Plate Tectonics: theory, types of margin & associated features

What you need to know
What the Earth's internal structure is like
What the plate tectonics theory is
What processes and landforms occur at the different plate margins and away from the margins

The Earth's internal structure:

The Earth is made up of 3 main sections: the core, mantle and crust.

The core:

At the centre of the earth lies the core. This is split into two sections: the inner and outer core.

The inner core is solid and is composed of iron and nickel. It is approximately 1,221 km thick and has a density of 12.8g/cm3 at the top of the section and 13.1g/cm3 at its deepest point.

The outer core is composed of liquid iron and nickel. It is approximately 2,259 km thick. Its density is 9.9g/cm3 at the top and 12.2g/cm3 at the bottom where it changes into the inner core.

The mantle:

The mantle is the thickest layer, being approximately 2,800 km thick. It makes up the bulk of the planet and lies between the core and the crust. Its density is 3.4g/cm3 at the top and 5.6g/cm3 at the bottom where it changes into the outer core. It is a solid layer but acts like a viscous liquid due to temperatures being close to the melting point of key minerals in this layer. All of this mantle rock is comprised of a variety of oxides. Their atomic elements include oxygen, silicon and magnesium.

The crust:

This is the thinnest layer and forms the outer shell on which life exists. It varies in thickness from just 1km in some places to more than 80 kilometres in others. There are two types of crust: oceanic and continental. **Oceanic crust** forms the bed of the world's oceans and is thinner and younger as it is constantly renewed when it is subducted into the mantle and reappears as new crustal material at subterranean constructive margins, such as the Mid-Atlantic Ridge. It is, on average, 6km thick. **Continental crust**, on the other hand, is older and much thicker (on average 36 km thick) and yet, despite its thickness, it is less dense material than that which forms oceanic crust. This means it floats on the mantle with more buoyancy and it is the denser oceanic crust that descends into the mantle when the two types of crustal material collide at destructive margins.

Radioactive decay in the core releases considerable heat and this moves through the mantle in the form of rising convection currents. As the currents approach the crust they spread out horizontally, cool and sink back down into the mantle. This heat conveyor belt within the mantle is responsible for the movement of the crustal plates that make up the Earth's surface as they are dragged across the earth by the dominant convection currents.

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Plate tectonics theory:

This is the scientific theory that attempts to explain why the Earth's crust acts the way it does and produces the landforms we can see on the Earth's surface. Plate tectonics grew out of a theory that was first developed in the early 20th century by the German meteorologist Alfred Wegener.

In 1912 he noticed that the coastlines of the east coast of South America and the west coast of Africa appeared to fit together like jigsaw pieces.

Further examination of the globe revealed that all of the Earth's continents fit together somehow and Wegener proposed an idea that all of the continents had at one time been connected in a single supercontinent called **Pangaea**. He believed that the continents gradually began to drift apart around 300 million years ago. This was his theory that became known as continental drift. The main issue with his theory was that he had no explanation as to why the continents moved like this. Further investigations into this provided him with fossil evidence linking continents together and he proposed that the spin of the Earth had split the continents and dragged them away from their central location; however, this was dismissed. In 1929 Arthur Holmes, a British geologist, came up with the theory of convection currents and he said that as a substance is heated its density decreases and it rises until it cools sufficiently to sink again. According to Holmes it was this heating and cooling cycle within the Earth's mantle that caused the continents to move. This theory gained very little attention at the time.

In the 1950s Wegener and Holmes' theories were taken more seriously and studies of palaeomagnetism began which involved **studying the rocks formed by underwater volcanic eruptions in relation to the Earth's magnetic field**. When basaltic lava cools on the sea floor, individual minerals separate - especially iron - and these minerals then align themselves on the sea floor in the direction of the magnetic pole. New technologies allowed these rocks to be dated and their pattern of movement mapped between their origin and sampling. The maps suggested the migration of seafloor rocks. More recently there has been a discovery that the Earth's magnetic field reverses periodically and it is possible to see an identical pattern between rock formations on either side of the mid Atlantic ridge. This is known as **Palaeomagnetism**.

The final confirmation was that of **sea floor spreading**. In 1962 Harry Hess dated the rocks of the Atlantic sea bed from the Mid-Atlantic Ridge outwards to the coast of North America. He discovered that the newest rocks were at the centre near Iceland, and the oldest at the coast. This suggested the earth's surface was splitting and expanding in certain places. However, given that the whole earth was known to be of a stable size and not inflating like a balloon, an area of the Earth where plate destruction was taking place had to be found to balance crustal expansion with crustal destruction. This evidence was discovered along the edges of the Pacific Ocean where a destructive plate boundary lies between the Pacific, Philippine, North American and Australian plates. Finally, by the mid-1960s a coherent theory of plate tectonics was accepted that accounted for different crustal rock types, orientations, continental shapes and an evidenced process that drove the movements.

The influence of gravity on plate movement
More recent theories of plate movement consider the effect of **gravitational forces** acting within the crust that also contribute to plate movement, although the impact is thought to be weaker than the effect of convectional movement in the mantle. However, there is debate about the relative influence of the various forces and they may account for different plate motions in contrasting parts of the earth's surface.

Gravitational sliding away from a spreading ocean ridge takes place with plate movement driven because of the higher elevation of plates at ocean ridges. As fresh magma wells up at mid-ocean ridges to form new young, oceanic lithosphere, a higher elevation is formed at spreading ridges. The new oceanic crust gradually cools and thickens with age and is pushed 'downhill' as new magma emerges from the active zone of divergence behind it (and thus adds distance from the ridge). This force is regarded as a secondary force and is referred to by some as **'ridge push'.**

Slab pull is thought to be a more significant gravitational force acting on plates. In the current understanding of plate motion the movement is driven by the weight of cold, older, dense plate material sinking into the mantle at deep ocean trenches and pulling the rest of the plate slab with them as gravity causes them to slide downwards.

Normal Geography Resource Package on Ridge Push / Slab Pull here:
https://583daeb7-8767-411c-9387-a7803a5f9622.filesusr.com/ugd/927b29_f1ab2a4e95c940299ce3f0bce83c83ac.pdf

Processes and landforms at plate margins

There are three types of plate margin: constructive, destructive and conservative. At each one there are distinctive landforms and events that characterise them.

Constructive:

This margin can be found on land as well as in the centre of oceans. The processes occurring here are that the plates are being pulled apart in a *pattern of divergence*. Most commonly found in oceans, the plate type is oceanic on both sides and upon moving apart a gap is left, which is immediately filled with magma that rises up from the mantle. Due to a lack of pressure, the lava that is produced from the gap has a low viscosity and a low silica content which makes it runny. The lava can then travel over a large area before it solidifies. As this process occurs along the ridge for hundreds or thousands of miles, a chain of submarine volcanoes are formed. This continual process creates shield volcanoes. **Transform faults** are formed at right angles to the margin and earthquakes can occur here. They are usually of low magnitude.

Where a constructive margin occurs on land it creates a **rift valley**. As the crust tears apart, sections of land drop and create deep rift valleys. Thinner crust allows gas and steam eruptions to occur.

Normal Geography Resource Package on Constructive Landforms here:
https://583daeb7-8767-411c-9387-a7803a5f9622.filesusr.com/ugd/927b29_5ca3b3a7a8b94c7286c6e9baff401e89.pdf

Destructive:

This margin is associated with converging plates, which are can involve two oceanic plates colliding, one continental and one oceanic, or two continental plates in collision.

Where two oceanic plates converge a volcanic island arc will result parallel to the plate margin - examples are Japan, and the Aleutian Islands; both curved lines of volcanoes. The volcanoes are very explosive, because the resulting magma from subduction is silica-rich andesitic magma with high levels of gas present and therefore very explosive.

Where continental crust and oceanic plate converge, the oceanic crust is subducted underneath the continental crust as it is denser. This area of subduction creates a deep section of the ocean known as an oceanic trench. The crust is pushed/pulled down at various angles. As the plate descends there is an increase in pressure, heat and friction and this causes the plate to melt. This molten material will then force its way back up to the surface where it will emerge through the crust as an explosive composite cone volcano. Fold mountain chains are also found along the edge of the continental plate, as the subduction of the oceanic plate crumples up the continental plate. Earthquakes at this margin can be of high magnitude due to the pressure that is built up between the two plates.

When two continental plates converge, neither plate can be subducted due to the plates having a similar density. This margin is also known as a collision zone. The plates collide into each other and crumple upwards to form fold mountains. Due to the lack of subduction there is no volcanic activity, but earthquakes are violent due to the constant friction that builds up between the two plates trying to override each other.

Conservative:

This margin is associated with plates that slide alongside each other. They can either slide in the same direction but at different speeds or in opposite directions. There are no volcanoes found at this margin due to the lack of material being destroyed. As they move past each other, friction builds up and energy is released as an earthquake. They are usually shallow focus earthquakes due to the lack of subduction. The means they can produce deadly, high magnitude earthquakes as friction is released close to the surface. *An Example is along the San Andreas Fault line, in California.*

Magma plumes:

Volcanic activity is also evident away from the plate margins and it is the locations of magma plumes which can cause this. Magma plumes are areas of hot, upwelling mantle. A **hot spot** develops above the plume in the crust. Magma generated by the hot spot rises through the rigid plates of the lithosphere and produces active low viscosity volcanoes at the Earth's surface.
As oceanic volcanoes move away from the hot spot with the migration of their tectonic plate, they cool and subside, producing older island chains. The Hawaiian Island chain is being constructed in this way. As continental volcanoes move away from the hot spot, they cool, subside, and become extinct.

