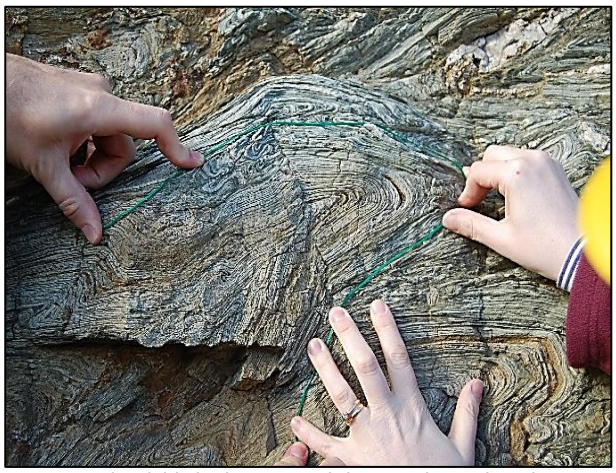
From folds to crustal shortening: visualising past processes by calculation
Modelling folding by calculation – thinking through the assumptions

Use a tape measure or a piece of string to measure around a fold (or folds) to give you the original length of the layer before folding. Then measure the new distance between the two ends of the string or tape, while it is still around the fold, to find out how far apart they are after being folded.



Measuring folds in the Precambrian South Stack rocks, Anglesey, UK. (*Chris King*).

Work out approximately the percentage of crustal shortening that has taken place, using this equation:

$$\text{Percentage of crustal shortening} = \frac{(\text{original length} - \text{new distance}) \times 100\%}{\text{original length}}$$

Make the measurement several times on different folds and then calculate the mean percentage – which will give a reasonable estimate of the actual amount of crustal shortening that has taken place.

This method gives an approximate figure because several assumptions are made. It is important that these are identified and considered as the whole calculation process is evaluated by the group.

- Different parts of different folds may have been measured – it is best to measure whole wavelengths to avoid this issue.
- The layers may not have deformed evenly because the competence (resistance to deformation) of different rock materials differs.
- The measurement may have been made on a face which is not parallel to the stress direction (so giving 'apparent' rather than 'true' measurements); this issue can be addressed as described in the 'Context' section below.
- The method assumes that the axial plane is always at right angles to the maximum stress direction and does not take account of the possibility of several phases of folding (polyphase folding).

The method can be used in the field or on a drawing or a photograph like the one below.

Folded rocks in Crete, the rucksack is 30cm across. (*Pete Loader*)

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The back up

Title: From folds to crustal shortening: visualising past processes by calculation.

Subtitle: Modelling folding by calculation – thinking through the assumptions.

Topic: A method of calculating approximate crustal shortening in the field (or from a diagram or photograph), then discussing the assumptions involved.

Age range of pupils: 14 years upwards

Time needed to complete activity: 20 minutes

Pupil learning outcomes: Pupils can:

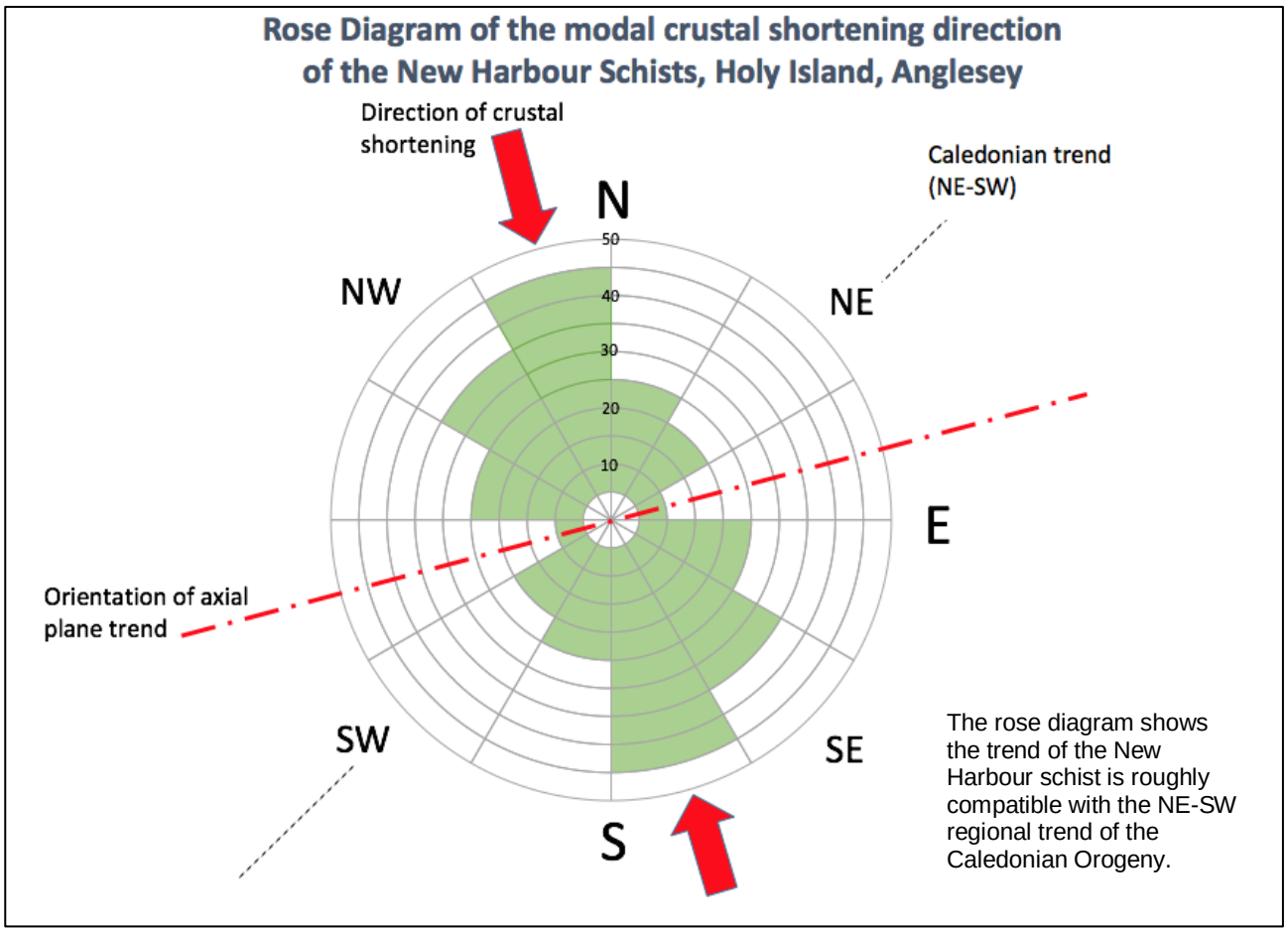
- make measurements in the field or from photographs/drawings;
- carry out simple calculations;
- calculate means (averages);
- evaluate the calculation method to explain the assumptions involved.

Context:

- The method can be used in the field or on photographs/drawings.
- There is an opportunity to use statistical methods to show the main direction of crustal shortening, through taking a large number of measurements and recording the orientation of the cliff face where the measurement was

taken. These are then plotted onto a rose diagram as shown in the example given below.

- Rather than asking each group of students to make all these measurements themselves, it is better to ask them to make just a few measurements to get the idea, before giving them the bulk of the data (which may, for example, have been collected over several years). Data collected by groups of students over a number of years is available for the South Stack Formation in Anglesey, on request.



An example of a rose diagram plot of data from Anglesey showing the orientation of the axial plane trend and the direction of crustal shortening at right angles to this. Note that since these are trend data, one side of the diagram has the same data as the other side. These data are based on work by students at St Bede's College, Manchester. The diagram has been redrawn by Pete Loader.

Following up the activity:
Try asking your pupils '*What was it like to be there – on the ground above where these rocks were being folded*?' through *'The view from above: living tectonism'* Earthlearningidea.

Underlying principles:

- During the crustal shortening caused by plate collision, deformation occurs.
- If the rock is ductile (plastic), deformation is by folding.
- The approximate amount of crustal shortening can be measured by measuring the length of a folded layer between two points and then the distance apart of the two points.
- The best estimate of the amount of crustal shortening can be gained by finding the mean of many of these measurements.
- It is best to measure 'whole folds' i.e. the whole fold wavelength, where possible.
- The method can only provide an estimate since the deformation of most rocks is uneven.
- Since all rock faces available for measurement will not be at right angles to the compression direction (giving a 'true' measurement), measures of 'apparent' crustal shortening can be made on many faces and the 'true' crustal shortening direction found statistically.

Thinking skill development:
Mathematical skills are required. Discussion of the crustal shortening calculation model related to past orogenic events, involves a range of evaluative skills.

Resource list:

- tape measure or string
- calculator or mobile/cell phone calculator
- pens, paper, clipboard (if in the field)

Useful links:
Try the '*The view from above: living tectonism'* Earthlearningidea.
Contact Earthlearningidea at: eli-team@earthlearninidea.com for the data collected by groups of students for the South Stack Formation in Anglesey.

Source: Devised by Pete Loader from an idea by Jo Conway.