Mapping Magnetic Anomalies
Modelling the palaeomagnetic evidence for plate tectonic boundaries on the ocean floor.

In the 1950s, exploration of the ocean floor by the US Navy recorded patterns of magnetic stripes where the magnetic field strength was alternately stronger or weaker than the average geomagnetic field strength. These positive and negative anomalies were interpreted in 1963 by British geologists, Vine and Matthews, as having been caused by the Earth's magnetic field reversing over time, supporting the theory of seafloor spreading from an ocean ridge system.

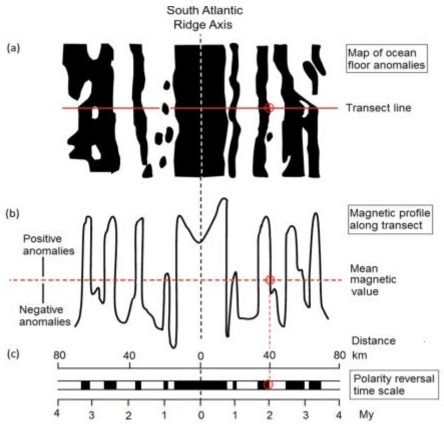


Fig 1: Ocean floor magnetic anomalies in the South Atlantic.
(a) The anomaly pattern (black positive – white negative);
(b) The magnetic anomaly profile along transect indicated;
(c) Comparison with the polarity reversal timescale - the start of the Olduvai normal polarity event indicated. (*Pete Loader*)

This Earthlearningidea is an attempt to simulate those magnetic surveys and model the palaeomagnetic evidence for plate tectonic theory. It also complements other Earthlearningidea activities referenced below.

Setup Instructions*

- Construct an ocean surface using building blocks (3.2 cm and 6.4 cm x 3.2 cm x 2.4 cm). Build the model with three rows, stacking the blocks 2 or 3 blocks high. An ocean ridge, (seen in section) can be simulated using different coloured blocks. (Fig. 2).
- Secure rounded neodymium magnets (100 mm x 3 mm) to the underside of each square block that forms the upper surface, positioned within the bricks central support tubes. Use a modelling clay/putty (e.g. Blu Tack™) to attach the magnets. This will allow for a semi-permanent fix, making it easy to remove the magnets if necessary. (Fig 2 - insert).
- Position the magnets so that opposite poles alternate on the uppermost surface to show a symmetrical geomagnetic pattern either side of the ocean ridge position. This imitates the pattern of normal and reversed palaeomagnetic anomalies acquired by new basalt crust when the Earth's magnetic field changes, with the crust then spreading laterally from the ridge (Fig 3).
- The location of the ocean ridge, with its symmetrical stripes, is offset on either side of the model to represent a transform fault between the two ridge offsets.

*Alternative: Instead of using building blocks, you could use a box lid and similarly secure neodymium magnets to the underside in a 3 cm grid to illustrate the ocean floor's palaeomagnetic pattern. Other models showing magnetic stripes can be found in the 'Follow up activities' on Page 3.

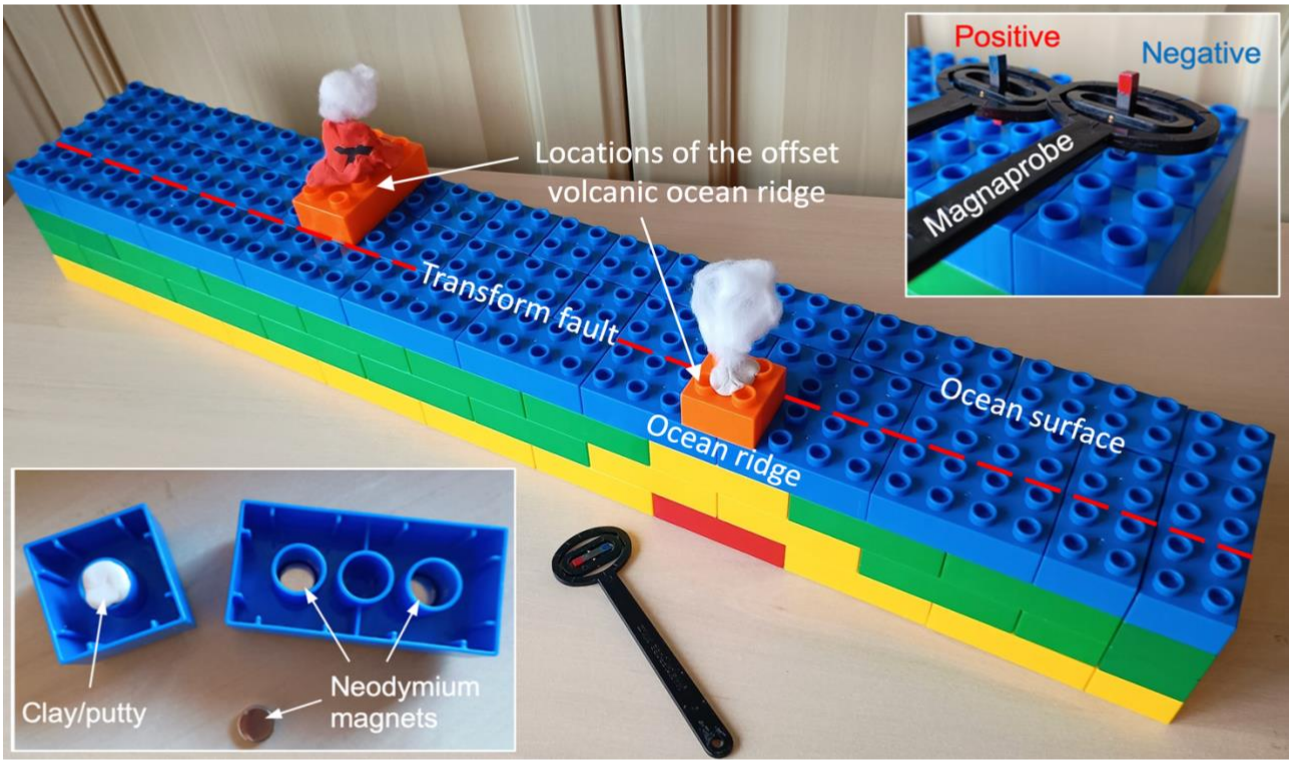


Fig 2: Palaeomagnetic mapping model and interpretation (with side covering removed to show the position of the offset ocean ridges). The insets demonstrate the magnetic set up and the mapping simulation using a *Magnaprobe™*. (*Pete Loader*)

Palaeomagnetic mapping simulation
Using a *Magnaprobe* or an equivalent recording device (e.g. a vertically oriented compass or a magnetized needle suspended on a thread), simulate the path a magnetometer aboard a research ship would follow over the ocean by moving the *Magnaprobe* along the centre of the three rows of blocks (Figs 2 & 3).

- For each block, record on the base map (Appendix 1) the magnetic inclination of the *Magnaprobe* as the north pole of its magnet is attracted or repelled. This will represent the 'palaeomagnetic anomaly' for each square block of ocean crust below that location. Mark a positive value (with a + sign) where the north pole of the *Magnaprobe* (compass or needle) is attracted towards the surface, and a negative value (with a - sign) where the north pole of the *Magnaprobe* is repelled away from the surface.
- Complete the base map by shading in each square that records a positive (normal) polarity and leaving blank those squares that record a negative (reversed) polarity. (Note that some squares on the base map have already been correctly shaded). This will create a 'palaeomagnetic anomaly' map of the simulated ocean floor beneath, equivalent to the black and white stripes recorded from real ocean surveys.

Interpretation
With the palaeomagnetic map complete, assign the following tasks to the students, explaining that the model shows at least two types of plate tectonic boundaries:

- Using the palaeomagnetic map you have produced, identify the possible location(s) of any ocean ridges on the model. Mark these on your map and the model. (*These are marked with orange blocks and volcanoes on Fig 2 for reference*). Explain your reason for this interpretation – *Symmetric magnetic stripe pattern that mirrors itself either side of the ocean ridges*.
- Identify any other plate boundary indicated by the data and explain to the class how it formed – *Transform fault where adjacent plates slide past each other horizontally resulting from spreading from offset ridges.*
- Check your answers by removing the covering to the side of the model to reveal the ocean floor profile and location of the ocean ridge (as shown in Fig 2).
- Compare your palaeomagnetic map with the Earth's geomagnetic polarity timescale in Appendix 1 (and Fig 4). The beginning of the Olduvai normal polarity event started 2 million years ago and is marked on the geomagnetic polarity timescale. If each block on the model represents 5 km, estimate the approximate rate of seafloor spreading of the plates represented by the model.
  - *40 km in 2 million years = 2 cm/yr*

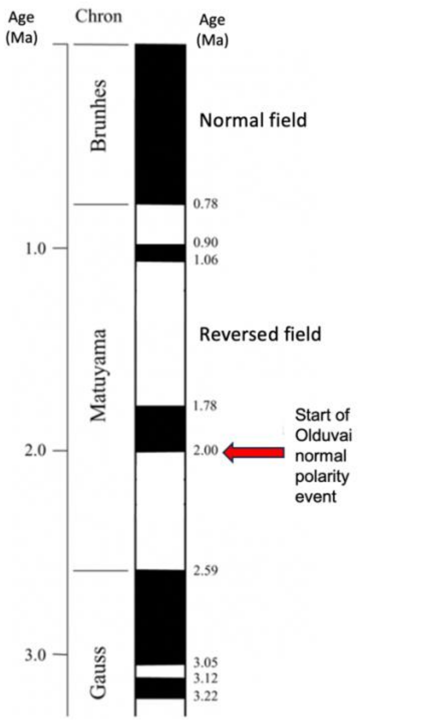


Fig 4: The Earth's geomagnetic polarity timescale with the beginning of the Olduvai normal polarity event identified. (*Credit: U.S. Geological Survey*)

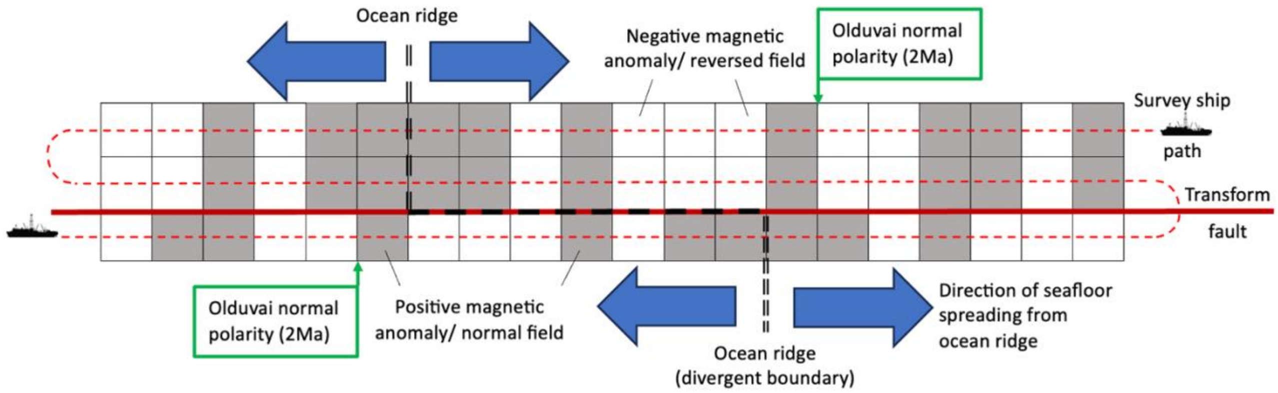


Fig 3: The 'palaeomagnetic' map of the model's surface showing the ocean ridge system offset by a transform fault. The pattern of anomalies about the ridge is consistent with the Earth's geomagnetic polarity timescale in Fig 4. The green arrows represent the beginning of the Olduvai normal polarity event – 2 million years ago. Alternative geomagnetic patterns can be easily established by rearranging the blocks on the model to create different ridge/fault situations and spreading rates. (*Pete Loader*)

The back up

Title: Mapping Magnetic Anomalies

Subtitle: Modelling the palaeomagnetic evidence for plate tectonic boundaries on the ocean floor

Topic: Modelling plate boundaries (divergent and transform) from a simulated geomagnetic data survey.

Age range of pupils: 14 – 18 years

Time needed to complete activity: 30 minutes (with the model already made)

Pupil learning outcomes: Pupils can:
- describe how the pattern of magnetic stripes was collected from ocean exploration surveys;
- explain that magnetic anomalies and magnetic stripes are associated with reversals in the Earth's geomagnetic field;
- identify evidence of plate boundaries from the pattern of palaeomagnetic anomalies;
- explain the palaeomagnetic evidence for transform fault movement;
- explain that geomagnetic field reversals are common on geological timescales and have been dated;
- calculate the rate of seafloor spreading from oceanic ridges using palaeomagnetic data.

Context: This activity can be used to help students to understand the movement of the lithosphere at plate boundaries, particularly along transform faults. It gives a hands-on experience of mapping the palaeomagnetic anomalies of the ocean floor and provides an appreciation of how that evidence can be interpreted and conclusions drawn.

Following up the activity: As an extension, the width of the stripes either side of one of the ridges could be made wider/narrower than on the other side of the transform fault to represent a different rate of seafloor spreading.
Students might look at a real palaeomagnetic map (Atlantic or Pacific) to describe how and explain why this differs from the one in the model.
In addition, students can attempt other related Earthlearningidea activities on this subject:
- https://www.earthlearningidea.com/PDF/455_GPTS.pdf
- https://www.earthlearningidea.com/PDF/81_Magnetic_stripes.pdf
- https://www.earthlearningidea.com/PDF/408_Hands_magnetic_stripes.pdf
- https://www.earthlearningidea.com/PDF/84_Transform_faults.pdf

Underlying principles:
- As magma rises from the mantle through rifts, new ocean lithosphere is formed at oceanic ridges.
- Magnetic minerals in the lavas record and 'lock in' the polarity of the Earth's magnetic field as the lavas solidify and continue to cool.
- As the plate continues to spread from the ridge and the Earth's magnetic field 'flips' from time to time, ocean floor 'magnetic stripes' are produced as anomalies in the geomagnetic field strength from the average. These represent normal fields (positive anomalies as today) and reversed fields (negative anomalies – opposite to today).
- Oceanic ridges and their magnetic stripes are offset by transform faults. These are a unique type of strike-slip fault that allows the plates to spread at the different rates (necessary on the spherical Earth's surface).
- Transform faults can be identified on the ocean floor by the displaced topography of oceanic ridges and the offset of their magnetic anomaly patterns. In the region between the two ridges both sides of the fault move in opposite directions relative to each other (black and red dotted line on Fig 3). However, outside of this region, the two sides of the fault move in the same direction (red lines). This means that the movement varies across the different segments of the fault.

Thinking skill development: The simulation allows a pattern to be developed through construction; cognitive conflict is caused when the pattern is revealed and the ocean ridge is seen to be offset. Metacognition requires the development of bridging skills in relating the simulation to the real Earth.

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™)
- 60 strong, rounded, neodymium magnets (100 mm x 3 mm).
- modelling clay/putty (e.g. Blu Tack™)
- magnetic recording device - Magnaprobe™ (compass or magnetised needle)
- base map and polarity timescale handout (Appendix 1)

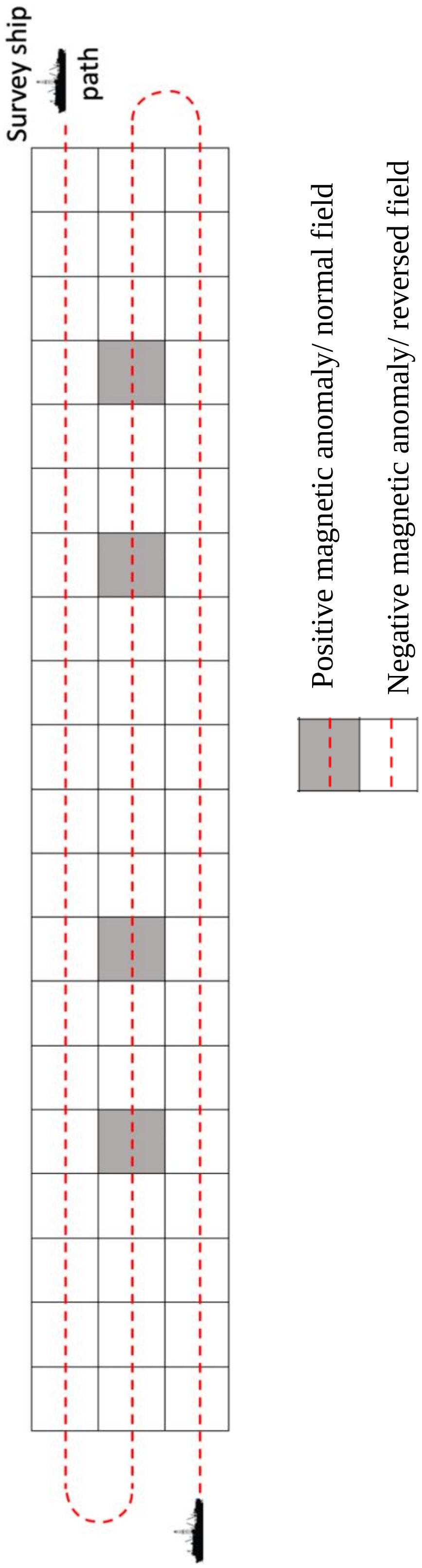
Useful links: How do the plates accommodate motion near spreading ridges?
https://www.iris.edu/hq/inclass/animation/fault_transform

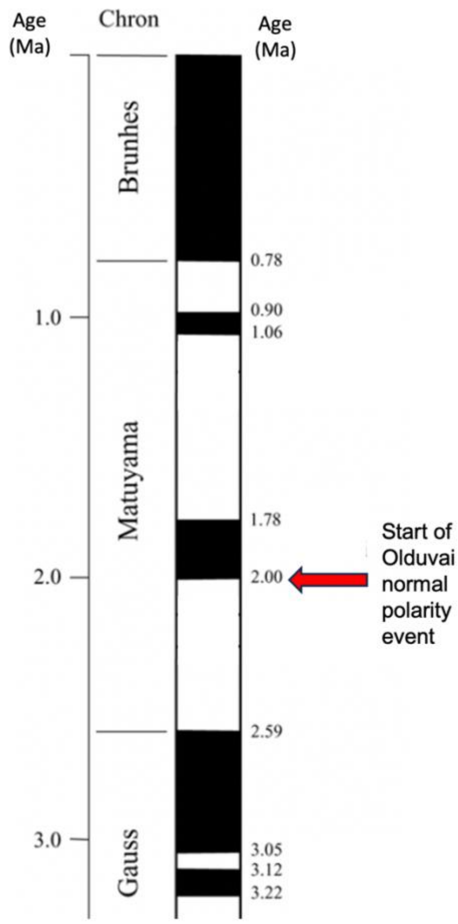
Source: Activity written by Pete Loader of the ELI Team for the EGU General Assembly 2025 GIFT Workshop.

Appendix 1

Mapping Magnetic Anomalies

Base map





Earth's geomagnetic polarity timescale