# Exercise: differential geometry of the Emigrant Gap anticline

Reading: Fundamentals of Structural Geology, Ch. 3
Mynatt, I., Bergbauer, S., and Pollard, D.D., 2007, Using differential geometry to describe 3-D folds, Journal of Structural Geology, v. 29, p. 1256-1266.

In this exercise you are asked to investigate data on sandstone bedding surfaces of the Cretaceous Frontier formation that crops out on the Emigrant Gap anticline, a doubly plunging fold located near Casper, Wyoming. The objectives are to quantify the surface shapes of these folded sandstone beds using the concepts and tools of differential geometry and to make inferences about their mechanical behavior.

The data consist of 2,529 point measurements of location on the top-most bedding surface of the A1 sandstone (Figure 1) in the northern part of the anticline. These data were collected using a Trimble™ Pro XL GPS receiver with approximately 5 readings per station and real time differential corrections. The estimated vertical precision is 0.5 to 1.5 m and horizontal precision is less than 0.7 m.

Figure 1. Tricia Fiore mapping the top of the Frontier A1 sandstone at the Emigrant Gap anticline using GPS. Note the weathering of the fractured sandstone: this process introduces some ambiguity in the identification of the top of the sandstone.

The data are separated into sets that come from the SW limb, the nose, and the NE limb respectively. A fourth data set is the combination of the other three. The four data sets with the number of stations () in each are:

  

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|---|---|
| A1_swlimb.txt | (282) |
| A1_nose.txt | (743) |
| A1_nelimb.txt | (1504) |
| A1_all.txt | (2529) |

1) Load the data set A1_all.txt in MatLab and display it using a three dimensional plot. Visually examine the data using the Zoom and Rotate 3D tools in each of the three regions: SW limb, nose, and NE limb. Do the data appear to define continuous surfaces in each region, or are there faults cutting and offsetting the A1 sandstone? In addressing this question compare the length scale of the vertical scatter in these data to the vertical precision of the GPS measurement and operator precision in identifying the top of the A1 sandstone.

2) Arrange the data set A1_all.txt in the 3D plot so you have a down plunge view of the fold. For a perfectly cylindrical fold this would be a view down the plunge of the fold axis. Do the combined data from the three regions appear to define a single continuous cylindrical surface? Describe possible discrepancies from this idealized fold shape and suggest whether these are a structural phenomenon (due to folding, faulting or other structural process…), or are due to instrument or operator error.

3) Load the two subsets of data, A1_nelimb.txt and A1_nose.txt, in MatLab and plot them separately in 3D as points and as structure contour maps. Describe how the bedding surfaces are folded and tilted in each of these locations.

4) Use the two-dimensional data interpolation functions of MatLab to interpolate the A1_nelimb.txt data subset. Compare and contrast the nearest neighbor, bilinear, and bicubic methods of interpolation using surface plots and structure contour maps.

5) Use the two-dimensional bicubic method to interpolate the A1_nose.txt data subset. Note that you may have to restrict the range of the grid to avoid spurious interpolations. Compute the unit normal vectors, **N**, at each grid intersection of the interpolated surface and plot these. Plot the orientations of normal vectors on a stereonet and evaluate the approximation of this surface to a cylindrical fold.

6) Compute the coefficients of the First Fundamental Form ($E$, $F$, and $G$) for the interpolated surfaces for the two subsets of data, A1_nelimb.txt and A1_nose.txt. Recall that $EG - F^2 > 0$. Compute this quantity to check your work. Also, recall that $F = 0$ if the two parameter curves are orthogonal. Is this the case for your parametric representation of the bedding surface?

7) Compute the coefficients of the Second Fundamental Form ($L$, $M$, $N$) for the interpolated surfaces for the two subsets of data, A1_nelimb.txt and A1_nose.txt.. Compute the quantity ($LN - M^2$) and use this to identify the shape of the surface near each grid intersection.

  

8) Compute the mean principal normal curvature and the Gaussian curvature and plot the two curvatures on the bedding surface. Categorize the shapes of the surface at each point on the bedding surface using the classification method of Figure 2 (Mynatt et. al., 2007). In doing so propose a threshold for the principal curvatures below which they are set to zero in order to include all members of the geologic curvature classification.

  