When did the poles 'flip'?

Simulating how the Earth's Geomagnetic Polarity Time Scale was established.

As molten volcanic rocks cool, iron-rich minerals aligned in the direction of the Earth's magnetic field are trapped, effectively recording the magnetic polarity of the Earth at that time. By studying the magnetic patterns preserved in both continental lava flows and those dredged from the ocean floor, scientists have discovered that the Earth's magnetic field has experienced many polarity reversals over time. In the past 5 million years, there have been, on average, 4 or 5 reversals every million years.

Continental lavas can easily be accessed and their ages determined using radiometric dating techniques. When combined with an analysis of their geomagnetic properties, this has enabled a Geomagnetic Polarity Time Scale (GPTS) to be accurately established for the last 83 million years of Earth's history. This Earth Learning Idea simulates how the GPTS was established.

Setup Instructions

- Construct a cliff face* using building blocks measuring 3.2 x 3.2 x 2.4 cm (Fig 1a). The model should be 10 rows high, with one section designed to be easily removable. This removable section will represent the lava flow 'samples' for analysis. (* *The cliff face is optional - only the 'sample' sequence is necessary for analysis*).
- Secure rounded neodymium magnets (10 mm x 3 mm) to the underside of each of the 10 lava sample blocks. Position the magnets within the central support tubes of each block. Use a modelling clay or putty (like Blu Tack™) to attach the magnets, allowing for a semi-permanent attachment that can be easily removed if needed (Fig 1b).
- Position the magnets so that opposite poles alternate on the uppermost surface of each block, following the pattern required to simulate the polarity reversal pattern (Fig 1c).
- Add appropriate radiometric dates to the 10 lava samples for analysis (Fig 1a).

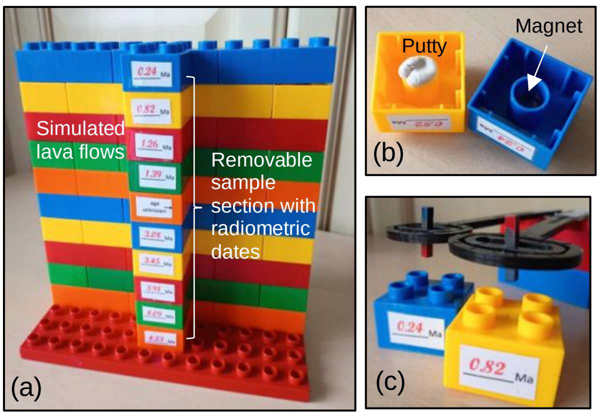

Fig 1: (a) Simulated lava flow sequence with radiometric dates; (b) Magnet set up; (c) Measuring magnetic polarity using a *Magnaprobe*, (blue-normal, yellow-reversed). (*Pete Loader*)

Creating a polarity time scale

- Direct students to the worksheet (Appendix 1), which includes both a blank and a simplified geomagnetic polarity time scale. Explain that each of the 10 blocks in the removable vertical sequence represents a sample of rock from each lava flow in the cliff for analysis.
- Ask students to remove each sample (1-10) from the vertical sequence and record its age on the blank column of the worksheet in its correct stratigraphic position.
- Next, students should measure the magnetic polarity of each block by using a Magnaprobe (or an equivalent device such as a vertically oriented compass or a magnetized needle suspended on a thread). They should record the effect on the device as the magnet's north pole is either attracted to, or repelled from, the lava sample. Record a positive value (+) when the north pole of the device is attracted to the block's top surface, and a negative value (–) when the north pole is repelled.
- Emphasize that the measurement should always be taken on the top of each block. Ask students why it's important to maintain the sample's original field orientation when taking the measurement. *The block must be positioned the same way up as it was in the lava flow to correctly record the magnetic field trapped when the lava cooled.*
- Shade in Appendix 1 for each lava sample that records a positive (normal) polarity, leaving blank those samples with a negative (reversed) polarity.
- Instruct students to complete the worksheet by correlating the simulated lavas with the established GPTS. They should draw lines from each dated lava sample in the simulation to the corresponding date on the established GPTS. (Two have already been completed).
- Ask students to discuss the possible age of the undated lava (6). *Normal period either between 3.05 – 2.59 Ma or 2.00 – 1.78 Ma.*

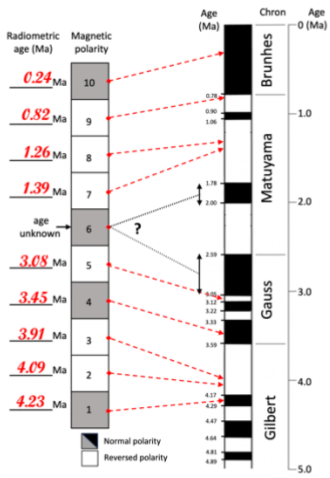

Fig 2: Final simulation and correlation (*Pete Loader*)

Through this process, students will observe that the magnetic polarity recorded in each lava sample matches the polarity identified in the established GPTS.

The ocean's magnetic stripes are dated by comparing this timescale to the pattern of magnetic anomalies found on the seafloor, which are more challenging to access directly.

The back up

Title: When did the poles 'flip'?

Subtitle: Simulating how the Earth's Geomagnetic Polarity Time Scale was established

Topic: The Earth's Geomagnetic Polarity Time Scale.

Age range of pupils: 14 - 18 years

Time needed to complete activity: 20 minutes

Pupil learning outcomes: Pupils can:
- describe the pattern of geomagnetic reversals collected from continental lava;
- record both the age and magnetic polarity of a simulated sample of lava and correlate this with the established geomagnetic polarity time scale for the Earth.
- explain that changes on geomagnetic polarity identified in continental lava result from reversals of the Earth's magnetic field;
- explain that geomagnetic field reversals are common on geological timescales and can been dated from more accessible continental lavas on land;
- explain that the ocean's magnetic stripes are dated by comparing this timescale to the pattern of magnetic anomalies found on the seafloor, which are more challenging to access directly.

Context: This activity can be used to help teach students to understand how the pattern of ocean floor anomalies (magnetic stripes) can be dated; something they rarely appreciate. It might be used prior to a lesson on the palaeomagnetic evidence for plate tectonics on the ocean floor.

Following up the activity: Each student can be given different 'samples' with differing ages (and polarities) and work as group to come up with a meaningful GPTS. This is best when samples are just younger than and just older than a specific reversal. Students might also research the current extension of the Geomagnetic Polarity Time Scale back to approximately 155 million years. In addition, students can attempt other related Earthlearningidea activities linked to this subject:
- https://www.earthlearningidea.com/PDF/457_Magnetic_anomalies.pdf
- https://www.earthlearningidea.com/PDF/81_Magnetic_stripes.pdf

Underlying principles:
- Magnetic minerals in continental lavas record and 'lock in' the polarity of the Earth's magnetic field as the lavas solidify and cool below their crystallising temperature, to a temperature known as the Curie Point.
- The Earth's magnetic field 'flips' from time to time. This creates periods of normal polarity (as today) and reversed polarity (opposite to today). Periods when the predominant magnetic field direction was either normal or reversed are called chrons.
- These polarity reversals occur randomly because of changes in the Earth's core.
- Through analysis of seafloor magnetic anomalies and dated reversal sequences on land, scientists have developed a Geomagnetic Polarity Time Scale - based on dating lava flows just younger than and just older than a specific reversal.
- The current time scale for the last 83 million years contains 184 polarity intervals (183 reversals) but has been extended back to 155 Ma and beyond.

Thinking skill development: The simulation allows a pattern to be developed through construction; cognitive conflict develops when the pattern becomes ambiguous through irregular and missing time intervals (e.g. students challenged to think about the possible age of lava flow 6). Metacognition requires the development of bridging skills in relating the simulation to the real GPTS.

Resource list:
- Large, coloured, children's building blocks - 3.2 cm and 6.4 cm x 3.2 cm x 2.4 cm (e.g. Lego™)
- 10 strong, rounded, neodymium magnets (10 mm x 3 mm).
- modelling clay/putty (e.g. Blu Tack™)
- magnetic recording device - Magnaprobe™ (compass or magnetised needle)
- worksheet (Appendix 1)

Useful links: The Geomagnetic Polarity Time Scale (GPTS) – Wood Hole Oceanographic Institution
https://website.whoi.edu/deeptow/research/jurassic-magnetism/jurassic-magnetism-1992-survey/the-geomagnetic-polarity-time-scale-gpts/

Source: Activity written by Pete Loader of the ELI Team (2025)

Appendix 1

Earth's Geomagnetic Polarity Time Scale