Ice-thickness from scratch: visualising past processes by calculation

Modelling glacial striation-formation by calculation – thinking through the assumptions

Where there is a glacially scratched (striated) surface in the field with till (boulder clay) deposited on top, you can calculate the approximate thickness of the ice sheet that made the scratches.

- Take a pointed fragment from near the base of the till (the calculation is simplified by choosing a fragment with a surface area on the opposite side to the point of around 100mm^2).
- Find a pebble of the same rock as the scratched bedrock.
- Put the pebble on an electronic balance and ensure the balance is returned to zero (tared).
- Scratch the pebble with the pointed fragment, whilst recording the downward force necessary to make the scratch, as shown in the photo (the horizontal force pushing the pointed fragment is not relevant to this activity and is not measured).
- Use a ruler and the needle from a pair of compasses to approximately measure the depth of a scratch on the pebble.
- Repeat the measurement for one of the deepest striations in the bedrock, as shown in the group of three photos.
- The downward force that made the striations on the bedrock platform can then be calculated from the equation:

$$\text{force (kg) to make striation} = \frac{\text{scratch force (kg)} \times \text{striation depth (mm)}}{\text{depth of scratch (mm)}}$$

Using an electronic balance to measure the force necessary to scratch a limestone pebble with a pointed till fragment, Traeth Bychan, Anglesey, UK. (*Peter Williams*).

Since 1000mm^3 of ice weighs around 1gm, if the surface area of the pointed fragment is around 100mm^2 then 10mm thickness of ice will exert 1gm downward force; thus 1kg downward force is exerted by 10m ice thickness.

So, the thickness of ice that made the striation can be calculated from:

force (kg) to make striation x 10 = approximate ice thickness (m)

This method, when used for the ice-striated surface at Traeth Bychan in Anglesey in the UK shown in the photos, gives the following measurements:

- scratch force measured on balance – 8kg
- depth of scratch on pebble – approx. 1 mm
- depth of striation – approx. 2 mm

Substituting these figures into the equations gives a minimum ice-thickness of 160m, which is likely to be of the correct order of magnitude.

The method using a pair of compasses and a ruler to measure the depth of glacial striations, Traeth Bychan, Anglesey, UK. (*Peter and Maggie Williams*).

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The purpose of carrying out this activity is not to find an accurate figure of possible ice-thickness, but to encourage pupils to use the calculation to think through the processes involved, together with all the assumptions that are being made in making the calculation. Discussion of the assumptions forms an important part of the activity and enables the process to be considered more clearly. The assumptions include:

- the mass of 1000mm^3 of ice is 1g – when the relative density of ice is only 0.9 and so the mass of 1000mm^3 of ice is only 0.9g;
- the downward force is caused only by the mass of ice directly above the fragment – in reality the force applied to each fragment will depend upon the two dimensional spacing of the fragments frozen into the ice and scratching the surface;
- the point of the fragment is not worn away in the process, increasing the surface area of the fragment in contact with the striated platform; the chances of this are reduced if the fragment chosen is harder than the rock of the platform, for example a chert (silica) fragment scratching a limestone platform;
- the surface area of the upper part of the fragment is not 100mm^2; if this is the case then the equation below can be used;
- accurate measurements are possible – in reality, they can only be approximate.

The back up

Title: Ice-thickness from scratch: visualising past processes by calculation.

Subtitle: Modelling glacial striation-formation by calculation – thinking through the assumptions.

Topic: A field simulation of the scratching of striations on bedrock by the debris frozen into an ice sheet, used to approximately calculate the thickness of the ice sheet and to discuss the assumptions made.

Age range of pupils: 14 years upwards

Time needed to complete activity: 15 minutes

Pupil learning outcomes: Pupils can:

- explain how the abrasion of fragments frozen into the bottom of ice sheets scratch striations into the underlying bedrock surface;
- calculate the thickness of ice that might be responsible for scratching the depth of striations measured;
- discuss the assumptions involved in the activity and the calculation.

Context:
The activity has been devised to enable pupils to gain a deeper understanding of the glacial processes which erode bedrock surfaces, such as the one shown in the photo.

The description of the activity takes pupils through the calculation and the thinking involved, step by step. An alternative is simply to input the data into this equation:

$$\text{ice sheet thickness} = \frac{\text{scratch force (kg)} \times 10 \times \text{striation depth (mm)}}{\text{fragment surface area (mm}^2\text{)} \times \text{scratch depth (mm)}}$$

Glacial striations in bedrock, Mount Rainier National Park, USA.

Following up the activity:
Measure the orientation of the striations to work out the trend of the ice-movement. The 'finger of faith' might also be able to feel which of the two trend directions feels most smooth, so indicating the ice-movement direction.

Underlying principles:

- Glacial striations are eroded by fragments frozen into the base of ice sheets, as the movement of the ice grinds the fragments across bedrock.
- The process can be simulated by using a pointed fragment from the till deposited on the striated surface, to scratch a pebble of the bedrock.
- A calculation of the possible thickness of the ice that eroded the striations can be made following the method described and using it to discuss all the assumptions made in the process.

Thinking skill development:
Arithmetical skills are required. Discussions of the assumptions involved in the simulation depend on a range of evaluative skills.

Resource list:

- an electronic balance recording in kg – cheap versions that can be used in the field are available for weighing mail
- a pair of compasses and a ruler

Useful links:
See the Earthlearningidea, *Grinding and gouging: How moving ice can grind away rocks* at: http://www.earthlearningidea.com/PDF/60_Grinding_gouging.pdf to simulate the ice erosion process.
A video of a similar activity can be found at: https://www.youtube.com/watch?v=hkFUoIG06Nc

Source: Chris King of the Earthlearningidea Team, with contributions by Martin Devon.