## Lab 12: CONSTRUCTING GEOLOGIC CROSS SECTIONS

Geologic cross sections are vertical slices through the earth that depict the surface and subsurface geology along chosen lines of section. A cross section ideally clarifies geometric and geologic age relationships that may be difficult or impossible to visualize solely from inspection of a geologic map. Accurate extrapolation of the surface geology to depth along a line of cross section is often the only rigorous way to predict the subsurface geology of a region, and thus is an important tool that all geologists must master. Today's lab deals with the mechanics of projecting surface geologic data into the subsurface and cross section construction.

## A. Selecting lines of section

Choosing a cross section line involves considerations and trade-offs among two important factors. First, one would ideally like to have good control on bed thicknesses and the location and attitudes of bedding contacts, faults, fold axes, unconformities, etc. along the entire length of the section. Unless data were collected during mapping with the cross section in mind, this ideal is rarely met. One usually has to project at least some data that is off the line of section into the cross section. There are rigorous means to do this, some of which are described below. Second, the cross section should show as much information as possible about the relative ages and geometries of the units and structures in the area. This can usually be achieved by selecting lines of section that are perpendicular or at a high angle to the regional strike of bedding, major faults or fold axes.

For either or both of these considerations to be met it is sometimes necessary to put bends or offsets in sections. Where possible, these should be placed in the areas of least complexity in order to maintain as much visual continuity as possible within the cross section. Offsetting of a section line should be done only parallel to the strike of the bedding or other feature at the point of offset.
******The preselected cross section line for today's lab nicely meets both criteria. It is perpendicular to the strike of bedding, fold axial traces, and faults, and includes all map units and structures. ${ }^{* * * * *}$

## B. Projection Techniques

I. Basic assumptions

Lacking subsurface or surface control that indicate otherwise, two assumptions are commonly made when projecting surface data to depth. They are: 1) Bed thicknesses remain constant; 2) Strike and dip angles do not change with depth.
Over small areas and shallow depths these assumptions may be valid; over larger areas and greater depths, and in folded regions, they aren't.

Both assumptions should be tested whenever possible by examining map relations in areas away from the section line; e.g. does the map show evidence that a unit thins or thickens along strike? or is there evidence that strike and dip change with elevation or location with respect to a fold or fault?
******For the cross section in today's lab we will assume constant bed thicknesses in order to constrain location of unit contacts with depth, but we will not be able to assume constant strike and dip with depth. The map pattern clearly shows evidence of several folds, which must affect the dip of units at depth. Strike and dip data around the folds, even if far from the line of cross section, can be projected into the line of cross section to derive dip angles at depth, as explained below. ${ }^{* * * * * * * ~}$

## II. Apparent Dips

True dip is the angle of dip perpendicular to strike; dip angles in all other orientations are apparent dips and must always be less than the true dip. It follows that in any cross section or part of a cross section that is not perpendicular to strike, the dip of planes in the cross section must be show as apparent rather than true dips. Apparent dips range from $0^{0}$ for strikes parallel to the line of section, to the true dip for strikes perpendicular to the line of section. The equation that relates true dip to apparent dip for any plane striking at an angle to the line of cross section is:

$$
\tan \mathbf{a}=(\tan \mathbf{b})(\cos \mathbf{c})
$$

where angle $\mathbf{a}$ is the apparent dip, angle $\mathbf{b}$ is the true dip, and angle $\mathbf{c}$ is the angle between the true dip direction and the apparent dip direction.
******For today's lab, it will not be necessary to calculate any apparent dips for the data that lie along the line of section; the line of cross section is, for all practical purposes, perpendicular to the strike of bedding and faults. However, for data that you wish to project into the line of section from off the cross section line, it may be neccessary to calculate apparent dips. Such data can be used, for example, to arrive at the precise shape of the fold hinges at depth. ${ }^{* * * * * *}$
III. Vertical Exaggeration, dip angles and thicknesses

It is often necessary to expand the vertical scale of a cross section relative to the horizontal scale in order to show thin beds or small features that might otherwise be impossible to represent. This vertical exaggeration is accomplished by simply choosing a vertical scale that is larger than the horizontal (map) scale. For example, for a map with a scale of 1 inch equal to 1000 feet, a cross section that has a vertical exaggeration of 2 X will have a vertical scale of 1 inch equal to 500 feet.

Vertically exaggerating a cross section correctly not only requires expanding the unit thicknesses but also increasing the dip angles. A vertically exaggerated dip can be calculated by the simple formula:

$$
\tan \mathbf{d}=(\mathbf{v})(\tan \mathbf{e})
$$

where $\mathbf{d}$ is the vertically exaggerated angle of dip, $\mathbf{v}$ is the exaggeration factor (e.g. 2 in the example above), and $\mathbf{e}$ is the true or apparent dip before exaggeration. A graph of this relationship is shown in Figure 1.
***** Today's lab requires a vertical exaggeration of 2 X . Using either the equation above or the graph in Figure 1, be sure to convert all dips to exaggerated dips. ${ }^{* * * * *}$
IV. Projecting data into the line of section

Data that do not lie directly along the line of section can be incorporated into the section if a few simple rules are followed. First, all data to be incorporated must be moved into the section along a direction parallel to strike. This ensures that the data remain in their proper location relative to other features in the section. Second, a correction must be made for the elevation of the data point. Planar features that are moved into the section from elevations above the topographic profile must remain above the profile and those below must remain below.

The situation is somewhat different for beds folded about a plunging axis, like those on the map for today's lab. Plunging, folded beds produce map patterns that are in essence "drawn-out" or "stretched-out" cross sections. The method of down plunge viewing is a very powerful technique that allows us to look at a map of plunging folds and visualize what a cross section through them should look like.

To try the technique, take the map, orient it so you are looking down the fold axes of the large plunging syncline (although not indicated on the map, the folds must plunge to the east). You will be looking at the map edge-on, or at a very low angle to the page. Next, tilt the map about $8^{\circ}$ (the assumed plunge of the folds) away from you. What you should now see is a foreshortened view of the map. This foreshortened is what the cross section of the syncline should look like.

To accurately portray this view in cross section, we need to show the "upplunge" data, the data that are closest to you in the down-plunge view, below the line of section. How far down below the surface should these data (e.g. contacts in the hinge of the fold) project? Use the amount of plunge and the distance from the line of section and figure it out.

The same projection technique can be used to visualize and project data above the line of section. These are the data that appears on the far side of the cross section line, down-plunge, when you hold the map for down-plunge viewing. Data that projects above the topography of the section line can be shown in the air as dashed lines. Such projections into the air above the section are nearly as important those projected down into the ground. They are an integral part of any section and must be included!

## C. Construction Details

In addition to the depicted surface and subsurface geology, all cross sections contain a range of other information pertaining to the location, scale, topography, rock units etc. Without this information, the cross section is incomplete. All cross sections should contain:

1) Title; stating name and location of section (i.e. "Geologic Cross Section AA' of the Austin West Quadrangle, Travis County, Texas)
2) The authors name and the date.
3) A labeled topographic profile, with the major geographic or physiographic features labeled above the section.
4) Vertical ends ticked off in bar scale fashion, with every second or fifth tick mark labeled with the appropriate elevation. The end bars should extend above the section line and be labeled at the top with the point on the map that they correspond to (e.g.A, A') and the direction (North, South, East, West, etc.).
5) A label above the topography for every bend in the section ("Bend in Section").
6) Abbreviated rock unit labels that match the labels on the map and explanation (e.g. Qal, Kgr5, etc.) for each unit in the section.
7) A statement about the vertical exaggeration, if any (i.e. No vertical exaggeration; vertical scale is 4X horizontal scale).
8) A bar scale showing the horizontal scale, in integer units.
9) Arrows or T (toward) and A (away) on all faults showing relative sense of motion.

The contacts and faults on the cross section should be shown with the same symbols as the map; dashed or solid lines and the line thicknesses should be maintained as closely as possible. When possible the same color scheme should be used. With a limited number of colored pencils this will not always be possible, but try to avoid radical departures from the map.

## ASSIGNMENT

Construct the geologic cross section A-A' of the appended map. Take the section to 1000 feet below sea level. Use a 2 X vertical exaggeration ( 1 " $=1000$ ' for the vertical scale, $1 "=2000$ ' for the horizontal scale). Don't forget to vertically exaggerate dips before plotting. Assume constant unit thicknesses unless otherwise indicated by the map pattern. Use strike lines to calculate dips of faults or beds when not indicated by strike and dip measurements on the map. Assume all folds plunges $8^{\circ}$ eastward.

Begin by using the down plunge method of viewing to visualize what your cross section will look like. First, examine the map key and note the relative age of the various units. Next, look at the strike and dip symbols near the section line, noting which are for overturned and which for upright bedding. Examine the traces of all faults. Are they steep or shallowly dipping, based on the rule of V's? Examine the axial trace symbols. Which folds are upright and which are overturned?

Now, pick the map up and view it down-plunge. How deep below the surface of the section is the major syncline hinge? What happens when folds die out along strike?

Using your down-plunge view, sketch a rough cross section, concentrating on the location, shape, and orientation of bedding, folds and faults.

Using this sketch as a guide, construct an accurate cross section.
Project data into the line of section to arrive at the proper distance below and above ground for the location of fold hinges.

