

## DOWN PLUNGE CROSS SECTIONS

### I Main Topics

- A Cylindrical folds
- B Downplunge cross-section views
- C Apparent dip

### II Cylindrical folds

- A Surface of a cylindrical fold is parallel to a line called the fold axis.
- B Cylindrical folds maintain their shape for “long” (infinite) distances in the direction of the fold axis (as opposed to folds bending in the shape of a bowl); they are two-dimensional structures because they do not change in shape along the dimension of the fold axis.
- C Planes tangent to cylindrically folded beds intersect in lines parallel to the fold axis.
- D Poles to cylindrically folded beds are contained in the plane perpendicular to the fold axis, so taking the cross-product of the poles gives the orientation of the fold axis.

### III Down-plunge cross-section views

- A Down-plunge cross-section views can be obtained directly from a geologic map by looking obliquely at the map down a fold axis.
- B Beds appear in true thickness
- C Graphical technique
  - 1 Find orientation of fold axis
  - 2 Draw a cross-section along a plane parallel to the fold axis. The fold axis will be contained in this plane and the fold axis will appear "in true length" and its plunge can be measured.
  - 3 Take an adjacent view of the above cross section where the line of sight is parallel to the fold axis. Viewed end-on, the fold axis will appear as a point. All the other lines lying in the surface of a cylindrical fold will also be viewed end-on, so the fold surface will appear as a curve.
- D Computer-assisted technique using Matlab
  - 1 Find three-dimensional coordinates of points on the folded units. This can be done by digitizing a geologic map, for example, by scanning a map and using Matlab's ginput function:  
[x,y] = ginput

- 2 Transform the coordinates of the digitized points by projecting them onto a new set of right-handed reference axes aligned with the fold axis.

a “Manual” procedure

- i Define the down-plunge (e.g., X,Y,Z) reference frame in terms of the geographic (e.g., x,y,z) reference frame.

For example, let the Y axis be the down-plunge direction, the X axis be horizontal and 90° clockwise from the fold axis trend, and the Z axis be “up” (but not vertical). This is the view one would get if you point your right arm and right index finger down the fold axis, with your thumb pointing to the right, and your middle finger pointing “up”.

- ii Transform the coordinates from the x,y,z reference frame to the X,Y,Z reference frame using the matrix transformation equations.

$$\text{For one point: } \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} a_{Xx} & a_{Xy} & a_{Xz} \\ a_{Yx} & a_{Yy} & a_{Yz} \\ a_{Zx} & a_{Zy} & a_{Zz} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$(3 \times 1) = (3 \times 3) (3 \times 1)$$

$$\text{For n points: } \begin{bmatrix} X_1 & X_2 & \dots & X_n \\ Y_1 & Y_2 & \dots & Y_n \\ Z_1 & Z_2 & \dots & Z_n \end{bmatrix} = \begin{bmatrix} a_{Xx} & a_{Xy} & a_{Xz} \\ a_{Yx} & a_{Yy} & a_{Yz} \\ a_{Zx} & a_{Zy} & a_{Zz} \end{bmatrix} \begin{bmatrix} x_1 & x_2 & \dots & x_n \\ y_1 & y_2 & \dots & y_n \\ z_1 & z_2 & \dots & z_n \end{bmatrix}$$

$$(3 \times n) = (3 \times 3) (3 \times n)$$

- iii Then prepare an (X,Z) plot using Matlab’s plot command:  
plot(X,Z)

The Y (down-plunge) coordinate is irrelevant for this view.

b “Automated Matlab 3-D visualization technique”

- i Use the Matlab command

plot3(x,y,z)

- ii Then use the “view” command to look down the fold axis  
view(-trend,plunge)

(Here the trend and plunge are in degrees, not radians)

## Lab 7

Exercise 1: Down-plunge views    Read *each* problem before you start to do it.

1A) Graphical solution (18 points total)

- a Draw in a top view a line OF that represents a fold axis that trends N70°W and plunges 30°. Show a north arrow on your top view. Draw an adjacent view “A” that shows the plunge of the line; you need to visualize how to look at the line so that you see its plunge. Adjacent to view “A” draw another view “B” that allows you to see line OF as viewed down-plunge (**not** up-plunge). In each view label points O and F, where O is the high point and F is the low point. **(2 points for the top view, 2 points for the second view, 1 point for the third view, 1 point for the north arrow, 3 points total for the labels; 9 points total)**

Assuming that point O is at the coordinate origin and that **x=east, y=north, and z = up**, find the direction cosines of line OF.

- b  $\alpha =$  \_\_\_\_\_ (1 point)
- c  $\beta =$  \_\_\_\_\_ (1 point)
- d  $\gamma =$  \_\_\_\_\_ (1 point)
- e The ratio of the length of OF to the length of the horizontal projection of OF is (to three significant figures) \_\_\_\_\_ (1 point)
- In the third (down-plunge) view**, draw and label two right-handed axes z” and x”; y” points into the page, so you can draw it. Draw the axes such that:
- f The z”-axis points **directly** from “line” OF toward the fold line separating views A and B. (1 point)
- g The x”-axis points away from “line” OF, parallel to the fold line separating views A and B, and is consistent with the y” axis pointing in the down-plunge direction. (1 point)

1B) Spherical projection (equal-angle) solution (36 points)

Here you will revisit the same line as in 1a, but you will obtain the down-plunge view of the line by successive rotations about the z, x', and y" axes using an equal-angle (stereonet) projection. Earlier we discussed how the rotations could be done about the x, y', and z", but they also could be done about the z, x', and y" axes. Use **one** spherical projection for this problem.

- a Plot a fold axis that plunges  $30^\circ$  in the direction N70°W. Label the line with an F. **Consider this line as being fixed in space.**

**(2 points for plotting the line, 1 point for the label; 3 points total)**

Plot three right-handed axes:

- b The x-axis trends due east and plunges  $0^\circ$ . Label it "x".  
**(2 points for plotting the line, 1 point for the label; 3 points total)**

- c The y-axis trends due north and plunges  $0^\circ$ . Label it "y".  
**(2 points for plotting the line, 1 point for the label; 3 points total)**

- d The **negative** z-axis, where the **positive** z-axis points up at  $90^\circ$ . Label it "-z".  
You can't plot the positive z-axis (as defined here) on a lower hemispherical projection, so that is why you are plotting the negative z-axis.

**(2 points for plotting the line, 1 point for the label; 3 points total)**

Now rotate the axes about the **positive** z-axis to yield a new set of axes (x', y', z') such that the trend of the y' axis matches trend of the **fixed** fold axis F.

- e The angle of rotation about z is: \_\_\_\_\_ **Pay attention to the sign of the angle!**  
**(1 point for the magnitude, 1 point for the sign; 2 point total)**

Plot the new right-handed axes:

- f The x'-axis. Label it "x'".  
**(2 points for plotting the line, 1 point for the label; 3 points total)**

- g The y'-axis. Label it "y'".  
**(2 points for plotting the line, 1 point for the label; 3 points total)**

- h The **negative** z'-axis. Label it "-z'".  
**(2 points for plotting the line, 1 point for the label; 3 points total)**

- i Draw a curved arrow that shows the angle of rotation connecting y to y' and label the curved arrow with the angle of rotation. **(1 point)**

Now rotate the axes about the **positive**  $x'$ -axis to yield a new set of axes ( $x''$ ,  $y''$ ,  $z''$ ) such that the trend and plunge of the  $y''$  axis matches trend of the **fixed** fold axis F.

- j The angle of rotation about  $x'$  is: \_\_\_\_\_ **Pay attention to the sign of the angle!**  
**(1 point for the magnitude, 1 point for the sign; 2 points total)**

Plot the new right-handed axes:

- k The  $x''$ -axis. Label it " $x''$ ".

**(2 points for plotting the line, 1 point for the label; 3 points total)**

- l The  $y''$ -axis. Label it " $y''$ ".

**(2 points for plotting the line, 1 point for the label; 3 points total)**

- m The **negative**  $z''$ -axis. Label it " $-z''$ ".

**(2 points for plotting the line, 1 point for the label; 3 points total)**

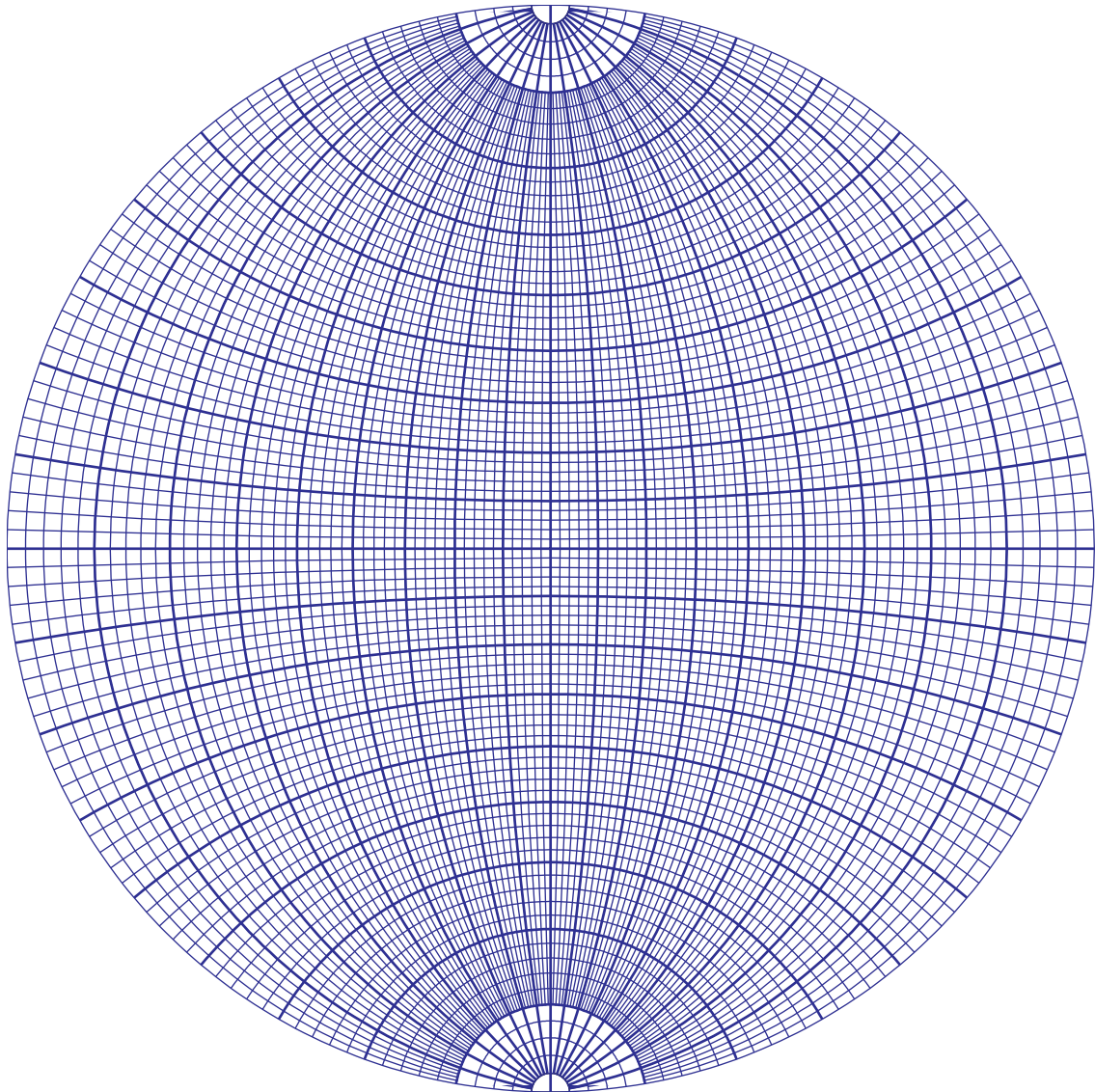
- n Draw an arrow that shows the angle of rotation connecting  $y'$  to  $y''$ , and label it with the angle of rotation.  
**(1 point)**

No third rotation is needed in this case to obtain the down plunge view of fold axis F.

This exercise should show you how three successive rotations about right-handed axes can rotate one reference frame to another.

# Equal-Angle Net (Wulff Net)

N



**Exercise 1C: Rotations using matrices and Matlab (40 points total)**

Start up Matlab after reading what the exercise asks for. Turn in your Matlab printout.

- a Using the expressions for a rotation about the z-axis (x3-axis) as described on page 2 of Lab 6 and your answers from exercise 1B, find matrix R1 that describes the rotation about the z-axis in exercise 1B. Enter the matrix elements in Matlab and include a copy of the printout. For example:

$$R1 = [a11, a12, a13; a21, a22, a23; a31, a32, a33] \quad (9 \text{ points})$$

- b Using the expressions for a rotation about the x-axis (x1-axis) as described on page 2 of Lab 6 and your answers from exercise 1B, find matrix R2 that describes the rotation about the x-axis in exercise 1B. Enter the matrix elements in Matlab and include a copy of the printout. For example:

$$R2 = [b11, b12, b13; b21, b22, b23; b31, b32, b33] \quad (9 \text{ points})$$

- c Using your answers for Ox, Oy, Oz, Fx, Fy, and Fz in exercise 1a, assign values to Ox, Oy, Oz, Fx, Fy, and Fz in Matlab and then type

$$O = [Ox; Oy; Oz] \quad (4 \text{ points})$$

$$F = [Fx; Fy; Fz] \quad (4 \text{ points})$$

- d Type

$$OF1 = R2*R1*[O,F] \quad (1 \text{ point})$$

- e Based on your answers for exercise 1A and 1C, describe what OF1 is:

----- (2 point)

- f Type

$$R = R2*R1 \quad (1 \text{ point})$$

- g Type

$$OF2 = R*F \quad (1 \text{ point})$$

- h Describe what R is: R is -----

----- (2 points)

- i Based on your answers for exercise 1A and 1C, describe what OF2 is:

----- (2 point)

- j Describe whether or not your answers here are consistent with the last three answers of exercise 1A: -----

----- (2 points)

- k Type

$$\text{plot}(OF(1,:),OF(3,:)) \quad (1 \text{ point})$$

- l Describe the meaning of this plot (and turn in a copy of it) -----

----- (2 points)

Exercise 2: Preparing a map from a cross section (46 points total)

- 2) A geologic map shows the intersection of one or more surfaces of geologic structures with the topographic surface. Although not usually thought of this way, this is an **essential** aspect of what a geologic map is. **Points** along the intersection of a geologic surface with a topographic surface are located where geologic structure contours at a given contour level intersect topographic contours **of that same level** (e.g., at the intersection of the 100-meter structure contour with the 100-meter topographic contour). By finding the intersection points of other structure contours with the corresponding topographic contours, one can find other points along the intersection of the geologic surface with the topographic surface. By connecting these points, as shown in Fig. 5.2 of Lecture 5, one can construct a geologic map.

To get the base map either use the attached map or get an electronic copy. To get an electronic copy, check your e-mail and open the attachment labeled Lab07\_Ex2.m. Copy the contents of this entire file. Then start up Matlab and open a new window. Paste the contents of Lab07\_Ex2.m into the opened window, and save the file as Lab07\_Ex2.m.

Then go to Matlab and type

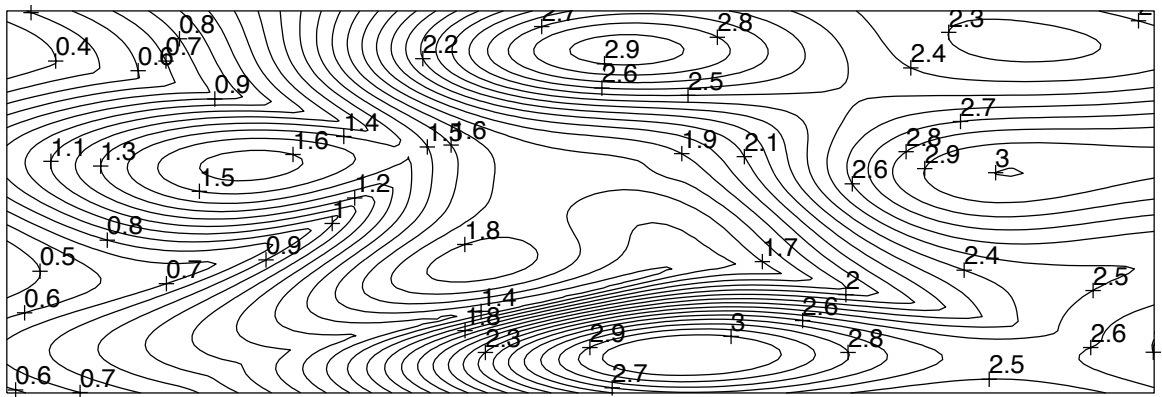
```
Lab07_Ex2
```

This should give you a copy of the figure.

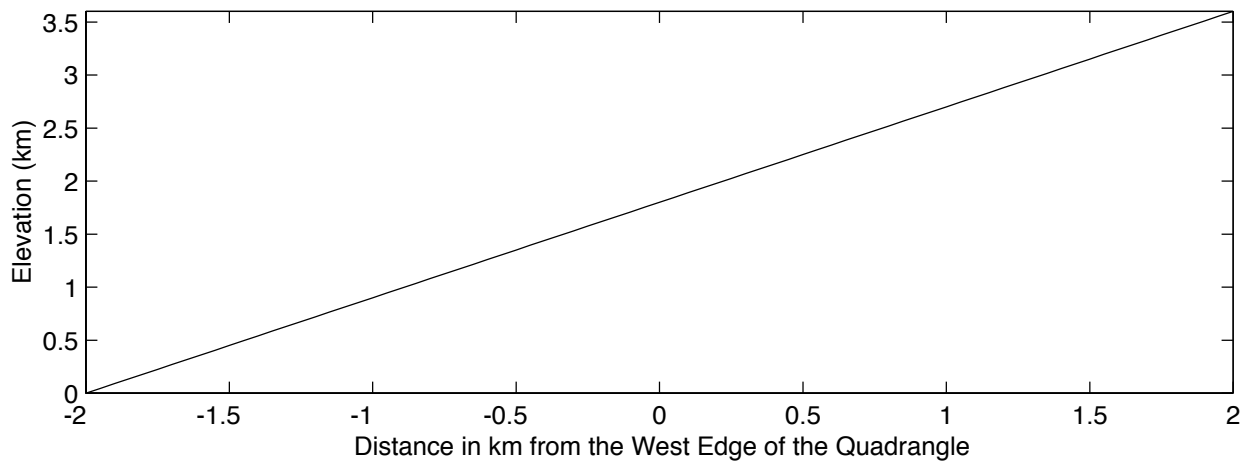
Draw (with light lines on the map) the structure contours for the dipping plane shown in the cross section; draw the structure contours at the same contour levels as the topographic contours. In other words if the topographic contours were at elevations of 0m, 100m, 200m, and 300m, then draw structure contours at 0m, 100m, 200m, and 300m. Find the intersection points of structure contours and the corresponding topographic contours, as shown in Fig. 5.2 of Lecture 5. Then construct a geologic map showing the surface trace of the plane by connecting the intersection points with one or more smooth curves, whichever is appropriate. **(1 point deducted for each incorrect intersection [43 points total for no deductions]; 1 point for each of 3 curves)**



Map of the GG303 Quadrangle (North to Top)



West-East Structure Strike-View Cross Section of the GG303 Quadrangle



**Exercise 3: Down-plunge views from a geologic map (34 points total)**

This exercise demonstrates the power of a computer and Matlab in 3-D visualization.

- a In Matlab, type  
     `help peaks` (1 point)
- b Then type  
     `help view` (1 point)
- c Then type  
     `peaks(20)` (1 point)

**Include copies of the plots or printouts resulting from these commands.**

- d Describe in your own words what the plot produced by `peaks(20)` shows **and** what the trend and plunge of the view direction is in that view.

The plot shows

-----  
 -----  
 ----- (1 points)

- e The trend of the view direction is \_\_\_\_\_ (1 point)

- f The plunge of the view direction is \_\_\_\_\_ (1 point)

- g Using the **view** command, prepare a plot of the `peaks(20)` function that shows an aerial view looking N10W at a plunge of 45°. (2 points)

- h Copy the body of the e-mail message that contains the digital geologic map. Start up Matlab. Next, under the File menu, open a new Matlab M-file window. Then paste the geologic map file you copied into the new window. Save the file as `Lab7.m`; Matlab should automatically add the suffix “.m”. If you have done everything correctly, you should be able to bring up the map by typing

`Lab7` (5 points)

- i Print a paper copy of the map. (1 point)

- j Now label points of known elevation along the contact; start at a low elevation and work to high elevations. Label the points on the map 1,2,3, etc. (2 points)

- k Now, to see how Matlab’s digitizing command works, type  
     `help ginput` (1 point)

- l Now type

`[x,y] = ginput`

and then digitize the points you labeled **in the order you labeled them**. You digitize the points by clicking on them. **Keep track of the elevations (“z-coordinate”) of each point as you digitize it.** Hit the Return key when you are done digitizing the points. You now have the x,y coordinates of the points. If you have correctly kept track

of the elevations of the points, you can create a new variable z and list the elevation of each point. For example, suppose you digitized 8 points. Their elevations might be:

`z = [100; 100; 100; 100; 200; 200; 300; 300];`

You would now have columns of the x,y,z coordinates of each point. **(0 points)**

m List the points by typing

`[x,y,z]`

**Make sure the points have the correct elevations.** **(5 points)**

n Plot the points in a three-dimensional plot by typing:

`plot3(x,y,z)`

**(1 point)**

o Finally, use the view command to take a down-plunge view.

**(1 point for plot, 2 points for correct view azimuth, 2 points for correct view inclination)** **(5 points total)**

Include copies of both of these last two plots.

p Describe the shape of the surface seen in the down-plunge view as accurately and quantitatively as you can (i.e., is it planar? Parabolic? Sinusoidal? Concave-up? Concave-down?)

-----  
-----

**(5 points)**

q Did the coordinate transformation make this shape easier to see than the geologic map?

Yes or no? \_\_\_\_\_

**(1 point)**

You can use Matlab's zoom command to zoom in and zoom out for more precise digitizing, but **coordinating the zoom command with the ginput command is a trickier than digitizing without zooming**. To zoom in on the map once the map is displayed, type

```
zoom on
```

Then click on the figure window and "drag with your mouse" around the area you want to zoom in on; this should zoom you in. Then go back to the command window and type

```
[x1,y1]=ginput
```

to prepare for digitizing. Now go to the figure window and click on it **but outside the area of the plot**. You should see digitizing crosshairs appear when you do this. Now click on the points you wish to digitize. Hit the Return key when you are done digitizing the points in the area you zoom in on. In an example file I worked on, I obtained this when I digitized two points:

```
x1 =  
    2.6932  
    2.7436  
y1 =  
    2.0748  
    1.9710
```

Now zoom back out to the original view. Do this by typing in the command window

```
zoom out
```

To repeat the process on points at a different place, figure out where you want to zoom in next and again type in the command window

```
zoom on
```

To digitize a new set of points and not overwrite the first set, type in the command window

```
[x2,y2]=ginput
```

(note the new name for the points!) and then click on the points you want to digitize. Hit the return key when you are done with the next set of points. This returns the new coordinates:

```
x2 =  
    2.5482  
    2.7346  
y2 =  
    3.1860  
    3.2019
```

To then zoom out and set the stage for repeating the process type

```
zoom out
```

To assemble all the digitized coordinates type

```
x = [x1;x2;x3; etc.];    y = [y1;y2;y3; etc.]
```