Lab 12: Virginia 3-point problem & cross section
EPSC 240, Geology in the Field
Nov 14, 2018

Due date: Monday Nov 26

Meet: 1:35 pm in FDA 348

Bring: Pencils, colours, ruler, protractor, calculator, stereonets, graph paper, laptop if you want to look at maps online.

Wear: Your choice

Instructions: Turn in answers to all **bold** questions.

This week (and next week) you will construct a cross section across an area of the Appalachian Mountains near Fort Lewis, Virginia. You can download the geologic map of Virginia as a .kml file to examine using Google Earth here: https://mrdata.usgs.gov/geology/state/state.php?state=VA. This map is clickable to give you formation names and ages.

A geological cross section is constructed to show the three-dimensional structure of an area. As most of our observations are of surface geology (other information could come from mines or boreholes, or geophysical surveys), the geologic map is the standard product to display geologic features (lithology and structure, with some orientation data). A cross section takes one line across the map and projects the geology to depth beneath that line. So, it makes a second 2-D representation through the 3-D earth.

As the data is mostly projected from surface observations, it becomes more and more unconstrained with depth. Even where there is some subsurface information, it is generally up to the geologist to make an interpretation based on strict adherence to the surface constraints, guidance from principles of geology and simplifying assumptions (e.g., principle of superposition, assumption of constant unit thickness). As you have seen on geologic maps, the pattern of contacts is controlled by the geology as well as the shape of the topography (a contact on a map is an intersection line between two surfaces: the contact surface and the landscape). Topography controls the apparent thickness of units. Thus, it will be important to take topography into account when constructing the cross section.

In the first part of the assignment we will practice using a method for determining the 3D orientation of contacts from sparse outcrops: a 3-point problem. Then, we will move on to working on the cross section. Begin by developing an understanding of the map (by constructing a legend) and constructing a topographic profile which will form the basis of your cross section. Use the contacts and measurements on the map and along with other methods (stereonets, 3-point problems) to determine the orientation of structures on the map and represent them accurately in your cross section. A list of general rules (and instructions) for drawing cross sections appears at the end of this assignment (adapted from the longer handout used in the structural geology class). Refer to it as you work through the procedure below.

Turn in:

- Solution to 3-point problem, including working. Hand in page below. (10%).
- Legend for geologic map. Hand in annotated map sheet. (15%)
- Cross Section on graph paper (topo profile: 15%, structures 20%, correct construction 25%)
- Any and all calculations and stereonets which contributed to the cross section (15%)

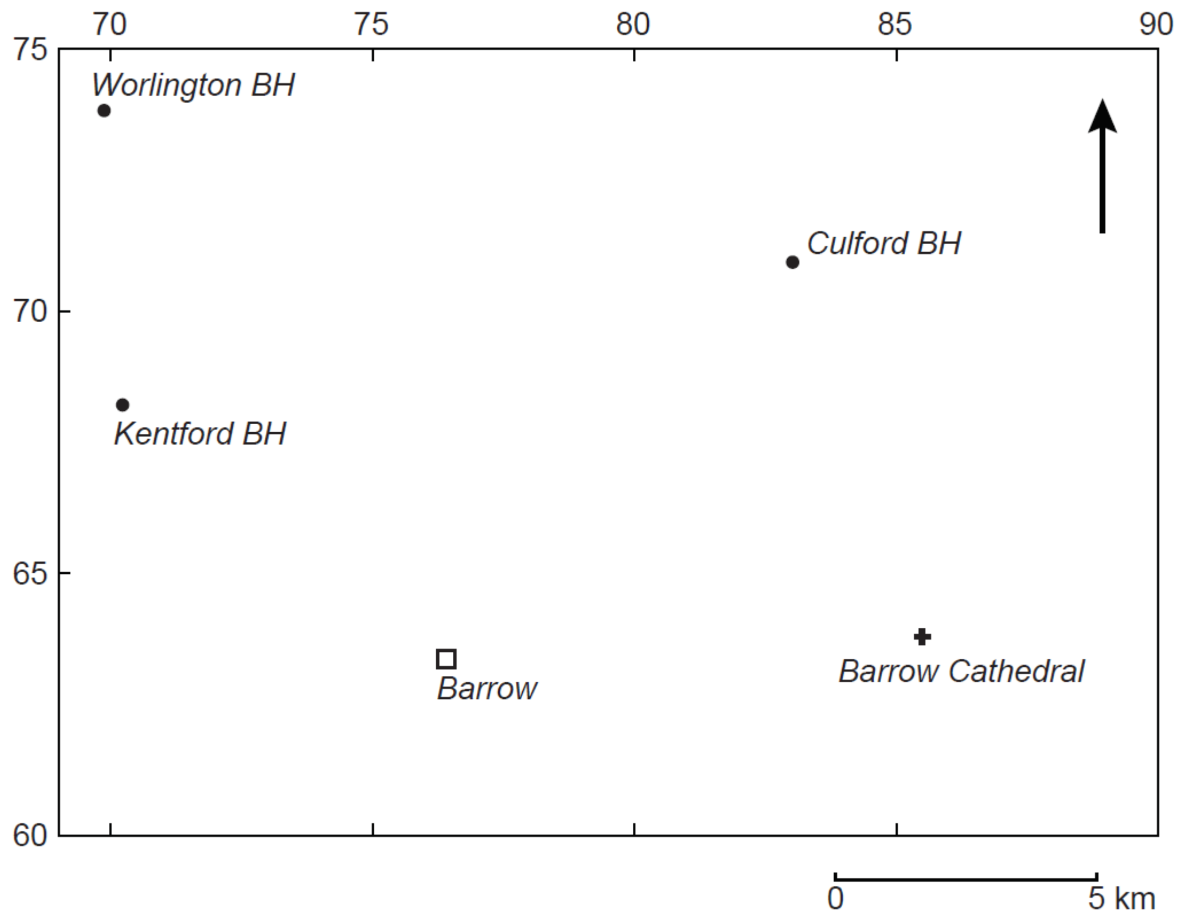

Figure 1: Map of the location of boreholes around the town of Barrow.

1. A 3-point problem

3-point problems are useful when you have information about where a contact between rock types crops out, but not the orientation of the contact. Using the location and elevation of outcrops of a contact, and some basic trigonometry, you can calculate the true strike and dip.

Refer to Figure 1. The base of a unit called the Lower Greensand is encountered in three boreholes at the following elevations relative to sea level (note negative values are below sea level in the list below):

- -150 m at the Culford Borehole
- -75 m at the Kentford Borehole
- -60 m at the Worlington Borehole

Use the 3-point problem method to determine the strike and dip of the base of the Lower Greensand. Predict the height of the base of the Lower Greensand below the Cathedral at Barrow.

2. Create a legend for the map

Create a legend for the geologic map on one or more sheets of white paper. You may create it by hand or use a computer (or some combination of your choice). A map legend should include:

- Horizontal scale
- North arrow
- Topographic contour interval
- Definition for every geographical symbol on the map (rivers, roads, landmarks, towns, etc)
- Definition for every geological symbol on the map (strike and dip symbols, contacts, faults, etc)

Name, age and description for each geological unit including symbol (e.g. Scy) and colour/pattern with a brief (10-15 words) description of the unit, arranged with oldest at the bottom and youngest on top. Make sure to check whether any geologic units which don't outcrop along your cross section line might project into it at depth if they dip or plunge toward the line, and include those in your legend.

Sources of information:

- The map provided
- Google earth
- The geologic map of Virginia https://mrdata.usgs.gov/geology/state/state.php?state=VA
- Freeman textbook
- The internet (especially Google Scholar)

3. Draw topographic profile along the line provided on the geologic map

We can think of the map as showing an x-y planar view of the 3D geologic patterns, and define x-direction as the cross section line. The z-direction (vertical) is shown on the map by the use of topographic contours. The cross section will be the x-z plane which intersects the map along the cross section line.

You will need a piece of graph paper on which to construct your cross section which is as long as the cross section line and about 4 inches wide. This can be constructed by cutting a piece of graph paper in half the long way and taping the ends together.

The cross section should have the same vertical scale and horizontal scale (this is called 'no vertical exaggeration'). On your graph paper, draw a line as long as your cross section line on the map (lightly, in pencil) and using your horizontal scale determined above, add a vertical scale to both ends of the line. Extend the vertical scale from sea level (at the bottom) to above the highest point on the topography of your cross section line (at the top). ** If you find it easier to project deeper than sea level, go right ahead ** (sea level is a minimum depth at which your cross section must be completely filled in with geology.)

Lay the thin strip of paper along your cross section line and mark the location of all major contours (bold lines) along the top of section. Transfer these down the page to the appropriate point on the z-axis for the height of the contour and mark a small dot. Check it carefully by comparing it to the map, and by looking at the elevation profile on Google Earth. When you are confident with your line, draw over it with fine black ink pen (this will make it last through the geologic colouring which is to come). Connect all these dots with a smooth line to form the topographic profile. Make sure you have a completed topographic profile by lab on Wednesday.

4. Constructing the geological cross section

In the same way that you transferred the topographic contours to construct your profile, mark the geologic contacts from where they intersect the cross section line. Transfer these to the topographic profile line on your map with a small tick mark. Transfer all the contacts the same way, whether they are conformable bedding contacts, intrusive, fault, unconformity, whatever, it doesn't matter for marking their location.

You have already determined the relative age and the lithology of the units on the map when you worked on the legend. Check the strike and dip symbols around the contacts to determine the orientation of conformable bedding contacts (where the orientation is the same on either side of a contact). For conformable contacts, where the strike direction is roughly perpendicular (±20°) to the cross section line, you can use your ruler to project the strike line into the line of section and plot the contact at its appropriate dip below at the same elevation as the measurement that was made at the ground surface.

For other types of contacts (faults, unconformities, intrusive contacts), the contact need not be parallel to local bedding measurements, so we cannot use them to assume the orientation of the contact. For these, you will need to use other methods (such as 3-point problems for planar features) to determine the contact orientation.

To fill in your geology, start with the youngest features and contacts (those which crosscut other contacts).

Draw these from the surface down to the 0' elevation (sea level) line, at the orientation you have determined in the previous step. Make them curved or straight as appropriate based on the structures you can see on the map. Progress to the older and older features until all your contacts are filled in. Add symbols to show the sense of motion on faults as appropriate (note: sometimes relative displacement which is hard to find on the surface is actually easier to see from the constructed cross section if the fault has slipped in the dip direction). The last step is to draw over your contacts with a fine black ink pen and neatly colour the units to match your map legend.