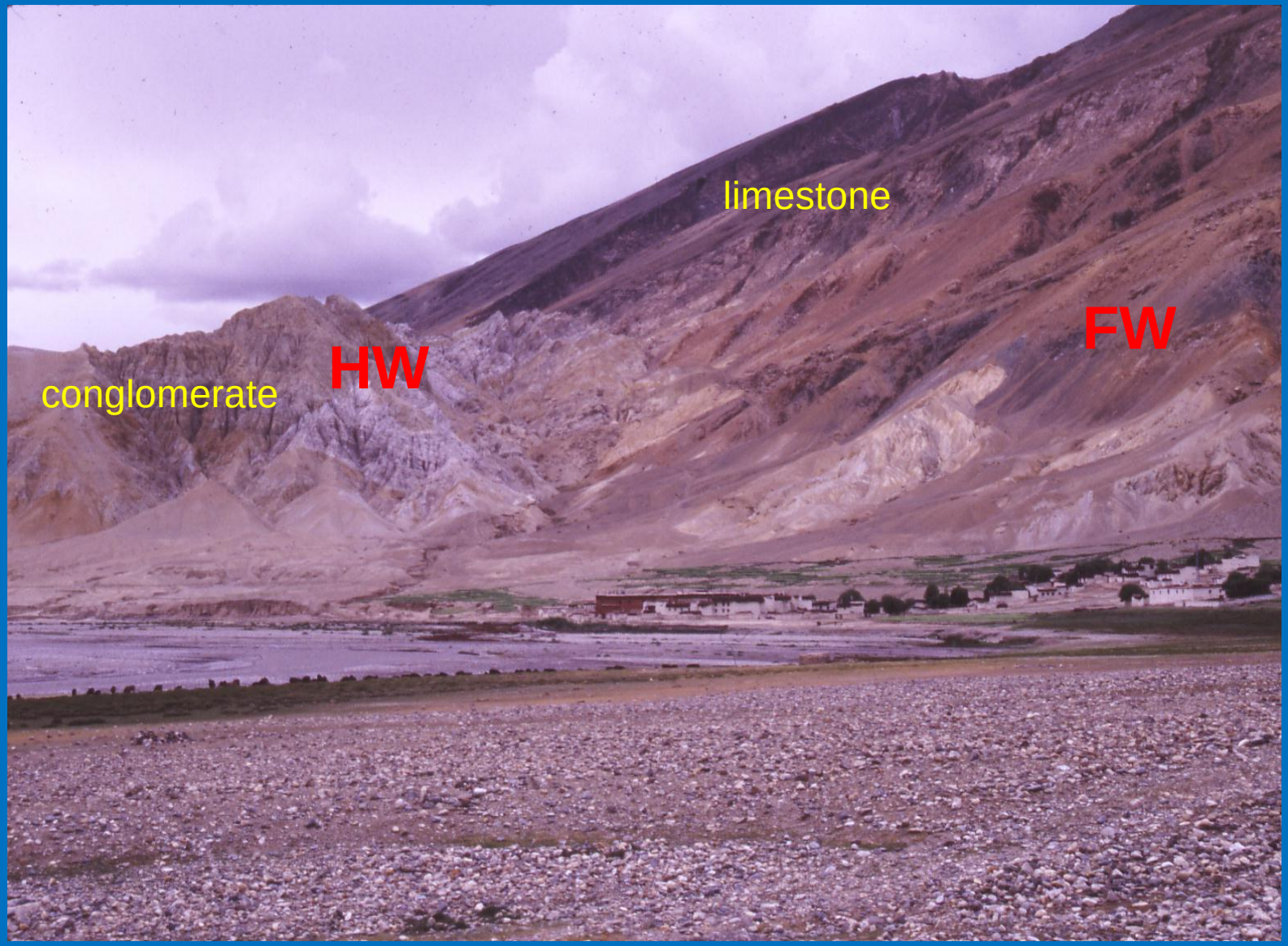


Graben: when two normal faults are on the either side of a wedge shaped block such that it appears downwards with respect to either blocks.

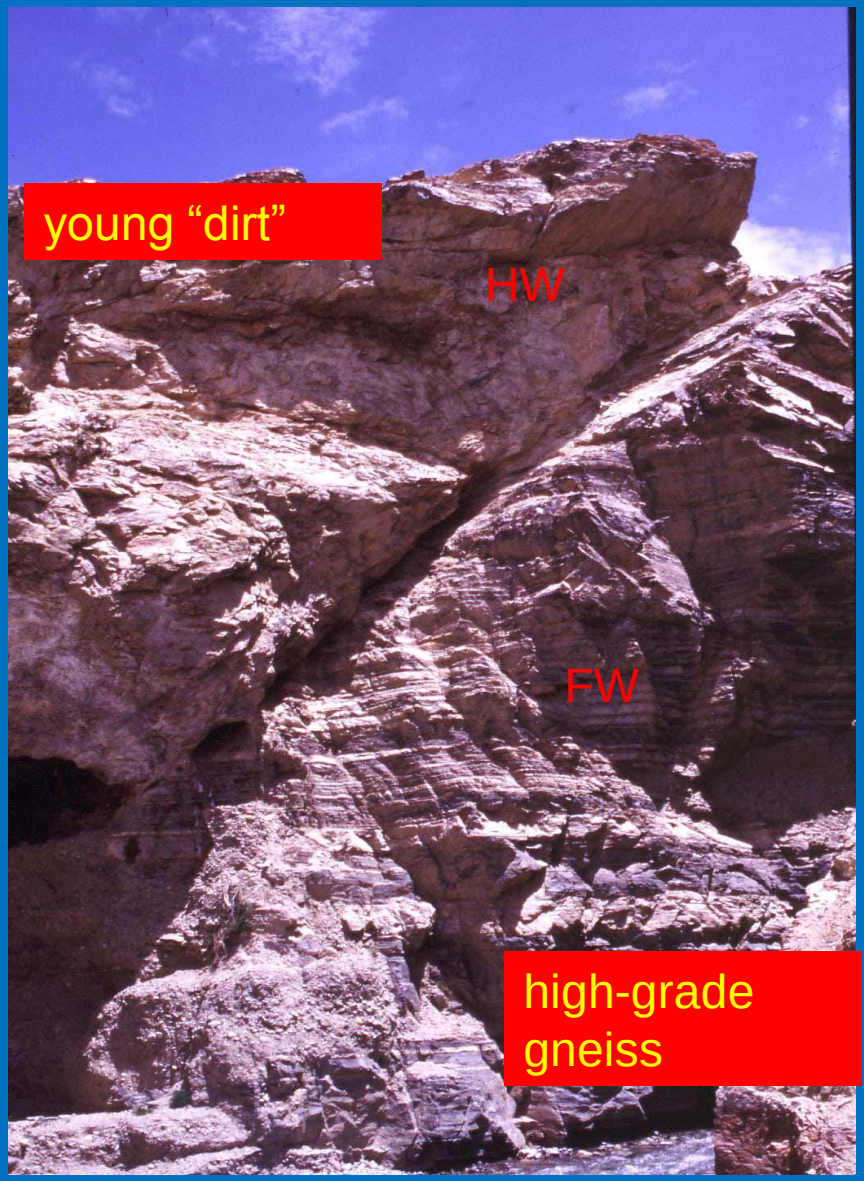




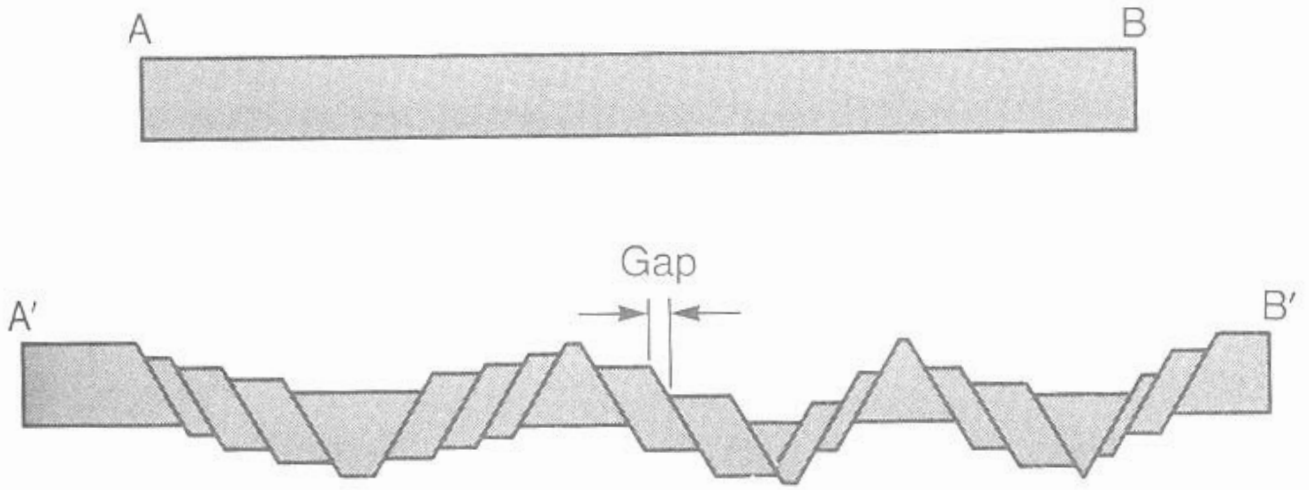
Normal faults <u>generally</u> place younger and/or lower-grade rocks (in HW) on top of older and/or higher-grade rocks (in FW)



Normal faults **generally** place younger and/or lower-grade rocks (in HW) on top of older and/or higher-grade rocks (in FW)



Normal faults accommodate lengthening



$$S = \frac{\ell_f}{\ell_o} = \frac{132\text{m}}{120\text{m}} = 1.1$$

% Lengthening = 10%

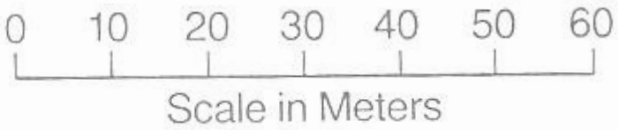
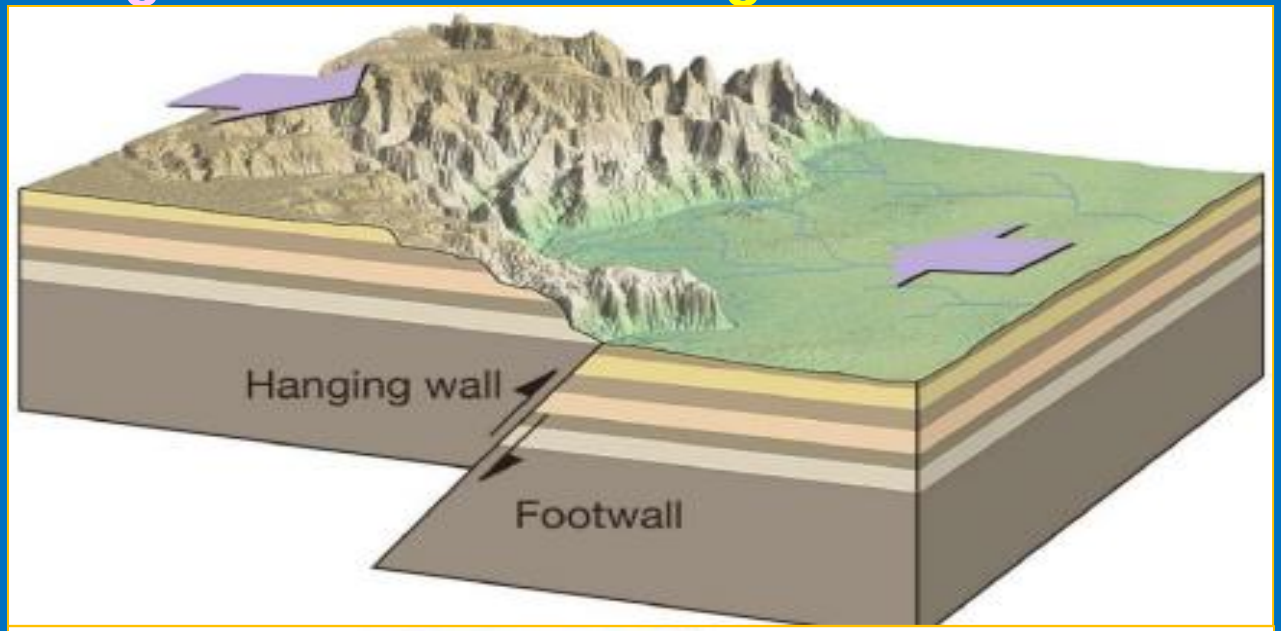
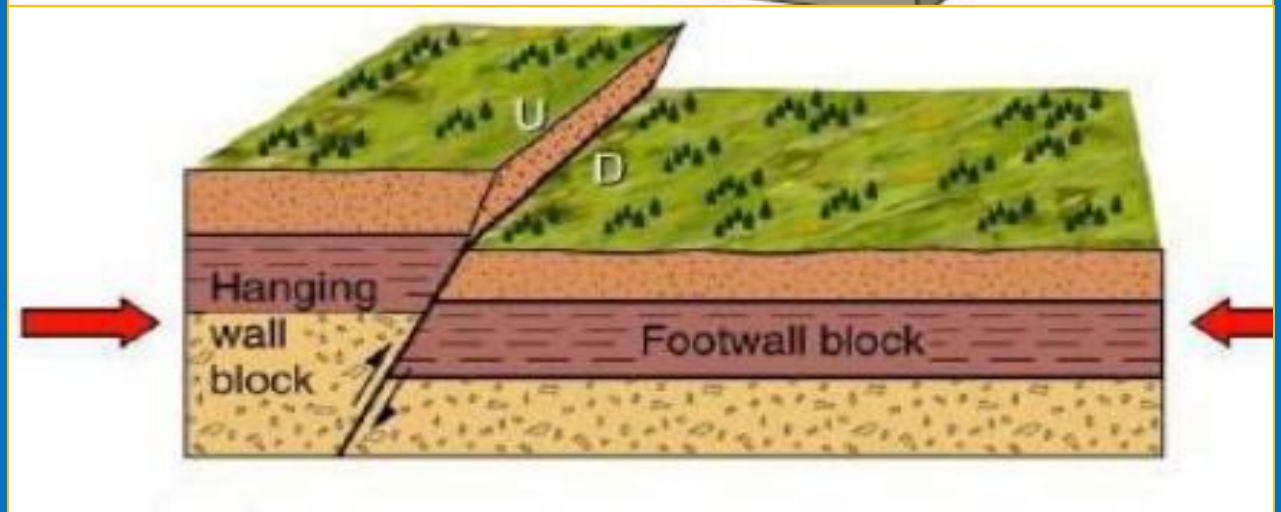


Figure 6.58 "Stretching" of a layer by normal-slip faulting. Stretch (S) measured parallel to the layer is 1.1. Total lengthening of the layer is 10%.

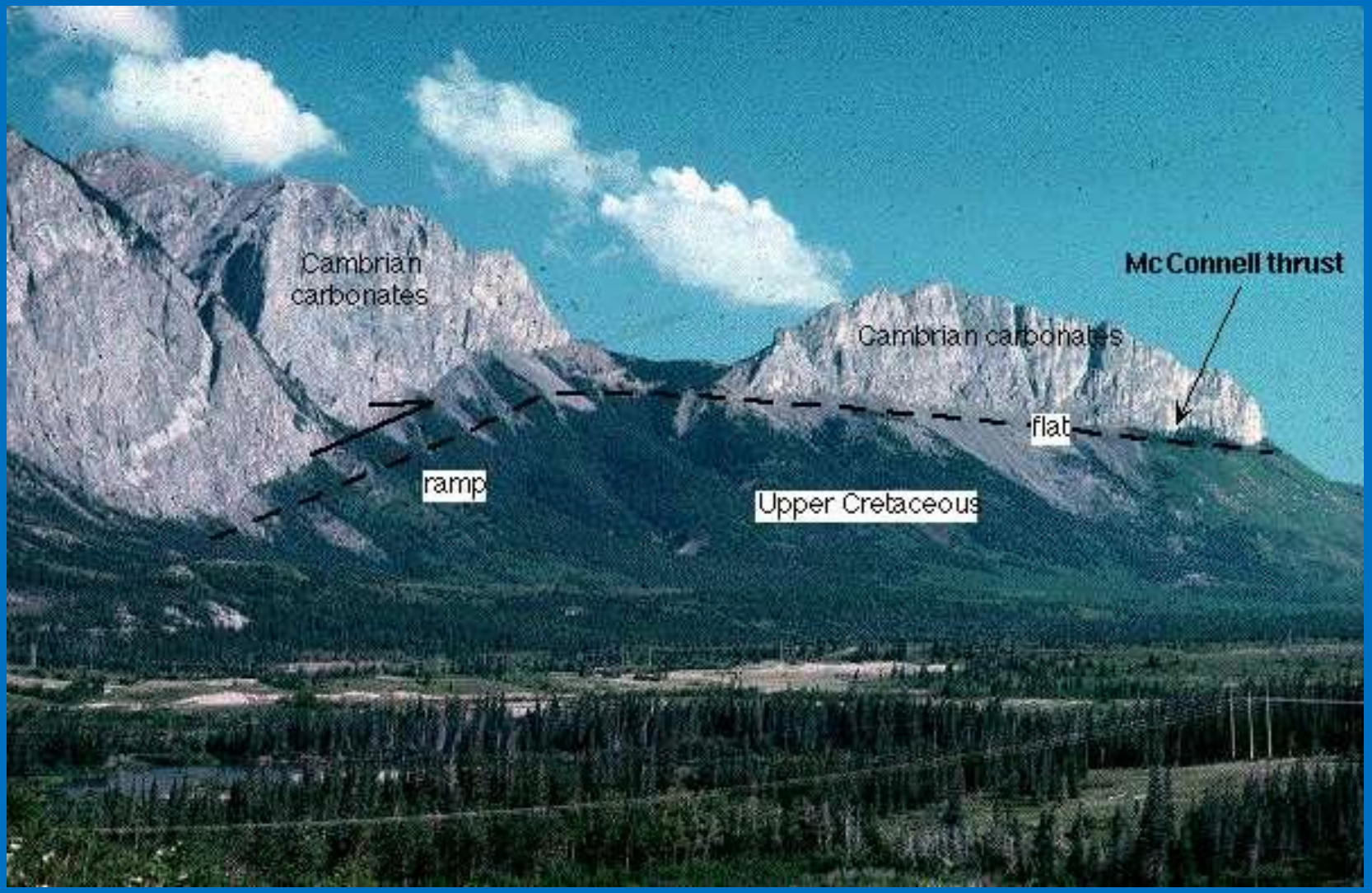
b. Reverse faults: this type of fault in which the hanging wall appears to have moved up with respect to the foot wall and dips at the angle **more than 45 degrees.**



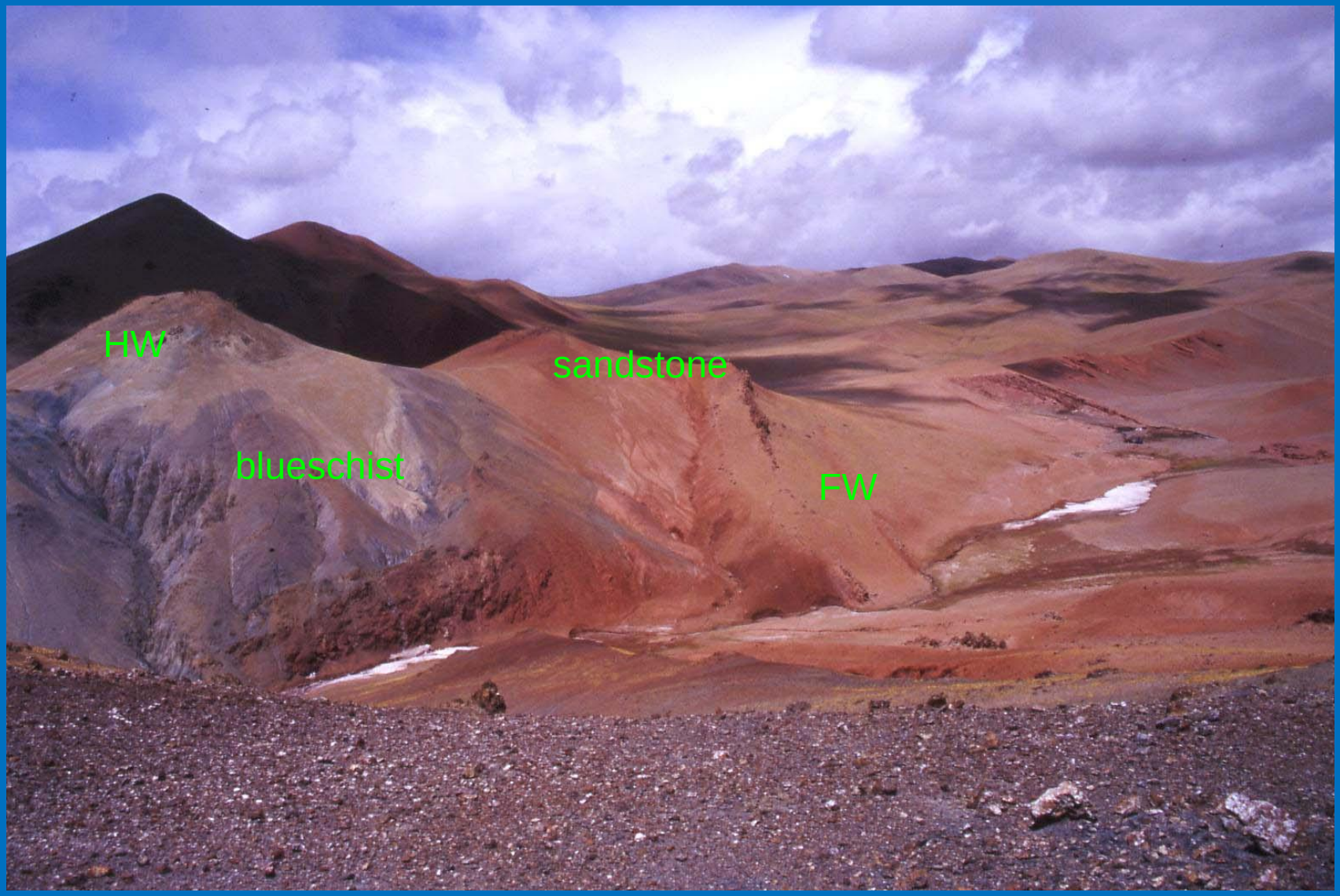


Thrust fault: these are variety of reverse faults in which the hanging wall has moved up with respect to footwall and the fault dip at the angle ***below 45 degrees.***

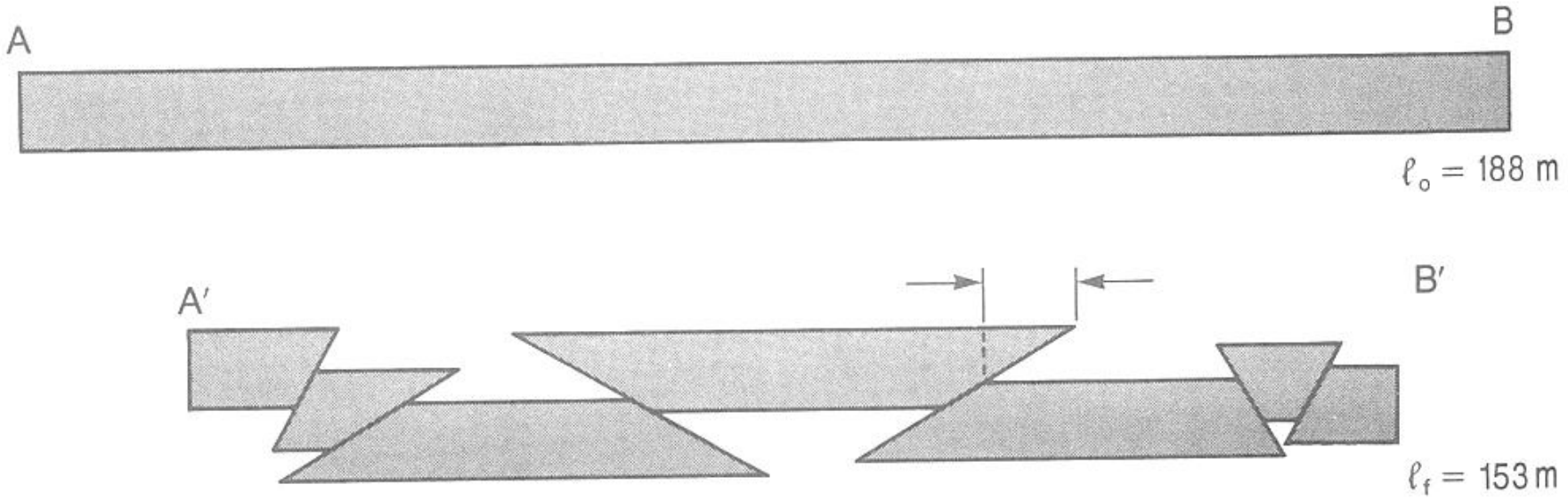
Thrust faults **generally** place older and/or higher-grade rocks (in HW) on top of younger and/or lower-grade rocks (in FW)



Thrust faults generally place older and/or higher-grade rocks (in HW) on top of younger and/or lower-grade rocks (in FW)

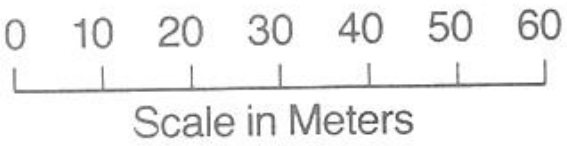


Thrust faults accommodate shortening



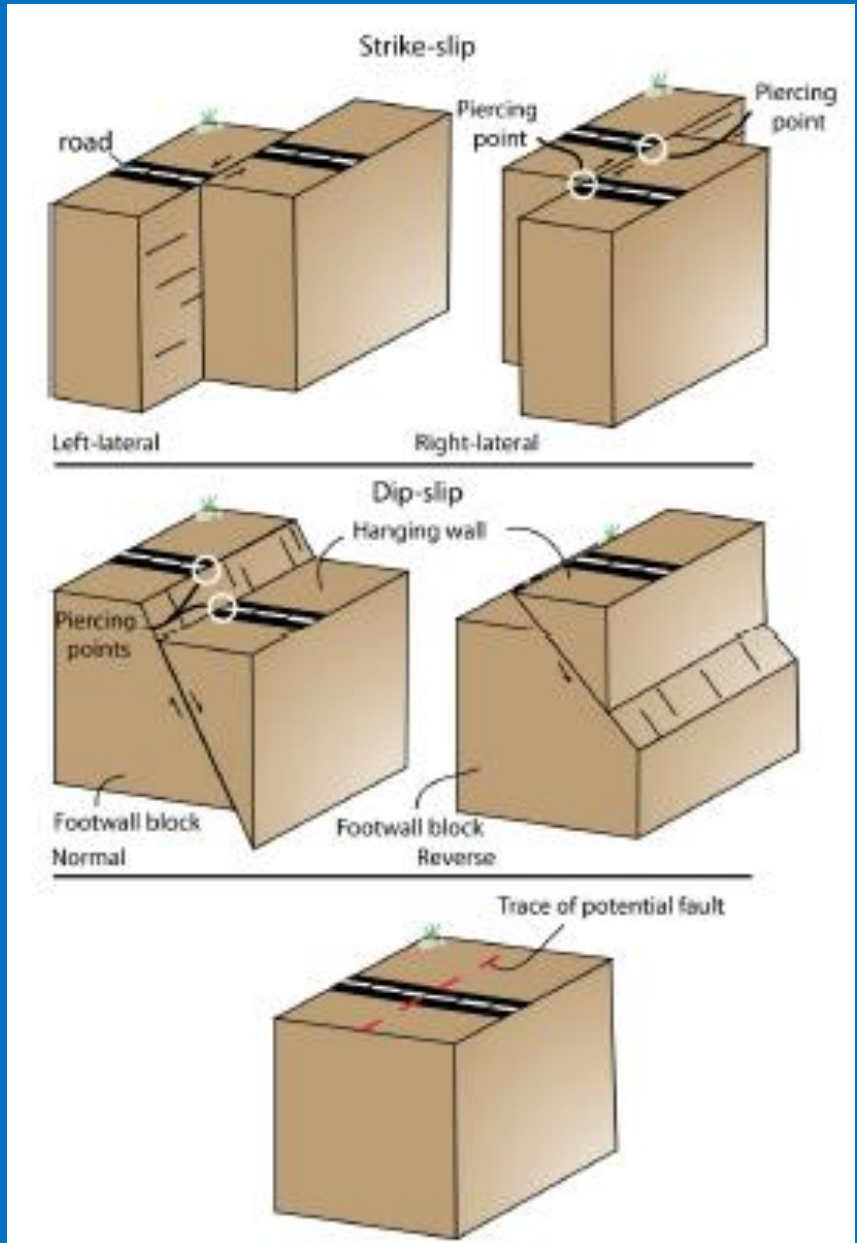
$$S = \frac{\ell_f}{\ell_o} = \frac{153}{188} = .81$$

% Lengthening = 19%

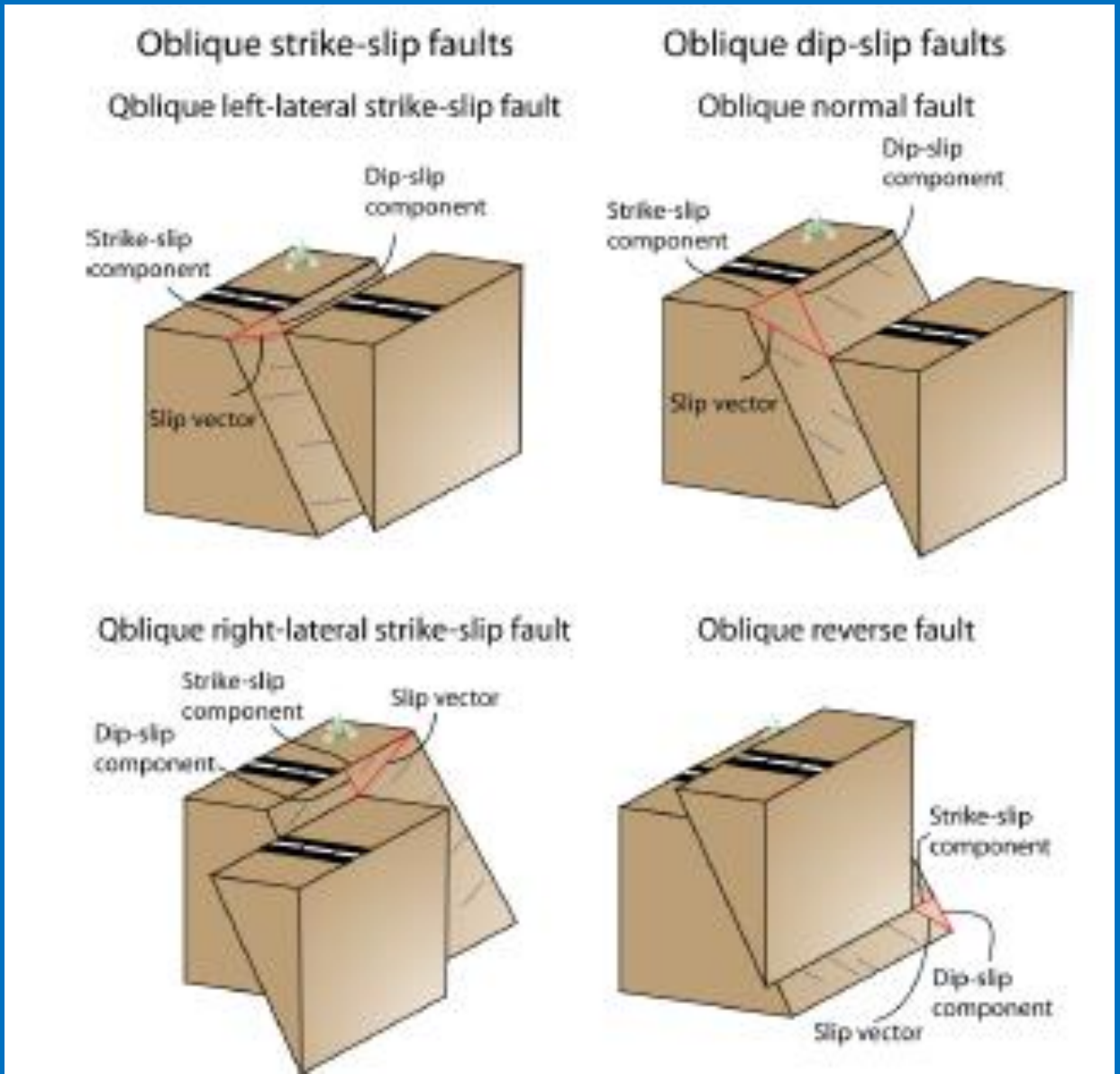


On the basis of attitude (dip and strike)

- **Strike slip faults:** faults that develop parallel to the strike of strata. In other words, the strike of the fault and that of disrupted layers are essentially parallel.
- **Dip slip faults:** faults that develop parallel to the dip of the strata. In other words, the fault strike is parallel to the dip of layers disrupted by faults.



- **Oblique faults: faults whose strike makes an oblique angle with the strike of the rock in which it has caused the displacement.**

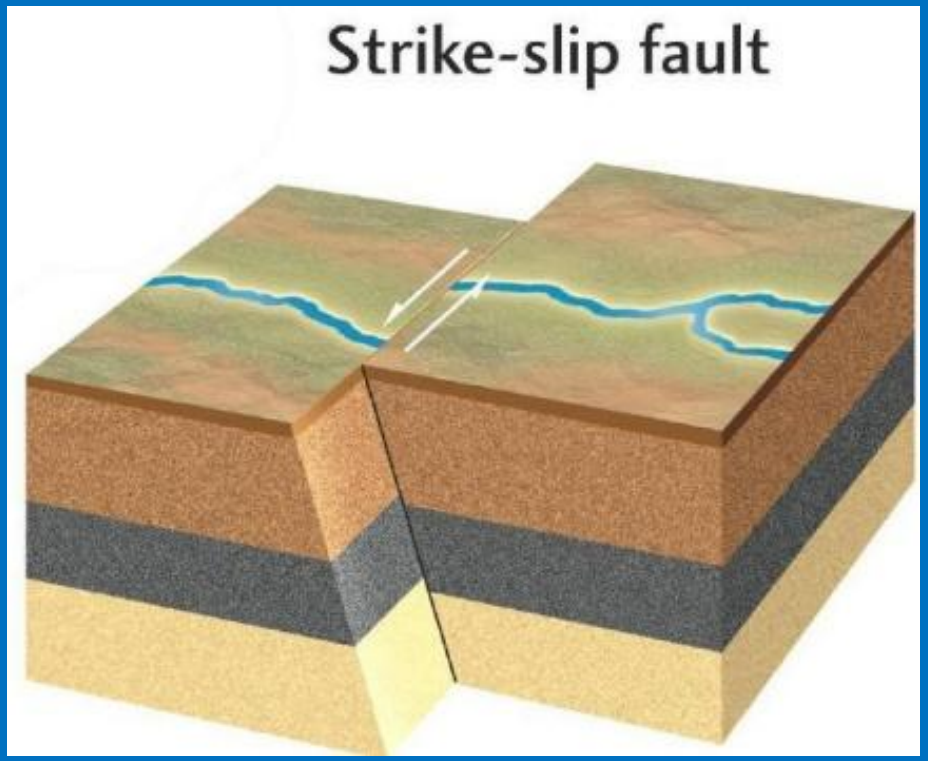


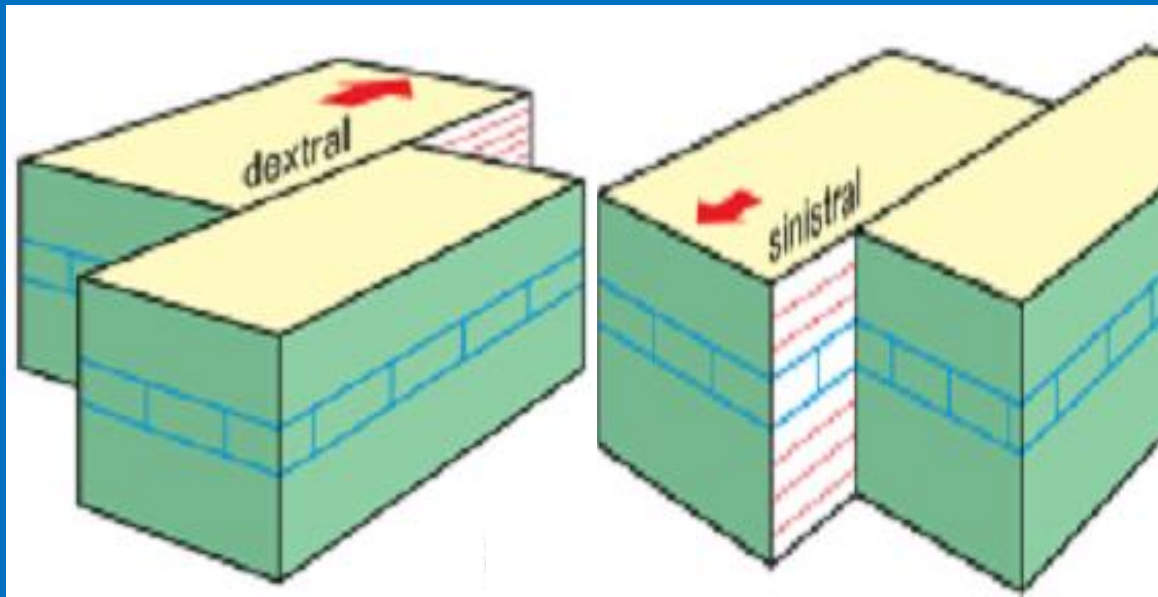
Strike – slip faults: it may be defined faults in which the faulted blocks have been moved against each in the horizontal direction along strikes.

There are two types of strike – slip faults:

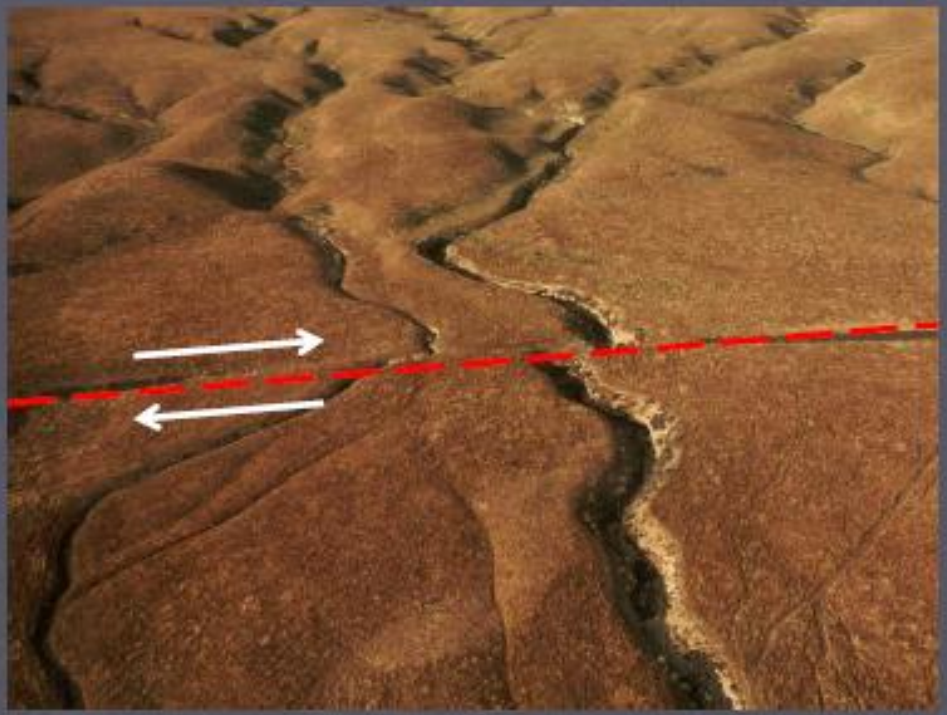
1. Right lateral strike-slip fault (dextral): Where the side opposite the observer moves to the right.

2.Left lateral strike-slip fault (sinistral): Where the side opposite the observer moves to the left.





EXAMPLES OF STRIKE-SLIP FAULTS

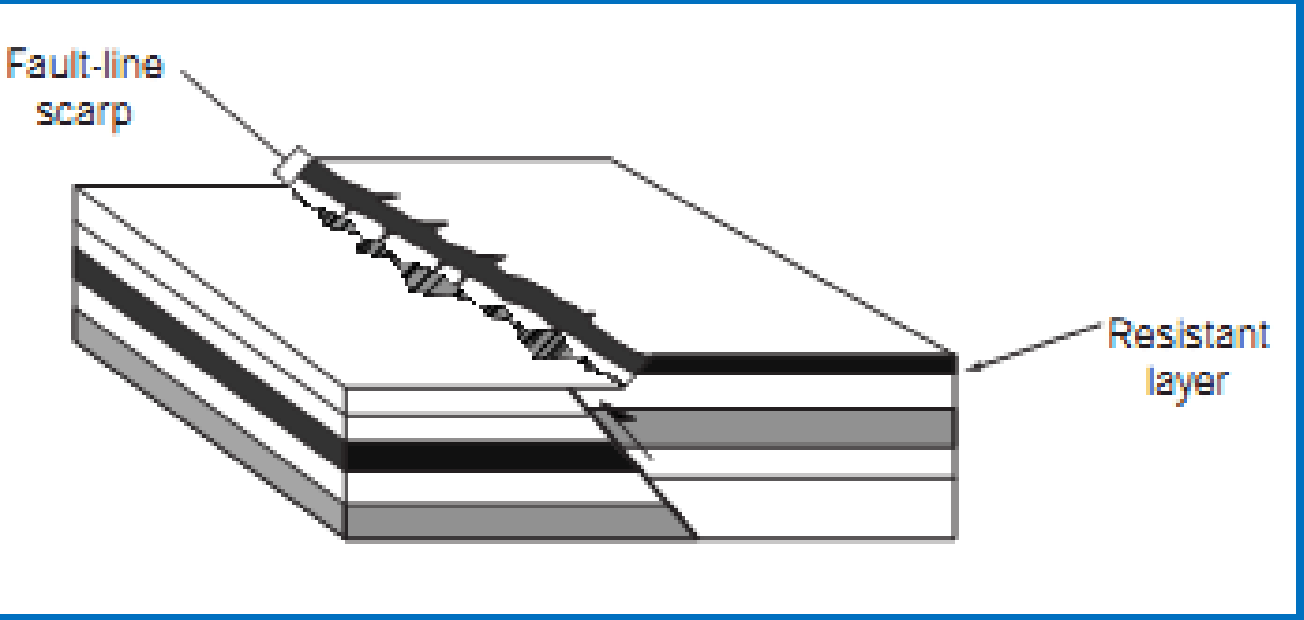


San Andreas Fault, CA
http://education.usgs.gov/california/pp1515/chapter2/fig2-21.jpg

Right Lateral Fault in Asphalt
www.uwsp.edu/.../fault_transform_photo.html

Right Lateral Slip, Izmit, Turkey, 1999 Quake
http://www.geo.uib.no/jordskjelv/index.php?topic=earthquakes&lang=en

Fault scarp: results when a fault displaces the ground surface



Seismic faulting along an emergent strike-slip fault typically creates a surface rupture, which is manifested by broken ground and fissures. Displacement on an emergent dip-slip fault creates a step in the ground surface, called a fault scarp

Fault scarp: results when a fault displaces the ground surface

Normal Fault Scarps, Turkey

Engineering consideration of faults

Faults cause very much shearing and crushing of rocks located in the fault zone making the rocks weak on one hand and porous, permeable on the other hand.

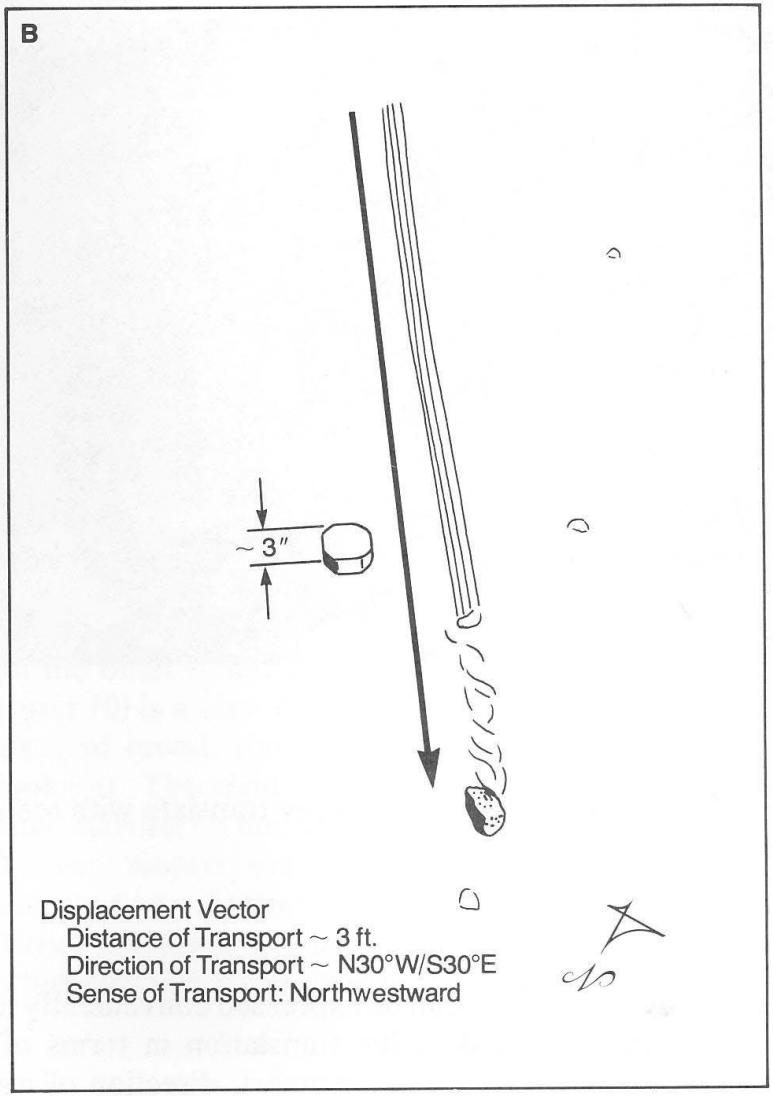
Following general conclusions can be drawn:

1. **The faulted rocks will form weak foundations for the dams.**
2. **The fault zones will provide easy pathways for the water and causes leakage when left untreated in the dams.**
3. **Once the fault zone becomes lubricated with water, the probability of further slipping becomes high. This may create critical condition within the foundation.**
4. **Faulting products like gouge create additional problems.**

The key to describing slip along a fault lies in measuring

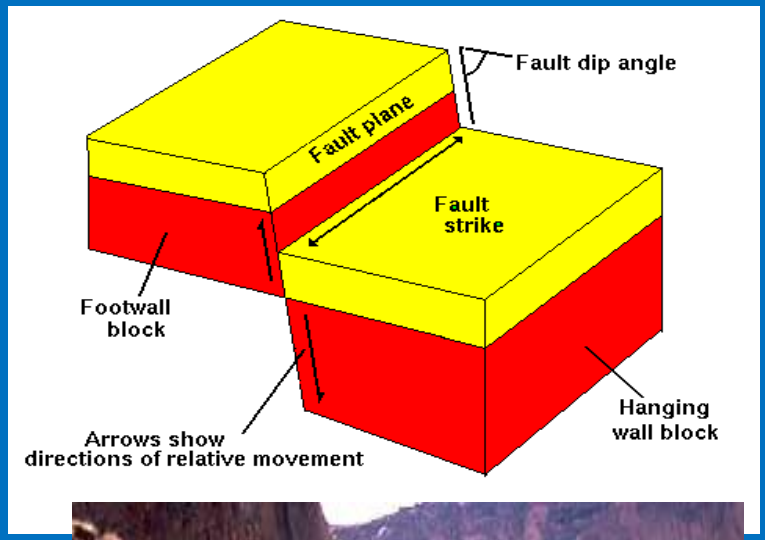
(1) Direction of displacement (2) Sense of displacement

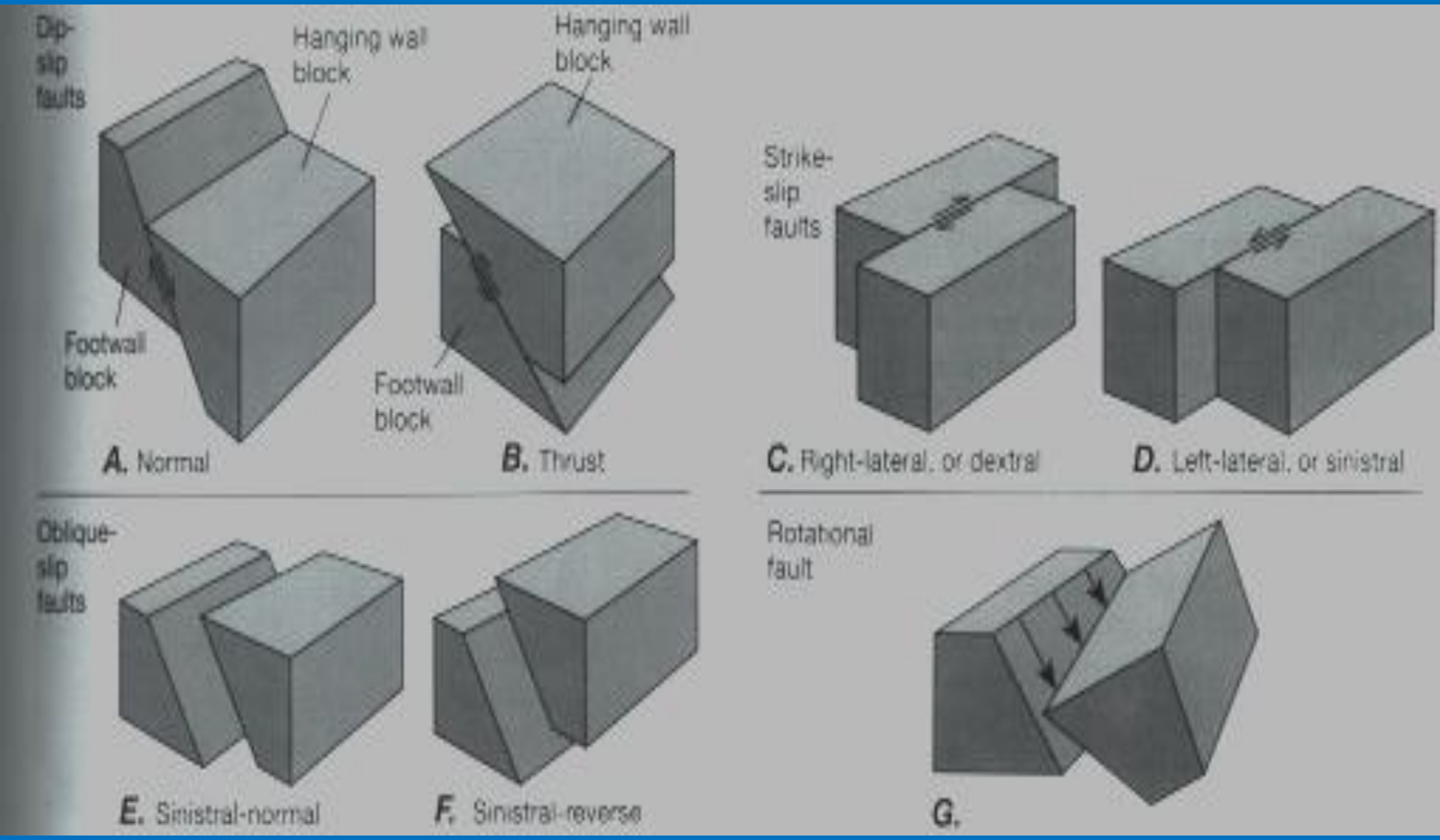
(3) Magnitude of displacement



Parts of the Fault

- **Fault plane:** Surface that the movement has taken place within the fault.On this surface the dip and strike of the fault is measured.
- **Hanging wall:** The rock mass resting on the fault plane.
- **Footwall:** The rock mass beneath the fault plane.
- **Slip:** Describes the movement parallel to the fault plane.
- **Dip slip:** Describes the up and down movement parallel to the dip direction of the fault.
- **Strike slip:** Applies where movement is parallel to strike of the fault plane.
- **Oblique slip:** Is a combination of strike slip and dip slip.
- **Net slip** (true displacement): Is the total amount of motion measured parallel to the direction of motion




Dip-slip faults
Hanging wall block
Footwall block
A. Normal
Hanging wall block
Footwall block
B. Thrust
Strike-slip faults
C. Right-lateral, or dextral
D. Left-lateral, or sinistral
Oblique-slip faults
E. Sinistral-normal
F. Sinistral-reverse
Rotational fault
G.

Faults- how are they defined?

Hanging wall

Footwall

Strike-slip fault; left-lateral (sinistral) vs. right-lateral (dextral)

Normal faults: younger/lower grade on older/higher grade

Lengthening

Thrust faults: older/higher grade on younger/lower grade

Shortening

Slip vs. Separation?

Fault scarp

Ref.Book

Twiss, R.J., and Moores, E.M., Structural Geology, 2nd Edition


BHUTAN
NEPAL
ARUNACHAL PRADESH
INDIA
MYANMAR
VIET
NAM
LAO
PDR
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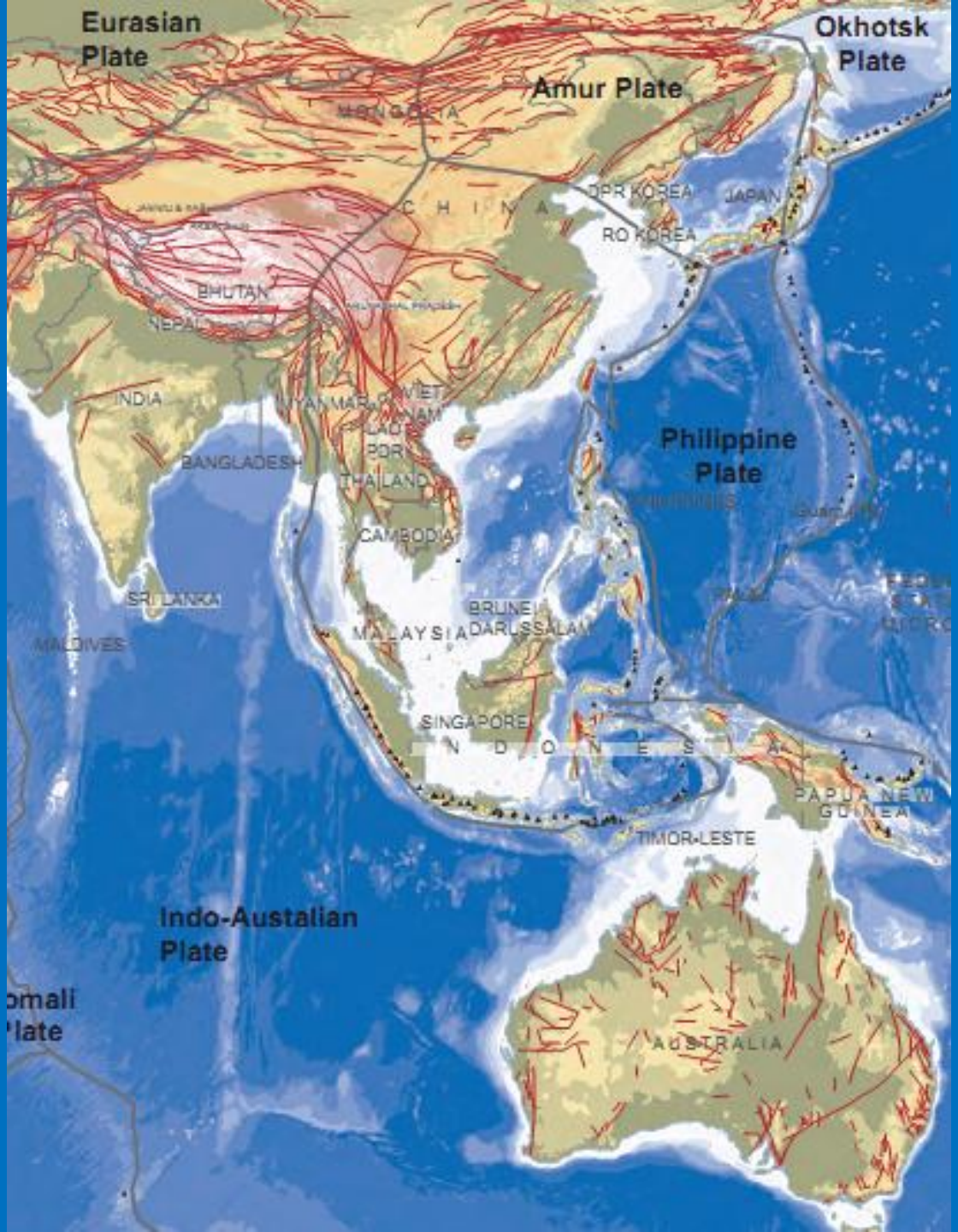
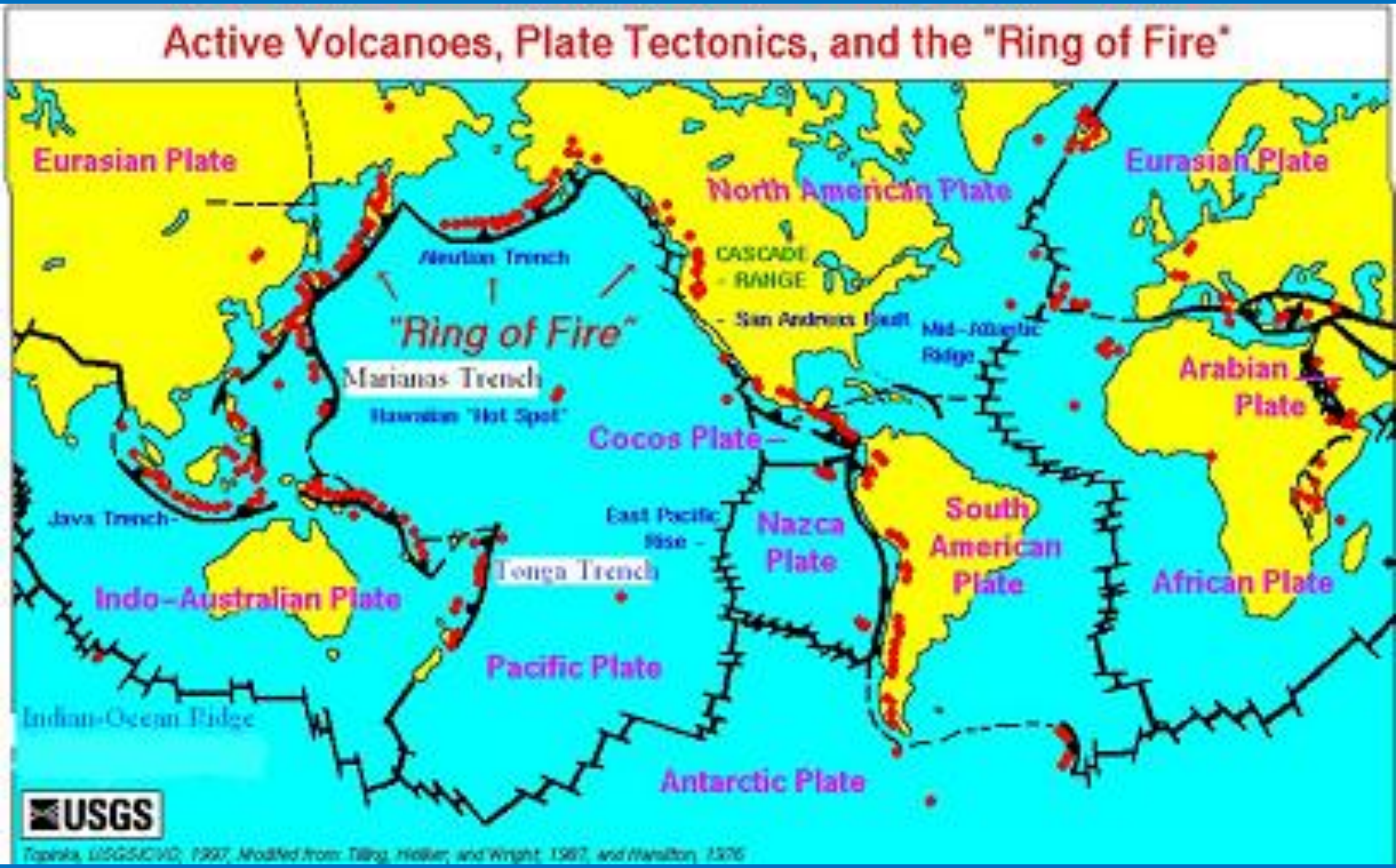
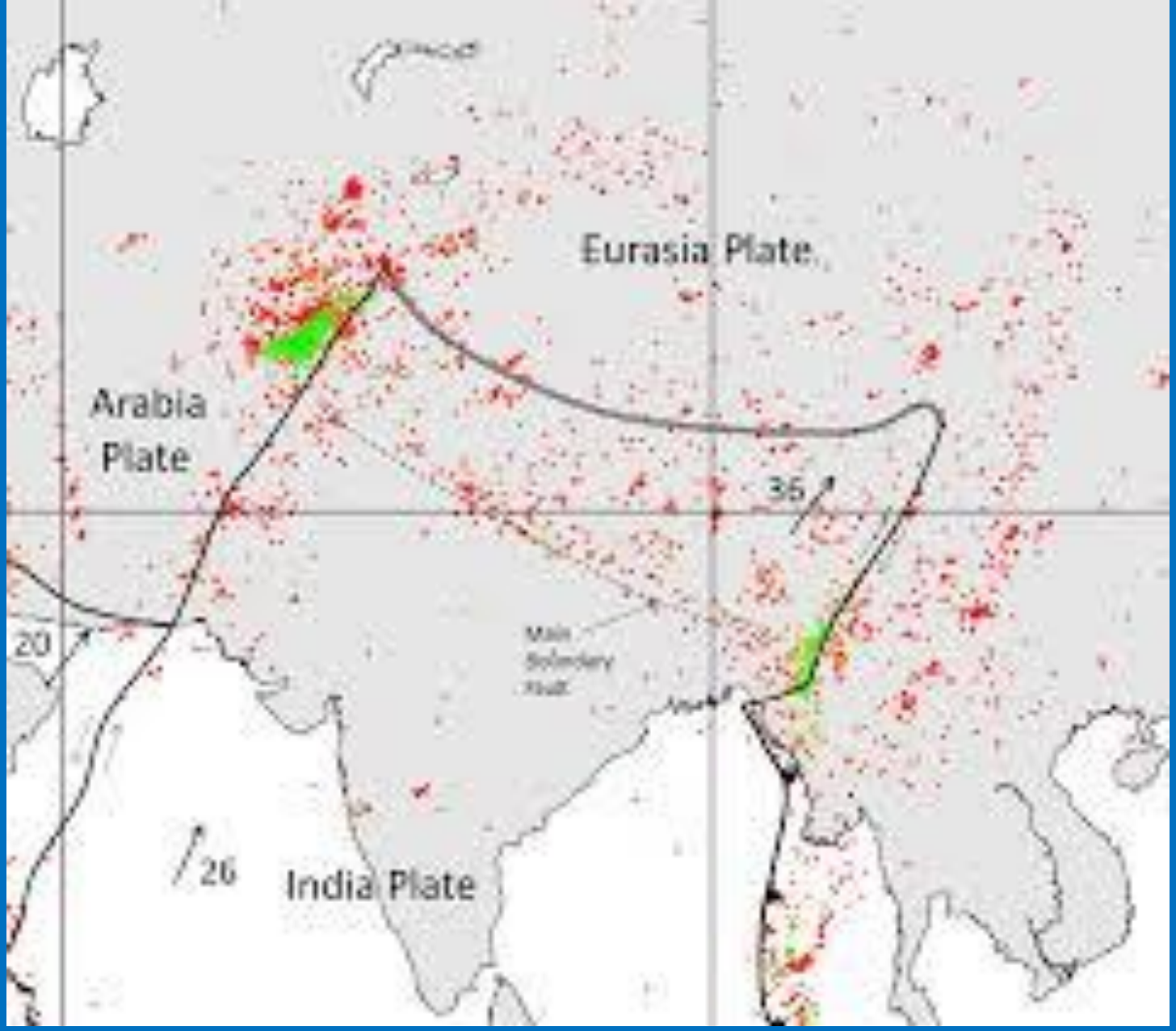
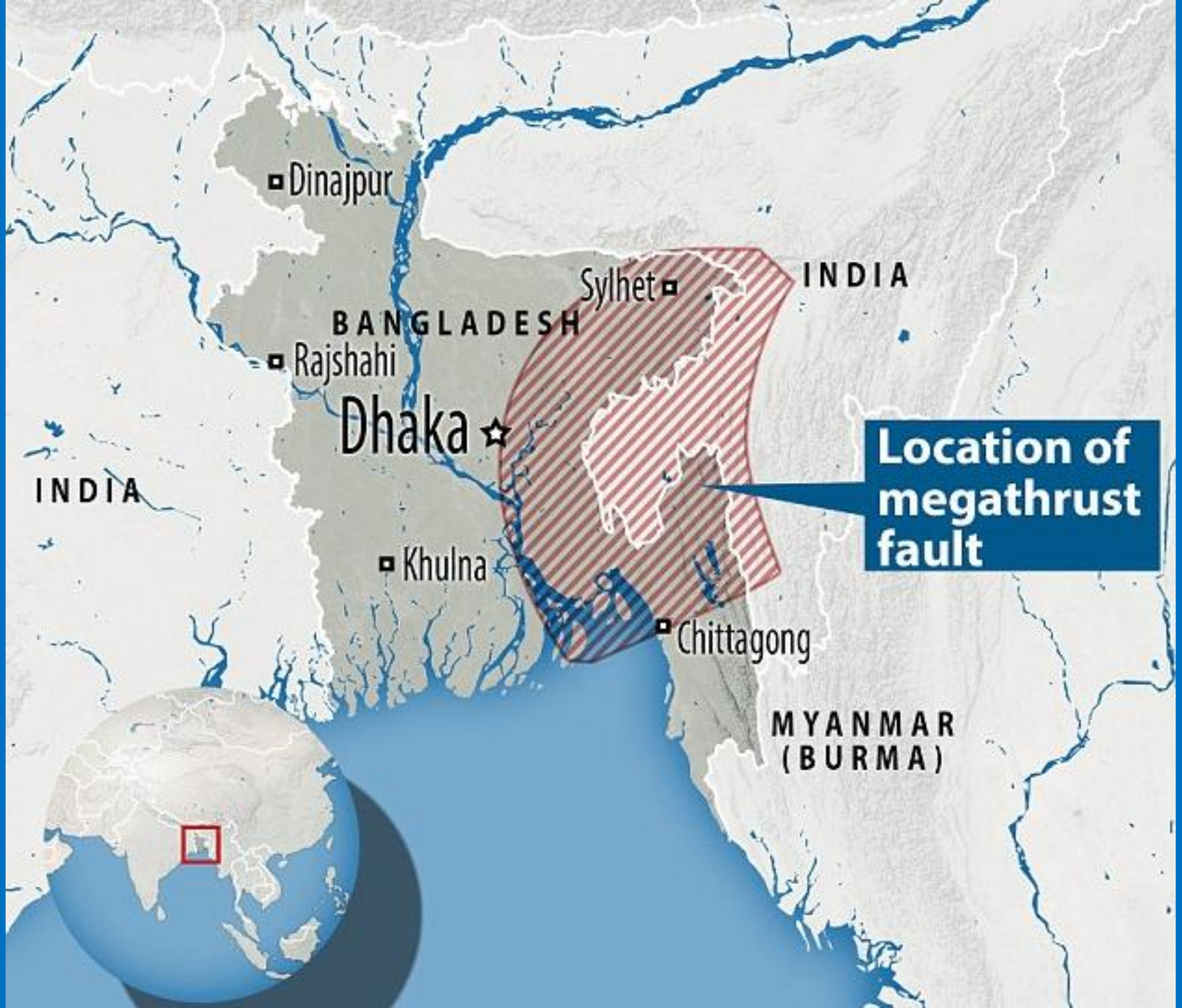
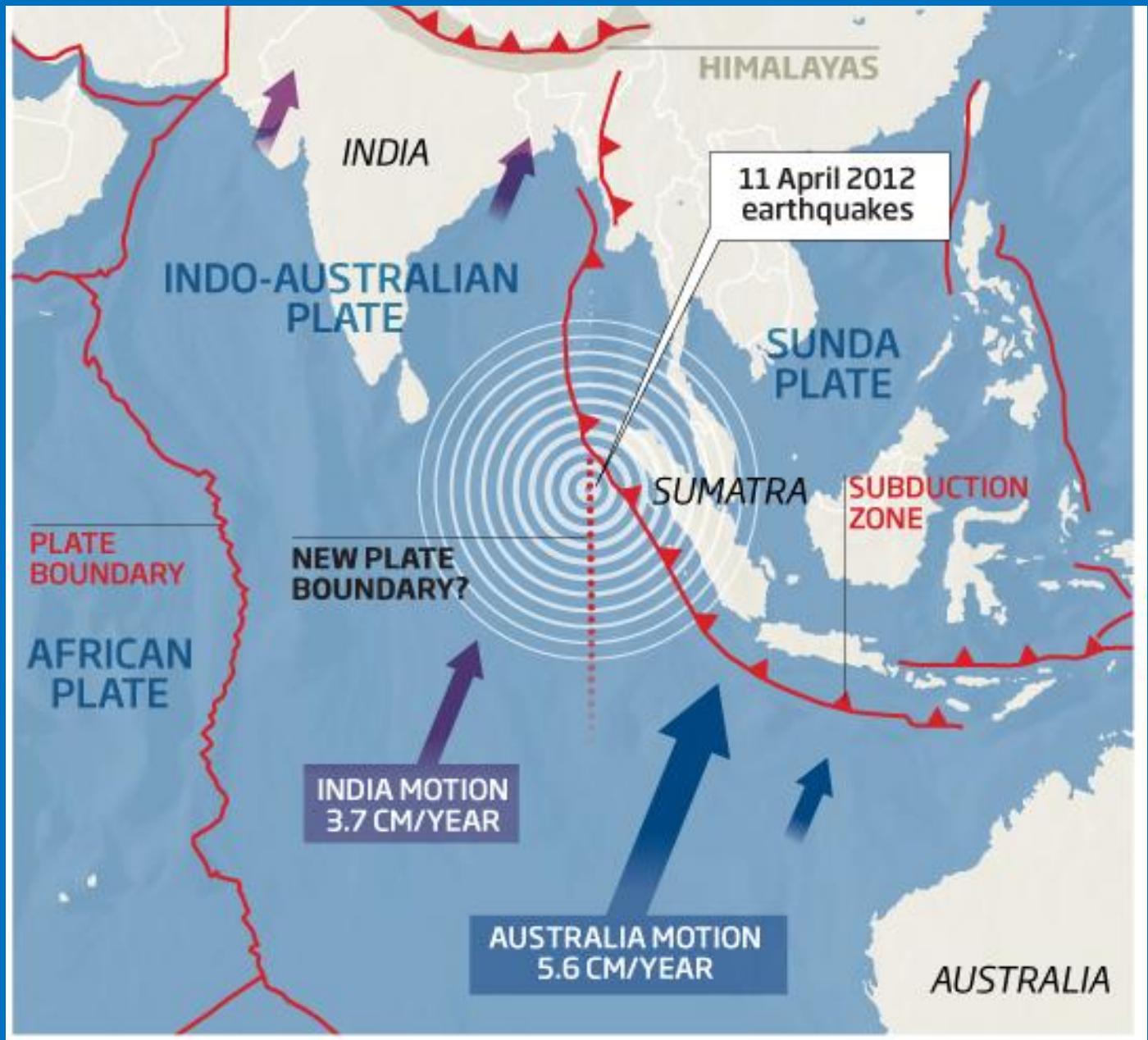

Eurasian Plate
Okhotsk Plate
Amur Plate
MONGOLIA
C H I N A
DPR KOREA
JAPAN
RO KOREA
BHUTAN
NEPAL
INDIA
BANGLADESH
MYANMAR
LAO PDR
THAILAND
CAMBODIA
Philippine Plate
SRI LANKA
MALDIVES
BRUNEI DARUSSALAM
MALAYSIA
SINGAPORE
I N D O N E S I A
PAPUA NEW GUINEA
TIMOR-LESTE
Indo-Austalian Plate
omali
late
AUSTRALIA


Active Volcanoes, Plate Tectonics, and the "Ring of Fire"
Eurasian Plate
North American Plate
Eurasian Plate
Aleutian Trench
CASCADE
RANGE
San Andreas Fault
Mid-Atlantic
Ridge
"Ring of Fire"
Marianas Trench
Hawaiian "Hot Spot"
Arabian
Plate
Cocos Plate
Java Trench
East Pacific
Rise
Nazca
Plate
South
American
Plate
Tonga Trench
Indo-Australian Plate
African Plate
Pacific Plate
Indian-Ocean Ridge
Antarctic Plate
USGS


Eurasia Plate
Arabia
Plate
35
20
26
India Plate


Dinajpur
Sylhet
INDIA
BANGLADESH
Rajshahi
Dhaka
INDIA
Location of megathrust fault
Khulna
Chittagong
MYANMAR (BURMA)



The Indo-Australian plate is moving north, but the Himalayas are impeding the western half of it. The result is an area of compression in the centre of the plate, which may be cracking under the strain


Dauki Fault