

EENS 1110	Physical Geology
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<b>Deformation of Rock</b>	

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Mount Everest is the highest peak on Earth at 29,028 feet above sea level. The rock at the top of the peak is a marine limestone, deposited on the sea floor about 450 million years ago! This is an amazing fact that begs the question - how did that rock get there? In this discussion we will try to answer that question. The topics we will cover include:

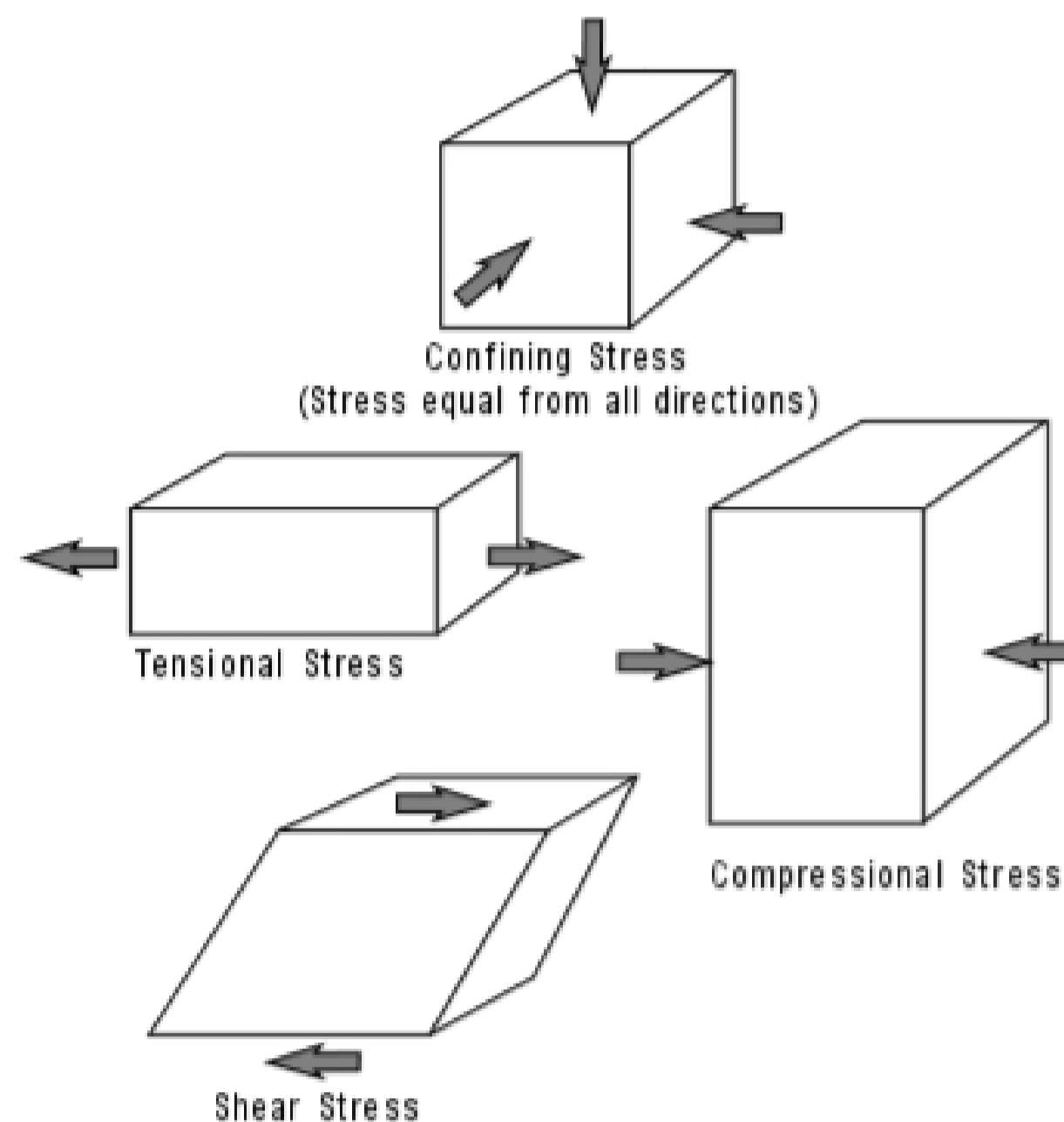
- Review of Stress and Strain
- Brittle Deformation – Faults and Joints
- Ductile deformation – Folds
- Mountain Building Processes

### Stress and Strain

We start our discussion with a brief review of the concepts of stress and strain. Recall that stress is a force acting on a material that produces a strain. Stress is a force applied over an area and therefore has units of Force/area (like  $\text{lb/in}^2$ ). Pressure is a stress where the forces act equally from all directions.

If stress is not equal from all directions then we say that the stress is a differential stress. Three kinds of differential stress occur.

1. *Tensional stress (or extensional stress)*, which stretches rock;
2. *Compressional stress*, which squeezes rock; and
3. *Shear stress*, which result in slippage and translation.

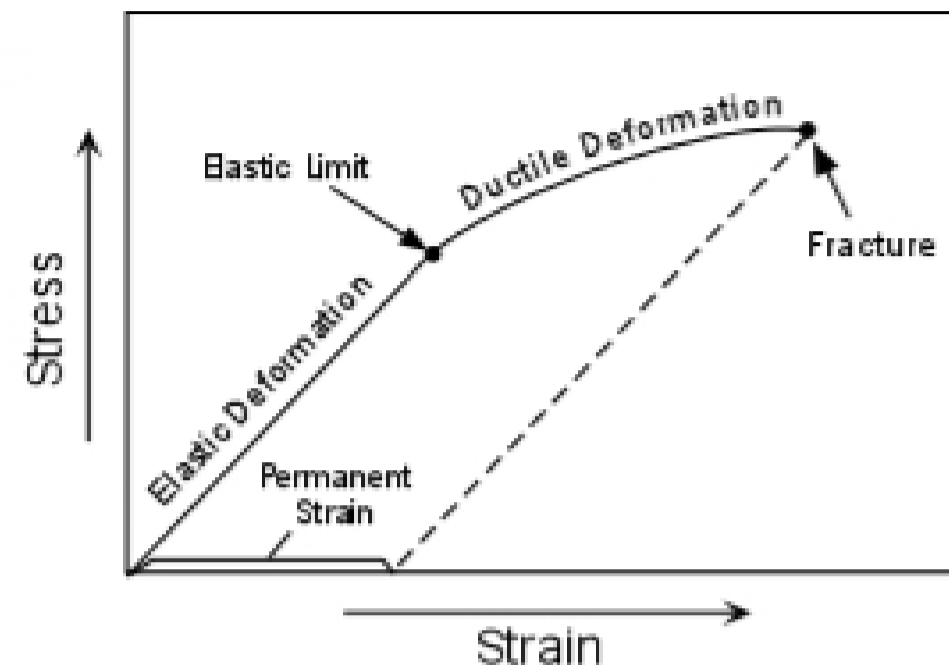


When rocks deform they are said to *strain*. A strain is a change in size, shape, or volume of a material. We here modify that definition somewhat to say that a strain also includes any kind of movement of the material, including translation and tilting.

## Stages of Deformation

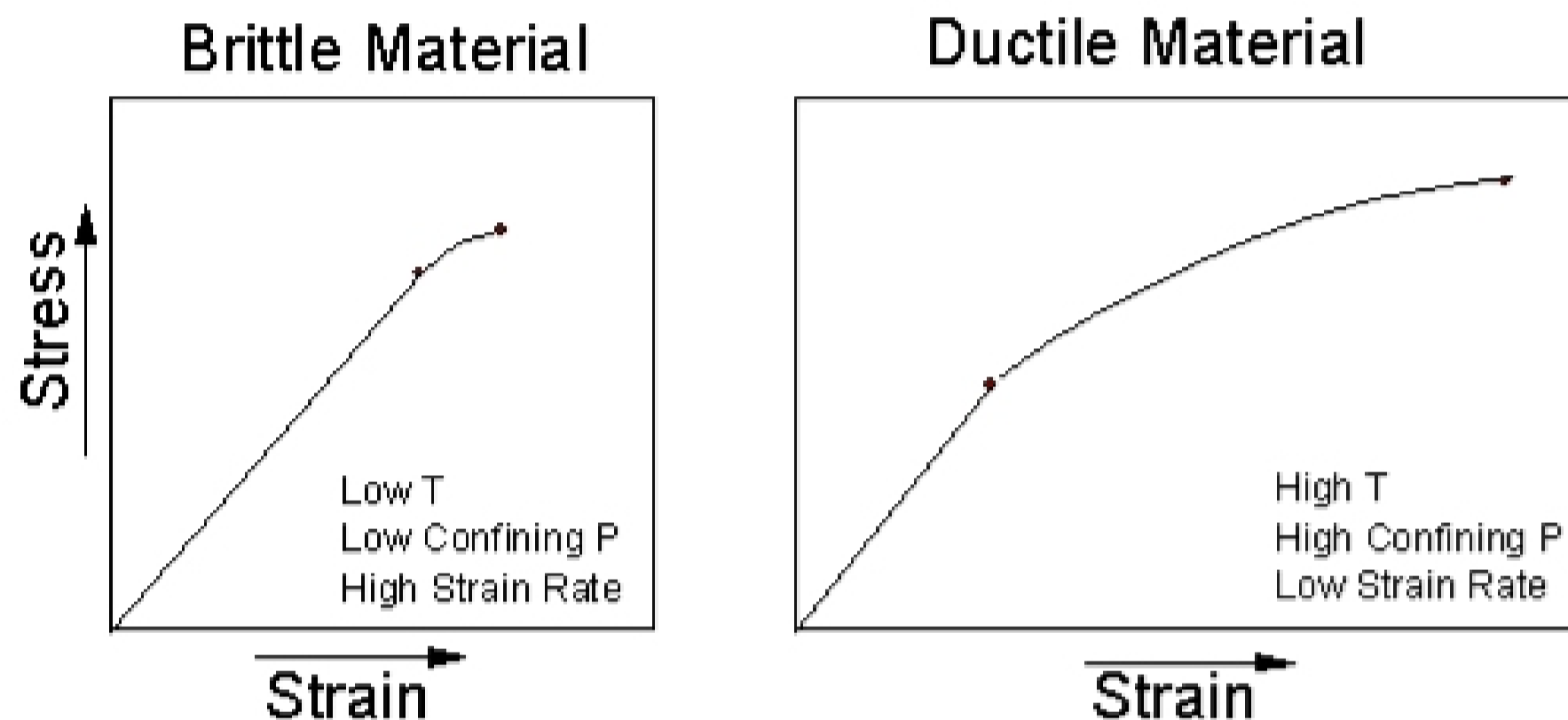
When a rock is subjected to increasing stress it passes through 3 successive stages of deformation.

- **Elastic Deformation** -- wherein the strain is reversible.
- **Ductile Deformation** -- wherein the strain is irreversible.
- **Fracture** - irreversible strain wherein the material breaks.



We can divide materials into two classes that depend on their relative behavior under stress.

- Brittle materials have a small or large region of elastic behavior but only a small region of ductile behavior before they fracture.
- Ductile materials have a small region of elastic behavior and a large region of ductile behavior before they fracture.



How a material behaves will depend on several factors. Among them are:

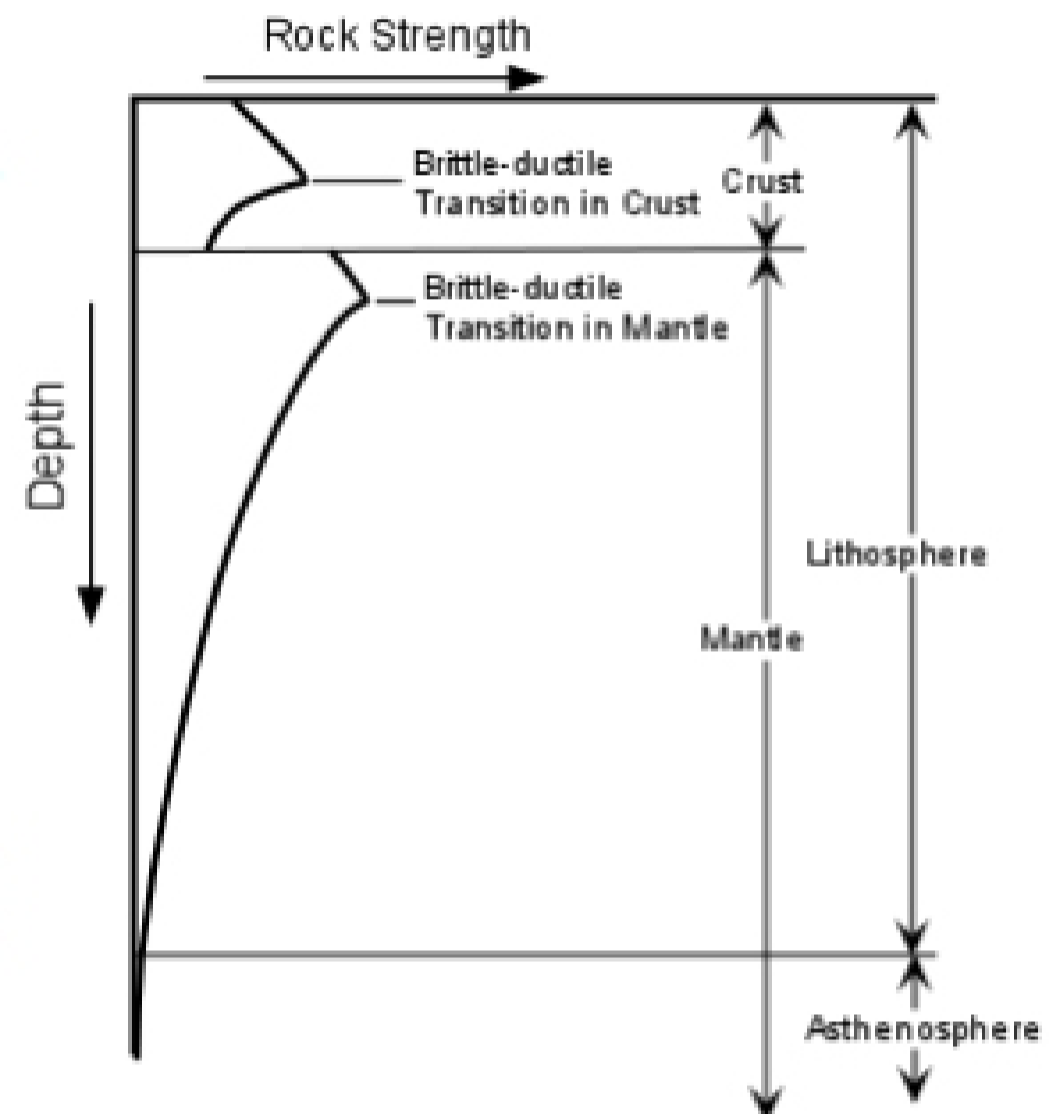
- **Temperature** - At high temperature molecules and their bonds can stretch and move, thus materials will behave in more ductile manner. At low Temperature, materials are brittle.
- **Confining Pressure** - At high confining pressure materials are less likely to fracture because the pressure of the surroundings tends to hinder the formation of fractures. At low confining stress, material will be brittle and tend to fracture sooner.
- **Strain rate** -- At high strain rates material tends to fracture. At low strain rates more time is available for individual atoms to move and therefore ductile behavior is favored.
- **Composition** -- Some minerals, like quartz, olivine, and feldspars are very brittle. Others,

like clay minerals, micas, and calcite are more ductile. This is due to the chemical bond types that hold them together. Thus, the mineralogical composition of the rock will be a factor in determining the deformational behavior of the rock. Another aspect is presence or absence of water. Water appears to weaken the chemical bonds and forms films around mineral grains along which slippage can take place. Thus wet rock tends to behave in ductile manner, while dry rocks tend to behave in brittle manner.

### Brittle-Ductile Properties of the Lithosphere

We all know that rocks near the surface of the Earth behave in a brittle manner. Crustal rocks are composed of minerals like quartz and feldspar which have high strength, particularly at low pressure and temperature. As we go deeper in the Earth the strength of these rocks initially increases.

At a depth of about 15 km we reach a point called the brittle-ductile transition zone. Below this point rock strength decreases because fractures become closed and the temperature is higher, making the rocks behave in a ductile manner. At the base of the crust the rock type changes to peridotite which is rich in olivine. Olivine is stronger than the minerals that make up most crustal rocks, so the upper part of the mantle is again strong. But, just as in the crust, increasing temperature eventually predominates and at a depth of about 40 km the brittle-ductile transition zone in the mantle occurs. Below this point rocks behave in an increasingly ductile manner.



### Deformation in Progress

Only in a few cases does deformation of rocks occur at a rate that is observable on human time scales. Abrupt deformation along faults, usually associated with earthquakes occurs on a time scale of minutes or seconds. Gradual deformation along faults or in areas of uplift or subsidence can be measured over periods of months to years with sensitive measuring instruments.

### Evidence of Past Deformation

Evidence of deformation that has occurred in the past is very evident in crustal rocks. For example, sedimentary strata and lava flows generally follow the law of original horizontality. Thus, when we see such strata inclined instead of horizontal, evidence of an episode of deformation.

Since many geologic features are planar in nature, we a way to uniquely define the orientation of a planar feature we first need to define two terms - strike and dip.

For an inclined plane the *strike* is the compass direction of any horizontal line on the plane. The *dip* is the angle between a horizontal plane and the inclined plane, measured perpendicular to