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.

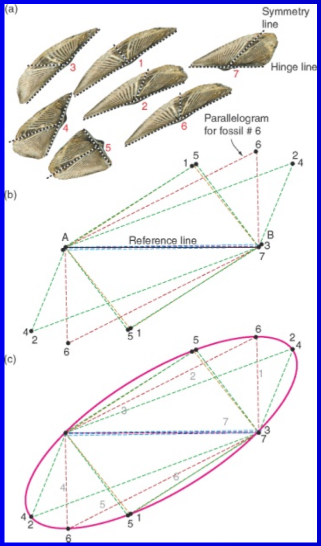
Belemnites – note that upper one shows sinistral shear strain while the lower one only shows stretching (must be close to maximum stretching directon.

Reduction spots

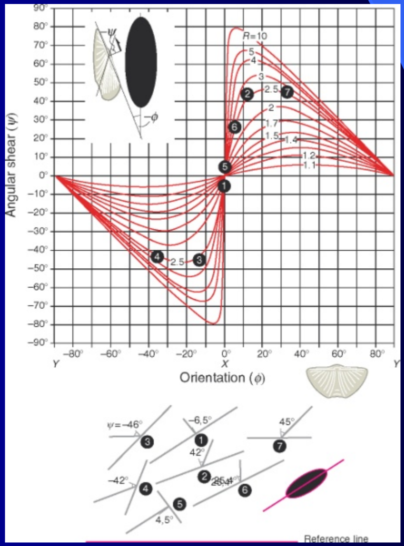
Finding strain by measuring angular changes:

- 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

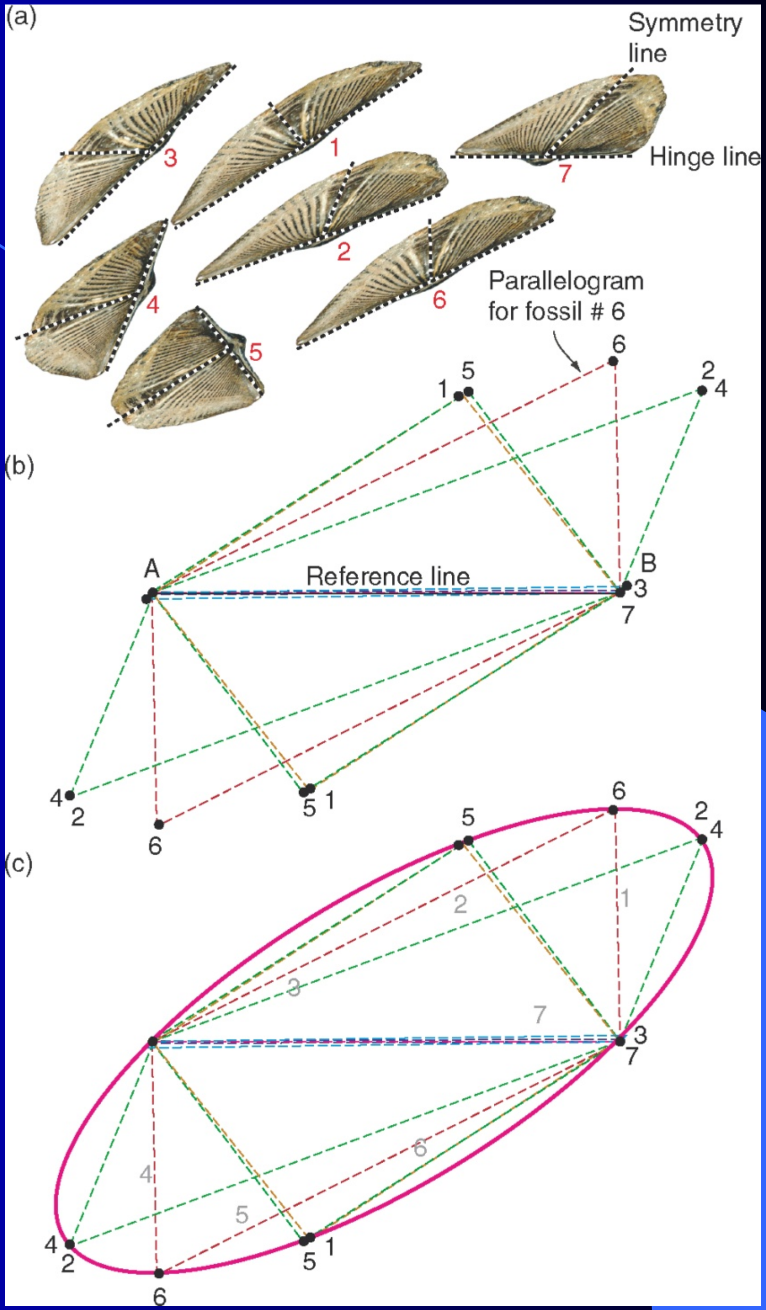


Breddin



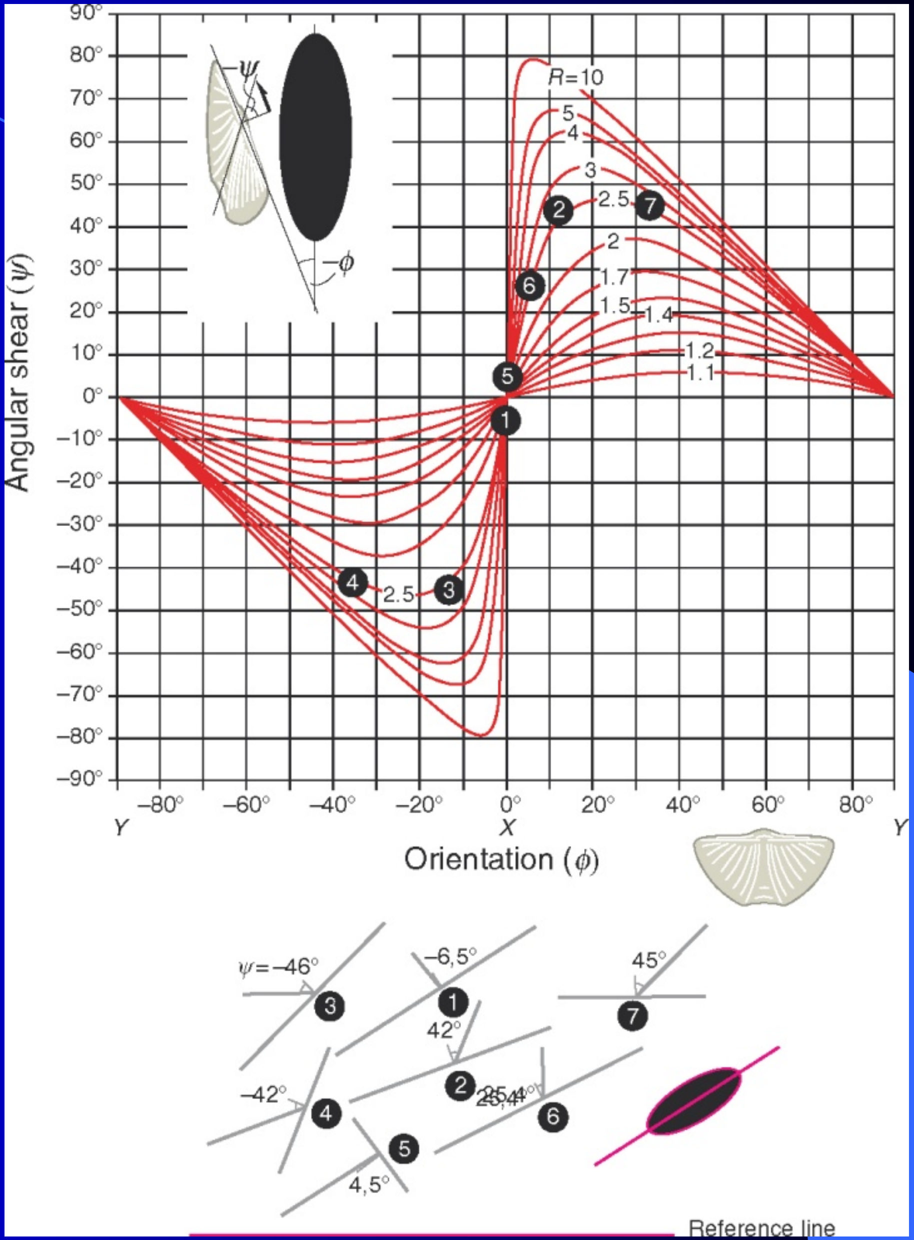
Wellman Method:

- 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 (ψ) and the orientations of the sheared line pairs with respect to the principal strains (φ).
- 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/φ-method

The R_f/φ-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) R_s = applied strain

R_f = final ellipticity for each deformation marker

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

If $R_s < R_i$

$R_{fmax} = R_s R_i$ and $R_{fmin} = R_i/R_s$

$R_s = (R_{fmax}/R_{fmin})^{1/2}$

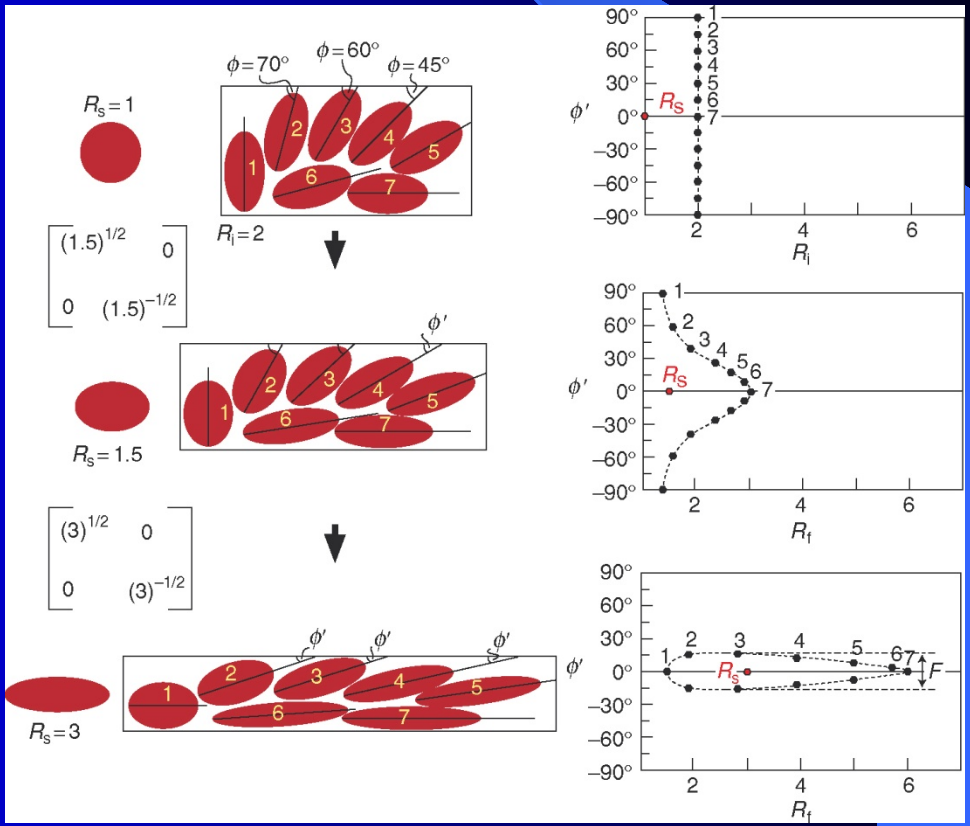
$R_i = (R_{fmax} R_{fmin})^{1/2}$

If $R_s > R_i$

$R_{fmax} = R_s R_i$ and $R_{fmin} = R_s/R_i$

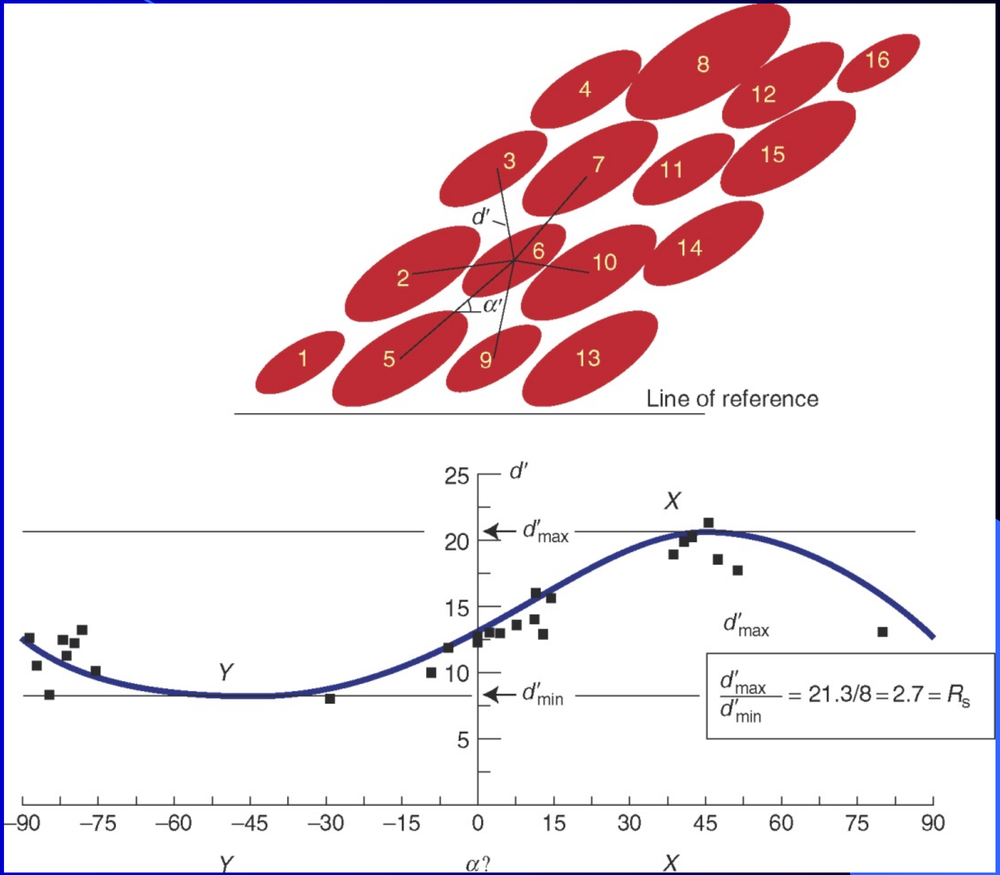
$R_s = (R_{fmax} R_{fmin})^{1/2}$

$R_i = (R_{fmax}/R_{fmin})^{1/2}$



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'_{max}) and minimum (d'_{min}).
- Ellipicity = $R_s = (d'_{max})/(d'_{min})$



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).