The Earth’s Crust

- The Earth’s crust is thin relative to the rest of the planet.
  - **25-70 km** thick below the continents
  - around **10 km** thick below the oceans.

- The crust is rich in lighter minerals such as silicon, calcium and aluminum and is less dense than the mantle. It rides over it causing the formation of oceans, mountains and volcanoes.

The continental crust is made up of igneous, metamorphic, and sedimentary rocks. It is not recycled within the Earth as often as oceanic crust, so some continental rocks are up to 4 billion years old.

More than two thirds of the Earth’s surface is composed of oceanic crust. Oceanic crust is continually formed from mantle material and so is relatively young. Even the oldest parts of the ocean floor are no more than 200 million years old.
Sediments eroded from continents and compressed into **sedimentary rock** can be later lifted and exposed in mountains.

Igneous rocks, such as basalt, form a major component of the crust and are essentially unchanged since their formation.

**Water**, as rain, drains to rivers and lakes, which flow back to the ocean **eroding** the landscape in the process.

The Earth's persistent **oceans of liquid water** cycle moisture through the atmosphere to the land and back again.
Types of Rock

- The Earth's crust is made up of solid, naturally occurring assemblages of minerals called **rocks**.

- The huge diversity of the Earth's rocks has developed over thousands of millions of years through:
  - **igneous activity** (volcanism)
  - **metamorphism** (changes in form)
  - **sedimentation** (formation of sediments and sedimentary rocks)
Types of Rock

- **Igneous rocks** solidify from volcanic magma. They vary in composition from basalt (<20% quartz) to granite (>20% quartz) and in texture from rapidly cooled glasses, such as obsidian, to slowly cooled coarse grains, such as granite.

- **Metamorphic rocks** result when pre-existing rock is transformed by heat and pressure. Metamorphic rocks are classified by texture and composition. Examples include gneiss, slate, marble and schist.

- **Sedimentary rocks** form when sediments accumulate in different depositional environments and then become compressed into brittle, layered rocks, e.g. shale, sandstone, limestone, and conglomerate.
**Rock Dynamics**

<table>
<thead>
<tr>
<th>Basalt</th>
<th>Andesite</th>
<th>Rhyolite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabbro</td>
<td>Diorite</td>
<td>Granite</td>
</tr>
<tr>
<td>Pyroxene</td>
<td>Amphibole</td>
<td>Mica</td>
</tr>
<tr>
<td>Olivine</td>
<td>Plagioclase feldspar</td>
<td>Alkali feldspar</td>
</tr>
</tbody>
</table>

- **Fine grained (volcanic)**
- **Course grained (plutonic)**

**Mineral content**
- MAFIC MINERALS (Mafic minerals)
  - Basalt: 48-58% Pyroxene, Olivine
  - Andesite: 59-65% Amphibole, Plagioclase feldspar
  - Rhyolite: 65-77% Mica, Alkali feldspar

**Silica content**
- 48-58% for Basalt
- 59-65% for Andesite
- 65-77% for Rhyolite

**Fluidity**
- Fluid, high mobility 1160°C for Basalt
- Viscous, low mobility 900°C for Rhyolite

**pH**
- Basic for Basalt
- Acidic for Rhyolite

*Mafic minerals contain magnesium, iron, and heavy elements. They are usually dark in color.*

*Felsic minerals contain lighter elements such as silicon, oxygen, and aluminum. They are usually light in color.*
The Rock Cycle

- The Earth's rocks are grouped together according to the way they formed as:
  - igneous
  - metamorphic
  - sedimentary rocks

- **Igneous rocks** are created by volcanism and may form above the surface as volcanic rocks or below the surface as plutonic rocks.

- Heat and pressure within the Earth can transform pre-existing rocks to form **metamorphic rocks**.

- When rocks are exposed at the surface, they are subjected to weathering and erosion and form **sediments**.
The rock cycle constantly redistributes material within and at the Earth’s surface over millions of years by melting, erosion, and metamorphism. It is the slowest of the Earth’s cycles and is responsible for concentrating the mineral resources on which humans depend.
The **lithosphere** comprises the crust and the uppermost region of the mantle.

The lithosphere carries the outer rock layer of the Earth, which is broken up into **seven** large, continent-sized tectonic plates and about a dozen smaller plates.

The lithosphere overlies the hotter, more fluid lower part of the mantle, the **asthenosphere**.
Plate Boundaries

Throughout geological time, the tectonic plates have moved about the Earth's surface, shuffling continents, opening and closing oceans, and building mountains.

The evidence for past plate movements has come from several sources:

- mapping of plate boundaries,
- the discovery of sea floor spreading,
- measurement of the direction and rate of plate movement,
- the distribution of ancient mountain chains, unusual deposits, and fossils
Plate Movement

- Heat from the mantle drives two kinds of asthenospheric movement:
  - convection
  - mantle plumes

- Plate motion is also partly driven by the weight of cold, dense plates sinking into the mantle at trenches.

- This heavier, cooler material sinking under the influence of gravity displaces heated material that rises as mantle plumes.
Divergent Plates

- The size of the plates is constantly changing, with some expanding and some getting smaller.
- These changes occur along plate boundaries, which are marked by well-defined zones of seismic and volcanic activity.
- Plate growth occurs at divergent boundaries along sea floor spreading ridges such as the Mid-Atlantic Ridge and the Red Sea.

Magma upwelling through fractures causes plates to diverge. The changing convection currents inside the Earth can form new boundaries and destroy old.
Sea floor Spreading

- Sea floor spreading occurs as magma wells up from the mantle below, forcing the plates apart.
- As the new rock cools and solidifies it picks up and preserves the direction of the Earth’s magnetic field.

New rock on either side of the ridge has the same magnetic information.

On average the Earth’s magnetic field reverses once every million years. This leaves magnetic bands in the crust.

The banding provides clear evidence of sea floor spreading and plate tectonics.
Plate attrition occurs at **convergent boundaries** marked by deep ocean trenches and **subduction zones**.

When an oceanic plate collides with a continental plate, it sinks into the mantle and eventually melts.
Plate Boundaries

- The Earth’s major earthquake and volcanic zones occur along plate boundaries.
- The movements of plates puts crustal rocks under strain.
- **Faults** are created where rocks fracture and slip past each other.
- Earthquakes are caused by the energy released during rapid slippage along faults.

**New Zealand’s alpine fault** is visible from space, marking a transform boundary between the Indo-Australian plate and the Pacific plate.
Continental Boundaries

- Where **continental plates** meet, the land may buckle and fold into **mountain ranges**.

- The highest mountains on Earth, the Himalayas, were formed in this way as the subcontinent of India collided with continental Asia.

- Few volcanoes form in these areas because the continental crust is so thick.
Transform Boundaries

- Plates may slide past each other at transform boundaries.
- Plate size is not affected because there is no construction or destruction of material at these boundaries. However, they are responsible for large earthquakes.
- Pressure from the plates causes the boundary to lock in position and earthquakes occur when the rock gives way to release the pressure.
Subduction Zones

- Subduction zones occur where dense oceanic plates collide with lighter continental plates.
- The denser material of the oceanic plate sinks underneath the continental plate and eventually melts.
Shield volcanoes have characteristically shallow slopes.

They are generally made from basaltic lava.

This lava is low in silica and is very fluid.

The lava tends to run down the slopes of the volcano quickly and spread out, causing the radius of the volcano to increase without increasing its height.
Shield Volcanoes

Fluid, basaltic magma low in silica

Low, shallow slopes formed from fluid lava

Large radius at base of volcano
Strato-volcanoes (or composite volcanoes) form from lava with medium levels of silica, which is less fluid than the lava that flows from shield volcanoes.

- Gas tends to be trapped in the magma below the surface leading to explosive eruptions that throw debris high into the atmosphere.
- The resulting volcano has steep sides near the summit and more shallow sides near the base.
Strato-volcanoes

- Built up layers from multiple eruptions
- Main crater
- Steep upper slopes
- Parasitic vent
- Shallow lower slopes
- Intrusions and dykes
- Built up layers from multiple eruptions
Dome Volcanoes

Also known as lava domes, these are **steep sided** volcanoes that form from silica-rich lava.

They can be very explosive, as gas trapped in the magma is not easily able to escape, causing it to build up over time.

Photo: Sam Beebe, Creative Commons share alike 2.0
Dome Volcanoes

- High summit and small radius of base due to lava piling up
- Steep slopes
- Layers formed from successive eruptions
- Viscous magma high in silica
Calderas form from the **collapsed remains** of large volcanoes.

If enough magma is ejected from the magma chamber during an eruption, the overlying rock may not be able to support the rest of the volcano.

This may then collapse, often causing an even larger eruption and leaving a **large crater** where the volcano once was.

The Santorini caldera is 12km across with cliffs rising 300m above the water and falling 400m below it.
Calderas

Collapsed crater may fill with water to form a lake.

Slopes may or may not be present depending on the size of the caldera.

Numerous fissures caused by collapse of magma chamber.

Resurgent dome.