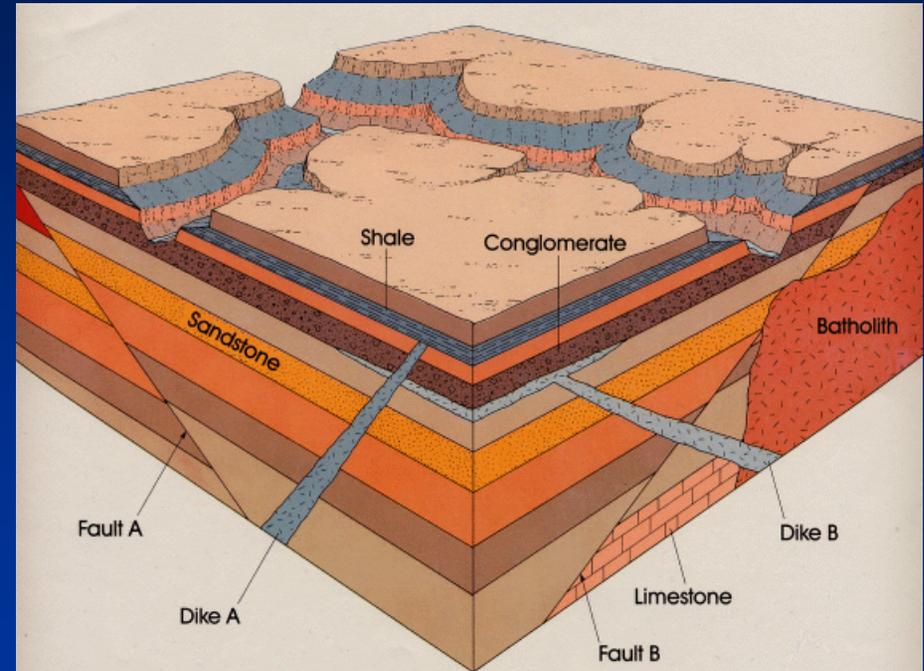


Structural Geology and Geology Maps Lab

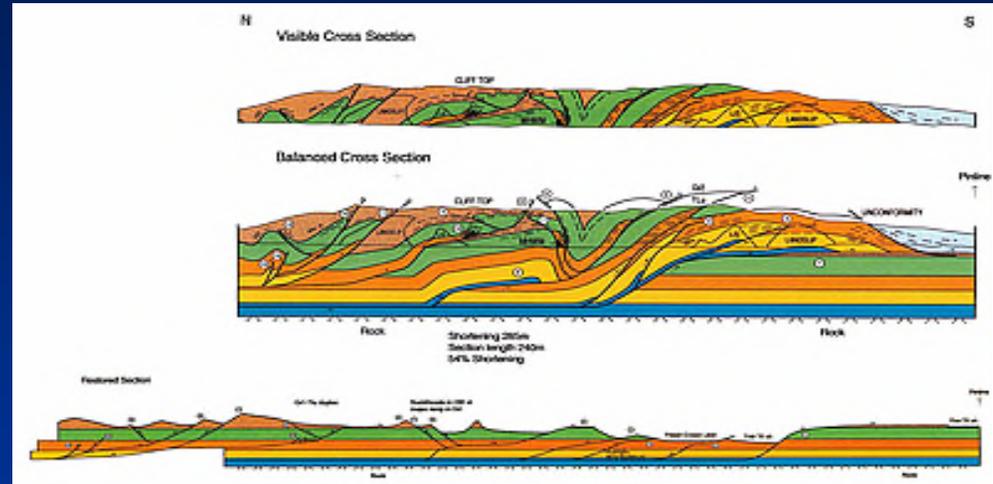


- EOSC110
Laboratory
Ray Rector: Instructor



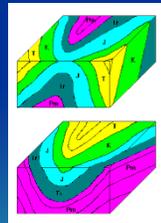
Structural Geology Lab

Pre-Lab Resources

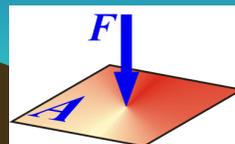


Pre-Lab Internet Links

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 planer disruption between adjacent blocks of rock with lateral offset between the two blocks

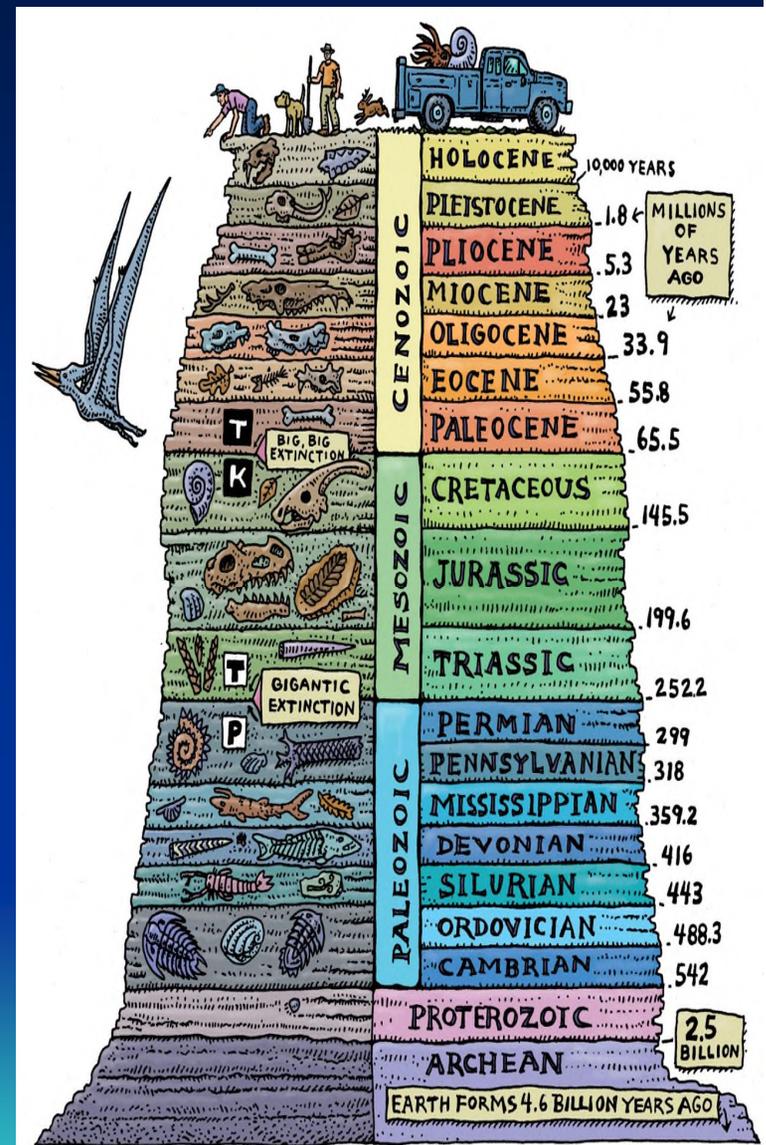


Joint: A planer disruption between adjacent blocks of rock with no lateral offset between the two blocks



Rock Formations and Geologic Time

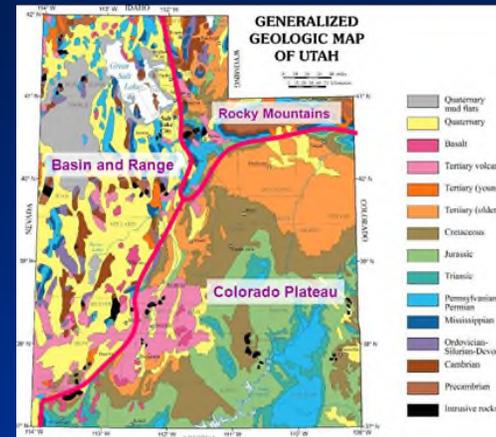
- 1) All formal geologic rock formations have a specific assigned age
- 2) All geologic rock formations have a specific range of lithology
- 3) Rock formations are listed in a temporally-ordered sequence in the “explanation” of a geologic map
- 4) Each rock formations has an assigned geologic period
- 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

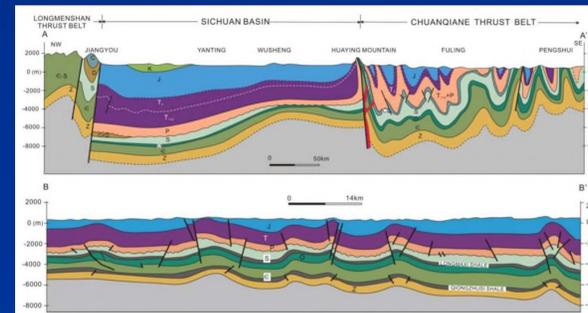
Geology Maps

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



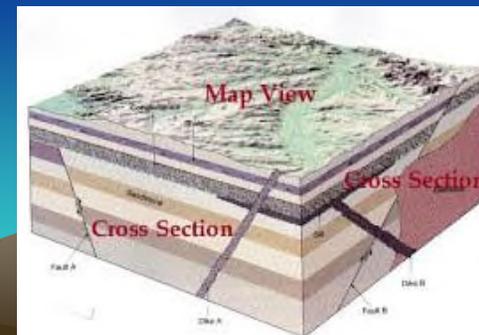
Geologic Cross Sections

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



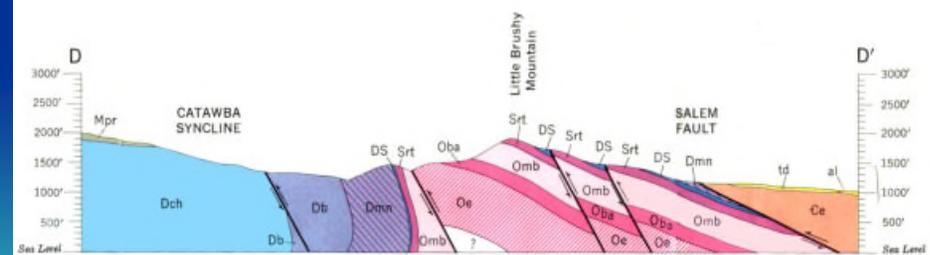
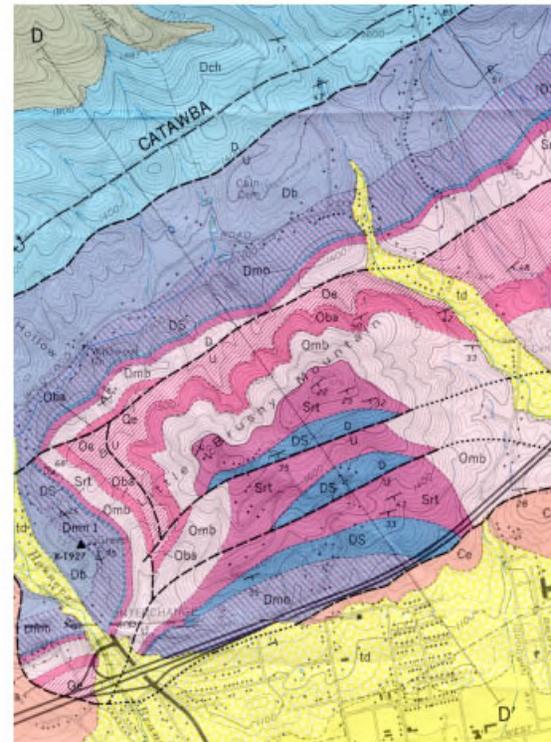
Block Diagrams

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)



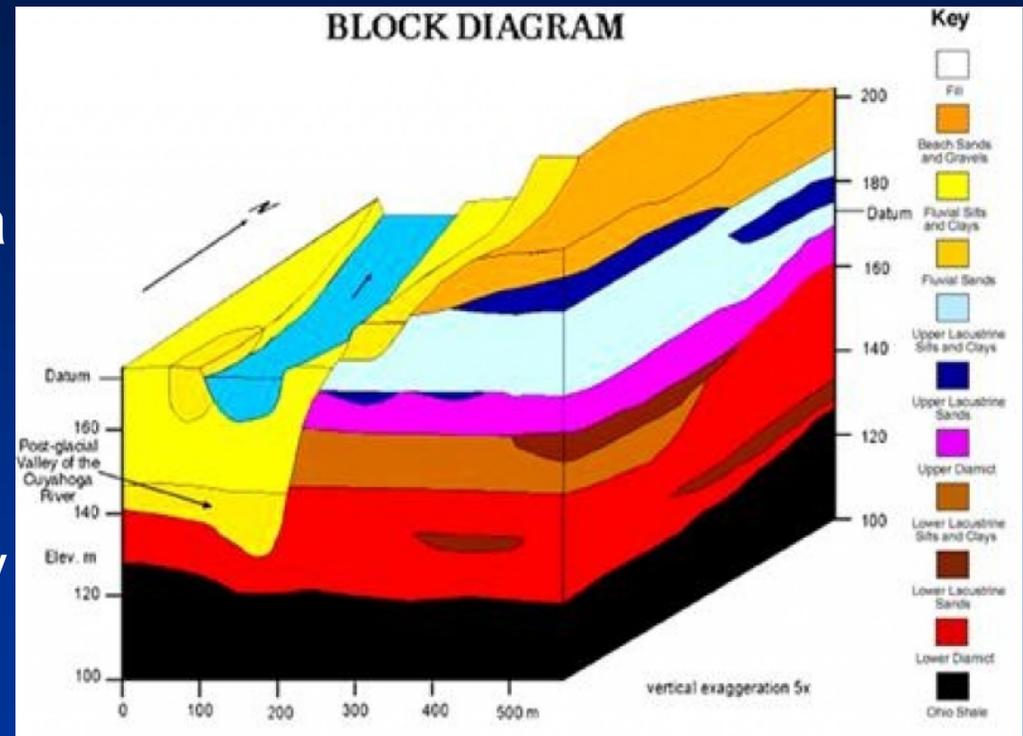
Rock Formations and Contacts on a Geologic Map and Cross Section

- 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.



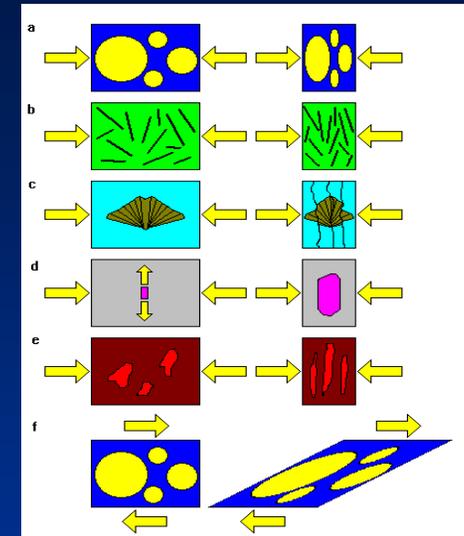
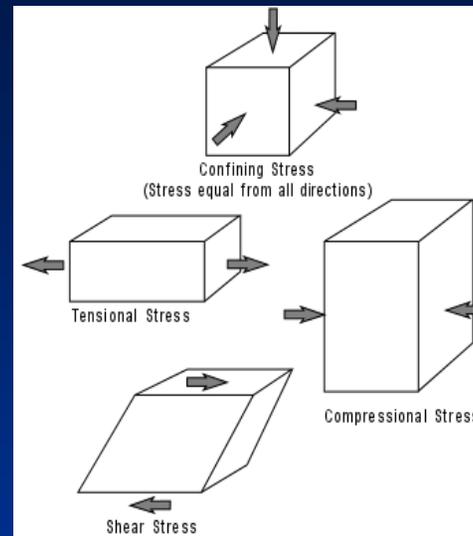
Origin and Nature of Rock Deformation

A. Stress Leads to Strain

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

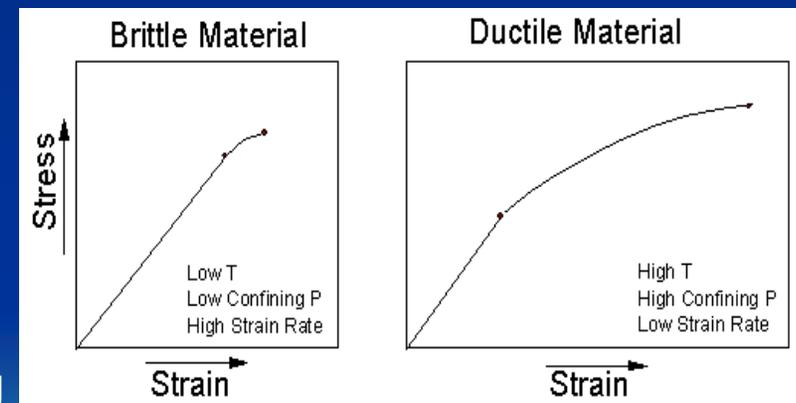
B. Different Types of Stress

- ✓ 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

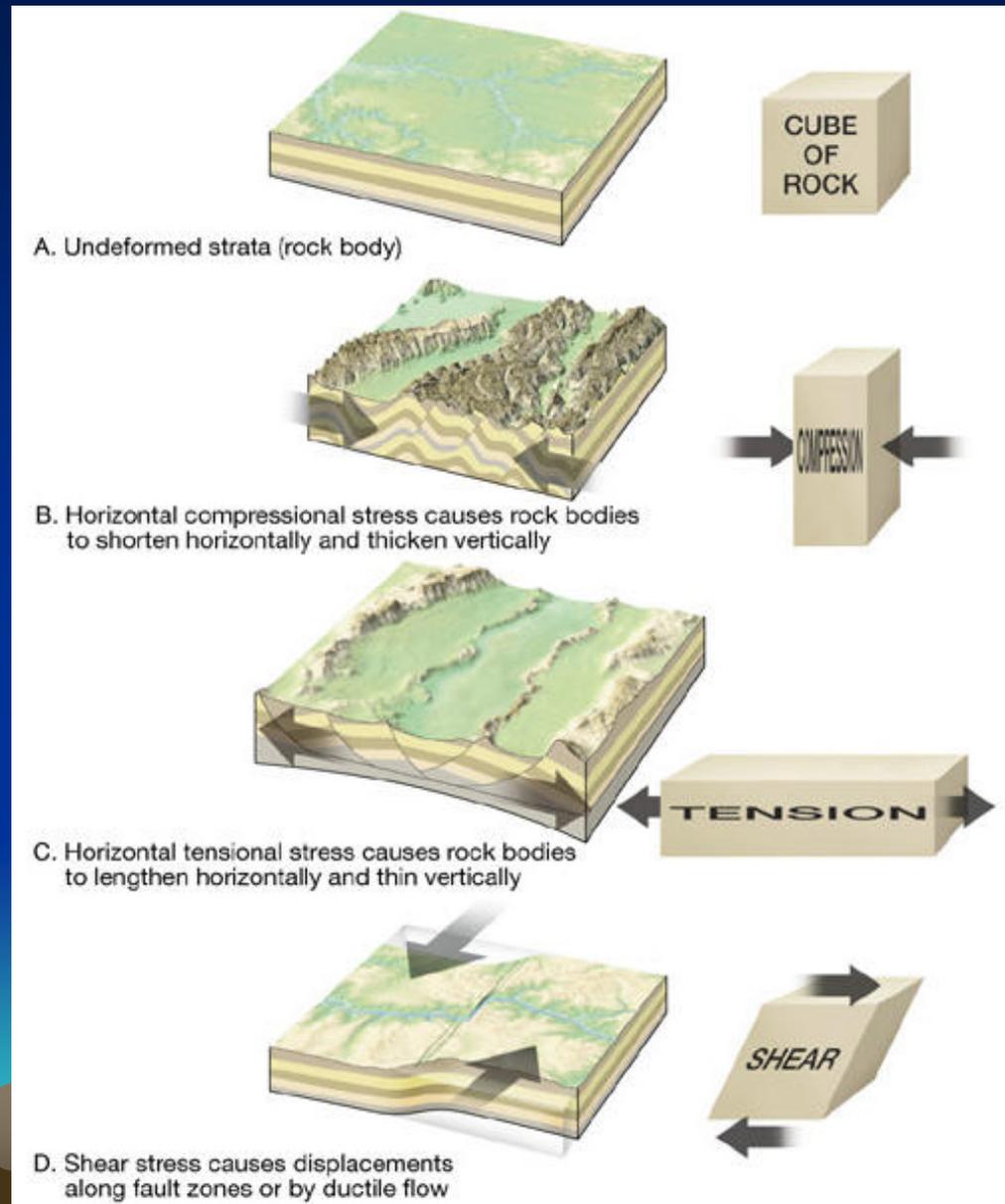
- ✓ Shorten horizontally
- ✓ Thicken vertically
- ✓ Folding and Reverse Faulting

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

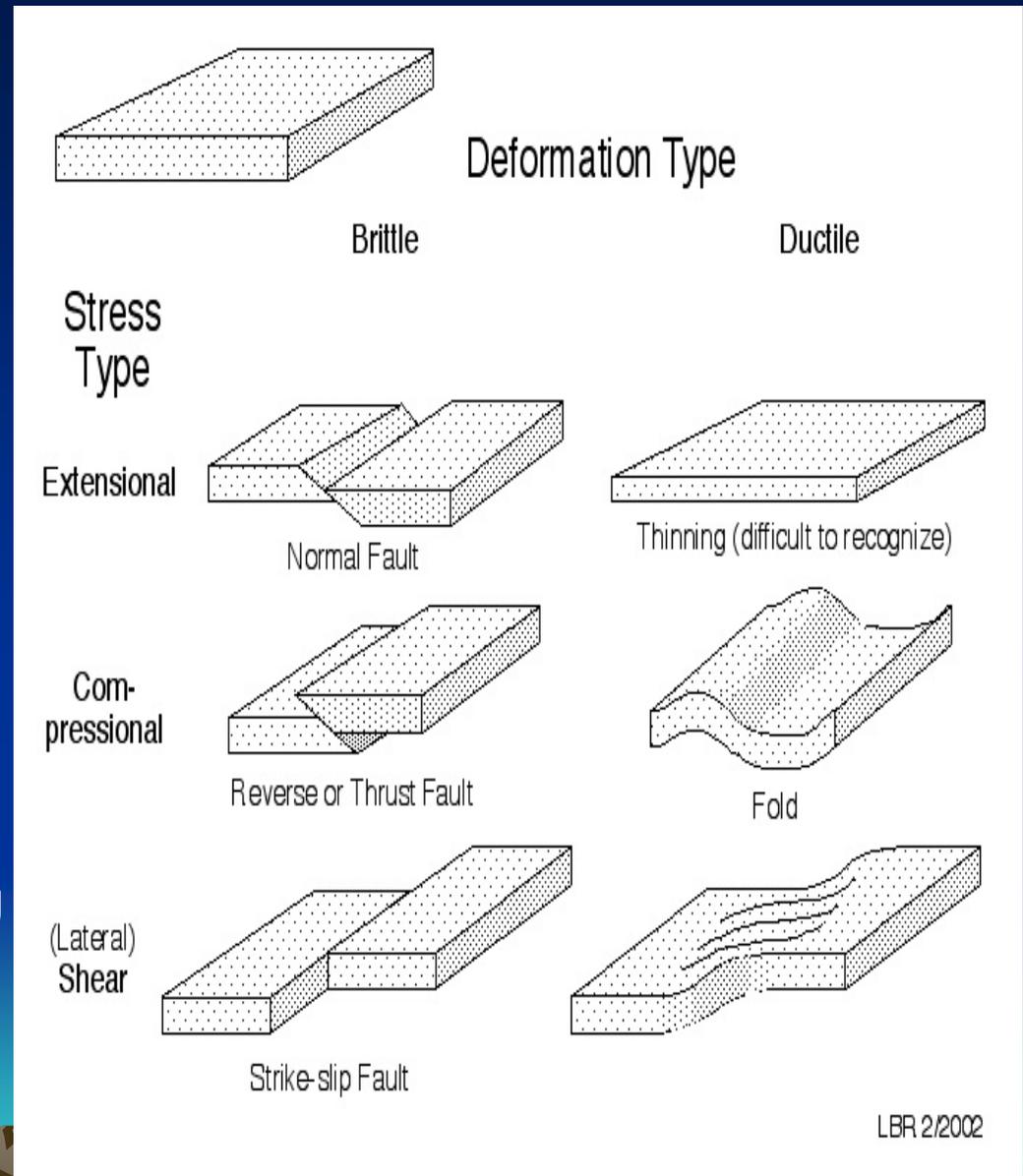
- ✓ Lengthen horizontally
- ✓ Thin vertically
- ✓ Tilting and Normal Faulting

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

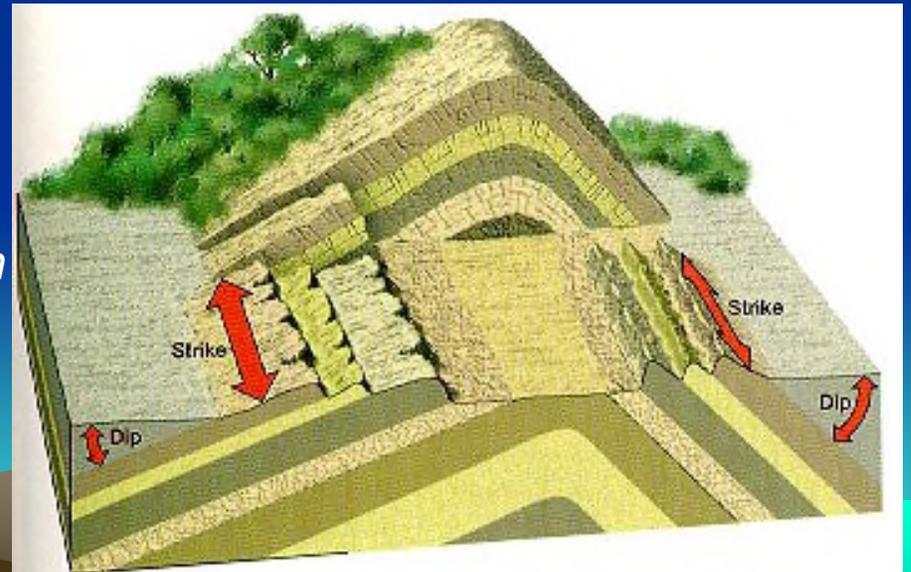
The Basic Rules of Structure

- 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

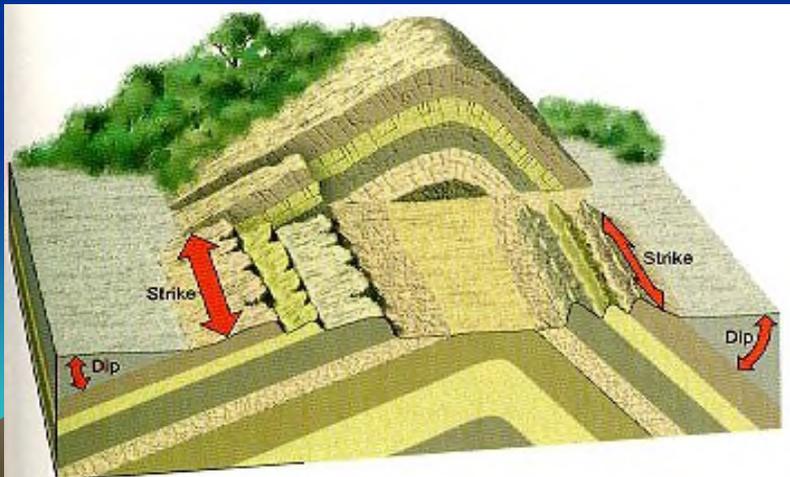
Strike and Dip



Measuring Strike Azimuth



Measuring Dip Angle



Strike Azimuth and Dip Angle



Completed Strike and Dip Measurement

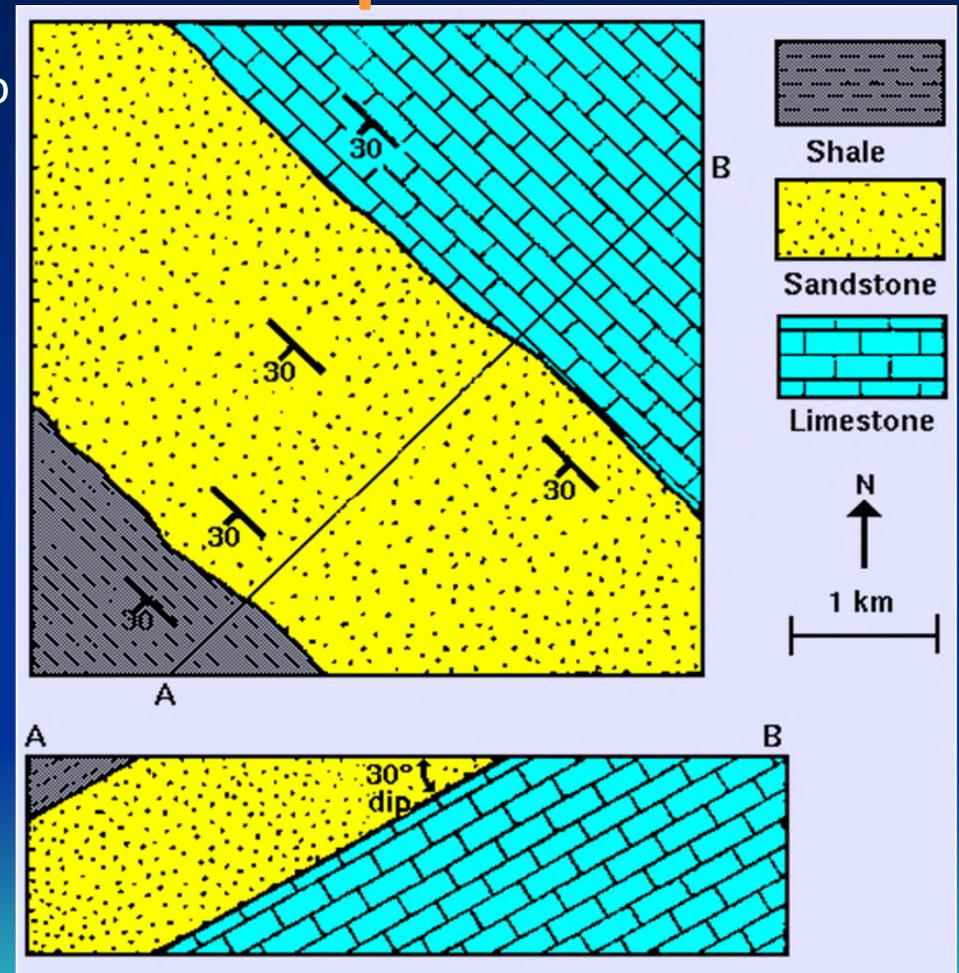
Spatial Orientation of Layers

Strike and Dip

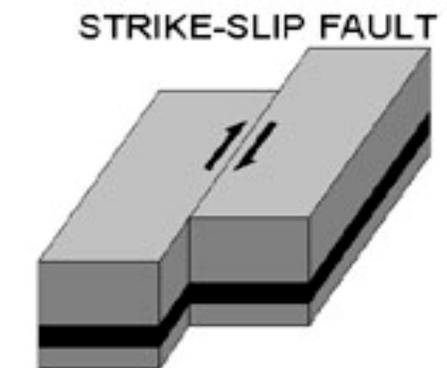
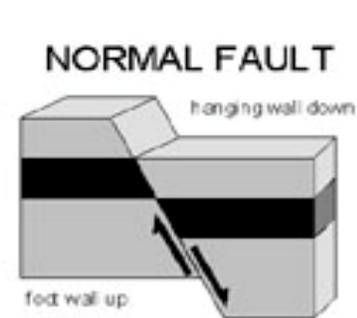
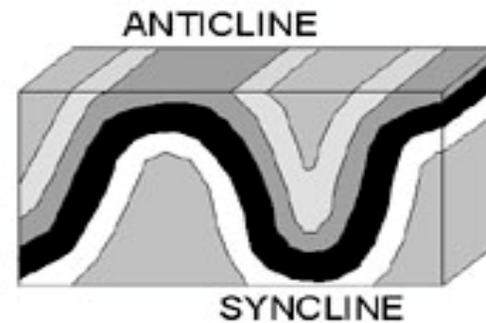
The **Strike** and **Dip** of a planar rock layer or feature is symbolized on a geology map by a



- ✓ 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

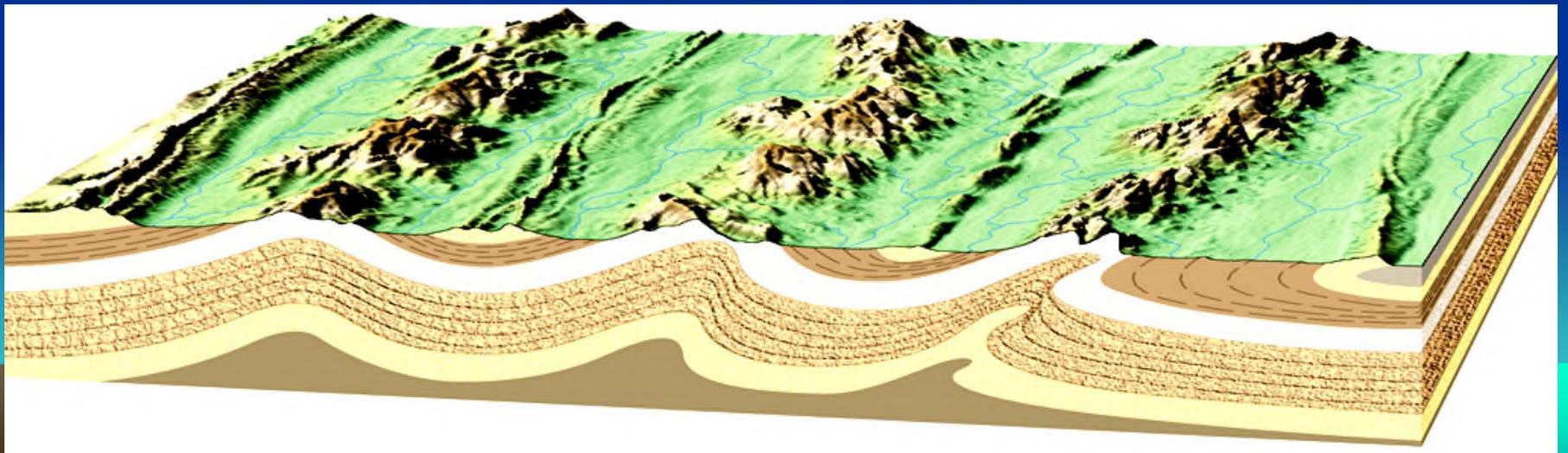
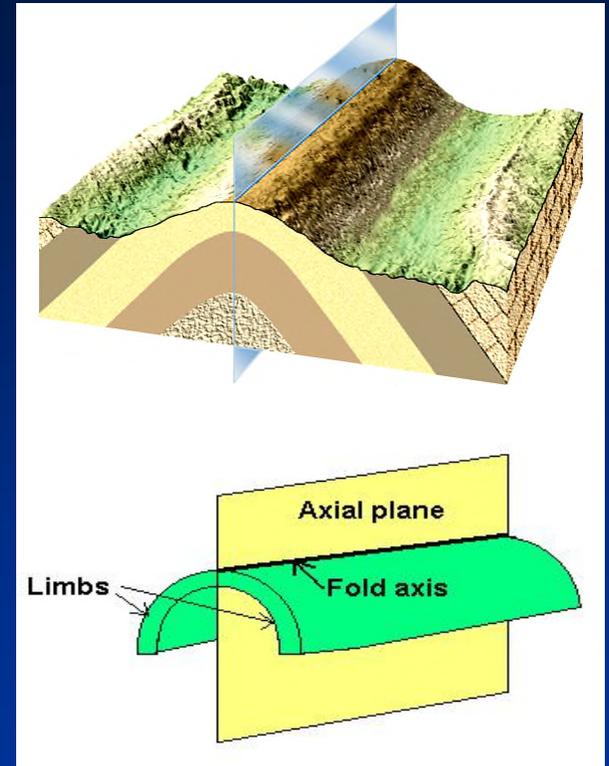


Anticline: Upwards-buckled fold with oldest rock at center and outward-dipping limbs

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



Fold Basics



Fold Basics

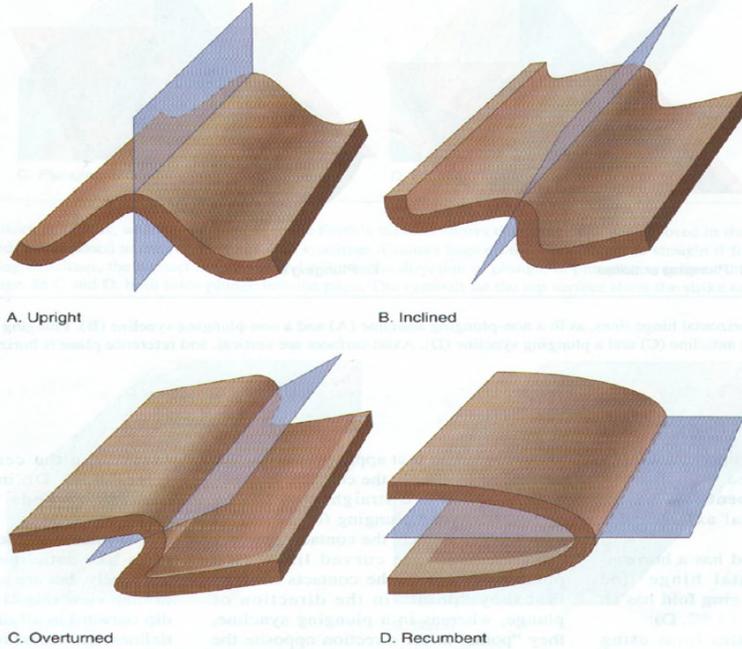
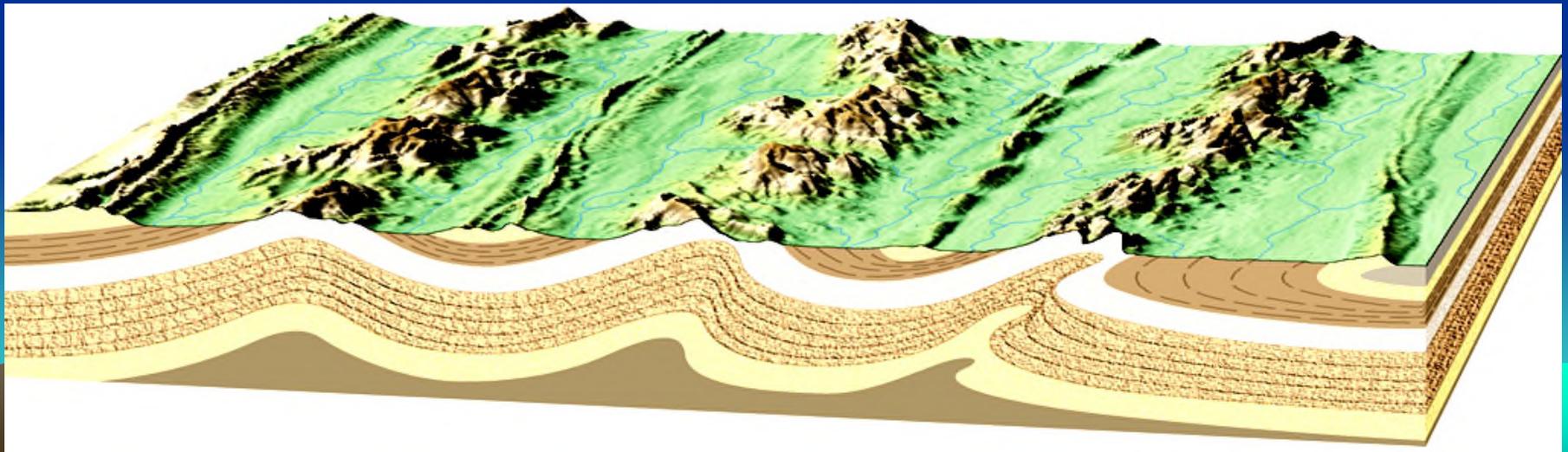
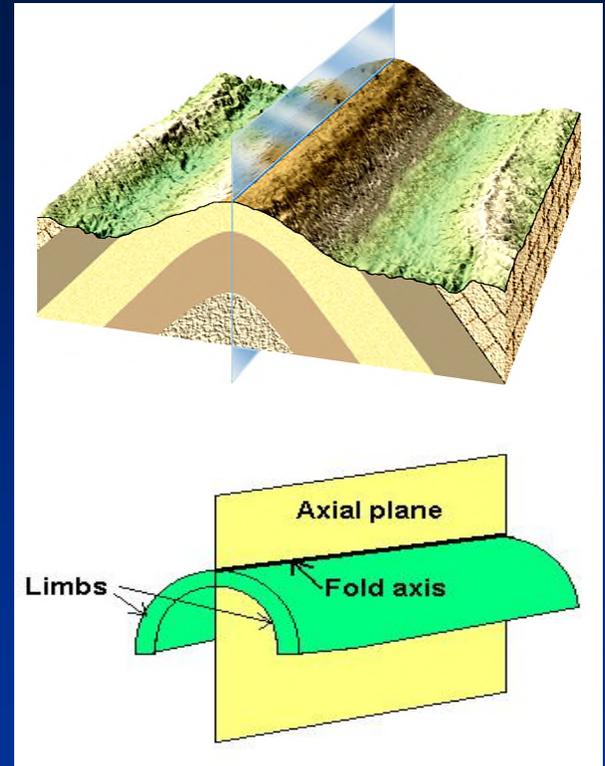
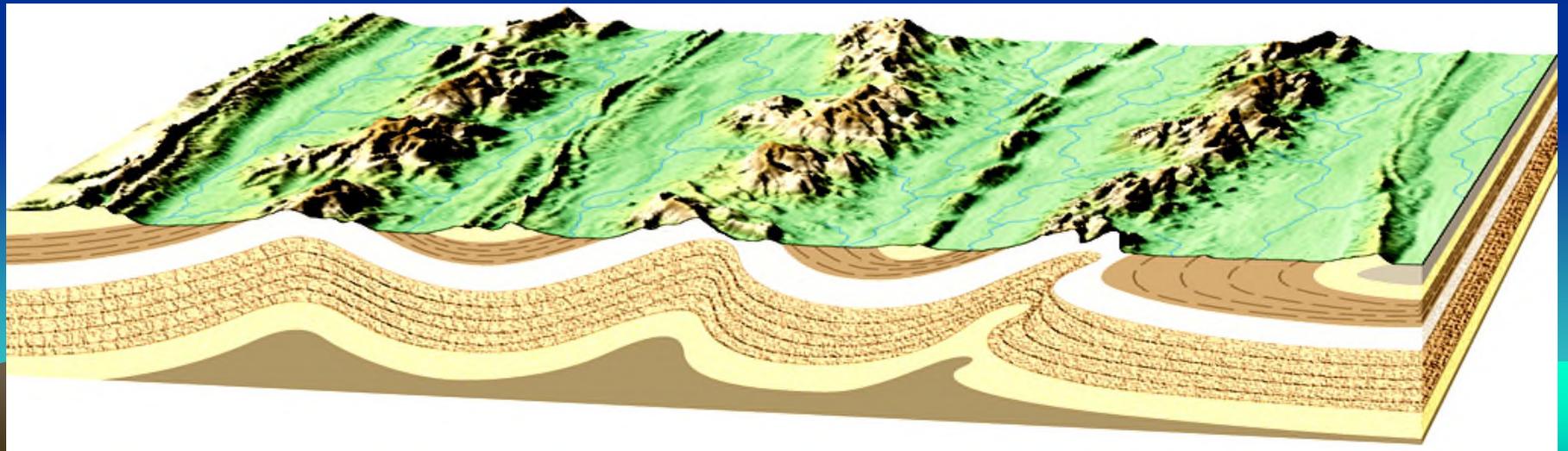


FIGURE 14.7 The axial surface of a fold can be: A. Vertical in **upright folds**; B. inclined in **inclined folds**; C. inclined so much that opposite limbs dip in the same direction in **overturned folds**; D. horizontal in **recumbent folds**. (Adapted from Jones, 2001: Laboratory Manual for Physical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



Fold Basics



Rules of Folds

Anticlines

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

Synclines

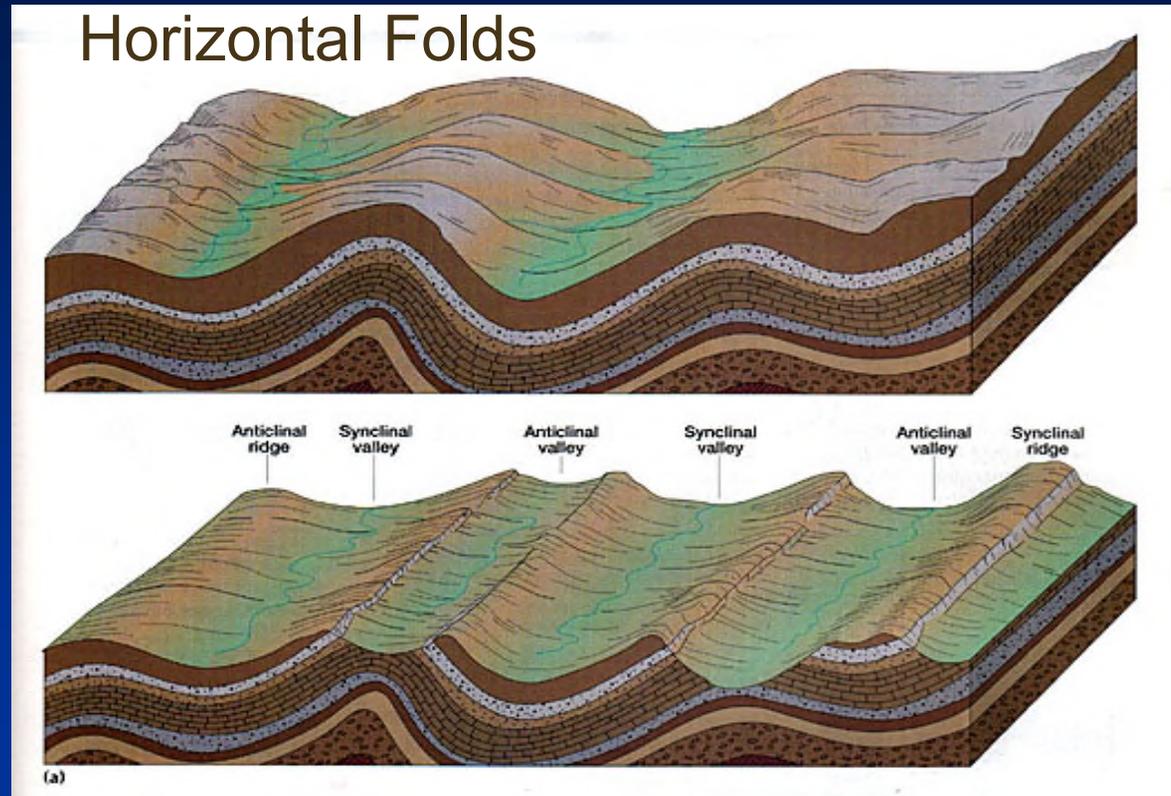
- 1) Youngest unit in center
- 2) Limbs dip inward

Horizontal Folds

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

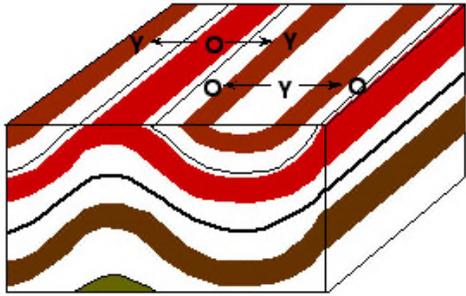
Plunging Folds

- 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



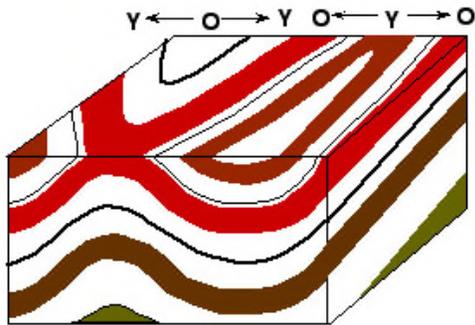
Plunging Folds

Plunging Folds

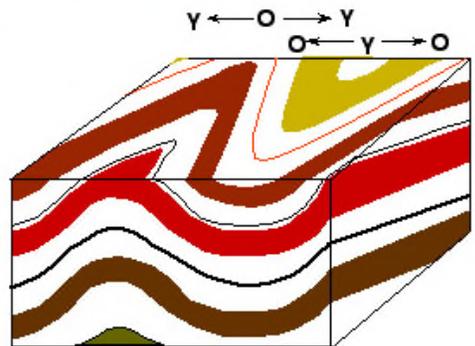


Anticline and Syncline in 3-dimensional view

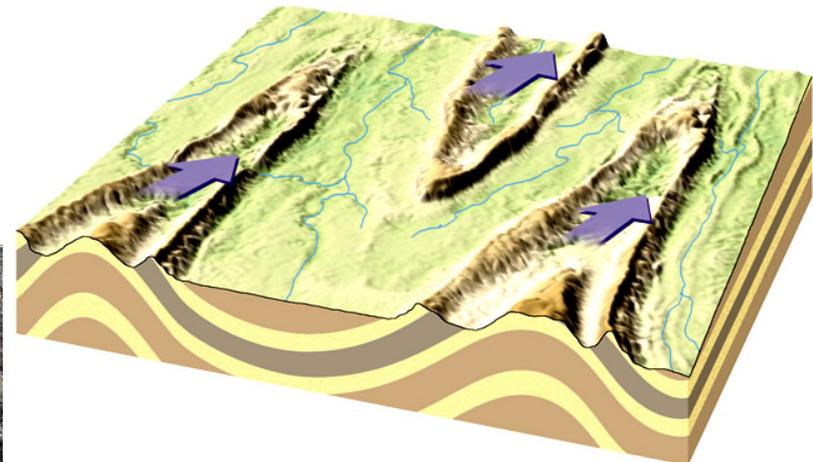
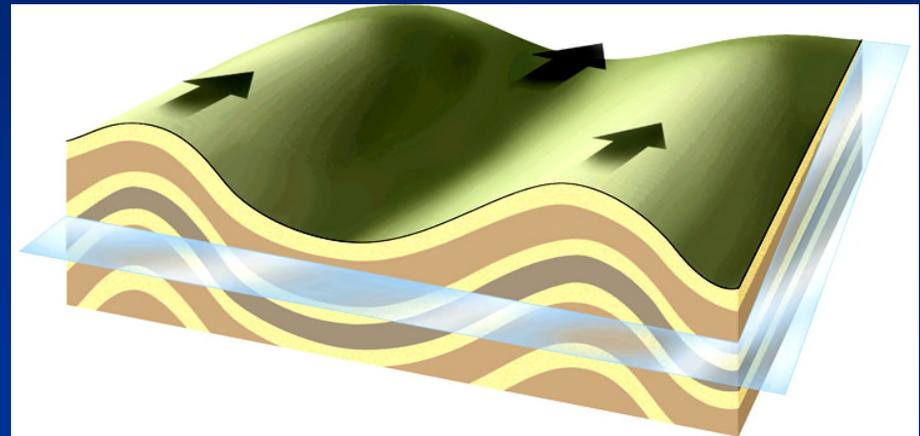
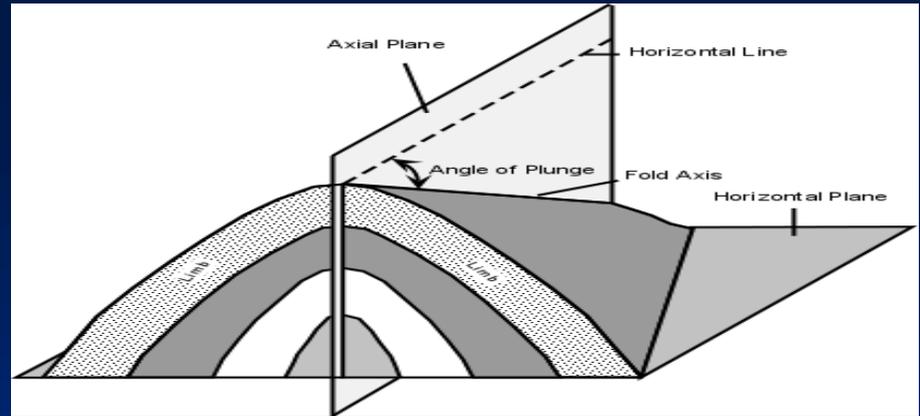
Oldest beds are in centers of anticlines; youngest beds are in centers of synclines.



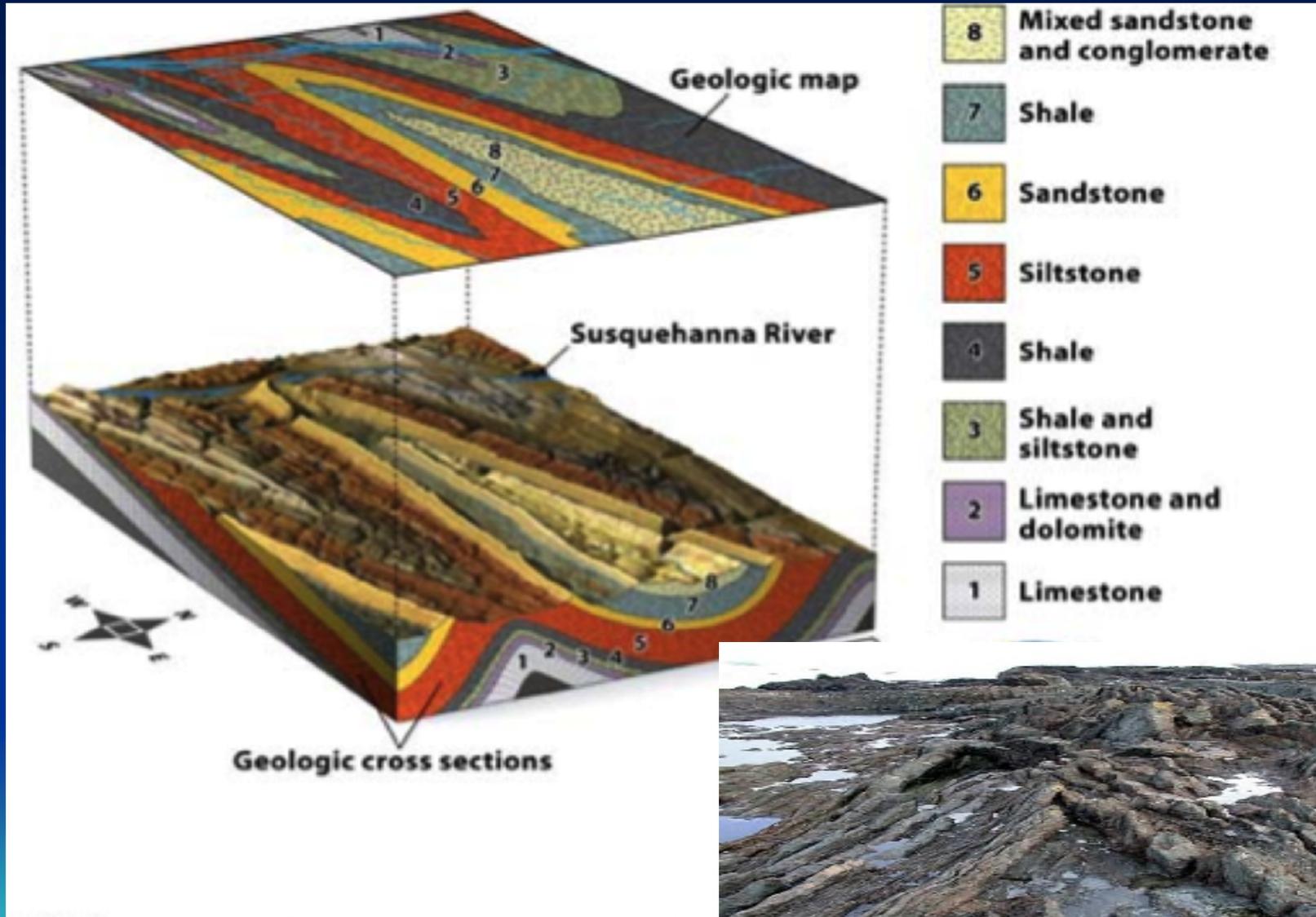
Anticline and Syncline plunging toward viewer



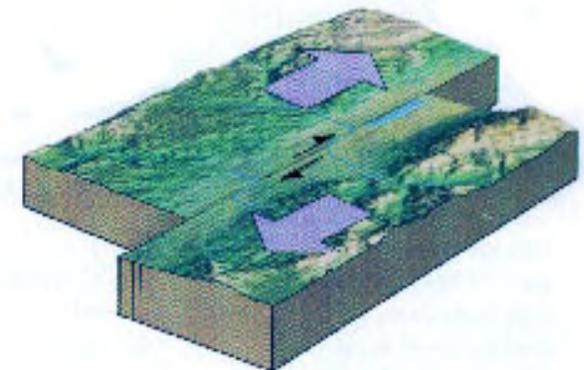
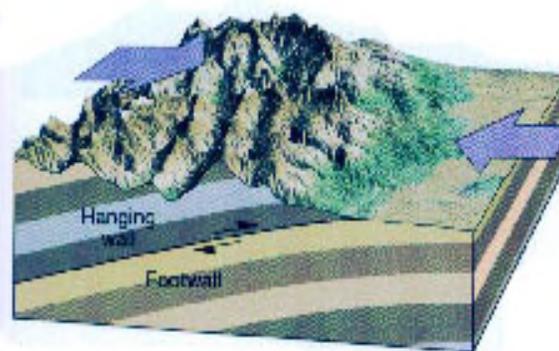
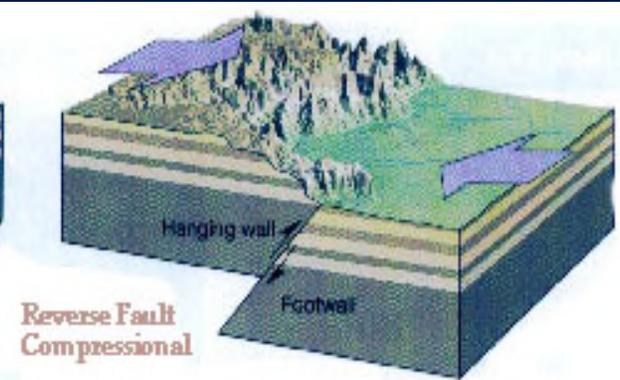
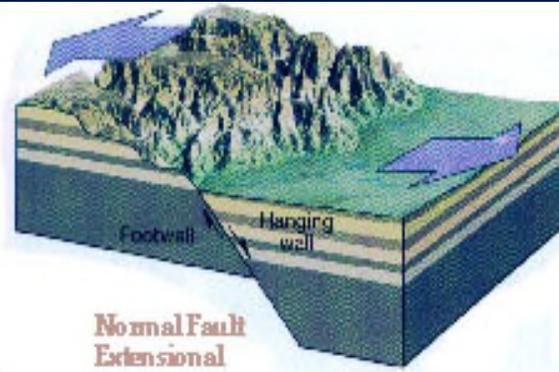
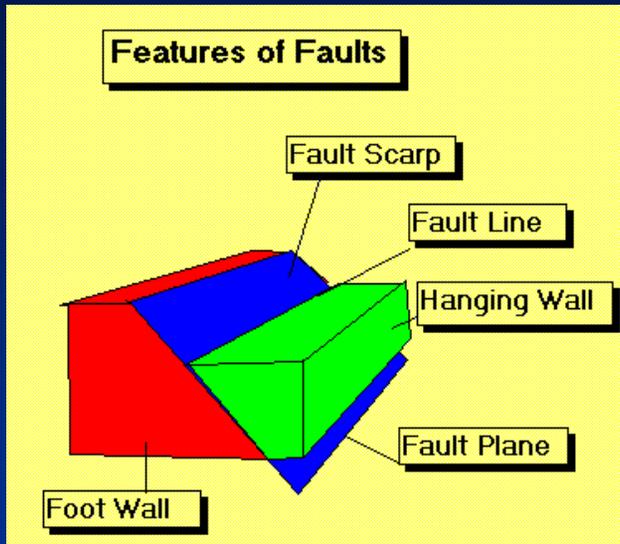
Anticline and Syncline plunging away from viewer



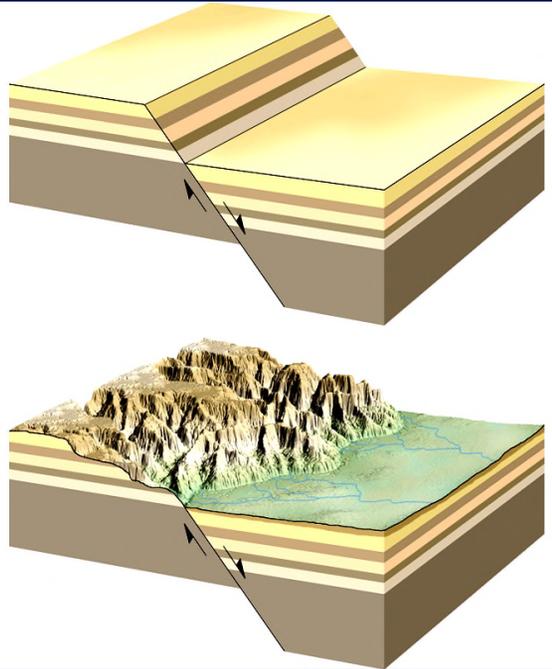
Plunging Folds



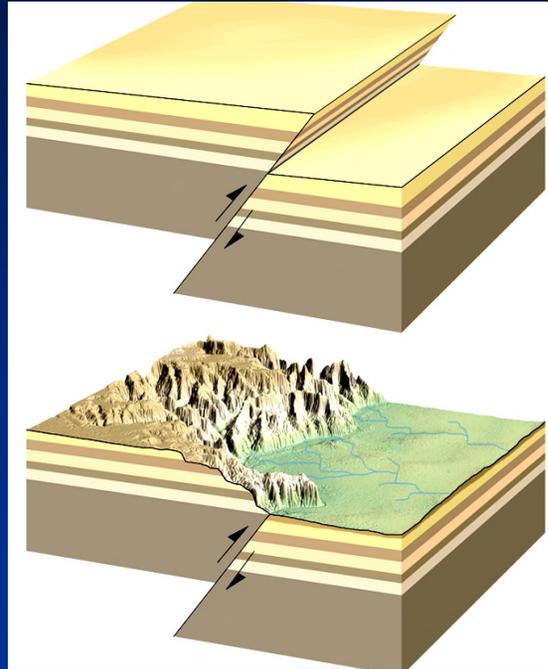
Fault Terminology



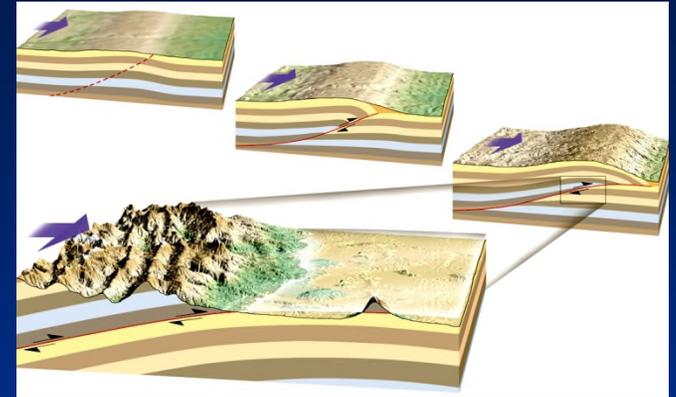
Types of Faults



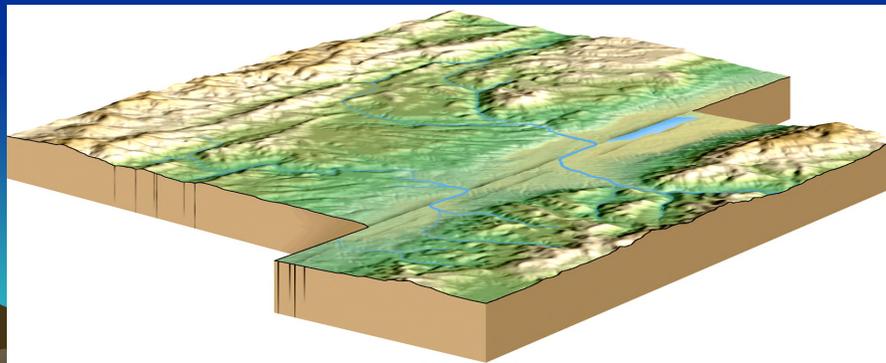
Normal Fault



Reverse Fault

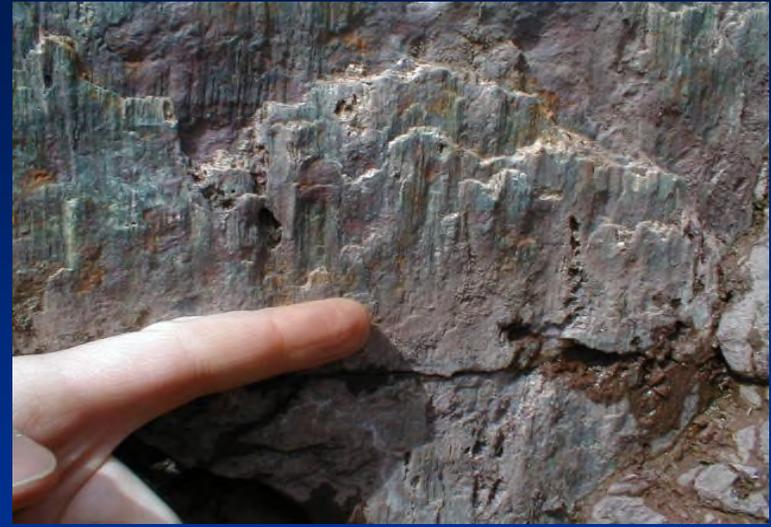
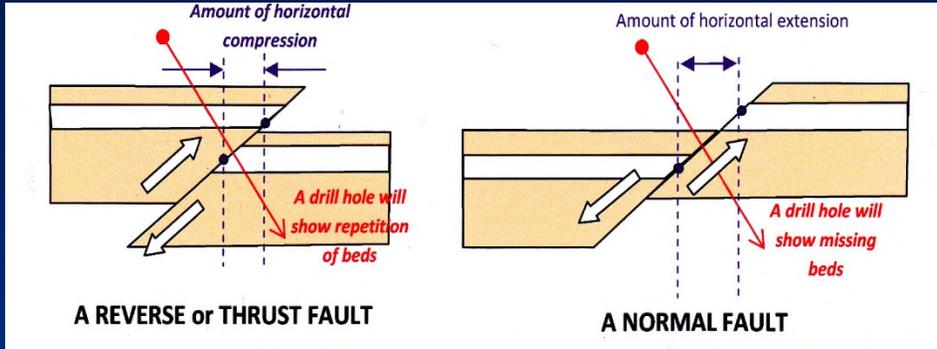


Thrust Fault

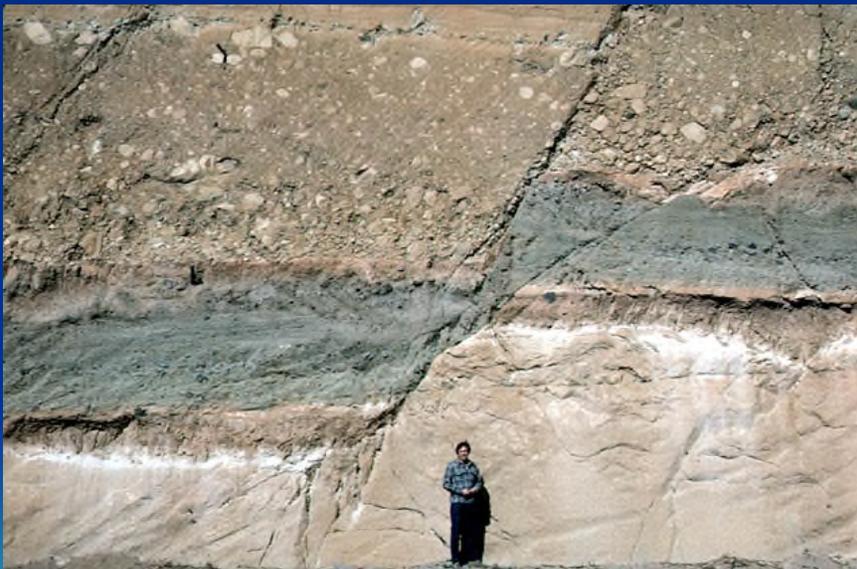


Strike-Slip Fault

Fault Offset and Slickensides



Dip-slip oriented slickensides



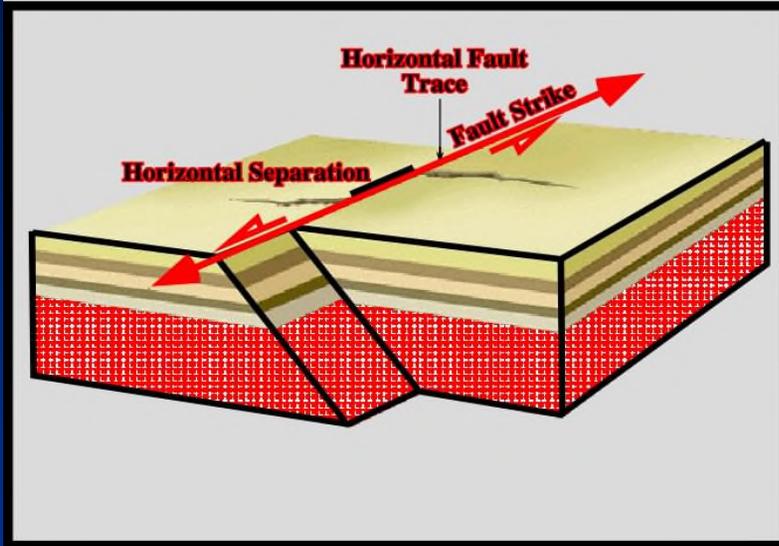
Normal-sense, dip-slip offset



Reverse-sense, dip-slip offset

Fault Slickensides

Strike Slip Movement

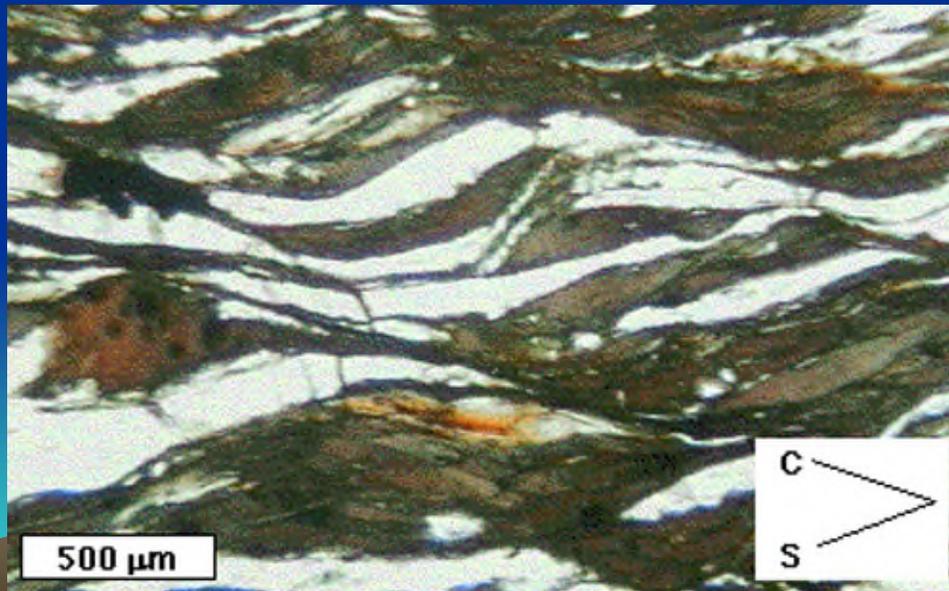
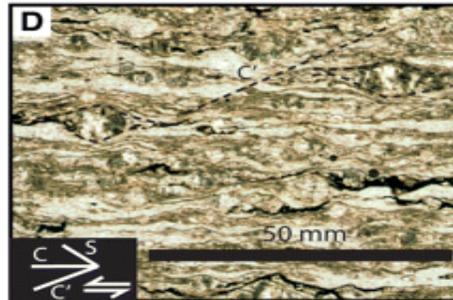
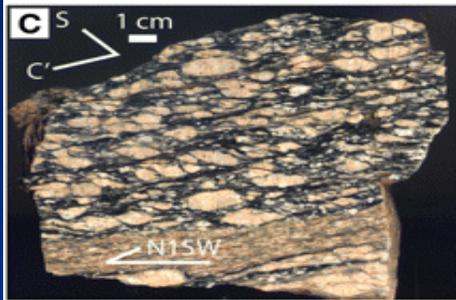
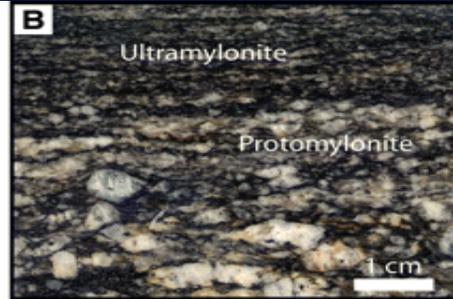
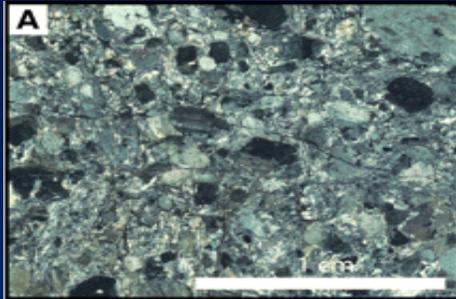


Strike-slip oriented slickensides



Right-lateral, strike-slip offset

Special Fault Rocks



Mylonite

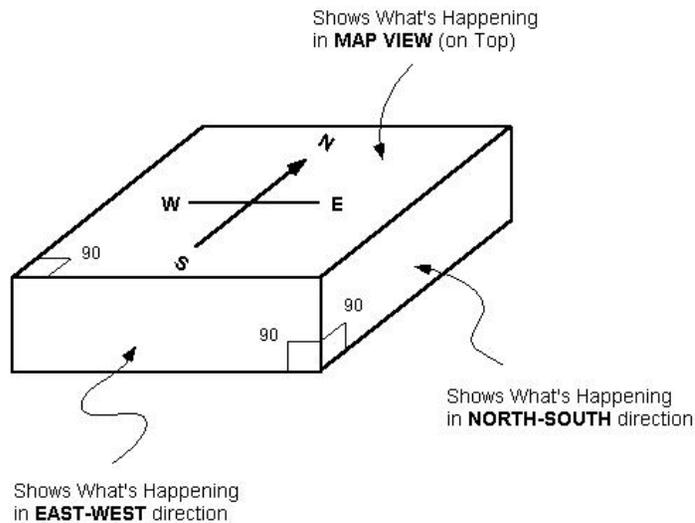
Brittle-ductile shear-like deformation along fault zone resulting in a special kind of foliation termed "S-C fabric".

The Basic Rules of Structure

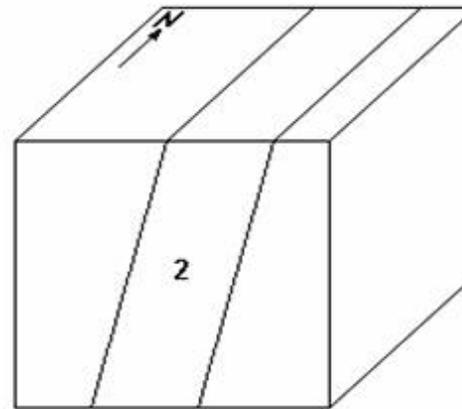
- 1) Strike of beds is always parallel to the direction of the contacts.
 - 2) Rock layers dip towards the youngest exposed rock layers.
 - 3) Oldest rocks exposed in the center of eroded anticlines and domes.
 - 4) Youngest rocks exposed in the center of eroded synclines and basins.
 - 5) Horizontal 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.
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 - ✓ 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.
- 

Working with Block Diagrams

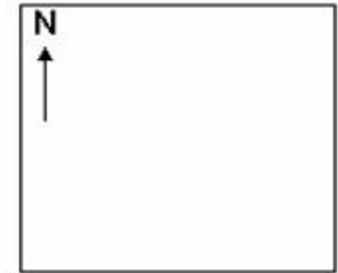
A GUIDE TO BLOCK DIAGRAMS



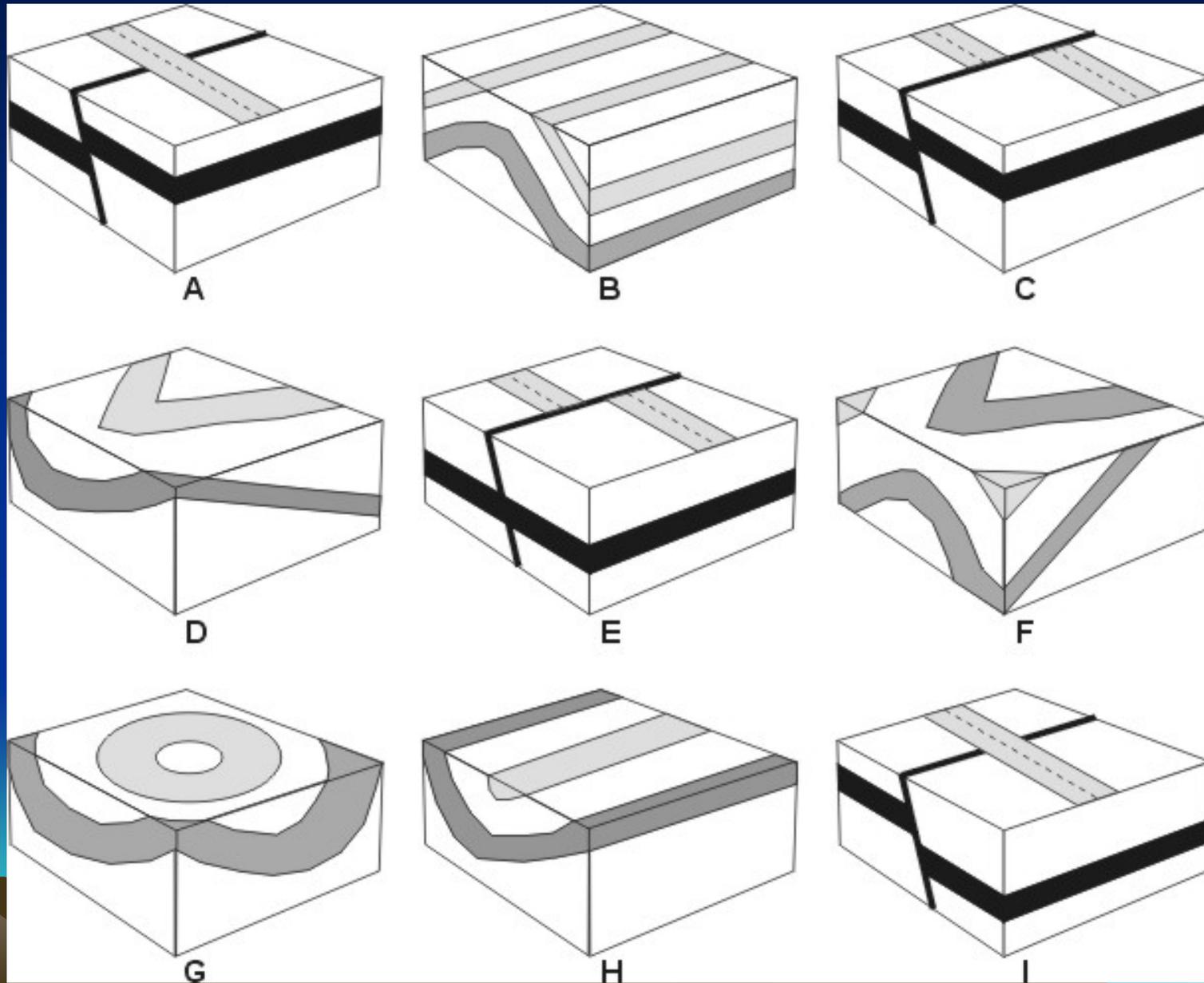
BLOCK DIAGRAM



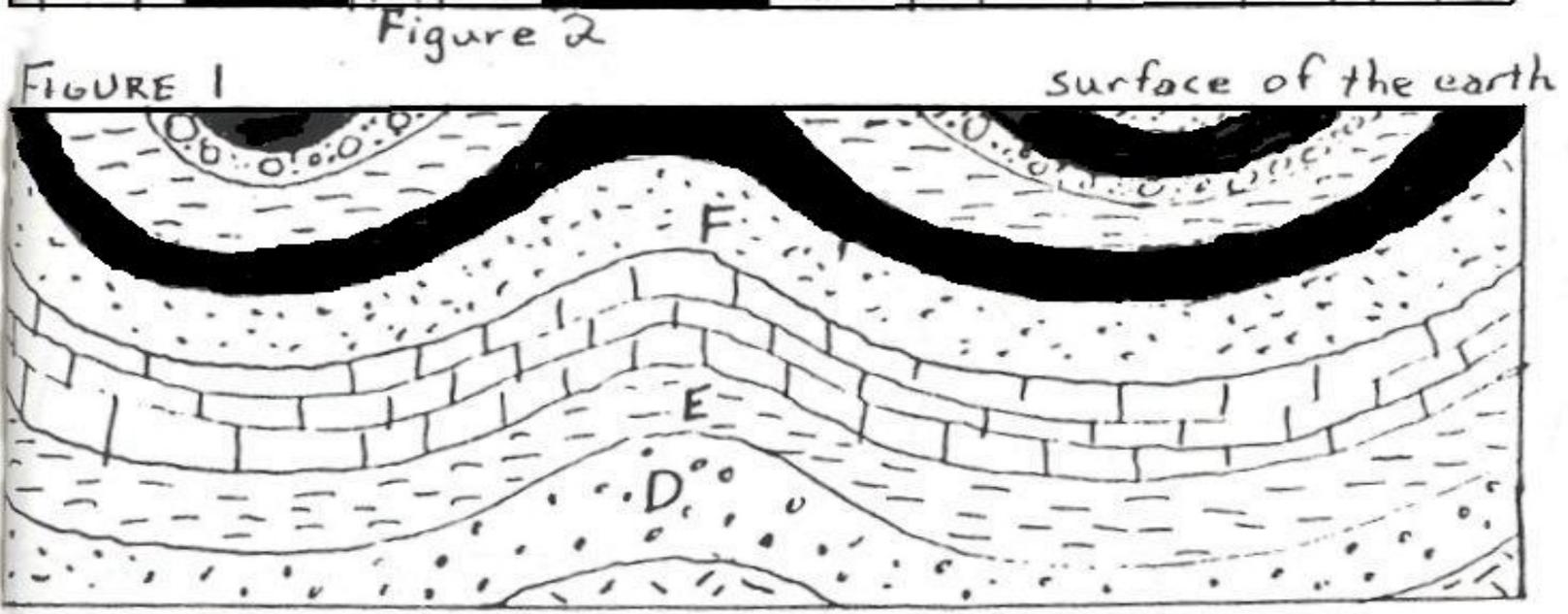
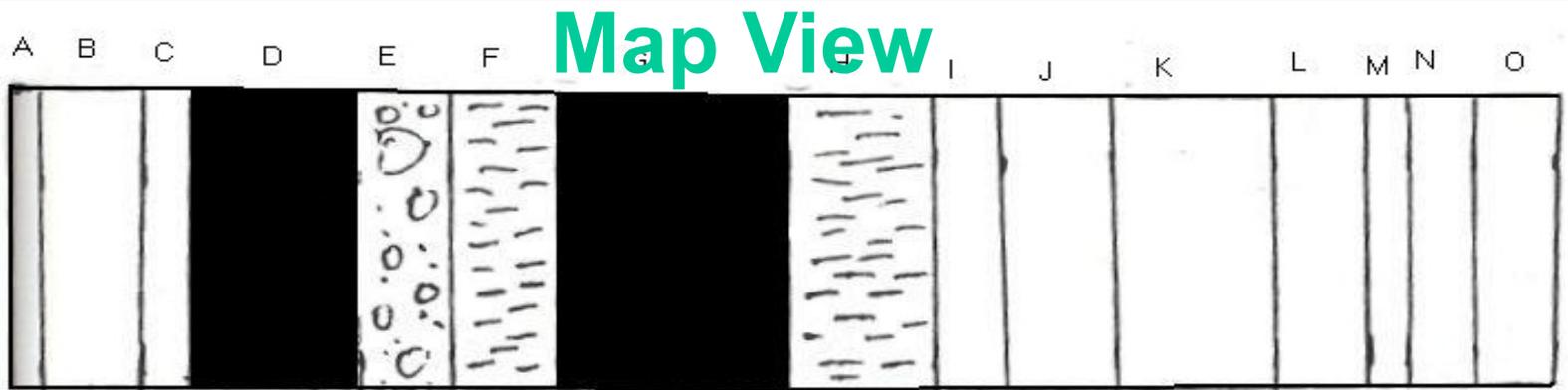
MAP VIEW



Working with Block Diagrams



Working with Block Diagrams



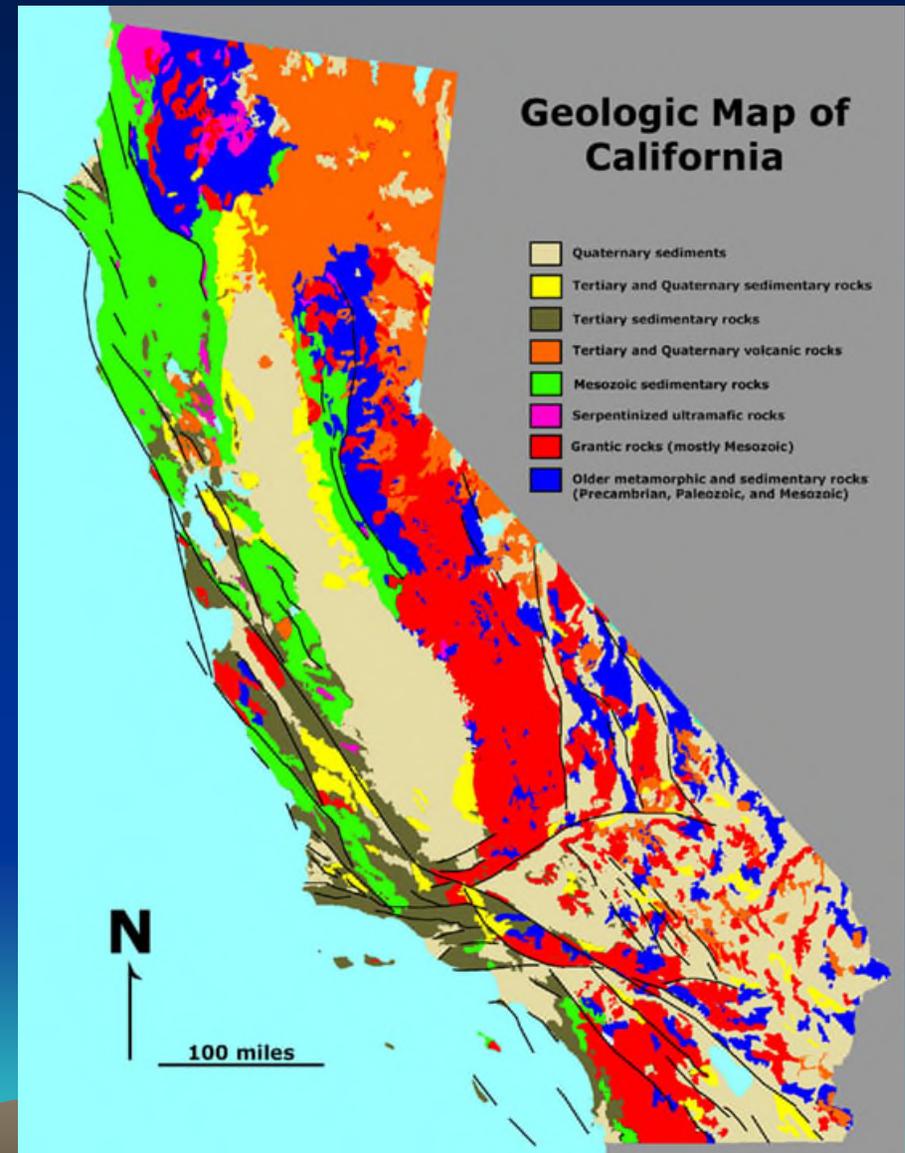
Cross Section View

Usefulness of Geology Maps

1) Geology maps have many vital uses:

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

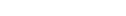
2) Geology maps are even useful when buying a home. Why?



Geology Map Key or Legend

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

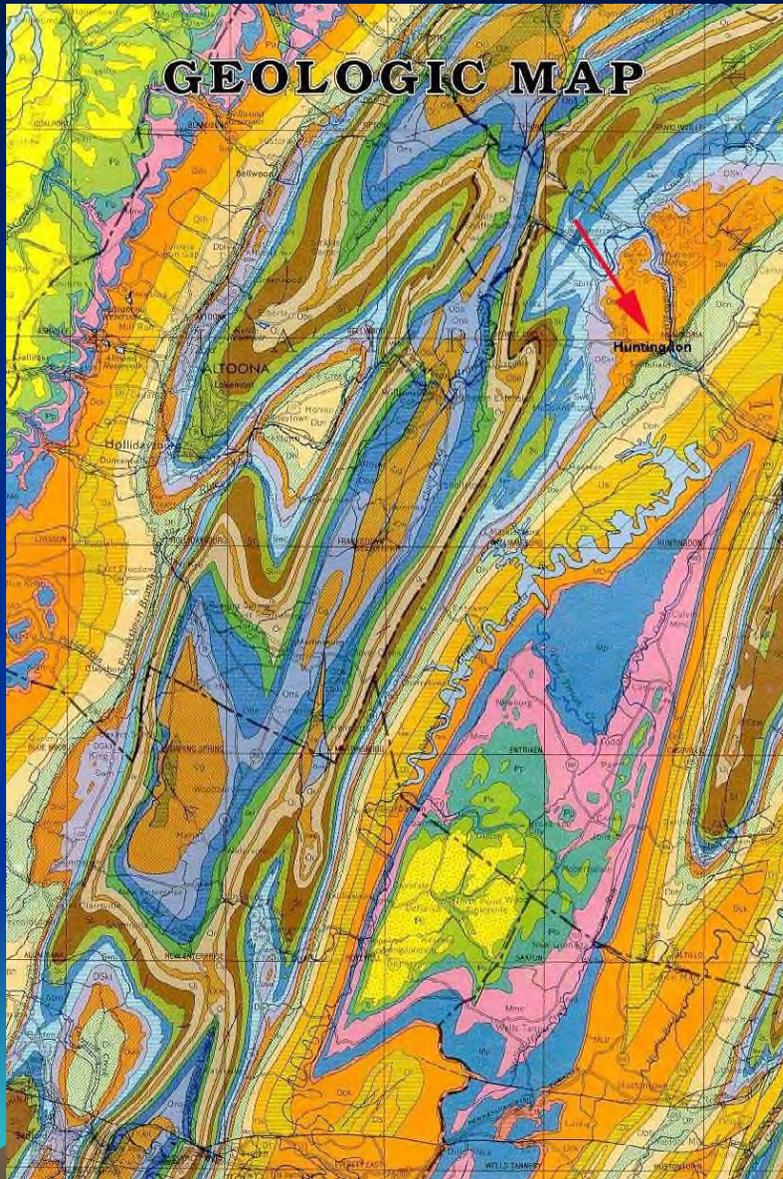
- ✓ Rock Names
- ✓ Rock Types
- ✓ Rock Ages
- ✓ Contacts
- ✓ Strike and Dip
- ✓ Faults and Folds

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
 Qhba - 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
 Tcs - Claremont shale (Miocene)	 Oblique fault with thrust or reverse component, uncertain
 Ts - Sostrate 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?



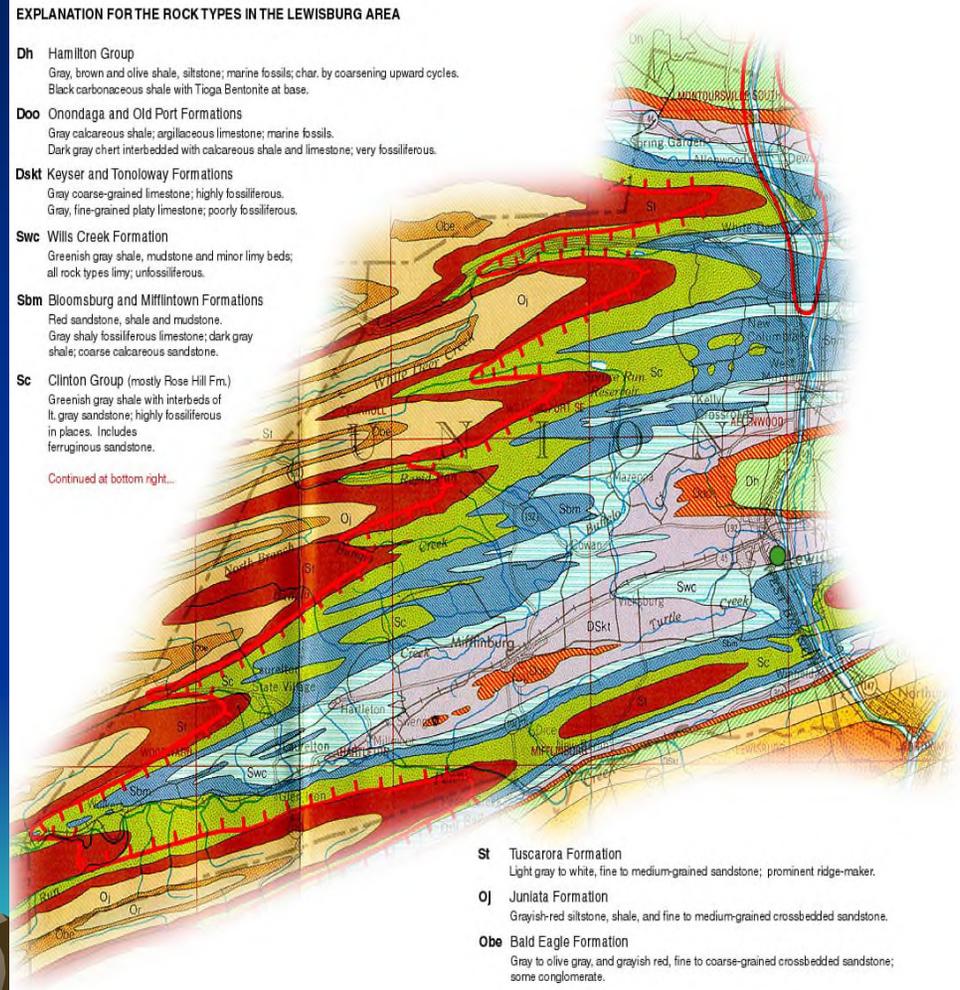
Union County Geology

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 Millintown 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



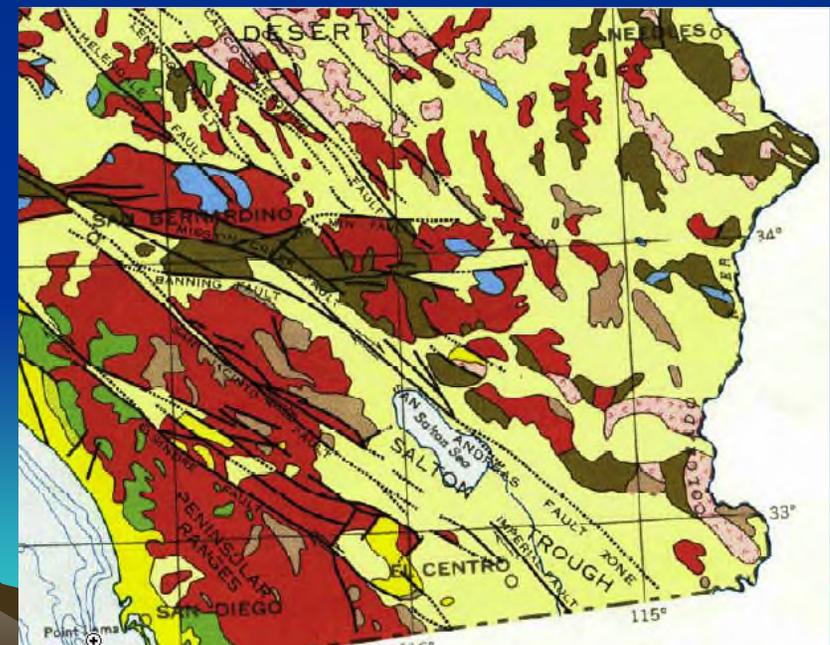
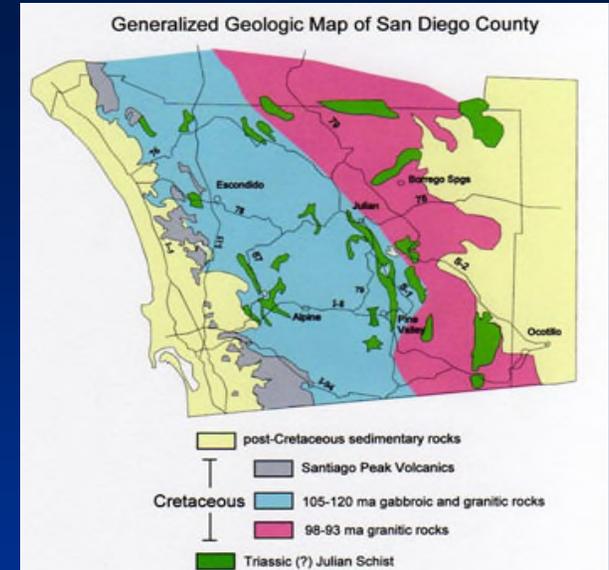
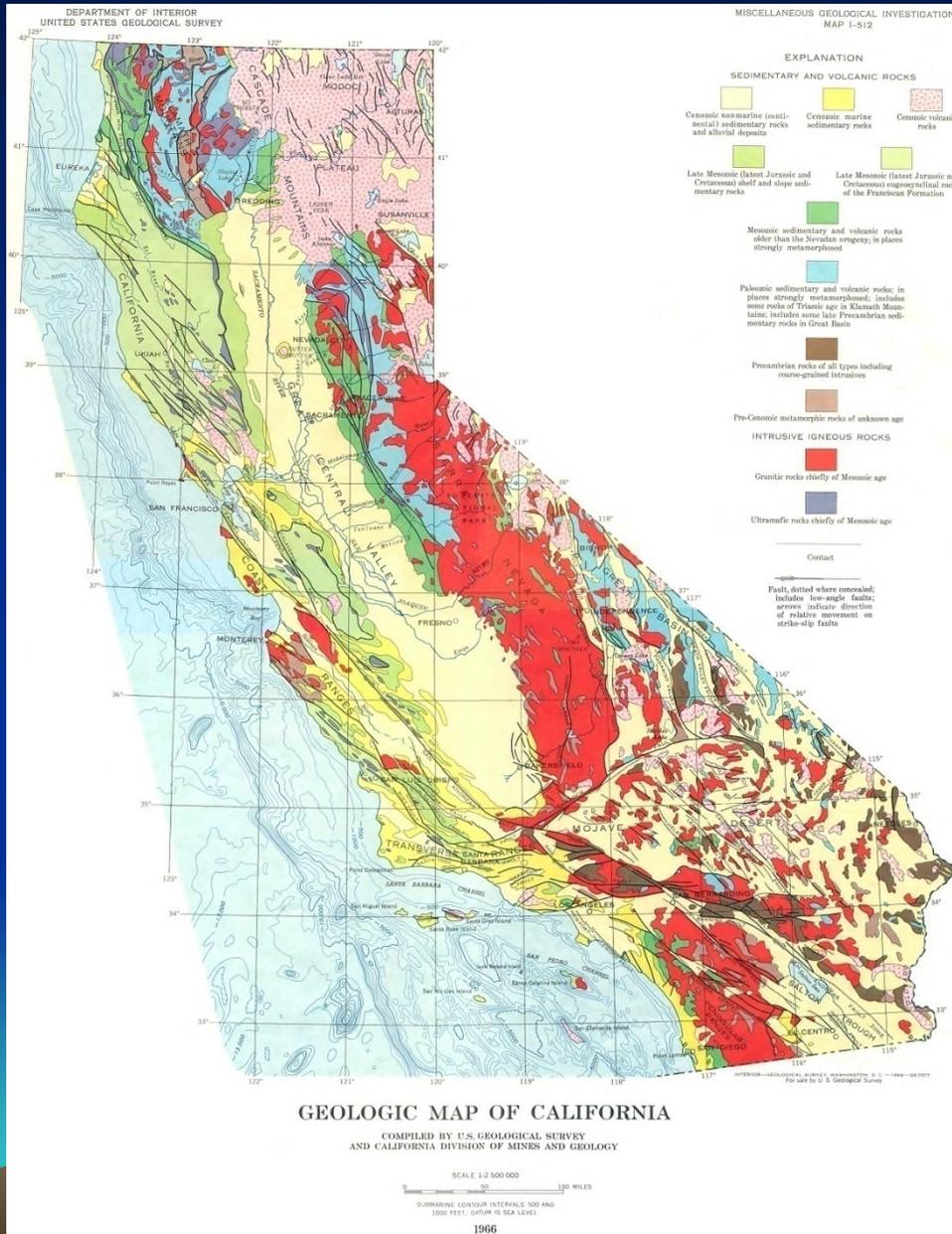
Geological Survey of Canada
Géologie Canada



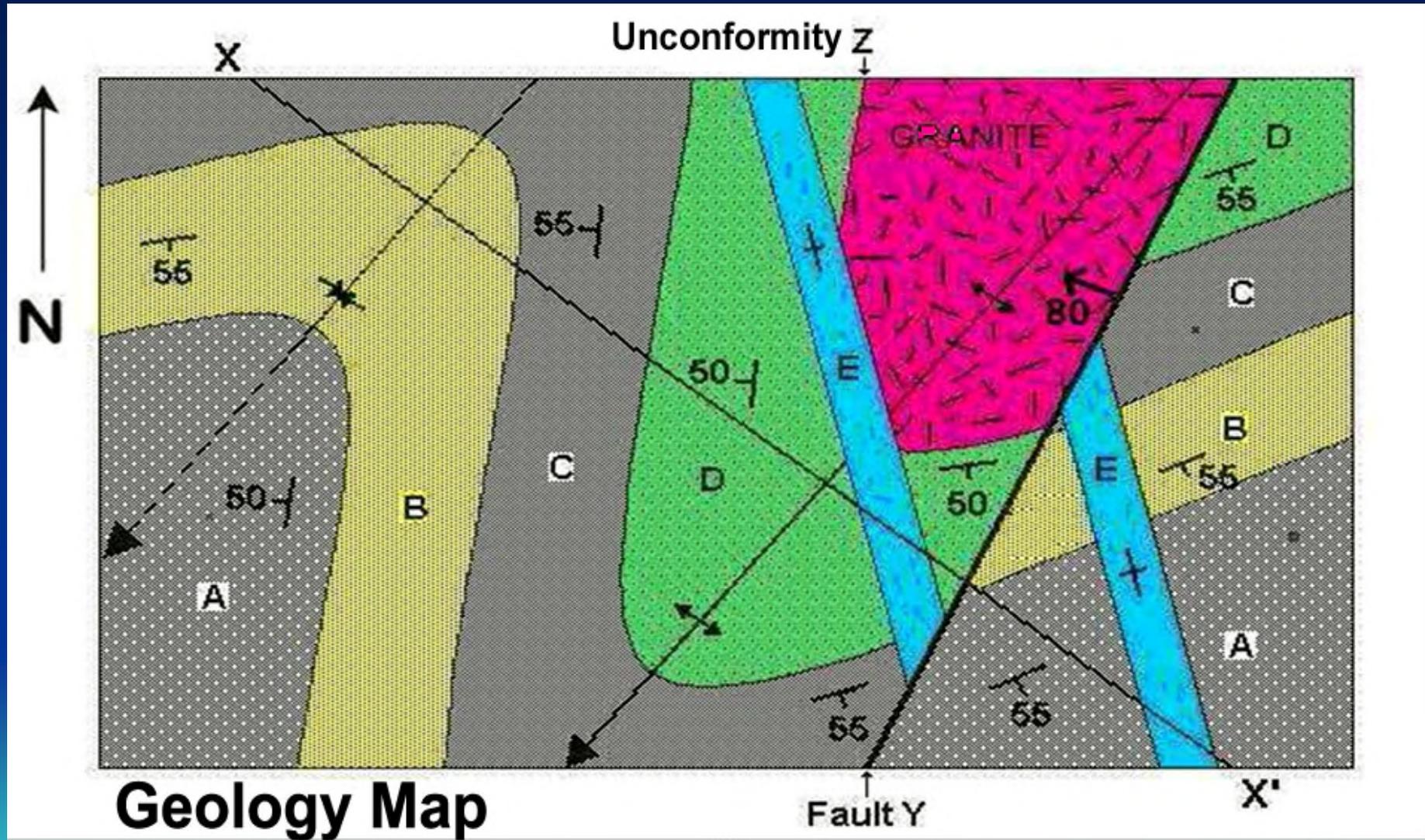
Comité de Recherche Mécanique



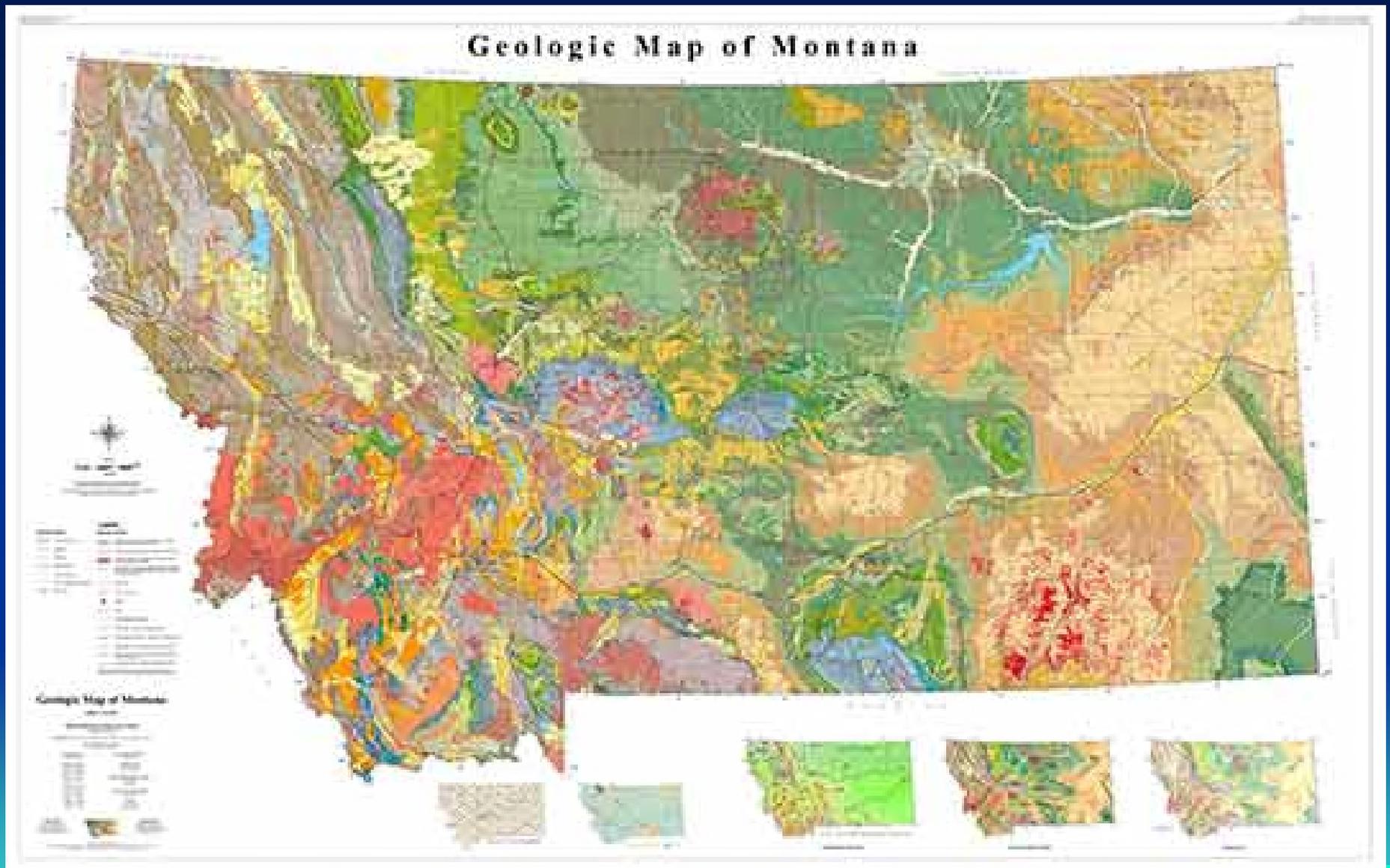
Geologic Maps of California



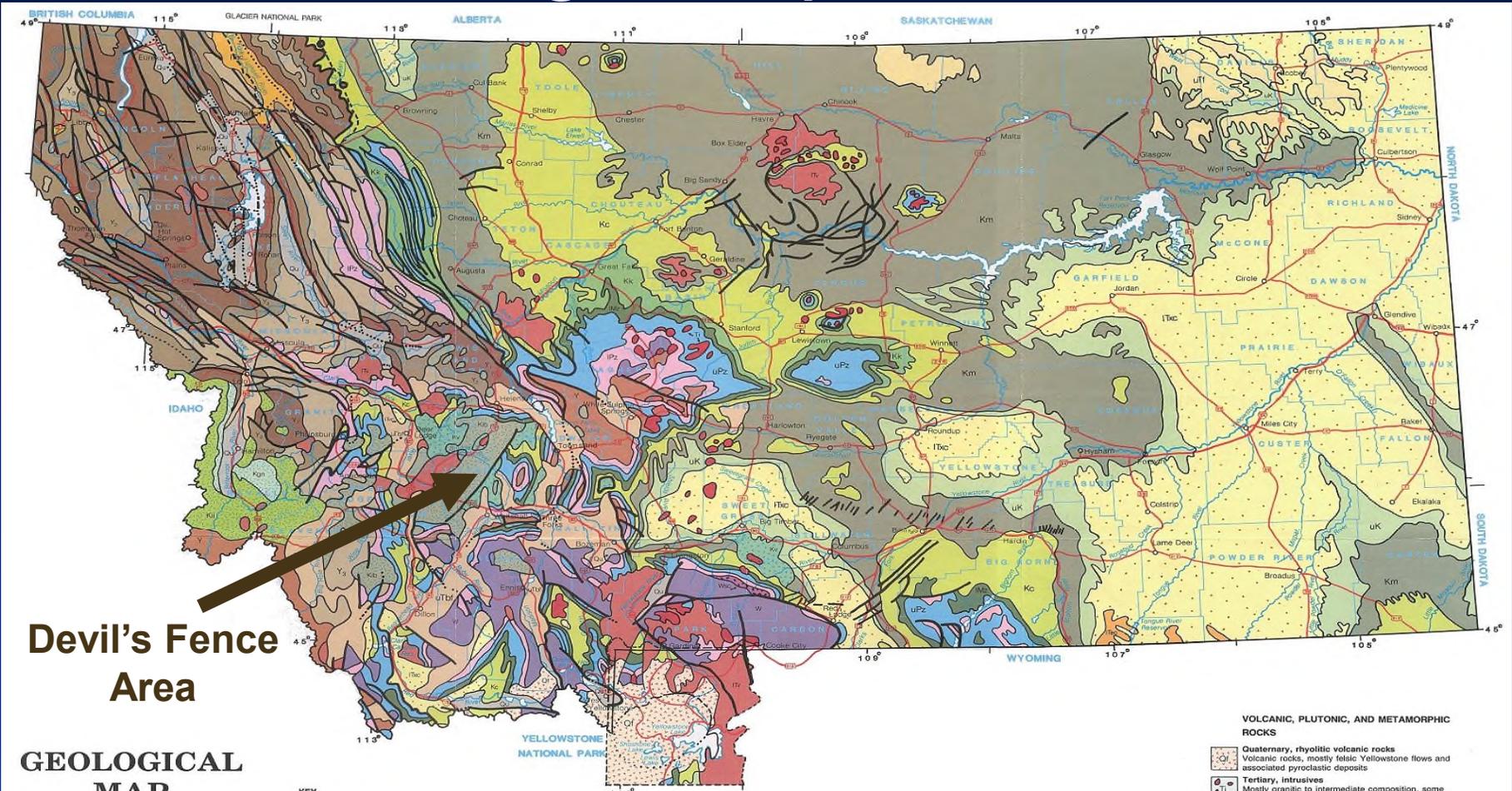
A Simplified Geology Map



Geologic Map of Montana

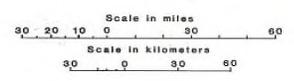


Geologic Map of Montana



Devil's Fence Area

GEOLOGICAL MAP of MONTANA and Yellowstone National Park



KEY
 Fault, sense of motion not indicated
 Contact

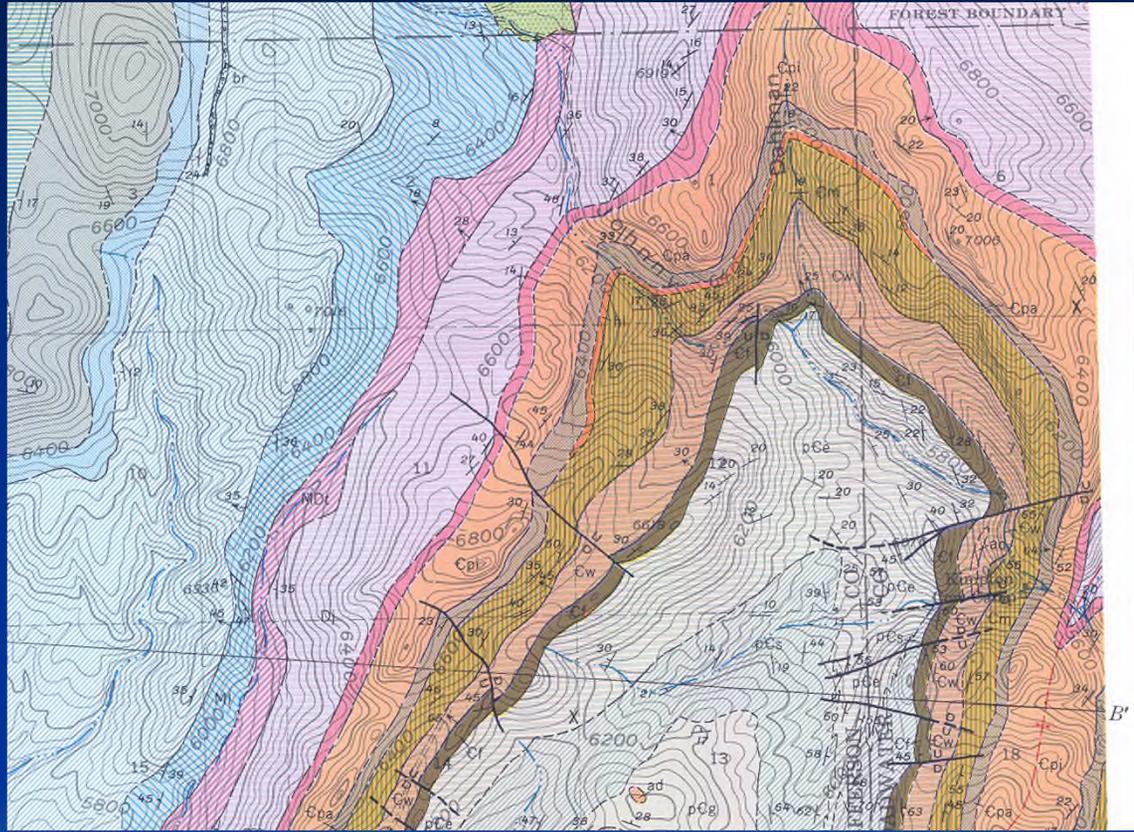
- CONTINENTAL AND MARINE DEPOSITS**
- Quaternary, extensive**
Stream, glacial, and lake deposits
 - Tertiary, Flaxville gravel**
Gravel and sand with some silt, volcanic ash, and marl
 - Tertiary, basin fill**
Oligocene through Pliocene basin fill composed of a heterogeneous mixture of gravel, sand, silt, and clay deposited by streams and in lakes
 - Eocene, continental deposits**
Includes fine to coarse-grained clastic rocks
 - Paleocene, continental deposits**
Including stream-deposited sediments of coal-bearing Fort Union Fm. In the east, Willow Creek Fm. in the north central, and Beaverhead conglomerate in the southwest

- uK** Upper Cretaceous, undifferentiated
Hell Creek sandstone and shale, St. Mary River mudstone, and volcaniclastic Livingston Gp. in southern-central Montana
- Km** Montana Group
Bearpaw shale, Judith River sandstone, altstone, and shale, Cloggett shale, Eagle sandstone, and Telegraph Creek sandy shale. Includes Fox Hills sandstone and Pierre shale in the extreme east
- Kc** Colorado Group
Includes mainly shale of the Niobrara, Belle Fourche, Mowry, and Thermopolis Formations
- Kk** Kootenai Formation
Conglomerate, sandstone, shale, and mudstone
- lMz** Lower Mesozoic
Includes calcareous fossiliferous sandstone, shale, and limestone of the Ellis Group in the central and south central, and the Dinwoody and Thayne Formations in the southwest as well as the Morrison shale, sandstone, and marl in the west

- uPz** Mississippian, Pennsylvanian, Permian
Includes Madison limestone, Big Snow dolomite and limestone, and Quadrant sandstone
- lPz** Devonian and Cambrian
Consists of Three Forks shale, Jefferson limestone, Pilgrim and Meagher limestone, Park and Wolsky shale, and Flathead sandstone
- Ys** Upper Belt-Missoula and Pegan Groups
Chiefly red, maroon, and purple argillites and impure quartzite and limestone
- Ym** Middle Belt-Wallace, Siyeh, Helena Fms.
Heterogeneous Wallace Fm. including argillite, limestone, sandstone, shale, and quartzite; Siyeh and Helena limestones
- Yr** Lower Belt-Ravalli and Prichard Fms.
Ravalli Fm. includes siliceous and sandy quartzite, argillite, and shale; Prichard Fm. consists of banded shale with interbedded sandstone
- Y** Undivided Belt Supergroup

- VOLCANIC, PLUTONIC, AND METAMORPHIC ROCKS**
- Quaternary, rhyolitic volcanic rocks**
Volcanic rocks, mostly felsic Yellowstone flows and associated pyroclastic deposits
 - Tertiary, intrusives**
Mostly granitic to intermediate composition, some alkaline especially in north-central Montana
 - Lower Tertiary, volcanic rocks**
Flows and associated pyroclastic deposits: latite, andesite, with some rhyolite and basalt and associated intrusive dikes and necks
 - Younger Cretaceous, granitic rocks**
Boulder Batholith and related rocks; predominantly quartz monzonite
 - Cretaceous, volcanic rocks**
Mafic to intermediate composition lava flows, ash flows, and other pyroclastic rocks with interbedded sedimentary rocks including Elkhorn Mountains volcanic rocks
 - Older Cretaceous, volcanic rocks**
Idaho Batholith and associated masses; monzonite and granodiorite
 - Border Zone of Idaho Batholith**
Metasedimentary rocks of Belt age intruded by granitic rocks
 - Stillwater Complex**
Layered mafic-ultramafic intrusive complex, includes anorthosite; associated with hornfels aureole
 - Archean, undifferentiated**
High-grade metamorphic rocks derived from igneous and sedimentary parent rocks. Lithologies include quartz-feldspathic gneiss, granulite, amphibolite, quartzite, and marble

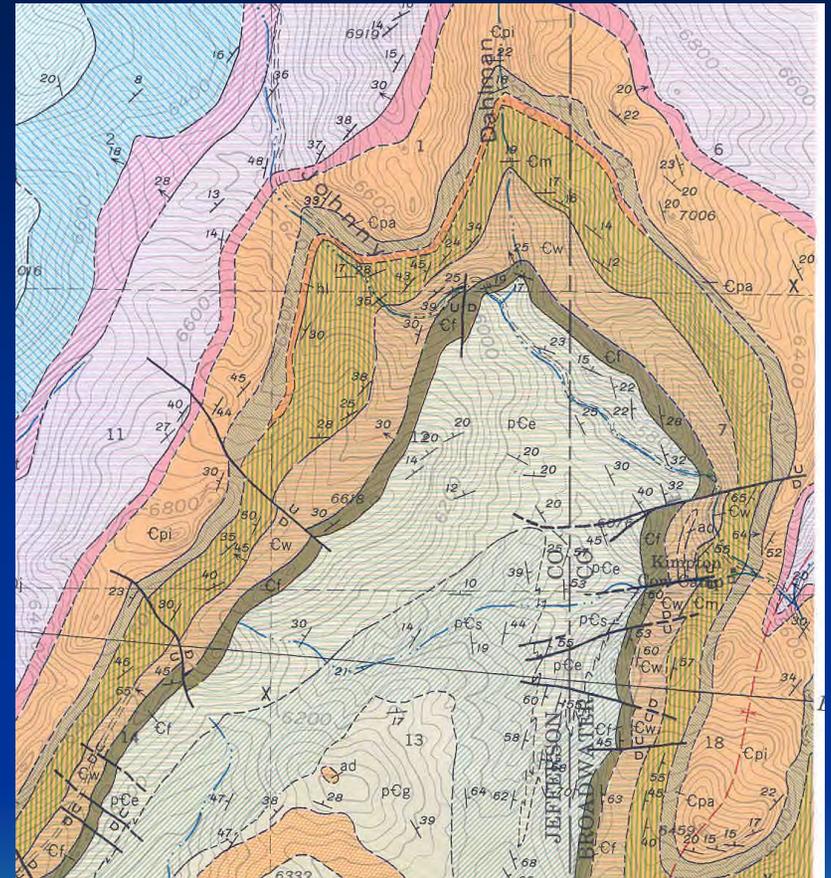
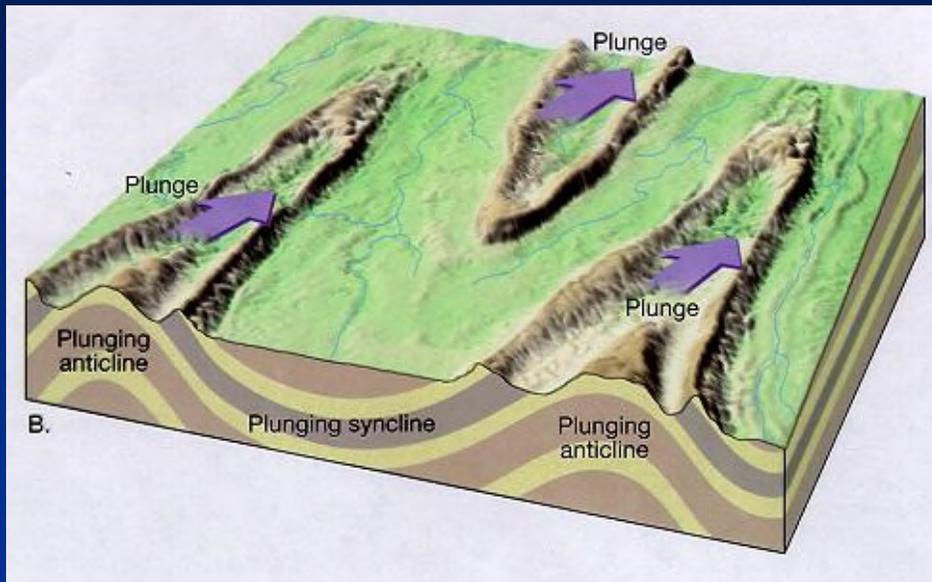
Devil's Fence Geology Map with Explanation



E X P L A

Upper Devonian and Mississippian	<p>Jefferson dolomite</p> <p>Dark-gray granular-weathering fetid well-bedded dolomite with subordinate amounts of dark-gray limestone and light-gray dolomite</p> <p>Dj</p>	DEVONIAN
	<p>Three Parks shale</p> <p>Predominantly greenish-gray and brown shale with subordinate amounts of interbedded sandstone and limestone. Dolomitic siltstone at top. Locally a 10- to 25-ft fossiliferous limestone unit, <i>l</i>, has been mapped</p> <p>Sd</p>	
Middle Devonian	<p>Lodgepole limestone</p> <p>Upper part of medium-gray fine- to medium-grained limestone in distinct beds as much as 2 ft thick alternating with zones of much thinner beds containing rare mudstone partings; lower part of medium-gray limestone in beds 1 in. to 1 ft thick with partings and interbeds of yellow to red calcareous mudstone; grades into Mission Canyon limestone through a 150- to 200-ft zone</p> <p>Lod</p>	MISSISSIPPIAN
	<p>Mission Canyon limestone</p> <p>Medium-gray to light-gray medium-grained thickly and indistinctly bedded limestone, with a few thin siliceous layers in lower 200 ft and sparse gray chert nodules and lentils in upper half. A breccia unit, <i>br</i>, about 200 ft below top of formation has been mapped locally</p> <p>Mcc</p>	
Lower Devonian	<p>Amnden formation</p> <p>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</p> <p>Amd</p>	CARBONIFEROUS
	<p>Quadrant formation</p> <p>Light-colored quartzitic sandstone and interbedded light-gray argillaceous sandy dolomite</p> <p>Pq</p>	
Upper Permian	<p>Phosphoria formation</p> <p>Brown and gray chert and sandstone, in part phosphatic; may locally contain one or two thin beds of Quadrant formation, <i>Pq</i></p> <p>Pp</p>	PERMIAN
	<p>Morrison and Swift formations</p> <p>Morrison formation, varicolored non-marine shale, mudstone, and siltstone, with thin beds of limestone and sandstone, and near the top a unit of black lentils; "pepper-and-salt" sandstone and grades into overlying Kostena formation</p> <p>Swift formation, grayish-brown punky calcareous marine sandstone, 20 to 25 ft thick, with a basal chert-pebble conglomerate</p> <p>M</p>	
Lower Permian	<p>Kostena formation</p> <p>Comprises three units. Upper unit is 10 to 25 ft of postuplift-bearing limestone overlain by a few feet to 30 ft of drab mudstone, middle unit is red and green mudstone and shale with concretions and lentils of limestone; lower unit is cross-bedded "pepper-and-salt" sandstone and interbedded shale and mudstone</p> <p>Kk</p>	PERMIAN
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Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
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Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
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Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
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Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
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Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
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Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	
Lower Permian	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</p>	PERMIAN
	<p>Lower Permian</p> <p>Lower Permian</p> <p>Ju</</p>	

Folds and Geologic Maps



Devil's Fence Topographic Feature



Geology Map La Jolla Quad

