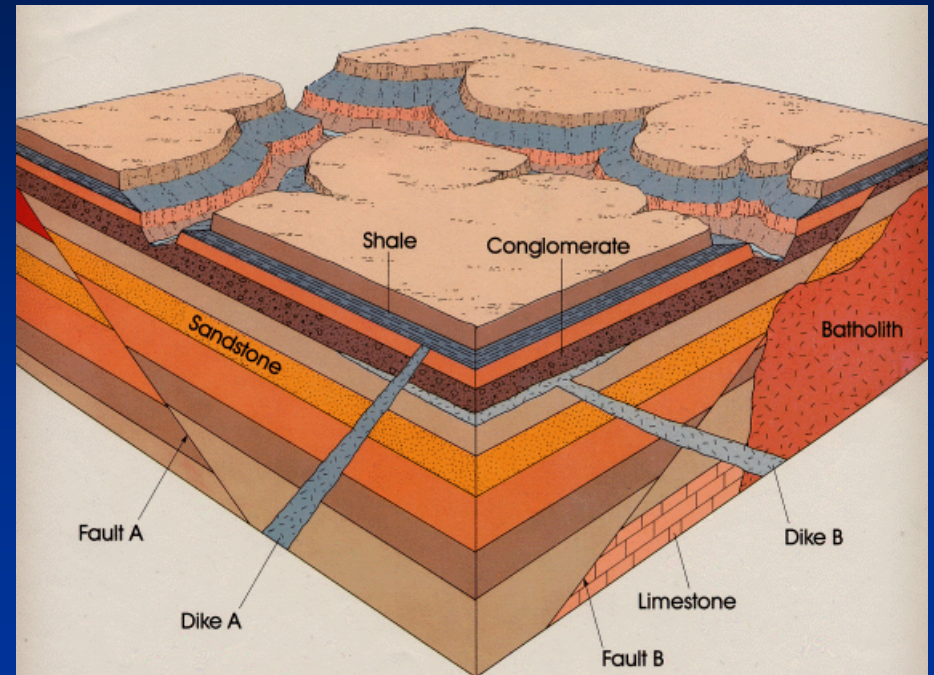


# Structural Geology and Geology Maps Lab

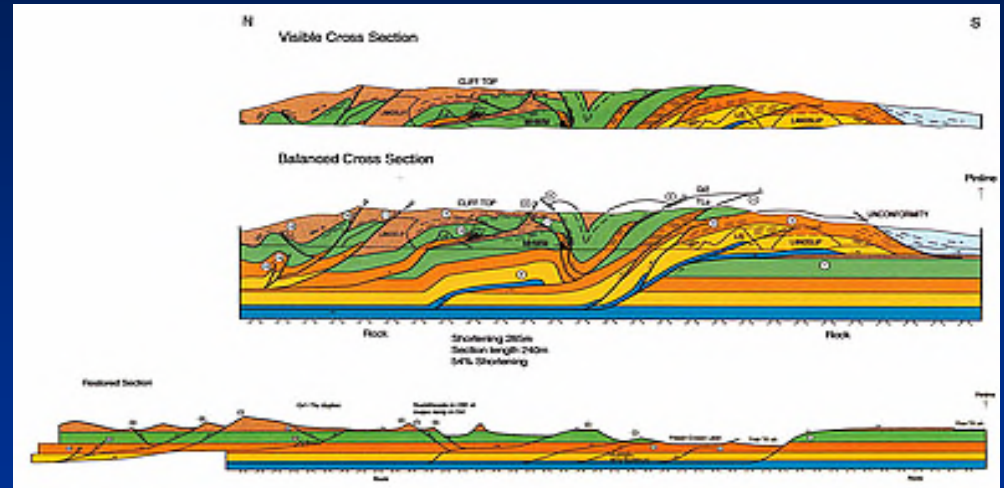


- EOSC110  
Laboratory
- Ray Rector: Instructor



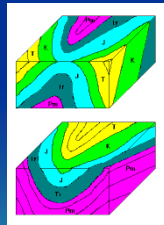
# Structural Geology Lab

## Pre-Lab Resources

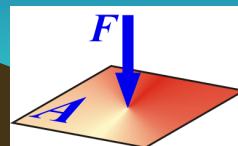


### Pre-Lab Internet Links

#### 1) Fundamentals of Structural Geology



#### 2) Visualizing Bed Attitude



# Structure Lab Learning Objectives

By the end of this lab, the student should be able to:

- 1) Explain the terminology and basic concepts of structural geology
- 2) Apply the general rules of structural geology to solving structure problems.
- 3) How to use field compass and inclinometer to determine strike and dip.
- 4) Identify the types of folds and faults, and correctly measure their attitude.
- 5) Correctly interpret and draw geologic block diagrams.
- 6) How to read a simplified geologic map.



# Some Common Geologic Terms of Structure

**Outcrop:** Exposure of bedrock at earth's surface



**Formation:** a mappable body of rock with a specific age, lithology, size, form, and external boundaries (contacts)



**Contact:** Boundary between adjacent rock formations or structural elements. Three types: *depositional, intrusive, and tectonic*



# Some Common Geologic Terms of Structure

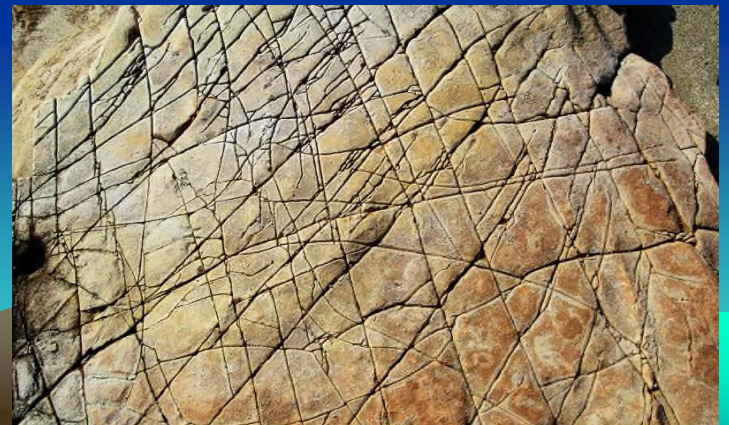
**Fold:** Layered rock units that are bent and buckled



**Fault:** A planar disruption between adjacent blocks of rock with lateral offset between the two blocks

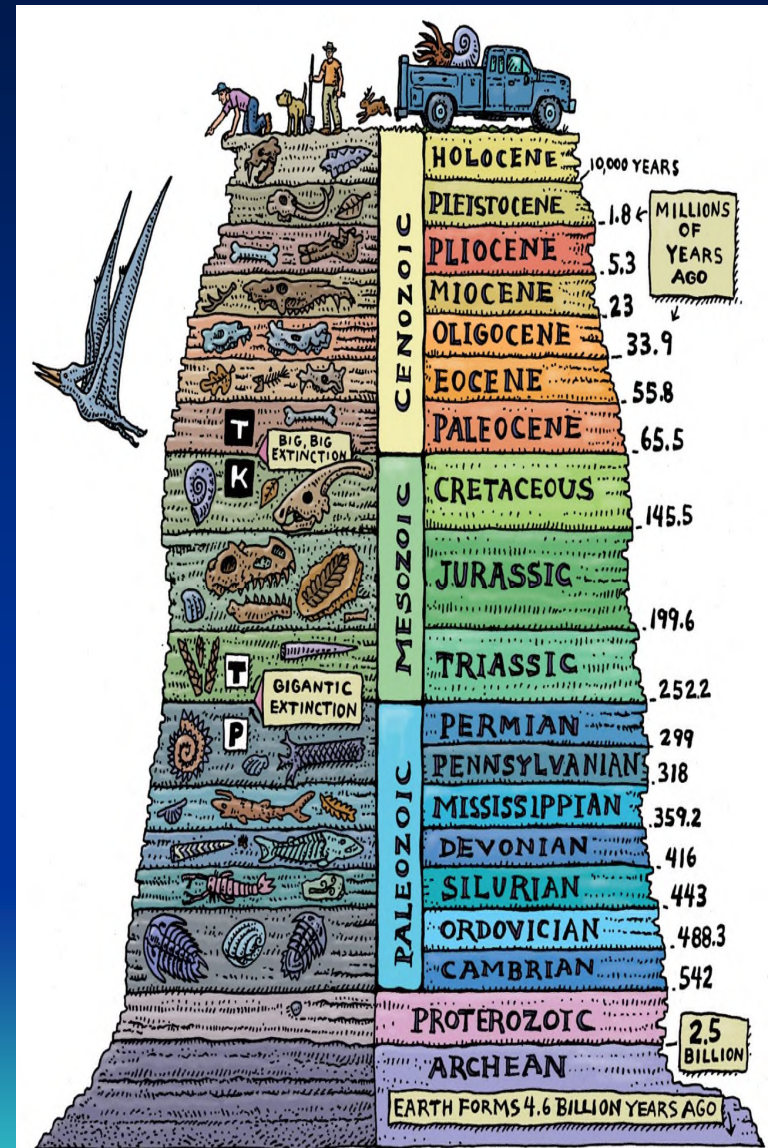


**Joint:** A planar disruption between adjacent blocks of rock with no lateral offset between the two blocks



# Rock Formations and Geologic Time

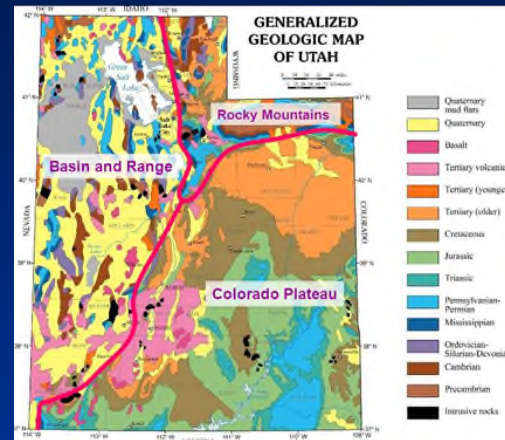
- 1) All formal geologic rock formations have a specific assigned age
- 2) All geologic rock formations have a specific range of lithology
- 3) Rock formations are listed in a temporally-ordered sequence in the “explanation” of a geologic map
- 4) Each rock formations has an assigned geologic period
- 5) Geologic period assignments of formations are further divided into lower (older), middle, and upper (younger)



# Geologic Structures are Graphically Depicted Using Various Illustration Models

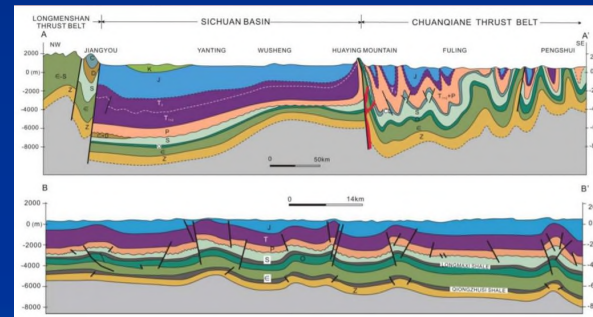
## Geology Maps

Two-dimensional (planar), horizontally-oriented illustrations of ground surface (map) highlighting geologic rock formations and rocks structures exposed at the surface



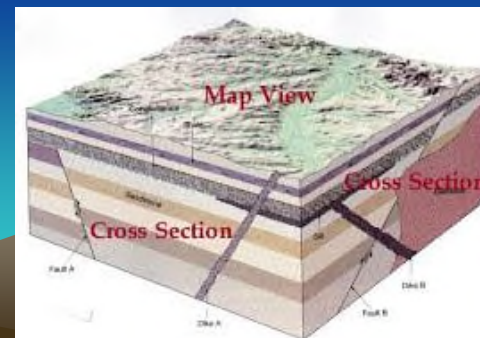
## Geologic Cross Sections

Two-dimensional (planar), vertically-oriented illustrations of geologic rock formations and rock structures



## Block Diagrams

Three-dimensional (orthogonal) illustrations of geologic rock formations and rock structures. Block diagrams include a geologic map view (top) and two geologic cross-sections (sides)



FORMATION

EXPLANATION

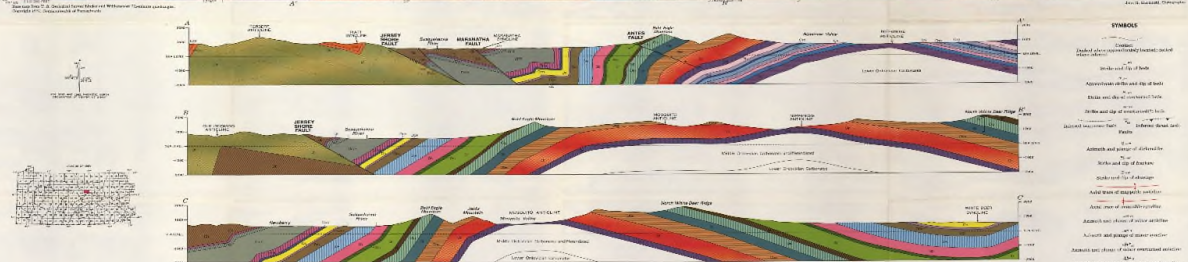
PHYSIOLOGICAL

UNIT

CHARACTERISTICS

EXPLANATION

# Map View of Geologic Formations



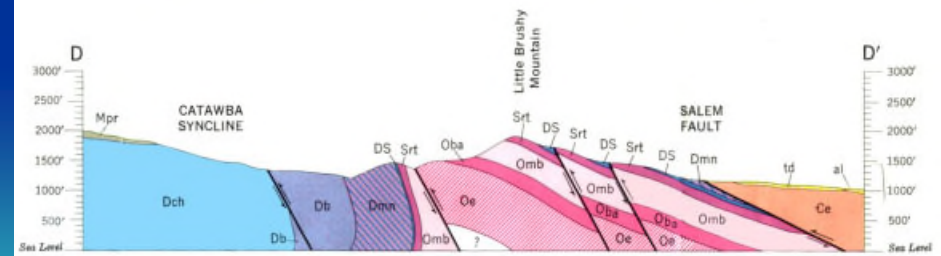
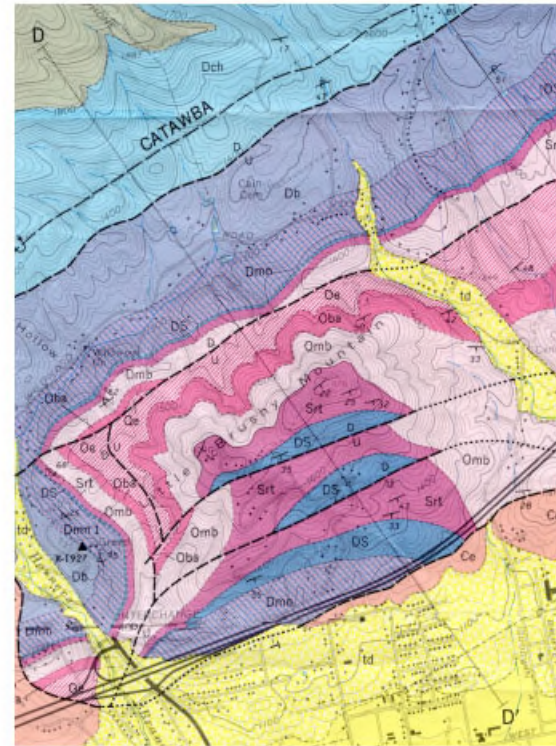
# Cross Sections of Formations and Structures

RODGER T. FAILL and RICHARD B. WEISS

10

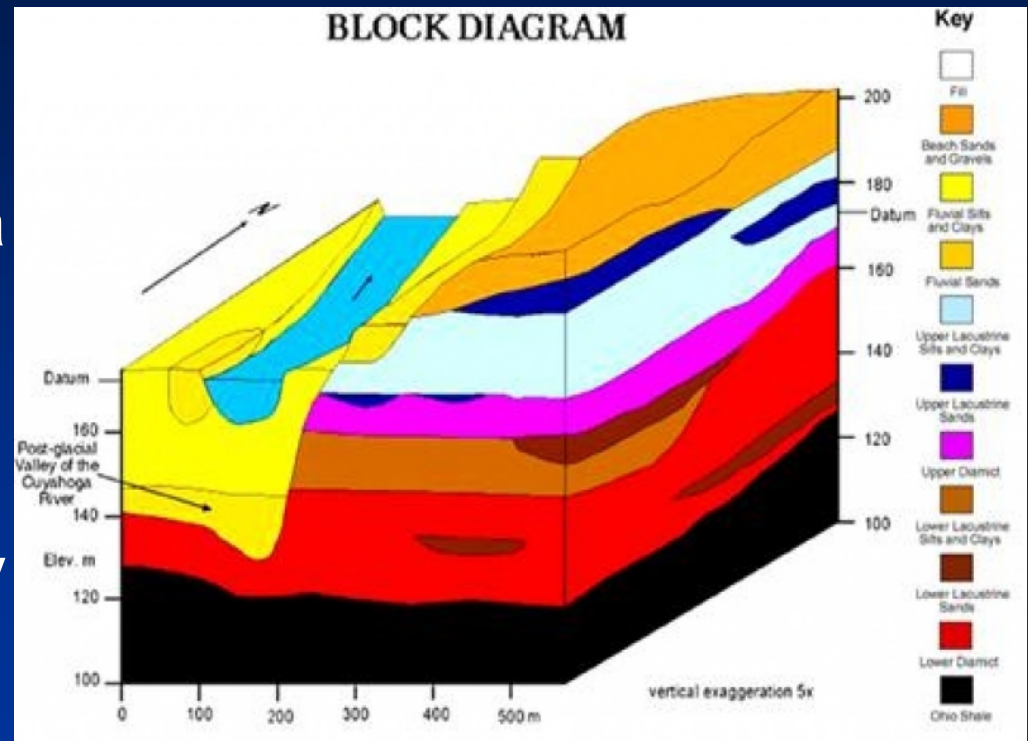
# Rock Formations and Contacts on a Geologic Map and Cross Section

- 1) Rock formations, contacts and structural elements are illustrated in a geologic map and cross sections
- 2) A geology map depicts the types of rock that crop out at the earth's surface over a given area of the earth, including the type of contact between adjacent rock formations.
- 3) Contacts types include depositional, erosional, intrusion, and tectonic/fault



# Geologic Structures and Block Diagrams

- 1) Geologic block diagrams combine a geologic map (top) with two cross-sections (sides) to create a three-dimensional block model of the crust.
- 2) Most block models are oriented in a particular way in respect to cardinal directions.
- 3) Block diagrams can be very helpful in analyzing various types of geologic structures, like stratigraphy, intrusions, folds and faults.



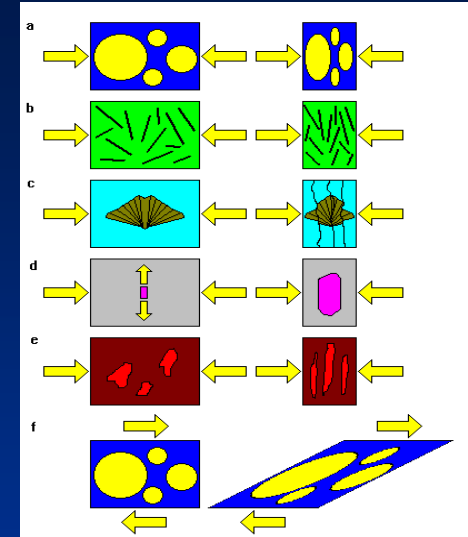
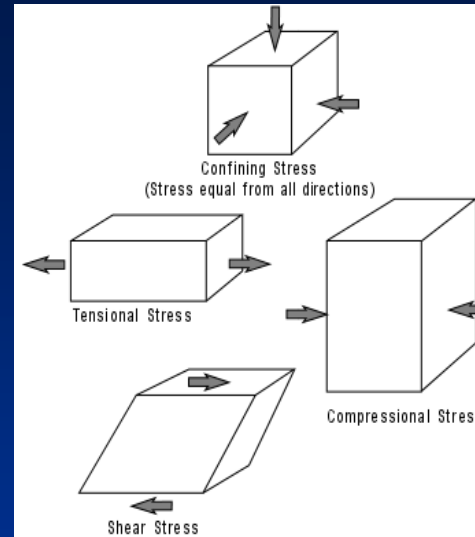
# Origin and Nature of Rock Deformation

## A. Stress Leads to Strain

- ✓ Stress is an applied force over an area
- ✓ Strain is the deformation of a solid body

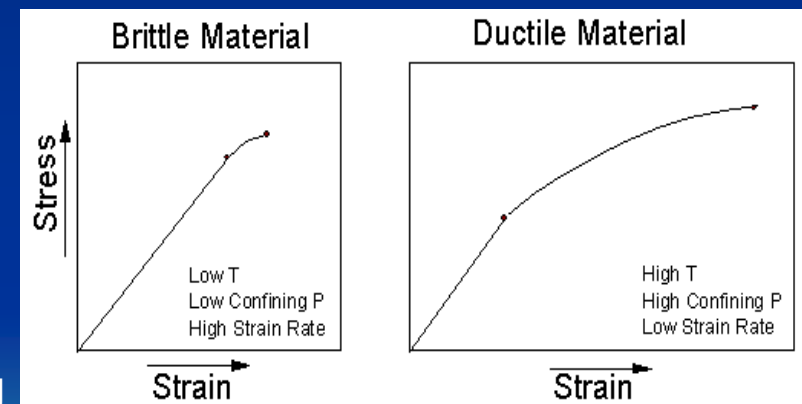
## B. Different Types of Stress

- ✓ Tensional = pulling apart forces
- ✓ Compressional = pushing together forces
- ✓ Shear = grinding past each other force



## C. Different Types of Strain

- ✓ Brittle = breaking into pieces
- ✓ Ductile = changing shape without breaking
- ✓ Elastic = deformed body returns to normal shape after stress released
- ✓ Plastic = deformed body remains deformed after stress released



Rocks strain in a predictable fashion, according to the amount and duration of strain under a given set of temperature-pressure conditions

# Resultant Rock Strain from Specific Stresses

## A. Undeformed Strata

- ✓ Original Horizontal layering

## B. Compressional Stresses

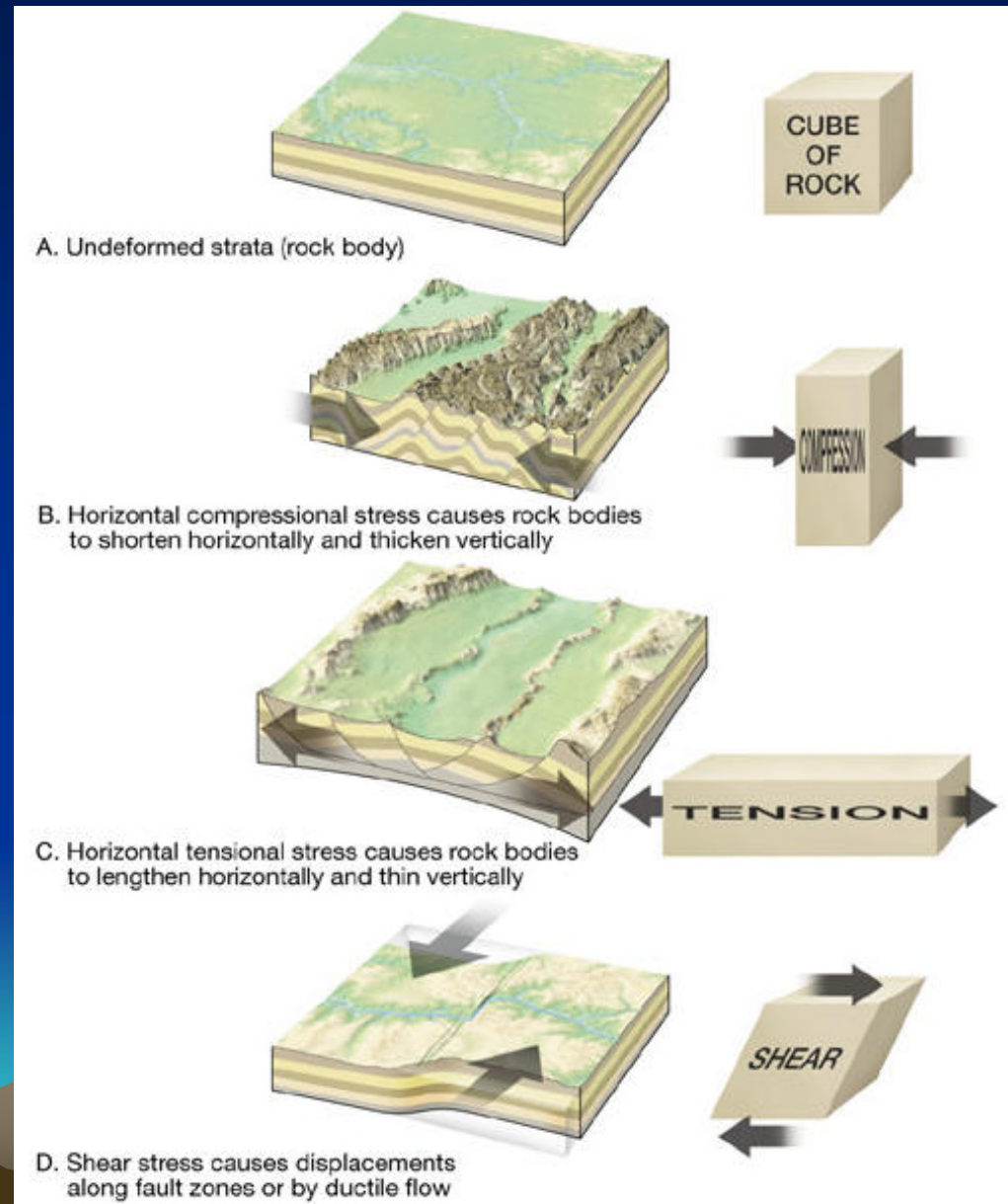
- ✓ Shorten horizontally
- ✓ Thicken vertically
- ✓ Folding and Reverse Faulting

## C. Tensional Stresses

- ✓ Lengthen horizontally
- ✓ Thin vertically
- ✓ Tilting and Normal Faulting

## D. Shear Stresses

- ✓ Lateral displacement
- ✓ Strike-slip Faulting



# Resultant Rock Strain from Specific Stresses

## A. Undeformed Strata

- ✓ Original Horizontal layering

## B. Tensional Stresses

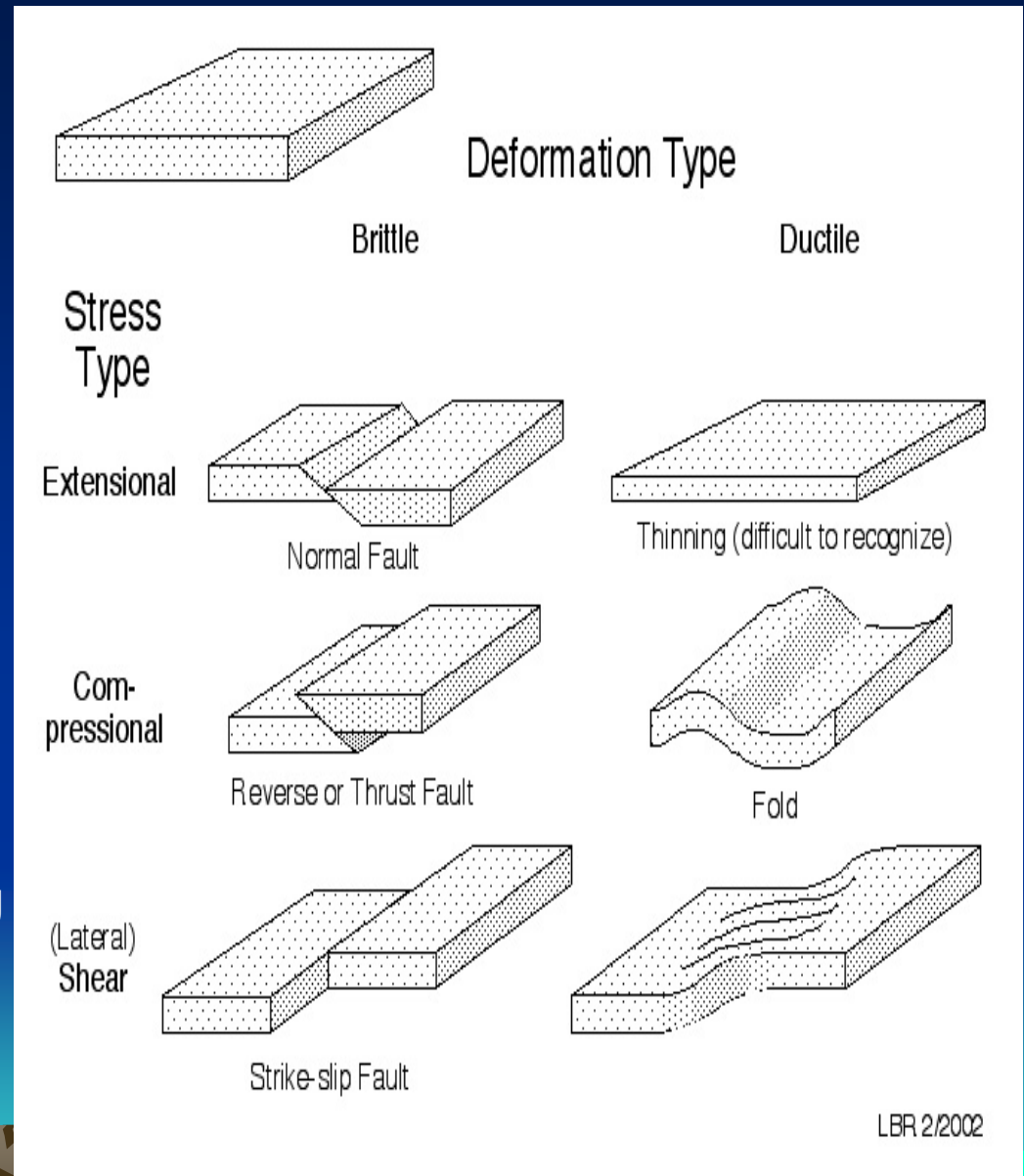
- ✓ Lengthen horizontally
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- ✓ Tilting and Normal Faulting

## C. Compressional Stresses

- ✓ Shorten horizontally
- ✓ Thicken vertically
- ✓ Folding and Reverse Faulting

## D. Shear Stresses

- ✓ Lateral displacement
- ✓ Strike-slip Faulting



# Geologic Structures



Rock Layering



Tilted Rock Layers



Folded Rock Layers



Faulted Rock Layers

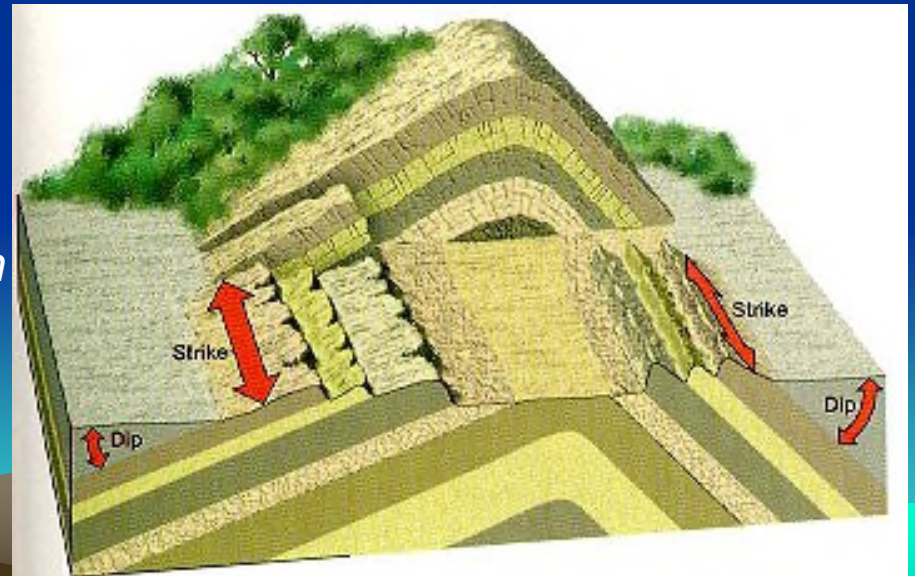
# The Basic Rules of Structure

- 1) Strike of beds is always parallel to the direction of the contacts.
- 2) Rock layers dip towards the youngest exposed rock layers.
- 3) Oldest rocks exposed in the center of eroded anticlines and domes.
- 4) Youngest rocks exposed in the center of eroded synclines and basins.
- 5) Horizontal folds form parallel sets of belt-like outcrop patterns.
- 6) Plunging anticlines form "V" or "U" shaped, belt-like outcrop patterns.
  - Anticline fold plunges toward *closed* end of "V" or "U" pattern.
- 7) Plunging synclines form "V" or "U" shaped, belt-like outcrop patterns.
  - Syncline fold plunges toward *open* end of "U" pattern.
- 8) Steeper the dip of the layer, the more narrow the width of its outcrop.
- 9) Hanging wall is towards the fault dip direction; foot opposite to fault dip direction
- 10) Hanging wall *moves up* relative to foot wall in reverse and thrust faults.
- 11) Hanging wall *moves down* relative to foot wall in normal faults.
- 12) Slickenside grooves oriented horizontal in fault scarp indicate strike-slip offset.
- 13) Slickenside grooves oriented vertical in fault scarp indicate dip-slip offset.

# Spatial Orientation of Layers

## Strike and Dip

- 1) The spatial orientation, or **attitude** of a planar rock layer or structural feature can be measured and recorded in the field.
- 2) Two spatial aspects are needed:
  - ✓ **Strike** = horizontal component
  - ✓ **Dip** = angle below the horizontal
- 3) The **Strike** is the line, or *trend* that represents the intersection of the planar feature with the horizontal.
- 4) **Strike** is measured with a compass.
- 5) **Dip** is the downward angle, or *inclination* of the feature from horizontal at a right angle to the strike.
- 6) **Dip** is measured with a clinometer.



# Using a Compass/Inclinometer to Determine Spatial Orientation of Layers

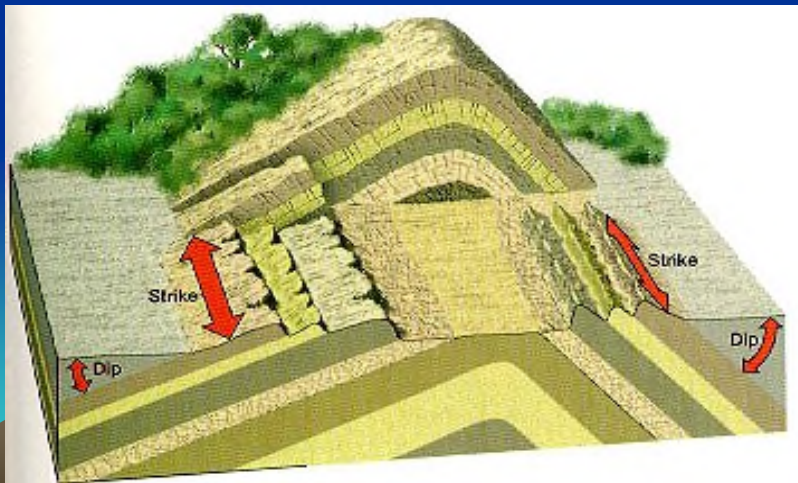
## Strike and Dip



Measuring Strike Azimuth



Measuring Dip Angle



Strike Azimuth and Dip Angle



Completed Strike and Dip Measurement

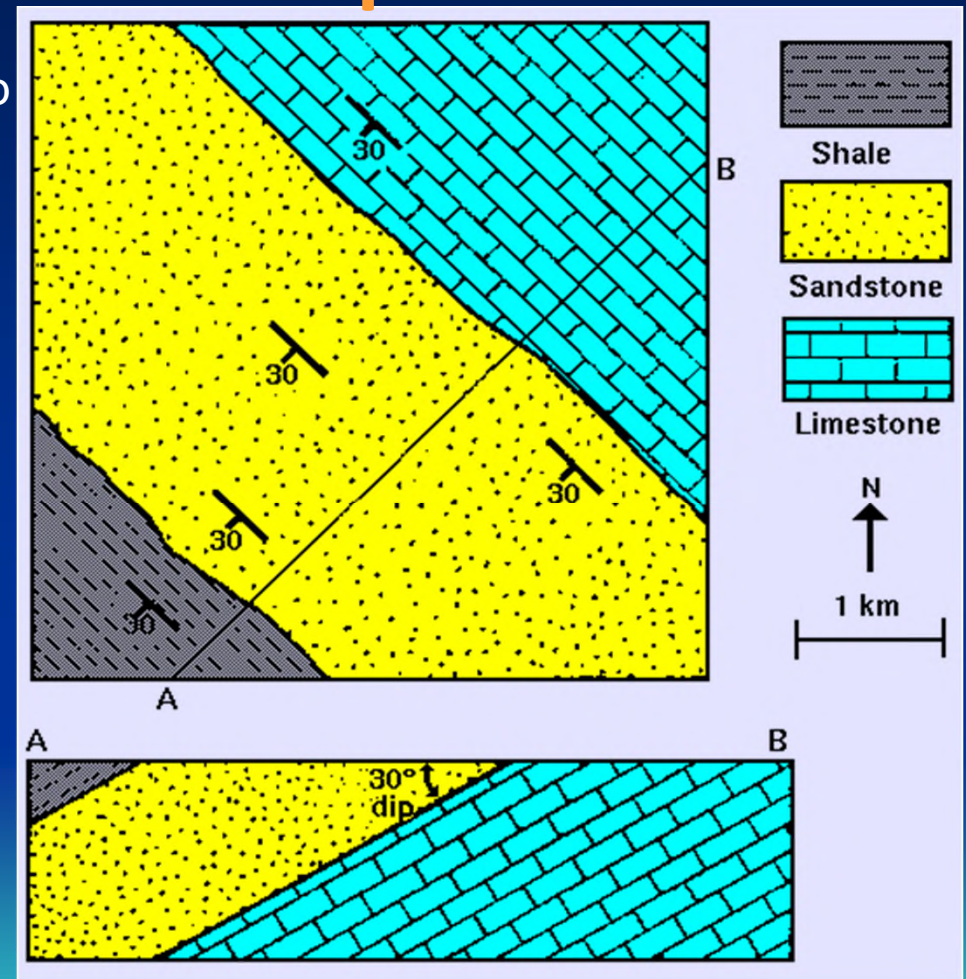
# Spatial Orientation of Layers

## Strike and Dip

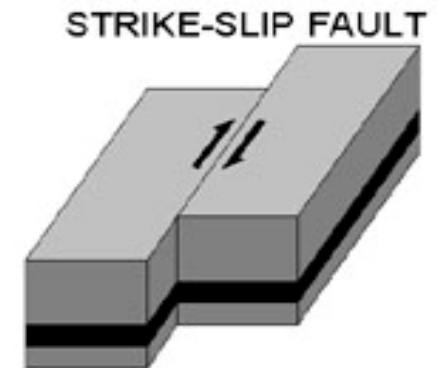
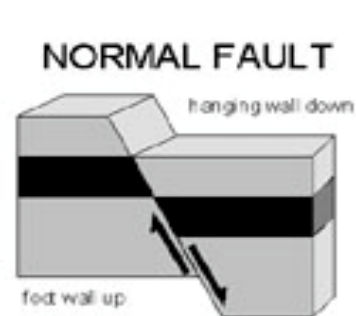
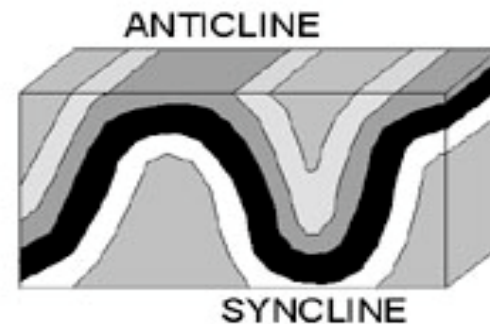
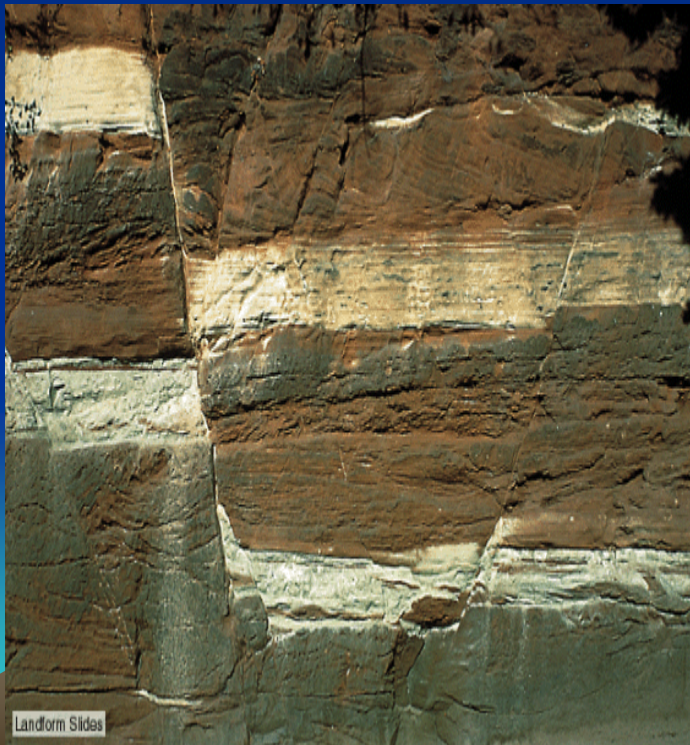
The **Strike** and **Dip** of a planar rock layer or feature is symbolized on a geology map by a



- ✓ The long bar is the strike trend
- ✓ The short bar points to the down dip direction with dip angle



# Folds and Faults



# General Geologic Terms of Folds

**Folds:** Buckled layers of rock formed by compressive stresses

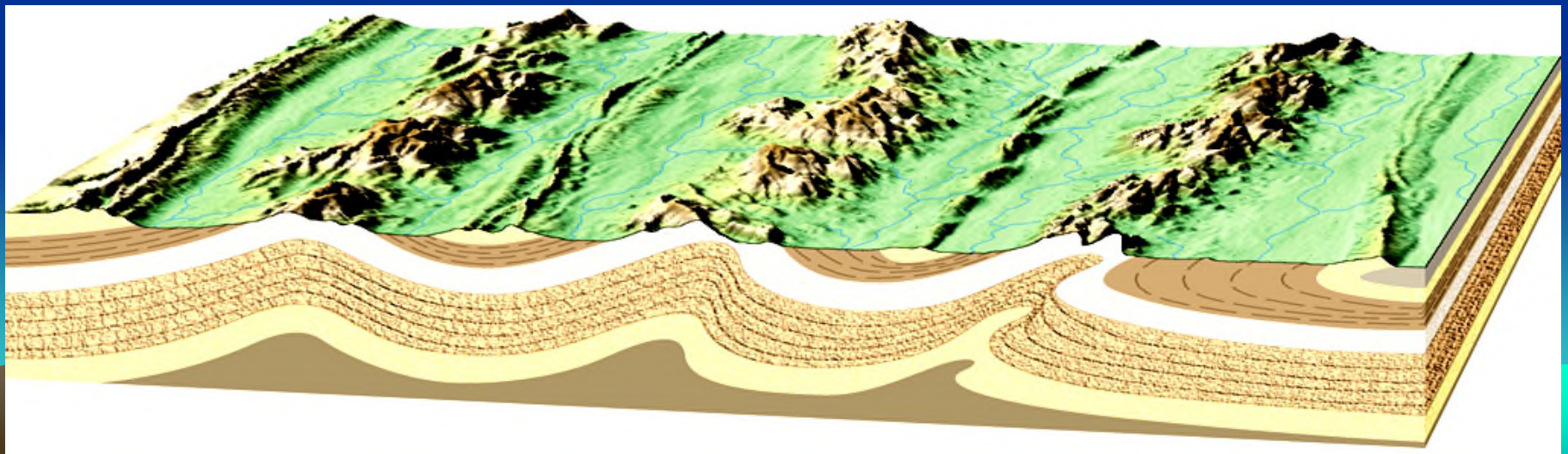
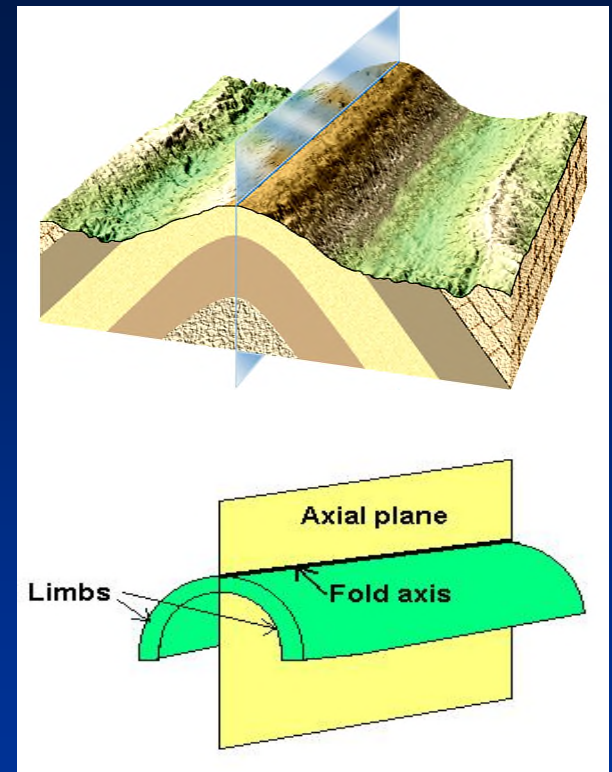


**Anticline:** Upwards-buckled fold with oldest rock at center and outward-dipping limbs

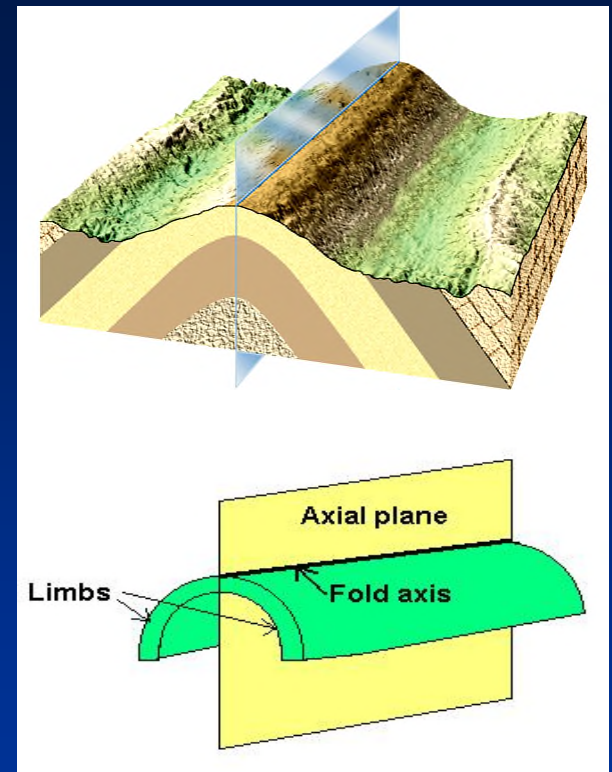
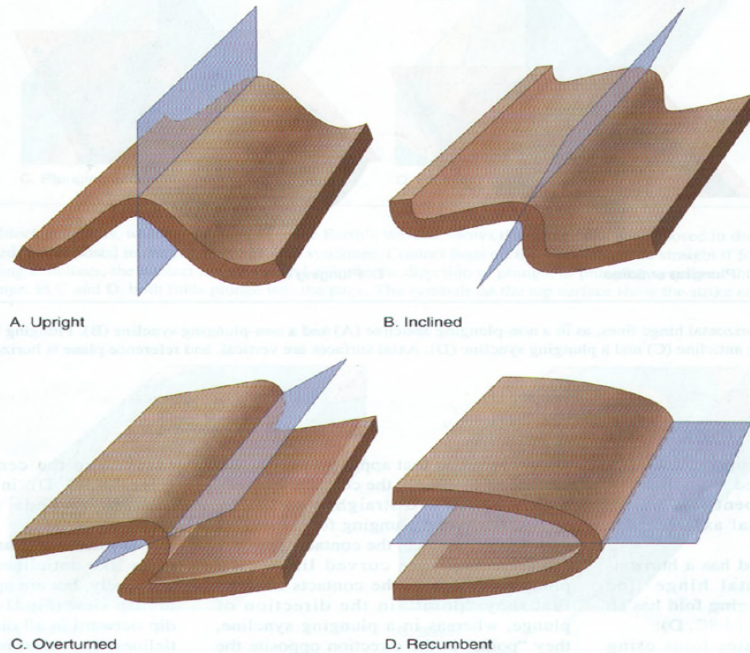
**Syncline:** Downwards-buckled fold with oldest rock at center and outward-dipping limbs



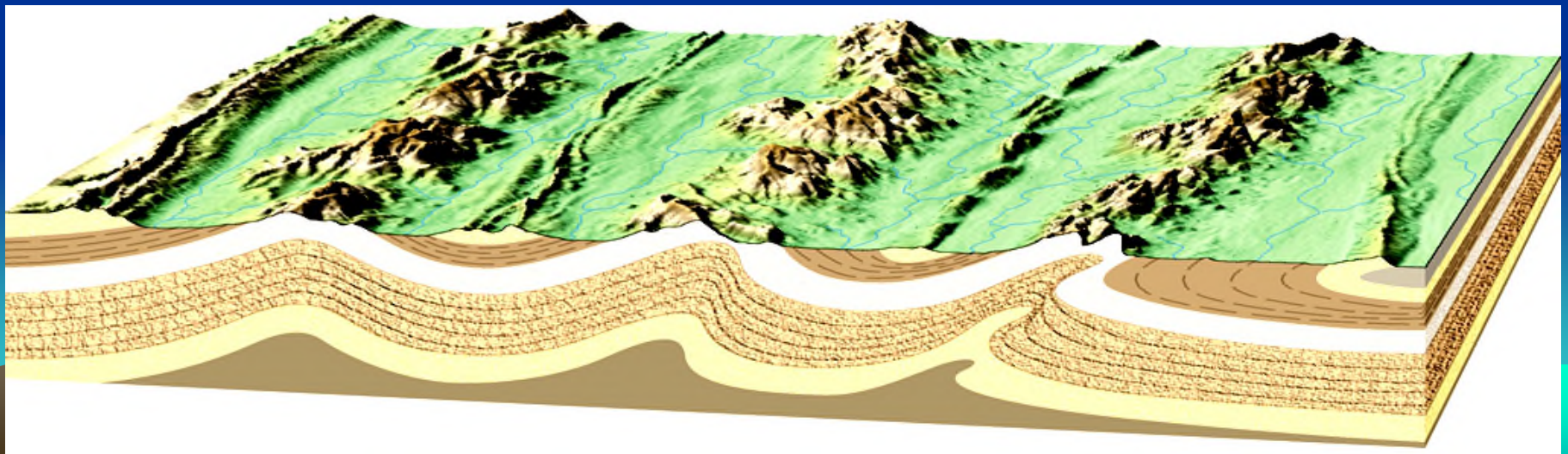
# Fold Basics



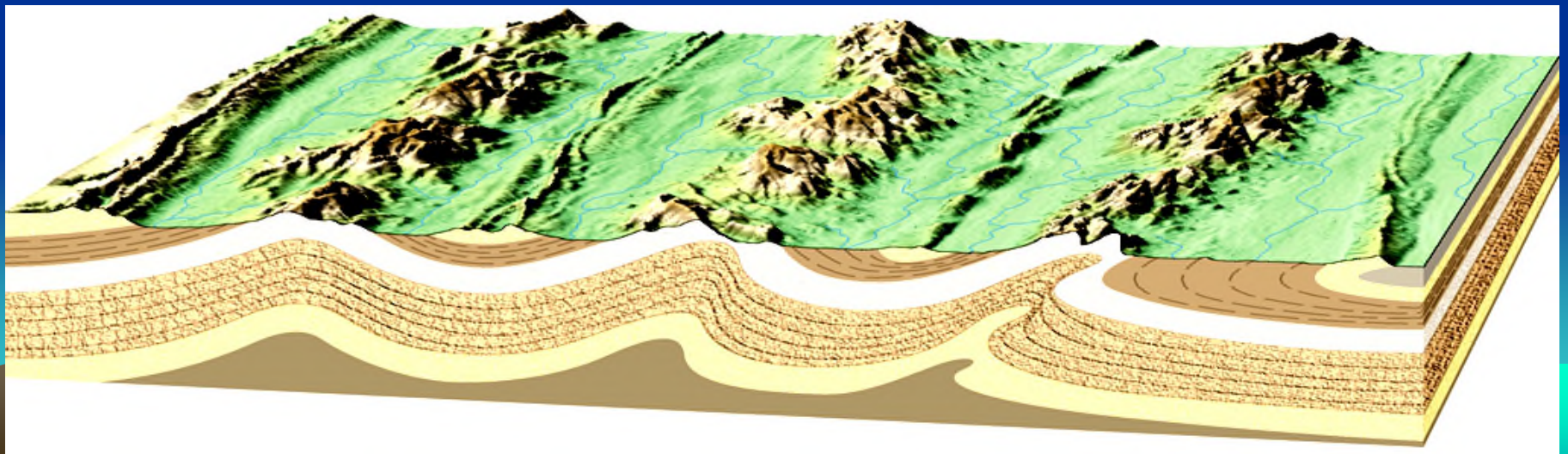
# Fold Basics



**FIGURE 14.7**  
 The axial surface of a fold can be: A. Vertical in **upright folds**; B. inclined in **inclined folds**; C. inclined so much that opposite limbs dip in the same direction in **overturned folds**; D. horizontal in **recumbent folds**. (Adapted from Jones, 2001: Laboratory Manual for Physical Geology, 3rd Edition)



# Fold Basics



# Rules of Folds

## Anticlines

- 1) Oldest unit in center
- 2) Limbs dip outward

## Synclines

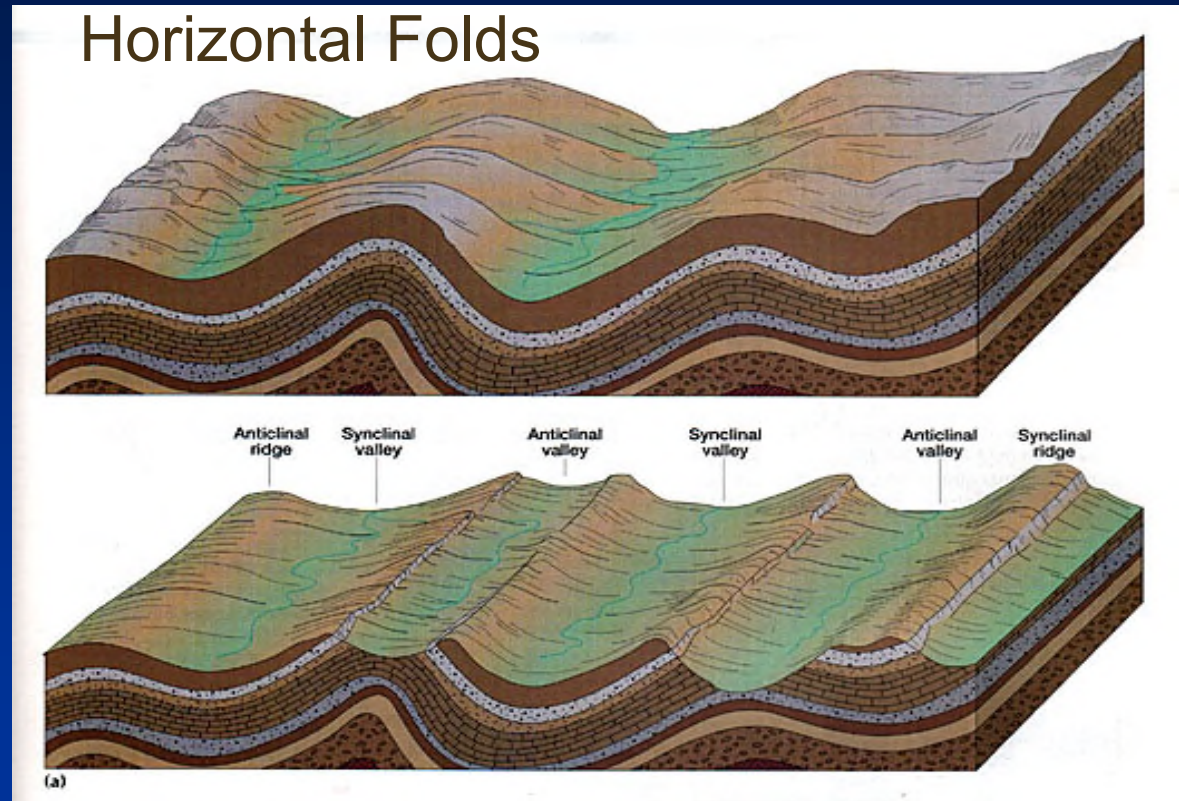
- 1) Youngest unit in center
- 2) Limbs dip inward

## Horizontal Folds

- 1) Strikes of opposing fold limbs are all parallel
- 2) Folds form parallel striped pattern on geology map

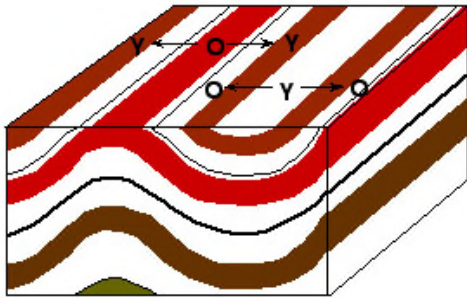
## Plunging Folds

- 1) Strikes of opposing fold limbs are not parallel
- 2) Folds form V-shaped pattern on geology map
- 3) Anticlines plunge toward closed end of "V"-shaped bedding pattern
- 4) Synclines plunge toward open end of "V"-shaped bedding pattern



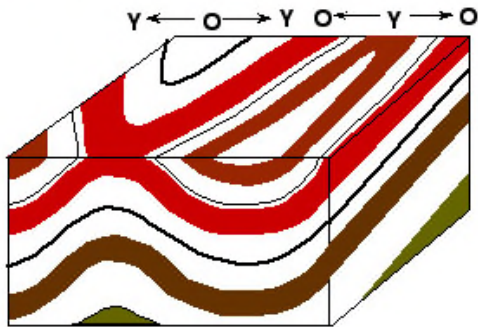
# Plunging Folds

## Plunging Folds

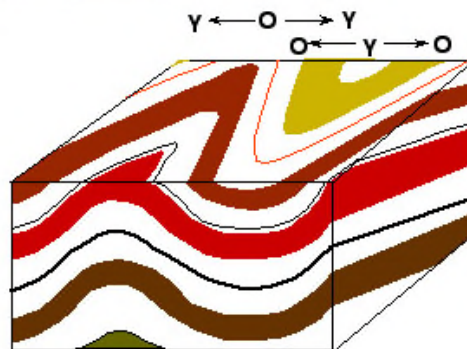


Anticline and Syncline  
in 3-dimensional view

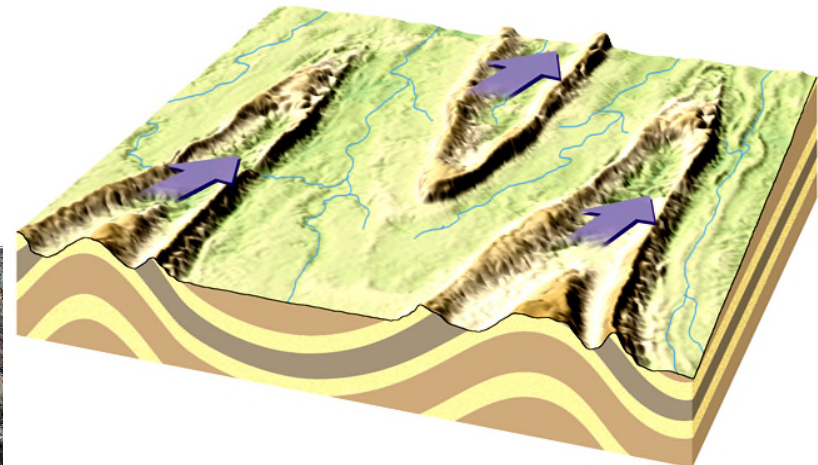
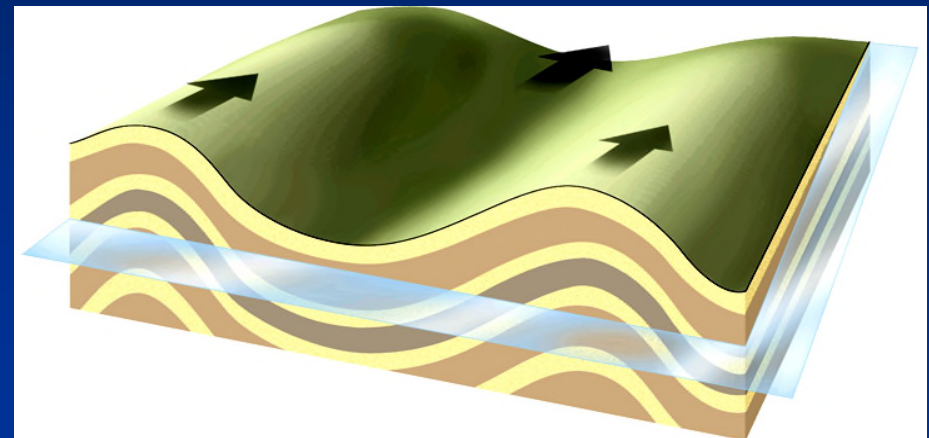
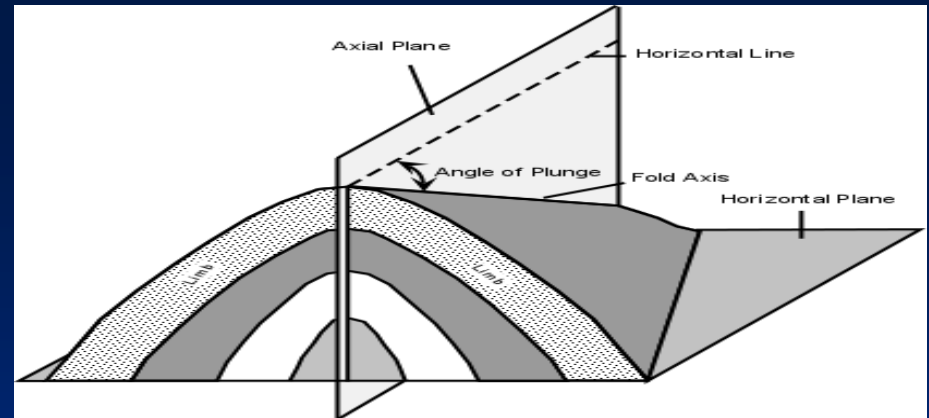
Oldest beds are in  
centers of anticlines;  
youngest beds are in  
centers of synclines.



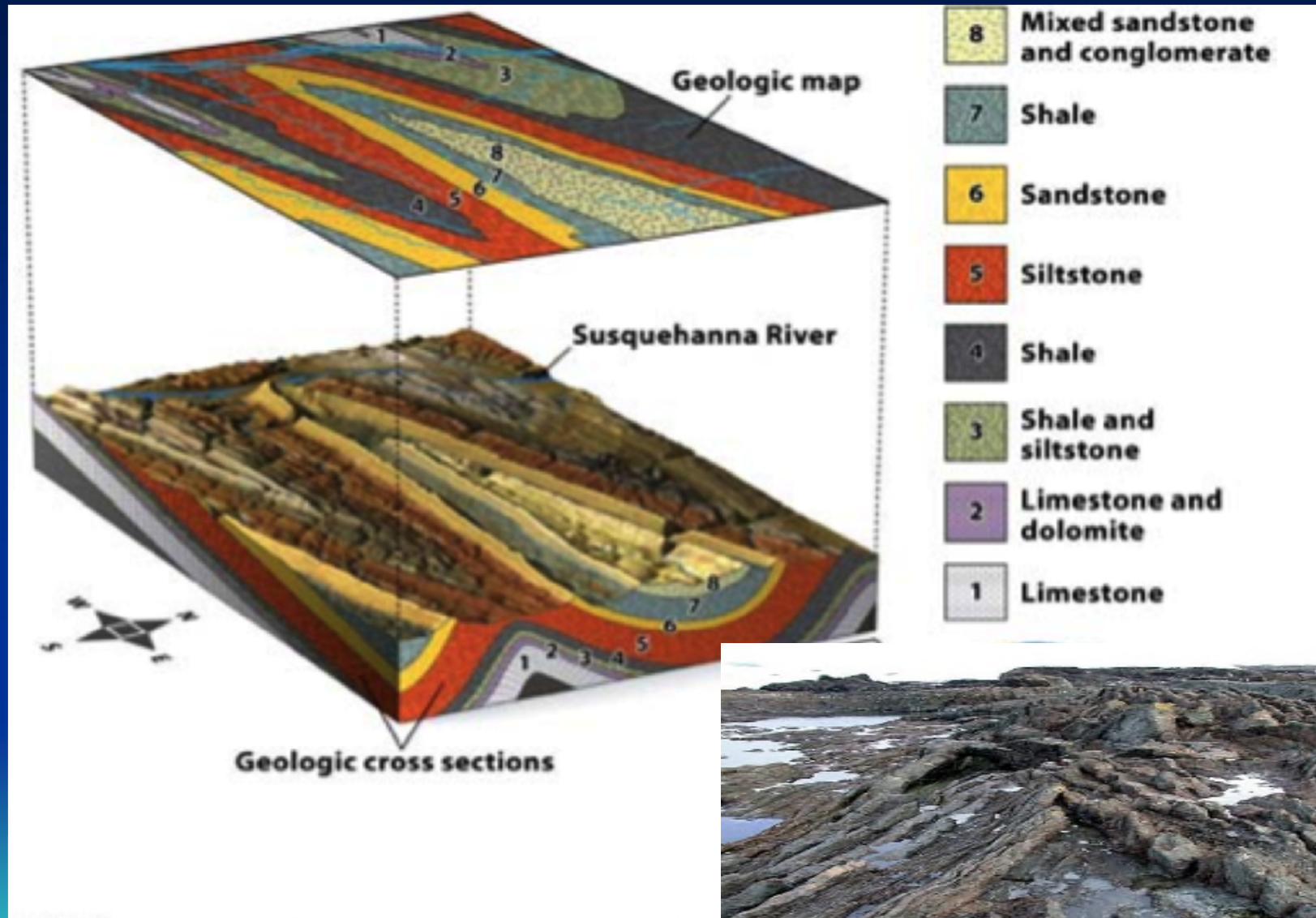
Anticline and Syncline  
plunging toward viewer



Anticline and Syncline  
plunging away from  
viewer

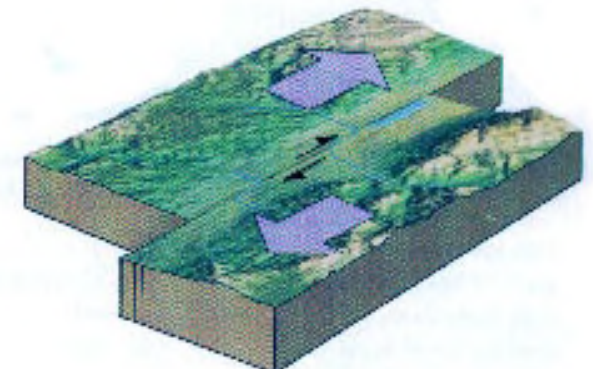
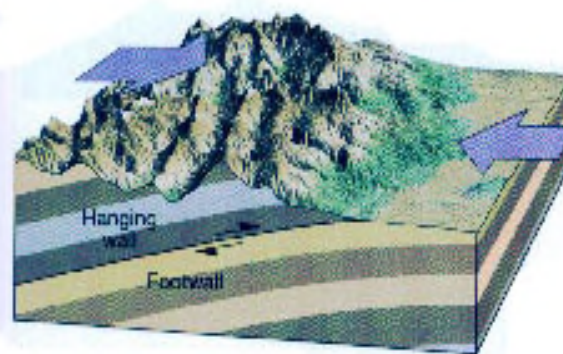
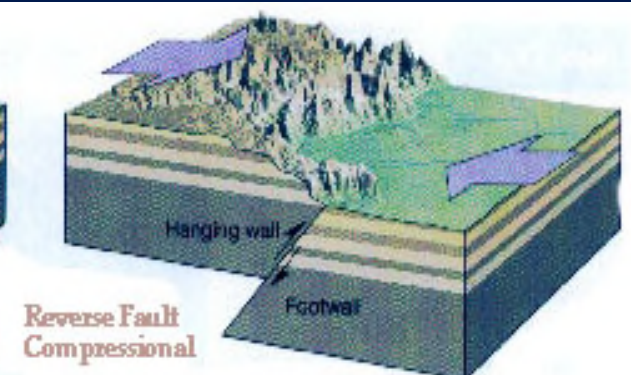
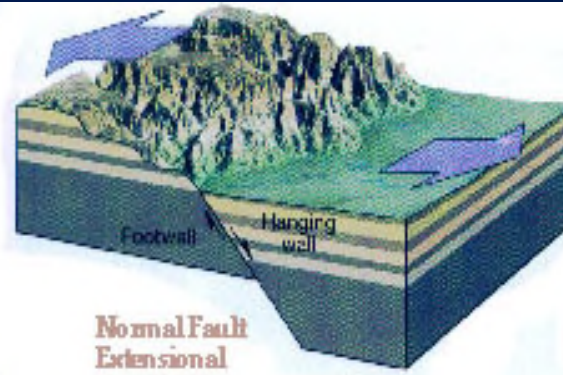
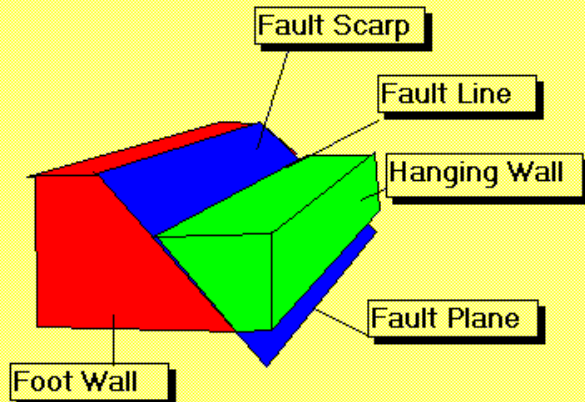


# Plunging Folds



# Fault Terminology

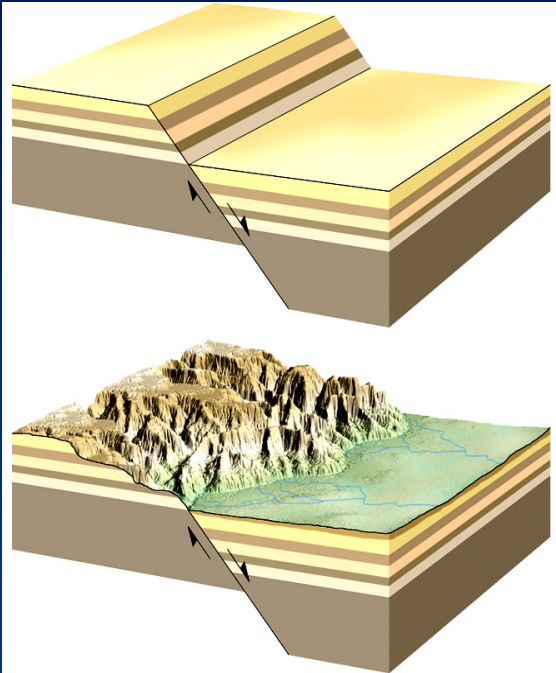
## Features of Faults



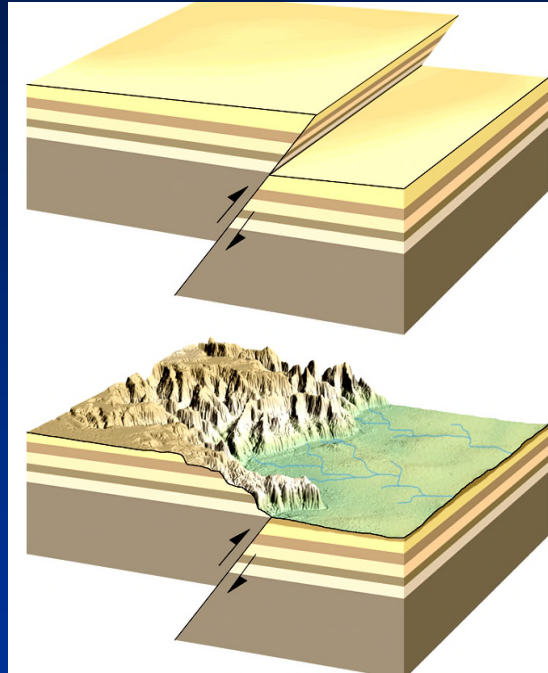
Thrust Fault-compressional

Strike-slip fault-shearing motion

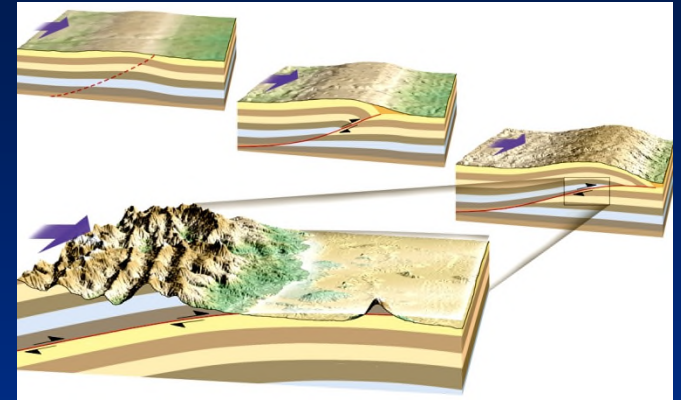
# Types of Faults



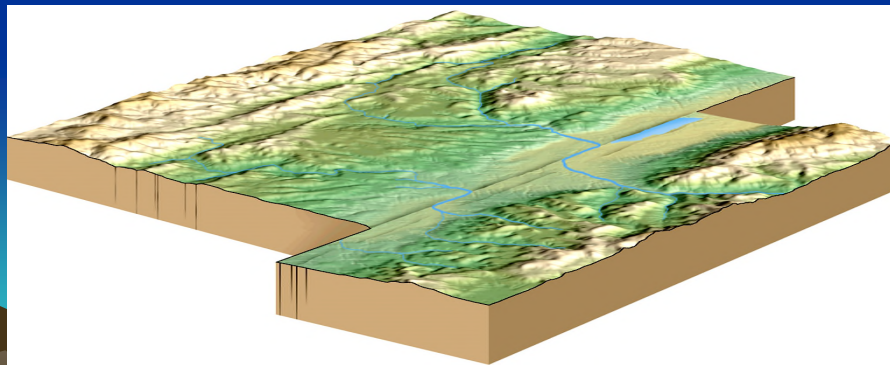
**Normal Fault**



**Reverse Fault**

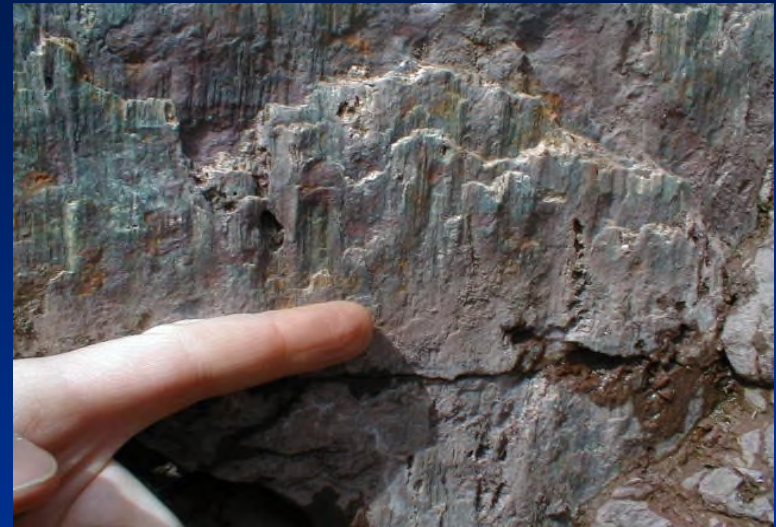
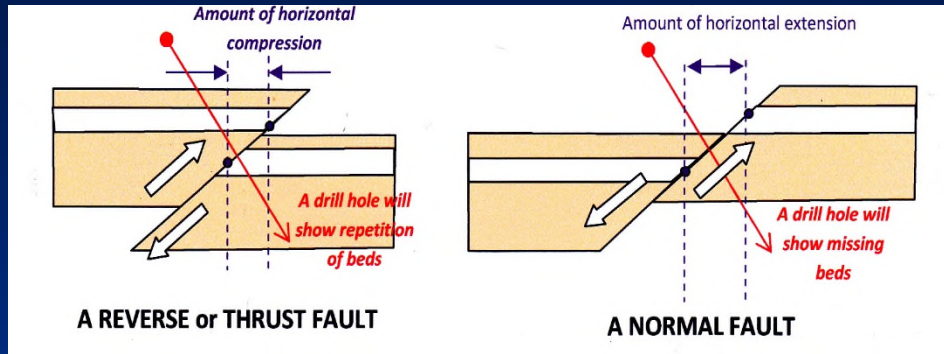


**Thrust Fault**



**Strike-Slip Fault**

# Fault Offset and Slickensides



Dip-slip oriented slickensides



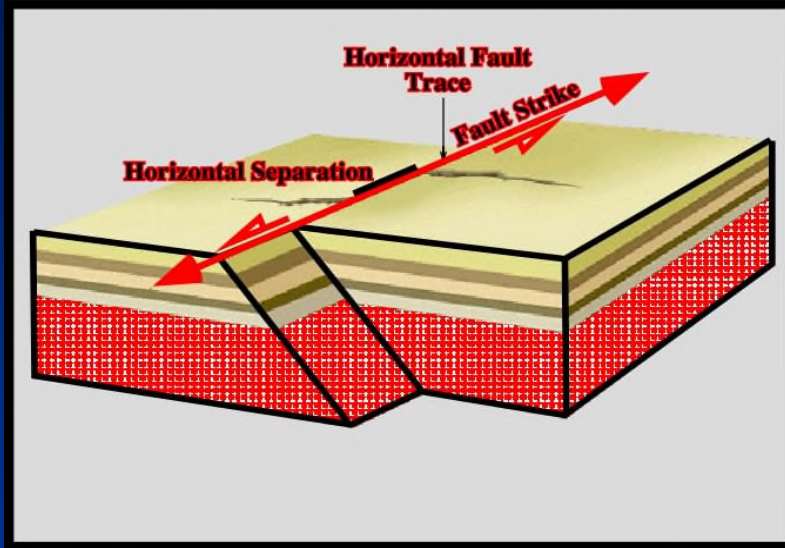
Normal-sense, dip-slip offset



Reverse-sense, dip-slip offset

# Fault Slickensides

## Strike Slip Movement

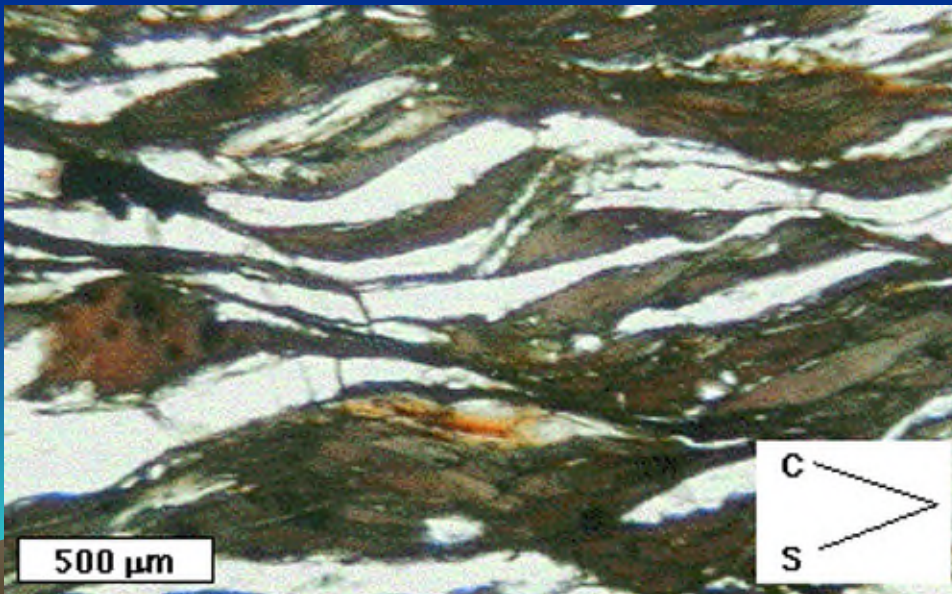
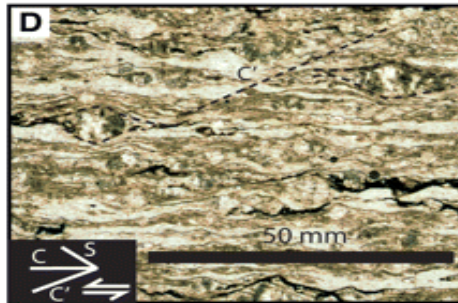
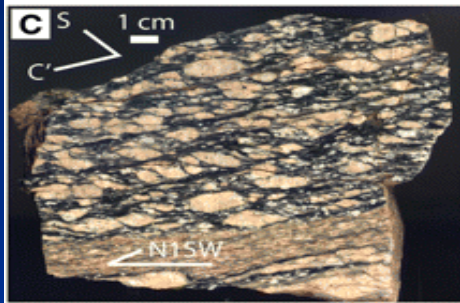
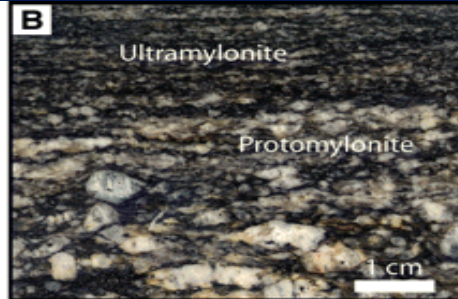
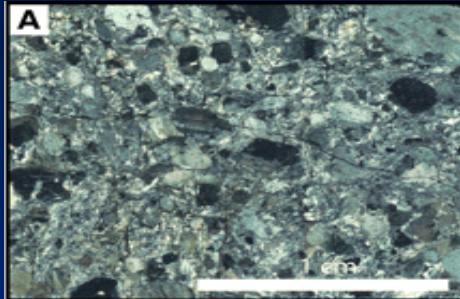


Strike-slip oriented slickensides



Right-lateral, strike-slip offset

# Special Fault Rocks



## Mylonite

Brittle-ductile shear-like deformation along fault zone resulting in a special kind of foliation termed "S-C fabric".

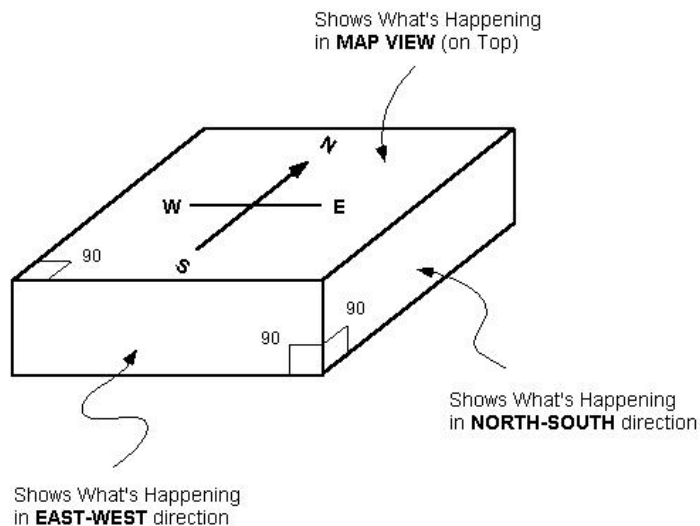
# The Basic Rules of Structure

- 1) Strike of beds is always parallel to the direction of the contacts.
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  - ✓ Syncline fold plunges toward *open* end of "U" pattern.
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- 10) Hanging wall *moves down* relative to foot wall in normal faults.

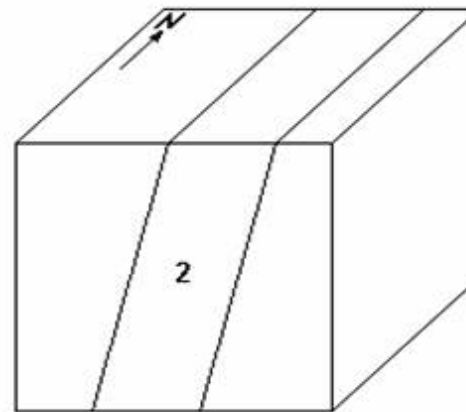


# Working with Block Diagrams

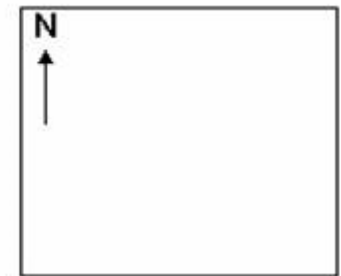
## A GUIDE TO BLOCK DIAGRAMS



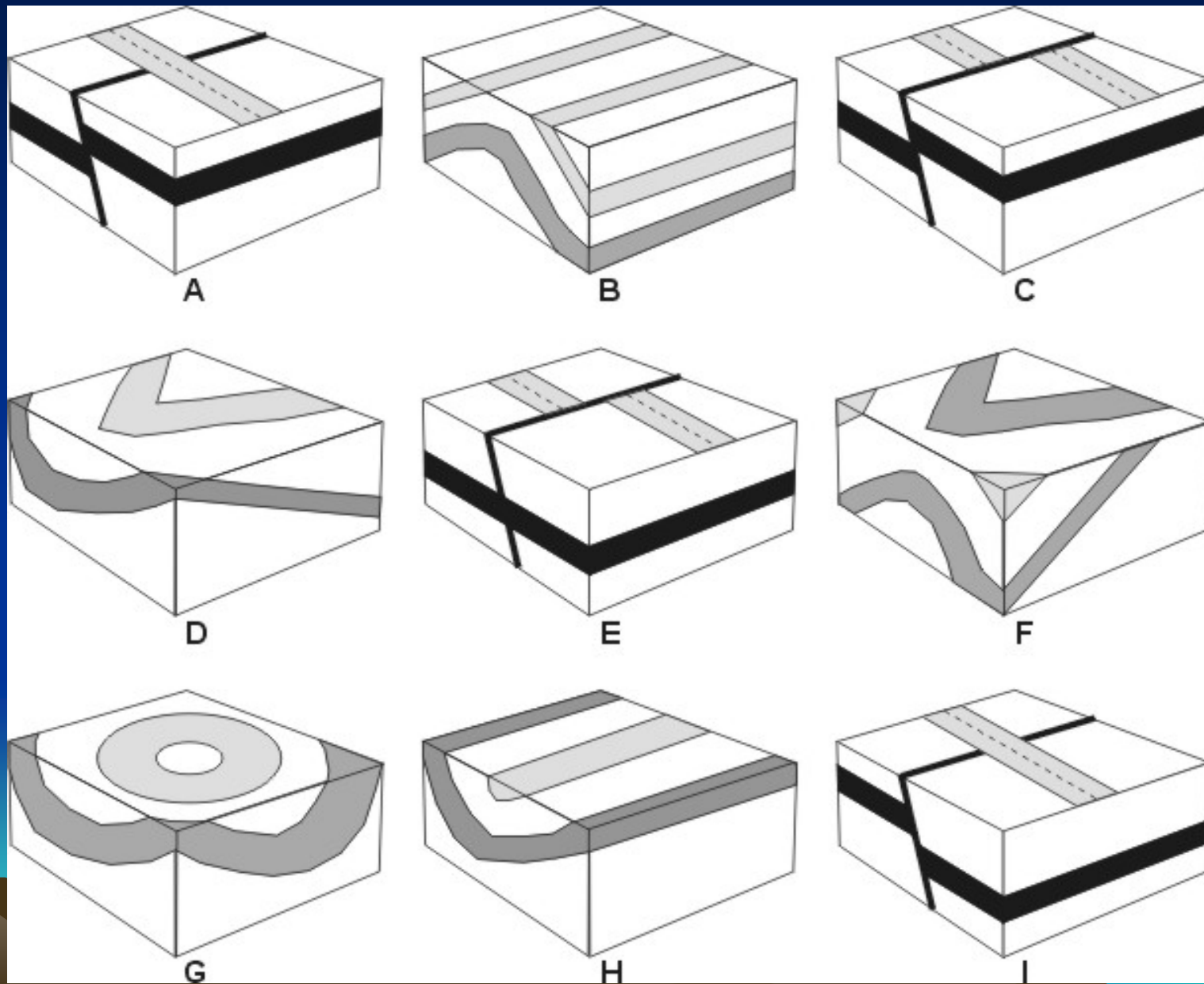
## BLOCK DIAGRAM



## MAP VIEW



# Working with Block Diagrams



# Working with Block Diagrams

## Map View

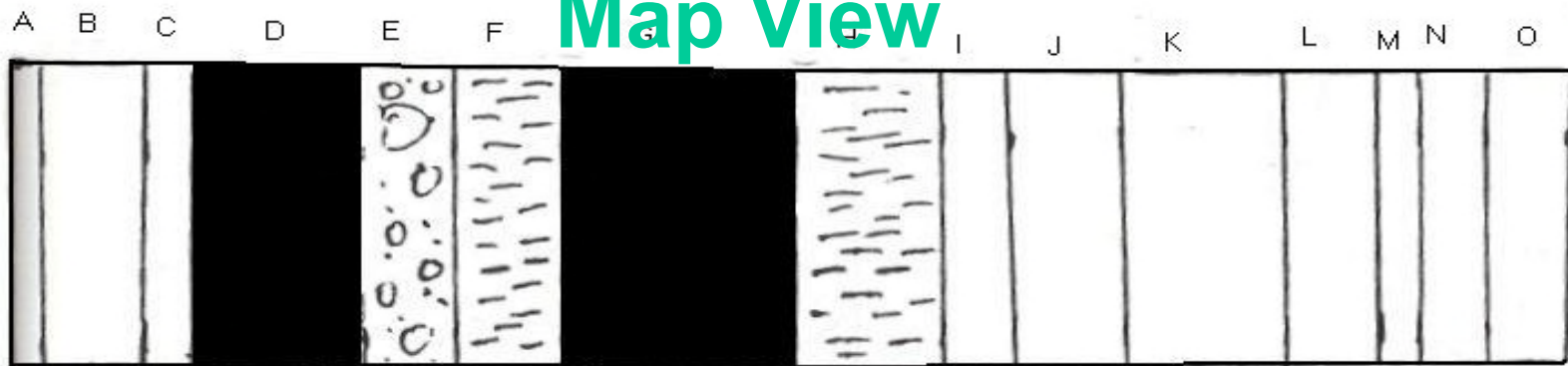
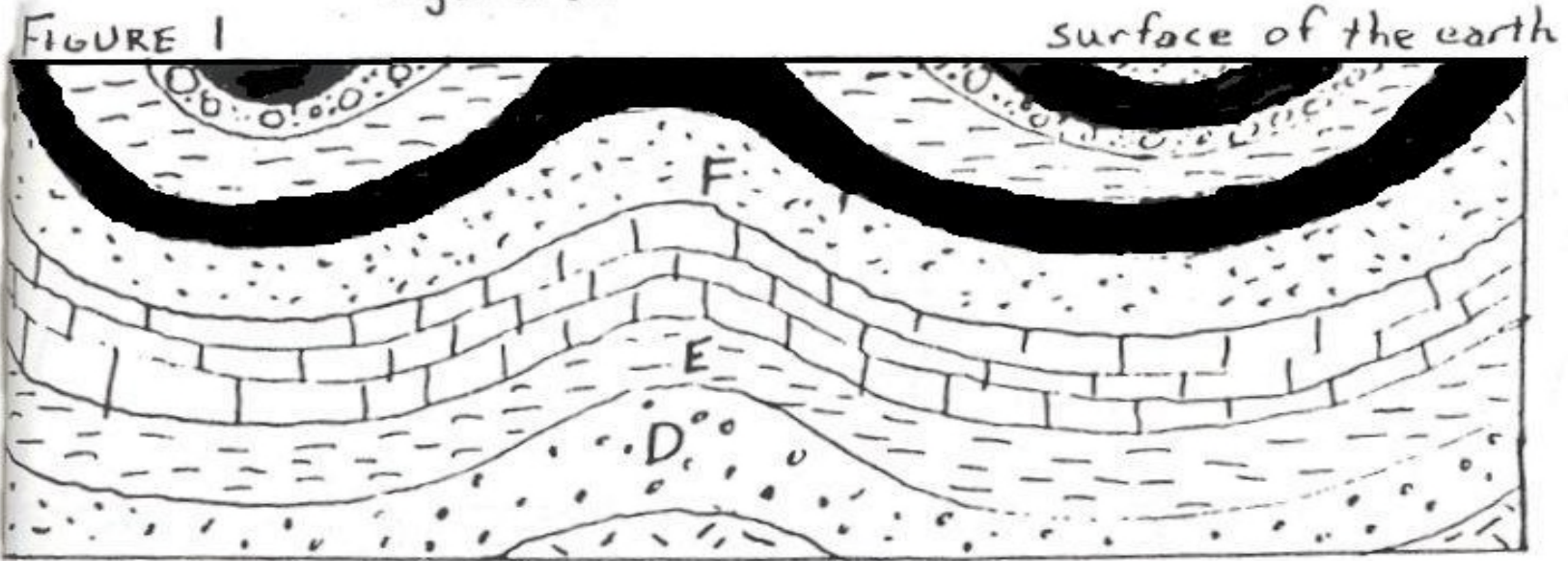


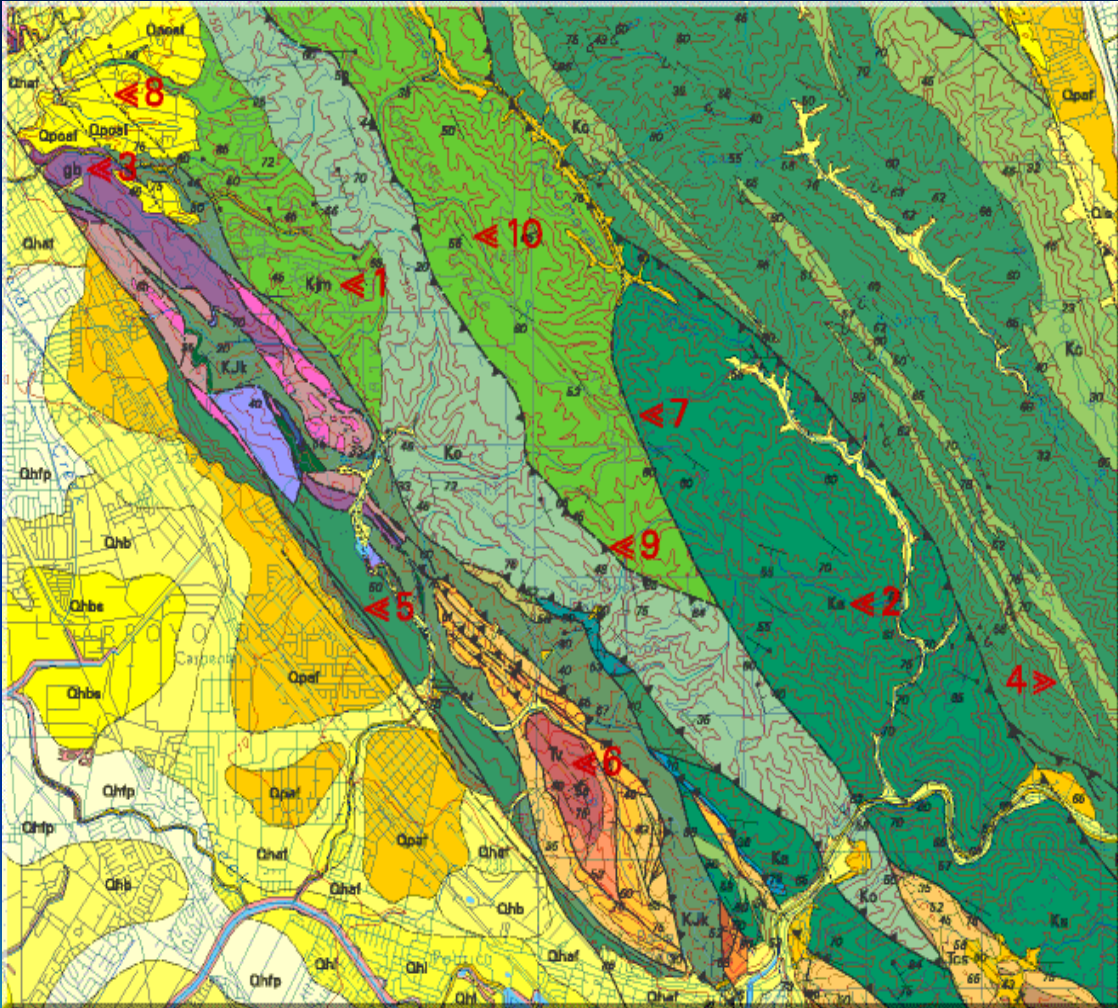
Figure 2



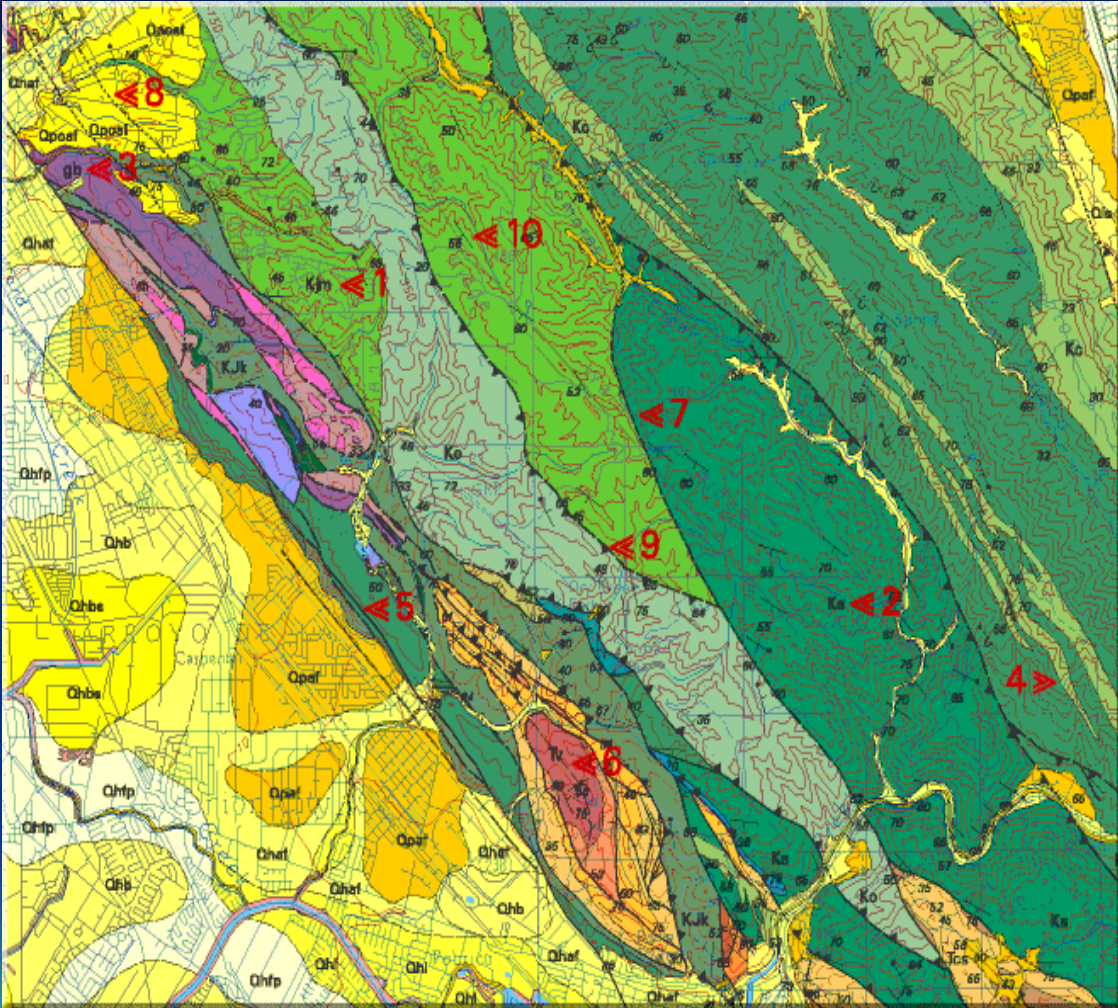
## Cross Section View

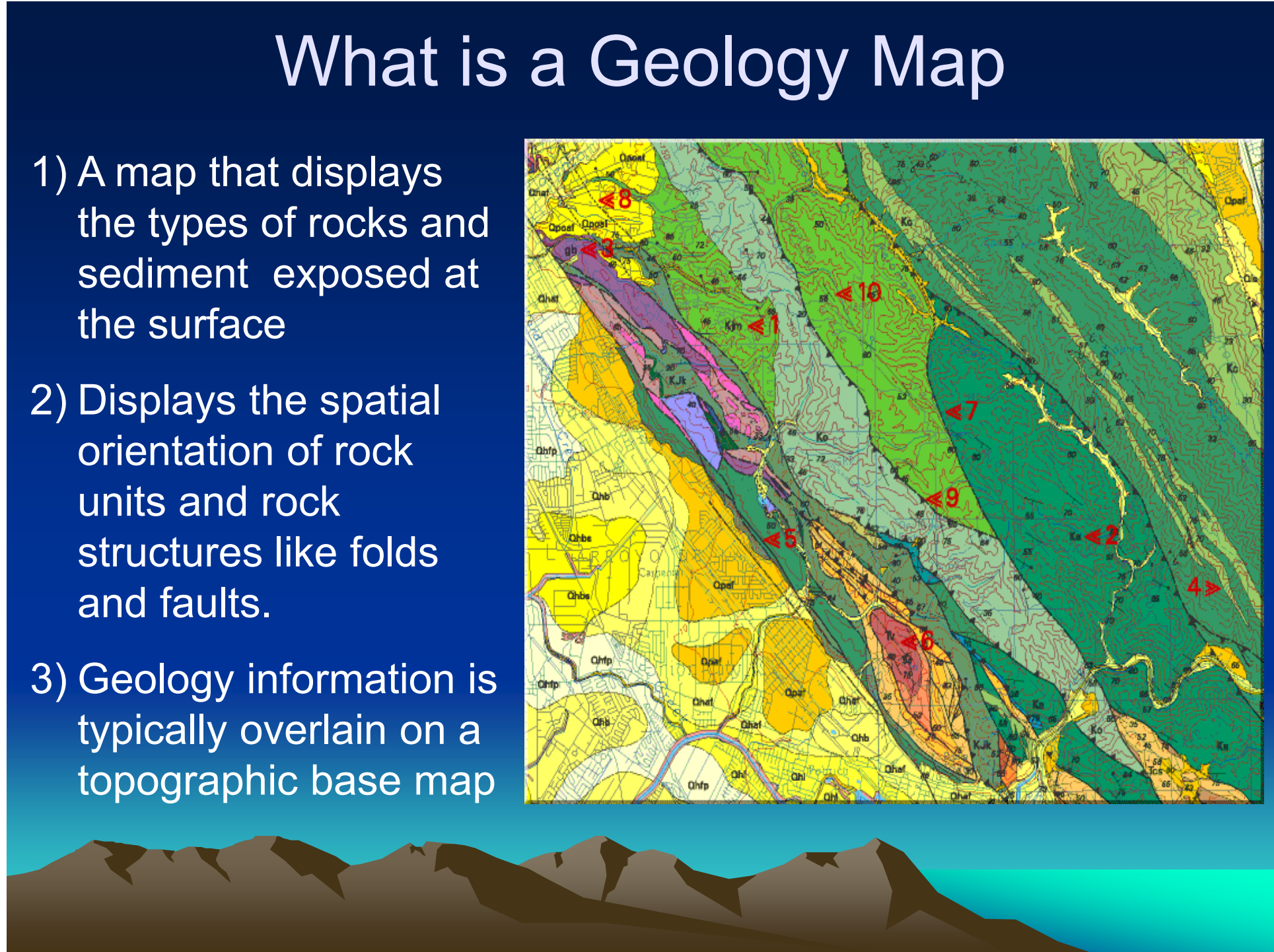
# What is a Geology Map

- 1) A map that displays the types of rocks and sediment exposed at the surface
- 2) Displays the spatial orientation of rock units and rock structures like folds and faults.
- 3) Geology information is typically overlain on a topographic base map



The image shows a geological map overlaid on a topographic base map. The map displays various rock units color-coded in yellow, orange, green, and purple. Topographic features like contour lines and a river are visible. Red arrows with numbers 1 through 10 point to specific geological features or units.

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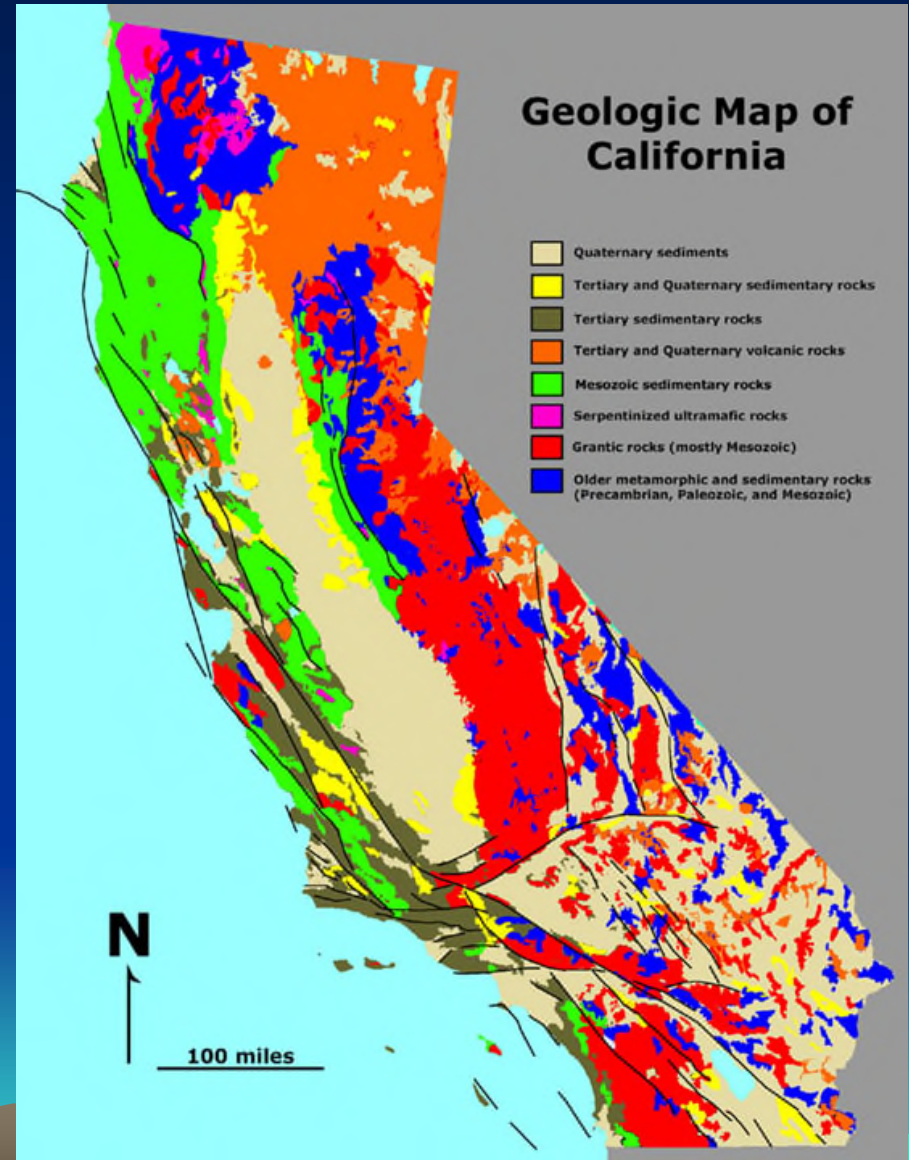


# Usefulness of Geology Maps

1) Geology maps have many vital uses:

- ✓ Mineral Prospecting
- ✓ Engineering
- ✓ Earthquakes
- ✓ Historical geology
- ✓ Landform studies
- ✓ Soil development
- ✓ Biological studies


































2) Geology maps are even useful when buying a home. Why?



# Geology Map Key or Legend

1) The map key lists and explains the geologic rock formations and the structural symbols

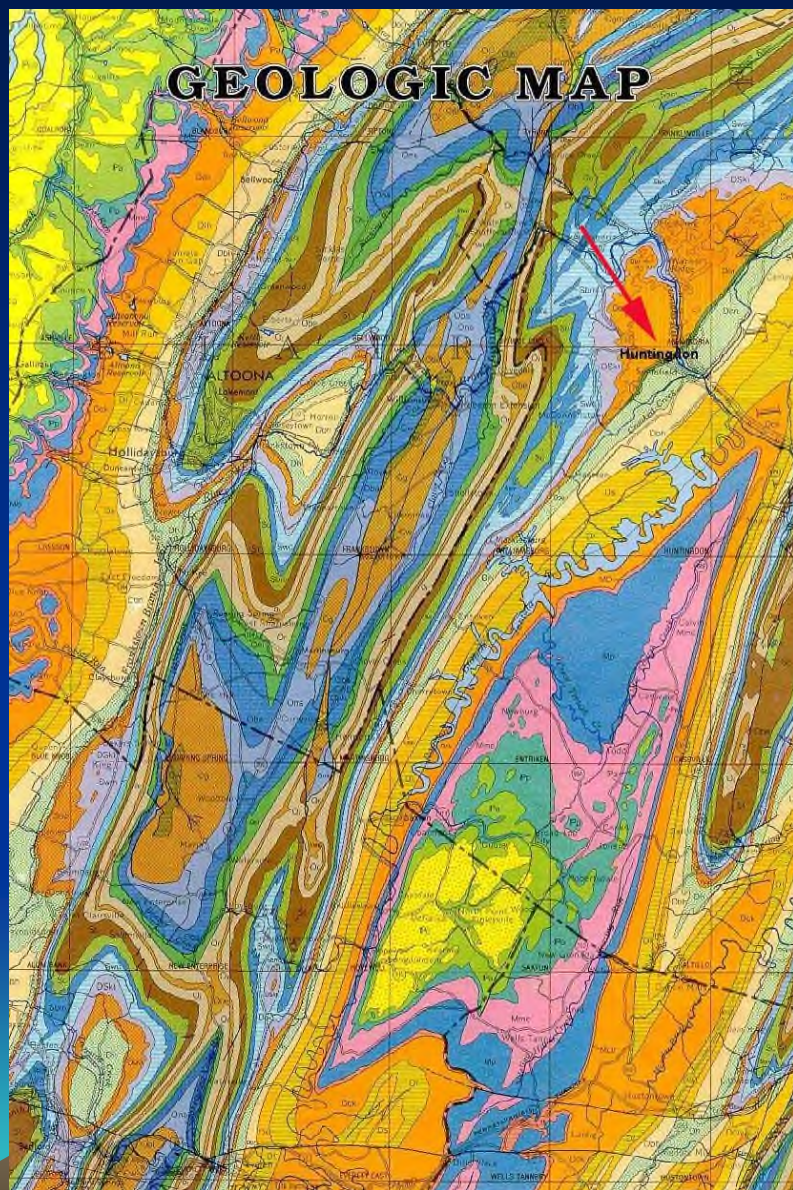
- ✓ Rock Names
- ✓ Rock Types
- ✓ Rock Ages
- ✓ Contacts
- ✓ Strike and Dip
- ✓ Faults and Folds

MAP KEY	
 af - Artificial Fill (Historic)	 Contact
 alf - Artificial Levee Fill (Historic)	 Contact, approximately located
 Qhaf - Alluvial Fan Deposits (Holocene)	 Contact, inferred
 Qhfp - Floodplain Deposits (Holocene)	 Contact, concealed
 Qhfb - Flood Basin Deposits (Holocene)	 Fault
 Qhbs - Salt Affected Flood Basin Deposits (Holocene)	 Fault, approximately located
 Qhl - Natural Levee Deposits (Holocene)	 Fault, inferred
 Qpaf - Alluvial Fan Deposits (Pleistocene)	 Fault, uncertain
 Qpof - Older Alluvial Fan Deposits (Pleistocene)	 Fault, concealed
 Tv - Unnamed volcanic rocks (Miocene)	 Fault, concealed and uncertain
 Tor - Orinda conglomerate (Miocene)	 Oblique fault with thrust or reverse component
 Tbr - Briones sandstone (Miocene)	 Oblique fault with thrust or reverse component, approximately located
 Tt - Tice shale (Miocene)	 Oblique fault with thrust or reverse component, inferred
 Tos - Claremont shale (Miocene)	 Oblique fault with thrust or reverse component, uncertain
 Ts - Soberanes sandstone (Miocene)	 Strike and dip of bedding
 Tsh - Unnamed shale and sandstone (Miocene)	 Strike and dip of overturned bedding
	 Strike and dip of vertical bedding

2) Each rock unit has a unique letter symbol and is color-coded

3) Map key is vital to understanding the accompanying geology map

# Geologic Maps – Artwork?



## Union County Geology

The map below is a scan from the Geologic Map of Pennsylvania (1980) focusing on Union County. The location of Bucknell University is represented by the green circle located along the eastern portion of the map. Descriptions for the rock types have been modified from the original map to more accurately describe the geology of the Union County area (from mapping by Dr. Richard P. Nickelsen, Bucknell University).

### EXPLANATION FOR THE ROCK TYPES IN THE LEWISBURG AREA

#### Dh Hamilton Group

Gray, brown and olive shale, siltstone; marine fossils; char. by coarsening upward cycles. Black carbonaceous shale with Tioga Bentonite at base.

#### Doo Onondaga and Old Port Formations

Gray calcareous shale; argillaceous limestone; marine fossils. Dark gray chert interbedded with calcareous shale and limestone; very fossiliferous.

#### Dskt Keyser and Tonoloway Formations

Gray coarse-grained limestone; highly fossiliferous. Gray, fine-grained platy limestone; poorly fossiliferous.

#### Swc Wills Creek Formation

Greenish gray shale, mudstone and minor limy beds; all rock types limy; unfossiliferous.

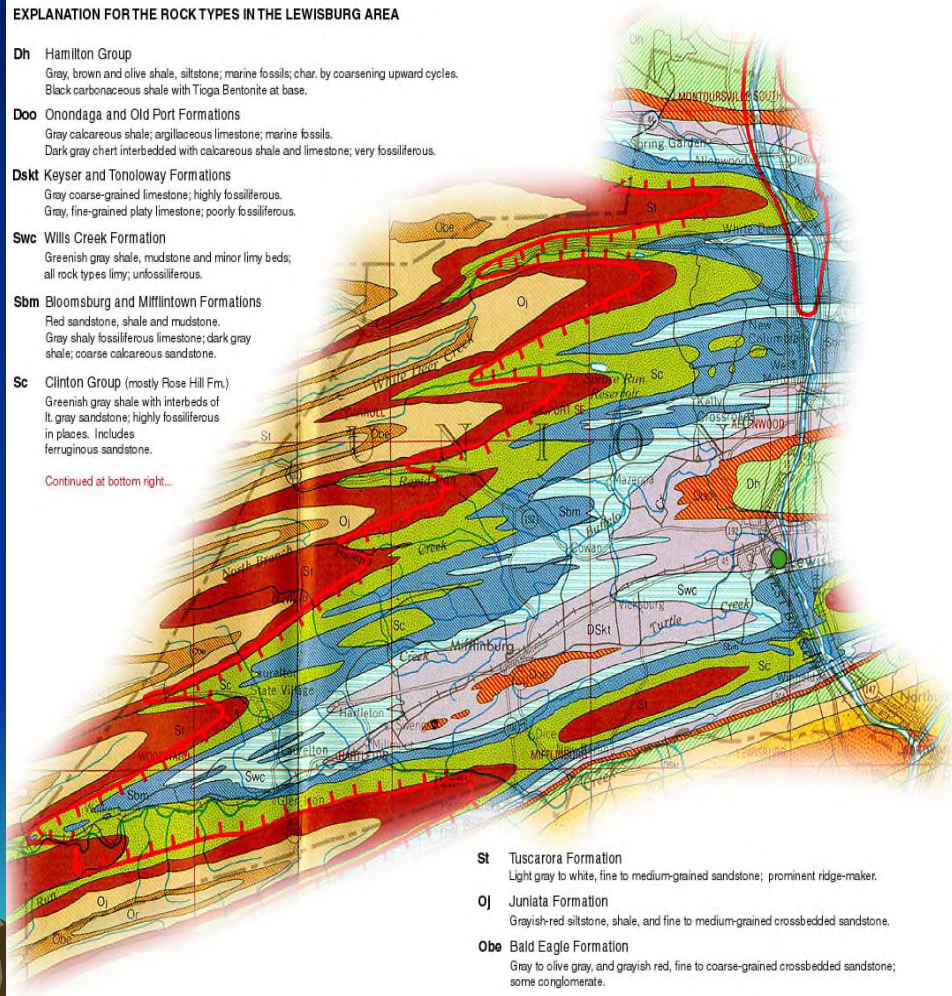
#### Sbm Bloomsburg and Mifflintown Formations

Red sandstone, shale and mudstone. Gray shaly fossiliferous limestone; dark gray shale; coarse calcareous sandstone.

#### Sc Clinton Group (mostly Rose Hill Fm.)

Greenish gray shale with interbeds of lt. gray sandstone; highly fossiliferous in places. Includes ferruginous sandstone.

Continued at bottom right...



#### St Tuscarora Formation

Light gray to white, fine to medium-grained sandstone; prominent ridge-maker.

#### Oj Juniata Formation

Grayish-red siltstone, shale, and fine to medium-grained crossbedded sandstone.

#### Obe Bald Eagle Formation

Gray to olive gray, and grayish red, fine to coarse-grained crossbedded sandstone; some conglomerate.

# The Basic Rules of Structure

- 1) Strike of beds is always parallel to the direction of the contacts.
- 2) Rock layers dip towards the youngest exposed rock layers.
- 3) Oldest rocks exposed in the center of eroded anticlines and domes.
- 4) Youngest rocks exposed in the center of eroded synclines and basins.
- 5) Horizontal folds form parallel sets of belt-like outcrop patterns.
- 6) Plunging anticlines form "V" or "U" shaped, belt-like outcrop patterns.
  - ✓ Anticline fold plunges toward *closed* end of "V" or "U" pattern.
- 7) Plunging synclines form "V" or "U" shaped, belt-like outcrop patterns.
  - ✓ Syncline fold plunges toward *open* end of "U" pattern.
- 8) Steeper the dip of the layer, the more narrow the width of its outcrop.
- 9) Hanging wall *moves up* relative to foot wall in reverse and thrust faults.
- 10) Hanging wall *moves down* relative to foot wall in normal faults.



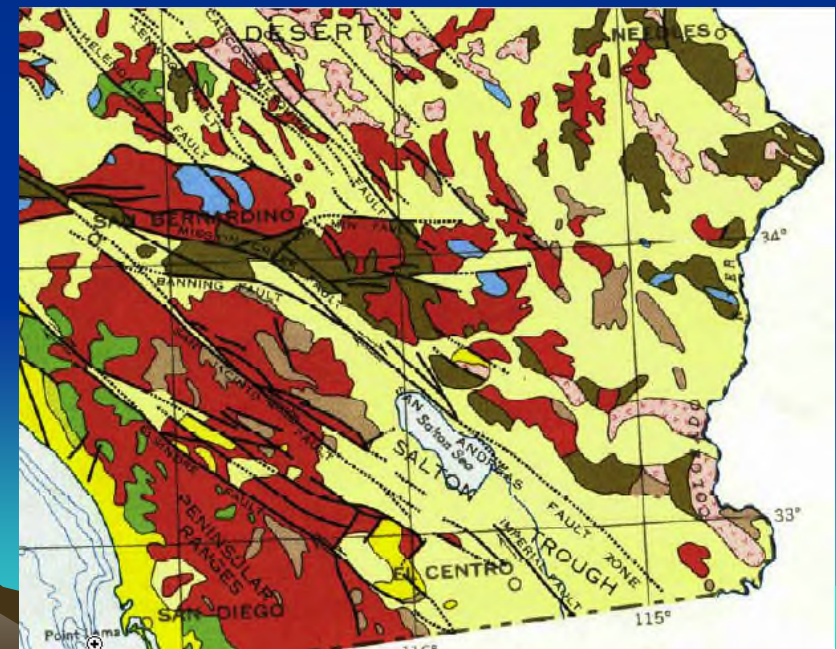
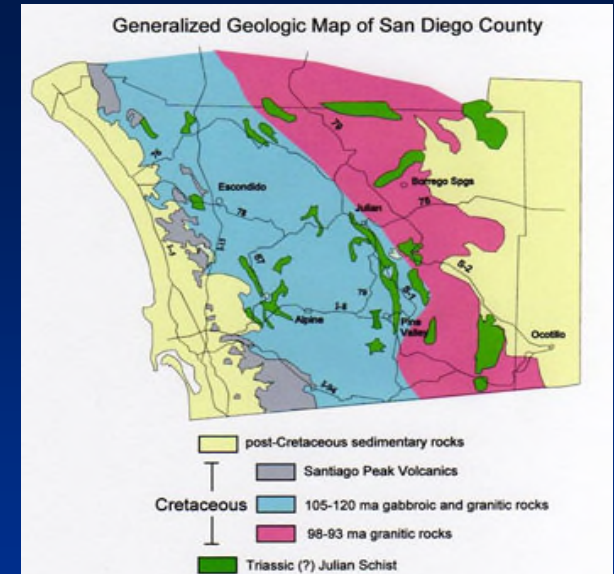
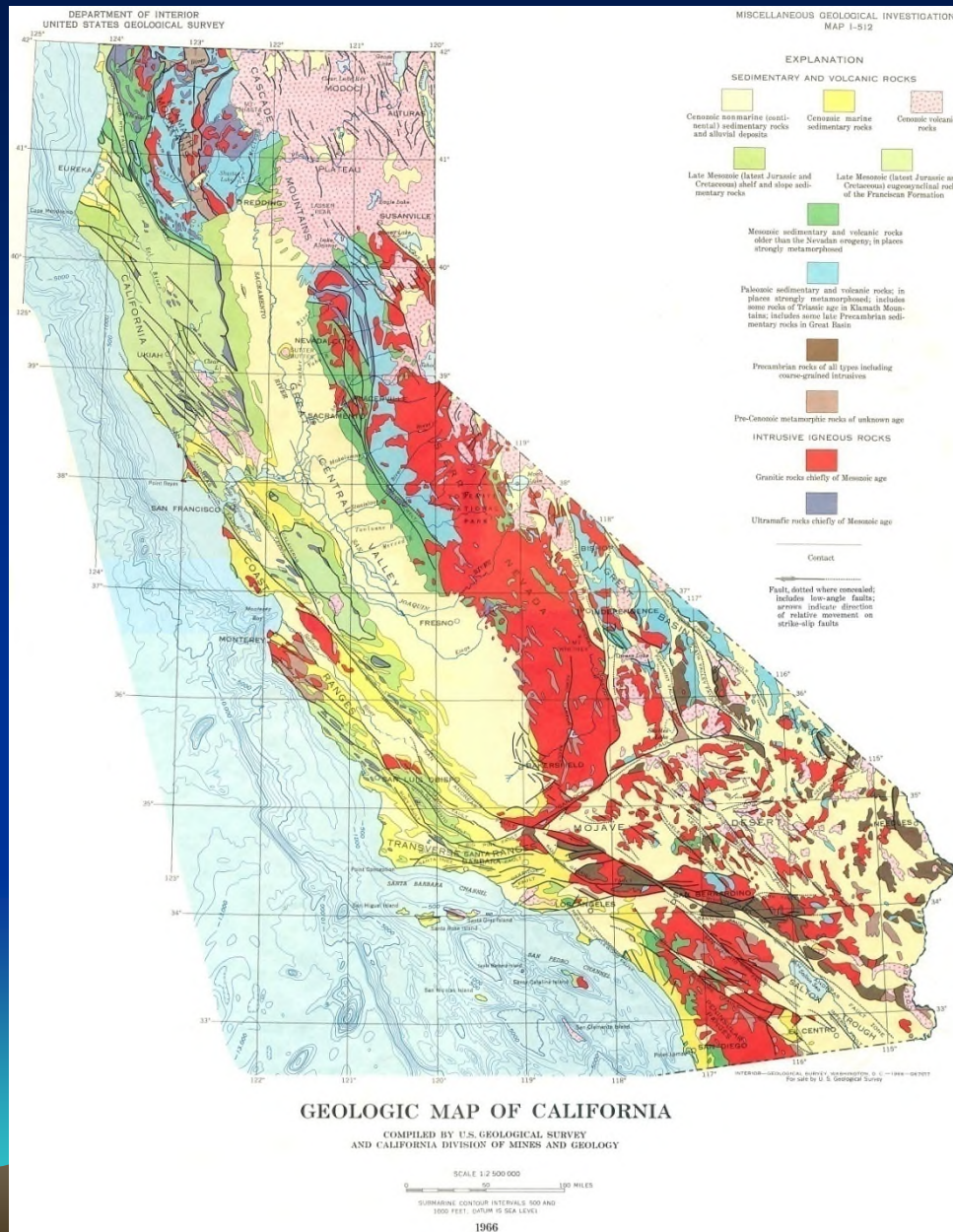
# Geologic Map of North America



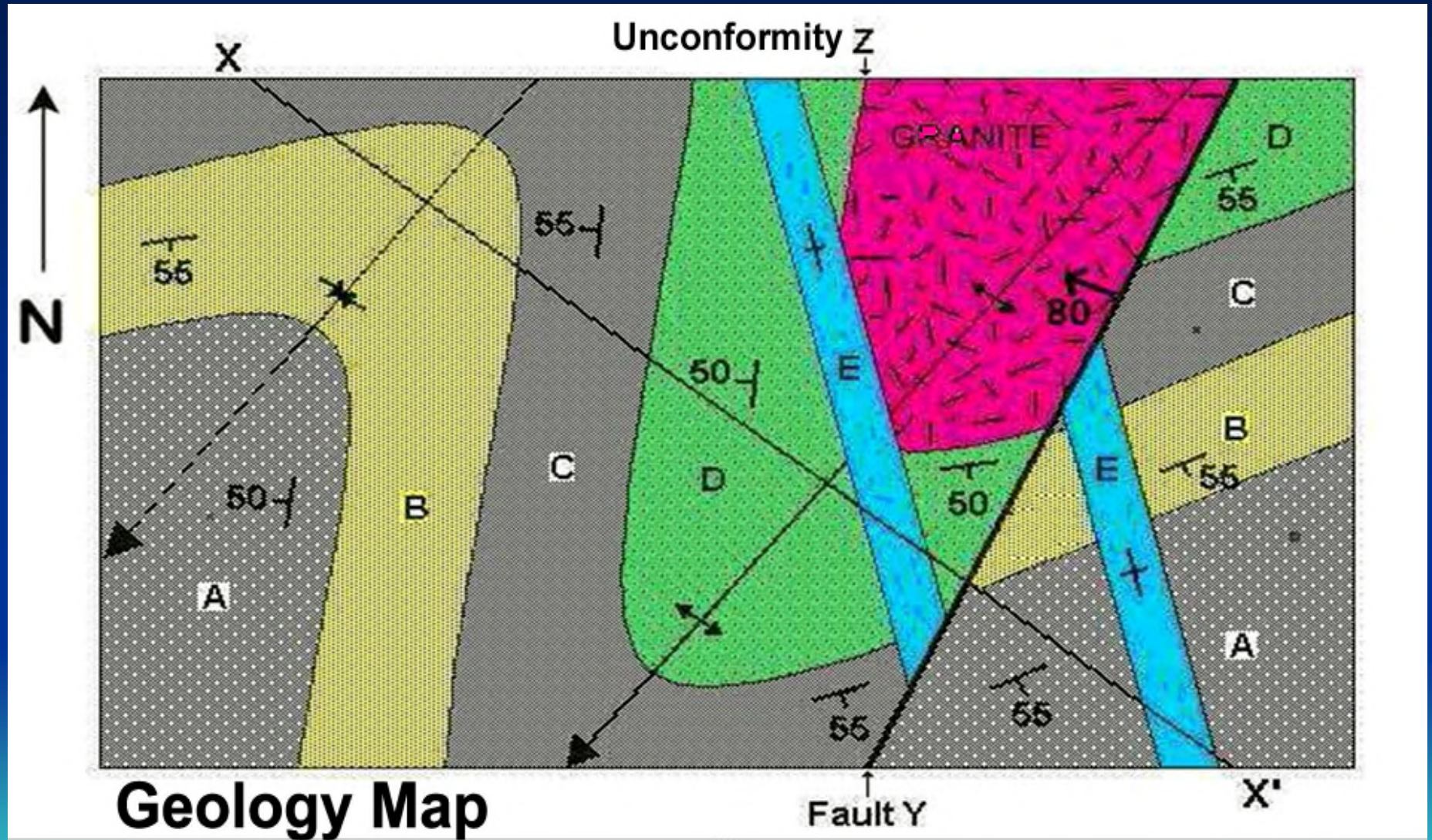
U.S. DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY



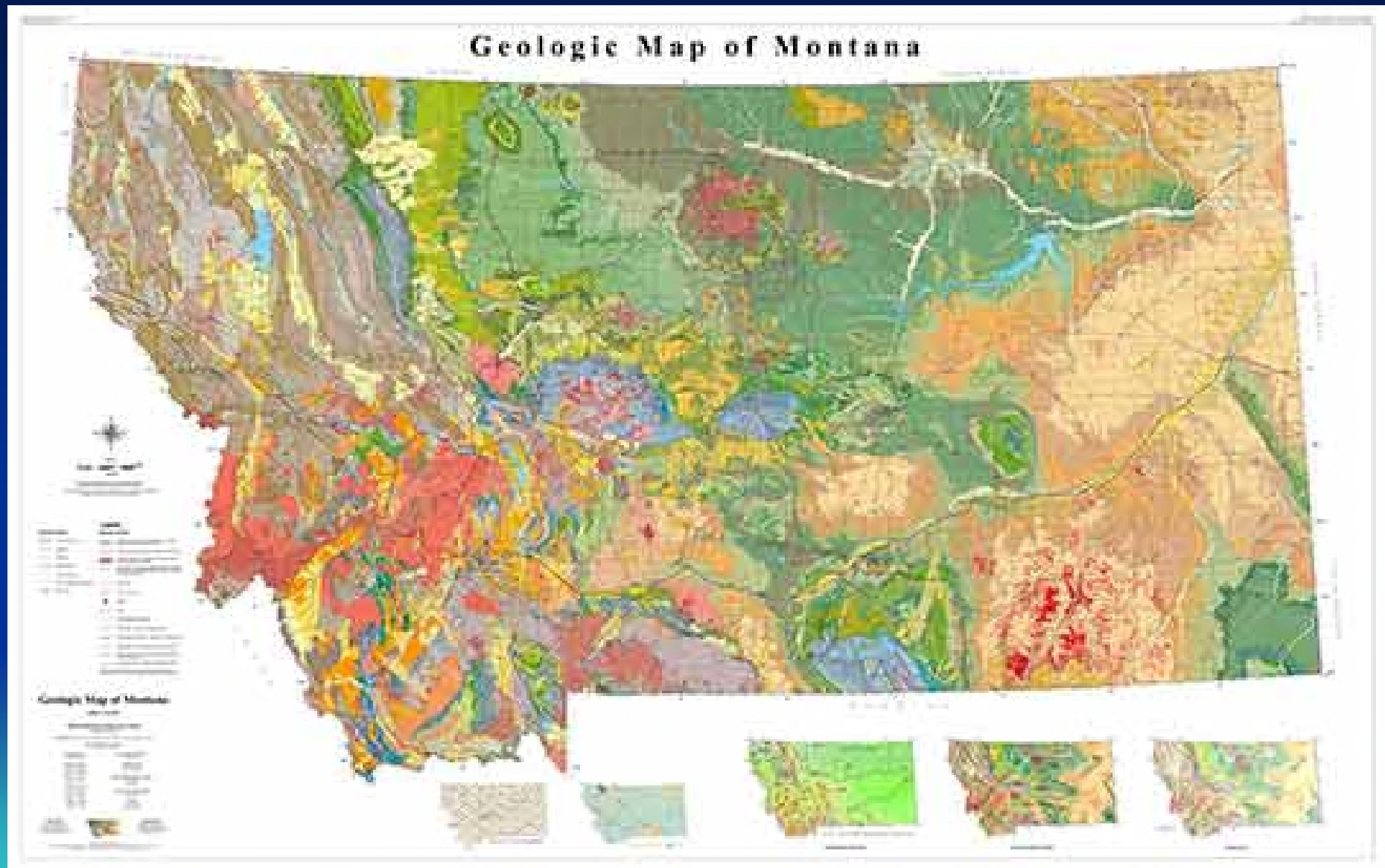
# Geologic Maps of California



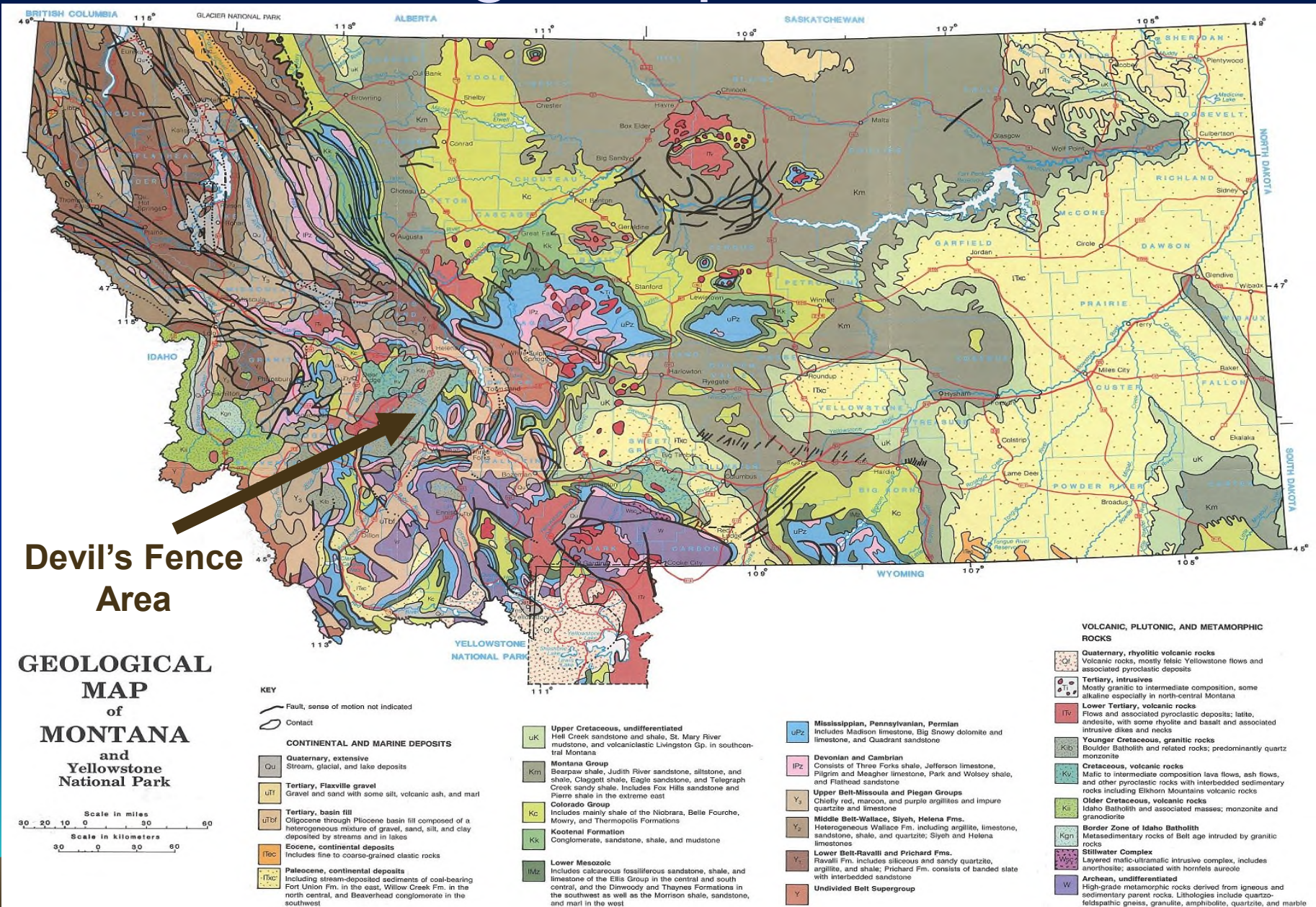
# A Simplified Geology Map



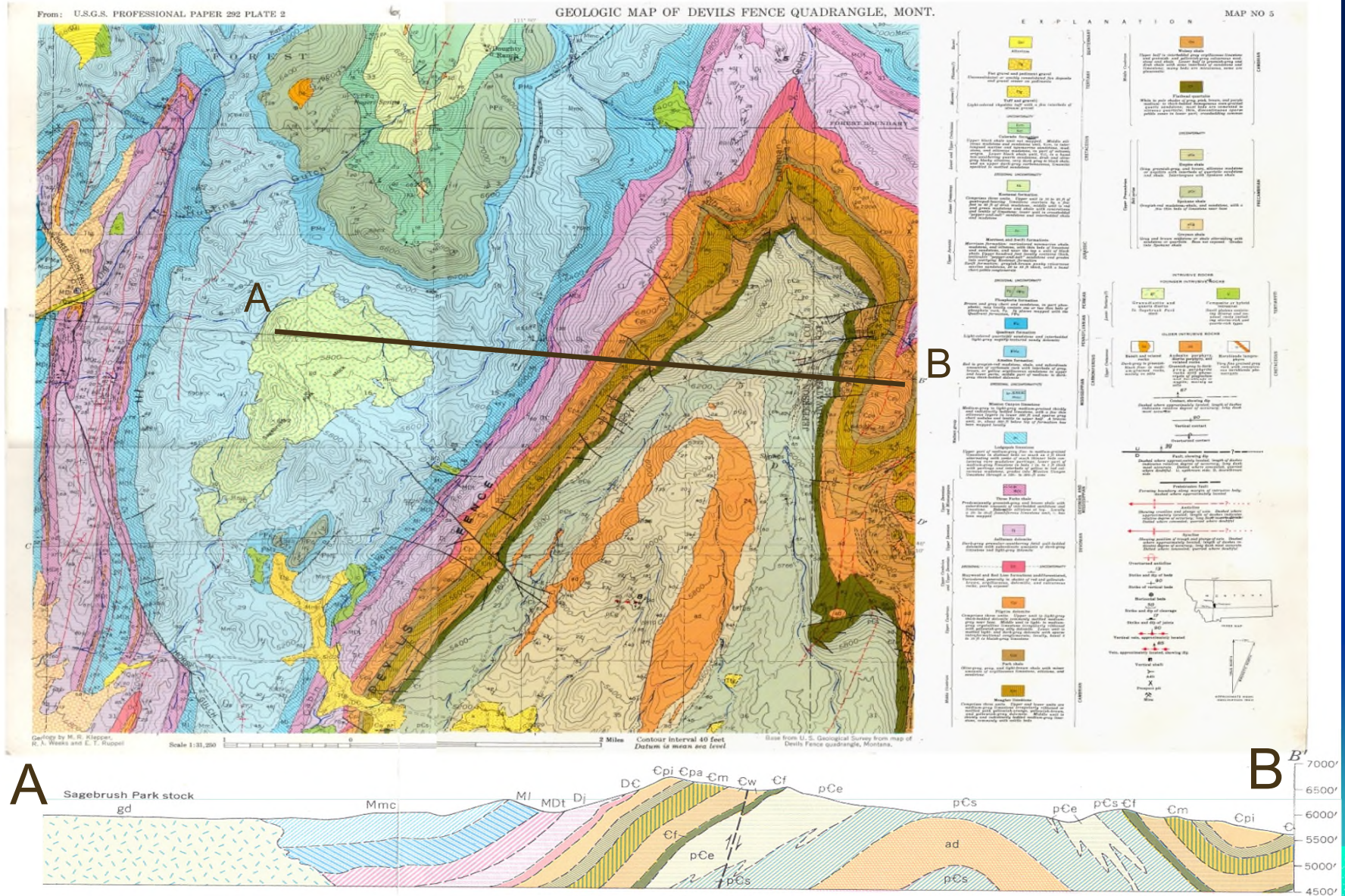
# Geologic Map of Montana



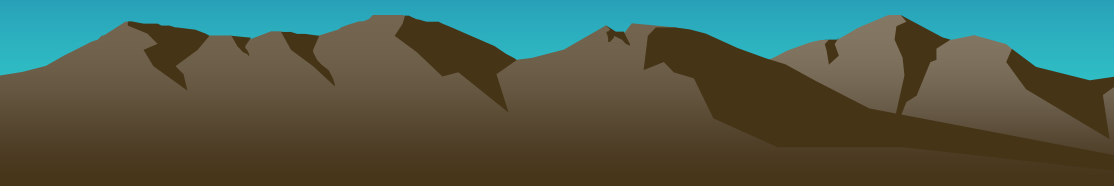
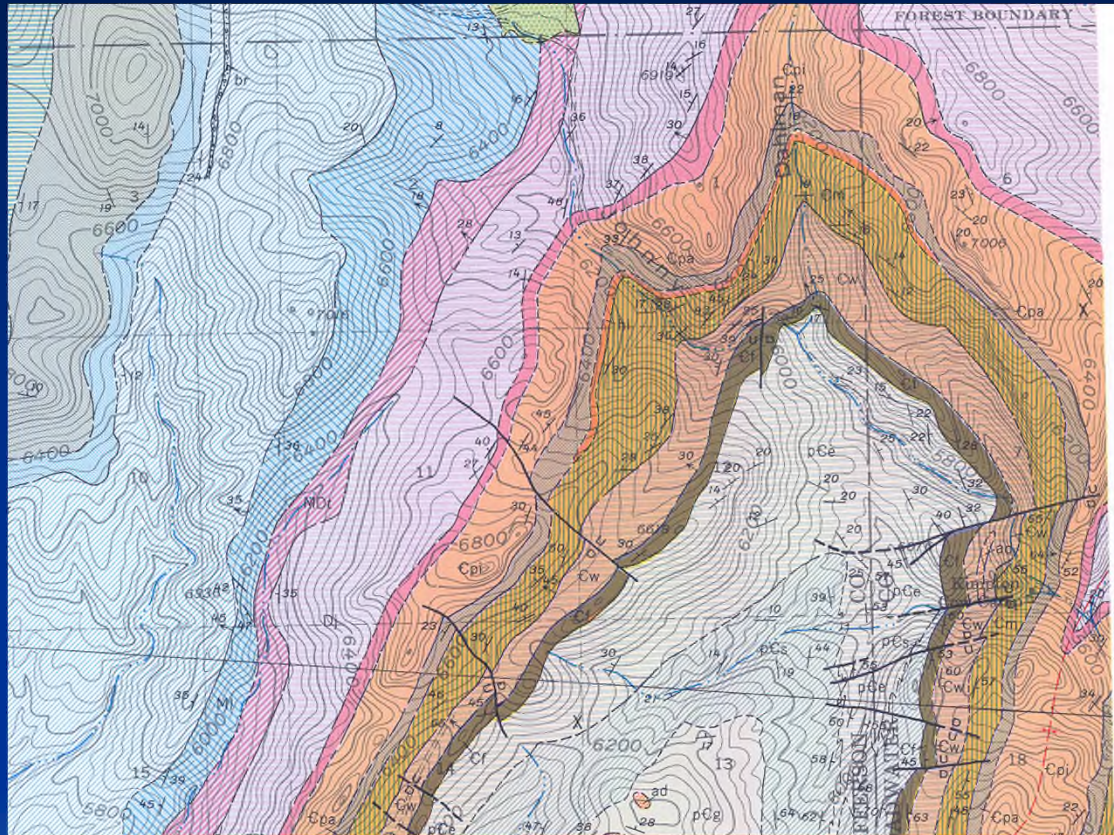
# Geologic Map of Montana



# Geologic Maps – Devil's Fence Quad



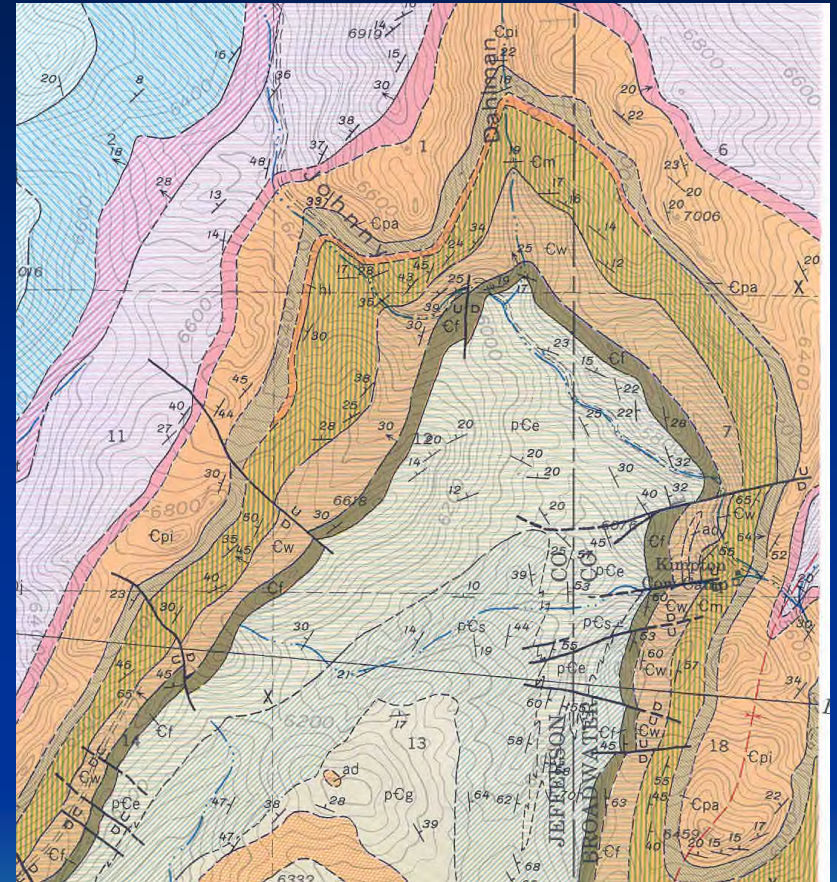
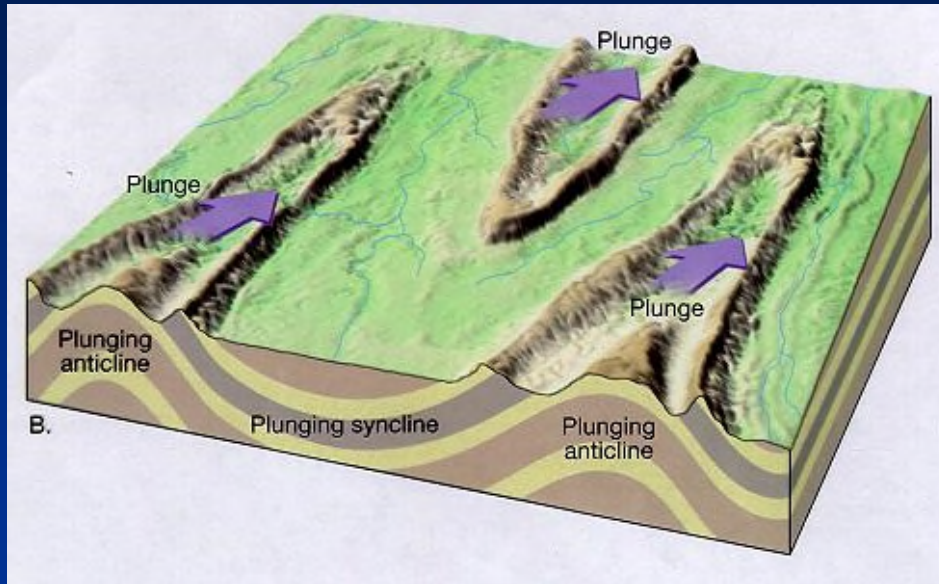
# Devil's Fence Geology Map with Explanation



**E X P L A N**

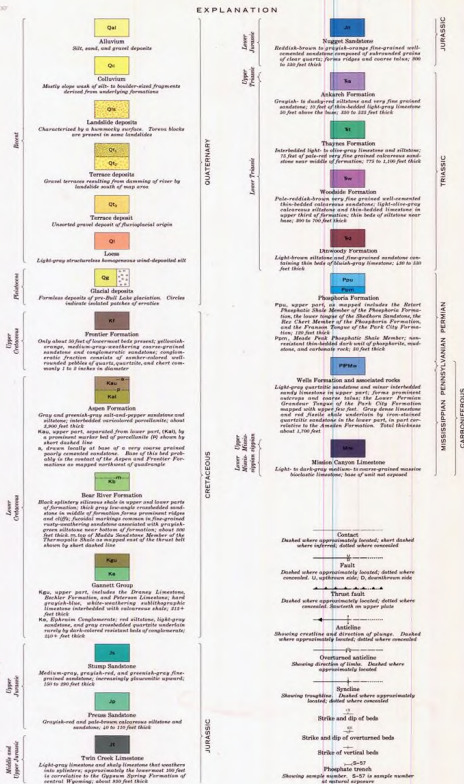
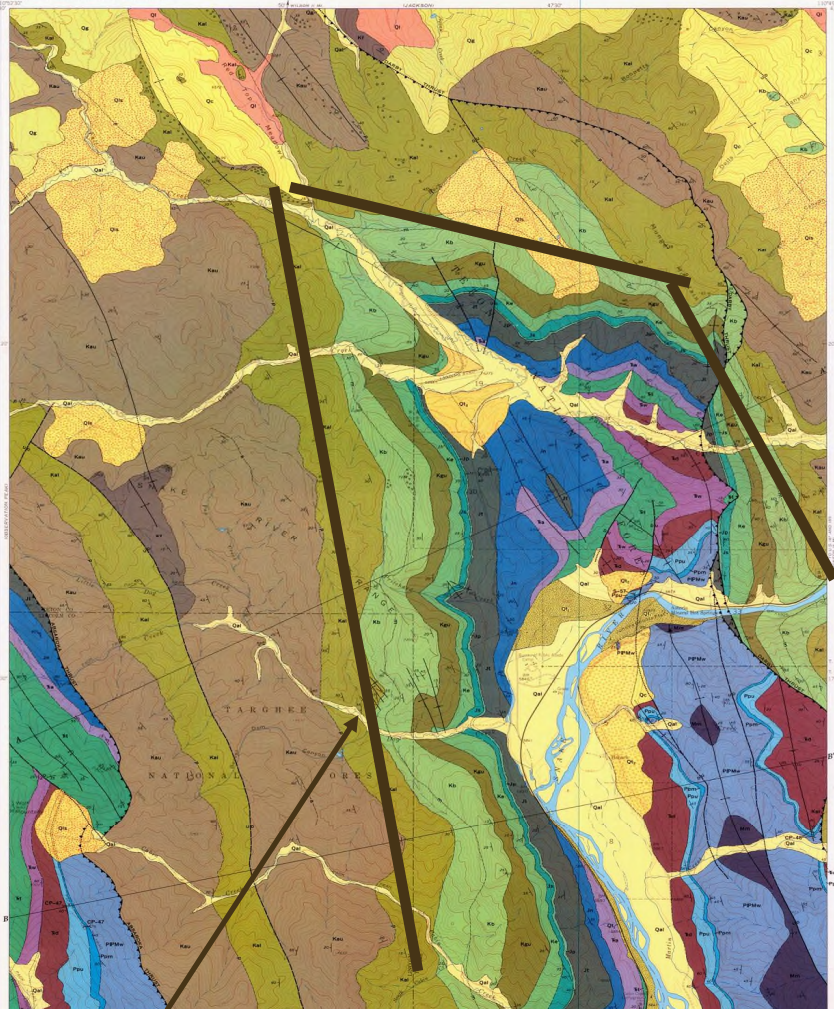
Geological Period	Geological Group	Formation	Description
QUATERNARY	Recent	Qal	Alluvium
		Tuf	Fan gravel and pediment gravel Unconsolidated or weakly consolidated fan deposits and gravel veneer on pediments
		Tuf	Tuff and gravel Light-colored rhyolitic tuff with a few interbeds of stream gravel
TERTIARY	Pliocene (?)	UNCONFORMITY	
		Kcc	Colorado formation
		Kcc	Upper black shale unit not mapped. Middle silty mudstone and sandstone unit, Kcc, is interbedded with massive sandstone, mudstone, and siliceous mudstone, in part of volcanic origin. Lower black shale unit, Kcc, is a basal tan-weathering quartz sandstone, drab and olive-gray blocky siltstone, very dark gray to black shale, and an upper dark-gray carbonaceous, laminitic siltstone to mudstone
CITIZEN	Lower and Upper Oligocene	UNCONFORMITY	
		Kk	Kootenai formation
		Kk	Comprises three units. Upper unit is 10 to 25 ft of grayish-brown limestone overlain by a few feet to 80 ft of drab mudstone; middle unit is red and green mudstone and shale with concretions and lentils of limestone; lower unit is crossbedded "paper-and-milk" sandstone and interbedded shale and mudstone
JURASSIC	Upper Jurassic	UNCONFORMITY	
		Morrison and Swift formations	
		Morrison and Swift formations	Morrison formation: varicolored micaceous shale, mudstone, and siltstone, with thin beds of limestone and sandstone, and near the top a unit of black shale. Upper hundred feet locally contains thick, lenticular, "paper-and-milk" sandstone and grades into overlying Kootenai formation. Swift formation: grayish-brown, blocky carbonaceous marine sandstone, 10 to 25 ft thick, with a basal chert-pebble conglomerate
PERMIAN	Middle Permian	UNCONFORMITY	
		Phosphoria formation	
		Phosphoria formation	Brown and gray chert and sandstone, in part phosphatic, may locally contain one or two thin beds of phosphatic rock, Pp. In places mapped with the Quadrant formation, PpQ
PENNSYLVANIAN	Middle Pennsylvanian	UNCONFORMITY	
		Quadrant formation	
		Quadrant formation	Light-colored quartzitic sandstone and interbedded light-gray supercrystalline sandy dolomite
MISSISSIPPIAN	Middle Mississippian	UNCONFORMITY	
		Amaden formation	
		Amaden formation	Red to grayish-red mudstone, shale, and subordinate amounts of carbonate rock with interbeds of gray, brown, or yellow argillaceous sandstone in upper and lower parts; middle part of medium- to dark-gray thick-bedded dolomite
DEVELOPMENTAL AND MISSISSIPPIAN	Upper Devonian	UNCONFORMITY	
		Mission Canyon limestone	
		Mission Canyon limestone	Medium-gray to light-gray medium-grained thickly and laterally bedded limestone, with a few thin siliceous layers in lower 200 ft and sparse gray chert nodules and lentils in upper half. A breccia has been mapped locally
DEVELOPMENTAL AND MISSISSIPPIAN	Upper Devonian	UNCONFORMITY	
		Lodgepole limestone	
		Lodgepole limestone	Upper part of medium-gray fine- to medium-grained limestone in distinctively bedded limestone, with alternating with zones of much thinner beds containing rare mudstone partings; lower part of medium-gray limestone in beds 1 to 2 ft thick with partings and interbeds of yellow to red calcareous mudstone; grades into Mission Canyon limestone through a 150- to 200-ft zone
DEVELOPMENTAL AND MISSISSIPPIAN	Upper Devonian	UNCONFORMITY	
		Three Forks shale	
		Three Forks shale	Pre dominantly gray to brown shale with subordinate amounts of interbedded sandstone and limestone. Dolomitic siltstone at top. Locally 10 to 25 ft fossiliferous limestone unit, if has been mapped
DEVELOPMENTAL AND MISSISSIPPIAN	Upper Devonian	UNCONFORMITY	
		Jefferson dolomite	
		Jefferson dolomite	Dark-gray granular-weathering bed well-bedded dolomite with subordinate amounts of dark-gray limestone and light-gray dolomite

# Folds and Geologic Maps



# Devil's Fence Topographic Feature



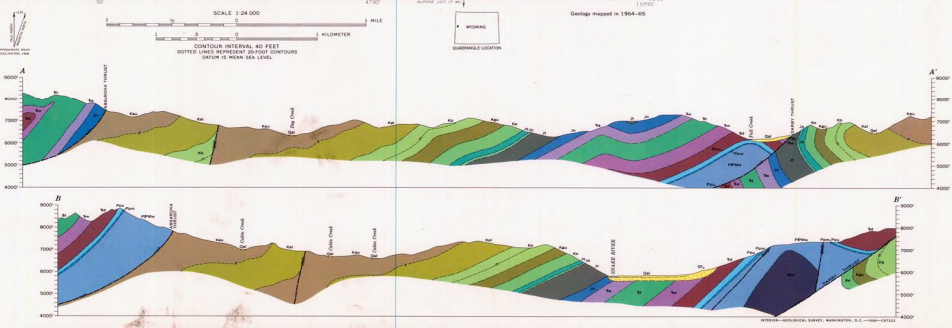


**ECONOMIC GEOLOGY**

The principal mineral resources of the Munger Mountain quadrangle are gravel, limestone, and sand. The Snake River is a relatively pure limestone in composition and available from outcrops of the Munger Mountain Formation near the Snake River. High magnesian limestone is available from outcrops of the Snake and Targhee Limestones near Arden, Red Springs and on Fall and Cedar Creeks. Sand is available from outcrops of the Snake River Formation and the Targhee Formation.

The phosphate-bearing Phosphatic Formation crops out in the northeast in the southeast part of the quadrangle. Phosphate is found in thin beds in the formation and in the Snake River Formation. The phosphate-bearing beds are thicker and more of higher grade in the Snake River. The phosphate was quarried and shipped to the B.W.R.S. in 1915. A 10-foot thick bed of phosphate is found in the Snake River Formation near the mouth of the Snake River. This is the thickest relatively high grade phosphate bed exposed, but is not of high grade. The bed is not being mined in the area.

Large Fold on Map



GEOLOGIC MAP OF THE MUNGER MOUNTAIN QUADRANGLE, TETON AND LINCOLN COUNTIES, WYOMING  
By Howard F. Albee 1968  
*Wyoming (Munger Mountain quad.)*  
Map 1

# Munger Mountain Geology Map

M(200)  
B  
75  
C.1

# Geology Map La Jolla Quad

