

Convergent boundaries are characterized by consumption of oceanic crust in subduction zones, with attendant arc volcanism, metamorphism and uplift. During their early phases, convergent boundaries are initiated by the rupture and sinking of oceanic crust, probably related to a change in plate motion, but the kinematics of this process are not well understood. Old, cool oceanic crust sinks into the mantle, undergoing extension in the trench and increasing amounts of compression as it sinks past the major phase transitions at 670-700 km depth. Dewatering of sediments and surficial basalts occurs early below the overlying accretionary wedge, while changes in mineralogy, from hydrated to non-hydrous minerals occur deeper and the released water dramatically reduces the melting point of upper mantle rocks. The resultant plutons intrude the overriding plate and can create arc volcanism, which in turn supply the abundant volcanoclastic sediments typical of arc and their associated forearc and accretionary complexes. Backarc rifting may be driven by convection associated with the subducting slab or with differential convergence rates. Back arc thrusting and metamorphism may also occur, related to the subduction of buoyant, young crust or the accretion of continental or arc crustal fragments--exotic terranes.

Major elements of a Convergent Margin

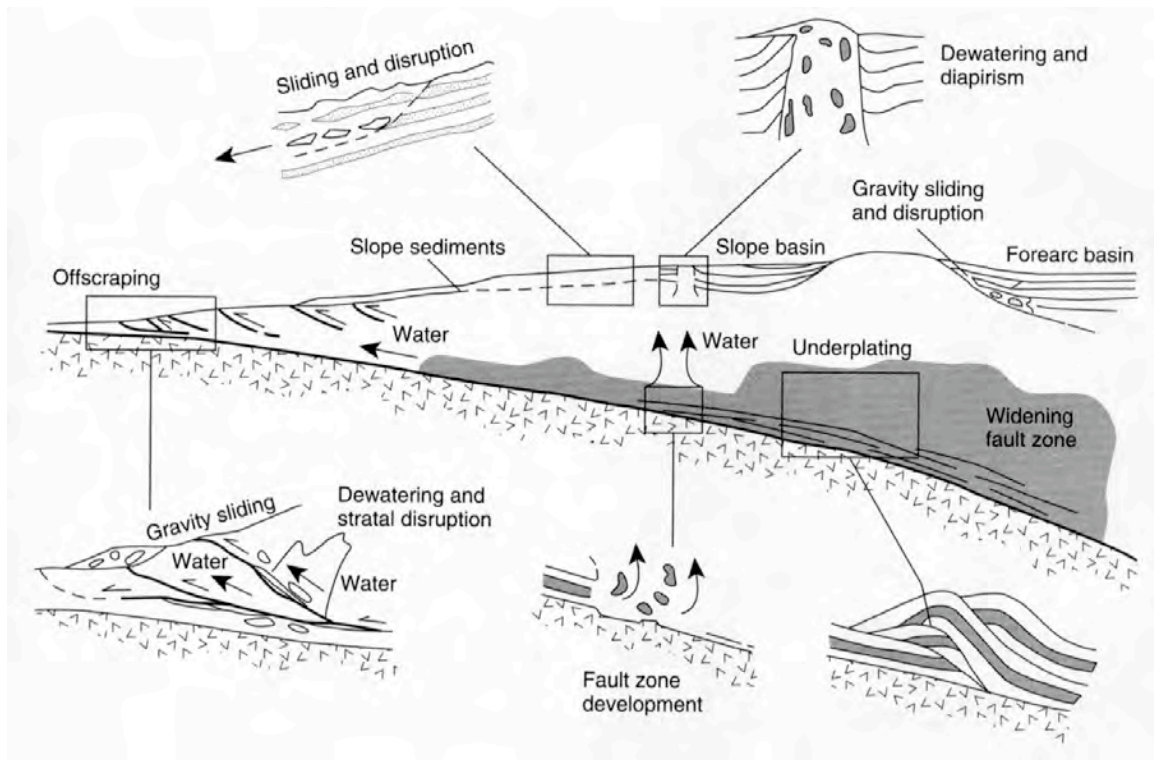
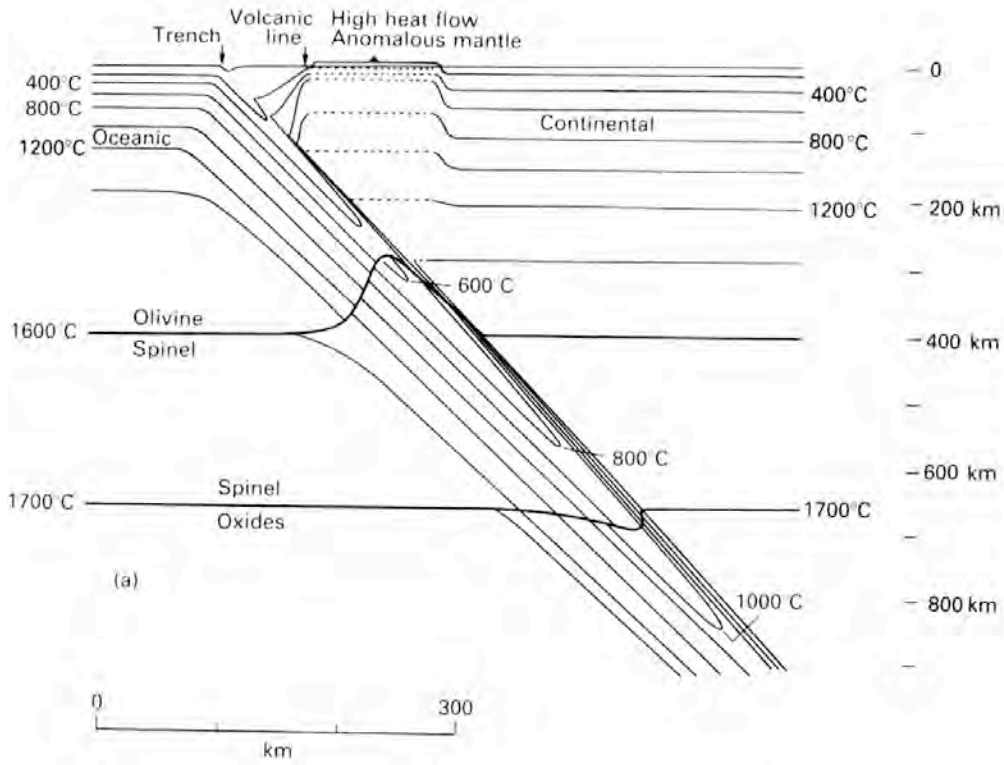
1. Trench
2. Accretionary Wedge
3. Forearc
4. Arc
5. Back arc

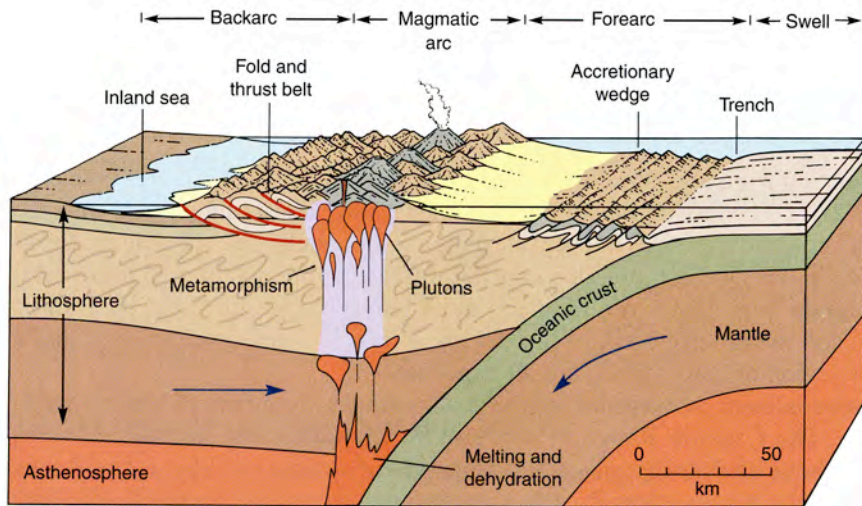
Thermal Structure and Seismicity of Subduction Zones

Benioff zone
tension, compression
phase boundaries as source of resistance
arcuate structure of subduction zones

Continent-Continent Collisions

evolution from continent-ocean systems
suture zone with ophiolites



Convergent margins:**Major elements:**

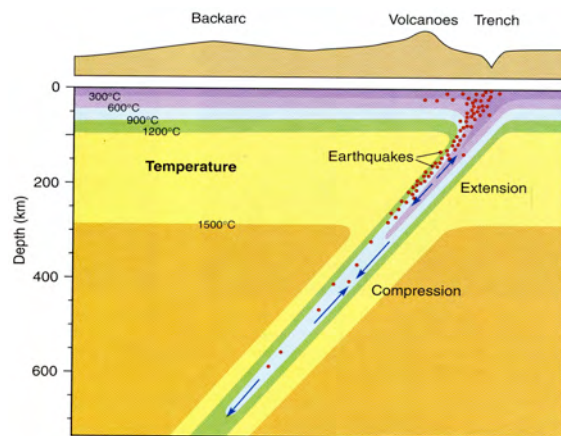
1. **Trench**—topographic depression associated with sinking oceanic crust—trench morphology and depth associated with sediment supply and age of subducting plate
 - a. **shallower when sediment supply high or crust is young**
 - b. zone of **extension and normal faulting** of down-going slab
 - c. why the **arcuate** shape? depression in sphere results in inward deflection (with no change in area) with same curvature as sphere (arc radius proportional to $\sin(\delta)$, where δ is the angle between the tangents to the original sphere and depression). This simple model relating slab dip to radius does a reasonable job of describing the curvature of subduction zones worldwide.

2. **Accretionary Wedge**—mixture of material scraped off the down-going slab and sediment derived from the nearby arc complex.
 - a. Average sediment cover on the oceanic crust is only a couple 100 m, so **most sediment** in accretionary complexes is **locally derived**.
 - b. However, pieces of **volcanic seamounts and ophiolites** may also be present
 - c. Also have **high P/low T metamorphic rocks** returned to the surface along faults in the complex.
 - d. **~20-60% of seafloor sediment may be subducted**. Folding and faulting create “**mélange**”
 - e. mixing also accentuated by **gravity sliding** in the over-steepened wedge—**Olistostromes**.

3. **Forearc**—Basin between the arc and the accretionary wedge—
 - a. filled **with turbidites and hemipelagic** sediment washed off the arc.

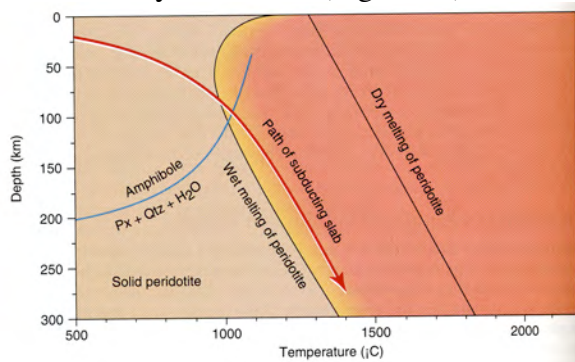
- b. May be separated from the accretionary wedge by an **ophiolite complex**—the upturned old ocean-continent junction.
4. **Arc**—Volcanics and associated intermediate plutonic rocks;
- a. often **intruded into former accretionary wedge** or forearc sediments;
 - b. plutons surrounded by **regionally metamorphosed** rock
 - c. **Accretionary wedges “pre-weather” rock**
 - i. so that later, when the rocks are intruded and partially melted, they are **more silica-rich than they were as volcanic rocks**;
 - ii. mean that crust **formed** by intruding old island arcs or accretionary complexes **is more differentiated** than it might be by partial melting and fractional crystallization alone.
5. **Back arc**—can be zone of **extension** (when favored by relative plate motion or steeply descending slab) or **compression** (shallowly descending slab). The apparent paradox of having extension in an overall compressional environment can be explained by the process of **slab roll back**. The descending slab acts as an anchor, but is able to move laterally simply because the slab is also gravitationally sinking into the mantle. Older, cold slabs sink faster and therefore extensional tectonics is more common where there is old subducting crust.

Thermal Structure and Seismicity of Subduction Zones



1. **Subducting slab is cold**—depresses isotherms several hundred km into the mantle; at 600 km temp may still be 600°C below the surrounding mantle (because rock is a poor conductor of heat).
 - a. May take 12 million years to equilibrate with heat of the mantle.
 - b. Hence slab is stronger than the mantle
2. Cold slab may **persist to great depth**--~2500 km depth in the case of the slab under N. America.
3. Hot arc due to **melting of asthenosphere** with addition of slab-derived water

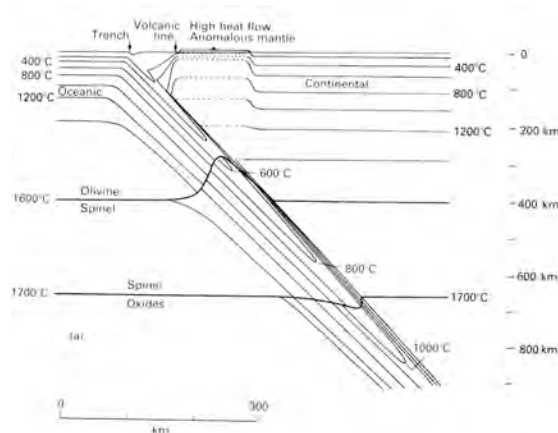
- a. (mostly **from dehydration reactions**, not physical squeezing water out of pore spaces);
- b. Melting occurs at much lower temperatures associated with water than under dry conditions (Fig 21.20).



- c. Cold slab drags the asthenosphere along with it setting up convection under the arc—promotes back-arc spreading.

Seismicity

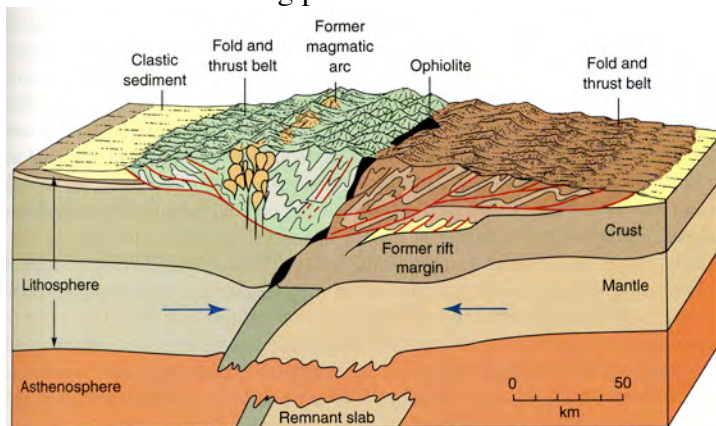
1. get **shallow, extensional earthquakes** near the trench where the slab bends into the subduction zone,
2. **compressional faulting** is associated with movement under the **accretionary wedge**, and
3. **extension below the overriding plate** where the slab is gravitationally sinking.
4. **Deepest earthquakes** associated with **compression** in the subducting slab. The observation that deep EQ have a compressive focal mechanism is often taken to indicate that there is a physical barrier to subduction. This may be related to the spinel to perovskite transition (670km) since this has a negative Clapeyron slope (the transition temperature decreases with increasing P)



Shallow earthquakes also associated with continent-continent collisions since the oceanic slab may be lost (or stop subducting) and so lose deep-focus quakes.

Continent-Continent Collisions

1. **Evolve from arc system** during subduction of oceanic crust,
2. to **fold and thrust belt** once the ocean crust has been consumed.
3. The former ocean-continent boundary winds up in the middle of the collision belt and most thrusting occurs on the side of the descending plate.
4. The **over-riding plate is typically stronger** since it has been resisting subduction and is not thinned on its seaward edge by rifting, unlike the descending plate.



Metamorphism:

1. Continent-continent collisions: See blends of different metamorphic style from the regional metamorphism associated with plutonism on the over-riding plate, to compressional metamorphism on the subducting plate. **Mostly High P, Medium to low T systems** except right around plutons
2. In **island arcs, get paired metamorphic belts**—low T/high P belt above the subduction zone and High T/low P around the arc.
3. Deepest zones produce **migmatite**—partially melted crustal rocks (at temps above 600°C that are dehydrated (amphiboles replaced by pyroxene). May be **source of granitic melts**.