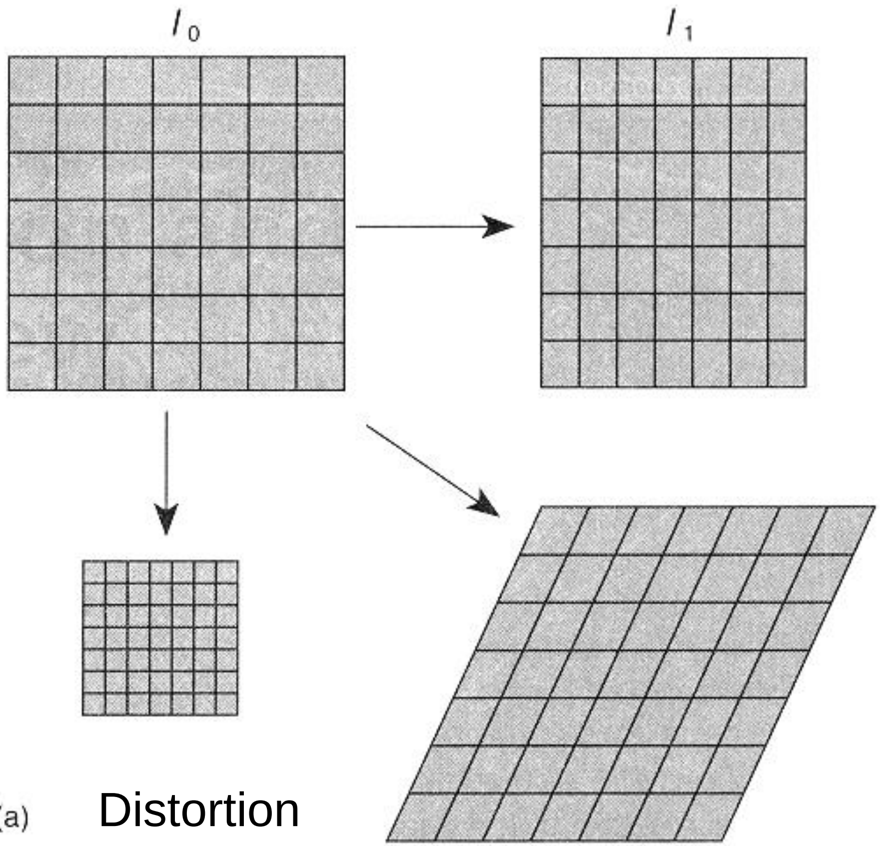
DEFORMATION

Definitions

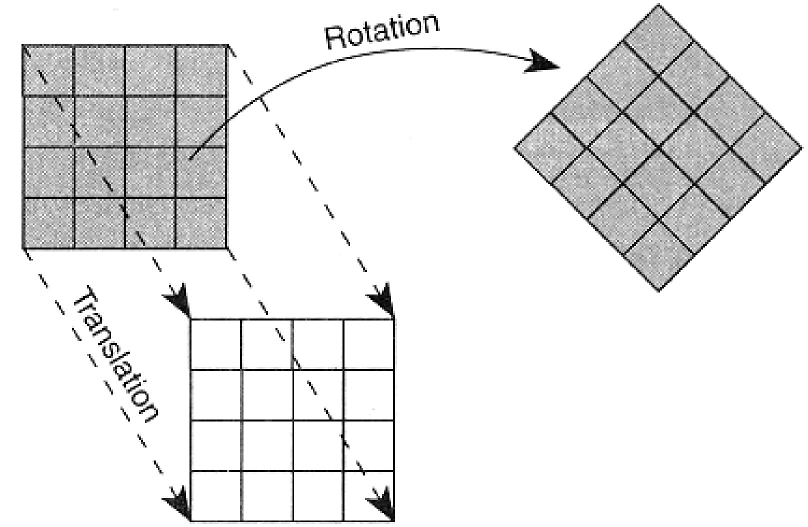
Stress (Gerilme) is a force exerted against an object/rock.

Deformation (Deformasyon): is a general term used for change in volume or shape (or both) of rocks

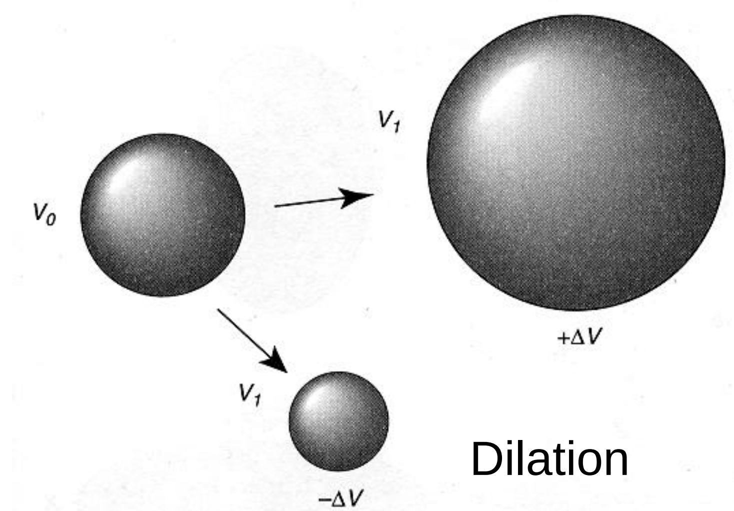
Strain (yamulma): Permanent deformation in the form of **distortion** *(change in shape)*, **translation** *(change in location/displacement)*, **rotation** *(angular displacement of a mass without distortion)* and **dilation** *(positive or negative change in volume).*



(a) Distortion



(b)



Dilation

Definitions (continued)

Elastic strain: strain that is recovered instantaneously on removal of stress. The object deformed elastically returns to the original undeformed shape after the stress is removed.

Plastic behavior: involves permanent strain that occurs without loss of cohesion and is the result of rearrangment of chemical bonds in crystal lattices in minerals.

Viscous behavior: is the behavior of fluids such a magma or of any other substance with little internal structure.

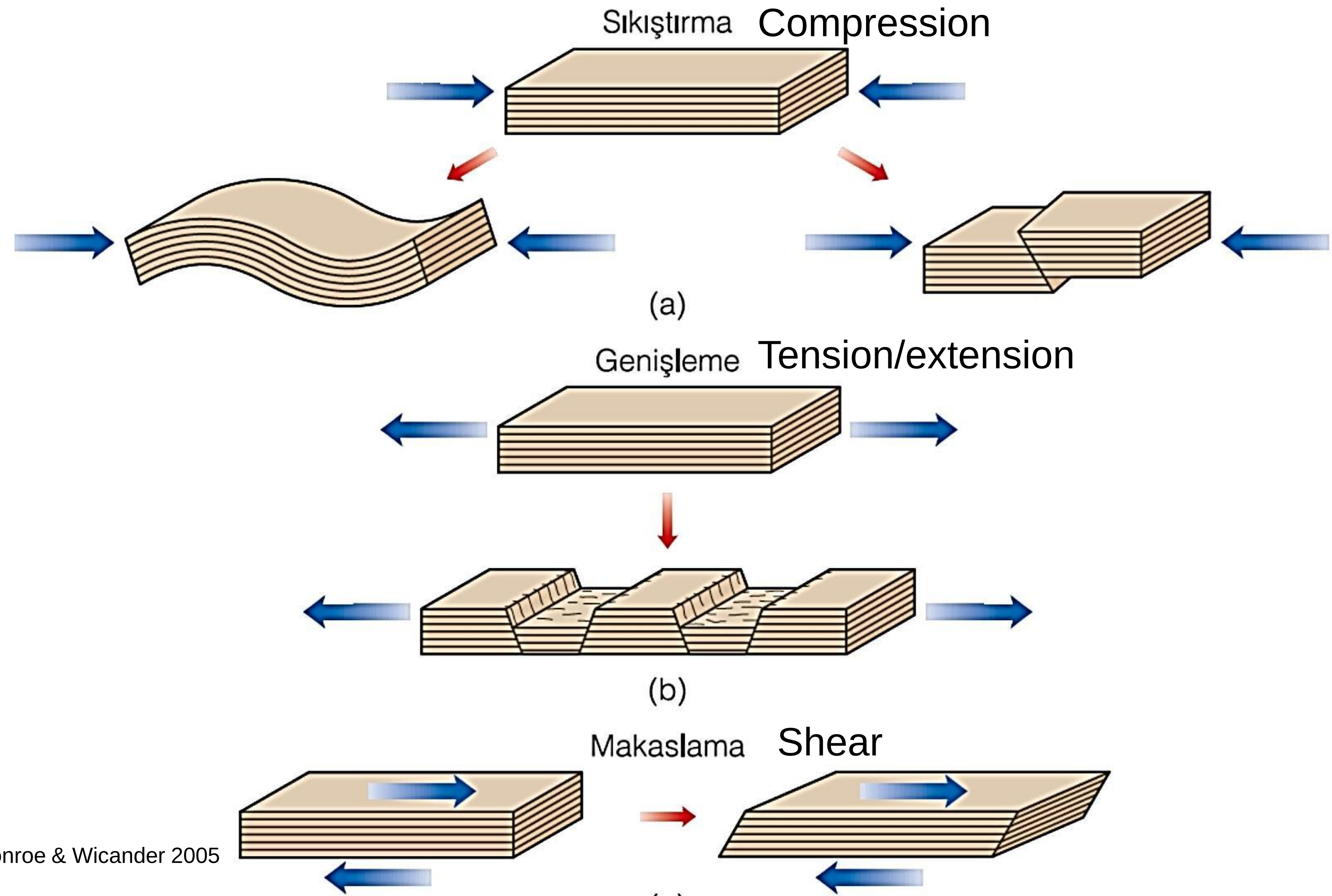
Homogeneous material: properties of a material is the same throught any sample of any size.

Inhomogenous material: *properties of material vary with location, either in a hand specimen or in a region.*

Isotropic material: has the same properties in all directions.

Anisotropic material: properties vary with direction.

Tectonic forces exert different types of stress on rocks in different geologic environments: **confining stress** or confining pressure, **directed stress** (compressive, tensional and shear).



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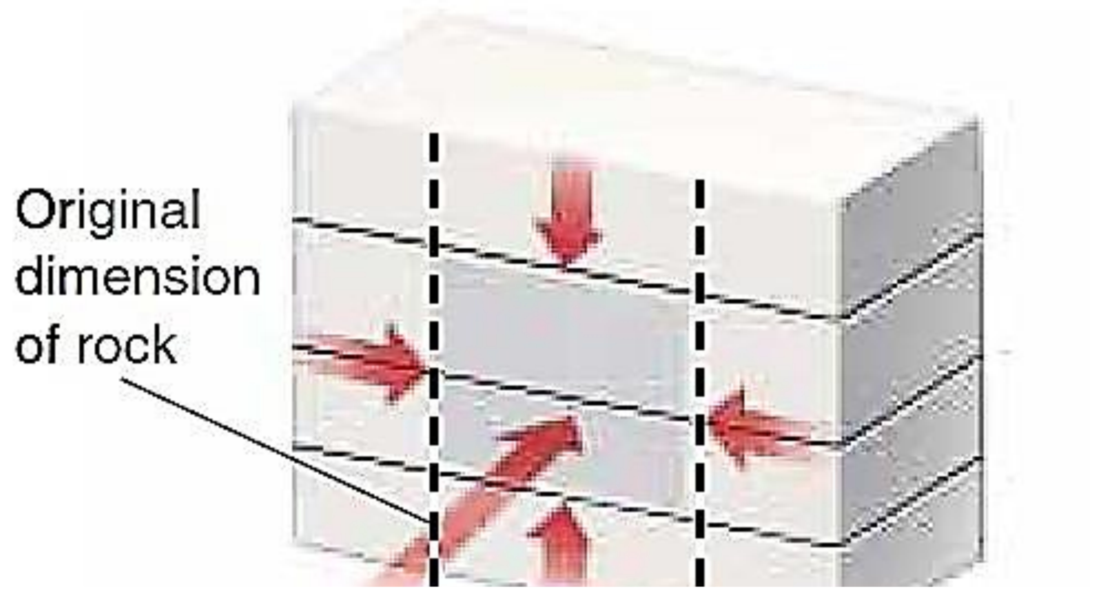
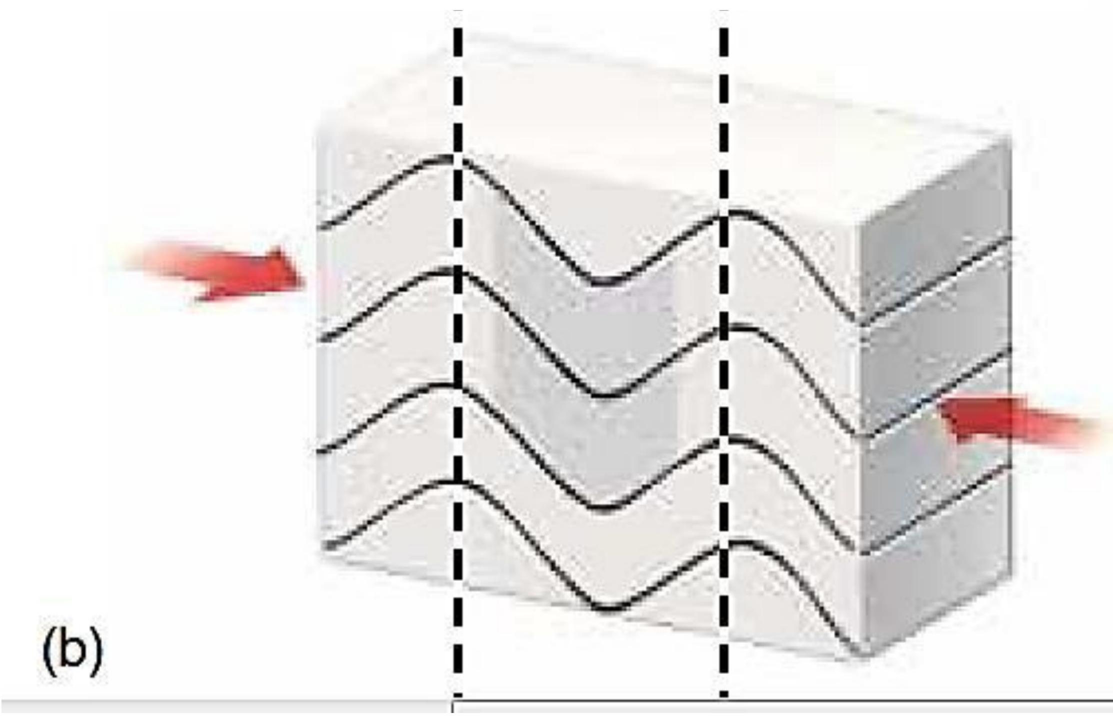
Stress and possible types of deformation. (a) Compression (Sıkıştırma), causes shortening of rock layers by **folding** or **reverse faulting**, (b) Tension/extension (Genişleme) lenghtens rock layers and causes **normal faulting**, (c) Shear stress (Makaslama) causes deformation by displacement along closely spaced planes (faulting)..

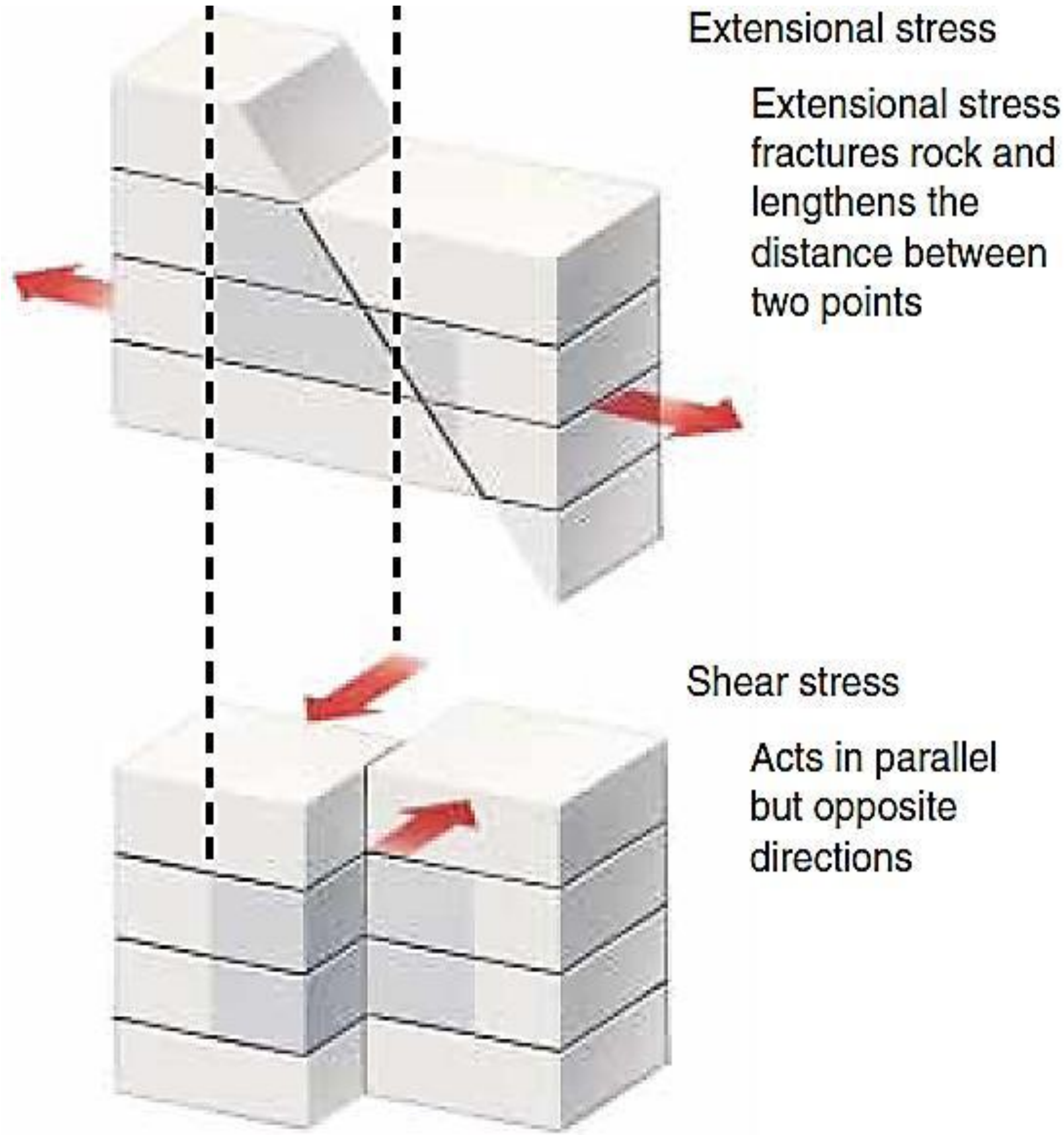
Confining stress or confining pressure, occurs when rock or sediment is buried (a). Confining pressure merely compresses rocks but **does not distort them**, because the compressive force acts equally in all directions. **Burial pressure** compacts sediment and is one step in the **lithification of sedimentary rocks**. Confining pressure also contributes to **metamorphism** during deep burial in sedimentary basins.



Directed stress acts most strongly in one direction. Tectonic processes create three types of directed stress: ***Compressional, extensional***, and ***shear***. **Compression** squeezes (compresses) rocks together in one direction. It frequently acts **horizontally**, s**hortening** the distance parallel to the squeezing direction. **Compressive stress** is common in ***convergent plate boundaries***, **where two plates converge**



Extensional stress (tensional stress) pulls rock apart and is the opposite of tectonic compression. Rocks at a ***divergent plate boundary*** stretch and pull apart because they are subject to extensional stress. **Shear stress** acts in **parallel but opposite directions**. Shearing deforms rock by causing one part of a rock mass to slide past the other part, as in a transform fault or a transform plate boundary.



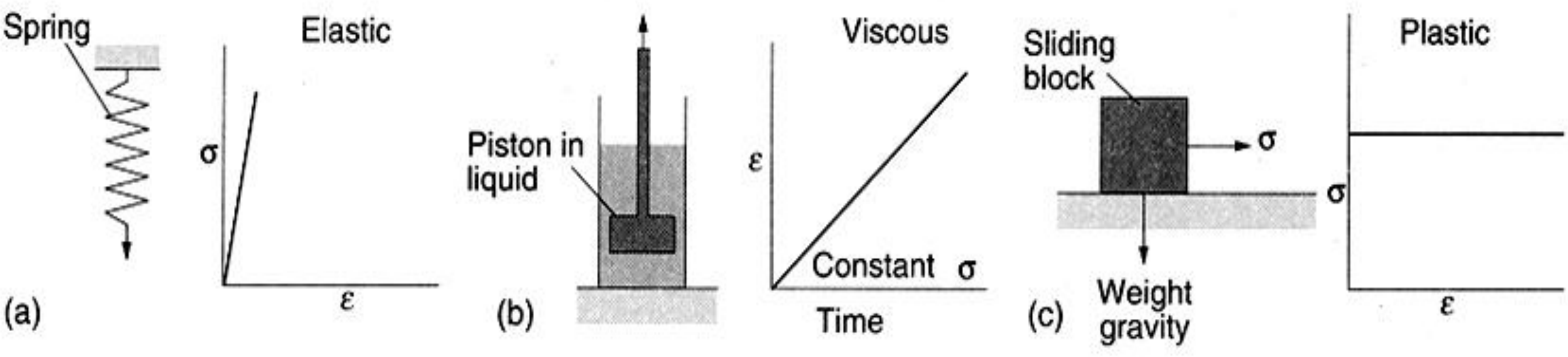

IRAN-ZANJAN

http://www.geo.umn.edu/courses/1001/Summer_Session/crops_offset.jpg

MECHANICAL BEHAVIORS OF ROCK MATERIALS

Idealized mechanical models that simulate the behavior of rocks, soils, concrete, steel, and ceramics have been used for many years because they enable us to simply and thereby understand the response of these real materials to stress.

Three main behavior types: **elastic**, **plastic** and **viscous**.



Ideal mechanical models and stress-strain or strain-time curves for material behavior. a) spring, b) piston in a liquid, c) sliding block. (Hatcher, R.D. 1995. Structural Geology. Principles, Concepts and Problems)

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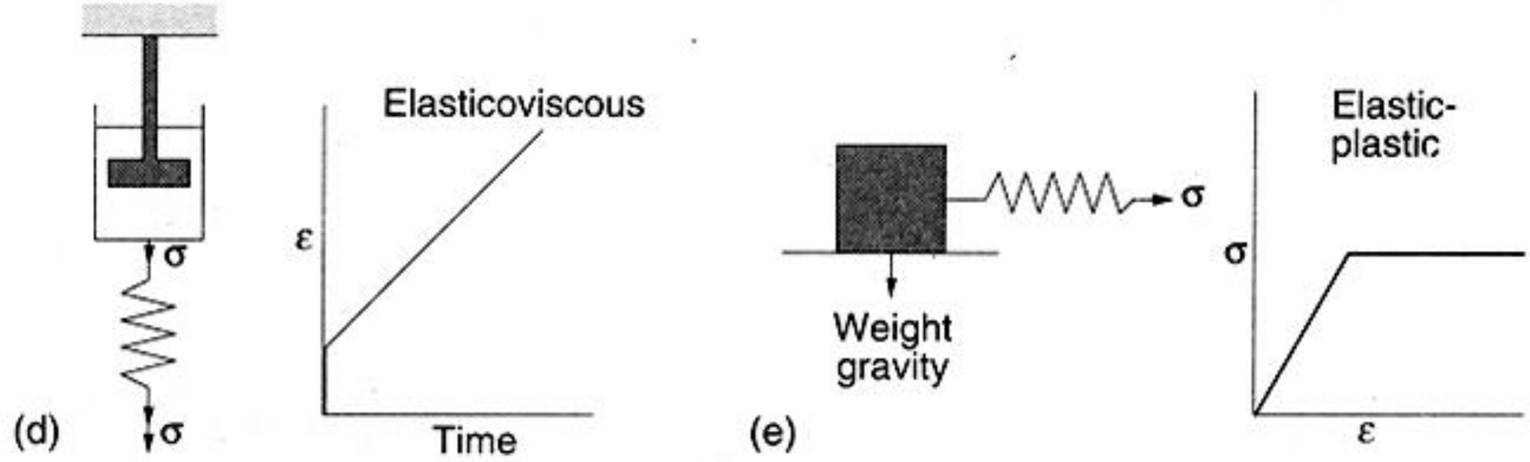


Combination of models, d) Elasticoviscous, e) elastic-plastic (Hatcher 1995)

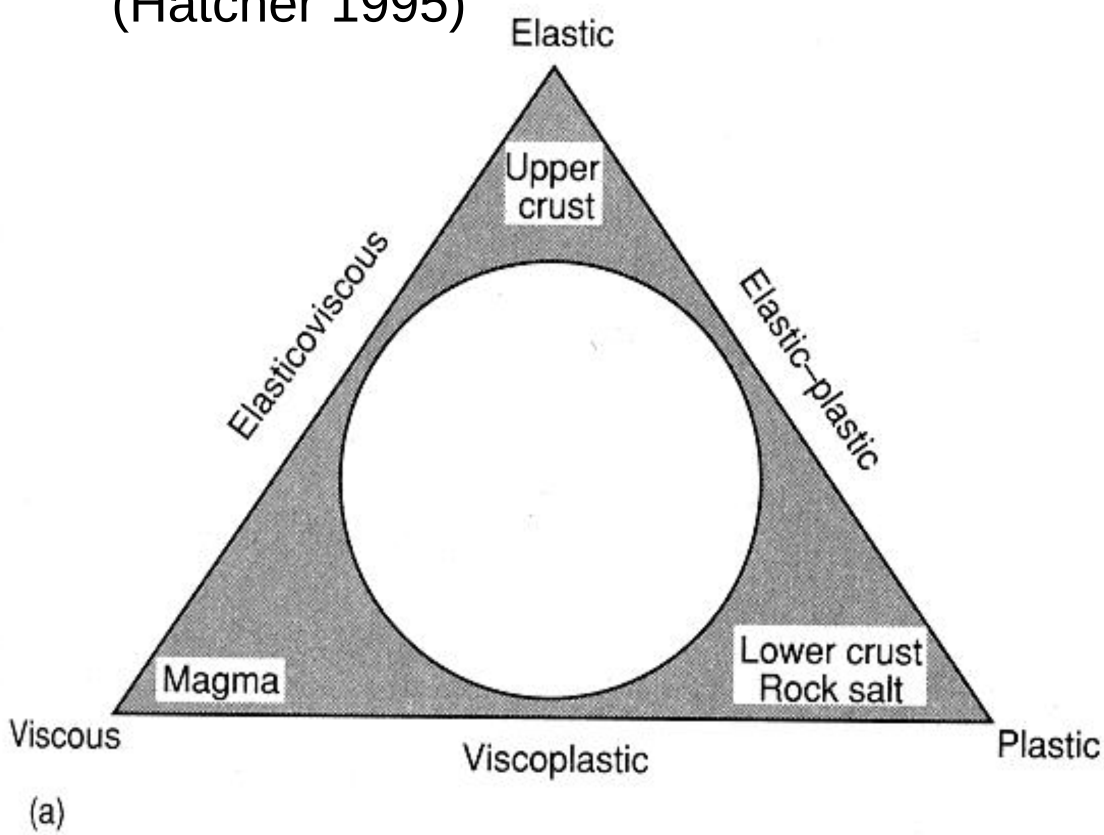
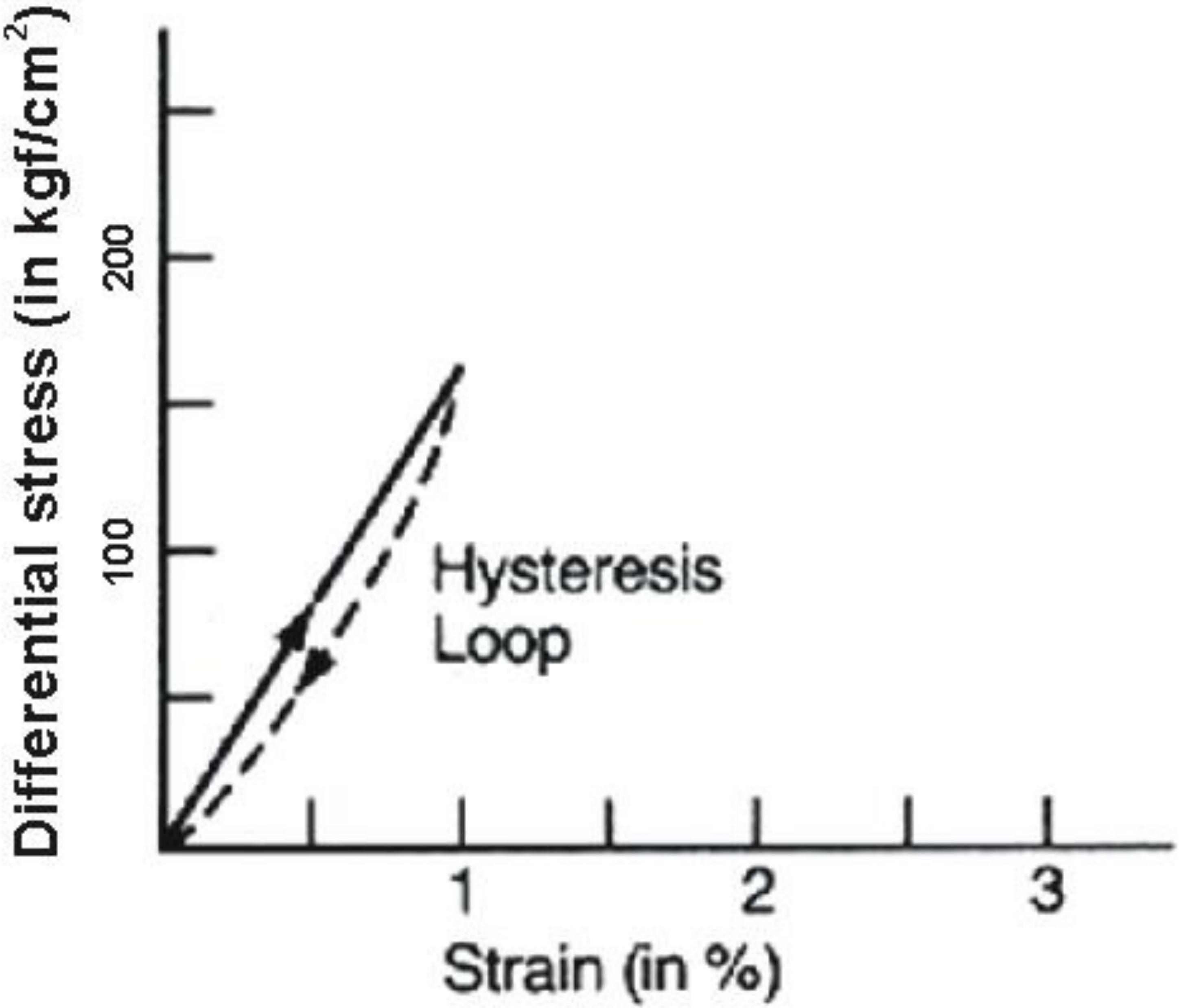


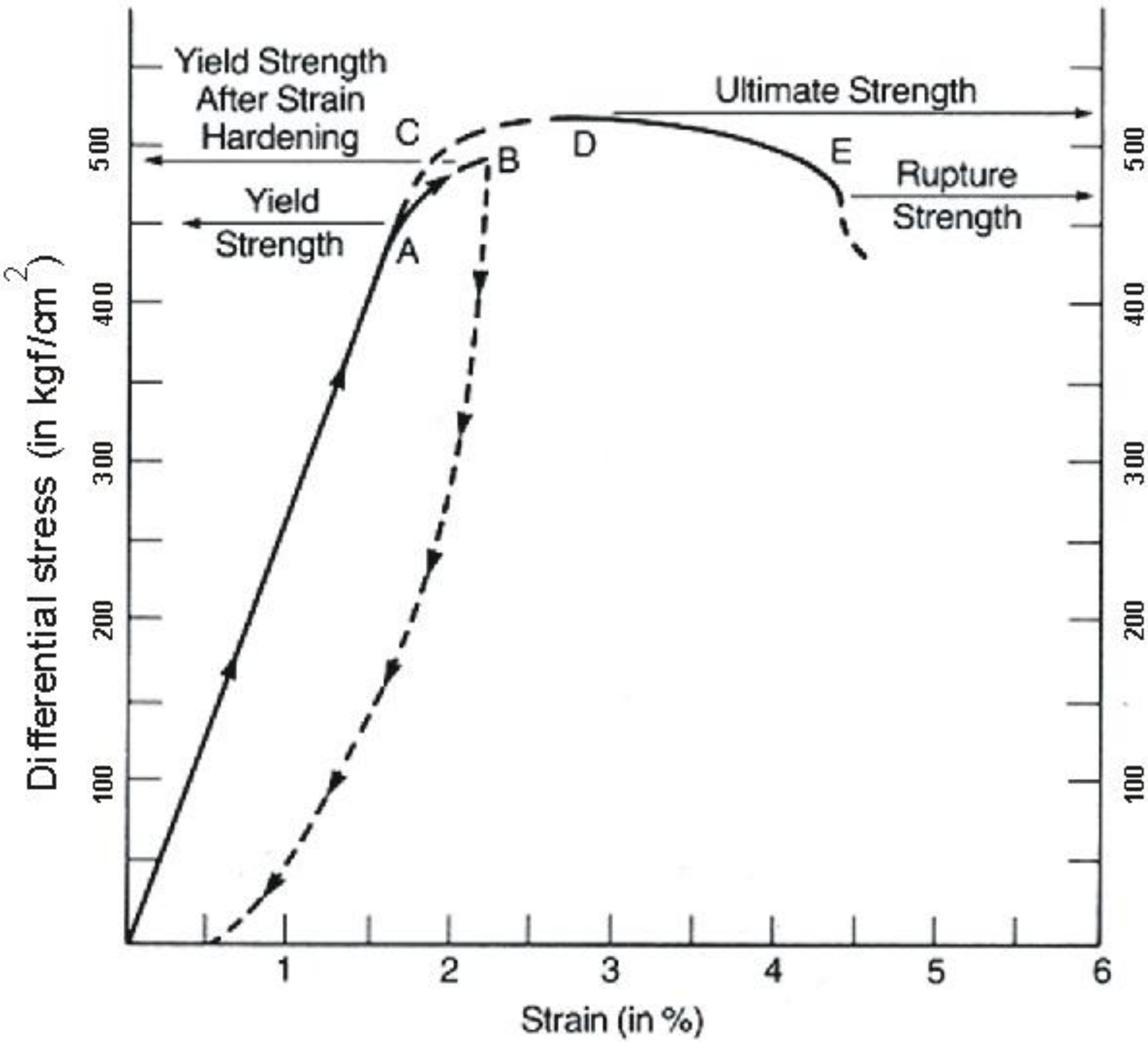
Diagram illustrating behavior of materials inside the Earth (Hatcher 1995)

STAGES OF DEFORMATION

When rock is subjected to directed stress (directed forces) it passes through ***two stages of deformation***, namely: **elastic deformation** and **plastic deformation.**

The ***relation existing between stress and strain*** is commonly expressed in graphs known as **stress-strain diagrams**. ***The stress*** is plotted on the ordinate (vertical axis), whereas ***the strain*** is plotted on abscissa (horizontal axis).


Differential stress (in kgf/cm^2)
200
100
Hysteresis
Loop
1
2
3
Strain (in %)


Yield Strength
After Strain
Hardening
C
B
D
Ultimate Strength
E
Rupture
Strength
Yield
Strength
A
Differential stress (in kgf/cm 2)
100
200
300
400
500
1
2
3
4
5
6
Strain (in %)

At first stage the deformation is **elastic**; that is, if the stress is withdrawn, the body returns to its original shape. There is always a limiting stress, called the ***elastic limit***; if this is exceeded, the body does not return to its original shape.

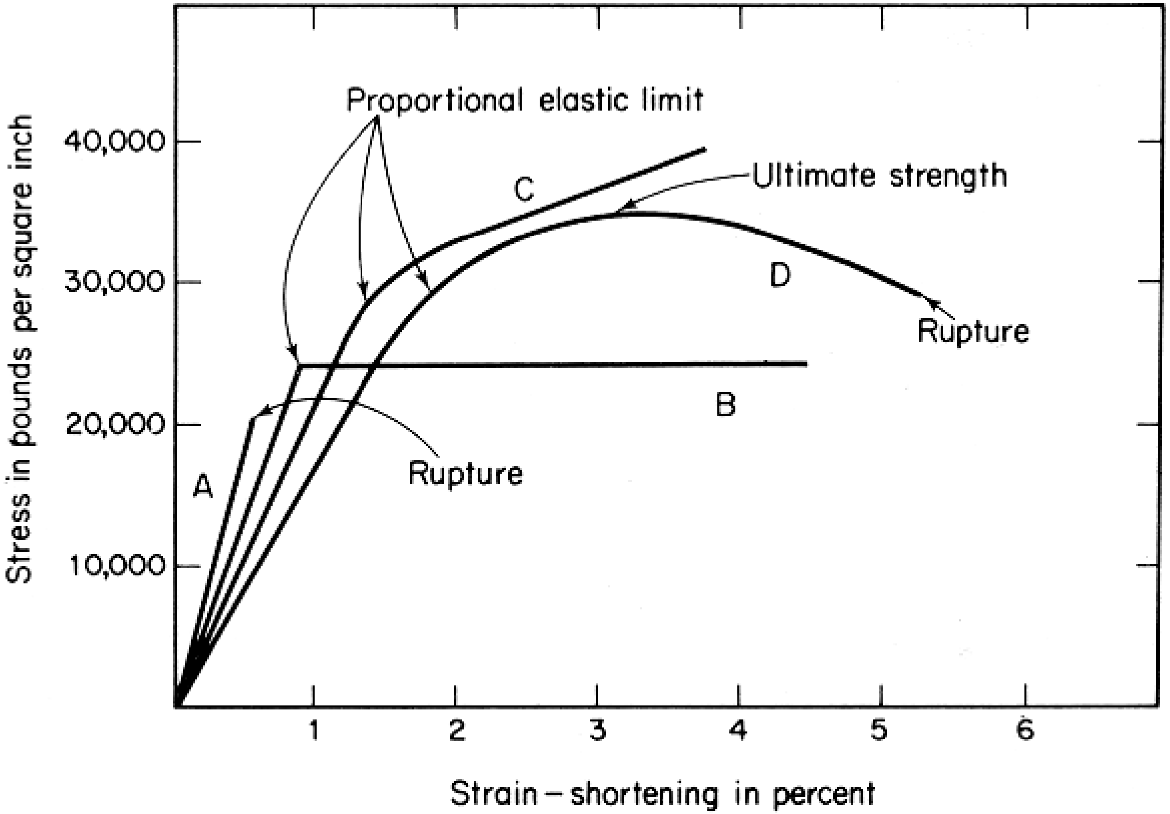
If the stress exceeds the elastic limit, the deformation is **plastic**; that is, the specimen only partially returns to original shape even if the stress is removed. **When there is a continued increase in the stress, one or more fractures develop, and the specimen fails by *rupture*.**

Based on stages of deformation there are two types of substances:

A) Brittle substances/materials, B) Ductile substances/materials.

Brittle substances are those that rupture before any significant plastic deformation takes place.

Ductile substances are those that undergo a large plastic deformation before rupture.



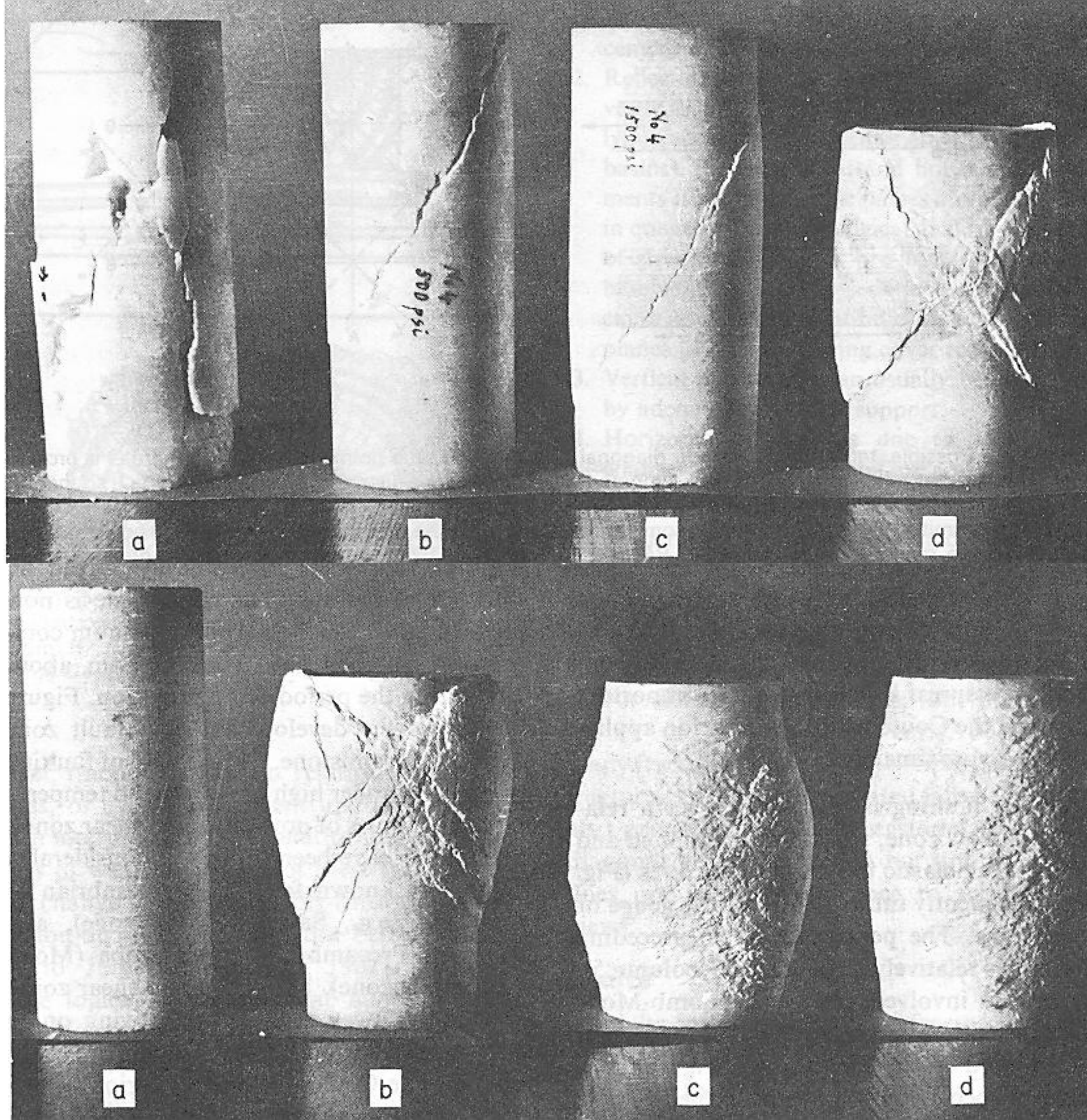
Curve A is the stress-strain diagram of a **brittle substance**. It deforms elastically up to a stress of 20,000 lb/in2 and has shortened one-half of one percent; it than fails by rupture.

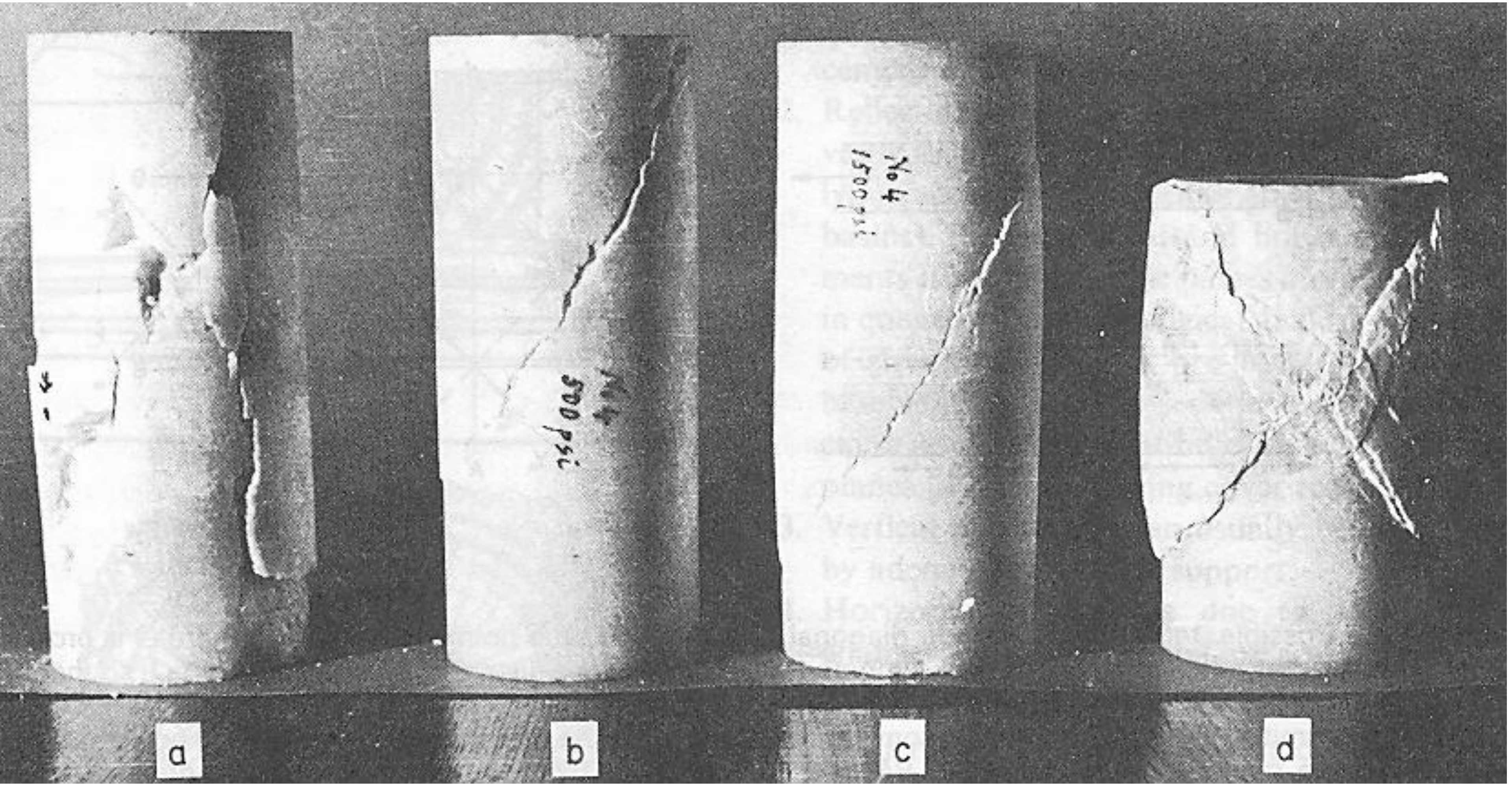
Curve B is ideal **plastic/ductile substance**. It behaves elastically at first. After proportional elastic limit the specimen deforms continously without any added stress.

Curve C represents a more **normal type of plastic behavior**.

Curve D represent a **very common type of plastic deformation**.

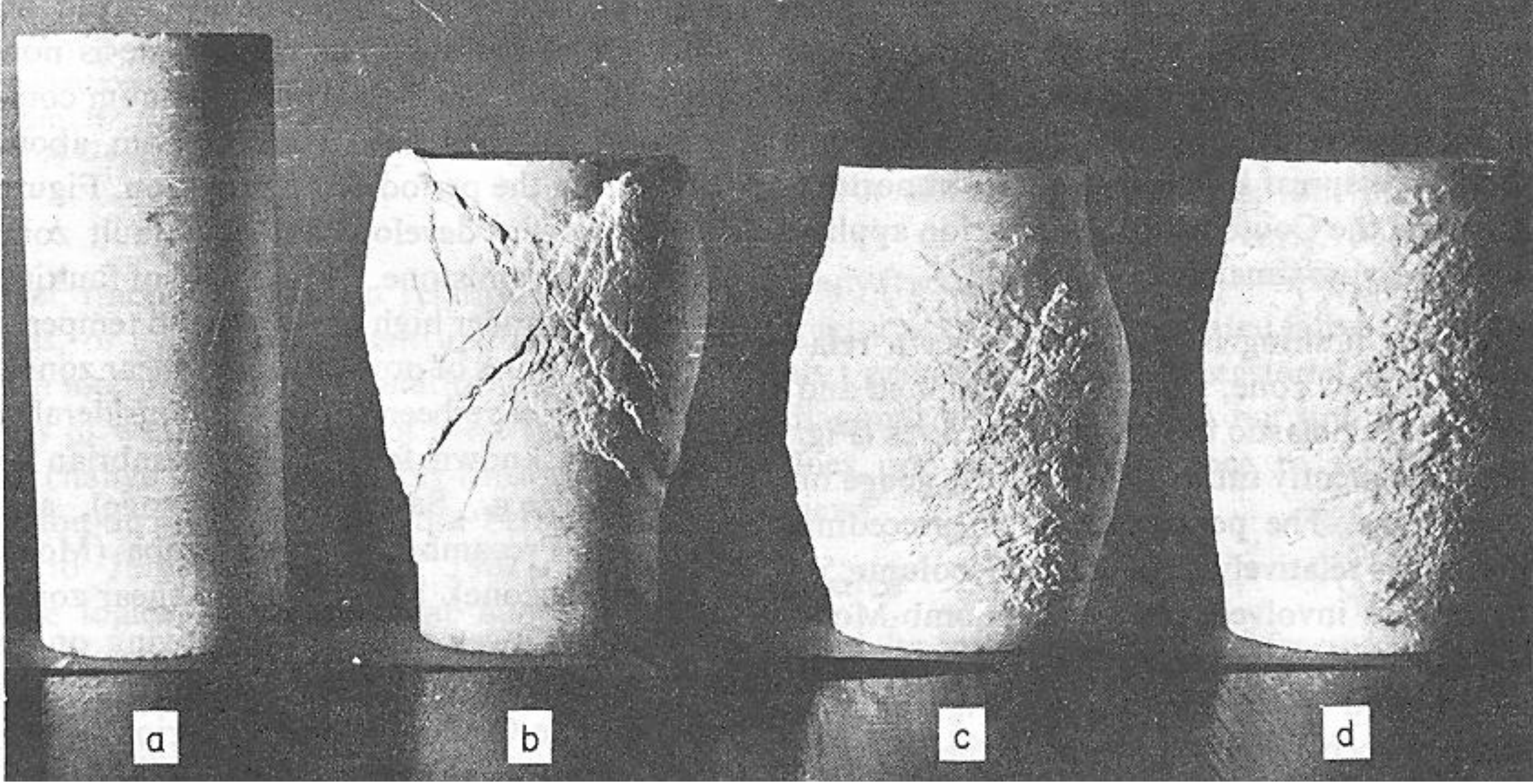
Surfaces of shearing developed in triaxial – test series under different conditions (From Badgley, P.C., 1965. Structural and Tectonic Principles)





Badgley 1965

From left to right: (a) failure of marble at atmospheric pressure; (b) at 35 kg/cm $^{-2}$ confining pressure, 1 percent strain; (c) at 100 kg/cm $^{-2}$ confining pressure, 2 percent strain; (d) at 210 kg/cm $^{-2}$ confining pressure, 12 ½ percent strain.



Badgley 1965

From left to right after 20 percent strain: : (a) undeformed; (b) at 280 kg/cm $^{-2}$ confining pressure (under conditions representative of the shallow crust); (c) at 460 kg/cm $^{-2}$ confining pressure; (d) at 1000 kg/cm $^{-2}$ confining pressure (under conditions of deeper crust)

DEFORMATION AND GEOLOGIC STRUCTURES

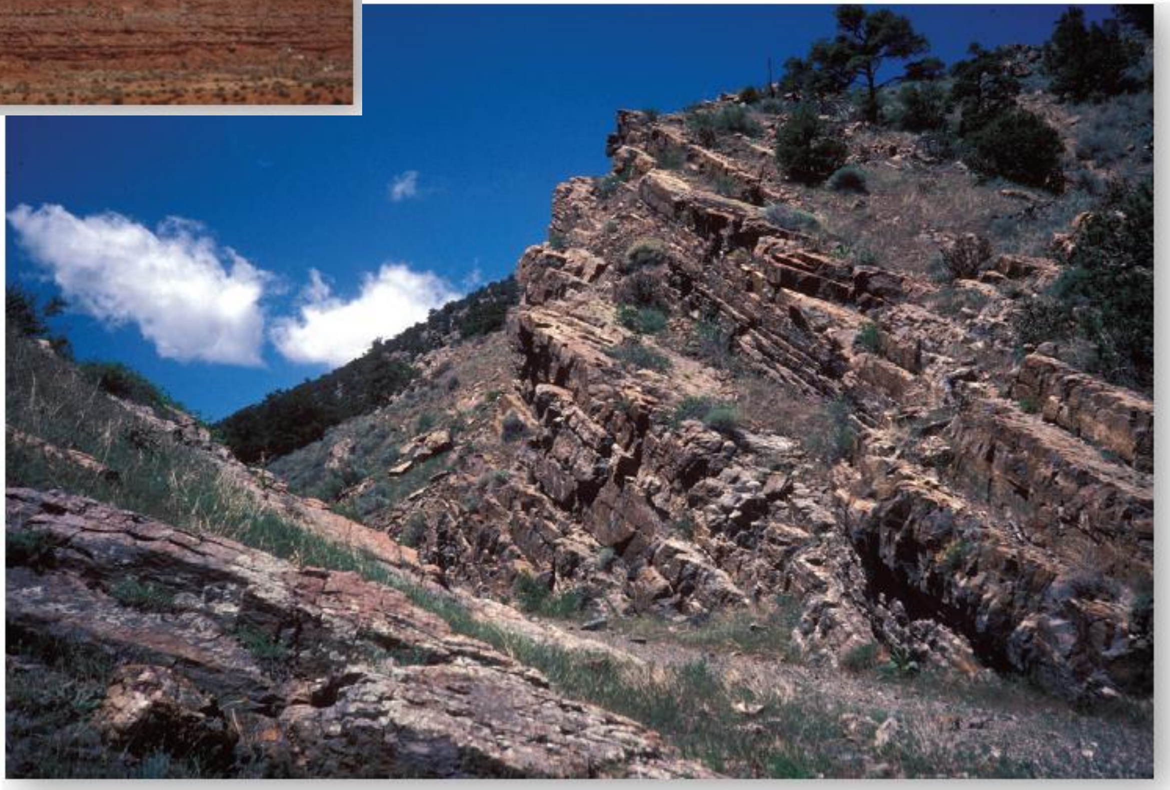
Deformation and its synonym ***strain*** refers to **changes in the shape** or **volume of rocks**. During deformation rocks might be crumpled into **folds**, (**plastic/ductile deformation**) or they might be **fractured** (**brittle deformation**). ***Any of these features resulting from deformation is referred to as*** **geologic structures.**

Bedding

The most important characteristics of sedimentary rocks are ***bedding.*** Bedding forms because sediment accumulates layer by layer. Nearly all sedimentary beds were originally horizontal because sediment accumulates on nearly level surfaces.

To describe the **orientation of beds** with respect to horizontal plane we use terms ***strike*** and ***dip***.

horizontal bed



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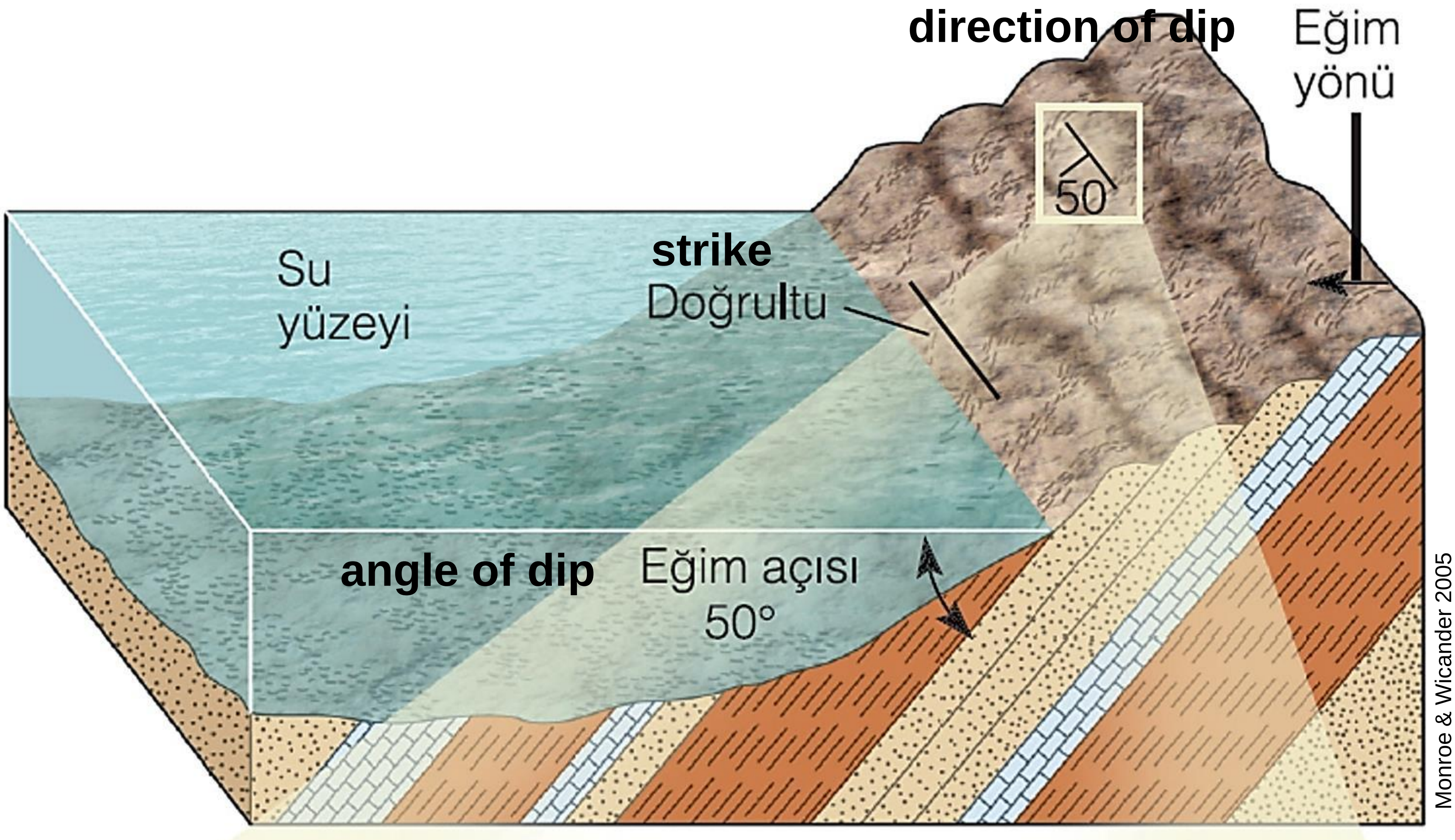
Inclined bed



The surface of a bed on above diagram is inclined plane and water surface is horizontal plane. **Strike of bed (Doğrultu) is the direction of a line formed by the intersection of a horizontal plane and inclined plane.** It is determined by measuring **the angle between north and intersection line**. **Dip** is a measure of an inclined plane's deviation from horizontal (it is angle between hor.plane and inclined plane measured on a vertical plane).

Ductile deformation - Folds and Folding

Folds are planar features formed by bending of beds. Up-arch shaped folds are named anticline, down arched folds are named sycline

Monroe & Wicander 2005

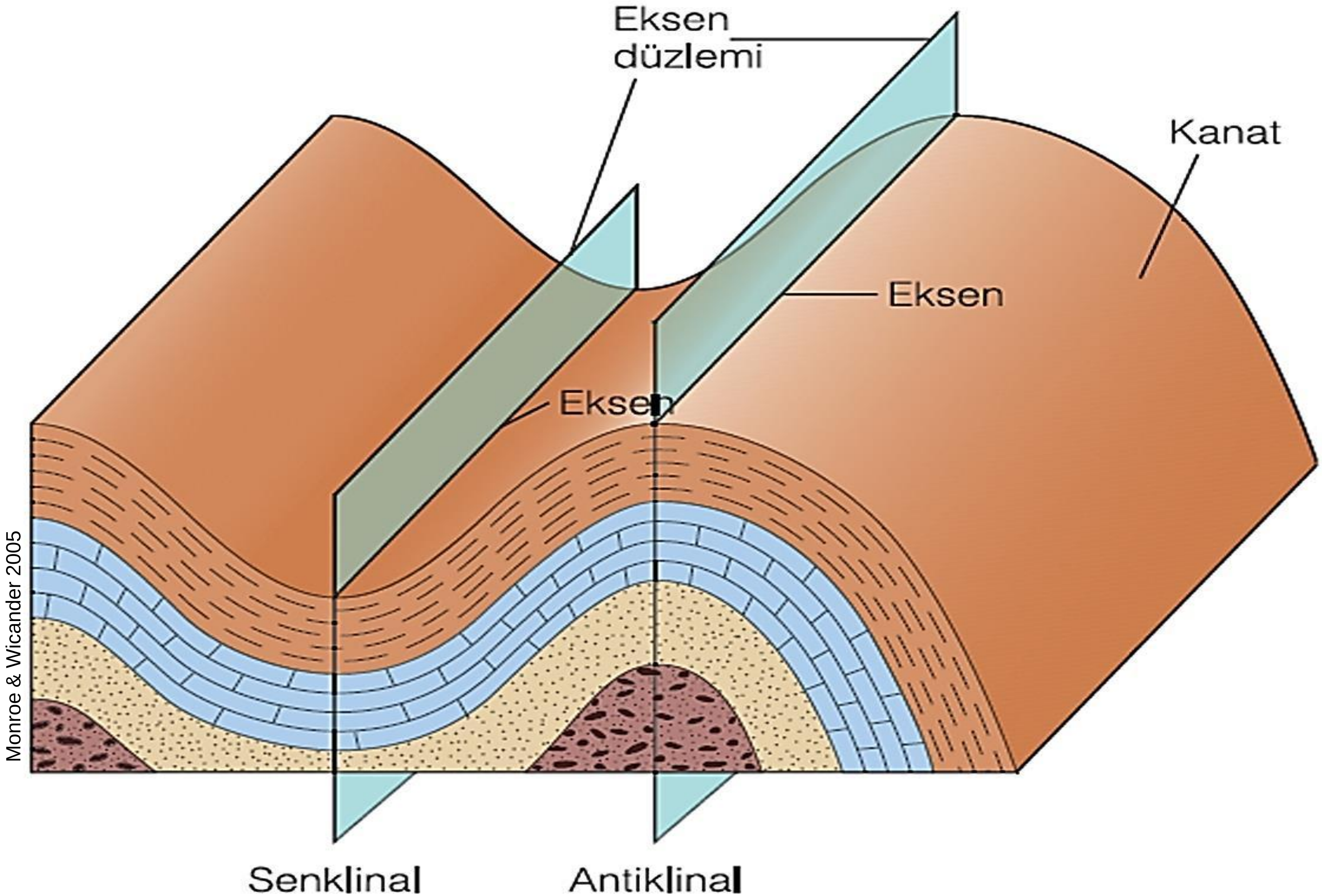
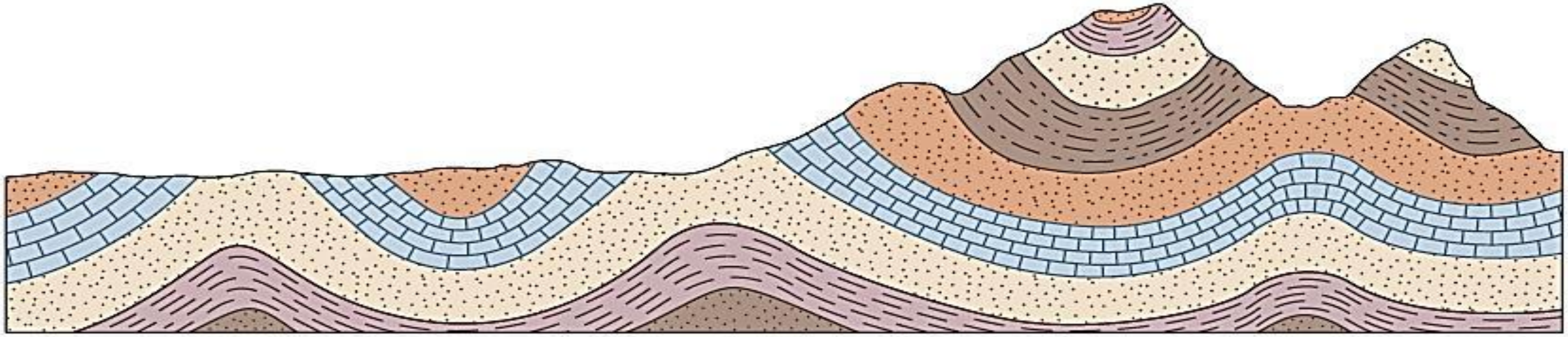
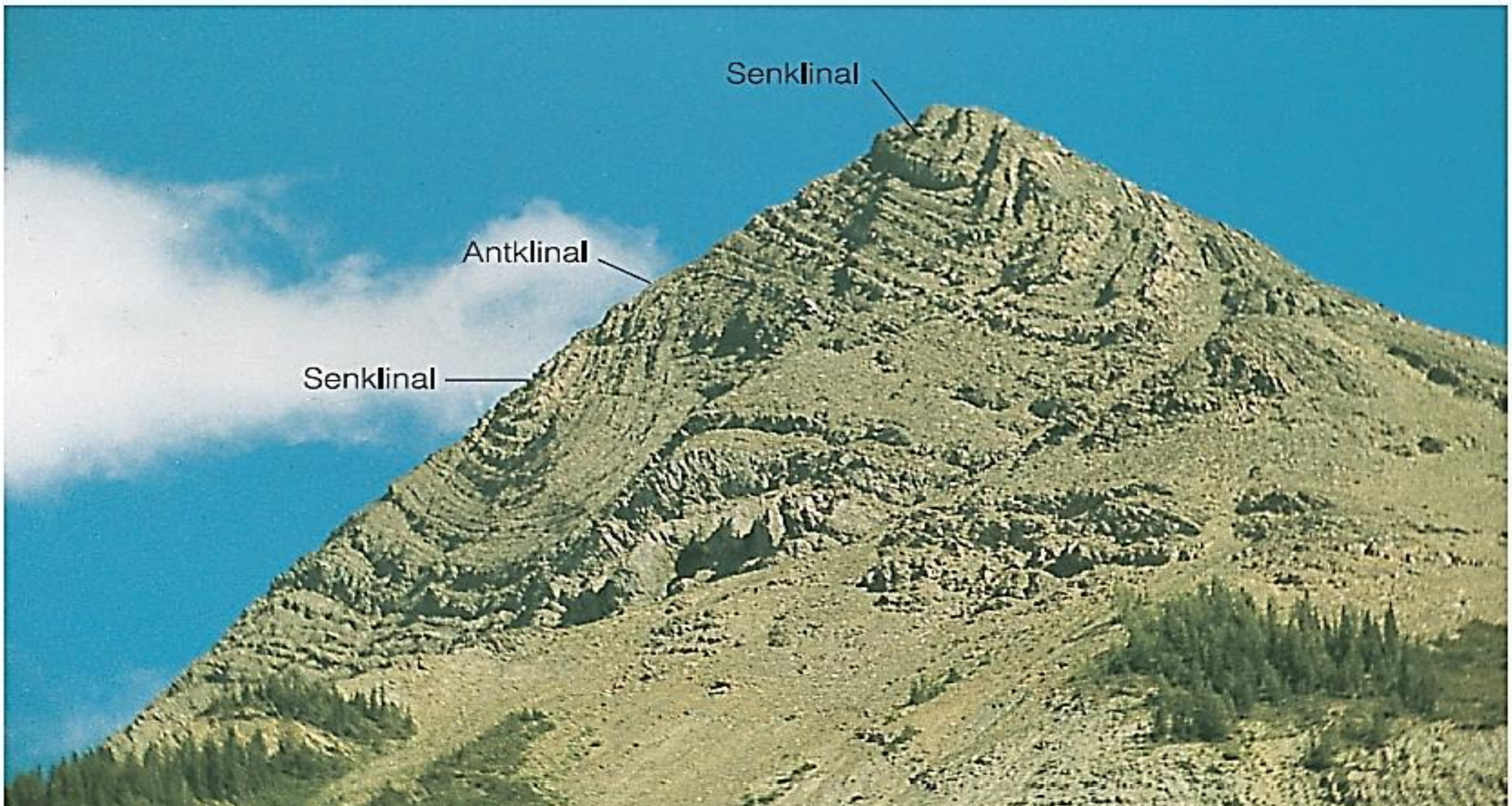


Diagram illustrating ***axis*** (eksen), ***axial plane*** (eksen düzlemi) and ***limbs/flanks*** (kanat) of an syncline and anticline.



(a)



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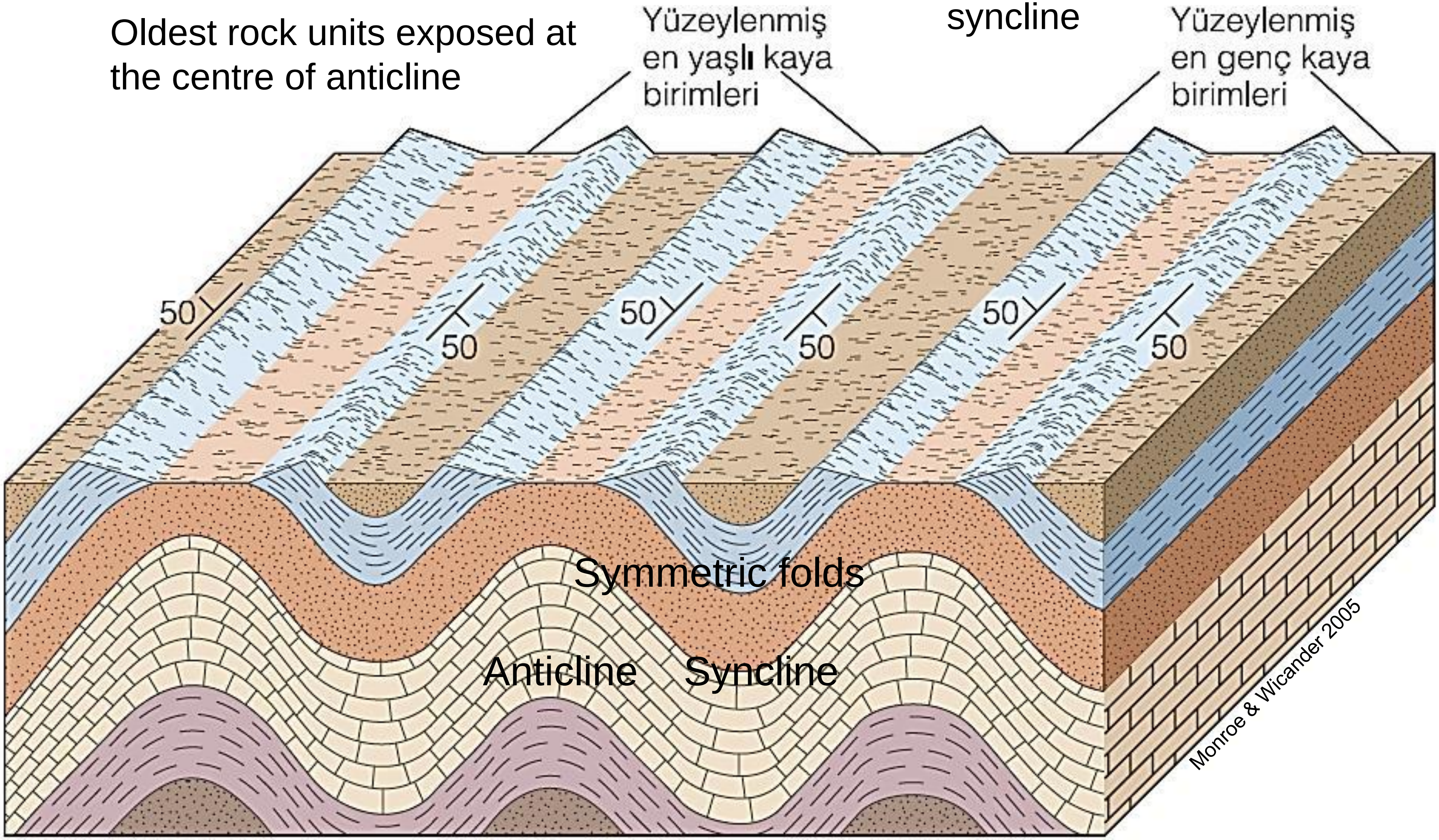
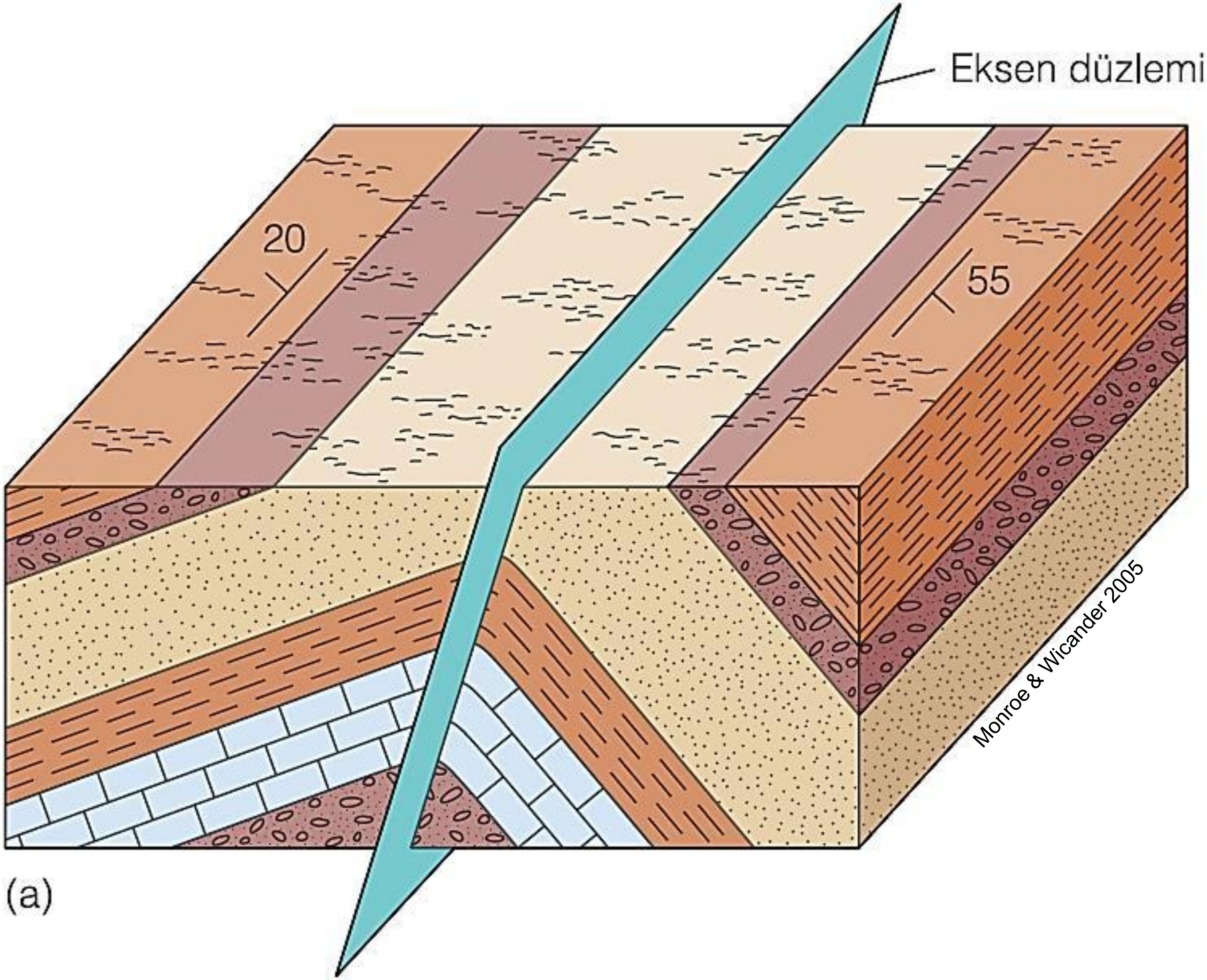
Youngest rock units exposed at the centre of syncline

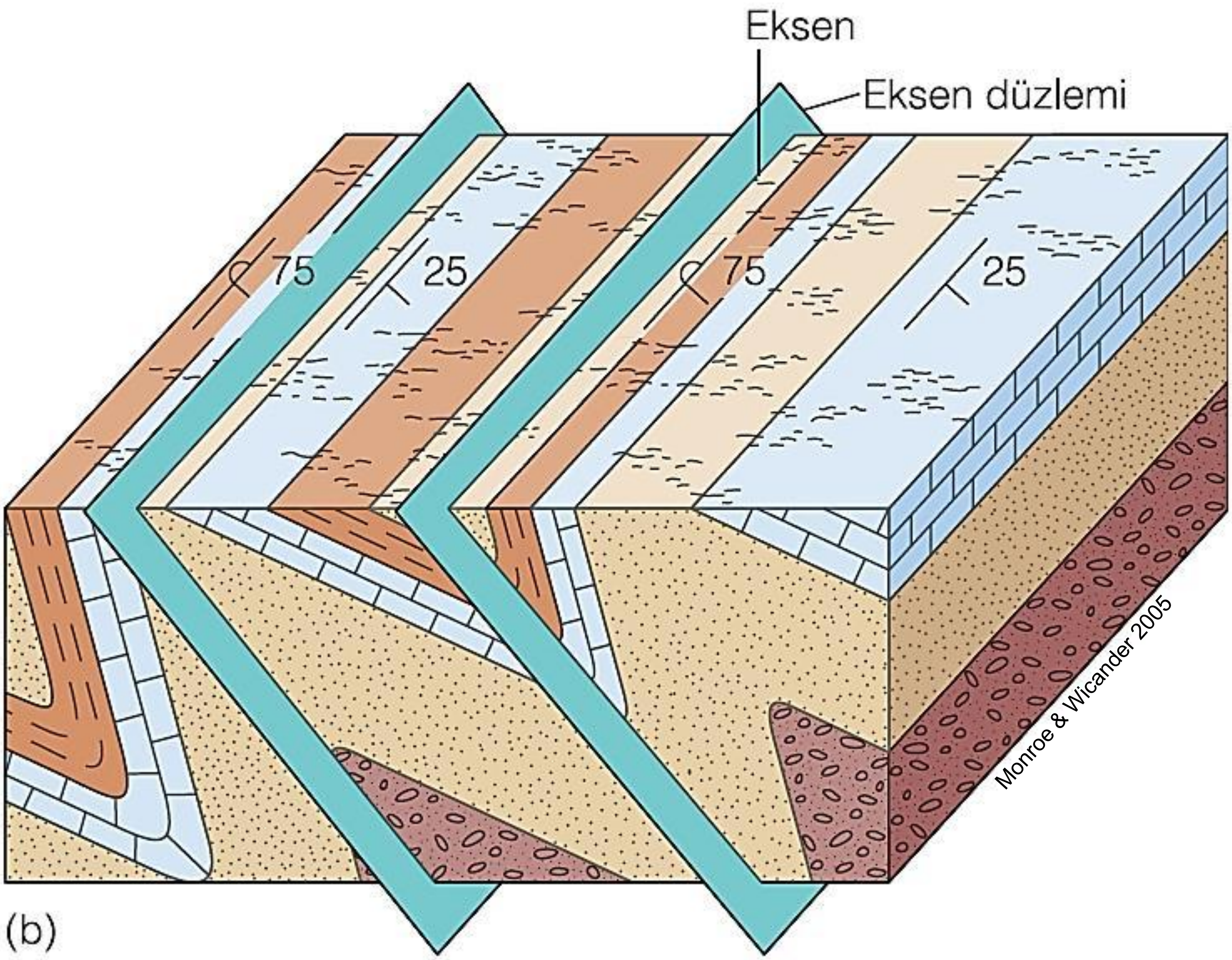
Oldest rock units exposed at the centre of anticline



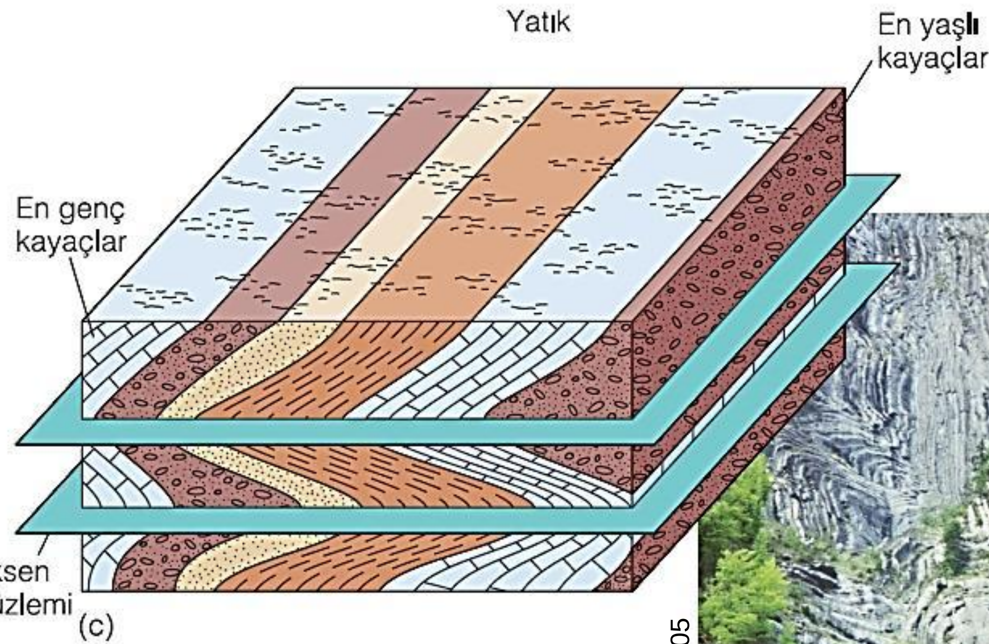
Surface and cross-sectional views of **symmetric folds**. Identifing eroded anticlines and synclines by strike, dip and relative ages of folded rock layers.



Surface and cross-sectional views of an **asymmetric anticline**. Axial plane is inclined and dip amount of limbs are different.



Surface and cross-sectional views of an **overturned fold**. Notice the special strike and dip symbol to indicate overturned beds.



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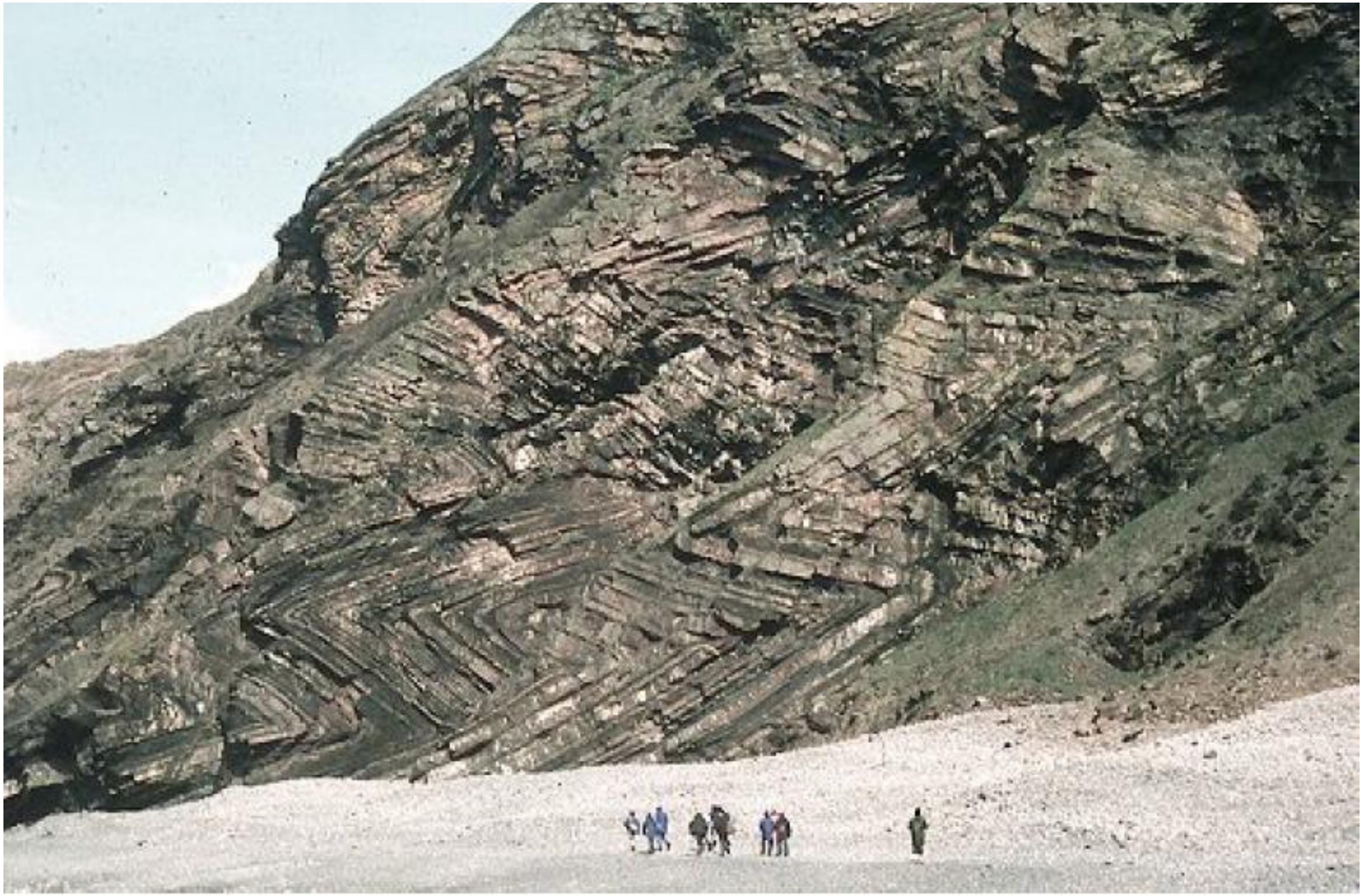
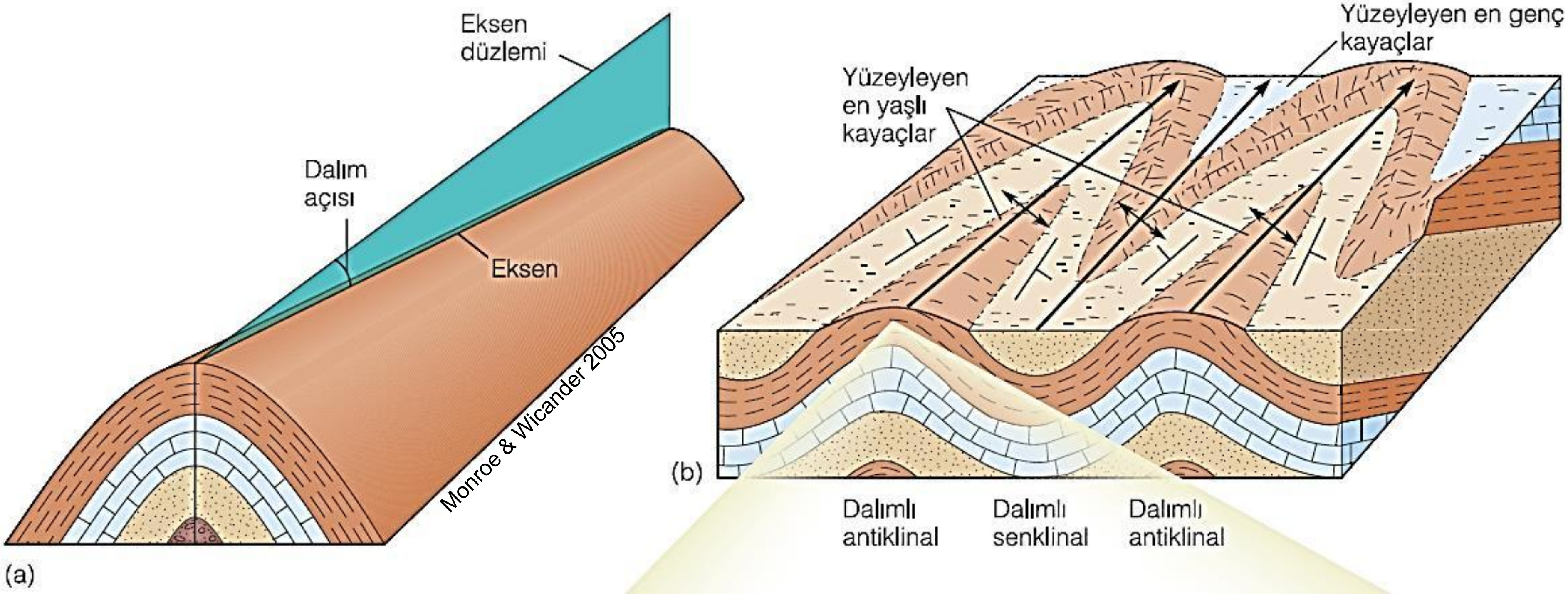
Surface and cross-sectional views of the **recumbent fold**. Axial plane is nearly horizontal.



zig-zag fold

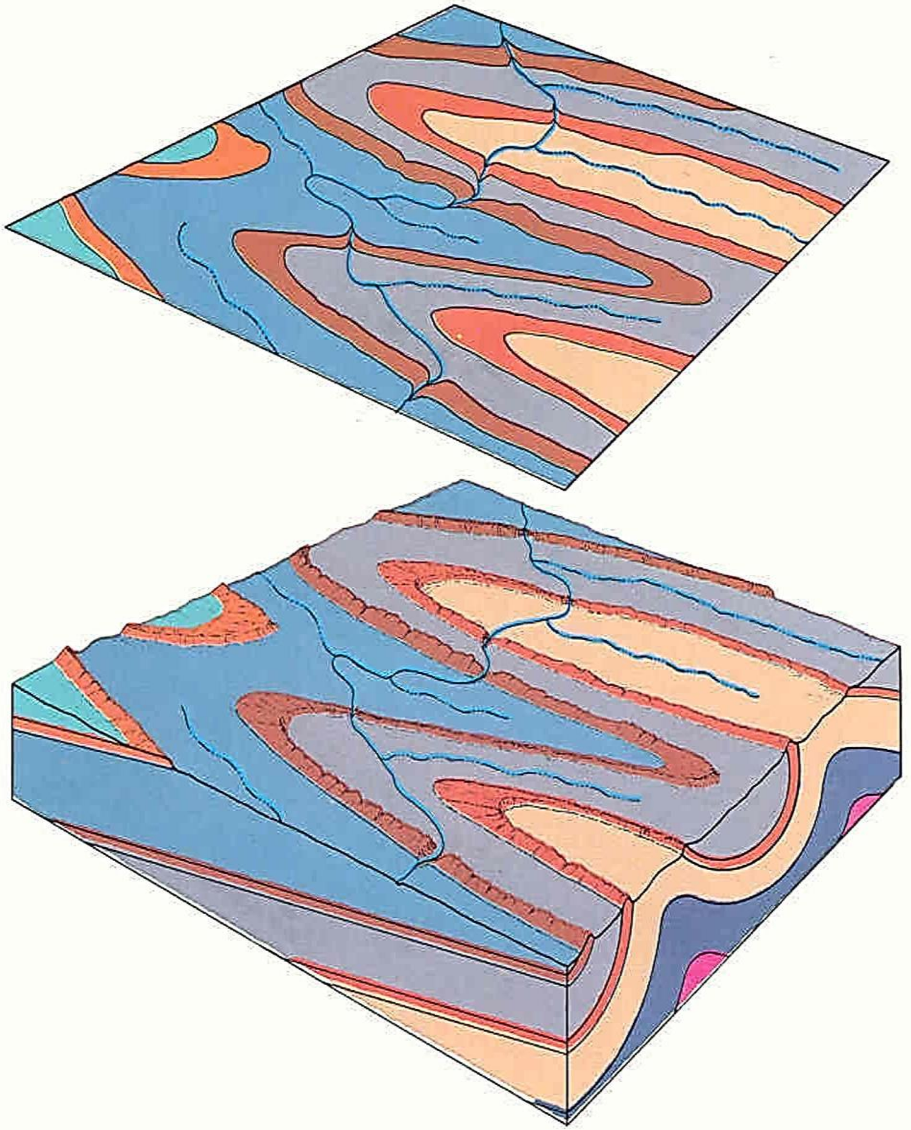


(a) **A plunging fold**. (b) Surface and cross-sectional views of plunging folds. The long arrow at the center of each fold is the symbol used to depict plungin anticline and synclines. The arrow at the end of the line shows the direction of plunge.

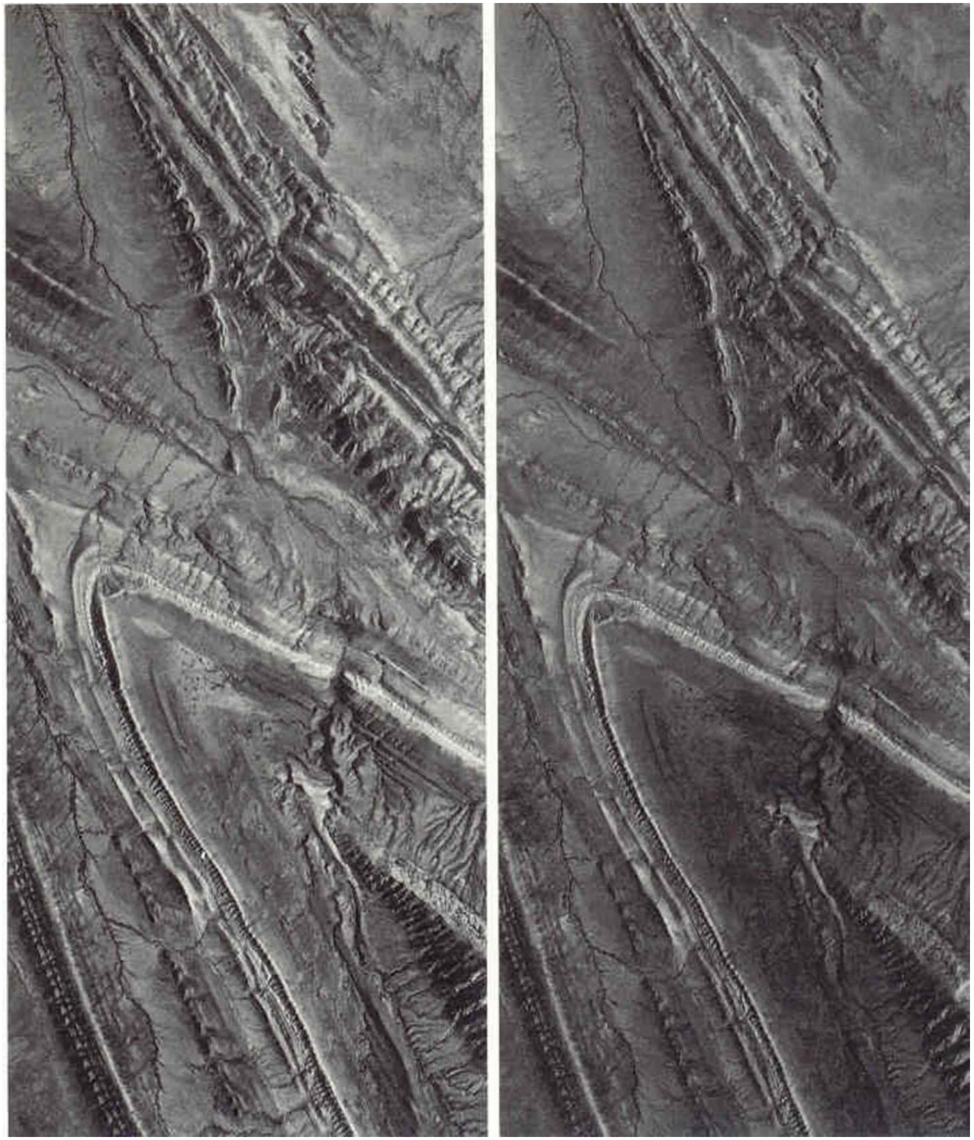
John S. Shelton

(c)

View of eroded, double plunging anticline.



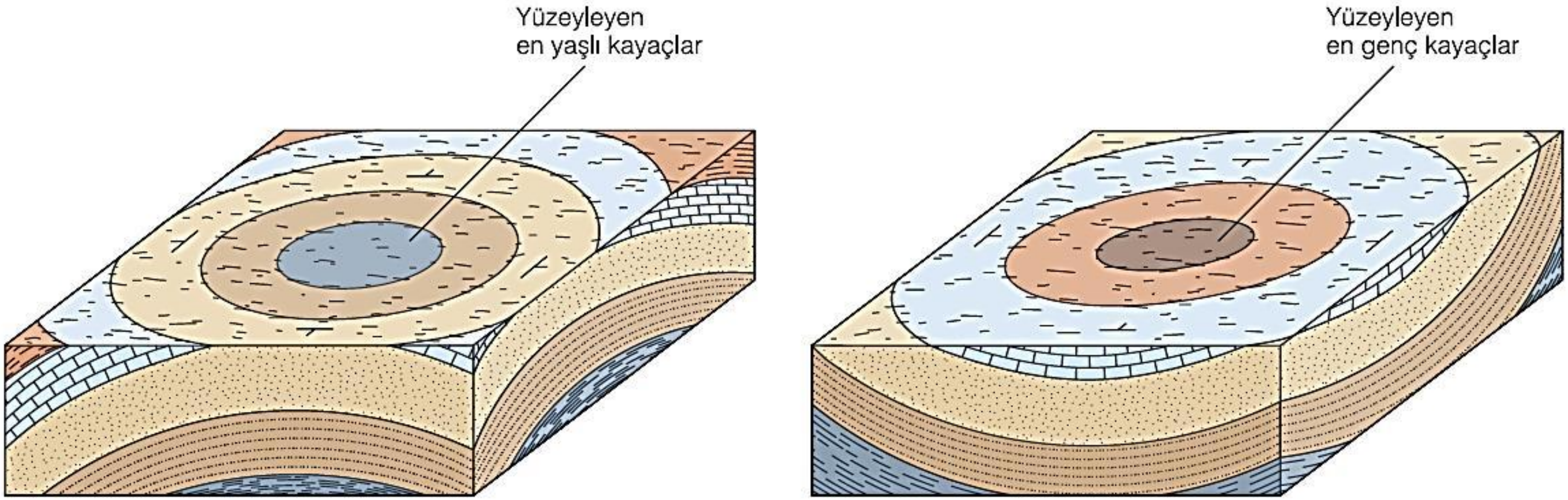
Geologic map (upper), surface and cross sectional view (lower) of plunging anticline and sycline.



Aerial photographs of plunging anticline and sycline.

Oldest exposed rocks

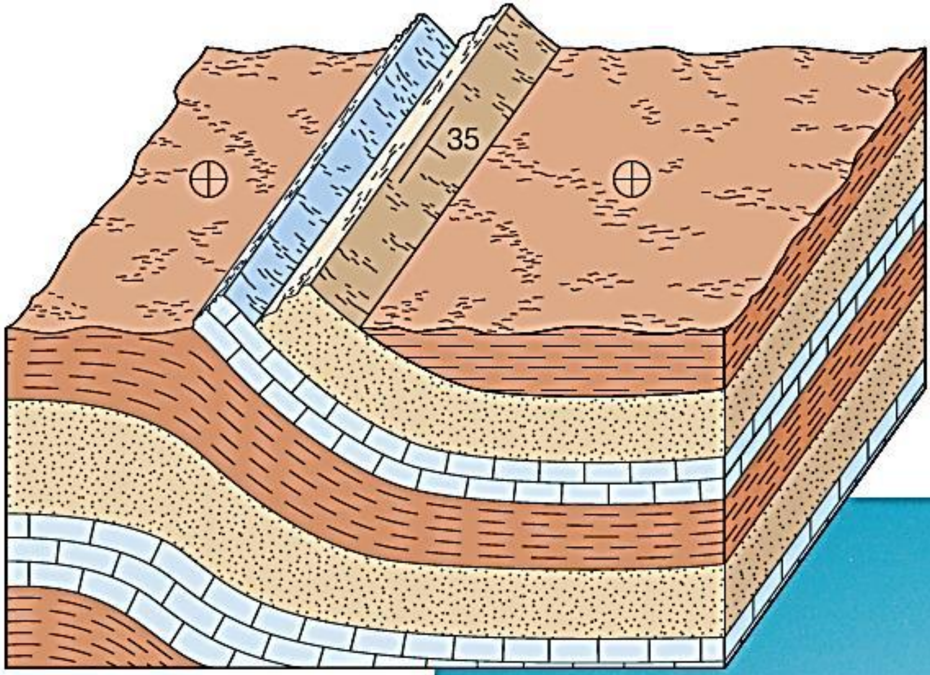
Youngest exposed rocks



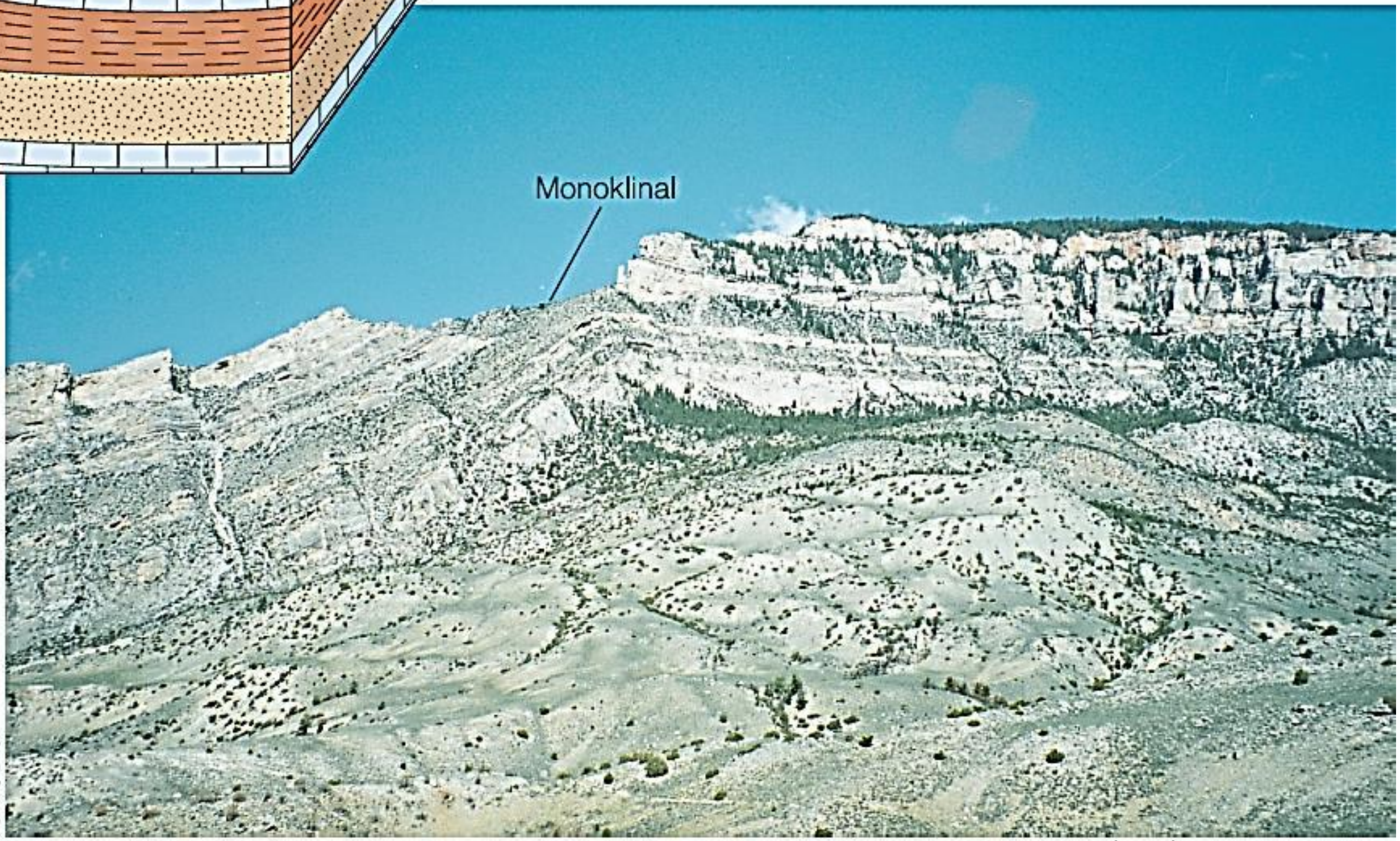
Monroe & Wicander 2005 (a) Dom (b) Havza

A **dome** (a) and a **basin** (b). Notice that in a dome oldest exposed rocks are in the center and all rocks dip outward from a central point, whereas in a basin the youngest exposed rocks are in the center all rocks dip inward a central point.

A monoclinal. A fold with one limb. They are mostly controlled by faults which does not penetrate to the surface.



(a)



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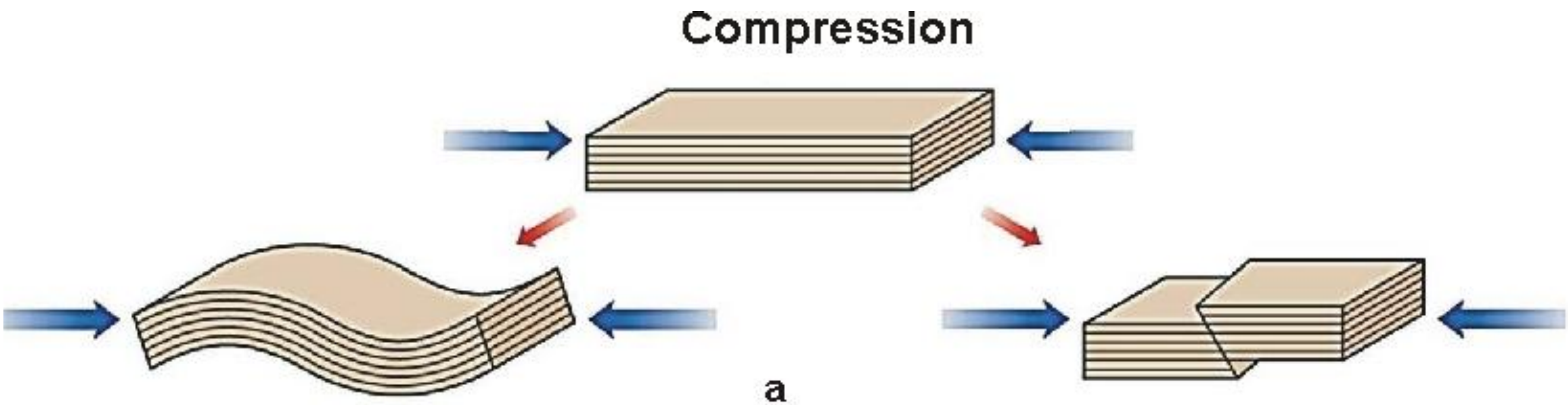
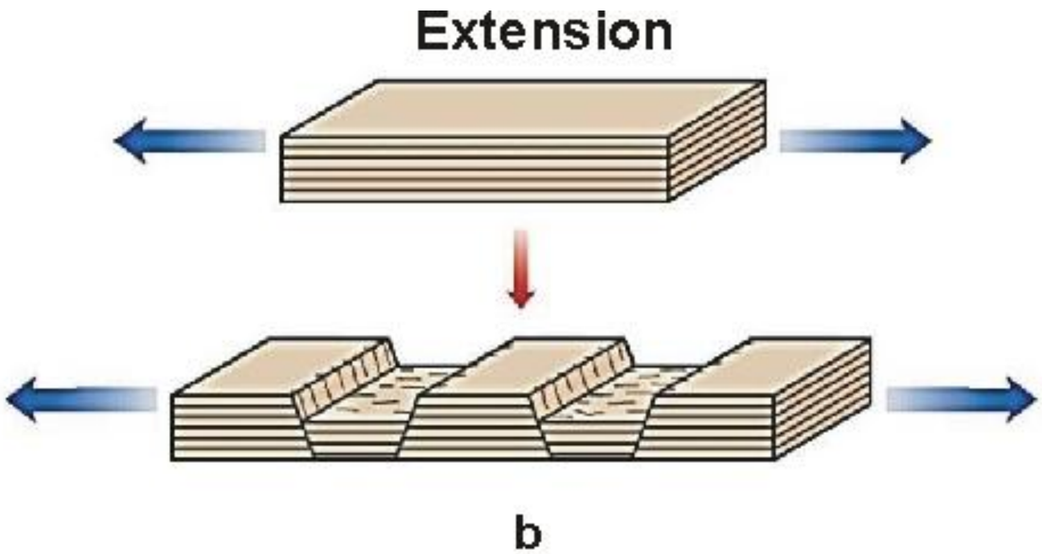
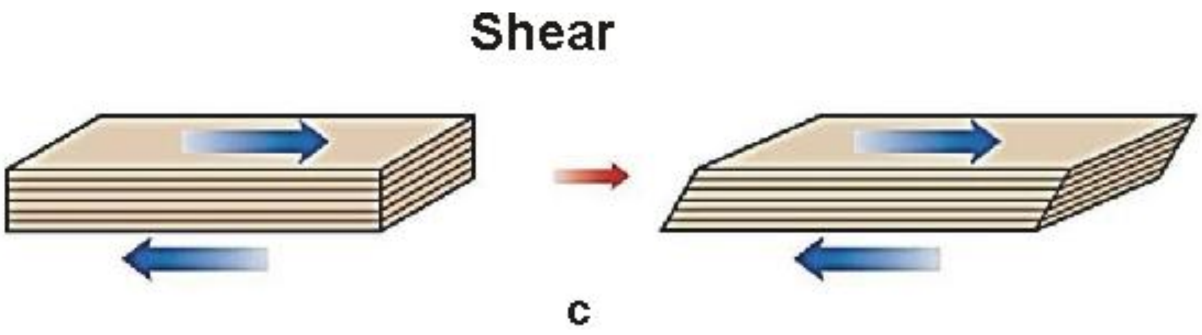
Stresses and possible types of deformation.



(a) Compression (Sıkıştırma) causes shortening of rock layers by folding or reverse faulting,



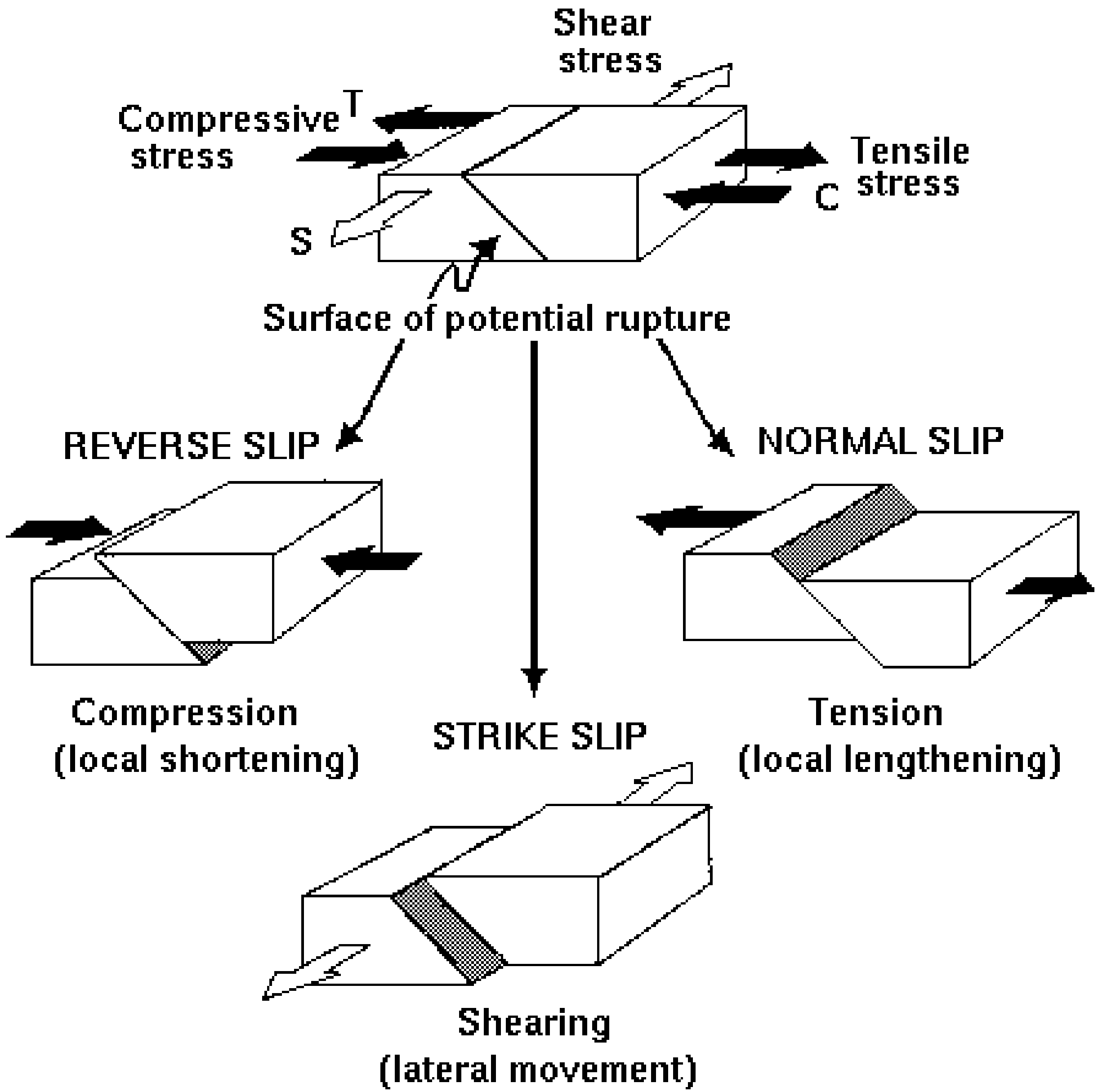
(b) Tension/extension (Genişleme) lenghtens rock layers and causes normal faulting,

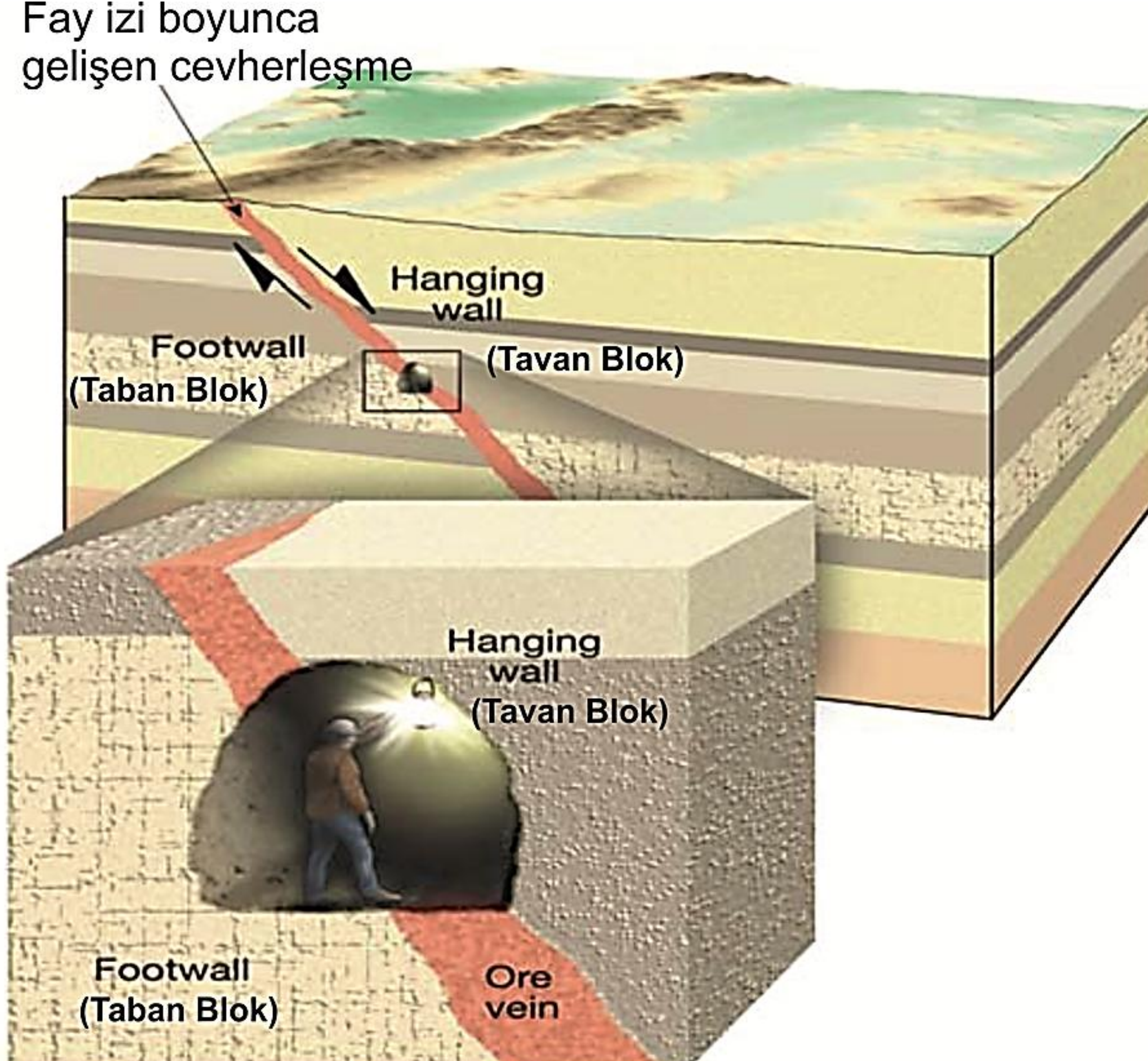


(c) Shear stress (Makaslama) causes deformation by displacement along closely spaced planes (faulting).

Brittle Deformation

FAULT is a structural plane along which considerable amount of movement is visible.




Fay izi boyunca
gelişen cevherleşme
Hanging
wall
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Footwall
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Hanging
wall
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Footwall
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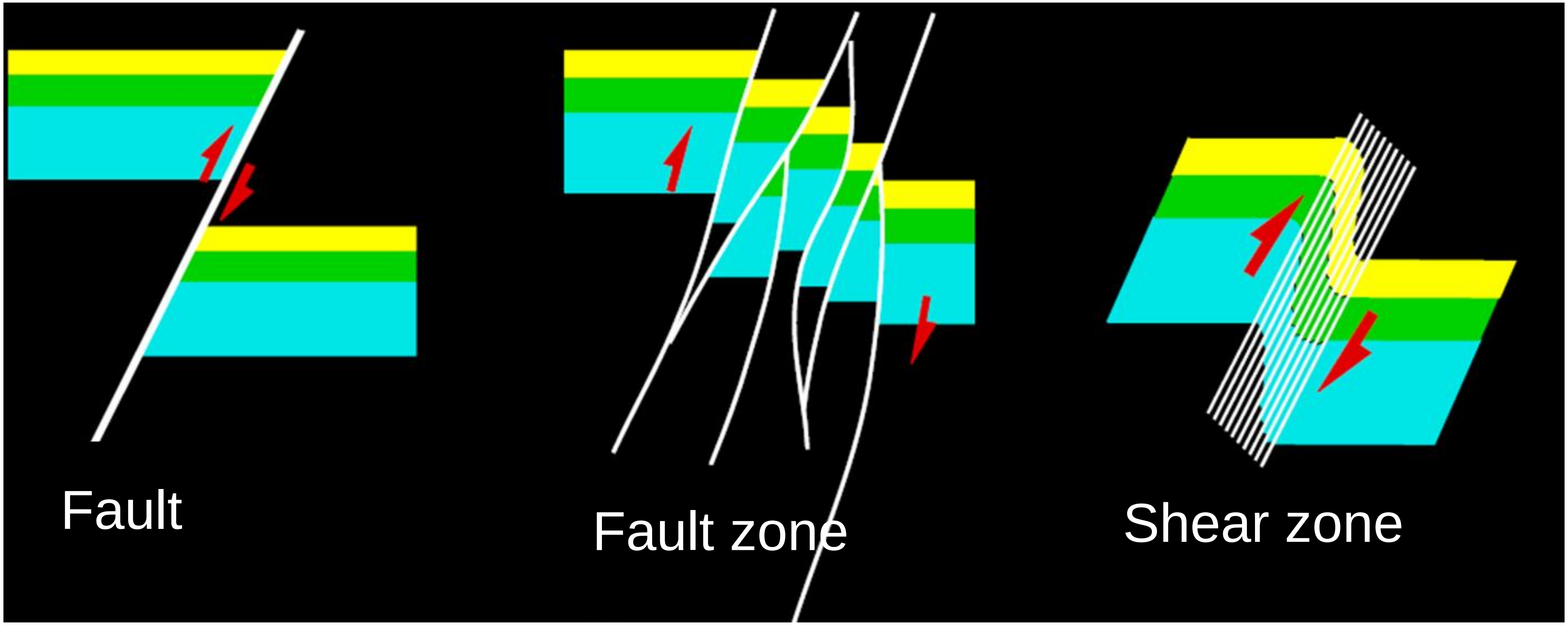
Ore
vein


Fault
Fault zone
Shear zone