Structural Geology Lab 2: Outcrop Patterns and Structure Contours

I. Geologic Map Symbols

A. Refer to Appendix F in back of lab manual for list of commonly used geologic map symbols

1. Emphasis:
   a. strike and dip of bedding
      (1) inclined
      (2) horizontal
      (3) vertical
      (4) overturned
   b. Fold axes
      (1) syncline
      (2) antincline
      (3) plunging folds
   c. strike and dip of joints
   d. strike and dip of foliation
   e. fault symbols
      (1) thrust
      (2) vertical

II. Outcrop, structure and age relationships

A. Folding of rocks
   1. Inclined sequence of sedimentary beds
      a. layer cake relations
         (1) oldest on bottom, youngest on top

      b. **Fold Types**

         (1) **Anticlines**-upfolded forms, results in older rocks becoming enclosed within younger strata

         (2) **synclines**-downfolded forms, results in younger rocks becoming enclosed within older strata.

         (3) **symmetrical folds** - both limbs of the fold dipping at same angle away from fold axis

         (4) **asymmetrical folds** - both limbs of the fold not dipping at same angle away from fold axis
         (5) **overturned folds** - condition in which one limb of fold has been tilted beyond vertical

         (6) **plunging folds**- axis of fold is tilted

         (7) **Domes**- more or less circular equivalent of anticline, oldest rocks exposed in center of dome

(8) **Structural Basin**- more or less circular equivalent of syncline, youngest rocks exposed in center of dome (not to be confused with depositional basin)

c. **Outcrops Patterns Associated with Folded Rocks**

(1) As rocks are folded, and subsequently subjected to erosion, regular patterns become evident in relation to type of rock that outcrops and age of the rock that outcrops in an area of folded strata. In essence, erosion exposes the interiors of the folds

(2) **Non-plunging Folds**- axis of fold is horizontal, results in parallel bands of dipping strata about the fold axis

(a) anticlines- oldest strata exposed along fold axis
(b) synclines- youngest strata exposed along fold axis

(3) **Plunging Folds**-axis of fold is tilted, results in alternating V-shaped bands of dipping strata oriented about the fold axis.

(a) anticlines- oldest strata exposed in the center of the V, V points in direction of plunge of fold axis

(b) syncline- youngest strata exposed in the center of the V, V points in opposite direction of plunge of fold axis.

(4) **Doubly Plunging Folds**- fold axis is plunging in two opposite directions, results in a flattened oval pattern, or a double V-shaped pattern <<<>>>>.

(a) anticlines- oldest strata exposed in center of flattened oval

(b) synclines-youngest strata exposed in center of flattened oval.

III. Using outcrop pattern to determine structural attitude

A. Comparison of Outcrop Pattern with Topographic Contours

1. The Law of "V's"

a. Contacts of horizontal beds appear parallel to contour lines
(1) Contacts V upstream, when crossing valleys

b. Contacts of vertical beds are not deflected at all when crossing valleys and ridges

c. Inclined planes V updip when crossing ridges

d. Planes that dip upstream, V upstream

e. Planes that dip downstream

(1) At angles the same as stream gradient:

(a) bed contacts appear to parallel stream bed

(2) At angles gentler than stream gradient, V upstream

(3) At angles greater than stream gradient, V downstream

Refer to Figures 2.2-2.7 in lab manual for visual summary

B. Using geologic contacts and topographic contours to determine strike and dip of beds

1. Identify a single geologic contact between beds in stratigraphic sequence
2. Find a single contour line that crosses the geologic contact at two points

a. A line connecting the points of equal elevation along the geologic contact defines STRIKE

3. To Determine Dip
   a. Take same geologic contact, and identify another (different) topographic contour line that crosses at two points, draw a line between them
      (1) You now have two strike lines on the same geologic bed
      (2) draw a line perpendicular to the strike lines and this will define DIP
         (a) remember that dip direction is in the direction of bed slope, or elevation decrease
      (3) Solve for dip using the following equation
         (a) Tan (Dip) = vertical /horizontal
            i) Inv Tan = angle of dip from horizontal

IV. Structure Contouring

A. Structure contour lines are similar to topographic contour lines

1. structure contours = lines connecting points of equal elevation on the surface of a bed of rock

a. Structure contour lines = "continuous strike lines"

2. Data

a. structure contour data is commonly derived from drilling of bore holes
   (1) The elevation of the top (or bottom) of a given unit is determined from drilling:

b. Elevation of top of bed = (surface el. of boring - depth to rock contact)

c. Data is plotted on a map base and contoured using the rules of drawing contour lines

(1) This can also be accomplished using Golden Software Surfer program

3. Structure Contour Interpretation

a. V-shape pattern with high elevations in center = plunging anticline
b. V-shape pattern with low elevations in center = plunging syncline
c. Bullseye patterns with high in middle = dome
d. bullseye patterns with low in middle = basin
e. Fault Interpretation
(1) Abrupt gaps or terminations in contour pattern = normal fault
(2) Overlaps in structure contour pattern = thrust or revers faults

4. Contour drawing techniques

a. Inverse distance method

(1) assume constant gradient between two data points and interpolate elevations

b. Data interpolation

(1) projecting from known control points to unknown areas

c. Contour intervals: follow rules same as topographic contours

V. Three-point Problems

A. Method of determining strike and dip of bed

1. If the elevations of three points on a given planar surface are known, then the strike and dip of the plane can be determined

B. Structure Contour/Graphical Approach

1. Determine elevation of three points known to lie on the surface of a plane (e.g. bed of rock, fault, etc.)

a. Identify the high, middle, and low elevation points
b. draw a line between the high and low elevation points ("line x-y")

c. Assuming a constant grade between the two points, the middle elevation must also occur somewhere on line x-y.
d. Determine total elevation difference between high and low points
e. Determine total map distance between high and low point along line x-y (using engineers scale)
f. Calculate a vertical-distance conversion factor:

(1) $\frac{\text{map distance (inches)}}{\text{Vertical difference (ft elevation)}}$

g. Now, subtract the low elevation from the middle elevation and multiply by the vertical-distance conversion factor in f above
h. you now have a measurement in inches, measure that distance along line x-y from the low el. point and make a tick mark
i. connect a line between the middle el. point and the tick mark in h... this is your line of strike (a line connecting points of equal elevation; relative to the middle point).
j. draw a line perpendicular to the strike line to the low elevation point... this is your dip direction
k. Calculate dip using Tan (dip)=V/H where V = middle el. - low el, and H = distance between strike line and low el. point, along the perpendicular dip line (from j above); units of V and H must be in ground units, like feet.
(1) divide V/H and press inv Tan on your calculator, this is the angle of dip as measured from horizontal

VI. Determining Outcrop Patterns From Structure Contour Data

A. Overlay of structure and topographic contours

1. Use tracing paper to overlay structure contours on topographic contours
2. Where lines of similar elevation intersect (i.e. structure = topographic contours); a rock outcrop point on the bedding plane contact can be expected

a. General Rules

(1) In areas where topographic contours are at higher elevations than structure contours, then the bedding plane is "buried at depth" below the earths surface

(2) In areas where structure contours are at higher elevations than topographic contours, then the bedding plane is above the topographic grade (i.e. it has been eroded away)

(3) In areas where structure contours and topographic contours intersect at the same elevation, the bedding

plane will outcrop at that point on the earth's surface

(a) A line connecting the intersection points of equal elevation on the map, will define the "crop line" of that bedding plane on the earth's surface.

Lab 2 Exercise / Assignment

In lab manual:

Problem 2.1 on p. 14 Outcrop Patterns

Problem 2.2 on p. 14 Drawing Structure Contours

In addition to the directions on p. 14, identify the anticline and syncline on the map, and draw in the appropriate map symbols identifying the trend and plunge of the axis of folds (see symbols in appendix F).

Problem 2.3 on p. 22 Solving a Three-Point Problem

Assume that the surface elevation is 10,000 Ft. First convert the depth data given, to elevations by taking: (Surface El - Depth to Top of SS). Use this converted elevation for points A,B, and C to solve the 3-point problem.

Problem 2.4 on p. 26 Using Structure Contour to I.D. Outcrop Pattern

Follow the example given on pp. 22-26. Would be a good idea to use tracing paper overlays with the map in Fig. 2.18 (p. 29)