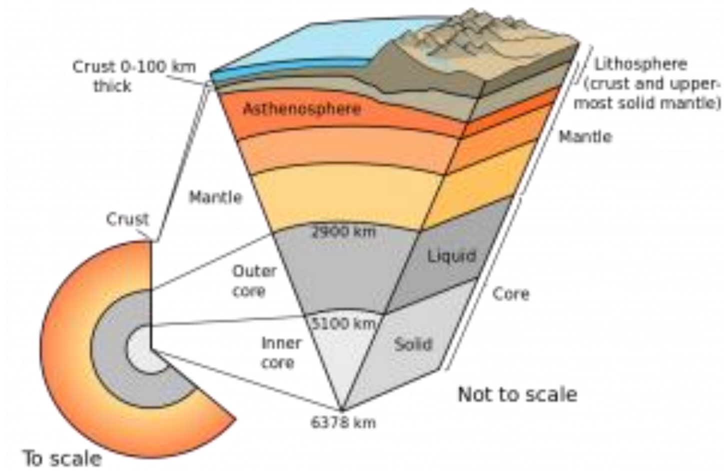
GEOGRAPHY: PLATE TECTONICS

STRUCTURE OF THE EARTH



INNER CORE
It is the only fully solid part of the inner earth. The solid state is a result of a very intense pressure-freezing process which occurs when temperature decreases or pressure increases (the pressure rises faster than the temperature → the higher the pressure, the higher the temperature needs to be to change chemical state). Because of gravity the heavier materials are moving towards the center which leads to the fact that inner layers are denser than the outer ones.

OUTER CORE
It is liquid & consists of iron & nickel. The outer core is a very hot & electrically conductive liquid in which convection (movement of heat, liquids & gases) takes place. Because of this convection the outer core is moving around the inner core. This moving creates in combination with the earth's rotation a dynamo effect where the earth's magnetic field is generated. It is responsible for the functioning of mechanical & biological compasses. Because the outer core isn't as dense as pure molten iron, there are different impurities (=Fremdstoffe) present which have a lighter chemical composition.

MANTLE
The mantle is less dense than the core because it is made out of minerals/rocks (the core consists of metals).

LOWER MANTLE
The lower mantle is about 73% of the mantle-crust mass which makes the Earth abundant in the chemical elements of silicon, magnesium & oxygen.

UPPER MANTLE
The upper mantle is made out of crystalline forms. Scientists speculate that the lower part of the upper mantle (the **asthenosphere**) could be partly liquid molten. The moving in the asthenosphere is the main reason for the plate tectonics.

CRUST
The crust is categorized into two parts. The **continental crust** is the second smallest area of the earth (depth of 0-50km). It is primarily composed of crystalline rocks made of low-density afloating minerals. The **oceanic crust** is the smallest part of the earth (depth of 0-10km). The ocean floor is covered in very dense basalt rocks originating from volcanic activity. There are also islands which emerged from that basalt (f.e. Iceland and Hawaii).

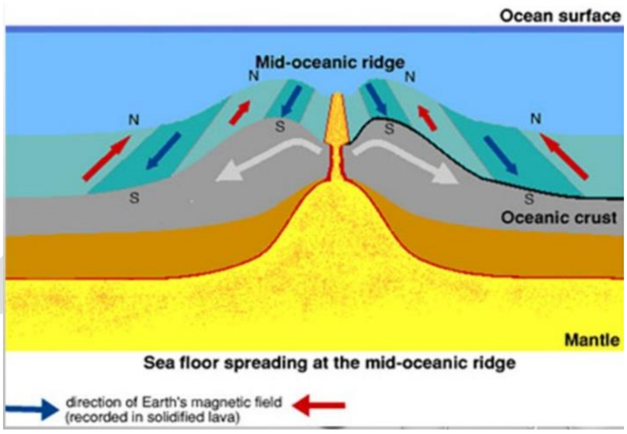
The continental & oceanic crust + the solid part of the upper mantle are referred as the **lithosphere** because of the cool & rocky conditions that exist in its chemical composition.

CONTINENTAL DRIFT

Continental drift is the theory that continents move slowly about the earth's surface, changing their positions relative to one another and to the poles of the earth. Because of the matching shapes of the continents Alfred Wegener found out that all the continents once were one big continent. Another evidence was similarities between the fossil plants & reptiles on the opposite coasts. Also the vertical uplift of landmass requires horizontal inflow of matter below which implies that flow & motion do take place within the earth.

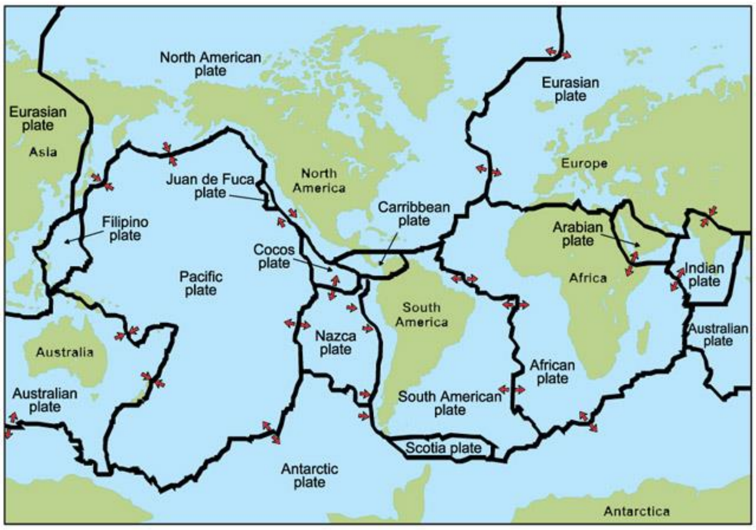
Until the discovery of the study of **paleomagnetism** scientists didn't believe Alfred Wegener's theory. Paleomagnetism defines the magnetism in ancient rocks. There is also a vast submarine mountain system lying along the middle of the oceans which consists of **mid-ocean ridges**. We believe, that these ridges represent places were molten material from the mantle is rising. As it reaches the surface, the material heaps up to form the ridge (it also moves out sideways away from the ridge). At the ridge the rock being formed from mantle material is magnetized in the direction of the magnetic field. As it moves away from the ridge it carries with it a record of the direction.

An examination of the paleomagnetism in rocks of different ages revealed the fact that **the earth's magnetic field has reversed its direction many times**. We can see this by drilling a core through undistributed rock: young rock on the top is magnetized in the present normal direction, the older one underneath in the reverse direction. This pattern of reversed magnetic directions provides evidence for the main mechanism of continental drift: **spreading of the sea floor** as new material wells up from the mantle.



If the horizontal mantle current meets an opposing current and they both turn downward into the mantle again at the site of a ridge, enormous pressure is produced in this region. This causes the continental & oceanic crust moving towards each other. The descending mantle current tends to drag (=mitreissen) the crust down with it, forming a **deep ocean trench** or piling up young mountains. At the same time, the continental crust tends to ride over the oceanic crust, because it is the lighter one.

There are striking similarities between the shape of the mid-ocean ridge and the shape of the coastlines on both sides. If we could push f.e. the continents bordering the Atlantic together, the continents would meet at the mid-Atlantic ridge (Europe is moving away from North America) & close up on the ocean that now separates them. This leads to the fact that spreading ocean floors will be very young near the mid-ocean ridge & progressively older toward the coasts → although young sediments & young volcanos can form anywhere on the ocean floors, older sediments & old volcanic islands should only be found toward the coasts.



Differences between Wegener's theory of Continental Drift & the modern **Plate Tectonics**: The entire crust of the earth is broken into six large plates and many smaller ones (Wegener believed that each continent is floating like a boat through the solid ocean floor). Any plate may consist in part of ocean floor & in part of a continent or islands.

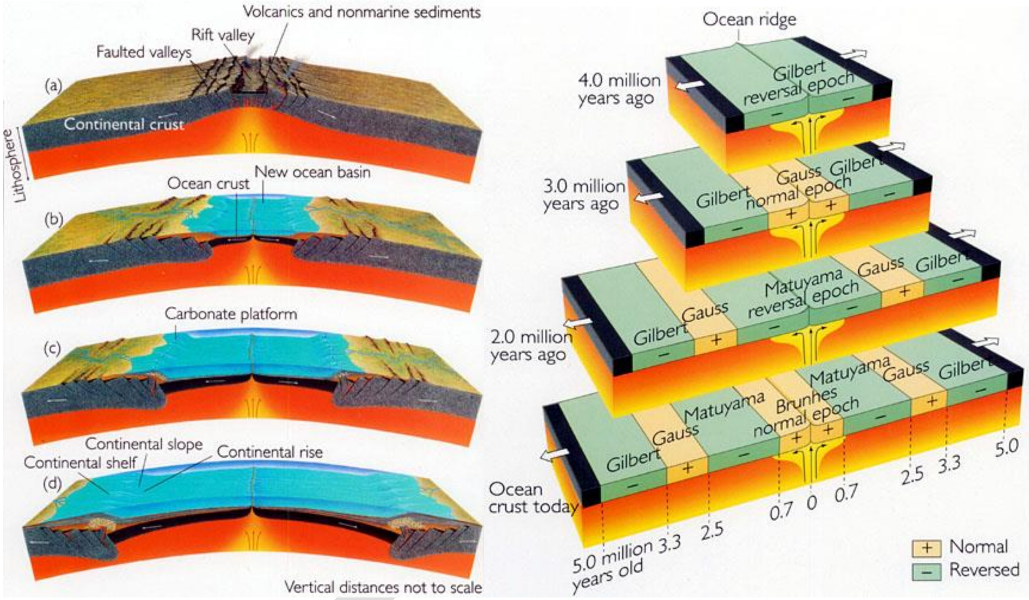
The boundaries between the plates are the mid ocean-ridges, where new oceanic crust is forms & plates move apart. Ocean trenches & young mountains are formed where plates come together & where older ocean crust is overridden & returned to the interior.
Places where continents seem to have bumped into each other: 1. At the mid-Atlantic ridge where the Atlantic was opened up. 2. The Himalayas where the Indian Peninsula detached itself from Gondwanaland & bumped into Asia. In this collision mountains piled up.

TECTONIC PROCESSES

DIVERGING PLATE BOUNDARY

Two plates are moving apart at ocean ridges or continental drifts → splitting of the crust. Through this gap the lava can easily escape (→ lava flow or volcanic eruption). The lava creates new crust & forms a mid-ocean-ridge. Example: Island (reason for volcanic eruptions & earthquakes on island).

Because of the opening up of a continent a continental rift zone is formed. It is a long, narrow fissure (=Spalt) in the earth.

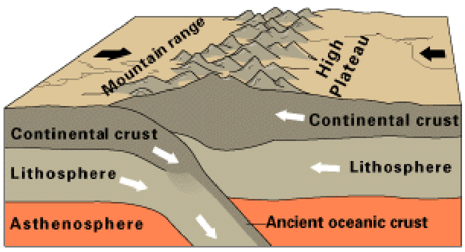


CONVERGENT PLATE BOUNDARY

Two plates are moving together & one plate is forced beneath another forming ocean trenches or mountain building. This process leads to a subduction of the crust → **destructive** plate boundary. The zone of friction (=Reibung/Spannung) is called benoiv. Right at the shore of the continent an accreationary wedge (=Keil) forms. Volcanoes are present along the coastal mountain range because the diving of one plate beneath another causes a rise in pressure of the magma. The mountain range is often folded/deformed due to enormous pressures. Therefore, in many cases the rocks there are metamorphic (rocks that change because of pressure & heat, minerals tend to become greener & increase in size).

OF TWO CONTINENTAL PLATES

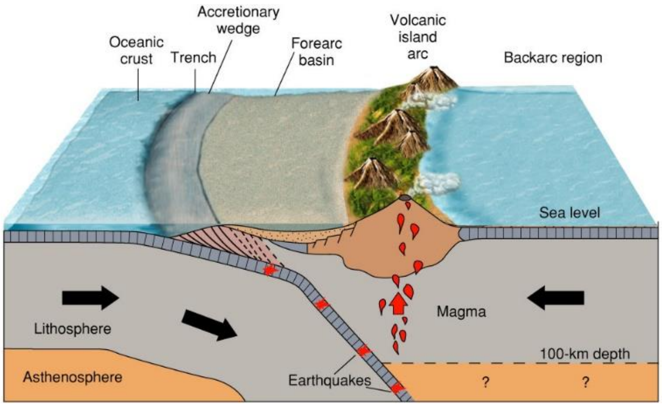
Because neither of the two plates can sink they are folded up into mountains. Example: As the Indian Plate collided with the Eurasian plate the Himalayas were formed.



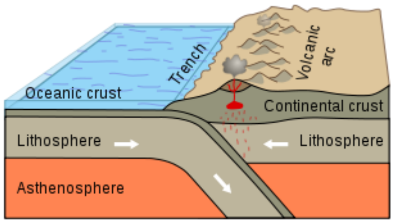
Continental-continental convergence

OF TWO OCEANIC PLATES

If one plate is warmer than the other, the colder one is diving underneath it. Further away from the coast a deep ocean trench occurs due to the downward bend of the crust. This tectonic process isn't causing a big mess because these plates are lighter.

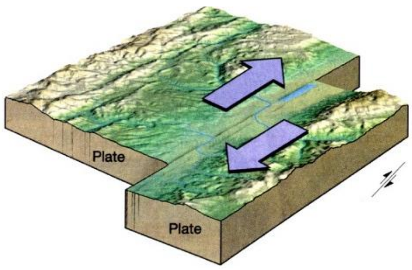


OF A CONTINENTAL & AN OCEANIC PLATE



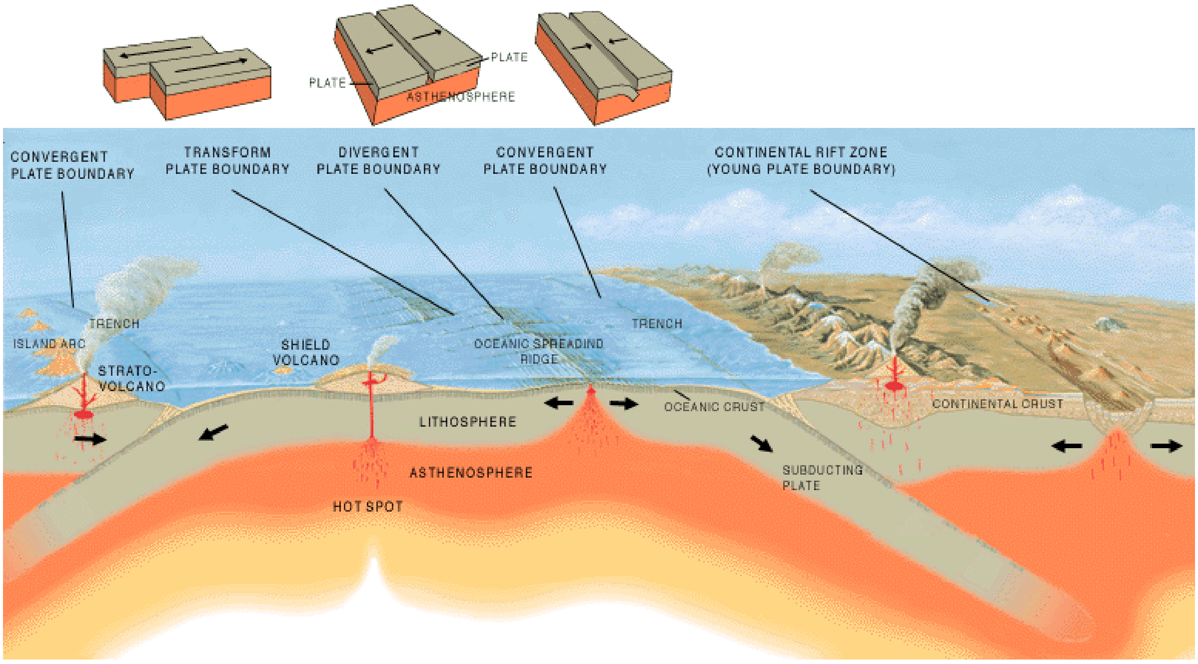
The denser oceanic plate dives underneath the less dense continental plate. Further away from the coast a deep ocean trench occurs due to the downward bend of the crust. Volcanic activity is common. Example: Nazca sinks under the South American plate.

TRANSFORM/CONSERVATIVE PLATE BOUNDARY



Two plates are moving past each other & are neither constructive nor destructive (→ no volcanic eruptions). The pressure builds up & when it is released earthquakes occur. Only example: San Andreas fault in California.

SUMMARY OF ALL FOUR TYPES



EARTHQUAKES

FORMATION

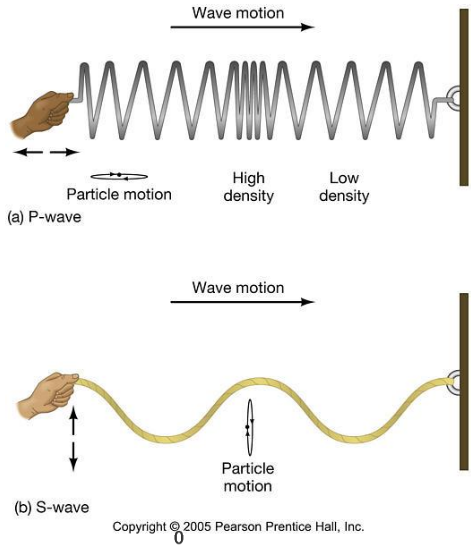
If energy is released in the earth's crust, the surface vibrates which causes an earthquake. This energy can be generated by a sudden dislocation of segments of the crust, by a volcanic eruption or by manmade explosions. In the process of breaking (if the crust is 'snapping' to a new position), vibrations (shock waves) are generated. These waves travel outward from the source of the earthquake along the surface & through the earth at varying speeds depending on the material on which they move.

Earthquakes tend to reoccur along faults, which reflect zones of weakness in the earth's crust (a fault is the result of a transform plate boundary). Even if a fault zone has recently experienced an earthquake, there is no guarantee that all the stress has been relieved. Another earthquake could still occur. Relieving stress along one part of the fault can also increase stress in another part.
The **focal depth** of an earthquake is the depth from the earth's surface to the region where an earthquake's energy originates (=> the **focus**). The foci of most earthquakes are concentrated in the crust & upper mantle. The **epicenter** of an earthquake is the point on the Earth's surface directly above the focus. The location of an earthquake is described by the geographic position & its focal depth. The further away from the ocean, the deeper are the foci of earthquakes because the contact zone of the two plates is deeper.

Liquefaction (= Verflüssigung) causes major damage during earthquakes. This happens when loosely packed, water-logged sediments lose their strength because of the strong shaking.

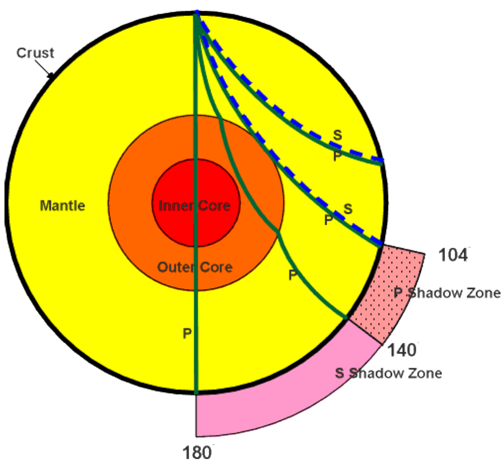
MEASUREMENT

The vibrations produced by earthquakes are detected, recorded & measured by **seismographs**. The **seismogram** (the lines made by a seismograph) reflects the changing intensity of the vibrations by responding to the motion of the ground surface beneath the instrument. From data expressed in seismograms you can determine the time, epicenter, focal depth & the type of faulting of an earthquake. You can also estimate how much energy was released (→ **magnitude** of the earthquake).



There are two general types of vibrations:

- **surface waves**: They travel along the earth's surface & have usually the strongest vibrations & probably cause most of the damage.
- **body waves**: They travel through the earth (from the focus to the distant points on the surface) & can move in all three directions. They can travel through solid rock.
  - **P waves** (compressional waves): They can travel through the Earth's outer molten core & are faster than S waves. P waves push tiny particles of earth material directly ahead or displace them behind their line of travel.
  - **S waves** (shear waves): They don't travel at the speed of P waves & displace material at right angles to their path. S waves are electromagnetic waves.



The **Moho** is the boundary between the crust & the mantle. It is 5-10km below the ocean floor & 20-90 km beneath continents. As the density of the mantle is higher than the density of the crust, P-waves can travel faster below the Moho. Therefore, the surface waves arrive before the P waves at the seismometer if they travel above the Moho.
The longer it takes to arrive for the surface waves after the P-waves, ...

The first indication of an earthquake is often a sharp thud (=dumpfer Schlag), signaling the arrival of compressional waves. This is followed by the S waves & then the 'ground roll' caused by the surface waves. The severity (=Schwere) can be expressed in several ways. The **Richter Scale** is a measure of the amplitude of the seismic waves & usually expresses the *magnitude* of an earthquake. The magnitude can be estimated from seismographic readings. This scale is logarithmic so that f.e. a recording of 7 indicates a disturbance with ground motion 10 times as large as a recording of 6. The scale is open, but there was never an earthquake with a magnitude of 10.

The **Mercalli Scale** is a subjective measure that describes how strong a shock was felt at a particular location → expresses the *intensity* of an earthquake. This scale ranges from I to XII.
Earthquakes of large magnitude do not necessarily cause the most intense surface effects. The effect depends on local surface & subsurface geological conditions: An area underlain by unstable ground (sand, clay,...) is likely to experience much more noticeable effects than an area equally distant from an earthquake's epicenter but underlain by firm ground (granite) → the intensity may be higher & the destruction bigger, but the earthquake isn't stronger!).

PREDICTION
Scientists estimate earthquakes in two ways: studying the history of large earthquakes in a specific area & the rate at which strain (=Spannung) accumulates in the rock.

1. They study the past frequency of past earthquakes in order to determine the future likelihood of similar large shocks. But in many places the assumption of random occurrence with time may not be true, because when strain is released along one part of the fault system, it may actually increase on another part.
2. Another way is to study how fast strain accumulates. When plate movements build the strain in the rocks to a critical level, the rocks will suddenly break & slip to a new position. Scientisty can measure how much strain accumulates along a fault segment each year, how much time has passed since the last earthquake along the segment & how much strain was released in the last earthquake. With this information they can calculate the time required for the accumulating strain to build to the level that results in an earthquake. Problem: such detailed information about faults is rare (only San Andreas fault).

Both of these methods are being tested along the part of the San Andreas fault.

VOLCANOES / HOT SPOTS
Most volcanoes & earthquakes are found along plate boundaries. There are a number of volcanoes that sit in the middle of plates. These volcanoes have formed above a hot spot - a single plume of rising mantle. Hot spots are found in the ocean & on continents.
Hot spot volcanism is unique because it doesn't occur at the boundaries of Earth's tectonic plates, where all other volcanism occurs. Instead it occurs at abnormally hot centers known as mantle plumes.

TSUNAMIS

Tsunamis are caused by large undersea disturbances that contain a strong vertical motion. Such quakes often occur where one of earth’s tectonic plate dives/’subducts’ beneath another. Sometimes they are also caused by landslides or volcanoes.

As waves spread from the epicenter in a typical arc-shaped pattern, their energy also spreads out. The extreme wavelength of tsunamis distinguishes them from ‘normal’ waves. Tsunamis slow when the lower part of the wave encounters the upward-sloping ocean floor. But while the front of the wave slows, the wave behind is still moving faster, causing a giant pile-up at the front. The kinetic energy that was spread through the ocean depth concentrates in a towering wave at the surface.

Like all waves, tsunamis have a rising & a falling motion. If you see the water retreating, you should immediately head away from the shore. Another quirk: Tsunami waves can be spaced as much as one hour apart, so subsequent (=folgende) waves can kill those who return to help victims of earlier waves.