Lab 4

Exercise 1:

In this exercise, you will use mplstereonet to solve an interesting problem. Determining, the normal and shear tractions on a plane under a 3D state of stress. For a given state of stress in 3D, the normal, σ, and shear, τ, tractions on a plane are ((Ragan, 1967):

$$\sigma = \sigma_1 l^2 + \sigma_2 m^2 + \sigma_3 n^2$$
$$\tau^2 = \left(\sigma_1 - \sigma_2\right)^2 l^2 m^2 + \left(\sigma_2 - \sigma_3\right)^2 m^2 n^2 + \left(\sigma_3 - \sigma_1\right)^2 n^2 l^2$$

where σ_1, σ_2 and σ_3 are the maximum, intermediate, and minimum principal stresses, and l, m and n are the direction cosines of the pole to the plane with respect to the $\sigma_1 \sigma_2 \sigma_3$ coordinate system. These are equal to the cosines of the angles the pole to the plane makes with σ_1, σ_2 and σ_3.

1. Write a Python function that returns the normal and shear tractions on a plane given the magnitude and orientation of the principal stresses, and the strike and dip of the plane. The function should work as:

sigma, tau = normal_and_shear(sigma_1, sigma_2, sigma_3, plane)

where sigma_1, sigma_2, and sigma_3 are 1x3 arrays containing the magnitude, trend, and plunge of the maximum, intermediate, and minimum principal stresses, respectively, and plane is a 1x2 array containing the strike and dip of the plane in right-hand-rule format.

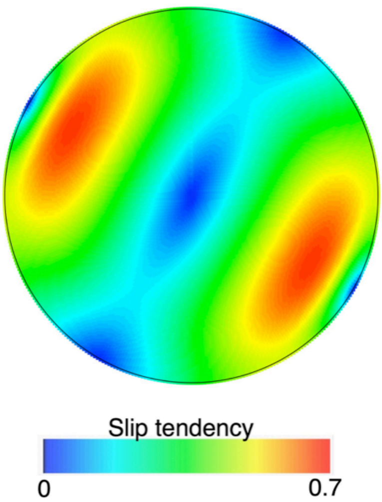
Hint: Use mplstereonet to solve this problem. If you import this library as mpl, you can compute the angle between the pole to the plane and one of the principal stresses using the mpl.angular_distance function. For example, the angle between sigma_1 and the pole to the plane is:

angle_ps1 = mpl.angular_distance(mpl.line(sigma_1[2], sigma_1[1]), mpl.pole(plane[0], plane[1]))

2. Test the normal_and_shear function above by solving the following problem:

In a sedimentary basin, the principal stresses are oriented (trend/plunge) σ_1 = 000/90, σ_2 = 030/00, and σ_3 = 120/00. At 5 km depth, σ_1 = 90 MPa, σ_2 = 65 MPa, and σ_3 = 25 MPa. Compute the normal and shear traction acting on a plane of orientation (strike and dip, RHR): 030/45. Hint: The answer should be 57.5 and 32.5 MPa for the normal and shear stress, respectively.

3. The slip tendency is the ratio of the maximum shear traction to the normal traction on a plane ($T_s = \tau/\sigma$). It is a proxy for the tendency of a surface to undergo slip. For the state of stress described in 2, compute the slip tendency on planes of any orientation and plot the poles coloured by slip tendency on a lower hemisphere equal area stereonet. Your plot should look like this:



Hint: Make an array of planes that encompass all possible orientations. This array, planes, will have nrows = nplanes, and 2 columns corresponding to strike and dip. Then, compute the slip tendency on all planes and store it in an array, slip_tend. Then compute the stereonet coordinates of all the poles to the planes:

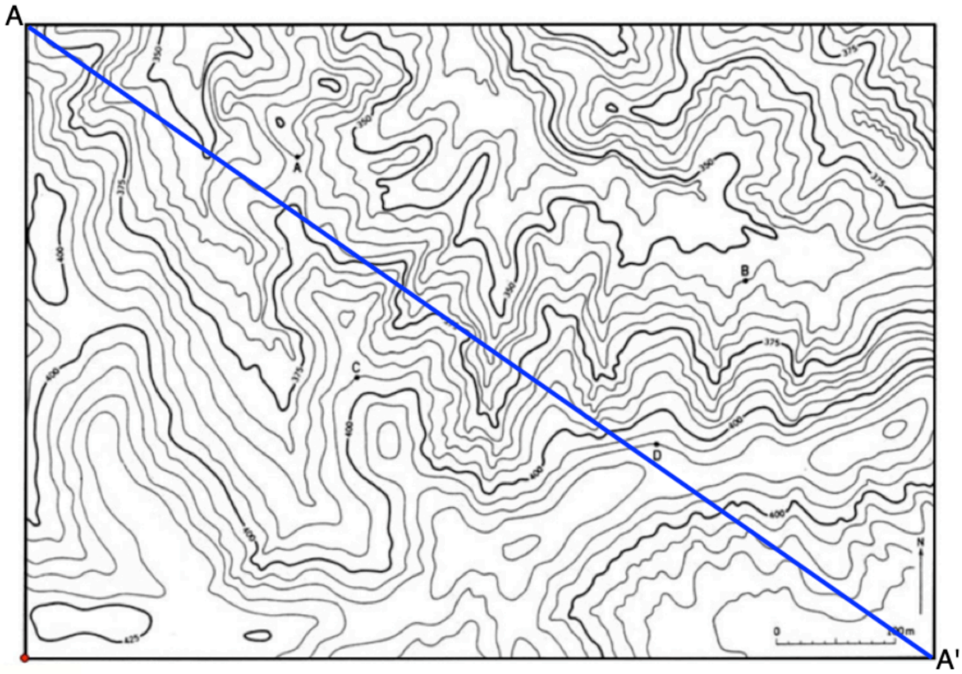
lons, lats = mpl.pole(planes[:,0], planes[:,1])

and plot the poles coloured by slip tendency:

ax.scatter(lons, lats, c=slip_tend, s=5, cmap='jet')

Exercise 2

For the topographic map in example 2 of the notebook on grids, construct a topographic profile from the NW to the SE corner of the map (line A-A' below):



Hint: Use the XG, YG and ZG arrays of the grid constructed in the example, and the scipy.interpolate.interp2d function.

Exercise 3:

Applying a procedure similar to the notebook on images, estimate the visual porosity in the epoxy sandstone thin section below (image kindly provided by Carita Augustsson. Image file in the data directory, ss_epoxy.jpg):