

**Introduction**

Happy Halloween! In this lab we will focus on interpreting geologic maps.

For the lay person, geologic maps are intriguing and mystifying images composed of swatches of color, curving and straight lines and all sorts of strange symbols. They juxtapose the familiar (roads, topography) against the obscure (the distribution of underlying rocks and structures). They have been shown in museums as works of art and hung on the walls for their aesthetic appeal. They dazzle.

For dedicated earth scientists, geologic maps are just as intriguing and mystifying. Even for the authors of most geologic maps, there are elements of the final product that continue to puzzle and defy simple explanation. But for geologists, maps are the fundamental tools of our trade. They synthesize and organize the observations and interpretations we make in the field into a format that allow us to make further interpretations and correlations. Once published, they are accessible and useful to other geologists.

In order for us to successfully create maps of our own, we must work to develop an intuition for what information is present in geologic maps and how we extract that information in an efficient manner. By the end of this course in the spring, I expect that each of you will be able to look over a geologic map and recognize the important structures and relations between units well enough that you could sketch out in your mind a number of rough cross-sections. This intuition and facility for geologic map interpretation is developed through two types of exercises: pouring over paper maps in the lab and making your own maps in the field. Today we will work on the first part and we'll save the second for the desert.

**Materials**

Geologic Maps and Legends	Tracing Paper with Grid Pattern
Index of Geologic Structural Symbols	Calculator with Trig functions
Index of Geologic Map Patterns	Rulers, colored pencils, protractors

**The Workflow**

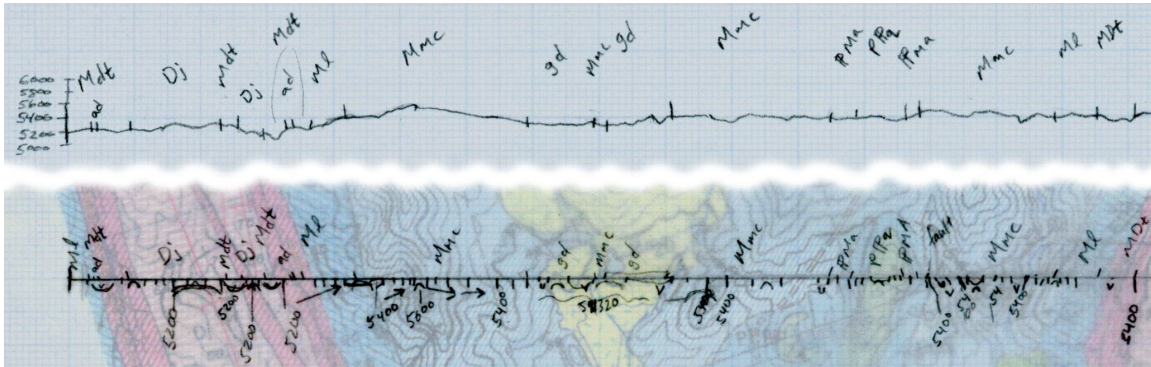
1. Discuss the types and scales of geologic maps that exist and the data and symbology used in each.
2. Discuss how the interaction between topography and geologic structures determines map pattern.
3. Pick a location to create your cross-section on the Devil's Fence Geologic Map.
4. Draft a topographic profile along your cross-section, locating unit contacts
5. Project adjacent structural data onto cross-section line, make apparent dip calculations, and draw these values onto the cross section.
6. Calculate unit thicknesses (necessary for drawing subsurface beds, drafting the stratigraphic column and identifying changes in unit thicknesses across the map area)
7. Draw the geologic cross section for the Devil's Fence Quadrangle.
8. Draw the stratigraphic column for geologic units in the Devil's Fence Quadrangle.

**1. Types and Scales of Geologic Maps**

Geologic maps come in numerous flavors. The data depicted on the map may be useful to mineral exploration, petroleum exploration, water resources, glacial geology, surface deposits, structural geology, marine geology, continental assemblage, etc. For example, for mineral exploration, local maps of the variation in the earth's gravity and magnetic fields is extremely useful in locating deposits. Some maps separate out discrete units according to their lithology while others separate out units according to deposit's age. Some maps describe tectonic units by lumping together all the formations that have the same tectonic origin. The level of detail in a particular map depends on its scale and on the intentions of the geologist drafting the map. For example, a geologic map at the scale of the world cannot possibly display separate units on Mt. Saint Helens, but a geologist creating a map just of the volcano would take great care to map each separate eruptive deposit. The scale of the map is also indicative of how the data was collected. For local maps, the data presented was likely collected by the field observations of the author. For larger scale maps, the data was likely collected by multiple workers at different times and compiled (and often simplified) by a only handful of individuals. Other maps at larger scales are based purely on remote sensing (using aerial photos or satellite imagery), not field observation. (show examples, Walther's law)



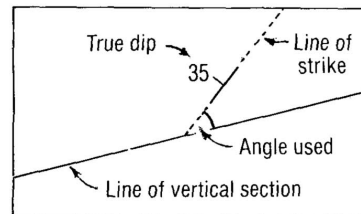
You are now ready to draft your topographic profile. It is much easier (and geologically correct) to make your cross section with *no vertical exaggeration*. Look along your cross section line and find the highest and lowest elevations. Next, find the scale bar on the map. Along the edge of a scrap piece of paper, draw ticks spaced according to the contour interval. (200 ft works for our map) Make sure you have enough ticks to cover the range of elevations along your profile. Next, project the ends of your section line up to about a third of the way down from the top of the tracing paper. (see figure above) This is where you will draw your topographic section. Use your paper with the contour interval ticks to make scales on both sides of the upper section line. If it is not clear where the elevations trace across, you can draw your own faint horizontal guides. You are now ready to project your data up from the section line to create the topographic profile with unit-contacts crossings. Your line should look something like:



### 5. Projecting structural data onto the section and calculating apparent dip

Because structural data on geologic maps is seldom found in straight lines, we have to project the structural data from the region onto our cross section line. In regions where the data is sparse you may need to go further out from your line. In regions where the data is rich close to the line, don't include data from very far away. There is no hard-and-fast rule on how far away to get data from, so use your best judgment. Try to get at least a few good structural measurements for each of the major units or structural features in your cross section.

In this lab, because of the relatively subdued regional topography, we will project structural data along-strike until it intersects the section line. Where the data intersects the line is where we will plot that values on the cross section. If there was greater variation in topography across the map, we could not simply project the data along strike to the section line.



Because the strike of the projected structural data is not perpendicular to the cross section line, we cannot directly use the dips measured in the field. If the strike is anything but perpendicular to the section line, the dips that we draw on our section will be less than the measured dips. We will determine this value, the apparent dip, for each structural data point along our section. We can determine apparent dip using either a stereo-net, a trigonometric calculation or a table of values. For this exercise we will use the table, but for reference, I will also provide the trigonometric calculation below.

True dip	ACUTE ANGLE BETWEEN STRIKE AND LINE OF VERTICAL SECTION															
	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	80
5	0.0	0.5	1.0	1.5	2.0	2.0	2.5	3.0	3.0	3.5	4.0	4.0	4.5	4.5	5.0	5.0
10	0.5	1.0	2.0	2.5	3.5	4.0	5.0	6.0	6.5	7.0	8.0	8.0	8.5	9.0	9.5	10.0
15	1.0	1.5	3.0	4.0	5.0	6.5	8.0	9.0	10.0	11.0	11.5	12.5	13.0	13.5	14.0	15.0
20	1.0	2.0	3.5	5.5	7.0	9.0	10.0	12.0	13.0	14.5	15.5	16.5	17.5	18.0	19.0	20.0
25	1.0	2.0	4.5	7.0	9.0	11.0	13.0	15.0	17.0	18.0	20.0	21.0	22.0	23.0	24.0	25.0
30	1.5	3.0	6.0	8.0	11.0	14.0	16.0	18.5	20.5	22.0	24.0	25.0	26.5	27.5	28.5	29.5
35	2.0	3.5	7.0	10.5	13.5	16.5	19.5	22.0	24.0	26.5	28.0	30.0	31.0	32.5	33.5	34.5
40	2.0	4.0	8.0	12.0	16.0	19.5	23.0	26.0	28.5	30.5	33.0	34.0	36.0	37.0	38.5	39.5
45	2.5	5.0	10.0	14.5	19.0	23.0	26.5	30.0	33.0	35.0	37.0	39.0	41.0	42.0	43.0	44.5
50	3.0	6.0	11.5	17.0	22.0	27.0	31.0	34.5	37.5	40.0	42.5	44.0	46.0	47.0	48.0	49.5
55	4.0	7.0	14.0	20.0	26.0	31.0	35.5	39.5	42.5	45.0	47.5	49.5	51.0	52.5	53.5	54.5
60	4.5	8.5	16.5	24.0	30.5	36.0	41.0	45.0	48.0	51.0	53.0	55.0	56.0	57.5	58.5	59.5
65	5.5	10.5	20.5	29.0	36.0	42.0	47.0	51.0	54.0	56.5	58.5	60.0	62.0	63.0	63.5	64.5
70	6.5	13.0	25.5	35.0	43.0	49.0	54.0	57.5	60.5	63.0	64.5	66.0	67.0	68.0	69.0	69.5
75	9.0	18.0	33.0	44.0	52.0	57.5	62.0	65.0	67.5	69.0	70.5	72.0	73.0	73.5	74.0	75.0
80	13.5	26.5	44.5	56.0	63.0	67.5	70.5	73.0	74.5	76.0	77.0	78.0	78.5	79.0	79.5	80.0
85	26.0	45.0	63.5	71.5	75.5	78.0	80.0	81.5	82.0	83.0	83.5	84.0	84.0	84.5	84.5	85.0

C. Trigonometric solution of apparent dip problems:

True dip from strike and one apparent dip:

$\alpha$  = plunge of the apparent dip,

$\delta$  = plunge of the true dip,

$\beta$  = angle between the strike of a plane and the trend of an apparent dip

$$\tan(\delta) = \tan(\alpha) / \sin(\beta)$$

the derivation is as follows (refer to the diagram below from the geometric relations)

$$\begin{aligned} AX &= BY \\ \tan AOX &= AX/OA = BY/OA \\ OA &= OB / (\cos AOB) = OB \sec AOB \\ \tan AOX &= BY / OB \sec AOB \\ BY &= OB (\tan BOY) = OB \tan BOY \\ \tan AOX &= OB \tan BOY / OB \sec AOB \\ \tan AOX &= \tan BOY \cos AOB \\ \tan AOX &= \tan BOY \sin(90 - AOB) \end{aligned}$$

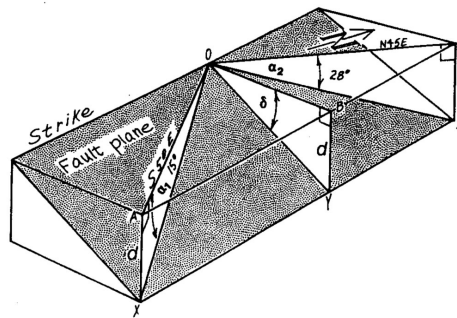
$$AOX = \alpha,$$

$$BOY = \delta,$$

$$90 - AOB = \beta$$

therefore:

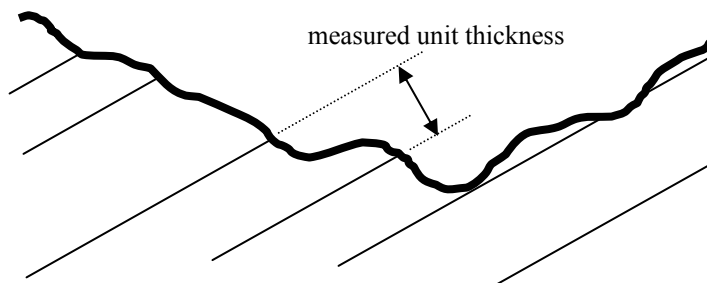
$$\tan(\alpha) = \tan(\delta) \sin(\beta)$$



To use the table on the previous page, measure the acute angle between the projected strike line and the section line and match this value with the measured dip of the bed. Locate the positions of the intersections between of the projected strikes and the section line and plot them on a line just above your lower reference line on the tracing paper. Once they are located, project them up onto your section and draw short line segments extending down below the surface at their apparent dip. Write the apparent dip value above the surface.

## 6. Calculating the thickness of the geologic units

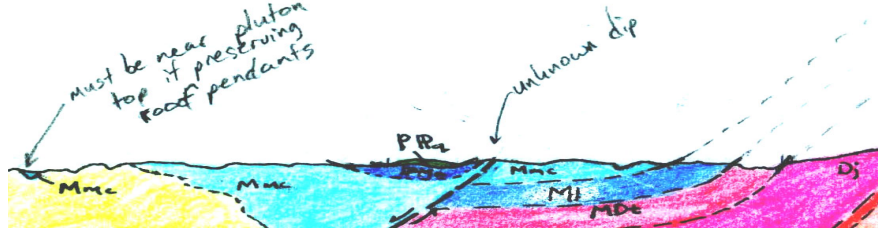
In order to construct a coarse, reconnaissance stratigraphic column or project units to depth in our cross sections, we need to know the thickness of the geologic units in our study area. Assuming that our cross section is approximately perpendicular to the strike of most units, we can calculate the thickness of the units using some trigonometry and our topographic cross section. To do this, we can take the apparent dip values within the unit (or better yet, the values at the upper and lower contacts of the unit) and project the unit contacts up into the air. The length of the line perpendicular to the contacts is the unit thickness. Note: If our section line was less perpendicular to the strikes of the units, would be underestimating the unit thicknesses. In that case, measure unit thicknesses separately using sections perpendicular to strike.





## 7. Drawing the geologic cross section

Now that we know the unit thicknesses and the apparent dips of the units, we can begin to draw the cross section. Ink your topographic profile, your unit contacts and your apparent dip at the surface. Be prepared to erase heavily as you try out different solutions. You may find correction fluid is your friend. Strive to maintain consistent unit thicknesses as you project units below the surface. If there are faults of known displacement, try to demonstrate this as well. If you are uncertain of the dip of the fault, just consider it vertical and make a note that the dip is uncertain. If there is a unit that there is no apparent dip data for, just keep it consistent with the units above and below it. Also, igneous intrusive units sometimes follow bedding planes and sometimes do not. Use the legend to help you decide which are which. Their map pattern in deformed regions should also help your visualize this. Also look at the map in regions adjacent to your cross section line and try to use clues from those regions to understand what might be going on below your area. If it helps you visualize the continuity of the structures, project the contacts up into the air using dashed lines. As well, try projecting your data to a depth that you feel you have moderate certainty about. Deeper than that should be the realm of light dashed lines with lots of question marks. Color in the units, shading boldly in regions well constrained by your data (the surface) and shading lightly in regions that are speculative (the deep subsurface). Feel free to add clearly drafted notes all over your cross section as you deem necessary. Label units and other items to inform your reader of what they are seeing. Here is a small portion of a cross section as an example



## 8. Drawing a stratigraphic column

Now that we have created a geologic cross section and know the unit thicknesses, we are ready to draft our stratigraphic column. We will create a column scaled according to unit thickness rather than geologic time. Start by summing the thicknesses of the units so that you know what scale to draw the column at so that it fits on one piece of paper. For the units that are not crossed by your cross section line, ask the members of the other groups what the thicknesses of these units were or calculate them by hand off the geologic map (remembering to take into account the structural dip of the beds). Pick some bottom unit as the base of the column and begin the elevation there as zero. Each subsequent unit then adds onto the height of the unit below it. The columns to include are (from left to right): age, height above arbitrary zero, unit thickness, lithologic column and notes. If you want to add one or change the order to increase clarity go for it... just strive to make it look good. Use the key to the geologic map (below) to help you understand the types of contacts between the units as well as the lithologic types. Use the symbology for lithologic units from Compton's book to help you decide how to draw each of the units. Like the cross section, annotate the heck out of the column; make it a useful graphic tool for understanding the geologic history of the Devil's Fence Region.

Types of unconformities

