But how old is it?
Investigating radioactive dating of rocks and minerals

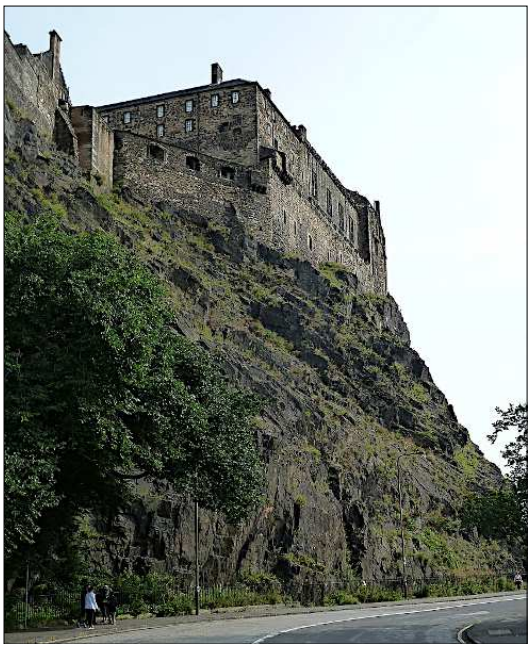
For many years rocks were put in sequence by relative dating methods explained in the Earthlearningidea 'Laying down the principles' https://www.earthlearningidea.com/PDF/Laying_down_the_principles.pdf

Ernest Rutherford was the first to suggest that the discovery of radioactivity could be used to date rocks, in 1905. It was found that the radioactive elements contained by some rocks and minerals break down to form other elements. Their decay over time happens in a predictable way that can be shown on a graph.

The radioactive element that decays is called the parent; the new element produced by the decay is the daughter. After a certain time, half the element has broken down to produce the daughter; this time is called the half-life.

Watch the video 'Radioactive countdown'. In order for the pupils to be able to carry out the instructions in the video, it will have to be paused on some slides. They will need graph paper, a pencil and ruler. https://www.earthlearningidea.com/Video/Radioactive_dating.html

Although all radioactive materials break down according to the pattern shown in the video, the lengths of their half lives vary enormously, from billions of years to microseconds and less. If we choose a radioactive element with a known rate of breakdown, we can measure the amounts of parent and daughter products, to give us the age when the element was first trapped in the newly forming mineral or rock. In most cases this then gives the age of the mineral or of the rock in which it is found. This method is called absolute dating because it gives an age in years, thousands, millions or billions of years. As the measurements involve a calculated small amount of error, radioactive or radiometric dating measurements are always given with the potential error shown.



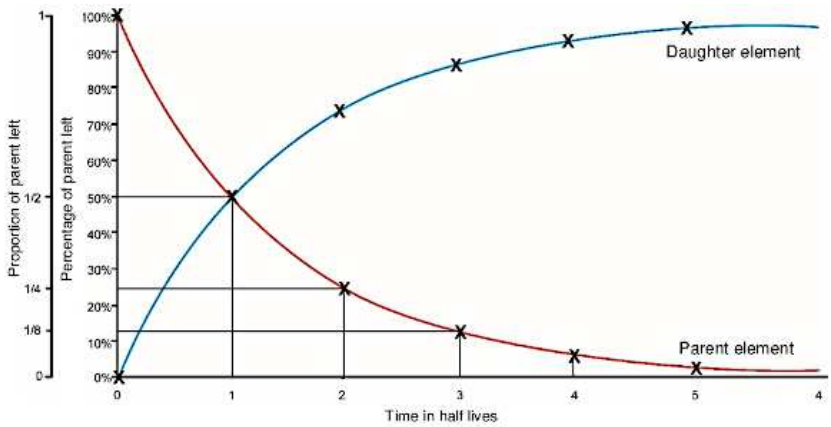
Edinburgh Castle - southern aspect

The city of Edinburgh in Scotland is built around an ancient volcano. Feldspar minerals from the volcanic rocks were used to date the eruption. The date given by the radioactive decay of the argon in the feldspar was 349 + or - 4 million years, showing that the volcano erupted in Carboniferous times between 353 and 345 million years ago.

Ask the pupils to:

- Think about how the three major rock types form - igneous, metamorphic and sedimentary. Where are radioactive minerals found? Which of the rock types do they think could be used for radioactive dating and why?

A. Radioactive dating can only be used for rocks or minerals which contain the right type of radioactive elements. This works well for most igneous and some metamorphic rocks. It is not so useful for sedimentary rocks, since the grains of sediment were formed earlier, before being eroded and deposited.



The radioactive decay curve for the breakdown of all radioactive materials,
Chris King

Use the radioactive decay curve to answer the following questions;

- If waste material from a nuclear reactor would only be safe after five half lives and it had a half life of 600 years - how long before it will be safe?

A 600 x 5 = 3000 or 3 thousand years

- If the radioactive materials in a dark igneous rock were 25% parent to 75% daughter atoms and the half life was 200 million years - how old would the rock be?

A 2 x 200 million = 400 million years

- If one sixteenth (6.25%) of the radioactive atoms in a granite were parent atoms and the other fifteen sixteenths were daughter atoms and the radioactivity in the rock had a half life of 180 million years - how old would it be?

A 6.25% of parent atoms have decayed so four half lives have passed
180 million x 4 = 720 million years old.

- If some radioactive rods from a nuclear reactor had just become safe after six half lives and three years - how long is the half life of the radioactivity?

A 6 half lives in 3 years so 1 half life must be 6 months.

The back up:

Title: But how old is it?

Subtitle: Investigating radioactive dating of rocks and minerals

Topic: This activity investigates how radioactive (radiometric) or absolute dating of rocks and minerals works

Age range of pupils: 12 plus

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:
- carry out an activity to demonstrate radioactive decay of parent to daughter atoms,
- explain the concept of half life
- plot and use a radioactive decay curve graph
- calculate ages of rocks from given data
- explain how radioactive dating is used;

Context:
Radioactive dating is a very important process for geologists and the geological timescale has accurate dates plus or minus a few years. The International Chronostratigraphic chart contains the absolute dates of the boundaries between the different elements of geological time and is published by the International Union of Geological Sciences' International Commission on Stratigraphy, see: https://stratigraphy.org/chart
This activity focuses on the absolute dating of rocks, but this method can also be used to date any material that contains elements that radioactively decay, such as the use of carbon-14 in archaeology.

Following up the activity:
- Pupils could be given more questions based on the radioactive decay curve, with more complex arithmetic involved.
- They could research the vital role that carbon-14 radioactive dating plays in archaeology.
- They could research the fact that in regions of the UK where underlying rocks are granites, shales or limestones, radioactive decay can release radon to the surface. Radon maps of the UK are published and houses in a high radon area should be well ventilated, since radon poses a cancer risk.

Underlying principles:
- Radioactive elements occur in many igneous and metamorphic rocks and minerals.
- The parent radioactive atoms decay to daughter atoms over time.
- The time it takes for half the parent atoms to decay to daughter atoms is called the half-life.
- If the half-life for a particular element is known and if the percentage of parent and daughter atoms in a mineral or rock is known, then the age of that mineral or rock can be calculated.
- The half life of every radioactive substance is different and fixed.
- The parent material never reaches 0% and the daughter material never reaches 100%.
- Although geologists knew the sequence of geological events, it was not until the radioactive dating of rocks was developed in 1905 that they could put ages in years and millions of years on these events.
- Uranium - lead dating , (U-Pb), is one of the oldest and most refined of the radioactive dating methods. It can be used to date rocks that formed and crystallised from about 1 million years to over 4.5 billion years.
- Other elements that are used in radioactive dating by geologists are potassium to argon, rubidium to strontium.
- If the element has a short half life, it decays relatively quickly so can be used only for dating young objects, e.g. carbon-14 has a half life of 5,730 + or - 40 years and can only be used to date objects up to 50,000 years old.

Thinking skill development:
As pupils draw their own radioactive decay curve, a pattern emerges. Working out the age of rocks or minerals by knowing their percentage of parent to daughter atoms can result in cognitive conflict. Discussion about the process involves metacognition and equating the coloured dots in the video to real parent and daughter atoms is bridging.

Resource list:
- graph paper, pencils, rulers or spreadsheet

Useful links:
Radioactive decay video:
https://www.youtube.com/watch?v=5_vKvJO7Kqw

Source: Elizabeth Devon of The Earthlearningidea Team with reference to Exploring Geoscience across the globe, IGEO
http://www.igeoscied.org/teaching-resources/geoscience-text-books/
and the ESEU KS4 material