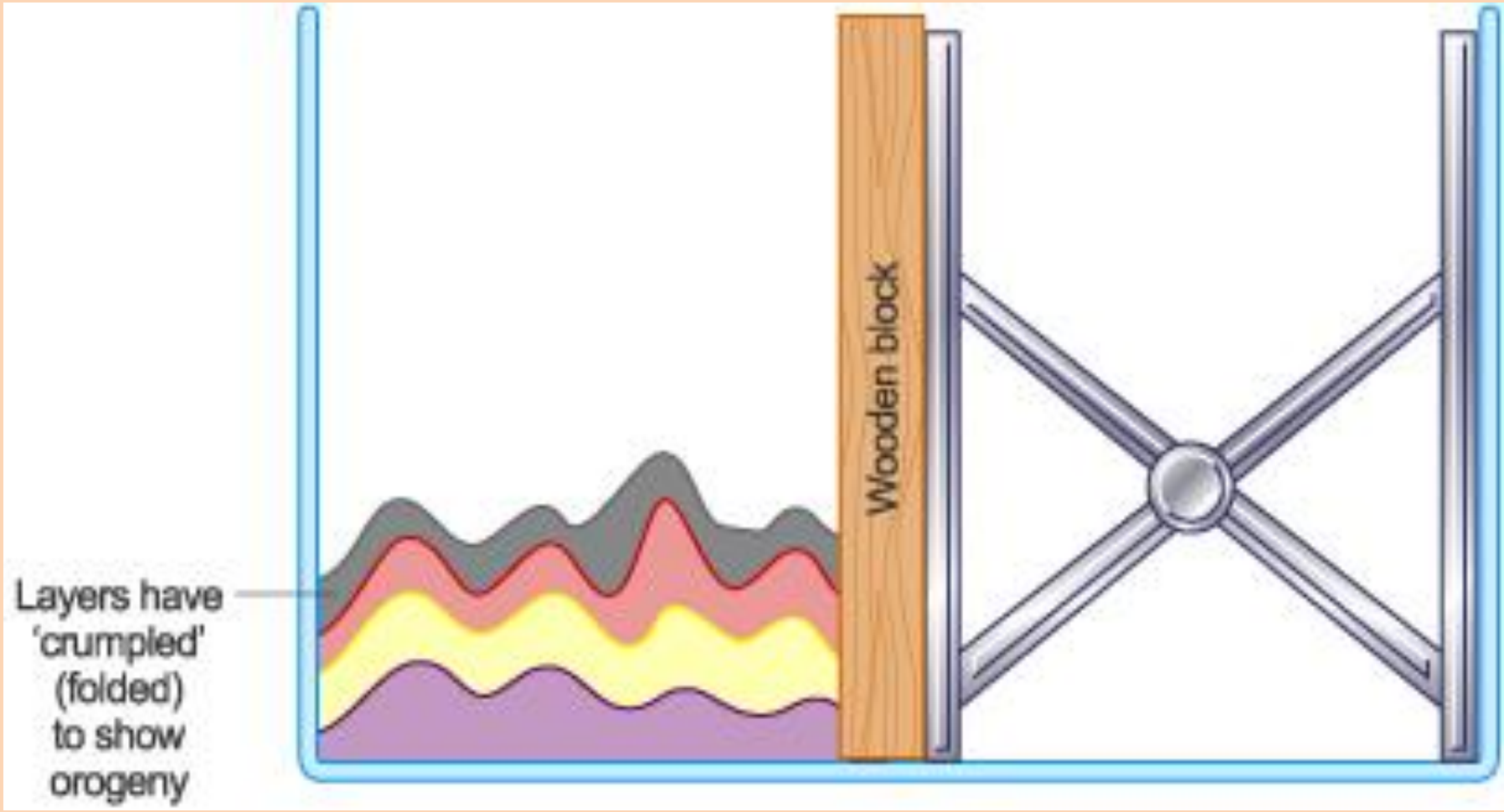
FOLD STRUCTURE

Simple physical model of folding in rocks



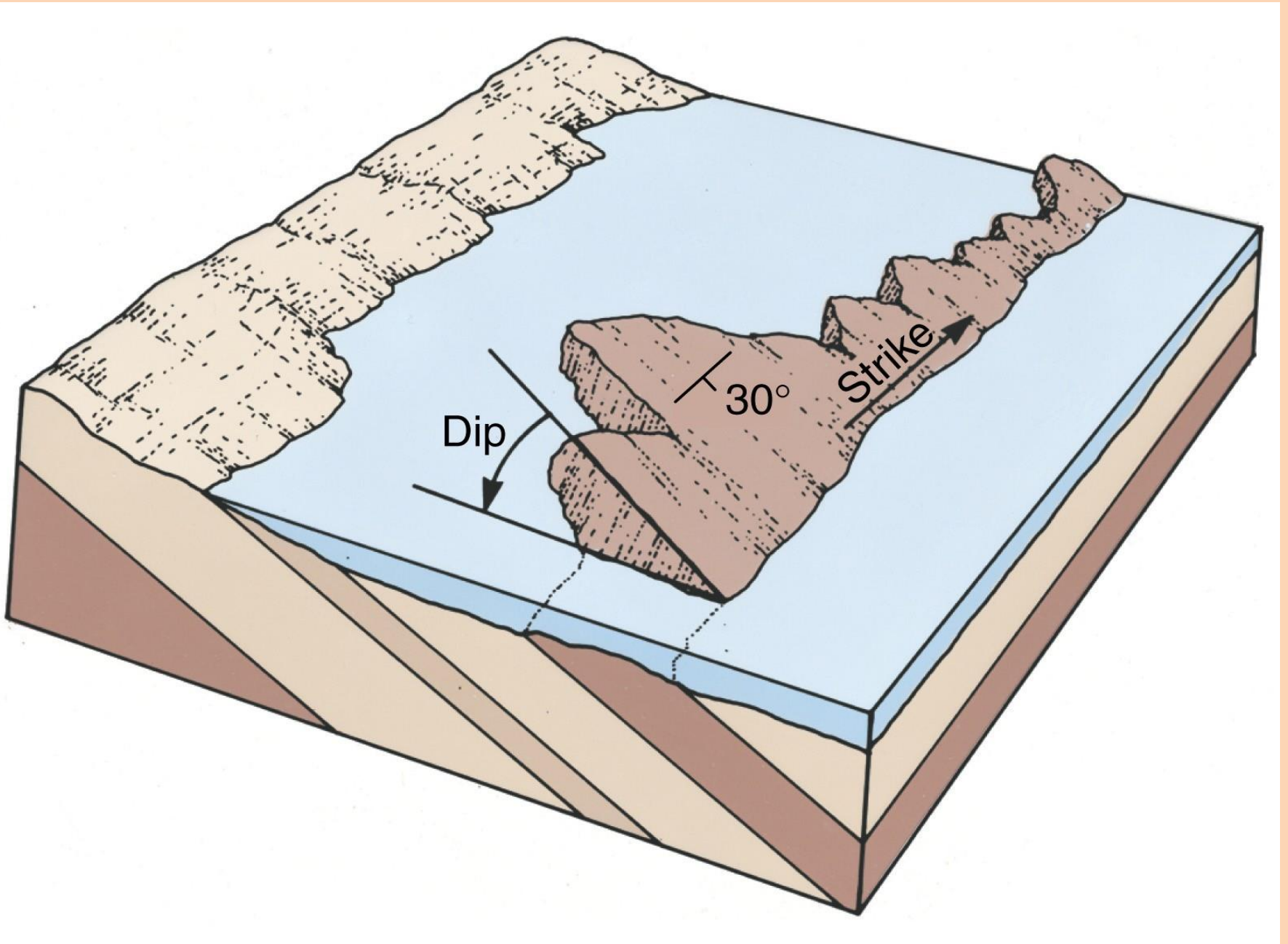
Folds

Warps in rock strata due to ductile deformation

- Generally indicate horizontal compression

Geometry of Rock Structures

- Structures defined by the orientation of planes
  - Dip : the angle of inclination downward from a horizontal plane
  - Strike : the compass bearing of a horizontal line where the inclined plane intersects an imaginary horizontal plane


Dip
30°
Strike

- Folds are described by:

1. The strike of their hinge line
   - The hinge line is the intersection of the hinge plane with the folded layer.
   - Hinge lines may be inclined in a plunging fold.
2. The angle of dip of their limbs

Hinge line: is the line of maximum curvature in a folded bed. It may be horizontal, vertical and inclined.

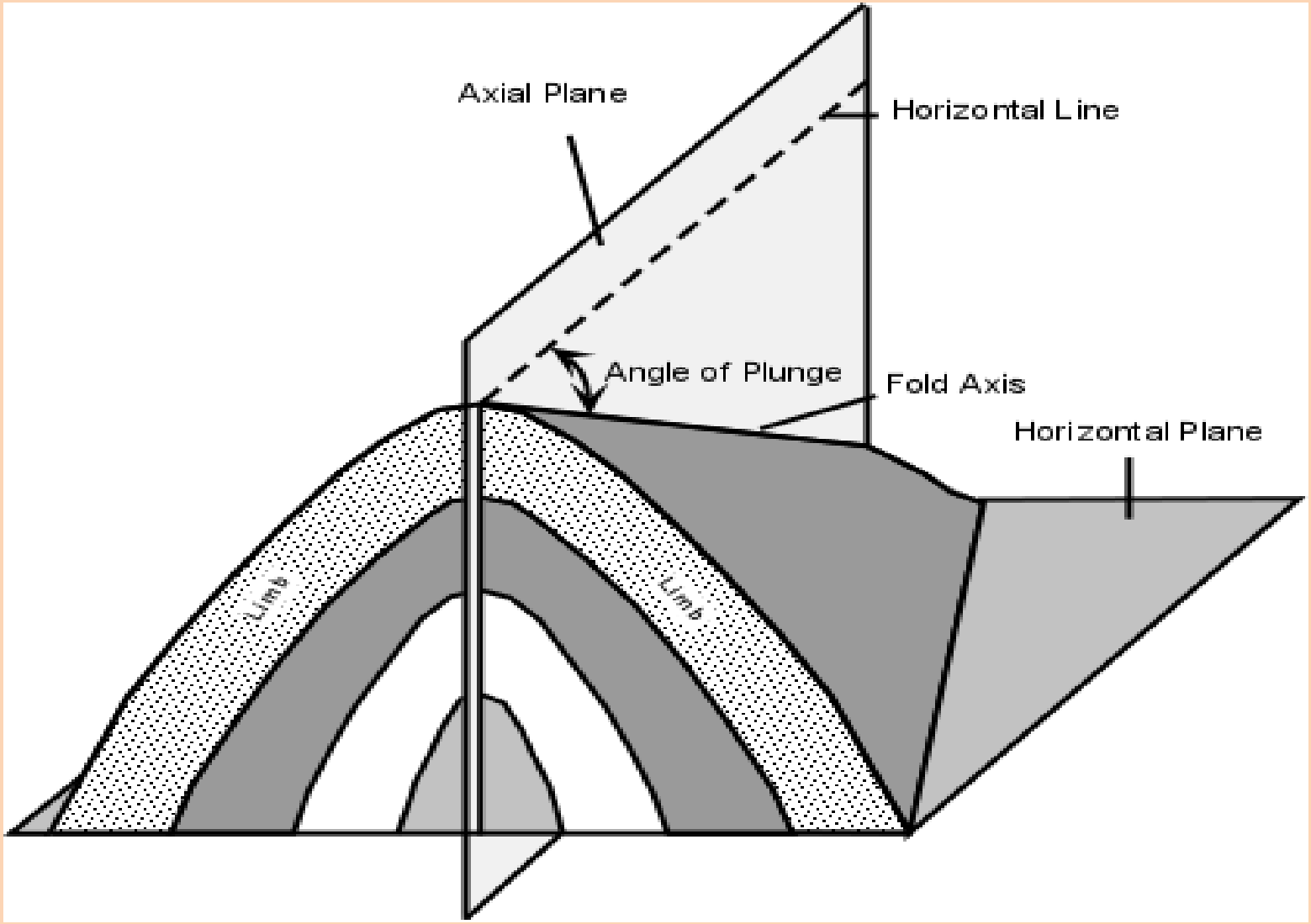
Axial plane: is the surface connecting all the hinges.

The axis: is a line parallel to the hinges. The term axis has also been used as synonymous with hinge.

Crest and crestal plane: the plane or surface formed by all the crests.

Trough: is the line occupying the lowest part of the fold.

Plunging fold



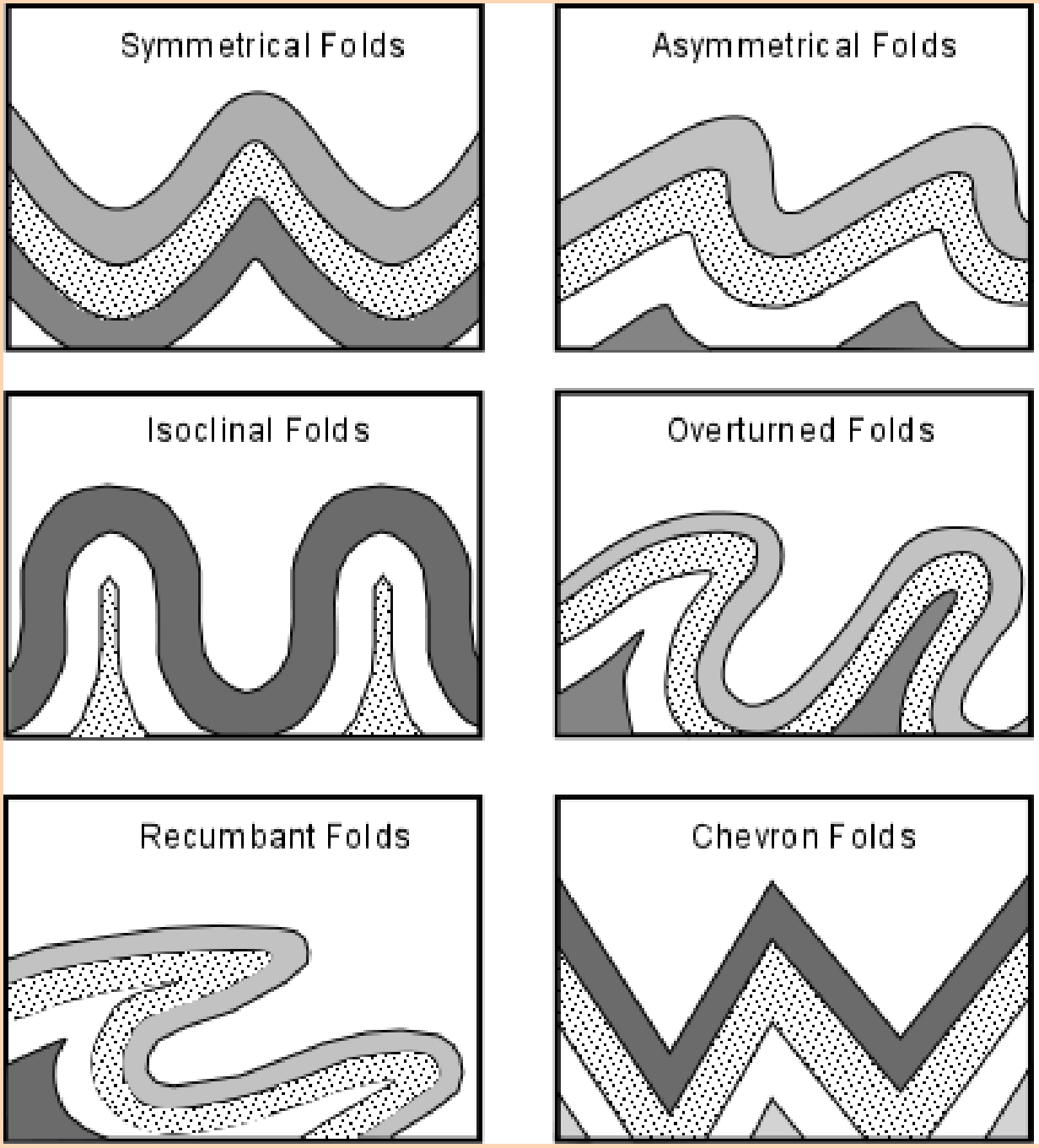
Folds are:

1. **Symmetrical** : axial surface is essentially vertical.

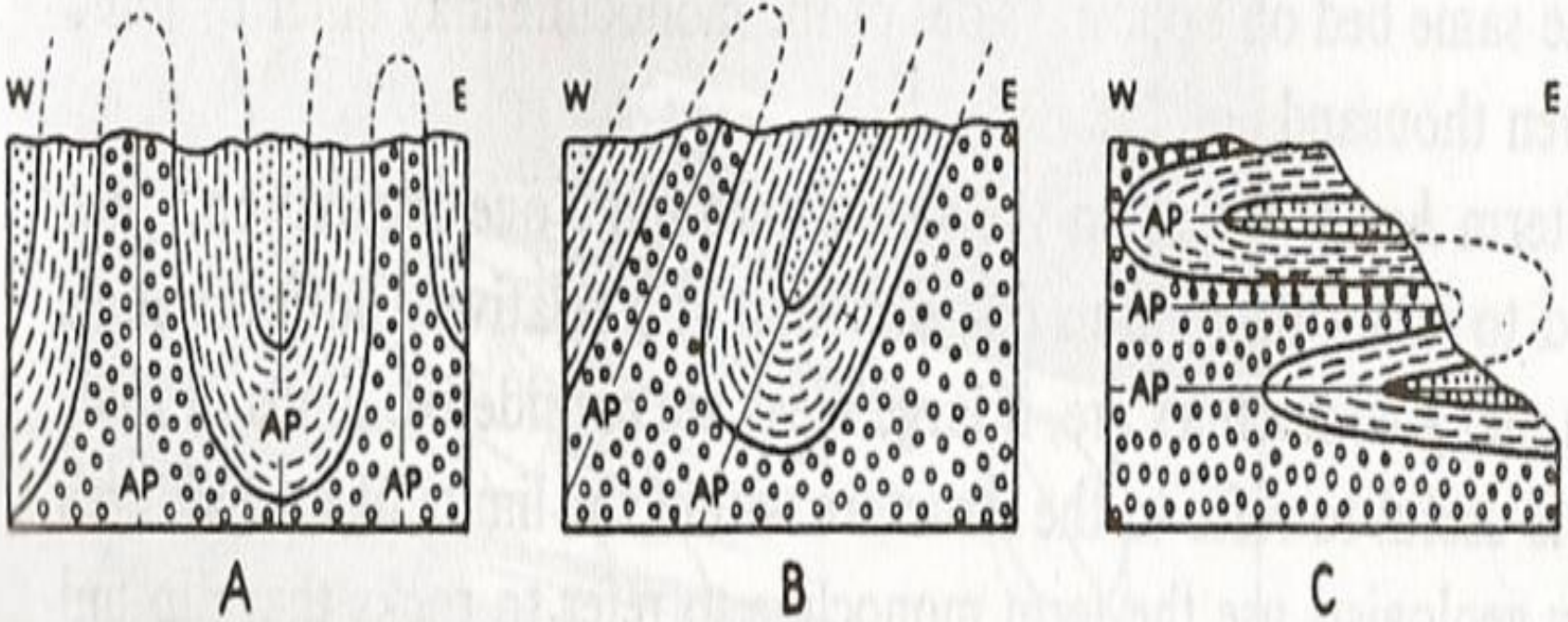
2. **Asymmetrical** : axial surface is inclined.

3. **Overturned** : axial plane is inclined and both limbs dip in the same direction, usually at different angles.

4. **Recumbent** : axial plane is horizontal.


Symmetrical Folds
Asymmetrical Folds
Isoclinal Folds
Overturned Folds
Recumbant Folds
Chevron Folds

5. **Isoclinal** : the two limbs dip at equal angle in the same direction.
6. **Chevron** : is one in which the hinges are sharp and angular.
7. **Box fold**: is one in which the crest is broad and flat; two hinges are present, one on either side of the flat crest.
8. **Fan fold**: is one in which both limbs are overturned. In the anticlinal fan fold, the two limbs dip toward each other, in the synclinal fan fold, the two limbs dip a way from each other.
9. **Closed or tight fold**: is one in which the deformation has been sufficiently intense to cause flowage of the more mobile beds so that these beds thicken and thin.



Isoclinal folds. *AP*, Axial planes. (A) Vertical isoclinal folds. (B) Inclined isoclinal folds. (C) Recumbent isoclinal folds.

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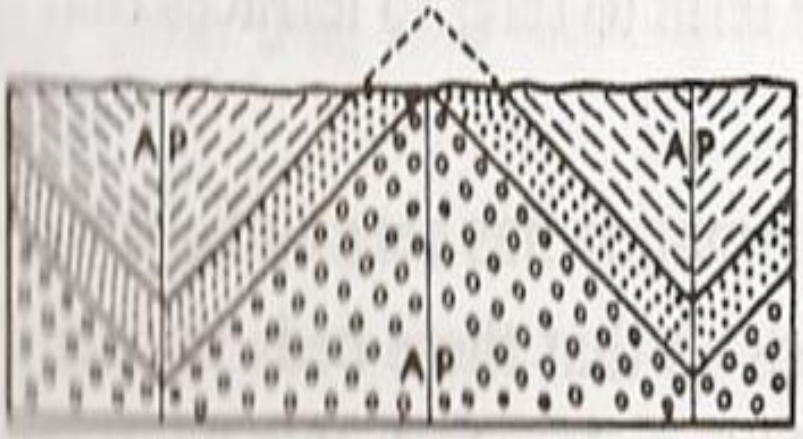
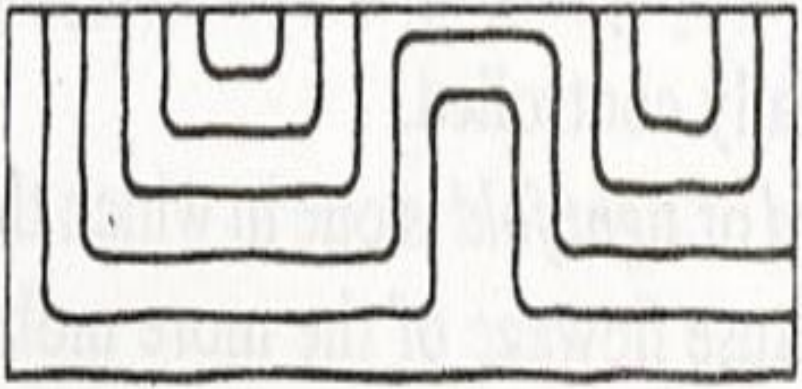


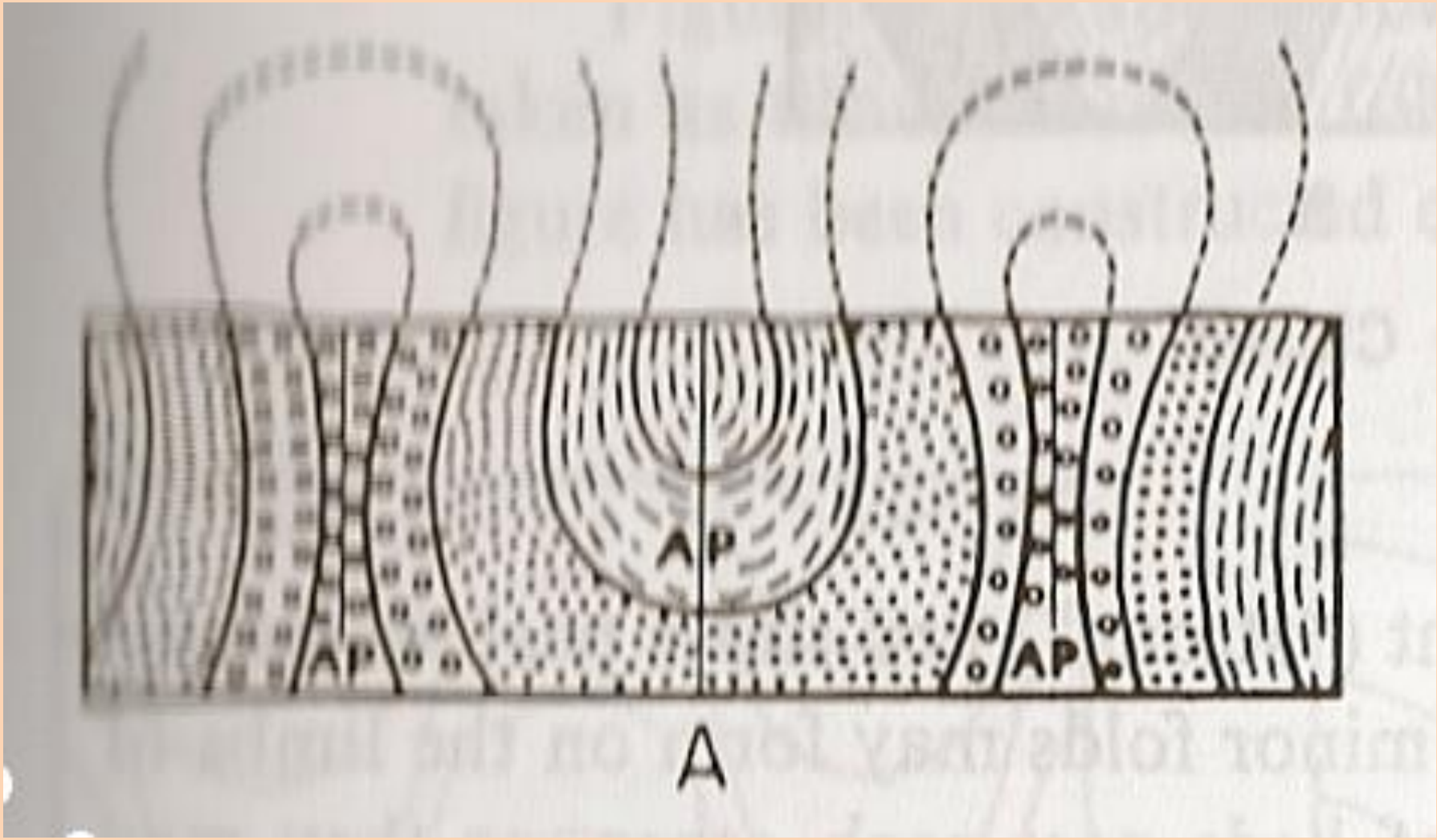
A

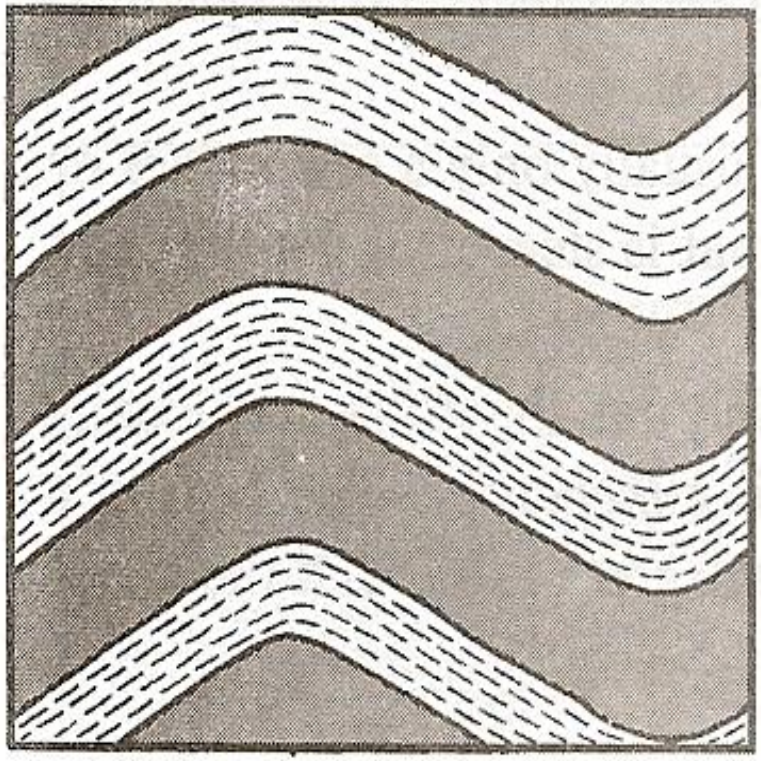


B

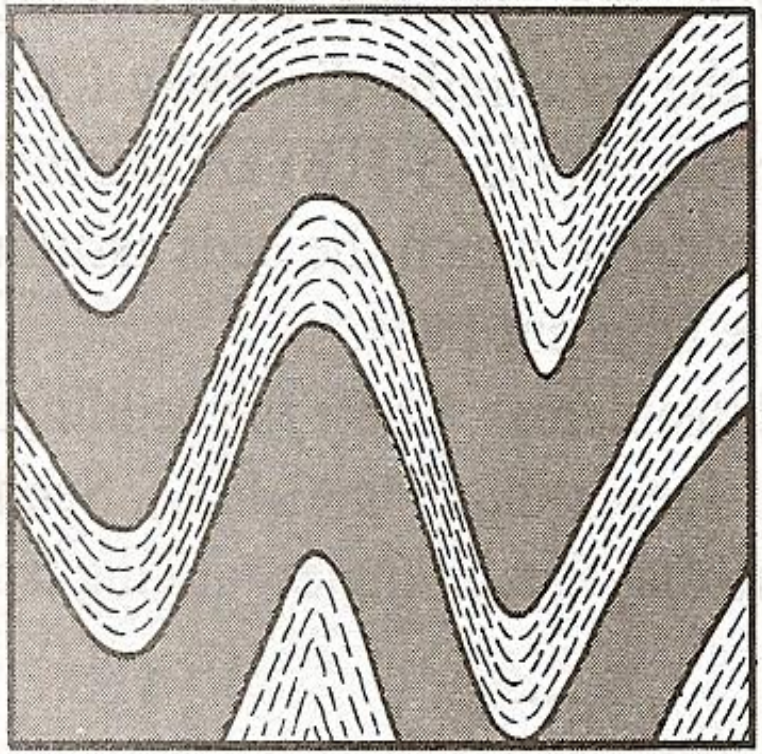
Some varieties of folds. *AP*, axial plane. (A) Chevron fold. (B) Box fold.

Fan Fold





Open Fold



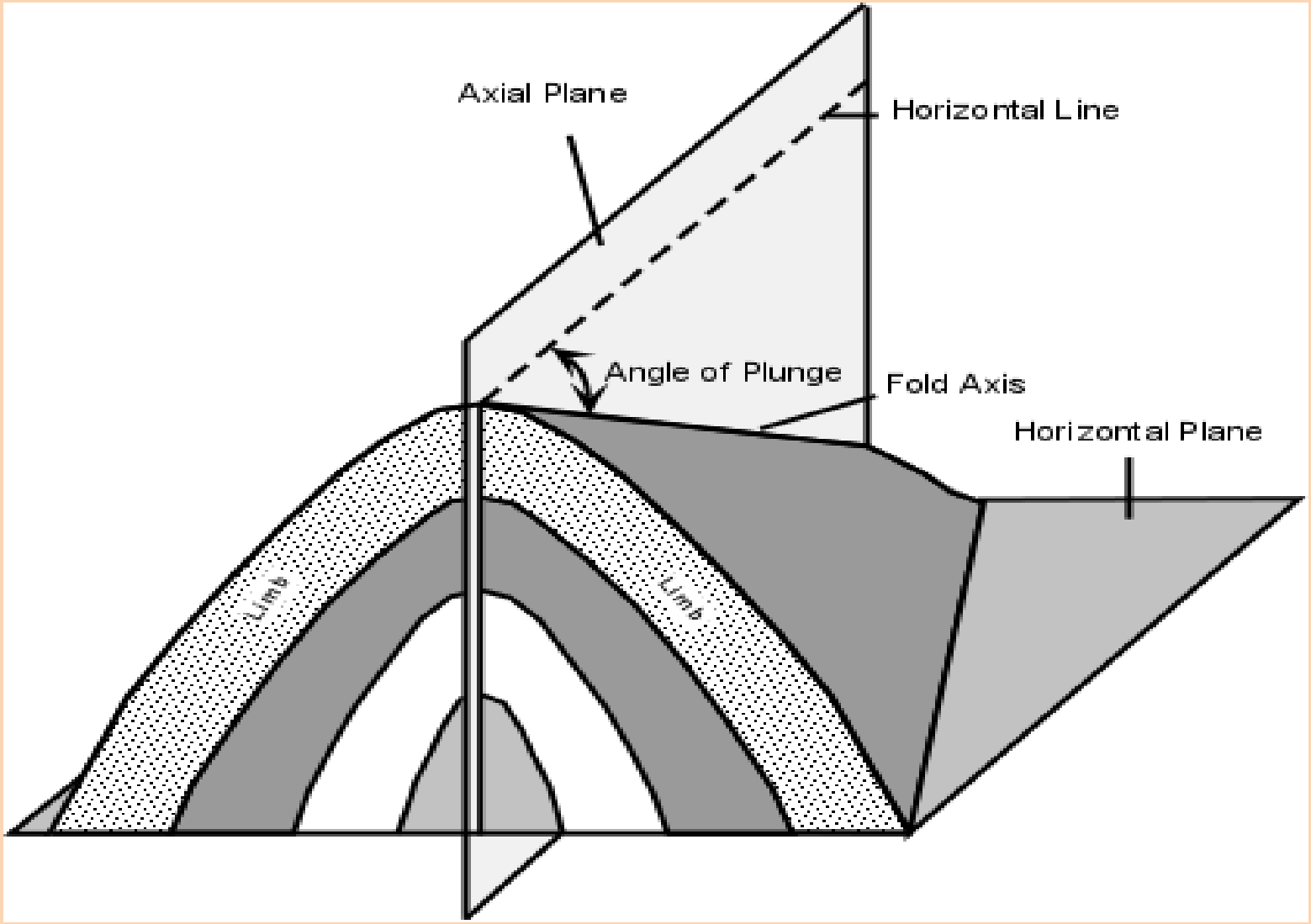
Closed Fold

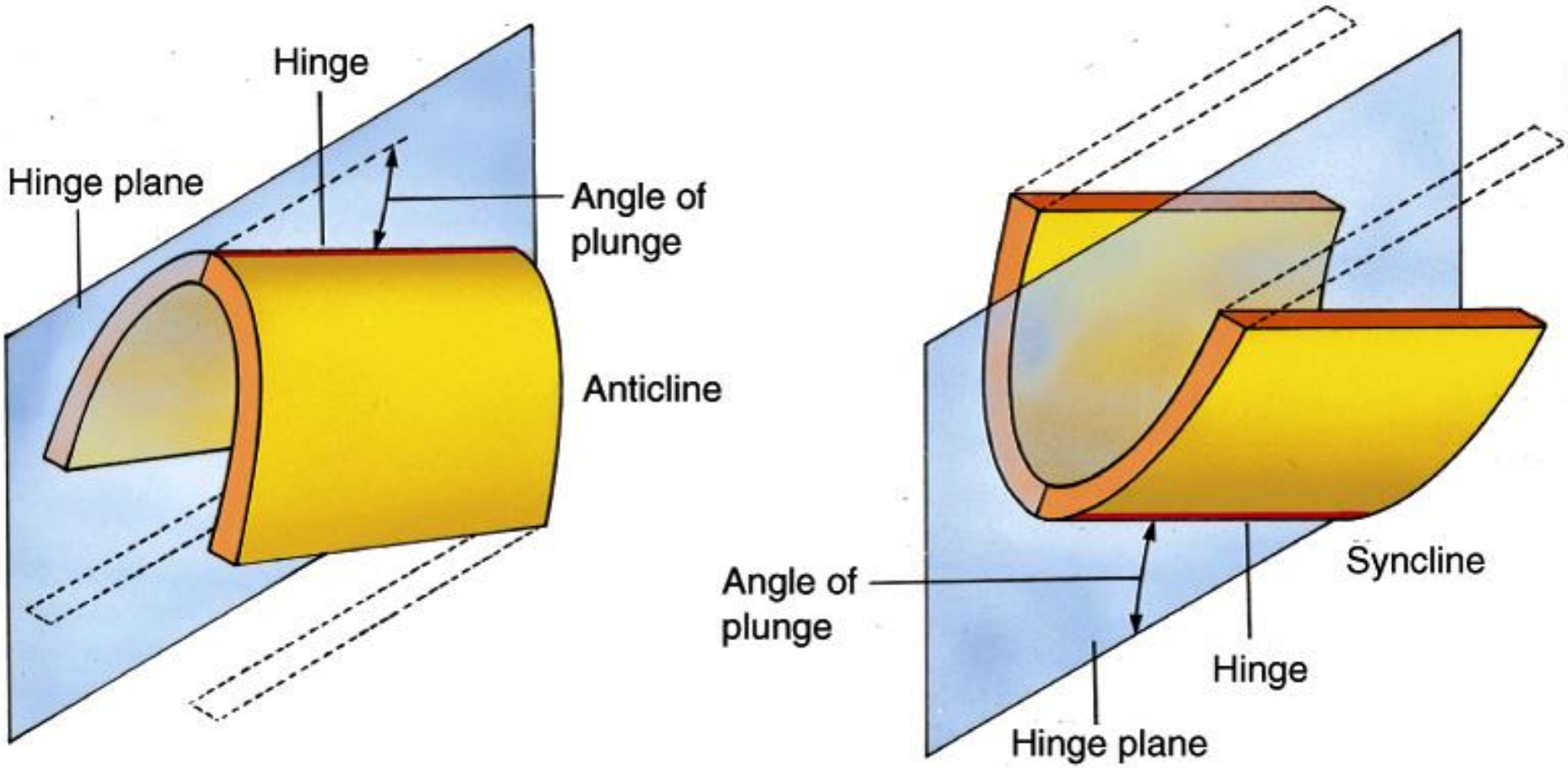
- Plunging folds: when the folds axis is dipping or plunging.

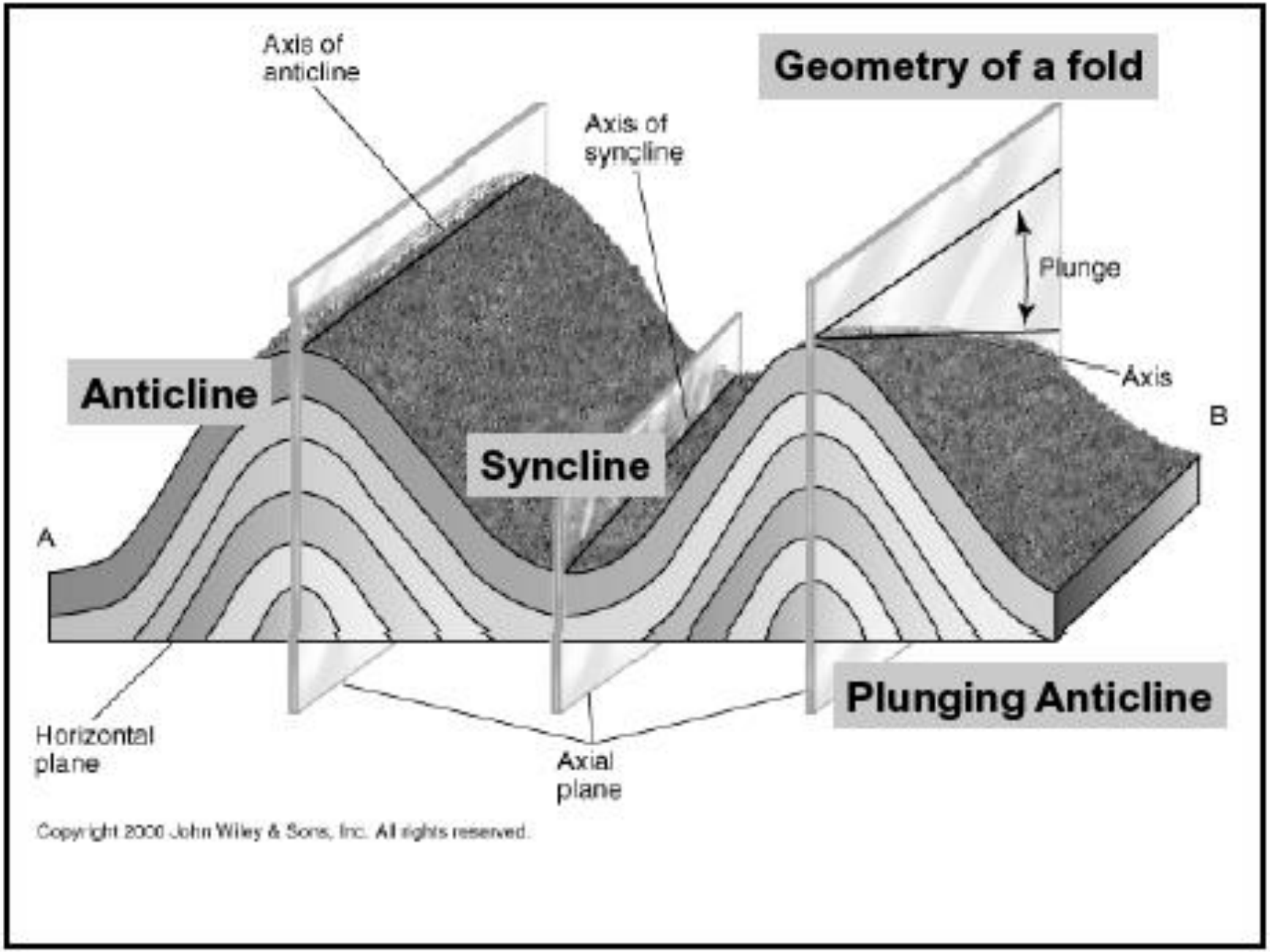
- Asymmetric Fold: one limb dips more steeply than the other.

- Overturned and Recumbent: folding is so extreme that beds are turned upside-down.

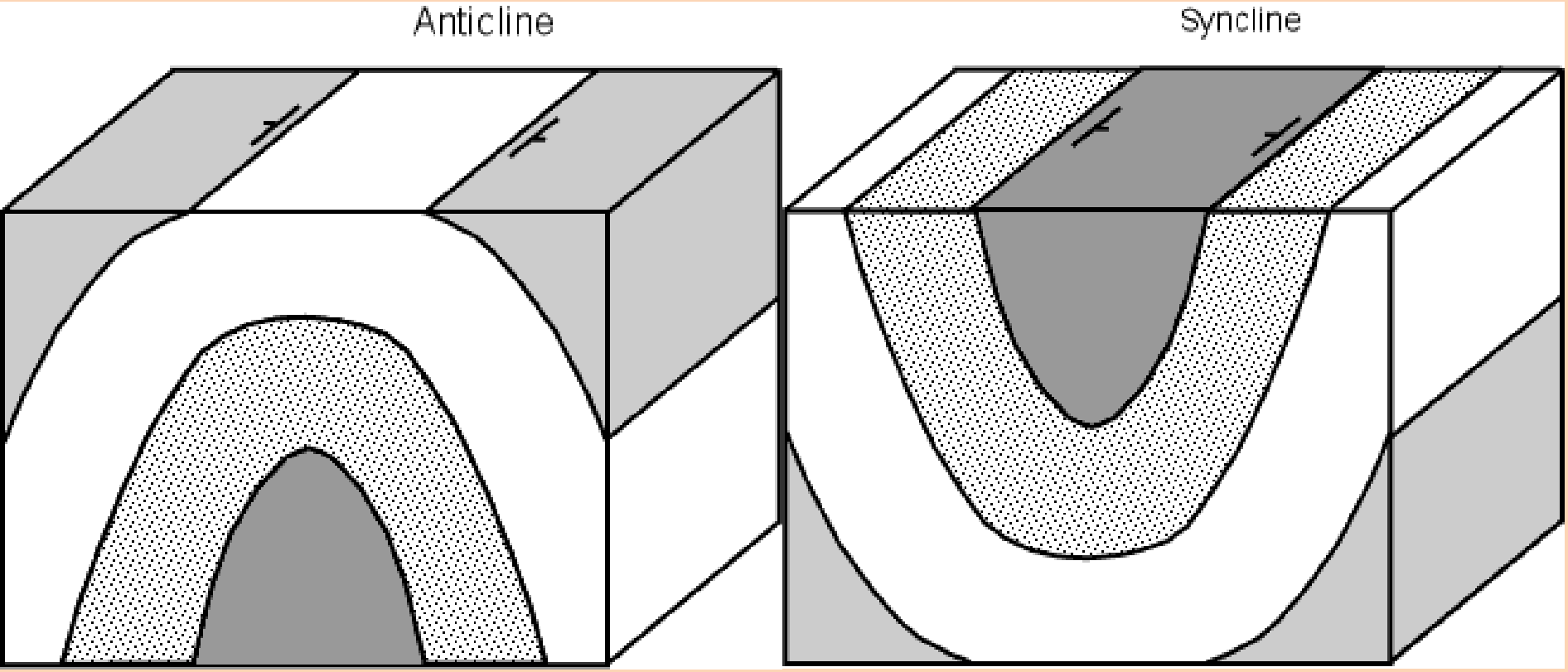
Plunging fold

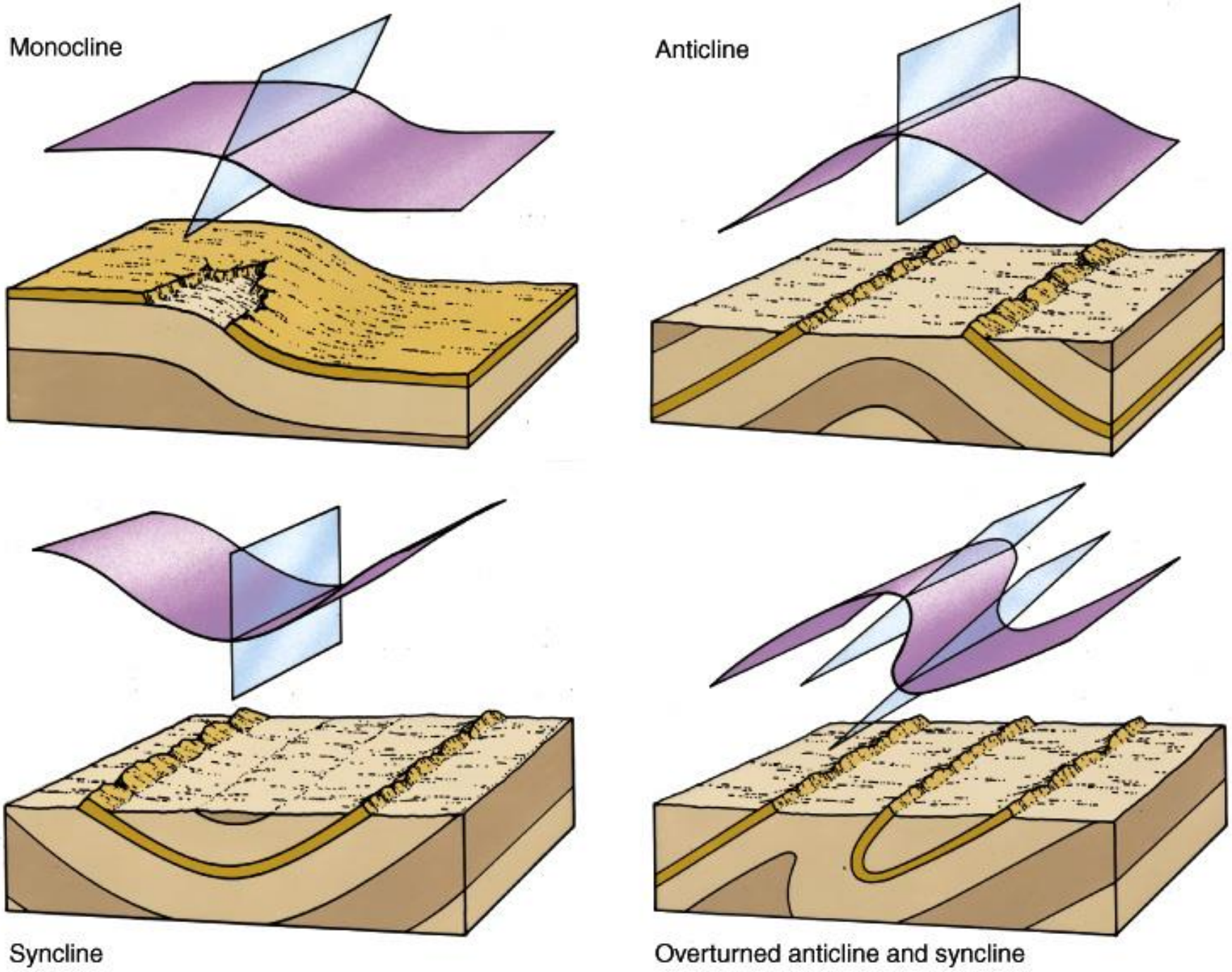



Hinge
Hinge plane
Angle of plunge
Anticline
Angle of plunge
Syncline
Hinge
Hinge plane



- Three simple fold forms exist:
  - *Synclines* warp downward
  - *Anticlines* warp upward
  - *Monoclines* dip in one direction

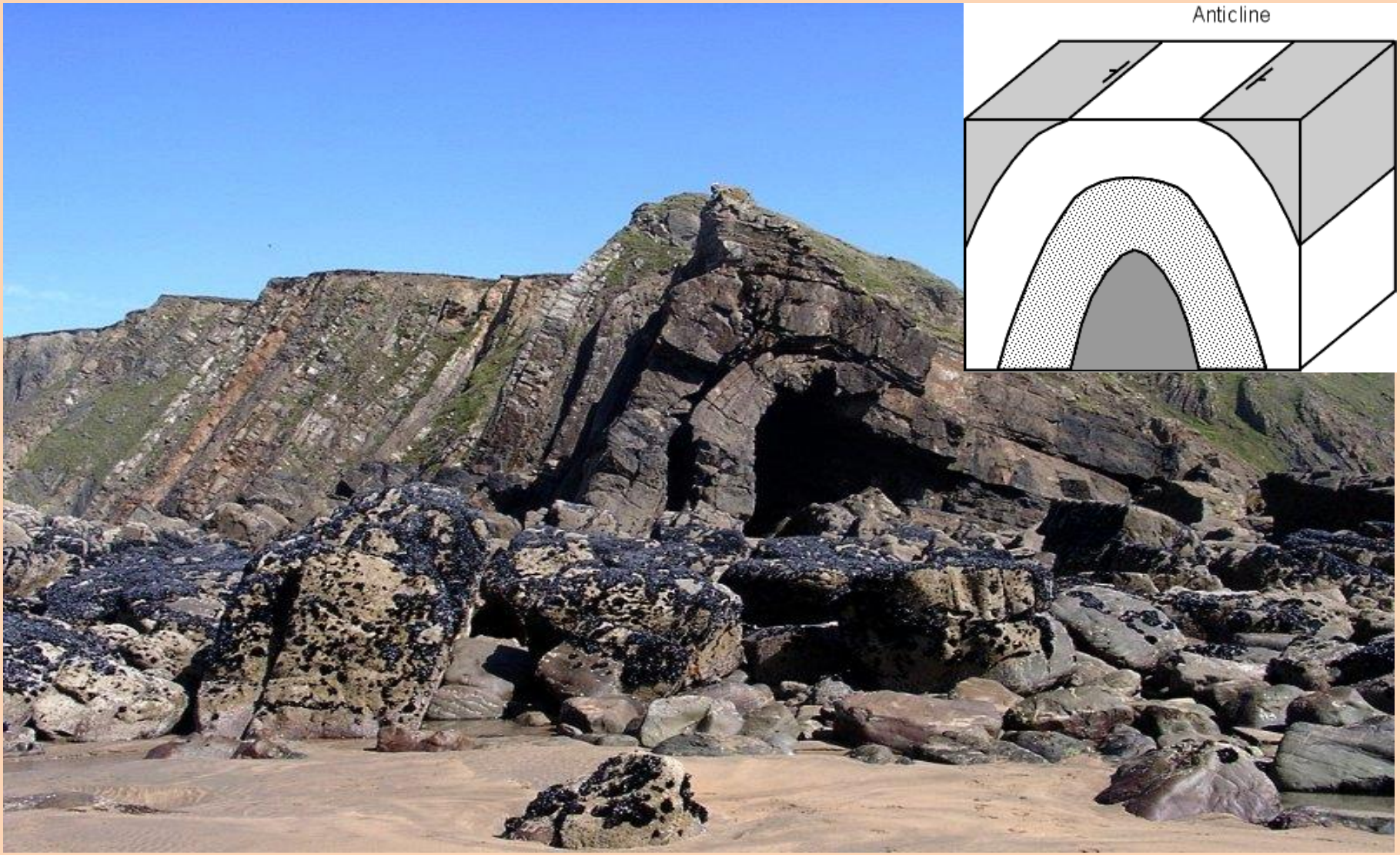



Monocline
Anticline
Syncline
Overturned anticline and syncline

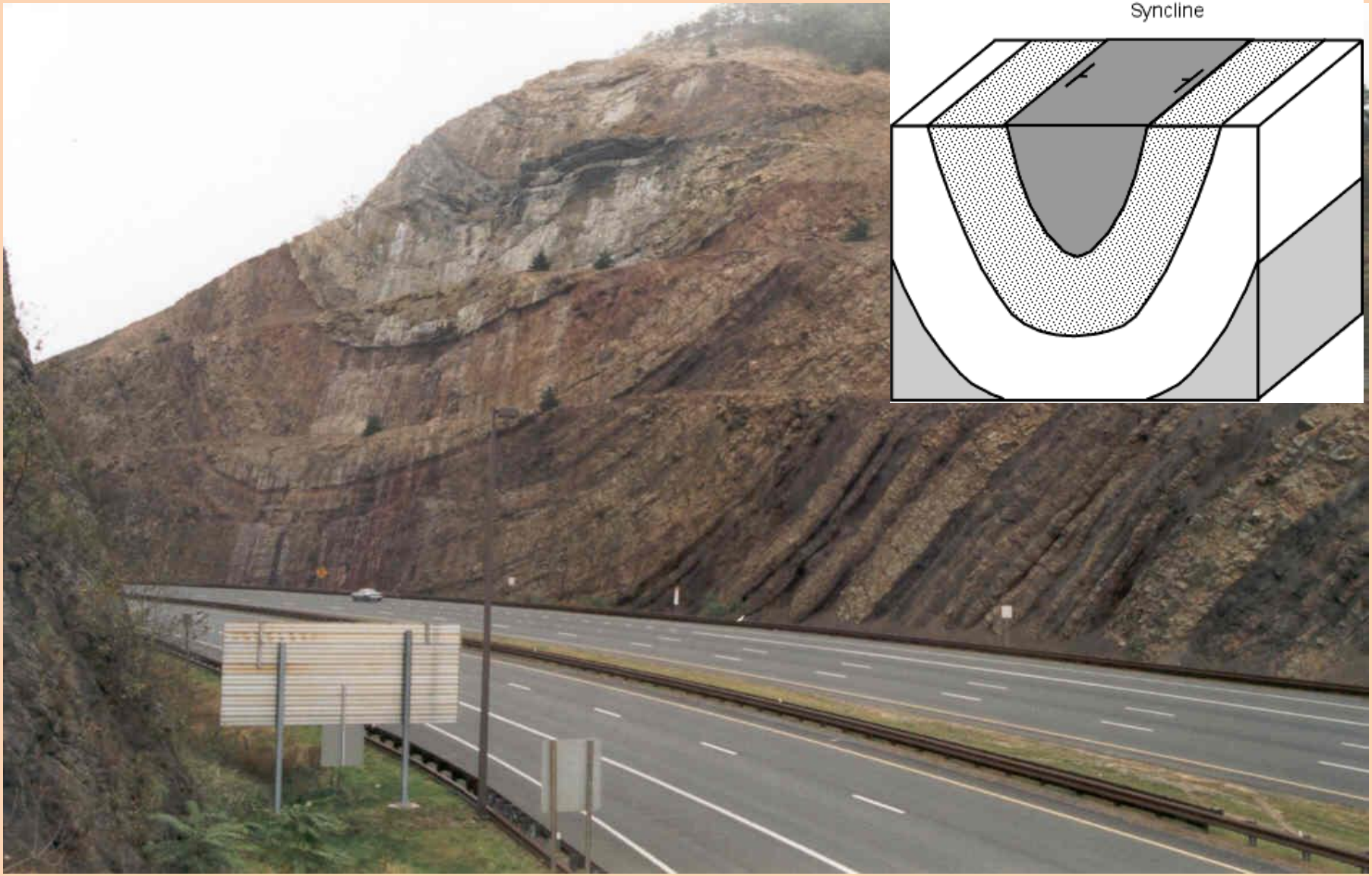
Anticlines & Synclines

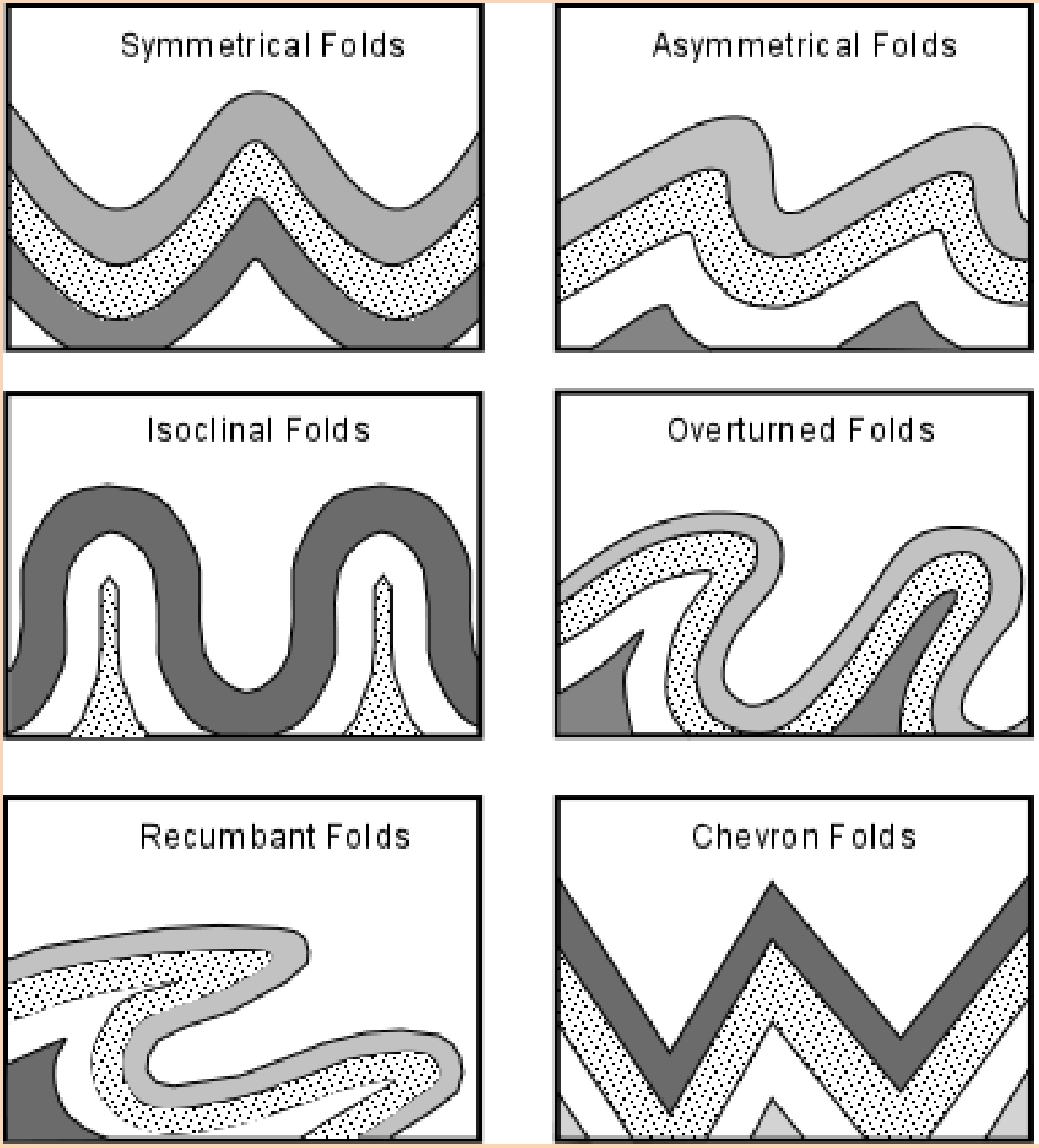
- Sequence of ages of strata indicate the geologic structure in folds:
  - Anticlines: oldest layers exposed at the center of the fold
  - Synclines: youngest strata exposed along the center of the fold

Anticline in its natural environment
-oldest rocks in the core of fold

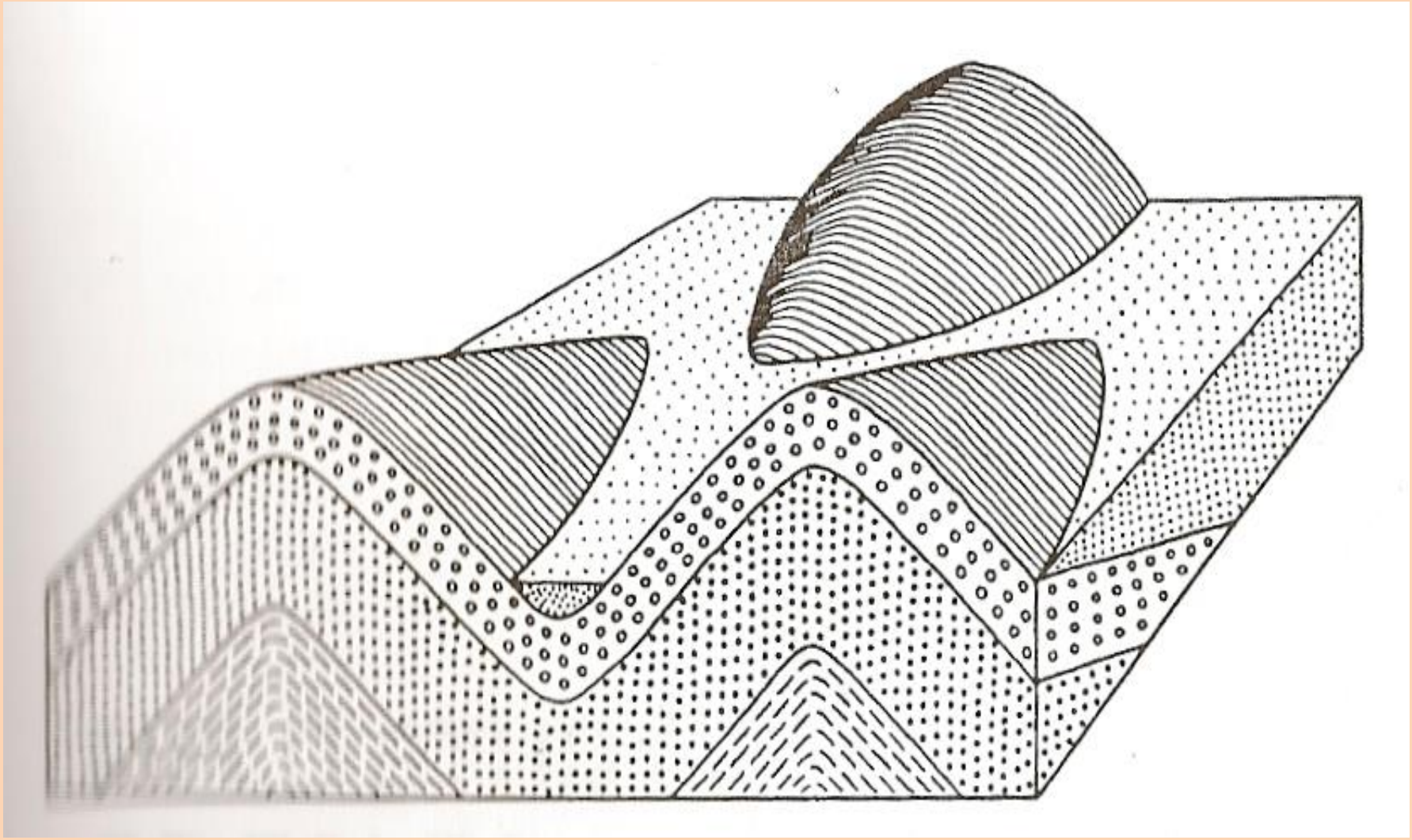


Syncline: youngest rocks in core of fold

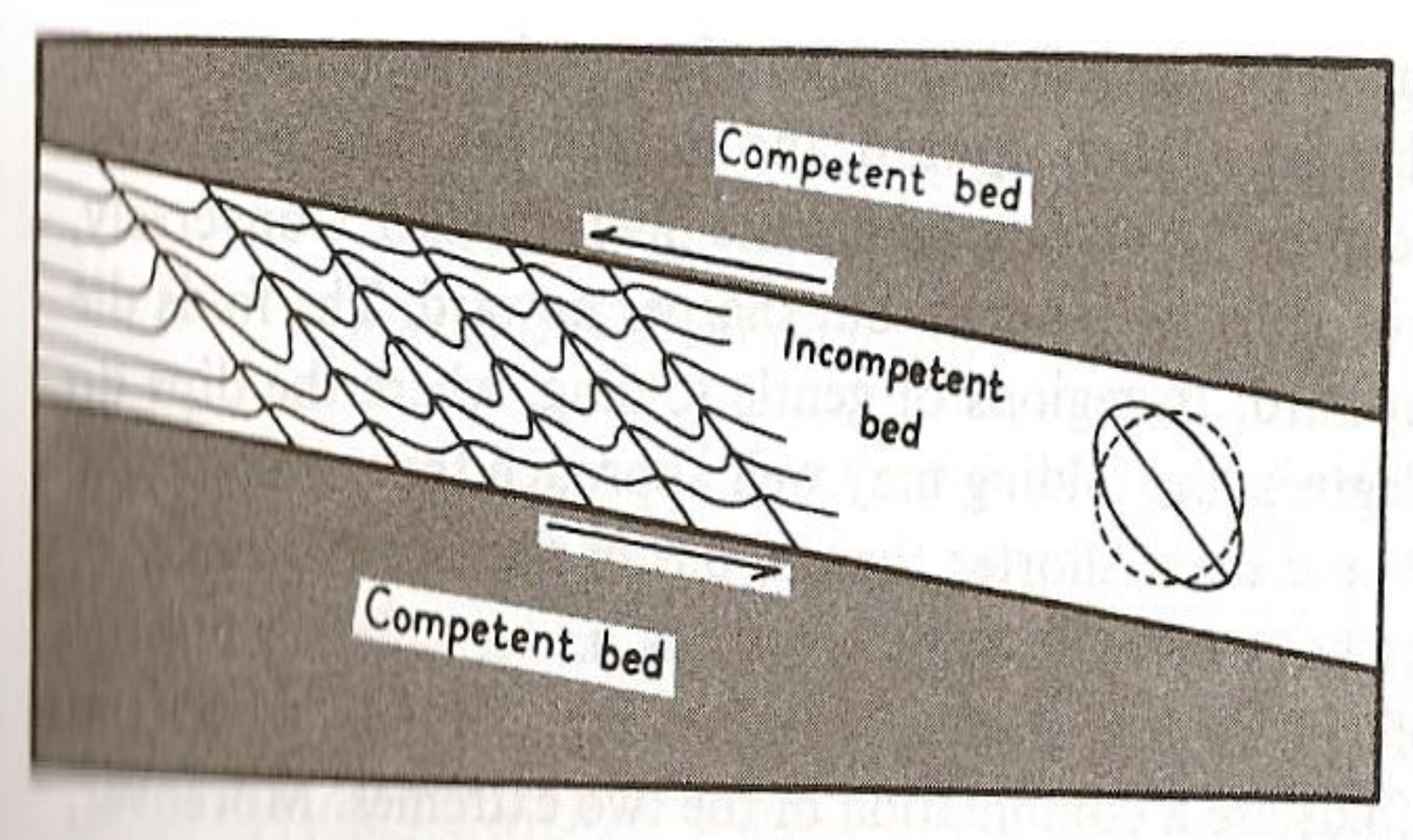


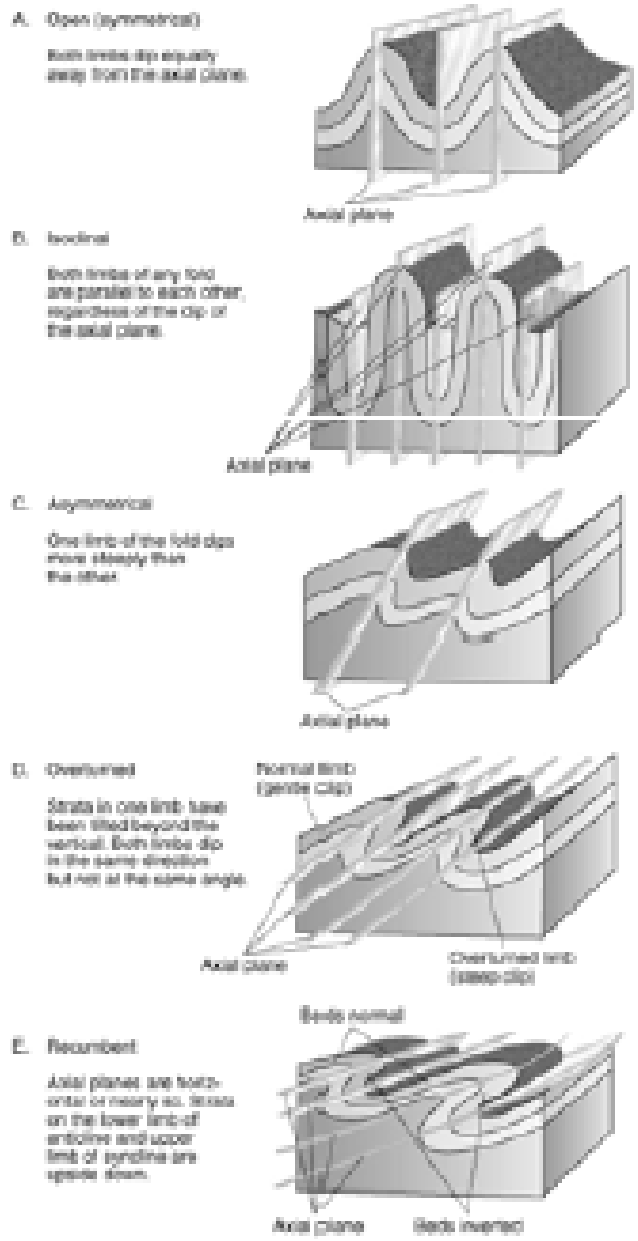

Symmetrical Folds
Asymmetrical Folds
Isoclinal Folds
Overturned Folds
Recumbant Folds
Chevron Folds

En Echelon Folds



Drag Fold





Open (symmetrical)

Isoclinal

Asymmetrical

Overturned

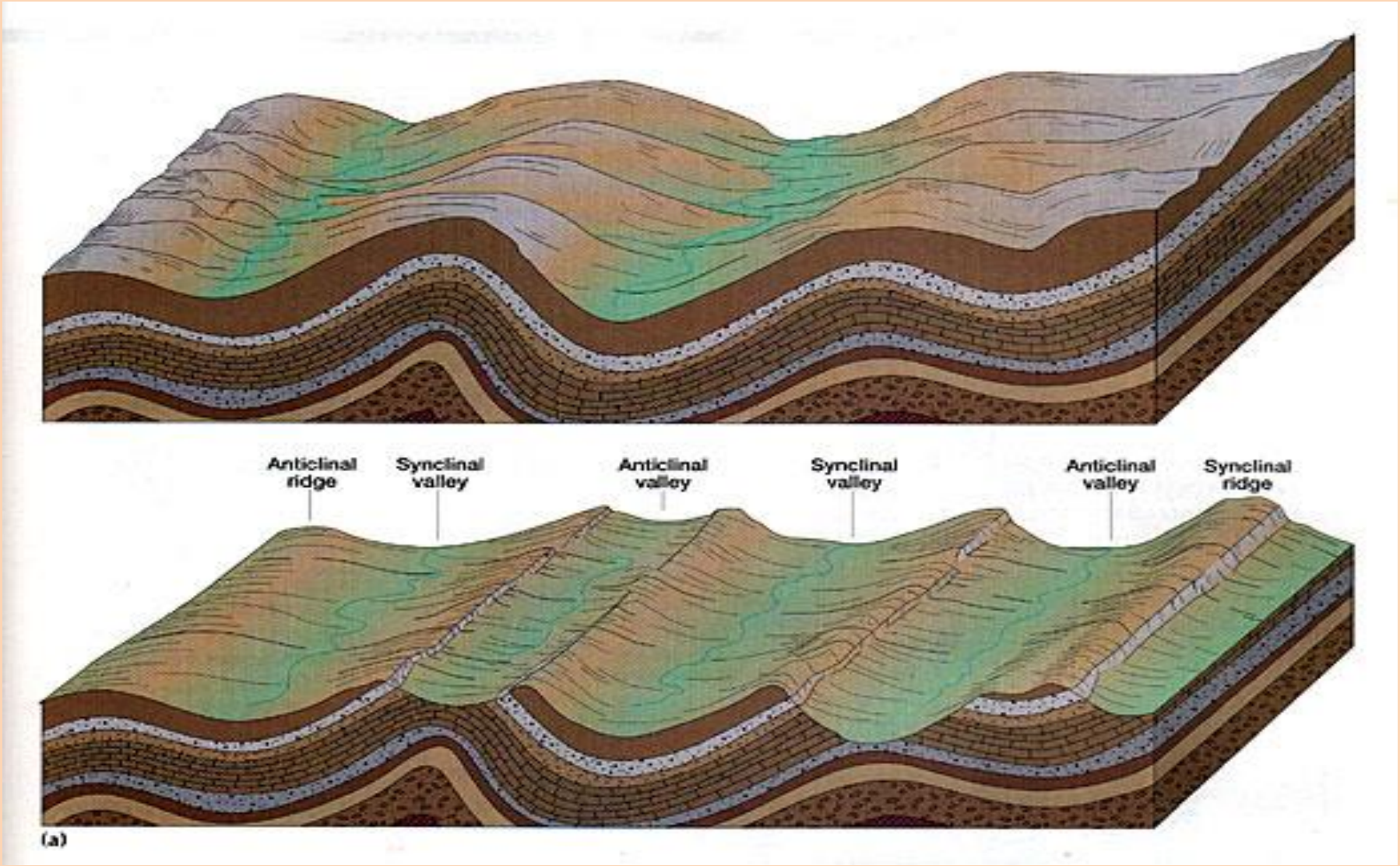
Recumbent

Anticline syncline

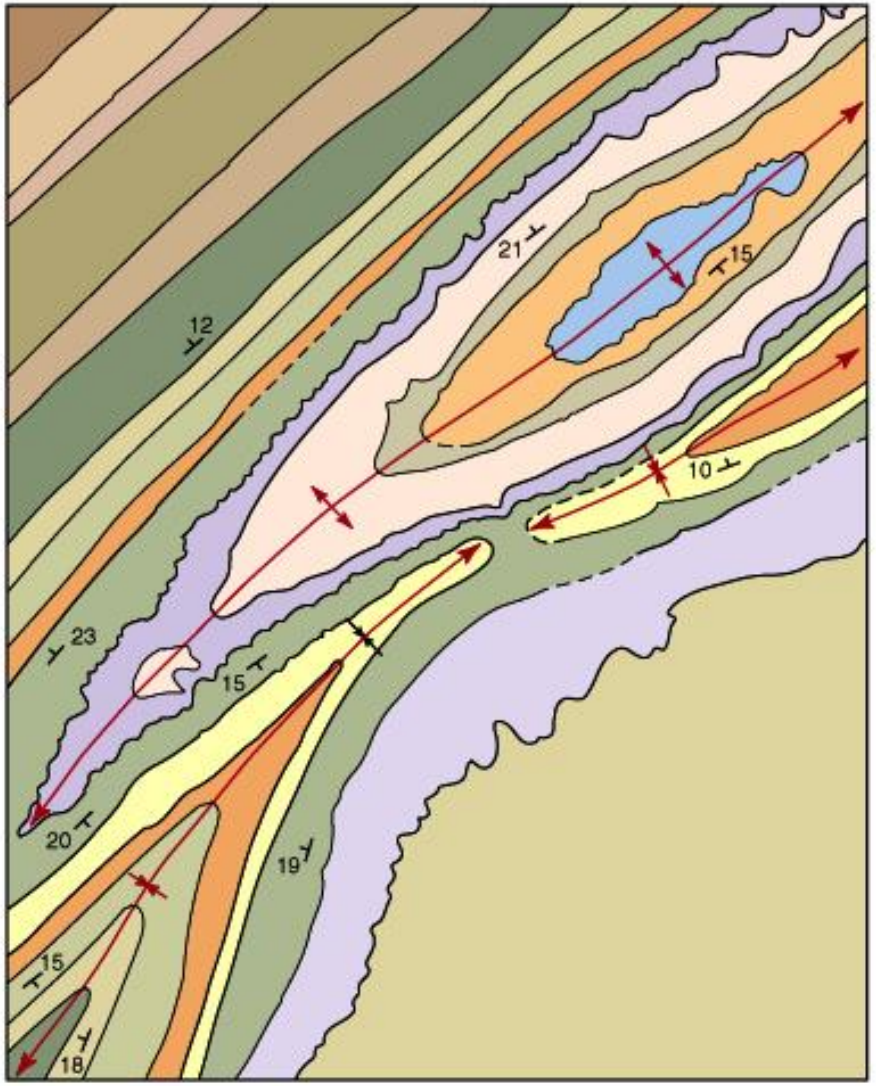
Fold Belts

- Orogenic belts consist of long linear series of folds
  - Fold geometry is not overly complex
  - Pattern of outcrops may appear complex
  - Complex folds may develop as folds are:
    - Re-folded
    - Cut by thrust faults

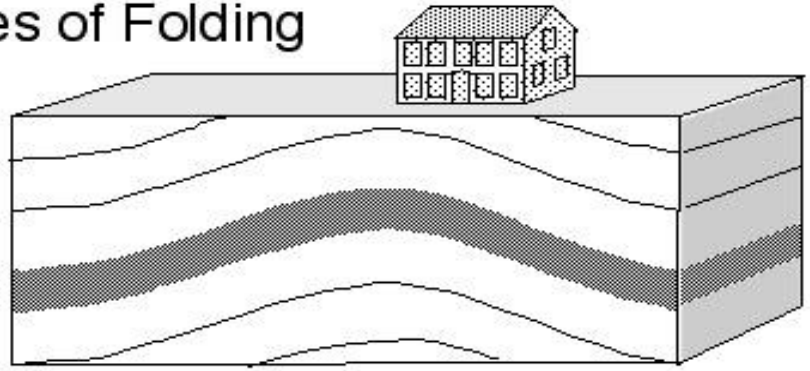
Folds occur as sets: *"Fold Belts"*



Orogenic belt with complex folding

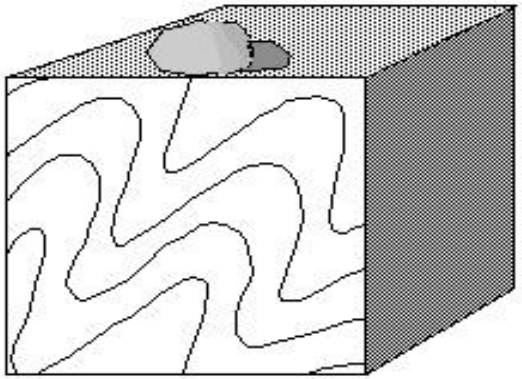


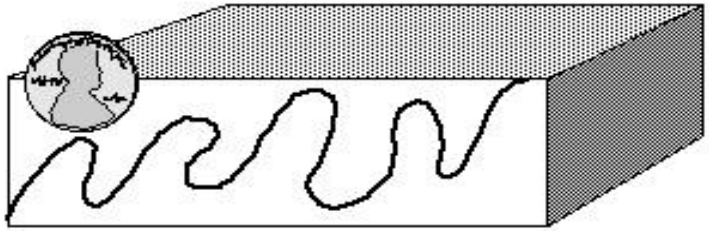
Scales of Folding



Sedimentary rocks:
folds a few meters to 100s of meters long

Metamorphic rocks:
folds a few centimeters to meters long



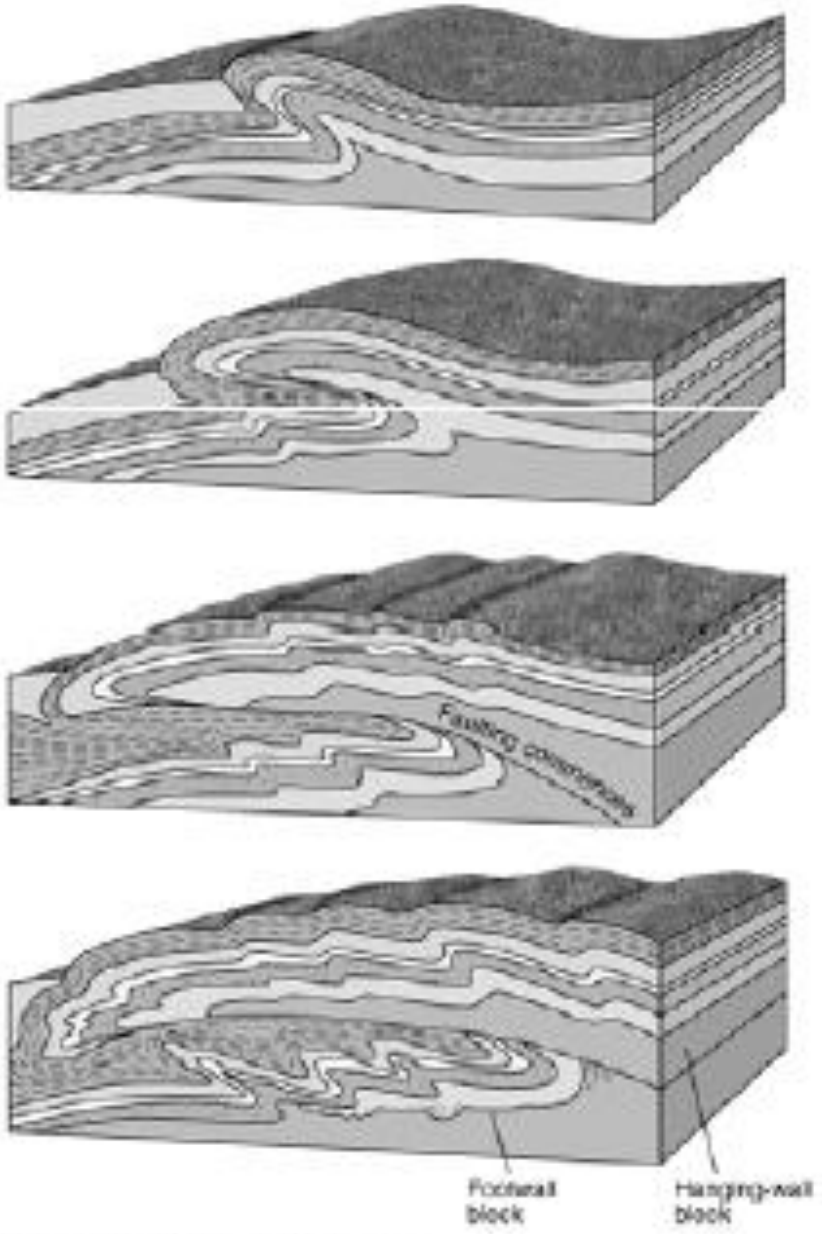


Very high-grade metamorphic rocks (near melting):
folds millimeters to centimeters long (ptigmatic folding)

Reason:
Higher temperatures allow more intense ductile deformation.

LBR 6/2002

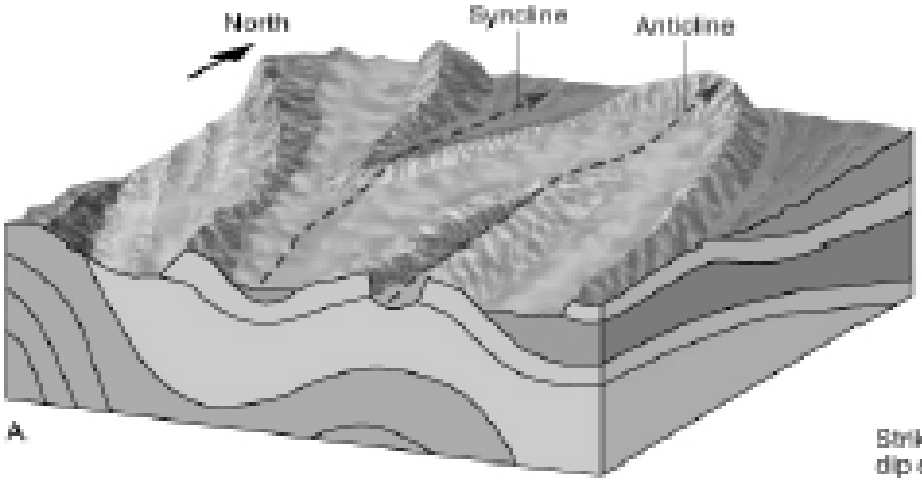
Folding (and Faulting) occurs at multiple scales

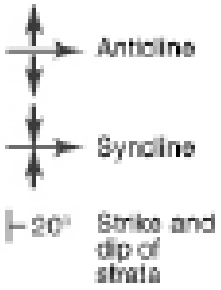


Evolution of a fold into a reverse fault

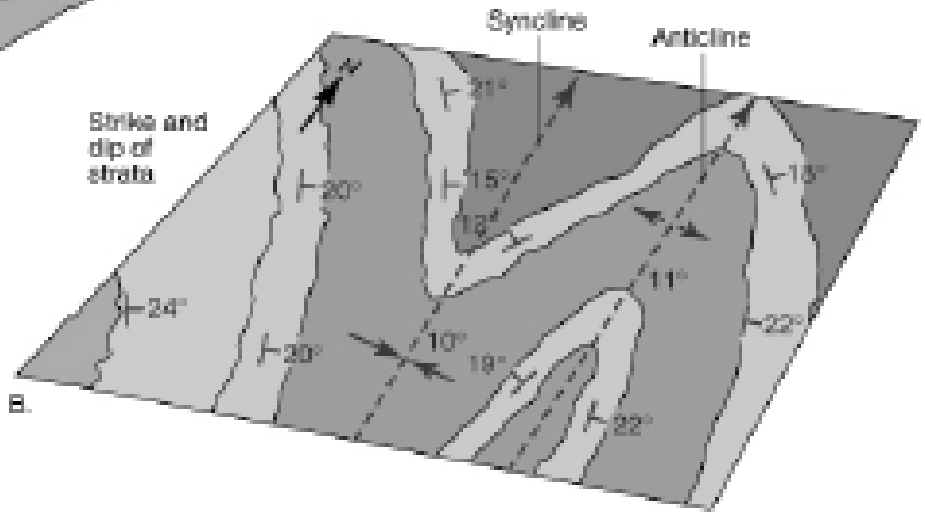
Plunging folds revealed by topography

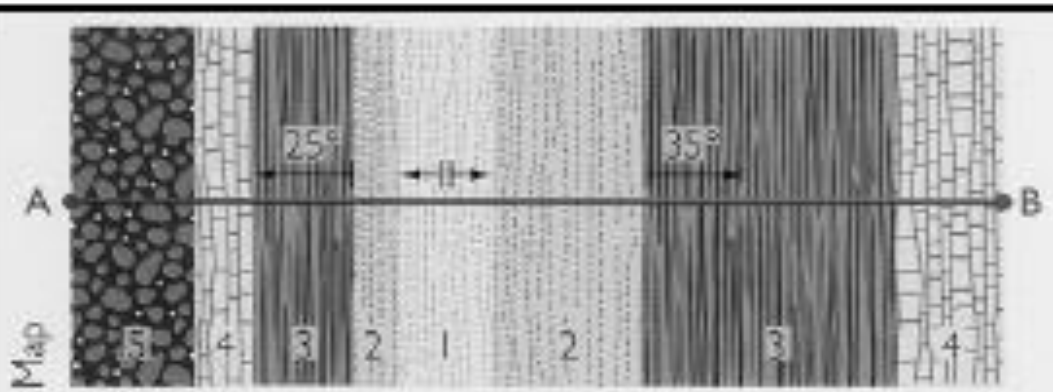
"Law of V's" - Plunging anticline points in direction of plunge
Plunging syncline opens in direction of plunge





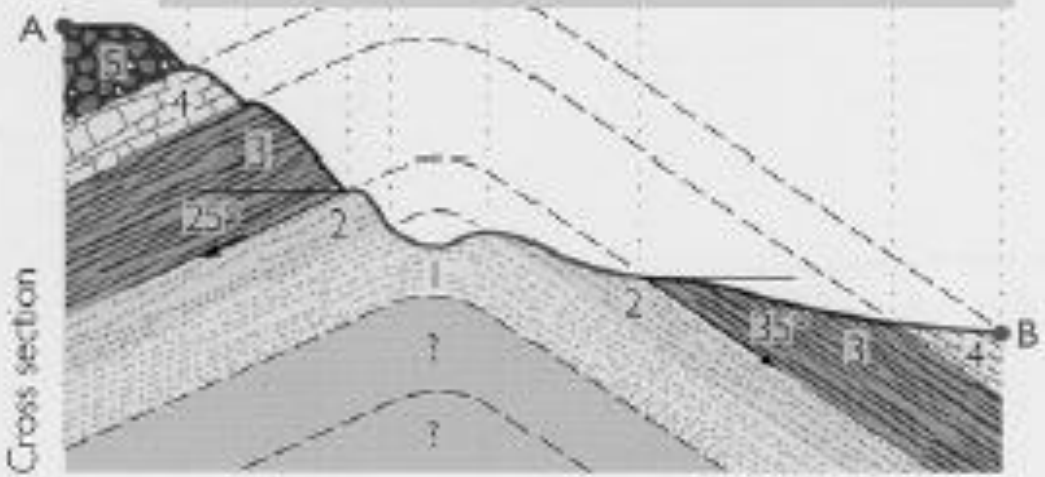
Geologic Map





Measuring orientation of rock outcrops

Erosion removes portions of a fold



What are the age relationships of these rocks?

1 Brown sandstone (oldest formation)

2 Red sandstone

3 Shale

4 Limestone

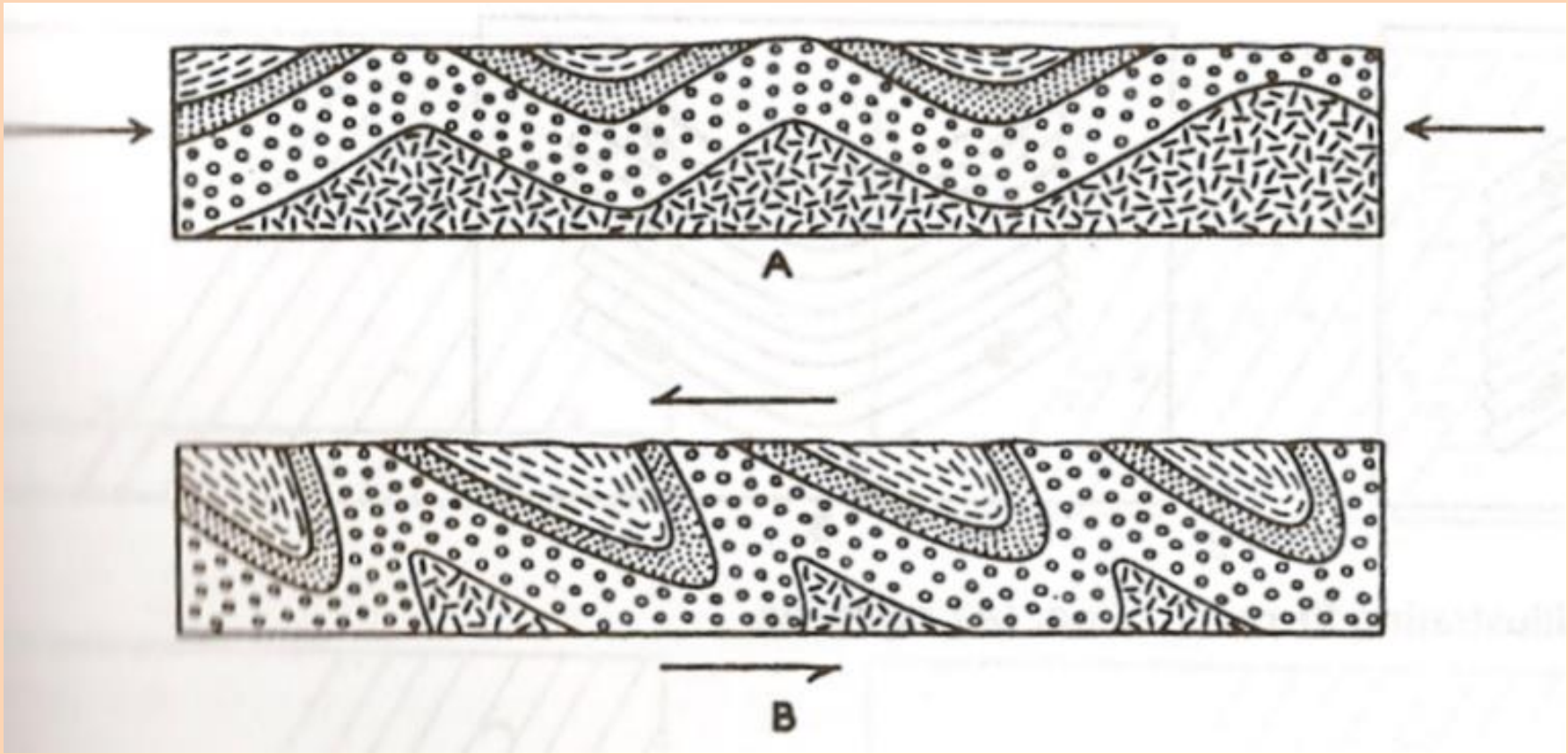
5 Conglomerate (youngest formation)

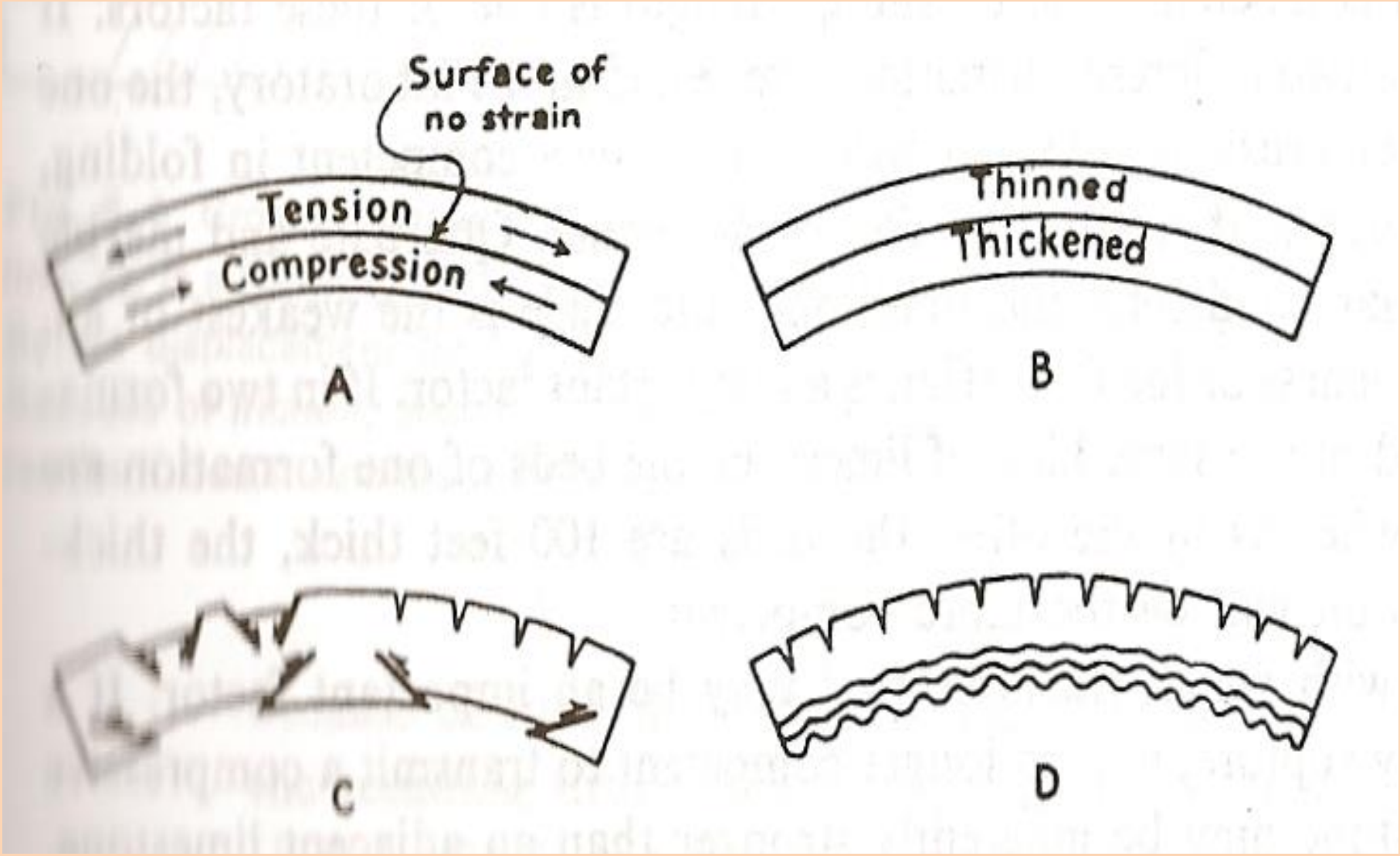
45°

Strike and Dip symbols on maps

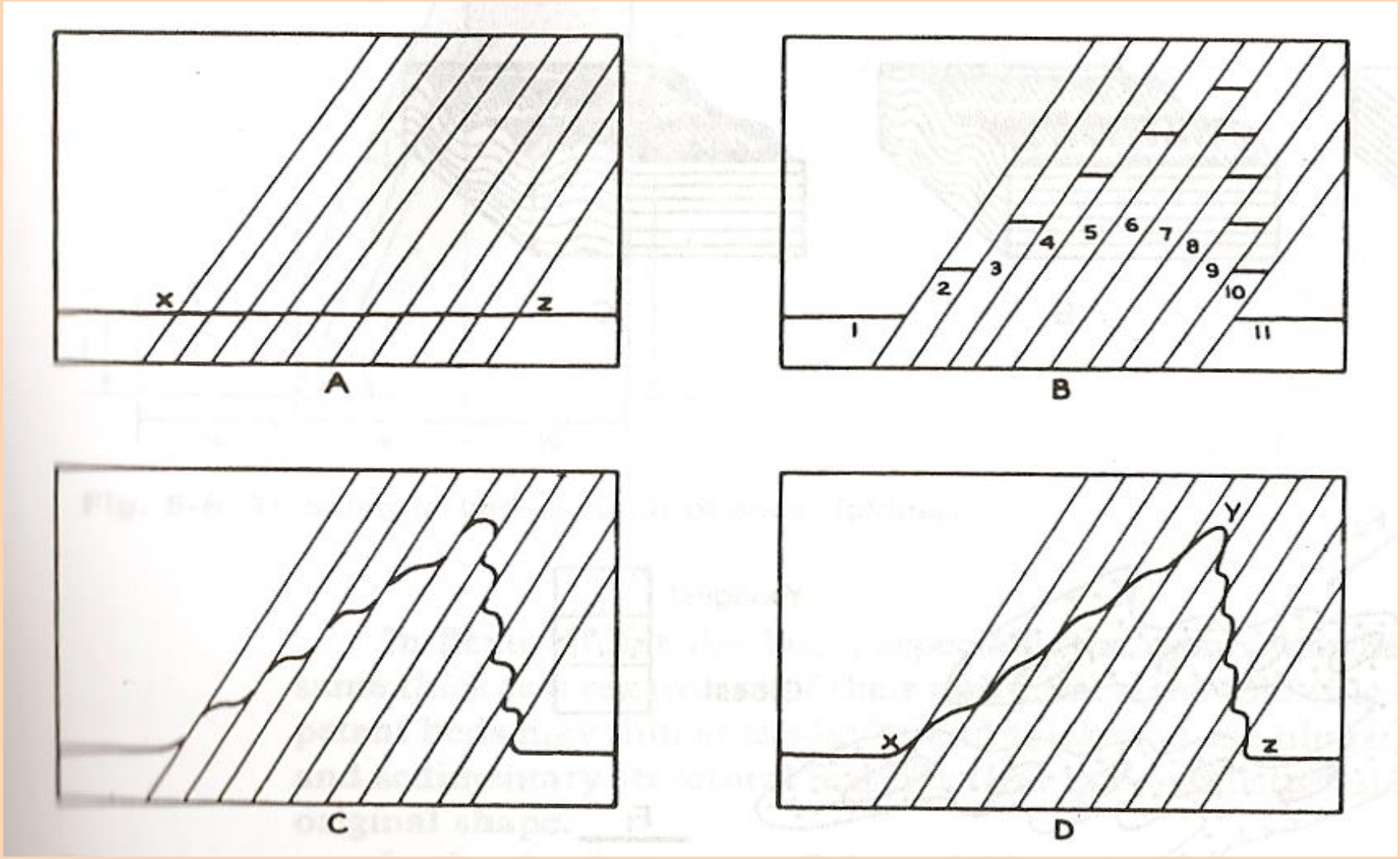
Mechanics and Causes of Folding

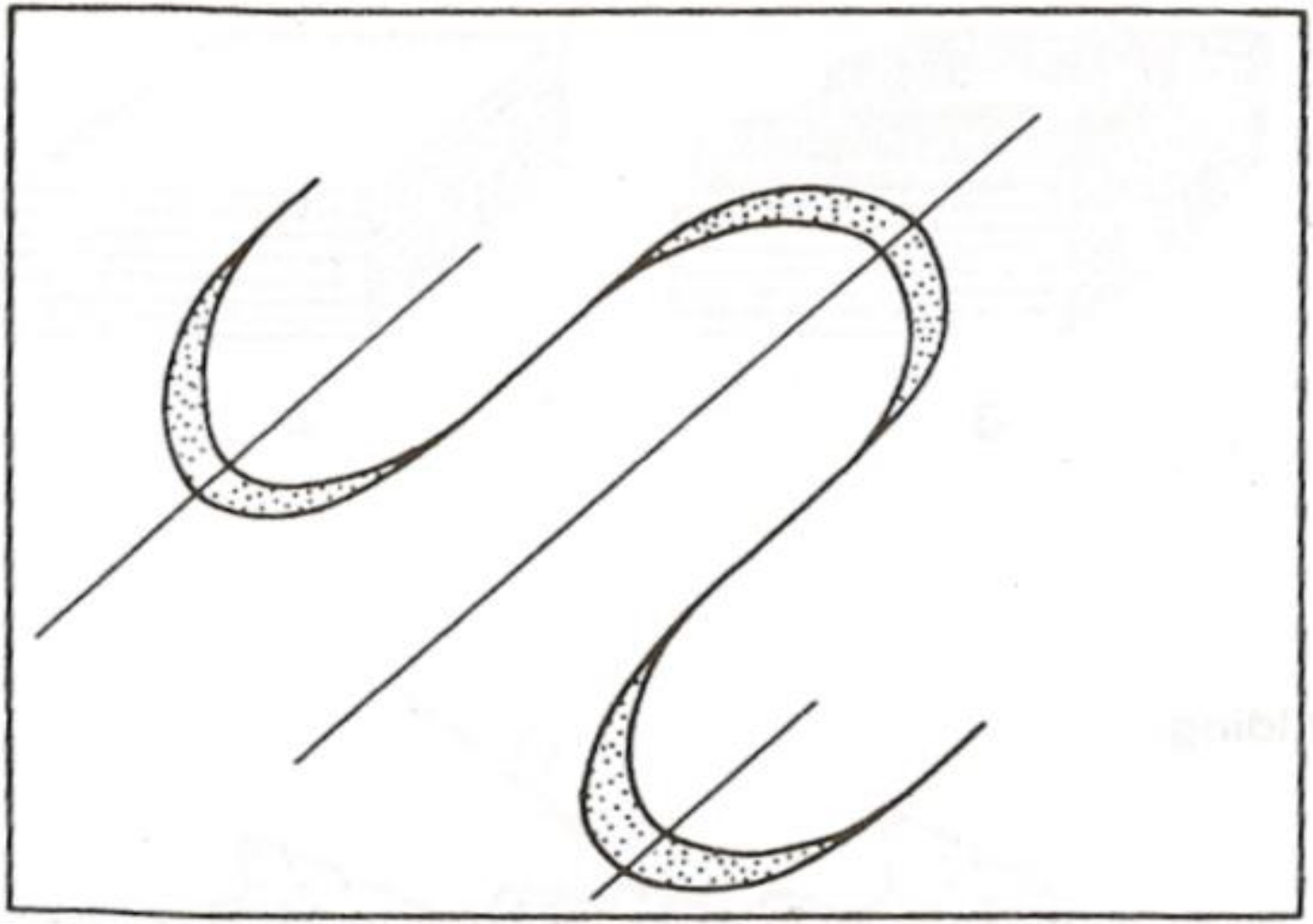
1. Flexure folding(true folding).




Surface of
no strain
Tension
Compression
A
Thinned
Thickened
B
C
D

Shear Folding





Bed deformed by shear or flow folding. The maximum thickness of the bed is at the hinge; the thickness is greatly reduced on the limbs.

Causes of Folds

1. Tectonic:
    a. Horizontal compression.
    b. Gravitational tectonics.
2. No tectonic:
    a. Hillside creep.
    b. Collapse structures.
    c. Glacial ice.
    d. Solution.
    e. Differential compaction of sediments.
    f. Contemporaneous deformation.

Draw the geologic map