GCSE Geology 2.3: Geochronological principles

Geological materials and events can be dated using **relative dating** and **absolute dating** methods.
Relative dating is a method by which geological material and events are considered to be simply older or younger than other materials/events.
Absolute dating gives an age in years for geological materials and events.

Basic principles

Uniformitarianism (simplified as 'the present is the key to the past') assumes that processes observable today also took place in the geological past.
For example, ripple marks observed on a beach today can be linked with ripple marks on the surface of a sandstone bed that is 300 million years old.
The ripple marks in the sandstone must have originally formed in the same way in a shallow marine environment under the influence of wave action.

Original horizontality – the concept that sedimentary rocks are originally deposited in horizontal layers/beds. Any sedimentary layer that is not horizontal now (i.e. it is dipping) must have been moved/tilted/folded by tectonic forces.

Lateral continuity – the concept that sedimentary rocks were originally deposited horizontally over vast areas of the Earth's surface in a continuous layer. Since then, tectonic activity and erosion have separated them into many separate smaller outcrops.

Superposition – the concept that if that one bed of sedimentary rock lies on top of another, then the one on the top is younger. This assumes that the beds have not been overturned and can be checked by looking for way-up structures such as graded bedding, cross bedding, ripple marks and desiccation cracks.

Cross-cutting relationships – if one rock is cut by another, then the rock doing the cutting is younger.

Included fragments – if one rock contains fragments of another rock, then the included fragments will be older than the rock they are in.

Some fossil groups show morphological change with time and can be used for relative dating and correlation. Such fossils are called **zone fossils.**

Cephalopods show distinct changes in suture lines from the Carboniferous to the Cretaceous. The suture line is where the internal chamber wall meets the outer edge of the shell.

Cephalopod type	Suture pattern	Age
Goniatite	Simple, smooth zig-zag suture	Carboniferous
Ceratite	More complex suture with alternating frilly/crenulated lobes and smooth saddles	Triassic
Ammonite	Very complex suture with very frilly/crenulated lobes and frilly/crenulated saddles	Cretaceous

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Graptolites show distinct changes in the number of stipes (branches) and the shape and spacing of the thecae along the stipes, from the early Ordovician to the late Silurian.
The number of stipes decreased from eight to one.
The stipes changed from hanging downwards (pendant), became horizontal and eventually pointed upwards (scandent).
The thecae started off on one side of the stipe, then were later present on both sides.
Thecae became wider spaced along the stipe over time.
Thecae changed from simple cups to more elaborate shapes over time.

Absolute dating uses the decay rate of radioactive isotopes to give an age, in years before present, for some rocks and minerals. Uranium-Lead has been used to establish the age of the Earth as 4.567 billion years old. Other methods include Potassium-Argon and Rubidium-Strontium.

Minerals such as feldspar and mica contain small amounts of unstable radioactive isotopes which begin to decay as soon as they have crystallised.
The method is based on the half-life concept – the amount of time it takes for half of the original radioactive material to decay to stable daughter atoms.
If the percentage of remaining radioactive parent atoms can be measured along with the percentage of daughter atoms, then the age can be calculated.

Number of half-lives elapsed	Percentage of parent isotope %	Percentage of daughter isotope %
0	100	0
1	50	50
2	25	75
3	12.5	87.5
4	6.25	93.75

A mineral sample has a ratio of 12.5% parent atoms to 87.5% daughter atoms. The half-life of the radioactive material (Uranium-235) is 700 million years.

The age of the sample is calculated by multiplying the number of half-lives elapsed by the length of the half-life.
In this case, 3 x 700 Ma = 2,100 million years old.

A number of scientists have attempted to date the Earth using a variety of methods since the 17th century.

Scientist	Date	Method	Age of the Earth
Archbishop Ussher	1650	Studying all the stories in the Old Testament of the Bible	Formed 4004 BC (so 6026 years old in the year 2022)
James Hutton	1785	The unconformity at Siccar Point; he realised the Earth was immeasurably old with 'no prospect of an end and no vestige of a beginning'	No actual age of the Earth stated
Lord Kelvin	1862	Simulated the rate of cooling of red hot iron balls and scaled up his calculations to an iron ball the size of the Earth	20-400 million years old
John Joly	1899	Calculated time taken for salt to accumulate in the oceans due to erosion of rocks on land	80-100 million years old
Arthur Holmes	1946	Radiometric dating using Uranium-Lead method	4,500 Ma +/- 100 Ma