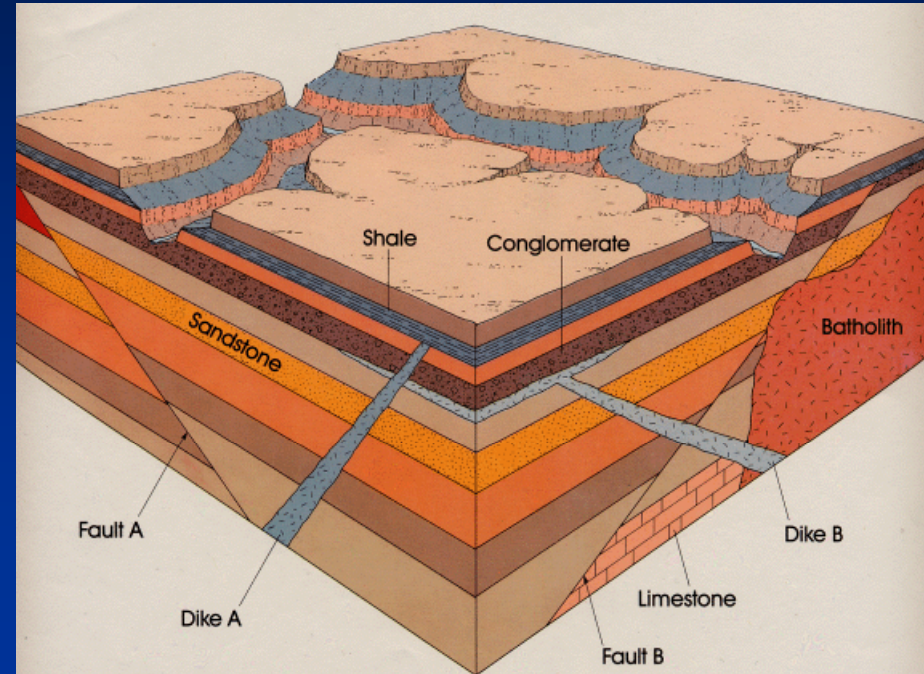


Structural Geology and Geology Maps Lab

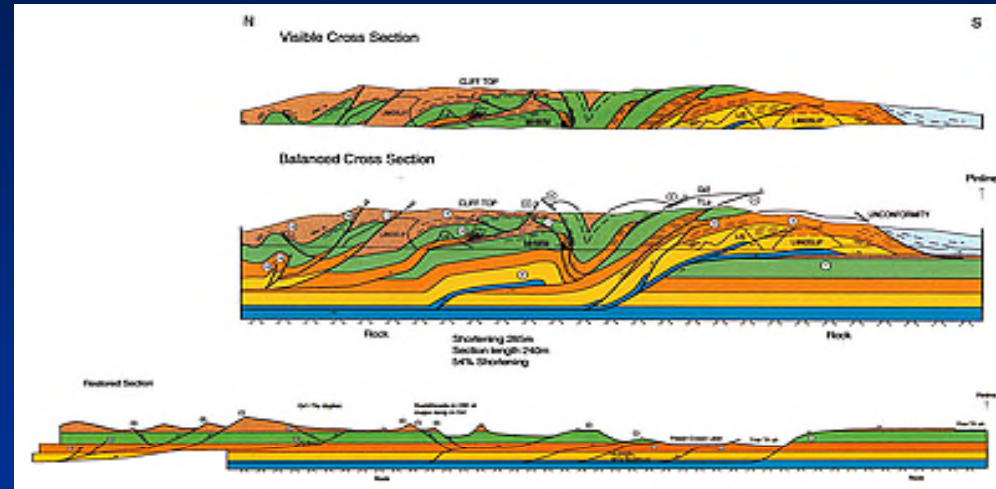


Geology 101 Lab
Ray Rector: Instructor



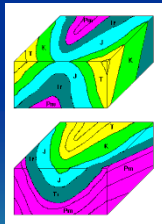
Structural Geology Lab

Pre-Lab Resources

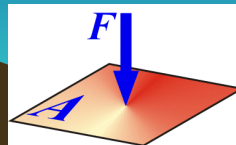


Pre-Lab Internet Links

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.



General Geologic Terms of Structure

Outcrop: Exposure of bedrock at earth's surface



Formation: mappable body of rock with definite age, lithology, and external boundaries (contacts)

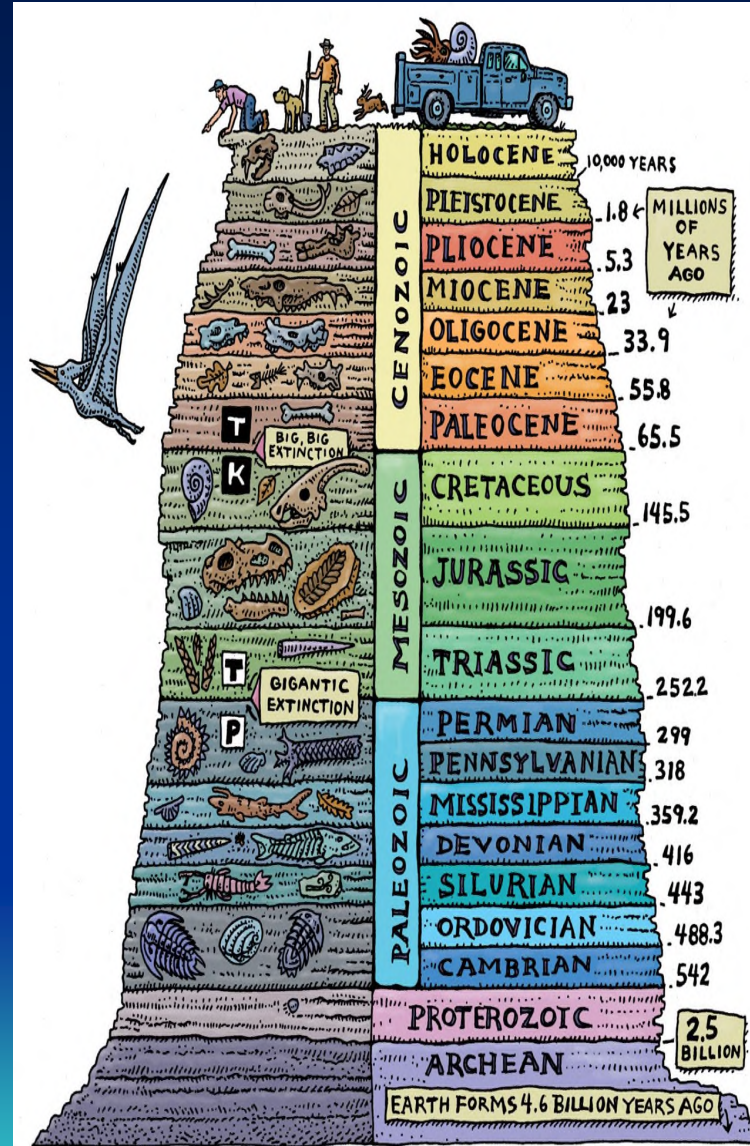


Contact: Boundary between adjacent rock bodies or structural elements



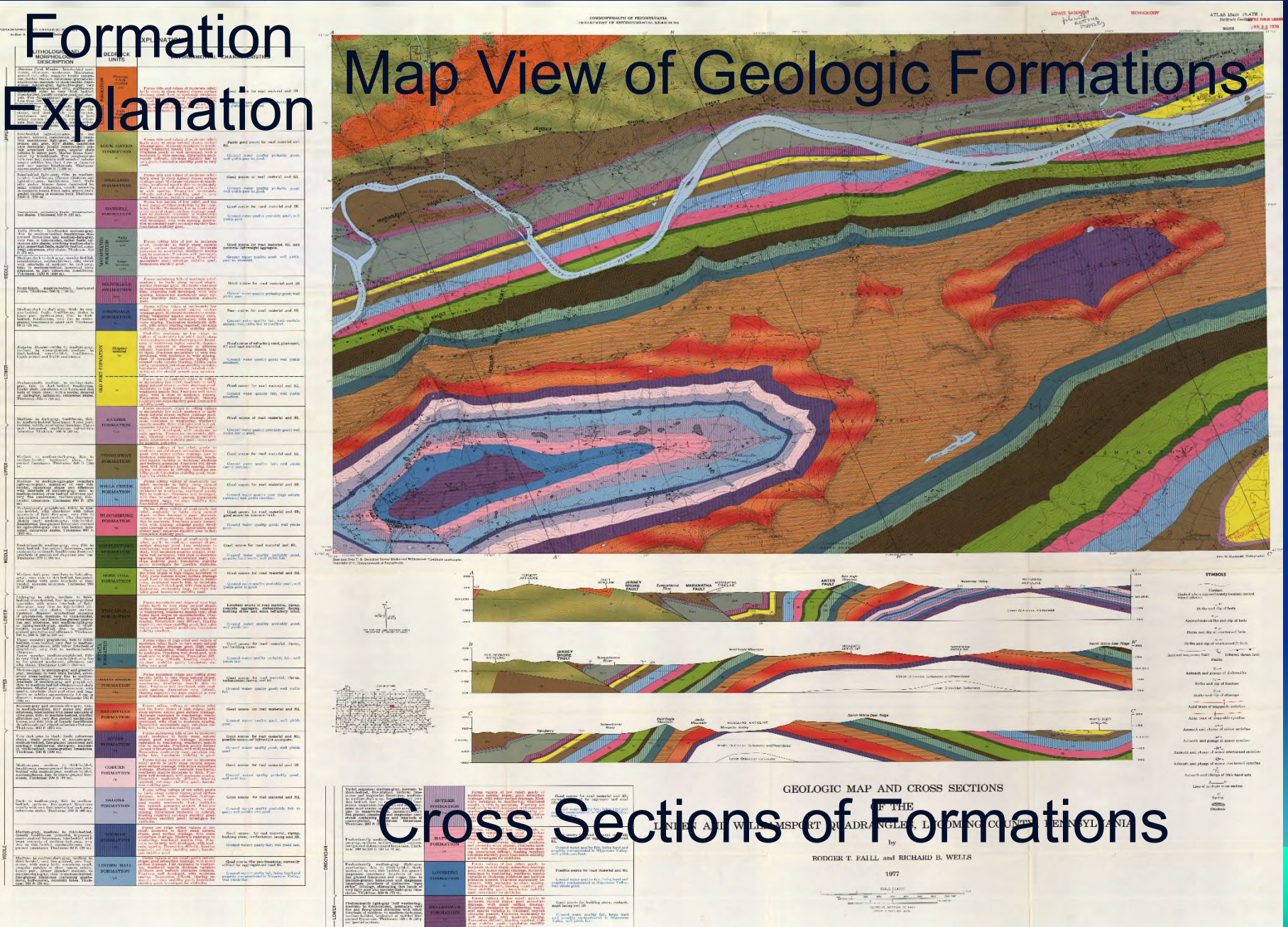
Rock Formations and Geologic Time

- 1) All 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)



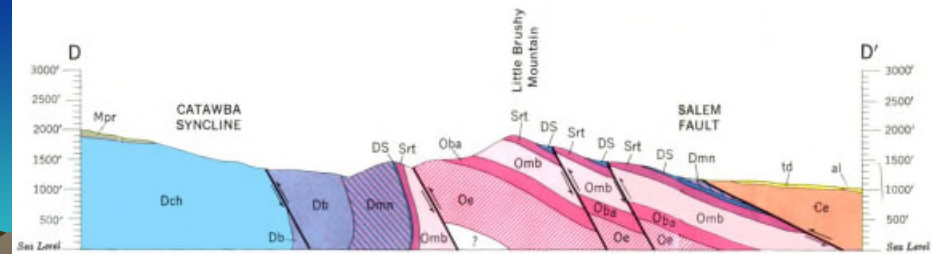
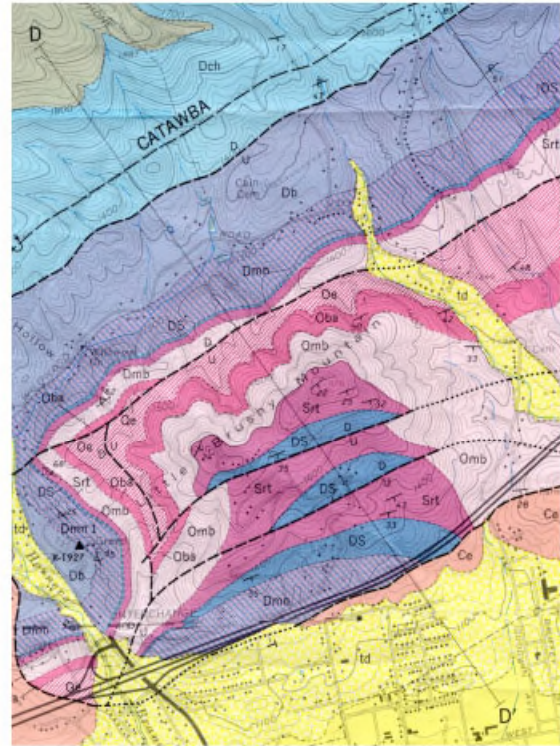
Formation

ETHOLOGICAL AND MORPHOLOGICAL DESCRIPTION	BEHAVIORAL UNITS	EXPLANATION	ENVIRONMENTAL CHARACTERISTICS
<p>Observation: Local Monkeys: Rhesus macaques (<i>Macaca mulatta</i>) and Japanese macaques (<i>Macaca fuscata</i>) were observed in their natural habitats. The subjects were habituated to human presence and allowed to interact freely. The observations were conducted over a period of 12 months, with data recorded on a daily basis. The subjects were observed in their natural habitats, and the data were recorded on a daily basis. The subjects were observed in their natural habitats, and the data were recorded on a daily basis.</p>	<p>Behavioral Units: The behavioral units were defined as discrete, observable actions that could be recorded and quantified. These units included: (1) Grooming: The act of one monkey grooming another, which is a social bonding behavior. (2) Feeding: The act of one monkey feeding another, which is a social bonding behavior. (3) Play: The act of one monkey playing with another, which is a social bonding behavior. (4) Aggression: The act of one monkey attacking another, which is a social bonding behavior. (5) Resting: The act of one monkey resting, which is a social bonding behavior.</p>	<p>Formal Theory: The formal theory of social bonding in primates is based on the idea that social bonding is a result of the interaction of genetic and environmental factors. The formal theory of social bonding in primates is based on the idea that social bonding is a result of the interaction of genetic and environmental factors. The formal theory of social bonding in primates is based on the idea that social bonding is a result of the interaction of genetic and environmental factors.</p>	<p>Environmental Characteristics: The environmental characteristics of the study included the natural habitat of the monkeys, the presence of human observers, and the availability of food and water. The environmental characteristics of the study included the natural habitat of the monkeys, the presence of human observers, and the availability of food and water. The environmental characteristics of the study included the natural habitat of the monkeys, the presence of human observers, and the availability of food and water.</p>



Rock Formations and Contacts on a Geologic Map

- 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

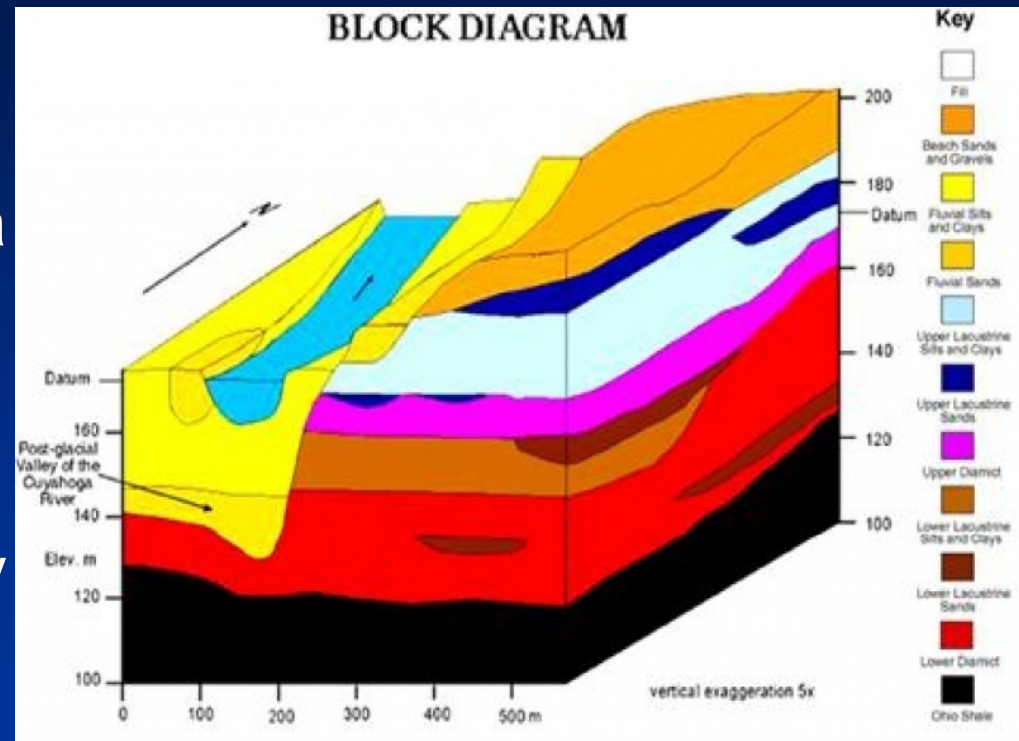


Rock Formations and Block Diagrams

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.



A 3D perspective view of a geological map. The map is tilted, showing various colored layers representing different geological formations. The colors include shades of blue, yellow, purple, brown, and red. The layers are labeled with letters and numbers, such as 'Ka', 'Kib', and 'Kib'. The map also shows topographic features like hills and valleys, and a network of roads or paths. The overall appearance is that of a physical model or a digital 3D rendering of a geological map.

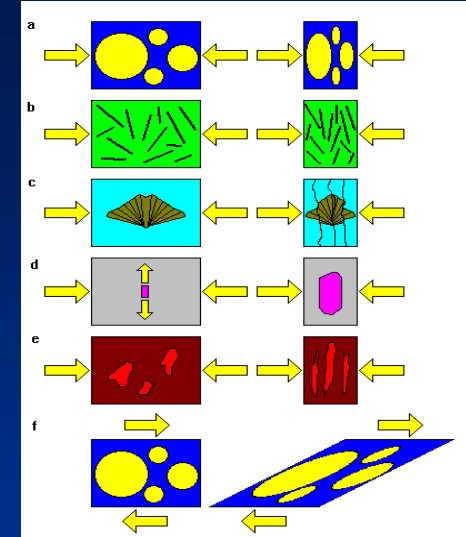
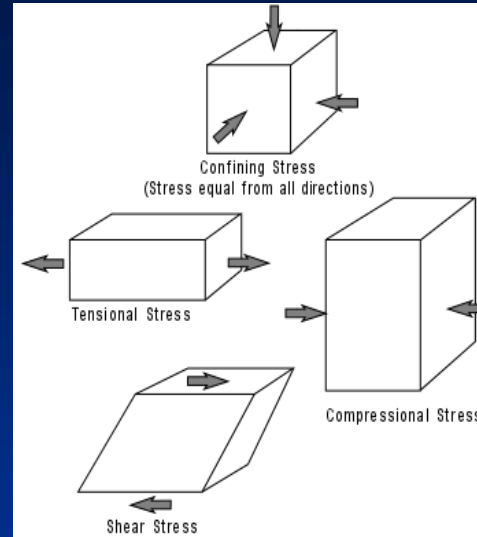
Origin and Nature of Rock Deformation

A. Stress Leads to Strain

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

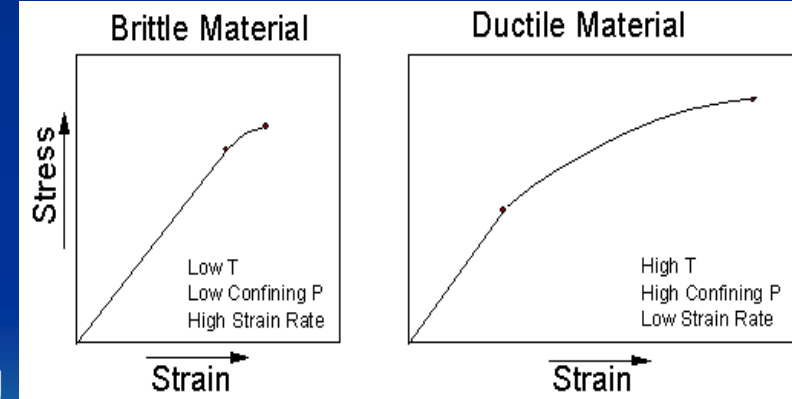
B. Different Types of Stress

- ✓ 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

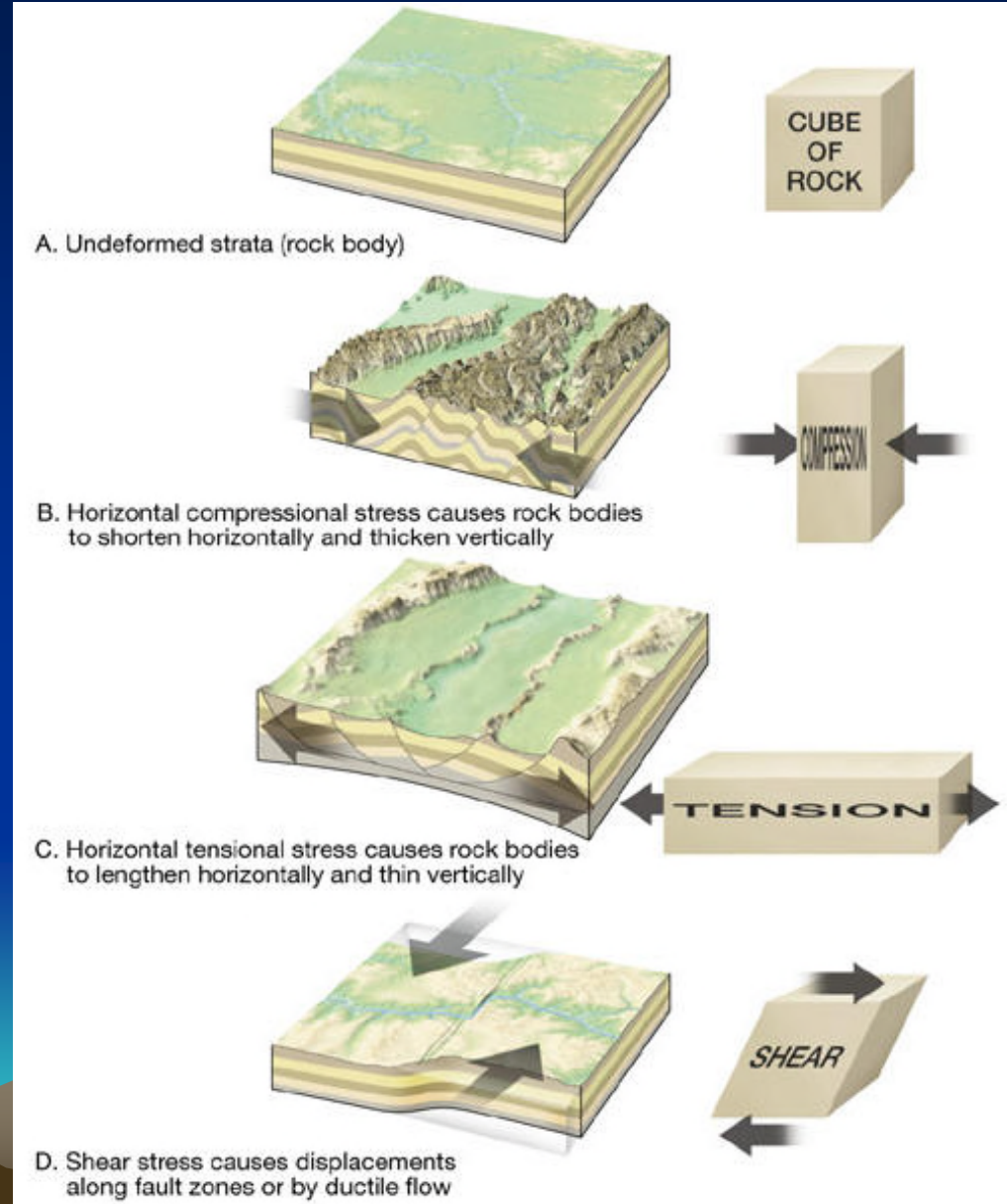
- ✓ Shorten horizontally
- ✓ Thicken vertically
- ✓ Folding and Reverse Faulting

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

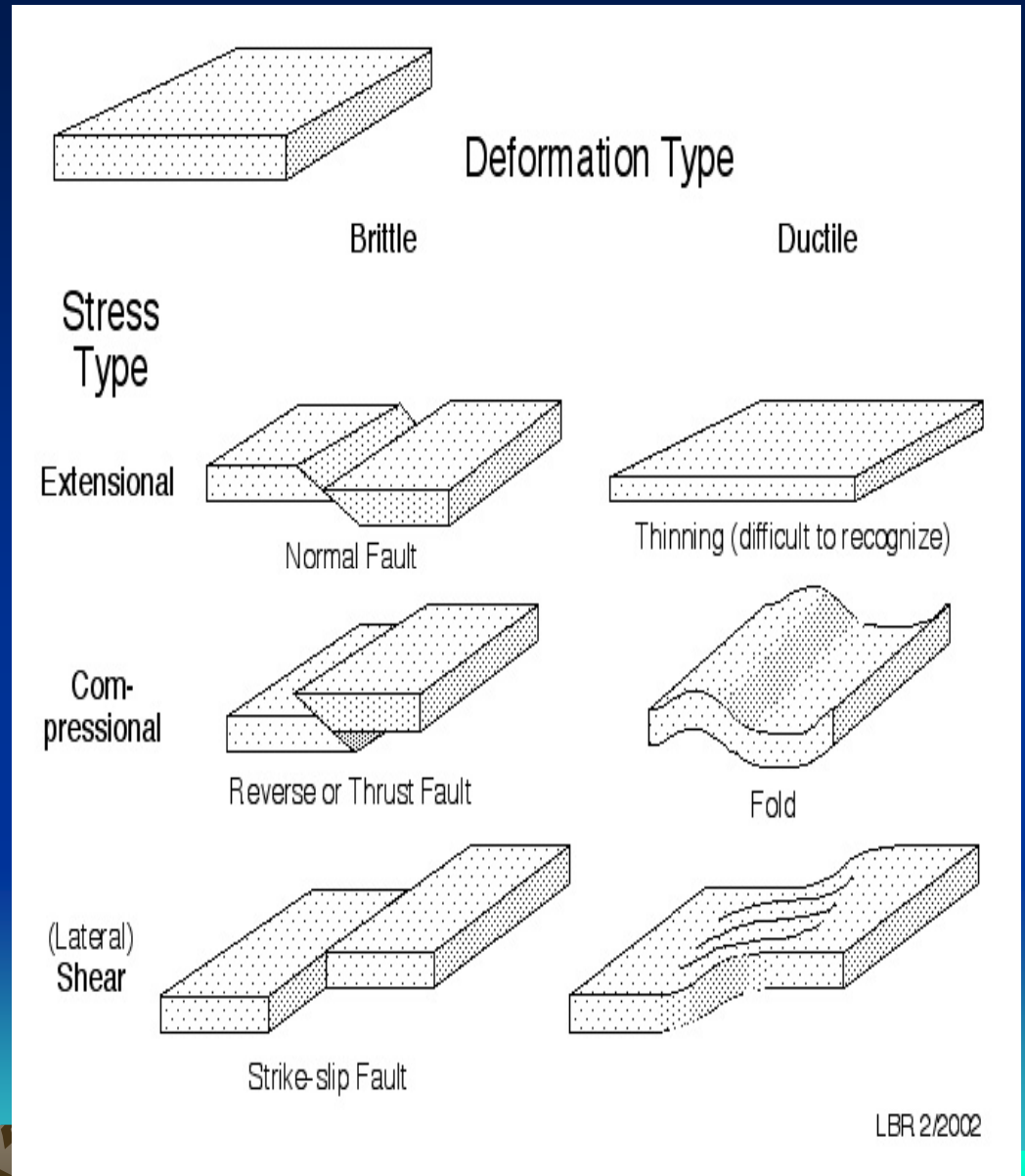
- ✓ Lengthen horizontally
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C. Compressional Stresses

- ✓ 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

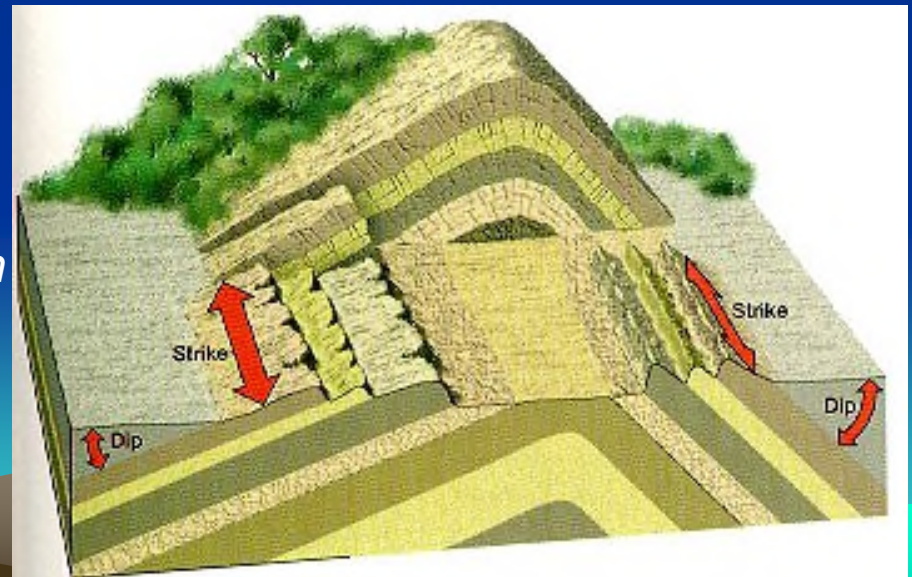
The Basic Rules of Structure

- 1) Strike of beds is always parallel to the direction of the contacts.
 - 2) Rock layers dip towards the youngest exposed rock layers.
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 - 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

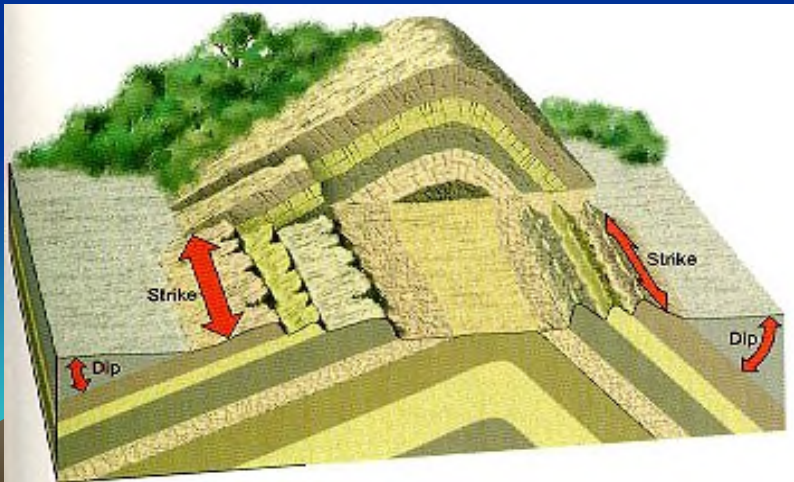
Strike and Dip



Measuring Strike Azimuth



Measuring Dip Angle



Strike Azimuth and Dip Angle



Completed Strike and Dip Measurement

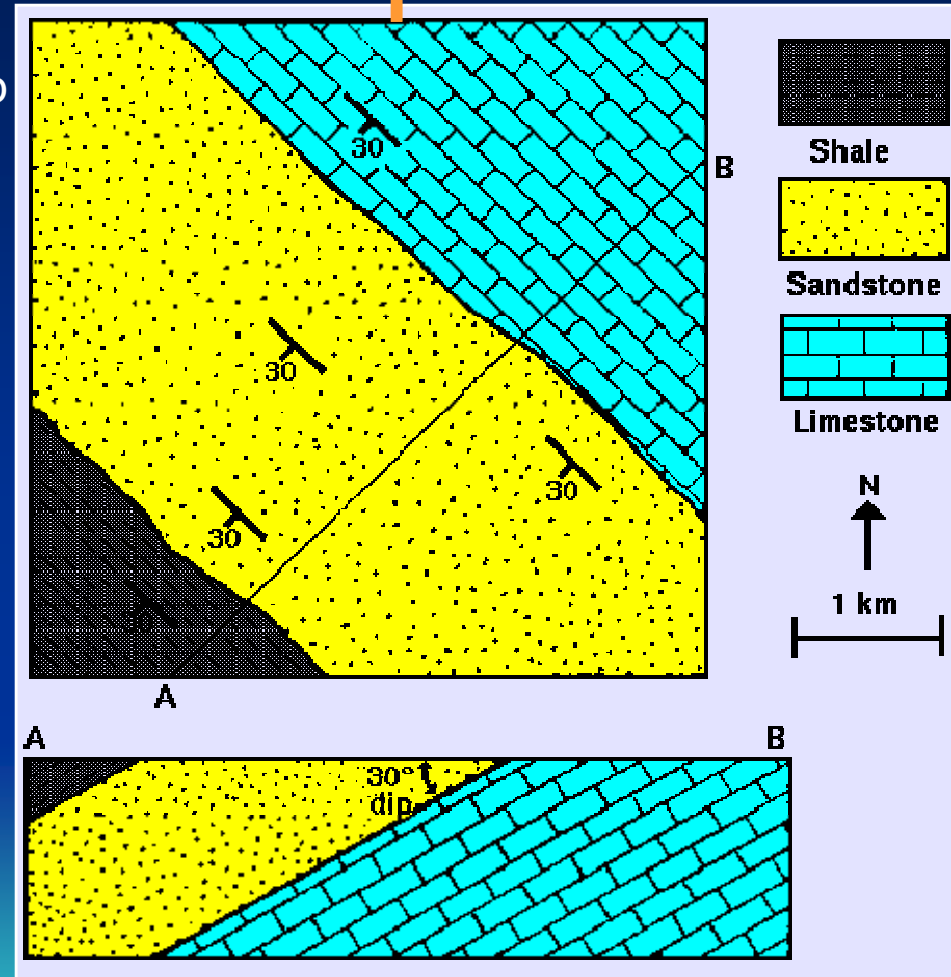
Spatial Orientation of Layers

Strike and Dip

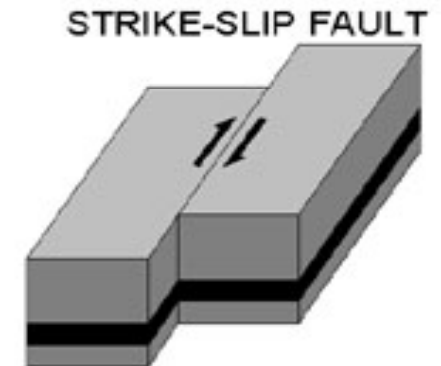
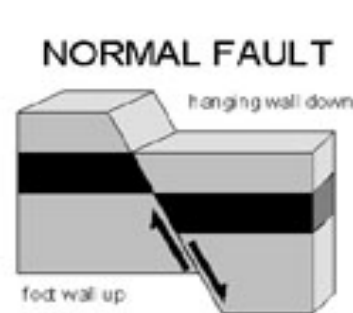
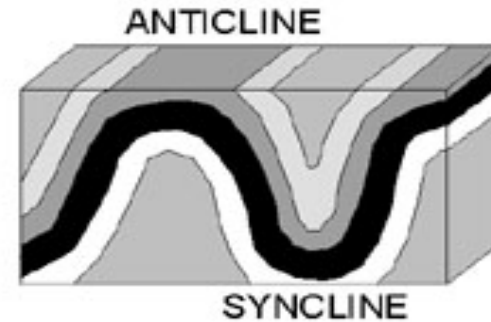
The **Strike** and **Dip** of a planar rock layer or feature is symbolized on a geology map by a



- ✓ 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

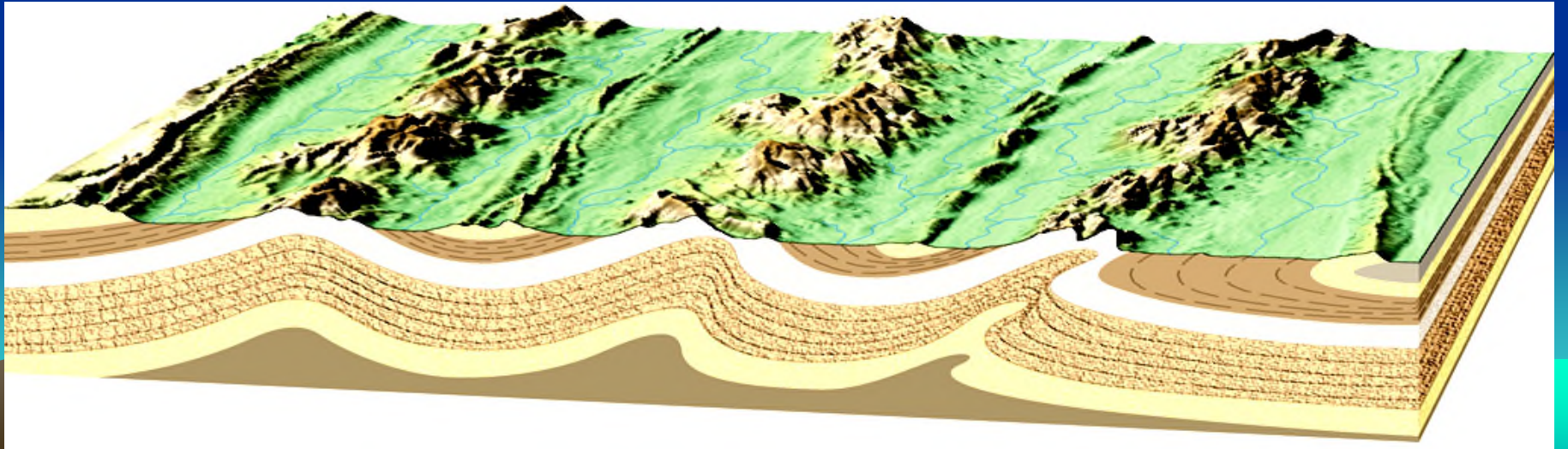
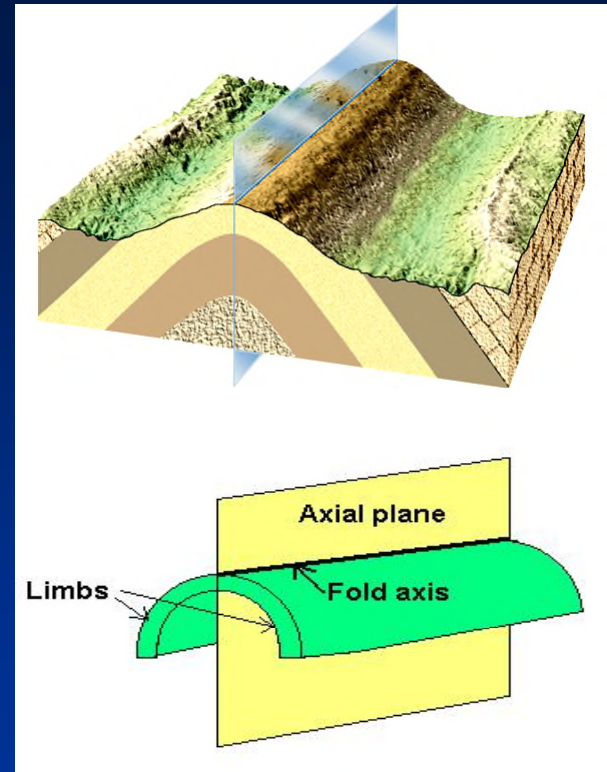


Anticline: Upwards-buckled fold with oldest rock at center and outward-dipping limbs

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



Fold Basics



Fold Basics

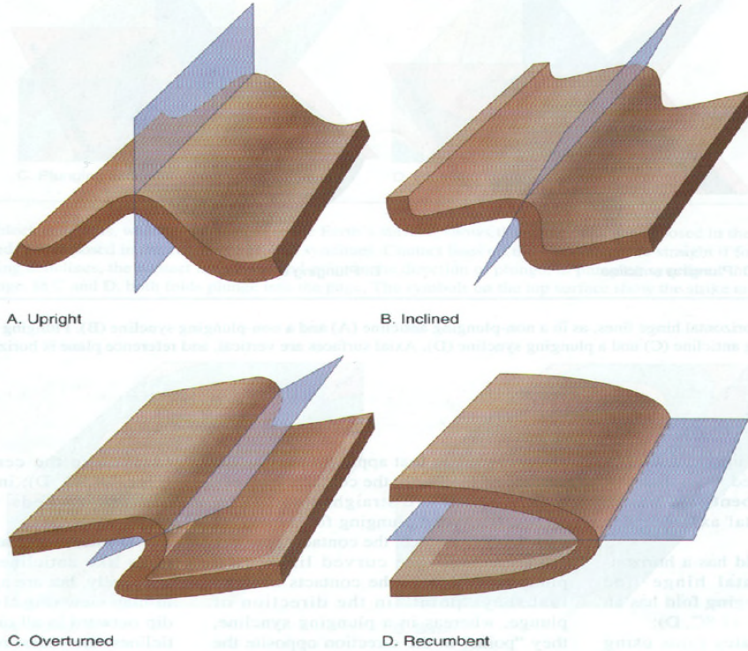
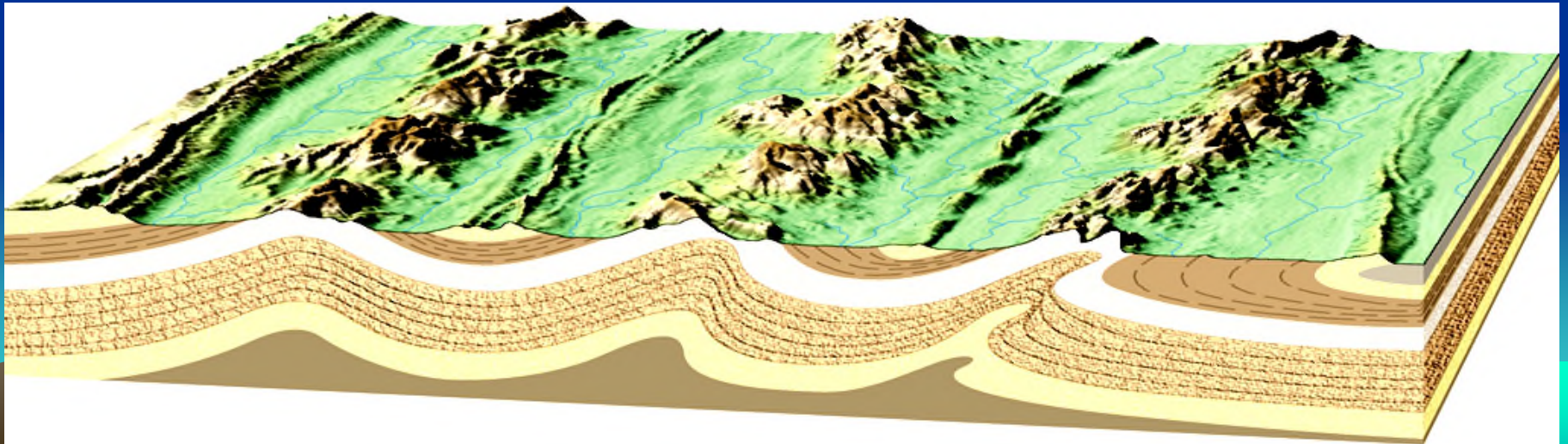
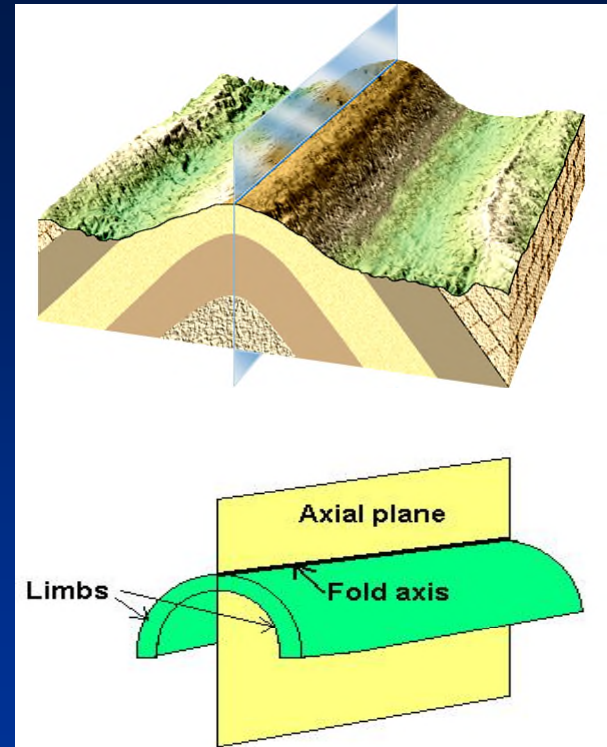
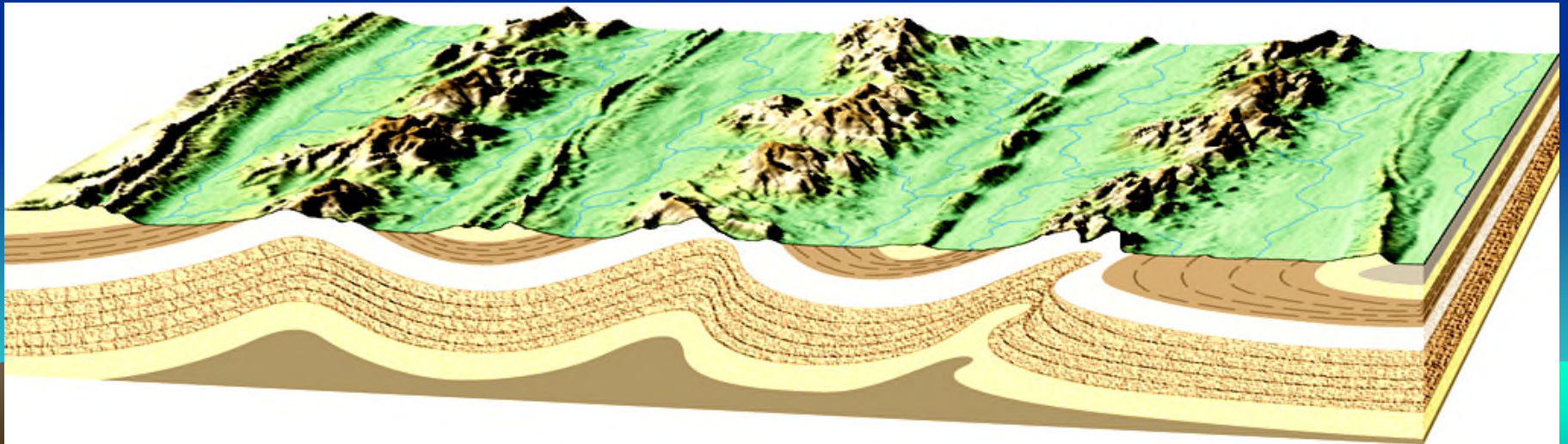


FIGURE 14.7

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

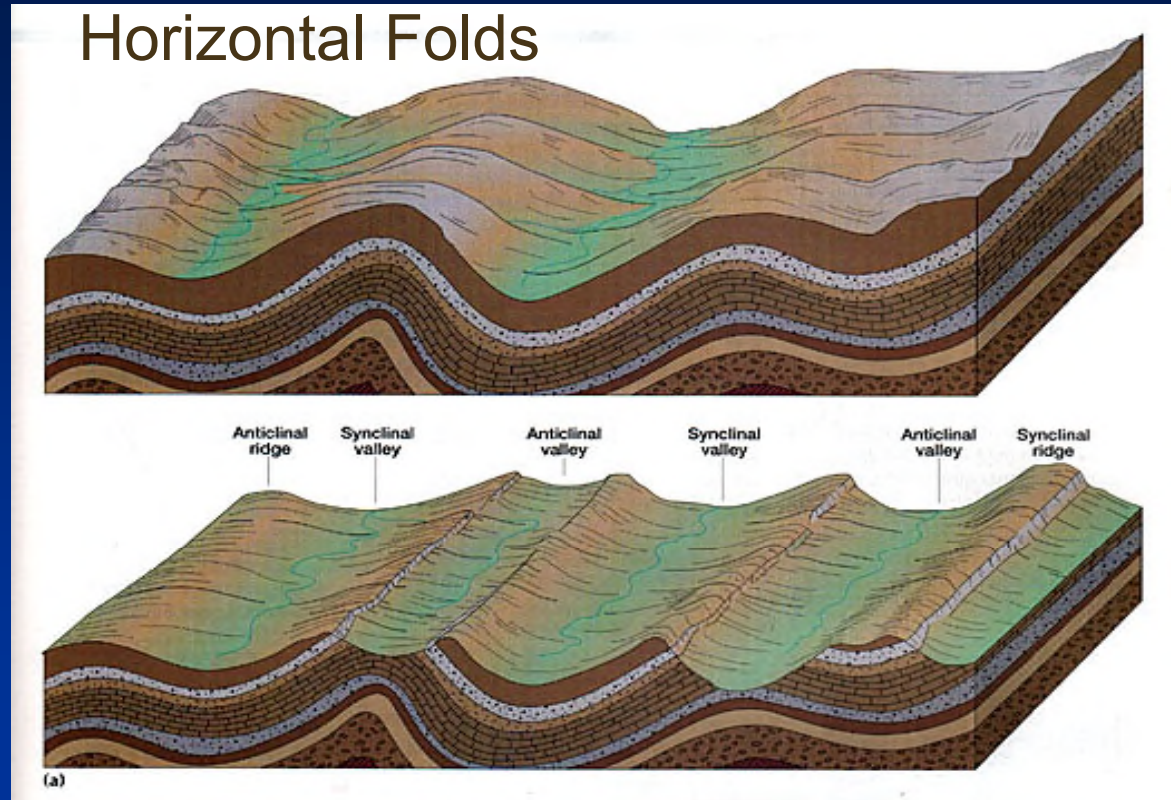
Horizontal Folds

- 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

Horizontal Folds

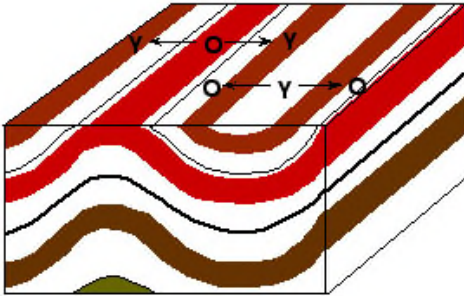


3) Anticlines plunge toward closed end of "V"-shaped bedding pattern

4) Synclines plunge toward open end of "V"-shaped bedding pattern

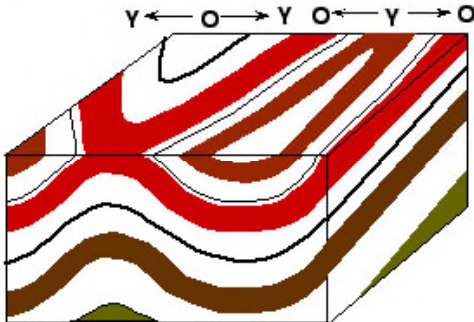
Plunging Folds

Plunging Folds

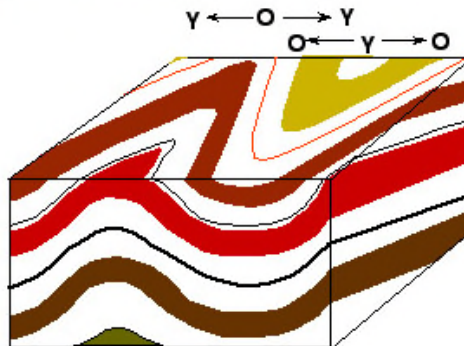


Anticline and Syncline in 3-dimensional view

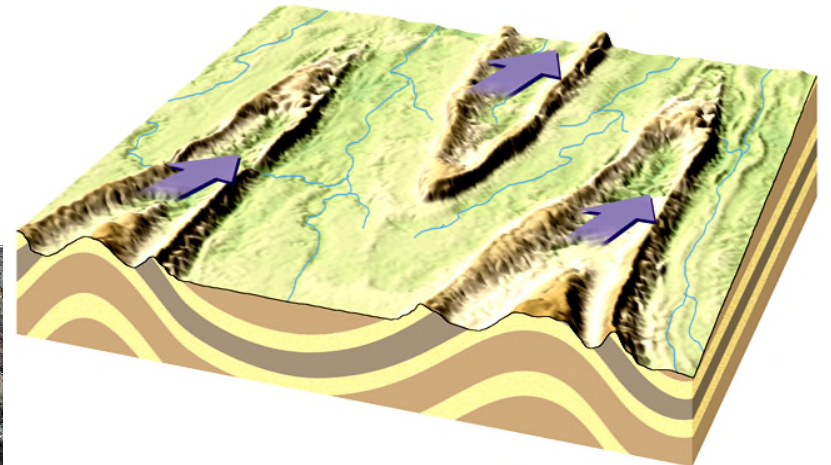
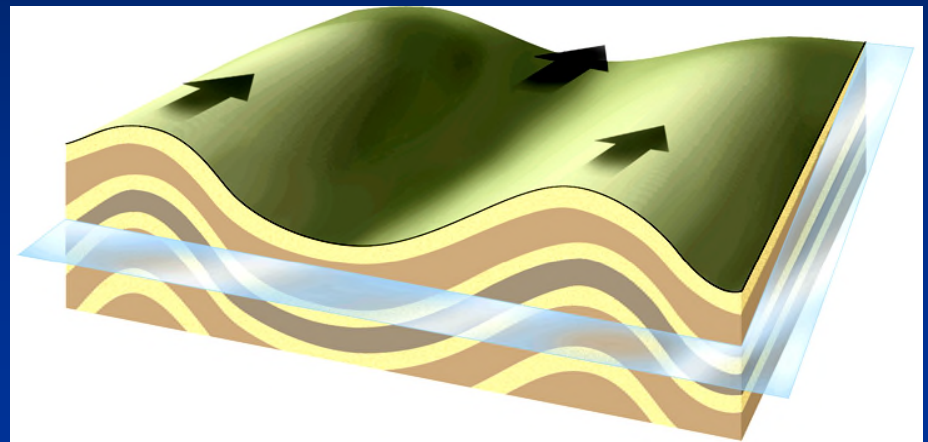
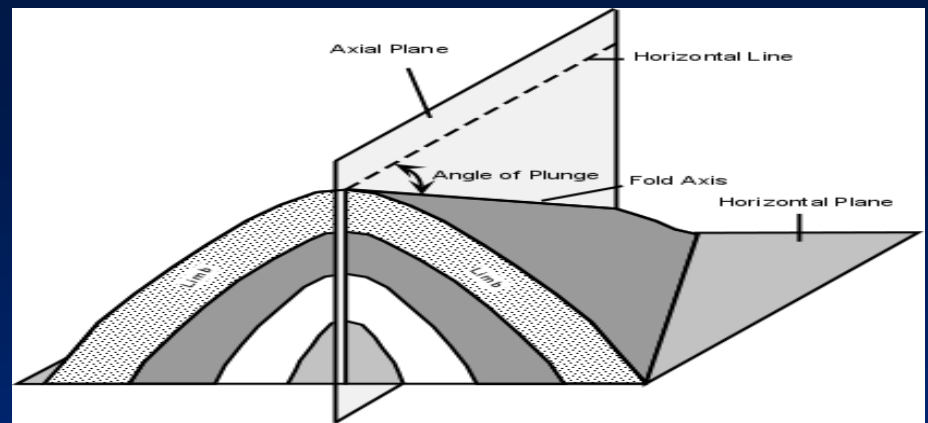
Oldest beds are in centers of anticlines; youngest beds are in centers of synclines.



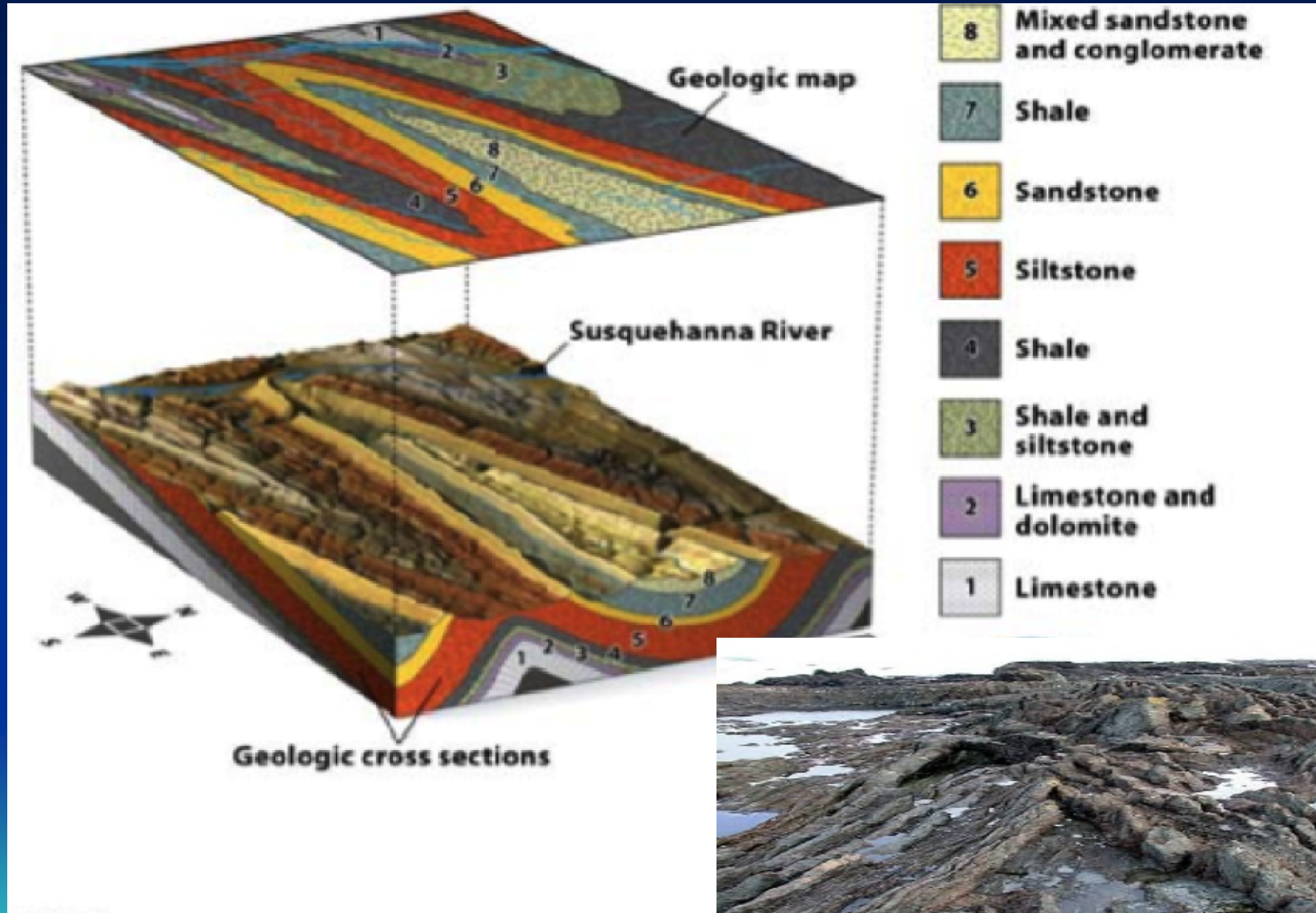
Anticline and Syncline
plunging toward viewer



Anticline and Syncline
plunging away from
viewer

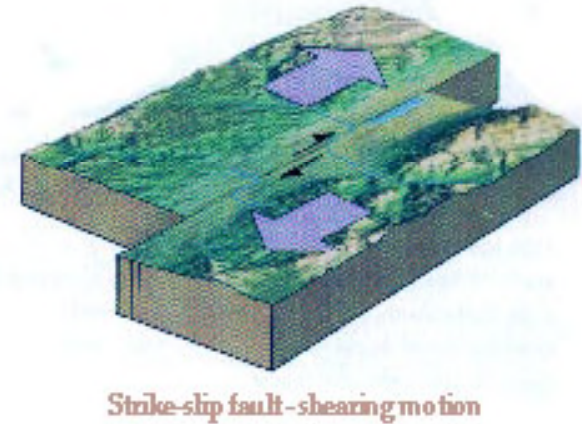
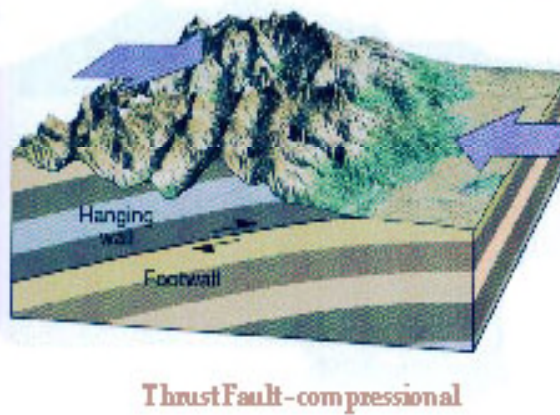
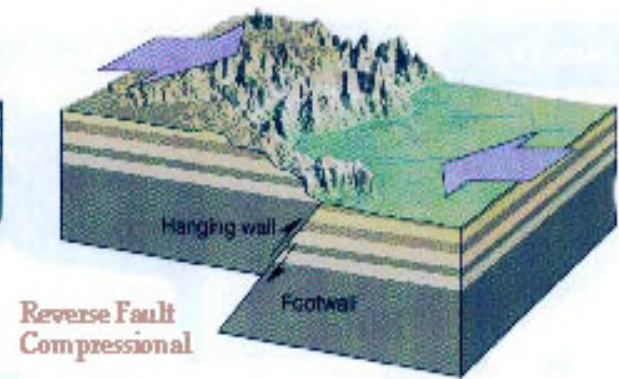
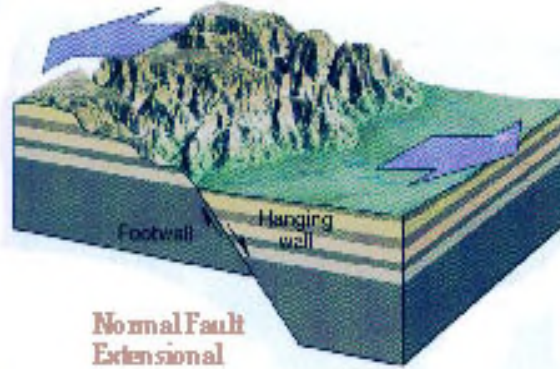
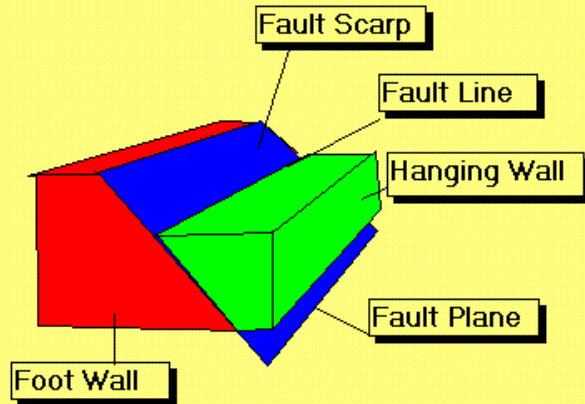


Plunging Folds

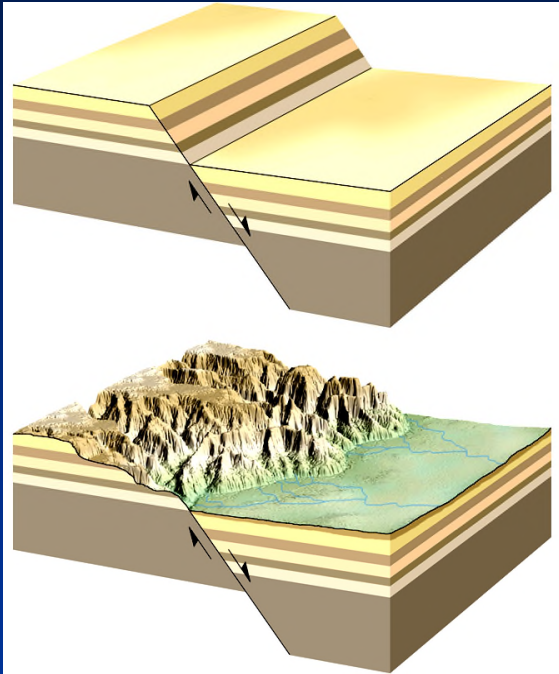


Fault Terminology

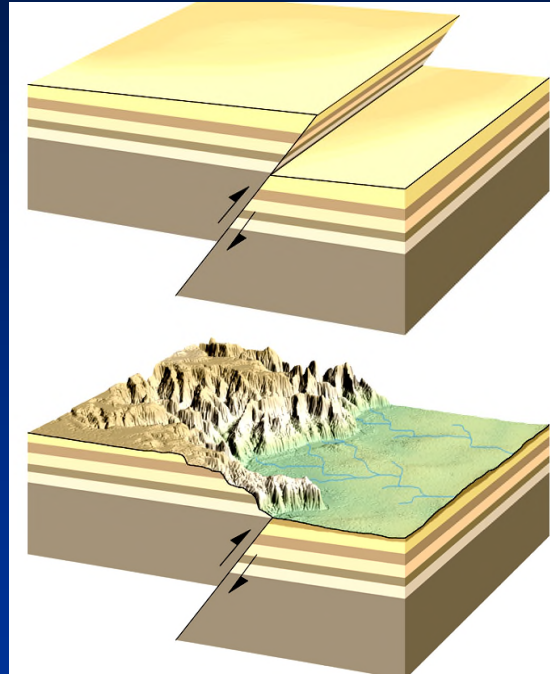
Features of Faults



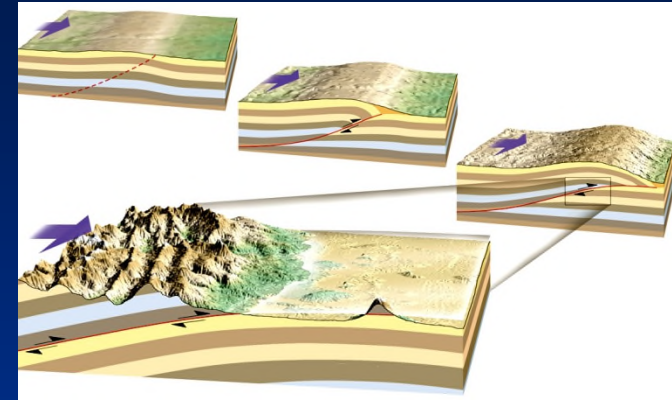
Types of Faults



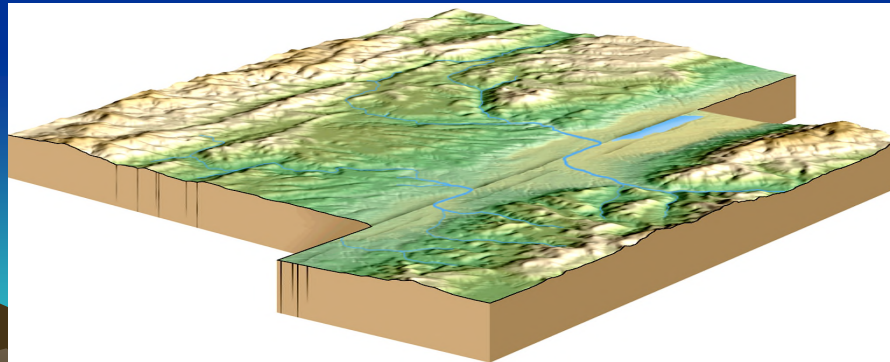
Normal Fault



Reverse Fault

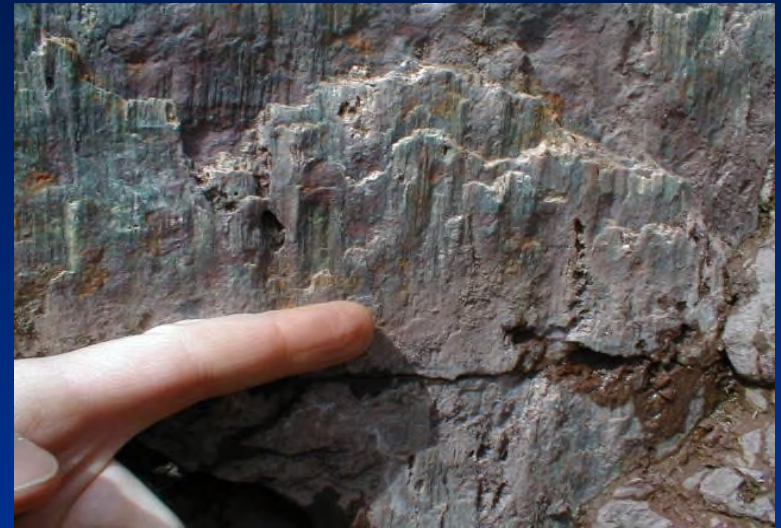
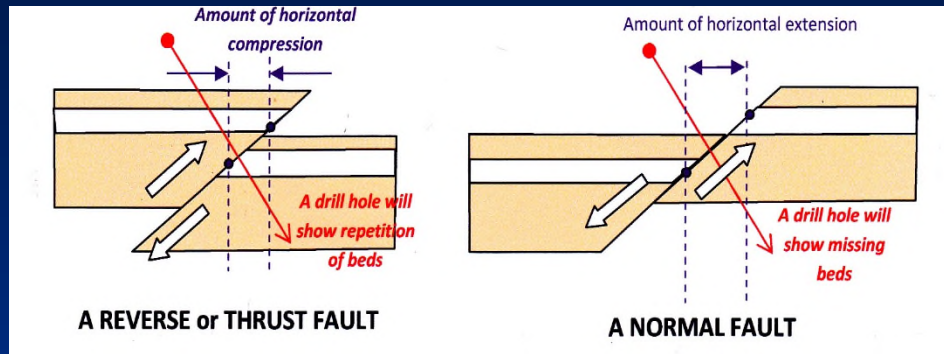


Thrust Fault

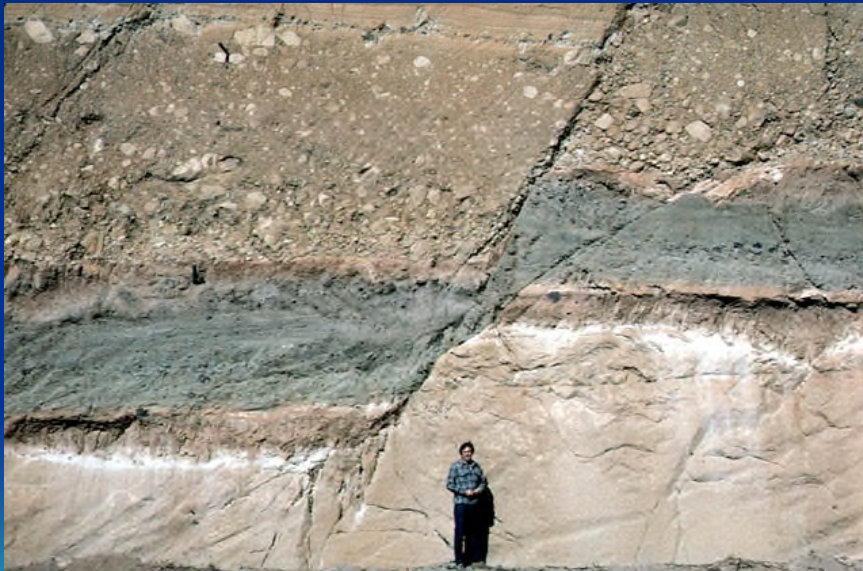


Strike-Slip Fault

Fault Offset and Slickensides



Dip-slip oriented slickensides



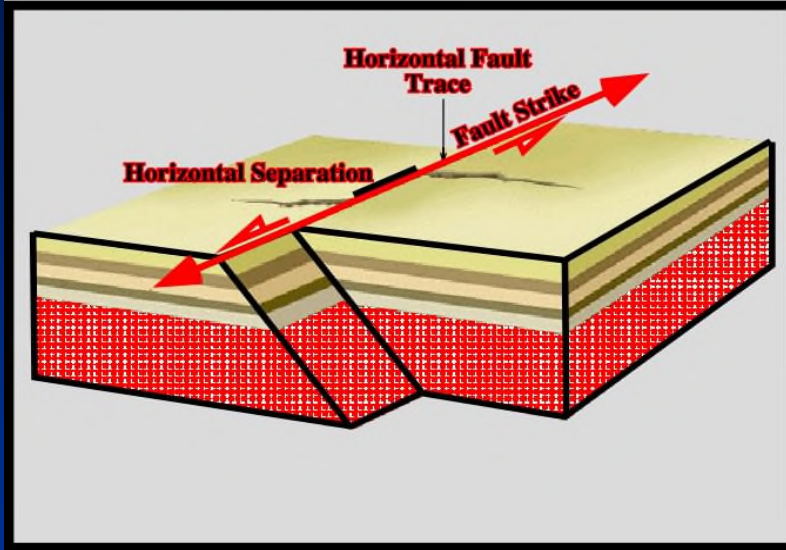
Normal-sense, dip-slip offset



Reverse-sense, dip-slip offset

Fault Slickensides

Strike Slip Movement

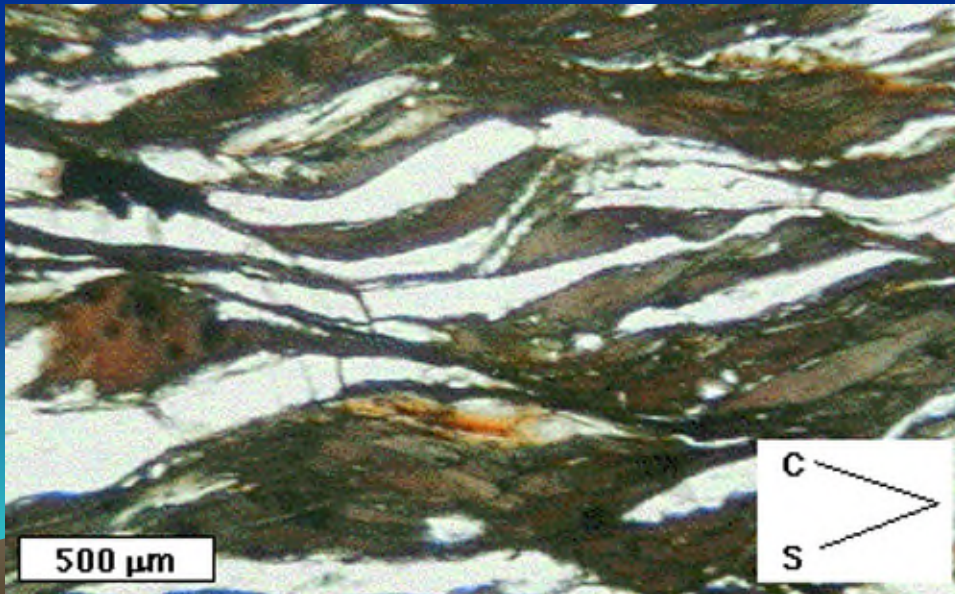
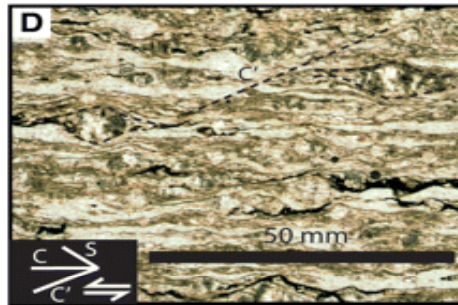
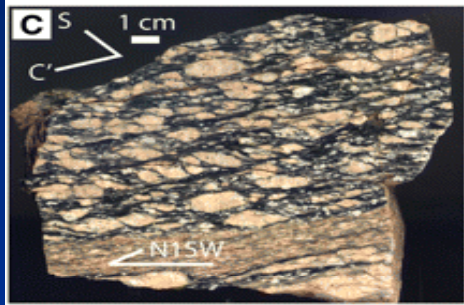
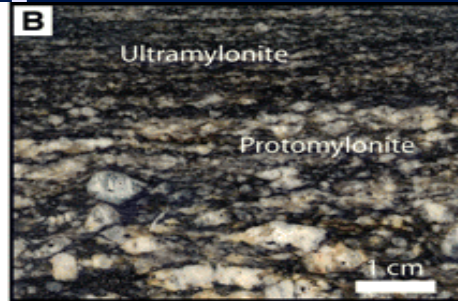
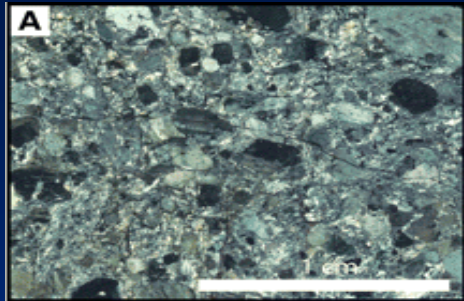


Strike-slip oriented slickensides



Right-lateral, strike-slip offset


Special Fault Rocks



Mylonite

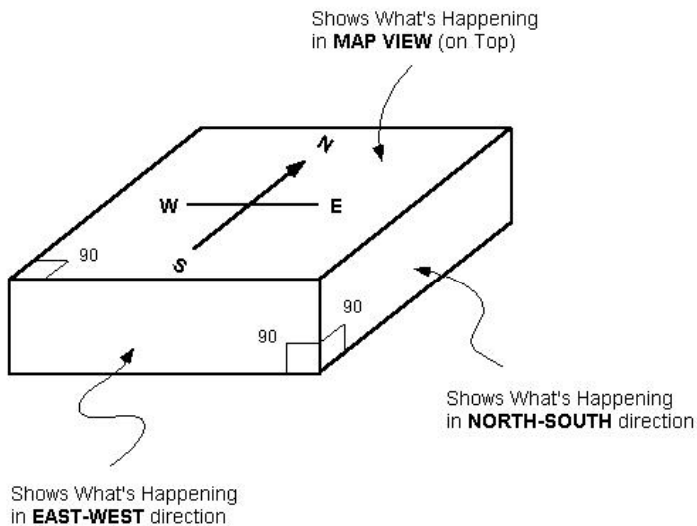
Brittle-ductile shear-like deformation along fault zone resulting in a special kind of foliation termed "S-C fabric".

The Basic Rules of Structure

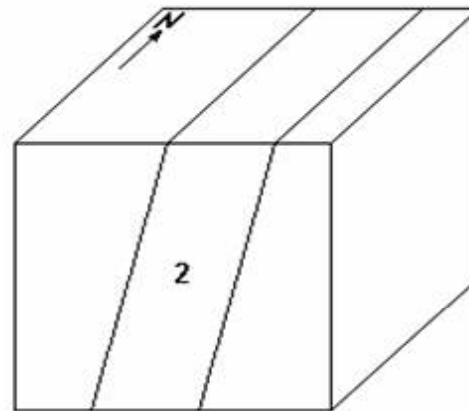
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 - 12) Slickenside grooves oriented horizontal in fault scarp indicate strike-slip offset.
 - 13) Slickenside grooves oriented vertical in fault scarp indicate dip-slip offset.
- 

Working with Block Diagrams

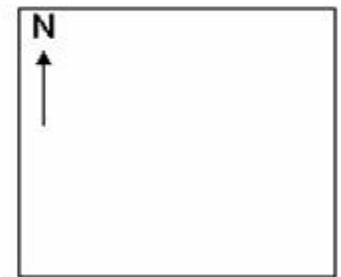
A GUIDE TO BLOCK DIAGRAMS



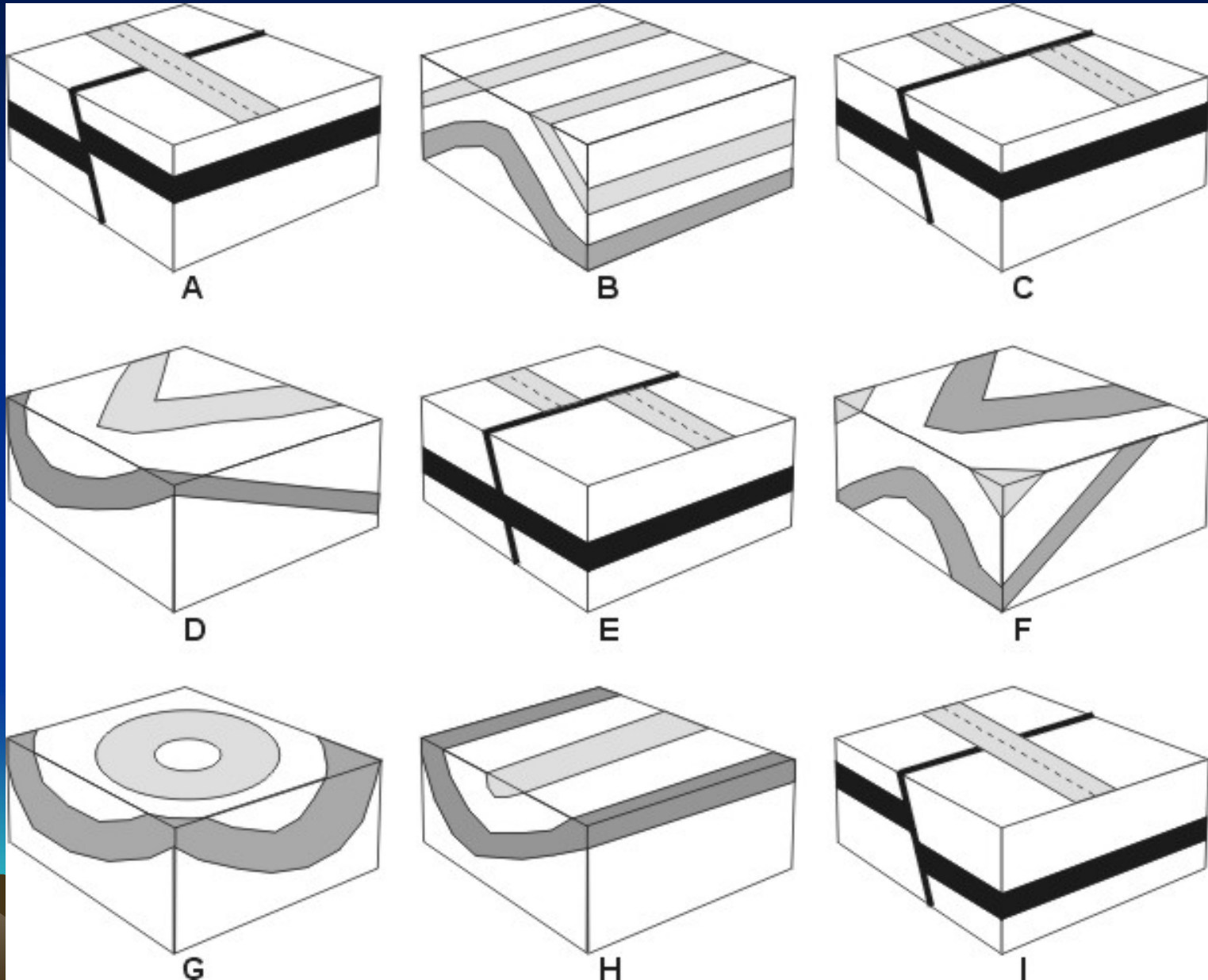
BLOCK DIAGRAM



MAP VIEW



Working with Block Diagrams



Working with Block Diagrams

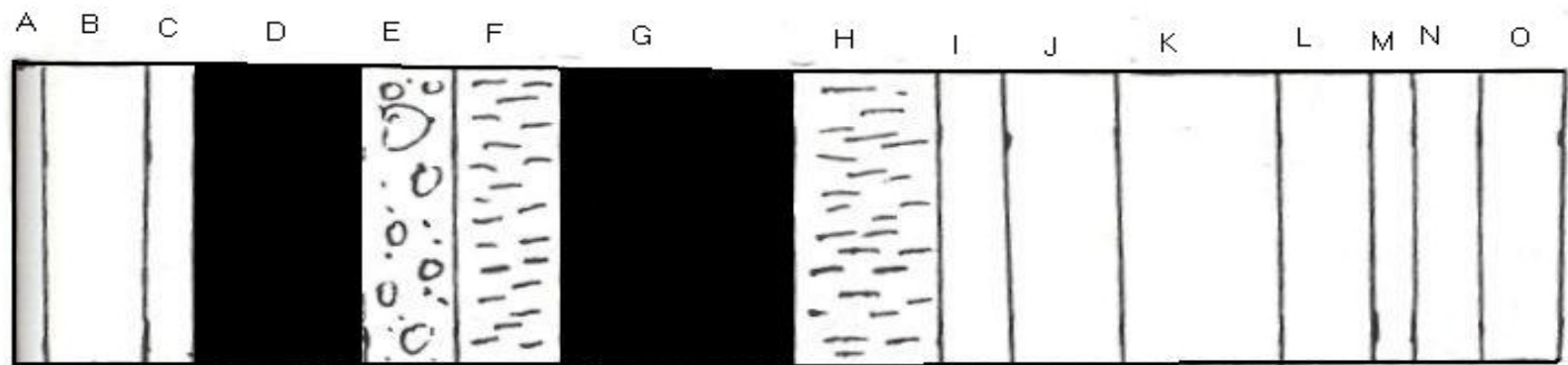
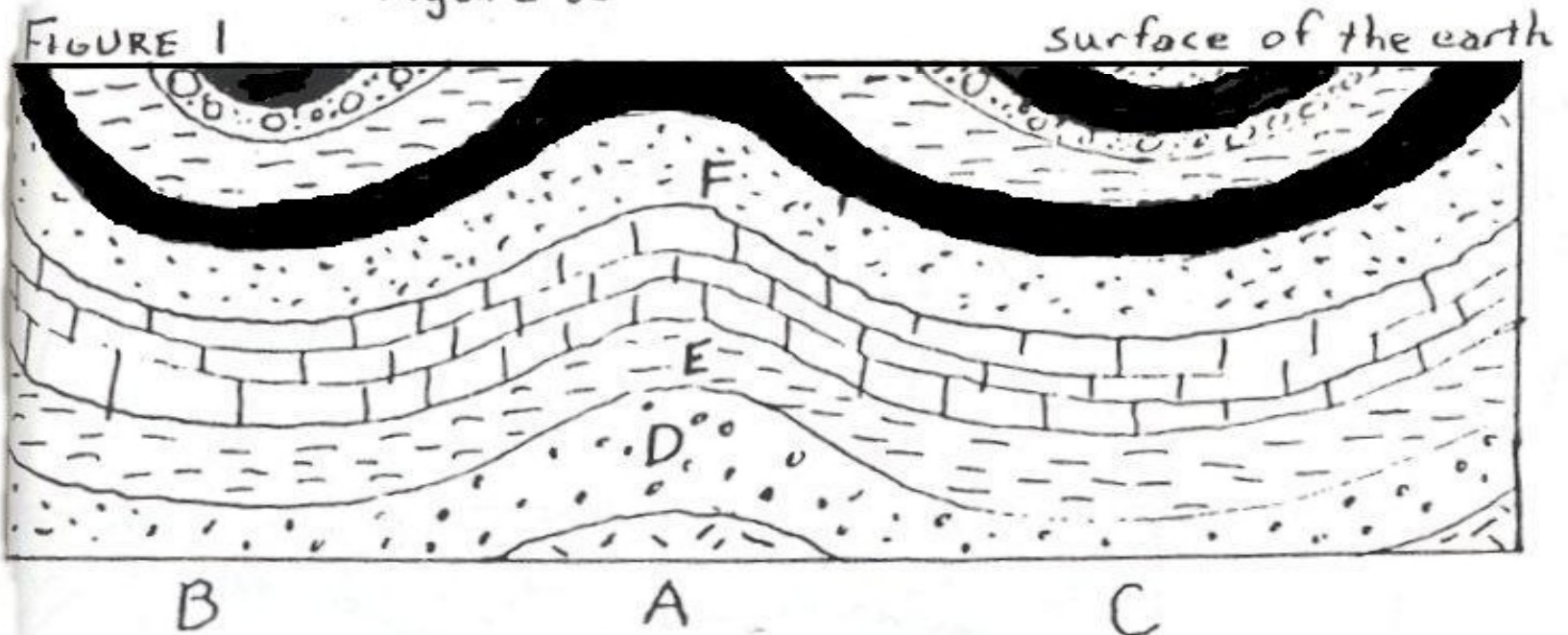
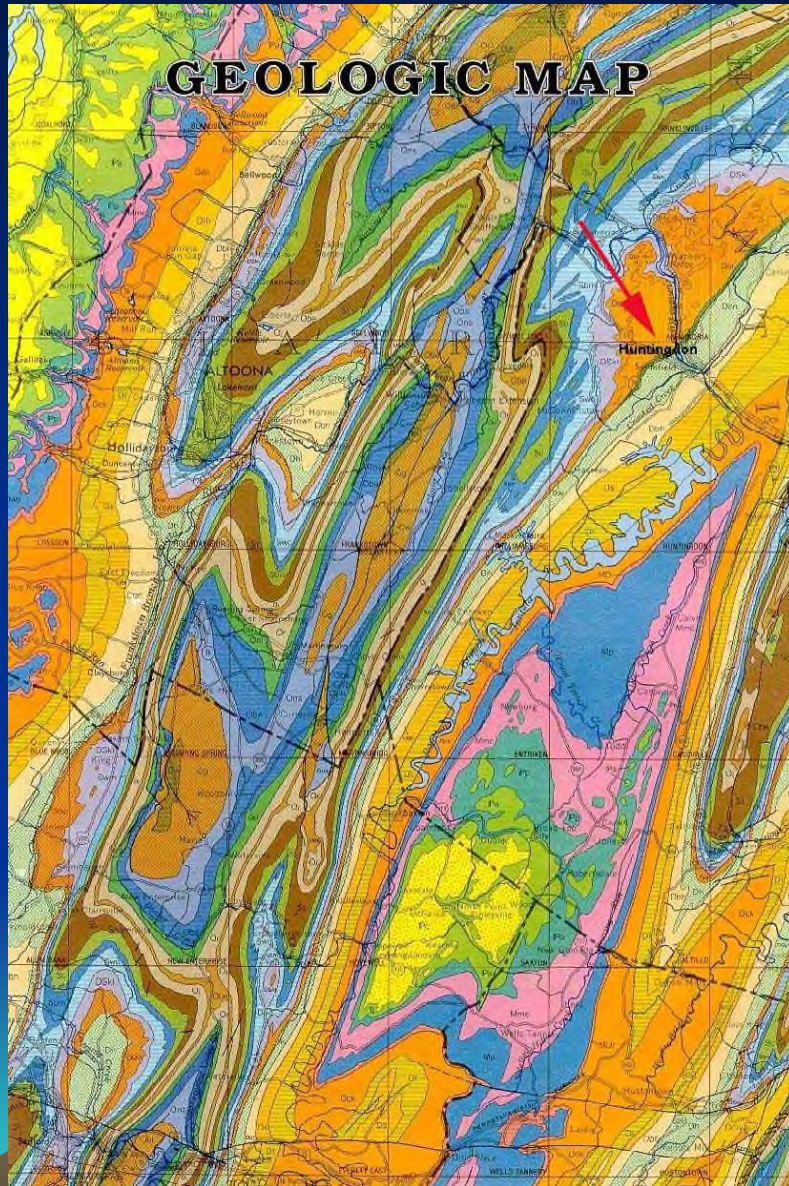


Figure 2



Geologic Maps = Science + Art



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 Willis Creek Formation

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

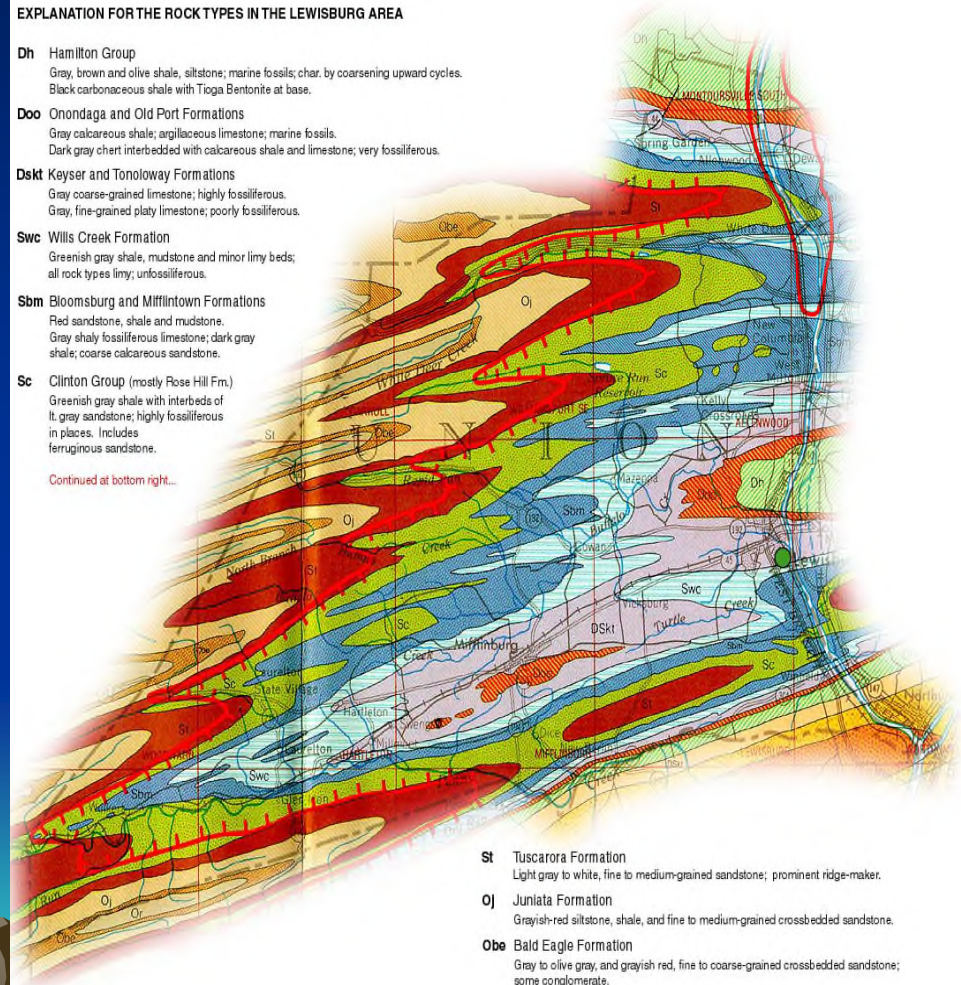
Sbm Bloomsburg and Mifflintown Formations

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

Sc Clinton Group (mostly Rose Hill Fm.)

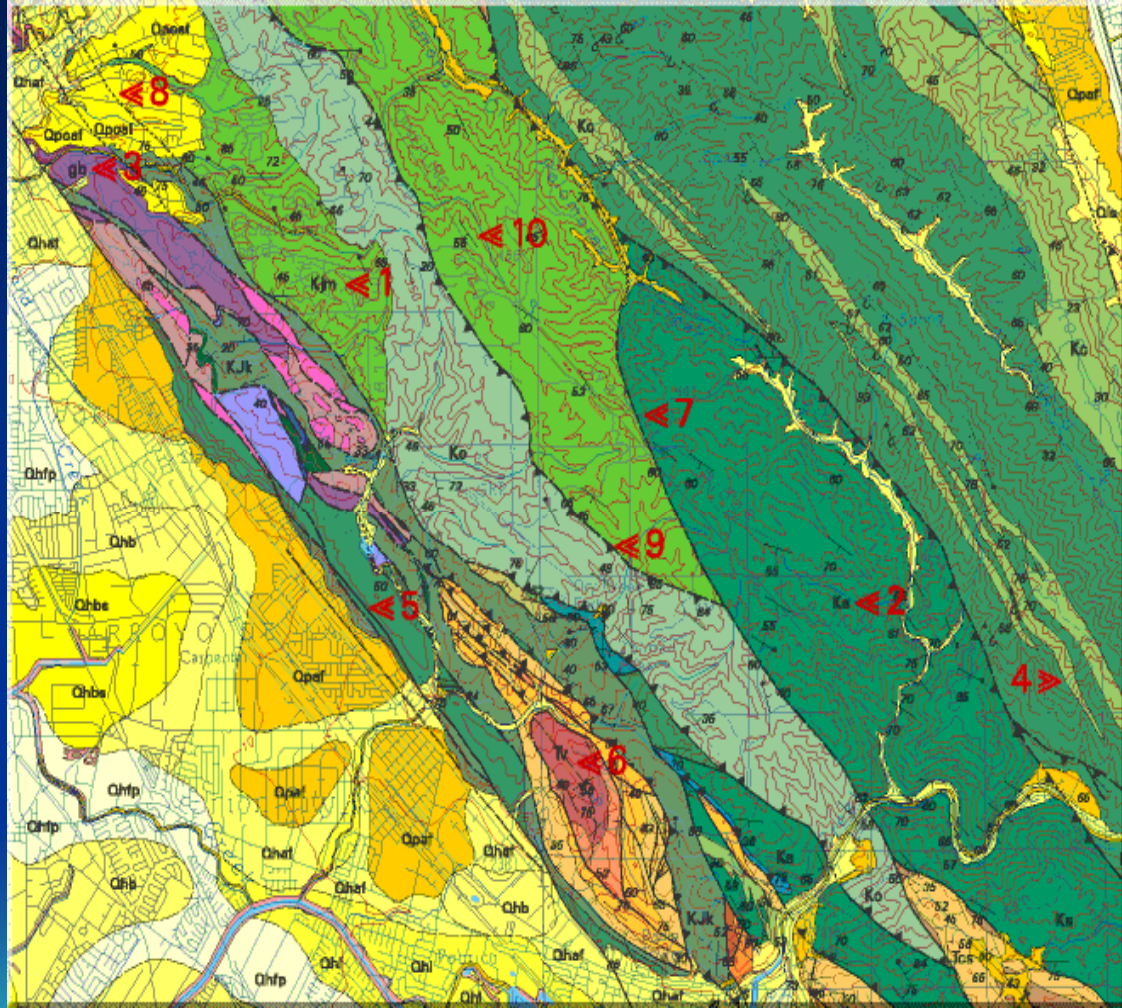
Greenish gray shale with interbeds of lt. gray sandstone; highly fossiliferous in places. Includes ferruginous sandstone.

Continued at bottom right...



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

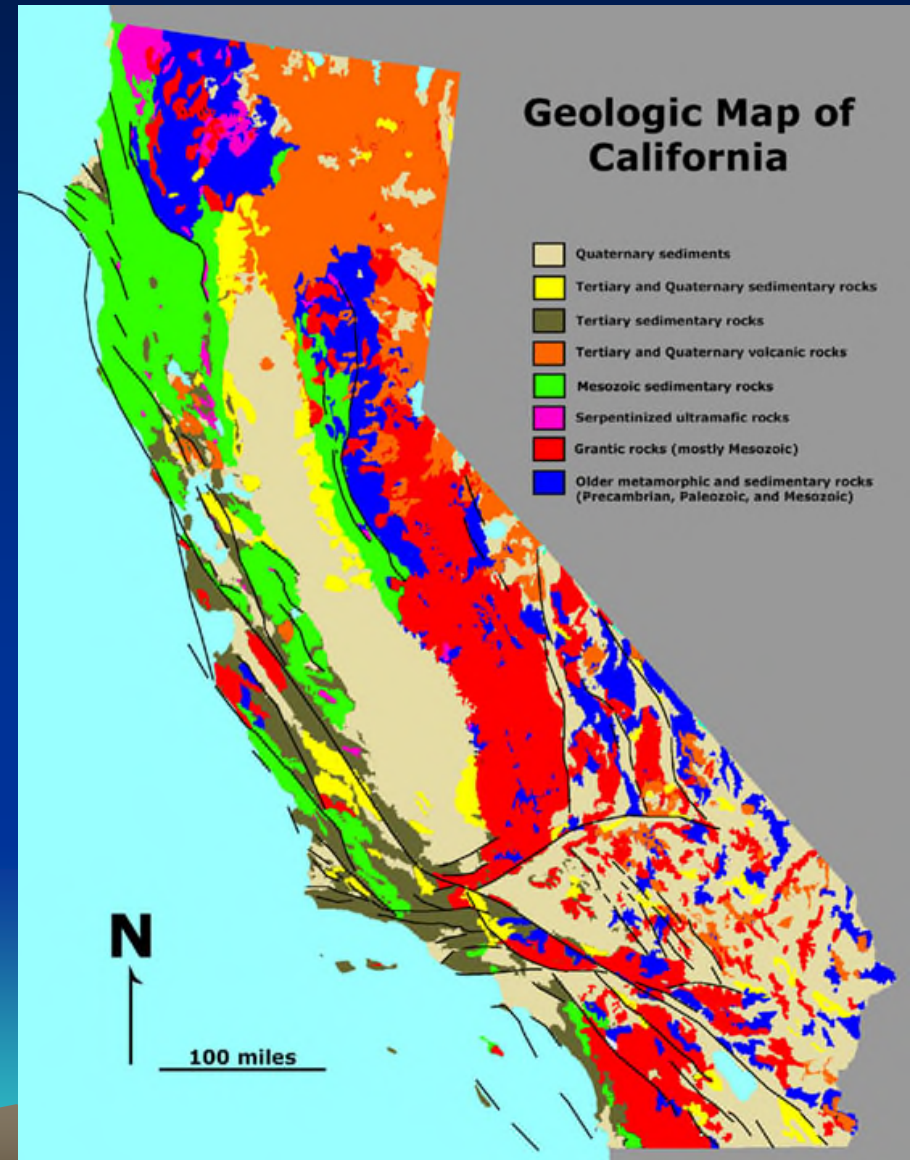


Usefulness of Geology Maps

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

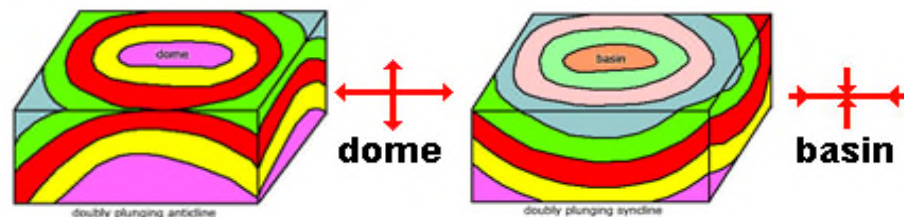
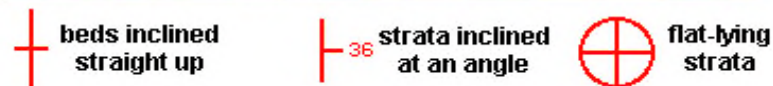
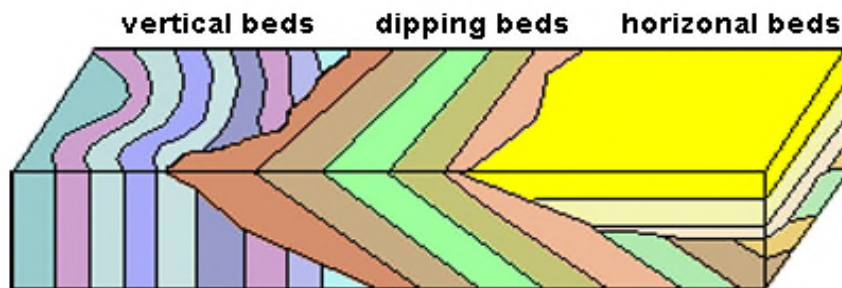
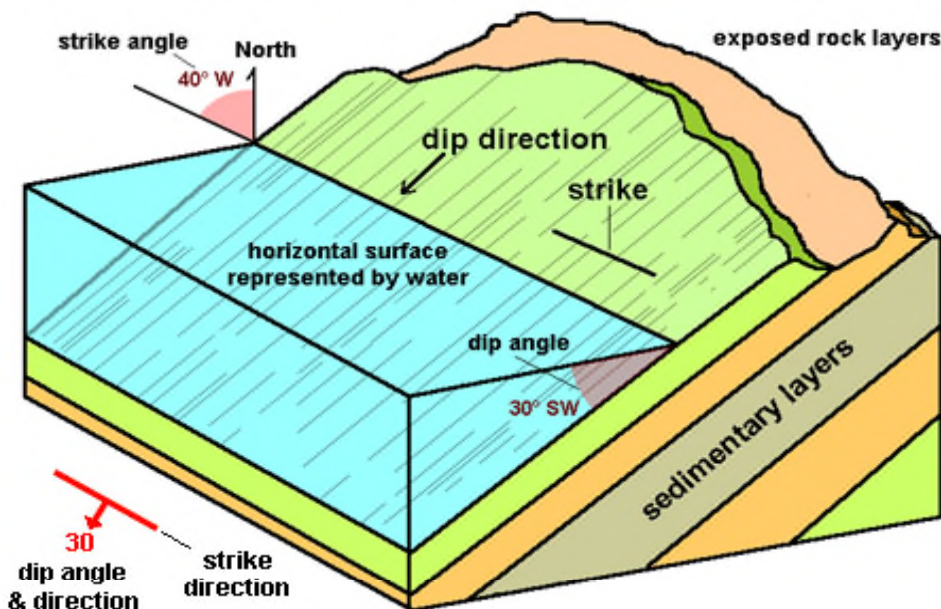
MAP KEY	
 af - Artificial Fill (Historic)	 Contact
 alf - Artificial Levee Fill (Historic)	 Contact, approximately located
 Qhuf - Alluvial Fan Deposits (Holocene)	 Contact, inferred
 Qhfp - Floodplain Deposits (Holocene)	 Contact, concealed
 Qhbf - Flood Basin Deposits (Holocene)	 Fault
 Qhbs - Salt 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 - Tide shale (Miocene)	 Oblique fault with thrust or reverse component, inferred
 Tcs - Claremont shale (Miocene)	 Oblique fault with thrust or reverse component, uncertain
 Ts - Sbrante 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

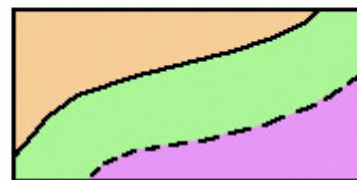
3) Map key is vital to understanding the accompanying geology map

Common Geologic Map Symbols

Describing orientation of geologic features with strike and dip



Rock Unit Boundaries - contacts between rock units of different age and/or different composition

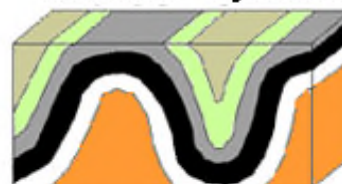


----- contact inferred

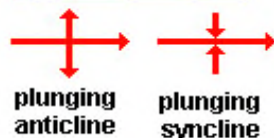
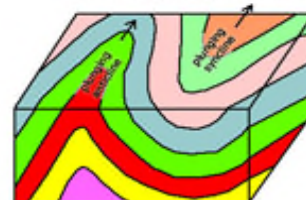


FOLDS

anticline syncline



plunging folds

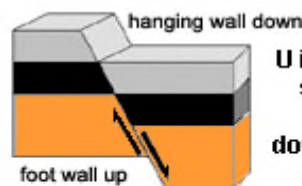


monocline



FAULTS

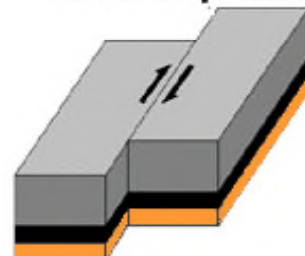
normal fault



U
D

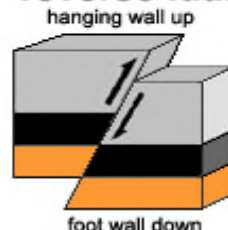
U is on the uplifted side (foot wall)
D is on the down-dropped side (hanging wall)

strike-slip fault



half arrows show direction of fault motion

reverse fault




triangles on upper plate (hanging wall)

thrust fault

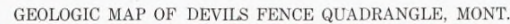


triangles on upper plate

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- 

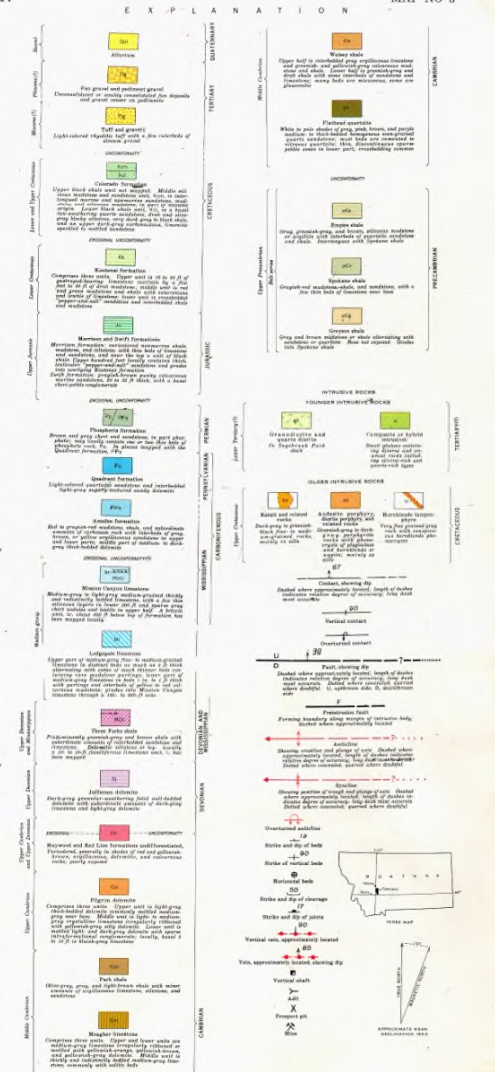
Geologic Maps – Devil's Fence Quad



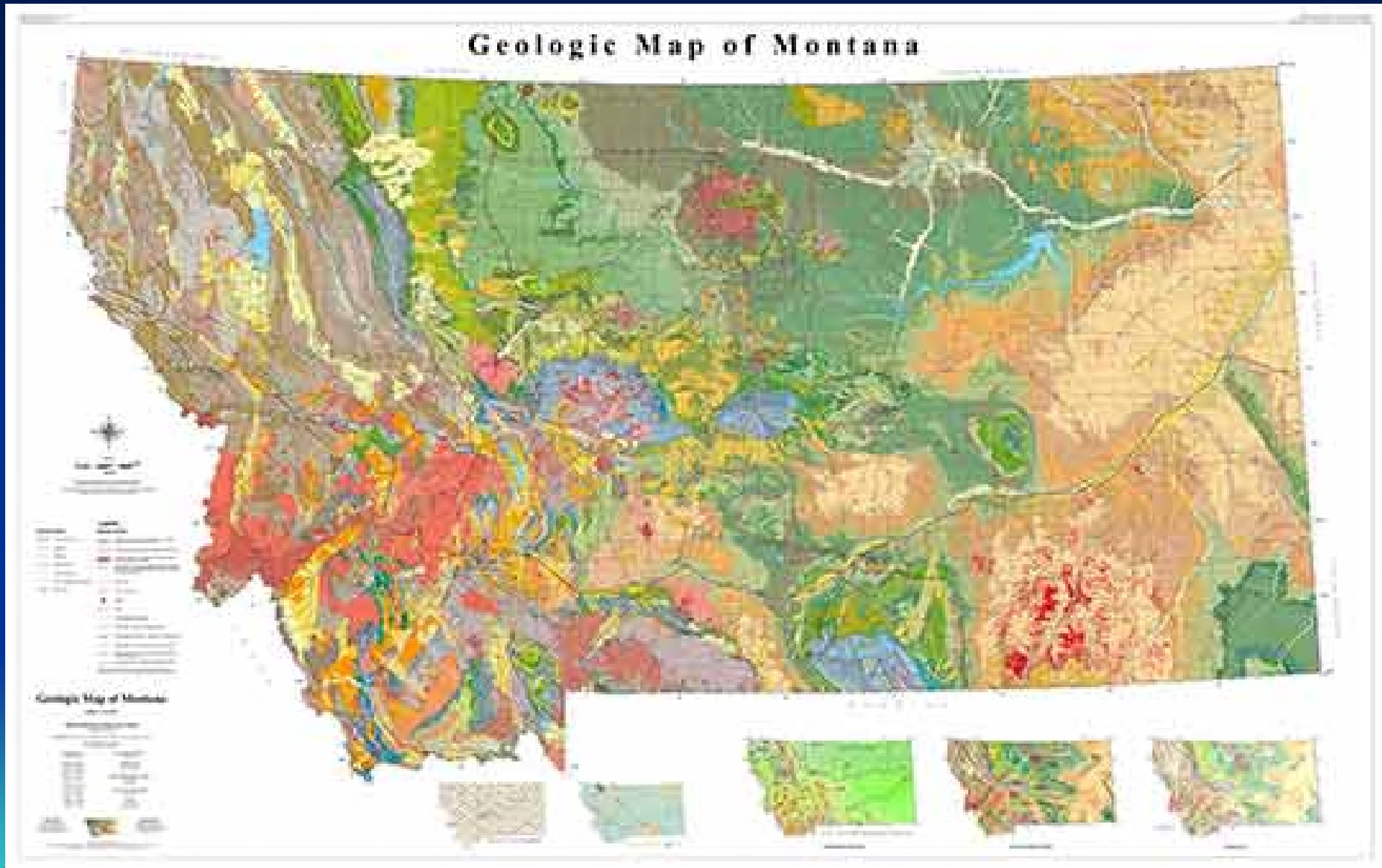
Scale 1:31,250

2 Miles Contour interval 40 feet
Datum is mean sea level

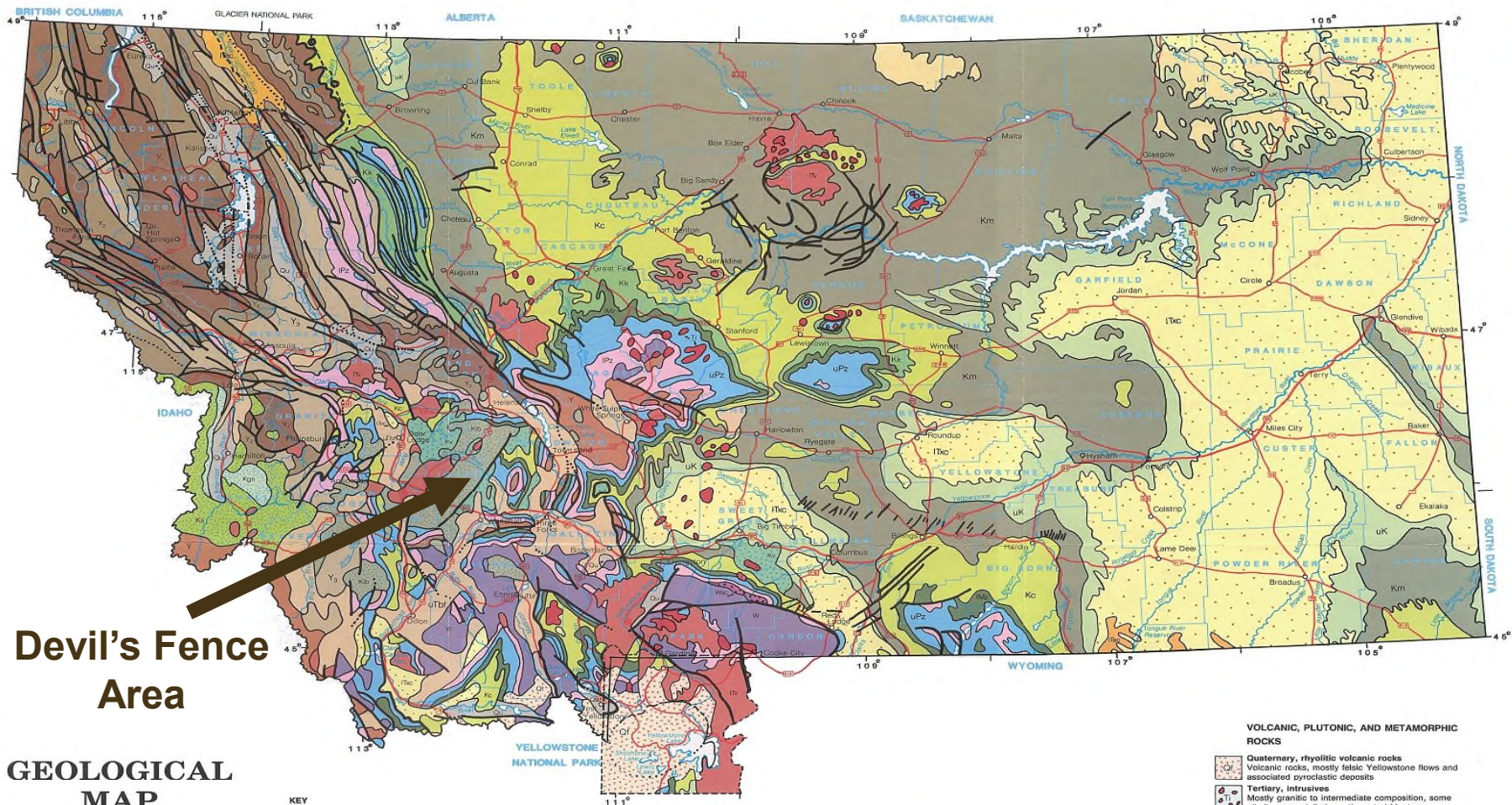
Base from U. S. Geological Survey from map of Devils Fence quadrangle, Montana.



Geologic Map of Montana

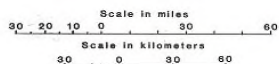


Geologic Map of Montana



**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

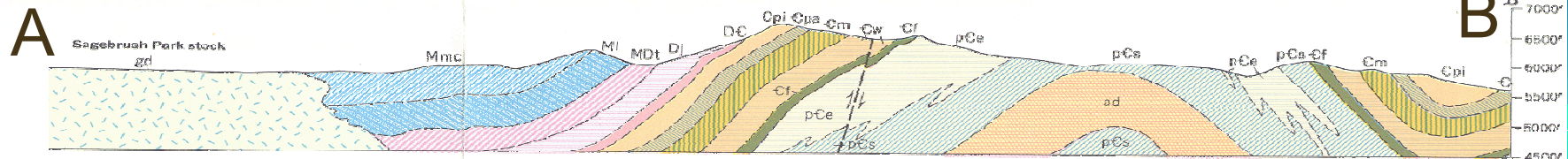
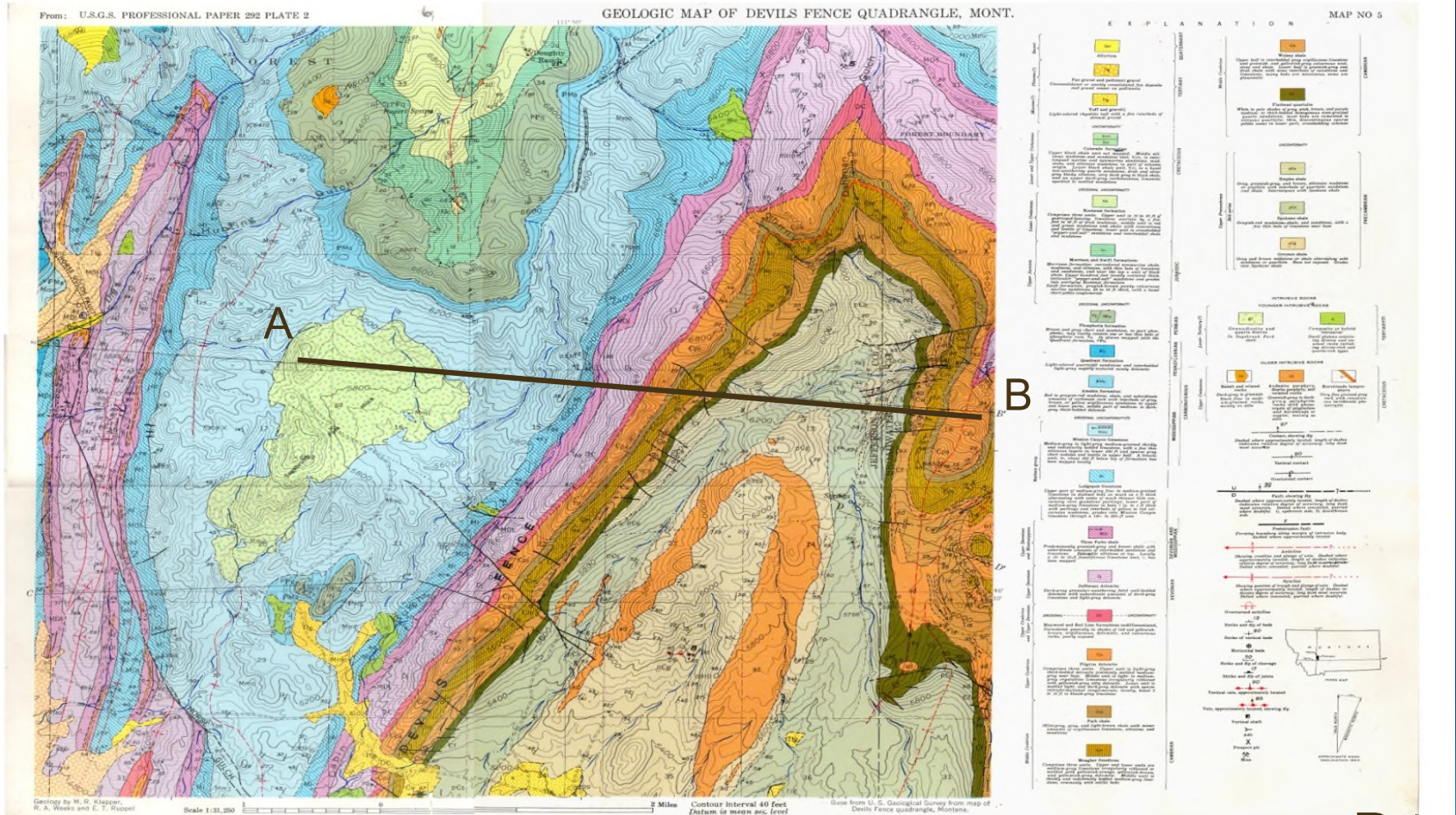
- Upper Cretaceous, undifferentiated
Hell Creek sandstone and shale, St. Mary River mudstone, and volcanoclastic Livingston Gp. in south-central Montana
- Montana Group
Bearpaw shale, Judith River sandstone, siltstone, and shale, Clegg shale, Eagle sandstone, and Telegraph Creek sandy shale. Includes Fox Hills sandstone and Pierre shale in the extreme east
- Colorado Group
Includes mainly shale of the Niobrara, Belle Fourche, Mowry, and Thermopsis Formations
- Kootenai Formation
Conglomerate, sandstone, shale, and mudstone
- Lower Mesozoic
Includes calcareous fossiliferous sandstone, shale, and limestone of the Ellis Group in the central and south central, and the Drivewy and Thynnes Formations in the southwest as well as the Morrison shale, sandstone, and marl in the west

- Mississippian, Pennsylvanian, Permian
Includes Madison limestone, Big Snowy dolomite and limestone, and Quadrant sandstone
- Devonian and Cambrian
Consists of Three Forks shale, Jefferson limestone, Pilgrim and Meagher limestone, Park and Wolsey shale, and Flathead sandstone
- Upper Belt-Missoula and Plegan Groups
Chiefly red, maroon, and purple argillites and impure quartzite and limestone
- Middle Belt-Wallace, Slioh, Helena Fms.
Heterogeneous Wallace Fm. including argillite, limestone, sandstone, shale, and quartzite; Slioh and Helena limestones
- Lower Belt-Ravalli and Prichard Fms.
Ravalli Fm. includes siliceous and sandy quartzite, argillite, and shale; Prichard Fm. consists of banded slate with interbedded sandstone
- Undivided Belt Supergroup

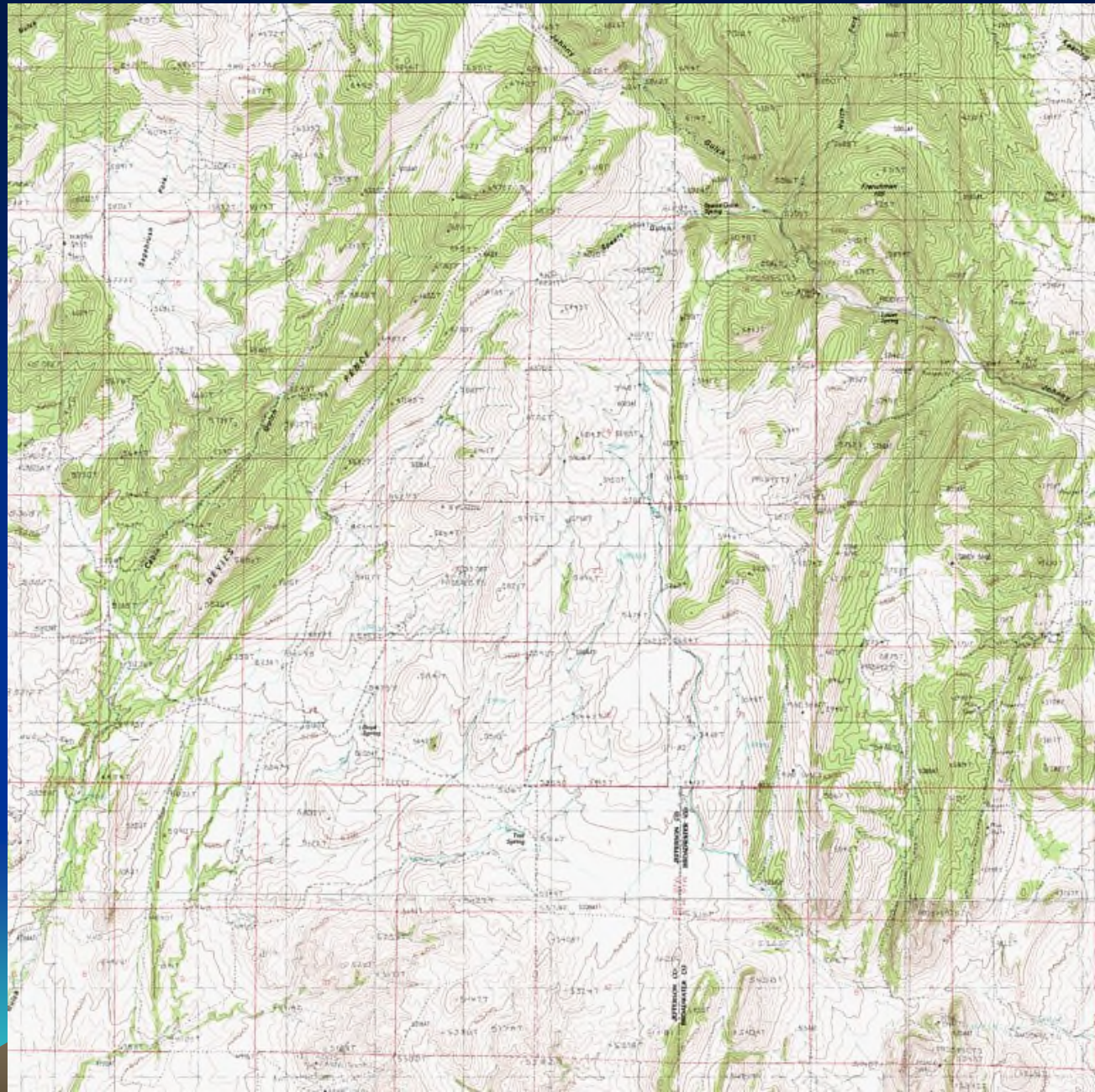
VOLCANIC, PLUTONIC, AND METAMORPHIC ROCKS

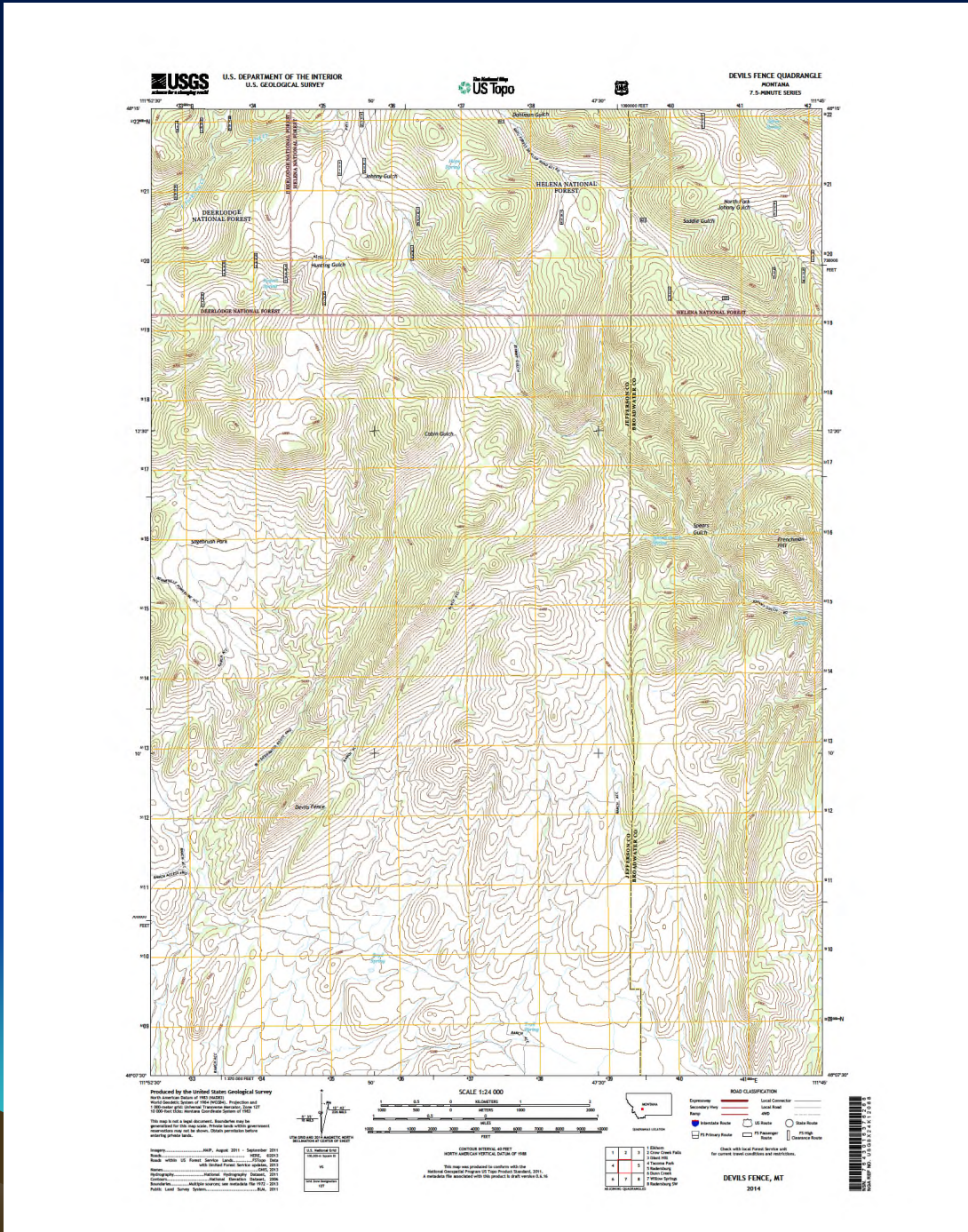
- Quaternary, rhyolitic volcanic rocks
Volcanic rocks, mostly felsic Yellowstone flows and associated pyroclastic deposits
- Tertiary, intrusives
Mostly granitic to intermediate composition, some alkaline especially in north-central Montana
- Lower Tertiary, volcanic rocks
Flows and associated pyroclastic 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 anorthositic; associated with hornfels aureole
- Archean, undifferentiated
High-grade metamorphic rocks derived from igneous and sedimentary parent rocks. Lithologies include quartzite, feldspathic gneiss, granulite, amphibolite, quartzite, and marble

Geologic Maps – Devil's Fence Quad



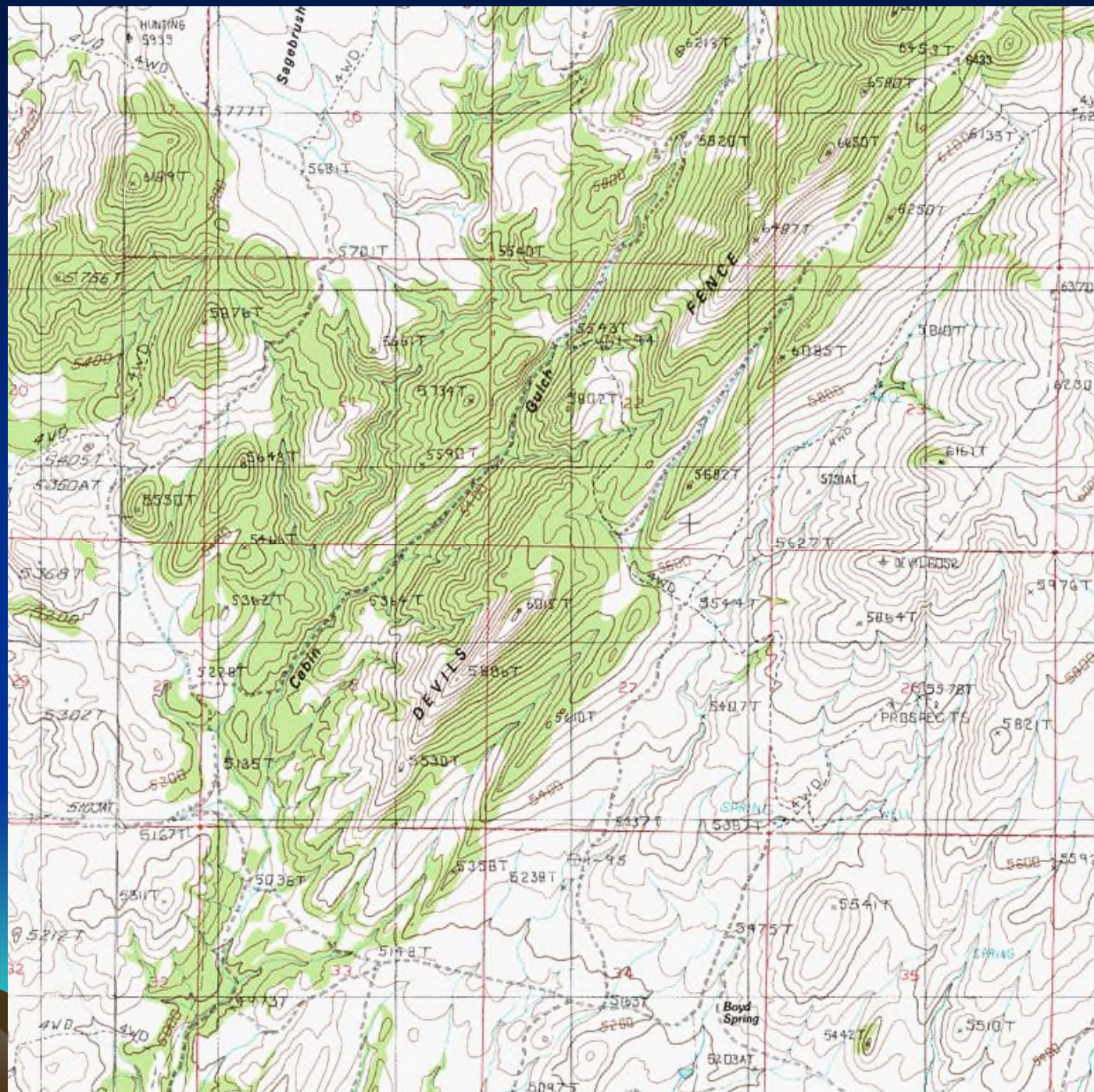
Devil's Fence Topo Quad



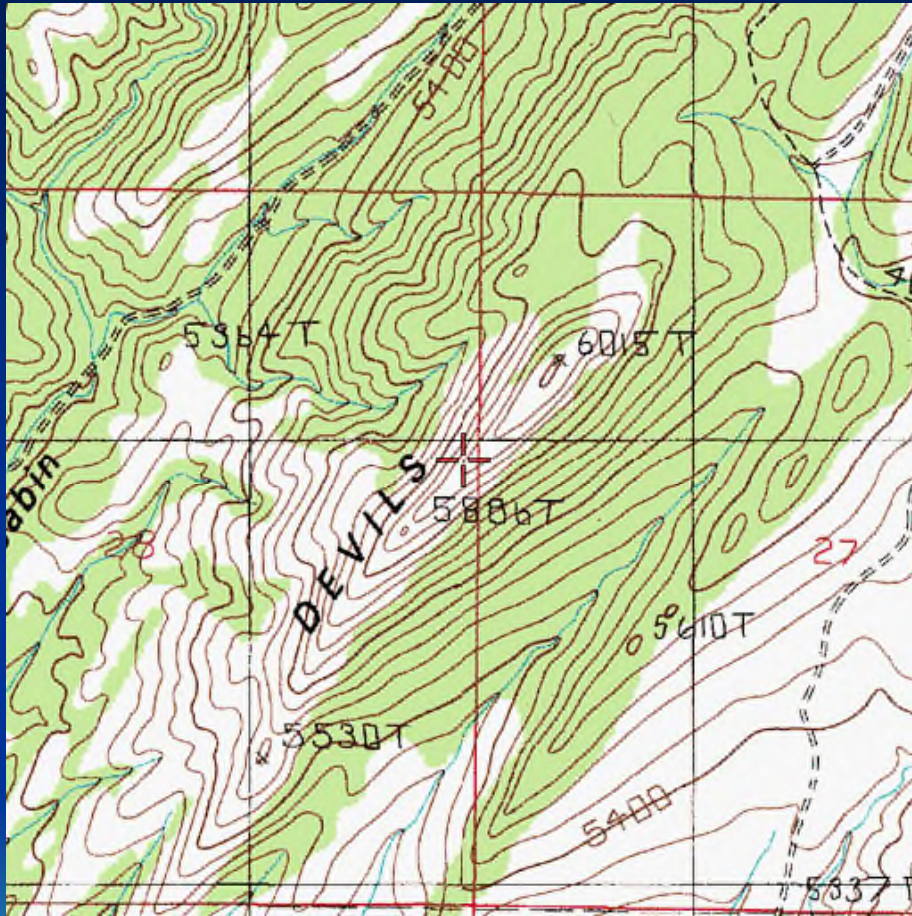


Devil's Fence Topographic Feature

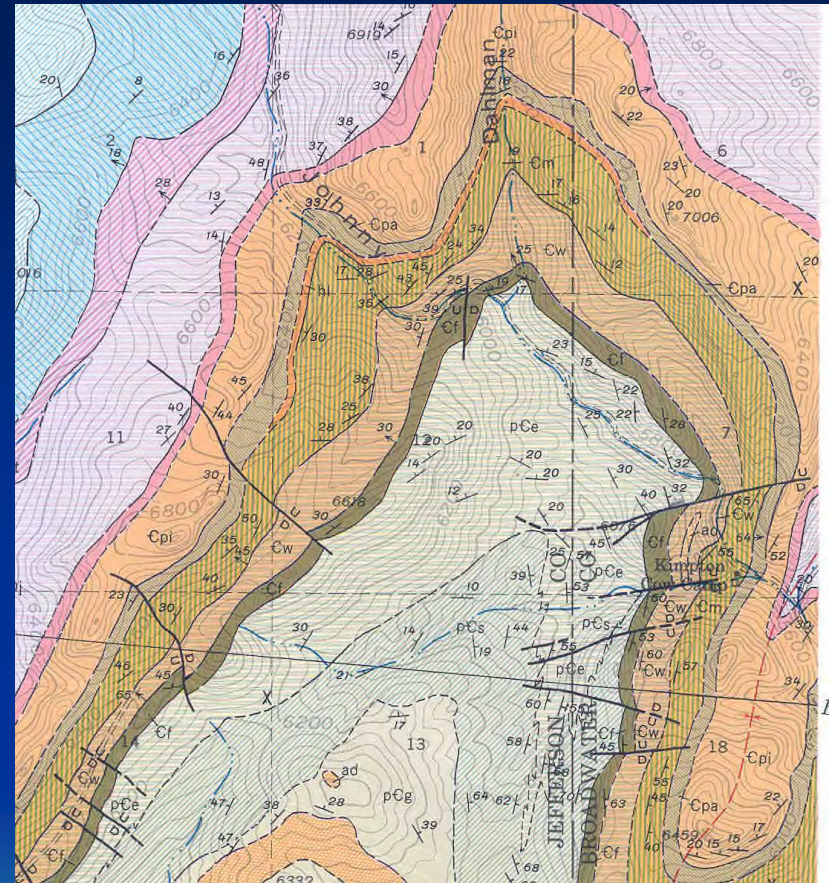
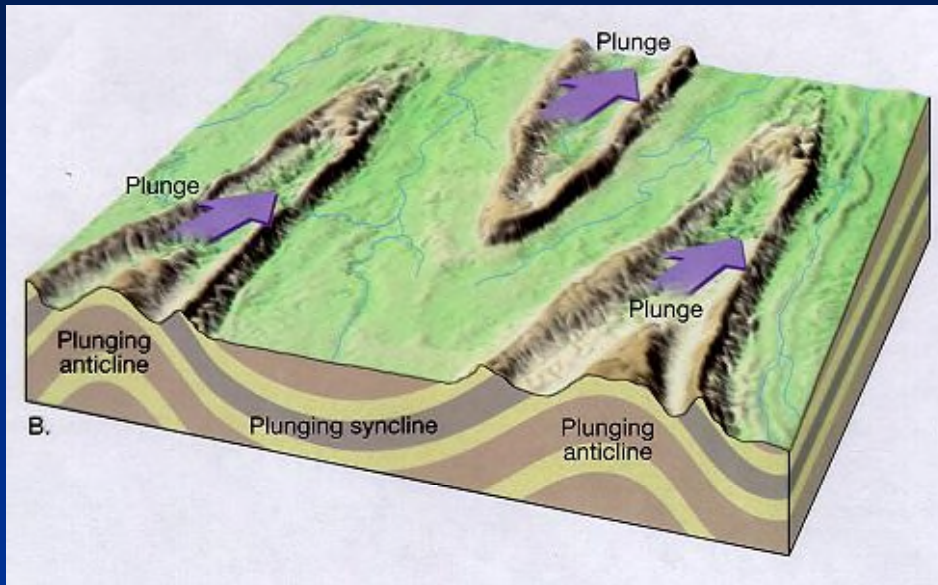




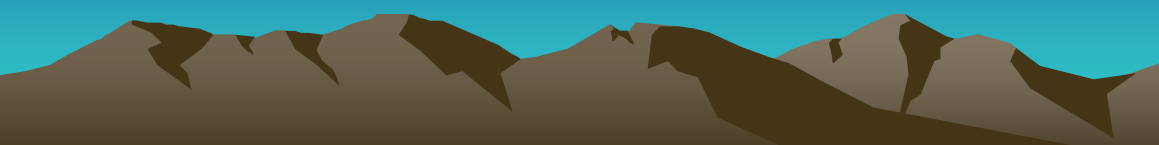
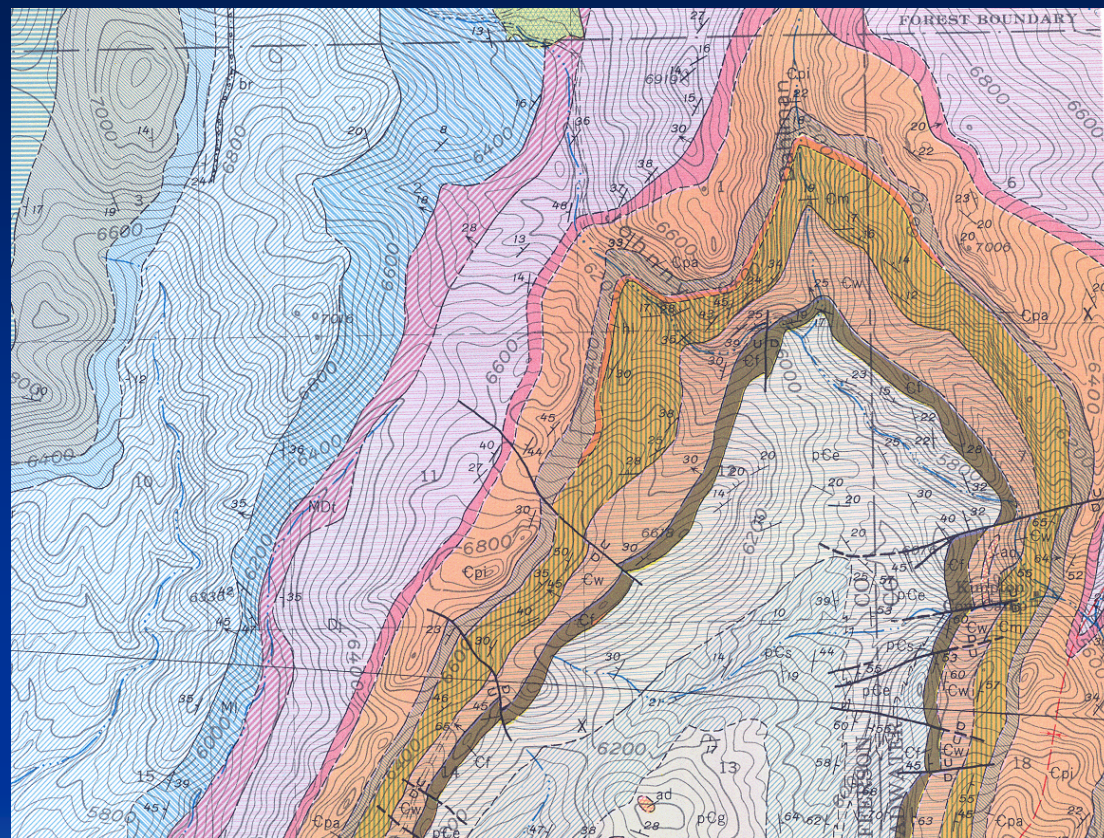
Devil's Fence Topography



Devil's Fence Folds



Devil's Fence Geology Map with Explanation



Geological Column Diagram

Quaternary

- Brown**: Qal, Alluvium
- Recent**: Fan gravel and pediment gravel; Unconsolidated or weakly consolidated fan deposits and gravel veneer on pediments
- Pleistocene (?)**: Tuff and gravel; Light-colored rhyolitic tuff with a few interbeds of stream gravel
- Unconformity**

Tertiary

- Upper Cambrian and Upper Devonian**: Pilgrim dolomite; Comprises three units. Upper unit is light-gray thick-bedded dolomite commonly mottled medium-gray near base. Middle unit is light to medium-gray crystalline limestone irregularly ribbed with yellowish-gray silty dolomite. Lower unit is mottled light- and dark-gray dolomite with sparse intraformational conglomerate; locally, basal 8 to 10 ft to black-gray limestone
- Middle Cambrian**: Park shale; Olive-gray, gray, and light-brown shale with minor amounts of argillaceous limestone, siltstone, and sandstone
- Unconformity**
- Lower Cambrian**: Meagher limestone; Comprises three units. Upper and lower units are medium-gray limestone irregularly ribbed or mottled with yellowish-orange, yellowish-brown, and yellowish-gray silty dolomite. Middle unit is thickly and indistinctly bedded medium-gray limestone, commonly with oolitic beds

Cretaceous

- Lower and Upper Cretaceous**: Colorado formation; Upper black shale unit not mapped. Middle silty-sandstone and sandstone unit, Kcm, is interbedded marine and nonmarine sandstone, mudstone, and silty-sandstone, in part of pelagic origin. Lower black shale unit, Kcl, is a basal fan-weathering quartz sandstone, dark and olive-gray blocky siltstone, very dark gray to black shale, and an upper dark-gray carbonaceous, limestonitic speckled to mottled sandstone
- Unconformity**
- Lower Cretaceous**: Kootenai formation; Comprises three units. Upper unit is 10 to 25 ft of grayish-brown limestone overlain by a few feet to 80 ft of dark 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
- Unconformity**
- Lower Cretaceous**: Morrison and Swift formations; Morrison formation, varicolored nonmarine 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 "pepper-and-salt" sandstone and grades into overlying Kootenai formation. Swift formation, grayish-brown punky calcareous marine sandstone, 20 to 45 ft thick, with a basal chert-pile conglomerate

Permian

- Lower Permian**: Phosphoria formation; Brown and gray chert and sandstone, in part phosphatic, may locally contain one or two thin beds of the Quadrum formation, Pq
- Unconformity**
- Lower Permian**: Quadrum formation; Light-colored quartitic sandstone and interbedded light-gray argillaceous-textured sandy dolomite

Carboniferous

- Lower Carboniferous**: Asmeson 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
- Unconformity**
- Lower Carboniferous**: Mission Canyon limestone; Medium-gray to light-gray medium-grained thickly and indistinctly bedded limestone, with a few thin silty-sandstone layers in lower 200 ft and sparse gray chert nodules and lentils in upper half. A breccia unit, br, about 200 ft below top of formation has been mapped locally
- Unconformity**
- Lower Carboniferous**: Lodgepole limestone; Upper part of medium-gray fine- to medium-grained limestone in distinct beds as much as 2 ft thick alternating with zones of much thicker beds containing rare mudstone and siltstone. 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

Mississippian

- Lower Mississippian**: Three Forks shale; Predominantly greenish-gray to brown shale with subordinate amounts of interbedded sandstone and limestone. Dolomitic siltstone at top. Locally a 10- to 25-ft fossiliferous limestone unit, il, has been mapped
- Unconformity**
- Lower Mississippian**: Jefferson dolomite; Dark-gray granular-weathering fetid well-bedded dolomite with subordinate amounts of dark-gray limestone and light-gray limestone


Devonian

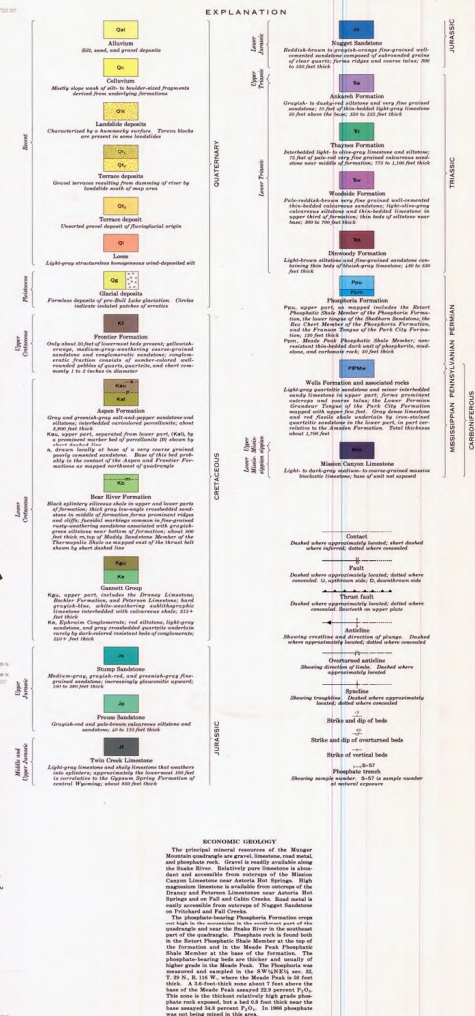
- Lower Devonian**: D1
- Upper Devonian**: D2

Precambrian

- Lower Precambrian**: G1, G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, G12, G13, G14, G15, G16, G17, G18, G19, G20, G21, G22, G23, G24, G25, G26, G27, G28, G29, G30, G31, G32, G33, G34, G35, G36, G37, G38, G39, G40, G41, G42, G43, G44, G45, G46, G47, G48, G49, G50, G51, G52, G53, G54, G55, G56, G57, G58, G59, G60, G61, G62, G63, G64, G65, G66, G67, G68, G69, G70, G71, G72, G73, G74, G75, G76, G77, G78, G79, G80, G81, G82, G83, G84, G85, G86, G87, G88, G89, G90, G91, G92, G93, G94, G95, G96, G97, G98, G99, G100

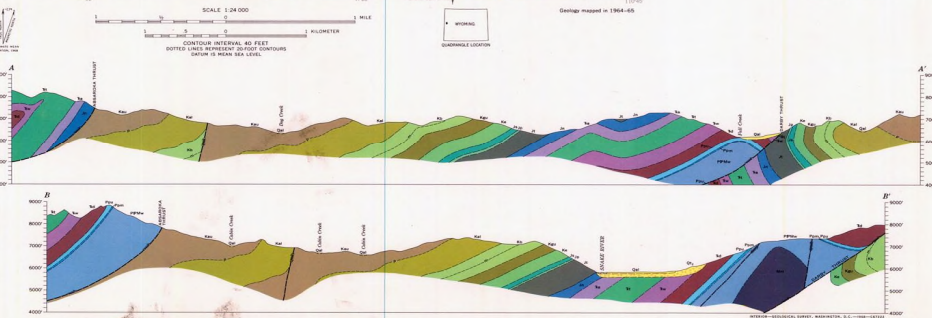
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- 



Mungar Mountain Geology Map

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.)
cop. 1.

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GEOLOGICAL SURVEY
 U. S. DEPARTMENT OF THE INTERIOR
 WASHINGTON, D. C. 20548
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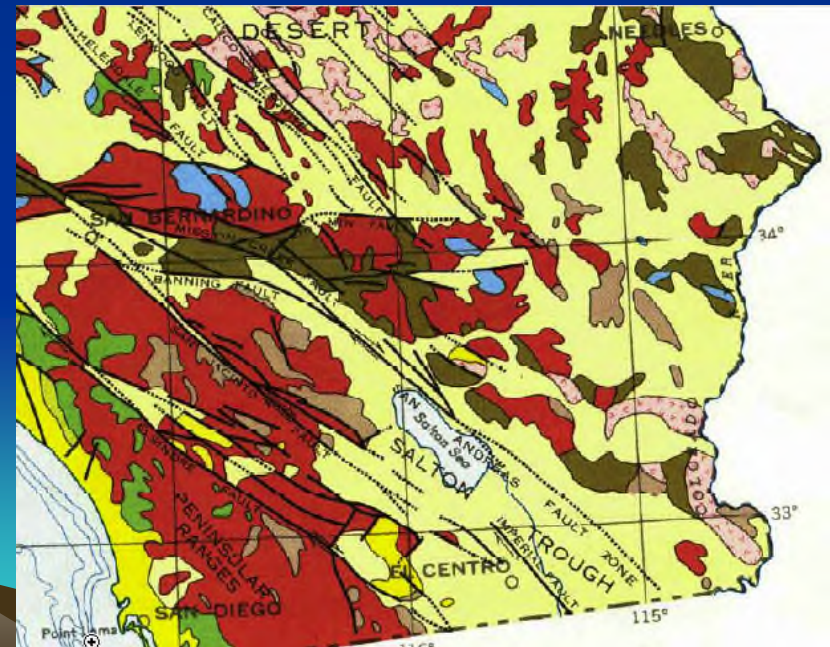
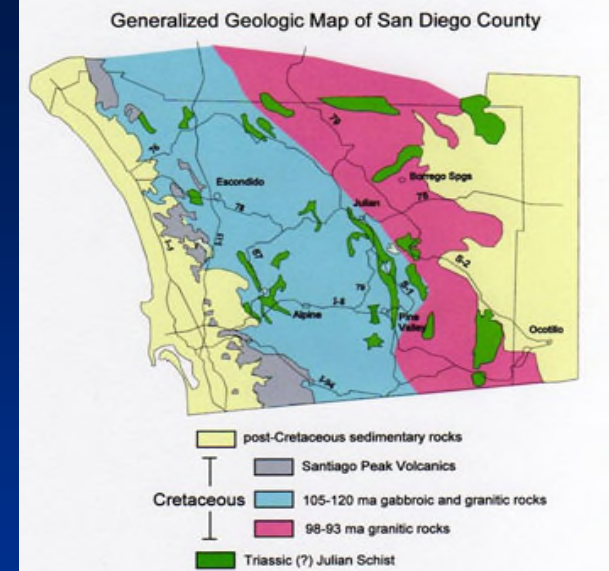
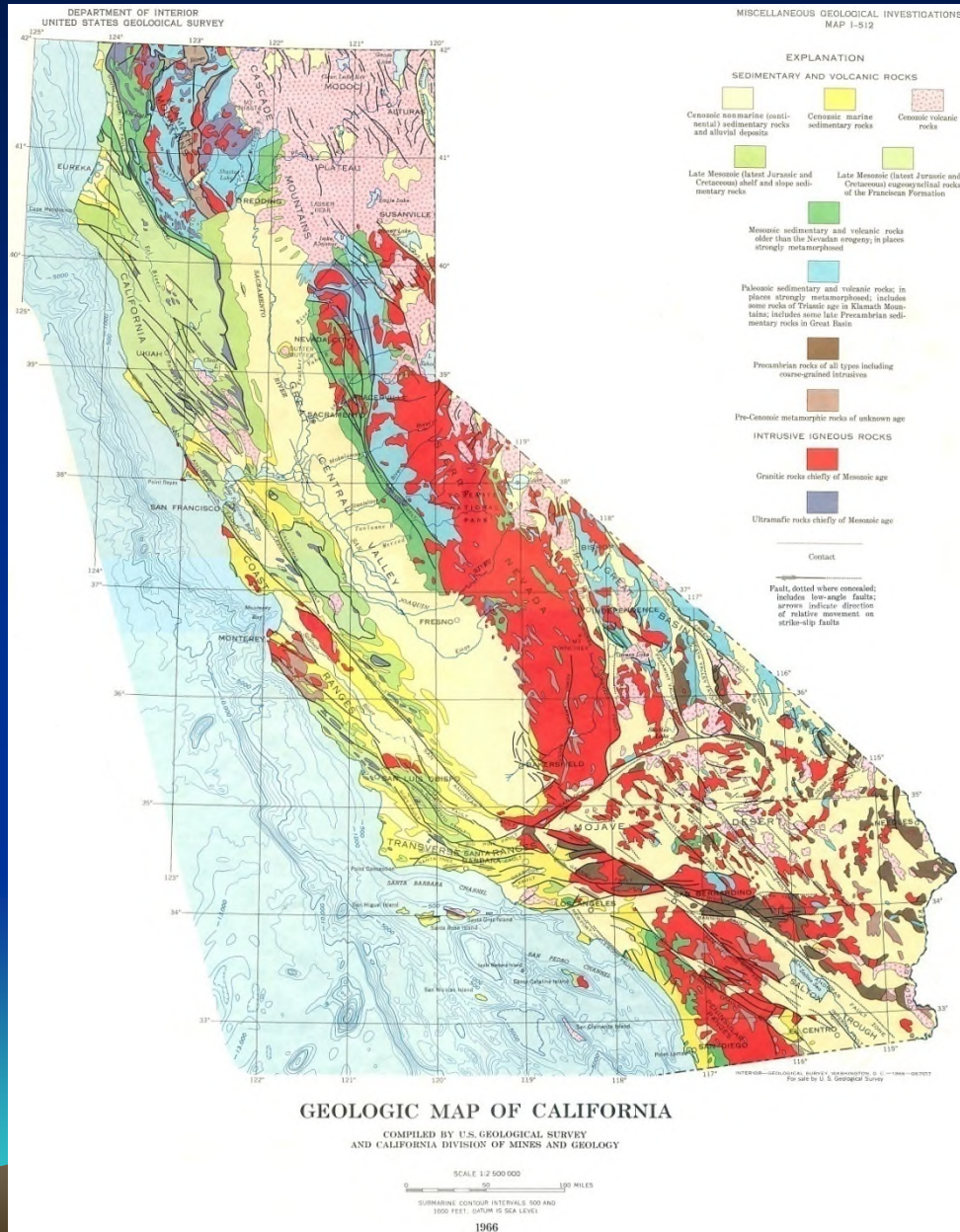
[NOTE.—The numbers in red indicate the local collecting localities. These localities are described in the following paper (No. 8) in the present volume, HANNA, An Insect Invertebrate Fauna from the La Jolla Quadrangle, California.]

[NOTE.—The numbers in red indicate the local collecting localities. These localities are described in the following paper (No. 8) in the present volume, HANNA, An Insect Invertebrate Fauna from the La Jolla Quadrangle, California.]


A detailed geologic map of North America, showing the United States, Canada, and Mexico. The map is color-coded to represent different geological formations and structures. The title "Geologic Map of North America" is prominently displayed in the upper left. Logos for the USGS, U.S. Department of the Interior, Geological Survey of Canada, and the Canadian Museum of Natural History are visible at the bottom. A scale bar and a north arrow are located in the bottom right corner.



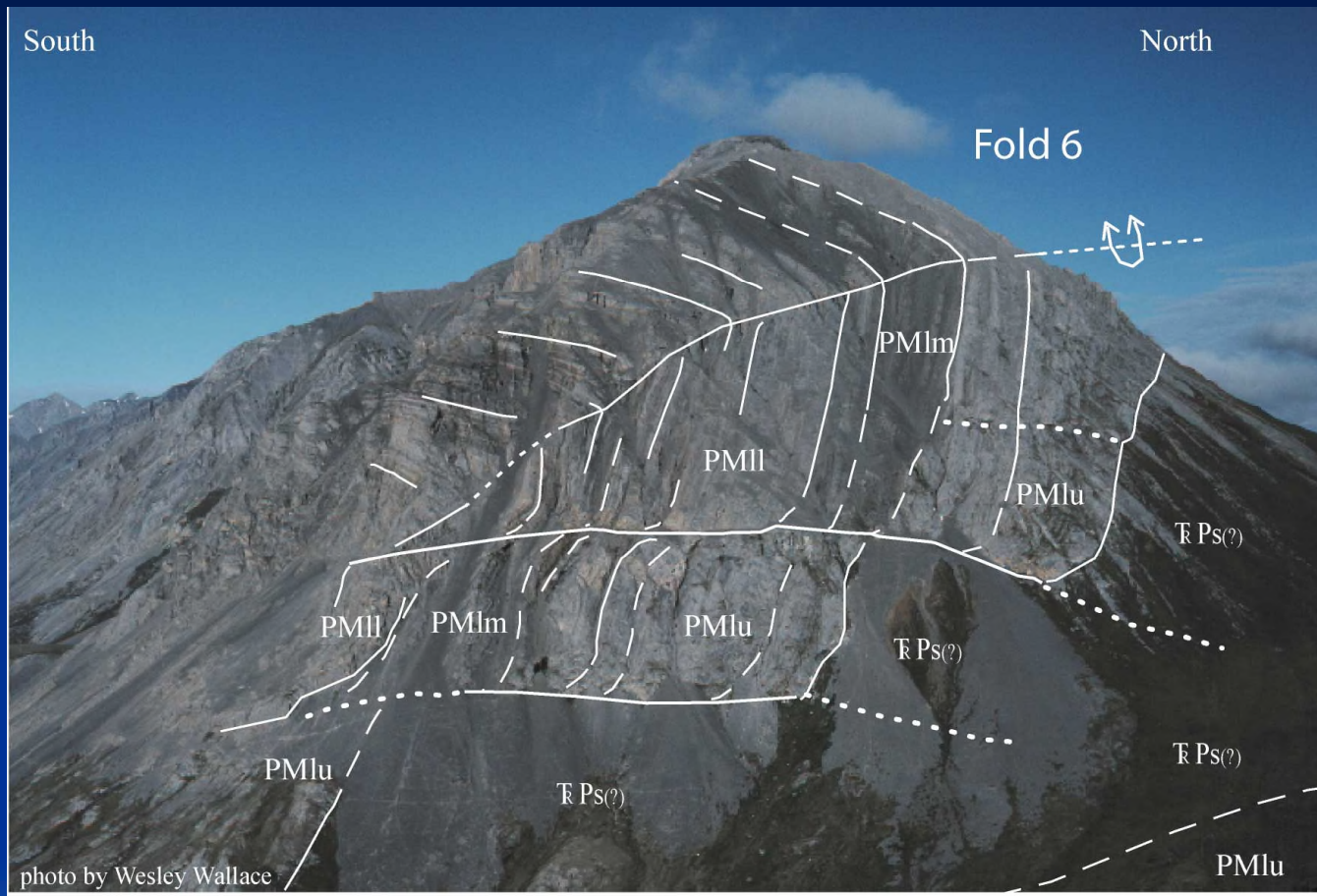
Geologic Maps of California



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 - 13) Slickenside grooves oriented vertical in fault scarp indicate dip-slip offset.
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Structure Web References



<http://www.nature.nps.gov/geology/usgsnps/gmap/gmap1.html#unique>

<http://www.globalchange.umich.edu/Ben/ES/earthstructure.htm>

<http://www.winona.edu/geology/MRW/maps.htm>

<http://www.nps.gov/archive/yell/slidefile/scenics/outsideynp/Page.htm>