University of Anbar

College of Science

Department of Applied Geology

Structural Geology

Title of the lecture

Deformation and Strain

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Deformation and strain

Deformation: The change in shape, position and/or volume of a rock in response to applied forces. Deformation is determined by comparing the rock's deformed and undeformed states. It can be broken down into rigid body deformation (translation and rotation) and non-rigid body deformation (strain and volume change).

Rigid body deformation

Rigid body deformation occurs where a rock mass moves or rotates with no change of shape (figure 1). This is only detectable if there is an external reference frame.

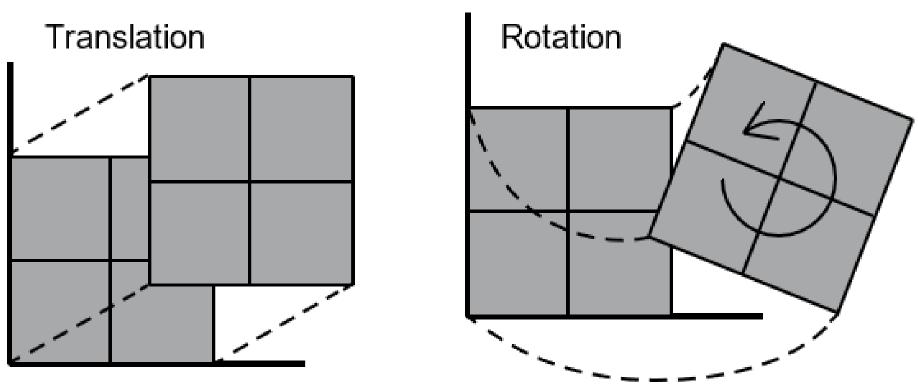

Figure 1: Ridge body deformation involves translation and / or rotation of an object.

1. **Translation**

   During translation every point in a rock body undergoes the same displacement. There is no distortion and no change of shape

2. **Rotation**

   Rotation is the same as translation only with a rotational component.

Non-rigid body deformation

1. **Strain**

   Strain is the change in shape of a rock body during deformation (figure 2).

2. **Volume change**

   Volume change occurs where a rock body increases or decreases in volume. In two dimensions this is a change in area. A rock body may retain the same shape if the volume (area) change is the same in all directions or it may change shape if the volume (area) change varies. Compaction is an example of a change in shape and reduction in volume due to vertical compression.

Figure 2: A sheared trilobite. An example of non- rigid body deformation.

Homogeneous / heterogeneous deformation

Homogeneous deformation

Homogeneous deformation occurs where deformation is constant across a rock body, that is different parts of an object deform by the same amount (figure 3a). In homogeneous deformation straight lines remain straight, parallel lines remain parallel and circles deform to ellipses.

Heterogeneous deformation

Heterogeneous deformation occurs where the deformation varies across a rock body, so different parts of an object deform by different amounts (figure 3b).

Whether deformation is homogeneous or heterogeneous can depend on scale; a large area of heterogeneous deformation may be broken down into smaller areas of homogeneous deformation for analysis.

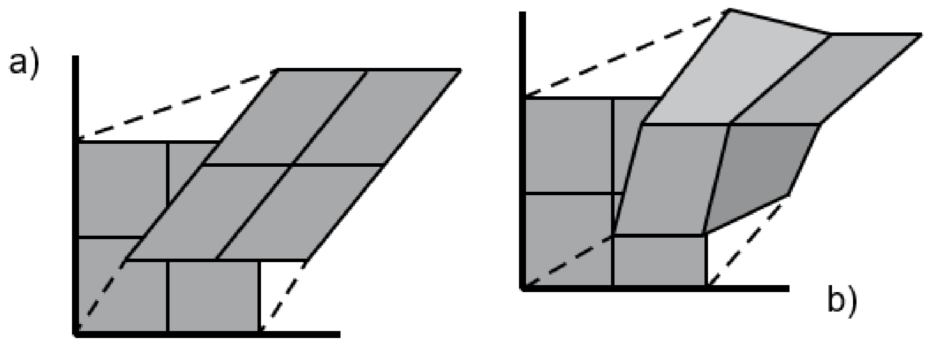

Figure 3: a) homogeneous deformation. b) heterogeneous deformation.

Strain parameters

The strain parameters **longitudinal strain** and **angular shear strain** are used to measure homogeneous strain.

Longitudinal strain

Longitudinal strain is strain in a single direction (1D) or the change in the length of a line. It may be measured in units (centimeters, kilometers etc.) or expressed as the ratio elongation (e).

$$\textbf{Elongation (e)} = (l_1 - l_0)/l_0$$

where: l_0 is the original length of the line. l_1 is the new (observed) length of the line.

Elongation is negative (-) for contraction (the line has decreased in length) (figure 4) and positive (+) for extension (the line has increased in length) (figure 5).

Figure 4: folded quartz vein, an example of negative elongation.

Figure 5: an extended belemnite, an example of positive elongation. The dark areas are the original fossil and white a calcite infill

Longitudinal strain can be used to calculate the extension or contraction along a cross section where a single marker horizon can be measured before and after deformation (figure 6).

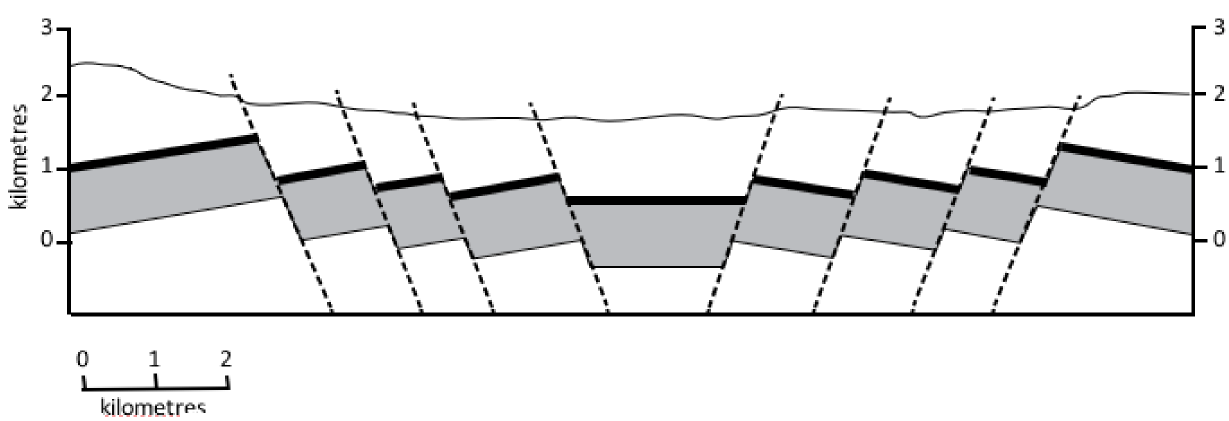

Figure 6: The black marker horizon can be used to calculate the longitudinal strain.

Angular shear strain

Angular shear strain is the strain in a plane (2D) or the change in angles. Angular shear is the deflection of an orthogonal marker. This is the change in angle between a pair of lines that were originally orthogonal. An example of an orthogonal marker would be a fossil with bilateral symmetry (the trilobite in figure 2). Shear strain (g) is the tangent of the change in angle between the originally orthogonal pair of lines (figure 7).

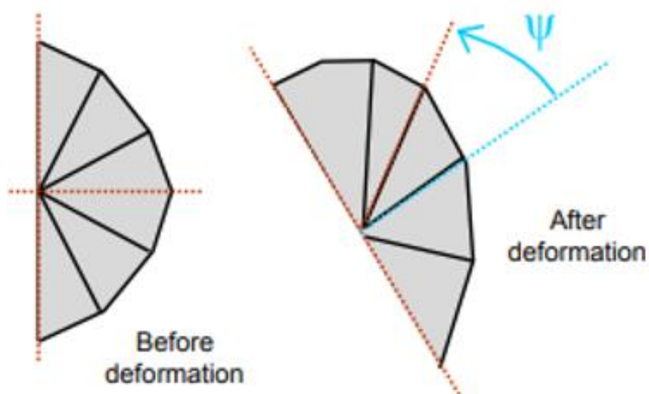

Figure 7: angular shear of an originally orthogonal marker (e.g., fossil with bilateral symmetry)

$$\text{Shear strain } \gamma = \tan \psi$$

where: g is the shear strain, y is the change in angle from the perpendicular.

Figure 8 shows sheared burrows (yellow lines). The burrows were originally perpendicular (white lines) to bedding (red line). The burrows are now at approximately 50° to bedding giving a shear strain of -1.2. Shear strain is negative as the burrows have rotated anticlockwise from their original position.

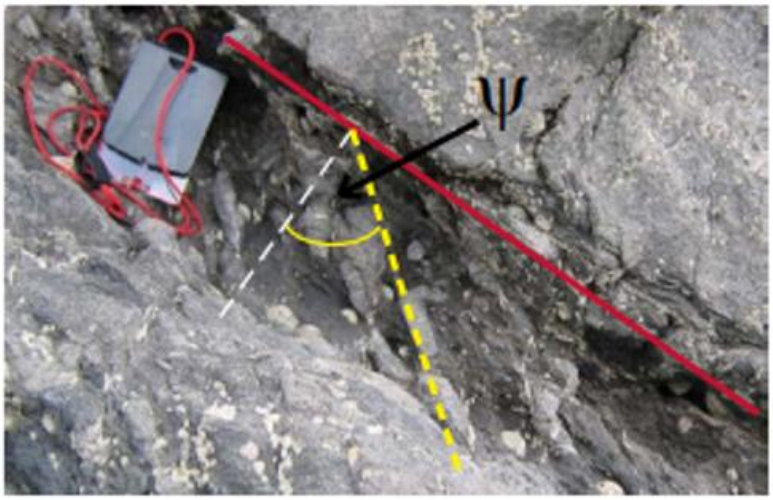

Figure 8: sheared burrows in the limb of a syncline.

Reference

Fossen, H. 2010. Structural Geology. Cambridge: Cambridge University Press.

Park, R.G. 1997. Foundations of structural geology. London : Chapman & Hall.