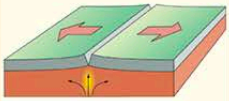
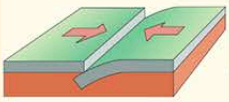
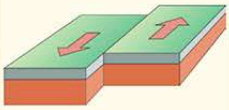
Lecture 4: Ocean Boundaries

Lecture 4: Plate Boundaries

If you have forgotten what the lithosphere is all about, flip back to the last lecture and remind yourself about how the lithosphere plates float around the Earth on a fluid asthenosphere, because we are going to discuss what happens when the plates collide and how that shapes the ocean.

WHAT ARE THE CHARACTERISTICS AT THE PLATE BOUNDARIES?

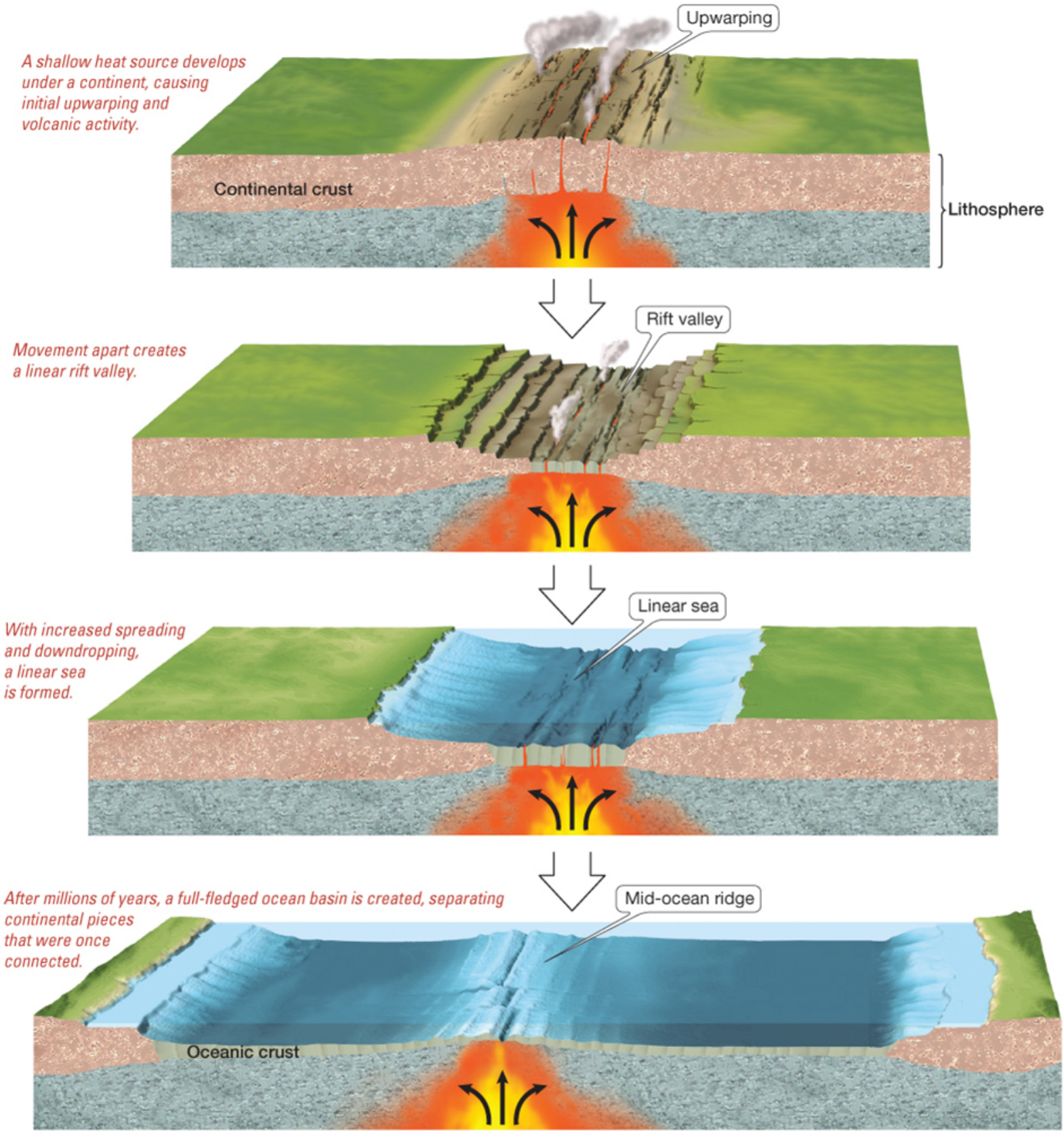
Plate boundaries are where two plates interact with each other. These boundaries are regions of tectonic activity and this tectonic activity results in mountain building, volcanic activity, and earthquakes. There are three major types of plate boundaries. *There are **divergent boundaries**, which are found along the mid-ocean ridges where the new lithosphere is being created which then pushes the older lithosphere apart. There are **convergent boundaries** where lithosphere plates are moving together with one plate being subducted beneath (moving under) the other. And finally, there are **transform boundaries** which are found where lithosphere plates slowly grid past each other.*

Plate boundary	Plate movement	Crust types	Sea floor created or destroyed?	Tectonic process	Sea floor feature(s)	Geographic examples
Divergent plate boundaries	Apart 	Oceanic–oceanic	New sea floor is created	Sea floor spreading	Mid-ocean ridge; volcanoes; young lava flows	Mid-Atlantic Ridge, East Pacific Rise
		Continental–continental	As a continent splits apart, new sea floor is created	Continental rifting	Rift valley; volcanoes; young lava flows	East African rift valleys, Red Sea, Gulf of California
Convergent plate boundaries	Together 	Oceanic–continental	Old sea floor is destroyed	Subduction	Trench; volcanic arc on land	Peru–Chile Trench, Andes Mountains
		Oceanic–oceanic	Old sea floor is destroyed	Subduction	Trench; volcanic arc as islands	Mariana Trench, Aleutian Islands
		Continental–continental	N/A	Collision	Tall mountains	Himalaya Mountains, Alps
Transform plate boundaries	Past each other 	Oceanic	N/A	Transform faulting	Fault	Mendocino Fault, Eltanin Fault (between mid-ocean ridges)
		Continental	N/A	Transform faulting	Fault	San Andreas Fault, Alpine Fault (New Zealand)

Divergent boundaries: Divergent boundaries occur where two plates move apart. Common features of these zones are rift valleys which is a linear depression which is the location where the two plates are being pulled apart or ocean floor rises or ridges. The pull is opening up crust, where the magma flows up to fill the void. This process continually forms about new ocean crust.

When two continental plates (we are talking continental plates, not oceanic plates for now) form a divergent boundary, the spreading of the seafloor eventually forms ocean basins over geologic time. Initially, the two continental plates begin to weaken at the boundary and the continental plate along boundary will warp upwards

as magma pushes up below the boundary. Next, the plates will begin to move apart creating what is called a rift valley, which is a depression in the earth. As the plates spread further and the rift valley widens, the ocean will begin to infill the depressed area and a linear sea is formed. Finally, over the course of millions of years, the spreading is so extensive that the depression is wide enough to be a full-fledged ocean basin with the divergent boundary running through it like an old scar. As the supercontinent Pangea began to split apart, several ocean basins were formed as the plates that we know today as continents diverged.



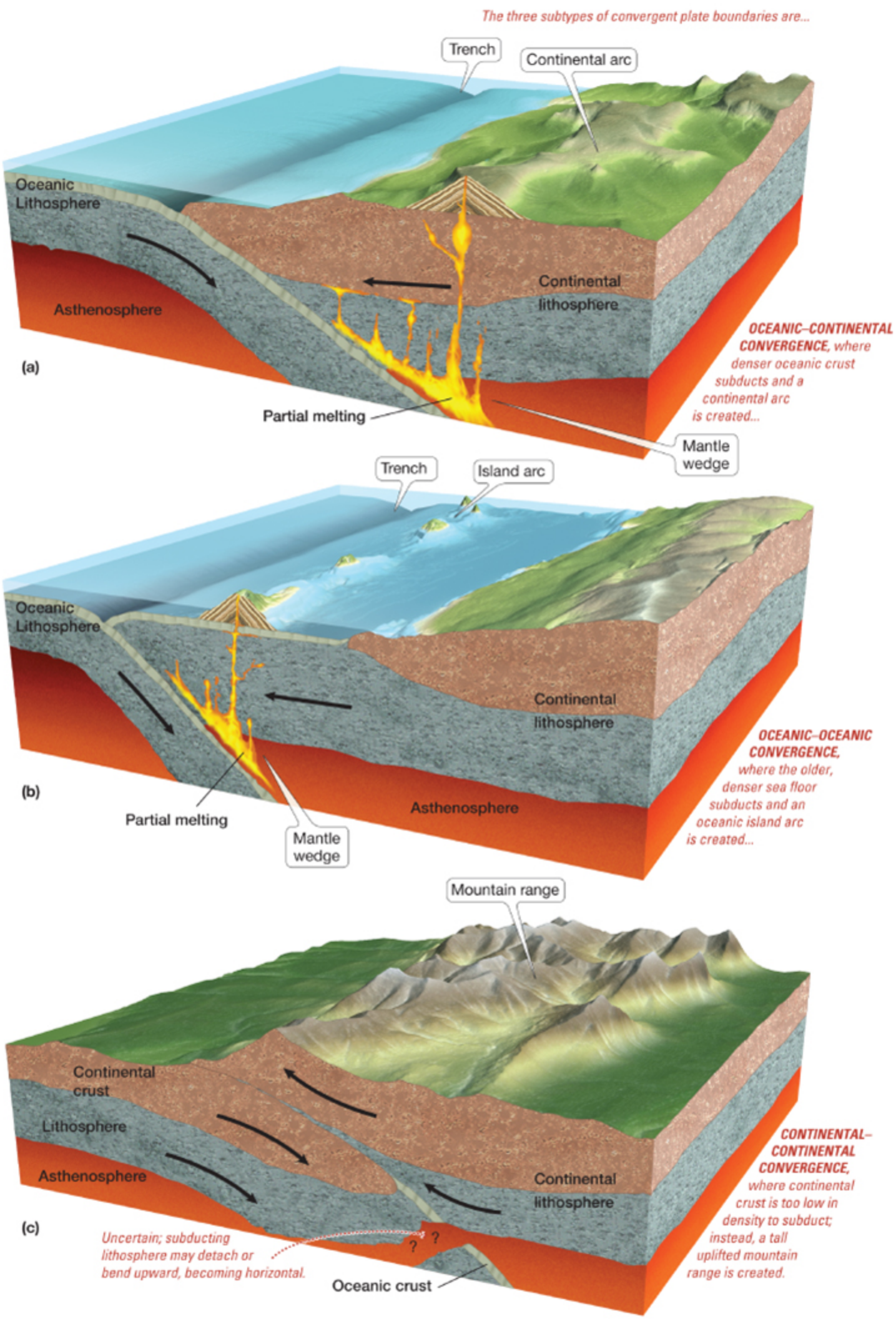
When two ocean plates form a divergent boundary, ocean rises or ocean ridges can form. The rate of spreading impacts the nature of the feature that is formed at the boundary. Faster spreading zones produce broader and less steep and jagged ocean bottom, which reflects the fast-forming rock that is spreading out rapidly. These zones are called oceanic rises. An example of a fast spreading boundary is the East Pacific rise. Slower zones of spreading are better developed (ie they form taller mountains). They are steep sloping zones

and are called oceanic ridges. An example is the Mid-Atlantic ridge, which stands 10,000 feet above the sea floor, forming the most extensive “mountain system’ on Earth. There have also recently been recognized ultra-slow spreading centers, so slow that the ocean mantle is sometimes exposed.

Earthquakes associated with divergent plate boundaries are related to how fast the sea floor spreads. The faster the sea floor spreads, the less the energy is released in a single earthquake. Compared to other boundaries the earthquakes at divergent boundaries, while significant, tend to be smaller than most reaching 4.5 to 6 on the Richter scale (recall earlier – this is an exponential scale).

Convergent boundaries. Convergent boundaries are where the two plates collide and ultimately cause the destruction of crust as one is subducted under the other. One characteristic feature associated with a convergent plate boundary is a deep-ocean trench. Another prominent feature is an arc-shaped row of highly active and explosive erupting volcanoes. These volcanic zones are known as a volcanic or island arc, which parallels the trench and occurs above the subduction zone. Volcanic arcs are formed by the subducting plate, which is heating up and releasing super heated gases that essentially partially melts the overlying mantle. This melted mantle is more buoyant than the surrounding rock and this rises up and feeds the active volcanoes above.

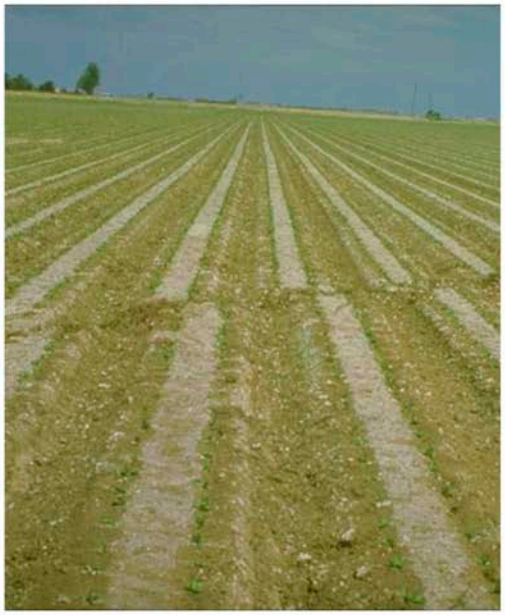
There are regions where an oceanic plate and continental plate converges. Where that happens, the denser plate is sub-ducted (is pushed under), and this denser plate is the oceanic plate. As the ocean plate is pushed down, it can melt and form volcanic mountain arcs along the edge of the continental plate – an example is the Cascade mountain range along the west coast of the US or the Andes along the coast of Chile. There are also convergence boundaries that involve two oceanic plates. At those boundaries, typically it is the oldest plate which is subducted. The older crust has had a longer time to cool and contract and therefore is the densest. These oceanic-oceanic convergence zones produce the deepest trenches on the planet, such as the Mariana Trench, and island or volcanic arcs such as the Aleutian Islands. Finally, there are continental to continental convergences. In contrast to the ocean lithosphere, continental crust does not always get denser with age. Since the density is close to being the same, no crust subducts under the other. The result is that crusts collide to create an uplift and forms mountain ranges. The biggest is the Himalaya mountains which were formed 45 million years ago. Note that because they are on land, mountain ranges tend to erode over time, so younger mountains are taller and craggier, while old mountains are smaller.


The three subtypes of convergent plate boundaries are...
Trench
Continental arc
Oceanic Lithosphere
Asthenosphere
Continental lithosphere
(a)
Partial melting
Mantle wedge
OCEANIC–CONTINENTAL CONVERGENCE, where denser oceanic crust subducts and a continental arc is created...
Trench
Island arc
Oceanic Lithosphere
Continental lithosphere
(b)
Partial melting
Mantle wedge
Asthenosphere
OCEANIC–OCEANIC CONVERGENCE, where the older, denser sea floor subducts and an oceanic island arc is created...
Mountain range
Continental crust
Lithosphere
Asthenosphere
Continental lithosphere
(c)
Uncertain; subducting lithosphere may detach or bend upward, becoming horizontal.
? ?
Oceanic crust
CONTINENTAL–CONTINENTAL CONVERGENCE, where continental crust is too low in density to subduct; instead, a tall uplifted mountain range is created.

Convergent zones also generate earthquakes, but generally they occur much deeper in the crust the spreading centers. They are among the deepest earthquakes in the world. These deep quakes tend to be extremely large, reflecting the large forces associated with the plates. These quakes can reach 9.5 on the Richter scale. Again, a key point to remember is that the Richter scales is a log function. The largest earthquake ever recorded was the 1960 Chilean earthquake centered near the Peru-Chile trench measuring 9.5 on the Richter scale.

Transform boundaries. Transform boundaries (also known as faults) are locations where two plates are sliding past one another. There are thousands of these transform faults. There are two common types of transform faults. The first most common type is found in the ocean and is known as the oceanic transform fault which tend to run perpendicular to the mid ocean ridges. These faults, or breaks in the plates, allow neighboring mid-ocean ridges to move at different rates. The second type generally cuts across continents and are known as continental transform faults.

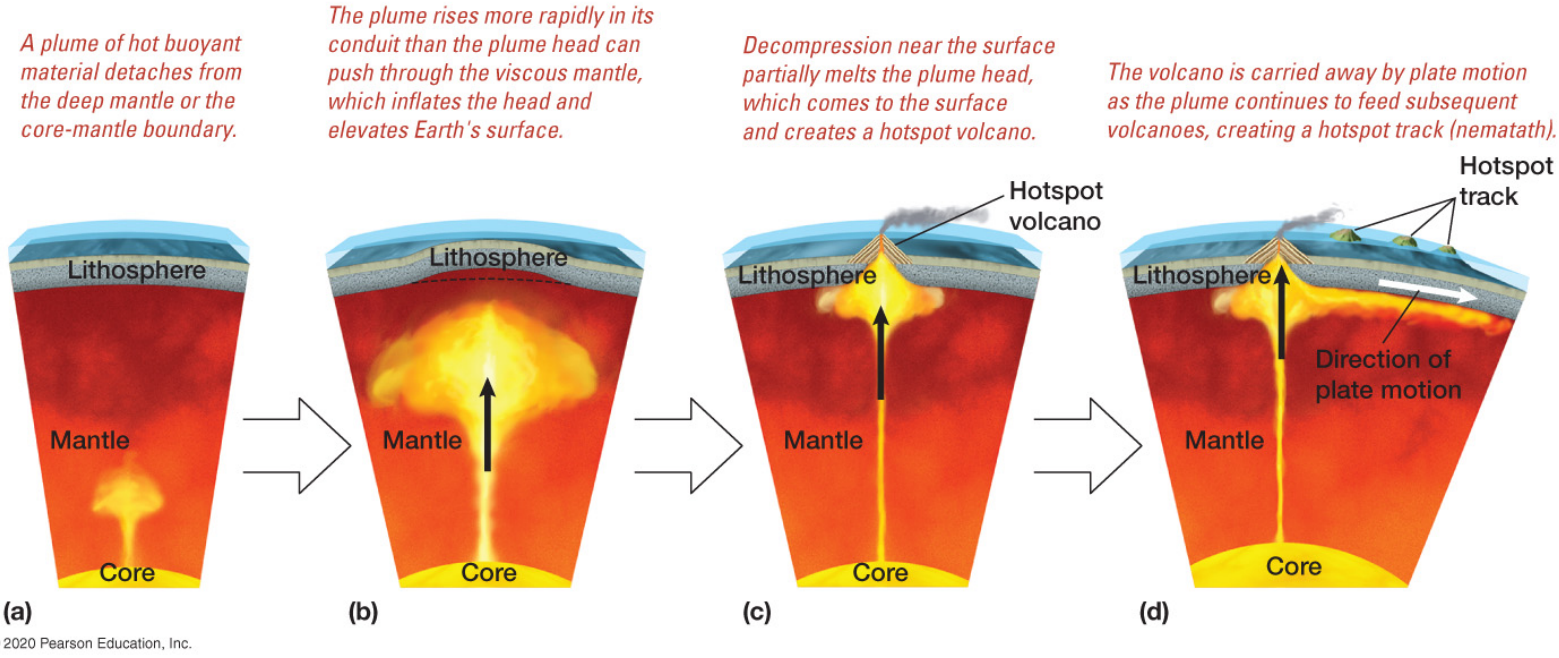
Transform Plate Boundaries



Transform faults produce shallow earthquakes. But in contrast to the divergent boundaries, the transform quakes tend to be very large with Richter scale signals around 7. One classic example is California's San Andreas Fault. Many people, and movies, sometime think that a big earthquake will split the land and send a bunch of California into the ocean. The truth is (as you now know) the state straddles 2 plates, along the San Andreas fault, that are slipping past one another (a transform fault). The plates will grind against one another,

but neither has anywhere to fall. These San Andreas quakes reflect the Pacific plate moving to the northwest past the north American plate at the rate of 5 centimeters per year. This means in 18.5 million years San Francisco will be adjacent to Los Angeles, but this will take one million generations of humans. A lot can happen in one million generations, so I don't advise you make real estate investment on this!

Ocean features can also be generated from hot spots in the mantle that are stationary. At these locations, a plume of molten mantle passes up through the lithosphere and breaks through the ocean crust. Think of it as a leaky spot in the mantle. As the lithosphere passes over that spot, the volcanic activity generated as the mantle breaks through appears to move (it isn't moving, the lithosphere is). The volcanic activity makes islands in the ocean, one after another in a row as the plate moves over the hot spot like a conveyor belt. Imagine you are carrying a bucket of concrete, but the bucket has a hole so the concrete is dripping out. As you walk, the blobs of concrete you leave behind will leave a trail of mini-mountains. An example of a hot spot process in action is the growth of the Hawaiian Island chain as the Pacific plate moves over a hot spot, with the island of Hawaii still active volcanically meaning it is still over the hot spot and still being formed.



Definitions:

Divergent Boundary = A tectonic boundary where two lithosphere plates are moving away from each other. These boundaries are found along the mid-ocean ridges where the new lithosphere is being created which then pushes the older lithosphere apart.

Convergent Boundary = A tectonic boundary where lithosphere plates are moving together with one plate being subducted (moving under) the other.

Transform Boundary = A tectonic boundary where lithosphere plates slowly grid past each other horizontally.

Hot Spot = stationary sources of heat in the mantle where a plume of magma penetrates the lithosphere above.