Objectives

- These exercises will develop the skills of 3D visualization and description of geologic structures using correct terminology.
- Enable students to communicate the 3D orientation of geologic structures to other co-workers, collaborators using precise terminology and symbols.
- Enable students to evaluate the geometry of geologic structures.
- After completion, can you i) visualize the orientation of a structure described in a report or an oral presentation, and ii) articulate the orientation of a given geologic structure to your colleagues?

Materials: pencil, colored pencils, trig-calculator, tracing paper, paper, ruler, protractor

I. Vocabulary

Many of the structures that we can observe in seismic lines, cores, or in outcrops can be approximated by *lines and planes*. In this lab you will learn the rudiments of structural orientation, including strike, dip, apparent dip, trend, plunge, and rake. You will then examine and use two different techniques to solve planar and linear geometric problems that you would typically encounter working in industry or conducting geologic field research. **MEMORIZE** the following terms and learn to visualize these features in 3-D.

**Attitude**: the orientation in space of a structural element; e.g., bed, fault, lineation, etc. The attitude of a planar structure is expressed by its **strike** and **dip**; the attitude of a line is expressed as **trend** and **plunge**.

**Bearing** (azimuth): The horizontal angle between a line and a specified coordinate direction, e.g., north, etc., or in degrees from 0-360.

**Quadrant**: Four quarters of the cardinal directions; e.g., NE, SE, SW, NW. Compasses in the U.S. predominantly use quadrants in which each quarter is divided into 90° increments beginning with 0° at both N and S and 90° at both E and W.

**Strike**: The bearing of a horizontal line contained within an inclined plane. The strike is a line produced by the intersection of a horizontal and inclined plane. Measured relative to north in quadrant space.

**Dip (δ)**: The vertical angle between an inclined plane and a horizontal line that is perpendicular to the strike line.

**Trend of Dip direction**: The bearing of a line that is perpendicular to the strike line that points to the dip direction.

**Trend**: The bearing of a line. Non-horizontal lines trend in the down-plunge direction.

**Plunge**: The vertical angle between a line and horizontal.

**Pitch or rake**: The angle measured *within* an inclined plane between a horizontal line (the strike line) and the line in question. (Measured with a protractor.)

**Apparent Dip (α)**: The vertical angle between an inclined plane and a horizontal line that is NOT perpendicular to the strike of the plane. For an inclined plane, the apparent dip is ALWAYS LESS THAN THE TRUE DIP. Apparent dip, therefore, really defines the inclination of a line and may be expressed with a trend and plunge or by its pitch (or rake).
II. Conventions for expressing strike & dip of a PLANE

Strike and dip can be expressed in a number of different ways and it is advantageous to be able to conceptualize these conventions.

In the U.S., strike is measured using the **quadrant method** in which the compass is divided into four quadrants (NE, SE, SW, NW). A fault plane that strikes north-west/south-east and dips 42° southwest would be expressed as **N45W/42SW**; meaning that the line produced by the intersection of an imaginary horizontal plane and the inclined fault plane trends 45° west of north. The dip of this plane, measured perpendicular to the strike, is 42° in the southwest direction. Quadrant data should always be recorded and displayed relative to **north** in the following way: e.g., NxW/ySW, where x is the measured strike and y is the measured dip.

The other convention is the **azimuthal method**, in which the compass is divided into 360° (0°/360° at the top, counting in a clockwise direction). Using the azimuthal method, the fault plane noted above would have a strike of either 315° or 135°. You would then have to specify the dip direction: 315/42SW.

**Dip direction** may be specified in two ways:

1) The *right-hand rule*: looking in the direction of the strike the plane should dip to your right. Therefore, in the above case, the strike would be 135° and the dip would be 42°. The convention for displaying *right-hand rule* data is strike first, then dip; e.g., 135°/42°.

2) Alternatively, you could specify the dip direction; e.g., 315° 42W. In this case, you do not have to look down the strike line and worry about the *right-hand rule* because the dip direction, “W”, is noted.

III. Conventions for expressing plunge & trend of a LINE

The convention for noting the trend of a line is that it should always be measured in the **down-plunge view**, and the plunge is always recorded first. For example, 36°/S54W means that a line plunges 36 degrees in a direction 54 degrees west of due south. When measuring a line in quadrant notation, you may use all quadrants, not just the north half.

IV. Map symbols and notation conventions

**PLANES**

The symbols to the left represent strike and dip symbols for planes of the various orientations noted. The long line represents the strike direction; the shorter tick points toward the dip direction. The bold italics notation is in quadrant form; the regular font is in azimuth with “right hand rule”.

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**On the left:**

- **Quadrant Notation:**
  - North (N)
  - East (E)
  - South (S)
  - West (W)

- **Azimuth Notation:**
  - North (N)
  - East (E)
  - South (S)
  - West (W)

**On the right:**

- **Quadrant Notation:**
  - NE (Northeast)
  - SE (Southeast)
  - SW (Southwest)
  - NW (Northwest)

- **Azimuth Notation:**
  - 0° (North)
  - 90° (East)
  - 180° (South)
  - 270° (West)

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LINES

The symbols to the left represent plunge and trend symbols for lines of the various orientations noted. The bold italics notation is in quadrant form; the regular font is in azimuth. Note that the direction of trend for a given line is always measured toward the plunge direction. For example, the measurement of 30°/S45°E defines a line that plunges 30° from horizontal toward the direction of S45°E.

V. True vs. Apparent Dip

The block diagram below (A) displays the difference between apparent dip and true dip. Apparent dip, $\alpha$, is the vertical angle measured from horizontal down to an inclined plane in a vertical plane that is NOT perpendicular to the strike line. The horizontal angle between the apparent dip direction and the strike line is $\beta$.

The true dip, $\delta$, is equal to the maximum dip of the plane and is therefore always greater than $\alpha$.

VI. Putting it all together

Example based on oblique block diagram and associated map view.

**Strike & Dip**
- Quadrant: N30°W/60°SW
- Azimuthal: 330°/60°SW; 150/60SW
- Azimuthal, r.h.r.: 150°/60°

**Dip Direction:**
- Quadrant: S60°W
- Azimuthal: 240°

**Apparent Dip Direction:**
- Quadrant: N90°W;
  S90°W; or due W
- Azimuthal: 270°

$\beta$ angle: 60° (acute angle)

Notice how the profile plane in Fig. B containing the apparent dip ($\alpha = 56°$) is not perpendicular to strike.

VII. Website Resources:

http://earthsci.org/education/fieldsk/compass/compass.html
http://www.geo.utexas.edu/courses/420k/PDF_files/Brunton_Compass_09.pdf This shows some examples of how geologists measure strike and dip.
http://www.fault-analysis-group.ucd.ie/structurecontours/contours/strike.html
True versus apparent dip model. Cut out along bold perimeter line.
Redrafted from the Fault Analysis Group, University College Dublin.
Cut out model to display strike/dip, plunge/trend and apparent dip. Cut out along perimeter line. Redrafted from the Fault Analysis Group, University College Dublin.

Cut out along bold line prior to lab.