The deep rock cycle explained by plate tectonics: lithification

A model showing how plate tectonics can explain sediments becoming sedimentary rocks

When rock cycle processes were first understood more than 200 years ago, the people studying them knew how the processes worked, but did not know the cause of the deep-Earth processes.

It wasn't until about fifty years ago, when plate tectonic theory was accepted, that the causes of these processes were first properly explained.

This Earthlearningidea models how the lithification of sediments into sedimentary rocks can be caused by subsiding basins linked to the movement of tectonic plates.

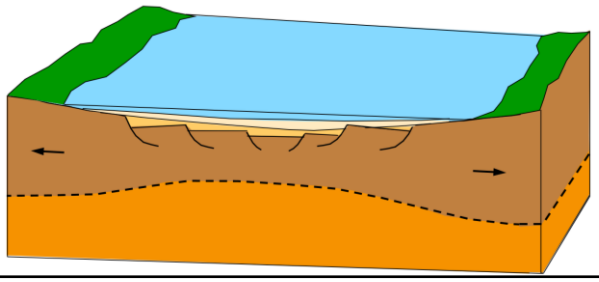
The process that changes loose sediments into sedimentary rocks is called lithification. Lithification happens when sediments are buried under thicker and thicker sequences of sediment. For mud or lime-mud, the pressure of the overlying layers of sediment on its own is enough to change mud into mudstone and lime-mud into limestone. For sands and lime-sands, water carrying dissolved chemicals circulates between the grains of sediment. Small crystals grow from this liquid, cementing the loose sediments into sandstones or limestones (as modelled in: https://www.earthlearningidea.com/PDF/Make_your_own_rock.pdf). These chemical reactions are speeded up as the sediments become buried moor deeply, because as rocks become buried, their temperature rises (the rise of temperature with depth is called the geothermal gradient – see 'Context' below)).

Most lithification happens as sedimentary basins become deeper and deeper, allowing thicker and thicker sediment sequences to build up. You can model how the moving apart of plates (divergence) can cause a deepening sedimentary basin as shown in the photographs.

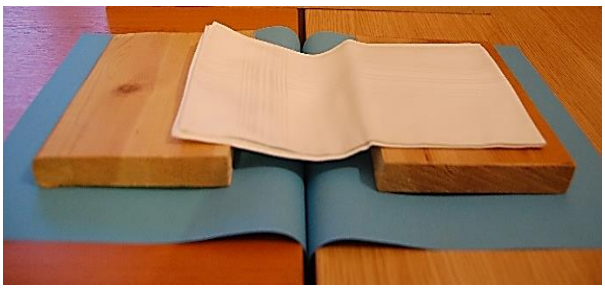
- Tape two pieces of A4 paper together along their short side (the green paper in the photograph).
- Put the taped part down the gap between two tables, so that the remaining parts of both sheets lie flat on the table.
- Put two wooden blocks on the pieces of paper, with their sides touching over the gap.
- Put a piece of cloth such as a folded handkerchief over the wooden blocks.
- The sheets of paper represent the plates.
- The wooden blocks represent two continents which will be pulled apart by plate movements.
- The folded cloth represents the many layers of sediment laid down by deposition on the continents.

- Pull the sheets of paper apart with your fingers – showing how plates can be pulled apart under continents.
- As you pull – the cloth will slide off one of the blocks and sag down between them.

- Note that the 'real world' situation is more complicated, with stretching and faulting occurring in the sagging sediments as shown in this diagram:



- The more you pull – the more the 'sedimentary basin' sags down.



- If the sedimentary basin then became filled with more and more sediment as it subsided – the sediment sequence would become thicker and thicker.
- The sediments near the bottom would be compressed by the pressure of the layers above and cement would be deposited by circulating liquids as the temperature rose – causing the lithification of sediments into sedimentary rocks

The back up

Title: The deep rock cycle explained by plate tectonics: lithification.

Subtitle: A model showing how plate tectonics can explain sediments becoming sedimentary rocks.

Topic: A simple model used to show how, as plates carrying continents are moved apart by plate tectonics, the sediments in between sag into a deepening sedimentary basin giving quicker lithification processes.

Age range of pupils: 14 years upwards

Time needed to complete activity: 10 minutes

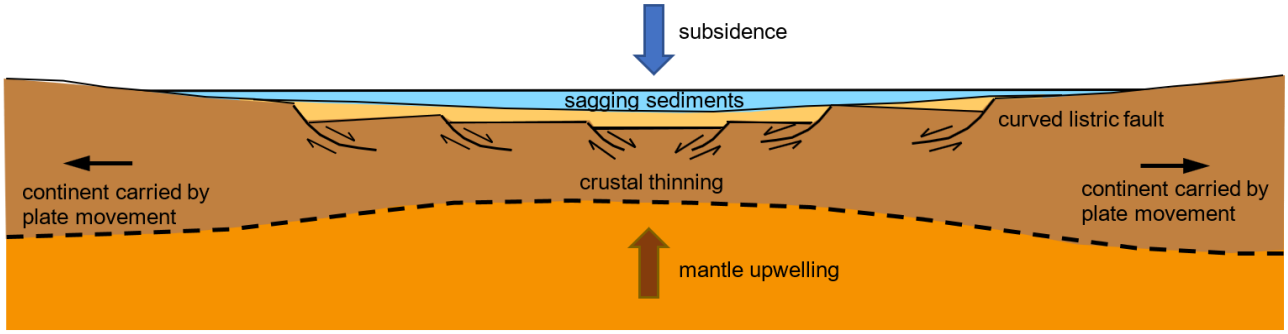
Pupil learning outcomes: Pupils can:
- explain how plates carrying continents are moved apart (diverge) through plate movements;
- explain how this results in sedimentary layers sagging into a deepening sedimentary basin;
- explain how this in turn leads to increased rates of lithification by compression by the overlying layers and cementation.

Context:
Rock cycle processes were first described by James Hutton and his colleagues around 230 years ago – see: https://www.earthlearningidea.com/PDF/93_James_Hutton.pdf.

The evidence for plate tectonics was first developed into a global theory by J. Tuzo Wilson around 50 years – see: https://www.earthlearningidea.com/PDF/91_Wegener.pdf.

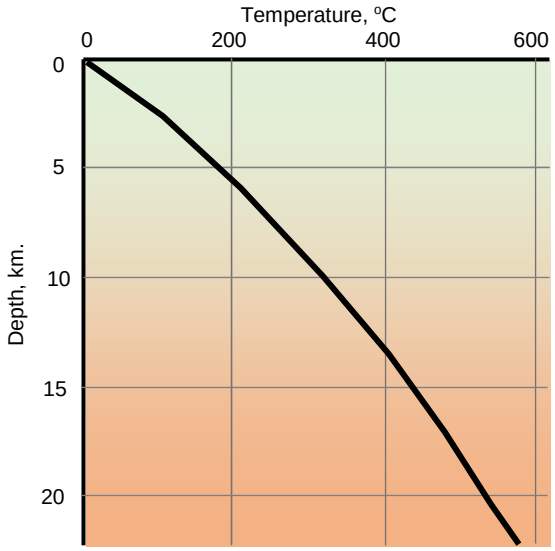
The rock cycle can be modelled in the classroom by: https://www.earthlearningidea.com/PDF/253_Rock_cycle_product_process.pdf. Rock cycle processes can also be modelled and discussed in the classroom, see: https://www.earthlearningidea.com/home/Teaching_strategies.html#rockcycle. Meanwhile, plate movement and plate tectonic processes can be modelled and discussed in the classroom as well, see: https://www.earthlearningidea.com/home/Teaching_strategies.html#platetectonics.

The result of plate movements carrying continents apart is 'crustal thinning' as the Earth's crust becomes stretched and faulted along large curved listric faults (large normal faults with curved surfaces). As the crust becomes thinner the sea floor sags, allowing the build-up of thick sediment sequences. As the sediments sag, lithification rates increase by compression (by the overlying layers) and cementation (by circulating fluids as the geothermal gradient increases).



The geothermal gradient is a graph showing how, as rocks become deeper, they become hotter. The heating is caused by radioactive decay in some minerals of the crust and mantle and some of the remaining heat from the early Earth.

A typical geothermal gradient is shown below.



Note that plate tectonic processes can cause crustal thinning in other ways too.

Following up the activity:
Try using a similar method to model how convergent plate movements cause the rock cycle processes of deformation and metamorphism (see: https://www.earthlearningidea.com/PDF/138_Rock_cycle_plates_def_met.pdf

Underlying principles:
- Plates carrying continents can be moved apart (diverge) by plate tectonics.
- As this happens a basin is formed first within, and then between the continents, into which the sediments sag.
- More and more sediments accumulate in the subsiding basin.
- The sediments at the bottom are more and more compressed by the thick overlying sediments, and greater cementation results from increased rates of chemical reaction as the temperature rises (the geothermal gradient increases).

- This process is called ‘crustal thinning’ and results from the stretching of the sediments and faulting along long curved listric faults.

Thinking skill development:
Understanding the model involves construction; applying the model to plate tectonic processes and the rock cycle processes of compaction and cementation to cause lithification, involves bridging.

Resource list:
- two pieces of A4 paper taped together (maybe coloured blue or green to represent oceanic plates)
- two wooden blocks of wood as shown in the photos, to represent continents
- some folded cloths such as handkerchiefs to represent sediments
- a narrow gap between tables or benches, that the ‘plates’ can be made to rise out of by pulling

Source: Chris King of the Earthlearningidea Team *(photos by Chris).*