Laying down the principles
Sequencing the events that form rocks through applying stratigraphic principles

There is a series of key scientific principles that helps us to sort out sequences of geological events. These have complex-sounding names, but are very simple to demonstrate, understand and use. Together they are called '**Stratigraphic Principles'**. Some are indeed 'principles' that generally apply (but there may be specific unusual circumstances when they don't), whilst others are 'laws' that always apply. Try teaching them using a demonstration like this.

Successive near-horizontal continuous layers in a plastic box full of water

(*Photo: Peter Kennett*)

Put some water into a transparent container (eg. glass jar, large drinking glass, or the box used to make Earthlearningidea 'mountains' and 'valleys') – this is a 'sedimentary basin'. Add some sand to make a layer on the bottom (eg. a layer about 3 mm thick), then add a second layer of different coloured sand. Repeat this to build up four layers of sand, two of one colour, two of another – this is a 'sedimentary sequence'. Then follow this questioning sequence (*answers in italics*):

'Superposition of Strata'
- Which layer was deposited last and so is the youngest? *The top layer.*
- This illustrates 'Superposition of Strata'.
- Is the layer on top of a sequence of sediments **always** the youngest (if so, it is a law) or is it just **usually** the youngest (a principle) because there are unusual situations when it may not be so? *Usually the youngest – a principle, '**the Principle of Superposition of Strata**'.*
- In what situations would it not apply? *If the whole sequence was overturned (turned upside down) by folding, for example, or if a slice of older rock was faulted over a younger sequence.*

'Original Horizontality'
- Are the layers nearly flat and horizontal? *Yes.*
- This is 'Original Horizontality'.
- Are sedimentary layers always laid down nearly flat and horizontal (law) or are there occasions when they are laid down at an angle (principle)? *They may be laid down at an angle – so this is a principle, '**the Principle of Original Horizontality**'.*
- In what situations would it not apply? *Layers on the face of a sand dune, a coral reef scree or a mountain scree slope (slopes of up to 30^{o}).*

'Lateral Continuity'
- Are the layers continuous across the 'sedimentary basin'? *Yes.*
- This is 'Lateral Continuity'.
- Are layers like these always laterally continuous across a basin (law) or might there be circumstances when they are not (principle)? *It is a principle – the '**Principle of Lateral Continuity**'.*
- When doesn't it apply? *No layers could ever be continuous forever. They stop for only two reasons. Either they meet an 'edge' such as the edge of the sedimentary basin (puddle, pond, lake or the sea) as in this demonstration, or they just peter out as the supply of material that forms them runs out.*

'Included Fragments'
- The sand grains are pieces (fragments) of minerals or rocks. Which came first (and so are oldest) the sand grains or the layers they make? *The sand grains.*
- The sand grains are 'Included Fragments' in the layers.
- Are included fragments always older than the rock in which they are found (law) or might there be situations where this isn't so (principle)? *It is a law, '**the Law of Included Fragments**'. Providing a fragment really is included (and doesn't just appear to be so) – it **must** be older than the rock in which it is found, whether this is a sedimentary, igneous or metamorphic rock.*

'Cross-Cutting Relationships'
- Take a solid object (eg. a ruler) and push it into the sand to cut the layers.

Cross-cutting the layers. (*Photo: Peter Kennett*)

Ask: Which came first, the layers or the cut? *The layers.*
- This is 'Cross-Cutting Relationships'.
- Are things that cut other things always younger (law) or might this not always be true (principle)? *It is a law, '**the Law of Cross-Cutting Relationships**'. Anything (fracture, fault, dyke, boundary) that definitely cuts something else must be younger.*

These are the five key stratigraphic principles.

Rock deformation and 'Faunal Succession'

Two other important guidelines in sequencing rocks are:
- rock deformation (folding, faulting, metamorphism) can only take place after the rock is formed – so is always 'younger' than the formation of the rock;

- fossils in rocks occur in a fixed, worldwide sequence which is never repeated - this is ***'the Law of Faunal Succession***' which can be used to sequence, correlate and relatively date fossil-containing rocks wherever they are found.

See how these principles can be applied to the structure of an oil prospect in the Earthlearningidea activity, 'Where shall we drill for oil?', to be published on 8th September 2008.

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The back up

Title: Laying down the principles

Subtitle: Sequencing the events that form rocks through applying stratigraphic principles

Topic: The relative dating of the events that form rocks and rock sequences through applying stratigraphic and other principles.

Age range of pupils: 11 – 18 years

Time needed to complete activity: 15 mins

Pupil learning outcomes: Pupils can:
- describe the principles used to understand and sequence sedimentary rocks (some of which can be applied to other types of rock);
- apply the principles in suitable situations;
- distinguish between a 'principle' and a 'law'.

Context:
The activity illustrates in a visual way most of the major principles/ laws/ guidelines that geoscientists use to work out the sequences of events that formed and deformed rock sequences (the relative dating of the events), and from those, the geological history of the rocks in an area. Broad application of these principles has allowed geoscientists to build up a picture of global geological history. It was only after this had been done that radiometric dating methods were able to add dates to the events in years/ millions of years (absolute dating methods).

The Stratigraphic Principles have been recognised for a long time:
- 'The principle of Superposition of Strata'
- 'The principle of Original Horizontality'
- 'The principle of Lateral Continuity'
- 'The law of Cross-Cutting Relationships' – the above four, all by Nicholas Steno, 1699
- 'The law of Faunal Succession' – William Smith, 1796
- 'The law of Included Fragments' – Charles Lyell, 1845

Following up the activity:
Ask the pupils how the apparatus demonstration could be extended to include rock deformation (*deform the layers after they have been deposited, eg. by moving the ruler sideways*) and the 'law of faunal succession' (*bury items from a known time sequence one by one as the layers are built up, eg. parts of different types of container used over the years, such as: a clay pot, a tin can, a plastic container*)

Underlying principles:
- These principles are the fundamental methods used by geoscientists to sequence rocks and rock events.

Thinking skill development:
- The principles are patterns applied to sequences (construction)
- How the principles should (and should not) be applied causes cognitive conflict
- Discussion of the application of the principles involves metacognition
- The principles can be applied (bridged) to a range of other contexts including archaeological and forensic ones.

Resource list:
- a transparent container (eg. glass jar, large drinking glass, or the box used to make Earthlearningidea 'mountains' and 'valleys')
- two cupfuls of sands of different colours (eg. red sand, yellow or white sand)
- a spoon or scoop to add the sand to the container
- water
- a ruler (15 or 30 cm long)

Useful links:
http://www.esta-uk.org/jesei/sequenc/home.htm
http://www.ucmp.berkeley.edu/fosrec/BarBar.html

Source: This activity was devised by Chris King of the Earthlearningidea team.