GCSE Geology 3.1: Planetary geology

There are similarities and differences between Earth and its planetary neighbours (the Moon and Mars) including rocks, landscapes, atmosphere, temperature, pressure and gravity. The principle of uniformitarianism is used to interpret geological processes operating on planetary bodies within the solar system.

Earth is called the 'Goldilocks Planet' as it is neither too hot nor too cold and just the correct distance from the Sun for water to be able to exist in a liquid state. Being a rocky dense planet, it has a strong gravitational pull which has helped it retain the dense atmosphere. The atmosphere protects from dangerous UV rays and also helps to moderate the temperature at the Earth's surface. The Earth's magnetic field deflects away charged particles from the solar wind.

Meteorites provide evidence for the composition of the Earth. Most meteorites are found in Antarctica and hot deserts.
Stony meteorites with a density of 3.6 g/cm^3 and rich in olivine are thought to be similar in composition to the upper mantle.
Stony-iron meteorites with a density of 4.8 g/cm^3 and contain olivine, nickel and iron are thought to be similar in composition to the lower mantle/outer core.
Iron meteorites with a density of 7.7 g/cm^3 and made up of iron and nickel are thought to be similar in composition to the inner core.

Meteorites are rare and poorly preserved on Earth but common and well preserved on the Moon and Mars.
On Earth, the atmosphere causes most meteorites to burn up before hitting the surface. Weathering and erosion quickly fills in craters with sediment and vegetation soon re-establishes itself. Two thirds of the Earth's surface is ocean and so many meteorites may land in the sea, never to be discovered. These would be destroyed at subduction zones.
On the Moon and Mars, there is little or no atmosphere, so meteorites do not burn up and instead impact the surface. Craters formed are preserved as there is an absence of water, so there is no weathering and erosion (except for wind erosion on Mars). As there are no oceans, all craters are visible and there is no vegetation to recolonise and mask the features.

Impacts from meteorites/comets may have had a significant effect on the evolution of the Earth and its biosphere (see Knowledge Organiser 2.5 for full details).

The Moon – formed around 4,500 Ma when another small planet (Theia) collided with Earth and was engulfed by it, increasing its mass. The debris left over from the collision coalesced to form the Moon. The Moon helps regulate Earth's orbit around the Sun and also causes tidal cycles. The Moon is tectonically inactive, meaning there are no volcanoes, no plate tectonic activity and no rock cycle processes except for meteorite impacts.

Three major landforms can be recognised:
Terrae are lighter-coloured areas which represent the lunar highlands/original crust as the Moon solidified.
Mare are the darker regions which represent large basaltic lava flows, probably caused by meteorite bombardment puncturing the thin early crust.
Meteorite craters with debris lines occurred later. The largest crater is the South Pole-Aitken Basin which is 2,500 km wide but just 13 km deep and is thought to have been formed by a very large meteorite impacting the Moon at a shallow angle with a glancing blow. Generally, the larger the meteorite craters, the older they are (more recent ones are smaller). Cross-cutting relationships of overlapping craters can be used to establish their relative ages.

Mars is a rocky planet approximately half the size of the Earth with a gravitational pull about one-third that of the Earth's. It has an atmosphere with a mass 1% that of Earth's and is made up of mainly carbon dioxide. It is currently volcanically inactive and there is no active plate tectonic activity. This suggests that the interior of Mars has cooled more than Earth and there is not enough heat within to drive volcanic or plate tectonic activity. The only erosive force occurring today is wind.

Mars was very different in the geological past. It has a number of extinct volcanoes with Olympus Mons (active 115-25 Ma) being the largest volcano in the solar system at 600 km wide and 22 km high. Much larger than any volcano on Earth, it developed because the heat/magma source feeding the volcano remained fixed in place for millions of years as there were no plate movements. In addition, weak gravity allowed the structure to continue to grow. As there was no water on Mars by this time, the processes of weathering and erosion (except wind) did not wear it down.

Although tectonically inactive today, there is some evidence that the Valles Marineris, a canyon 4000 km long, 200 km wide and 8 km deep, may represent the initial stage in the formation of a divergent plate boundary with a rift valley structure running along its centre. Further tectonic activity is indicated by the 150 km left-lateral displacement of a meteorite crater on the northern rim of the canyon. This movement suggests that shear stress was operating in the Martian crust, similar to conservative plate boundaries on Earth.

Mars clearly had water in its early history and probably a much thicker atmosphere than today. Evidence for this lies in a variety of rock types and geological structures photographed by the various Mars rovers and satellites.

It has branching river channels with a dendritic/tree-like pattern that are the same as river drainage networks on Earth. Some channels eventually split into many distributaries forming a structure resembling a delta, as in the Jezero crater.

Sediments that are moderately sorted with subrounded-to-rounded clasts suggest that water has transported weathered and eroded material then deposited it when there was a reduction in energy/gradient. These can be classified as conglomerates.

Some meteorite craters appear to have been the location of lakes, such as the Jezero crater. These lakes later dried up/evaporated leaving desiccation cracks in the fine-grained sediment (mud) on the bottom of the lake/crater.

Sand dunes have been identified on Mars, much larger than those on Earth, with some reaching up to 700 metres in height. The internal structure of these dunes show large-scale cross bedding (dune bedding) exactly the same as their equivalents on Earth. The dunes are interpreted as being formed by sand blown in a series of mega-ripples by a unidirectional current. Sand dunes cover large areas on Mars as there is an absence of moisture and vegetation to anchor the sand.