University of Anbar

College of Science

Department of Applied Geology

Structural Geology

Title of the lecture

Ductile Deformation and Folds

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2022

Ductile deformation

Ductile deformation occurs where rocks change shape smoothly, without breaking, in response to stress. This shape change is pervasive – it affects all of the rock. Large scale ductile deformation occurs at higher temperatures and pressures and so deeper in the crust than brittle deformation. However, ductile deformation can also occur at shallower levels in the crust in association with the formation of faults or in weaker rocks (e.g. salt). Folds, cleavage, boudinage and shear zones are all examples of ductile deformation.

Folds

Folds can form on all scales and under a variety of conditions. Active folding is the response of layers of different competence to layer parallel compression Passive folding occurs where layering has no mechanical influence on the folds formed, such as when layers fold in response to movement along a fault.

Fold terminology (figure 1)

Hinge: Point of maximum curvature on a fold (2D term).

Hinge line: Line of maximum curvature along a fold (3D term).

Axial plane: A plane that connects all the hinge lines through a fold, also known as the axial surface (3D term).

Axial trace: Where only an edge of the axial plane is seen, e.g. when a fold is seen in cross section or on a map. The hinge line runs along the top of the axial plane and so is also an axial trace (2D term).

Facing: The direction of younging along the fold axial plane. In an upward facing fold the beds are the right way up and get younger from the bottom to the top of the axial plane.

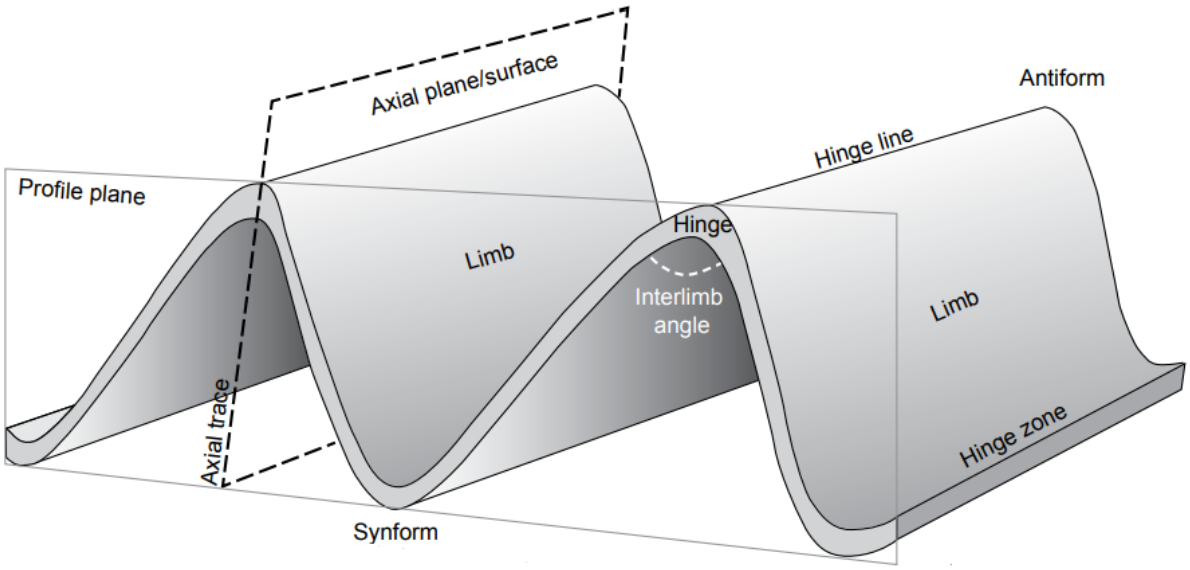

Figure 1: Terminology used to describe a fold.

Interlimb angle: The angle between the two limbs of a fold.

Limb: Bed segments between hinges.

Profile plane: The true cross section through a fold, perpendicular to the axial plane.

Anticline: A fold with older rocks in its core.

Antiform: A fold where the limbs close upwards.

Syncline: A fold with younger rocks at in the core.

Synform: A fold where the limbs close downwards.

Folds can be classified in a variety of ways.

Orientation of a fold Orientation of a fold is defined by the orientation of its axial plane (figure 2) and its hinge line, whether horizontal or plunging (figure 3). An **upright fold** has a vertical axial plane. An **inclined fold** has a dipping plane and a **recumbent fold** has a horizontal axial plane.

A **non-plunging fold** has a horizontal hinge line, whilst a **plunging fold** has a inclined hinge line. Where a hinge line is straight the fold is said to be **cylindrical.** Where a hinge line curves the fold is **non-cylindrical**. Curvature of the hinge line results in folds that close in the direction in which their limbs converge. Double plunging folds (or pericline) form elongate domes or basins.

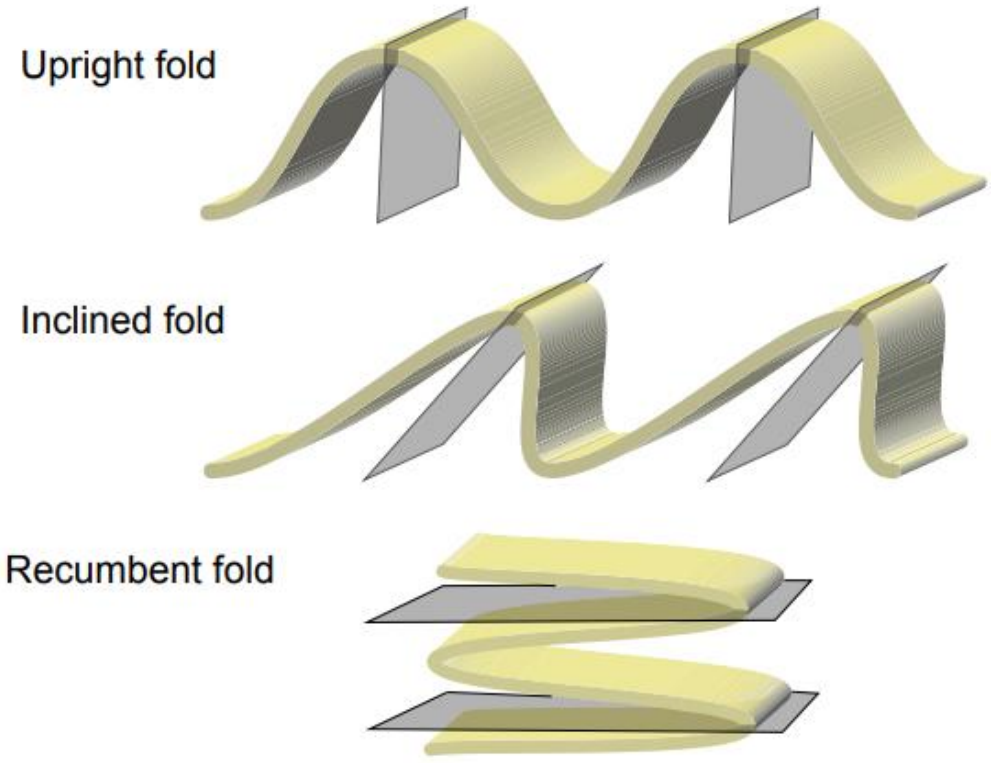

Figure 2: Orientation of fold axial plane.

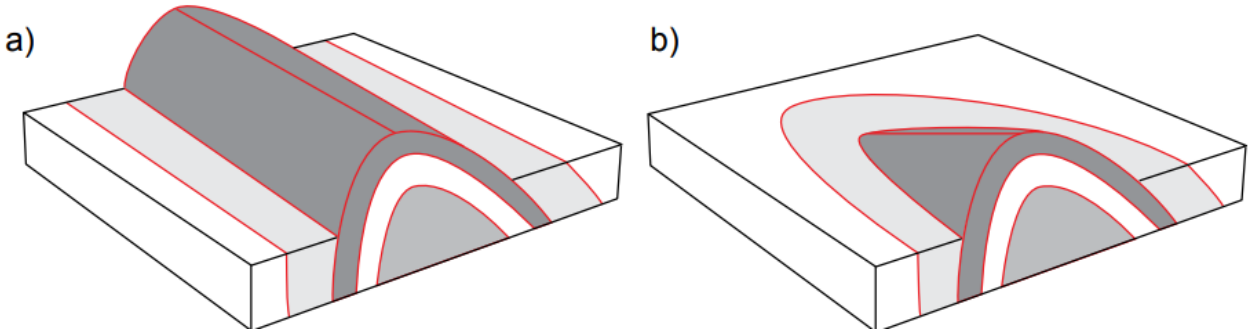

Figure 3: a) A non-plunging fold. b) A plunging fold.

Tightness

The tightness of a fold is a measure of the interlimb angle, the angle between the limbs (figure 4) and relates to the amount of strain during deformation.

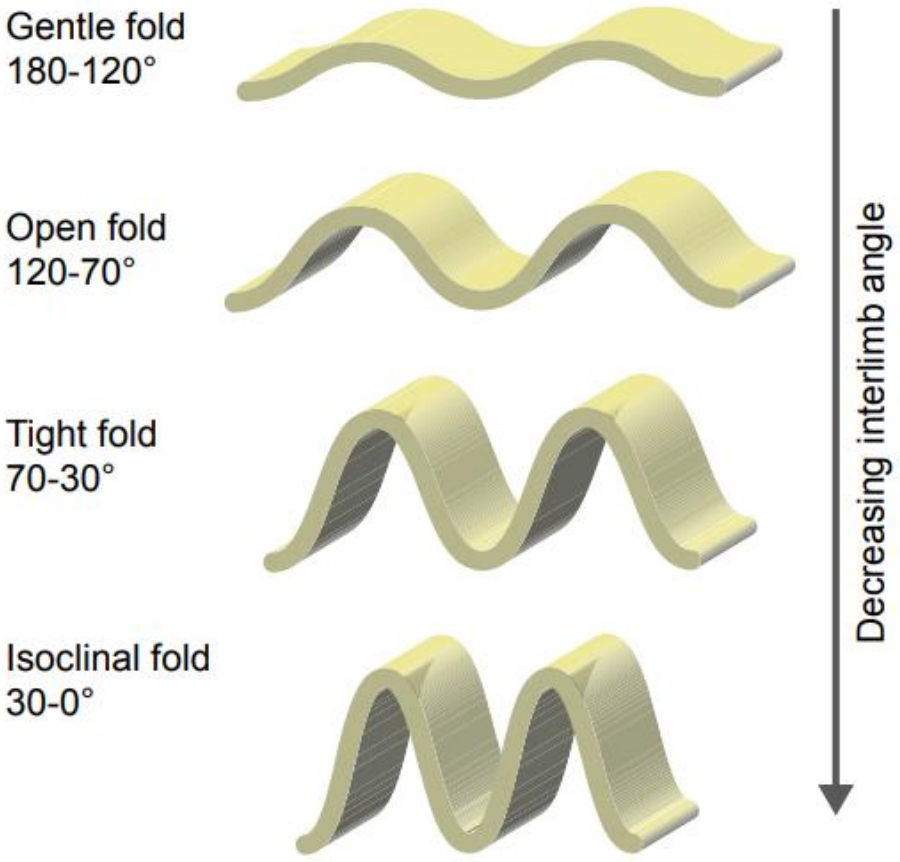

Figure 4: Interlimb angle: Folds become tighter with increased compression.

Fold symmetry and vergence:

The symmetry of a fold relates to its limb lengths (figure 5). **Symmetric folds** have equal limb lengths and the two sides of the fold are mirror images (figure 5). **Asymmetric folds** have a shorter and a longer limb (figures 5). A series of folds with the same asymmetry are said to have **vergence**. The direction of vergence is determined by the sense of displacement of the upper limb relative to the lower limb. When viewed down plunge, a fold verges to the right where there is apparent clockwise rotation of the short limb and to the left where there is apparent anti-clockwise rotation of the short limb.

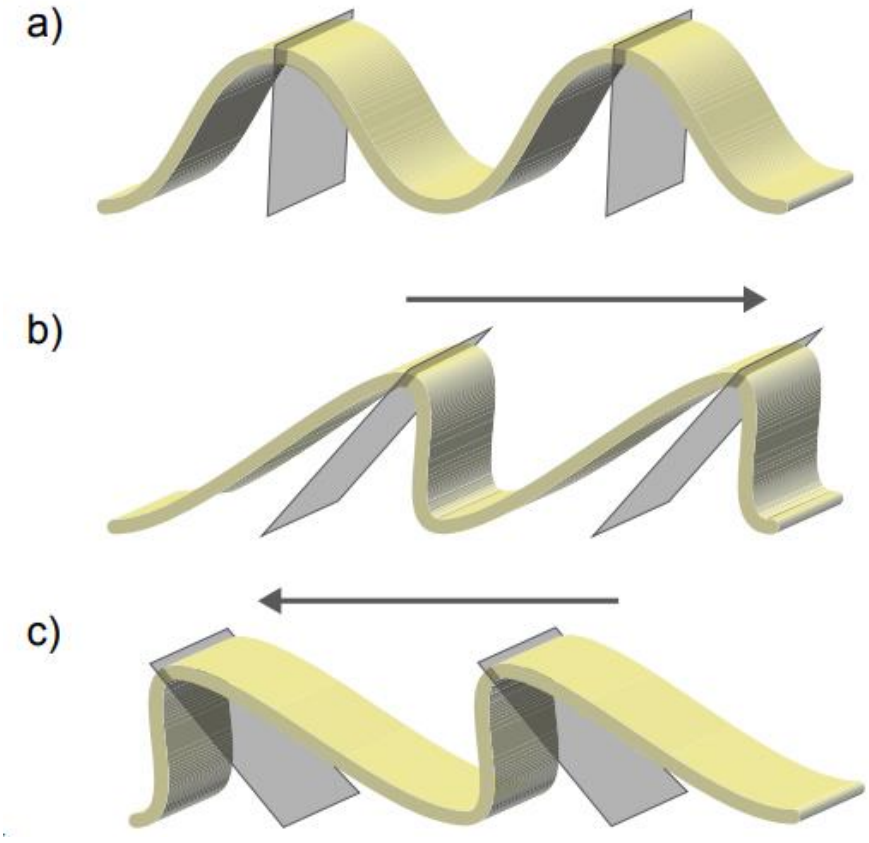

Figure 5: a) Symmetric fold with neutral vergence. b) Asymmetric fold verging to the right. c) Asymmetric fold verging to the left.

Reference

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

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