LABORATORY 3: Rotational Problems with the Stereonet.

I. Plotting the Pole to a Plane.

a) Any planar attitude may be represented instead as the perpendicular line to the pole- this is referred to as the *pole*.

b) The pole is useful in rotation problems precisely because we can directly rotate it about any specified rotation axis. This cannot usually be done with a plane plotted as a great circle. Therefore, the first step of many rotational problems is to plot planar attitudes as a pole. Since the pole represents the attitude of a line its orientation is described by a plunge and bearing, and it plots as a point on the stereonet.

c) Steps for plotting the pole:

1. Arrange the tracing paper on the net as you would for plotting the great circle for the planar attitude. Plot the great circle at this time for reference. Do not rotate the tracing paper from this position yet.

2. With the tracing paper still in (1) position, count 90° along the east-west line from the point where the plotted great circle intersects the east-west line. The direction to count this angle should always be toward the center of the net.

3. After counting 90° plot a point at this position on the east-west line. This represents the attitude of a line perpendicular (i.e. pole) to the plotted plane. After some practice, you will not need the great circle reference for plotting the pole.

II. Fold Geometry Elements

a) Many type of rotation problems consist of undoing the deformational effects of folding- i.e. "unfolding" the fold. To understand the problem you must have a clear understanding of the terminology used to describe folds:

1. *Fold Hinge*: the line formed by connecting points of maximum curvature within a specific folded surface. The hinge is a physical entity that you can actually see and touch.

2. *Fold Axis*: the imaginary line that, if moved parallel to itself, could sweep out the folded surface of a fold. Unlike the fold hinge this is an imaginary line, however, it is always parallel to the fold hinge.

3. *Axial Plane*: the imaginary plane that cuts the fold symmetrically, and which also contains the hinge lines of all affected surfaces.

4. *Fold Limb*: the part of a fold contained between adjacent axial planes. Although these elements are rarely perfect planes, we can often approximate their geometric relationships by assuming that they are planes over short distances.

5. *Overturned Limb*: an overturned limb is a limb of a fold that has been rotated past the vertical during deformation. To put such a limb back to its unfolded position it must sweep past the vertical.

6. *Interlimb Angle*: the angle between the fold limbs measured within the plane perpendicular to the hinge line. This angle is always in the range 0 to 180° and, therefore, can be either acute or obtuse. The interlimb angle of a fold is always cut by the axial plane, and, in the case of a kink or chevron fold, will bisect the interlimb angle.

7. *Axial Trace*: the axial trace of a fold is simply the strike of the axial plane. The axial trace of a fold can always be measured from a geologic map if the map is relatively flat. In that case, the axial trace is simply the line on the map that connects points of maximum curvature between folded contacts.

III. Finding Paleocurrent Direction from Crossbed Data.

a) The bearing of the true dip of *crossbedding* indicates the *paleocurrent* direction when the bed was deposited. If stratigraphy containing crossbeds has been tilted from folding or faulting one can "undo" the deformation by rotating the *primary bedding* back to its original horizontal position. In this undeformed position the true dip direction of the *foreset beds* is the paleocurrent direction.

b) Note that a simple one-step rotation to "undo" deformation is only applicable if the kinematic model for deformation indicated that the tilting of strata was done by rotation about a horizontal axis. It is appropriate to unfold the limb of a fold in this manner only if the plunge of the hinge is 0°.

c) Steps for finding the paleocurrent direction:

1. Plot primary (topset / bottomset) bedding as a great circle on the net. Plot the crossbed (foreset) attitude as a pole since it is this entity that we wish to track through a rotation.

2. Move the strike line of primary bedding great circle to the N-S position and visually imagine the rotation necessary about the horizontal N-S axis to move this plane to the horizontal. This angle is always equal to the true dip angle of primary bedding.

3. Move the pole to crossbedding along whatever small circle that it falls upon, the same number of degrees and in the same rotational sense as in step 2. At this position, the pole represents the attitude of the perpendicular to crossbedding before deformation.

4. The paleocurrent direction is the bearing of the true dip of the plane represented by the new pole position. This bearing is always 180° to the bearing of the rotated pole position.

5. If, during rotation of the pole, the primitive is encountered remember that the pole reflects to the diametrically opposed position on the net.

d) Example:

1. Given primary bedding of N-S, 35E, find the paleocurrent directions from crossbed attitudes (1) N69E, 44 SE and (2) N62E, 80NW.

IV. Unfolding a plunging fold to find the original attitude of a lineation.

a) These types of problems always involve the determination of the bearing of a lineation before is attitude was changed by a later phase of folding. The solution involves unfolding the fold limbs about the hinge line of the fold until both limbs are coplanar. Then, as a last step, the unfolded plane is brought to the horizontal if the lineation is a primary sedimentary feature. As the limb attitudes are rotated, any lineation that is contained in a limb is moved with the limb, the angle that it makes with the hinge always being preserved.

b) At this point it helps to visualize the elements of the problem. If two limb attitudes are plotted, they intersect at the hinge of the fold. Move the hinge line to the E-W line of the net. If both limbs could be rotated such that they merged with the great circle that runs through the hinge point, you would have "unfolded" the fold. If one of the limbs sweeps past the vertical it must be an overturned limb.

c) Steps of the problem:

1. Plot one or both limbs and the hinge of the fold, depending on the specific problem. You must know the hinge attitude before continuing.

2. Plot the lineation that will be rotated as a point. The lineation will always fall on one of the limb great circles. The limbs, by definition, also intersect at the hinge of the fold.

3. Move the tracing paper so that the limb containing the lineation falls on a great circle. Measure the angle between the lineation and the hinge line of the fold. This angle must be preserved through any subsequent rotation steps.

4. Now move the hinge line to the E-W line. Imagine how the limb containing the lineation moves to the "unfolded" position. This is the great circle that passes through the hinge line. Plot the rotated position of the lineation by counting the angle between the hinge line and lineation measured in step (3) above.

5. If the lineation is a primary sedimentary structure it must be rotated to the horizontal. Move the great circle representing the unfolded fold to the primitive through its true dip angle. The lineation will track along a small circle until it encounters the primitive. The bearing of the lineation at this position is the answer.

6. Be careful when you visualize the rotation of the limb if it may be an overturned limb. Remember that both limbs must have the opposite sense of rotation during the unfolding rotation.

d) Example problem- given two limb attitudes (1) N72W, 40NE and (2) N70E, 80NW, the axial trace (N80E) of the fold from a geologic map, and a *sole mark* that trends N0E on the overturned limb, find:

1. The hinge attitude. (30, N64E)

2. The original bearing of sole marks. The sole marks trend along a bearing of N0E in the overturned limb. (S60E)

3. The attitude of the axial plane. (N80E,64NW)

4. The interlimb angle of the fold. (52)

Remember that a sole mark is a primary sedimentary structure that has a linear geometry, therefore, it should have an original plunge angle of 0 and its bearing should be parallel to the paleocurrent direction.

V. Rotational fault problems.

a) A *rotational fault* has displacement that is characterized by motion of one fault block relative to another about a *rotational axis* perpendicular to the fault surface. Usually the problem will ask you to predict the attitude of a planar structure, such as bedding, after some amount of rotation within one block.

b) The rotational axis must always be perpendicular to the fault surface, therefore, if you are given the attitude of the fault you can then plot the rotational axis as the pole to the fault.

c) Since you are to rotate a planar structure in one of the fault blocks, you must plot this structure as a pole.

d) Before actually plotting the solution on the net, make sure that you are clear about the sense of the rotation. Usually the problem specifies a specific orientation in which to visualize the rotations, such as "... as viewed from the southeast looking northwest the motion of the southeast fault block is clockwise".

e) Problem solution steps:

1. Plot fault surface as a great circle. Plot rotational axis as pole to the fault surface. Label rotational axis point with an "R" for reference.

2. Plot the pole to bedding. Label this as point "P".

3. Plot the great circle that contains both "R" and "P", but only between the points "R" and where the great circle intersects the fault. Label the intersection point with the fault as point "L".

4. While visualizing the sense of rotation, move point "L" along the fault surface the amount of the rotation. Label this new point as point "L prime".

5. Plot the great circle that contains both "R" and "L prime". While maintaining the original angle between "R" and "P", plot the "P prime" position along the great circle containing "R" and "L prime". Be careful when plotting this position since it is always possible to count the angle from "R" in two directions- only one position will be correct.

6. The "P prime" position represents the rotated position of the pole to the planar structure. The answer is the attitude of the plane represented by "P prime".

f) Example problem: given a planar fault N30E, 60SE; bedding within the northwest

fault block N90E, 40S; and that the southeast block has been rotated 120 degrees anticlockwise as viewed in the bearing direction of the rotational axis, find the rotated position of bedding in the southeast block.

1. Rotated attitude: (N40E,70NW)

EXERCISE 3A: Rotations with the Stereonet.

This laboratory exercise will test your knowledge of rotation operations with the equal-area stereonet. Use a 3.5 inch radius equal area stereonet to solve the below problems.

Problem 1. A planar limb of a fold (N53°E, 50°SE) contains a crossbed with orientation N22°E, 72°NW. Assuming that the plunge of the fold hinge is 0°, find the original orientation of the crossbed, and the bearing of the paleocurrent.

Problem 2. Given the axis of a rotational fault (42°, S48°E), bedding orientation (N37°W, 66°SW) in the undeformed southeast fault block, and that the northwest fault block was rotated 70° clockwise (as viewed downplunge) about the fault rotational axis, find the rotated attitude of bedding in the northwest fault block.

Problem 3. Given two planar limbs of a syncline (N8°E, 56°SE and N32°W, 80°NE), find the orientation of the fold axis. If there is presently a N90°E bearing ripple-mark lineation on the overturned limb, find the original bearing of this lineation, assuming that it was originally horizontal. How many degrees must the overturned limb be rotated about the fold axis to "unfold" this fold?

Problem 4. The planar limbs of an upright chevron fold (axial plane dip > 45°) have the following attitude:

1. N23°E, 57°SE
2. N12°W,71°SW

With this data, and assuming that the axial plane bisects the interlimb angle, find:

(a) Plunge and bearing of the fold hinge.
(b) Interlimb angle of the fold.
(c) Axial plane attitude of the fold.

Problem 5. The pre-Cretaceous unconformity in Alabama is relatively planar and forms the depositional contact between older folded Paleozoic strata and younger conformable Cretaceous Tuscaloosa Group sediments. The attitude of Tuscaloosa Group strata at an exposure was found to be N15°E,44°NW. At the same exposure, and below the unconformity, an anticline in the Pennsylvanian Pottsville formation had limb attitudes of:

1. N60°E,73°NW
2. N20°E,41°SE

Flute casts occur along Pottsville bedding plane contacts and have a rake angle of 55°NE in the

northwest-dipping limb of the anticline.

(a) Find the attitude of each of the two fold limbs before tilting of the unconformity by deformation.
(b) Find the attitude of the fold hinge before tilting of the unconformity.
(c) Determine the possible paleocurrent direction(s) at the time of deposition of the Pottsville strata.
(d) Find the present attitude of flute casts in the southeast dipping limb of the anticline.

EXERCISE 3B: Rotations with the Stereonet.

This laboratory exercise will test your knowledge of rotation operations with the equal-area stereonet. Use a 3.5 inch radius equal area stereonet to solve the below problems.

Problem 1. The limb of a fold (N53E, 50SE) contains a crossbed with orientation of N22E, 72NW. Find (a) the original attitude of the crossbed, and (b) the paleocurrent direction bearing.

Problem 2. Given the axis of a rotational fault (42, S48E), and that the SE fault block originally containing bedding (N37W, 66SW) has rotated about the rotational axis 70 degrees counterclockwise as viewed down-plunge of the rotational axis, find the new attitude of bedding.

Problem 3. Given two limbs on a syncline (N08E,56SE and N32W,80NE), find (a) the orientation of the fold hinge. If there is an east trending ripple mark lineation on the overturned limb, find (b) the original bearing of this lineation. How many degrees (c) was the overturned limb rotated about the hinge line to retro-deform the fold?

Problem 4. Given a fault (N90E,90) and the attitude of bedding in the south fault block of N49E,42SE, find the attitude of the same bedding in the north block if it has been rotated 150 degrees counterclockwise relative to the south block as viewed from the south block looking toward the north block.

Problem 5. A fold has an axial trace of N44W and a hinge attitude of 56,N30E. What is (a) the full axial plane attitude? Assuming that the fold is symmetrical and that the interlimb angle is 26 degrees, find (b) the attitude of the two limbs. A flute cast lineation trends N08W on the overturned fold limb. What is (c) the paleocurrent direction indicated by this primary lineation?