Strain in Rocks

Strain markers – objects that reveal the state of strain in a rock.

- One-dimensional strain markers – objects for which we know the original length – boudinaged dikes or layers, minerals or linear fossils, rock layers

- Two-dimensional strain analysis – objects of known initial shape (reduction spots, oolites, pillow lavas, conglomerates, breccias, corals, columnar basalts) or which contain linear markers with a variety of orientations (dikes with different orientations)

- Strain extracted from sections (2-D) is the most common type of strain data, and sectional data can be combined to estimate a 3-D strain ellipsoid.

Belemnites – note that upper one shows sinistral shear strain while the lower one only shows stretching (must be close to maximum stretching direction.)

Reduction spots
Finding strain by measuring angular changes:

- Must know original angle between sets of lines – undeformed objects outside the zone of strain or lines that we know were originally orthogonal.

- Strain can be estimated from the change in angular relations.

- Assume there is no **strain partitioning**. Strain partitioning occurs if there are contrasting mechanical properties of the objects that are being measured with respect to the enclosing rock.

- If two originally orthogonal lines remain orthogonal after deformation, they must represent the principal strains and thus the orientation of the strain ellipsoid.

- The two most common methods used to find strain from initially orthogonal lines are the Wellman and Breddin methods.
Wellman Method:

- Use an object that has orthogonal lines of symmetry in the undeformed state.

- Draw a reference line. Reference line has two defined endpoints (A and B).

- In this example a pair of lines are drawn parallel to the hinge line and symmetry line for each fossil.

- The lines intersect at the endpoints of the reference line.

- If the rock is unstrained the lines will define a rectangle. If the rock is strained they will define parallelograms.

- Fit an ellipse to the numbered corners of the parallelograms.

- If no ellipse can be fitted then the strain is heterogeneous (or the assumption of orthogonal lines is wrong).
Breddin graph:

- Input data are the angular shears ($\psi$) and the orientations of the sheared line pairs with respect to the principal strains ($\phi$).

- Note that the orientation can be positive or negative.

- The R-value (ellipticity of the strain ellipse) is found by inspection.

- If the orientation of the principal axes is unknown, the data are plotted with respect to an arbitrarily drawn reference line.

- The data are then moved horizontally on the graph until they fit one of the curves.

- The orientations of the strain axes are found at the intersections with the horizontal axis.
Elliptical Objects and the $R_f/\phi$-method

The $R_f/\phi$-method handles initially non-spherical markers, but the method requires a significant variation in the orientations of the long axes.

$R_i = X/Y =$ initial ellipticity (undeformed state) \hspace{1cm} $R_s =$ applied strain

$R_f =$ final ellipticity for each deformation marker

$\phi' =$ angle between long axis of the ellipse and a reference line (horizontal in figure)

If $R_s < R_i$

$R_{f,max} = R_s R_i$ and $R_{f,min} = R_i/R_s$

$R_s = (R_{f,max}/R_{f,min})^{1/2}$

$R_i = (R_{f,max} R_{f,min})^{1/2}$

If $R_s > R_i$

$R_{f,max} = R_s R_i$ and $R_{f,min} = R_s/R_i$

$R_s = (R_{f,max} R_{f,min})^{1/2}$

$R_i = (R_{f,max}/R_{f,min})^{1/2}$
Center-to-Center Method

• Assume that the circular objects have a more or less statistically uniform distribution. Distance between neighboring particles ~constant before deformation.

• Measure the distance and direction between the center of an ellipse and the neighboring ellipses. Do this for all the ellipses.

• Graph the distances between the centers and the angles between the center tie lines and a reference line.

• A straight line is found if there is no deformation. A deformed section yields a curve with maximum ($d'_{\text{max}}$) and minimum ($d'_{\text{min}}$).

• Ellipicity = $R_s = \frac{d'_{\text{max}}}{d'_{\text{min}}}$
Strain in 3-Dimensions

- 3-Dimensional strain is usually found by combining 2-dimensional data from several differently oriented sections.

- The strain must be homogeneous at the scale of observation.

- The mechanical properties of the objects and host rocks must be similar, i.e. they had the same competency.

- If the markers and host have the same competency, the markers are referred to as **passive strain markers**.

- If the markers and host have different competencies, the markers are referred to as **active strain markers**.

- In the graph to the right we see an example of differences in strain markers. The competent clasts (granite) are less strained than the less competent clasts (greenstone).