University of Anbar

College of Science

Department of Applied Geology

Structural Geology

Title of the lecture

Introduction to structural geology

Assistant Prof. Dr. Abdulkhaleq A. Alhadithi

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Introduction to structural geology

Structural geology is the study of how rocks deform and the processes of deformation. **Deformation** is the change in shape, position and/or volume of an object in response to applied forces. It is closely related to the concept of **strain** - the permanent change in shape (in 1D, 2D or 3D) of a rock body as a result of deformation, so closely related, in fact, the two terms are often used interchangeably. However, deformation includes rigid translation and/or rotation (e.g., a fault block that moves but undergoes no internal strain) and volume change (e.g., compaction) of a rock body, whereas strain is purely the change in shape of a rock body.

Deformation is caused by forces acting on the rock body. **These forces maybe due to gravity (vertical force) or the movement of the tectonic plates (horizontal forces).** The effect of these forces on a rock depends on the area over which they are applied: **force/area=stress**. Therefore, at its simplest, stress causes strain.

Depending on lithospheric conditions at the time of deformation, rocks may respond to stress in a brittle or ductile manner. During brittle deformation rocks fracture with strain localized along a plane whilst the rocks to either side remaining unaffected (e.g., faults and joints). During ductile deformation rocks change shape smoothly and strain is pervasive throughout the rock body (e.g., folds).

Stress and Strain - Rock Deformation

Stress: Pressure Applied to Rock

Rock can be subject to several different kinds of stress:

1. **lithostatic stress:** Rock beneath the Earth's surface experiences equal pressure exerted on it from all directions because of the weight of the overlying rock. It is like the hydrostatic stress (water pressure) that a person feels pressing all around their body when diving down deep in water.

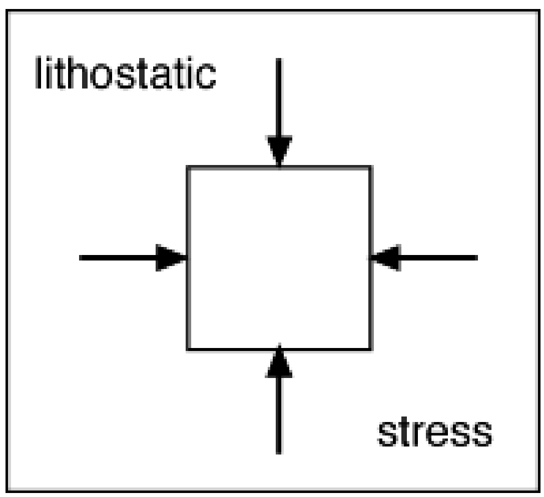

Figure 1: lithostatic stress

2. **differential (deviatoric) stress:** In many cases, rock may experience an additional, unequal stress due to tectonic forces. There are three basic kinds.
   Tensional stress (stretching)
   compressional stress (squeezing)
   shearing stress (side to side shearing)

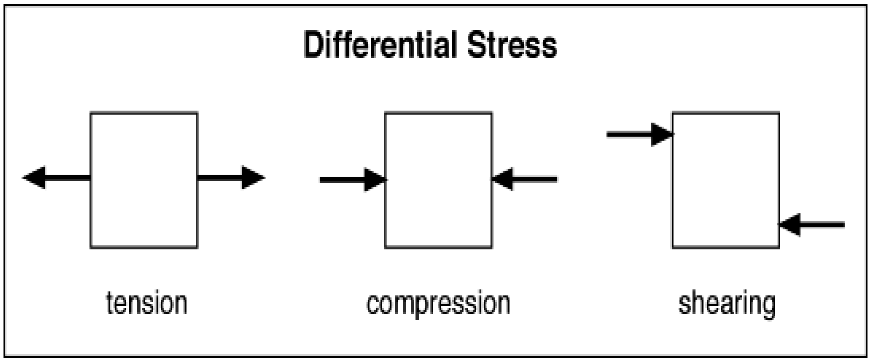

Figure 2: differential stress

Strain: Rock Deformation in Response to Stress**.** Rock responds to stress differently depending on the pressure, temperature (depth in Earth) and mineral composition of the rock.

elastic deformation: For small differential stresses, less than the **yield strength**, rock deforms like a spring. It changes shape by a very small amount in response to the stress, but the deformation is not permanent. If the stress could be reversed the rock would return to its original shape.

brittle deformation: Near the Earth's surface rock behaves in its familiar brittle fashion. If a differential stress is applied that is greater than the rock's yield strength, the rock fractures. **It breaks.** Note: the part of the rock that didn't break springs back to its original shape. This **elastic rebound** is what causes earthquakes.

ductile deformation: Deeper than 10-20 km the enormous lithostatic stress makes it nearly impossible to produce a fracture (crack - with space between masses of rock) but the high temperature makes rock softer, less brittle, more malleable. Rock undergoes plastic deformation when a differential stress is applied that is stronger than its yield strength. **It flows.** This occurs in the lower continental crust and in the mantle.

Elastic limit or yield point: at which a material can no longer deform elastically. When the elastic limit is exceeded by an applied stress, permanent deformation occurs.

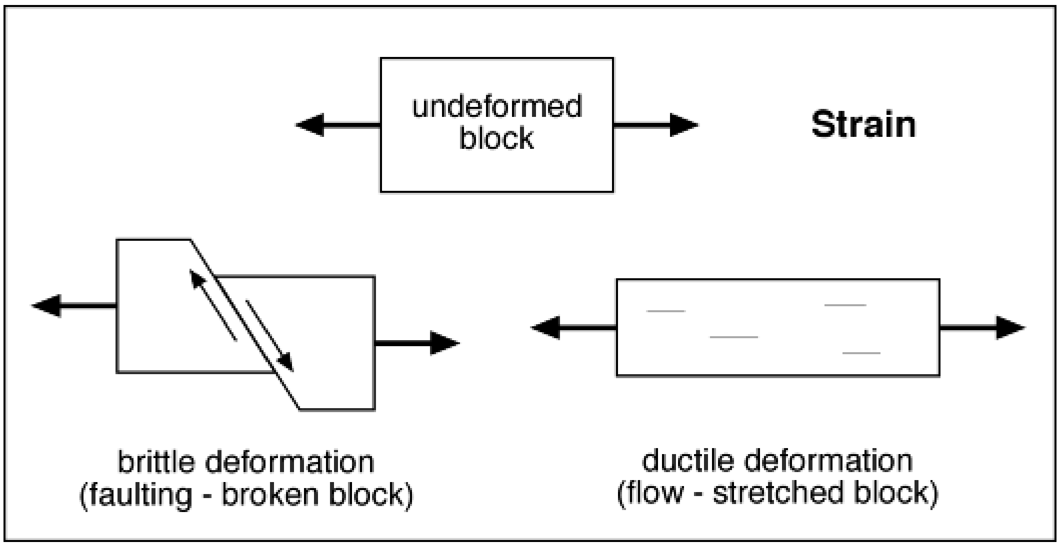

Figure 3: brittle and ductile deformations

Stress – strain relationships

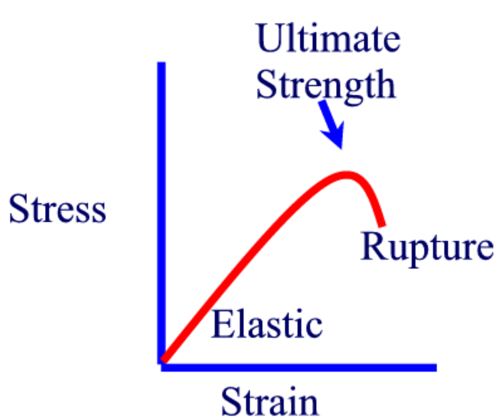

Figure 4: Stress-strain curve of brittle rocks exhibit elastic behavior before rupture.

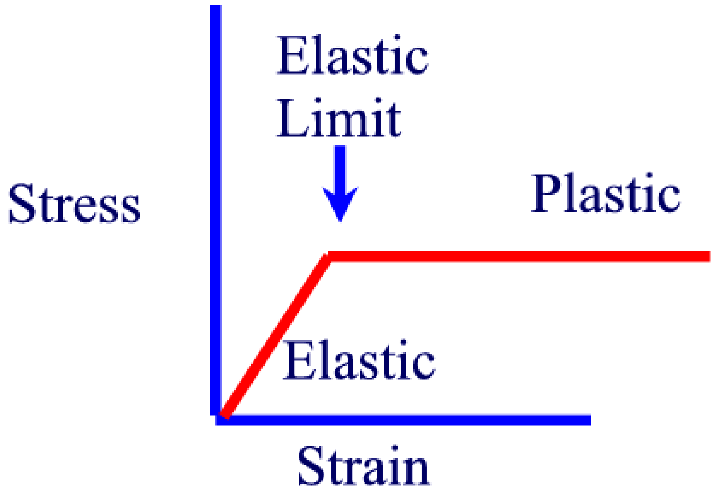

Figure 5: Stress-strain curve of ductile rocks exhibit elastic-plastic behavior before rupture.

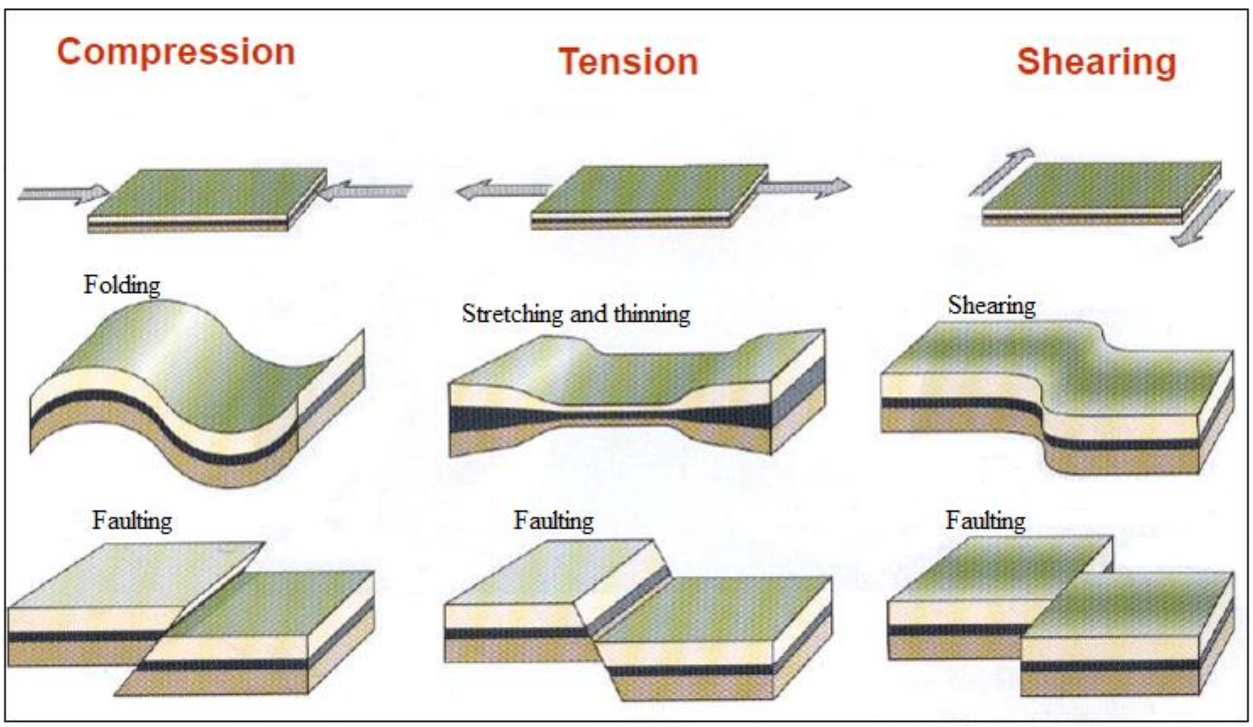

Figure 6: Rocks are deformed by folding or by faulting when they are subject to different kinds of stress. Geologists see the pattern of deformations in the field and infer the nature of the force that caused it.

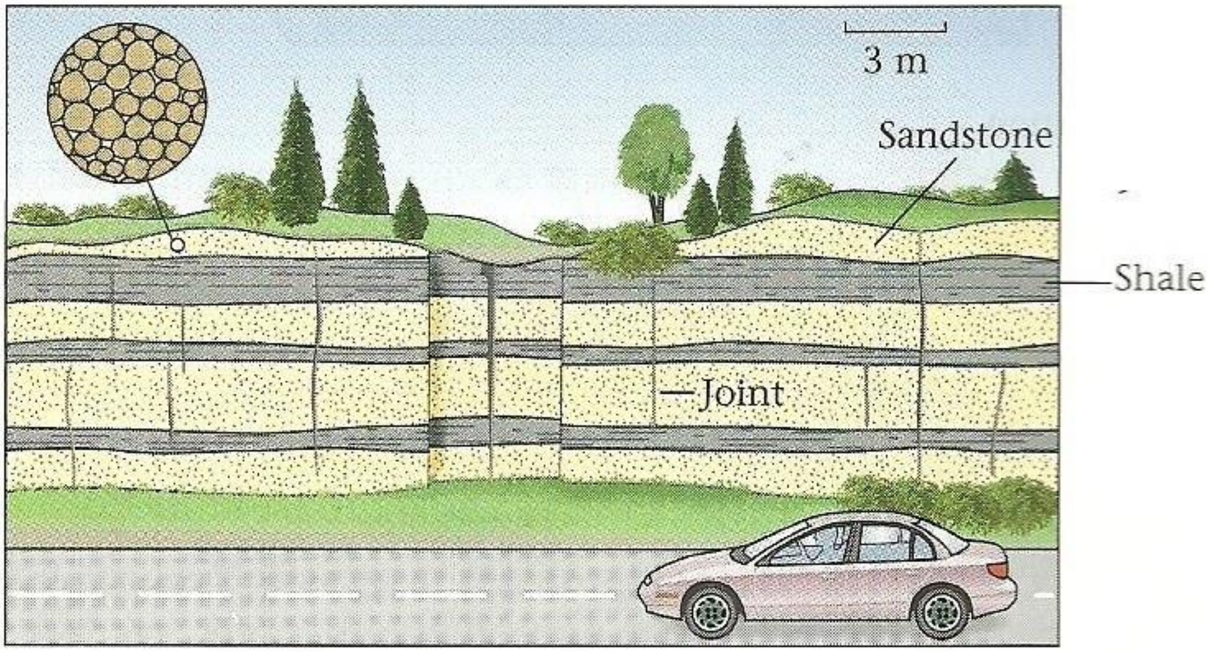

Figure 7: A region has not undergone deformation by orogeny. Beds of shale alternate with beds of sandstone of Paleozoic strata have been cut by some vertical joints. Inset: Undeformed sandstone has spherical grains.

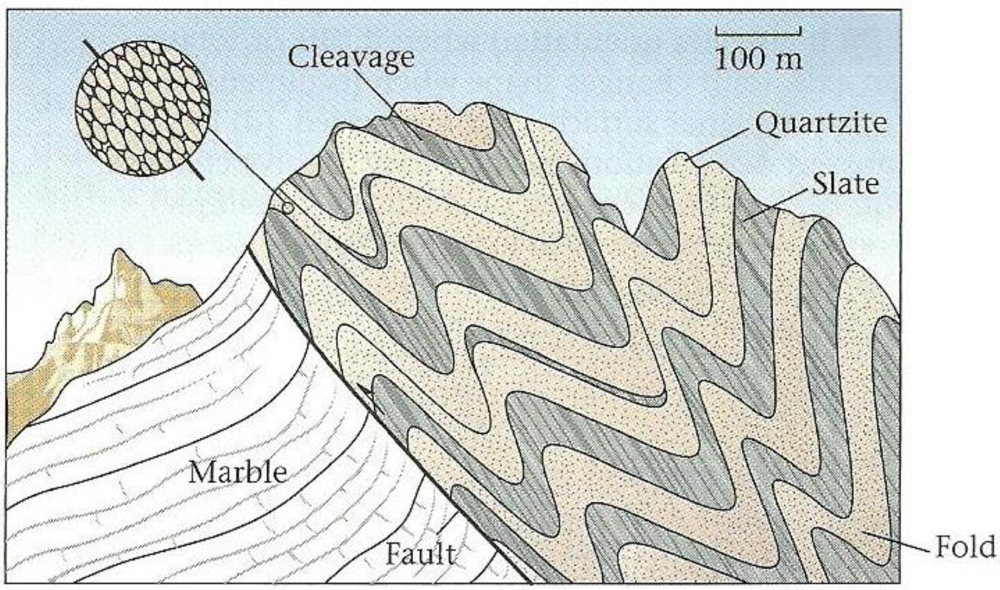

Figure 8: A region has undergone deformation by orogen Mountain-face exposure, folded layers of quartzite and slate and fault. Inset: Grains of quartz in the quartzite have become flattened, and are aligned parallel to one another. The slate has slaty cleavage.

The reference

Stephen, M., (2004) Essentials of geology, first edition, printed in United State of America, P 536.