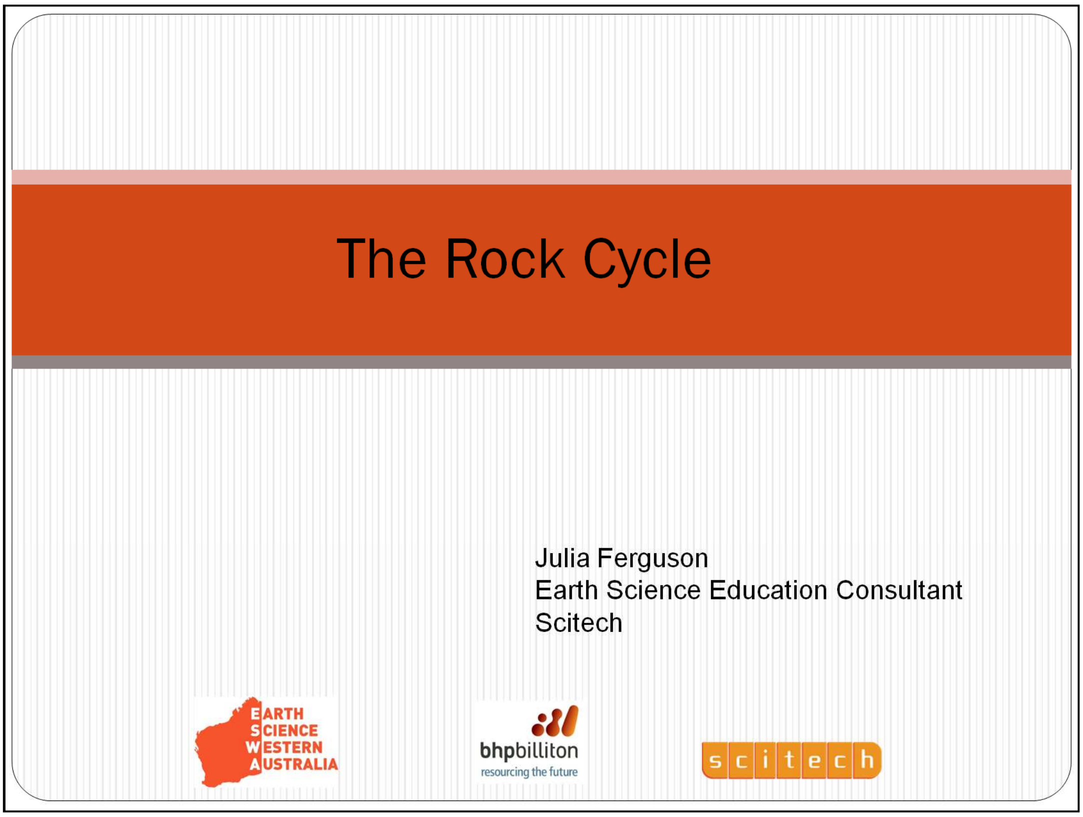
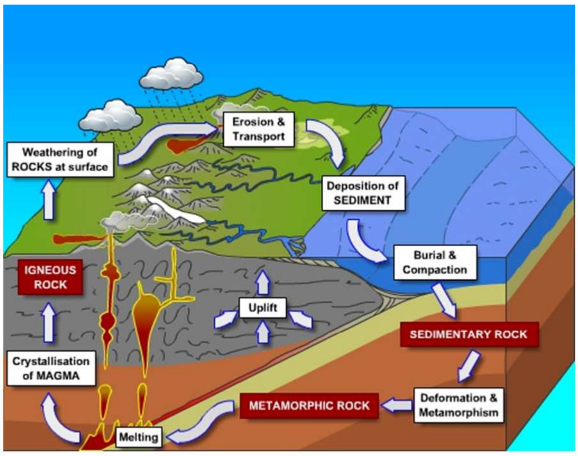


Where possible Western Australian examples have been used.

The slide showing the whole rock cycle has been repeated at the beginning of each new Earth process section to allow students to fill in each sequential section of their worksheet.

The rock cycle



The "Rock Cycle" is an important concept to learn in Earth Sciences. It describes the constant movement and recycling of materials in the upper layers of our Earth. When volcanoes erupt no "new" material is created to form lava flows. The volcanic outpourings have been formed from recycled rock drawn down into the mantle and raised again.

The mass (amount of matter) of the Earth is the almost exactly same as when it first coalesced out of the dust disc that became our solar system about 4,600 billion years ago. A little has been added from meteorites and asteroids and a little lost from dust rising into the upper atmosphere.

Ancient zircons found at Jack Hills in Western Australia indicate that some of our most ancient rocks were weathered, eroded and deposited in seas about 4.4 billion years ago. These are the oldest sedimentary debris found so far on Earth.

The first Earth process for students to copy into the activity sheet is "Weathering at the surface"

Weathering of rocks at the surface

Weathering of limestone near Fremantle WA

Process "<u>Weathering</u>". "Weathering" describes the initial breakdown of rocks by physical and chemical means. This slide is of a vertical section cut into limestone (pale yellowish grey) demonstrating the in situ breakdown of rock into soil.

Rocks can be ***physically*** broken into smaller fragments by differential expansion due to heat, frost cracking, plant roots and Earth movements.

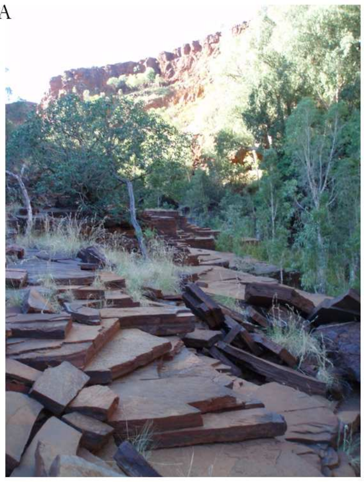
The action of plant humus and acid rain will ***chemically*** break down components of the rocks as will oxidation of exposed minerals. The "rusty" surface found on most boulders is due to oxidation. Most weathering involves both physical and chemical processes

Many students confuse weathering with erosion. The process of erosion requires materials to be physically removed. In the soil profile above the debris remains with the weathered parent rock.

Weathering of rocks at the surface

Frost shattering at Karinjini WA

Physical Weathering



Physical weathering. Water has entered cracks in these rocks and has frozen during the cold desert nights. Water takes up more room when it freezes and this pushes the rocks apart allowing more water to penetrate further. This form of weathering increases the surface area of rock available for chemical breakdown.

Students can replicate this by partially filling a plastic cool drink bottle with water, marking the level on the side of the bottle, capping it , freezing and noting the new level of ice. Filling the bottle full and screwing down the cap will result in the bottle breaking.

This process is weathering as nothing has moved away. The debris remains on the parent rock. Western Australia has some of the deepest weathered soil profiles in the world. Weathering can penetrate to over 200m.

Weathering of rocks at the surface

Chemical Weathering. This sample demonstrates the chemically weathered oxidised crust of a claystone pellet sediment. (Rivers have torn up an old clay bed, rolled the fragments into pellets and redeposited them within a new clay matrix of a slightly different colour). Oxygen from the air bonds with iron in the clay pellets and ground water to form a rusty crust.

Iron + Oxygen = Iron oxide (rust)

Calcium carbonate has also been deposited by water movement. This crust sometimes forms a barrier which protects the fresh rock from oxygen and further weathering. This is the source of “Cap Rock” which forms the top of breakaway country and protects the softer underlying rock and soil. Google Image has good pictures of these features.

Geologists often look for this weathered rich rust crust when prospecting minerals such as copper and nickel which can be hosted in iron rich igneous rocks. Over mineralised areas, the weathered crust can become a thick gossan much prized by prospectors. Groundwater brings dissolved mineral salts to the gossan at the surface leaving colourful minerals such as greenish Malachite and blue Azurite (copper ores).

Students can oxidise iron by exposing steel wool (from the kitchen section of the supermarket) to oxygen in the atmosphere. Damp steel wool oxidises much faster than dry. Students can design their own experiments.

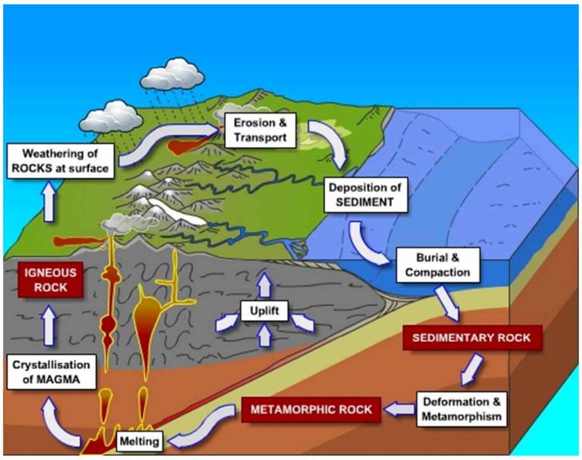
Weathering of rocks at the surface

Chemical weathering by groundwater behind Geraldton WA

Chemical Weathering. When plants die, they can rot to form a mild acid called humic acid (after humus Latin = soil). Humic acid in groundwater can dissolve lime rich rocks such as the one above. The cavity created became a home for bats whose droppings also contributed to rock breakdown. This change to the rock is classified as weathering as the debris remains in situ.

Students can create their own experiments to demonstrate chemical weathering. Humic acid can be made by adding water to potting mix or rotting plant material and leaving it to steep for about a week. The acid can be recovered by straining the mix through a Jay cloth or piece of rag. Vinegar can be substituted for humic acid. Chalk sticks, limestone lumps or small pieces of concrete are left to stand in the acid for 10 days in one container (experimental model). In a similar container a similar lump of chalk etc is left to stand in fresh water (control model). Students can discuss what to measure and how to limit their variables to make this a fair test.

The rock cycle



Process **Erosion**. During erosion the debris or product of weathering is removed. (Latin *e= away from rodos = to gnaw)* mostly by wind or water (including ice). Although there are no glaciers working on the Australian mainland today, in the geological past great glaciers have scoured their way across Western Australia leaving scratches which can still be seen today. Erosion sculpts the landscape.

Erosion and Transport

Swan river in flood WA   Erosion by water

Erosion by river water. Storm water has great erosive power. Two hours after this photograph was taken, the power of the water surges had washed away part of the wall. Without the protective wall the path was soon eroded too.

After rainfall ceases, the power of the river gradually decreases.

Students might give examples of

•Road wash-aways

•Beach undercutting

•Damage to houses and bridges during flooding

•Rivers such as the Gascoyne cutting deep gorges

We use the erosive power of water when we shower. Water carries the dirt away.

Erosion and Transport

Erosion of land surface into gutters   Erosion by water

Erosion by rainwater. Water can erode degraded farmland. Without vegetation to hold it together, water run-off from a storm can cut down through topsoil and carry off the most fertile part. This also leaves the exposed soil open to later wind erosion. Landcare wise farmers plant bands of vegetation and raise contour ridges to prevent this. Landslips and landslides are catastrophic examples of this form of erosion.

Students might give examples of

•Locally degraded land

•Run-off gutters from roads

•Gutters formed under down pipes

Erosion and Transport

Wave cut erosion at Point Peron WA

Bottom of earlier (Ice Age) wave cut platform

Present wave cut platform level

Erosion by seawater. Waves can undercut land and carry the debris out to sea. Here limestone cliffs are being undercut by wave action. The flat top of the limestone cliff is an earlier wave cut platform from times when sea levels were higher during the Ice Age. Sea walls and groynes can reduce wave impact.

Students might give examples of

•Sea stacks and arches collapsing in the Great Australian Bight

•Storm surge walls/barriers protecting Karratha and Port Hedland during cyclones.

•Building groynes at popular beaches to prevent loss of sand and tourists

•American “stars” homes in California collapsing into the sea

Erosion and Transport

Wave Rock near Hyden WA Erosion by wind

Erosion by wind. Sand grains carried by wind have worn away this rock and carried away the debris. Here at Wave Rock in the wheat belt of W.A., humic acid has chemically started the breakdown of granite at ground level. Wind blown sand erosion has started at this weakened level and worked upwards creating the cave like curve. If you have walked along a beach you will also have noted that wind and sand "sting" is strongest closest to the ground.

Constant abrasion by wind blown sand causes "desert varnish" on exposed rock in our interior.

Students might give examples of:

•Car "Duco" or paintwork being rendered dull by inland dust and wind

•Ankle sting from wind blown sand

•Sand blasting waterside restaurant windows rendering them opaque

•"Desert Polish" of stones lying on the land surface. The abrasive wind and sand leaves a unique opaque patina.

•A hand lens or magnifying glass can be used to see that the surface of individual grains of desert sands (silica) have been rendered opaque.

Erosion and Transport

Physical, chemical and biological erosion

Erosion multifactorial. Wind, water, gunpowder, human feet and souveniring tourists have eroded these 2,500 year old steps of the Parthenon in Athens.

Students might mention human erosion examples:

•Worn paths formed through lawns eroded by human feet and bicycles

•Wheel tracks cut into arable land and salt lakes

•Worn patches on sports grounds where most "play" occurs

•Worn steps at the entrance to public buildings including schools

•Elbow polish on school canteen benches

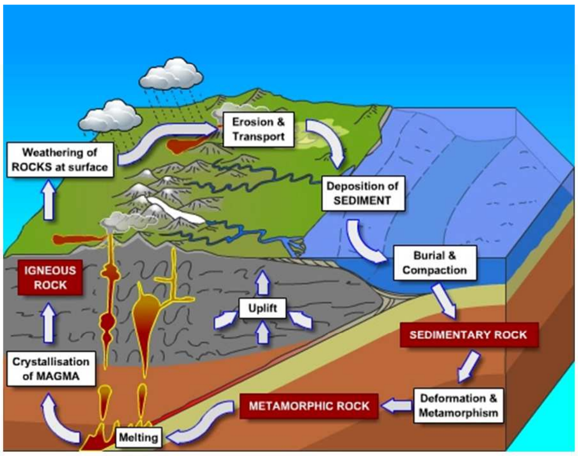
•Paint worn off doorways as people rub against them

•Hand polish on door edges

The flume tube experiment will demonstrate the erosive power of water.

Decrease of grain size and increase of roundness of fragments can be demonstrated using broken pieces of teacher's chalk or waxy crayon. Three students place the same material into three similar containers. Students shake their container vigorously for 1 minute, 5 minutes and 10 minutes each. The changes to size and shape of the fragments can be compared. The greater distance from source/longer period of erosion, the smaller the size of material and the rounder it becomes.

The rock cycle



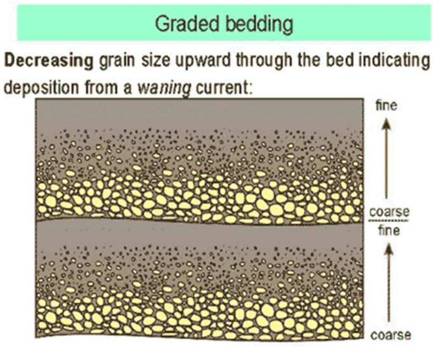
Process **Sedimentation** (*Latin sedeo* = *sit*) Wind and water deposit the transported debris to form sediments. Materials are often sorted by grain size or density to form beds or layers. Almost all sediments produced, whether on land or at the coast, are eventually transported to deep basins in the oceans.

Deposition of sediment

Old sand dune sediments near Mundijong WA

Deposition by wind forming dune bedding. These recent (Pleistocene or Ice Age) calcareous sandy sediments are formed from materials weathered from rocks of the Darling Ranges which have been transported by ancient rivers into the sea. There it was mixed with broken shells lying on the sea bed. The sea has thrown the debris up onto the shore and winds have blown them to become dune sediments. They dune bedding is massive. These sands comprise the yellow builders sand used as foundation pads for houses and form the base of many major roads in the coastal plains of Western Australia.

Deposition of sediment



Deposition – graded bedding. Heavy fragments (pebbles, boulders) can only be carried by strong winds and fast flowing streams. Rivers are strong after rain but their power decreases after it stops. This results in grain size decreasing upwards to create graded bedding. Grain size also decreases from source as friction slows river speed. Large fragments are deposited close to source to form conglomerates whilst finer clay sediments can be carried far away, well out to sea. The further a fragment is carried from source, the rounder it becomes due to friction.

Brighter students may realise that the next fall of rain will produce an erosive phase by the river which may cut into the sediments previously deposited before starting to deposit its debris and cross bedding is produced.

Sometimes graded bedding can be imitated using soil, water and a large glass jar with lid. Sediments of mixed sizes are placed in the bottom half of the jar, well covered with water and the lid firmly placed on top. The jar is shaken vigorously and then left to sit. As the water agitation/energy decreases it is less able to keep the larger fragment afloat. The resulting “bed” should grade for coarse at the base, to fine at the top.

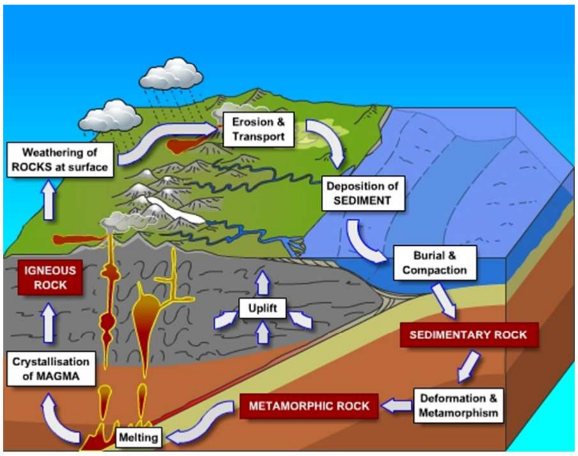
Deposition of sediment

Graded bedding in quartzite

Deposition by water. This ancient sandstone rock demonstrates grain size decreasing from coarse at the base to fine on top. This is graded bedding. (Weathering is apparent on its upper surface where it was exposed to the environment after burial, compaction and uplift).

Students can make their own example of graded bedding in the “Rock God” experiment. Using the worksheet provided, in the left column they write about what is happening to the river. In the left column they spread glue and then stick the appropriate sediment size onto the sheet to provide a picture of the strata which would have been formed as a result of the events described in the right column. The story can be of one wet season or many. It is difficult to stick pebbles onto paper. In this case the pebbles can be drawn.

The rock cycle



Process **Burial & Compaction.** As more beds of sediment are added water and air is squashed out of pores between the grains. Pore spaces can be filled by cementing agents from groundwater. Calcium carbonate, silica and iron ore are the most common cementing agents. Beds become compacted but retain many of their original sedimentary features. The process of turning a sediment into a rock is called lithification.

Burial, cementation and compaction

Fossil beach. Cemented on left and cemented and compacted on right

Compaction and compression. The shells of this Myalup Pleistocene beach (left) have been cemented by calcium carbonate in groundwater. There is little compaction as the deposit is recent. The rock is therefore quite soft and crumbly.

The older Karratha beach deposit (right) is more much compacted and has been cemented by silica to form a very hard rock. In both cases fossil beach shells remain visible.

A brave teacher who wishes to demonstrate the effect of compaction can half fill a large jar with sand and place a very ripe tomato or two on top. The jar is then filled to the top with more sand. Using their fist or a potato masher, the sand and tomato beds are compressed firmly. The difference of level between compacted and uncompacted sediment can be observed. (It takes a lot of vegetation to make a narrow band of coal)

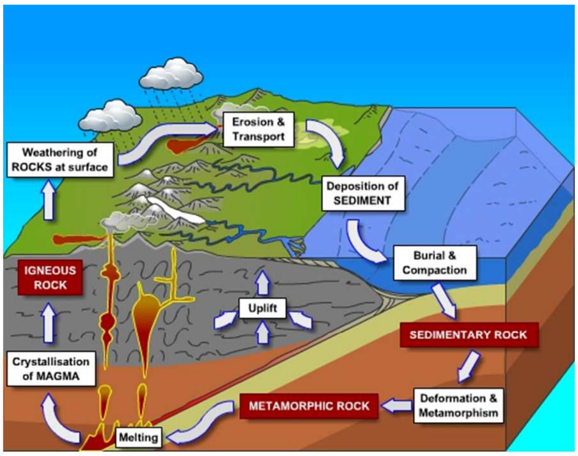
Burial, cementation and compaction

Students can create their own rock columns by placing layers of coarse to fine sediments into plastic drink cups and pressing them down firmly. The cementing groundwater can be made from a supersaturated solution of Epsom salts. (Keep adding Epsom salts to hot water and stir until no more can be dissolved). Soak the sediments and leave for a couple of weeks to dry. The plastic can be removed and students can challenge each other to guess “Way up”.

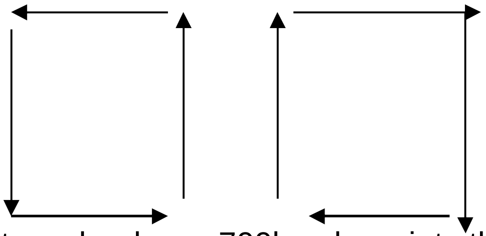
Possible extension – Fossils and geological time

If plastic dinosaurs or equivalent are placed in only one bed by each student, they can be used as index fossils. Since the dinosaurs represent the same period of time, students can arrange their columns to line up the dinosaur beds and find who has the oldest beds and who has the youngest.

The rock cycle



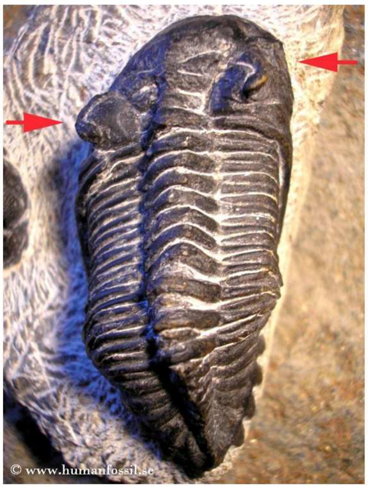
Process **Deformation and Metamorphism** (Greek *meta = change morphe = form)* Material is drawn down into the Earth at subduction zones. Heat from radioactive decay melts rock making it less dense. Rock in the asthenosphere can be heated to between 200^{0}C and 500^{0}C. This melted rock rises and simple convection cells are formed. As one part of the cell rises the other is drawn down.



Rock from the crust can be drawn 700km down into the mantle. With increasing depth the mass of overlying sediment can cause fossils and sedimentary structures to become deformed and some mineral grains to melt and recrystallise. Pressure causes these minerals to orient themselves and form cleavage. Metamorphic rock usually retains some of its sedimentary features. Bedding may be evident by variation in composition of layers and cleavage (sometimes) following bedding. Original fossils may still be interpreted by their outlines.

Heat and pressure causes rock to become plastic and fold and faults occur.

Deformation and metamorphism



Deformation. Both these trilobites (extinct arthropods) are of the same age, however the specimen on the right has been deformed as the rock metamorphosed. Only selective parts of animals are strong enough to withstand burial and deformation.

Deformation and metamorphism

Fold in ancient Archaean rock near Cue WA

Deformation. Under great pressure and temperature even hard rock like this sandstone can become “plastic” and deform. Note the rusty weathered surface of the folded sediment..

Deformation and metamorphism

Limestone

Marble

Metamorphism. Soft porous limestone on the left has been metamorphosed by heat and pressure within the Earth to become solid marble. The chemical composition of both rocks is still the same ($CaCO_3$) but recrystallisation gives the metamorphosed marble different properties.. Although limestone will easily absorb water poured on its surface, marble is hard, shiny and water resistant, which makes it excellent for kitchen bench tops and flooring.

Similar changes in physical properties can be seen when cooking (metamorphosing) food.

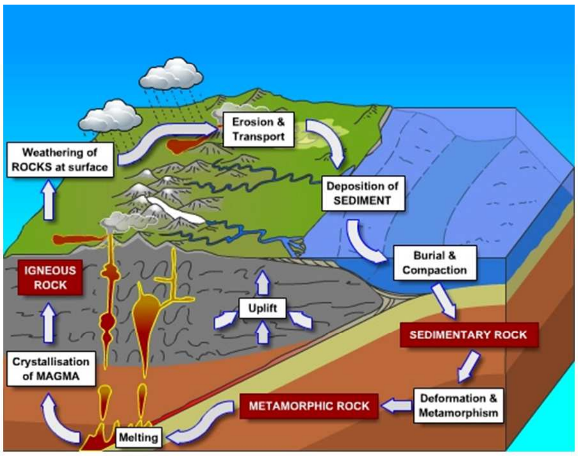
Hard potatoes become	soft mash
Sugar becomes	toffee
Raw egg becomes	scrambled egg

.

Deformation and metamorphism

Metamorphism. Even igneous rock can become metamorphosed. This rock was formed from two quite different igneous rocks, a dark basalt and a light granite. These have been partially melted together to become a gneiss. Gneisses can be found in the Yilgarn and Pilbarra.

The rock cycle



Process **<u>Melting.</u>** Molten rock is much less dense than solid rock. It will begin to rise towards the surface. If it moves quickly and is still liquid when it reaches the surface it will become a volcano. At depth molten rock can cut across bedding to form dykes or run parallel to bedding forming sills.

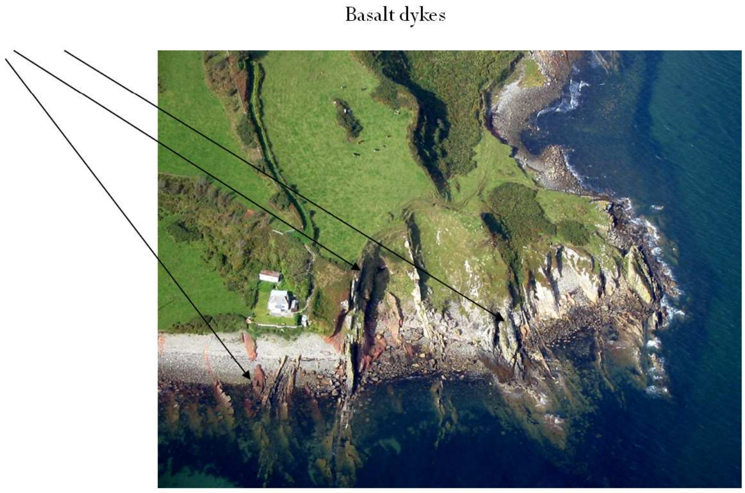
If the rock solidifies at depth, then it requires uplift from folding and faulting to rise.

Melting

Mundaring granite WA

Melting No sedimentary structures from the original rock remain. The minerals have melted and recrystallised and the rock has become a granite. In the same way the ingredients for a chocolate cake, flour, eggs, sugar, milk and chocolate change completely on cooking.

Melting

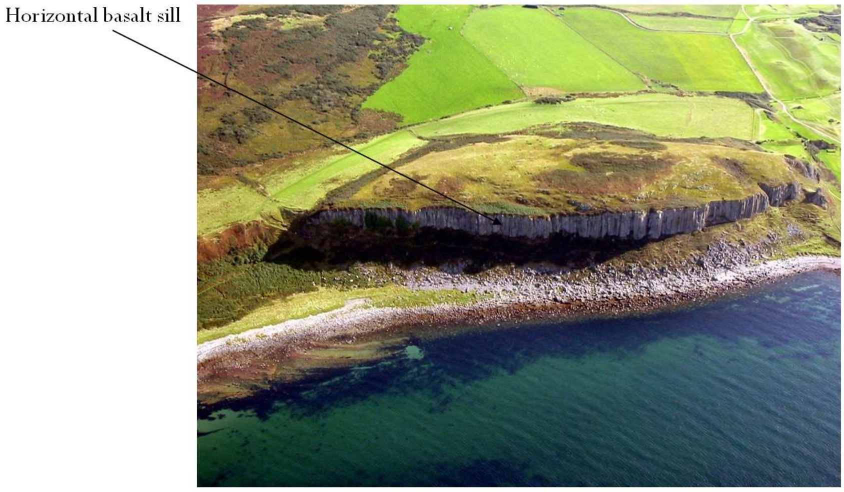


Melting. At depth rock was melted became ***magma*** and rose. Liquid basalt magma was intruded into cracks in up-domed red sandstone to form intrusive ***dykes.*** Since basalt is much harder than sandstone, when the rock was later weathered the basalt remained to form upstanding “walls”.

The great Jimberlana dyke near Norseman is over 180 km long and is 550 million years old

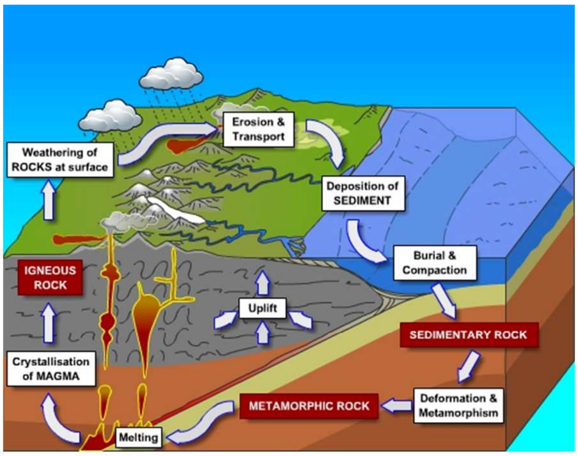
More information on melting can be found at http://amonline.net.au/geoscience/earth/magmatism.htm

Melting



Melting. At depth rock melted, formed magma and rose. Basalt (the magma) intruded along a weak bedding plane in sandstone to create this intrusive horizontal sill.

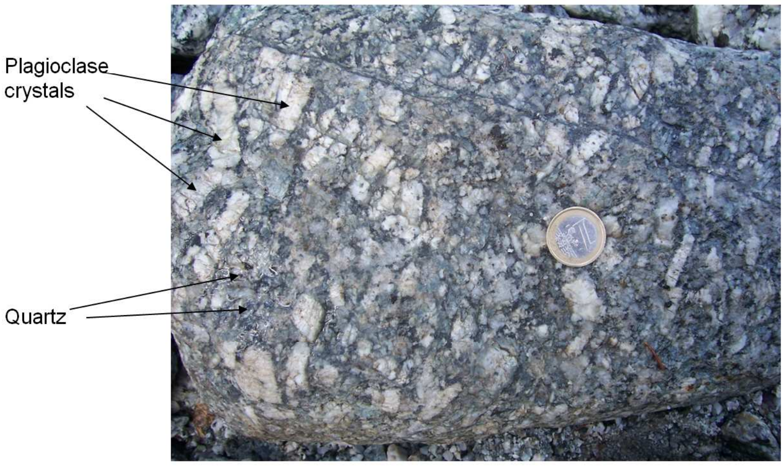
The rock cycle



Process **Crystallisation of magma** Molten rocks will crystallise when cooled. Slow cooling allows for the formation of large well shaped crystals. Rapid cooling, such as when a lava pours out into the air, results in minute crypto-crystalline rocks. Molten rock (magma) from the crust produces lighter rocks rich in silica whereas inclusion of mantle will create darker iron and magnesium rich rocks. Magma collects in chambers called batholiths.

Students can copy this process by allowing half of a super-saturated salt solution to cool slowly over several days and form large cubic crystals. The other half of the solution can be heated and allowed to almost boil dry (Careful – the solution can spit! Glasses must be worn). Rapidly dried salt has no obvious crystals.

Crystallisation of magma

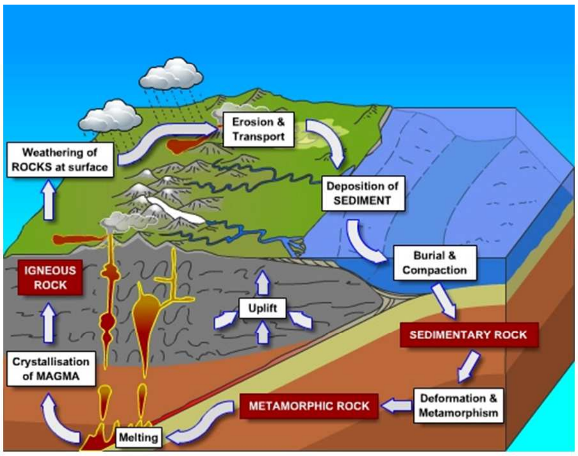


Rock solidifying at depth is able to form large crystals if it cools slowly. Later crystallising minerals must fill in the spaces that are left and their crystals will be smaller and less perfectly formed. Large well formed plagioclase crystals are obvious in this rock. Students can copy this process by allowing half of a super-saturated solution of Epsom Salts (magnesium sulphate) to cool slowly. The other half is mixed with a similar solution of sugar. Crystals vie for space in the mixed solutions.

Crystallisation of magma

The Petri dish on the left had only Epsom salts (magnesium sulphate) and fine needle-like crystals have formed. The Petri dish on the right however contained a mixture of sugar and Epsom Salts and sugar. The two substances have had to compete for crystallisation space and neither crystal shape is very evident.

The rock cycle



And the cycle begins again. Not all rocks go through the whole cycle before returning to the surface to be weathered. Pleistocene deposits on Western Australia's coastline have already been uplifted and are being weathered and eroded without being deformed, melted and recrystallised.