Exercise: mapping the faults at Chimney Rock

Reading: Fundamentals of Structural Geology, Ch. 2, p. 52 – 69
Maerten et al., 2001, JSG, v. 23, p. 585 - 592

In this exercise we consider some basic concepts and tools for mapping and characterizing geological structures including the orientations of linear and planar structural elements and their stereographic projection. These concepts are reviewed in Chapter 2 of Fundamentals of Structural Geology. The field data are from the normal faults of the Chimney Rock region of eastern Utah (Figure 1) which is described in the Journal of Structural Geology article by Maerten et al., 2001.

Figure 1. Outcrops from the Chimney Rock region of Navajo Sandstone (bottom of canyon) and the overlying Carmel Formation which includes shale and ledge-forming limestone layers. The blue-gray limestone layer crops out near the horizon.

1) Describe the geological features found on Maerten's map and stratigraphic section from the Chimney Rock region including: a) the stratigraphy; b) the structures; and c) the trace of the Blueberry fault and intersecting faults.

2) The GPS data for normal faults from the Chimney Rock area were gathered using a data dictionary that prompted the geologist to record the following information for each data station along the faults (Figure 2):

Easting Northing Elevation strike dip rake quality size formation (1)

Here strike and dip refer to the fault surface and rake refers to slickenlines on the fault surface. Ten tab-delimited text files contain these data for the following faults (numbers in parentheses are the number of data stations):

Blueberry_fault.txt	(92)
Glass_fault.txt	(60)
North_fault.txt	(49)
Canyon_fault.txt	(11)
Cottonwood_fault.txt	(24)
Hidden_fault.txt	(21)
La_Sal_fault.txt	(13)
Middle_fault.txt	(7)
Short_fault.txt	(35)
Wrong_fault.txt	(19)

Write a MATLAB script that reads the ten text data files for the faults into ten data arrays, parses the orientation data to extract local strike and dip (α_s, ϕ_d,) of the fault surfaces. Convert these orientations into azimuth of plunge and plunge angle (α_p, ϕ_p) of the normals (poles) to the fault surfaces.

Figure 2. Laurent Maerten inspects a normal fault from the Chimney Rock area of eastern Utah during his mapping campaign. Footwall (to the right) is massive Navajo Sandstone and hanging wall (to the left) is bedded Carmel Formation with Blue-gray Limestone on the upper left horizon.

3) Planar elements may be plotted as great circles on the stereonet, but given the great number of elements in these data files the result may be difficult to interpret. The attitude of a planar element also may be plotted as a normal using the general equations (2.72) for plotting the attitude of a linear element (α_p, ϕ_p) as a point on the stereonet. Plot the fault surface data for the ten faults as normals on a stereonet using a different color/symbol for each fault and provide a legend to identify the fault color/symbol. Indicate how many sets of faults are represented. How does your result compare to the description of the fault sets from Maerten (JSG, 2001)? Recall that a fault set is defined by grouping faults with similar orientations.

4) Choose the fault with the most data stations for each set that you have distinguished in part 3). For each fault transform the azimuth of plunge and plunge angles (α_p, ϕ_p) of surfaces to direction cosines using (2.101). Use these direction cosines to define the components of unit vectors **u**(i) that represent the orientations of the normals to the fault surfaces. Compute the components of the vector **U** that has the mean direction for each set using (2.105) and use (2.106) to recover the direction cosines of this vector. Convert these model angles to field angles using (2.102) and plot the mean direction for each fault set on the stereographic projection along with the data for those sets.

5) Compute the spherical variance of the normals to surfaces of each fault set identified in part 4). Evaluate your results indicating how tightly the data are clustered and how reliable the definition of the set is, given the number of data stations and the spherical variance. Selectively remove outliers from the sets and recomputed the spherical variances. Comment on your results and on the appropriateness of ignoring selected field data.

6) Focus your attention on the Blueberry fault which has m = 92 data stations. Write a MATLAB script that reads the text data file into a data array and parses the orientation data into local strike and dip (α_s, ϕ_d,) of the fault surface and the rake angle, θ_r, of the slickenlines (Figure 3). Study your data and eliminate stations that do not include all three types of orientation data. Decimate the data to consider only those stations with a “good” quality rating. How many data stations remain? Are these appropriate steps to take when analyzing field data or should you always utilize all of the collected data?

7) Using the decimated data set for the Blueberry fault from part 6) plot the great circles representing the fault surfaces using (2.78) and the azimuth of dip, α_d, and the angle of dip, ϕ_d. On the same stereonet plot the points representing the slickenlines on these surfaces. Given the local strike and dip of the fault surface, (α_s, ϕ_d,), and the rake of the slickenline in that surface, θ_r, the azimuth and plunge of the slickenline are:

$$\begin{aligned} \alpha_p &= \alpha_s + \tan^{-1}\left[(\sin\theta_r)(\cos\phi_d)/(\cos\theta_r)\right] \\ \phi_p &= \sin^{-1}\left[(\sin\theta_r)(\sin\phi_d)\right] \end{aligned} \tag{2}$$

Remember to use the function ATAN2(x, y) for the arctangent. The orientation of the slickenline may be plotted on the stereonet using these angles and (2.72). Describe the relationship between the fault attitude and slickenline rakes for a pure normal fault. Is the data for the Blueberry fault supportive of the statement that this is a pure normal fault (Figure 3)? Explain your reasoning.

Figure 3. Example of slickenlines on a normal fault surface in the Navajo Sandstone of the Chimney Rock area. Pen for scale and marking direction of these striations.

