

# Forces on rocks...and what happens

Plate tectonics can generate tremendous forces that can

bend

fold &

break rocks

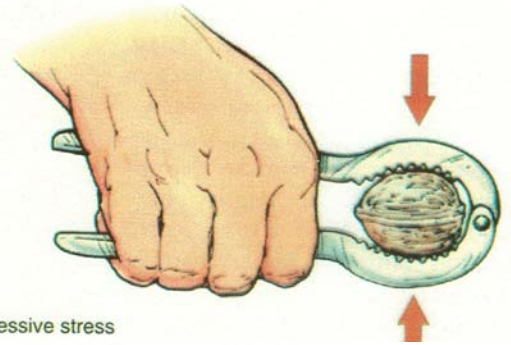
# Stress and strain

***Stress*** is the force applied to a rock

***Strain*** is the resulting deformation  
of the rock

# Types of stress and strain

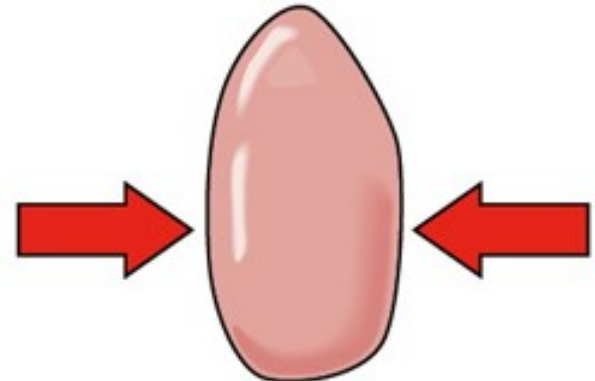
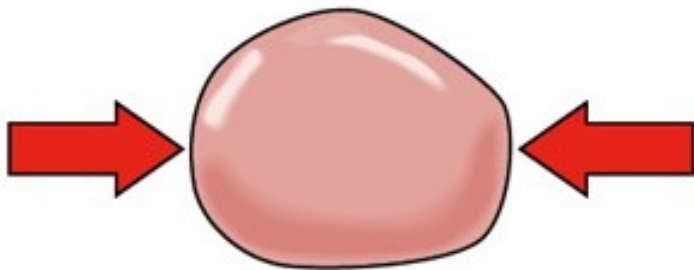
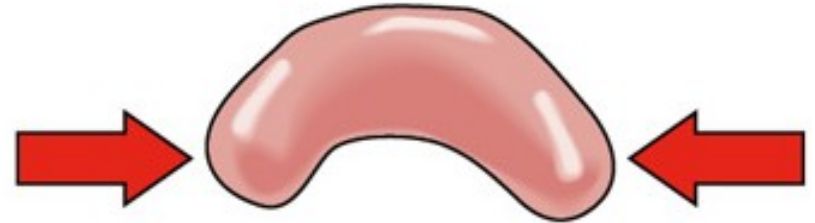
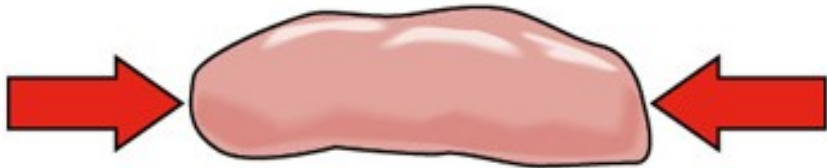
Pushing – *compressional*



(a) Compressive stress

Compressive stress

Shortening strain

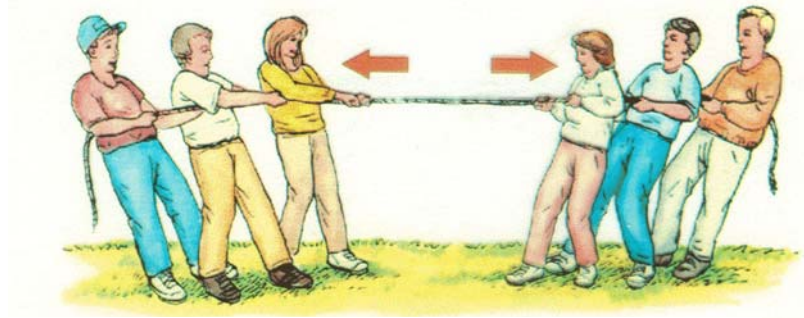


Stress

Strain

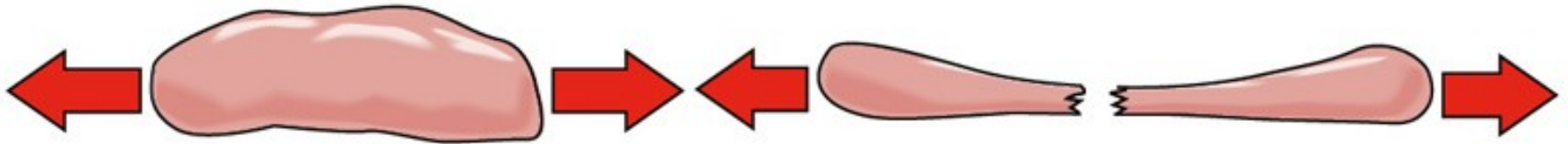
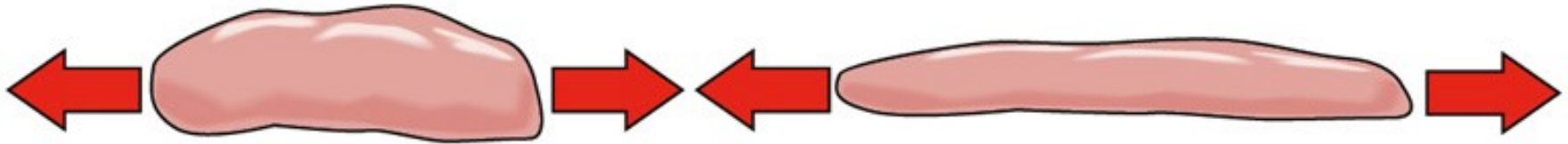
# Types of stress and strain

Pulling – *Extensional*



Tensional stress

Stretching or extensional strain



Stress

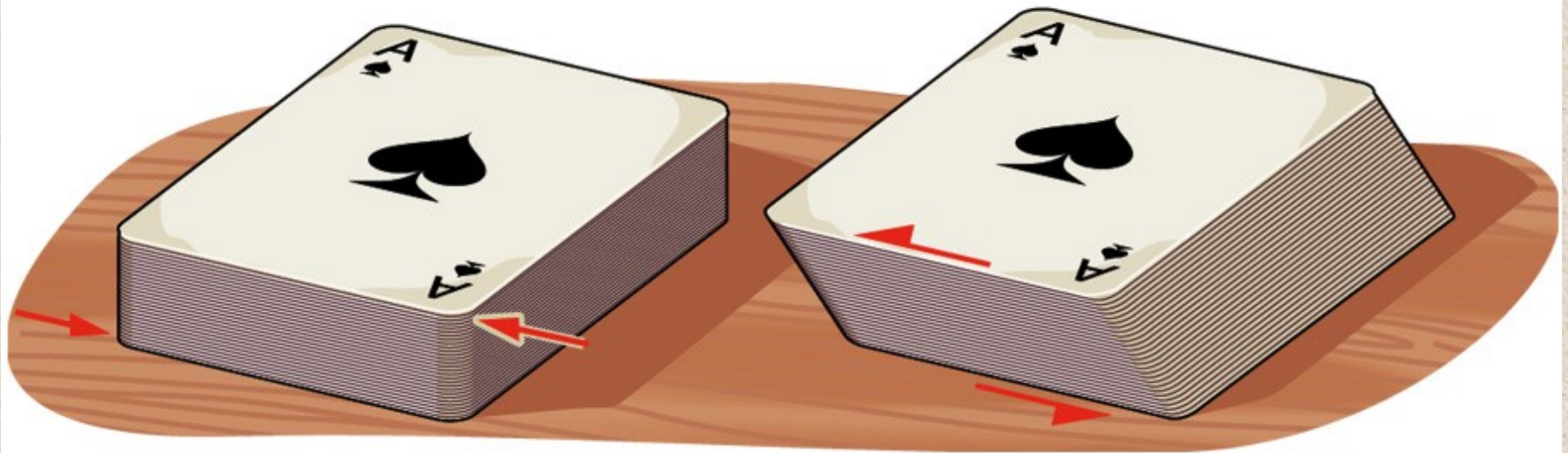
Strain

# Shear stress

Force from two opposing directions

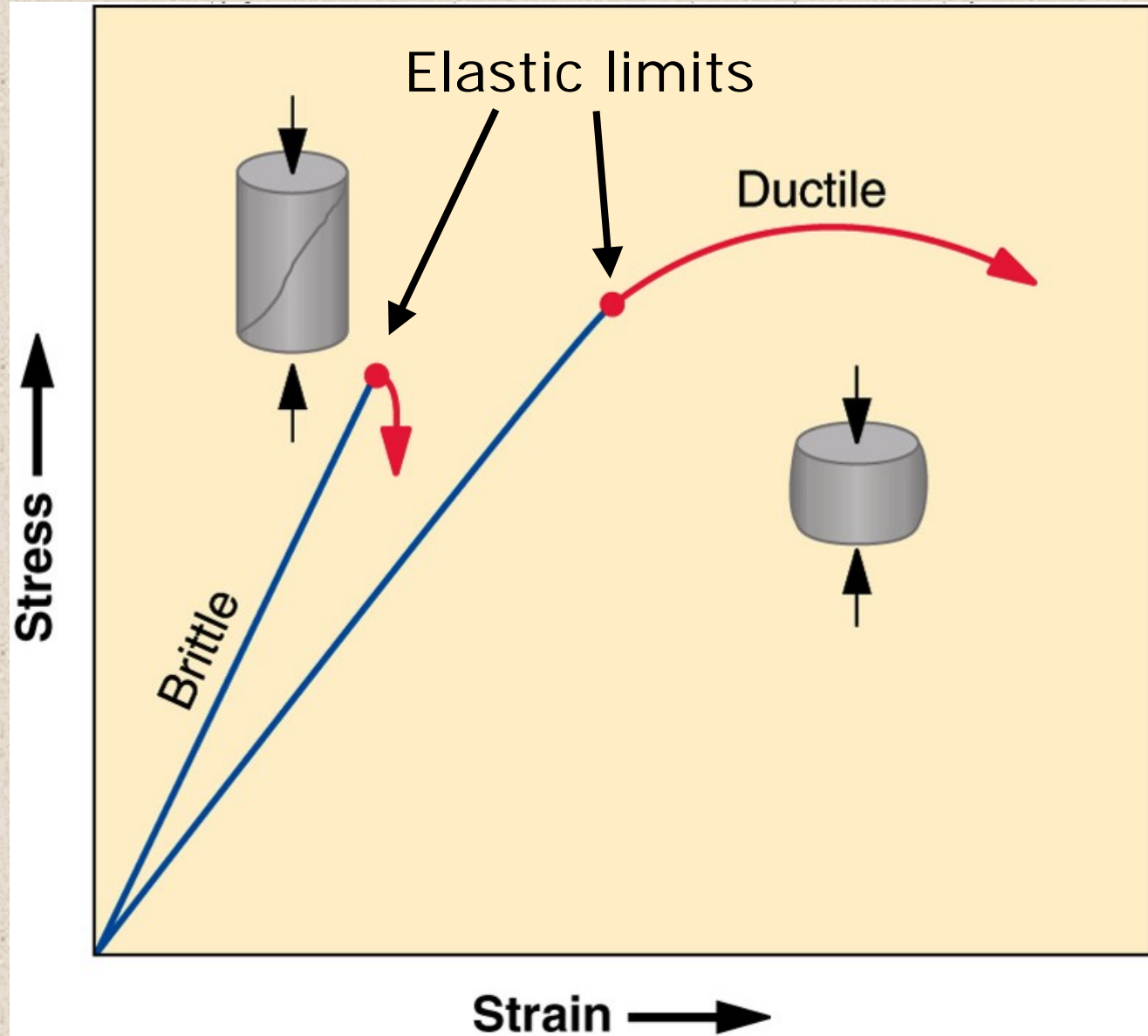
Shear stress

Shear strain



# The elastic limit

Rocks may stretch, but only so far



# The elastic limit

**Elastic** – rock deforms, but can return to its original shape (rubber band)

**Ductile** – rock deforms, but does not return (or plastic) to its original shape (silly putty or toothpaste)

**Brittle** – past the elastic limit, rock breaks (rubber band snaps)

# The Sugar Daddy model

Put one Sugar Daddy in the freezer and one in your pocket

Elastic – Is a Sugar Daddy *elastic* ?

Ductile – Which Sugar Daddy (cold, warm) bends?

Brittle – Which Sugar Daddy snaps?



# The Sugar Daddy model

Applied to rocks of the lithosphere:

Warm rocks – tend to be **ductile** – these will fold

Cold rocks – **brittle** – these will fault

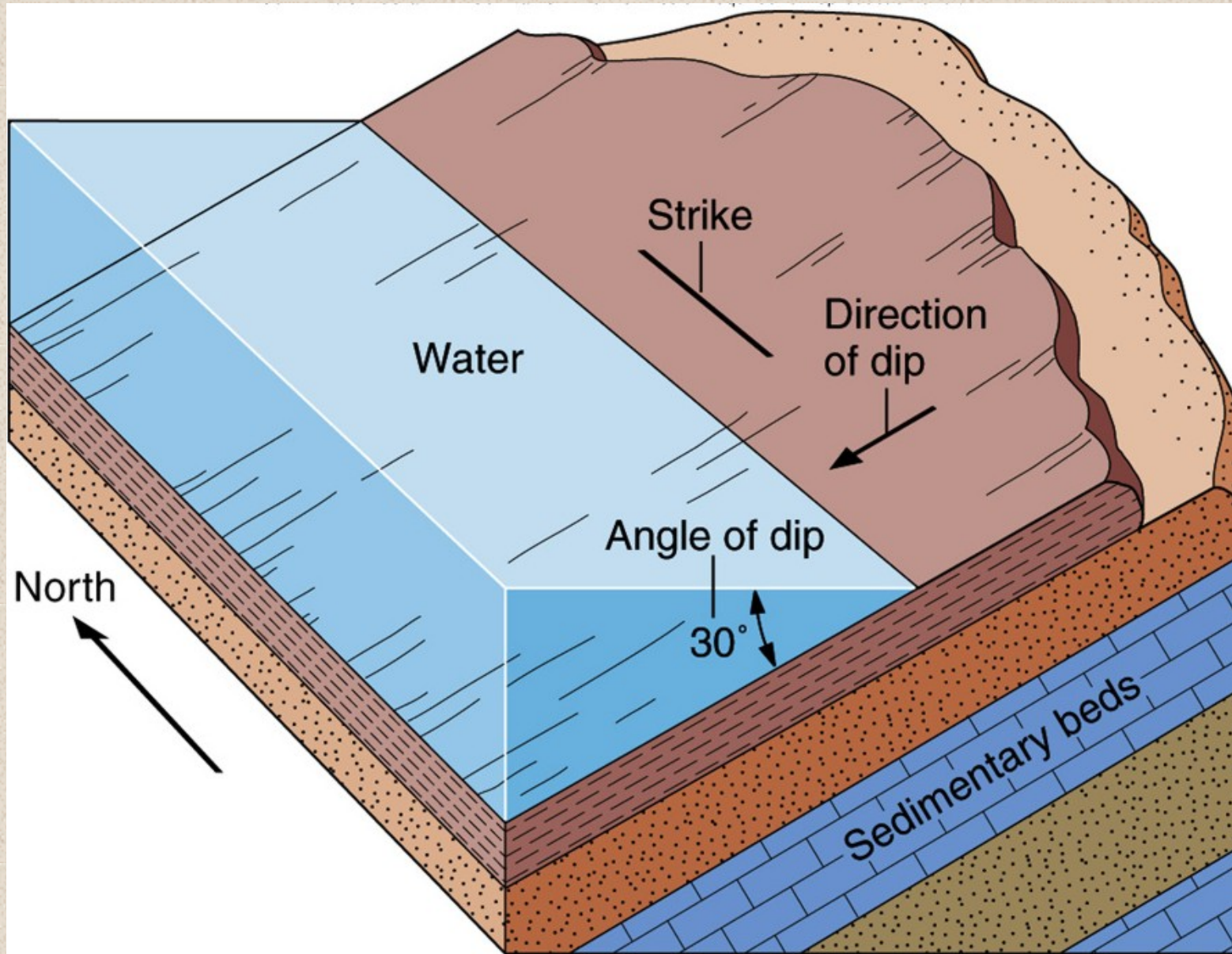
Rocks under high pressure – ductile, fold

Pressure applied slowly – ductile, fold

Pressure applied quickly – snap, earthquake

# Words to explain angles of rocks

**Dip**  
and  
**Strike**



# Words to explain angles of rocks

## Principle of Original Horizontality

most sedimentary rocks were deposited in flat-lying layers

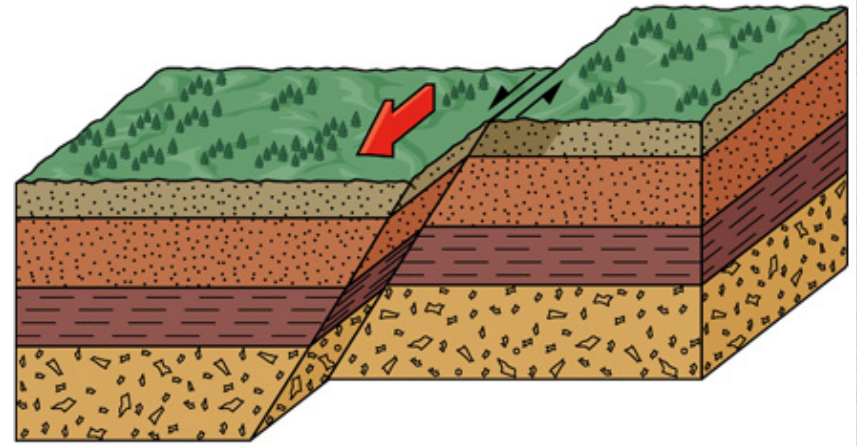
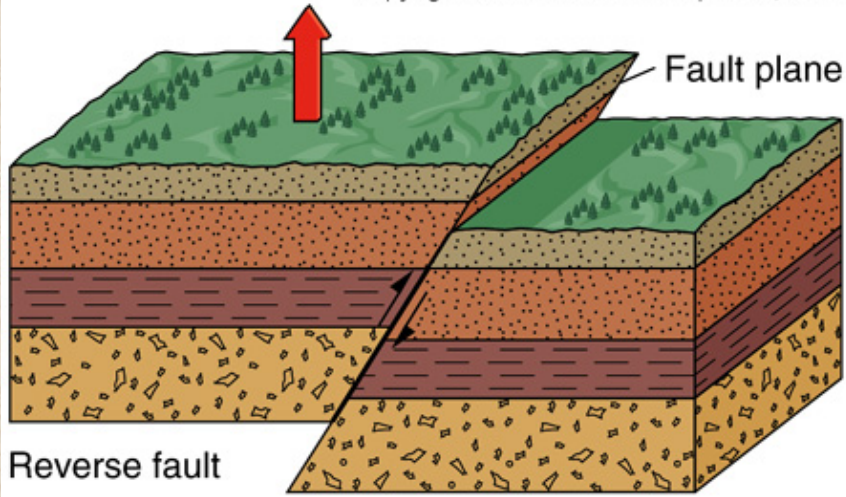
examples: lake bed (ancestral Lake Erie)  
continental shelf

***Dip*** – a marble would roll down this direction  
(and *apparent dip*)

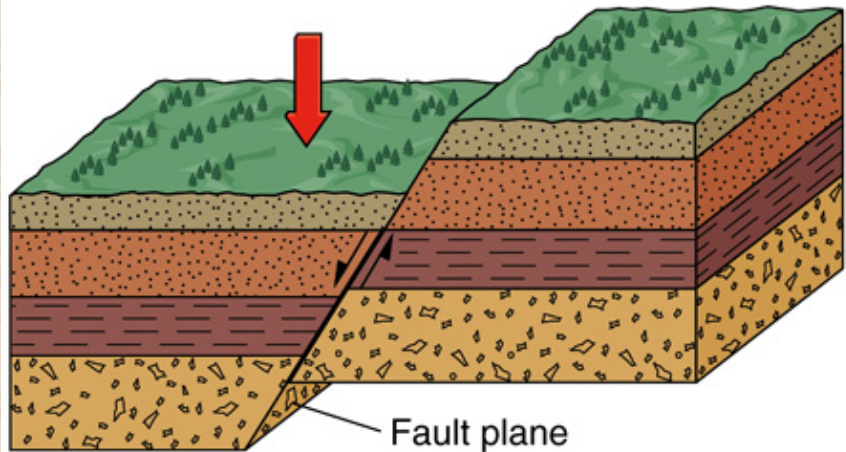
***Strike*** – intersection of the dipping bed and  
a horizontal plane  
(think of water level)

# Types of faults, directions of motion

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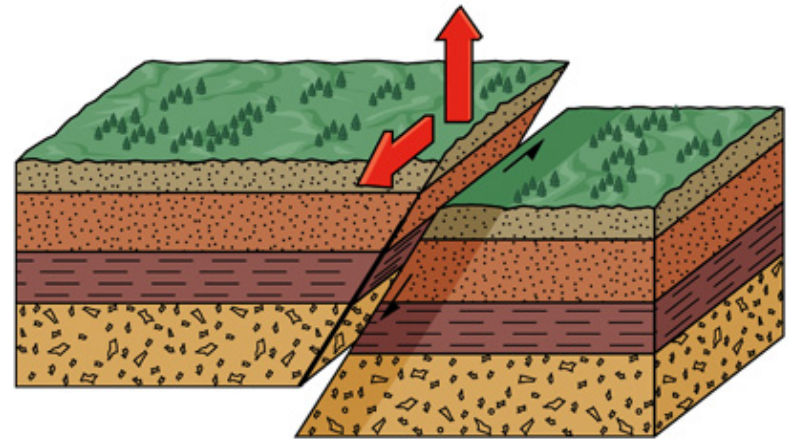


**B** Strike-slip faults



Normal fault

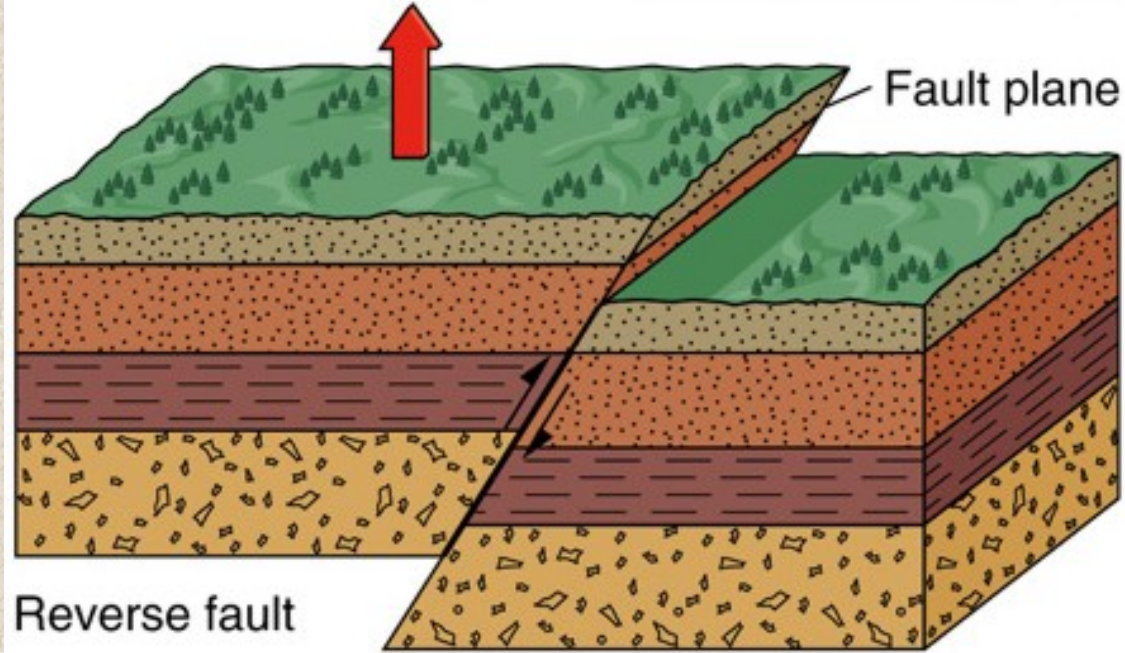
**A** Dip-slip faults



**C** Oblique-slip fault

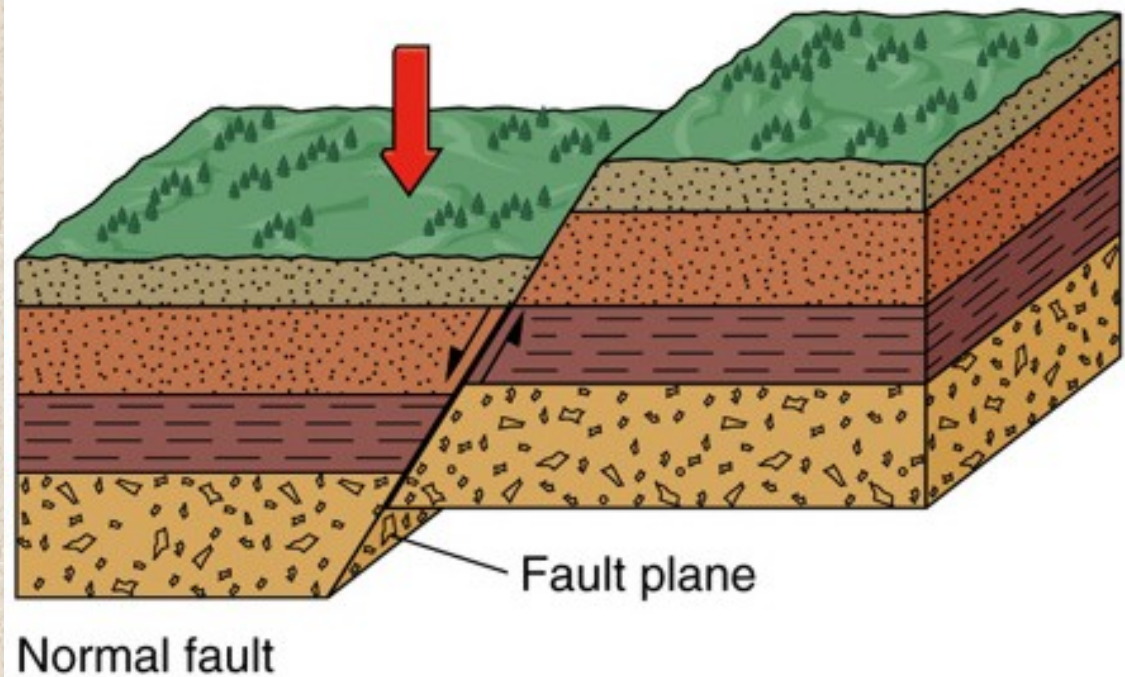
# Dip-slip faults

Reverse fault  
(or thrust  
fault)

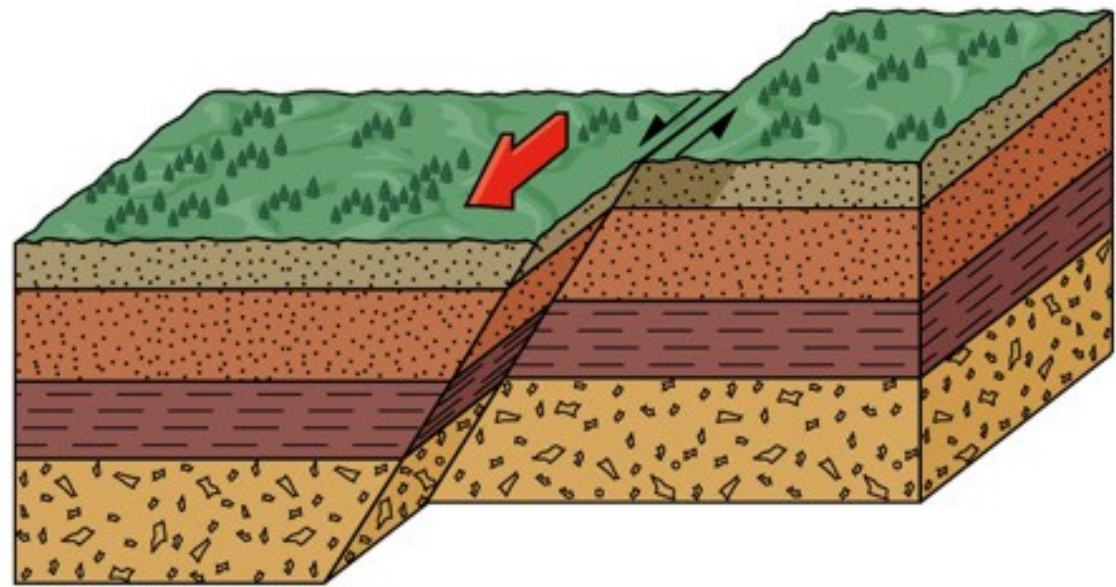


Normal fault

*Vertical movement  
along the  
fault plane*

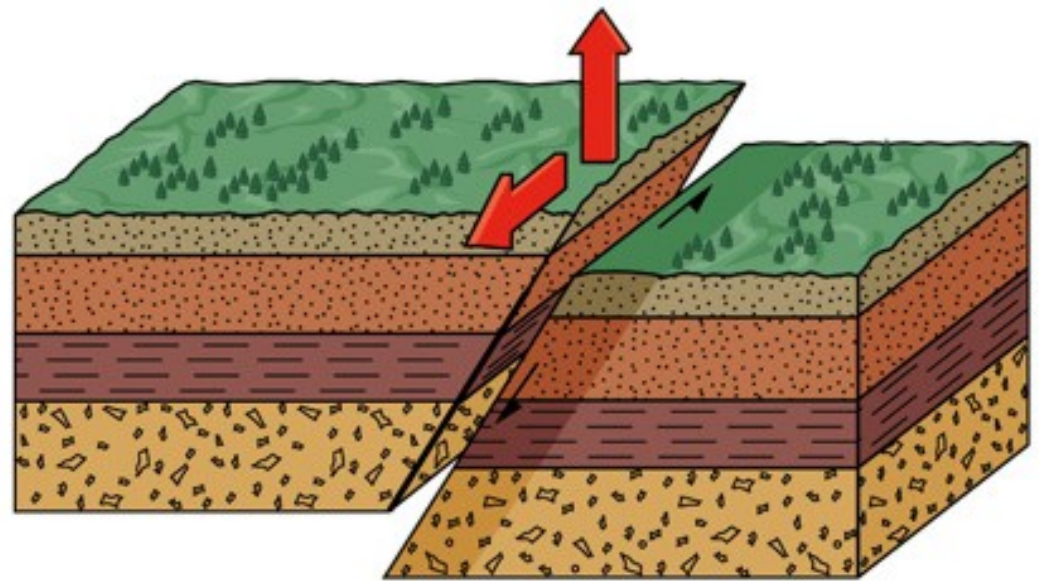


Strike-slip fault



**B** Strike-slip faults

Oblique-slip fault



**C** Oblique-slip fault

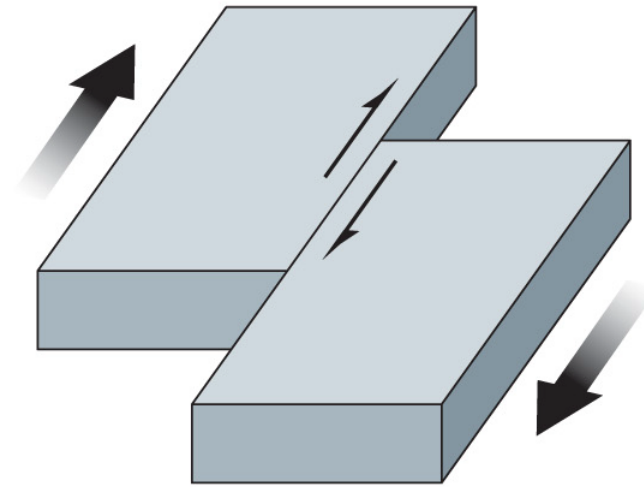
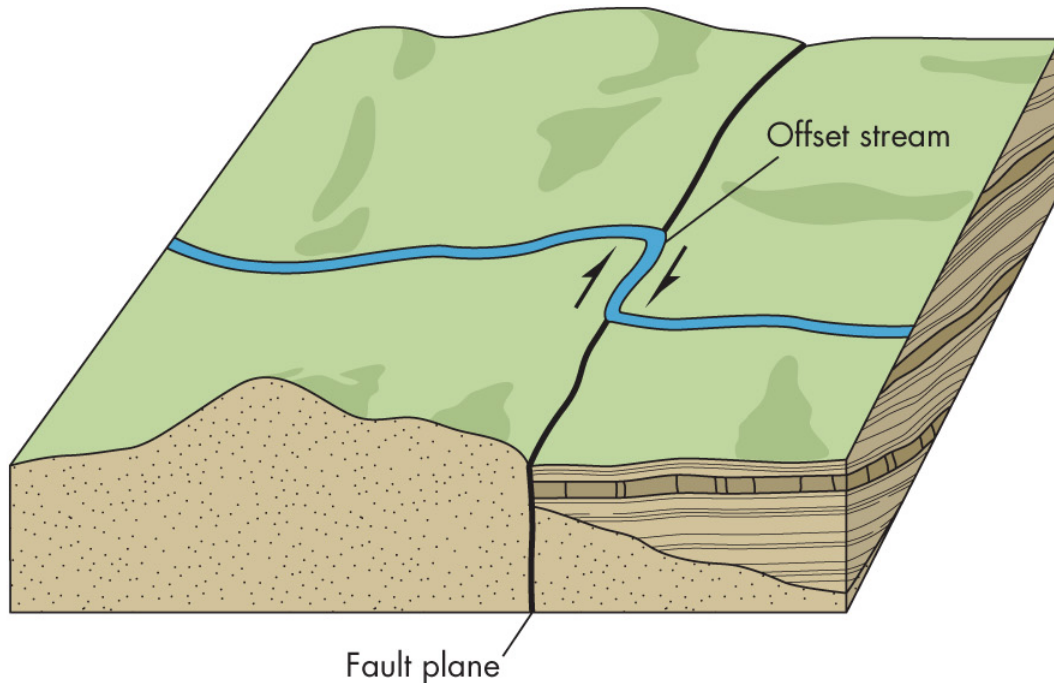
*Lateral movement  
along the  
fault plane*

# Types of strike-slip faults

right-lateral – if you are standing, facing the fault, the other block is moving to your right

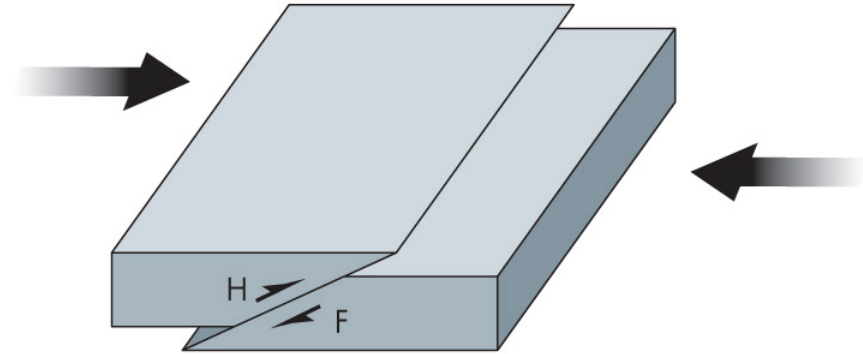
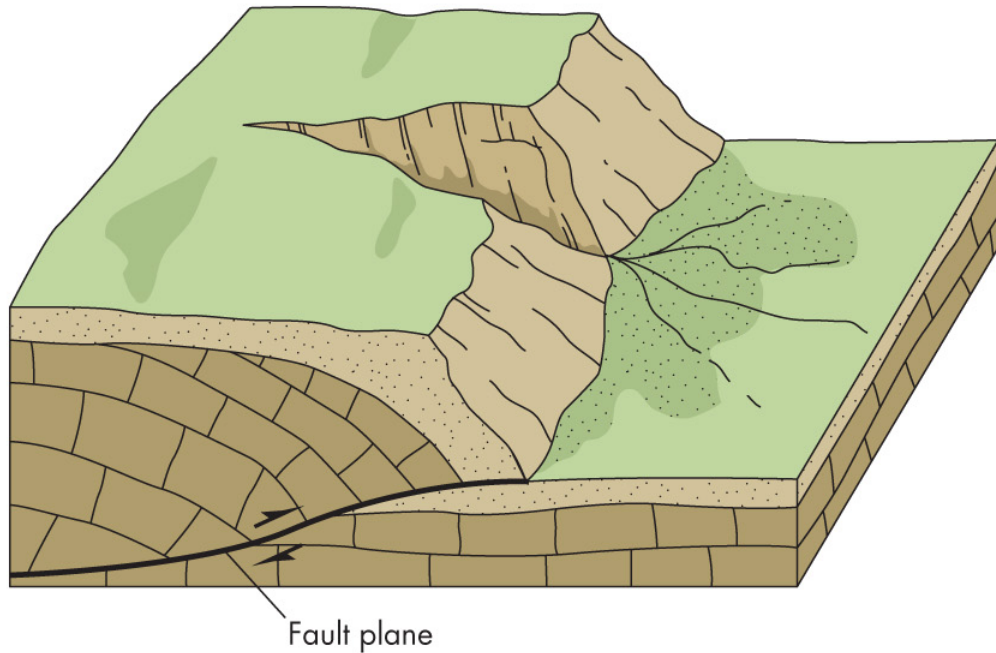
left-lateral – movement to the left

From your book: Which type of fault?

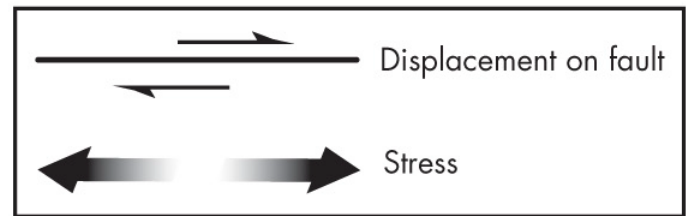
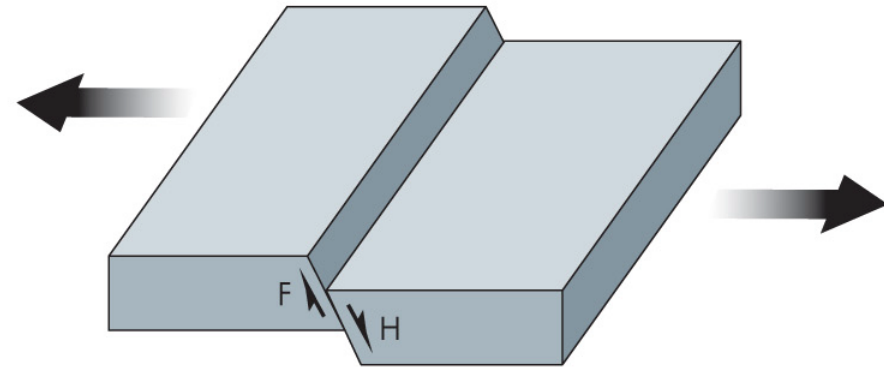
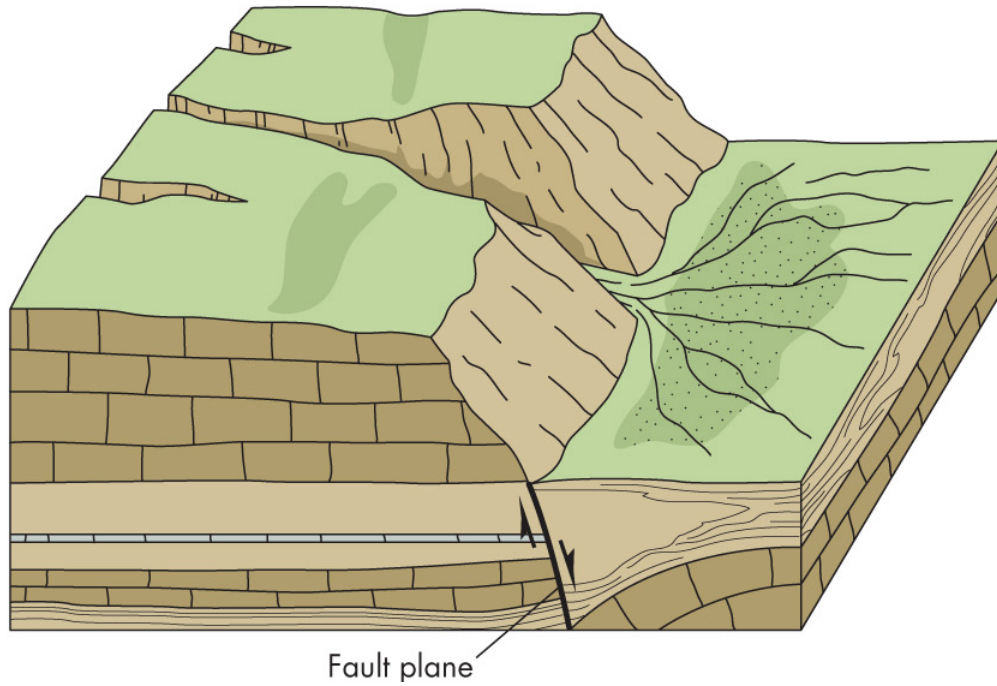




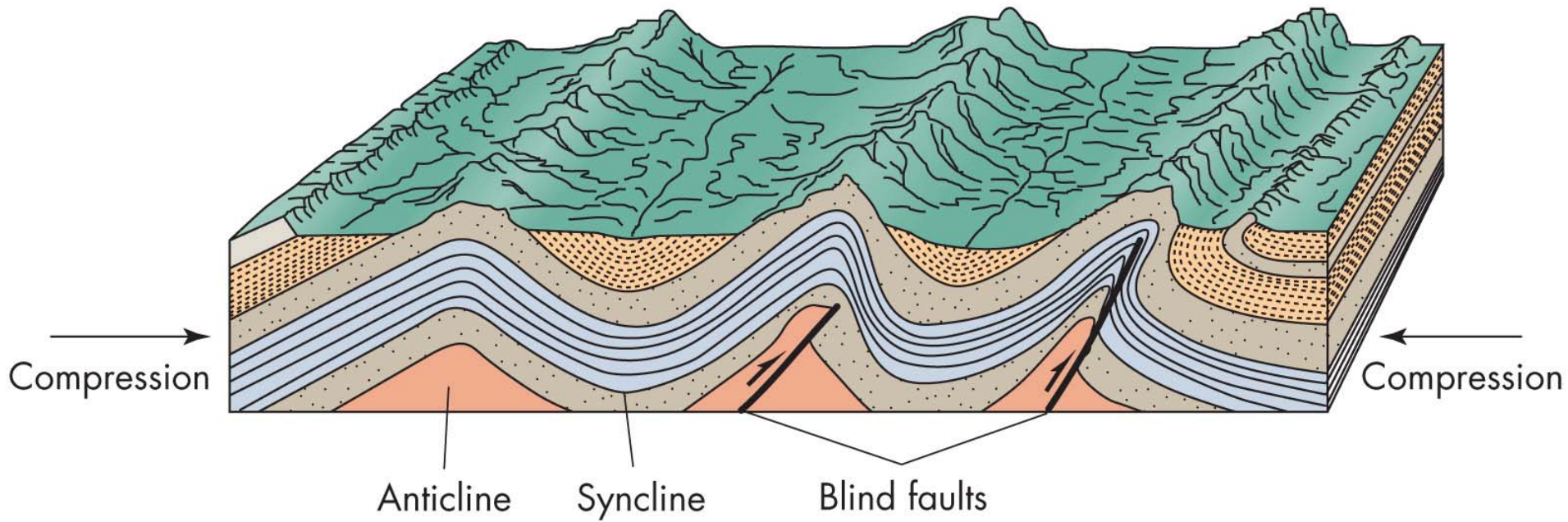
From your book: Which type of fault?



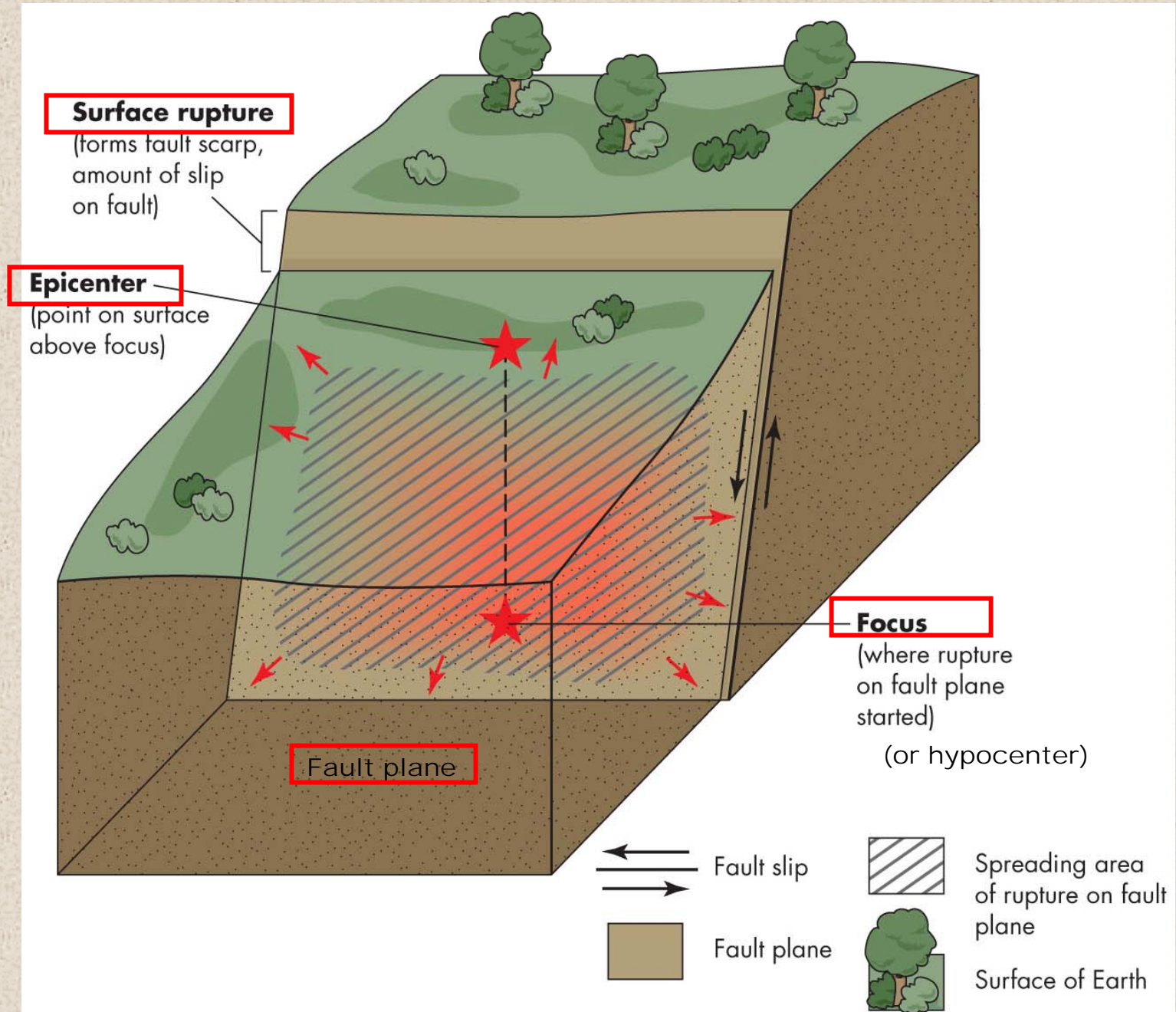
From your book: Which type of fault?



# A blind fault



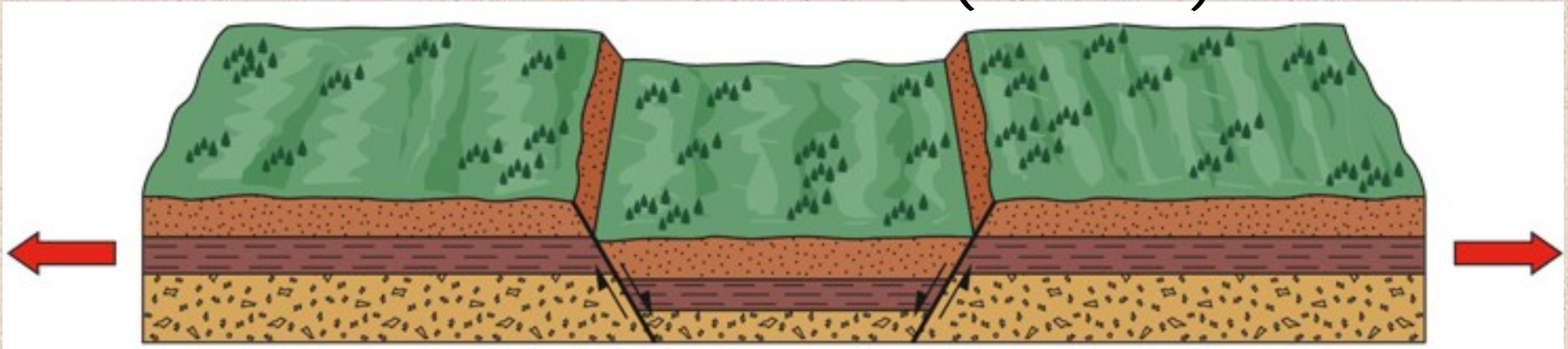
# An earthquake is movement on a fault



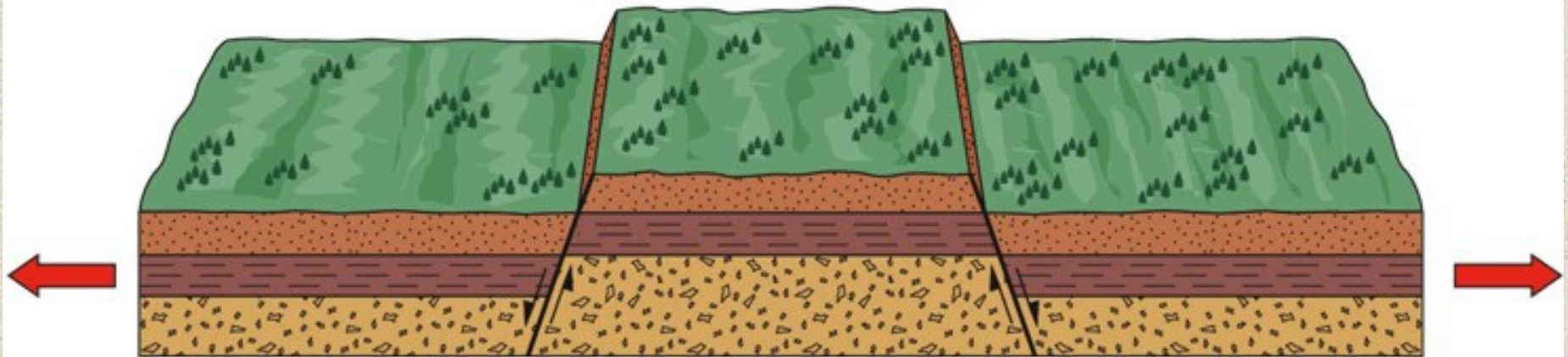
# Animation: Types of faults and motions

Paired faults form structures:

Graben ("ditch")



C Graben



D Horst

Horst



Photo by Diane Carlson

# Examples of faults

**Normal faulting along I-40  
near Kingman, AZ**





# Examples of faults



**Normal fault in the  
Sierra Nevada  
Mountains, CA**

# Examples of faults

Normal fault in the  
Sierra Nevada  
Mountains, CA



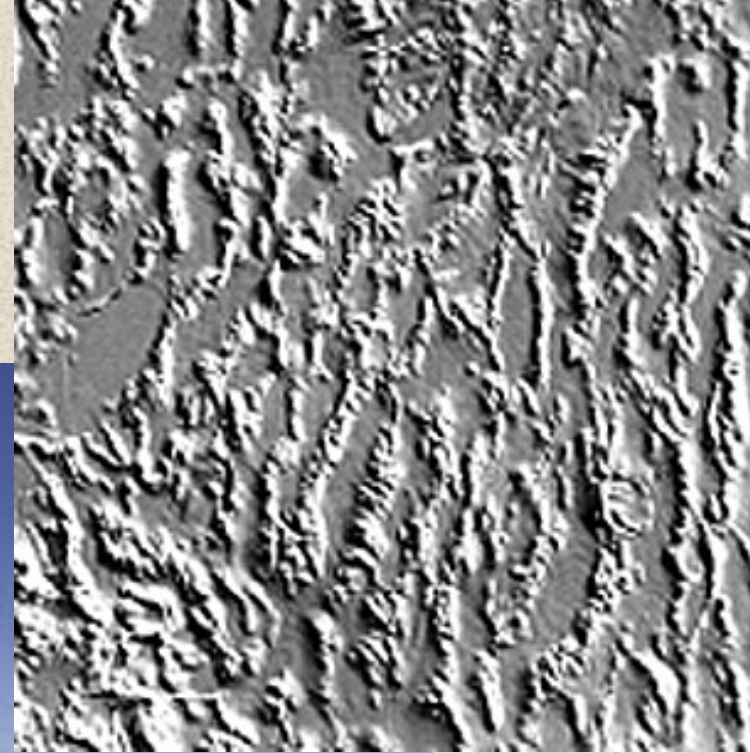
# Normal faults

Ridge and basin created by normal faulting  
Tule Lake, California



# Basin & range

Regional effect of extension

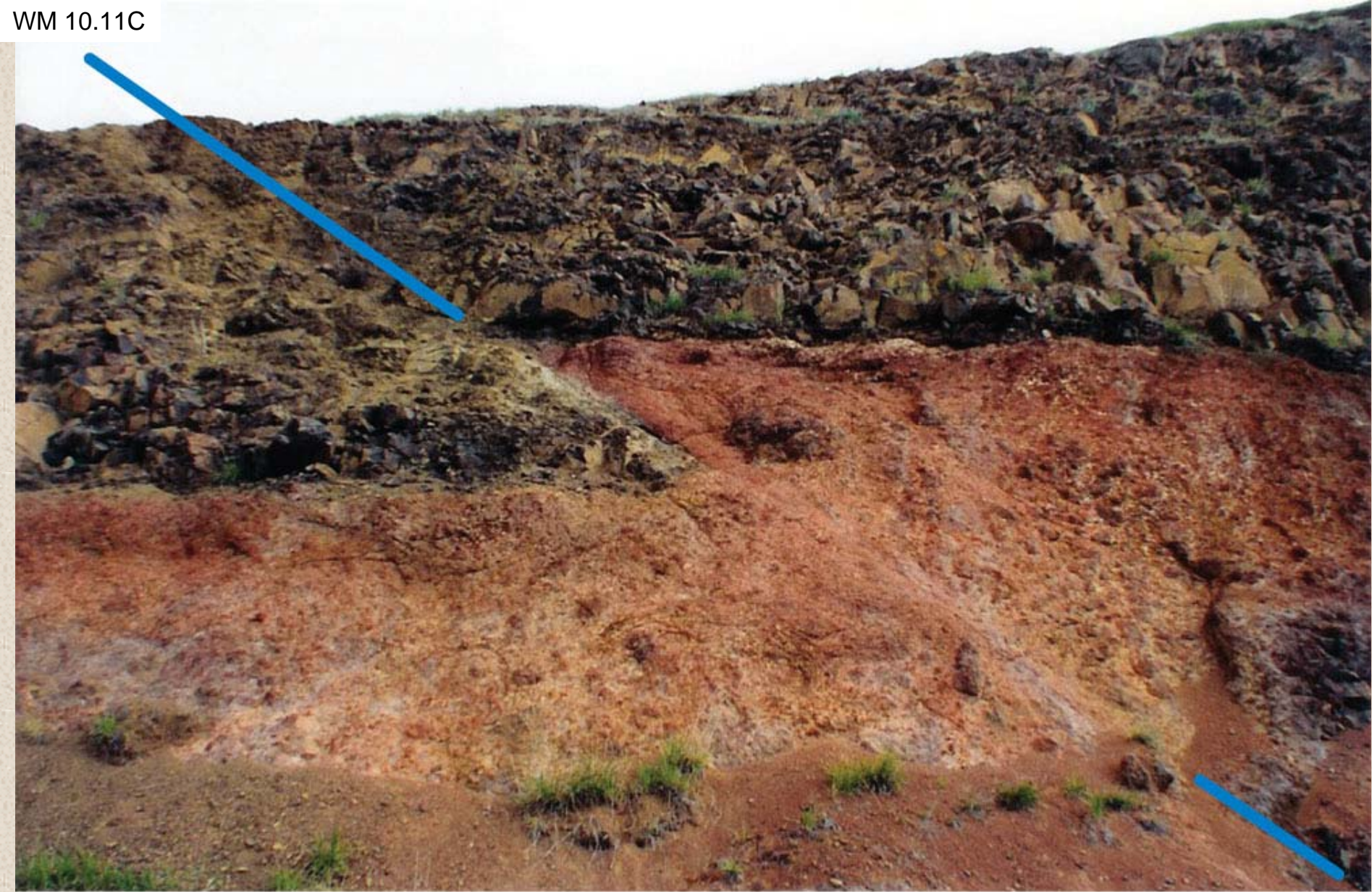




**Reverse faults in the  
San Andreas fault zone  
near Palmdale, CA**



**Reverse fault in the San  
Andreas fault zone,  
Cajon Pass, CA**



Reverse fault in Oregon

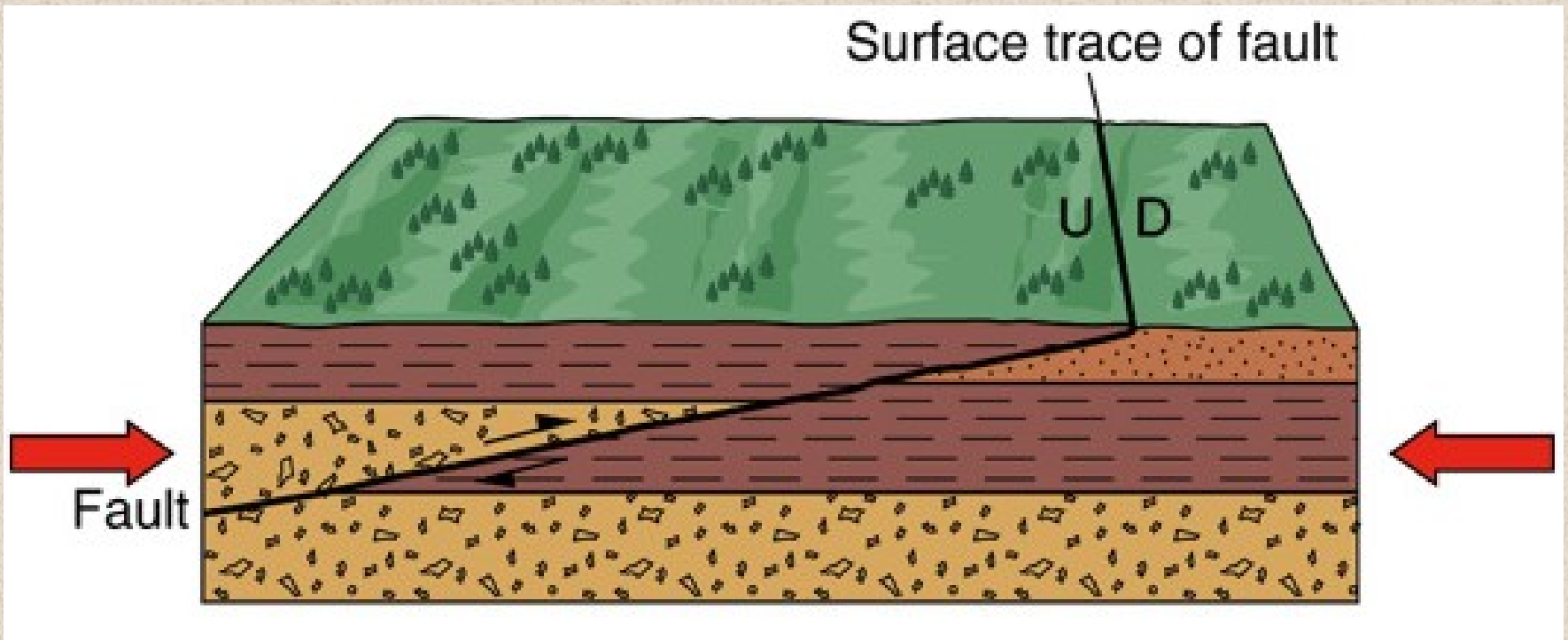


Photo by Diane Carlson



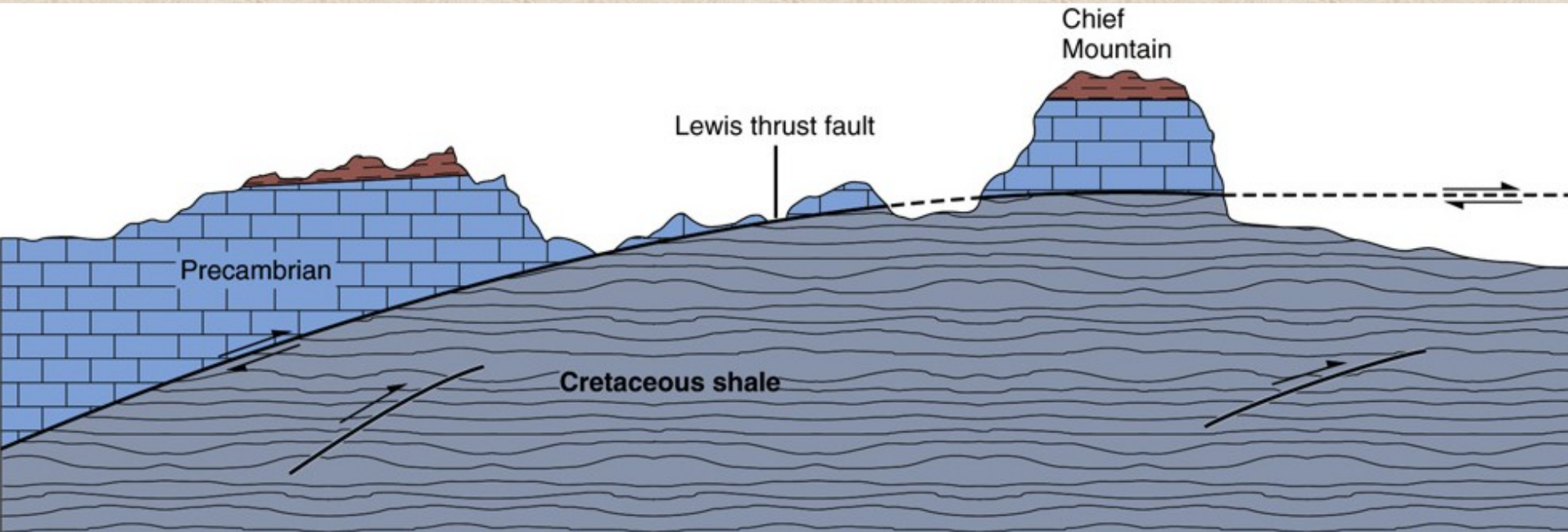
# Low-angle thrust fault

Head-on collision between large tectonic pieces  
Pushed up and over



# Large-scale thrust faults

## Chief Mountain thrust fault in Glacier National Park, Montana



# Large-scale thrust fault

Precambrian



Cretaceous

# Chief Mountain

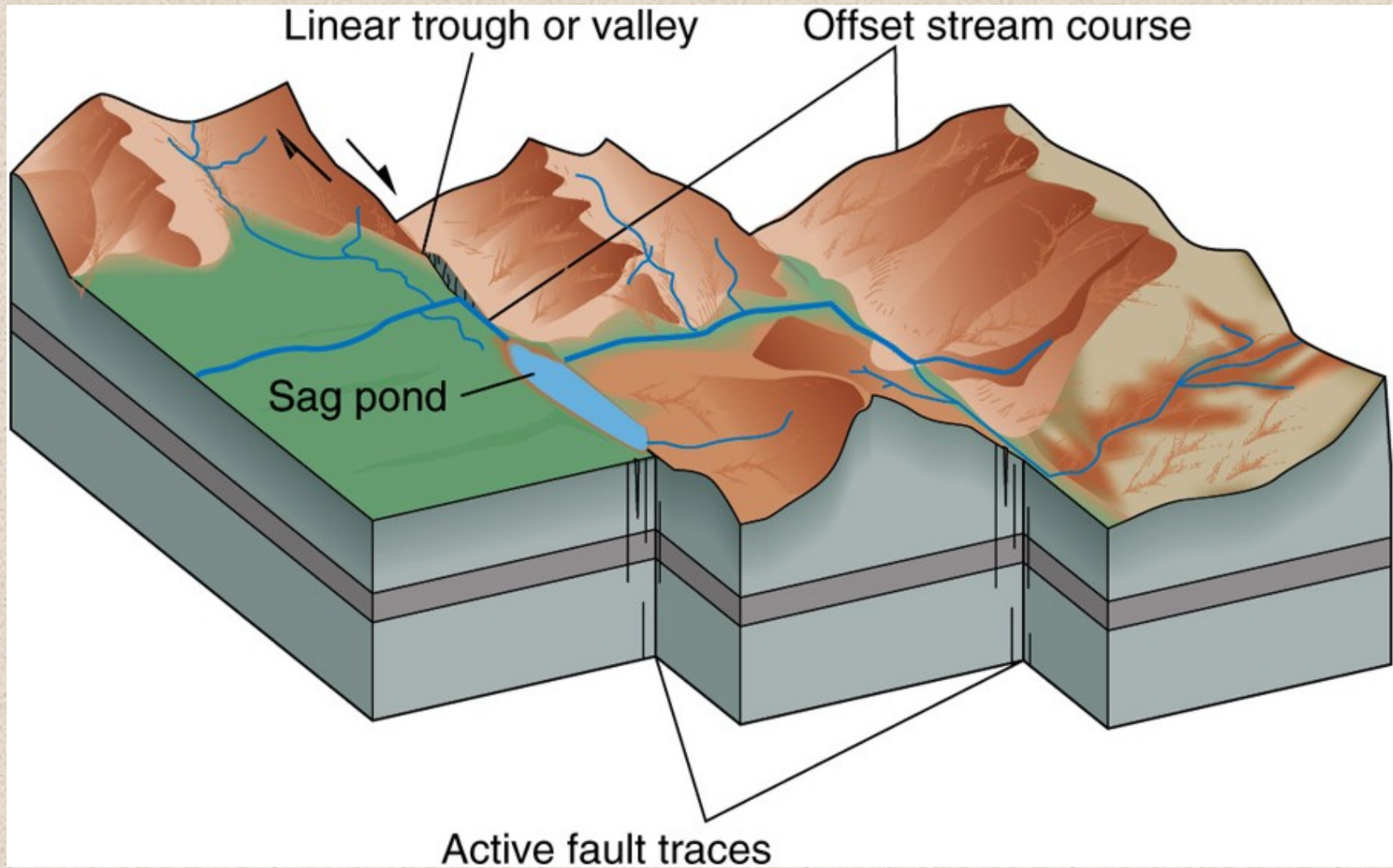


# Clues for finding faults

Lineations

Offsets of streams

Long lakes





**Strike-slip faulting from the 1979  
El Centro, CA earthquake**



**Strike-slip faulting from the 1979  
Imperial Valley, CA earthquake**

# Offset bedding





# Stream offset



**San Andreas strike-slip fault  
in the Carrizo Plain, CA**

# Stream offset



Photo by C. C. Plummer

# Fault scarp



Mojave Desert, CA traced for 70 km

# Fault scarp and rills



# Sag pond (in fault zone)



# Offsets of geologic features

## Cindercone in Nevada



# Offsets of geologic features



**Strike-slip fault near Las Vegas, NV**

# Offsets of man-made features



**Creep along a branch of the San Andreas fault in Hollister, CA**





**Creep along a branch of the San  
Andreas fault in Hollister, CA**

**The Hayward fault cuts through the Memorial Stadium at the University of California at Berkeley.**



**Strike-slip displacement  
within the stadium is 2-5  
mm or 0.1-0.2 in per year.**

Metal plate visible in  
photo of upper level.

Several inches of  
right lateral displacement  
clearly visible at top



UC Berkeley Memorial Stadium  
Section K/KK  
Outside stadium looking east

**Strike-slip displacement  
within the stadium is 2-5  
mm or 0.1-0.2 in per year.**



Photo by: D. P. Zéccos  
Geoengineer Website  
<http://www.geoengineer.org>

# San Andreas fault *zone*

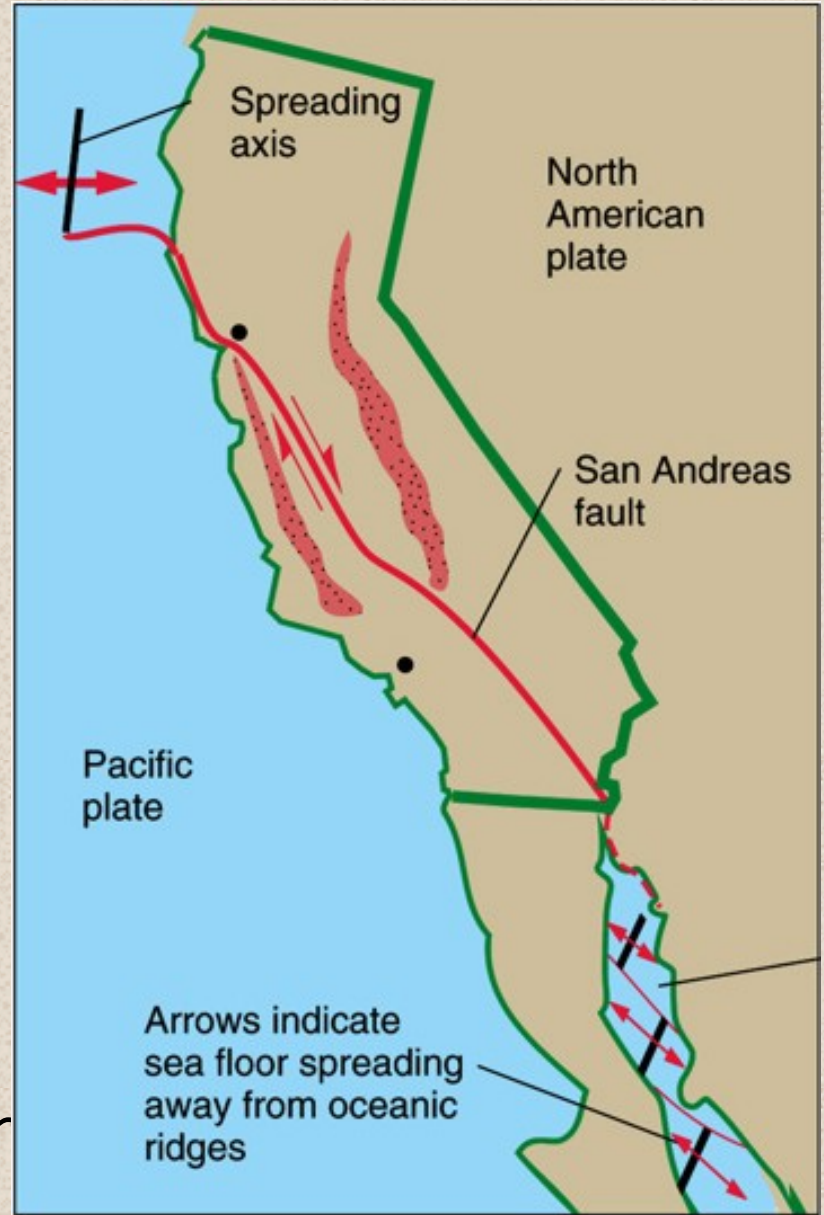
A whole system  
of faults

Most of the  
movement  
is SSE to NNW

*What is the name for  
this type of fault?*



# Large-scale offsets



San  
Francisco  
area

San  
Francisco Bay  
is bounded  
by two major  
faults

San Andreas  
Hayward



# Looking west

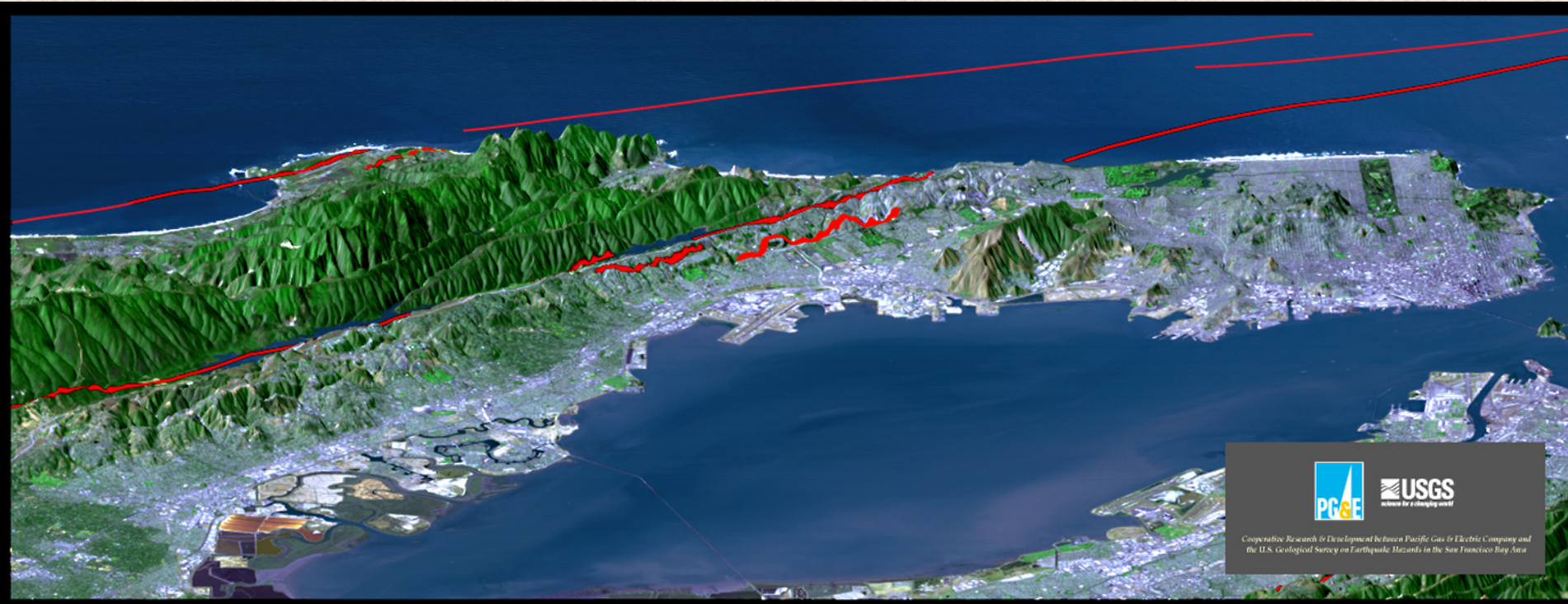


*Cooperative Research & Development between Pacific Gas & Electric Company and the U.S. Geological Survey on Earthquake Hazards in the San Francisco Bay Area*



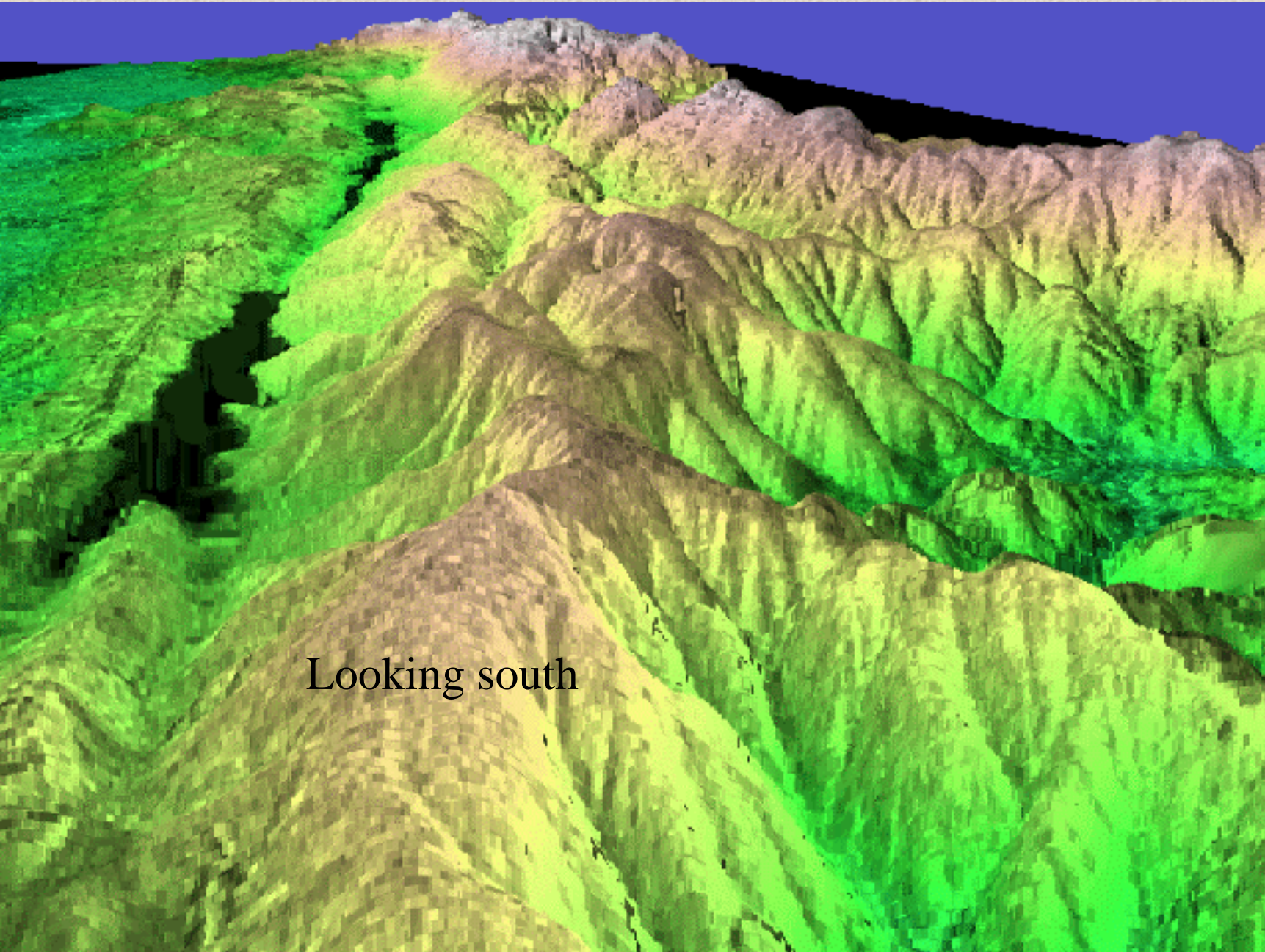


# Peninsula with faults



Cooperative Research & Development between Pacific Gas & Electric Company and the U.S. Geological Survey on Earthquake Hazards in the San Francisco Bay Area

# San Andreas Lake



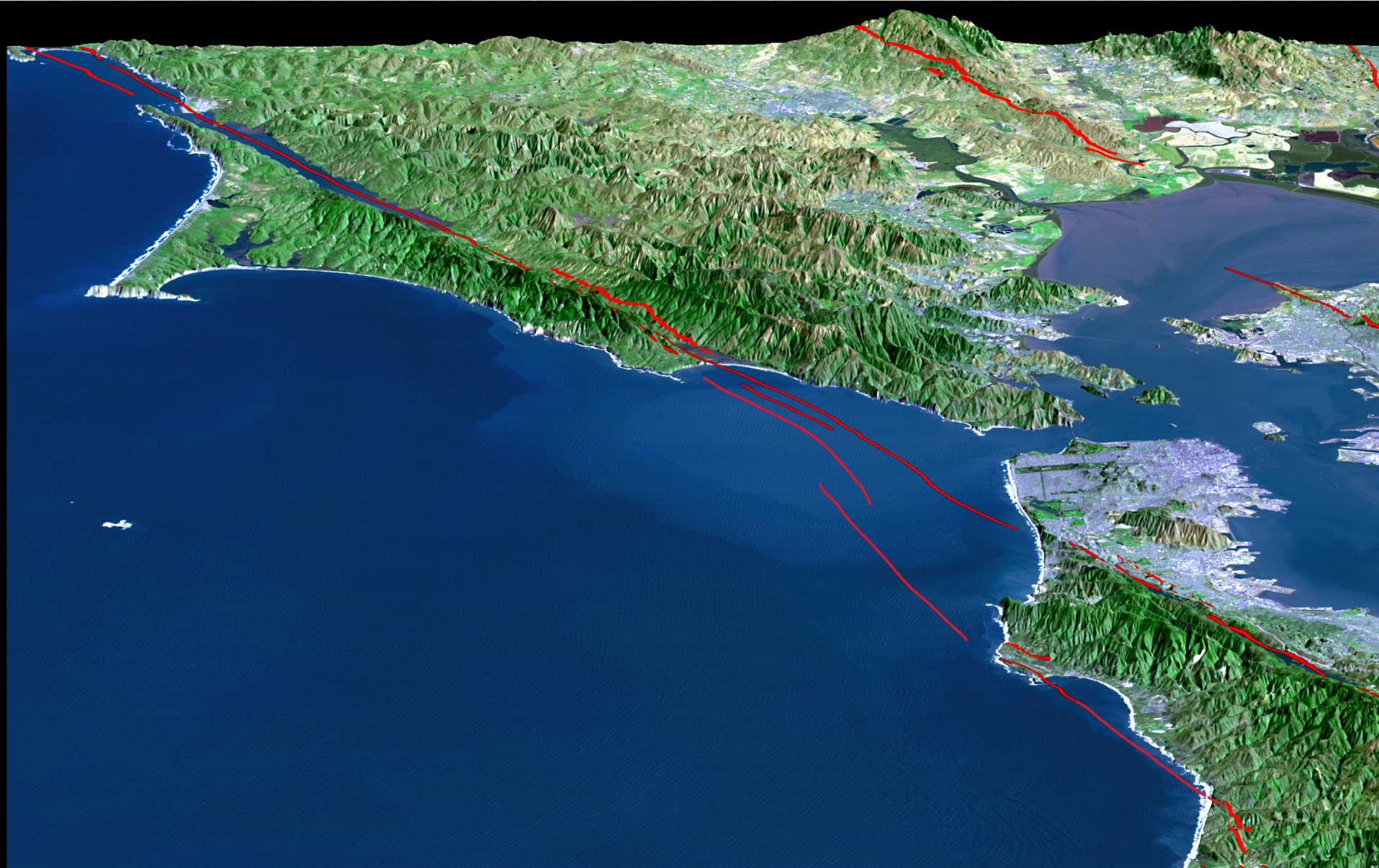
Looking south

# San Andreas Lake

Looking north



# North side of Golden Gate



# Tomales Bay



# A quick review

Stress and strain

Types of stress & strain

Pushing – compressional

Pulling – extensional

Opposing directions – shear

Elastic limit

Brittle & ductile

# A quick review

Angles of rocks

Strike & dip

Types of faults

Normal (dip-slip)

Reverse (or thrust)

Strike-slip

Graben

Horst