Geologic Mapping

Science Olympiad Coaches Clinic

October 6, 2018

Southeast Raleigh High School

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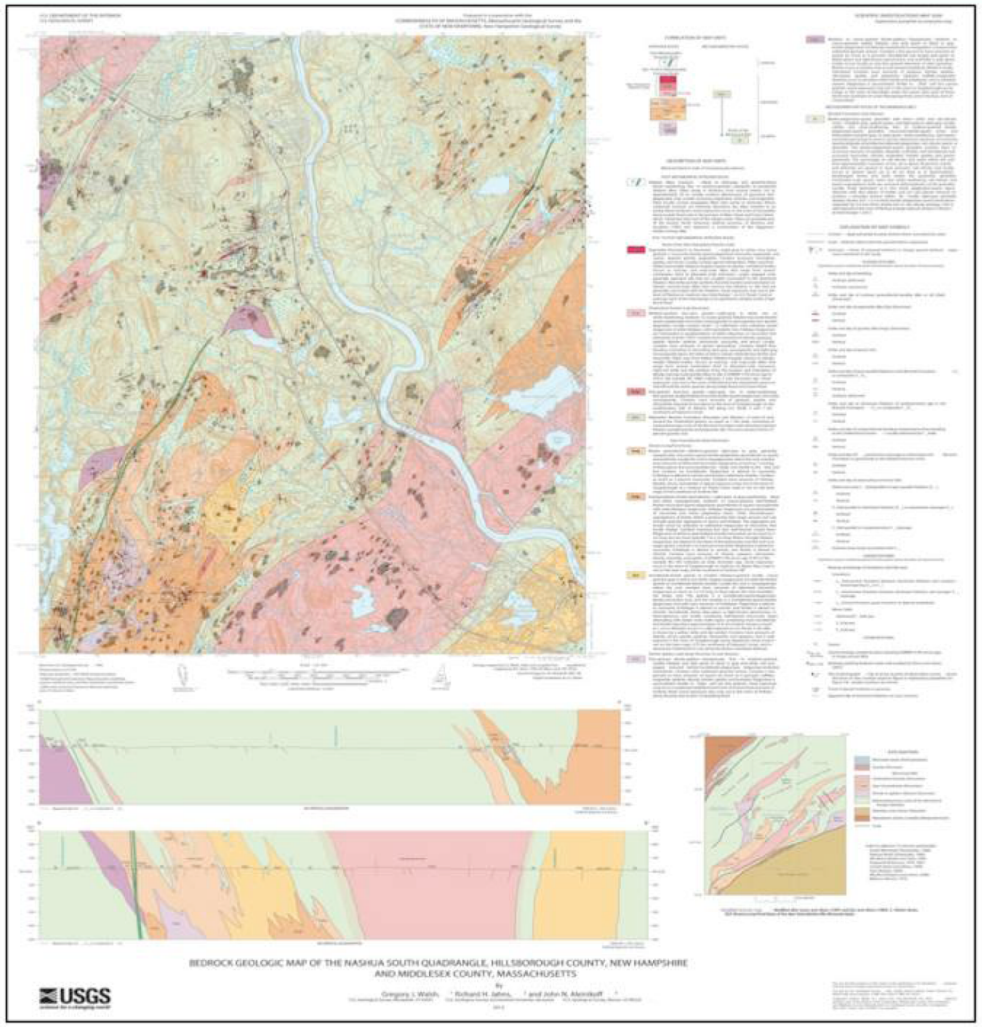
OUTLINE

MAP PARTS
STRATIGRAPHY
GEOLOGIC STRUCTURES
    FLAT LAYERS, DIPPING LAYERS (& map expression)
    FAULTS
    FOLDS
STRIKE & DIP
CROSS SECTIONS
TYPES OF CONTACTS
INTRUSIONS

Other stuff they want:
Construct topo profile and geol cross section
Know plate tectonics, rocks, and geol principles
Stereonets
Map projections
Structural geometric problems?
Geohazards
Groundwater and exploration stuff
Measure S/D and T/P with Brunton

Map Components

- Scale, north arrow, coordinates, contour lines, etc. (a topographic base map)
- Description of map units
- Explanation of symbols
- Cross section
- Other supplemental components

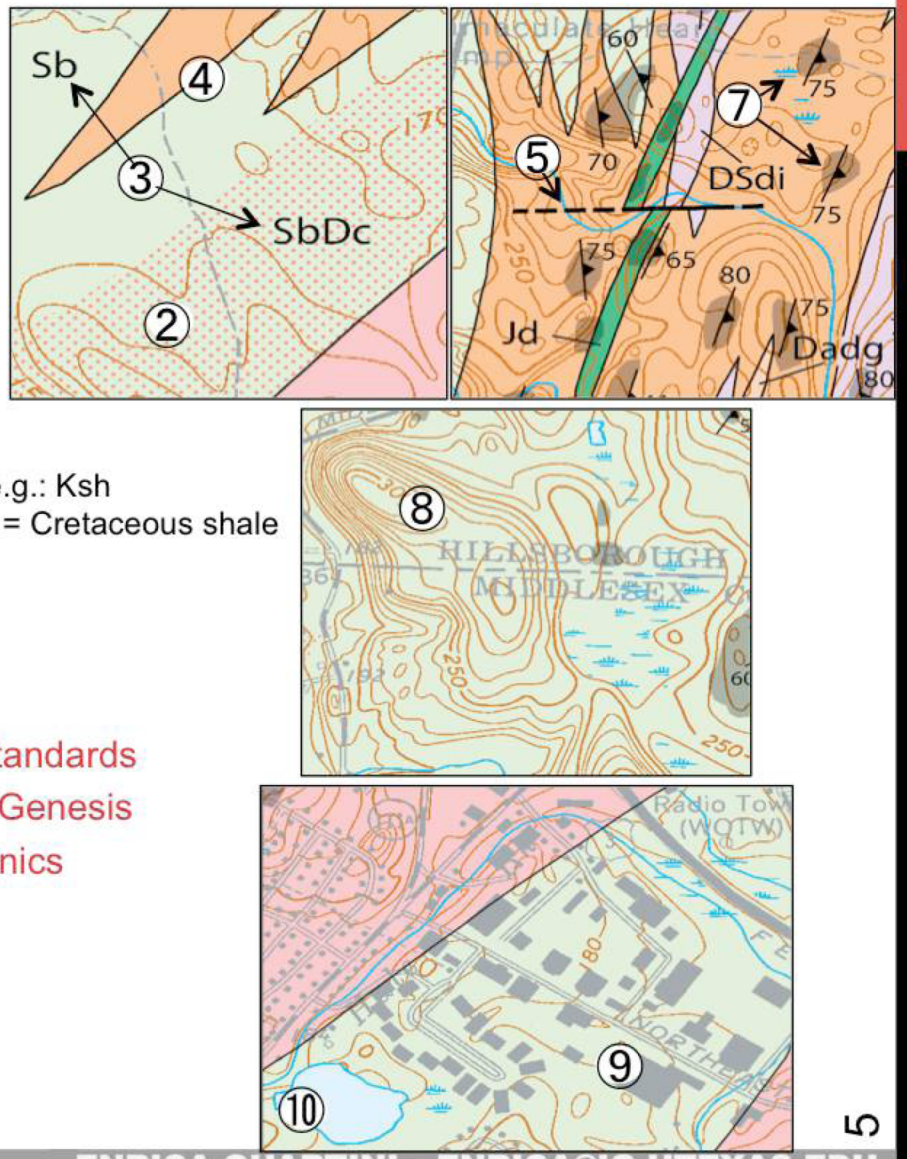


a. Map

- **Geologic Units (Formations):**
  - ① Color
    - American and International Standards
    - Palette for Different Rock Types
  - ② Symbols: patterns on colors
  - ③ Set of letters
    - First letter: Age → Geological Time Scale
    - Follows: Name of Rock Unit or Rock Type e.g.: Ksh = Cretaceous shale
  - ④ Contact lines
    - Depositional
    - Tectonic
    - Contact Types
    - Unconformities

- **Geologic Structures**
  - ⑤ Faults
  - ⑥ Folds
  - ⑦ Strike/Dip, Plunge/Trend
    - Symbols Standards
    - Types and Genesis
    - Plate Tectonics

- **Topography**
  - ⑧ Contour lines
  - ⑨ Roads, Towns
  - ⑩ Rivers, Lakes



THE GEOLOGICAL TIME SCALE

ERA/EON	PERIOD	APPROX. AGE RANGE (M.Y.B.P.)[1]	LIFE FORMS
CENOZOIC ERA	Quaternary (Q)	2 - present	humans
	Tertiary (T)	65 - 2	mammals and flowering plants
MESOZOIC ERA	Cretaceous (K)	146 - 65	dinosaurs peak and then go extinct
	Jurassic (J)	208 - 146	first birds; large dinosaurs
	Triassic (Tr)	245 - 208	first dinosaurs; conifers
PALEOZOIC ERA	Permian (P)	286 - 245	reptiles and amphibians; many marine invertebrates go extinct
	Pennsylvanian (IP)	333 - 286	coal swamps; insects
	Mississippian (M)	362 - 333	crinoids
	Devonian (D)	418 - 362	fish and marine invertebrates
	Silurian (S)	443 - 418	coral reefs; fish; simple land plants
	Ordovician (O)	490 - 443	graptolites; molluscs
	Cambrian (C)	544 - 490	marine invertebrates (e.g. trilobites)
PROTEROZOIC[2] EON	Z-youngest Y-middle X-oldest	2,500 - 544	bacteria; algae; fungi, worms toward end
ARCHEAN[2] EON	A	4,600 - 2,500	algae and bacteria

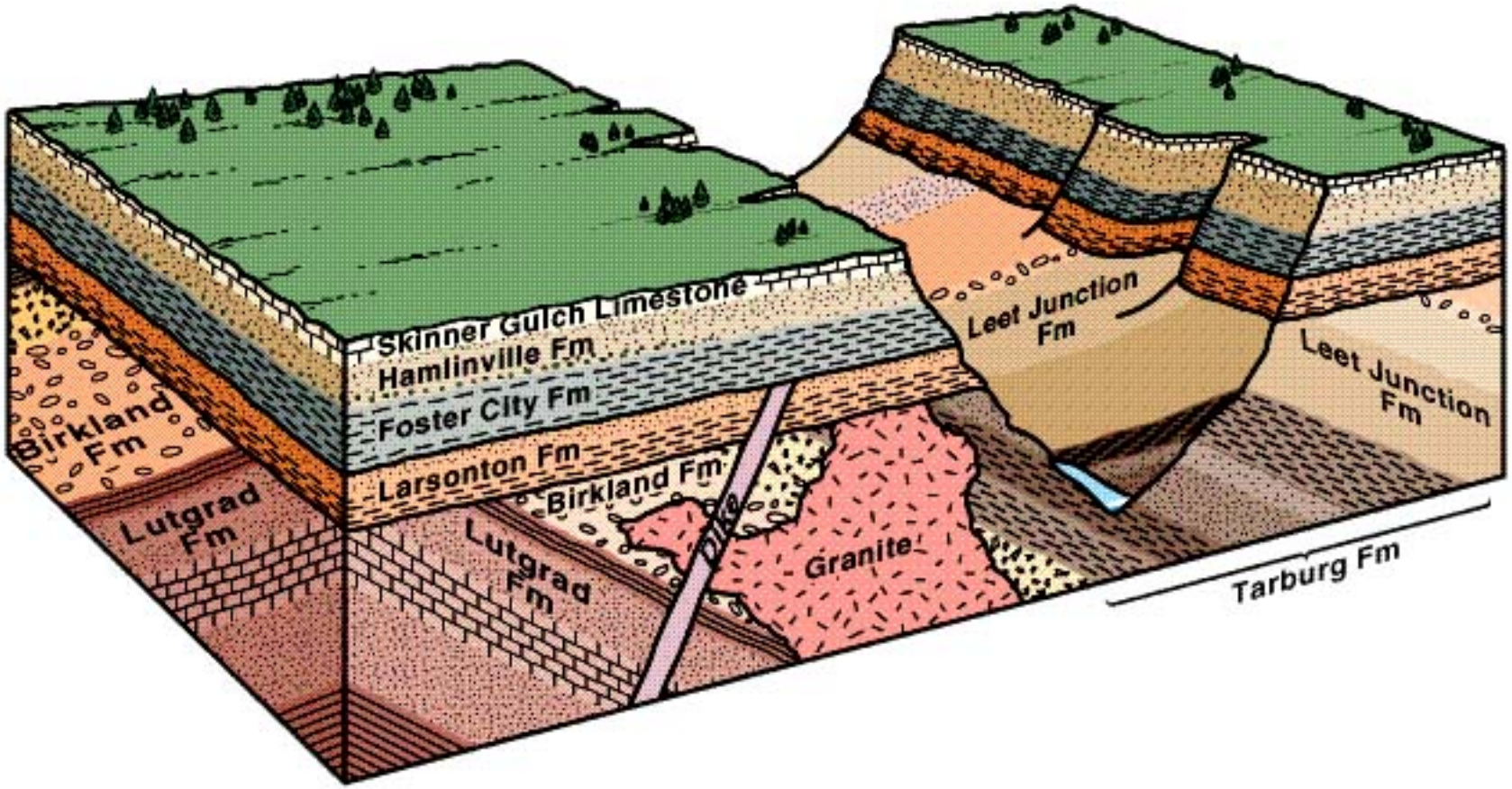
[1] M.Y.B.P.: million years before present

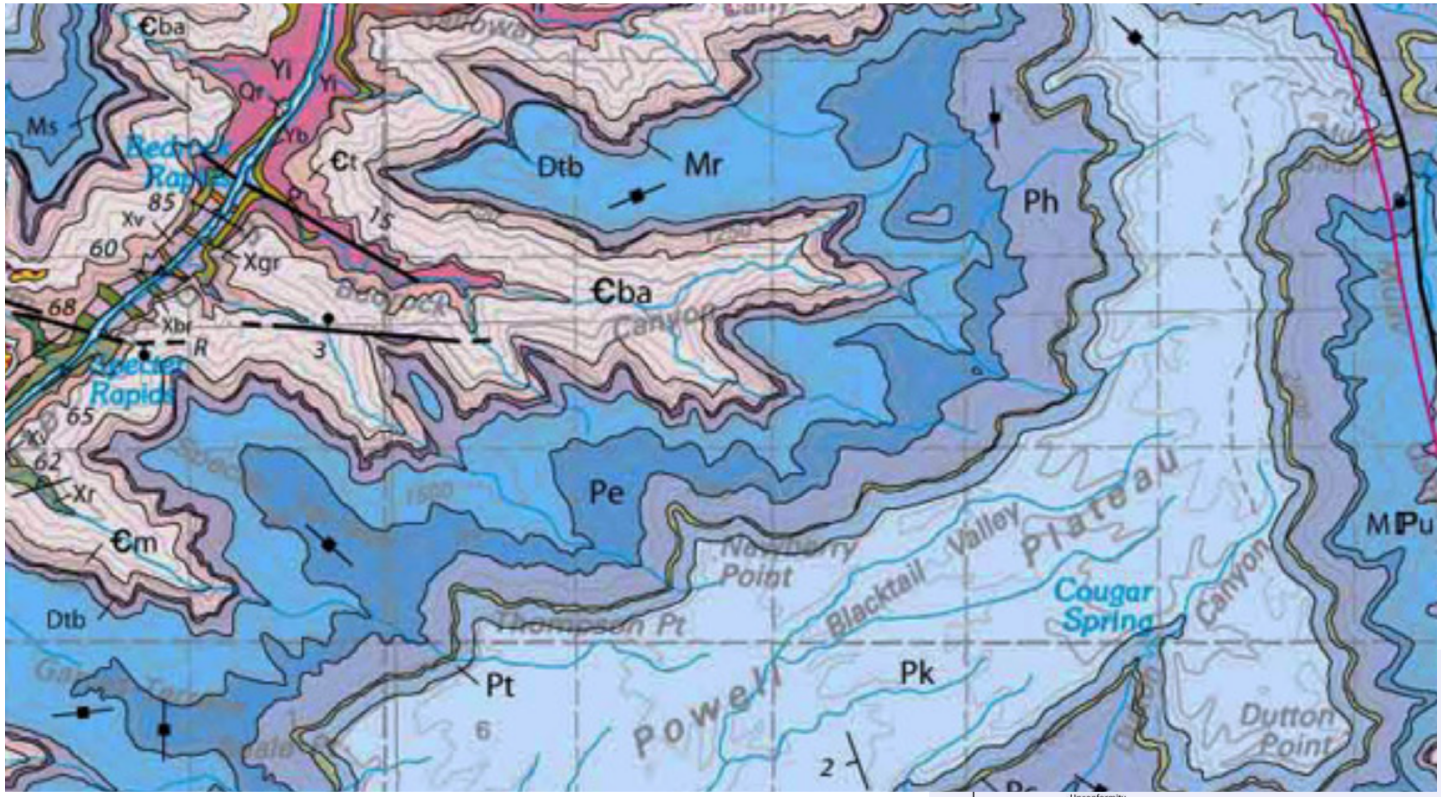
[2] The Proterozoic and the Archean together are referred to as ***Precambrian***.

Stratigraphic Principles

- 1. **Original Horizontality of Sedimentary Beds**. Sedimentary rock layers are deposited in sheets that are horizontal, or nearly so, parallel to the Earth's surface. If they are no longer horizontal, then they have been tilted or folded.
- 2. **Original Lateral Continuity of Sedimentary Beds**. Sedimentary layers are deposited in continuous sheets that gradually disappear at their edges (like a pancake). If a layer is no longer continuous, then erosion must have removed part of it.
- 3. **Principle of Superposition of Sedimentary Beds**. In a sequence of rock layers, the layers on top are younger than those underneath (unless the whole package has been turned upside down).
- 4. **Concept of Inclusions**. A rock which contains pieces of another rock within it (inclusions) must be younger than the inclusions. In an igneous rock, the inclusions are xenoliths; in a sedimentary rock, the inclusions are clasts.
- 5. **Principle of Cross-Cutting Relationships**. If one rock body cuts across another rock body, the one that does the cutting is younger and the one that gets cut is older.
- 6. **Direction of Dip**. Unless they are overturned, sedimentary beds in a dipping sequence dip toward the younger beds. This can be easily demonstrated by tilting a sequence of layers.
- 7. **Deformed or Metamorphosed Rocks**. If folding or regional metamorphism has affected some rocks in an area but not others, then the unaffected rocks must be younger, unless the rocks are separated by a fault.
- 8. **Principle of Unconformities**. The presence of an unconformity within a sequence of rocks means that the area was uplifted and subjected to erosion that removed some layers. This erosion took place *after* the deposition of the layer beneath the unconformity, but *before* the layer above was deposited.
- 9. **Law of Faunal Succession**. In a sequence of sedimentary rocks, the animal and plant fossils follow a consistent evolutionary sequence, which does not reverse itself.

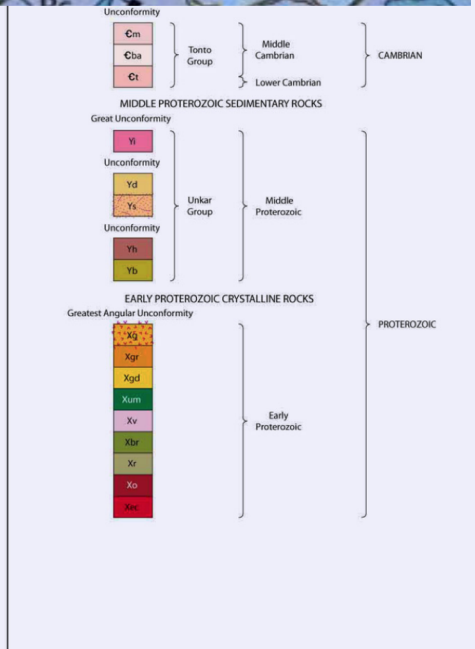
Minor Canyon

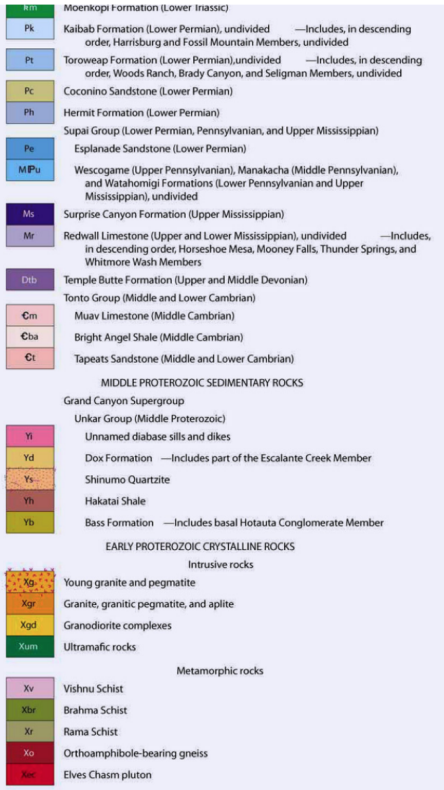




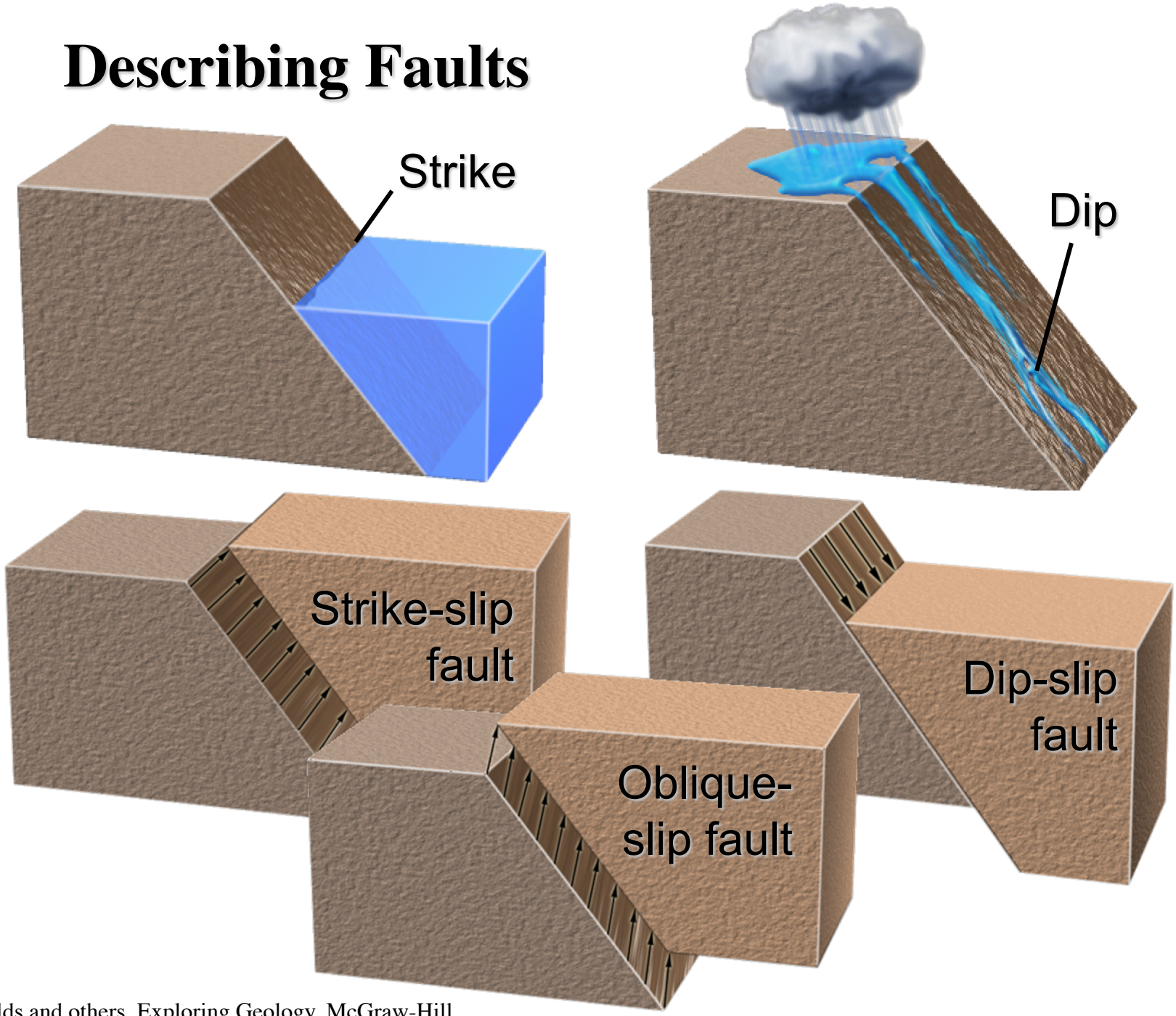
Geologic Map and Map Units for a Portion of Grand Canyon

http://www.wired.com/images_blogs/wiredscience/2013/07/Grand_Canyon_national_park_geologic_map.jpg



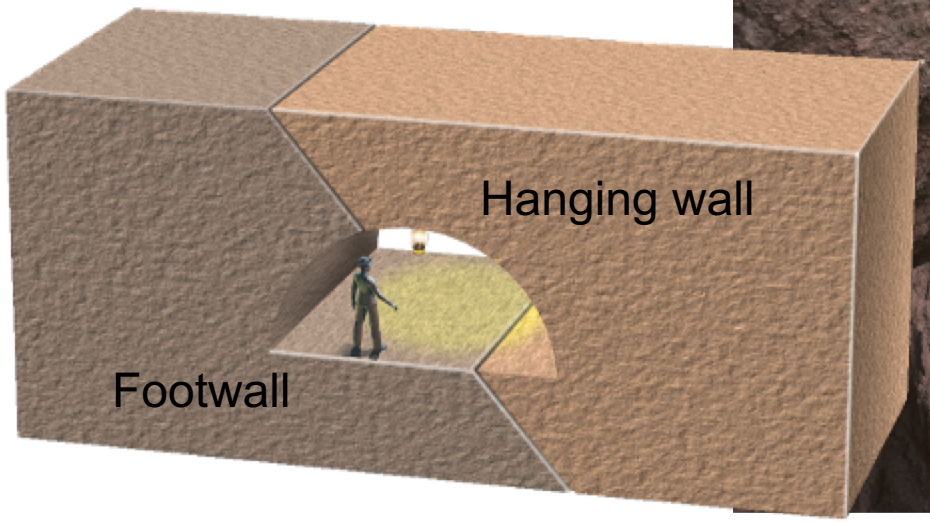


Describing Faults



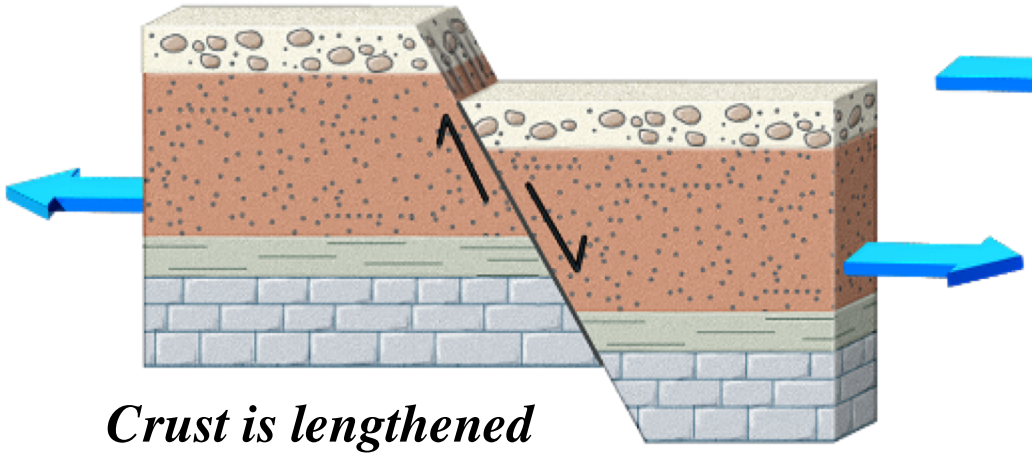
Reynolds and others, Exploring Geology, McGraw-Hill

Parts of Fault

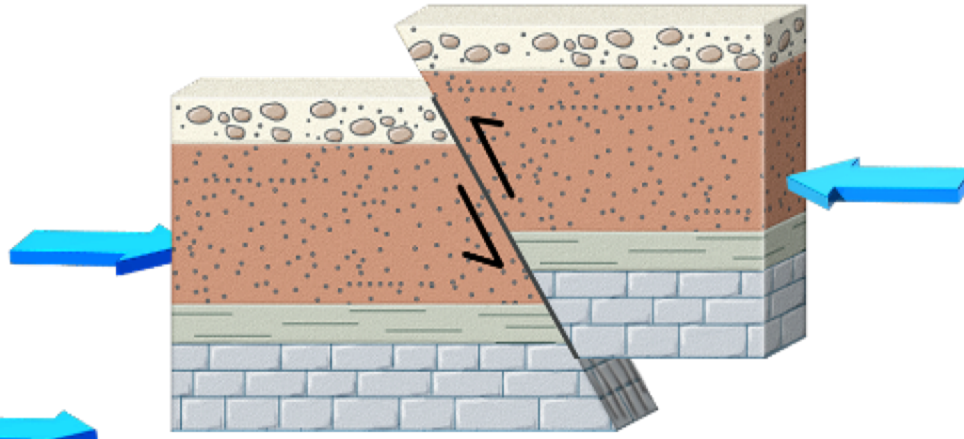


Sense of Movement

Normal fault



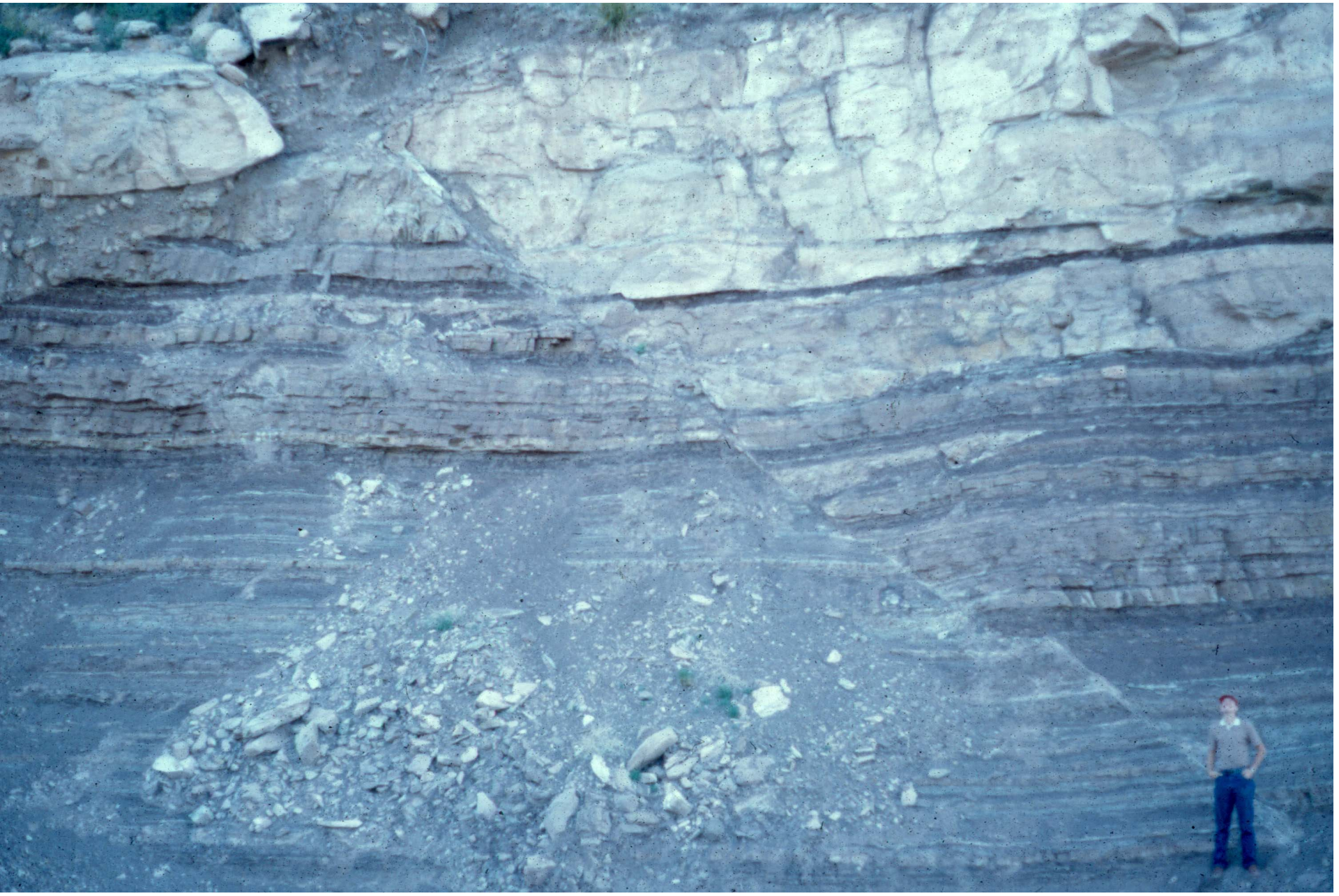
Crust is lengthened



Reverse fault or thrust fault

Crust is shortened

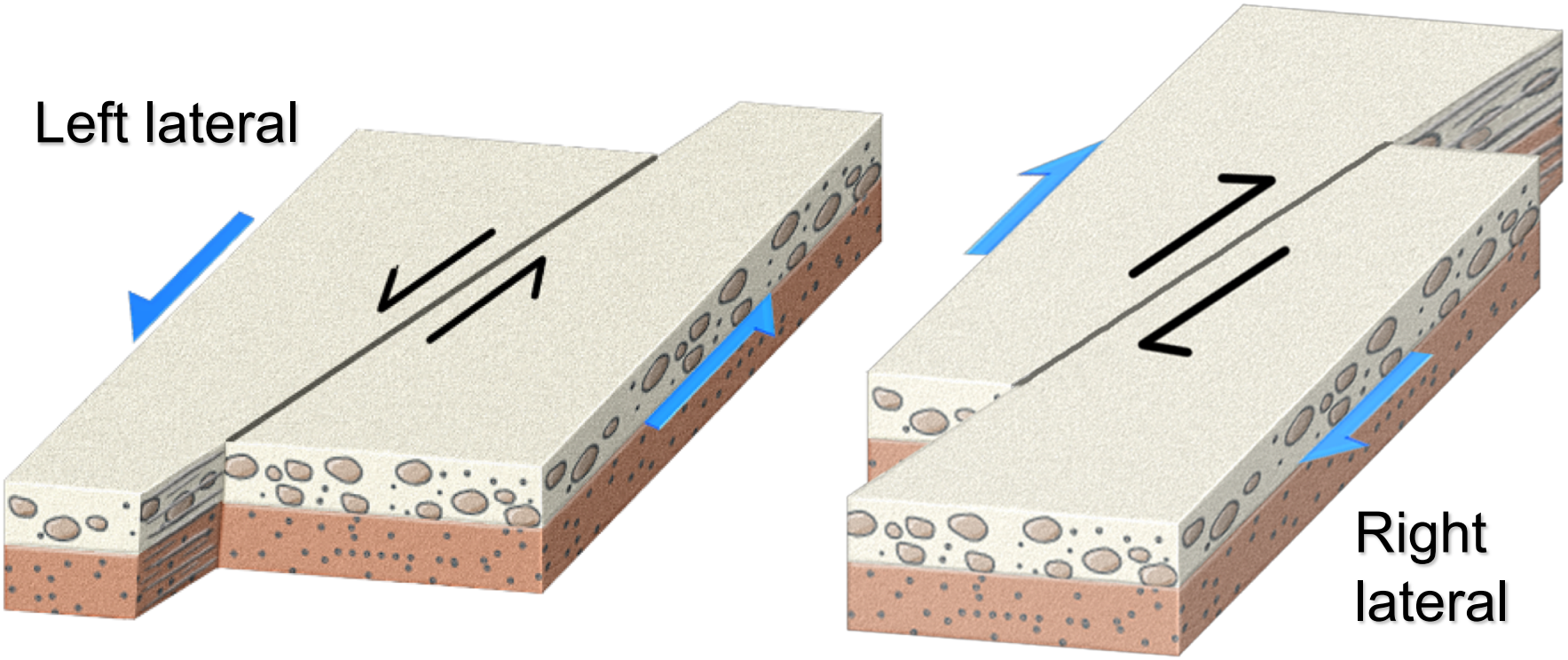
Roadcut somewhere in Colorado



Palmdale, California

Strike-Slip Faults

Two sides move horizontally relative to one another



Block on opposite side moves to left

Block on opposite side moves to right

Carizzo Plain, California

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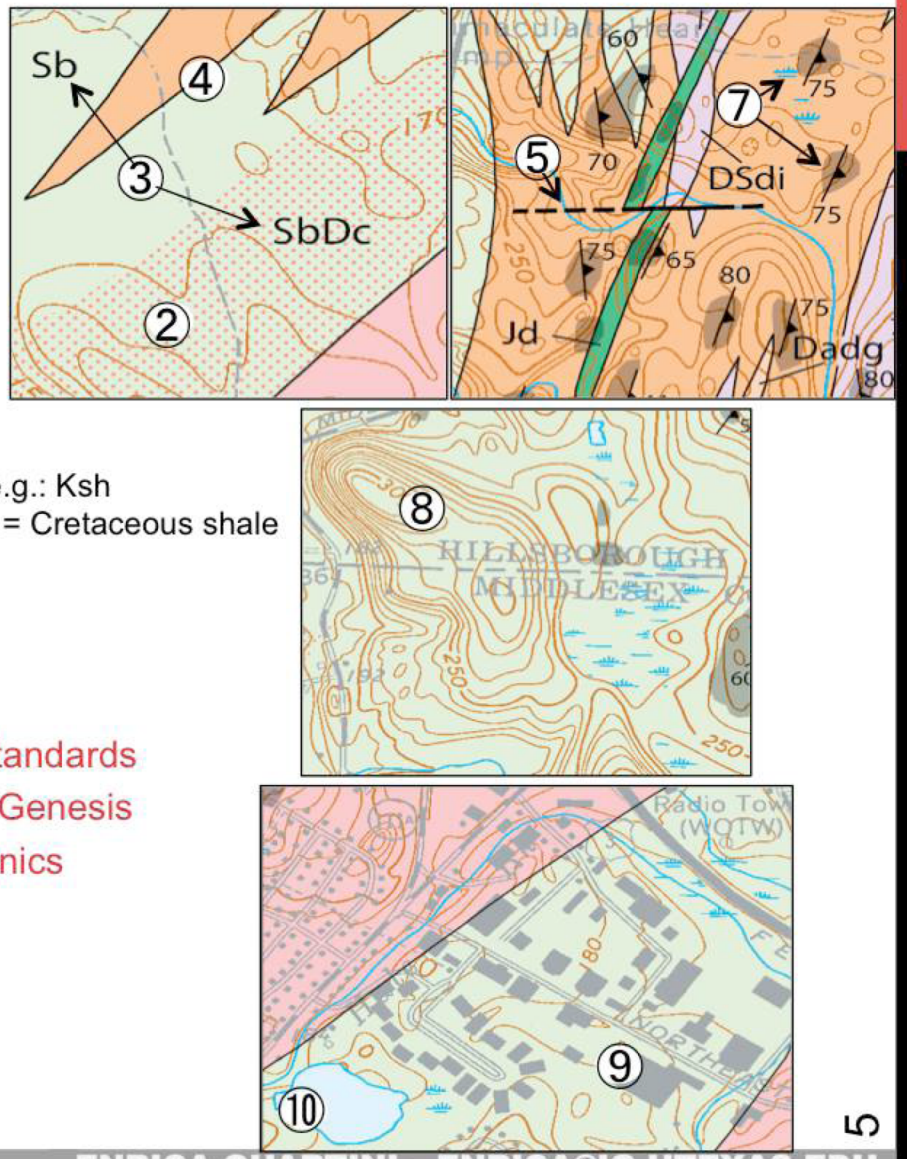
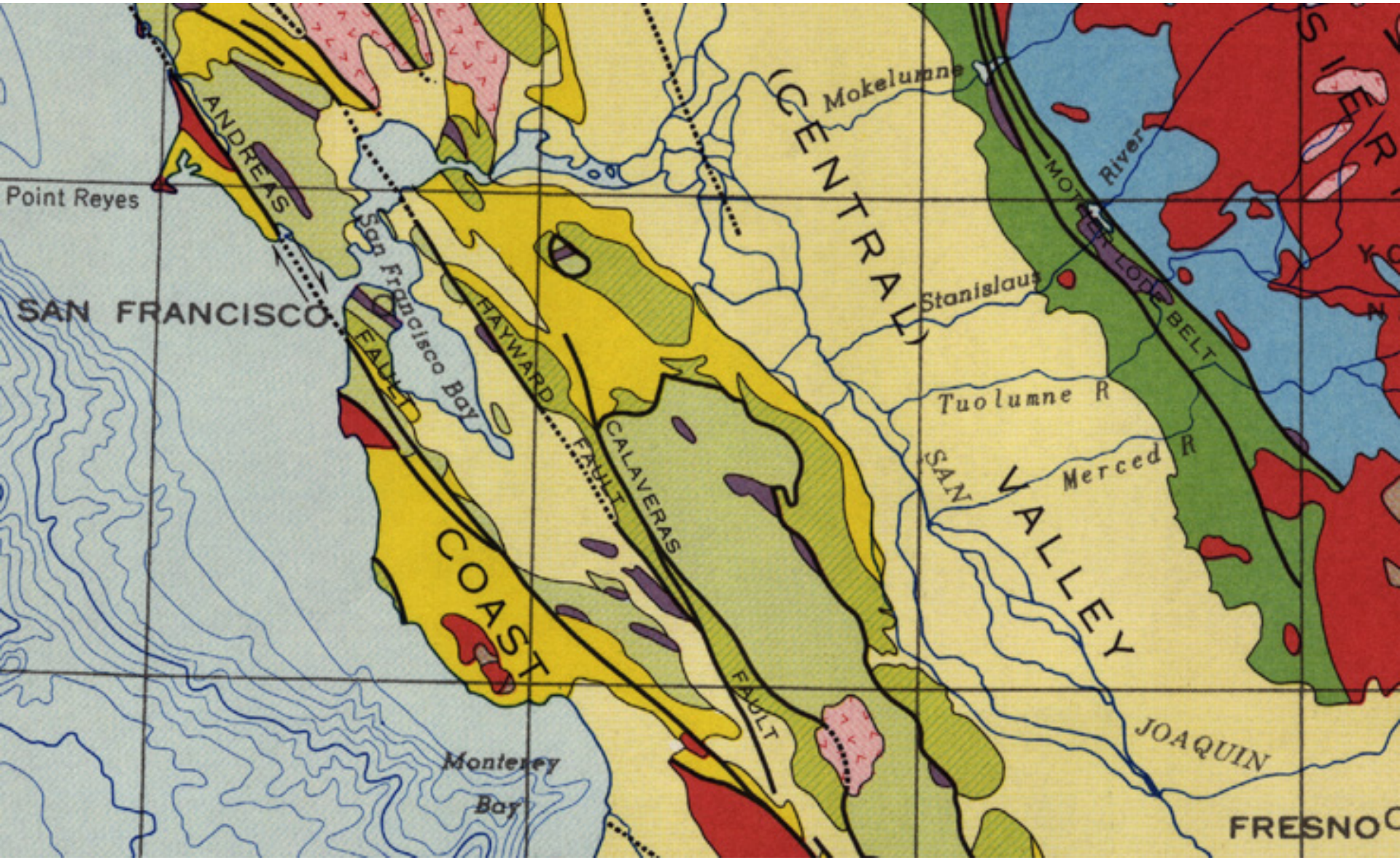
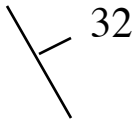


Geologic Map of portion of California

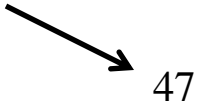


http://www.conservation.ca.gov/cgs/information/PublishingImages/california_geology_simplified_map.jpg

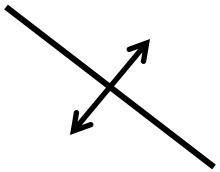
Map Symbols for Structures



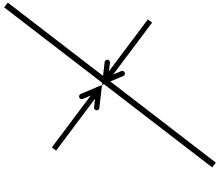
strike and dip (of a plane)



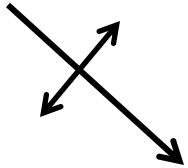
trend and plunge (of a line)



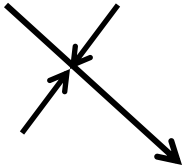
anticline



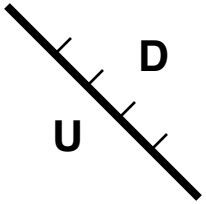
syncline



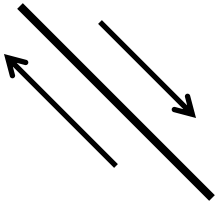
plunging anticline



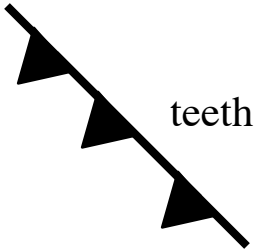
plunging syncline



normal fault

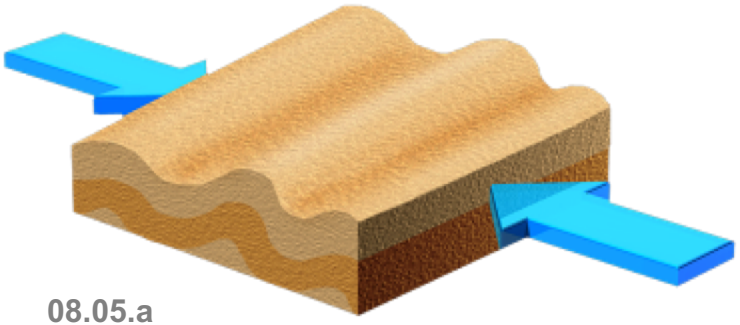


strike-slip fault



thrust fault

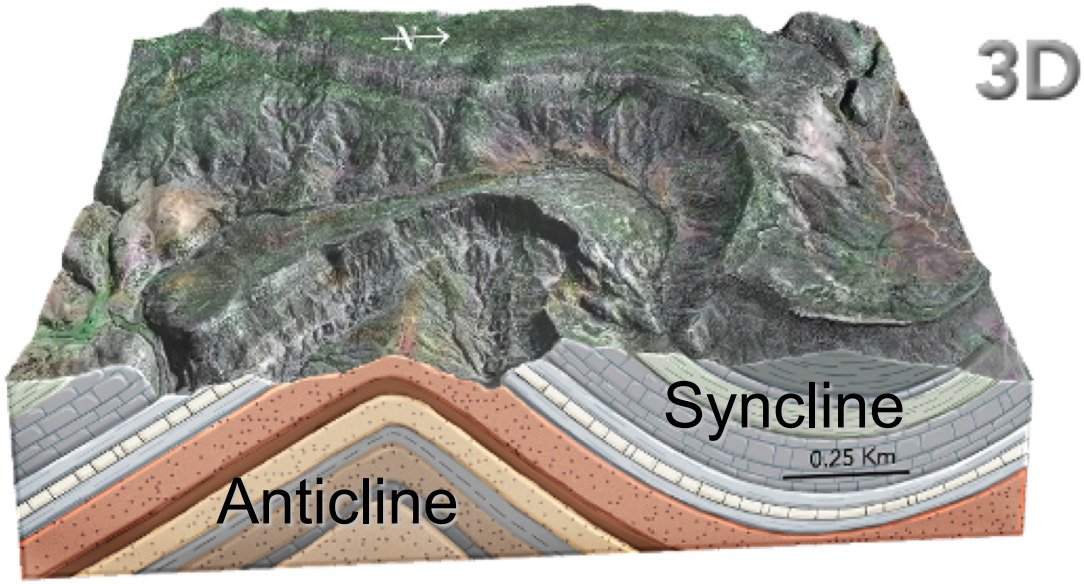
Folds

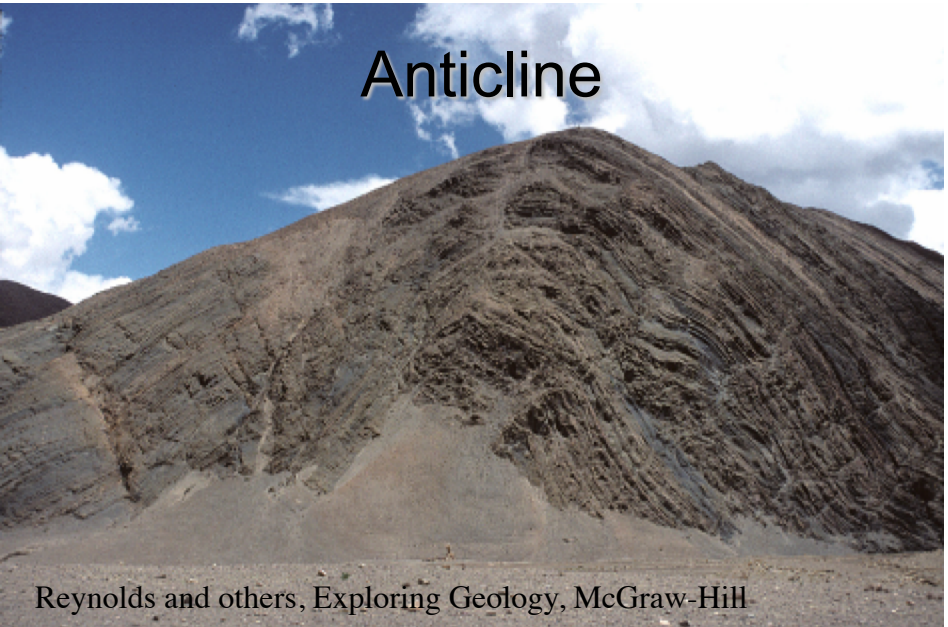


08.05.a

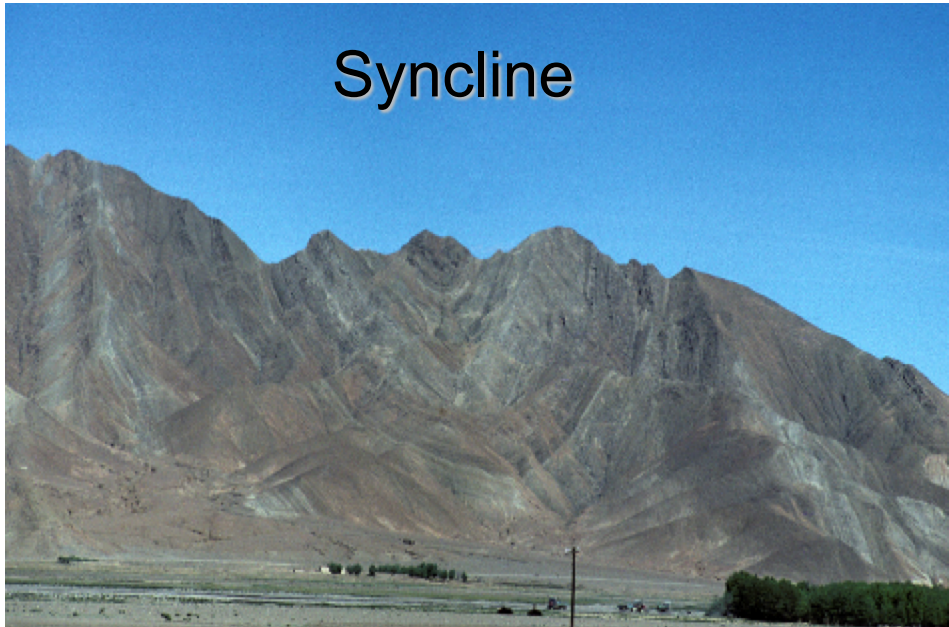
Layers can be folded

Crust is shortened

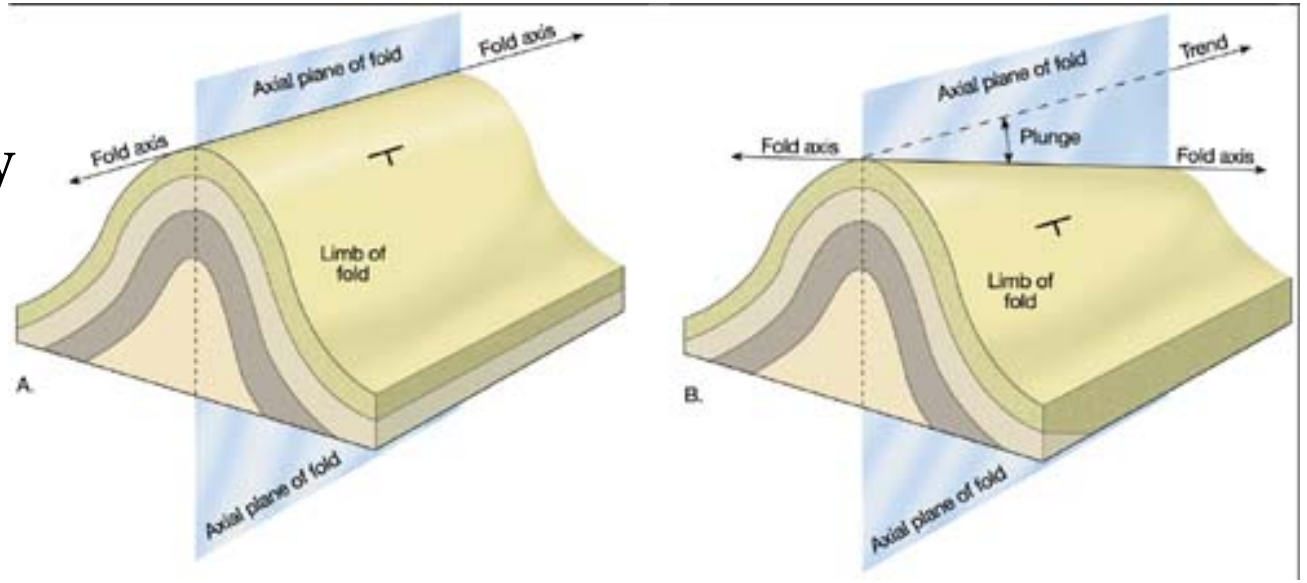




Reynolds and others, Exploring Geology, McGraw-Hill

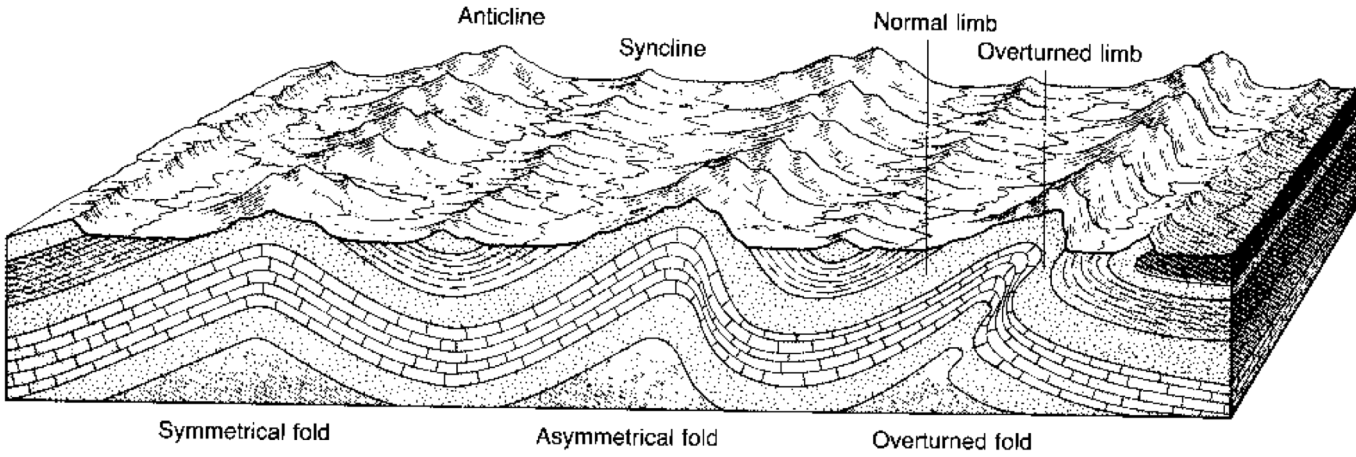


Fold terminology



http://faculty.chemeketa.edu/afrank1/structure_time/structure/structure%20diagram3.jpg

Fold axis
Fold axial plane (surface)
Fold limbs
Plunging folds
Asymmetric folds
Overturned folds
Recumbent folds



http://geophysics.ou.edu/geol1114/notes/structure/recumb-overturn.gif

Anticline: beds dip out *away* from the middle (fold axis); on a geologic map, the *oldest* rocks are exposed in the middle.

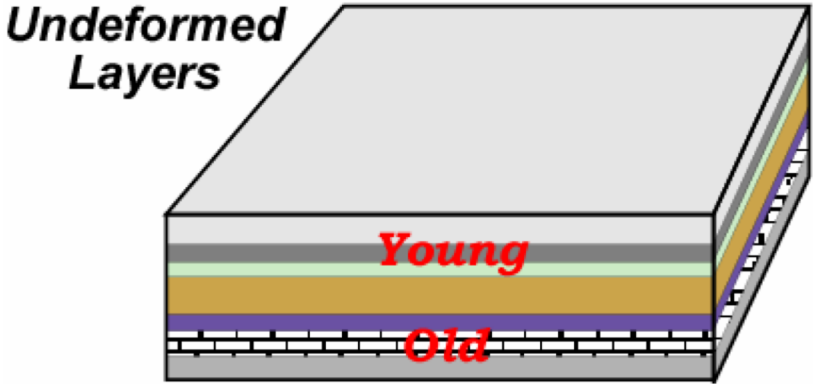
Syncline: beds dip in *toward* the middle (fold axis); on a geologic map, the *youngest* rocks are exposed in the middle.

Roadcut on I-81, Pennsylvania

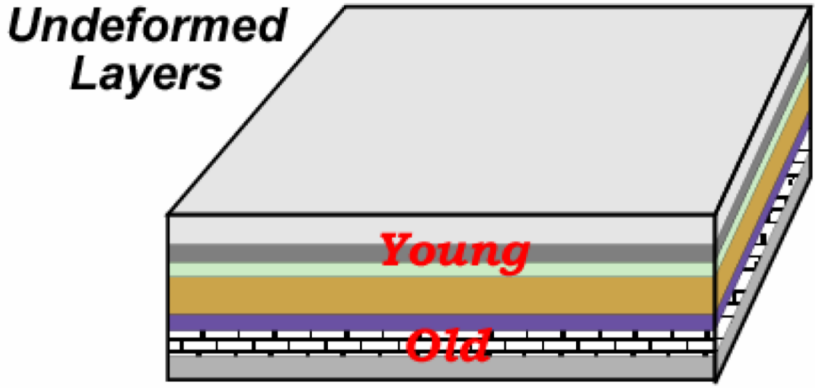
Western Maryland

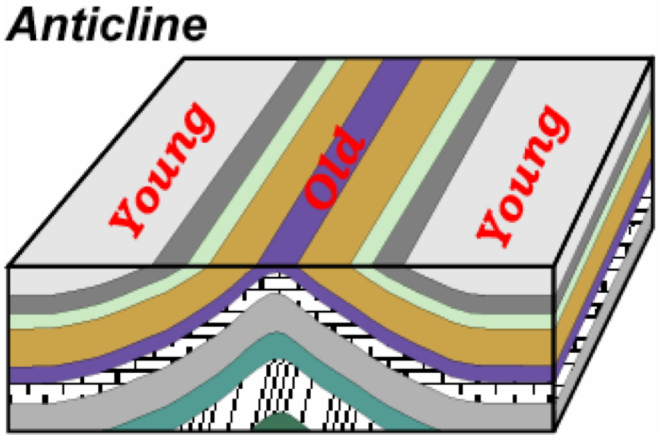
Old Woman Mountains, California

Folds



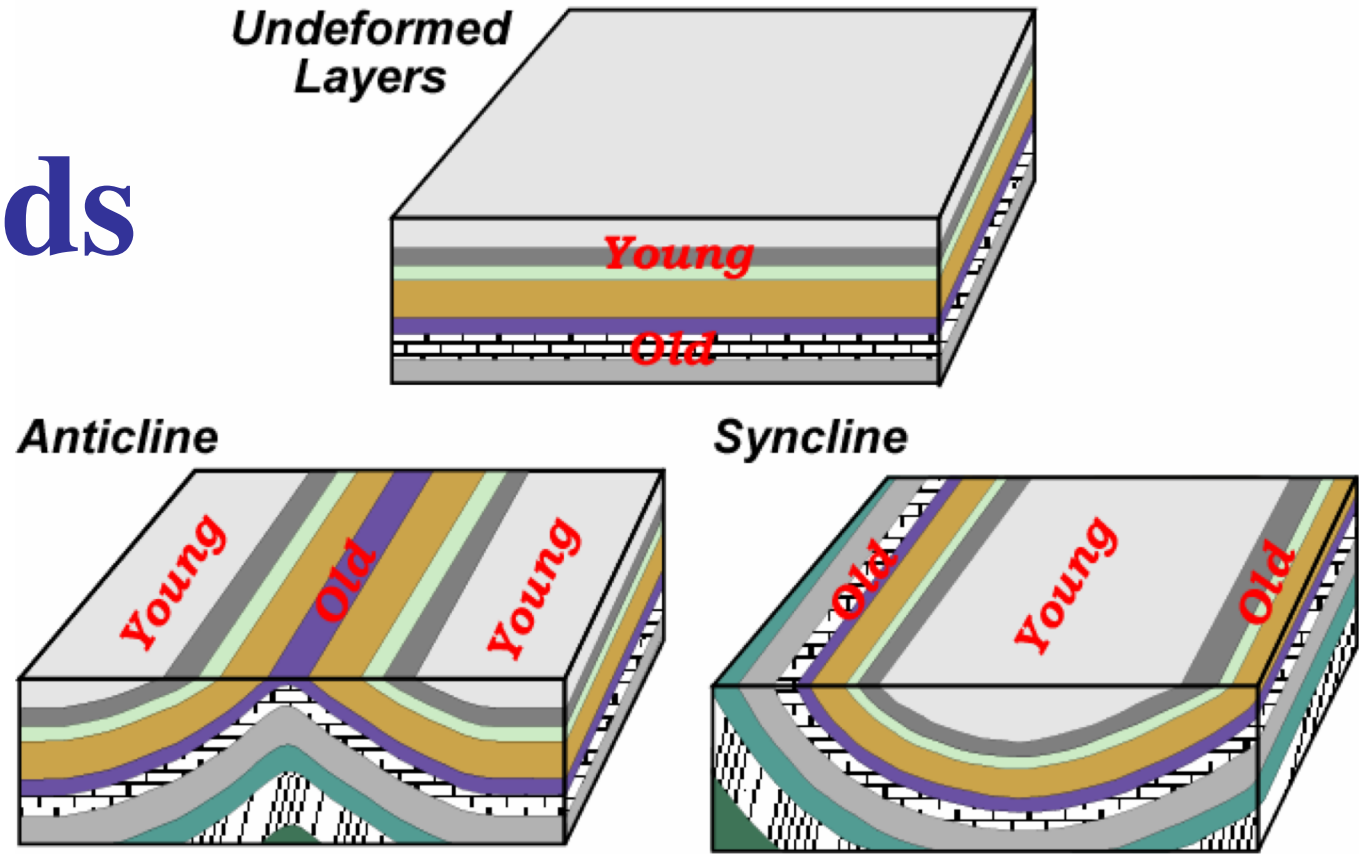
Folds





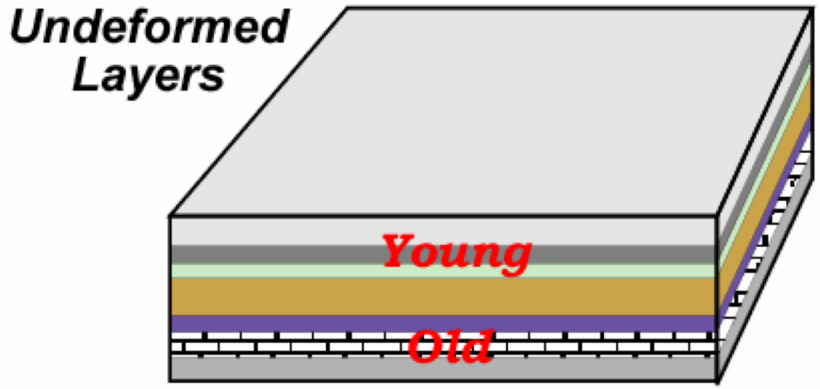
An <u>Anticline</u> is an <u>upfold</u>, with <u>older</u> layers in the center.

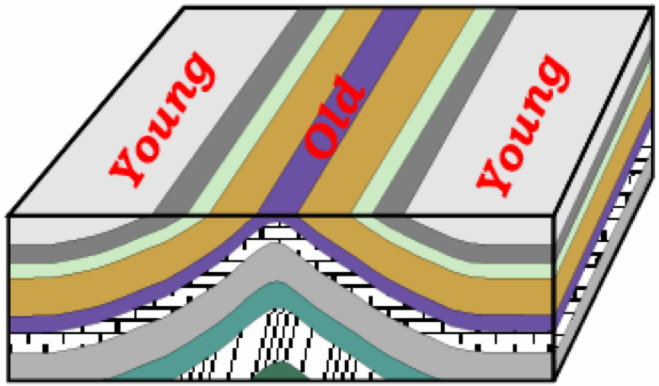
Folds

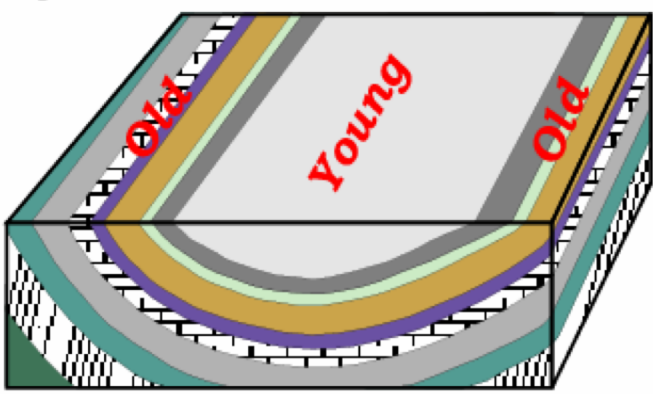


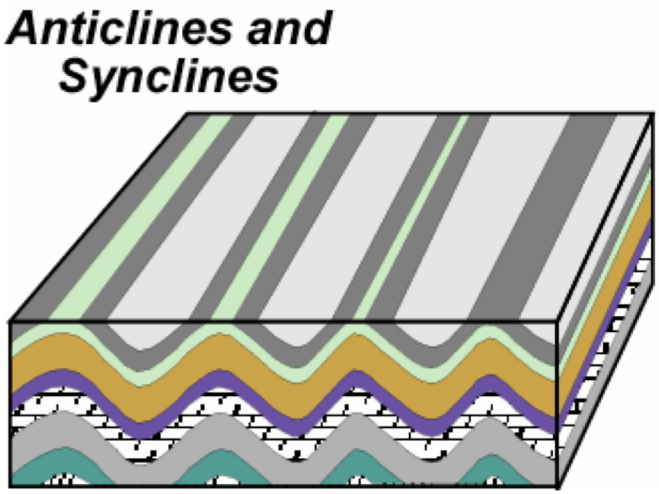
A <u>syncline</u> is a <u>downfold</u>, with <u>younger</u> layers in the center.

Folds



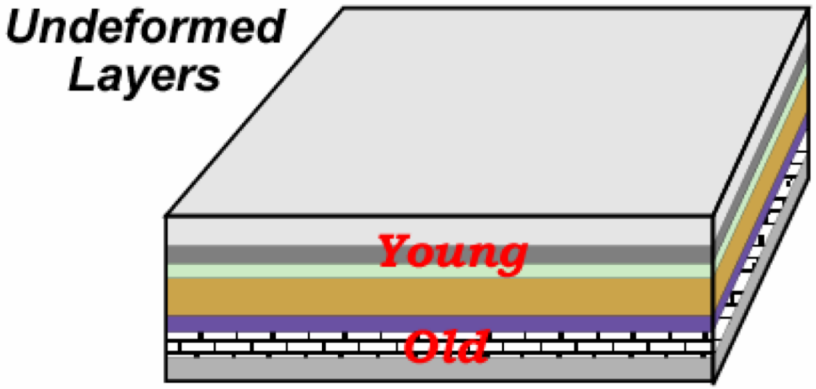




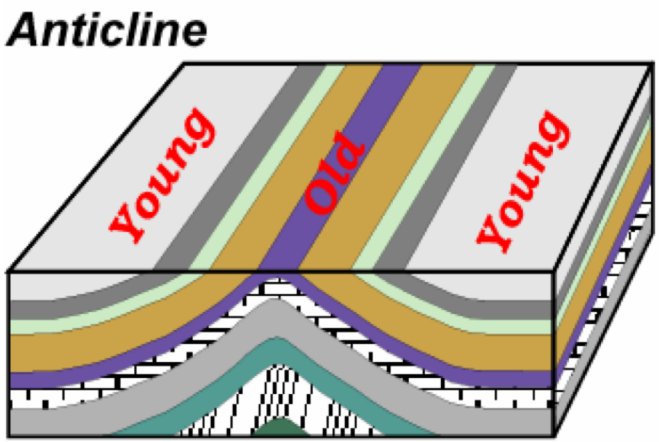


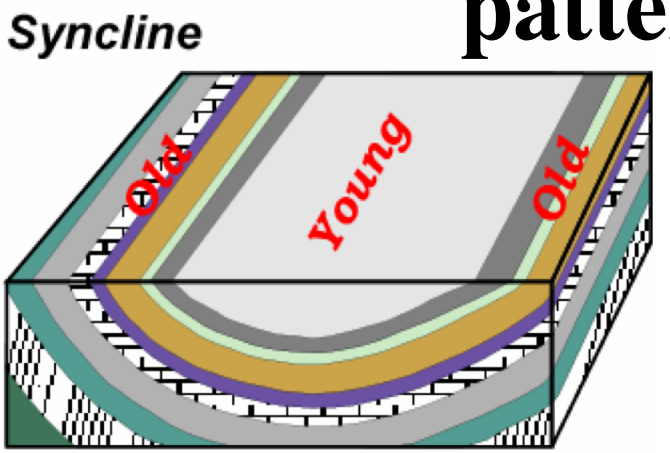
Folded layers form a series of anticlines and synclines, like pushing on a rug. Viewed from above, they make a striped pattern.

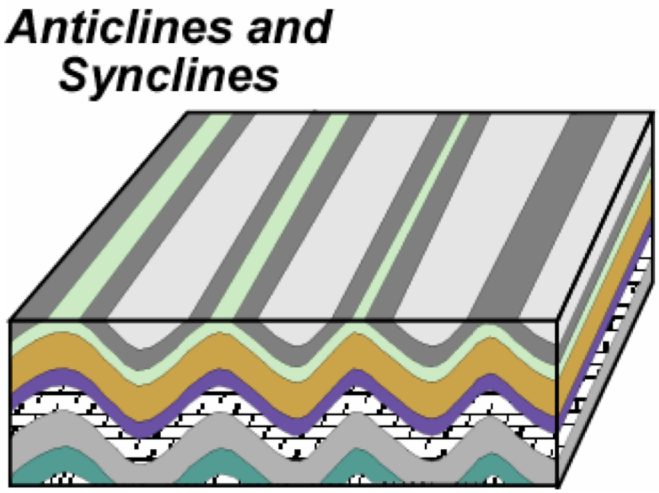
Folds

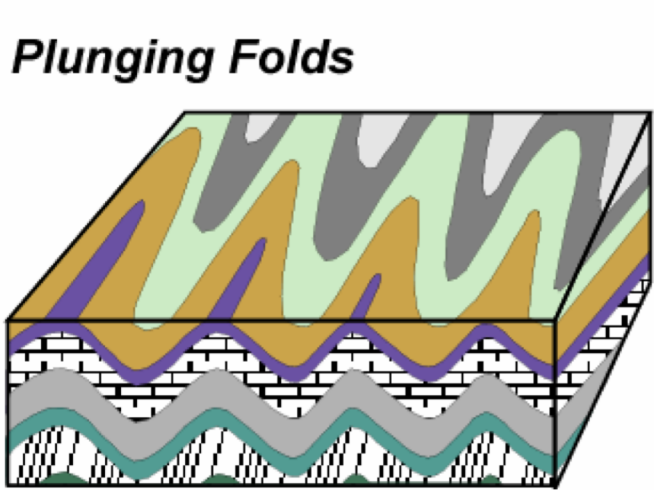


Plunging folds make horseshoe-shaped patterns.

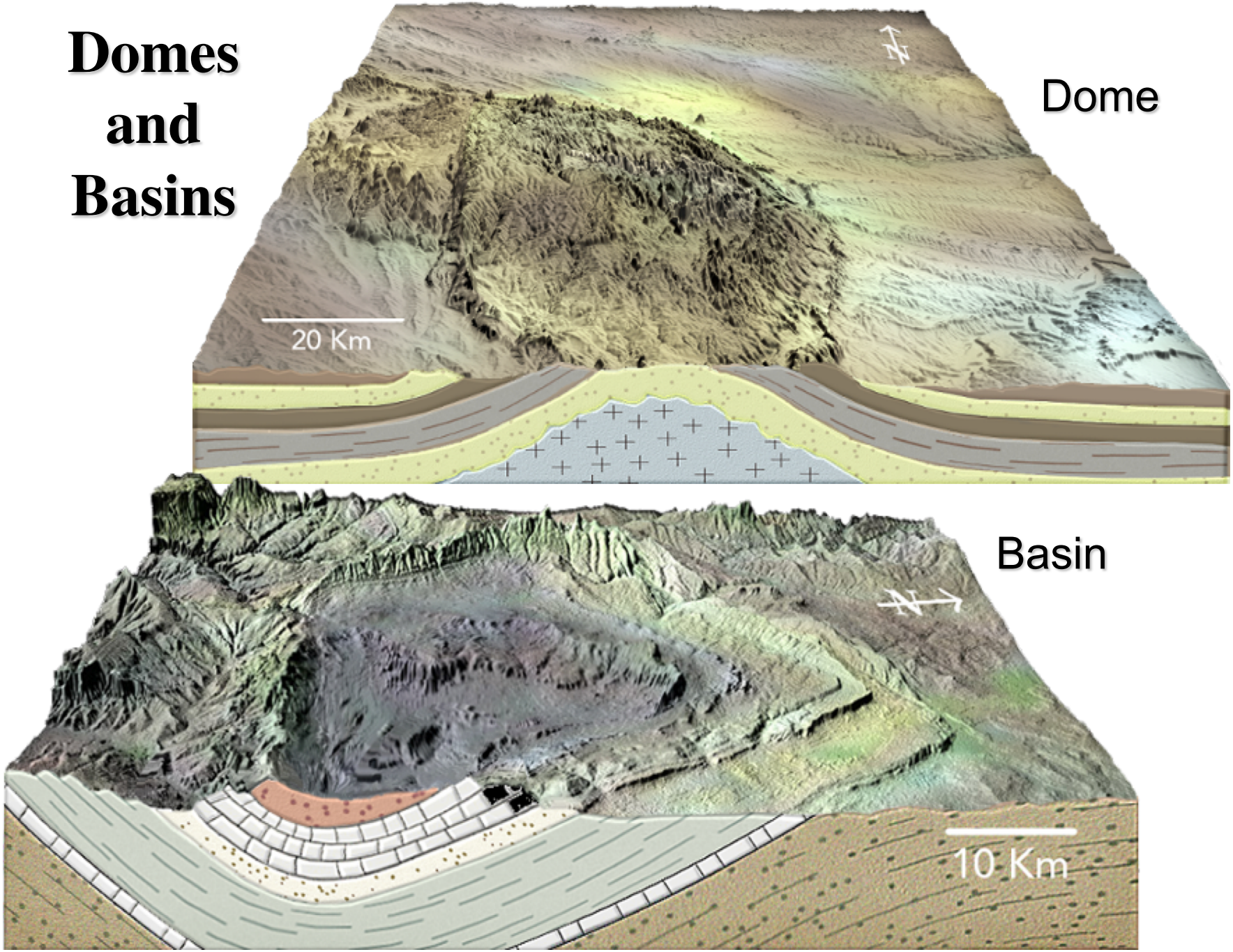






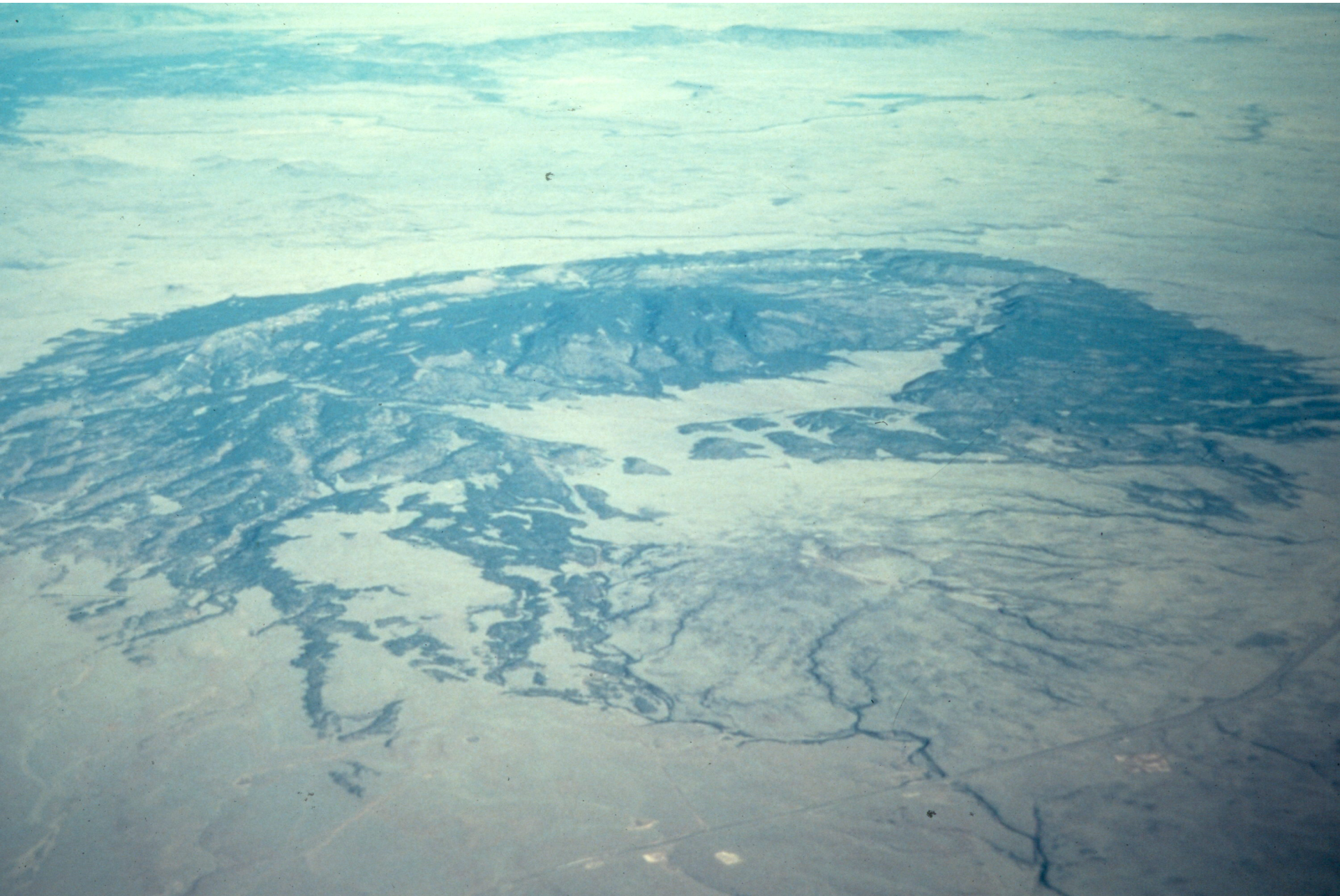


Domes and Basins



Reynolds and others, Exploring Geology, McGraw-Hill

Aerial view, Wyoming



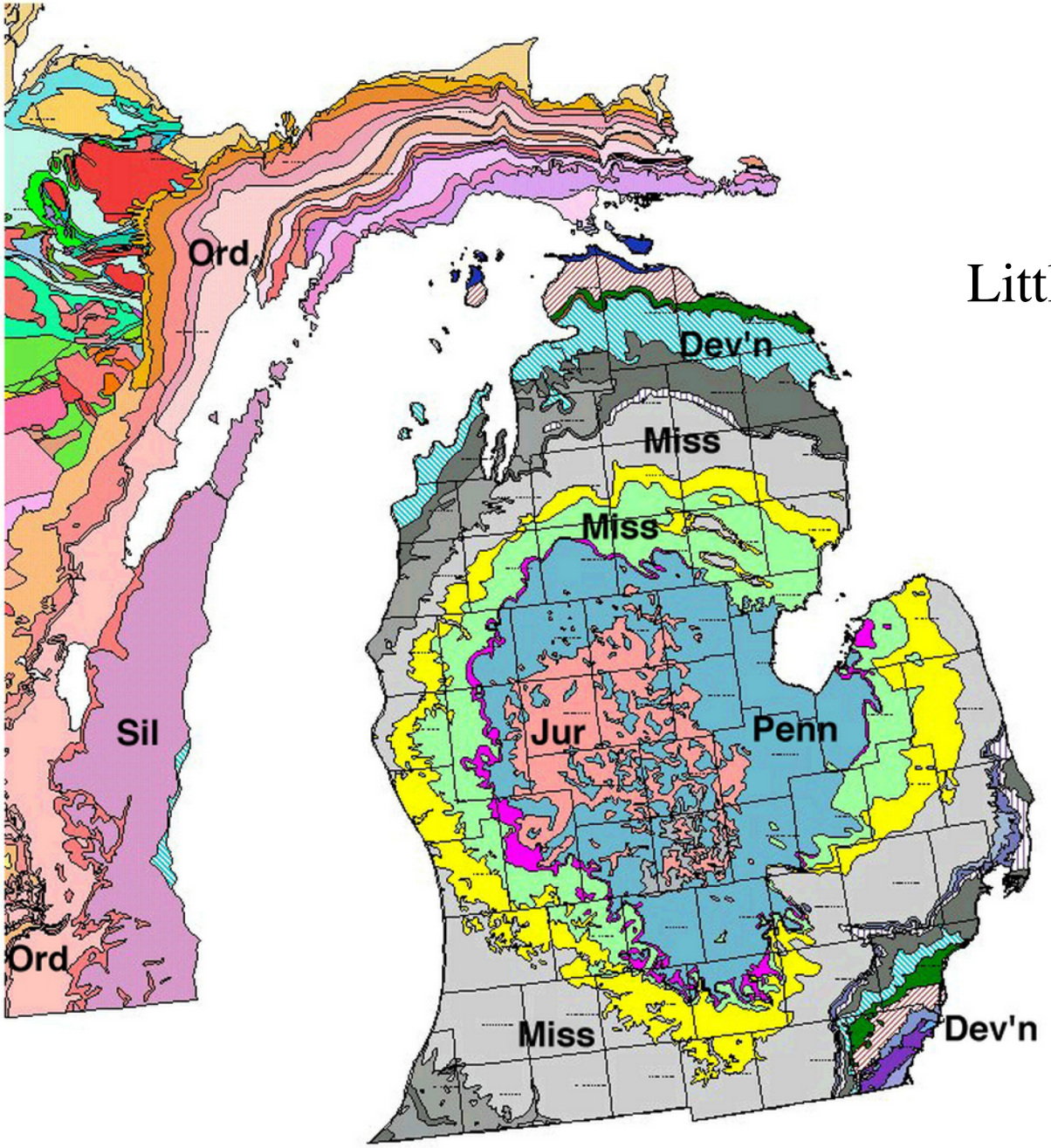
Ozark Mountains, Arkansas

Mosquito Range
near Alma,
Colorado

Complex Folds

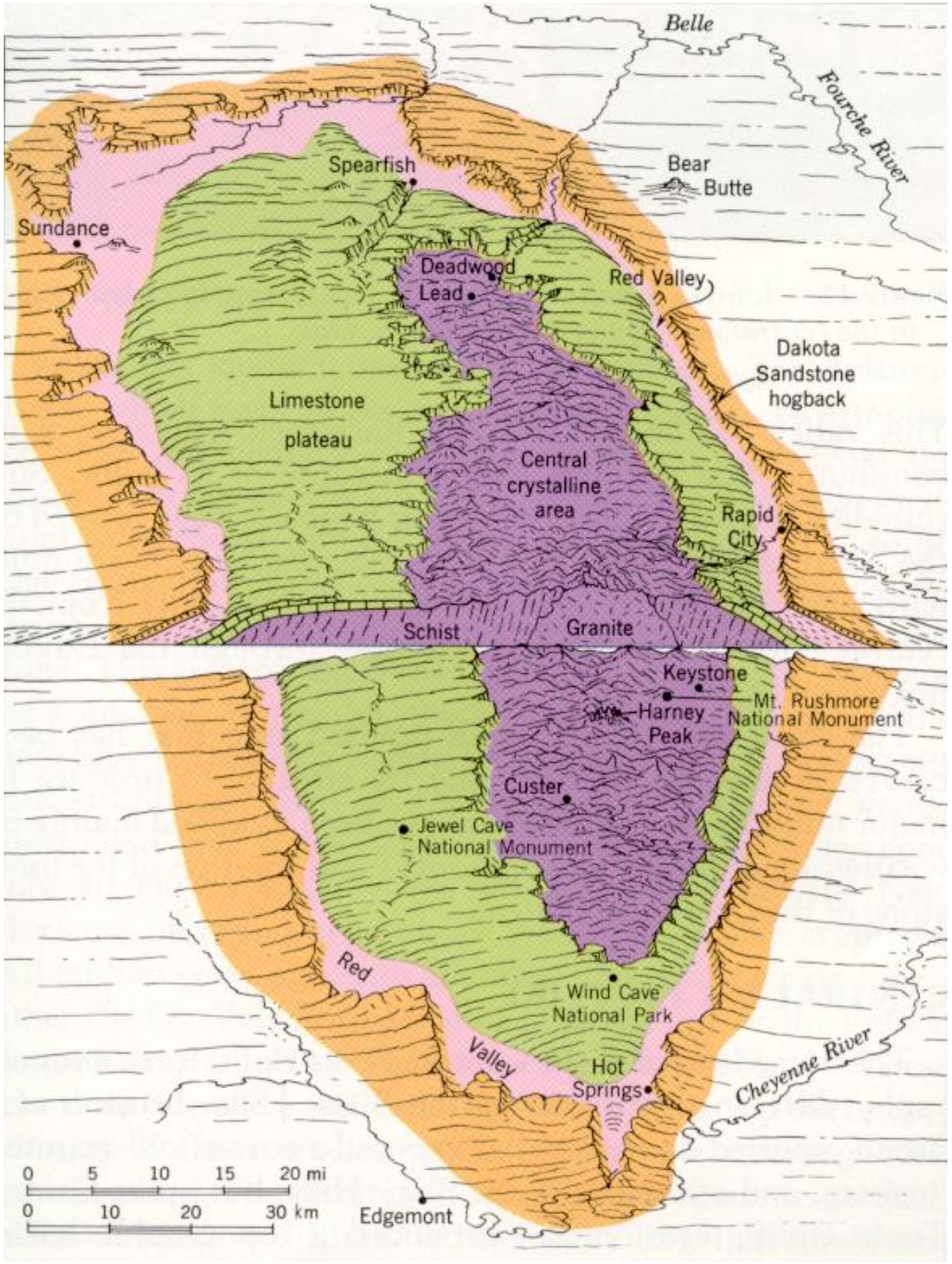
Roadcut on I-84 near New York-
Connecticut Border

Roadcut on US 11 near Canton, New York



Geologic Map of Michigan (and a Little piece of Wisconsin)

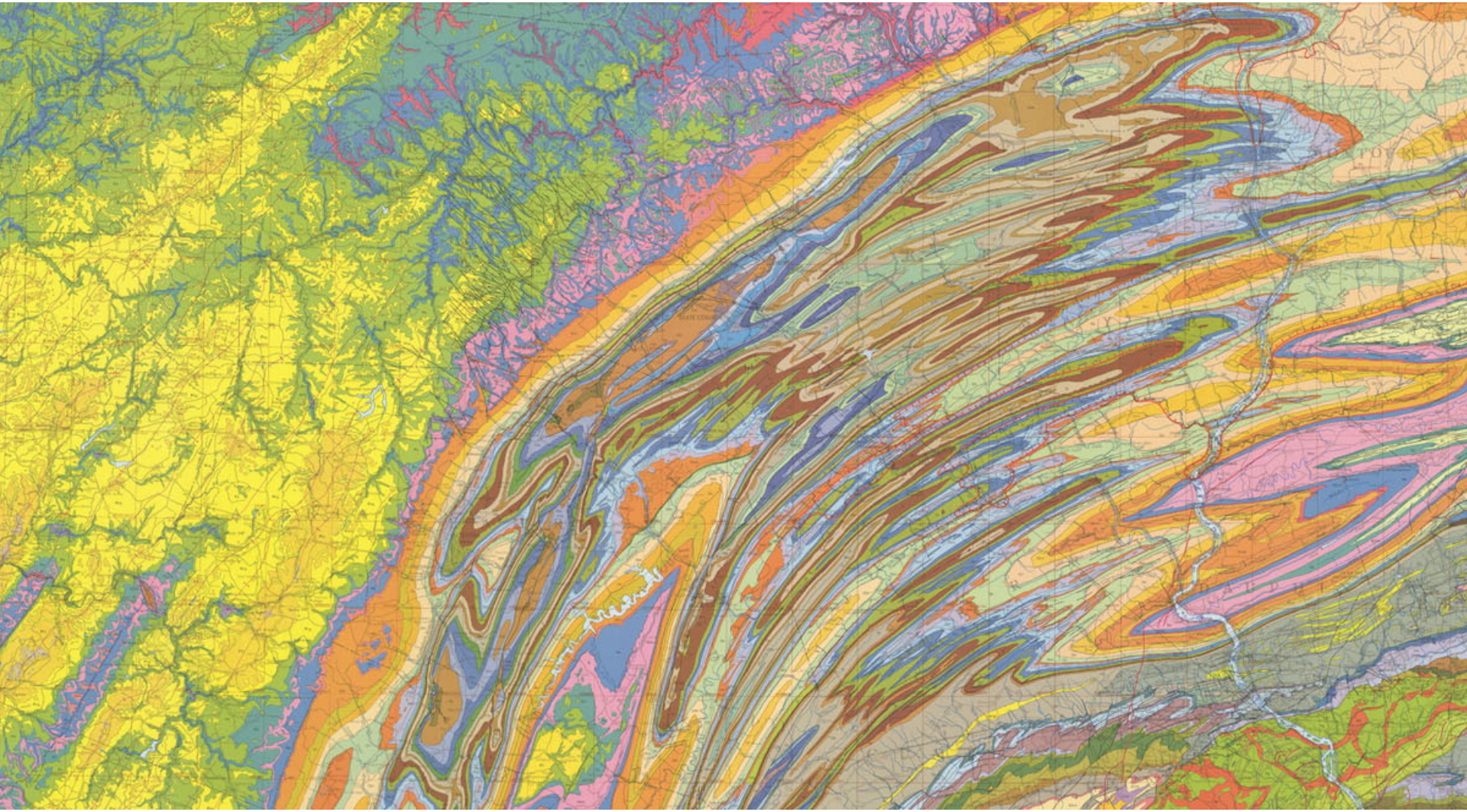
http://www.geo.mtu.edu/svl/geoscience/figures/digital%20geologic%20map%20of%20michigan.jpg



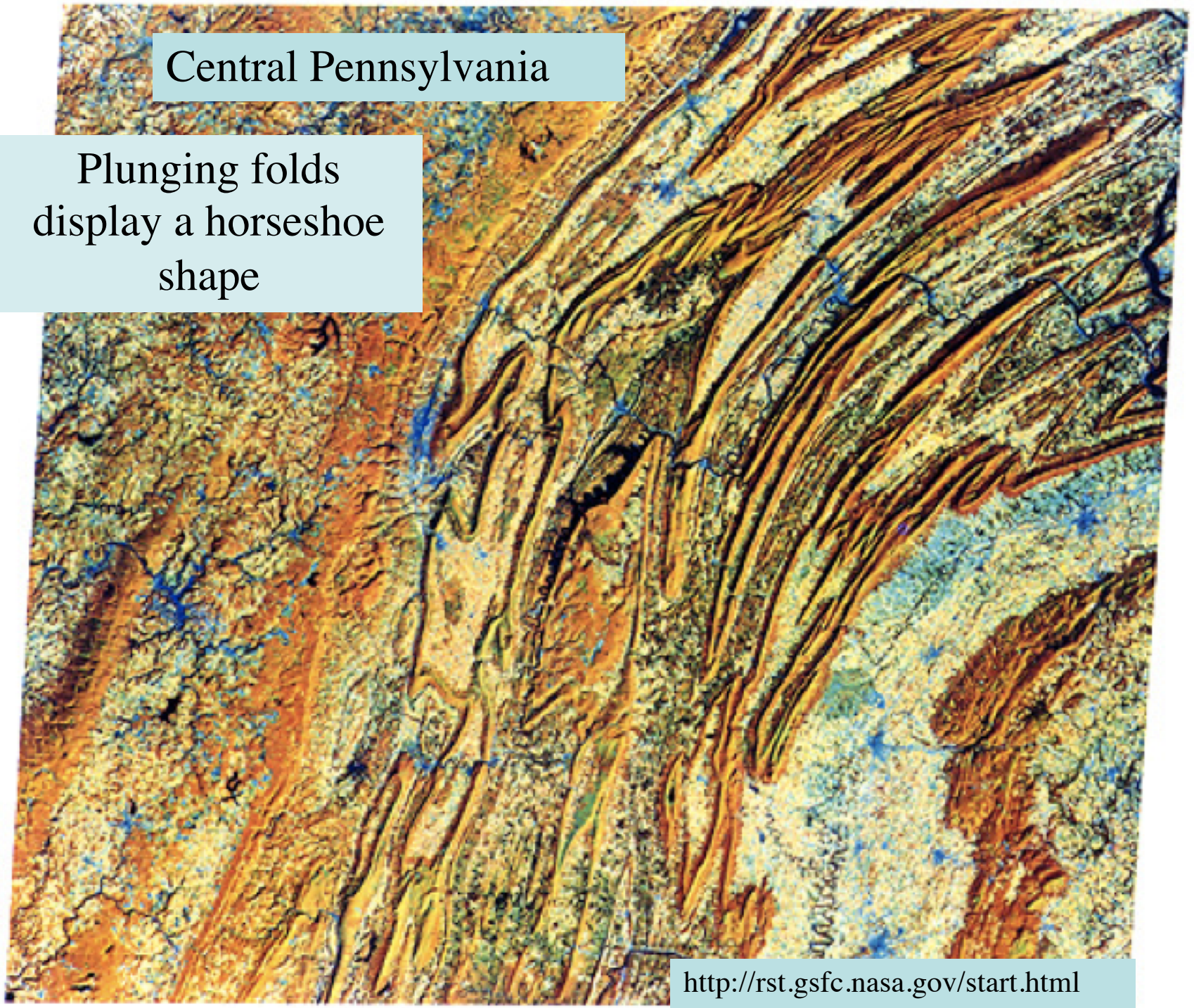
Geologic Map of the Black Hills, SD

http://library.ndsu.edu/exhibits/text/greatplains/fig10.jpg

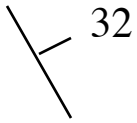
Geologic Map of Central Pennsylvania



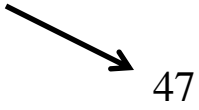
http://www.dcnr.state.pa.us/cs/groups/public/documents/multimedia/dcnr_015952.jpg


Central Pennsylvania
Plunging folds display a horseshoe shape
http://rst.gsfc.nasa.gov/start.html

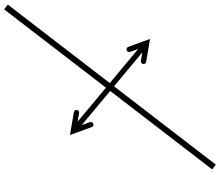
Map Symbols for Structures



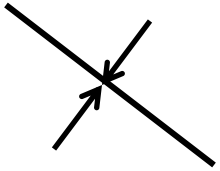
strike and dip (of a plane)



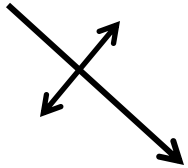
trend and plunge (of a line)



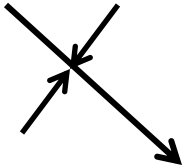
anticline



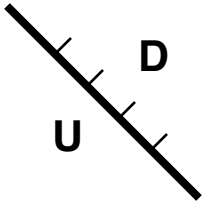
syncline



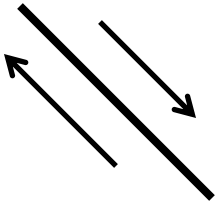
plunging anticline



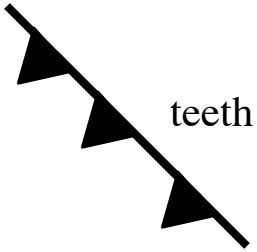
plunging syncline



normal fault



strike-slip fault



thrust fault

Strike and Dip

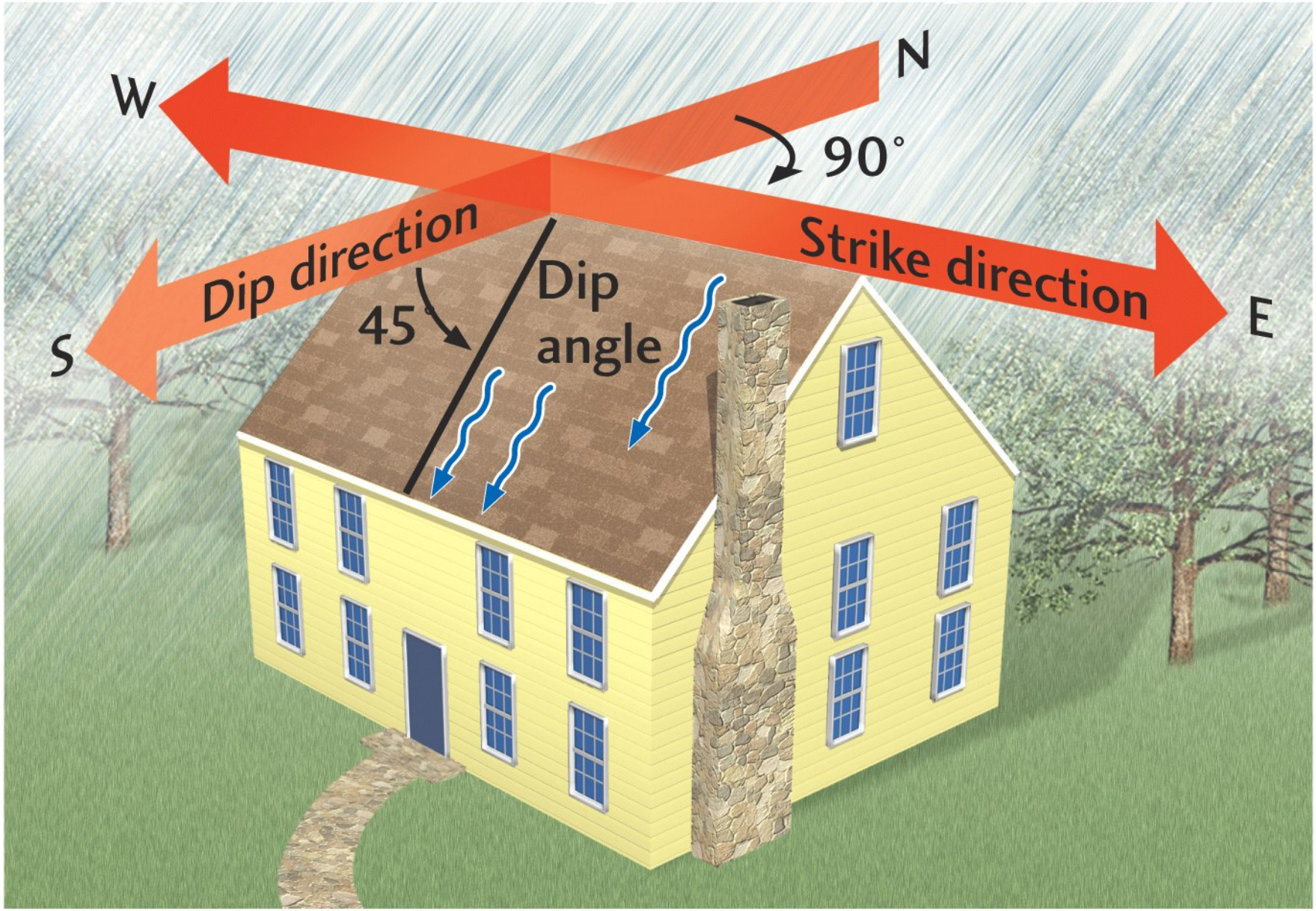
Strike: the compass direction of a horizontal line in a dipping bed.

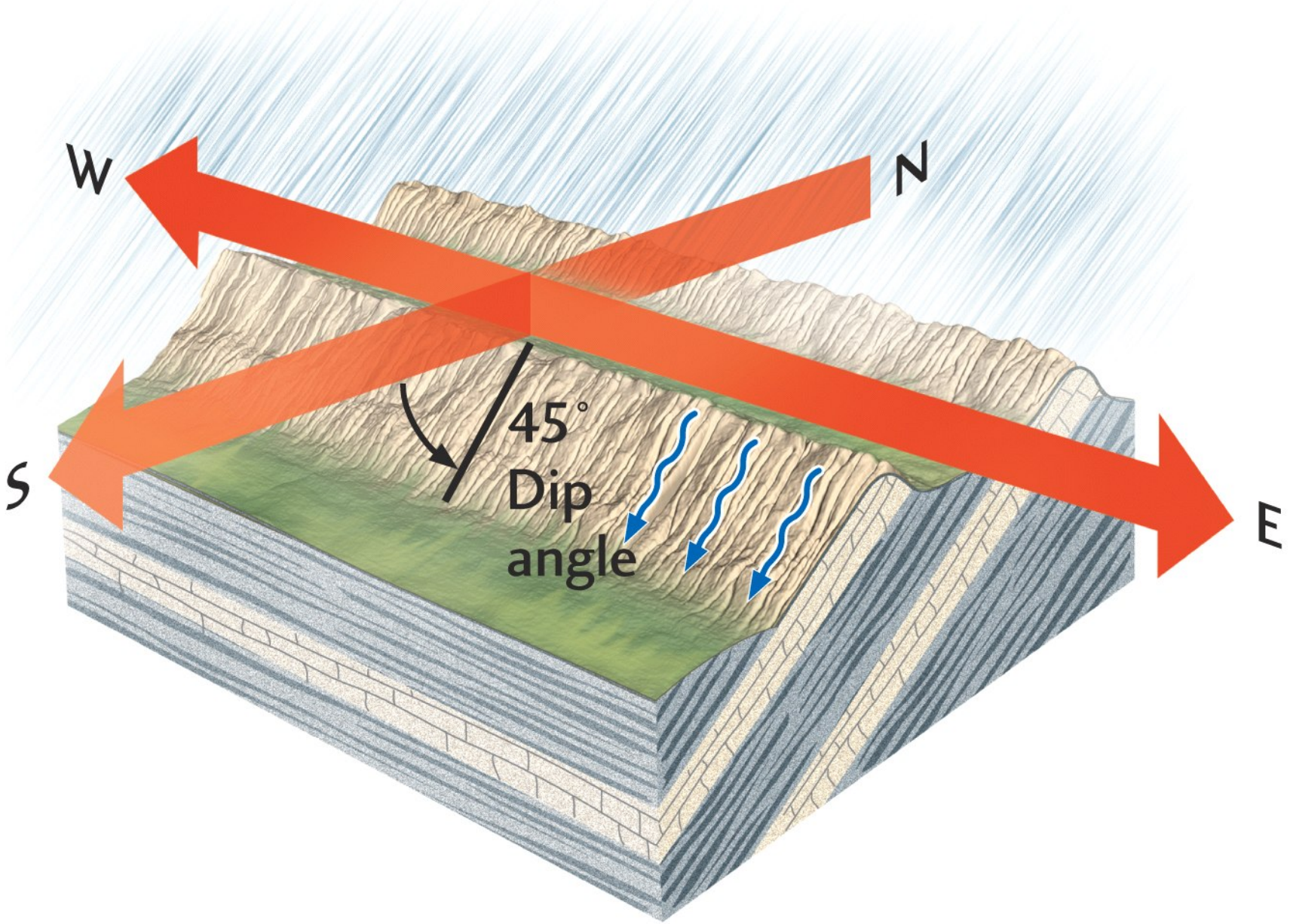
Dip: the downward angle from horizontal that the bed makes. Dip direction is always perpendicular to strike.

Example: N35° E, 20° NW


strike


strike
dip


N
W
90°
Dip direction
Strike direction
S
E
45°
Dip
angle


W
N
S
E
45°
Dip
angle

Tilted rock layers showing strike and dip

Measuring strike and dip with a Brunton compass

Compass

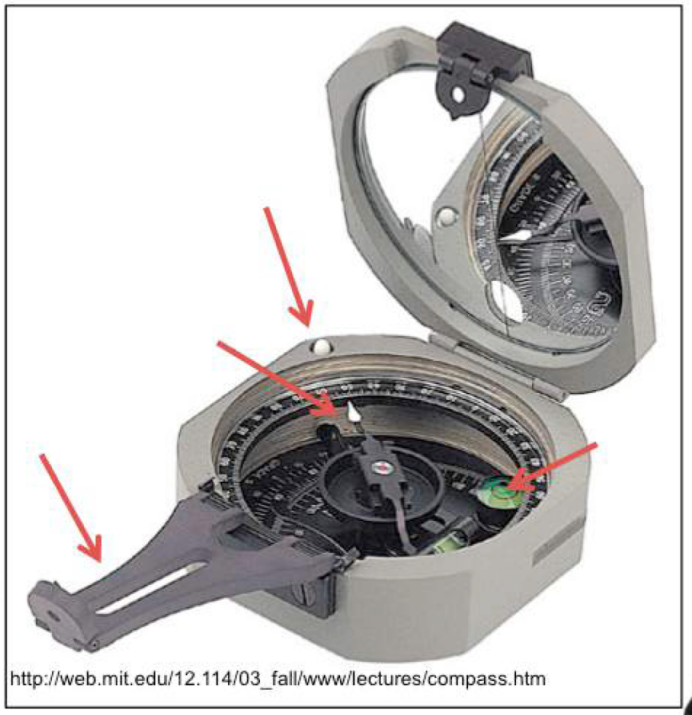
① **Types of Compasses**
- Brunton
- Others

(- Differences, - Applications)

② **Parts of a Compass**
- Identify → Uses

③ Types of Measurements

④ Field Operation



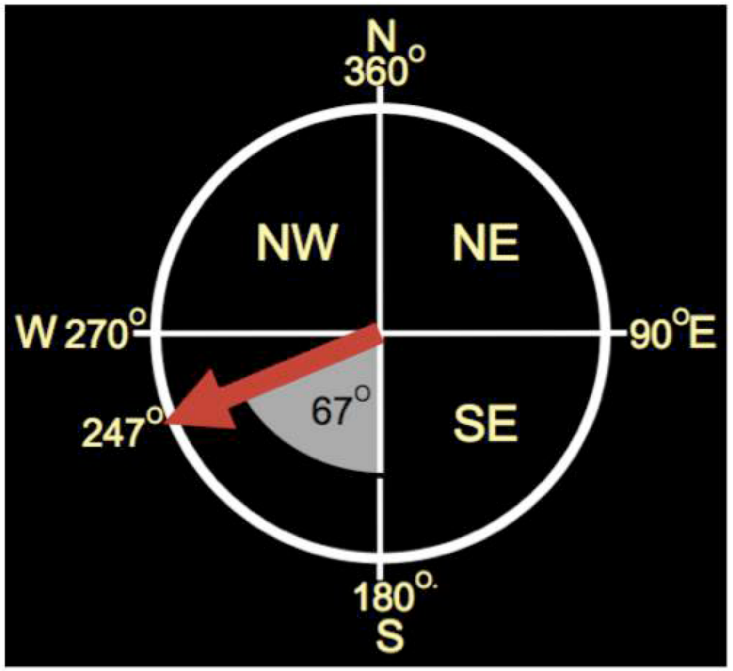
http://web.mit.edu/12.114/03_fall/www/lectures/compass.htm

a. Taking Measurements

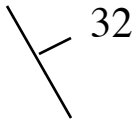
- **Bearing** → Geologic Map (e.g. type)
  → Magnetic Declination
- **Planes**
  ① Strike
  ② Dip
- **Lines**
  ① Plunge
  ② Trend
  ③ Rake
- **Geologic Units**
  ① Identify Units
  ② Measure Unit Thickness
  ③ Describe Units

b. Recording Measurements

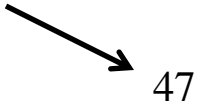
- **Bearing**
  - ① Azimuth: 247°
  - ② Quadrant: S 67° W
    - Definition
    - Differences
    - Uses
- Plane
- Line
- Geologic Units



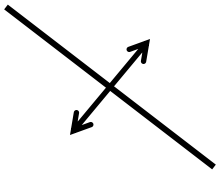
Map Symbols for Structures



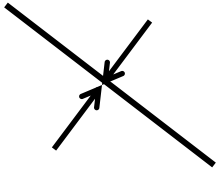
strike and dip (of a plane)



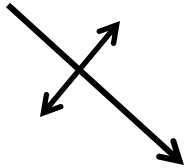
trend and plunge (of a line)



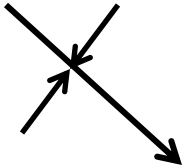
anticline



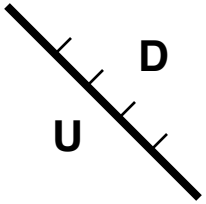
syncline



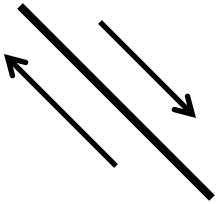
plunging anticline



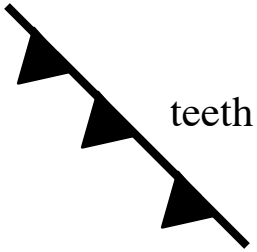
plunging syncline



normal fault



strike-slip fault



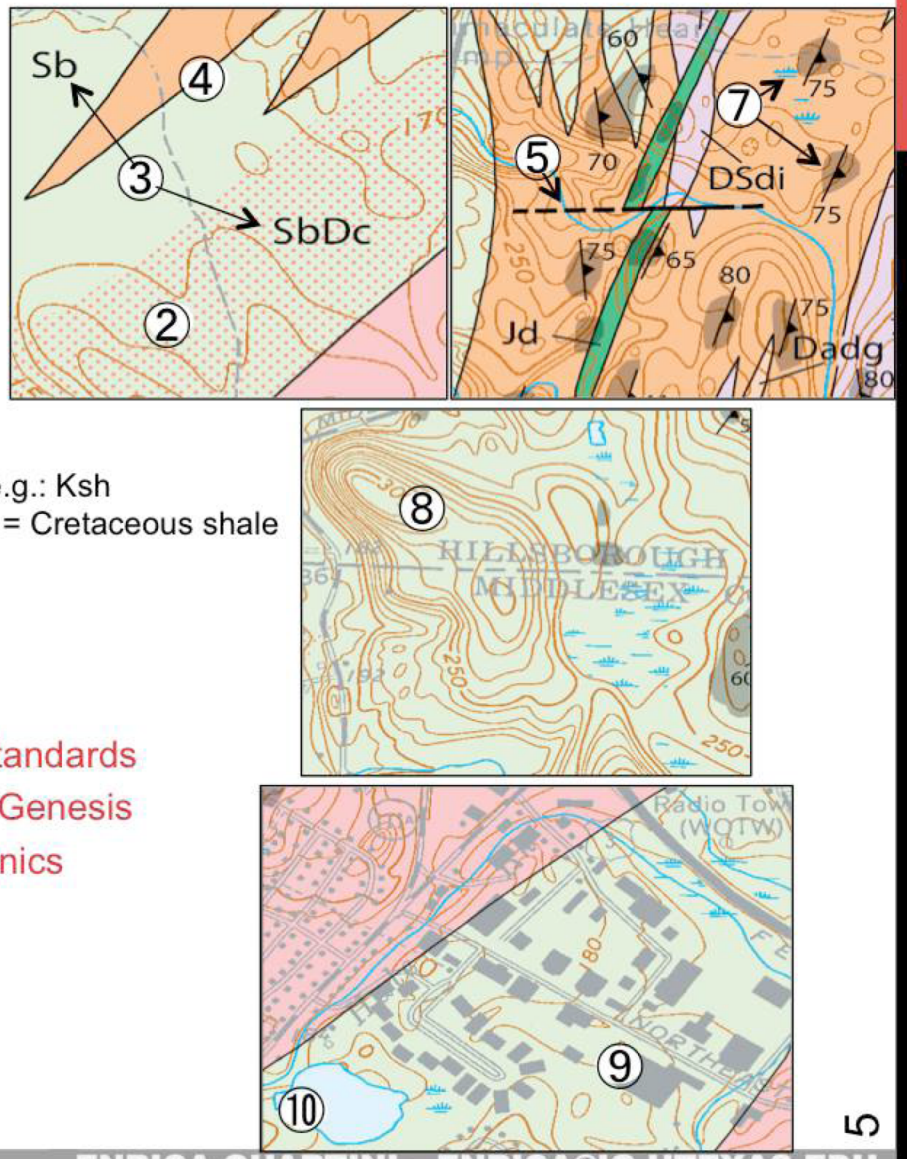
thrust fault

a. Map

- **Geologic Units (Formations):**
  - ① Color
    - American and International Standards
    - Palette for Different Rock Types
  - ② Symbols: patterns on colors
  - ③ Set of letters
    - First letter: Age → Geological Time Scale
    - Follows: Name of Rock Unit or Rock Type e.g.: Ksh = Cretaceous shale
  - ④ Contact lines
    - Depositional
    - Tectonic
    - Contact Types
    - Unconformities

- **Geologic Structures**
  - ⑤ Faults
  - ⑥ Folds
  - ⑦ Strike/Dip, Plunge/Trend
    - Symbols Standards
    - Types and Genesis
    - Plate Tectonics

- **Topography**
  - ⑧ Contour lines
  - ⑨ Roads, Towns
  - ⑩ Rivers, Lakes



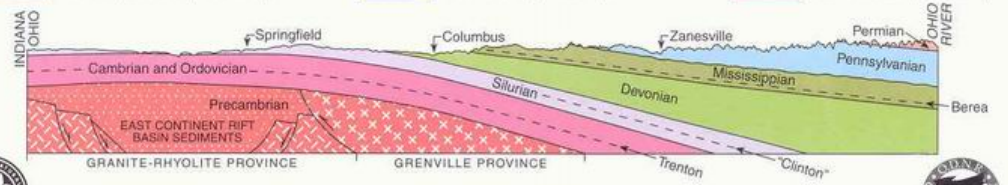
Cross sections

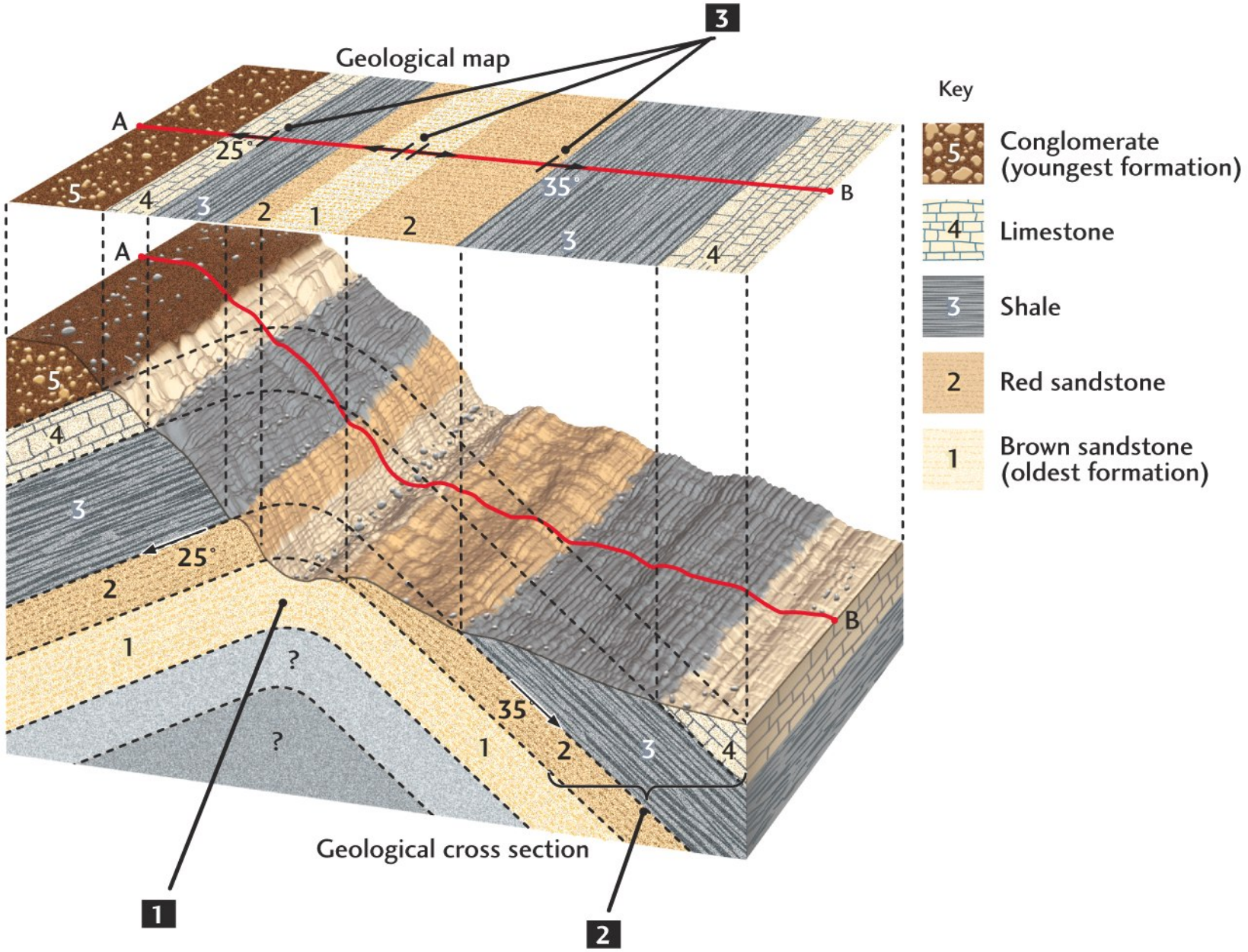
- Shows interpretation of what the rocks do underground
- Based on surface observations and geologic principles
- May have vertical exaggeration
- A block diagram has two cross sections

GEOLOGIC MAP AND CROSS SECTION OF OHIO

GEOLOGIC SYSTEM (million years before present)

Permian (286-245)	Mississippian (360-320)	Silurian (438-408)
Pennsylvanian (320-286)	Devonian (408-360)	Ordovician (505-438)





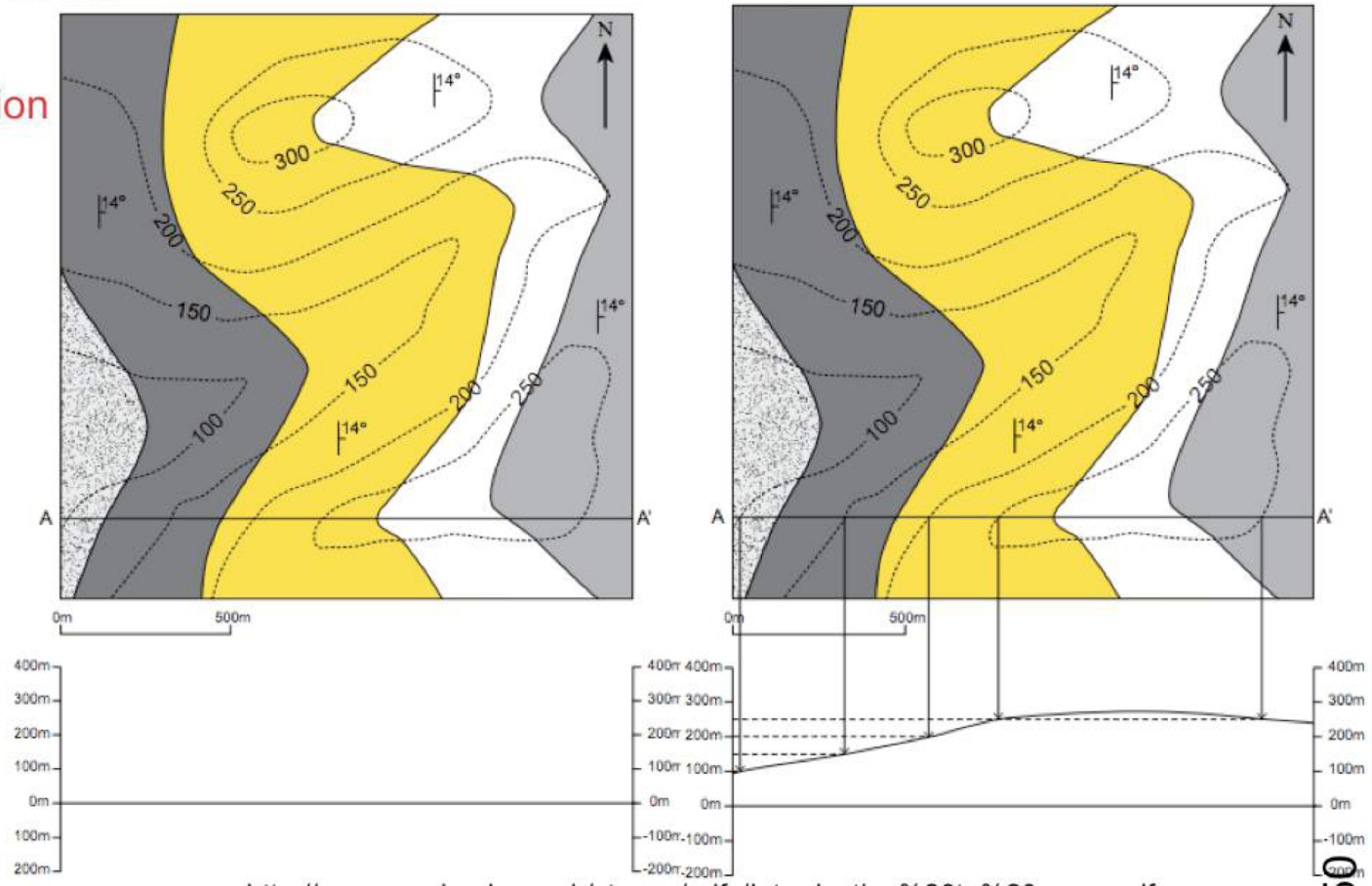
Constructing a cross section

➢ Cross Section

a. Topographic Profile

→ Map Symbols

→ Vertical exaggeration

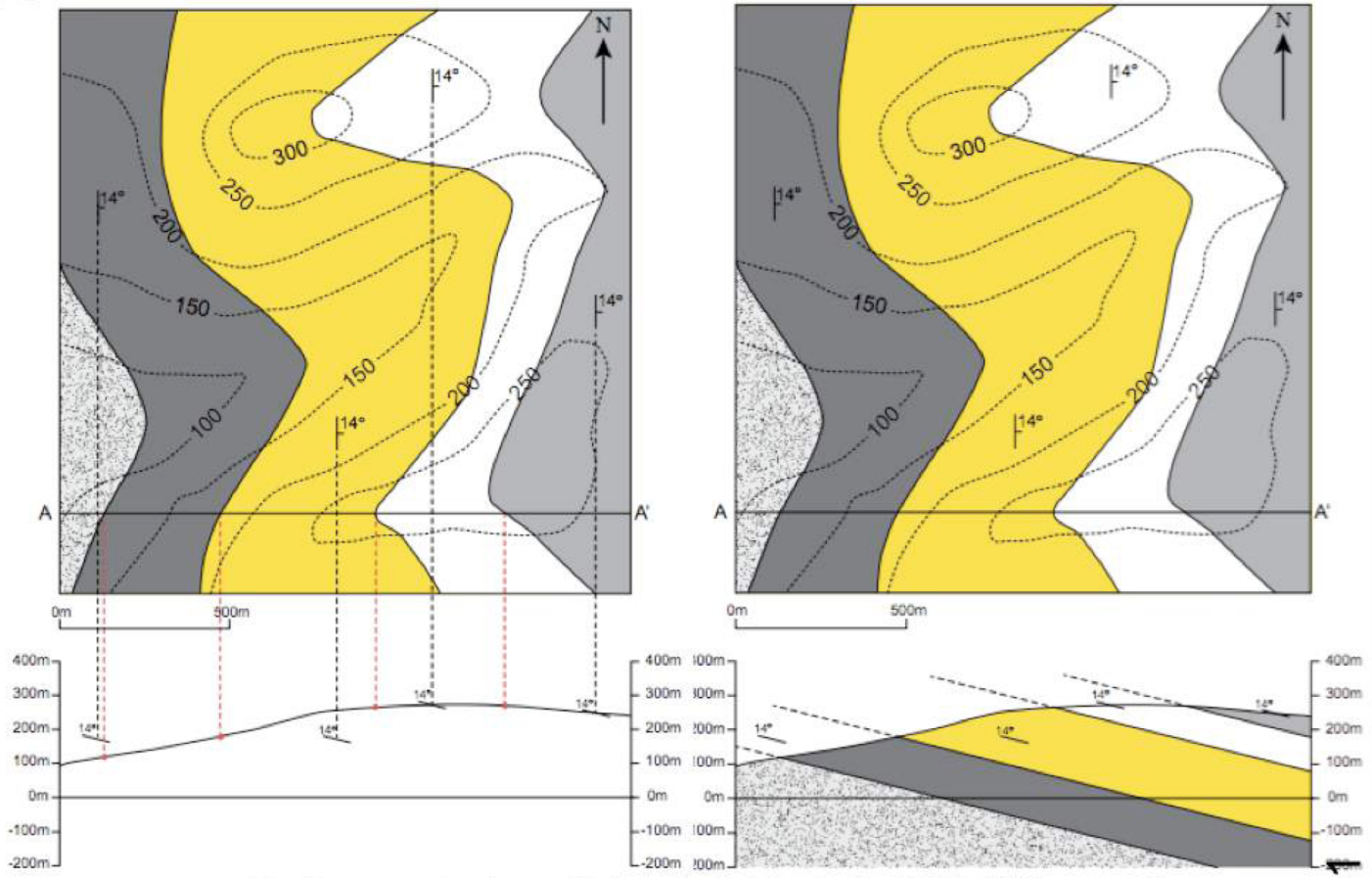


http://www.see.leeds.ac.uk/stepup/pdfs/Introduction%20to%20maps.pdf

Cross Section

b. Projecting mapped features

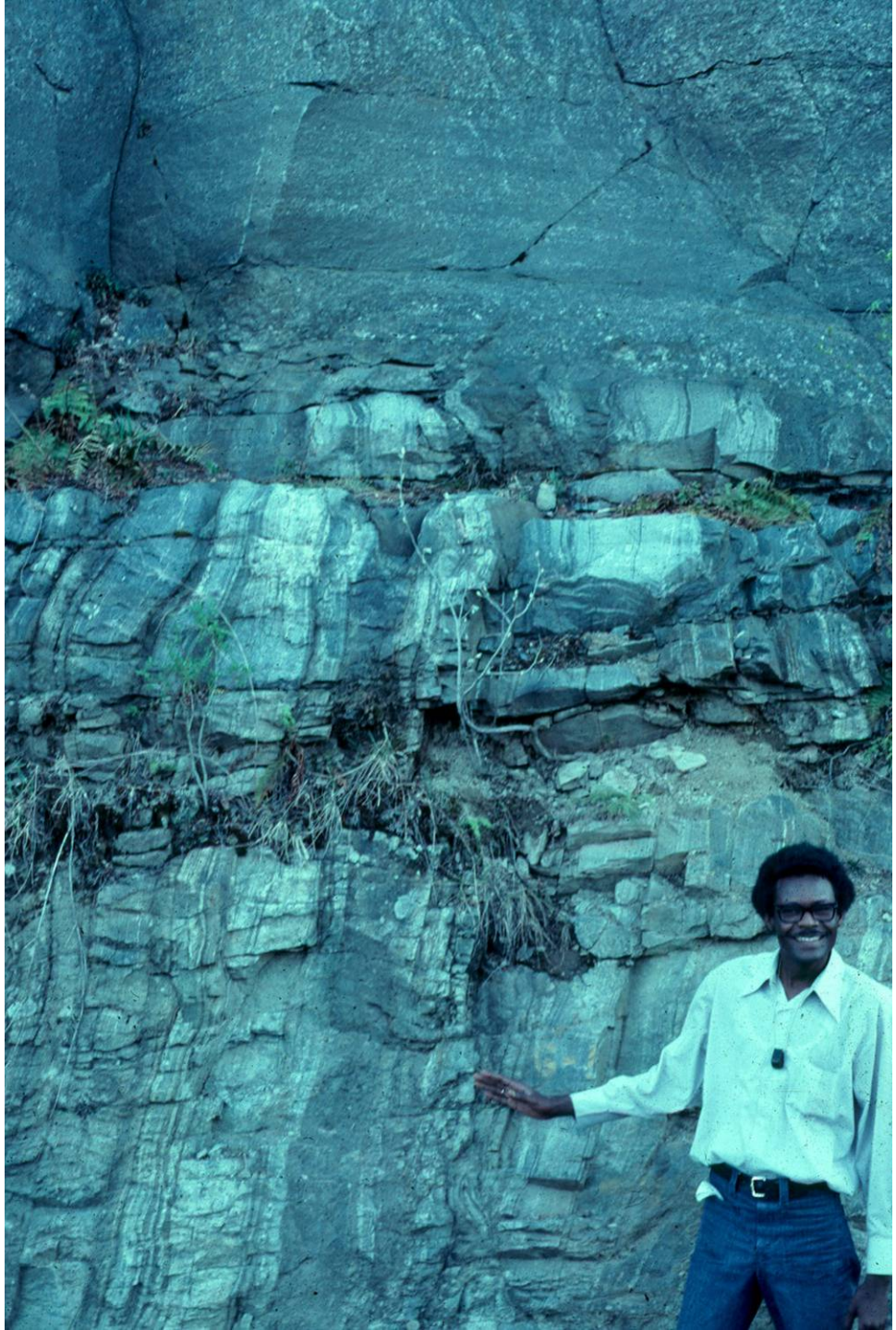
→ Map Symbols
→ Apparent Dip
→ True Dip



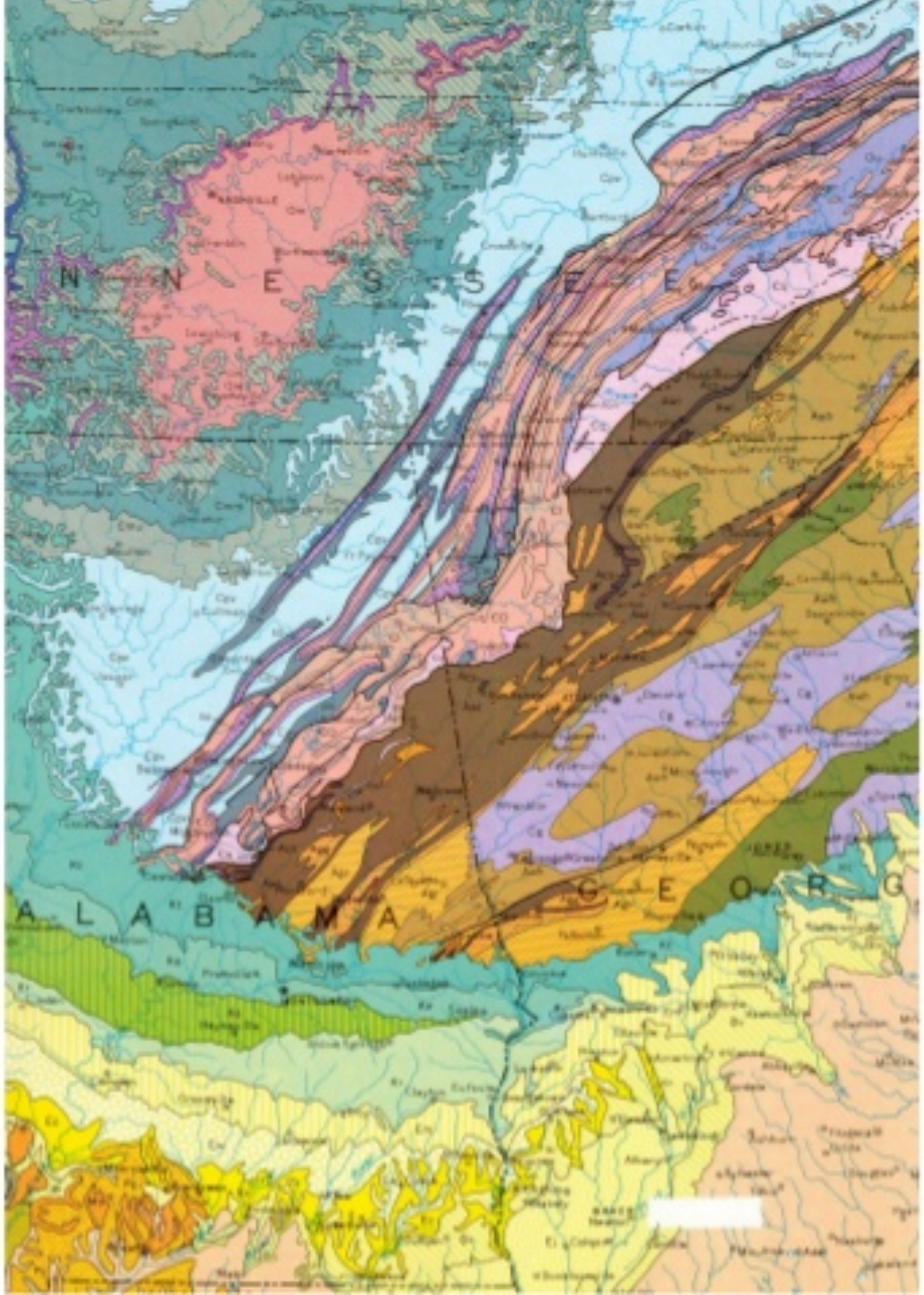
http://www.see.leeds.ac.uk/stepup/pdfs/Introduction%20to%20maps.pdf

Types of contacts on a geologic map

- Conformable (beds in sequence) contact
- Unconformity (period of erosion before younger layer deposited)
  - Disconformity (sed rx below), nonconformity (ig/met rx below), angular unconformity
- Fault contact
- Intrusive contact



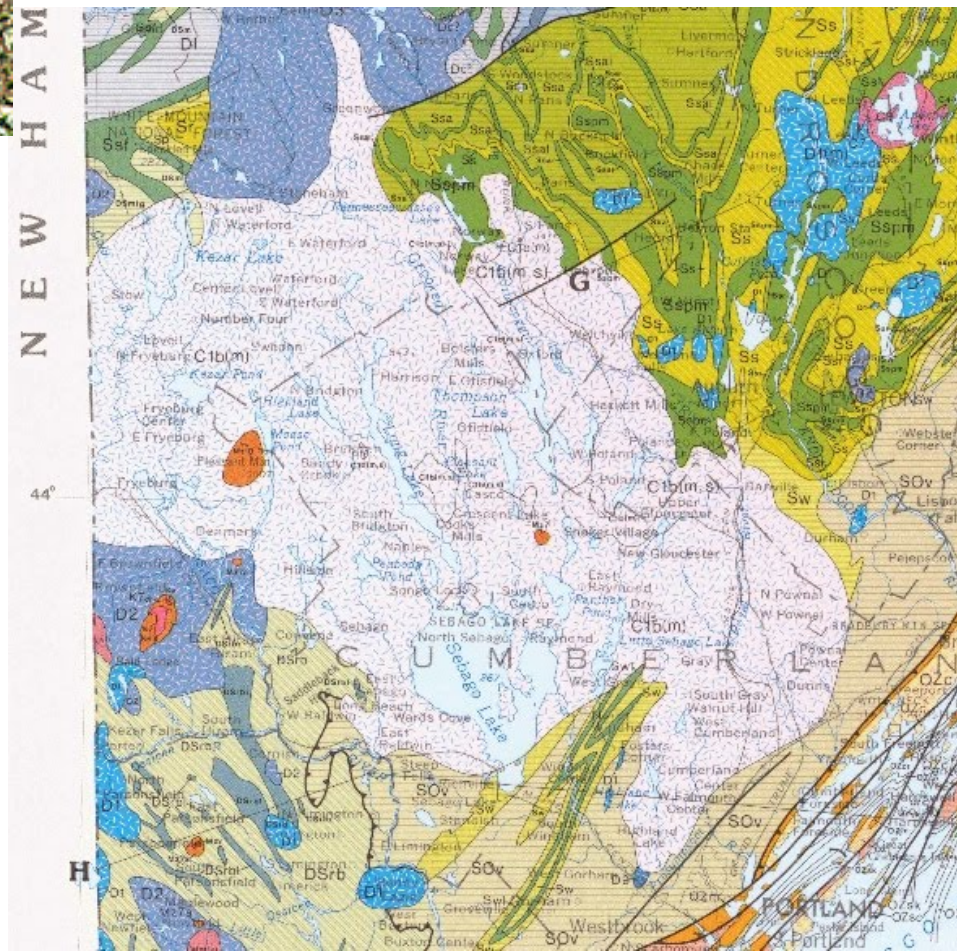
Geologic Map of the southern Appalachians. Note the Nashville Dome, folds, faults, and an unconformity.



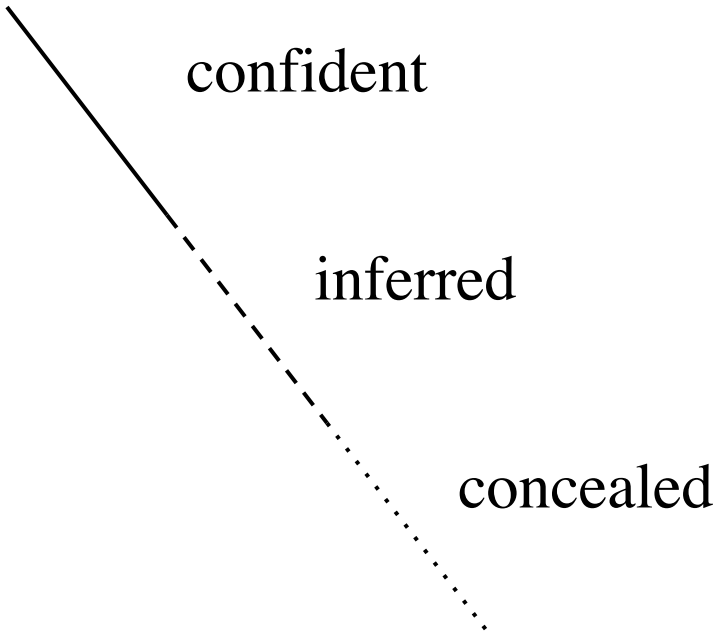
http://image.slidesharecdn.com/geologicmaps-141012161350-conversion-gate01/95/geologic-maps-21-638.jpg?cb=1413130482

Intrusions, such as this **dike**, typically cut across layers

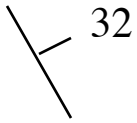
On a geologic map, look for truncation of contacts by an igneous rock type



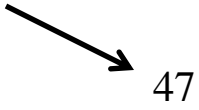
Contacts



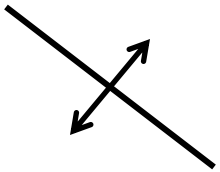
Map Symbols for Structures



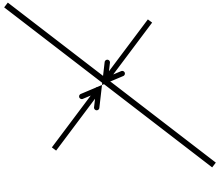
strike and dip (of a plane)



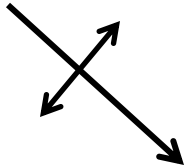
trend and plunge (of a line)



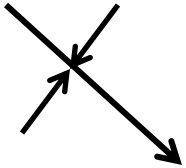
anticline



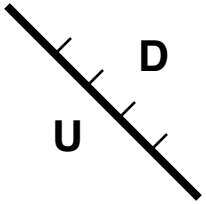
syncline



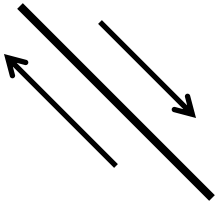
plunging anticline



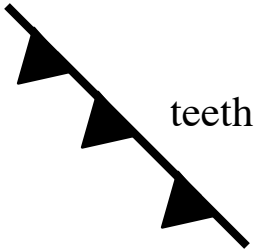
plunging syncline



normal fault



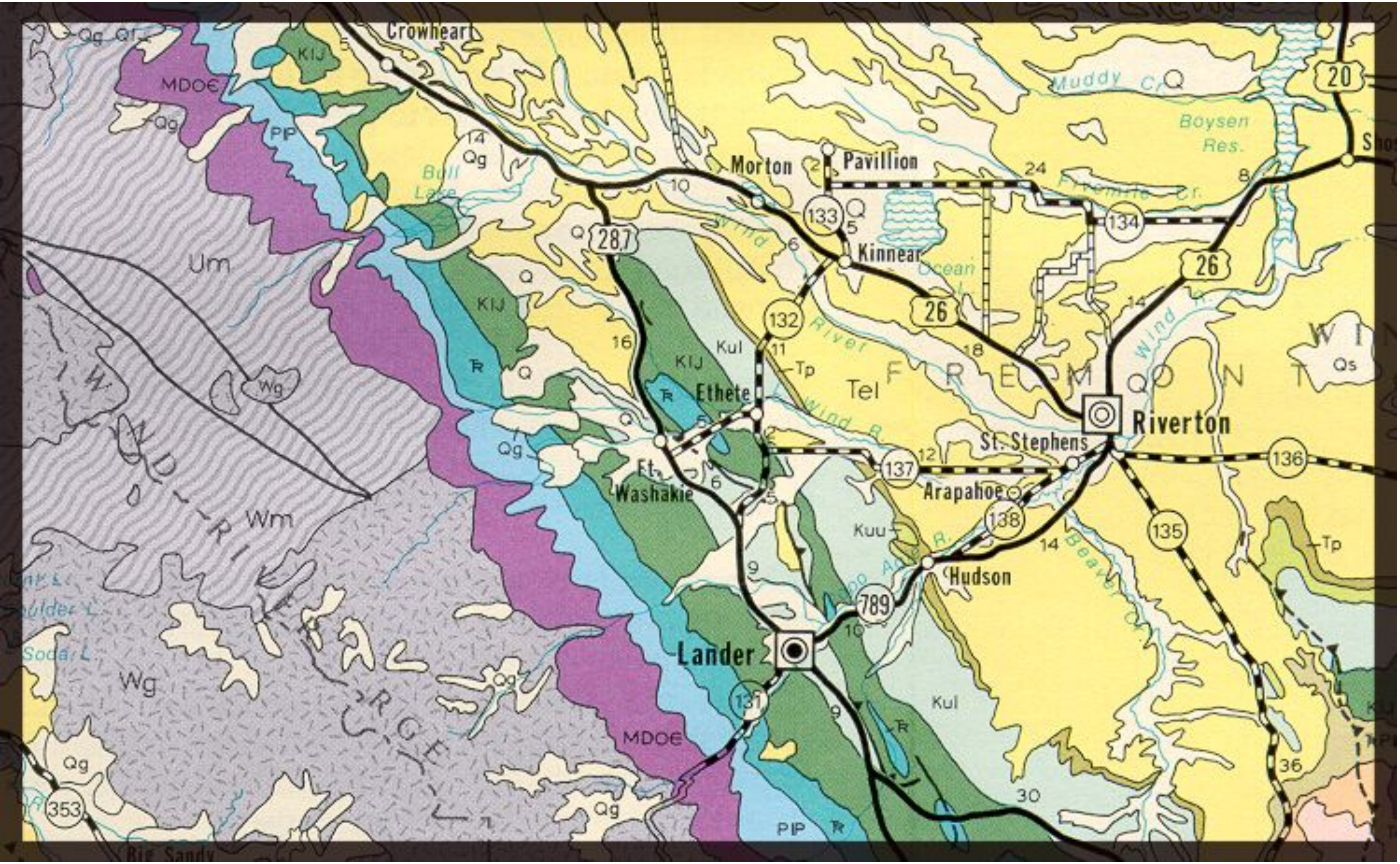
strike-slip fault



thrust fault

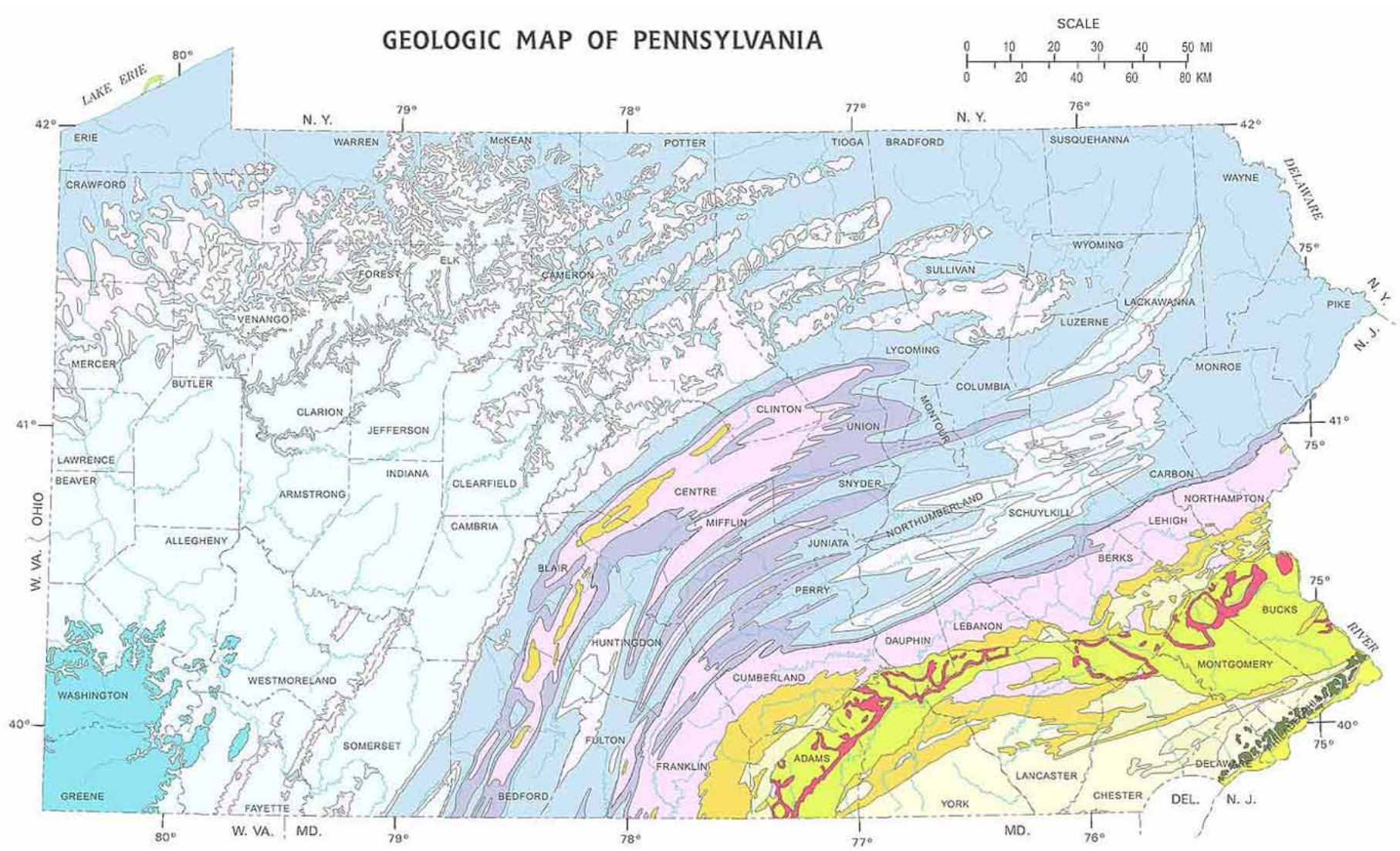
Rule of V's

On a geological map, when contacts cross a stream valley, they make a "V" that points in the same direction that the layers dip.



Crowheart
Morton
Pavillion
Kinnear
Ethete
Ft. Washakie
Riverton
St. Stephens
Arapahoe
Hudson
Lander
Muddy Cr.
Boysen Res.
Bull Lake
Wind River
Ocean L.
Wind R.
Beaver Cr.
Popo Agie R.
Soda L.
Boulder L.
Big Sandy
WIND RIVER RANGE
FREMONT COUNTY
20
26
287
132
133
134
135
136
137
138
789
131
353
MDOЄ
PIP
KIJ
Kul
Kuu
Tel
Tp
Qg
Qs
Q
Um
Wm
Wg

GEOLOGIC MAP OF PENNSYLVANIA



EXPLANATION

QUATERNARY (0–2 mil. yrs.)
Sand, gravel, and silt.
Sand and gravel.

TERTIARY (2–67 mil. yrs.)
Sand, gravel, silt, and clay.
Sand and gravel.

JURASSIC AND TRIASSIC (140–250 mil. yrs.)
Red sandstone, shale, and conglomerate (green), intruded by diabase (red).
Building stone, iron.

PERMIAN (250–290 mil. yrs.)
Cyclic sequences of shale, sandstone, limestone, and coal.
Lime, clay.

PENNSYLVANIAN (290–330 mil. yrs.)
Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, coal, and limestone.
Coal, clay, lime, building stone.

MISSISSIPPIAN (330–365 mil. yrs.)
Red and gray sandstone, shale, and limestone.
Flagstone, limestone, clay.

DEVONIAN (365–405 mil. yrs.)
Red sandstone, gray shale, black shale, limestone, and chert.
Flagstone, silica sand, clay, lime.

SILURIAN (405–430 mil. yrs.)
Red and gray sandstone, conglomerate, shale, and limestone.
Lime, building stone.

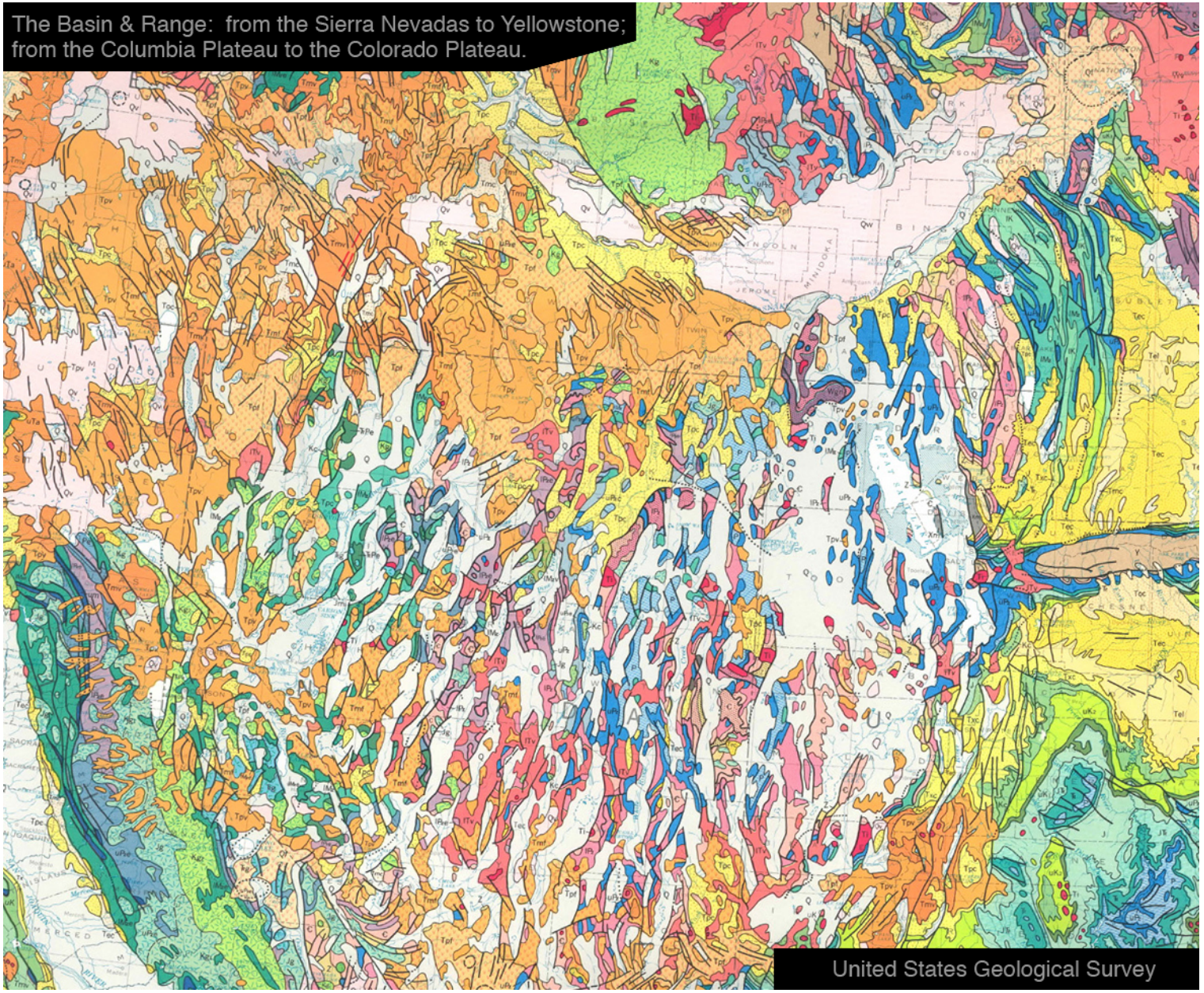
ORDOVICIAN (430–500 mil. yrs.)
Shale, limestone, dolomite, and sandstone.
Slate, limestone, zinc, clay.

CAMBRIAN (500–570 mil. yrs.)
Limestone, dolomite, sandstone, shale, quartzite, and phyllite.
Lime, building stone.

LOWER PALEOZOIC (430–570 mil. yrs.)
Metamorphic rocks (metasedimentary and meta-igneous); schist, gneiss, quartzite, serpentine, slate, and marble.
Building stone, talc.

PRECAMBRIAN (older than 570 mil. yrs.)
Gneiss, granite, anorthosite, metadiabase, metabasalt, metarhyolite, and marble.
Building stone, graphite, sericite.

http://www.newtowngrant.org/PA/geology1.jpg



Geologic Map of parts of Nevada and neighboring states

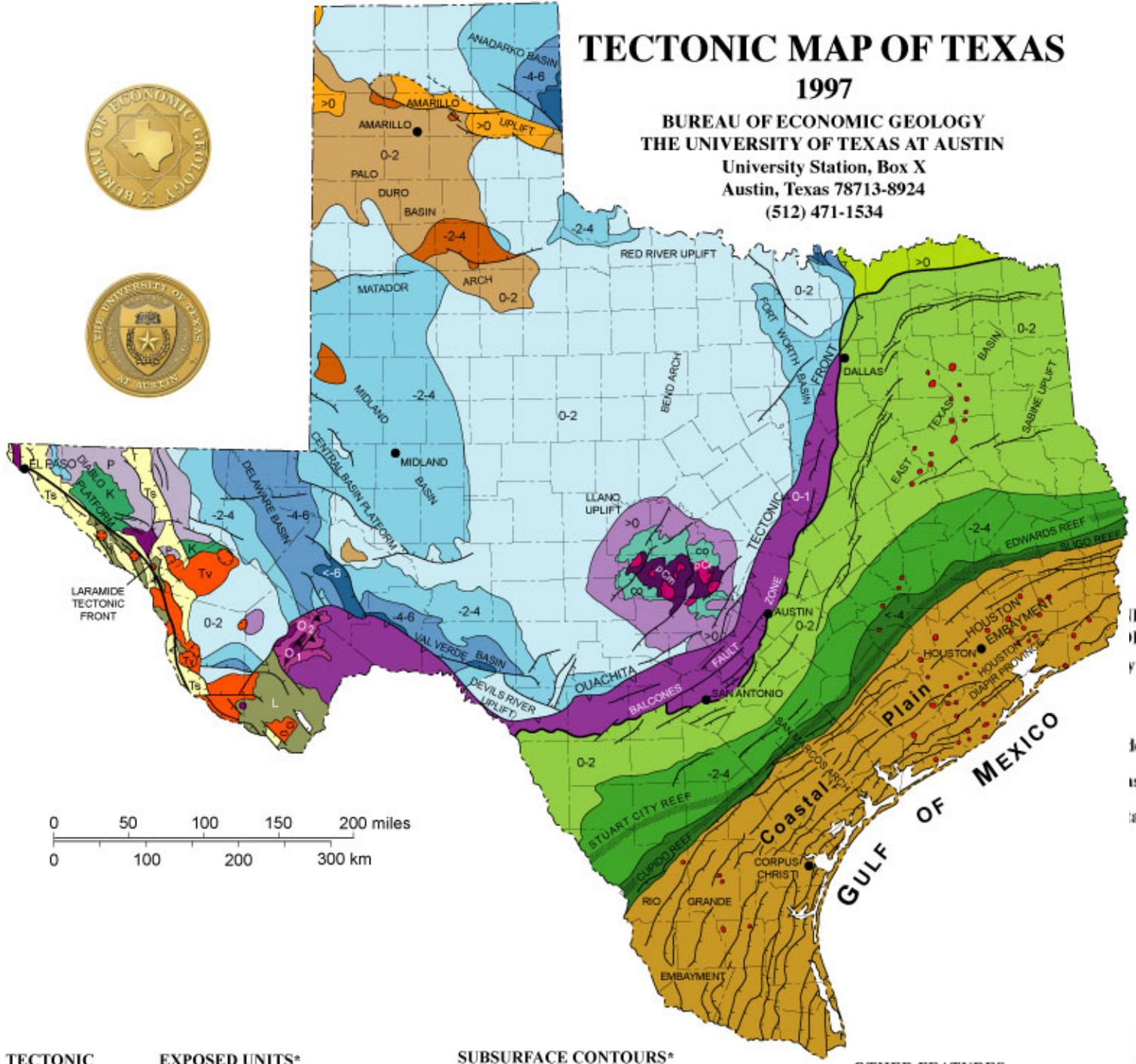
http://www.gly.uga.edu/railsback/DPT/Basin&RangeGeolMapforDPT.jpg

TECTONIC MAP OF TEXAS

1997

BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN
University Station, Box X
Austin, Texas 78713-8924
(512) 471-1534

http://www.lib.utexas.edu/geo/pics/tectonic2.jpg



EXPOSED UNITS*

- Ts — Late Tertiary extensional basin
- Tv — Trans-Pecos igneous
- L — Deformed Cretaceous strata
- K — Cretaceous strata
- **Foreland:**
  - P — Upper Paleozoic
  - CO — Lower Paleozoic
- **Marathon:**
  - O_2 — Upper Paleozoic flysch
  - O_1 — Lower Paleozoic
- pCi — Precambrian igneous
- pCm — Precambrian metamorphic

TECTONIC EPISODE

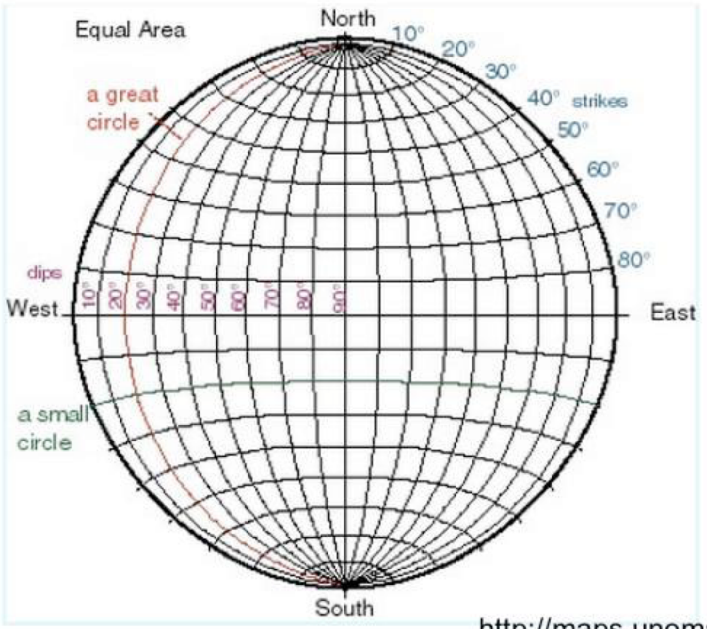
EXPOSED UNITS*

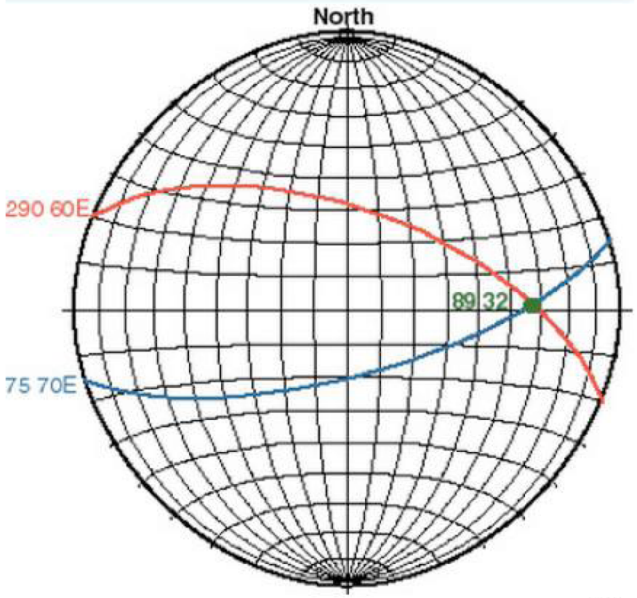
SUBSURFACE CONTOURS*
(elevation in kilometers**)

OTHER FEATURES

c. Representing Measurements

- **Strike and Dip of Planes**
  - ① Map Symbols
    - Inclined, horizontal, vertical
    - Legend
  - ② Stereonets
    - → Definitnion
    - → Uses





http://maps.unomaha.edu/maher/geol3300/lab/lab5.html

1. Reading 2. Drawing 3. Interpreting

Map Components

a. Map

b. Legend

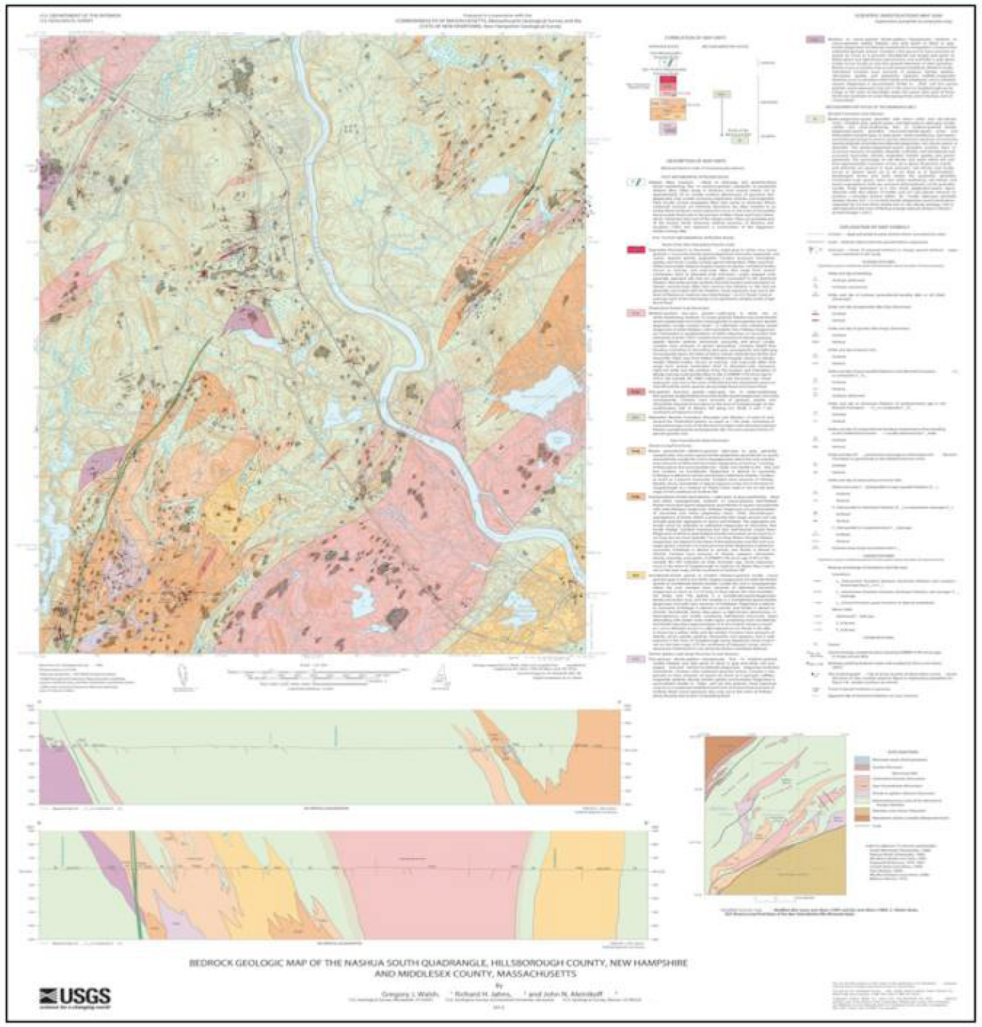
c. Map Margins

d. Cross Section

e. Correlation Map Unit

f. Geologic Structure map

g. Source of Geological Data



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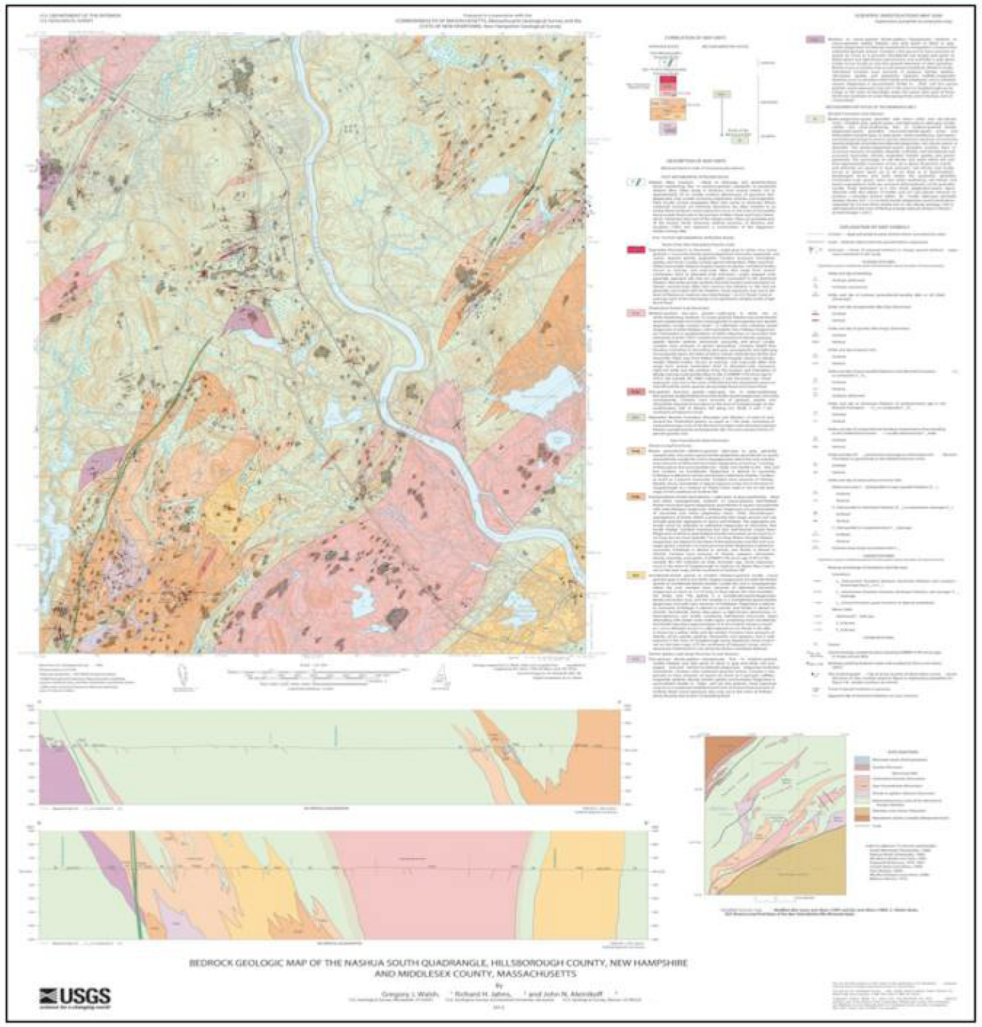
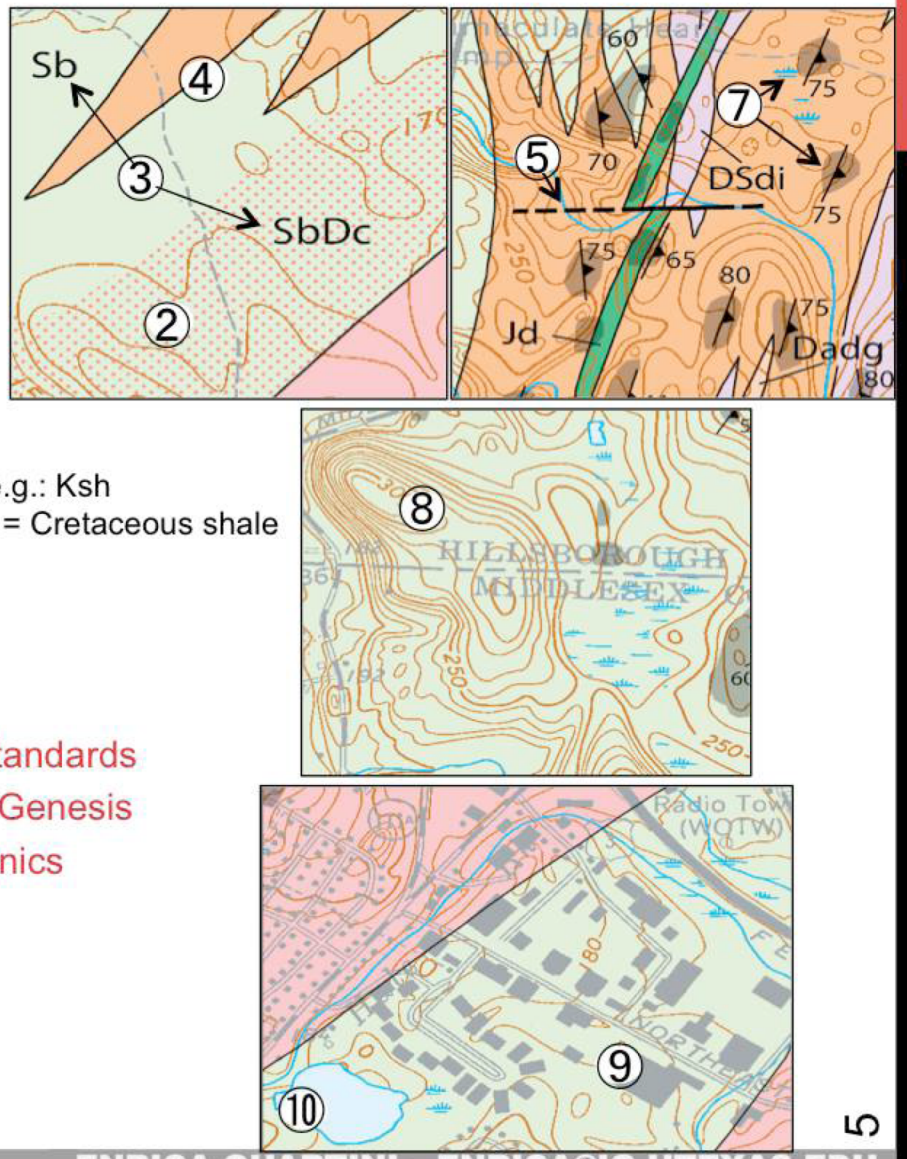


a. Map

- **Geologic Units (Formations):**
  - ① Color
    - American and International Standards
    - Palette for Different Rock Types
  - ② Symbols: patterns on colors
  - ③ Set of letters
    - First letter: Age → Geological Time Scale
    - Follows: Name of Rock Unit or Rock Type e.g.: Ksh = Cretaceous shale
  - ④ Contact lines
    - Depositional
    - Tectonic
    - Contact Types
    - Unconformities

- **Geologic Structures**
  - ⑤ Faults
  - ⑥ Folds
  - ⑦ Strike/Dip, Plunge/Trend
    - Symbols Standards
    - Types and Genesis
    - Plate Tectonics

- **Topography**
  - ⑧ Contour lines
  - ⑨ Roads, Towns
  - ⑩ Rivers, Lakes



Resources

Reading geologic maps: http://education.usgs.gov/
http://geomaps.wr.usgs.gov/parks/gmap/index.html#what
http://geology.about.com/

Download geologic maps: http://store.usgs.gov/

Map Projections: http://pubs.usgs.gov/fs/2001/0077/report.pdf
http://egsc.usgs.gov/isb//pubs/MapProjections/projections.html

Geohazards: http://geohazards.usgs.gov/

Other Links

- http://avenzamaps.com
- http://store.usgs.gov
- https://www.nc-maps.com/
- https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-publications
- https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html