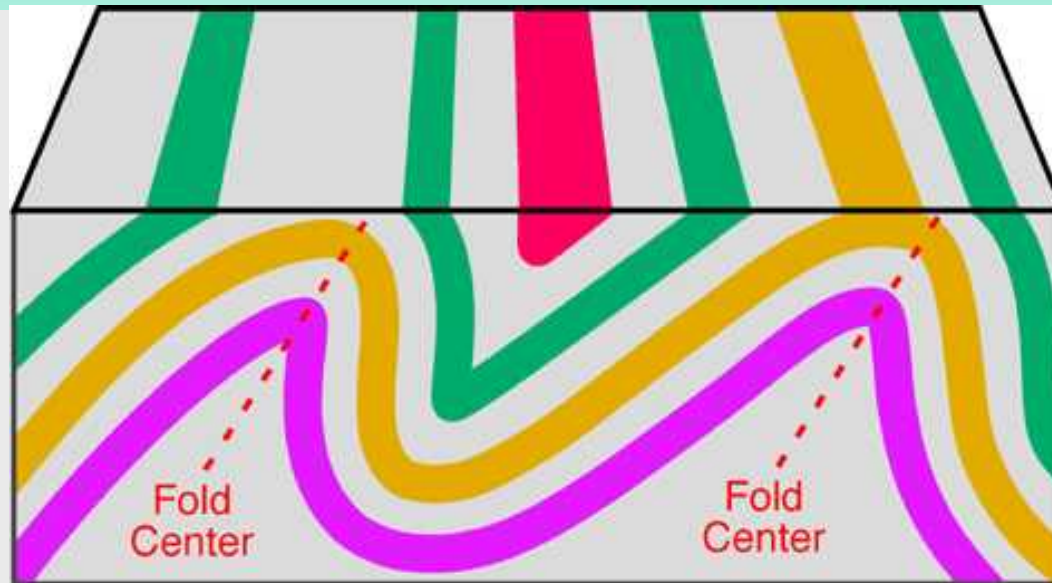


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## Lecture # 6



# Geological Structures ( Folds, Faults and Joints)

**Instructor:**

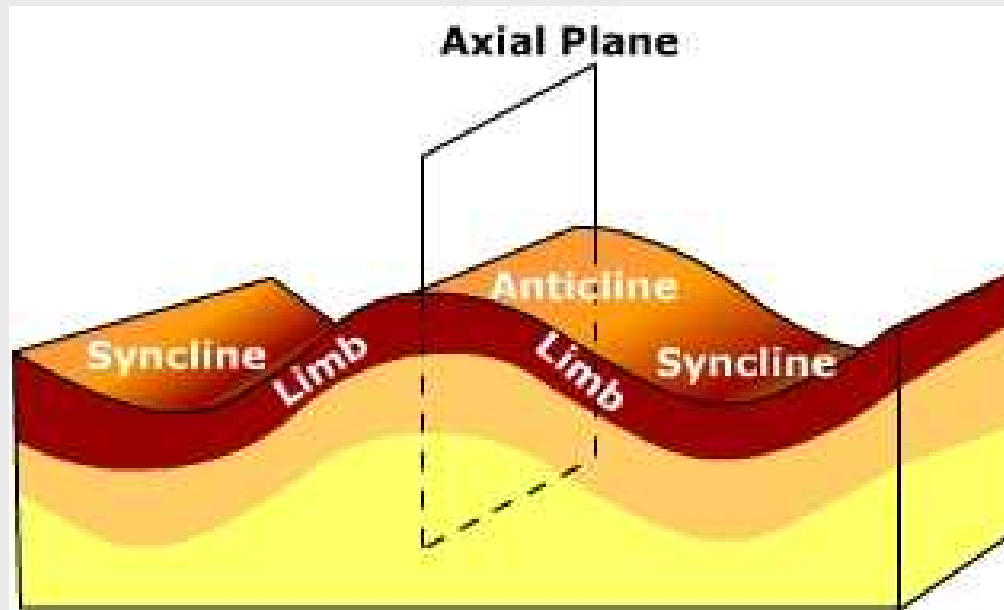
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# Geological Structures: Folds

The wavy undulations in the rock beds are called **folds**. This is when the rocks deform by plastic deformation. The process of folding occurs when rock is compressed, as it is along colliding plate boundaries. They consist of arches and troughs in alternate manner. The size of folds vary greatly. Width of some folds are measured in kilometers while those of others in meters or centimeters.



# Geological Structures: Folds

## Terminology:

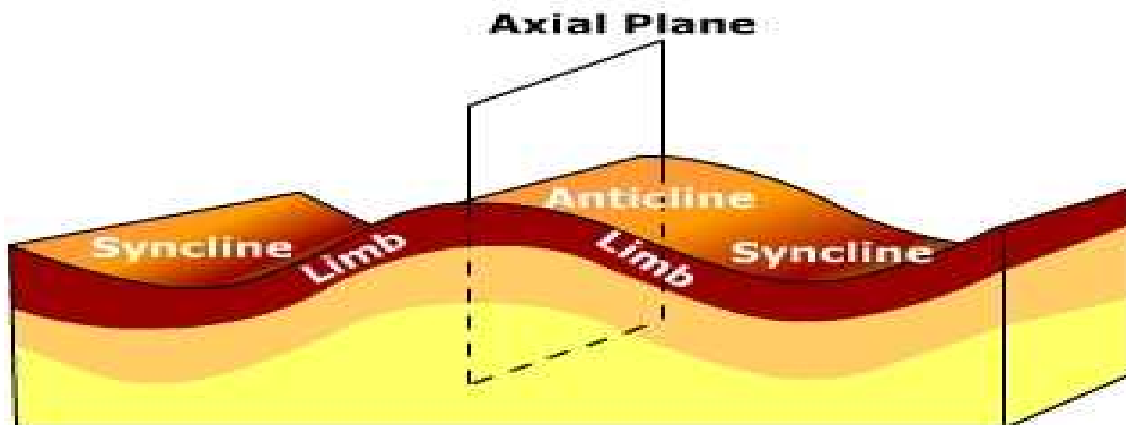
**Anticline:** It is an up fold where the limbs dip away from the axis.

**Syncline:** It is a down fold where the limbs dip towards the axis.

**Limbs:** The sloping side of a fold from crest to trough is called the limb.

**Axial Plane:** It is an imaginary plane or surface which divides the fold into equal halves.

**Axis:** The line of intersection of the axial plane with the surface of any of the constituent rock beds is known as the axis of the fold.

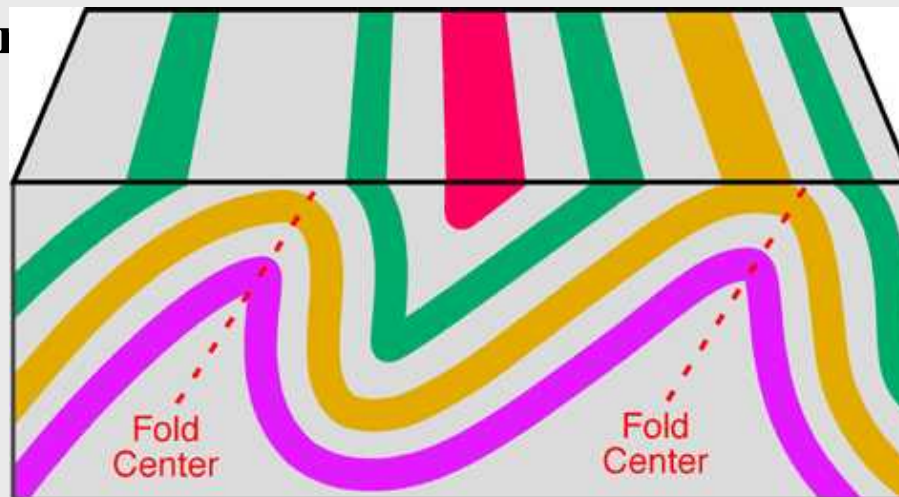


## Types of folds

**Symmetrical Folds:** A 'symmetrical folds' is one where the axial plane is vertical and the two limbs have the same amount of dip.

**Asymmetrical folds:** An asymmetrical folds is one where the axial plane is inclined and the limbs dip at different angles, and in opposite directions.

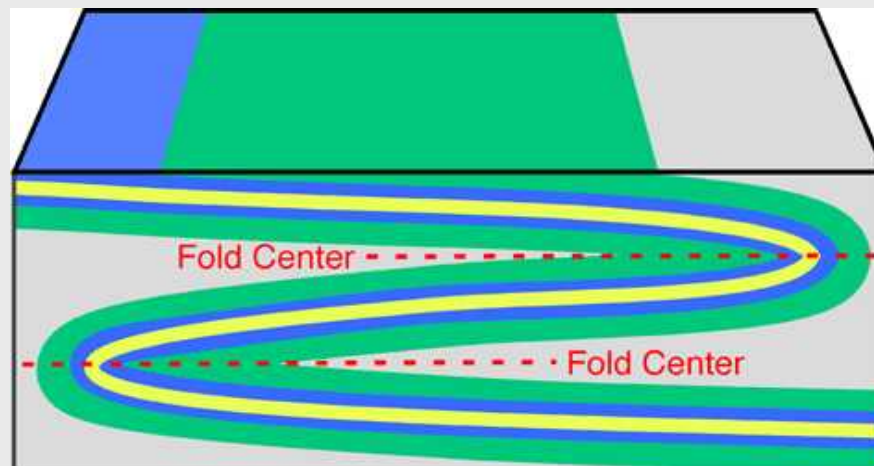
**Overtured folds:** Overtured folds is one in which the axial plane is inclined and one limb is turned past the vertical. If the compression is more pronounced further folding may occur.



# Types of folds

**Recumbent fold:** A recumbent fold develops if the center of the fold moves from being once vertical to a horizontal position. Recumbent folds are commonly found in the core of mountain ranges and indicate that compression and/or shear forces were stronger in one direction. Extreme stress and pressure sometimes causes the rocks to shear along a plane of weakness creating a fault.

**Isoclinal fold:** This type of fold shows parallel limbs which dip at the same angle and in the same directions.



## Types of folds

**Fan Folds:** In 'fan folds' the beds in the limbs of the anticline are seen to dip in from both sides towards the axial plane. The beds within the anticline are much compressed below while they open out above. The crests and troughs of fan folds are generally sufficiently rounded.

## Types of folds

**Dip:** It is the angle of inclination of a rock bed with the horizontal plane.

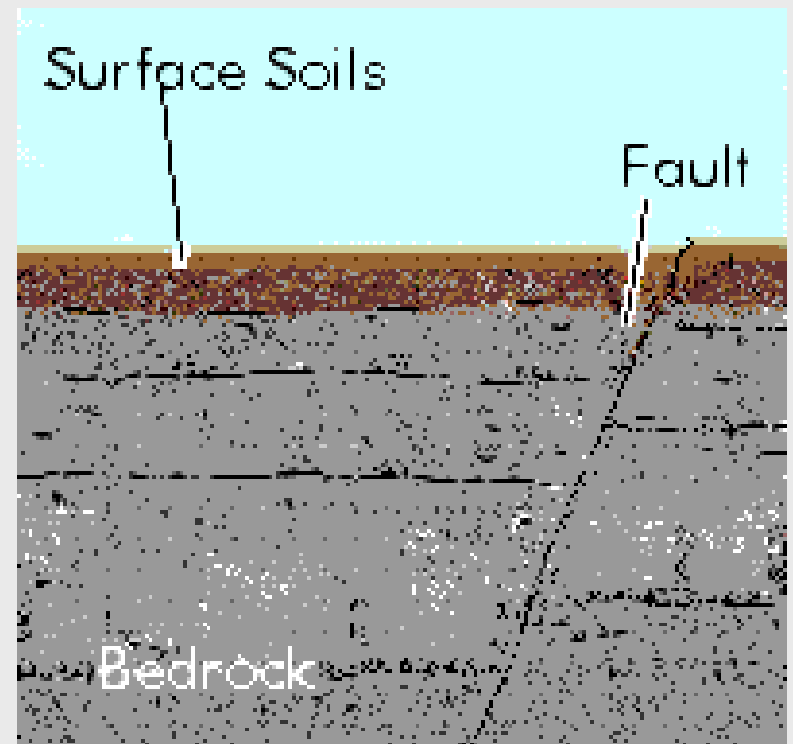
**Strike:** It is the direction of a line formed by the intersection of the plane of a bed with a horizontal plane. The strike is always at right angles to the true dip.



## Geological Features: Faults

**A fault is a fracture within some particular rocky mass within the earth's crust.**

- The depth and length of faults vary greatly. Some faults can be many miles long.
- Earthquakes are caused by **Active faults**, *that is, faults along which the two sides of the fracture move with respect to each other.*
- An earthquake is caused by the sudden movement of the two sides of a fault with respect to another.



**A Fault**

# Terminology related to faults

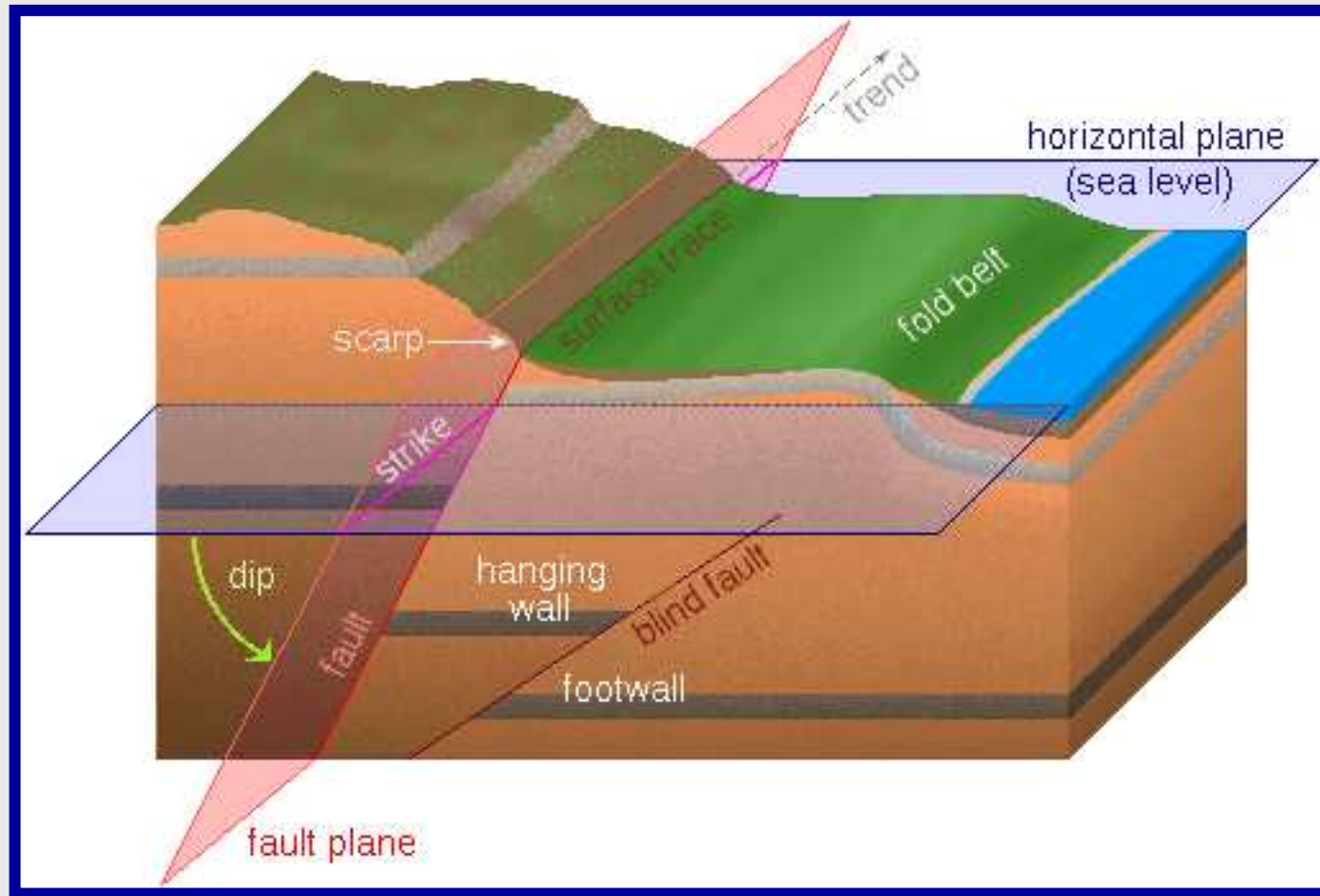
## **Dip:**

The angle between a geologic surface -- for example, a fault plane -- and the horizontal. The direction of dip can be thought of as the direction a ball, if placed upon the tilted surface, would roll. Thus, a ball placed on a north-dipping fault plane would roll northward

## **Strike:**

The direction, or trend, of the line marking the intersection of a fault plane (or another planar geologic feature) with the horizontal. Strike is always at a right angle to dip.

# Geological Features: Faults



90° dip = vertical fault plane

0° strike = North parallel fault plane

# Terminology related to faults

## **Hanging wall**

Of the two sides of a fault, the side above the fault plane. It is called the hanging wall because where inactive faults have been "filled in" with mineral deposits and then mined, this is the side on which miners can hang their lanterns

## **Footwall**

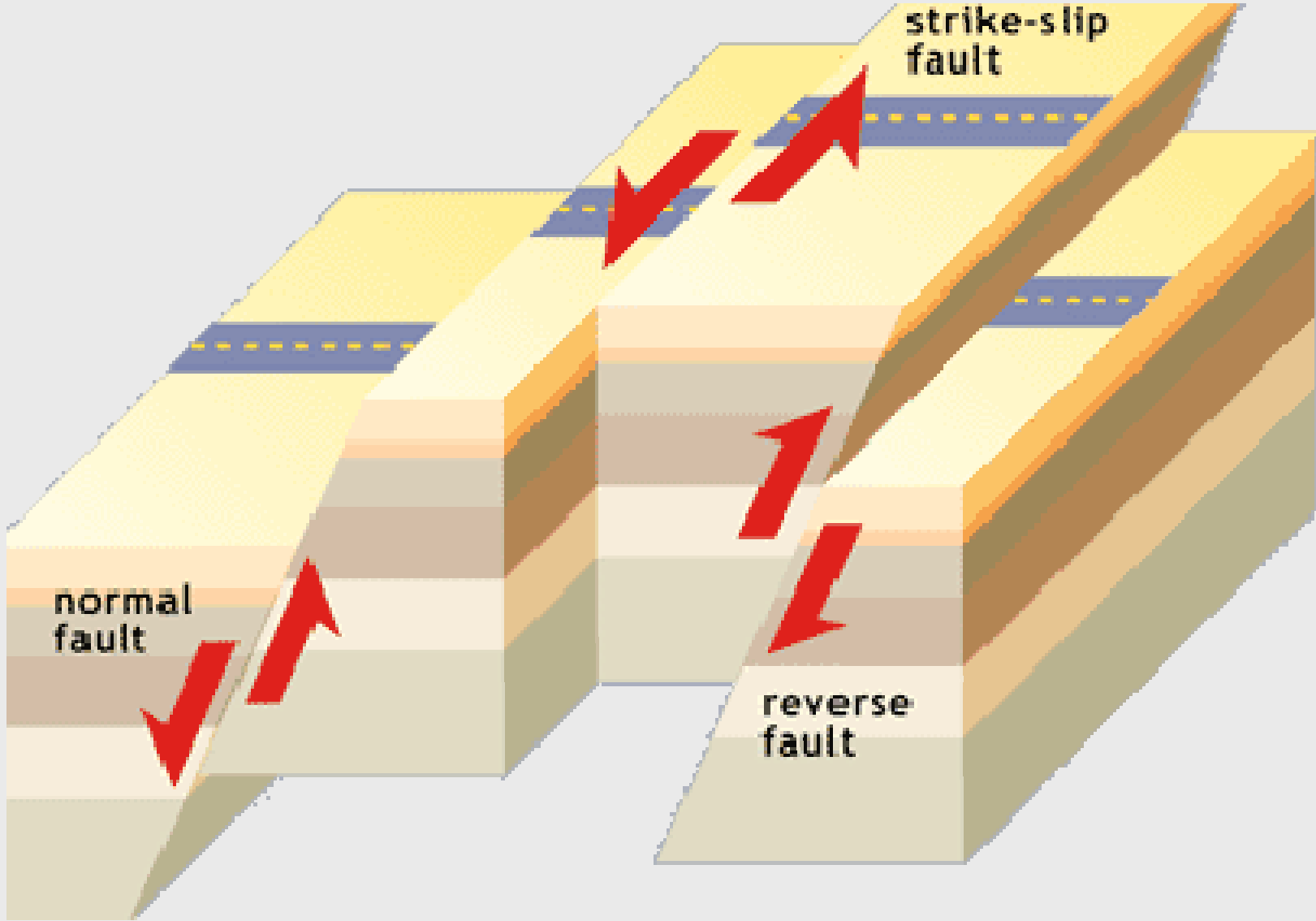
Of the two sides of a non-vertical fault, the side below the fault plane. It is called the footwall because where inactive faults have been "filled in" with mineral deposits and then mined, this is the side on which miners walk

# Faults Type

Faults can be divided into three categories

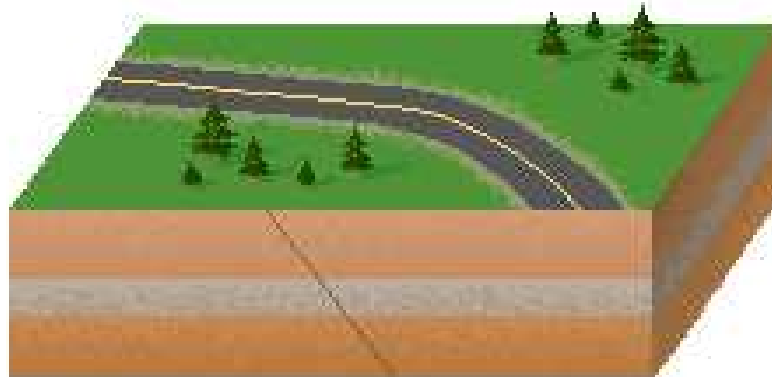
- 1) Dip-Slip Faults:** Fault surfaces are inclined (i.e. not vertical, not horizontal). Motion is up or down along fault
  - i. Normal or Listric** -Hanging block moves down
  - ii. Reverse or Thrust** -Hanging block moves up
  
- 2) Strike-Slip Faults:** Fault surfaces are vertical. Motion is horizontal
  - i. Right-Lateral**
  - ii. Left-Lateral**
  
- 3) Oblique-Slip Faults:** Fault surfaces are inclined. Motion up and down and horizontal. Combination of Dip-Slip and Strike-Slip Motion

# Faults Type



# Normal dip-slip fault

The normal fault is not necessarily normal in the sense that it is common....because.... it is not the most common of faults. However what is normal about them is that their movement tends to follow the gravitational pull on the fault blocks involved.



Hanging wall moves down

# Normal dip-slip fault



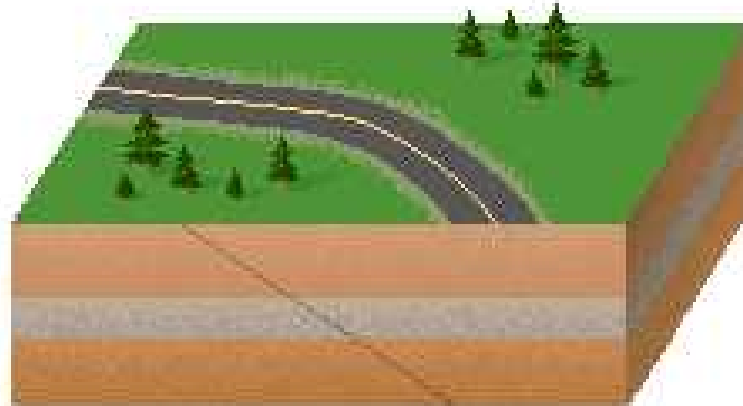


# Normal dip-slip fault

- **The fault plane on the normal fault is generally very steep.**
- **In a normal fault the two involved blocks are (by gravity) pulling away from one another causing one of the fault blocks to slip upward and the other downward with respect to the fault plane (it is hard to determine whether both or just one block has moved.).**
- **The exposed upward block forms a cliff-like feature known as a fault **scarp**. A scarp may range from a few to hundreds of meters in height and their length may continue for 300 or more kilometers (around 200 miles).**

# Reverse dip-slip fault

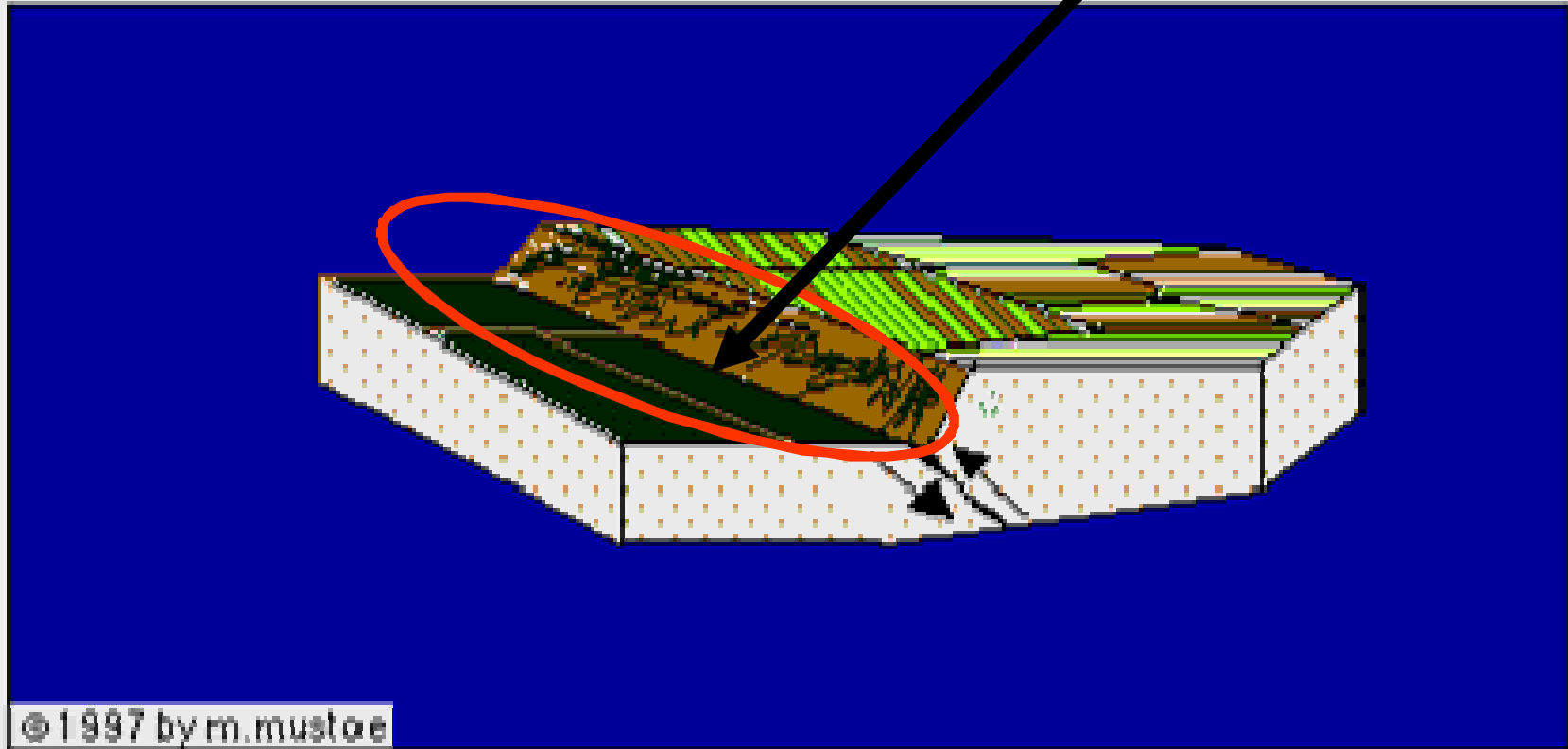
- The reverse fault is a normal fault except the general movement of the fault blocks is toward each other, not away from each other as in the normal fault.
- This forms a **Thrust** fault type expression on the surface with material overlaying other material



Hanging wall moves up

# Normal dip-slip fault

Scarp



# Normal dip-slip fault



## **Normal dip-slip fault**

- **They are normally associated with areas of folded surfaces and or mountainous regions.**
- **The dip angles of thrust faults are normally not as steep as a normal fault.**
- **In the 1994 Northridge, California event, a deep thrust fault located about 18 km under the city of Los Angeles produced an earthquake that registered a magnitude of 6.7.**

## Normal dip-slip fault

The Sierra Nevada in California is bounded on the east by a great fault scarp that produced a magnitude 8 earthquake in 1872. The scarp rises over 10,000 feet. Mount Whitney, highest point in the conterminous U.S., is just out of the picture to the left.



# Normal dip-slip fault

## (Real Example)

- The night of 17 August , 1959 marks the anniversary of a little talked about yet profoundly significant earthquake known as the Hebgen Lake, or Montana-Yellowstone Earthquake.
- On that night nearly 18,000 campers and park personnel, felt a shock that had originated ten miles below the surface in the vicinity of the Madison River Canyon.
- As a result of that 7.1 magnitude earthquake, 43 million cubic yards of rock slid as a block into the Madison Canyon damming up the Madison River, below Hebgen Dam.

# Normal dip-slip fault

## (Real Example)

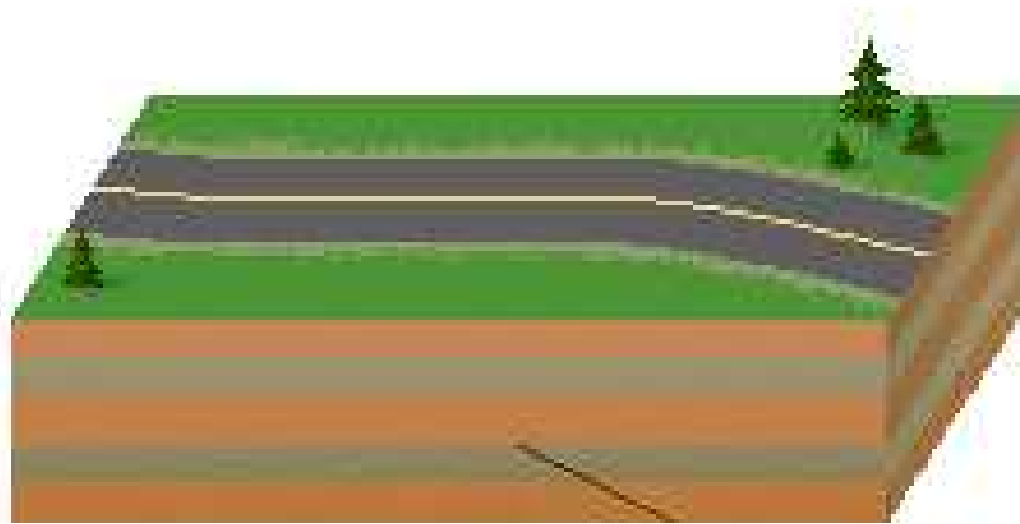
- The lake basin behind Hebgen dam tilted with the south side rising and the north side dropping.
- This caused a seiche...a lake tsunami...that crested the dam four times and kept the lake in motion for nearly 11 hours.
- The shock wave was felt in an area of 500,000 square miles. It caused wells to fluctuate in Texas and as far away as Hawaii and Puerto Rico.
- Nine people lost their lives and 19 were listed as missing in this event.



## Blind thrust fault

- A shallow-dipping reverse fault which terminates before it reaches the surface. When it breaks, therefore, it may produce uplift, but never any clear surface rupture.
- Many still-unknown blind thrust faults may exist in southern California. Two examples of known blind thrust faults: the Elysian Park Thrust, which runs underneath downtown Los Angeles and the Northridge Thrust Fault, which ruptured in the 1994 Northridge quake.

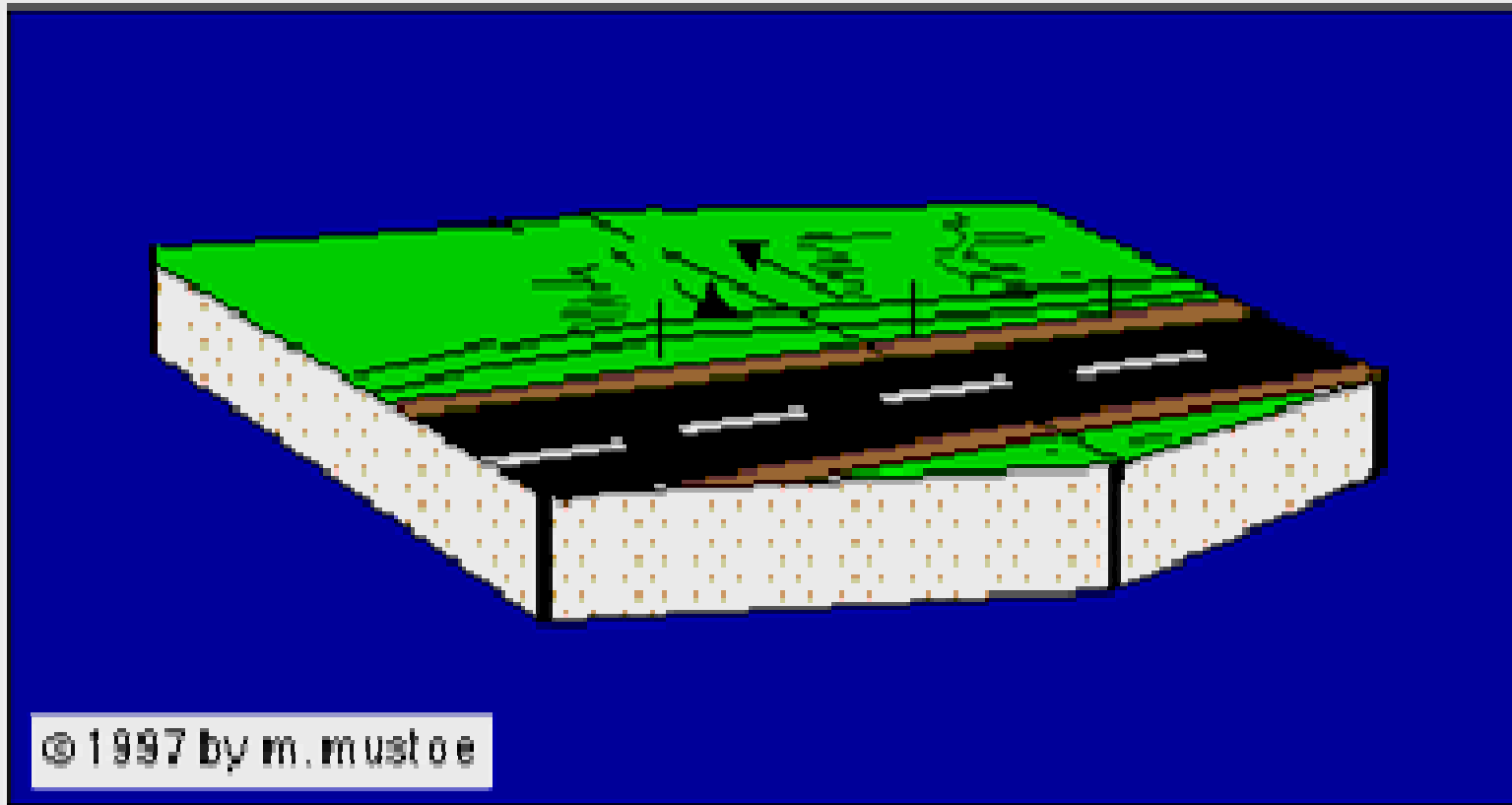
# Blind thrust fault



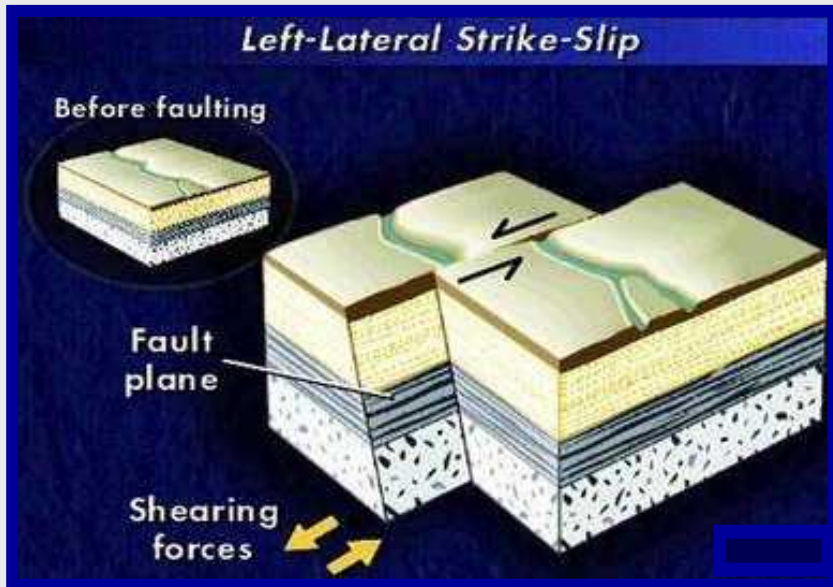
## Strike slip fault

- Movement on a strike slip fault is generally horizontal.
- On the surface, scarps form as hills crossing the fault zone are torn apart by movement over time. Actually anything crossing this fault zone is either slowly torn apart, or offset.
- Probably the most well known and well studied fault is the transcurrent (strike-slip) fault known as the San Andreas fault of California.
- This fault marks the margin line between the Pacific and North American Plates.
- Rivers crossing the fault line are called offset streams and are classic signatures of fault activity along the San Andreas. These faults can be very long, the San Andreas is nearly 600 miles long.

# Strike slip fault



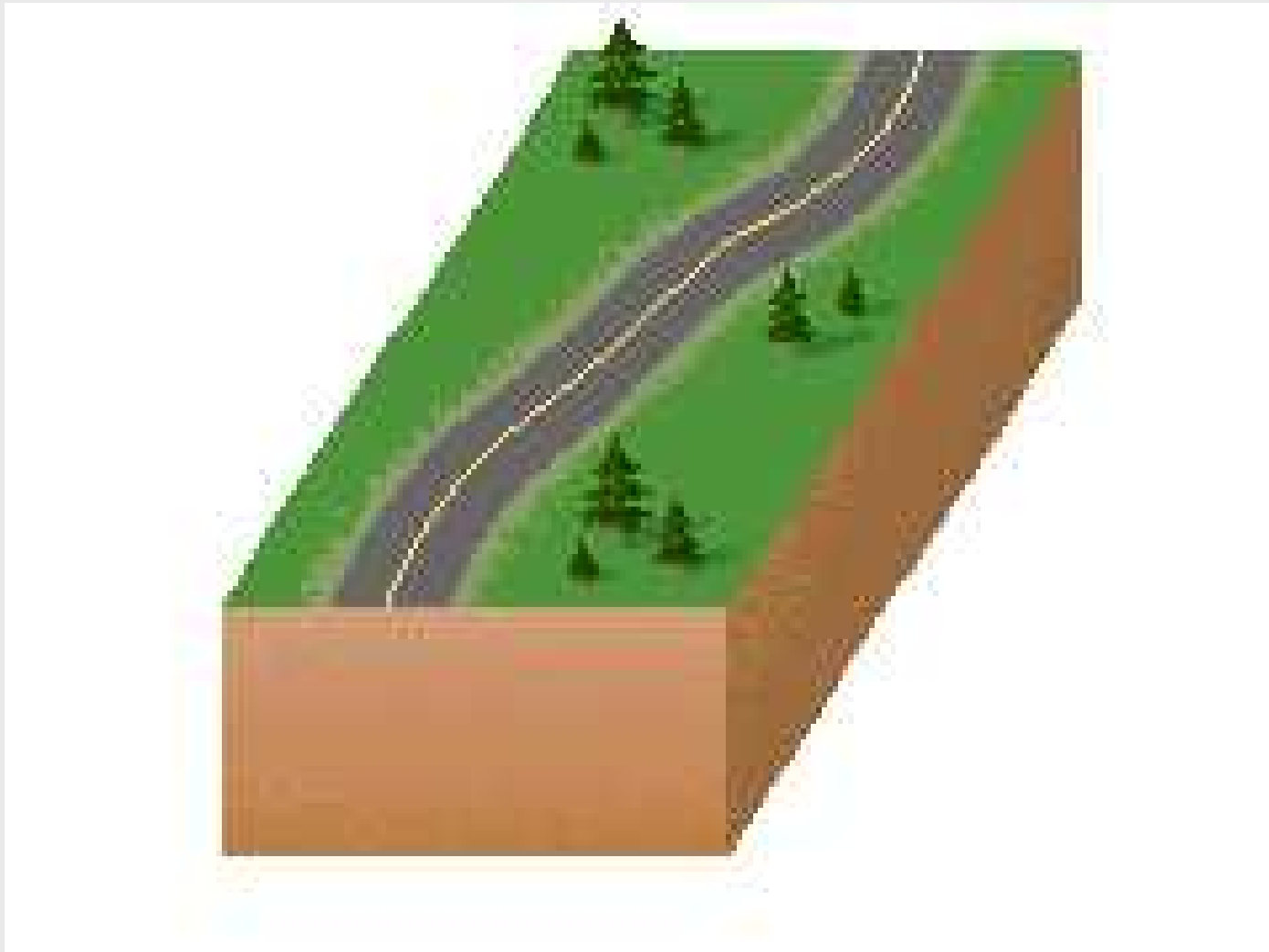
# Strike slip fault



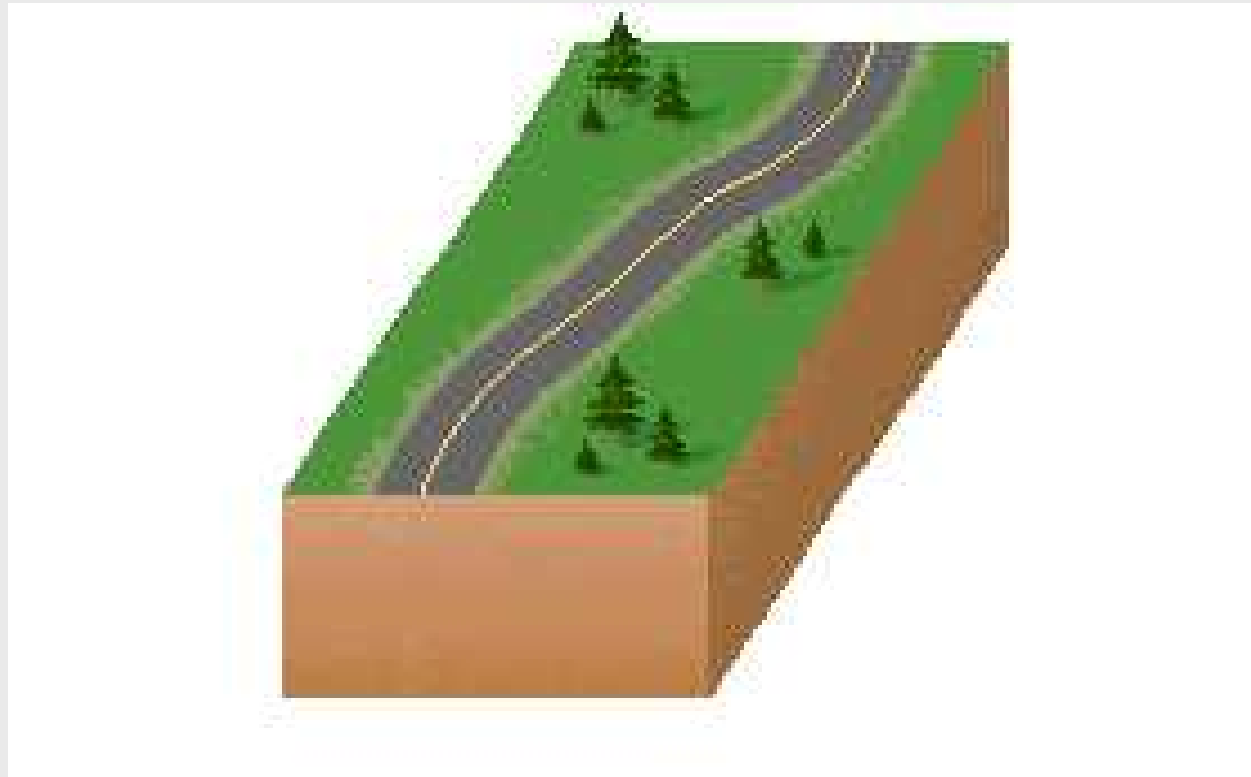
Displacement in horizontal direction



## Strike-Slip Fault – Left Lateral

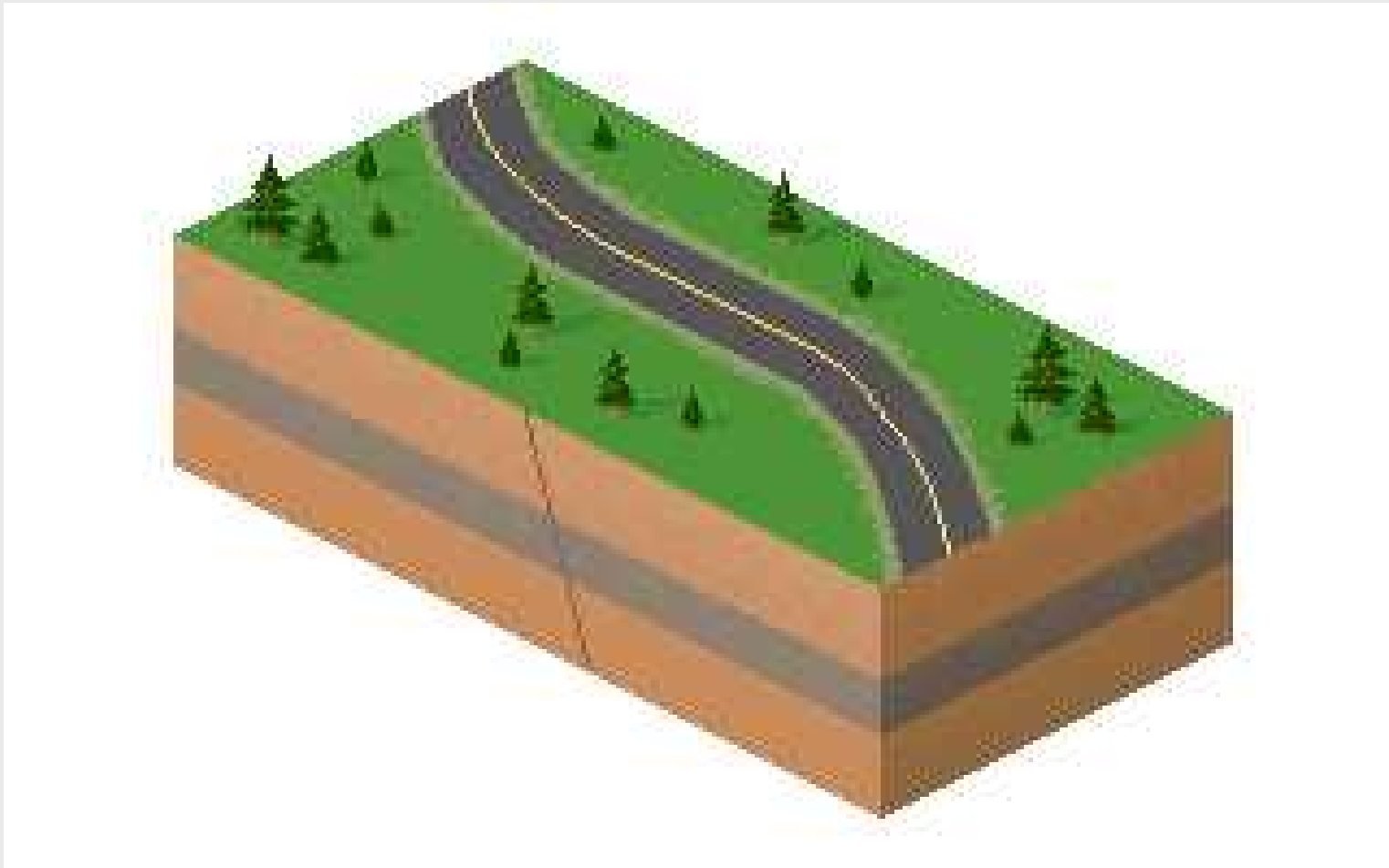


## Strike-Slip Fault – Right Lateral



## Oblique-slip fault

Displacement in both vertical and horizontal directions

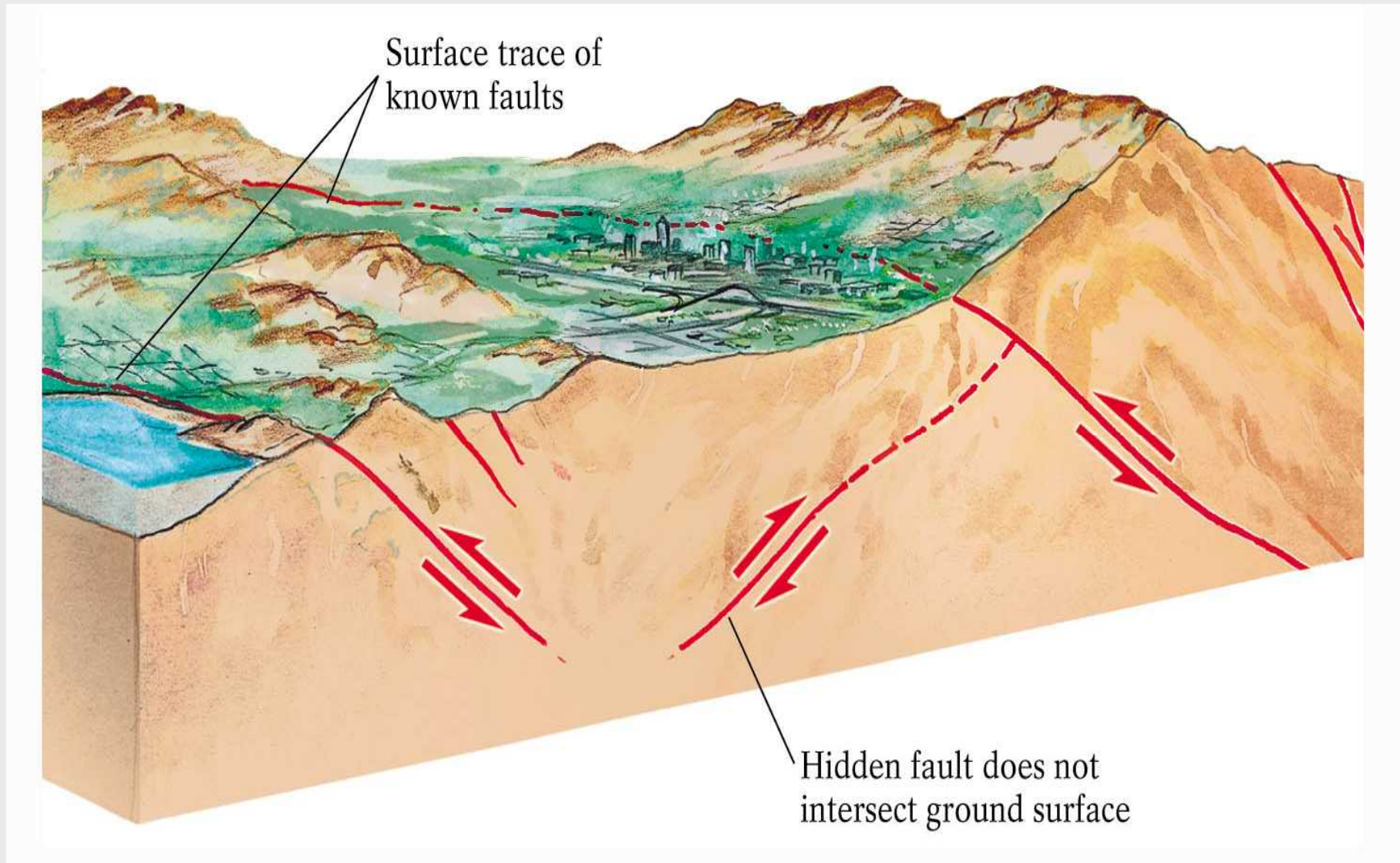




# Oblique-slip fault

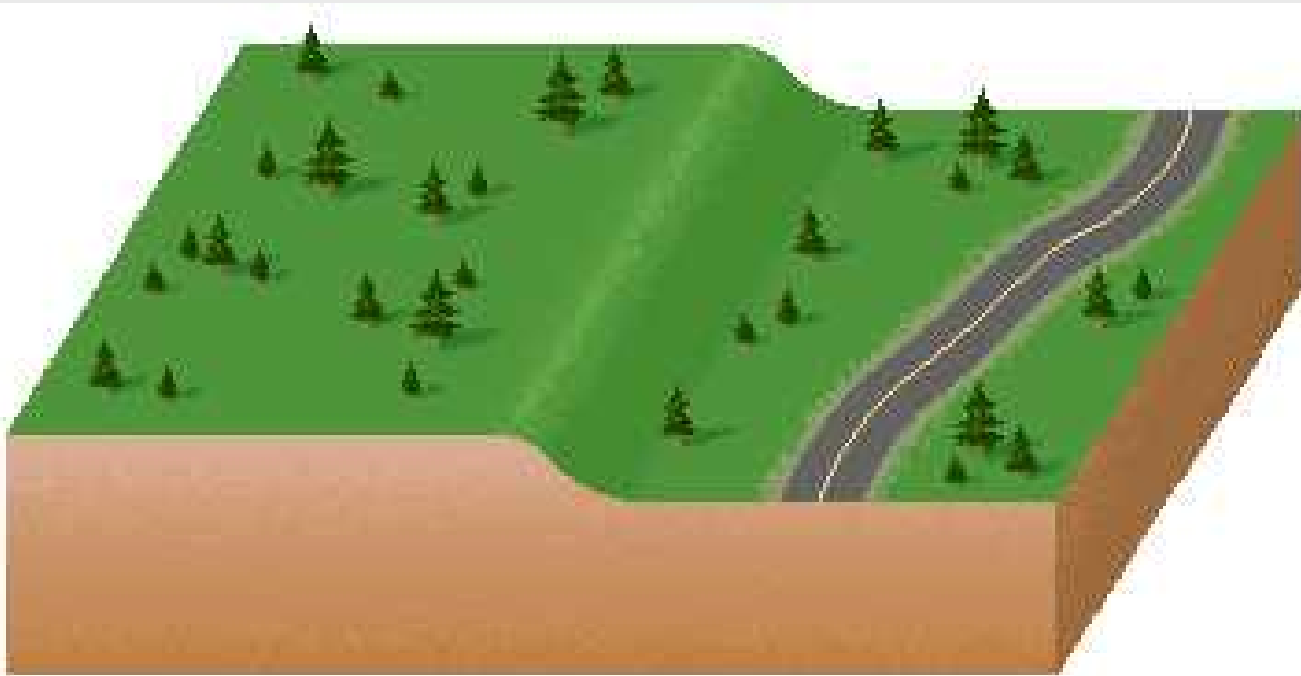


## Blind/Hidden faults



# SCARP FORMATION

Scarps can be created by non-vertical motion. (More generally, apparent offset does not always equate with actual displacement.)



## Sequence of Events

- 1) Tectonic loading of faults
- 2) Earthquakes
- 3) Seismic waves
- 4) Shaking (ground motion)
- 5) Structural failure

# Geological Structures: Joints

## **Joints:**

Joints are cracks or fractures present in the rocks along which there has been no displacement. Joints occur in all types of rocks. They may be vertical, inclined or even horizontal. Their dip and strike are measured in the same way as that of sedimentary strata.

**Formation of Joints:** Joints are formed as a result of contraction due to cooling or consolidation of rocks. They are also formed when rocks are subjected to compression or tension during earth movements.

# Classification of joints

## **Tension Joints:**

Tension joints are those which are formed as a result of tensional forces. These joints are relatively open and have rough and irregular surfaces.

Shear Joints: Shear joints are those which are formed due to shearing stresses involved in the folding and faulting of rocks. These joints are rather clean cut and tightly closed.