GLG490/598: SUBDUCTION ZONES
FALL 2003
PROFESSORS MATT FOUCH & SIMON PEACOCK

SUPPLEMENT TO HOMEWORK #4

USING EARTHQUAKE FIRST MOTIONS TO DETERMINE FAULT PLANE SOLUTIONS

(From *Fowler* [1990])

To use earthquake first-motion directions you need to have tracing paper, pencil, eraser, pin and an equal-area projection net (also known as Lambert or Schmidt equal-area projection net). On that base projection, great circles are the north-south lines of longitude; azimuth, or strike, is measured by counting lines of latitude clockwise around the edge of the projection.

Example 1. Plot seismograph station S on an equal-area projection. In this example, the azimuth is N20°E from the earthquake to the station; the angle of first-motion is 40° from the vertical (*50° from the horizontal*).

1. Pin the tracing paper onto the base projection through its center.
2. Mark N, the north axis.
3. Mark the azimuth N20°E as x at the edge of the projection (Fig. 1a.)
4. Rotate the tracing paper so that x is at the top of the projection.
5. Mark the point S 40° from the center (*or 50° from the top*) of the projection towards x (Fig. 1b.)
6. Rotate the tracing paper so that N is again at the top of the projection (Fig. 1c.)

S is now correctly plotted on the projection of the lower focal hemisphere.

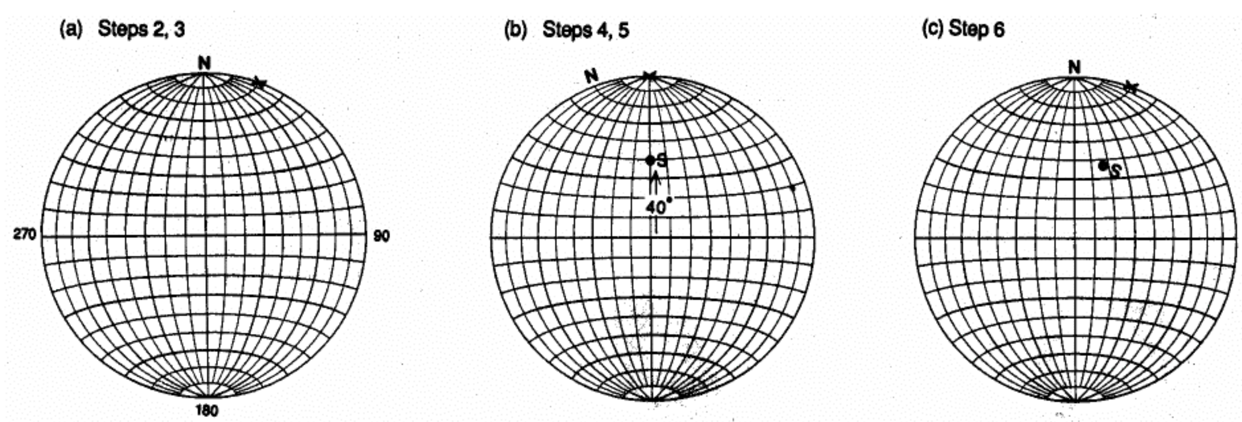

Figure 1. How to plot a seismograph station on an equal-area projection of the lower focal hemisphere.

Example 2. Find the great circle that joins the two points R and S.

1. Plot the points R and S as described in Example 1 (Fig. 2a.)
2. Rotate the tracing paper until R and S both lie on the same great circle (line of longitude.)
3. Trace that great circle (Fig. 2b.)
4. Rotate the tracing paper so that N is again at the top of the projection (Fig. 2c.)

The great circle that joins points R and S is now drawn.

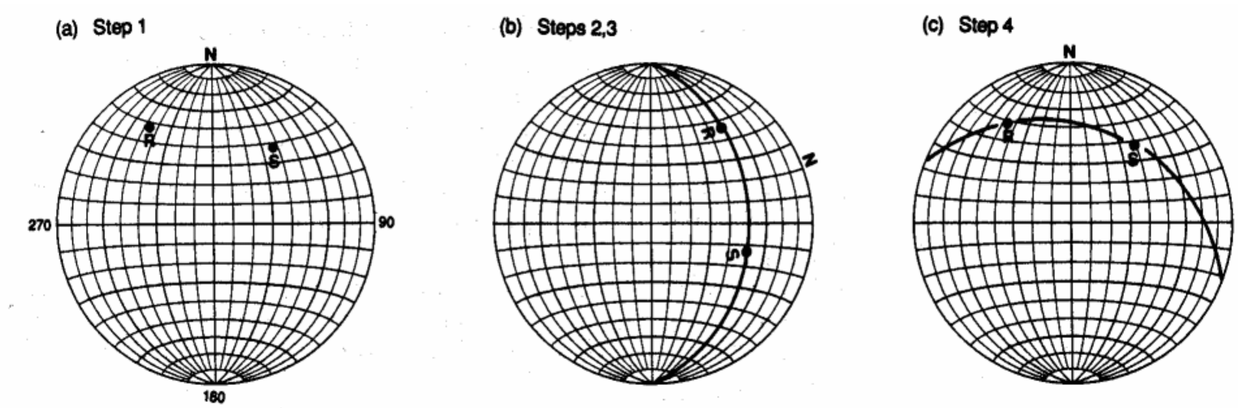

Figure 2. How to find the great circle that joins two points on the surface of the earth.

Example 3. Determine the fault plane, auxiliary plane and slip vector for an earthquake, given the direction of first motion at several seismograph stations.

The fault plane and the auxiliary plane plot on the projection of the lower focal hemisphere as great circles. The fault plane and the auxiliary plane are orthogonal. This means that we need to find two orthogonal great circles that separate the positive first motions from the negative first motions.

1. Pin the tracing paper onto the base projection through its center.
2. Put the first motions onto the tracing paper (Fig. 3a).
3. Rotate the tracing paper until you find a great circle that separates positive and negative first motions. Recall that nodal arrivals will fall on or close to the nodal plane.
4. Trace that great circle; it is nodal plane 1.
5. The dip of nodal plane 1, δ_1, is measured along the equator of the base projection from the outside edge to the great circle. (A horizontal plane with zero dip plots around the edge of the projection. A vertical plane, with 90° dip plots as a straight north-south line.)
6. Count 90° along the equator of the base projection from its intersection with nodal plane 1.
7. Mark that point P_1 on the tracing paper; it is normal to nodal plane 1 (Fig. 3b). (Sometimes the normal to a great circle is called the pole.)

8. The second nodal plane must separate the remaining positive and negative first motions, and since it is also normal to nodal plane 1, point P_l must lie on it. So, rotate the tracing paper until you find such a great circle.
9. Trace that great circle; it is nodal plane 2 (Fig. 3c). If you cannot find nodal plane 2, go back to step 3 and check that nodal plane 1 was correct.
10. Repeat steps 5, 6 and 7 to find the dip of nodal plane 2, δ_2, and point P_2, the normal to nodal plane 2 (Fig. 3c).
11. Rotate the tracing paper so that N is again at the top of the projection.
12. The strike of the nodal planes is measured clockwise around the outside of the projection from N, 78° and 147° (Fig. 3d).
13. The slip vector is the normal to the auxiliary plane. Thus, if nodal plane 2 is the fault plane, point P_1 is the slip vector; and if nodal plane 1 is the fault plane, point P_2 is the slip vector. The strike of the horizontal component of the possible slip vector is measured clockwise around the outside of the projection from N (Fig. 3e).

This earthquake was therefore a combination of normal faulting and strike-slip on either a fault plane striking 78° and dipping at 60° with the strike of horizontal component of slip 238°, or a fault plane striking 147° and dipping at 60° with the strike of the horizontal component of slip 348°.

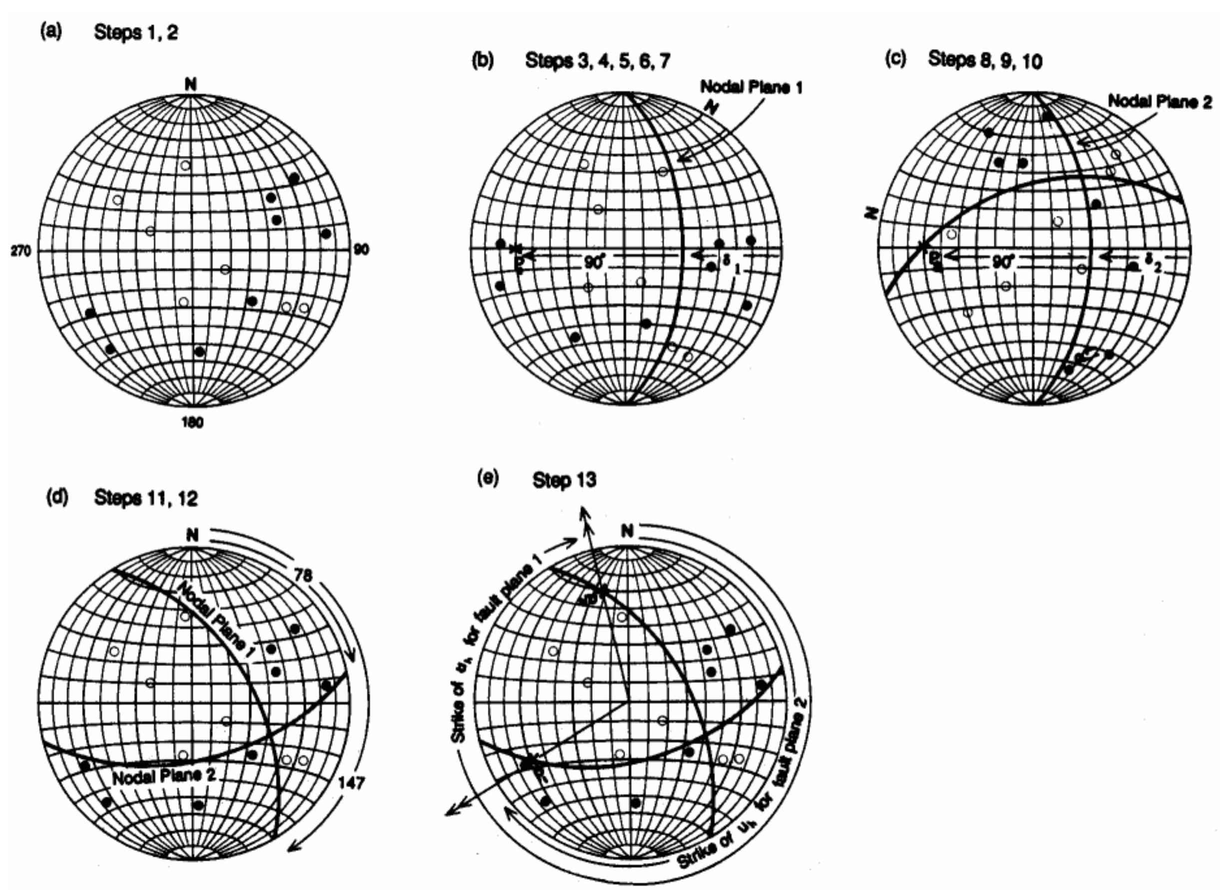

Figure 3. How to determine the fault plane, auxiliary plane and azimuth of the slip vector for an earthquake.