Metamorphic Rocks

Rocks changed because of changes in their environment, up to (but not including) melting

Igneous dikes intruding metamorphic rock as observed in the wall of an open-pit mine at the Homestake gold mine, Black Hills, South Dakota

Important Factors in Metamorphism

- Pressure and stress
- Temperature
- Chemistry (reactivity)
- Pre-existing rock fabric
- Time

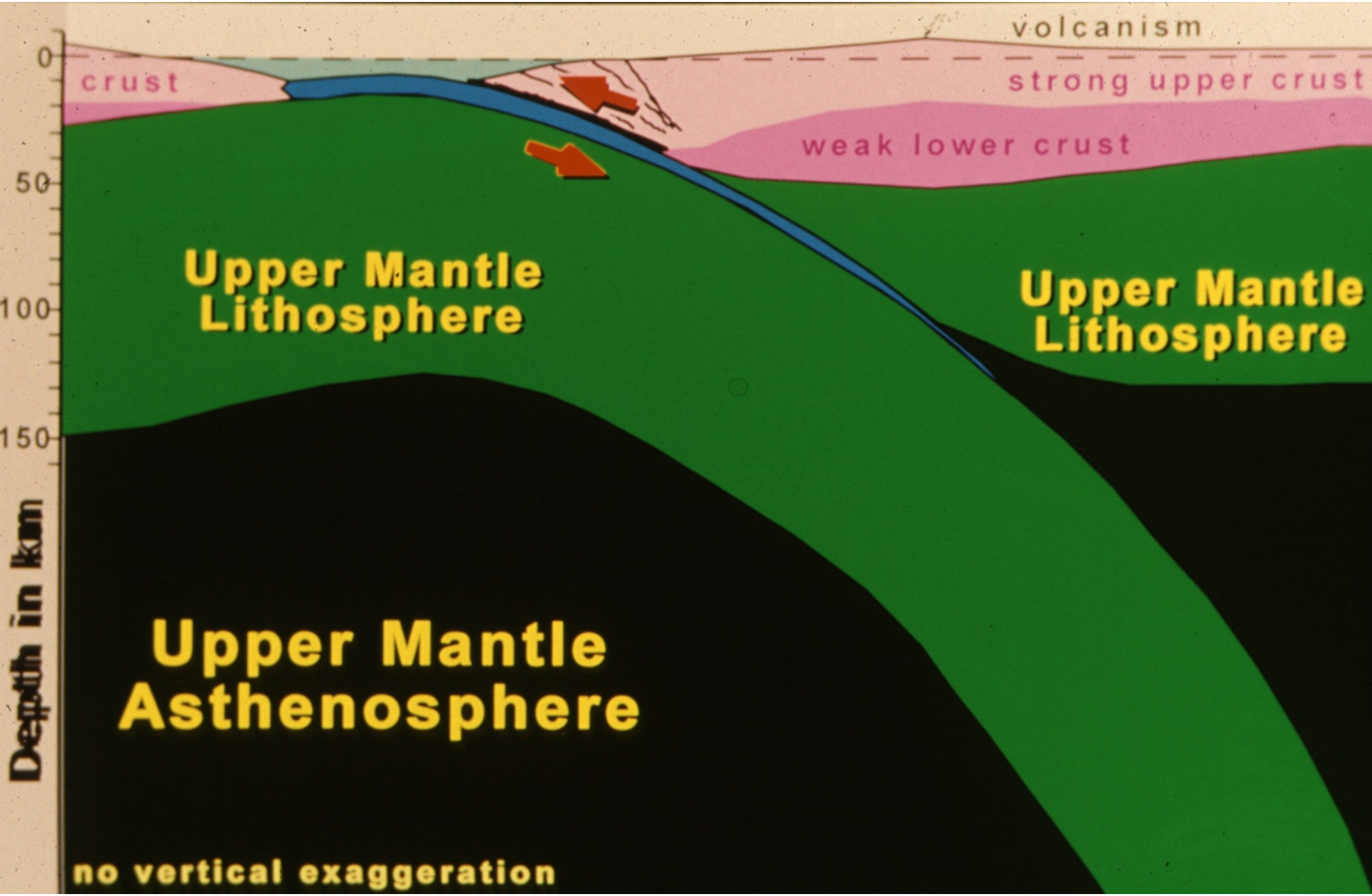
Pressure is a system or field of forces directed *perpendicular* to all surfaces of a given solid object with the same magnitude everywhere.

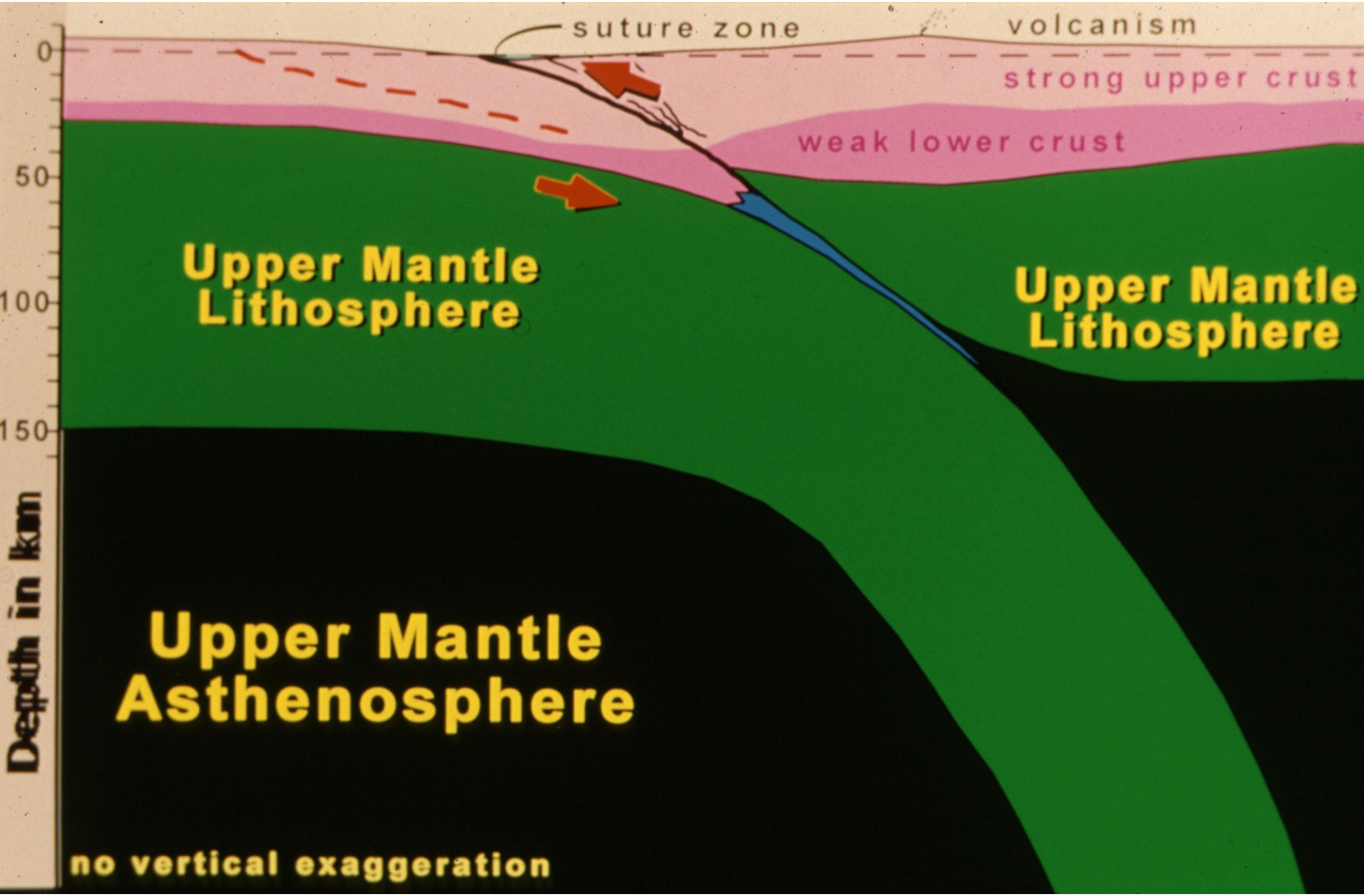
Stress is a system or field of forces acting on a surface in which the magnitude of the stress is dependent on the orientation of the surface.

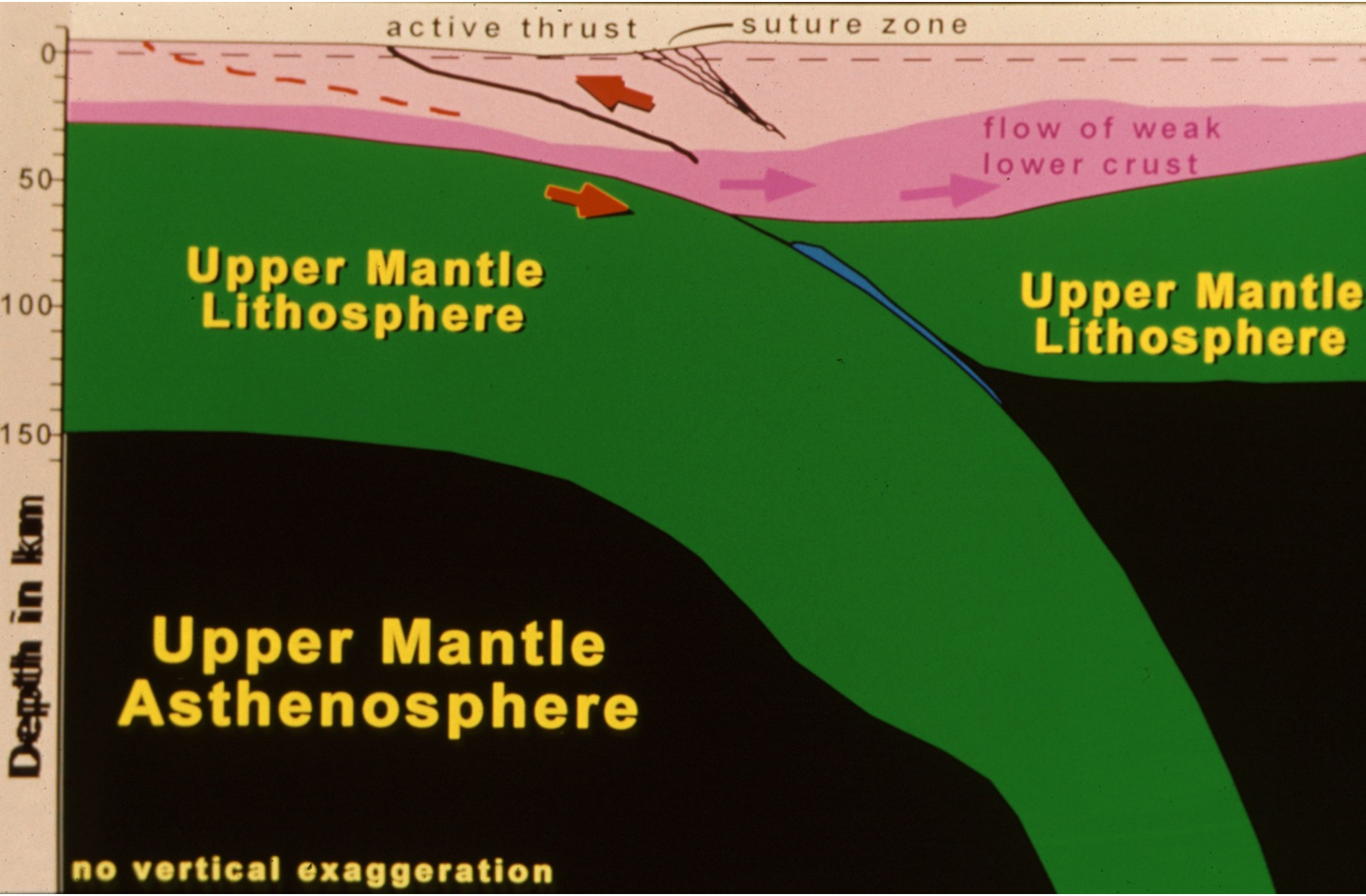
Some Types of Metamorphism

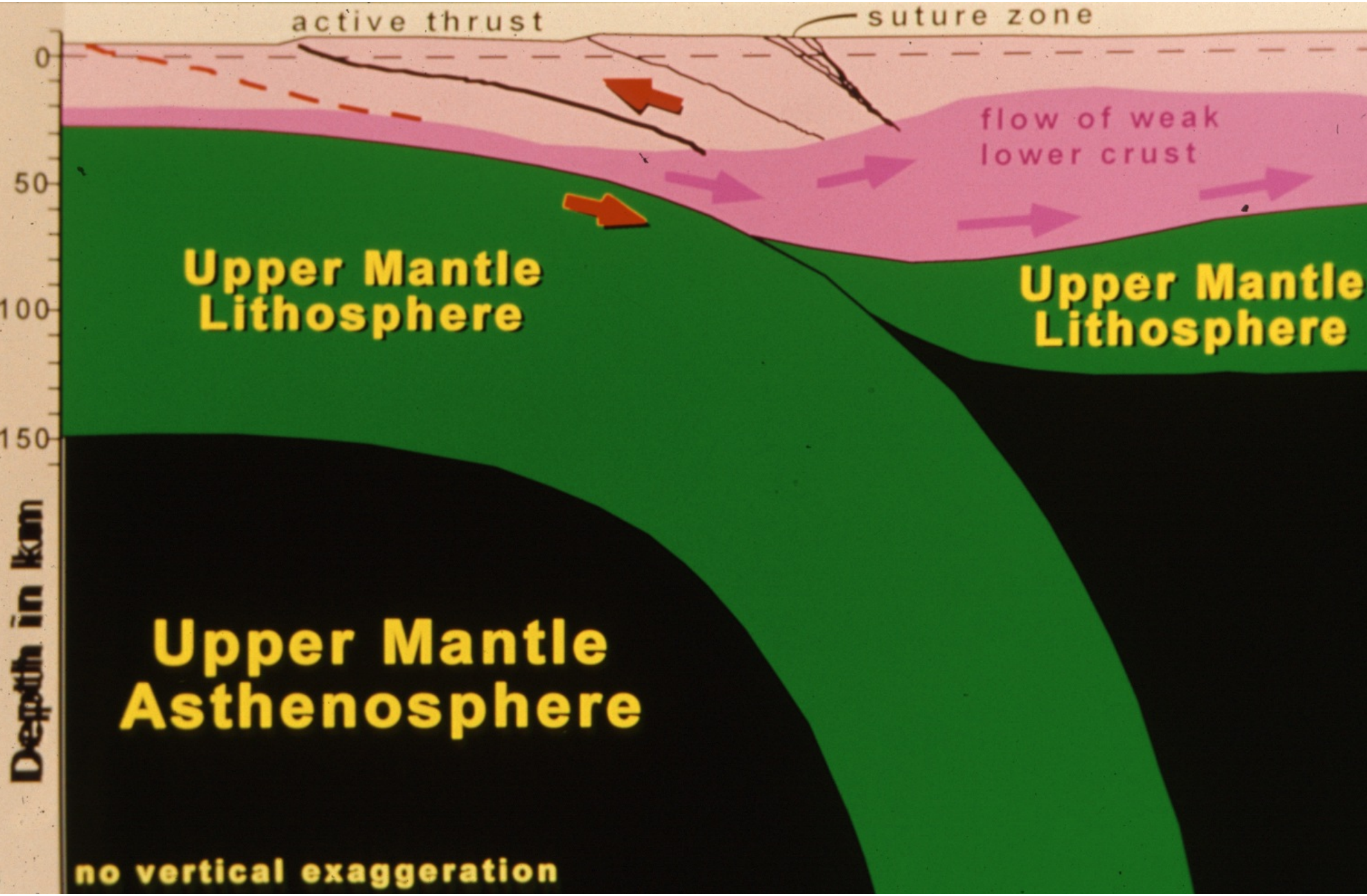
- Contact
- Burial
- Regional
- Hydrothermal
- Subduction-related

Regional Metamorphism


volcanism
0
crust
strong upper crust
weak lower crust
50
Upper Mantle
Lithosphere
100
Upper Mantle
Lithosphere
150
Depth in km
Upper Mantle
Asthenosphere
no vertical exaggeration


suture zone
volcanism
strong upper crust
weak lower crust
0
50
100
150
Depth in km
Upper Mantle Lithosphere
Upper Mantle Lithosphere
Upper Mantle Asthenosphere
no vertical exaggeration


active thrust
suture zone
0
50
100
150
Depth in km
flow of weak
lower crust
Upper Mantle
Lithosphere
Upper Mantle
Lithosphere
Upper Mantle
Asthenosphere
no vertical exaggeration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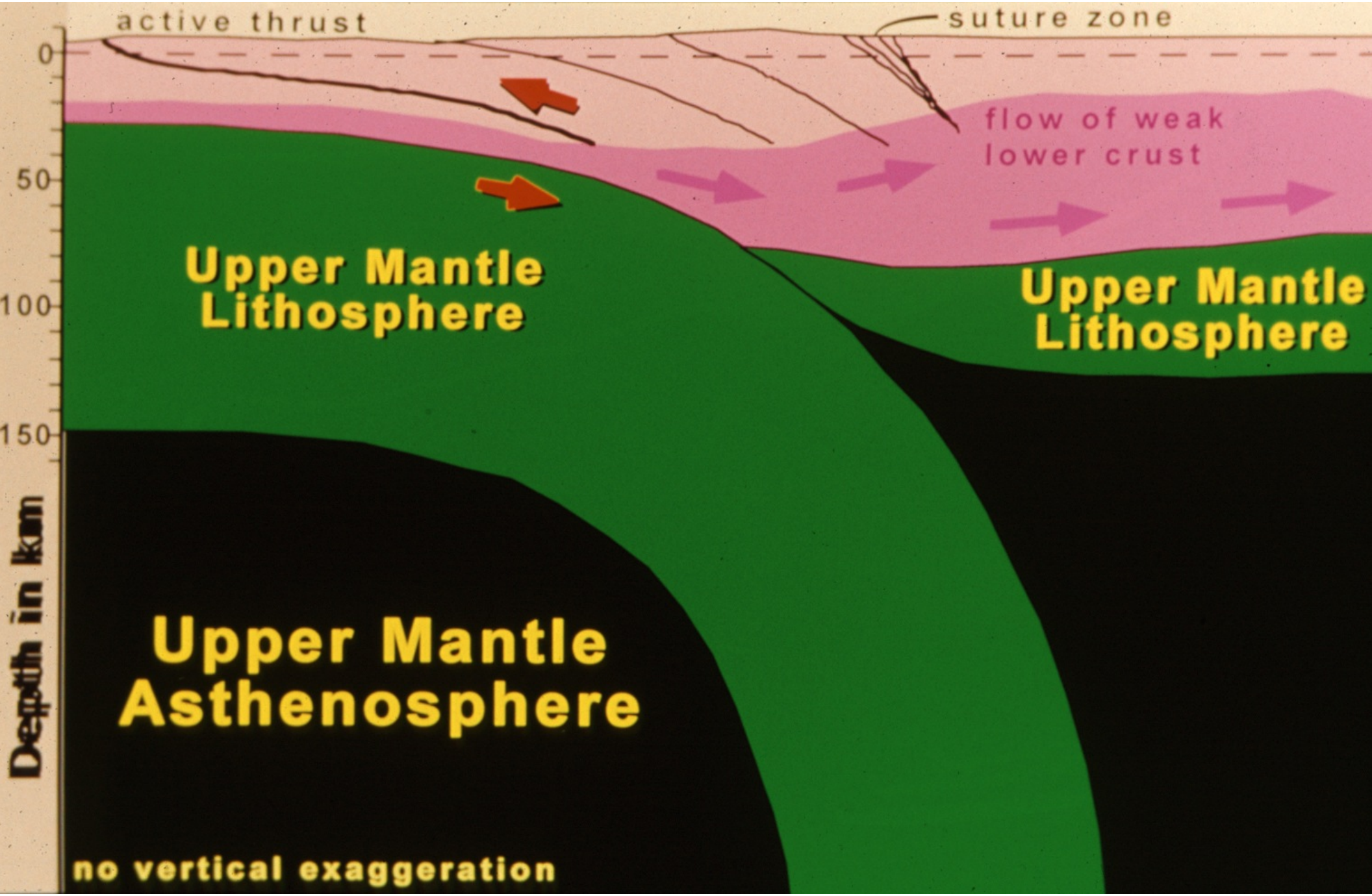
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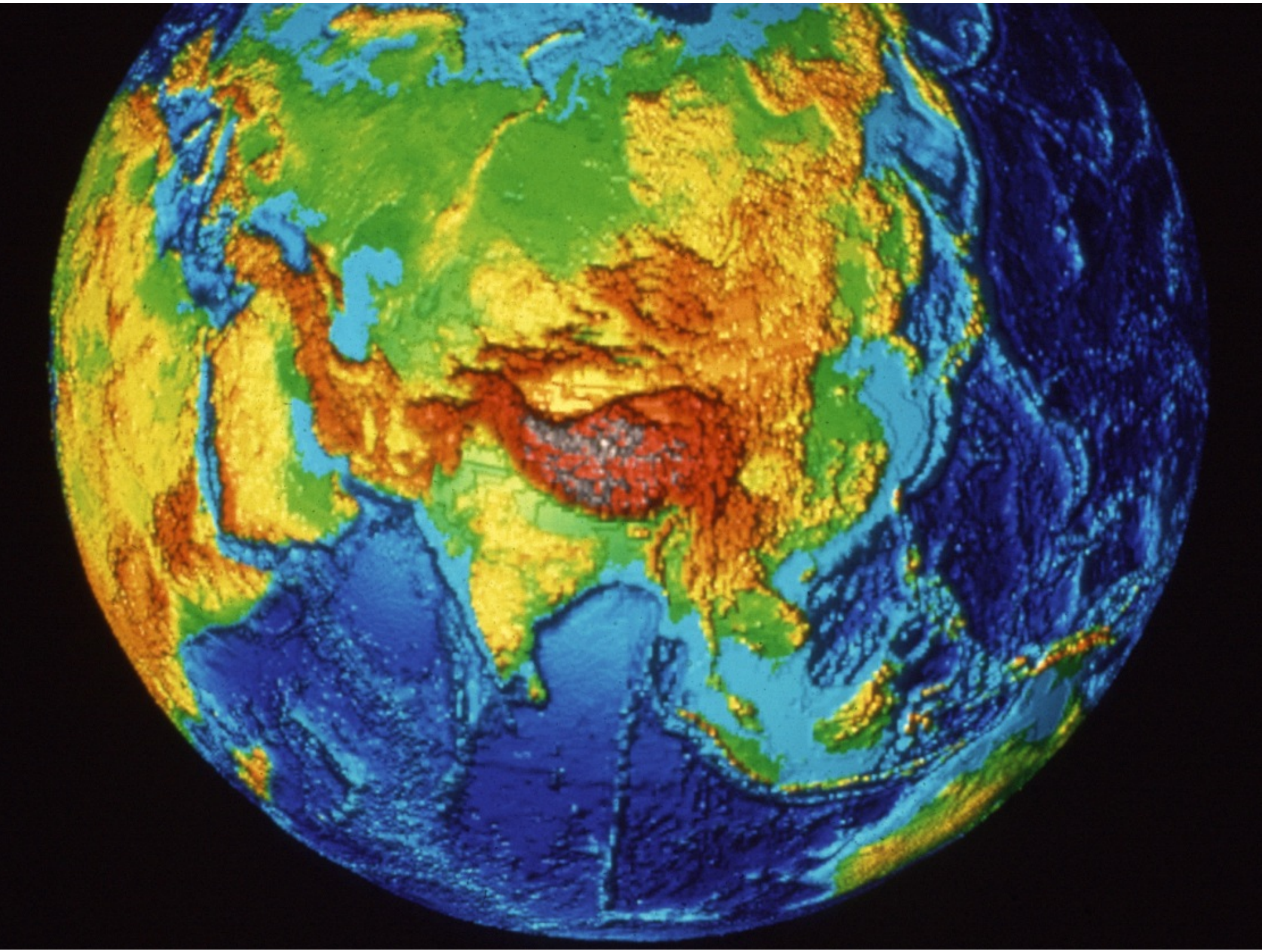
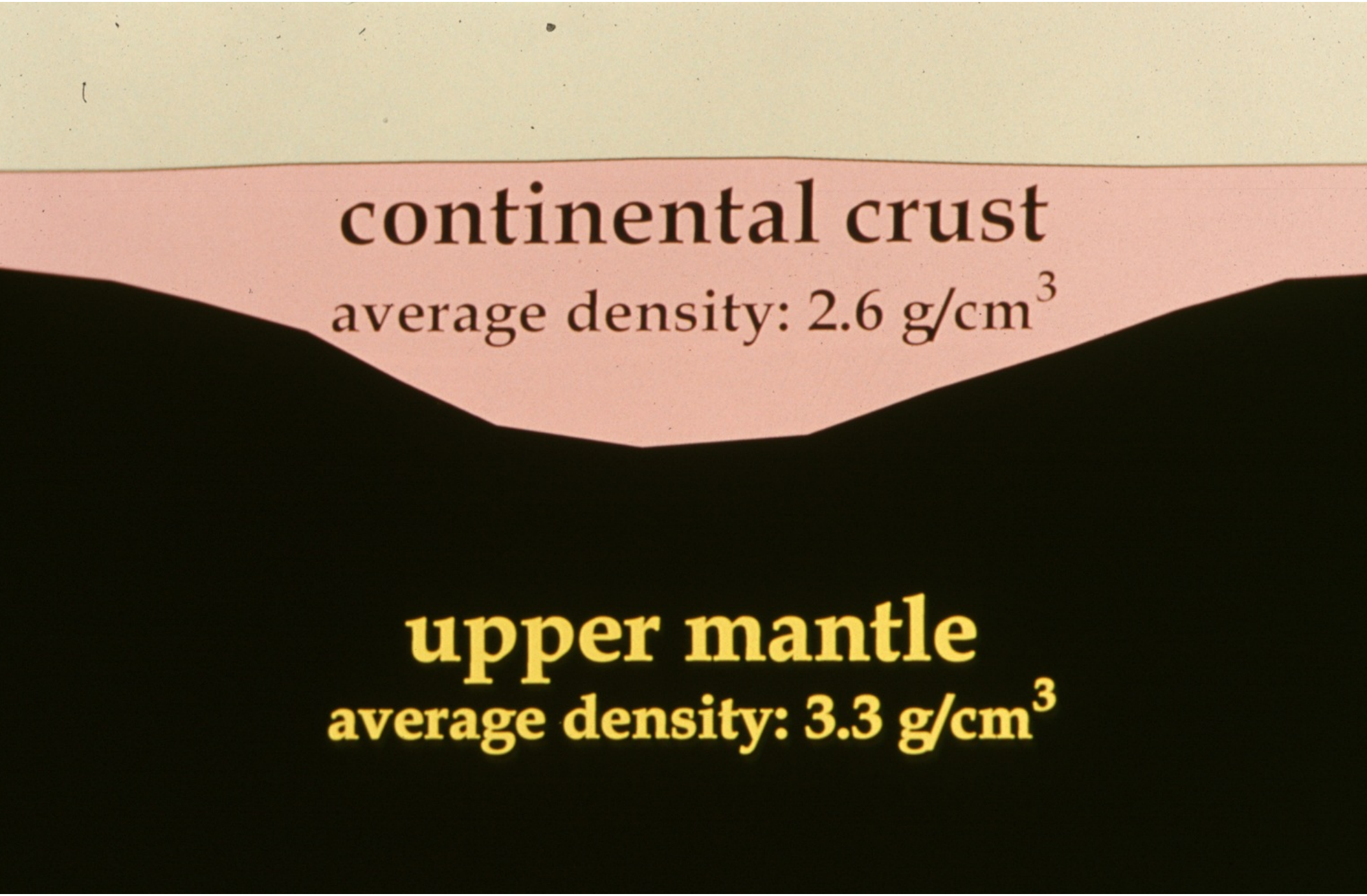
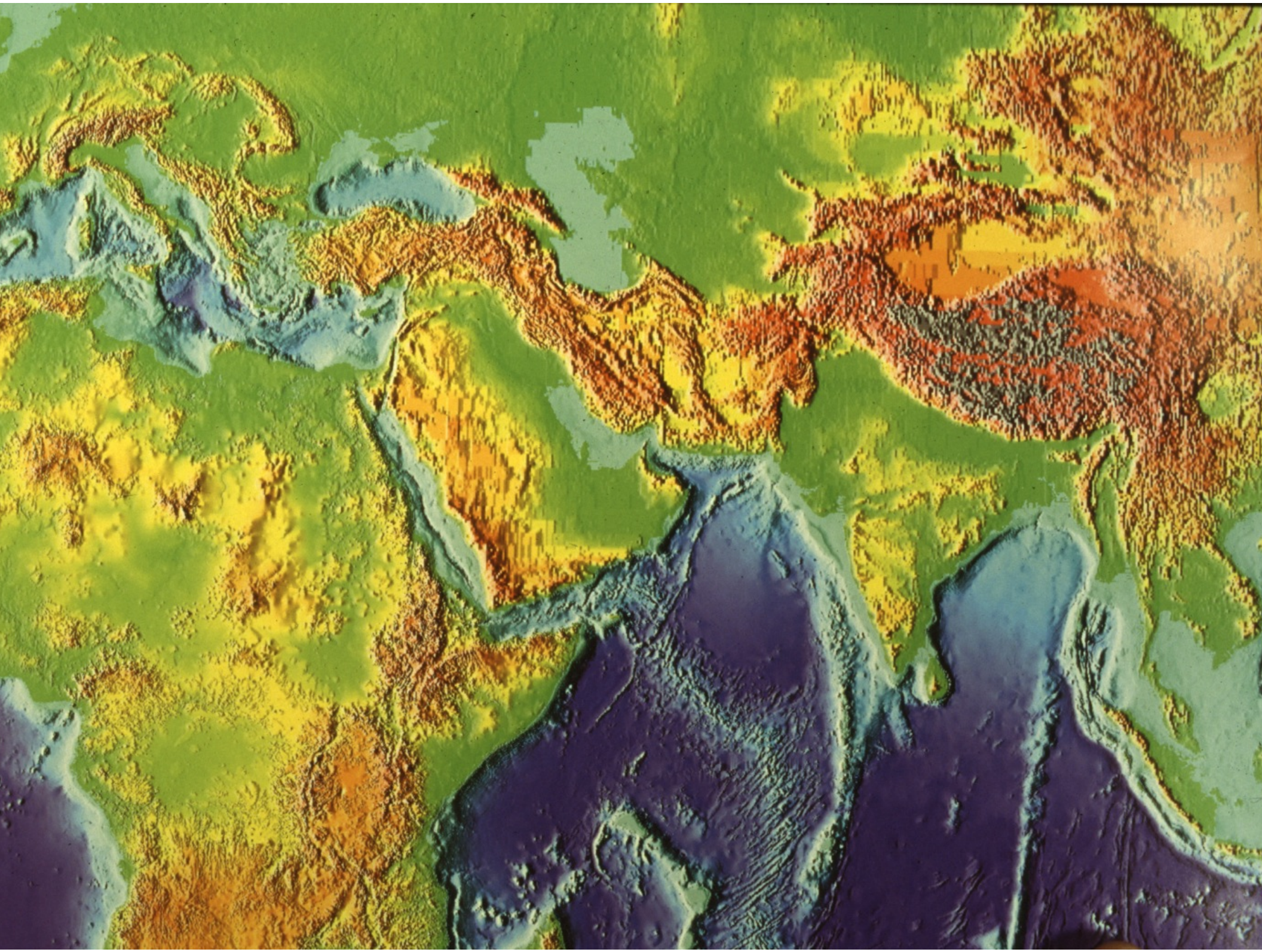




Less dense continental crust displacing more dense upper mantle, resulting in uplift driven by buoyancy forces.



Hydrothermal Metamorphism

Metamorphic Grades

- **Low-grade** metamorphism involves lower temperature and more water-bearing minerals, such as clays, micas, amphiboles, "wet" quartz
- Intermediate-grade
- **High-grade** metamorphism involves higher temperature and more "dry" minerals, such as garnet, kyanite, sillimanite

Some Metamorphic Processes

Recrystallization: changing grain size without changing the mineral type

- ***Closed*** system: mineral A in, mineral A out

Neomineralization: changing the mineral type

- ***Closed*** system: mineral A in, mineral B out

Metasomatism: changing the rock chemistry

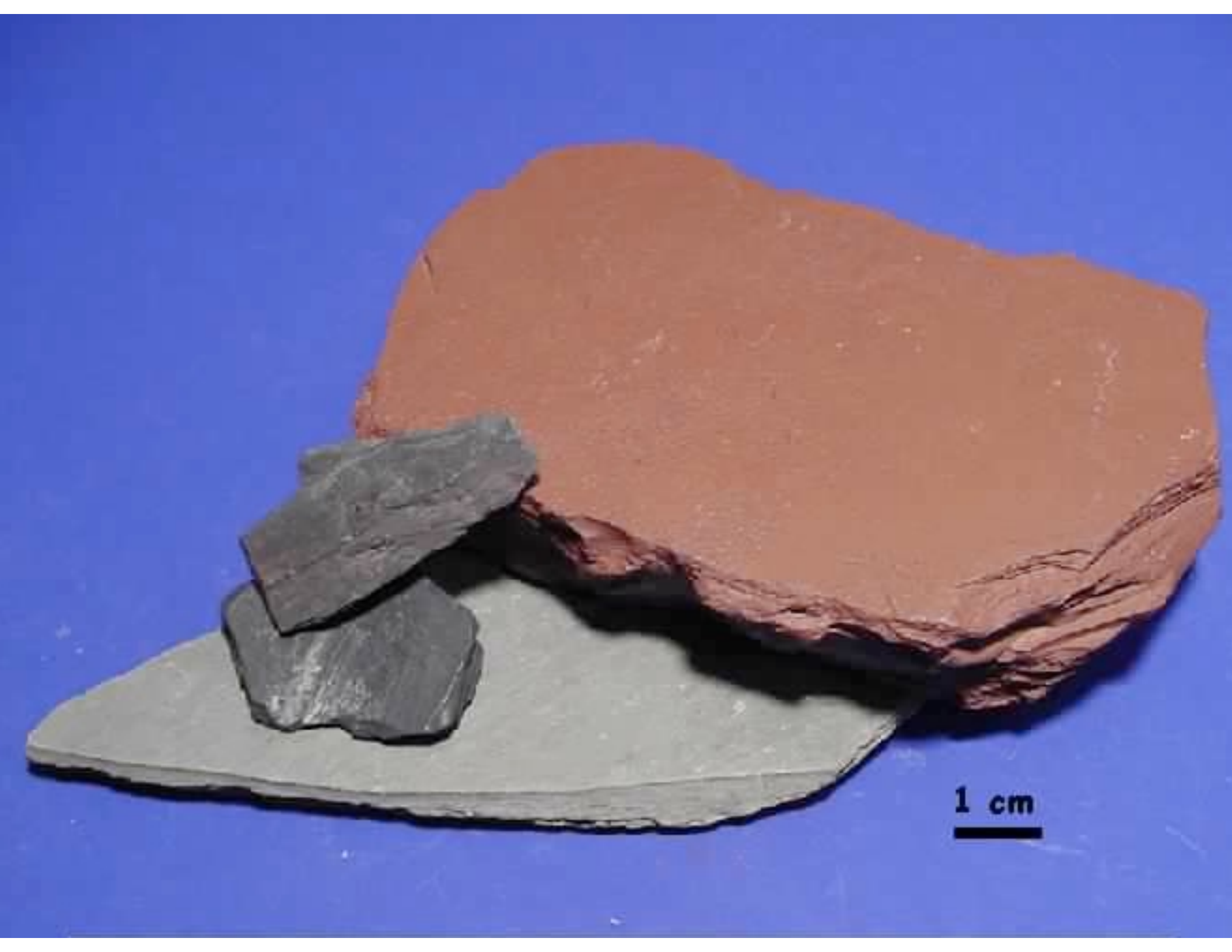
- ***Open*** system: mineral A in, mineral C out

"Directions" of Metamorphism

- **Prograde** metamorphism involves ***increasing*** the magnitude of environmental variables such as temperature, pressure, stress
- **Retrograde** metamorphism involves ***decreasing*** the magnitude of critical environmental variables

Foliated Metamorphic Rock

- **slate** (slaty cleavage)
- **phyllite** (phyllitic layering)
- **schist** (schistocity)
- **gneiss** (gneissic layering or compositional banding

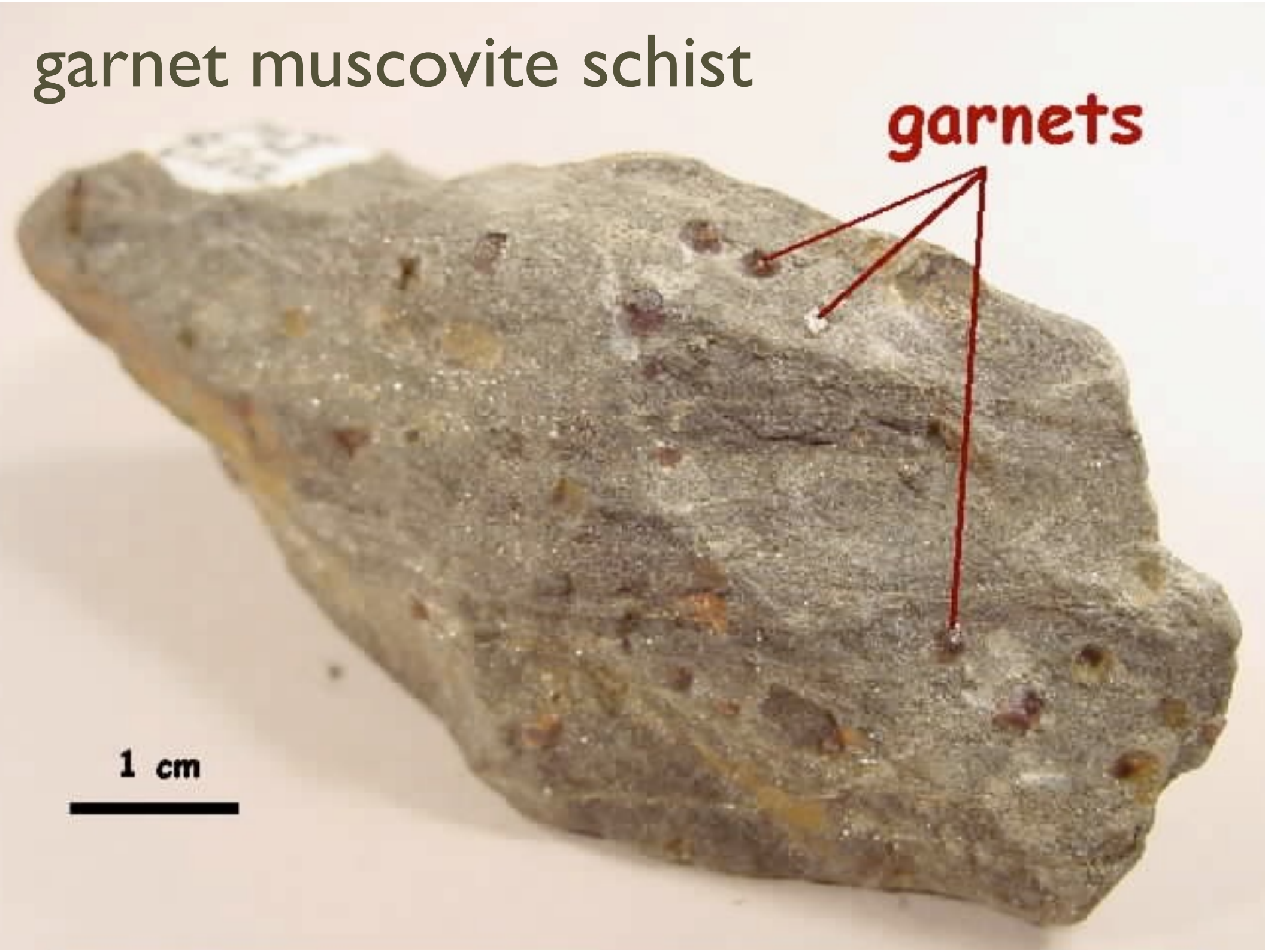

1 cm

phyllite, pronounced “FILL-ite”

phyllite, displaying silky sheen


Schist

garnet muscovite schist




gneiss

Metamorphic rock that might not be foliated

- quartzite
  - might display relict bedding
  - metamorphosed quartz sandstone
- marble
  - might display relict bedding
  - metamorphosed limestone

quartzite

Glamorous wife of a paunchy geology professor stands perilously close to a dark foliated metamorphic rock (a phyllite) in contact with a light-colored non-foliated metamorphic rock (a quartzite). Van Hise Rock near Rock Springs, Wisconsin.

relict bedding preserved in Baraboo quartzite


marble
1 cm


amphibolite
1 cm