UNIVERSITY OF ZAMBIA, GEOLOGY DEPARTMENT

GGY_3049: STRUCTURAL GEOLOGY

Introduction to forces

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Introduction to Forces

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Forces

- Force is classically **defined** as that which changes, or tends **to change, the state of rest or state of motion of a body:**

- Only a force can cause something to **move** that had been **stationary**.
- Only a force can cause something to **change its speed**.
- Only a force can cause something to **change its course** of travel.

Responses of rocks to stresses generated by forces:

- Rocks respond to stress generated from forces by
  - Translation,
  - rotations,
  - distortions, and
  - dilations

Newton, through his *first law of motion*, describes the concept of **force** in this way:

- an object at rest will remain at rest and an object in motion will continue in motion with a constant velocity unless it experiences ***a net force,*** *in which case it is caused to accelerate (or deaccelerate).*

- A **net force** arises when forces are not balanced.
- In his *second law of motion*, **Newton** observed that the:

- **Acceleration** of an object is directly proportional to the **net force** on it, and
- **Inversely proportional** to the **mass** of the object.

- In fact, the definition of force is **based upon *mass (m)*** and *acceleration* ***(a):***

  Force = mass x acceleration

  $F = ma$

- **Mass** and **acceleration** are reciprocal.

  $m_1a_1 = m_2a_2$

- Thus, if a given force accelerates a **1 kg** object by **3 m/s²**, it will accelerate a **2 kg** object by **1.5 m/s²**, for:

  1 kg x 3 m/s^2 = 2 kg x 1.5 m/s^2

1.1. Mass & weight

- The mass **(*m*)** of a body is the **amount of material** the body contains.

- The mass of a body can be expressed in units of kilograms **(International System),** grams **(CGS system)**, or slugs **(English standard).**

- **Mass** can be readily calculated if **Volume** and **Density** are known.

1.2. Volume (V)

- **Volume (*V*)** is the **space occupied** by the **mass** and is expressed commonly in units of cubic centimeters or cubic meters **(cm^3 or m^3)**.

1.3. Density

- **Density *(p)*** is the measure of the **mass of a body per unit volume**, and is most commonly expressed in grams per cubic centimeter or kilograms per cubic meter **[g/cm^3** or **kg/m^3]**
- The relationship among **mass, volume**, and **density** is:

$$m = pV$$
$$p = m/v$$
$$v = m/p$$

- Mass causes a body to have weight in a gravitational field, but mass and weight are not the same.

- The **weight** of a body of a given mass is the **magnitude of the force of gravity acting on the mass**, and it **varies according to location**.

- The force of gravity on the mass of a body on the moon will be less than the force of gravity acting on the same body on Earth.

1.4. Unit of Force

- The Newton (N) is the **basic unit of force** in the **International System**.

- A **Newton** is the **force required to impart** an **acceleration** of **one meter per second per second [1m/s²]** to a body of **one kilogram [1kg] mass.**

1.4. Unit of Force cont'd

- In the CGS [centimeter – gram - second] system, the basic unit of force is dyne, which is the **force required to impart an acceleration of one centimeter per second per second [1cm/s^2] to a body whose mass is one gram [g]**.

- A force of 1 Newton is equivalent to the force of 10^5 dynes.

1.5. Forces as Vector

- Describing the **magnitude** of a force, in either newtons or dynes, is not sufficient to completely define the force.

- Forces are vector quantities, and therefore, the **direction** in which the force acts also must be specified**.**

1.5. Forces as Vector cont'd.

- The vector property of forces permit them to be **added** and **subtracted** using principles of vector algebra, and this in turn makes it possible to evaluate whether forces on a body are in **balance**.

- **Force** is thus an **explicitly definable vector quantity** that **changes** or tends to produce a change in the **motion** of a body. E.g. The locomotive of a train exerts the force that moves the cars.

- Force is defined by its **magnitude** and **direction,**

- hence it may be expressed by an **arrow**, the **length of which is proportional to the magnitude of the force**, and the **direction of which indicates the direction in which the force is acting.**

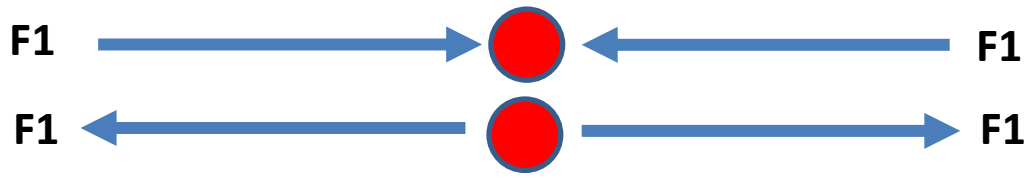
Forces:

1.6. Unbalanced & Balanced force

- An **unbalanced force** is one that causes a change in the motion of a body.
- The acceleration is the **rate of change of velocity.**
- If a train starts from rest and acquires a velocity of 20 miles per hour at the end of 10 minutes, the acceleration is two miles per minute.

- A body **dropped from a high building** is subjected to a an unbalanced force because of the **gravitational pull of the earth**, and the body accelerates at the rate of approximately 32 feet per second per second.

- Balanced forces exist where no change in motion occurs. If a train is moving at a **constant velocity,** the frictional resistance of the tracks and the air equals the force exerted by the locomotive.
- If a man **pushes** against a **wall** that he cannot move, the wall is exerting a force **equal** and **opposite** to that exerted by the man.



Balanced Forces

- **Most problems confronting the structural geologist** may be analyzed by **assuming balanced forces.**
- This is because the **velocity of rock bodies is so small that acceleration is negligible**.

- However, **along faults**, the motion causing earthquakes may be rapid that **acceleration is important.**

1.8. Types of forces

- There are **two** **fundamental classes** of **forces** that affect **geologic bodies**:
  - *Body Force,* and
  - *Contact Force*.
- Body forces act on the **mass of a body** in a way that **depends on the amount of material in the body** but is **independent on the force created by adjacent** surrounding materials.

- Contact forces are *pushes or pulls* across real or imaginary surfaces of contact, such as a **fault between adjacent parts** of a rock body.

The most important body forces are:

- Gravitational forces, and
- Electromagnetic forces.

The **force of gravity** is ultimately responsible for many geologic actions, such as the **downhill flow of lava or glaciers**, **rock slides** and avalanches, vertical rise of magma, settling of crystals within certain magmas, and plate tectonic forces including **“ridge push’** and **“slab pull”.**

- The body force called **gravity** can create **structural deformation** at a scale that is commonly large and visible.

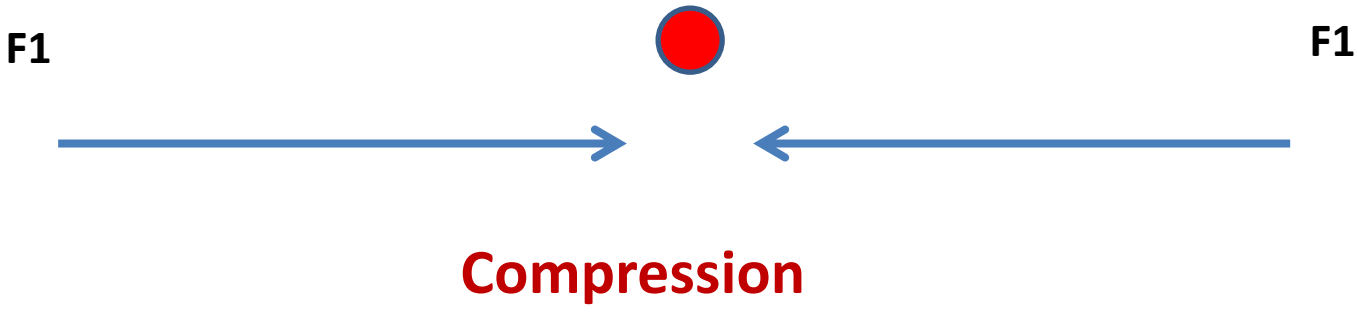
- In contrast, **electromagnetic forces** are body forces whose structural geologic presence dwells in the **submicroscopic realm**.

Differential forces

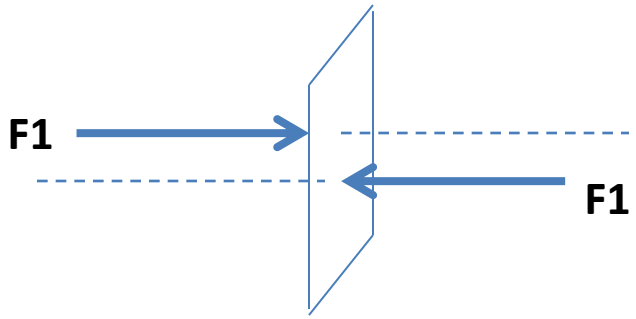
- In many instances the forces acting on a body **are not equal on all sides.**
- A body is said to be under *tension* when it is subjected to external forces that tend to **pull it apart.**
- **Tension** may be **represented by two arrows** that are on the same straight line and are directed away from each other.

Tension

- A body is said to be under *compression* when it is subjected to **external forces** that tend to **compress** it.
- Compression may be **represented by two arrows** that are on the same straight line and are directed towards each other.

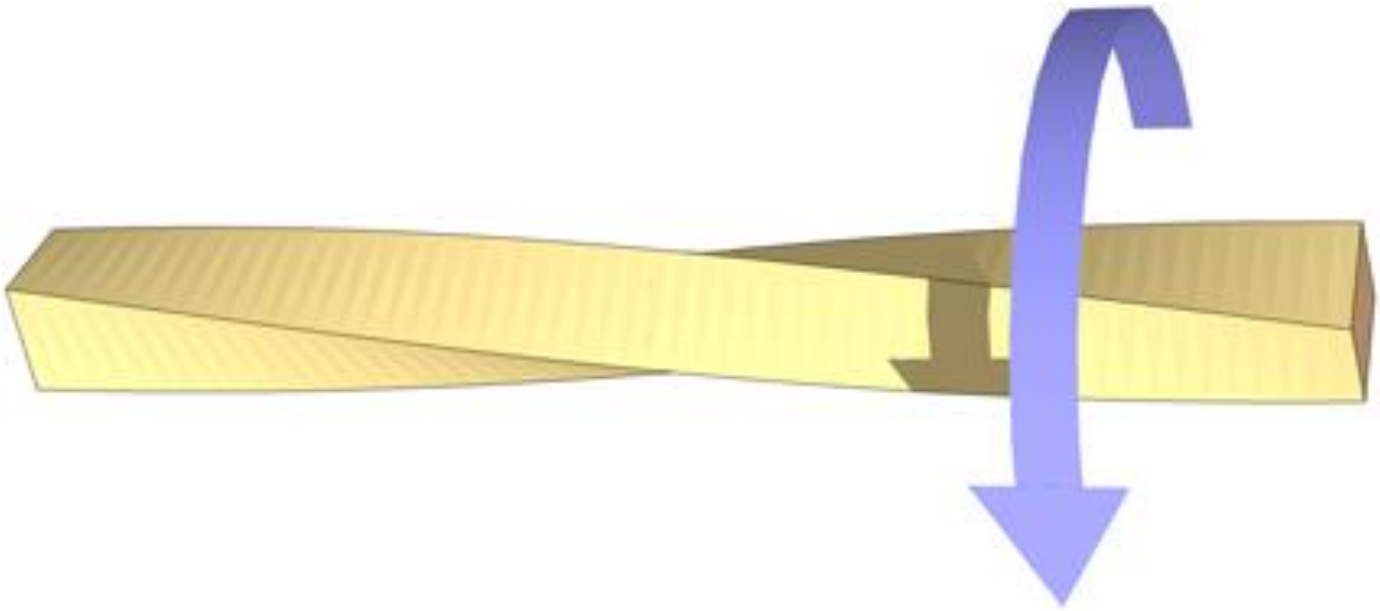


- A ***couple*** consists of **two equal forces** that act in opposite directions in the **same plane**, but **not along the same line**.



- ***Torsion*** or **torque** results from **twisting**. If the two ends of a rod are turned in opposite directions, the rod is subjected to torsion.

- In the field of solid mechanics, torsion is the **twisting** of an object due to an applied torque.
- Torsion is expressed in either the Pascal (Pa), an **SI unit for newtons per square metre**, or in pounds per square inch (psi) while
- **Torque is expressed in newton metres (N·m)** or foot-pound force (ft·lbf).



Thank You