

What caused these rocks to look the way they do?

A) Erosion

B) Earthquakes

C) Glaciers

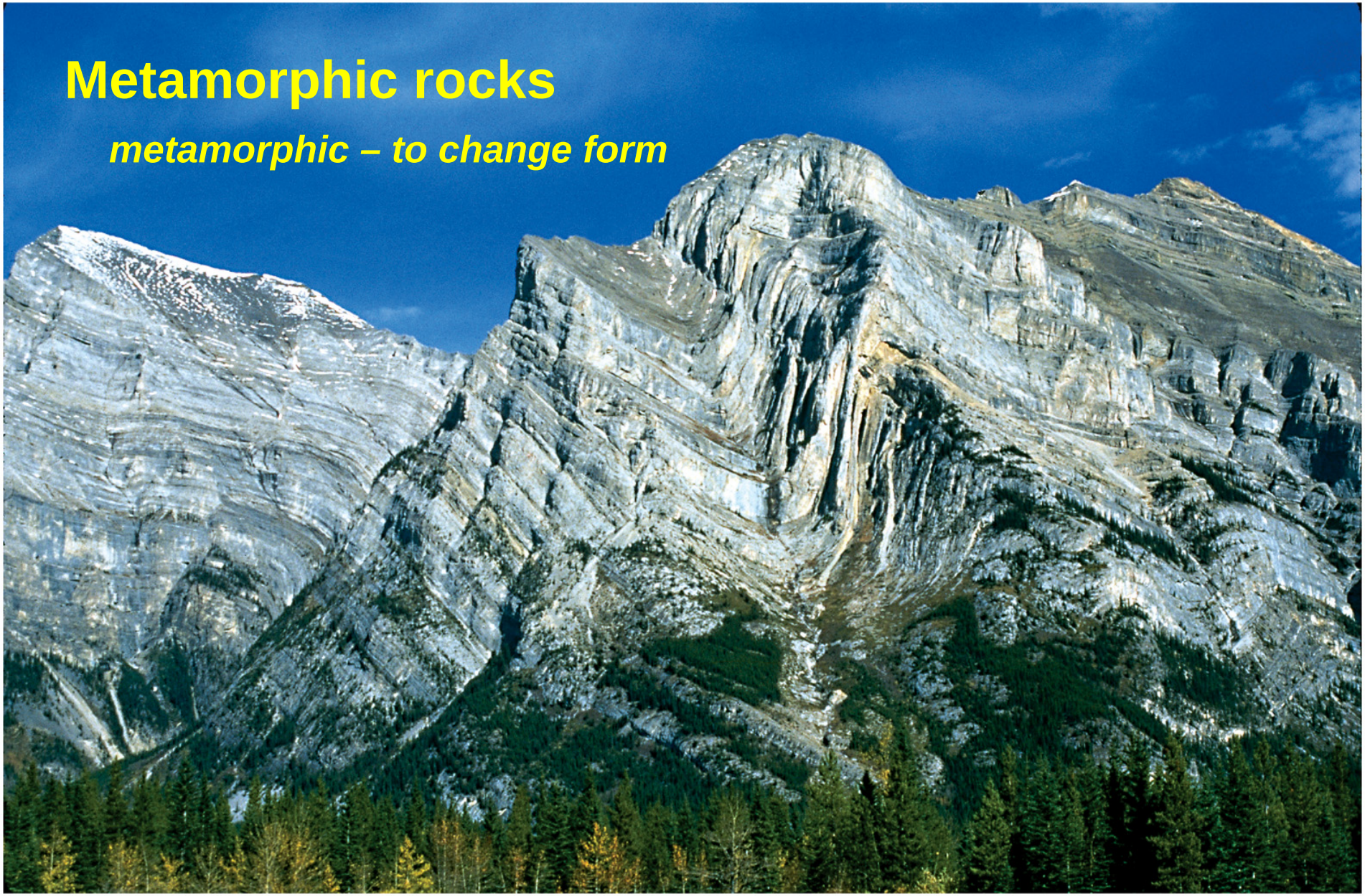
D) Pressure

E) Groundwater

Mount Kidd, Alberta, Canada

Metamorphic rocks

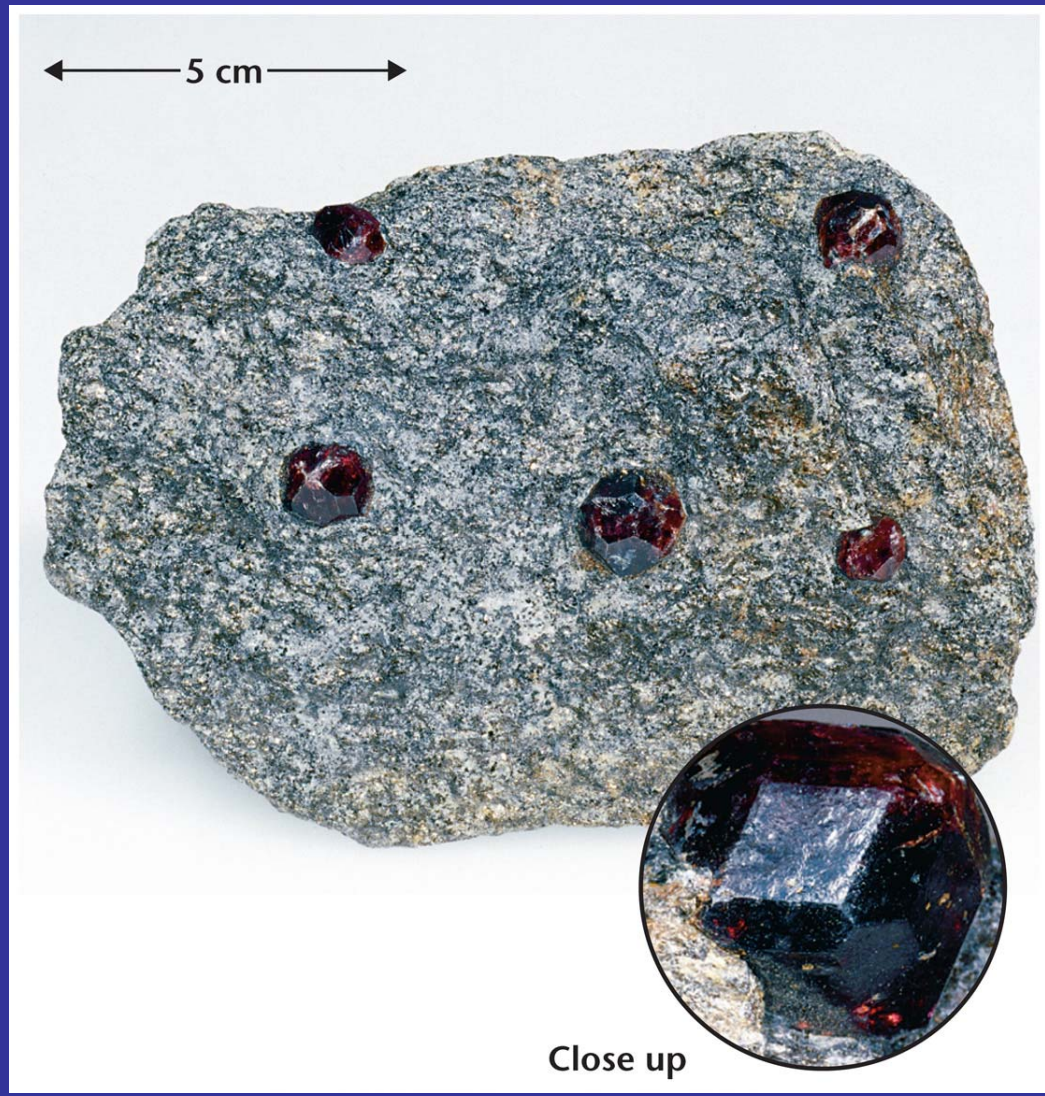
metamorphic – to change form



Mount Kidd, Alberta, Canada

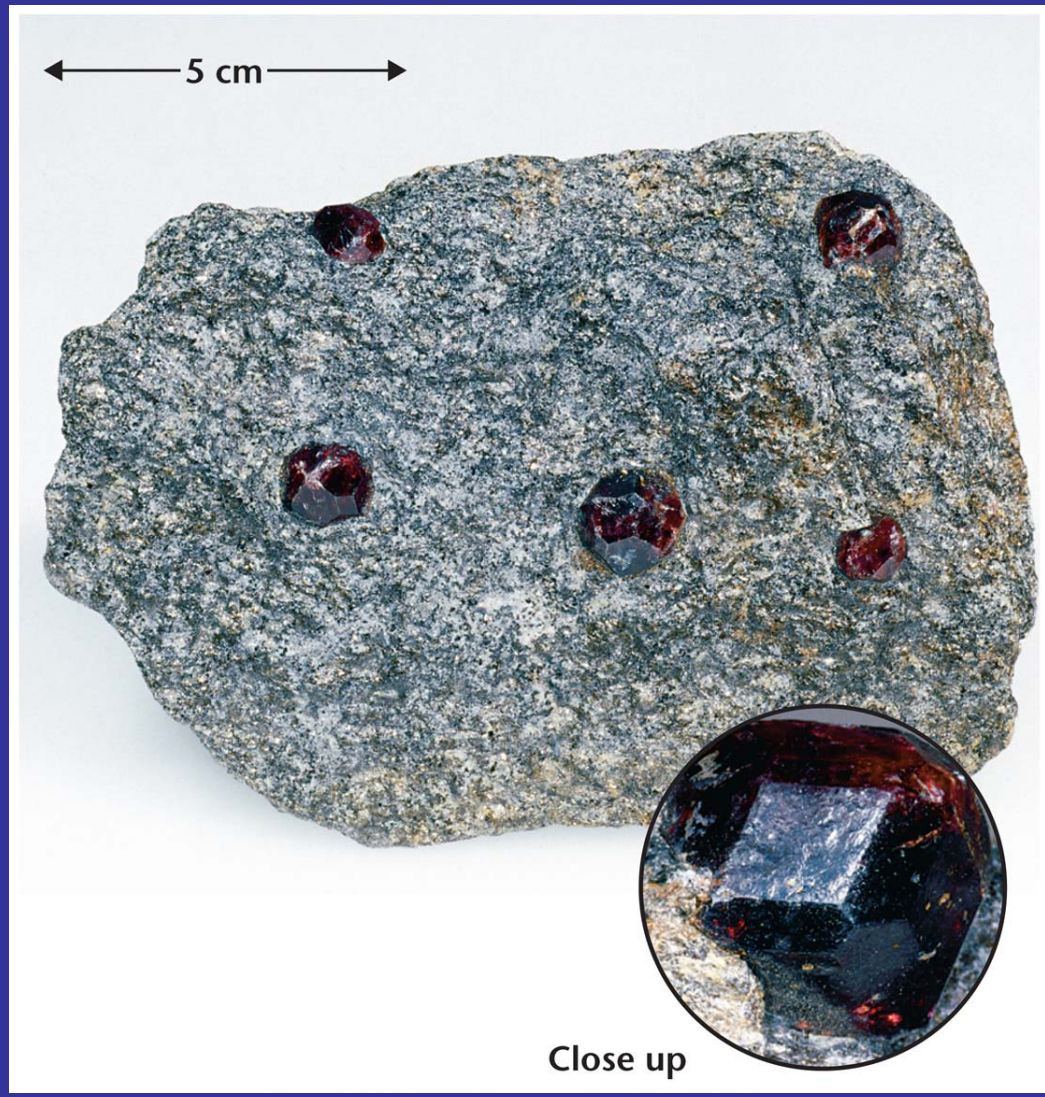
Before - Shale

After - Schist



Before - Shale

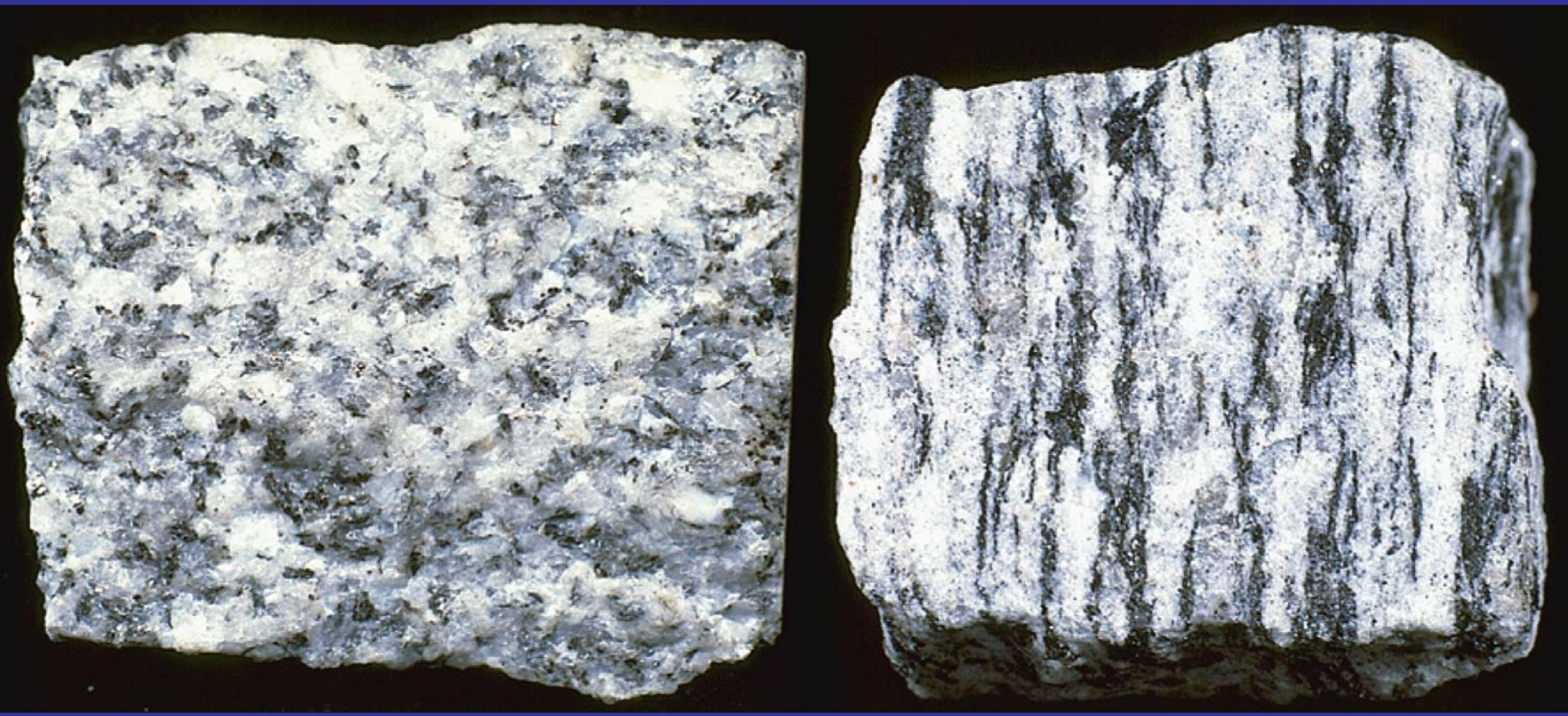
After - Schist



Heating causes recrystallization

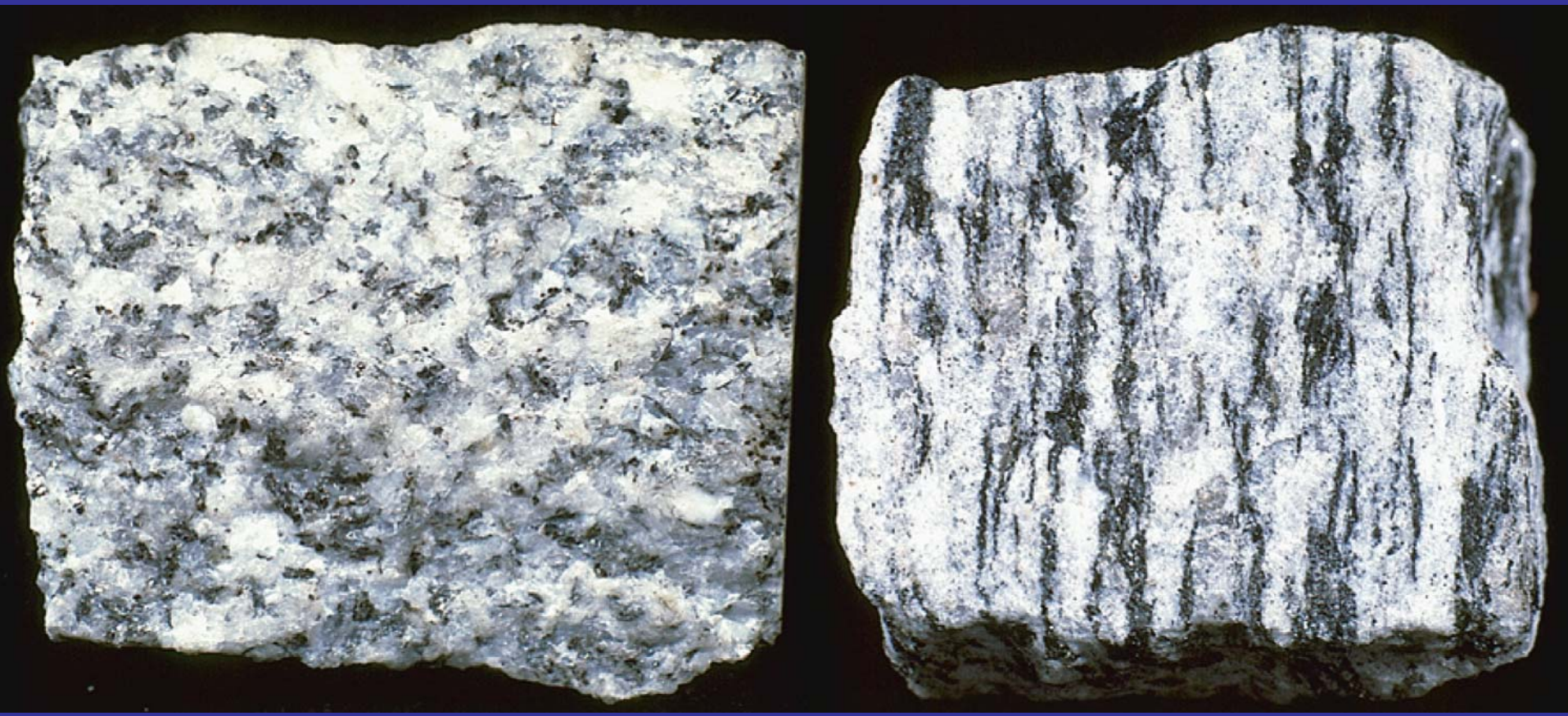
Before

After



Before -
Granite

After -
Gneiss



Pressure - mechanical rotation of grains results in alignment



Before





After



Before -
Pillow Basalt



Chemical fluid
circulation



After -
Sulfide deposits

What forces/processes will change a rock's form?

1. Heat



2. Pressure



3. Chemical Fluids







What happens as you go down in a mine?

A) Pressure decreases

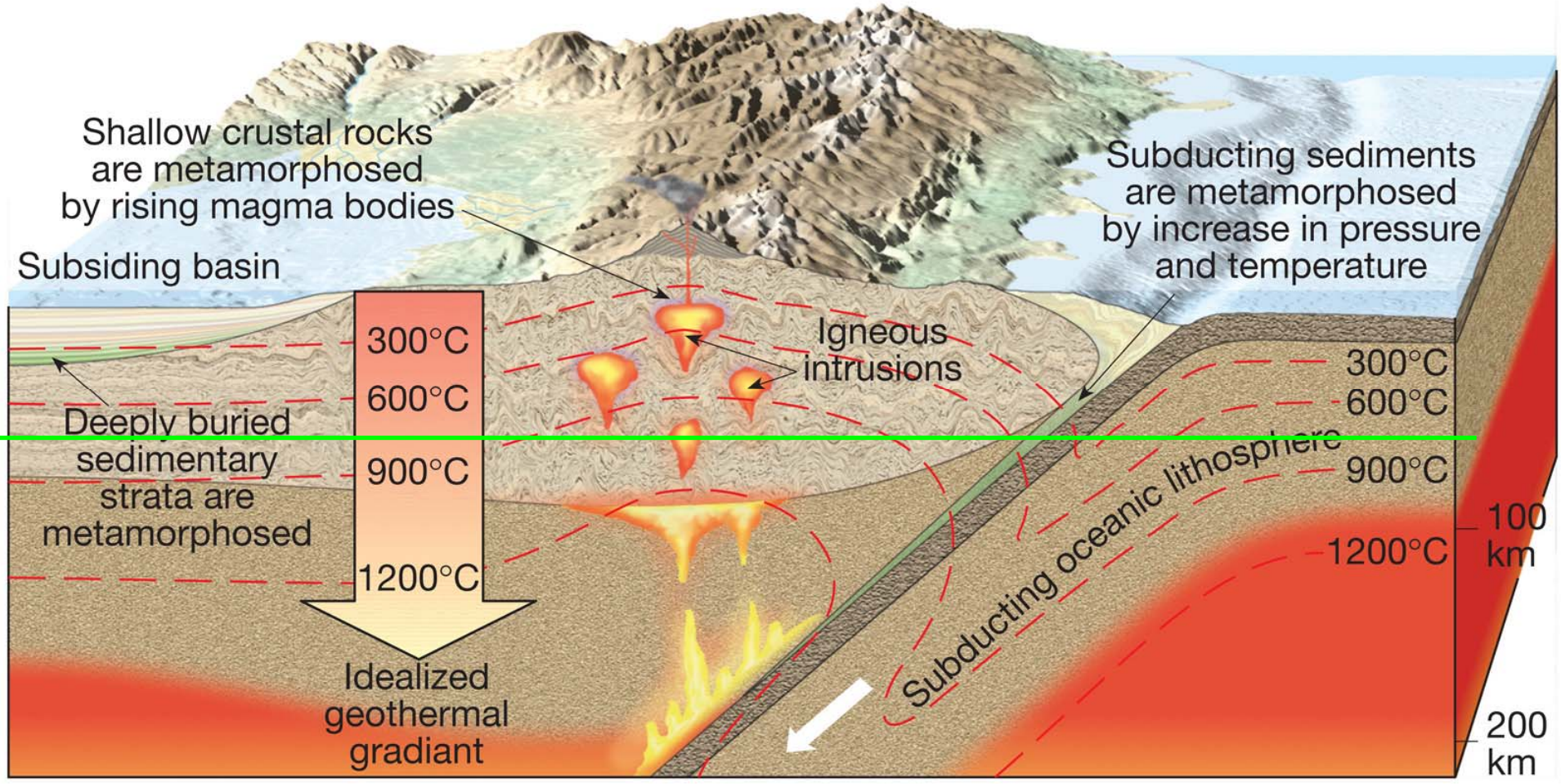
B) Temperature increases

C) Oxygen decreases

D) Water increases

E) Earthquakes increase

Earth's Geothermal Gradient
30°C per kilometer of depth



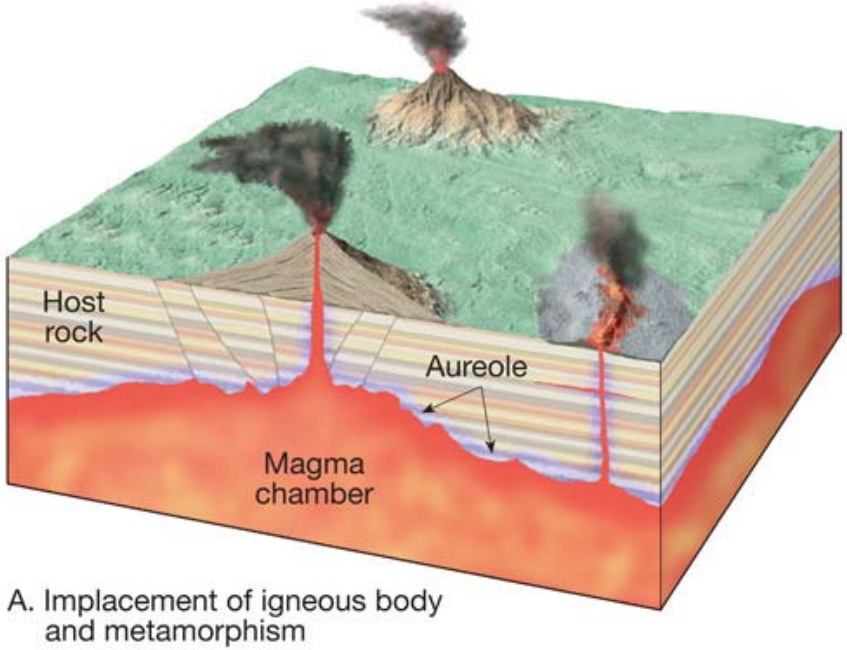
What kind of boundary is this?



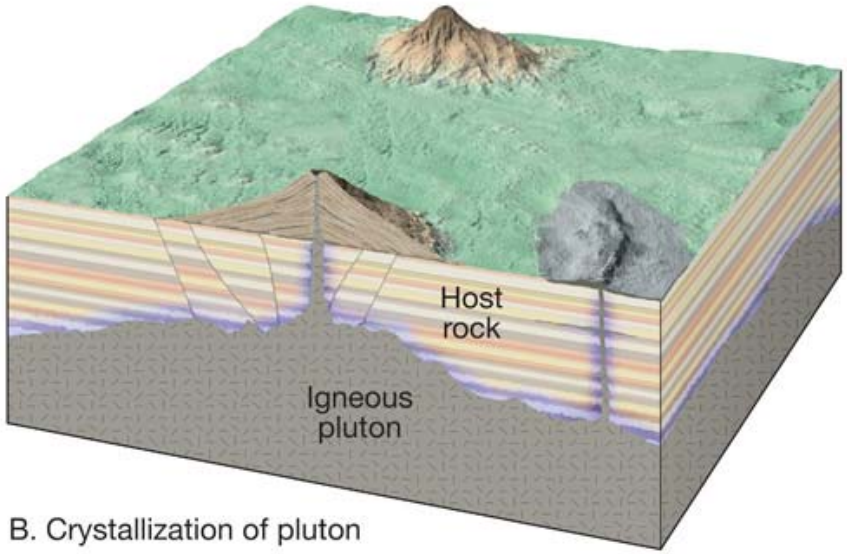
Patagonia, Argentina


Roof pendant
Igneous
pluton

Contact Metamorphism

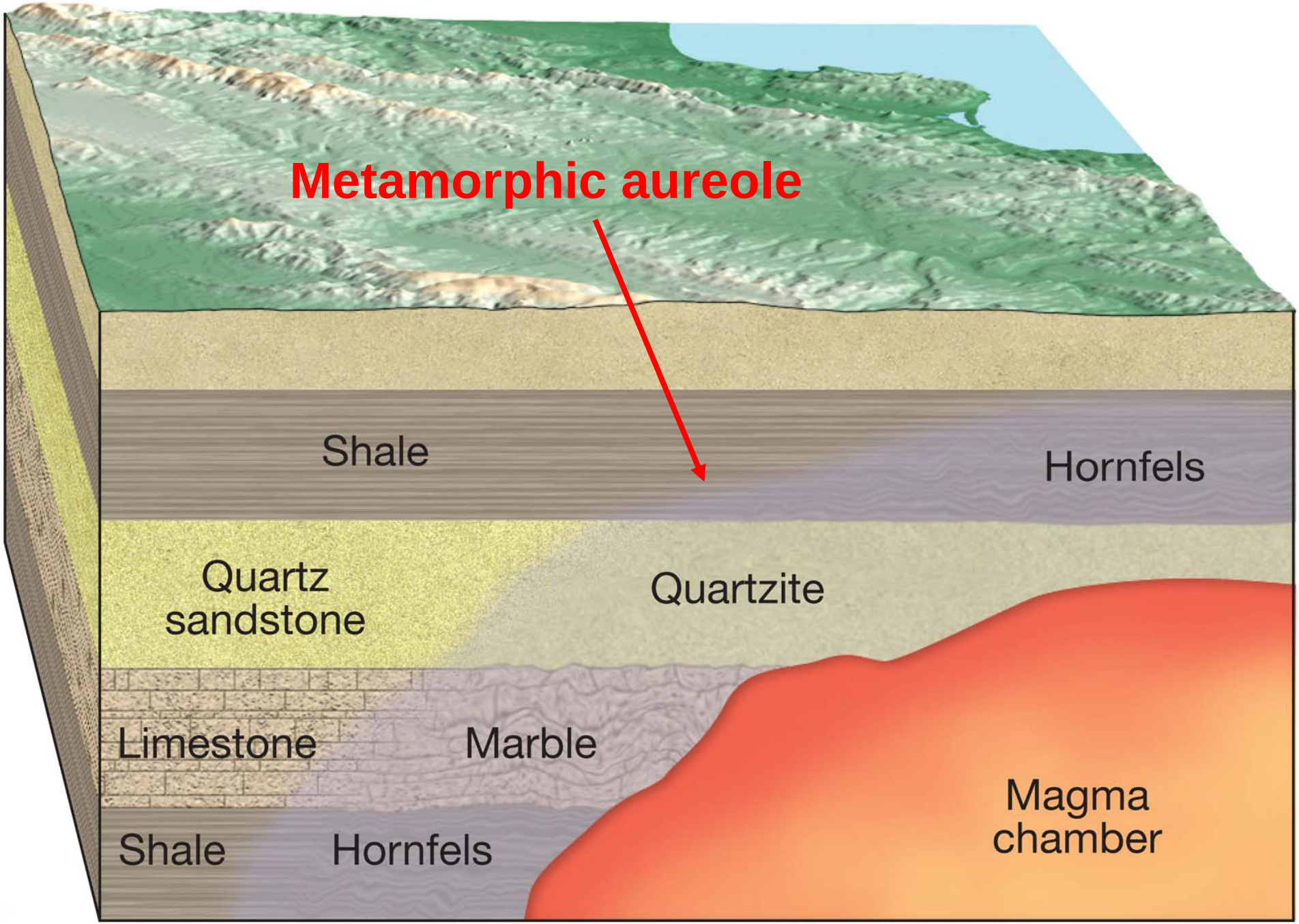


A. Implacement of igneous body and metamorphism



B. Crystallization of pluton

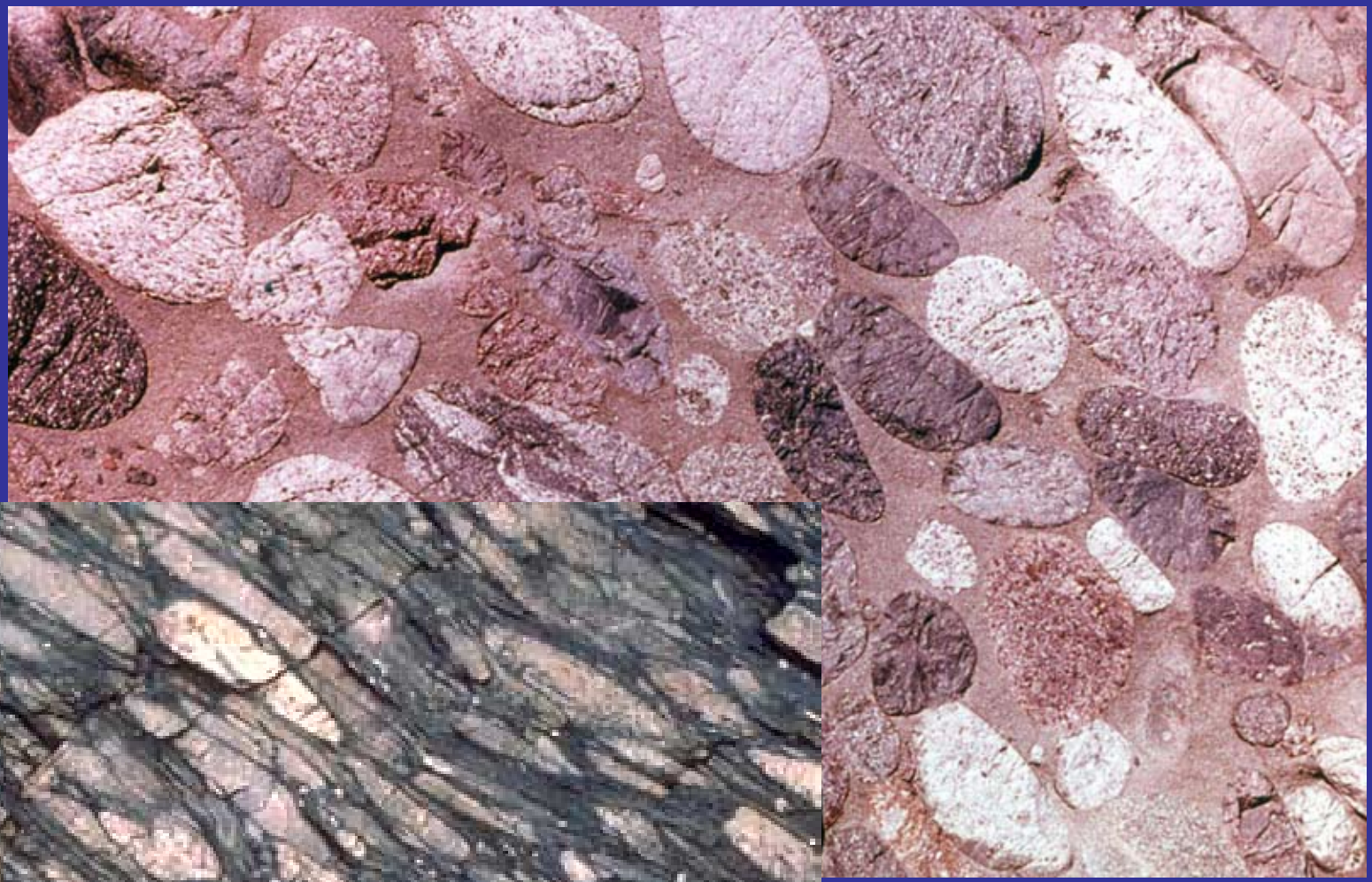



Metamorphic aureole
Shale
Hornfels
Quartz sandstone
Quartzite
Limestone
Marble
Shale
Hornfels
Magma chamber

Metamorphic heating is the result of:

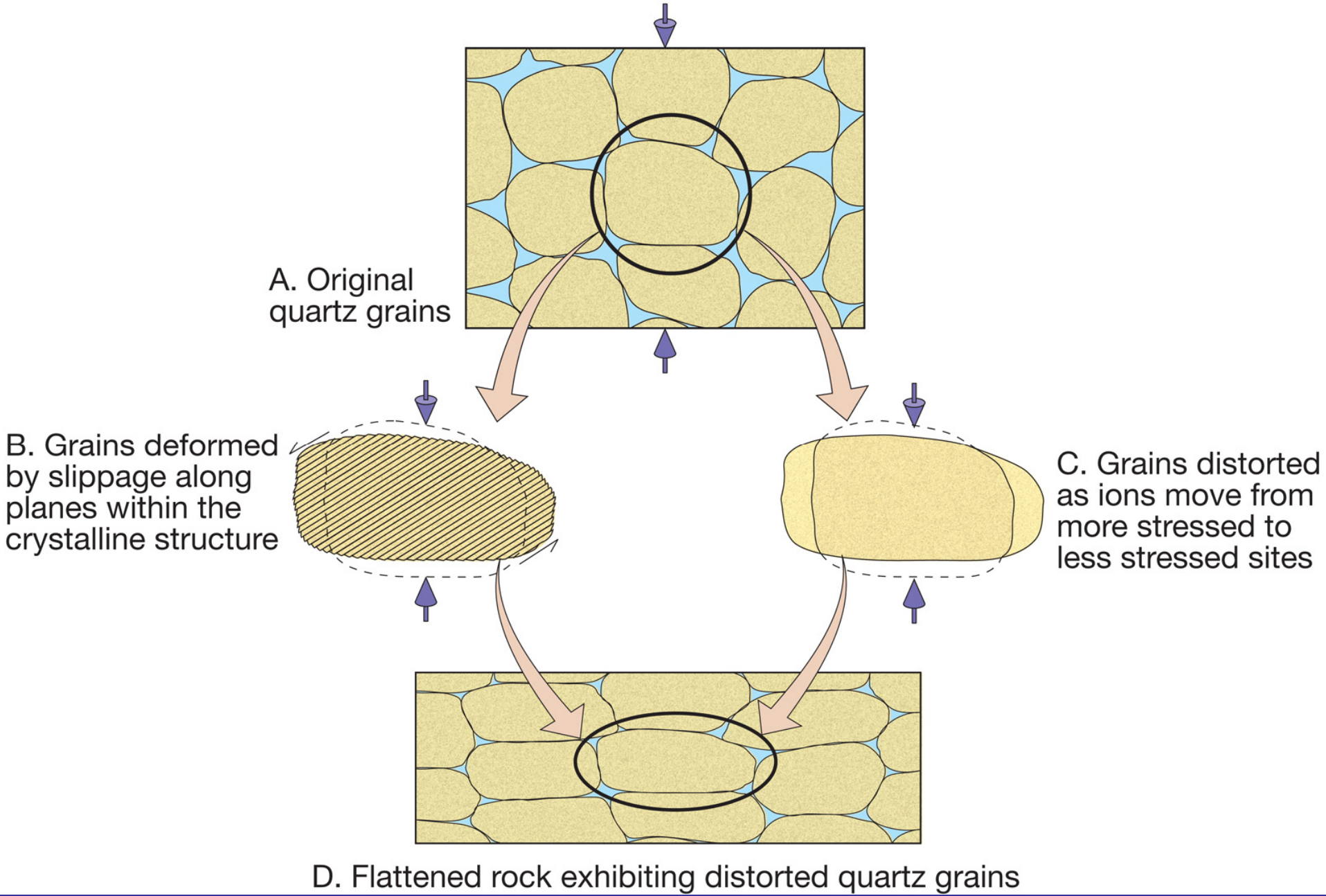
1. **Increasing depth (burial)**
2. **Pressure**
3. **Volcanic activity**

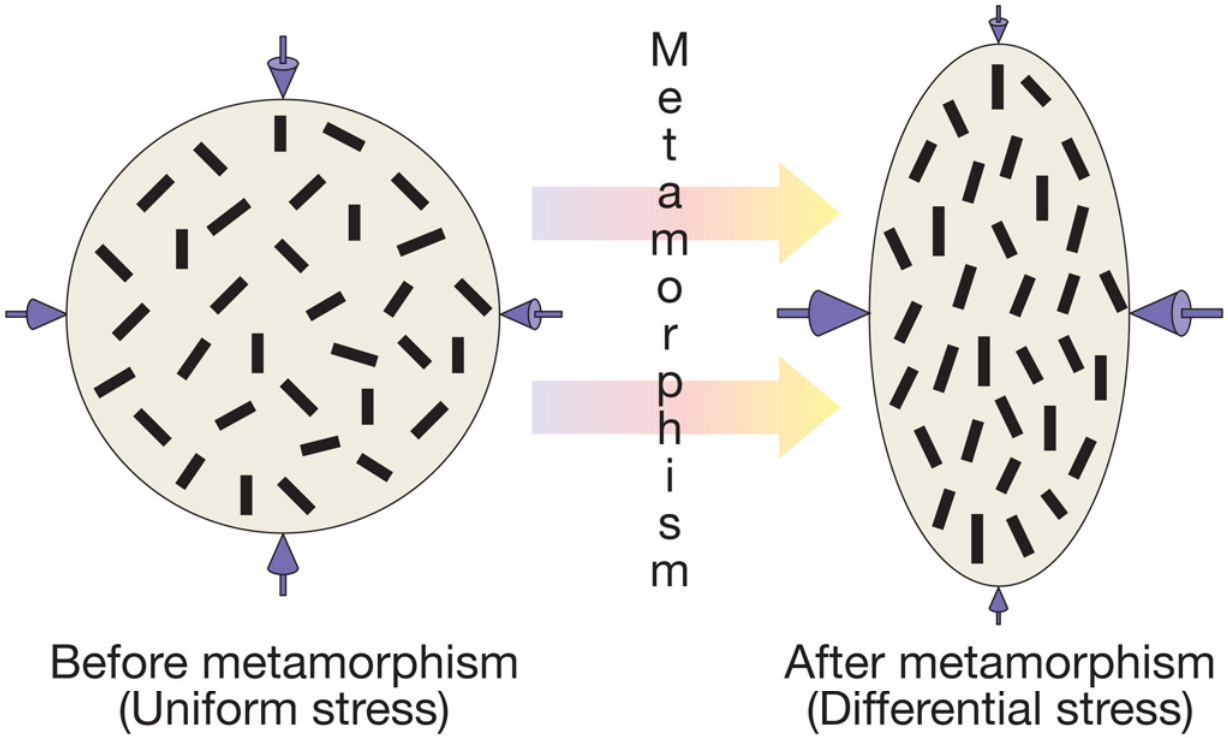




Metaconglomerate

Pressure deforms structures / grains







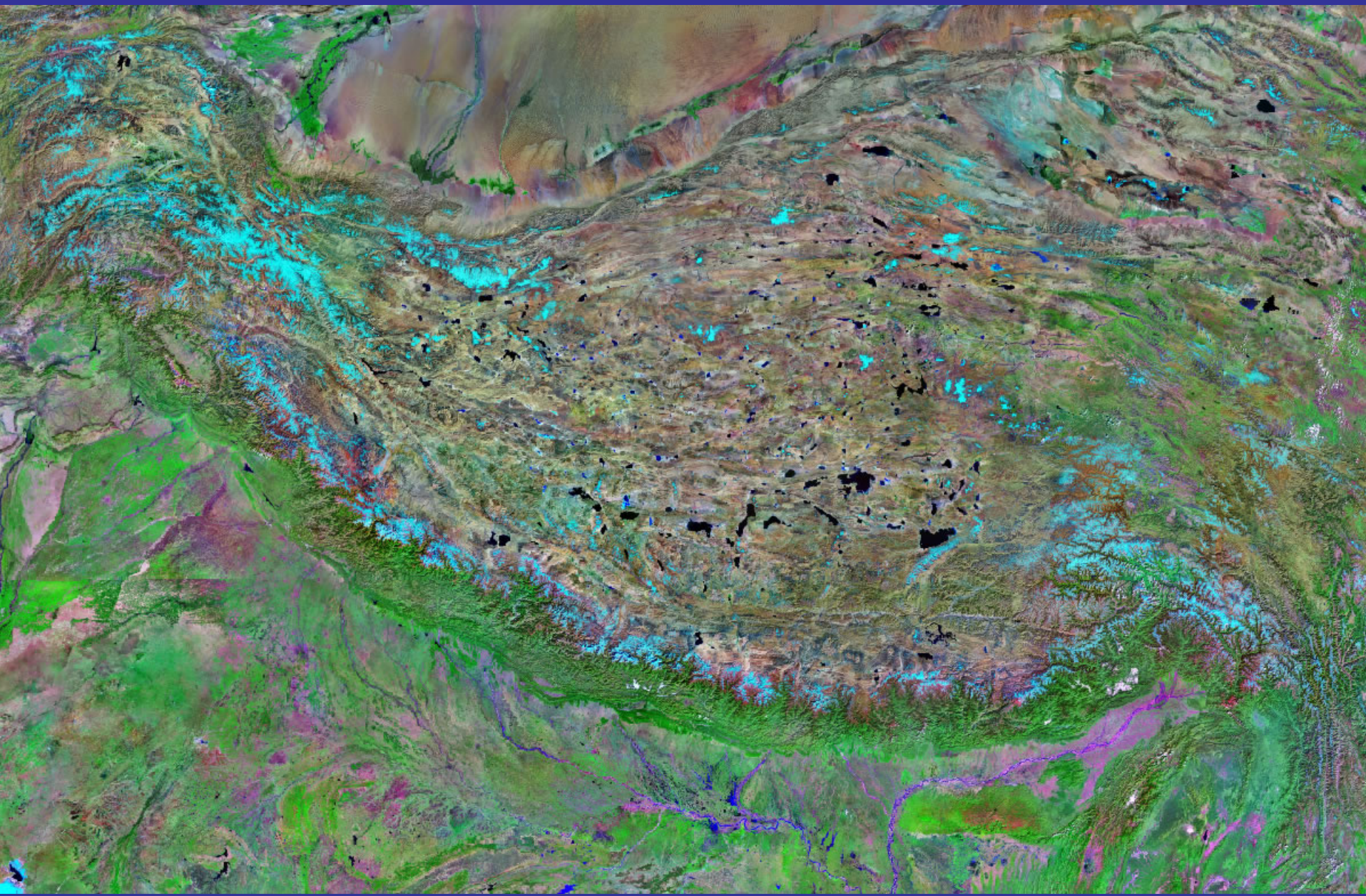


Pressure also <u>reorients</u> grains

Foliation – reorganization of mineral grains into a planar orientation



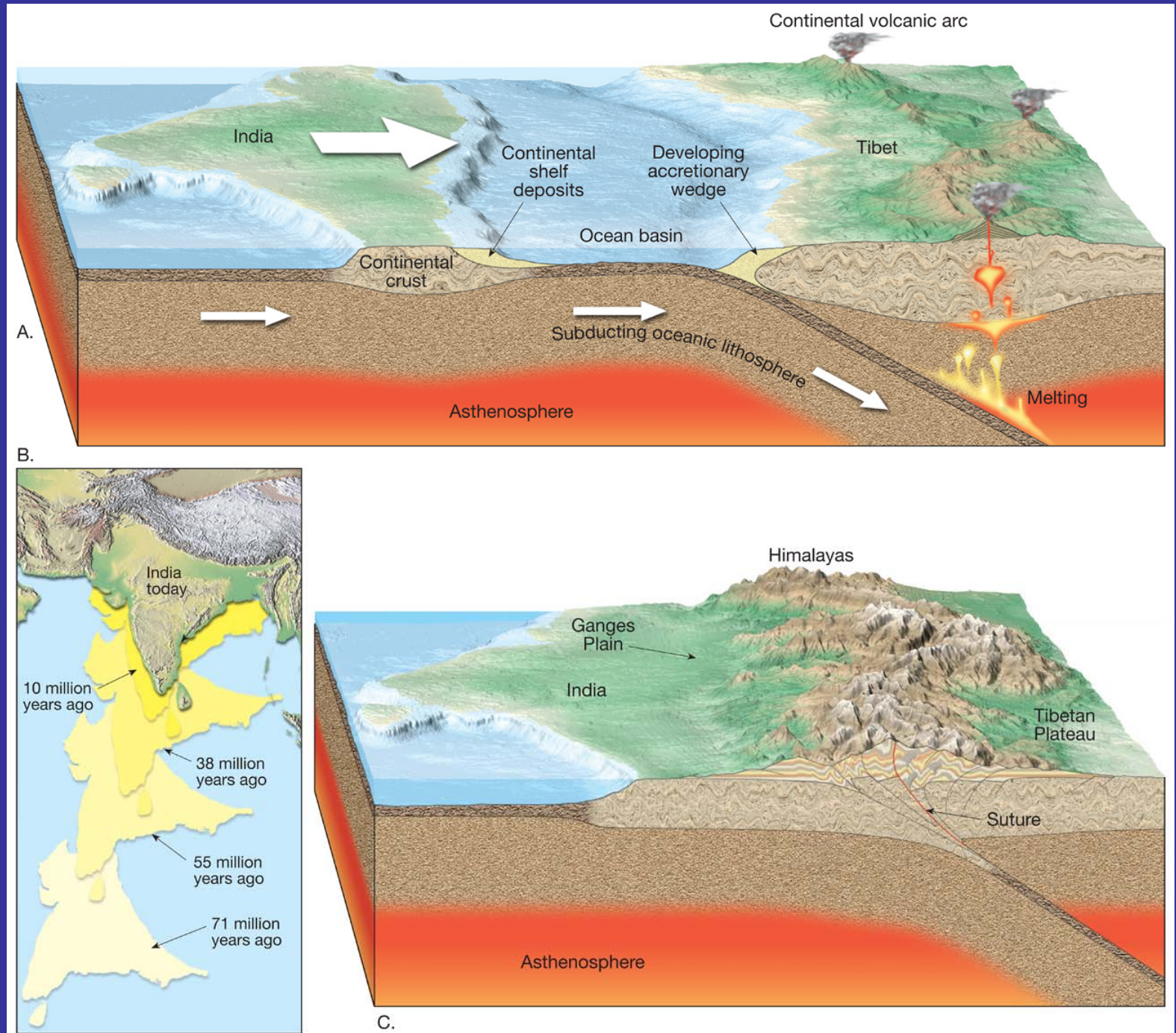
Regional metamorphism (modern)

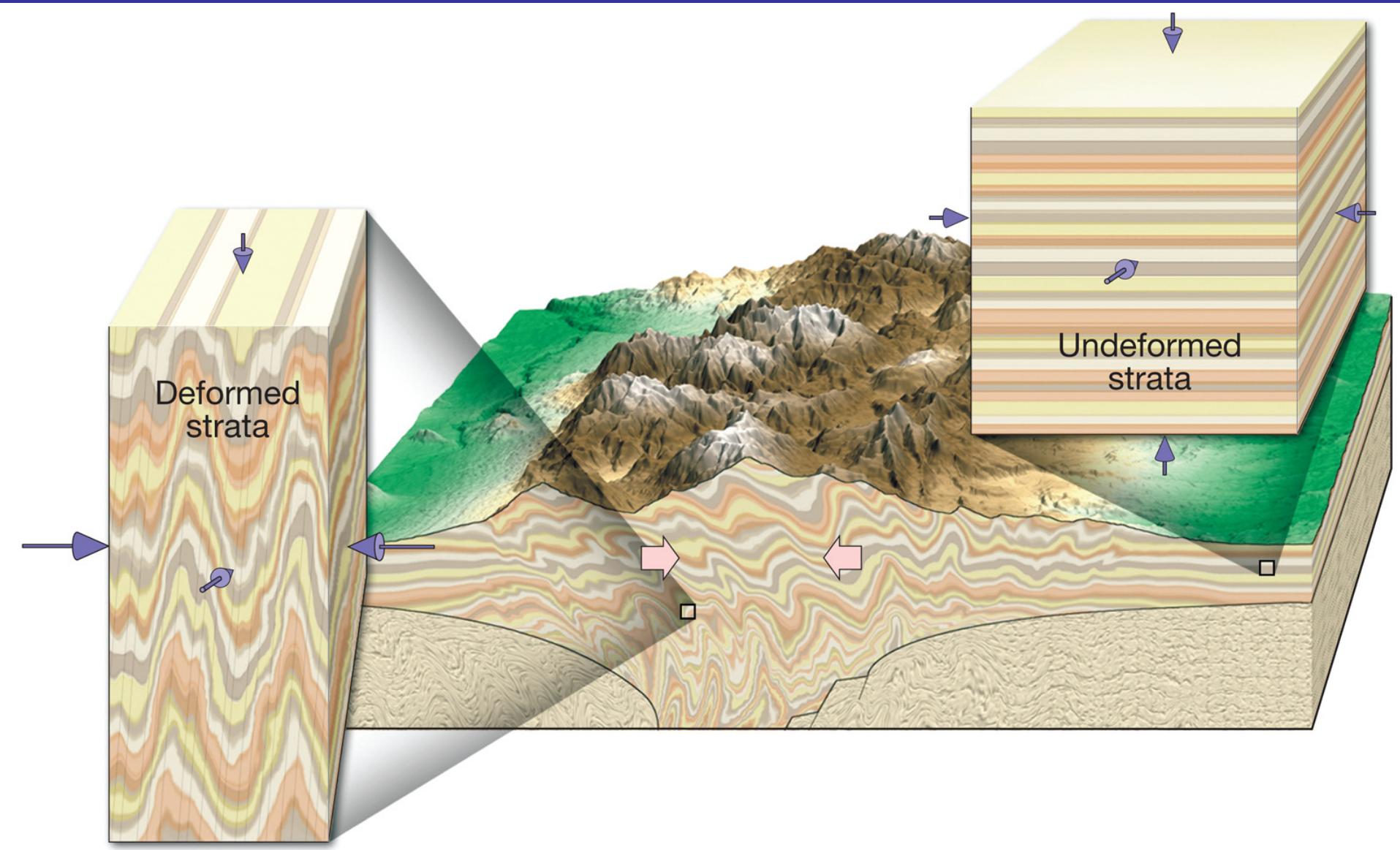


Regional metamorphism (modern)

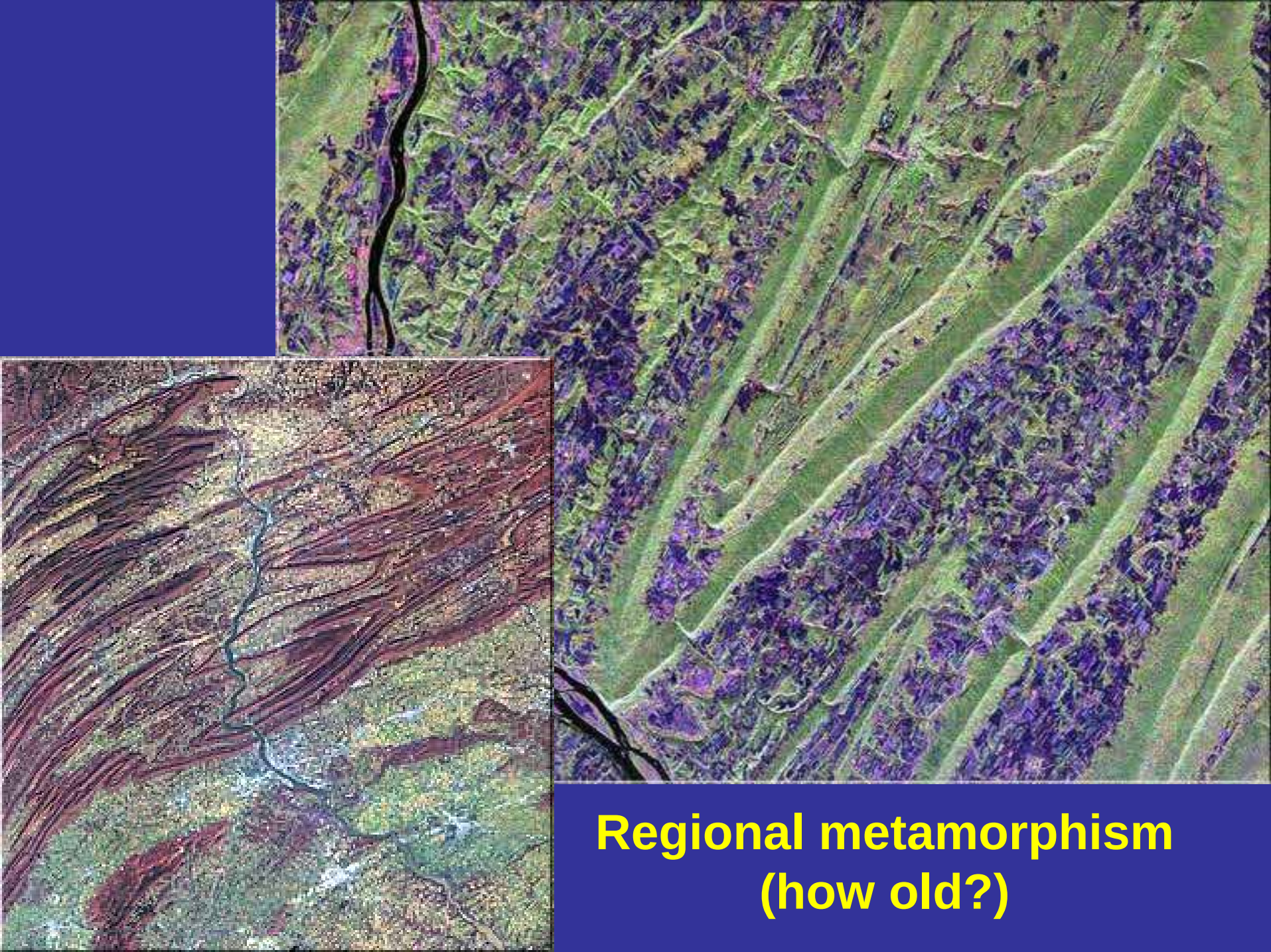


Himalayan Mountains


Continental volcanic arc
India
Continental shelf deposits
Developing accretionary wedge
Tibet
Ocean basin
Continental crust
A.
Subducting oceanic lithosphere
Asthenosphere
Melting
B.
India today
10 million years ago
38 million years ago
55 million years ago
71 million years ago
Himalayas
Ganges Plain
India
Tibetan Plateau
Suture
Asthenosphere
C.



B. Differential stress



Regional metamorphism (how old?)

Regional metamorphism – Appalachian Mountains



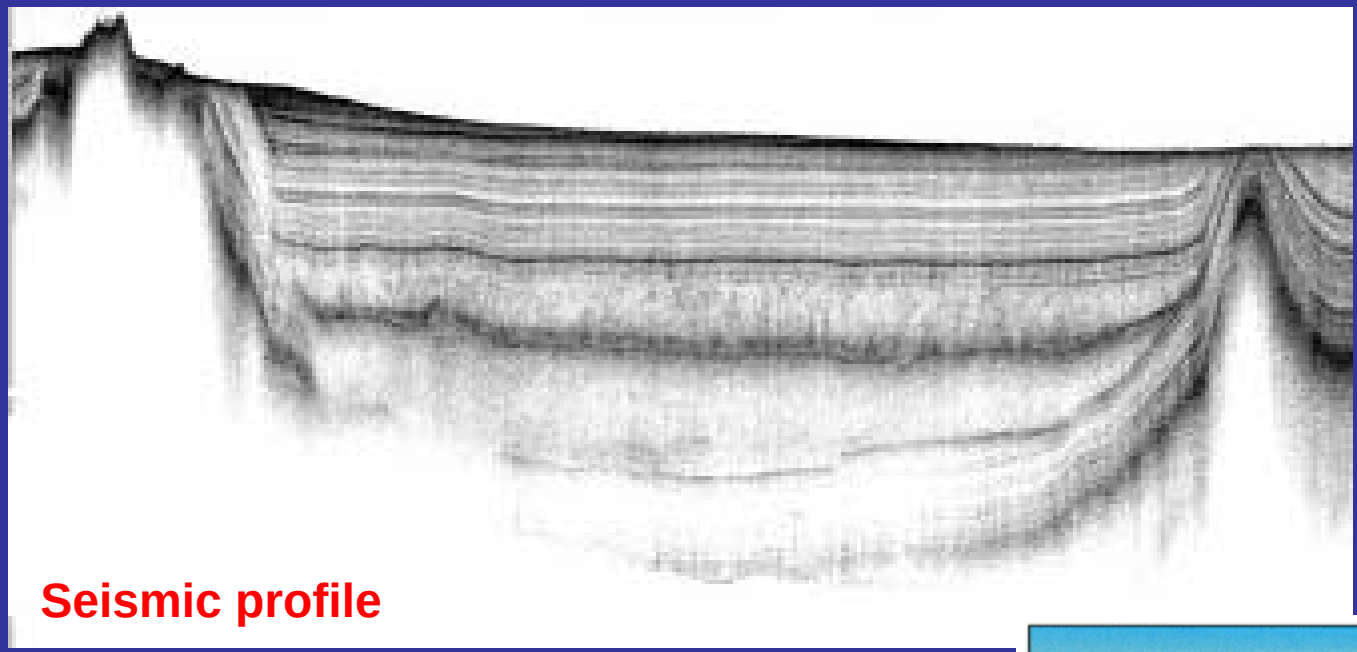




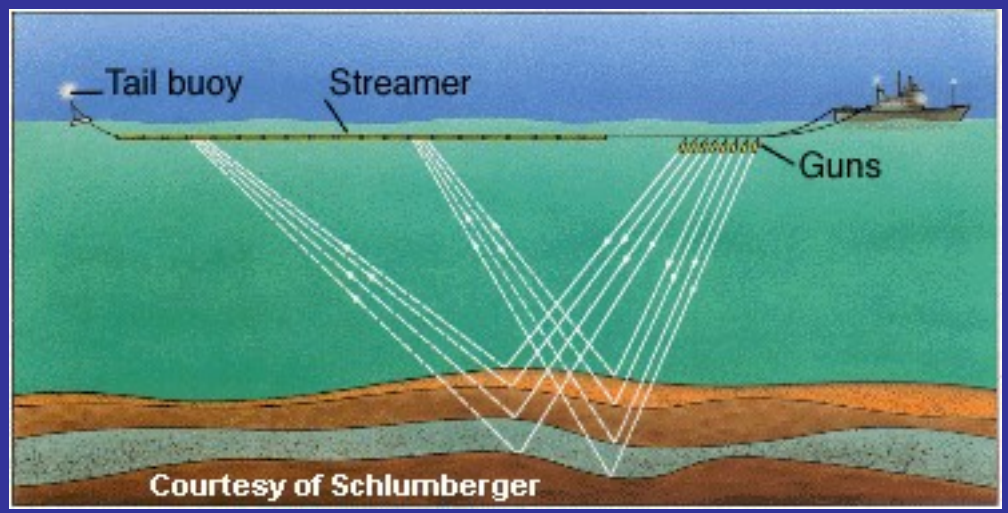


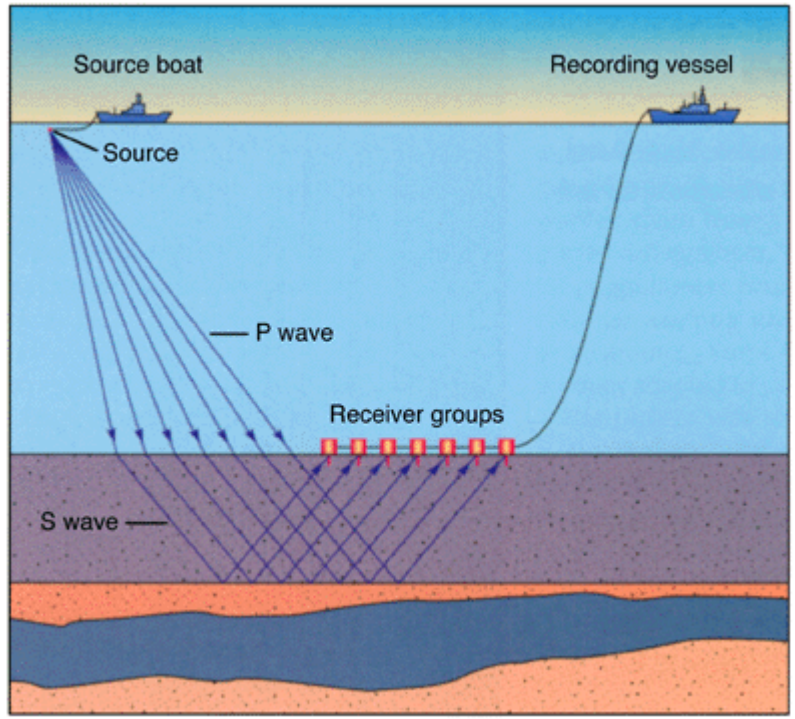


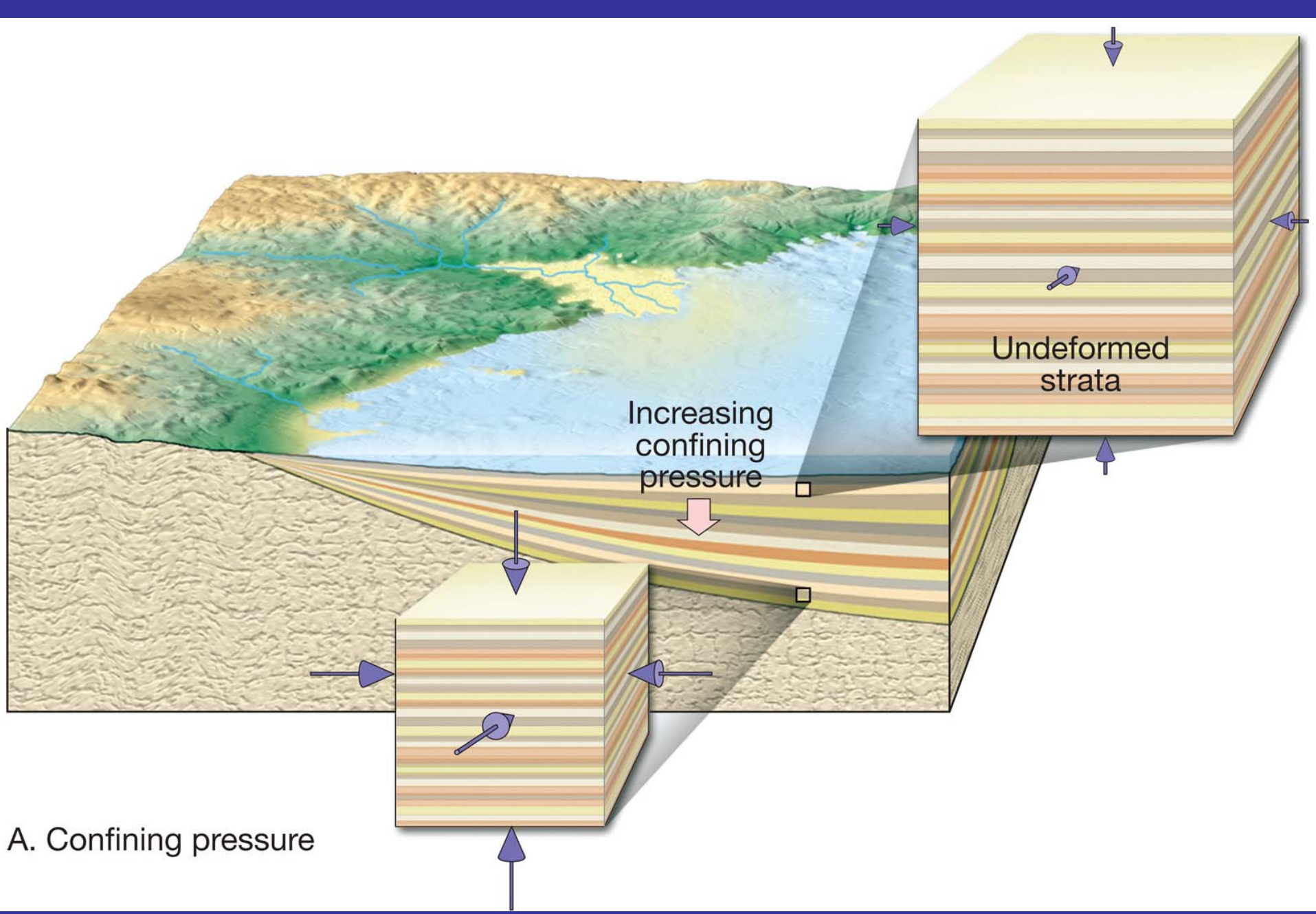
Burial Metamorphism



Seismic profile





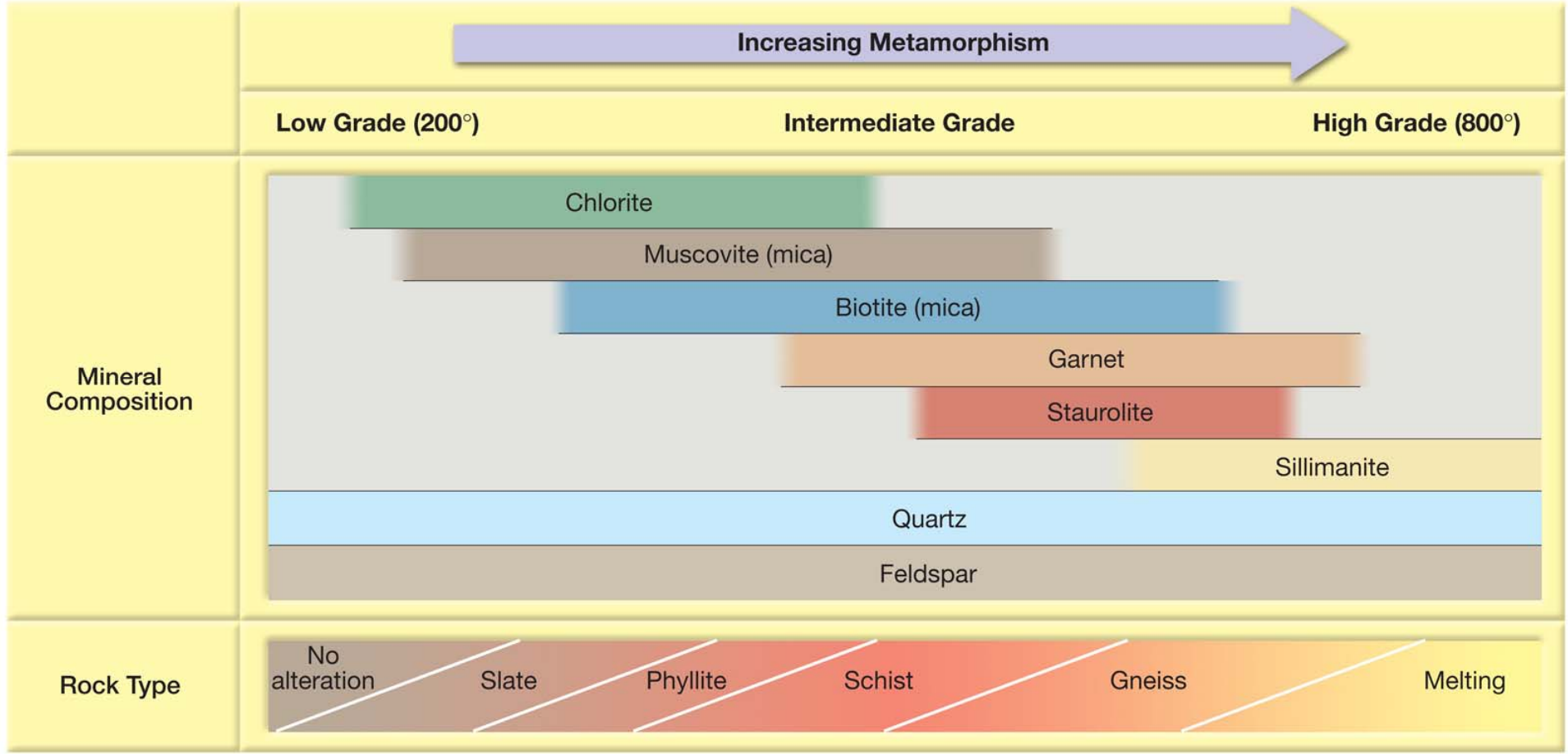


A. Confining pressure

Metamorphic pressure occurs due to:

1. **Tectonics**
2. **Burial**

Metamorphic changes & temperature





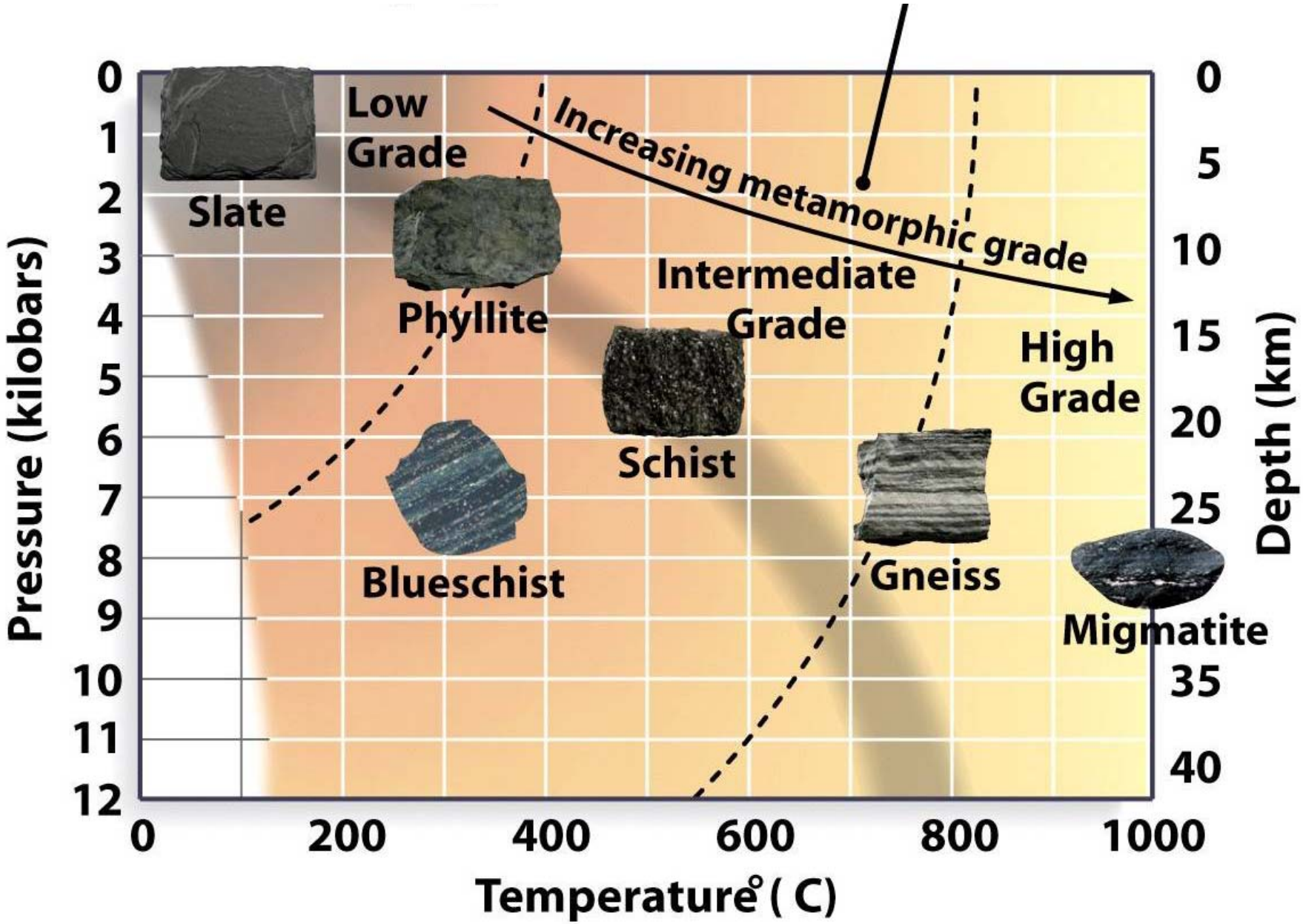




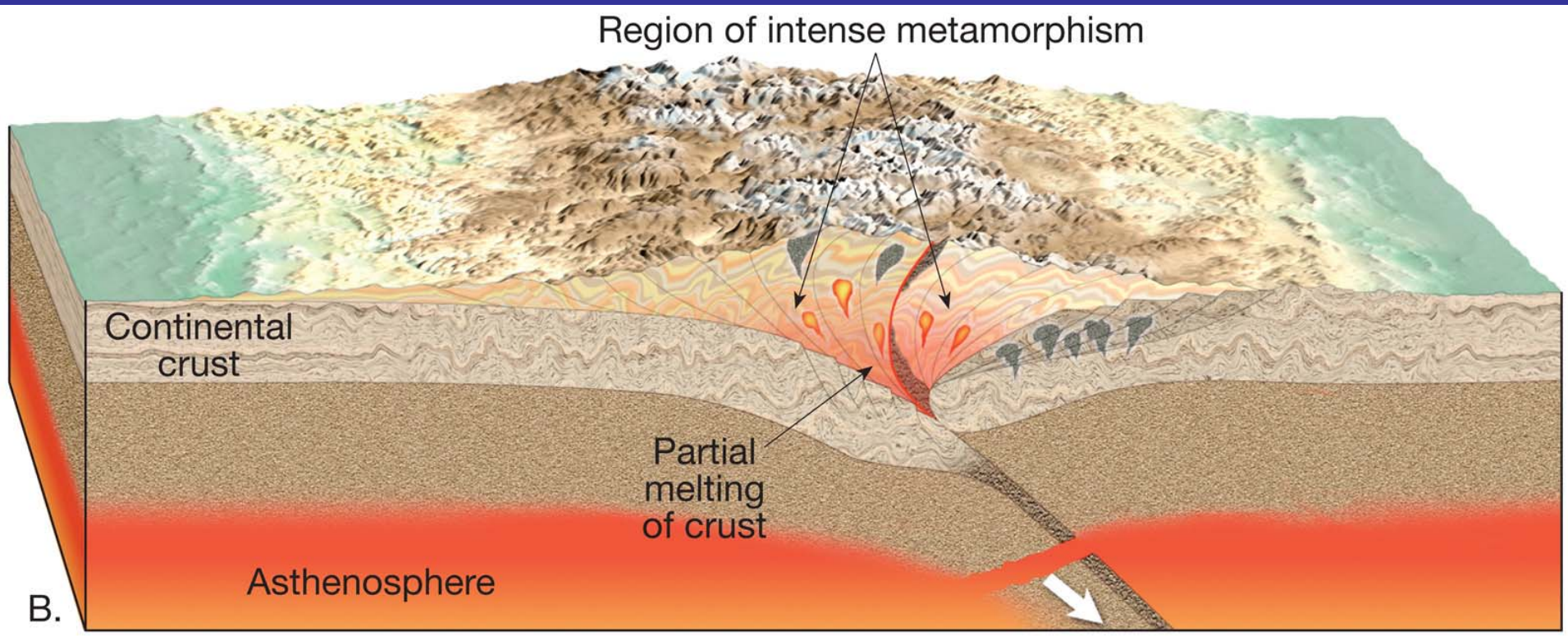




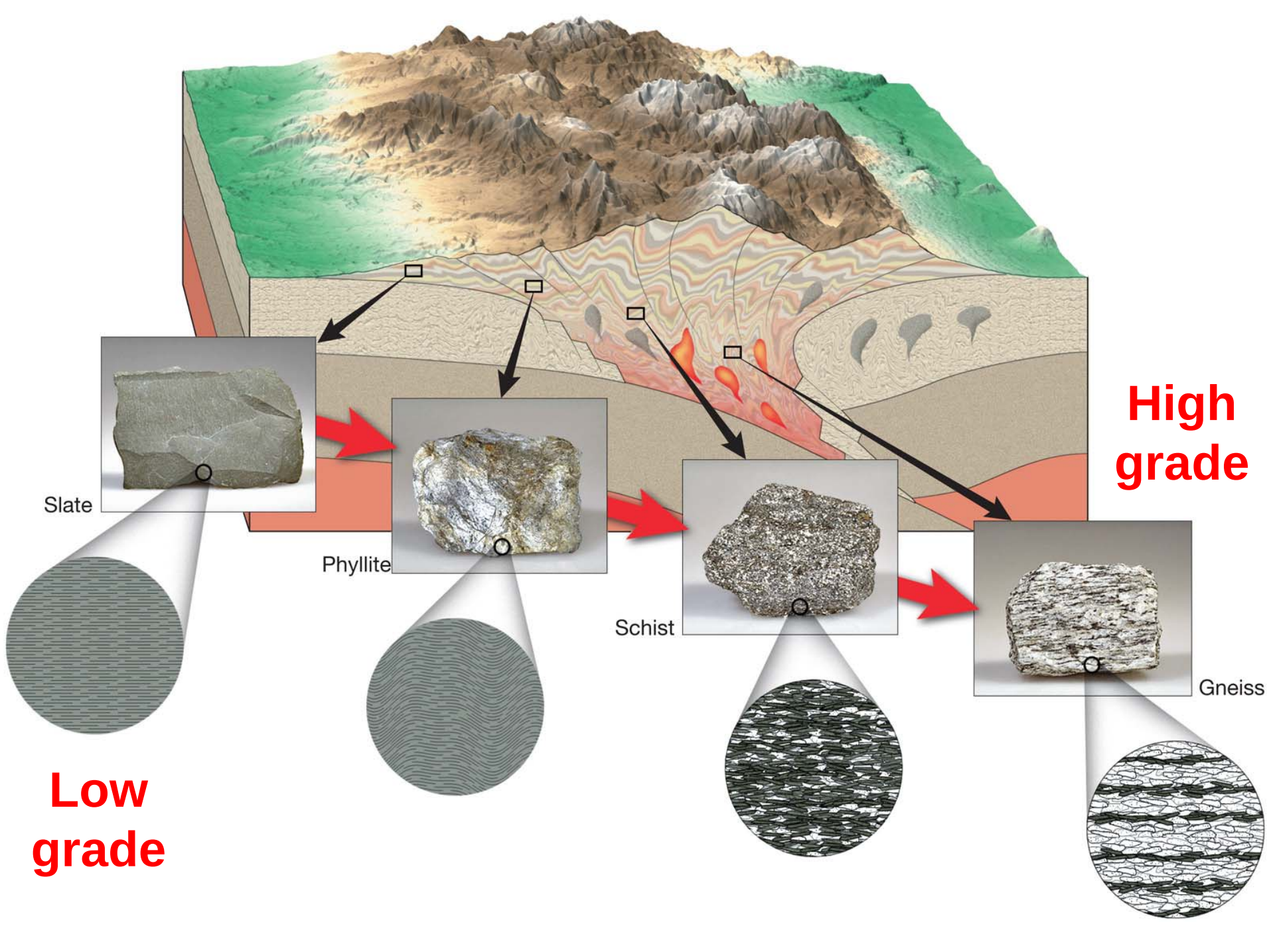
temperature and pressure affect metamorphic grade



How are temperature and pressure changing?



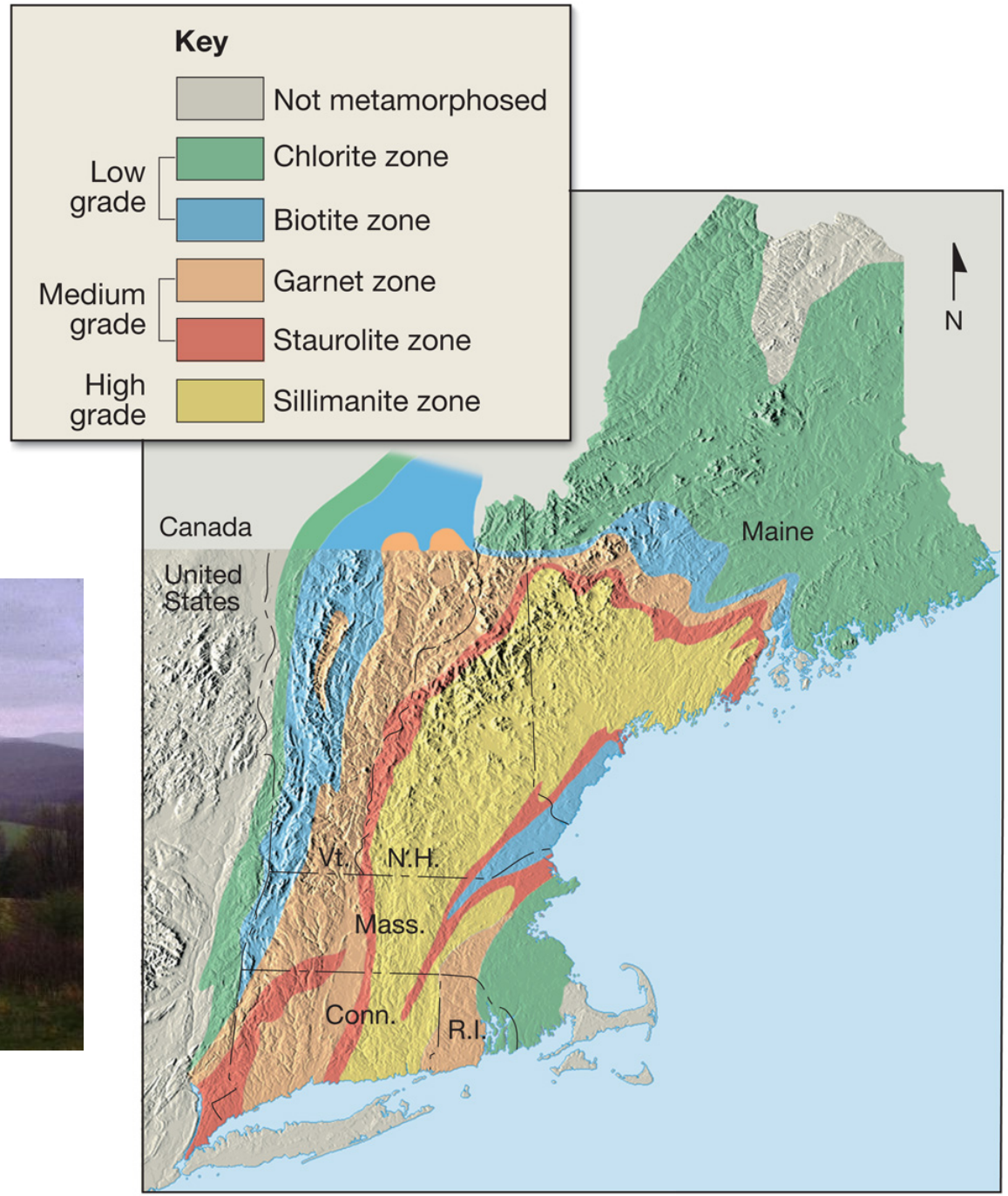
What kind of boundary is this?

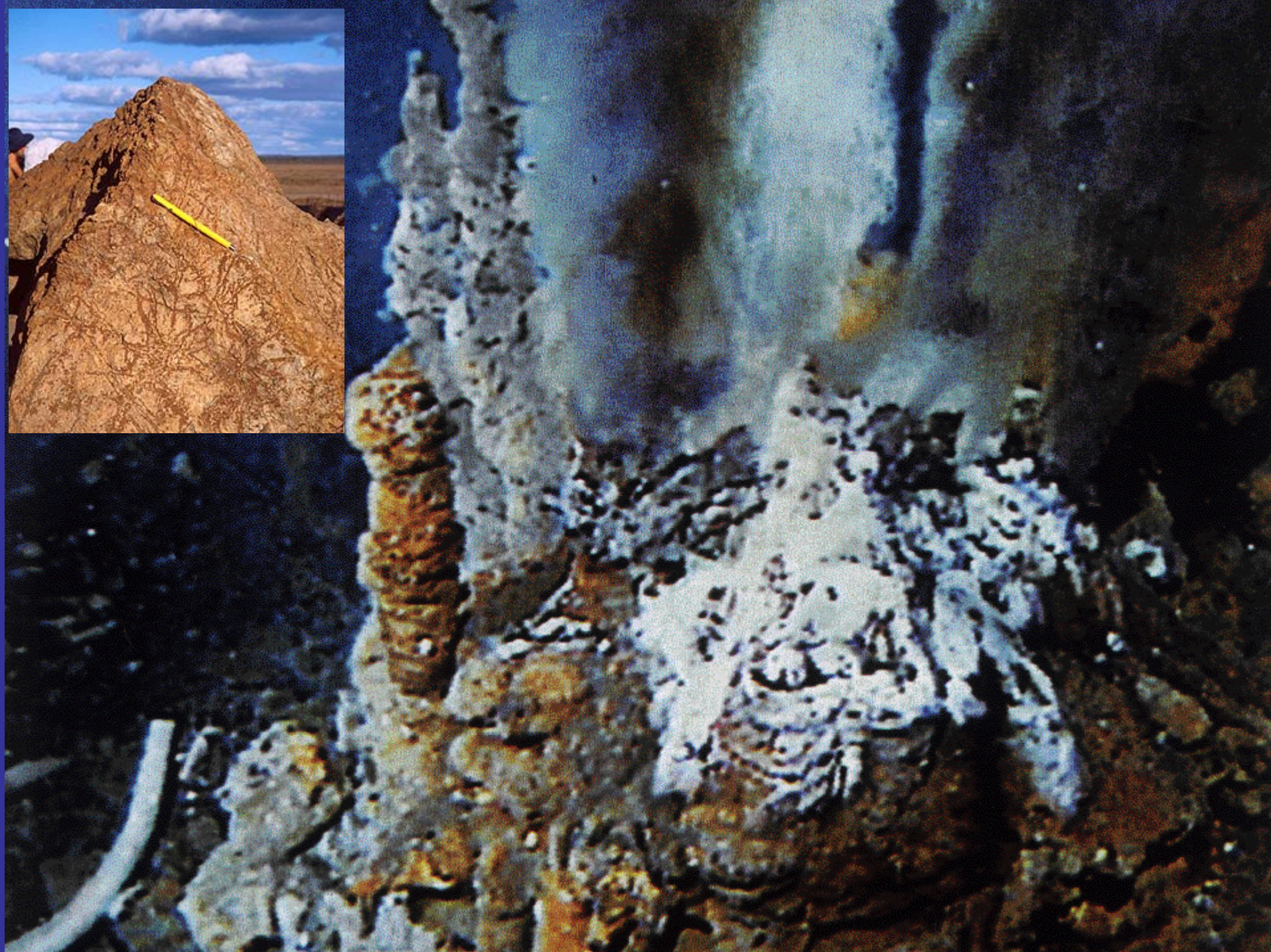

Slate
Phyllite
Schist
Gneiss
High grade
Low grade





Appalachian Metamorphism

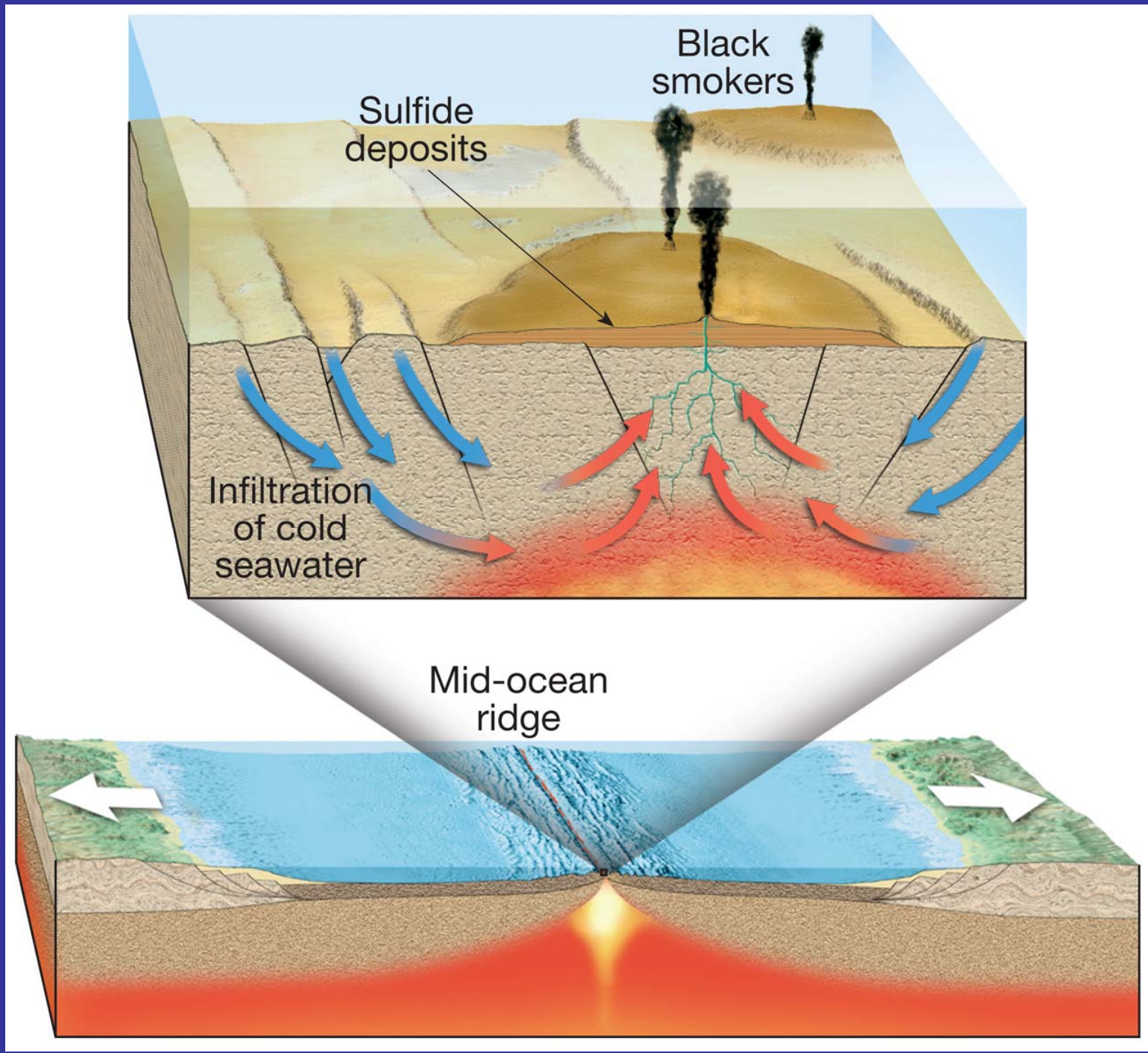




Olivine
Pyroxene

↓

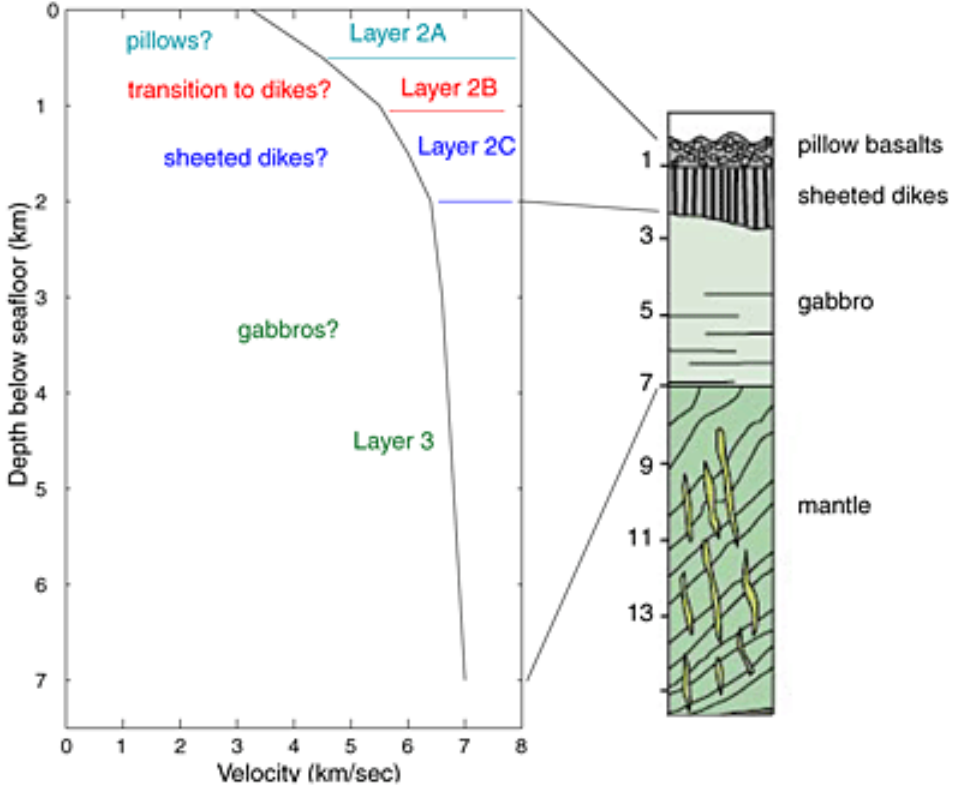
Serpentine
Chlorite
Talc





Tethys Ocean 245-66 Mya

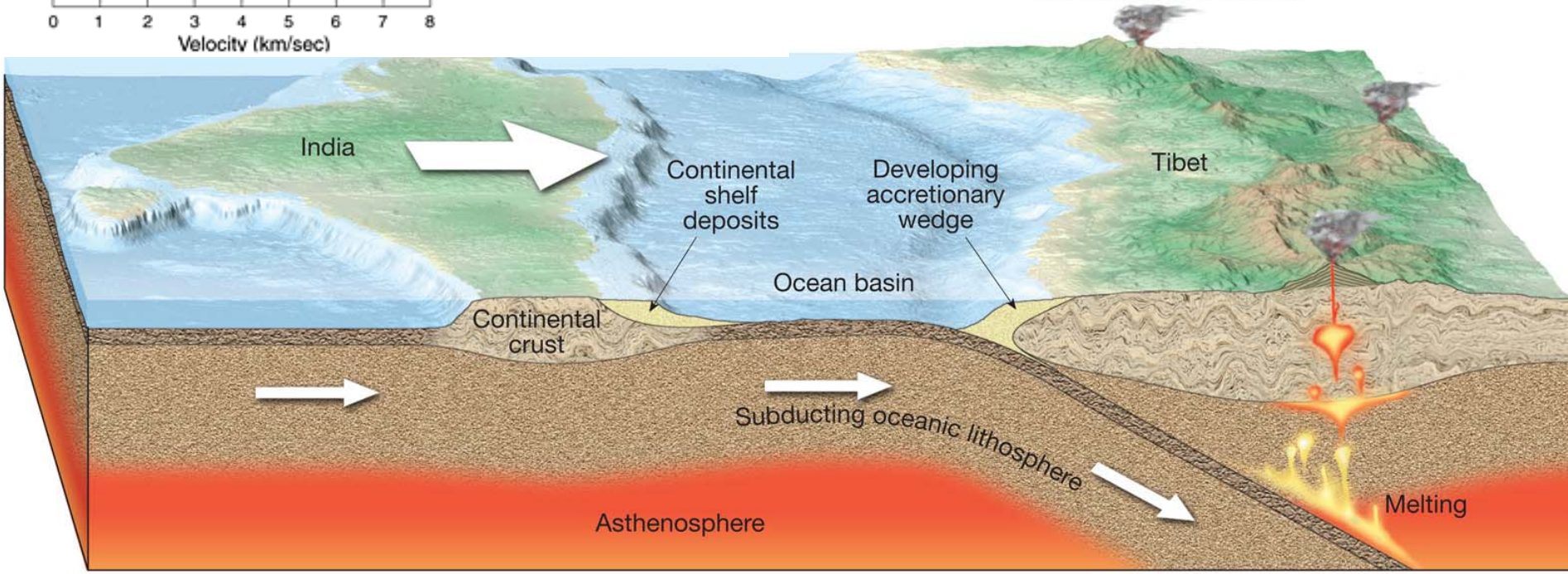




Ophiolite



Continental volcanic arc





What are these things?



A) Dinosaur eggs
B) Pahoehoe flows
C) Metaconglomerates
D) Spheroidal weathering
E) Pillow basalts





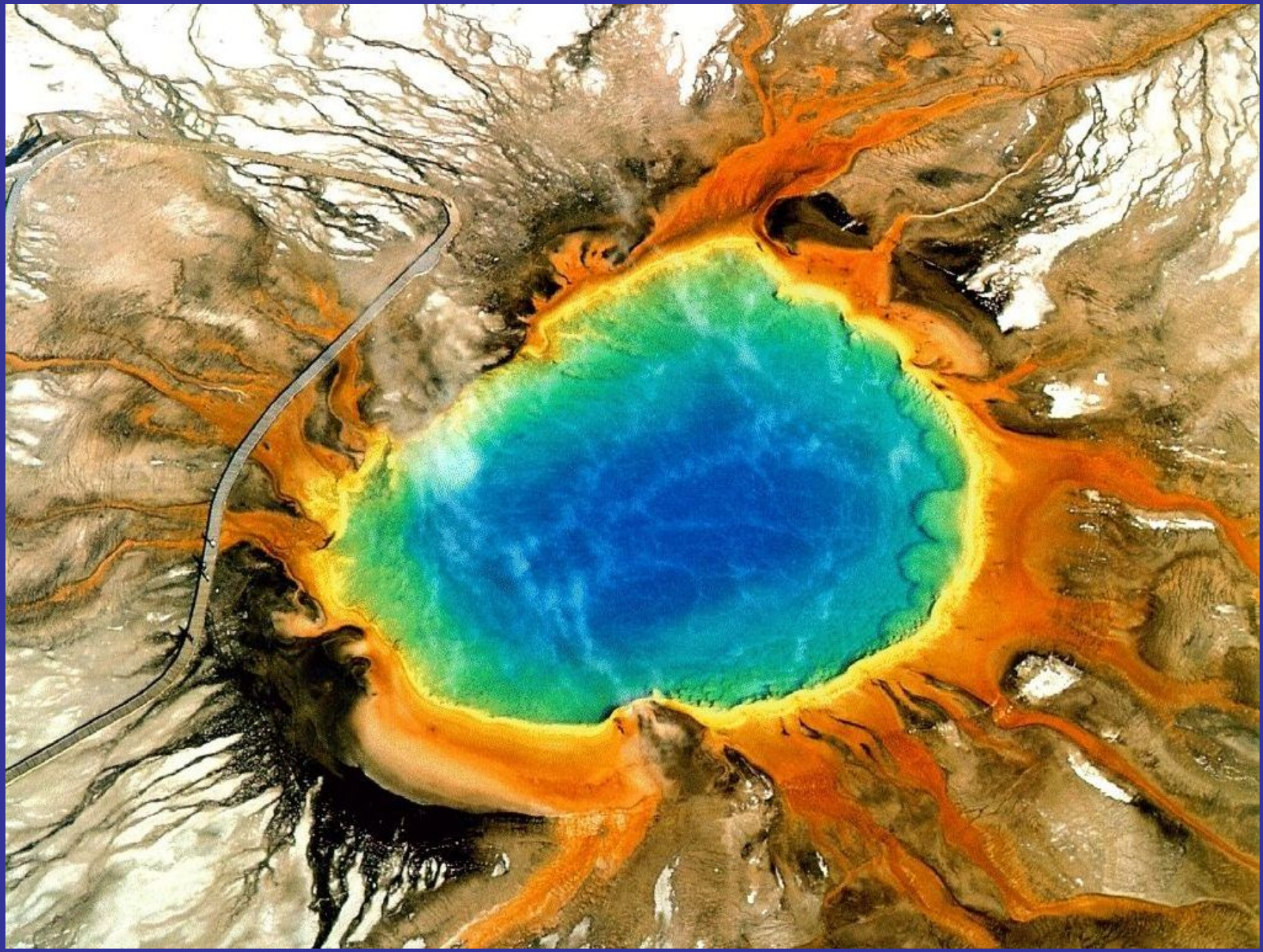


Pillow basalts – form under water

(divergent boundaries, hotspots)



200,000 tons from 3,500-1,200 BC !



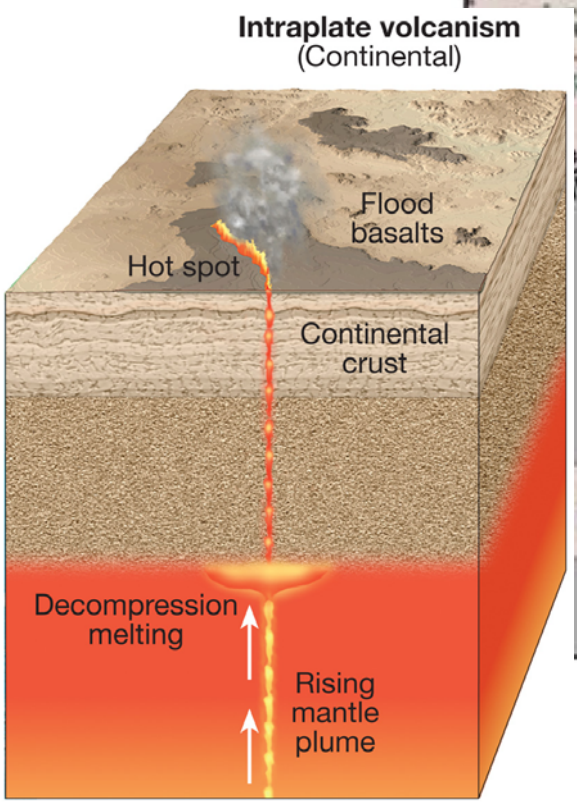


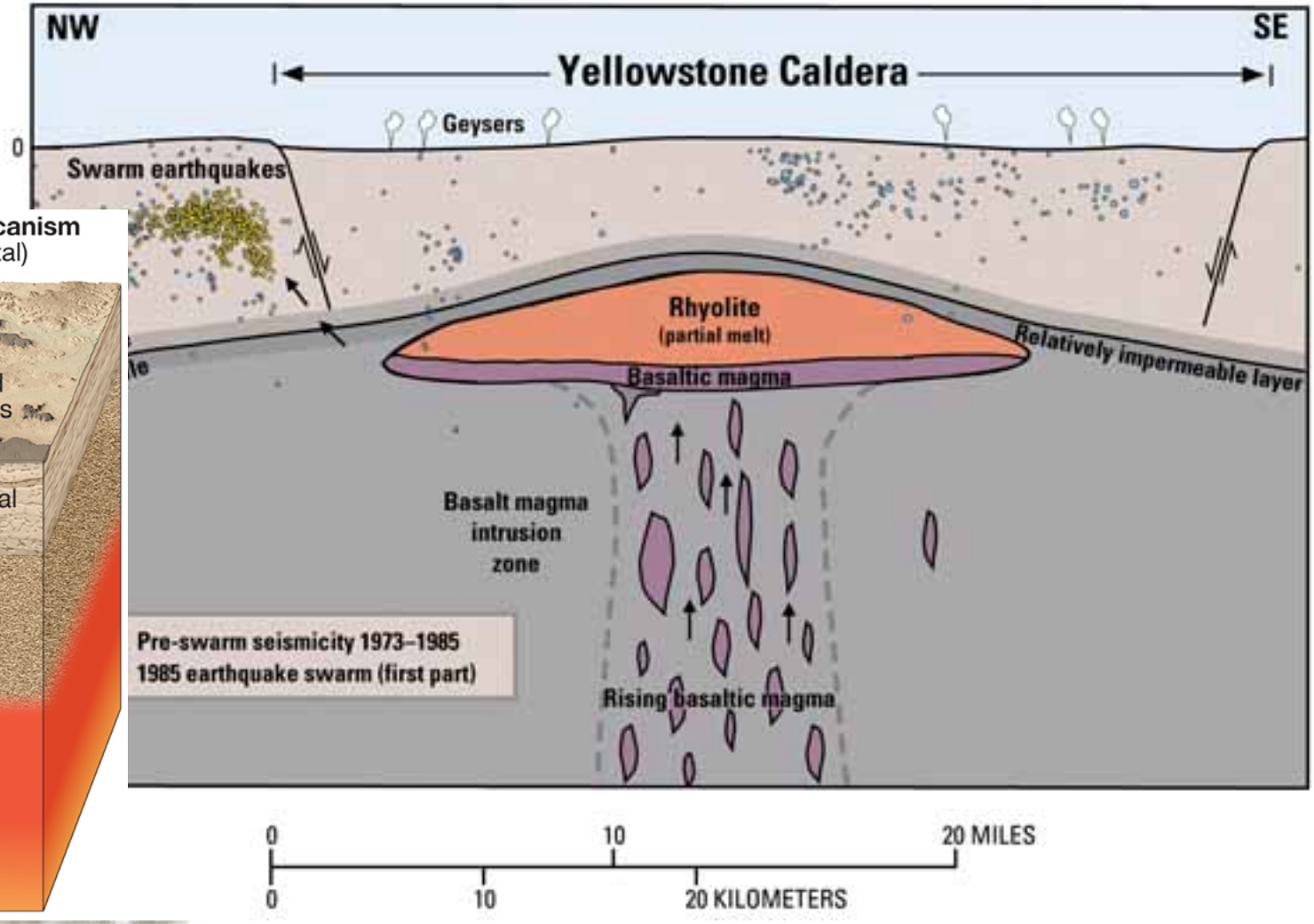


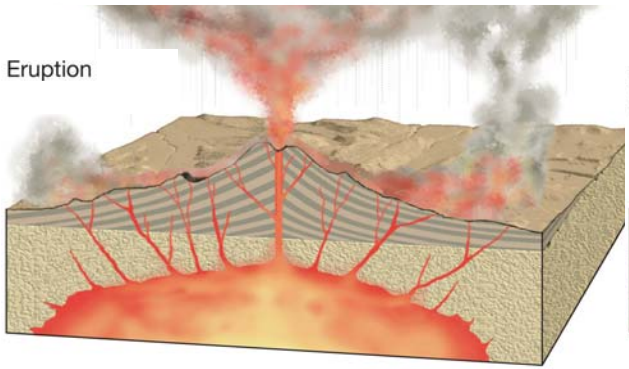


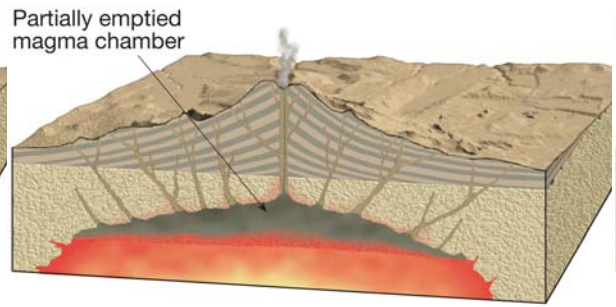
Old Faithful

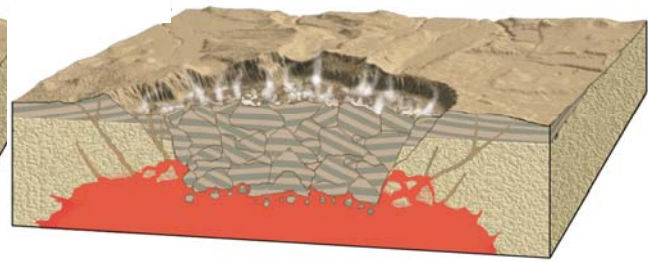
gold, silver
mercury, sulphur


Intraplate volcanism
(Continental)
Flood basalts
Hot spot
Continental crust
Decompression melting
Rising mantle plume


NW
SE
Yellowstone Caldera
Geysers
0
Swarm earthquakes
Rhyolite
(partial melt)
Basaltic magma
Relatively impermeable layer
Basalt magma intrusion zone
Pre-swarm seismicity 1973–1985
1985 earthquake swarm (first part)
Rising basaltic magma
0
10
20 MILES
0
10
20 KILOMETERS


Eruption


Partially emptied magma chamber


Collapse

Metamorphic deposits related to chemical fluid circulation can be found:

1. **At mid-ocean ridges**

2. **In ophiolite complexes (uplifted MORs)**

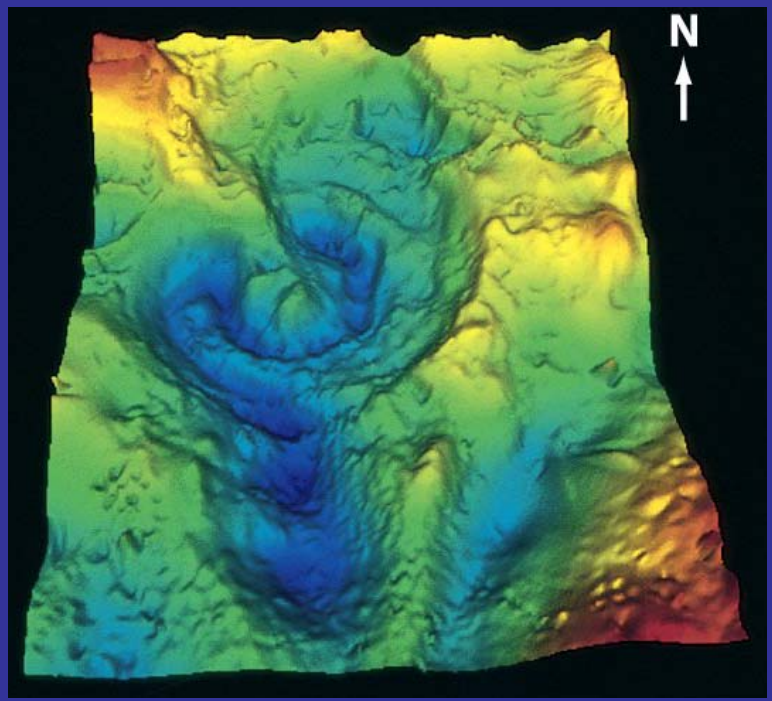
3. **Anywhere hydrothermal fluids circulate (geysers, hot springs, other volcanic systems, etc.)**

End of the Dinosaurs

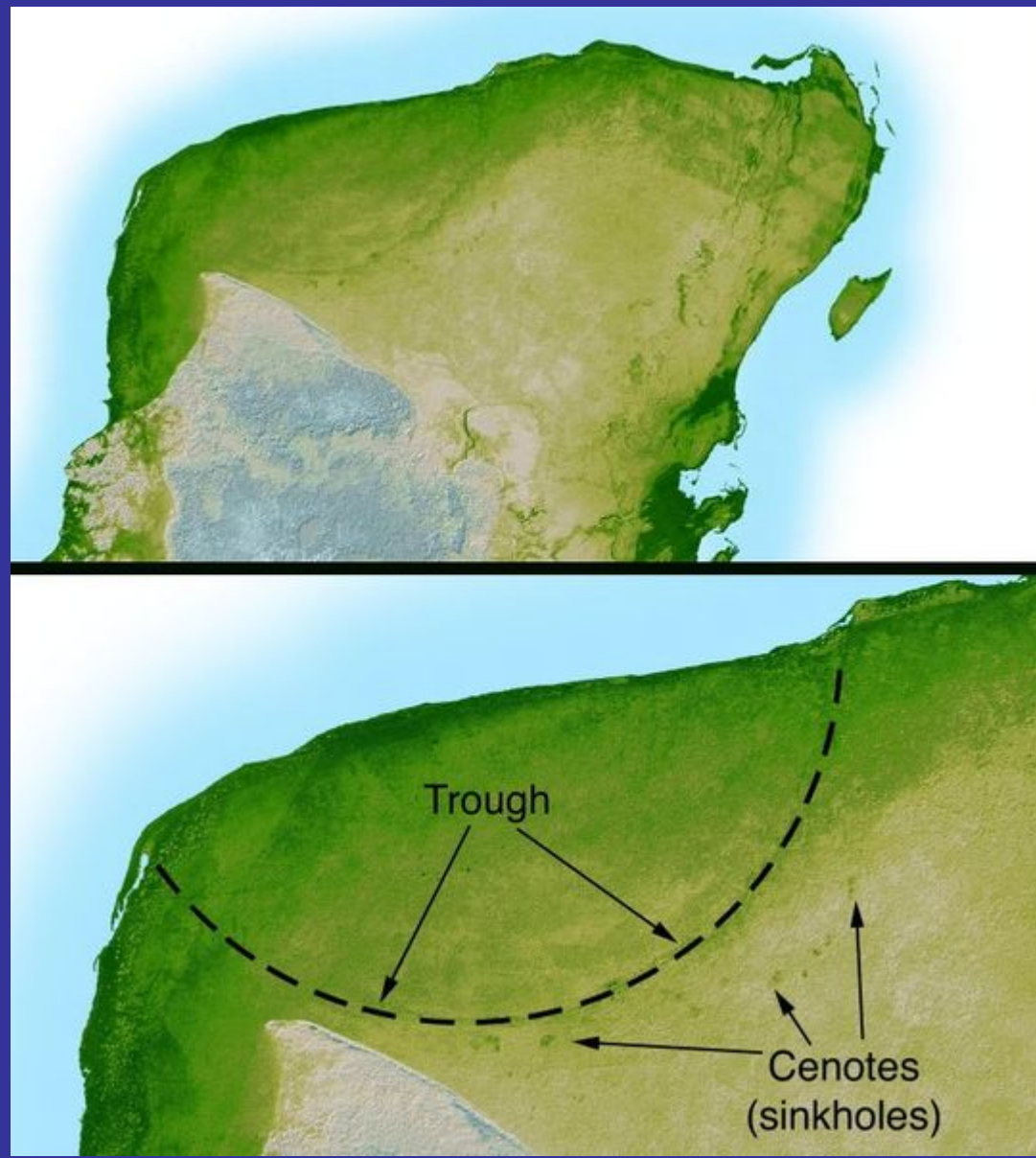


Chicxulub Crater – >180km across





Andesite layer 1.3km down



10 km across ***(not to scale!)***



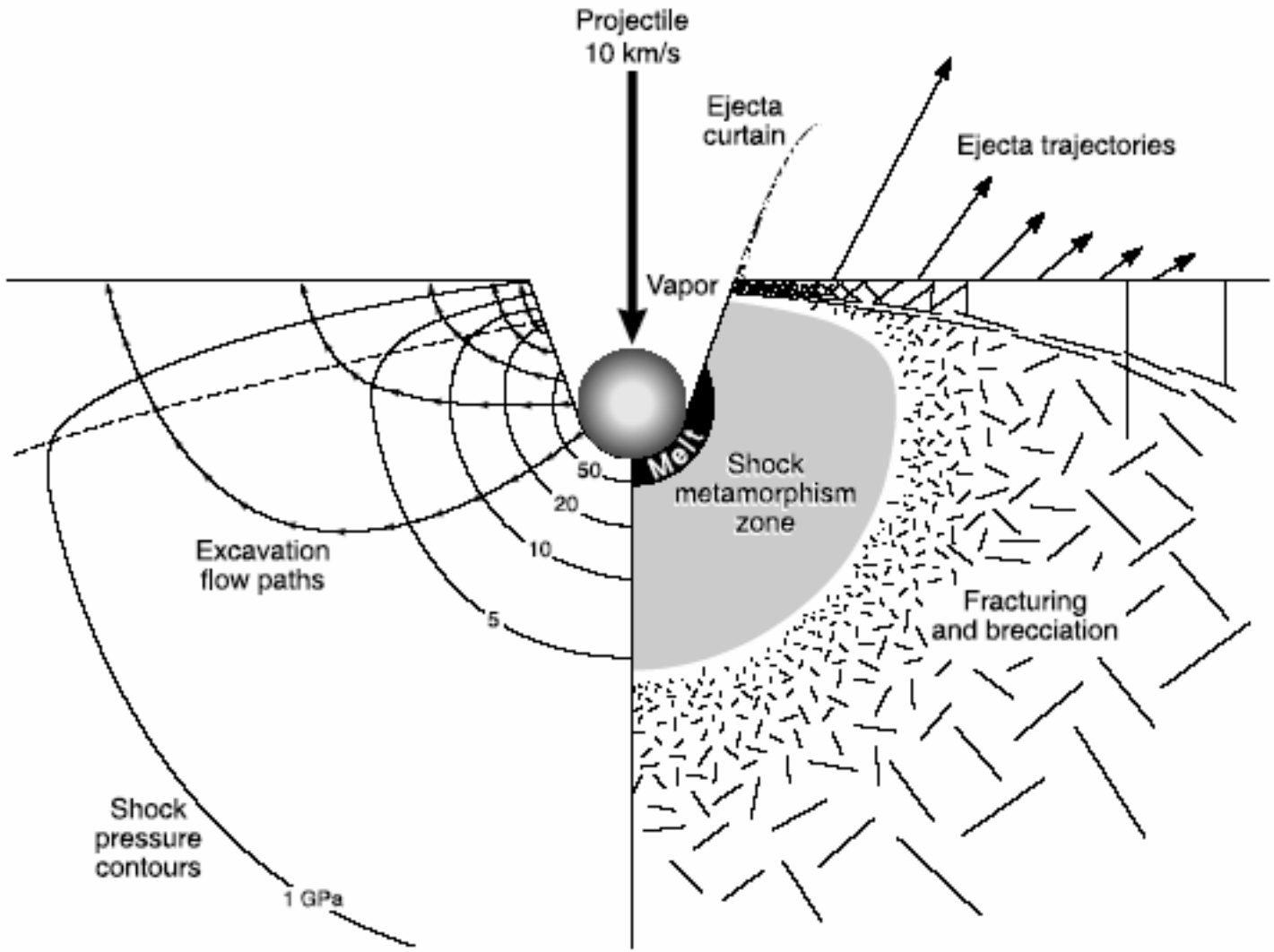
2 million times more powerful than largest nuclear explosion

K/T Boundary

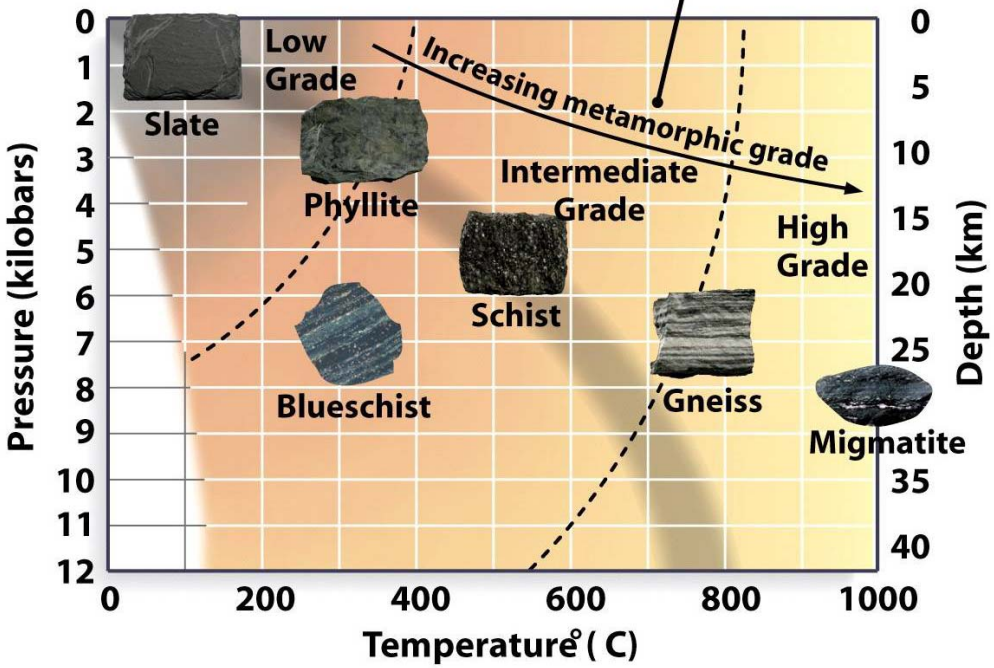
65 Mya



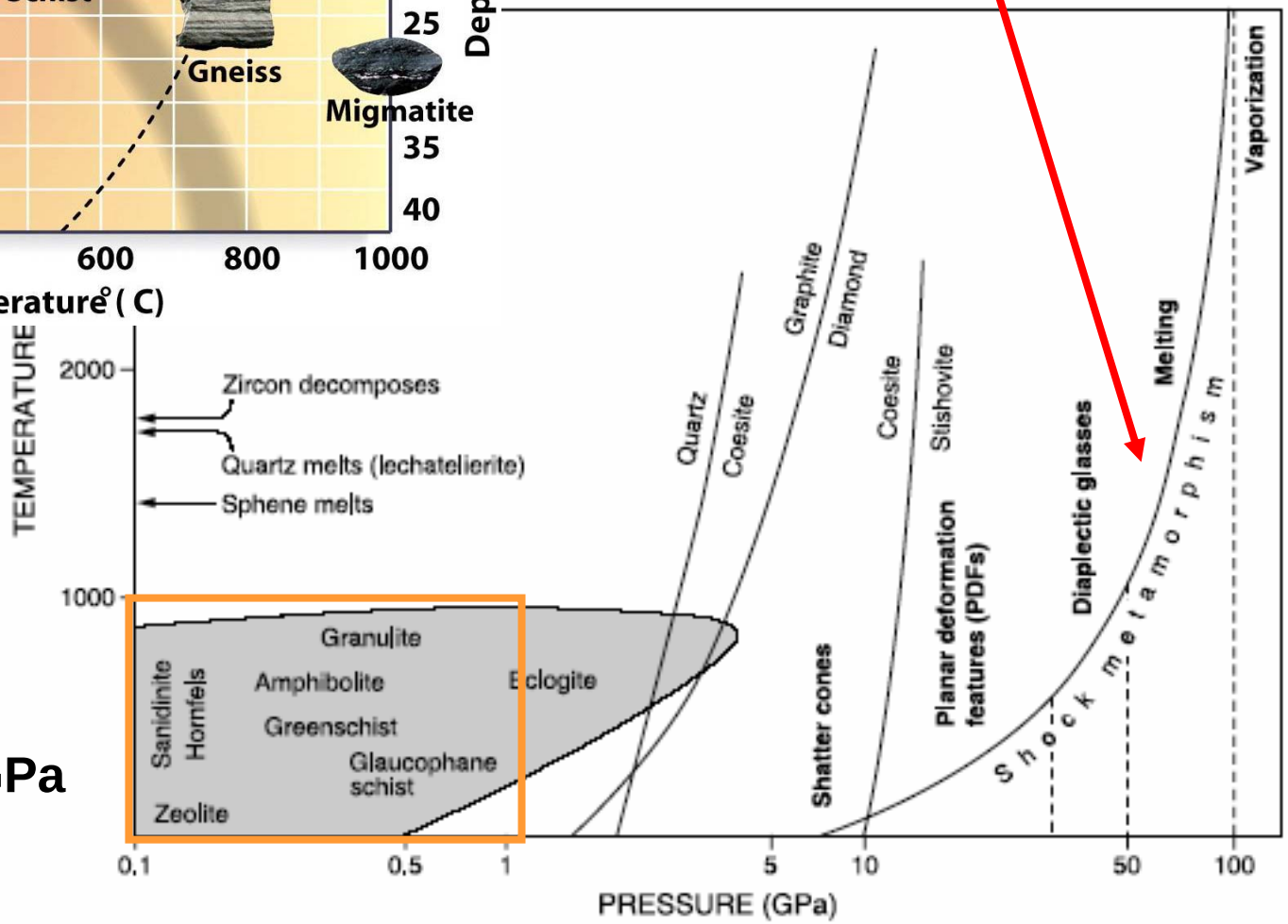
spherules


Projectile
10 km/s
Ejecta
curtain
Ejecta trajectories
Vapor
Melt
Shock
metamorphism
zone
Fracturing
and brecciation
50
20
10
5
Excavation
flow paths
Shock
pressure
contours
1 GPa

Normal metamorphism



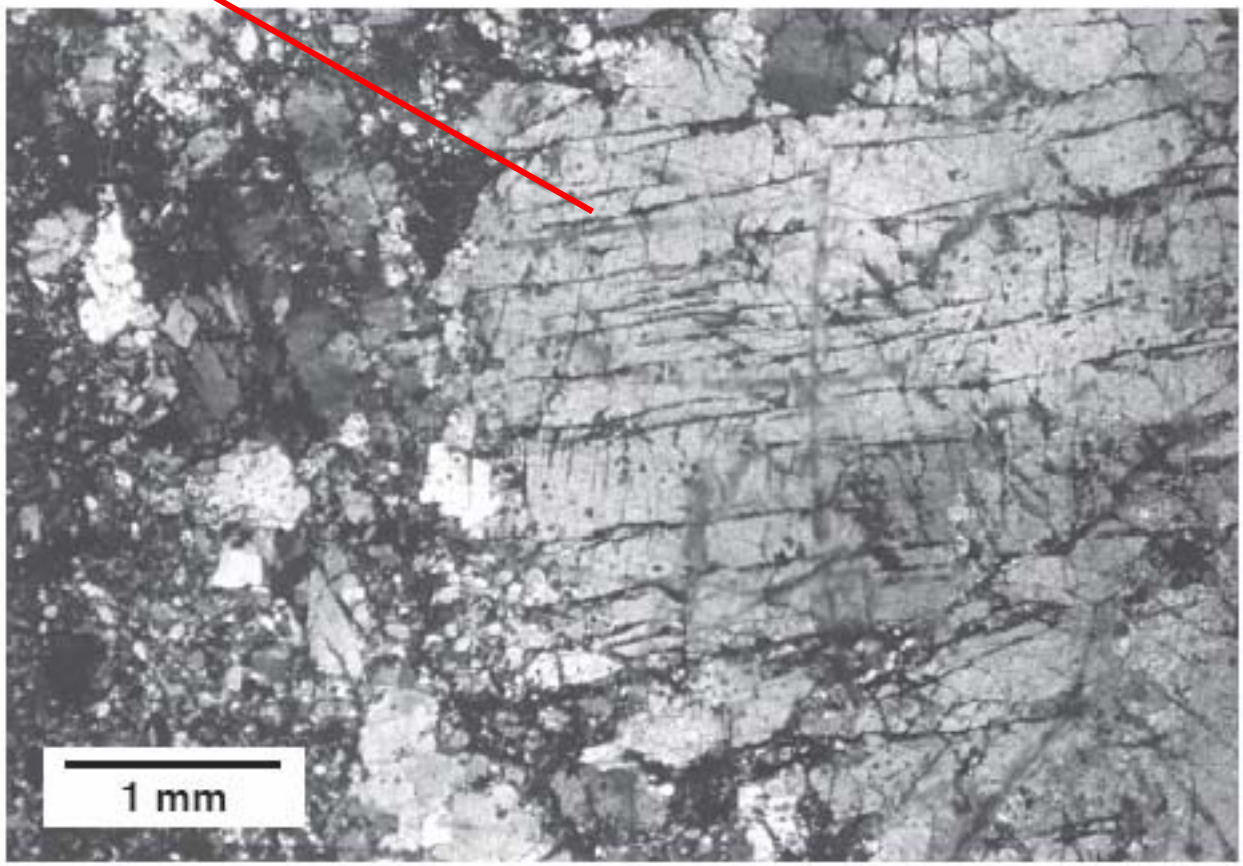
Shock metamorphism

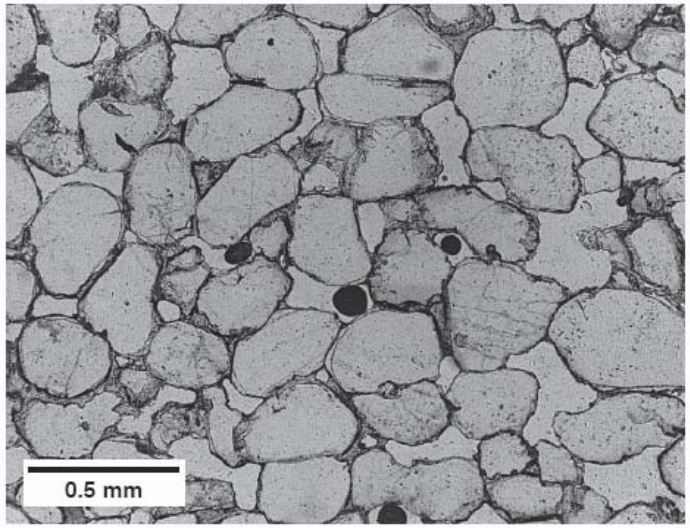


10 kilobars = 1 GPa

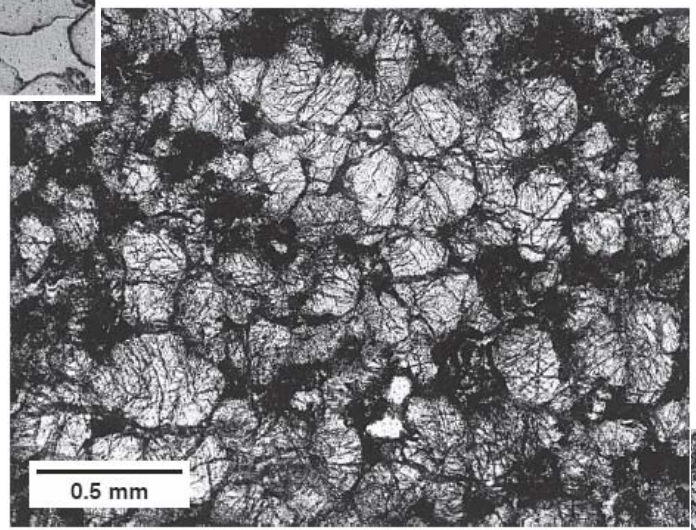
Normal Metamorphism	Shock Metamorphism
10-50km depth	Surface
1-10 Gpa	100-400 Gpa
<1,000° C	up to 10,000° C
Millions of years	Instantaneous
Large crystals	Glass

Big grain is quartz. What is weird here?

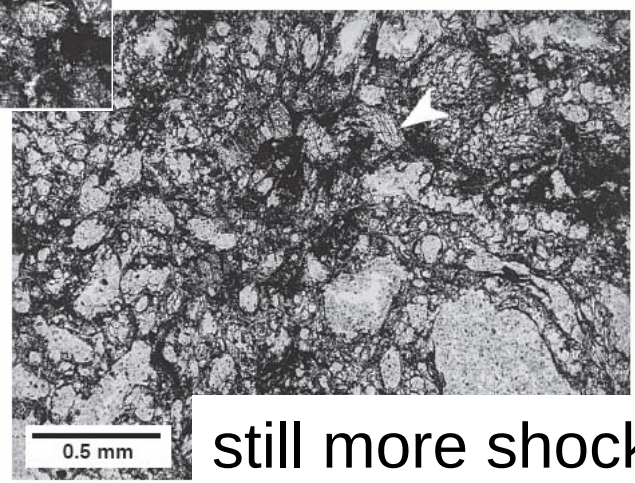




unshocked
quartz
sandstone



same rock
moderate shock

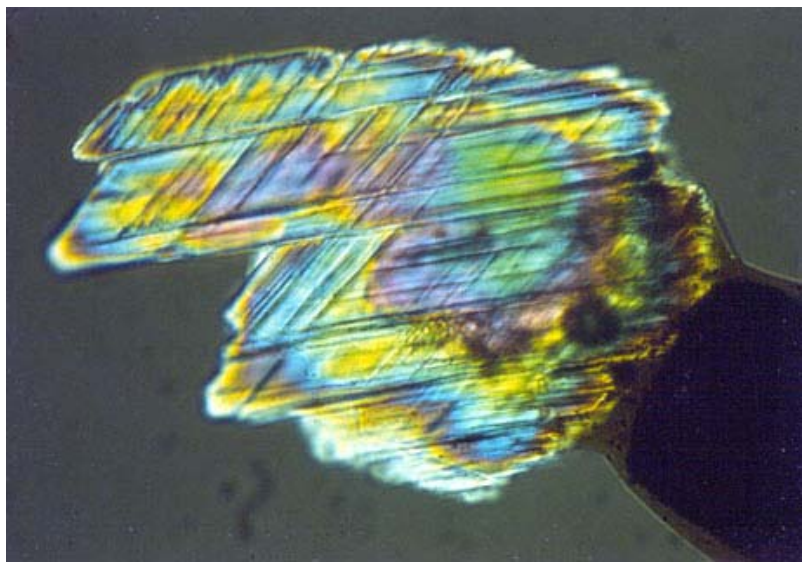


still more shock

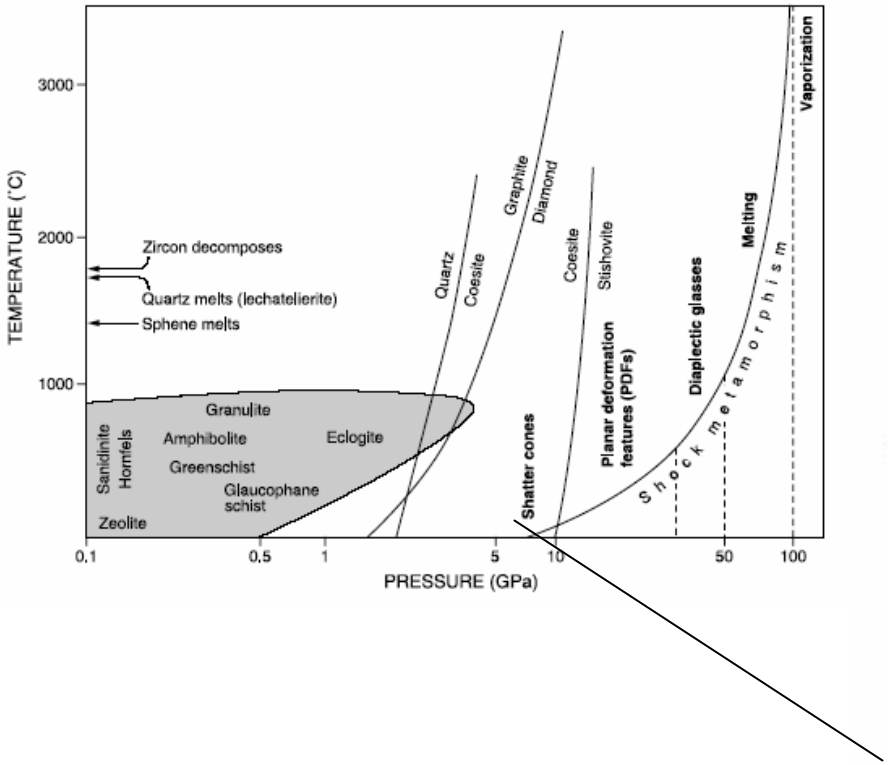




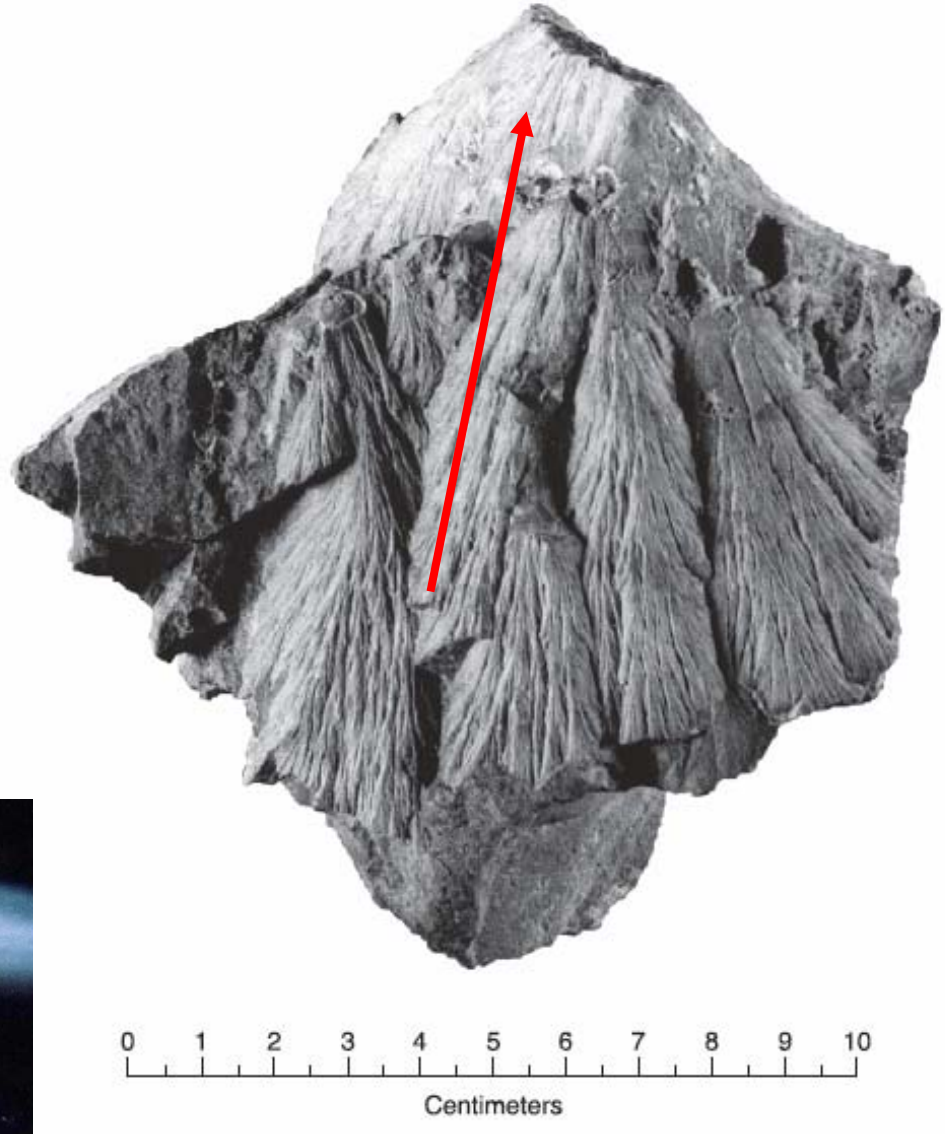




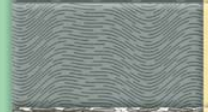
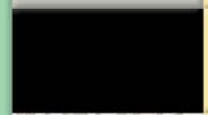
Starkville South KTB section



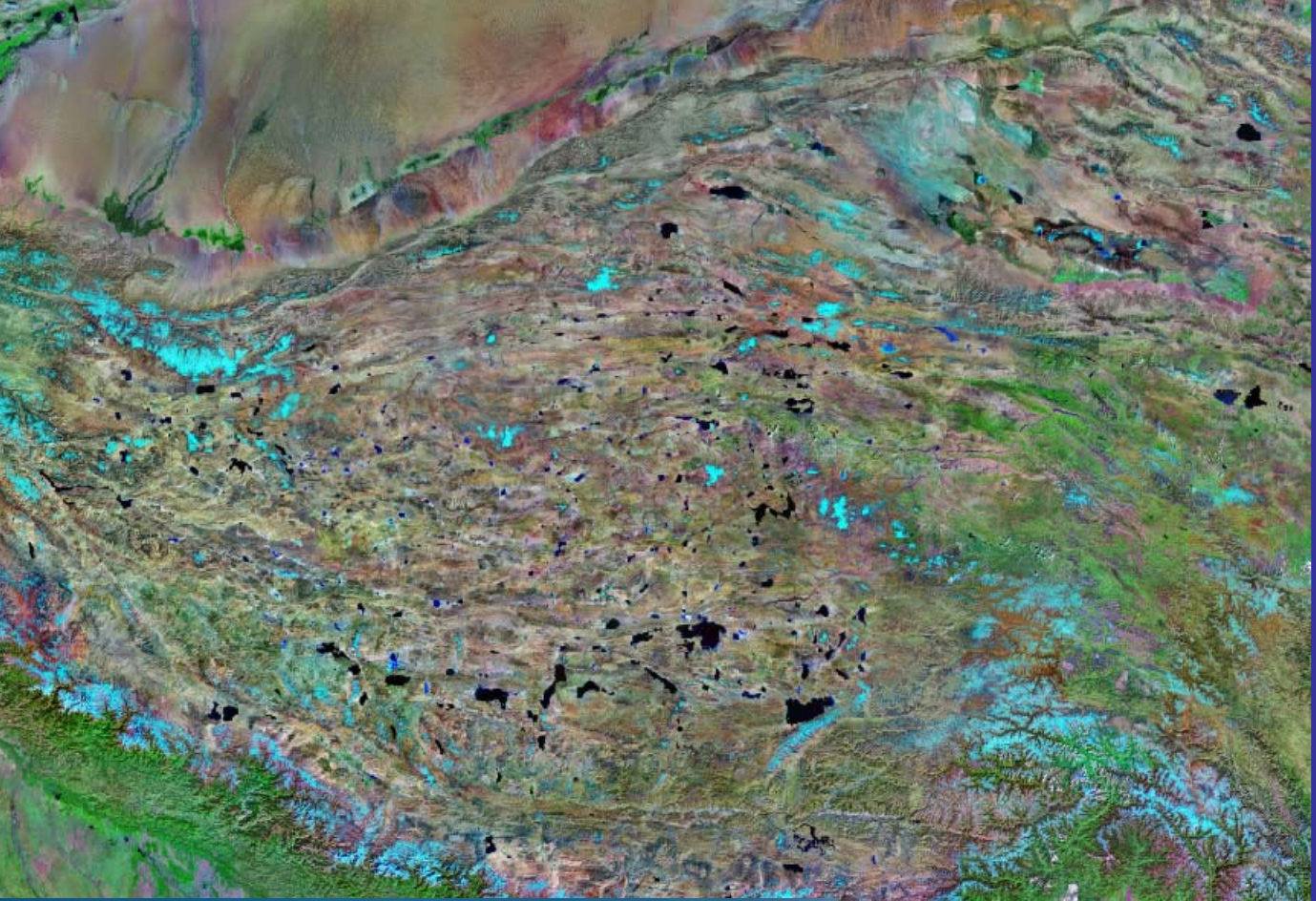




Shatter cone

Rock Name	Texture	Grain Size	Comments	Parent Rock
Slate	Foliated 	Very fine	Excellent rock cleavage, smooth dull surfaces	Shale, mudstone, or siltstone
Phyllite	Foliated 	Fine	Breaks along wavy surfaces, glossy sheen	Slate
Schist	Foliated 	Medium to Coarse	Micaceous minerals dominate, scaly foliation	Phyllite
Gneiss	Foliated 	Medium to Coarse	Compositional banding due to segregation of minerals	Schist, granite, or volcanic rocks
Migmatite	Foliated 	Medium to Coarse	Banded rock with zones of light-colored crystalline minerals	Gneiss, schist
Mylonite	Weakly Foliated 	Fine	When very fine-grained, resembles chert, often breaks into slabs	Any rock type
Metaconglomerate	Weakly Foliated 	Coarse-grained	Stretched pebbles with preferred orientation	Quartz-rich conglomerate
Marble	Nonfoliated 	Medium to coarse	Interlocking calcite or dolomite grains	Limestone, dolostone
Quartzite	Nonfoliated 	Medium to coarse	Fused quartz grains, massive, very hard	Quartz sandstone
Hornfels	Nonfoliated 	Fine	Usually, dark massive rock with dull luster	Any rock type
Anthracite	Nonfoliated 	Fine	Shiny black rock that may exhibit conchoidal fracture	Bituminous coal
Fault breccia	Nonfoliated 	Medium to very coarse	Broken fragments in a haphazard arrangement	Any rock type

Increasing Metamorphism





What kind of metamorphism do you expect to find at a convergent boundary?

A) Shock metamorphism
B) Burial metamorphism
C) Hydrothermal alteration
D) Regional metamorphism
E) Contact metamorphism

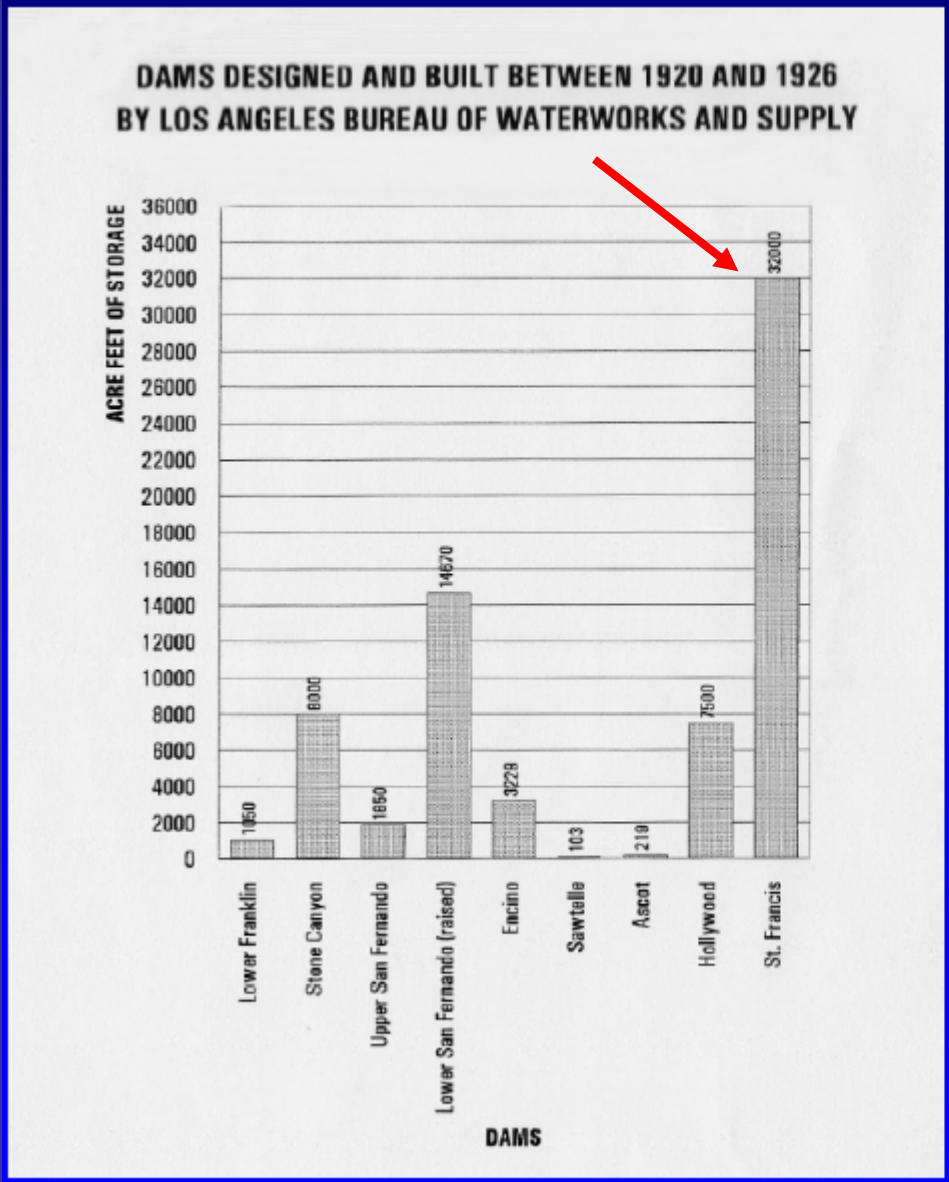


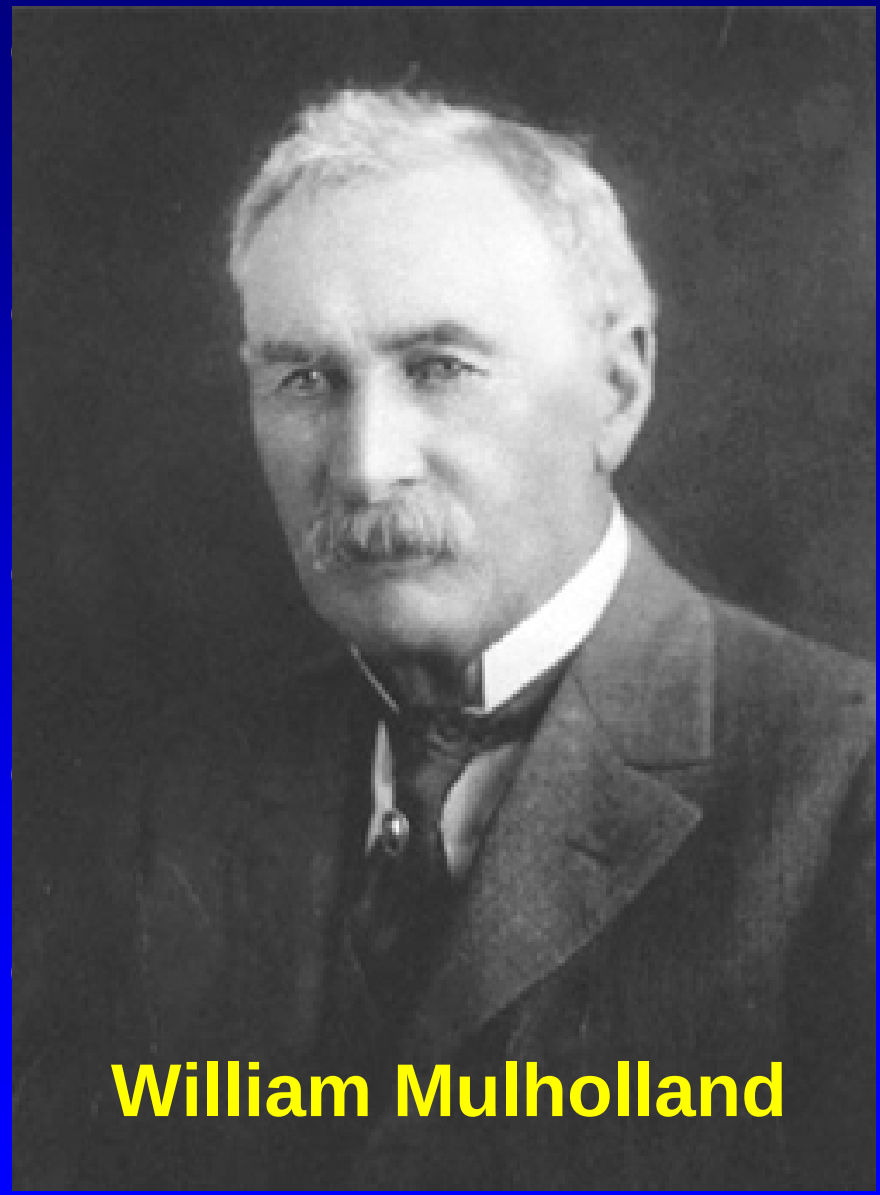


St. Francis Dam Failure, 1928

What can happen when you don’t pay attention to geology!

Another Water Crisis 1918-26







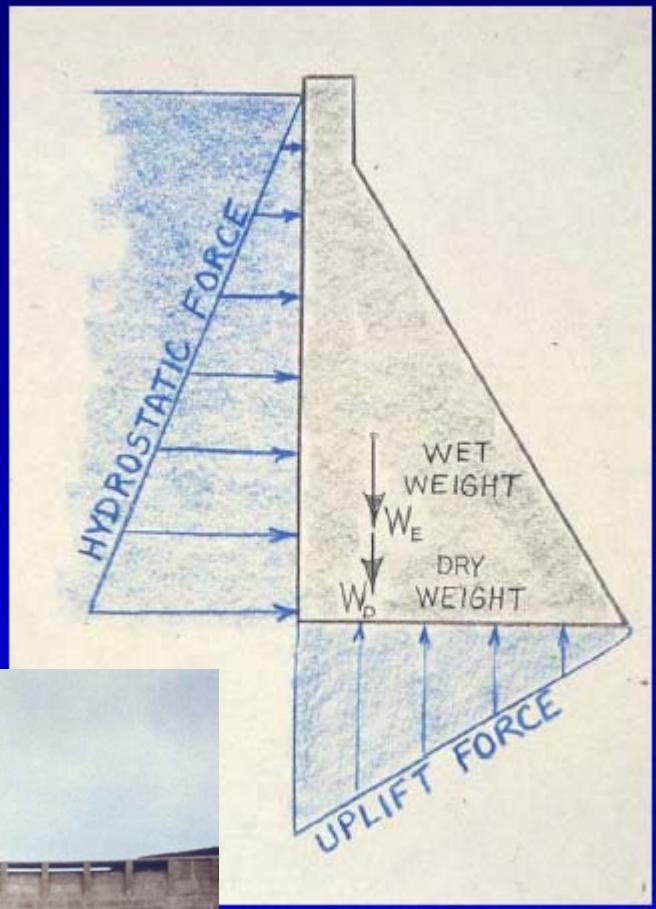


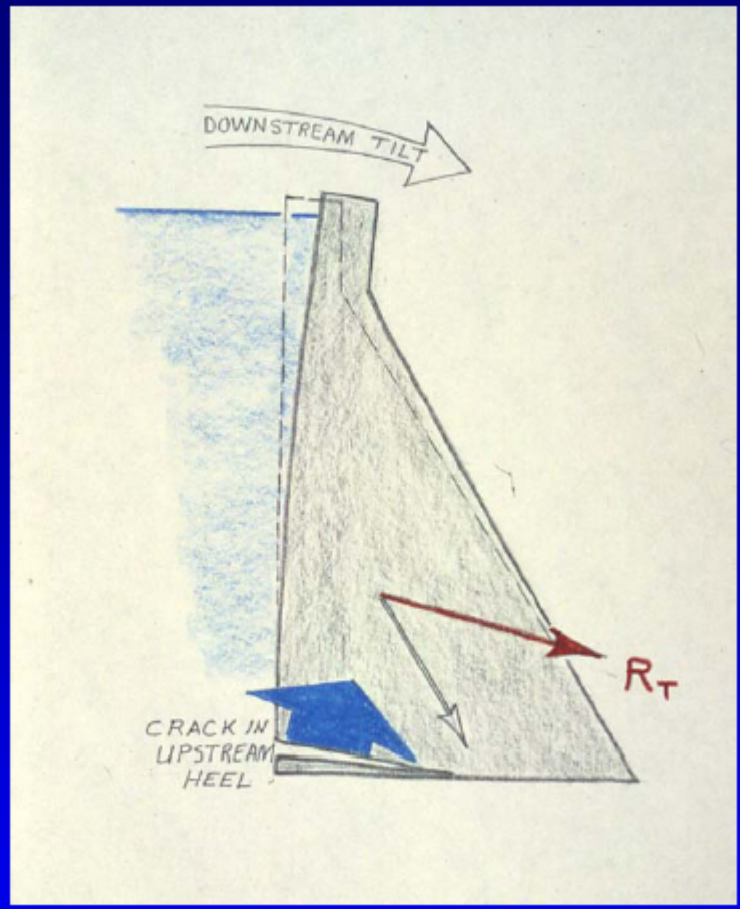
Pelona Schist texture?

A) Lineated
B) Foliated
C) Faulted
D) Weathered
E) Cooked

Foliation – reorganization of mineral grains into a planar orientation



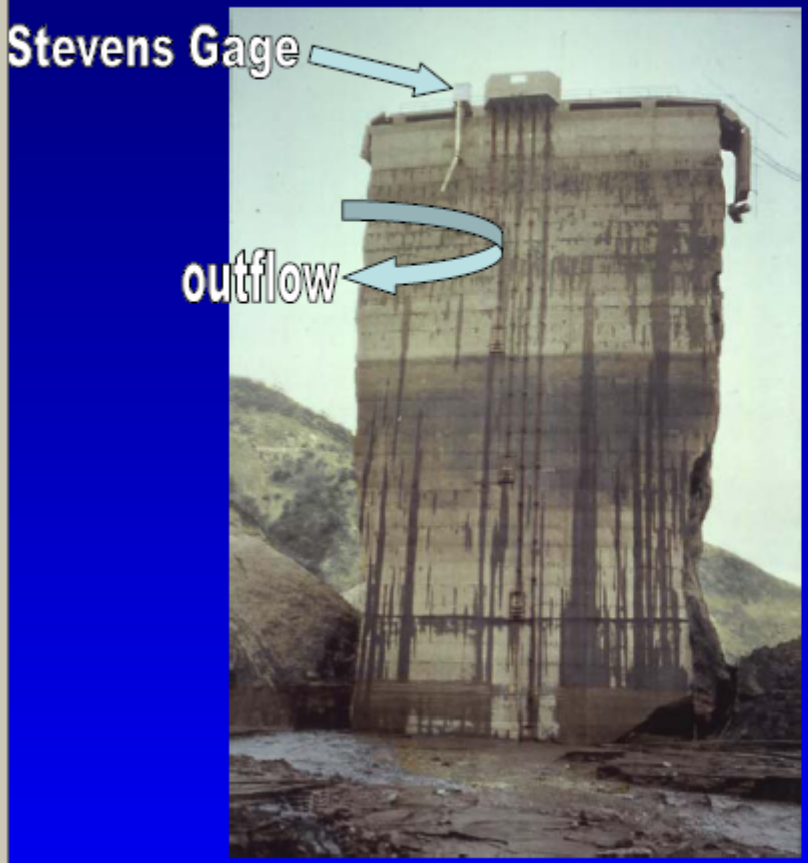


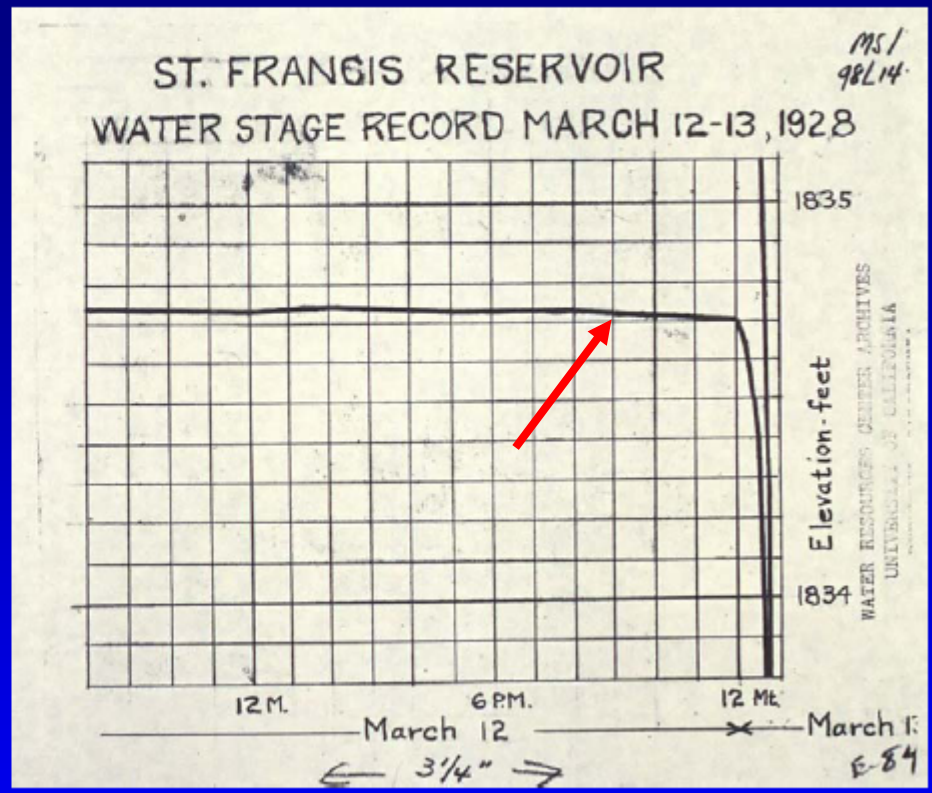




What happens when you make the dam <u>taller</u> but not <u>thicker</u>?

The Stevens Stage Record





8:00pm – slight drop
11:57pm – total failure

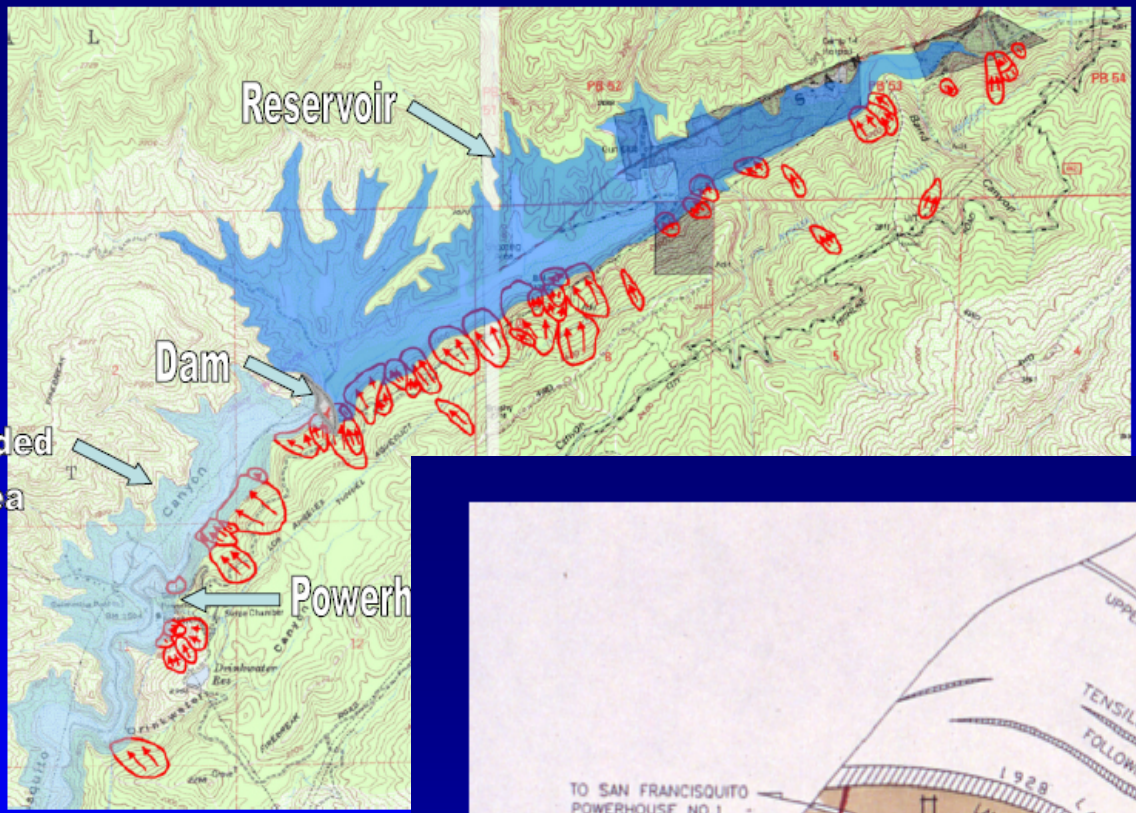
The East Abutment Landslide



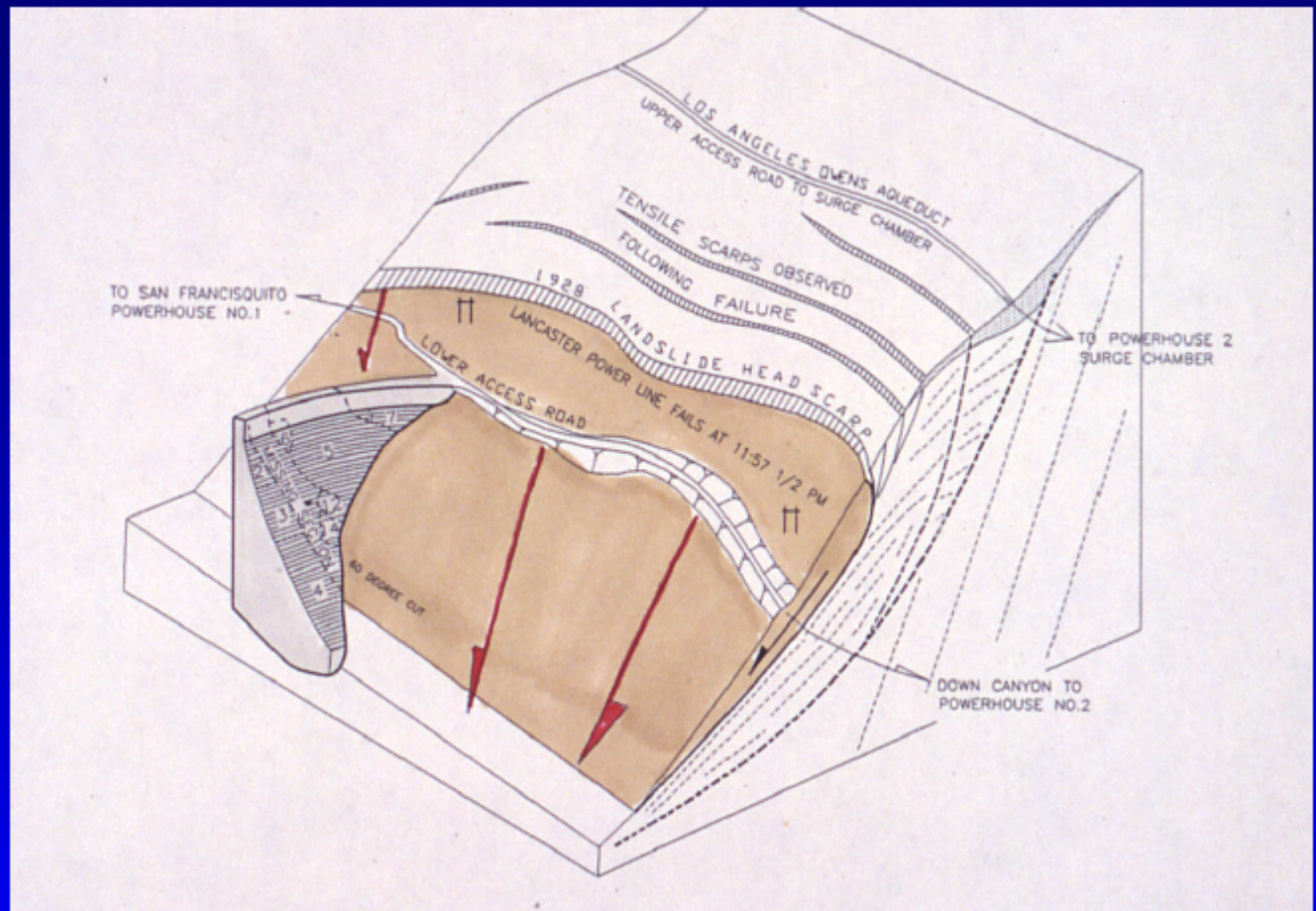




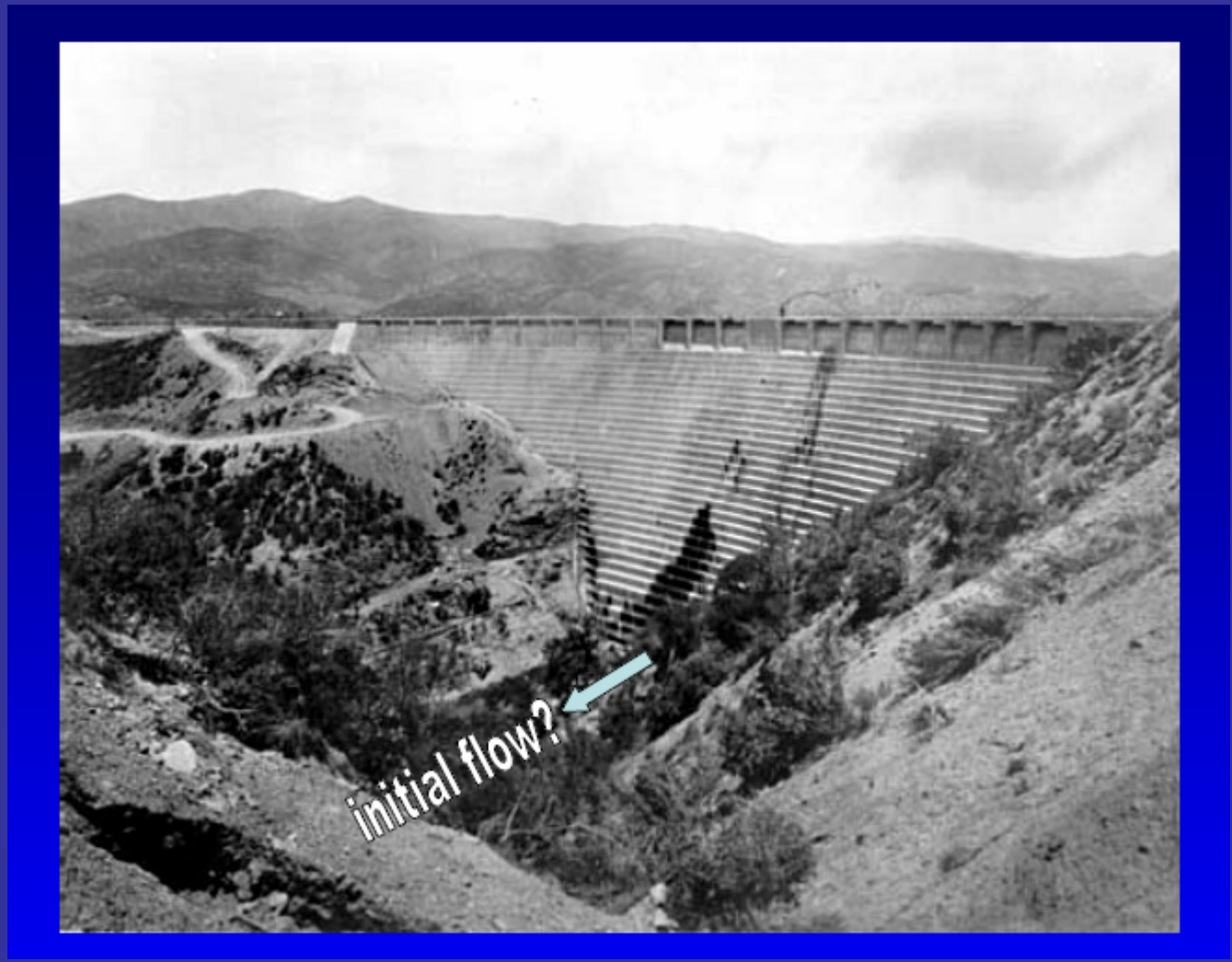
700,000 cubic yards



Other mapped landslides in Pelona Schist



Part of much larger, ancient landslide



Lights near dam one hour before failure


St Francis Dam





Tidal wave of destruction





140 feet thick
18 miles per hour

How fast can a human run?

Tidal wave of destruction





140 feet thick
18 miles per hour

Michael Johnson – 23 mph (for 10 seconds)

64 victims at Powerhouse 2



1.5 miles downstream

PATH OF DESTRUCTION





84 of 140 workers killed at SoCal Edison camp

INTO THE SEA







5:30am
2 miles wide
600 dead
bodies as far south as Mexico