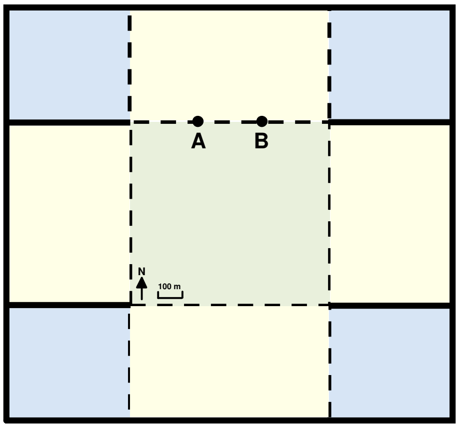
Geological mapwork from models 5: folded geology on block models

Draw and make your own 3D models of areas with folded rocks

Use the models from previous Earthlearningidea (ELI) mapwork exercises to plot the geology of simple folded sequences. Use the colour/ shading and symbols used on the previous models.

Plain – version 3
Use a new full-sized model of a flat region (from ELI 'Geological mapwork from models 1', which you may have already used to make versions 1 and 2) to plot and complete version 3 using the following geology.

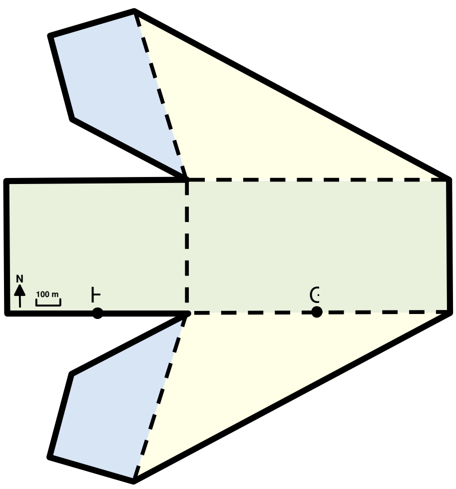


The geology of the area has a sequence of sandstones overlain by limestones which have been gently folded. The limestone/ sandstone boundary crops out at locality A, a third of the way along the northern side of the area, where it has a true dip of 30^o (downwards from the horizontal) towards the west. The same boundary crops out at locality B, two thirds of the way along the northern side of the area, but here it has a true dip of 30^o towards the east.

When you have drawn in the geology, complete the following sentences:

1. The rock formations are folded into *an anticline / a syncline*
2. The fold *has equally dipping limbs/ one limb dipping more steeply than the other*
3. The fold axis trends *N-S/ NW-SE/ E-W/ NE-SW*

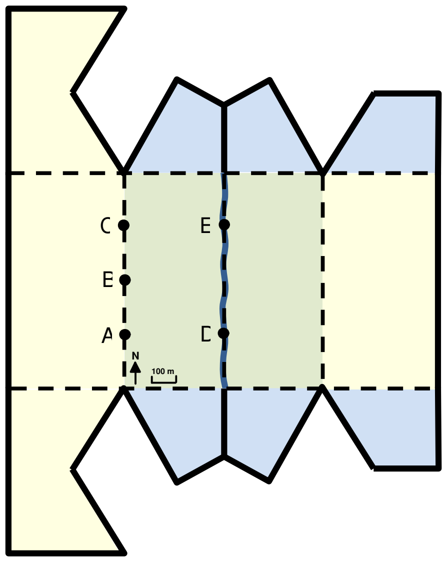
Cuesta – version 3
Use a model of the cuesta (ELI 'Geological mapwork from models 2') to show the following geology.



The area contains a mudstone formation, overlain by a limestone formation. The limestone/ mudstone boundary crops out half way down the shallow slope at locality G, where it dips west at 20^o (from the horizontal). The same boundary crops out half way down the steeper slope, at locality H, dipping east at 35^o. This is an example of inverted topography where the shape of the geology is opposite from the shape of the landscape.

Answer the same three questions as for the previous model.

Valley with horizontal floor – version 2
Plot the following geology onto a full size cut-out of this model (ELI 'Geological mapwork from models 3'). Localities A, B and C are equal distances apart and from the SW and NW corners. Locality D is due East of locality A, while E is due East of C.



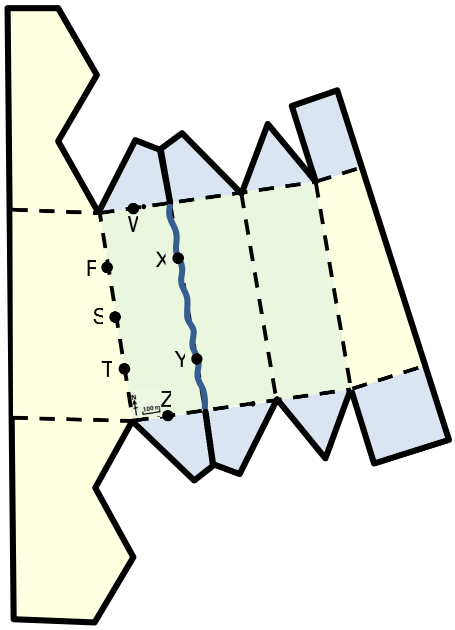
The area has a sequence of limestone overlying sandstone above mudstone. The limestone/ sandstone boundary was found at locality A dipping South at 30^o from the horizontal. The limestone/ sandstone boundary was also found at locality B, dipping at 10^o towards the North. The sandstone/ mudstone boundary was found on the valley floor; at locality D it was dipping 30^{o}S and at locality E it was dipping at 10^{o}N. Borehole data from elsewhere showed that the sandstone has a vertical thickness of 150m.

When you have drawn in all the geological boundaries on the top and sides of the model, complete the following sentences:

1. The rock formations are folded into *an anticline / a syncline*
2. The fold *has equally dipping limbs/ one limb dipping more steeply than the other*
3. The fold axis trends *N-S/ NW-SE/ E-W/ NE-SW*
4. The axial plane of the fold is *vertical/ inclined (not vertical)*

Then use a dashed line to draw the axial plane on the top and sides of the model.

Sloping ridge and valley – version 3
Plot the geology onto this cut-out model (ELI 'Geological mapwork from models 4'). Localities R, S and T are equal distances apart and from the NW and SW corners. Locality X is due East of R, whilst Y is due East of T. Localities W and Z are each half way along the valley slope.



Note that plutons are usually shown on coloured geological maps in a bright red colour; on black and white maps, they are usually denoted by + symbols scattered randomly across the outcrop.

The geology of the area has a succession of sandstone overlying mudstone which has been folded into an open fold with an E-W axis; a horizontal conglomerate has been laid unconformably on top of this folded sequence. The sandstone/ mudstone boundary is exposed at localities W and X, where it dips S at 10° (from the horizontal). The sandstone/ mudstone boundary is also exposed at localities Y and Z, where it dips N at 30° (again, from the horizontal). The horizontal unconformity is found at locality T, with the conglomerate lying on the unconformity surface. A small circular pluton of 100m radius with vertical sides is found centred on the NE corner of the area; it has a 50m wide metamorphic aureole.

When you have finished the geology, try completing the following sentences:

1. In a valley, the outcrop of a geological boundary or bed normally Vs in the *opposite direction to / in the direction of* the dip of the beds.
2. The rock formations are folded into *an anticline / a syncline*
3. The fold *has equally dipping limbs/ one limb dipping more steeply than the other*
4. The fold axis trends *N-S/ NW-SE/ E-W/ NE-SW*
5. The axial plane of the fold is *vertical/ inclined towards the N/ inclined towards the S*

Finally, draw the axial plane on the model.

………

The back up

Title: Geological mapwork from models 5: folded geology on block models

Subtitle: Draw and make your own 3D models of areas with folded rocks

Topic: Part of a series introducing simple geological mapwork – through 3D models. A table of the progression and spiralling of spatial thinking skills involved through the series is given on the final page.

Age range of pupils: 14 – 19 years

Time needed to complete activity: 90 mins for all four models.

Pupil learning outcomes: Pupils can:
- add geological data to 3D block models,
- link up the data with geological boundaries,
- interpret these into 3D pictures of the geology.

Context:
Pupils use new print-outs of the models from previous mapwork exercises to draw in and appreciate how folded geological structures appear on landforms of increasing complexity.

Plain – version 3. The geology here is of an open upright anticline with limbs dipping at angles of 30°. The geological boundaries appear as straight lines on the top of the model.
The correct responses to the questions are: '*an anticline'; 'has equally dipping limbs'* and *'N-S'*.

Cuesta - version 3. This is an inclined syncline, with the tougher limestone forming the top of the asymmetrical ridge, illustrating inverted topography.
The responses to the questions are: '*a syncline';' has one limb dipping more steeply than the other'* and *'N-S'*.

Valley with horizontal floor – version 2. After the geology of the limestone/ sandstone boundary on the western side has been plotted, the boundary on the southern and northern cross sections is shown by horizontal lines (apparent dip = 0°). These intersect the map surface and allow the boundary to be drawn on the map surface and the eastern cross section to be drawn as well. The sandstone/ mudstone boundary is then added to the map, by drawing the boundary parallel to the other boundaries. The borehole data allows the sandstone/ mudstone boundary to be added to the western and eastern cross sections.

The responses to the questions are: '*an anticline';' has one limb dipping more steeply than the other', 'E-W'* and *'inclined (not vertical)'*. The fold axis should be drawn E-W through the corners of the diamond-shaped outcrop of the mudstone on the map. On the cross sections, the axial plane dips south at an angle bisecting the angle of the two limbs, (80°N).

Sloping ridge and valley – version 3. This is plotted by drawing the northern outcrop of the sandstone/ mudstone boundary by linking points W and X with a straight line and drawing a line on the opposite side of the stream to complete a symmetrical 'V'. Then point W is plotted on the Northern cross section of the model, allowing a horizontal line to be drawn across the cross section. From where the horizontal line meets the NW corner, the boundary is drawn dipping South at 10°. The same procedure is used to plot the 30° Northward-dipping Southern sandstone/ mudstone boundary. The unconformable horizontal conglomerate is plotted as in previous models and only appears on the upper sections of the ridges. The small circular pluton with its aureole is plotted at the end. The responses to the questions are: *'in the direction of',* '*a syncline'; 'has one limb dipping more steeply than the other', 'E-W'* and *'inclined towards the S'*.

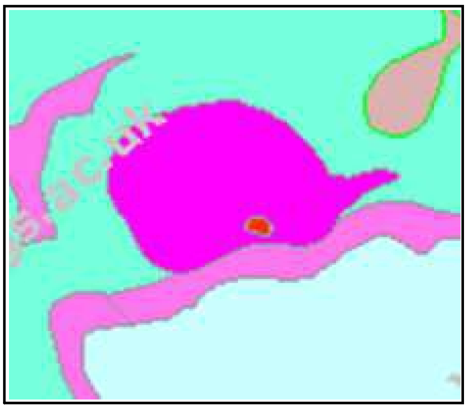
Following up the activity:

For each of the models, pupils could be asked:

1. to draw a geological map of the area;
2. to construct a geological cross section diagonally across the block;
3. if there were rock exposures in the area, what the dip of the beds would be, and how this should be shown on the geological map.

Pupils could be shown a real example of a small circular pluton on a geological map by accessing the BGS 'OpenGeoscience' website at http://www.bgs.ac.uk/OpenGeoscience/, and clicking on 'Geology of Britain'. Switch the basemap to 'imagery' and then enter '*Priestcliffe Ditch'* into the 'Go to Location' box. To the south west of the marker is a roughly circular pluton and, if the slider at the top of the map is moved to the 'Transparency = none' position, the map looks as shown.

Note that the 'Transparency' slider can be moved back to show the geography of the area too – when it can be seen that some of the igneous rock forming the pluton has now been quarried away.



Derived from the 1:50 000 scale BGS digital geological map, British Geological Survey © NERC. All rights reserved. IPR/137-12CT

With a single mouse click on the circular pluton on the BGS website, you can discover that the igneous rock forming the pluton is 'micrograbbro' a medium-grained dark-coloured rock, ideal for road-making and the ballast (gravel) for railways.

Underlying principles:

- The three dimensional geological structure of an area can be plotted on block diagrams.

Thinking skill development:

The drawing of geology onto three dimensional models involves spatial thinking skills. The more complex the geology becomes, the more spatial interpretation is needed, including interpolation and extrapolation skills.

Resource list:

- print-offs of the ELI mapwork models 1 - 4, per pupil
- scissors (if these are not available, place a ruler flat along the edge to be cut, and tear the paper along the ruler)
- paper clips, four per model
- drawing materials, including pencil, eraser, ruler, protractor and pencil crayons

Useful links:

Higher level mapwork exercises with online tutorials are available for free download from the Open University: http://podcast.open.ac.uk/ oulearn/science/podcast-s260_mapwork#

Source: Devised by Chris King of the Earthlearningidea team, based on exercises published in '*Geology Teaching'* the journal of the Association of Teachers of Geology in 1980 (Volume 5, No. 1, pages 15 – 19).

The progression and spiralling of spatial thinking skills shown by the Earthlearningidea ‘Geological mapwork from scratch’ exercises and the ‘Geological mapwork from models’ exercises

Exercise		Topographic surface	Geological surfaces	Strategies and skills
Mapwork from scratch 1: a conical hill		Conical hill	Flat and horizontal	• Plot and draw simple topographic cross sections • Add geological boundary intersections and join with straight, horizontal lines
Mapwork from scratch 2: valley with simple geology		Sloping valley	Flat and horizontal	• Plot and draw simple topographic cross sections • Add geological boundary intersections and join with straight, horizontal lines • Sketch geology onto a 3D block diagram
Mapwork from scratch 3: valley with dipping geology		Sloping valley	Dipping surfaces	• Draw true dip on a cross section using a protractor • Add geological boundary intersections and join with straight lines • Appreciate that apparent dip is always less than true dip • Appreciate that, in valleys, geological boundaries usually ‘V’ in the direction of dip. • Sketch geology onto a 3D block diagram • Begin to compile a list of mapwork rules
Mapwork from models 1	Plain version 1	Flat	Flat and horizontal	• Add geological boundary data to cross sections and join with straight, horizontal lines
	Plain version 2	Flat	Dipping surfaces; vertical feature	• Add geological boundary data to cross sections and join with straight lines • Use boundaries on the cross sections which intersect the topographic surface to draw a boundary on the surface • Add a vertical feature (dyke)
Mapwork from models 2	Cuesta version 1	Asymmetrical ridge	Flat and horizontal	• Add geological boundary data to cross sections to construct straight, horizontal lines
	Cuesta version 2	Asymmetrical ridge	Dipping surfaces; vertical feature	• Draw true dip on a cross section using a protractor • Add parallel geological boundaries • Add a vertical feature (fault) that moves a geological boundary • Appreciate the link between tough and weak geological formations and topography
Mapwork from models 3: valley with horizontal floor		Valley with horizontal floor	Dipping surfaces; vertical feature	• Draw true dip on a cross section using a protractor • Add parallel geological boundaries • Use boundaries on the cross sections which intersect the topographic surface to draw in boundaries on the surface • Construct parallel boundaries on the surface • Appreciate that, in valleys, geological boundaries usually ‘V’ in the direction of dip • Appreciate that apparent thickness is always greater than true thickness • Add a vertical feature (dyke)
Mapwork from models 4	Ridge/ valley with sloping floor version 1	Ridge/ valley with sloping floor	Dipping surfaces	• Add geological boundary data to cross sections to construct straight lines • Add parallel geological boundaries • Appreciate the link between tough and weak geological formations and topography • Interpolate approximate true dip from apparent dip
	Ridge/ valley with sloping floor version 2	Ridge/ valley with sloping floor	Dipping surfaces	• Draw true dip on a cross section using a protractor • Add parallel geological boundaries to cross sections • Use boundaries on the cross sections which intersect the topographic surface to draw in boundaries on the surface • Construct parallel boundaries on the surface • Appreciate that, in valleys, geological boundaries usually ‘V’ in the direction of dip and the opposite is true of ridges
Mapwork from models 5: plain; cuesta; valley with horizontal floor; ridge/ valley with sloping floor		All the model landforms above	Surfaces folded into open folds	The strategies and skills described in the box above and, in addition: • Identify folds with equally dipping limbs, and those with limbs dipping at different angles • Appreciate inverted topography • Draw fold axes and fold axial planes • Draw an unconformity and a pluton with a metamorphic aureole
Mapwork from models 6: plain with faulted rocks 1		Flat	Normal and tear dip faults; dipping bedding	• Draw the effects of a normal and a tear dip fault on cross sections • Use these to explain how different types of fault can have similar effects on outcrop patterns of dipping beds (but different effects of vertical features)
Mapwork from models 7: plain with faulted rocks 2		Flat	Normal and reverse strike faults; dipping bedding	• Draw the effects of normal and reverse strike faults on cross sections • Use these to explain how different types of fault can have similar effects on outcrop patterns
Mapwork from models 8: plain with faulted rocks 3		Flat	Normal, reverse, thrust and strike-slip faults at 45^{o} to the strike; dipping bedding	• Draw the effects of different sorts of faults on cross sections • Use this to explain how different types of fault can have similar effects on outcrop patterns
DIY dip and strike model		Dipping surface	Dipping bed	• Measuring dip, strike and apparent dip on a model dipping surface, using a DIY clinometer if no other clinometer is available
Geological mapwork: Surface geology and the geological map		Not given, assumed fairly flat	Relatively complex	• Match surface geological features to places on a geological map where they might be found.