

## Crustal Deformation

Folding and faulting are the most common forms of deformation in the rocks that make the earth's crust.

**Fold** - bend or undulation in a rock.

**Fault** - rock breakage and slippage.

Structures are important because:

1) they are used to interpret the geologic past by unraveling the complex events that make up a geologic terrain.

2) they have economic significance. Most occurrences of oil and gas are associated with geologic structures that act to trap these fluids in reservoirs.

3) hydrothermal minerals occur along rock fractures - a major source of metallic ores.

4) the orientation and characteristics of rock structures must be considered when selecting sites for major construction projects such as bridges, hydroelectric dams, and nuclear power plants.

5) ground water flow; supply and pollution.

a) wells in hard rock are often located in brittle fault zones.

b) ground water flows along prominent joint or fracture sets.

## Deformation

**Deformation** - changes in volume or shape of a rock body. Deformation is the result of stress.

**Stress** - the force that acts on a rock to change its shape and/or volume.

1) **compressional stress** - squeezes or shortens a rock body.

2) **tensional stress** - acts in opposing directions, elongating, or pulling apart, the rock unit.

3) **shear stress** - results in relatively brittle rock being broken into thin slabs that are forced to slide past one another.

The three types of stresses are present at plate boundaries:

1) compressive forces dominate at convergent boundaries;

2) tensional forces dominate at divergent boundaries;

3) shearing forces dominate at transform fault boundaries.

## Types of Deformation

**brittle deformation** - material experiences little change until it breaks (fracture) suddenly when deformed.

In near surface environments, where the confining pressure and temperatures are low.

**ductile deformation** - involves flow rather than fracture when a directional force is applied.

occurs at great depths, where confining pressures are high.

Ductile substances undergo smooth and continuous plastic deformation.

Mineralogy, or the composition of rocks, can also have an effect on how a rock deforms. Rocks which are strong tend to fail by brittle fracture, while weak rocks generally deform by ductile flow.

Weak rocks include rock salt, gypsum, marble, and shale.

Quartzite, granite and gneiss are strong and brittle.

### **Descriptions of Rock Structures**

Deformation generates features known as **rock structures**. These are displayed on a variety of scales.

Structures are generally characterized on a regional scale. Bedrock, or **rock outcrops** (sites where bedrock is exposed at the surface), can either be highly visible, or concealed.

Geologic mapping is most easily accomplished in areas where sedimentary strata are exposed.

Sediments are usually deposited in horizontal layers, so inclined strata indicate that a period of deformation has occurred following deposition.

Two measurements are used to establish the orientation of deformed sedimentary beds (or fault surfaces) are:

1) **strike** - the trend, or direction, of the strata;

defined as the direction of the line produced by the intersection of the surface represented by the inclined strata with a horizontal surface (surface of the land);

2) **dip** - the angle of inclination of the bedding surface.

defined as the angle of maximum inclination of a bed measured in the direction perpendicular to strike.

These data are plotted on a topographic map. Using this data, the geologist is better able to reconstruct the pre-erosional structures and interpret the regions geologic history.

### **Folds**

During mountain building, flat-lying sedimentary rocks are often bent into a series of wavelike undulations - **folds**.

**Folds** - formed by compression resulting in shortening and thickening of the crust. variety of sizes and configurations:

1) broad flexures where rock units hundreds of meters thick are slightly warped.

2) very tight microscopic structures found in sedimentary rocks.

### **Parts of a Fold**

1) **limbs** - the two sides of a fold.

2) **axial plane** - an imaginary surface that divides a fold as symmetrically as possible, with one limb on either side of the plane.

3) **fold axis** - a line drawn along the points of maximum curvature of each layer.

Also defined as the intersection of the axial plane with the beds. In some folds, the axis

is completely horizontal. However, in more complex folding, the fold axis is often inclined at an angle known as the **plunge** - a **plunging fold**.

### Types of folds

1) **anticline** - formed by upfolding, or arching, of rock layers. It is a structure in which the oldest strata are found in the center.

2) **syncline** - a downfold, or trough, with youngest strata in the center.

Folds are described as **symmetrical** when the limbs on either side of the axial plane diverge at the same angle and **asymmetrical** when they do not. An asymmetrical fold is said to be **overturned** if one limb is tilted beyond the vertical.

Folds do not continue forever; rather, their ends die out much like the wrinkles in cloth. Some folds are said to be **plunging** since the axis of the fold penetrates into the ground.

### Domes and Basins

Broad upwarps in basement rock may deform the overlying sedimentary strata and generate large folds.

**dome (anticlinal structure)** - a circular or elongated structure produced by upwarping.

The oldest beds are in the core; the flanking formations are successively younger and dip away from the core.

**basins (synclinal structure)** - a downwarped circular or elongated structure. The beds dip radially toward a central point; youngest beds in the core.

### Fractures

While some rocks fold under stress, others break or fracture.

There are two types of fractures:

1) **joint** - a crack along which no appreciable movement has occurred.

2) **fault** - a fracture with relative movement of rocks on both sides of it, parallel to the fracture.

### Faults

**Faults** are fractures in the crust along which appreciable displacement has taken place.

Faults can occur as single discrete breaks, or as part of a large fault system.

For example, the San Andreas fault has displacement of hundreds of kilometers and consist of many interconnecting fault surfaces. These so called **fault zones** can be several kilometers wide.

Sudden movements along faults are the cause of most earthquakes. However, many faults are inactive and thus are the remnants of previous deformation.

### Classification of Faults

**1) Dip-Slip Faults** - are faults where the movement is primarily vertical. Called dip-slip since the displacement is along the inclination, or dip, of the fault plane (surface along which the formation fractures and slips).

Two types of dip-slip faults are recognized. Use the terms hanging wall and footwall to distinguish between the two of them. In mining operations, miners would walk on the rocks below the fault trace (the **foot wall**), and hang their lanterns on the rocks above (the **hanging wall**).

#### a) Normal Faults

hanging wall moves down relative to the footwall.  
 indicate the existence of tensional stresses that pull the crust apart.  
 occur at spreading centers where plate divergence is prevalent. Here a central block called a **graben** is bounded by normal faults and drops as the plates separate. These grabens produce an elongated valley bounded by upward structures called **horsts**. Grabens are common in the Great Rift Valley of East Africa.

In the western United States, normal faults are also associated with structures called **fault-block mountains**. Examples are found in the Basin and Range Province. Here the crust has been elongated and broken to create more than 200 relatively small mountain ranges.

#### b) Reverse Faults

hanging wall moves up relative to the foot wall.  
 the rocks above the fault plane move upward relative to the rocks below.  
 result from strong compressional stresses.  
**Thrust faults** - low angles reverse faults. In compressional settings, crustal blocks are displaced toward one another, with the hanging wall being displaced upward relative to the footwall. The region where this is most pronounced are convergent boundaries. Compressional forces generally produce folds as well as faults and result in a thickening and shortening of the material involved.

In mountainous thrust terranes, thrust faults have displaced strata as far as 50 kms over adjacent rock units.

#### c) Strike-Slip Faults

dominant displacement horizontal and parallel to the strike of the fault plane.  
 Because of their large size and linear nature, many strike slip faults produce a trace that is visible over a great distance. Rather than a single fracture along which movement takes place, large strike-slip faults consist of a zone of roughly parallel fractures up to several kilometers in width.

Many major strike slip faults cut through the lithosphere and accommodate motion between two large crustal plates - **transform fault**.

## **Joints**

**Joints** - fractures along which no appreciable displacement has occurred.

most occur in roughly parallel groups.

produced when rocks are deformed, particularly by the tensional and shearing stresses associated with crustal movements.

Many rocks are broken by two or even three sets of intersecting joints that slice the rock into numerous regularly shaped blocks.

They can be important as:

- 1) chemical weathering is concentrated along joints;
- 2) ground water movement and the resulting solution activity in soluble rocks are controlled by these patterns; and
- 3) they can influence the direction of stream flow.