

## **EOSC 110 – Reading Week Activity, February 2015.**

### **Visible Geology: Building structural geology skills by exploring 3D models online**

Geological maps show where rocks of different ages occur on the Earth's surface. The patterns of rock ages provide information about the structures beneath the surface. Interpreting structures based on map patterns is difficult and takes practice. This activity provides a fun and interactive way of building some of the necessary skills.

The sequence starts simple and builds towards more sophisticated capabilities. During the activity you will develop your abilities to:

- I. Recognize when rocks are tilted underground, and use the pattern of oldest and youngest rocks to determine which direction the layers are tilted
- II. Recognize the surface patterns that indicate rocks have experienced ductile deformation – i.e. they have been folded. Use those patterns to determine in what manner the folds are oriented, both for simple folds (anticlines and synclines) and folds that are themselves tilted (plunging anticlines and synclines).
- III. Recognize the surface patterns that indicate rocks have experienced brittle deformation – i.e. they have been faulted. Use patterns of the ages of faulted rocks to determine in which direction motion has occurred along the fault. Identify some ways that our knowledge of faulting structures is limited when only surface rocks and their ages are known.
- IV. Recognize on a map when the boundary between rocks represents an unconformity - that is, when ages of rocks do not change in a continuous way across the boundary due to erosion or non-deposition.
- V. Account for the ways that simple topographic features like valleys and hills will affect the patterns on geologic maps.

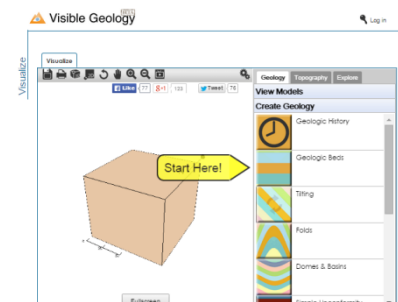
While working through this sequence we recommend that you make a collection of “technical geological terms” with definitions. Be precise and concise, and don't forget words that may sound familiar but which are used for specific reasons in geological contexts. For example, new words like anticline and syncline are easy to define, but you also must be sure to use words like “bed”, “dip”, “strike” etc. with precision.

This exercise makes use of an online interactive geological visualization tool called Visual Geology developed by Rowan Crockett, currently (2015) a graduate student in the Department of Earth Ocean and Atmospheric Sciences.

### **Getting started with Visible Geology**

**To begin, for this exercise use either the Chrome or Internet Explorer Browser in Windows. On a Mac use either Chrome or Firefox. Other configurations (like Safari, or Firefox on Windows) have been found to cause problems. Please let us know if you have difficulties – we cannot test drive every configuration!**

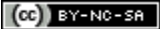
Install Chrome by pointing any browser to <http://www.google.com/chrome/> and follow “download” directions. You could work with a partner or study group if you are reluctant to install Chrome but you will recall that you learn much better if you actually manipulate the models and this modelling tool yourself.



Once you have Chrome running, start Visible Geology by going to the website at <http://visiblegeology.com> and click the big “Visualize” button.

**If you want a little help**, here are four short and efficient tutorial video clips on YouTube:

---

 Visible Geology learning activity by F.Jones and L. Porritt, 2015.

Licensed under a [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-nc-sa/4.0/).

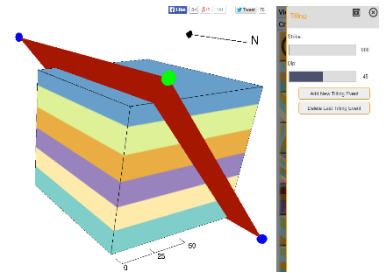
- Introduction: What you can do in VG [https://www.youtube.com/watch?v=CITO\\_y7Hhqk](https://www.youtube.com/watch?v=CITO_y7Hhqk) (2:04 mins)
- First things you should do: <https://www.youtube.com/watch?v=nUBKM8A7ICY> (1:17 mins)
- Geology tutorial; [https://www.youtube.com/watch?v=TATPGHC\\_w4E](https://www.youtube.com/watch?v=TATPGHC_w4E) (1:12 mins)
- Using and correcting beds & tilt: <https://www.youtube.com/watch?v=Rqy4nWPOqPM> (1:20 mins)

Start by simulating a geological layer in the ground by clicking the “Geologic Beds” tool. A layer is added by clicking the little blank document icon. You do not have to “edit” each layer, but you can if you like. Add six or more layers before returning to the 3D view of your new model of cube containing horizontal beds or layers.

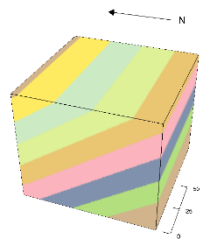
## I. Consider tilted rocks

- 1) Explore this simple 3D model of a cube of ground consisting of flat, horizontal beds by answering these questions to yourself or with a study buddy:
  - a) Which layer represents the “oldest” layer in this sequence of undisturbed or undeformed rock beds?
  - b) Which layer represents the “youngest” layer?
  - c) Which geological principle have you applied to make these decisions?
  - d) Click the 2D icon near the upper left of your Visible Geology window. What is the resulting geologic map look like? Pretty boring I hope!

- 2) Tilt this model by clicking the “Tilting” tool. You can drag the blue and green balls around, and you can adjust the Strike and Dip sliders on the right side.
  - a) When **dip** is 35 degrees what does this angle represent? Define in your own mind as precisely as you can. Refer to North, South, East and West in your answers.
  - b) When **strike** is 270 degrees, what does this angle represent? Hint – compare strike angles of 90 and 270 degrees.



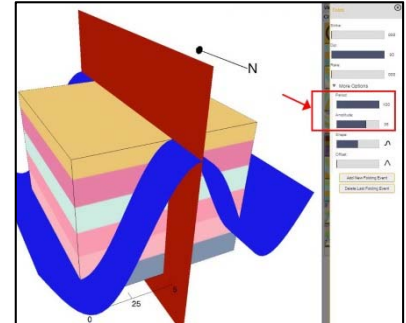
- 3) Set tilt parameters of **Strike** = 270 degrees and **Dip** = 35 degrees, click the “Add New Tilting Event” button and go back to your 3D view. You should see something similar to the figure here with beds tilted this way relative to the North arrow. Your colours will be uniquely yours – Visible Geology generates bed colours randomly.
  - a) Which are oldest rocks in this cubic volume of ground?
  - b) Which are youngest rocks in this cubic volume of ground?
  - c) Simulate a map-only view of this geological setting by clicking the 2D icon (icon near top left).
    - i) Where are oldest visible rocks on this map? Answer again in terms of North, South, East and West.
    - ii) Where are youngest visible rocks on this map?
    - iii) If the tilt was less (dip angle smaller) would you see more or fewer layers on the map?
    - iv) If the tilt was more (dip angle larger) would you see more or fewer layers on the map?
    - v) What is the relation between age of rocks on the surface and tilt or dip?
  - d) Click the “Tilting” tool again and click “Delete Last Tilting Event”. Change strike to 90 degrees, click the “Add New Tilting Event” button and go back to your 3D view. Explore the model a bit, then set the view to the 2D (or map) mode.
    - i) Now where are the oldest and youngest rocks?
    - ii) What is the relation between age of rocks on the surface and dip? Is this relation the same as you defined for the previous tilted model? You should be able to define a relationship between age



sequence visible ON THE SURFACE and dip that works in all settings; eg “*younger towards the east means dip is down to the east*” or something like that.

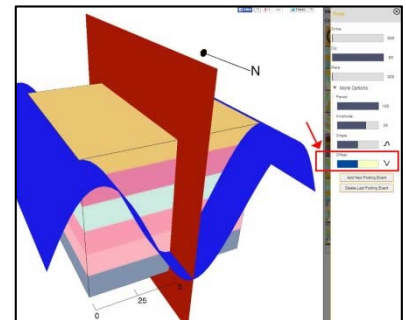
## II. Consider folded rocks

- 4) Next we’ll explore how **ductile or folding structures** will appear on a map. Click “Tilting” and then “Delete Last Tilting Event” until you are left with horizontal beds. Return to 3D view and click the “Folds” tool button. You should see your horizontal beds intersected with a red plane and a blue “sine wave”. Click the “Add New Folding Event” button to see what the program does to simulate folding structures in your geological model. Then click “Delete Last Folding Event”.



We want a single fold. Make it by clicking “> **More Options**” and setting **Period** = 100. Also set **Amplitude** = 35 (pointed to in the figure). “Add” this folding event and return to the 3D view. Explore your new geological scenario with layers that were folded after being deposited.

- Where are oldest layers? Do they outcrop? Are they buried?
- Where are youngest layers? Do they outcrop? Are they buried?
- Switch to map (2D) view and describe the pattern of oldest and youngest layers that would be visible on the ground’s **surface**.
- Compare this pattern to the pattern for simple dipping beds. Is the “rule” relating old/young pattern and “dip” of buried beds consistent for dipping and folded layers?



- Next you will fold your layers in the “opposite” direction.
  - Click “Folds” and “Delete” the last folding event.
  - Move the “**Offset**” slider to midway. This should shift the “sine wave” so the peak is down in the model’s centre. “Add” this folding event and return to 3D view. Explore a little, then switch to map (2D) model.

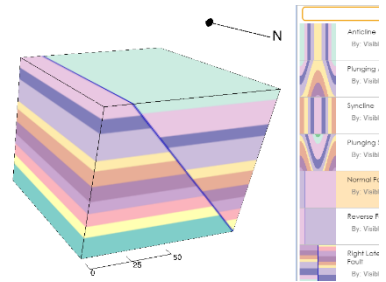
- Where are oldest and youngest layers? Do they outcrop? Are they buried?
- Is the pattern relating “dip” to young/old rock sequences still consistent with previous situations?

- 5) Now what happens if the folded rocks get tilted? How does the map change? We will use prepared models for this section. Above the set of tool buttons there is a label “**View Models**”. Click it. Pick the “Anticline”.
- Which of the two folds you just finished working with does this look like? Now you can define “Anticline”!
  - Guess what type of fold is called a “Syncline” ... Click the Syncline button under “**View Models**” to check.
  - Now choose the “Plunging Anticline” model.
  - How is this different from the Anticline model? What direction is the “Plunge” – defined in the same way you defined “dip” for undistorted layers earlier.
  - Switch to 2D or map mode. Where are oldest and youngest visible layers on this map of the simulated earth’s surface? What is the sequence of younger to older rocks in North/South and East/West directions.
  - Now PREDICT what pattern you will see if the subsurface structure was in fact a plunging ANTICLINE.
  - Pick the Plunging Anticline and confirm your prediction about patterns that reveal this is a plunging anticline.

- h) Finally – for this model – which layers have experienced the most erosion in order to arrive at the flat topography represented by your map.

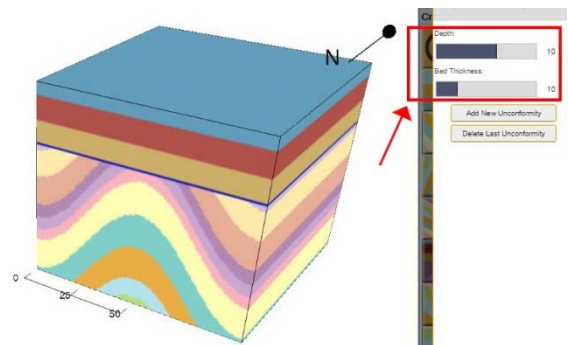
### III. Consider faulted rocks

- 6) Next we will explore briefly the patterns on a geological map caused by brittle deformation or faulting. From the **View Models** menu pick the “Normal Fault” prepared model.
- Explore this model – which side of the fault has “dropped”?
  - If you look at only the map (2D) view, are younger rocks visible on the side that dropped or the other side?
  - Choose the “Reverse Fault” and answer the same questions: Which side of the fault has dropped and are younger rocks visible on the surface on the dropped side or the other side?
  - Now – what’s the difference between a “normal” and “reverse” fault, in terms of whether younger or older rocks are on the upper side of a tilted fault?
  - Consider the 2D map view of either of these two situations.
    - Looking at patterns of younger and older rocks, can you tell which side “dropped” relative to the other?
    - Can you tell whether the fault is tilted to the left, vertical or right?
    - Therefore, can you tell whether you are looking at a normal or reverse fault given only ages of rocks on the surface?

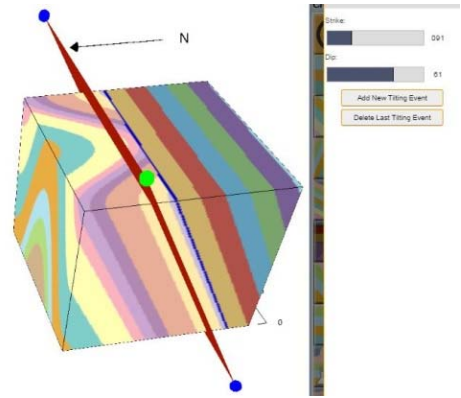


### IV. Unconformities

- 7) Now we increase the complexity and consider map patterns where rocks of non-continuous ages are next to each other. That is, some erosion occurred before new layers were added. Load the syncline model from “**View Models**”. Click the “**Create Geology**” (bottom right) and pick the “**Simple Unconformity**” tool. Set both the “Depth” and “Bed Thickness” parameters (red arrow in the figure) to roughly 10 and click “Add New Unconformity”.
- Which rock unit is the oldest of all?
  - Which is the youngest of all?
  - Which is the youngest rock unit of the syncline?
  - If the two faces you can see in the figure to the right were visible cliff faces, which would have a visible angular unconformity? Which face would have a visible disconformity?



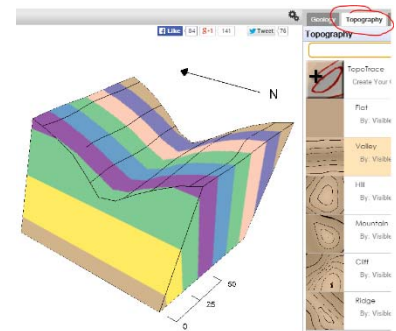
- e) To make a map view that exhibits an unconformity we will tilt this whole structure so that erosion will reveal the angular unconformity at the surface. Click the “Tilt” tool and set the tilt to have Strike of roughly 90 degrees and Dip of roughly 60 degrees. Add this new tilting event and return to 3D viewing mode. After exploring a little in 3D mode, switch to 2D mode and be sure you can label



- ...
- the youngest and oldest rocks of the syncline that are visible on the surface (i.e. visible in the map only);
  - the youngest and oldest rocks of the layered rocks lying unconformably on top of the syncline rocks, and
  - the youngest and oldest rocks of the entire geological package in this cube.
  - the youngest and oldest rocks of all the rocks visible at the surface – i.e. on a geological map.
  - ALSO – assuming you were GIVEN the ages of these rocks (which is the normal situation with a map) be sure you can identify the unconformity and explain how you know it is an unconformity IN TERMS OF the rocks’ ages.

## V. Topography

- 8) We must now explore how real topography (rather than simple flat land) affects the patterns on a map.



- Start by reloading Visible Geology with the browser’s window-reload button. Make a simple model with 6 or more layers that was tilted with Strike=0 (not 90) and dip of roughly 60 degrees.
- Click the little grey “Topography” tab, top right between “Geology” and “Explore” and set the view to 2D mode. In this mode, click the “Valley” topography. How has this changed the pattern of rocks on the geology map? Click the “Ridge” topography. Compare the directions of “V” shapes for tilted layers with valley or ridge topography.
- Also, view the ridge and valley models in 3D and consider how the scale of topographic features compares to the scale of geologic rock unit variations. Would topography have this pronounced effect if layers were (for example) several hundreds of meters thick while topographic features like valleys and ridges were only 10s of meters in depth or height?
- Try some other types of topographies. While exploring, think about a variety of reasons why the boundaries between rock units are not smooth. This has to do with “real” ground, not simply the geometry of layers, tilts and topographic features.
- Finally, open a Syncline or Anticline model from “View Models” and explore the effects of topography on this type of folded structure.

- 9) The last step is to try out your new map reading skills with the online activity in the course’s CONNECT website.