Geologic Maps: Faults and Folds

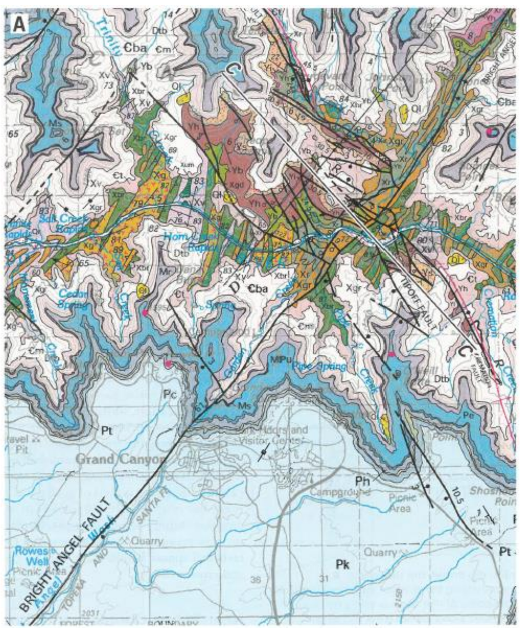
Recall:

Based on the principle of original horizontality, all sediments are assumed to have been deposited horizontally, and if they are no longer horizontal, they have been deformed post-lithification. We have learned that under high temperatures and pressures, differential stress and confining pressure exerted on rocks can result in metamorphism. Rock layers can also be deformed and changed under a range of temperature and pressure conditions: in the shallow crust, they can undergo **brittle deformation**, which results in faulting, displacement, and tilting; in the deep crust and upper mantle, they can undergo **ductile deformation**, which results in folding, foliation, and metamorphism. Without deformation, the youngest layer on the surface would be flat and continuous across the continent.

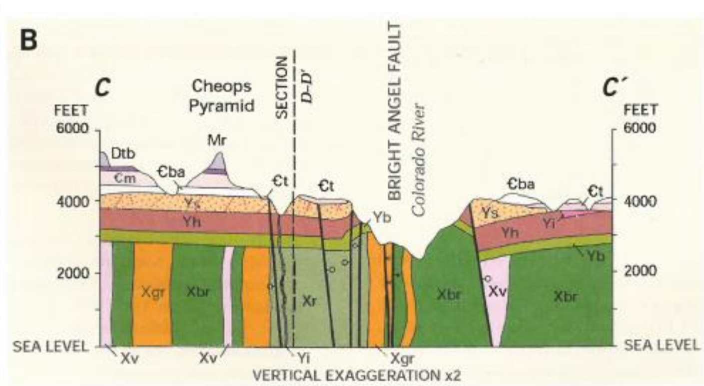
Learn:

Geologic maps show the distribution of different rock types across the surface of the Earth. They capture the complexities of rock layers that have been deformed – folded, tilted, faulted – and differentially eroded. They are a 2D projection of the 3D structure of rock formations under our feet. We can construct a cross-section through the geologic map to help us visualize the geometry of rock layers.

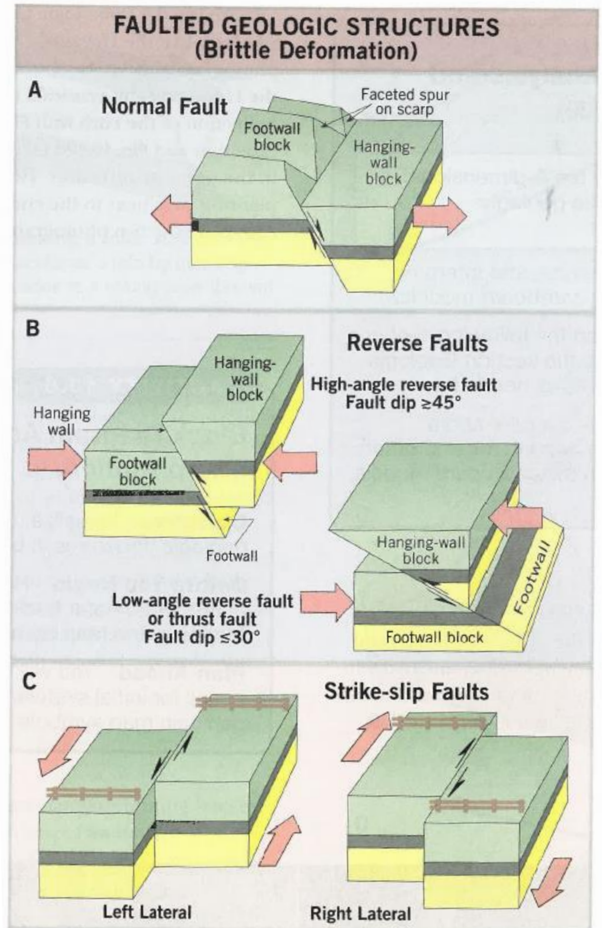
In order to describe the deformation that rock layers have undergone, geologists need to employ geometry, characterizing the strike, dip direction, and dip angle of a surface. The **dip** is the direction a ball will roll if you set it on the rock layer; the **dip angle** is how steep the surface is, at an angle measured between the dip vector and the horizon. The **strike** is the line on the rock surface parallel to the horizon and perpendicular to the dip vector.

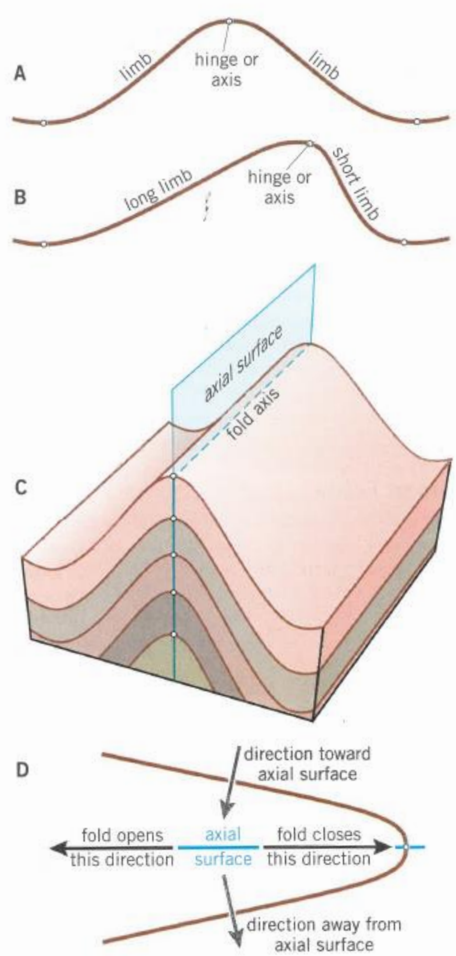


Sample Geologic map (A) and cross-section (B). Part of a geologic map of the Grand Canyon by George Billingsley, published in 2000 by the USGS. In the cross-section, we can see horizontal beds overlying tilted (near-vertical) Precambrian rock units along the C-C' line of section; this line is also crossed by several normal (extensional) faults.



Brittle deformation in rock layers results in faulting. Differential stress can result in three types of movement: 1) extension, where the rocks are pulled apart; 2) compression, where the rocks are pushed together; 3) shearing, where the rocks are slid past each other. Extensional stress results in **normal faulting**, which is recognizable by the hanging wall block slipping down relative to the footwall block. Compressional stress results in reverse or thrust faulting, which is recognizable by the hanging wall black sliding up relative to the footwall block. Shear stress results in strike-slip faulting, with predominantly horizontal motion either to the right or the left.





Ductile deformation in rock layers results in folding. Folds are described by their geometry: the **hinge** or **axis** of a fold is where the layer is curved most tightly; the **limbs** of a fold are the flat sides of the fold on either side of the hinge and are the same length in a **symmetric fold** but different lengths in an **asymmetric fold**; the **axial surface** that is a plane connecting the axes of all the layers in a fold.

Figure 10.14 Terms used to describe folds. **A.** The fold hinge (or axis) is where the fold is most tightly curved. This symmetric fold has limbs that are the same length. **B.** This asymmetric fold has limbs that are different lengths. **C.** The axial surface is formed by combining all of the fold axes. **D.** Explanation of the opening and closing directions of a fold and the meaning of "toward" or "away from" the axial surface of a fold.

Types of folds:

- Horizontal vs. vertical folds
    - Fig. 10.15A shows a horizontal syncline: a **syncline** is a fold in which the layers are younger as you move from the outer part of the fold toward the axial surface (resembles a “sink”).
    - Fig. 10.15B shows a horizontal anticline: an **anticline** is a fold in which the layers are older as you move from the outer part of the fold toward the axial surface (resembles an “A”)

- Plunging folds
    - Fig. 10.15C&D show plunging folds, which have an axis that is not horizontal or vertical but plunges or is inclined.

- Upright vs. inclined folds
    - Fig. 10.15E shows an inclined fold with an inclined axial surface. Notice that the fold axis is horizontal, but the axial surface is inclined at an angle

- Overturned folds
    - Fig. 10.15E has one limb that is overturned, meaning the normal superposed sequence (following the principle of superposition) is reversed – older beds are higher along that limb and younger beds are lower. If both limbs are overturned, it is called an inverted fold.

- **Monocline**
    - Fig. 10.15F shows a planar, near-horizontal upper part that flexes down to a planar, near-horizontal lower part, like a curved step (mono = one; cline = dip).

- Structural **basin**
    - Fig. 10.15G shows a bowl displayed as concentric circle rock formations, with the youngest rock layer is in the center of the basin.

- **Dome**
    - Fig. 10.15H shows an upside-down bowl, displayed as concentric rock formations where the oldest rock layer is in the center of the basin.

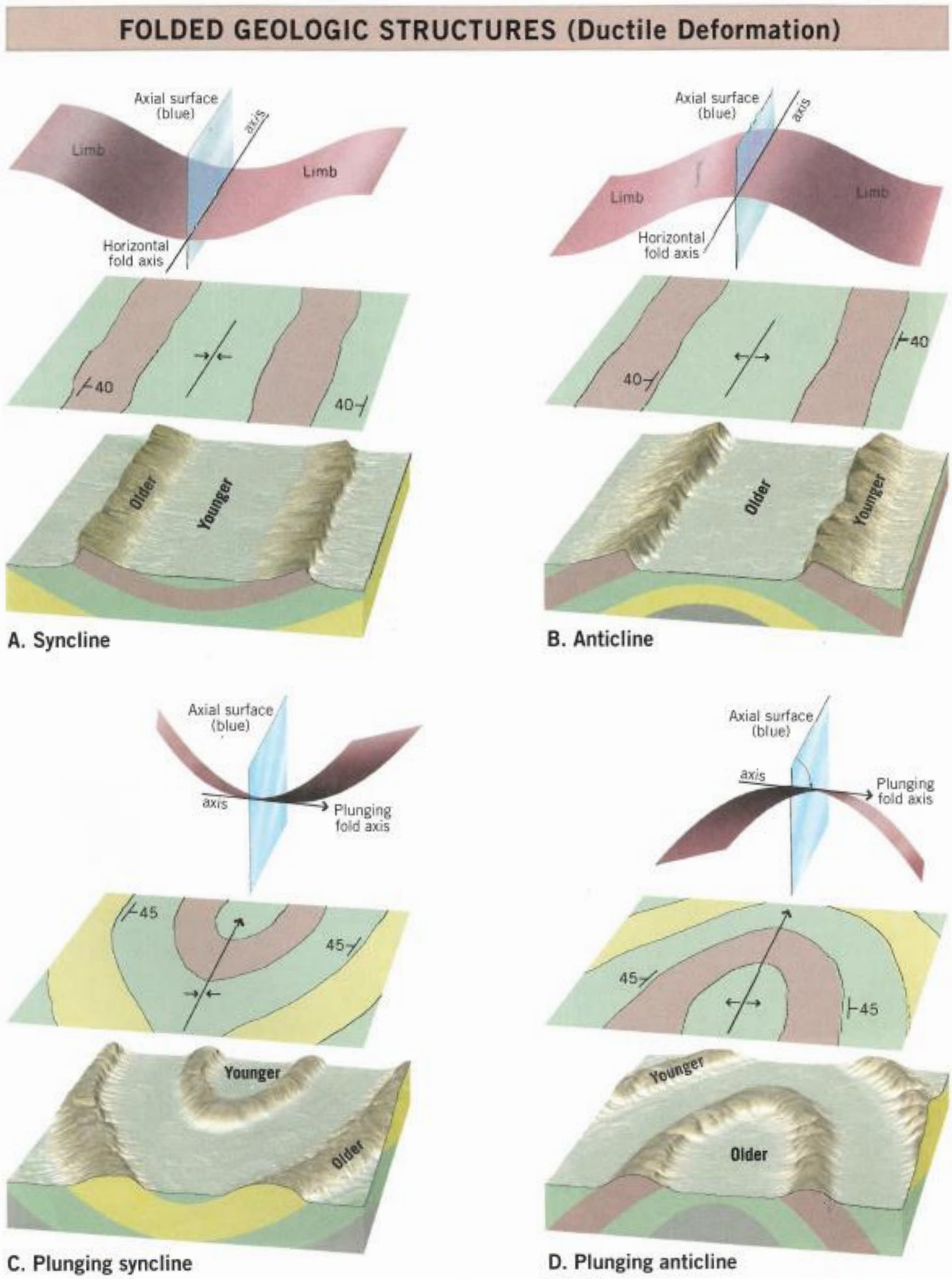
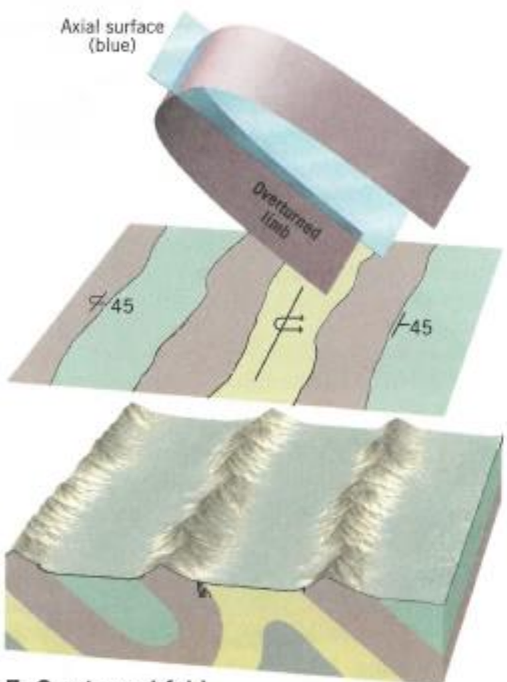
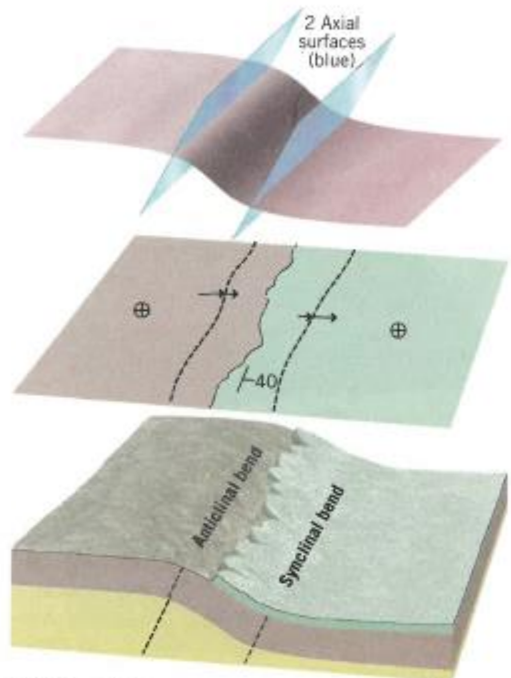


Figure 10.15 Folds in block diagrams with geologic maps. The symbols used in these figures are defined in **Fig. 10.4**.

FOLDED GEOLOGIC STRUCTURES (Ductile Deformation)

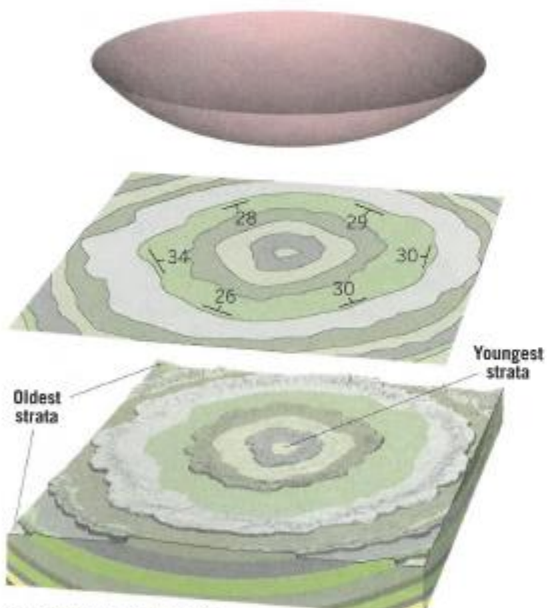


E. Overturned fold



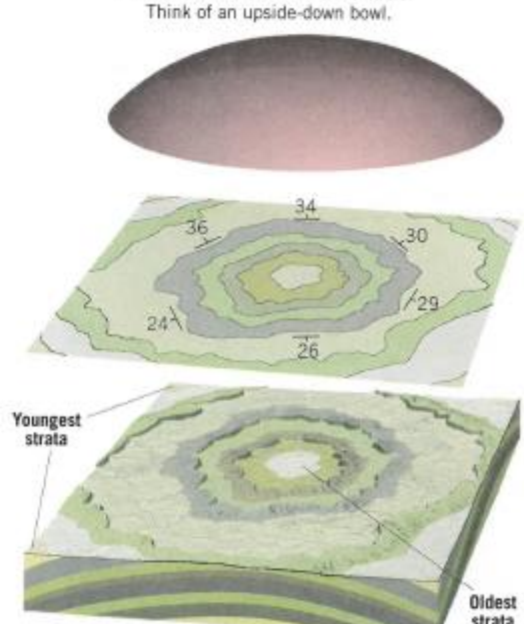
F. Monocline

Basins are somewhat circular or oval, with the youngest strata in the middle. Think of a bowl.



G. Structural basin

Domes are somewhat circular or oval, with the oldest strata in the middle. Think of an upside-down bowl.



H. Dome

Figure 10.15 *(continued)*

How to Draw a Geologic Cross-Section

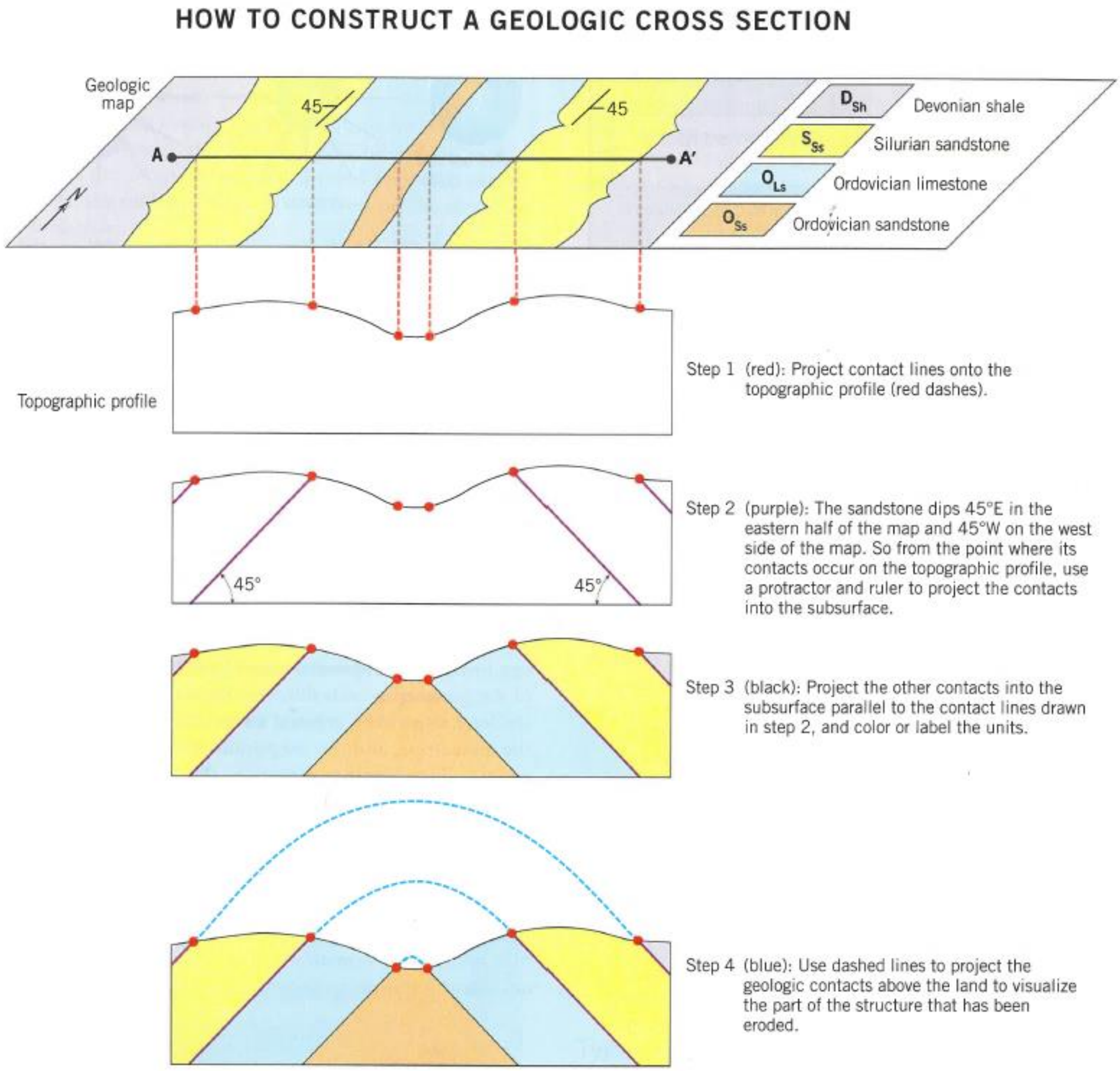


Figure 10.5 Geologic cross-section construction. Follow the four steps in the illustration to construct a cross-section.