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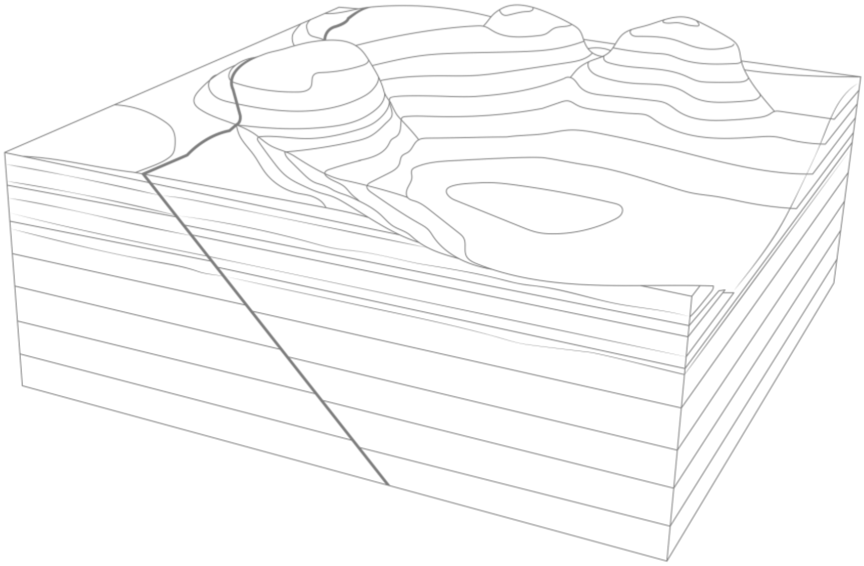


Lesson plan

Cross-sections, cores and apparent versus true dip

Dr. Henry Hoult & Dr. Kate Pedley

Learning objectives:

- Identify good places to draw a cross-section to represent the geological units present in a mapped area.
- Use drill cores to identify subsurface units within the area that don't outcrop at the surface.
- Calculate the apparent dip of layers when the line of cross-section is not drawn parallel to the dip direction of the layers.

Key Visible Geology skills:

- Manipulate layers
- Apply a cross-section
- Apply cores
- Use the Apparent Dip module

Timelines:

- Workflow 1 – 6: ~30 mins

Glossary:

- See page 5

Cross-sections, cores and apparent versus true dip

Cross-sections are 2D geological drawings of the subsurface that are made by inferring how the rocks observed at the surface would likely project downward into the Earth. They are an incredibly useful tool for geologists to show what the subsurface may look like **based on the rocks that outcrop at the surface**. In areas of complex geology, this can help represent the extent of structures *where only a part of it* is visible at the surface. For example, a fold where only one limb is visible or a fault plane that displaces layers at the surface. Through this, cross-sections become an important way to visualise **geological histories** of an area. However, choosing where to draw the line of a cross-section to best represent your mapped area takes a little bit of thought! If you choose a poor location for your cross-section, you may miss most of the geological units in an area. You may also have to do some extra calculations to convert your *measured* dip angles at the surface to **apparent dip** angles for your cross-section! To find out more about cross-sections and how to identify the best place to draw one within your area, read on!

Workflow

1. Begin by adding layers to your model until the block is completely filled in. Then, tilt the layers, and add decals on the top surface to highlight the tilt angle and the orientation (i.e., the strike and dip) of the layers.

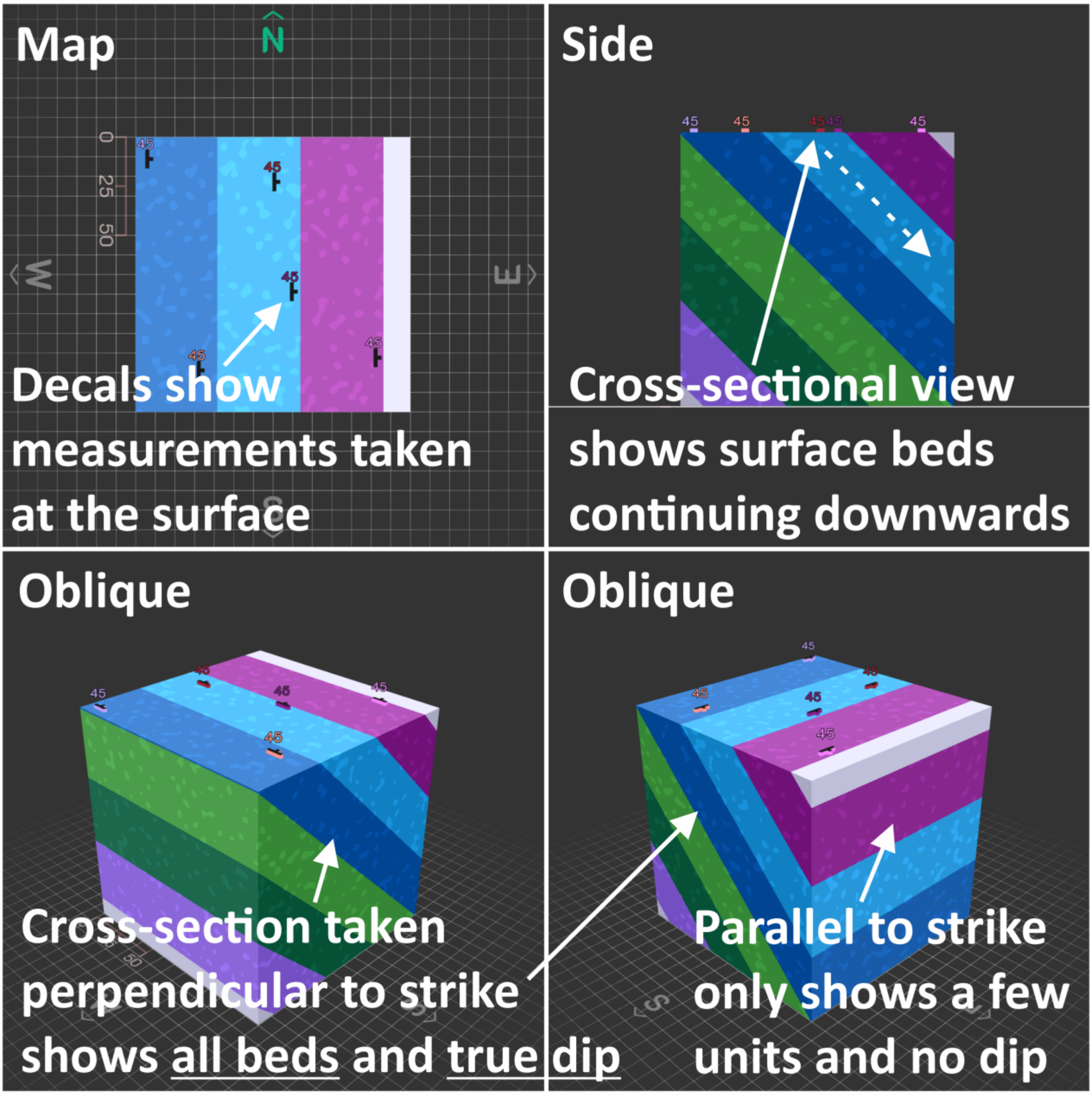
   Layers -> Add layers -> Apply

   Events -> Tilt -> Strike = 000, Dip = 45 -> Apply

   Decals -> Add decals across the surface (at least 5)

ⓘ Learning observation!

Visible Geology shows you cross-sections automatically – the sides of your block model! You can see straight away how the angle of the layers and the number of layers visible changes depending on the side of the block model you are looking at. In map view, four layers are present (these would be the mapped units at the Earth's surface). On the sides of the block cut **perpendicular to the strike of the layers**, each layer is visible dipping at 45° (the same as the decals – this is the **true dip**), and every layer present within the block is visible (including the layers at the bottom that do not appear at the surface). However, on the sides of the block cut **parallel to the strike of the layers**, each layer is **horizontal** and only a few layers are visible on each side.



In this example, if we are drawing a line of cross-section that we want to use to show the **full geological history** of our block model, a line drawn **perpendicular to the strike** would be the most useful. This would give us every layer, shown with their true dip angle.

2. So, let's add a cross-section along that orientation through the middle of your block!

   xSection -> New -> move the red crosses until your cross-section cuts across your block perpendicular to the strike

3. As we noticed earlier, there are layers present at the bottom of the block that do not outcrop at the surface. To investigate these areas, we can **drill cores** down into the earth that can reveal units not visible at the surface. Add some drill cores at the end of your model where they will intersect the hidden layers below.

   Core -> New -> move the red cross until the core cuts down through to the layers at the bottom that don't appear at the surface

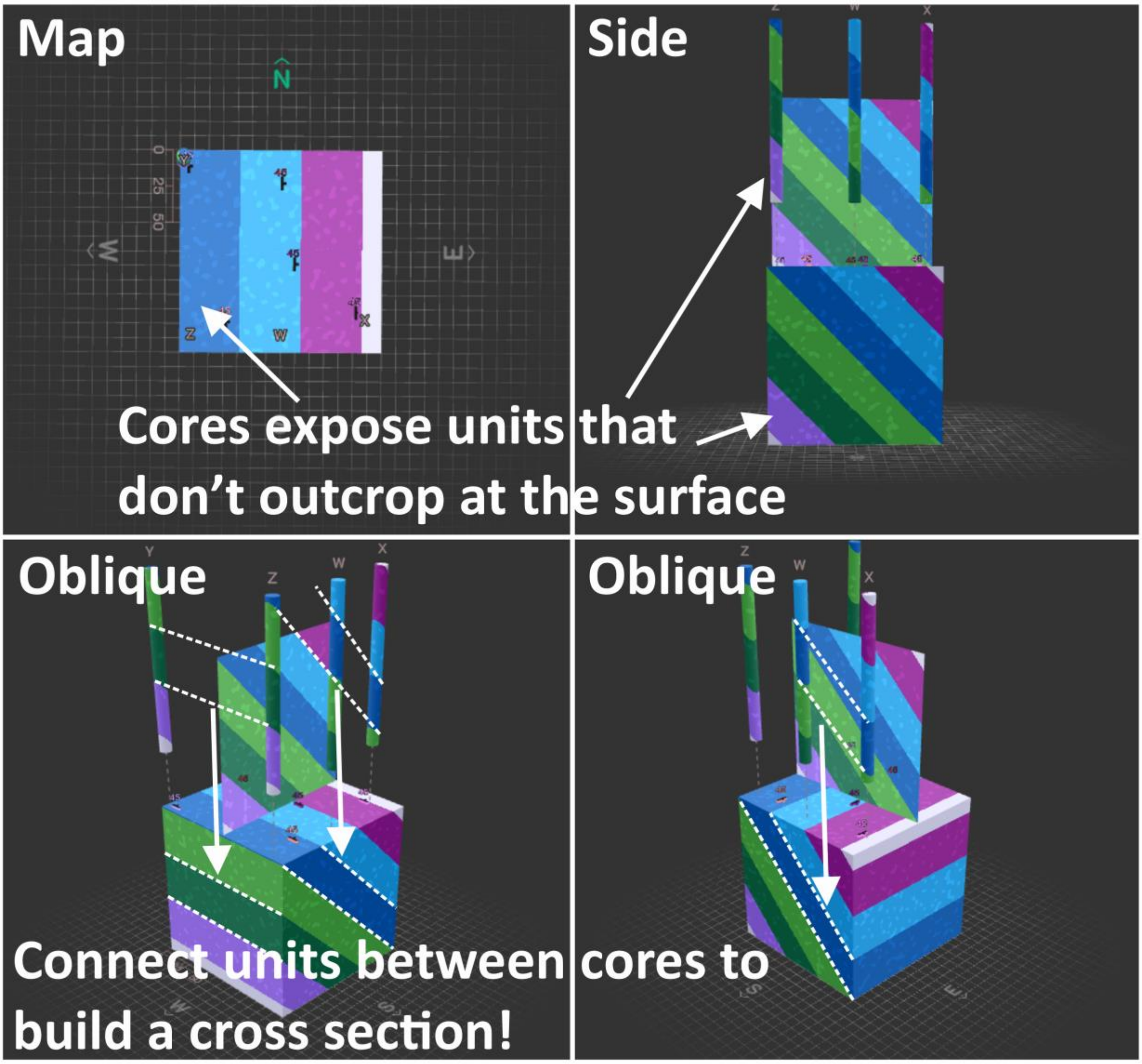
4. You might have noticed that because your cores are **along strike** relative to each other, the same layers are visible in both. In fact, if you connected the same layers between one core and the other, you would construct a cross-section! Add two more cores in the direction perpendicular to the strike of the layers to highlight this.

   Core -> New -> move the red cross until the core is in the far corner on the same side as your previous core

   Core -> New -> add a final core midway between the last core you just added and the first

ⓘ Learning observation!

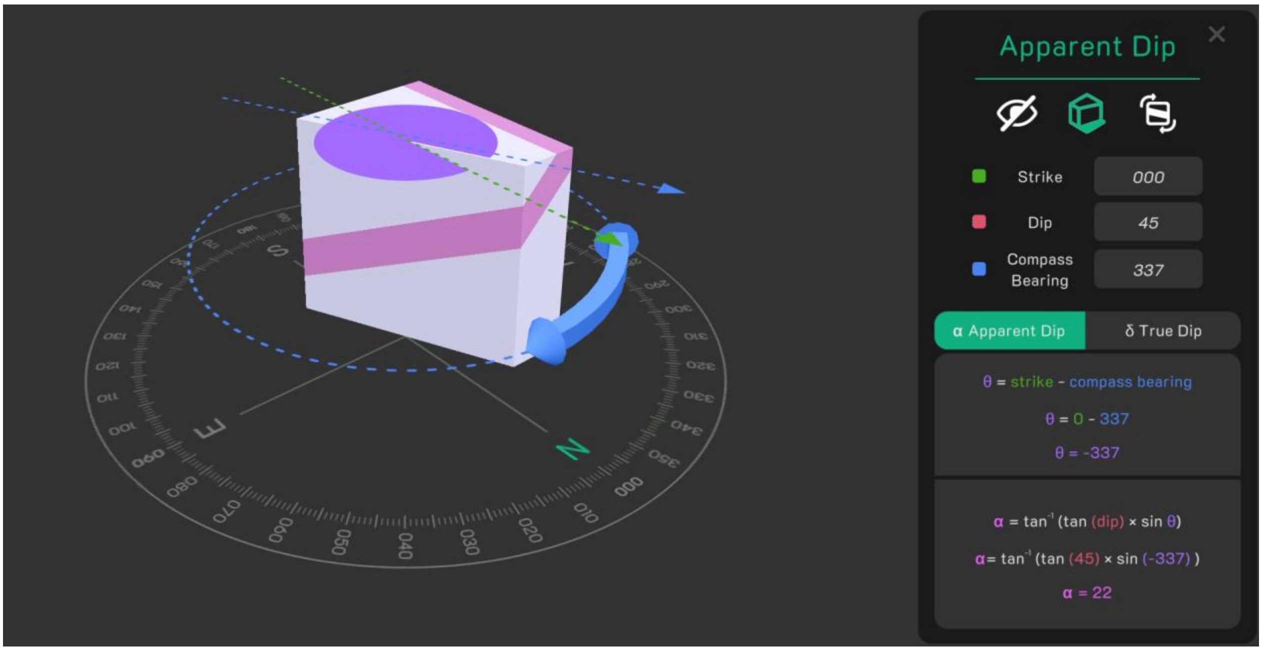
Drill cores give a single slice down through the subsurface. **Connecting the layers** present in multiple cores drilled across an area constructs a **cross-section** of the geological structure of that area. Our model is quite simple, so only a few cores are needed to accurately represent the geology (we can also see what the actual geology is because we made the model!). However, for more complex areas in the real world where we cannot see the subsurface, **more cores provide a better picture of the subsurface**, decreasing the chances of a subsurface unit being missed.



5. So far, we have created a cross-section perpendicular to the strike of the geological layers. This means the dip angle of the layers in the cross section is **the same as the true dip** of the layers and is **the same as the decals** (i.e., field measurements). However, sometimes it is necessary to draw a line of cross-section that is not exactly perpendicular to the dip angle of some units within a mapping area. As we saw earlier, this means the dip/tilt angle of the layers is no longer the same as the **true dip** and some maths has to be applied to calculate the **apparent dip**. The apparent dip is the angle they would appear at in cross-section and it *depends on the angle between the line of cross-section and the strike of the tilted layers*. This sounds complicated but luckily for us, Visible Geology has a neat tool to visualise this process and breakdown the maths! So, let's leave geology explorer and head over to the apparent dip tool!

   Menu -> Apparent Dip

6. The pink layer in this new block is a geological layer. The big blue arrow lets you adjust the orientation of your line of cross section (the side of the block in this model). Move the blue arrow around and see how the tilt angle of the pink layer on the exposed surface (i.e., the **apparent dip**) changes as you move it! Note that the **true dip** of the pink layer **never changes**, just the angle of the exposed surface/cross-section!
   a. The Apparent Dip tab in the panel on the right-hand side shows you the equations used to calculate the **apparent dip**, based on the difference in orientation between the line of cross-section, the **true dip** and the strike of the pink layer. Keep a track of the equations as you move the blue arrow until you are comfortable with the values being used to calculate the apparent dip!
   b. You can also use the strike, orientation of cross-section and the **apparent dip** at a given location to calculate the **true dip** of the layers. Switch to the True Dip tab to see how the equations change!



Questions

- What might be some of the pros and cons of collecting lots of drill cores within a mapping area?
- When might you not want to draw a line of cross-section exactly perpendicular to the strike of tilted layers within a mapping area?
- Can you think of any scenarios where you might have the apparent dip and strike of layers, but not the true dip?

Real-world examples

The crossbedding in this sandstone at Vermillion Cliffs National Monument, USA, appear to be dipping down in different directions (white arrows) even though this is the same layer (tinted blue). This illustrates the concept of apparent dip where the eroded rock face is exposing a natural cross-section cutting across the layer, not at right angles to strike. Can you see which direction the true dip would be in for the layer as a whole? Photo: Kate Pedley.

Glossary:

Cross-section: A 2D slice cut through an object.

Line of cross-section: The line on a geological map marking where a cross-section has been created based on the geological units outcropping along that line.

Dip: The maximum downward tilt angle of a surface from horizontal, measured in degrees. Will *always* be orientated perpendicular (90^{o}) to the strike.

Strike: The orientation of a horizontal line (tilt = 0^{o}) along a planar surface (i.e., the direction the plane is travelling in). Will *always* be orientated perpendicular (90^{o}) to the dip.

Apparent dip: The dip of a geological layer as it appears in cross-section where the orientation of the cross section is not perpendicular to the strike of that layer.

True dip: The real dip of a geological layer.

Drill core: A core cut from drilling down into the Earth.

Geological history: The story of how each geological rock type within a given area was created (and deformed/eroded if appropriate), written in chronological order from oldest to youngest.