GEO203 Field Experience 3

Local and Regional Geology of Princeton, NJ

Sunday, November 6, 2022

Name: ______________________________________

Route of the Day

$\boxed{\text{Stop 1}}$ Washington Rd, just north of Lake Carnegie

$\boxed{\text{Stop 2}}$ Princeton Professional Center, Mt. Lucas Rd., Princeton

$\boxed{\text{Stop 3}}$ Herrontown Woods, Princeton

$\boxed{\text{Stop 4}}$ Rte 539 N of Frenchtown, NJ

$\boxed{\text{Stop 5}}$ Rte 611 south of Riegelsville, PA

At each stop

- Keep oriented – locate each stop on the various maps/images provided.
- Record observations on the pages provided for each stop - what do you see? Describe the rocks and structures present at the stop. Use annotated sketches or diagrams to show relationships or to emphasize particular features. Be sure to include something to indicate the scale.
- Interpret what you are seeing in terms of geologic processes and geologic history.
- Understand the context - how does this stop relate to others on the trip? How do they fit together in the regional picture?

What to turn in

This notes you take in this guidebook will be neither collected nor graded - but will be the basis on which you'll answer the required questions on the next page. (These will be submitted via a Jupyter notebook that will be published on Monday.)

Questions to answer *Jupyter notebook will be uploaded on Monday*

1. We will see four geologic formations today: Stockton, Passaic, Rocky Hill, Highlands. Make a list, with the youngest formation at the top of the list and the others in progressively order of age with the oldest at the bottom. In a few sentences name and describe the rock type(s) of each formation.

2. Compare/contrast the Passaic formation you saw at stops 4 (Frenchtown) and 5 (Riegelsville). The rocks are of similar age, and both lie within the Newark rift basin that marks the initial breakup of Pangea. There are no major faults or other deformational structures between them. Yet the rocks at the two stops have different rock types and sedimentary structures. What are the differences, and why are the rocks so different at these two places.

3. Describe evidence for the "Border Fault" at stop 5. The fault itself is not exposed. What is the evidence that there is a fault there, and that there is a major amount of displacement along it?

4. In bullet-list form, make a sequential., generalized list of events that summarize the geologic history of the area, based on observations and discussions during the trip. Your list should include things we saw evidence for, including:
    - formation of the various geologic units
    - igneous events
    - deformation events
    - episodes of erosion and exposure

Two equally important characteristics of rocks:

Rock composition: the minerals, fossils, and other material that make up a rock. Rock composition gives information about the source material for the rock, as well as about processes that occurred during rock formation. In the field, composition is mostly based on identifying the minerals present in a rock. When mineral grains are large, this is relatively easy if you are familiar with a dozen or so common rock-forming minerals. When grains are small, this is difficult but you can often use color to give you general clues about composition.

Rock texture: how the compositional components of a rock are put together. Rock texture gives much information about processes that occurred during rock formation. Train your eye by considering three important observations:

- Is the rock layered? *Most sedimentary rocks are layered. Most igneous rocks are not layered. Metamorphic rocks can be layered or unlayered.*
- Does the rock have clastic or crystalline texture? In *clastic* rocks, discrete grains are held together by cementing material between the grains. In *crystalline* rocks, mineral grains are intergrown so that their grain boundaries interfinger in a jigsaw-puzzle type pattern. N.B. If grains are too small, you can't make this observation with your naked eye. *Most sedimentary rocks are clastic, with the exception of chemical sediments that precipitate out of water. Virtually all igneous and metamorphic rocks are crystalline.*
- What is the grain size or range of grain sizes in the rock? Once a rock has been classified by igneous, metamorphic, or sedimentary ,further classification is partly based on grain size.

Common sedimentary rocks (mostly clastic, some limestones are crystalline):

Limestone: comprised primarily of the mineral calcite ($CaCO_3$, applying acid will result in the formation of bubbles (release of CO_2 gas)). Calcite occurs as fossils (shells, etc.) and/or as a chemical sediment formed by precipitating out of water. Dolostone (dolomite) is similar to limestone, but some of the Ca is replaced by Mg. This rock only bubbles if pulverized into small particles before HCl is applied.

Shale: clastic sedimentary rock comprised of clay particles too small to see with the naked eye. Usually a soft, finely-layered rock that looks like compressed mud.

Sandstone: clastic sedimentary rock comprised of sand grains or other sand-sized particles that be been cemented together. Usually gritty to the touch.

Conglomerate: clastic sedimentary rock comprised of poorly-sorted particles of a variety of sizes (clay, sand, pebbles) that have been cemented together.

Common igneous rocks:

		COMPO-SITION	
		Dark in color, dense	Light in color and density
		low in Si, high in Fe & Mg	high in Si, low in Fe & Mg
		minerals: pyroxene, fedlspar, olivine	minerals: quartz, feldspar, mica
TEXTURE	Fine-grained (aphanitic) --> cooled quickly --> extrusive, volcanic	**BASALT**	**RHYOLITE**
TEXTURE	Coarse-grained (phaneritic) --> cooled slowly --> intrusive, plutonic	**GABBRO**	**GRANITE**

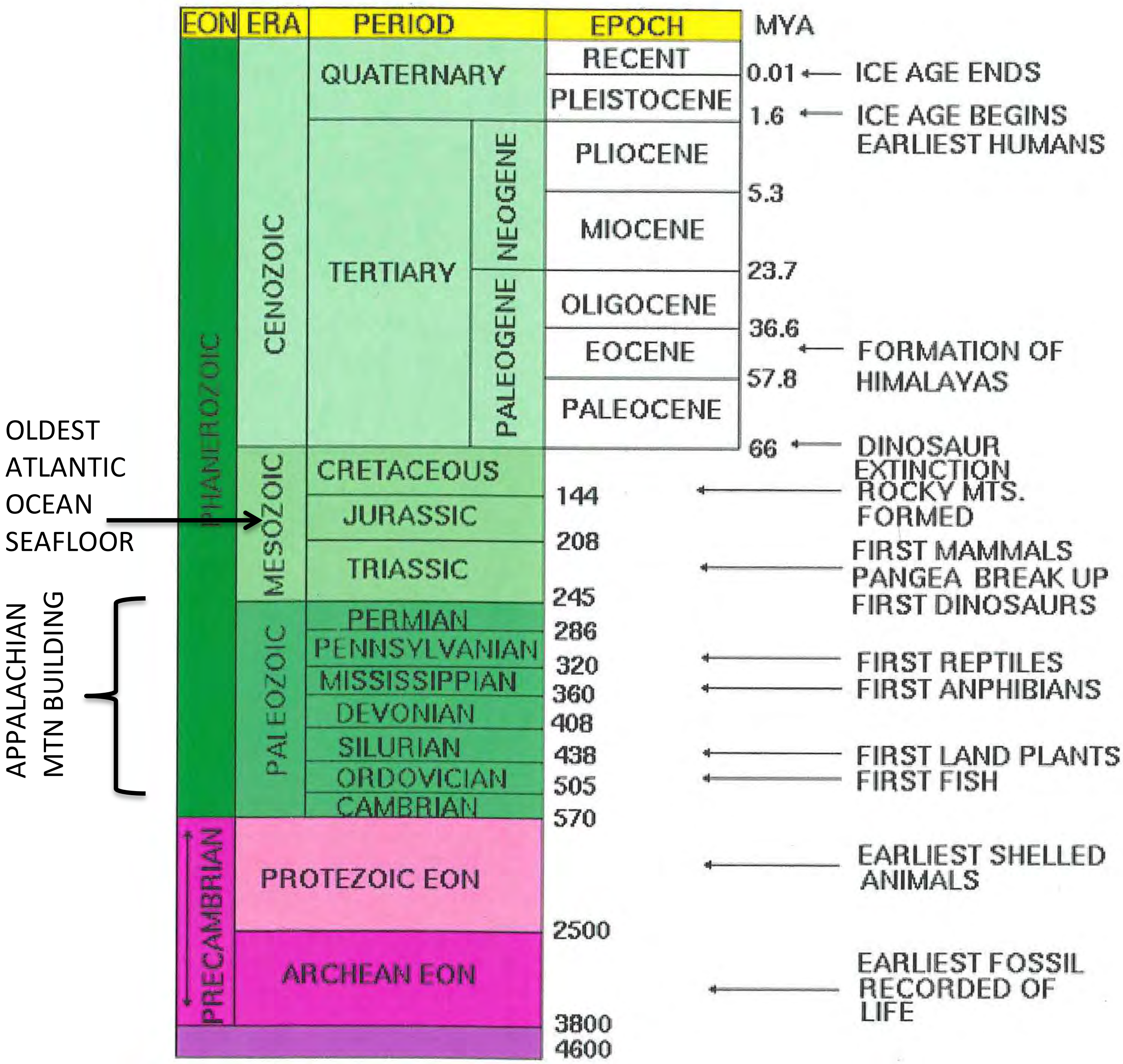
Common metamorphic rocks (crystalline texture; can be layered or unlayered):

Slate: finely-layered rock which splits parallel to the alignment of fine-grained platy minerals (micas)
Schist: coarser-grained rock with layering defined by parallel alignment of micas
Gneiss: coarse- grained rock characterized bysegregation of minerals into different layers
Marble: metamorphic rock comprised primarily of calcite
Quartzite: metamorphic rock comprised primarily of quartz

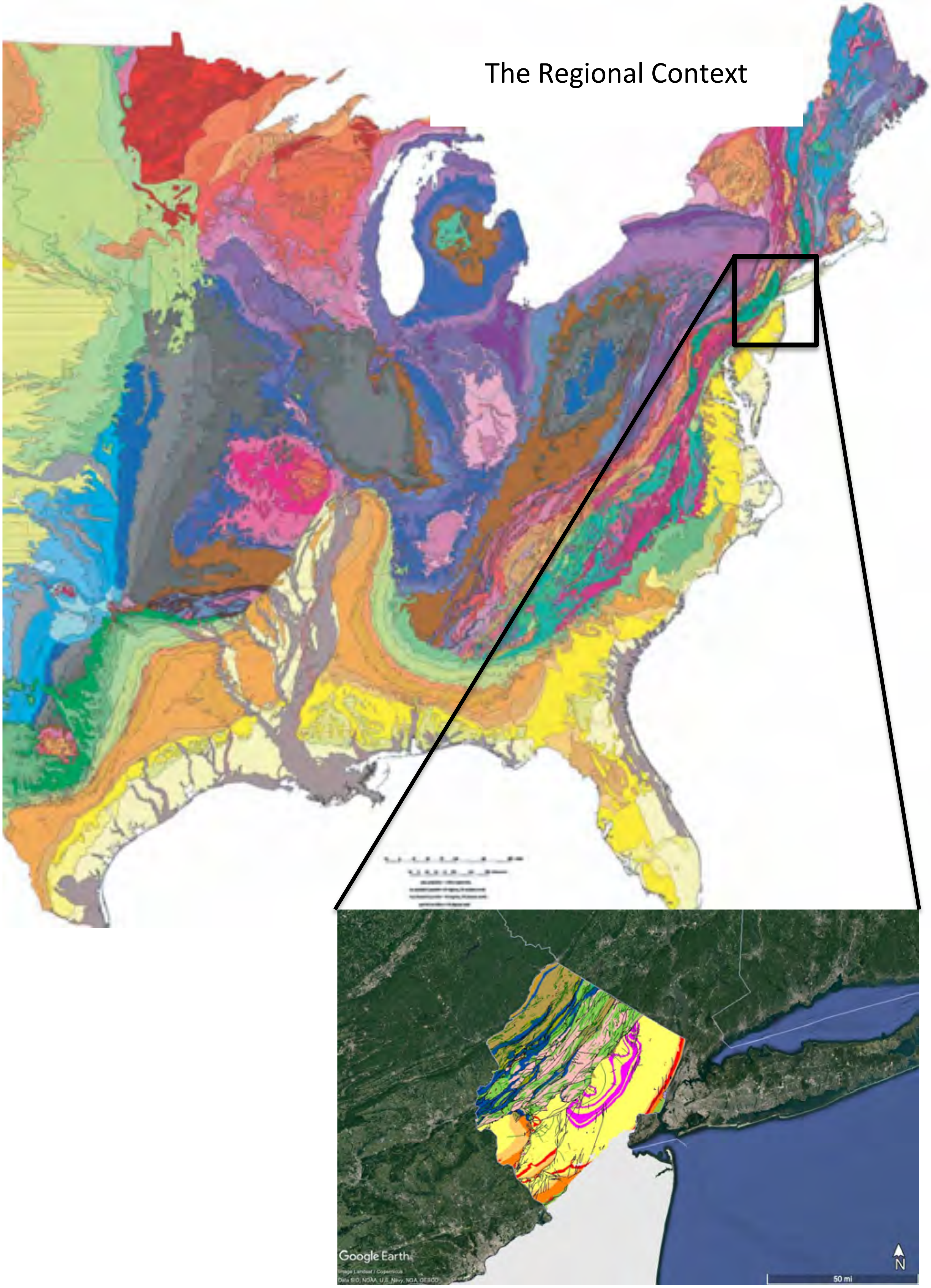
Principles of relative dating of geologic structures and events:

Principle of original horizontality of sedimentary layering - sediments are deposited as horizontal layers
Principle of superposition of undeformed sedimentary layering - oldest on the bottom
Principle of igneous intrusions - intrusions must be younger that the rocks they intrude
Principle of cross-cutting relationships – structures must be younger than structures/rock units they cut

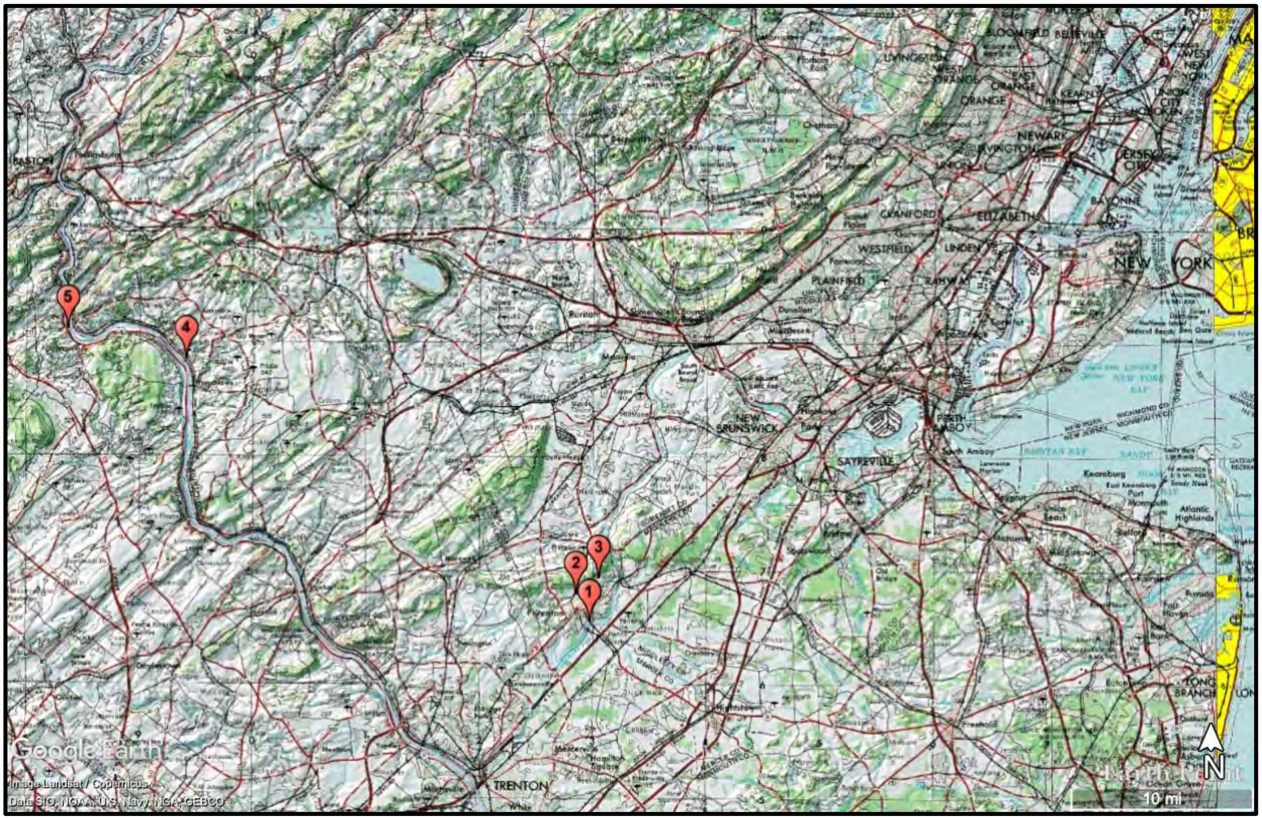
(Simplified) **GEOLOGIC TIME SCALE**

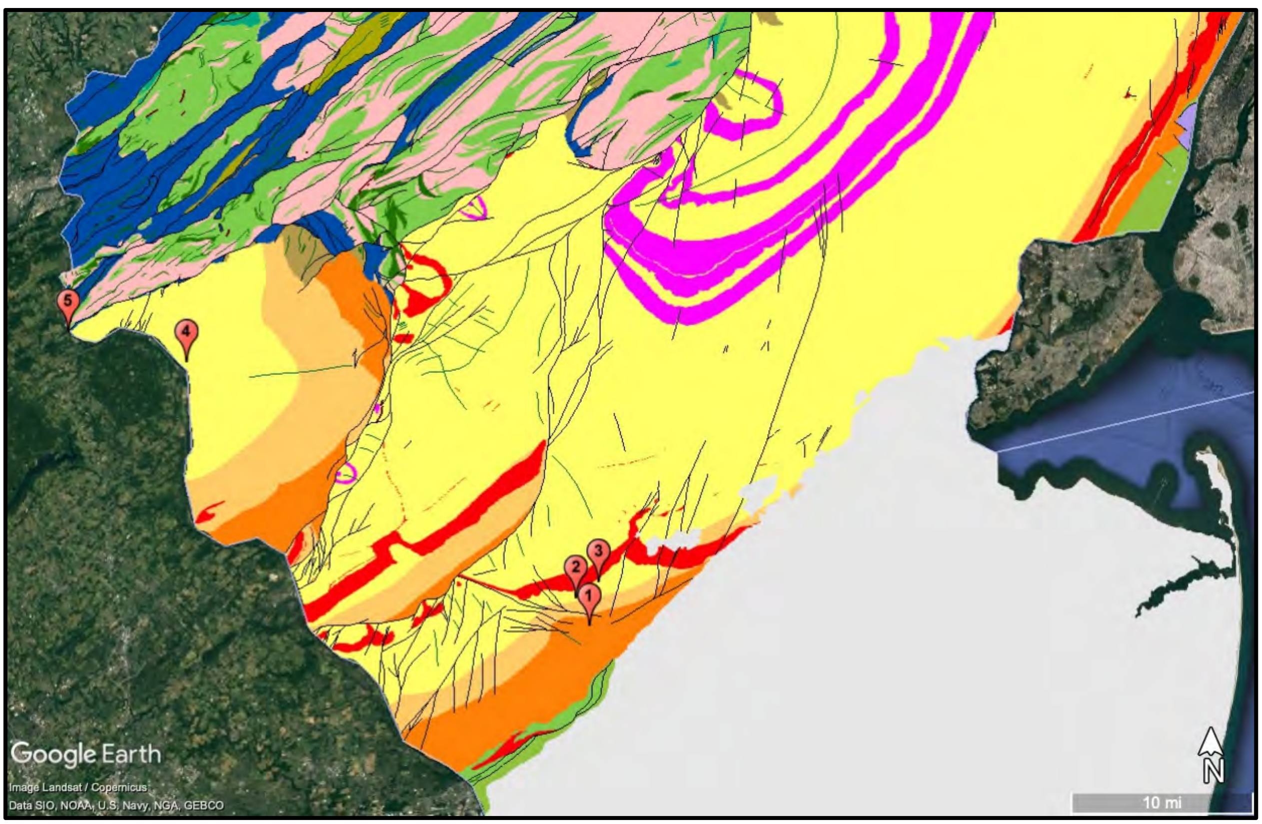


The Regional Context



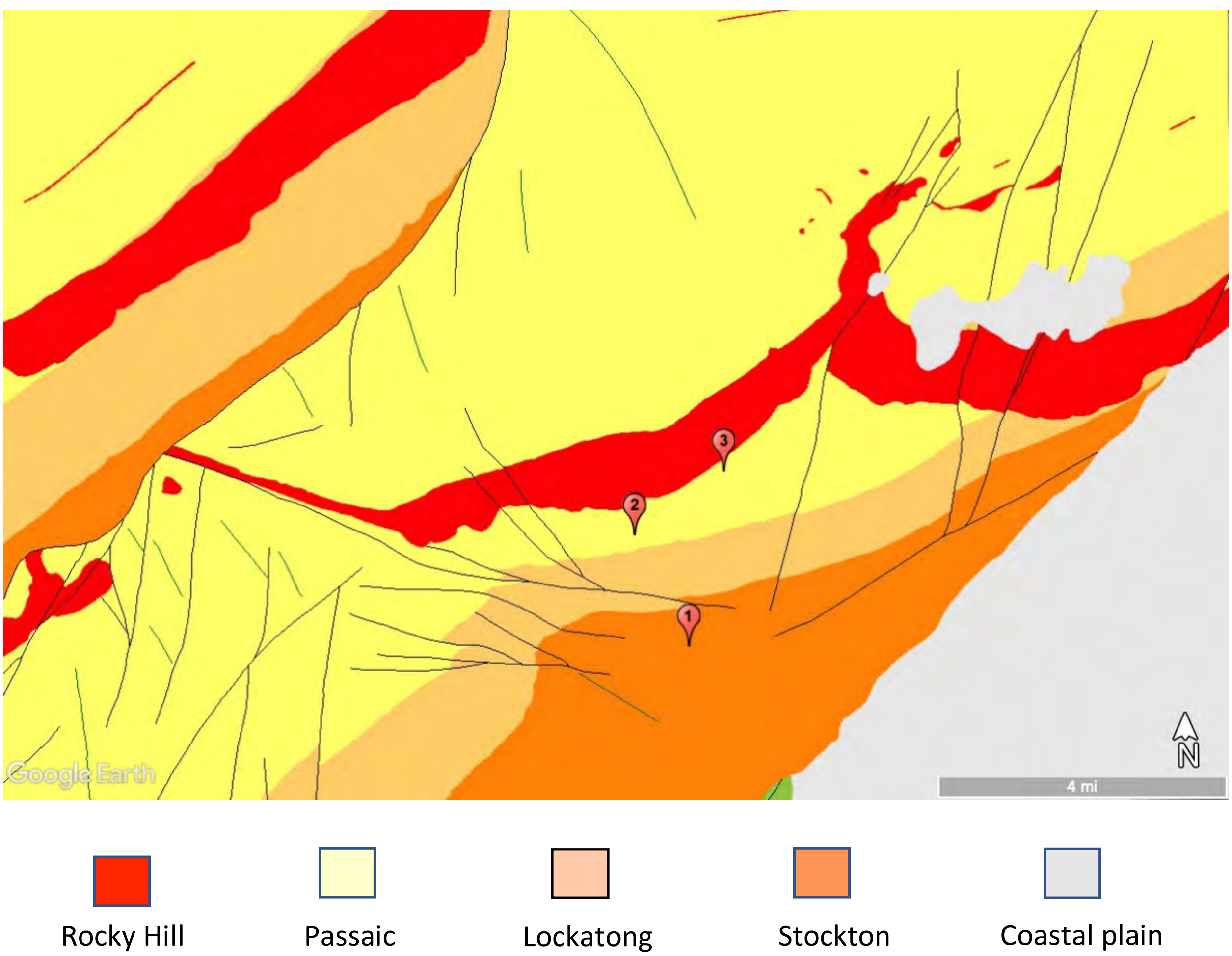
Overview of stops: topography, geology

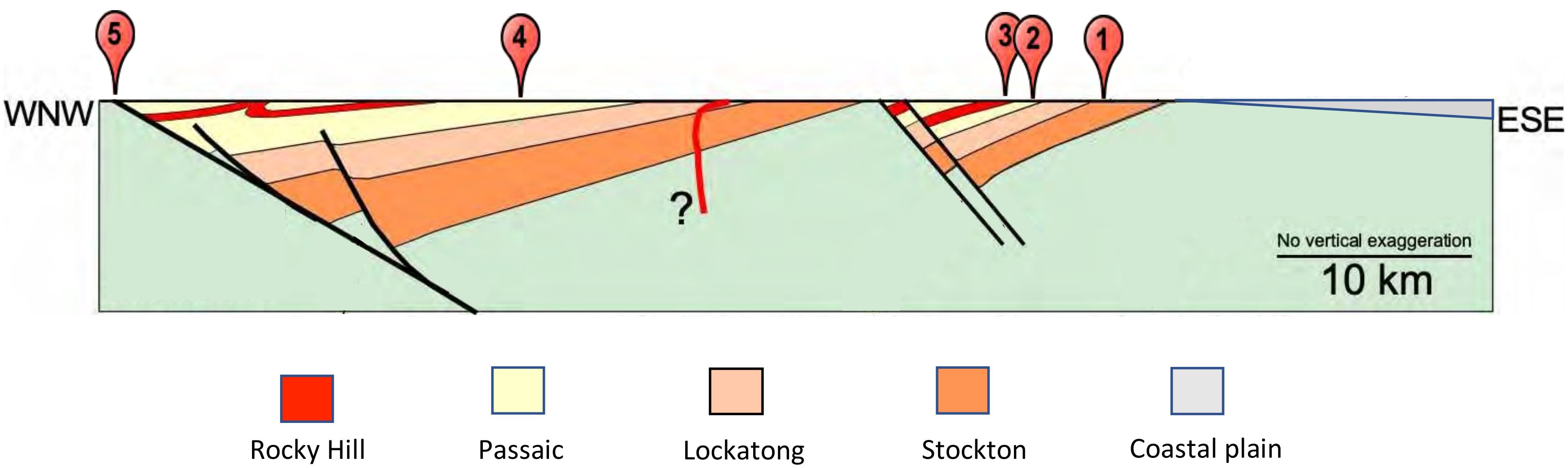




Rocky Hill | Passaic | Lockatong | Stockton | Coastal plain

Close-up of Princeton area stops



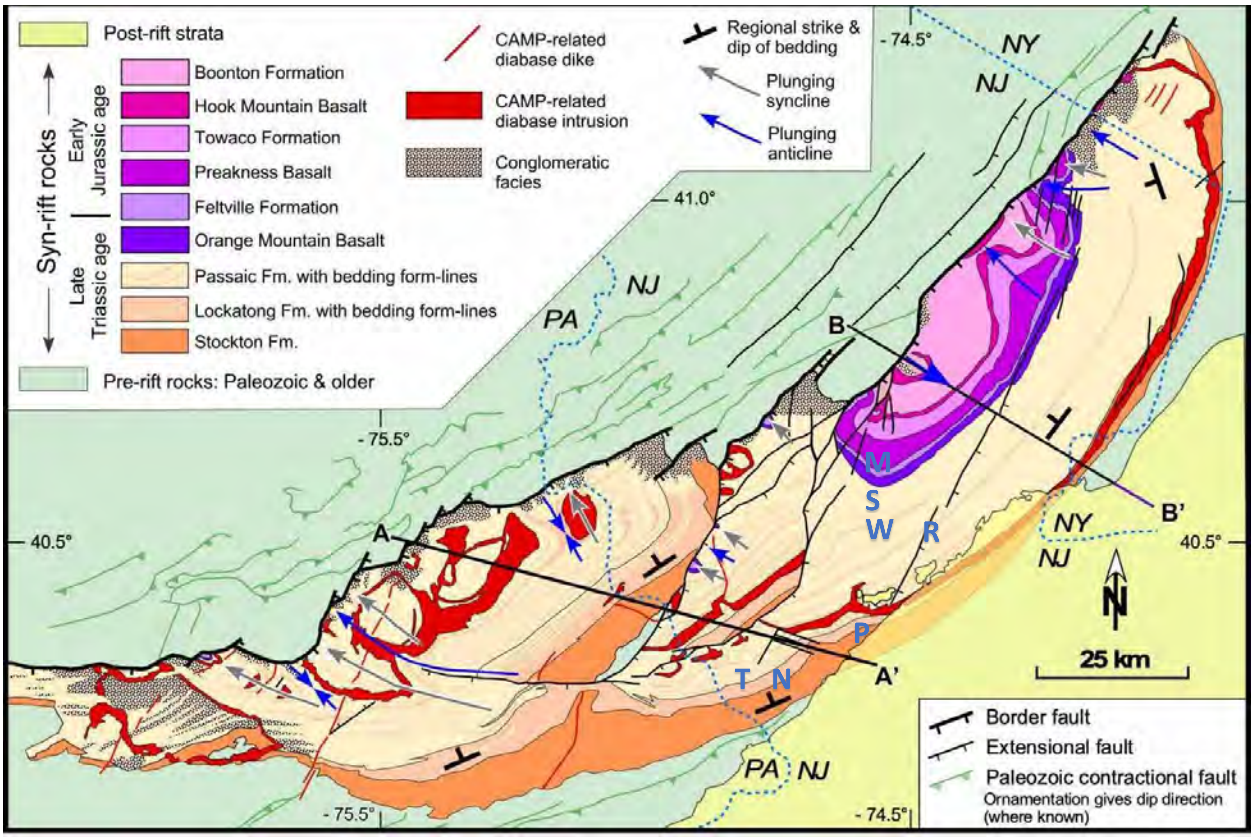

5
4
3
2
1
WNW
ESE
?
No vertical exaggeration
10 km
Rocky Hill
Passaic
Lockatong
Stockton
Coastal plain

Newark Basin Coring Project

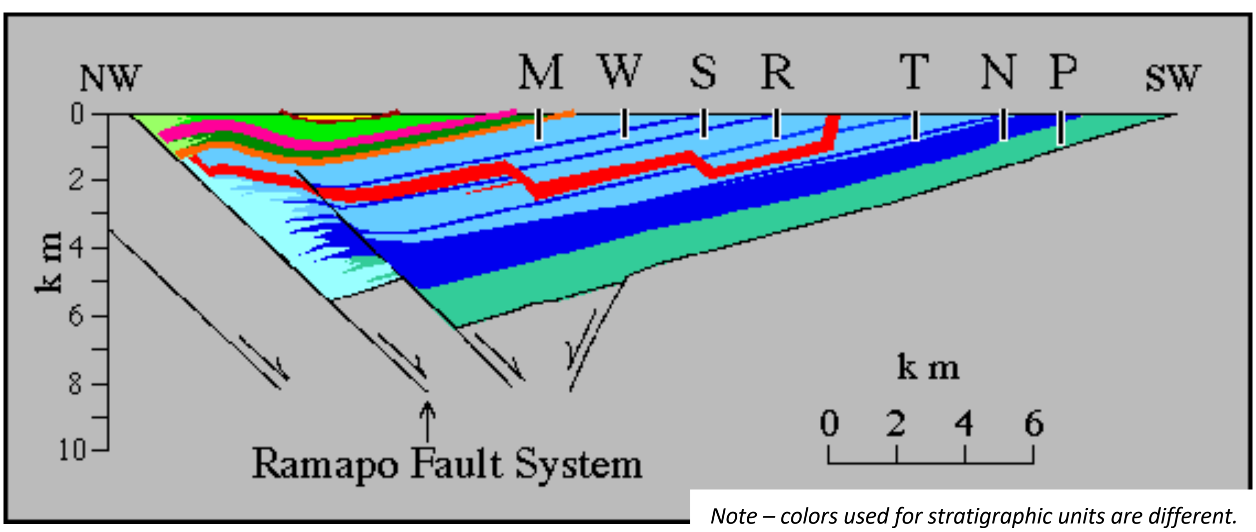
The 1989-1994 NSF-funded Newark Basin Coring Project (NBCP) had three main goals:

- recover a detailed record of ancient continental climate,
- unravel the history of one of the largest/longest lived rift basins
- produce a magnetic polarity time scale for the Late Triassic.

6668m of nearly continuous core stored at the Rutgers Core Repository



M, W, S, R, T, N, P = *locations of cores and* **P** = *Princeton, Forrestal Campus*

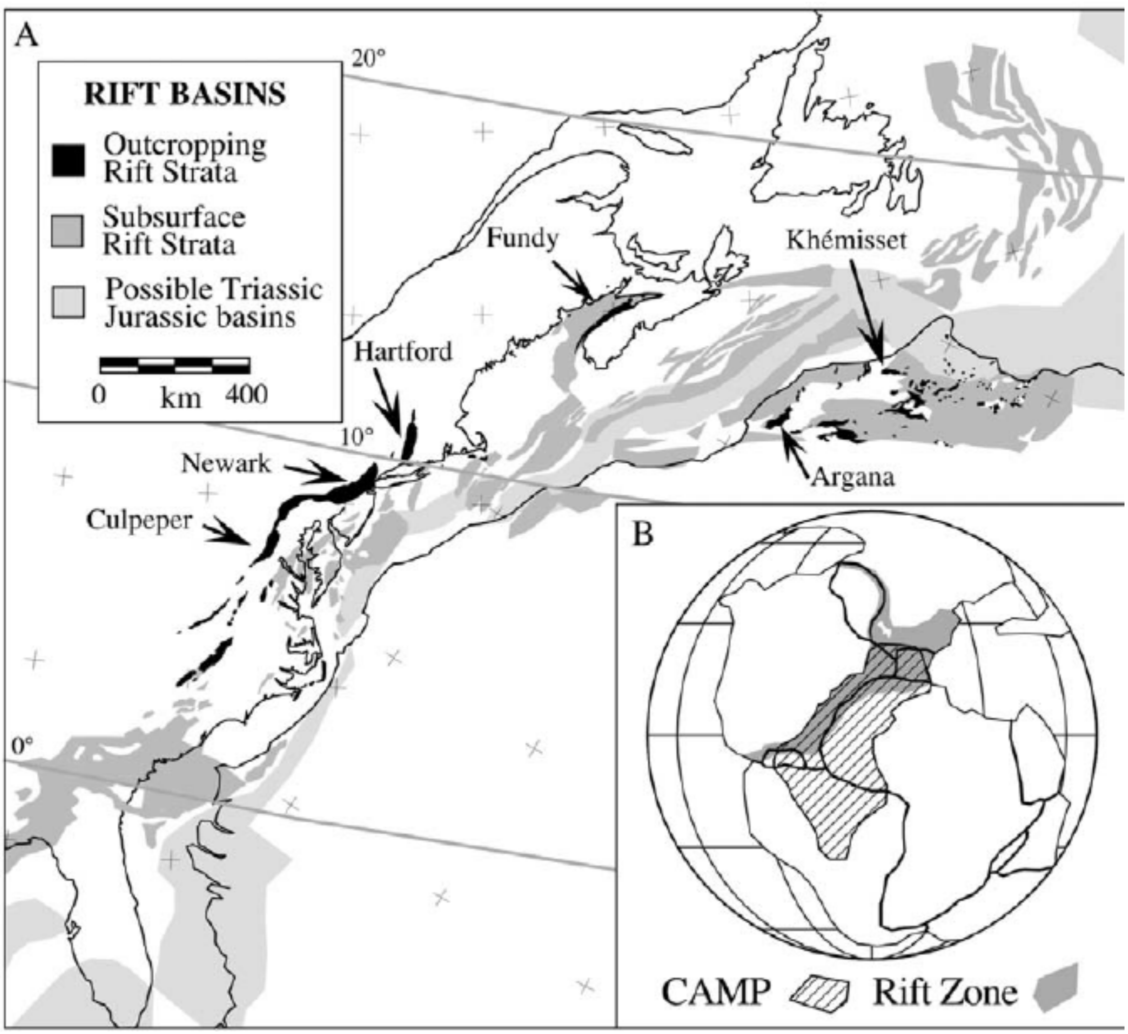


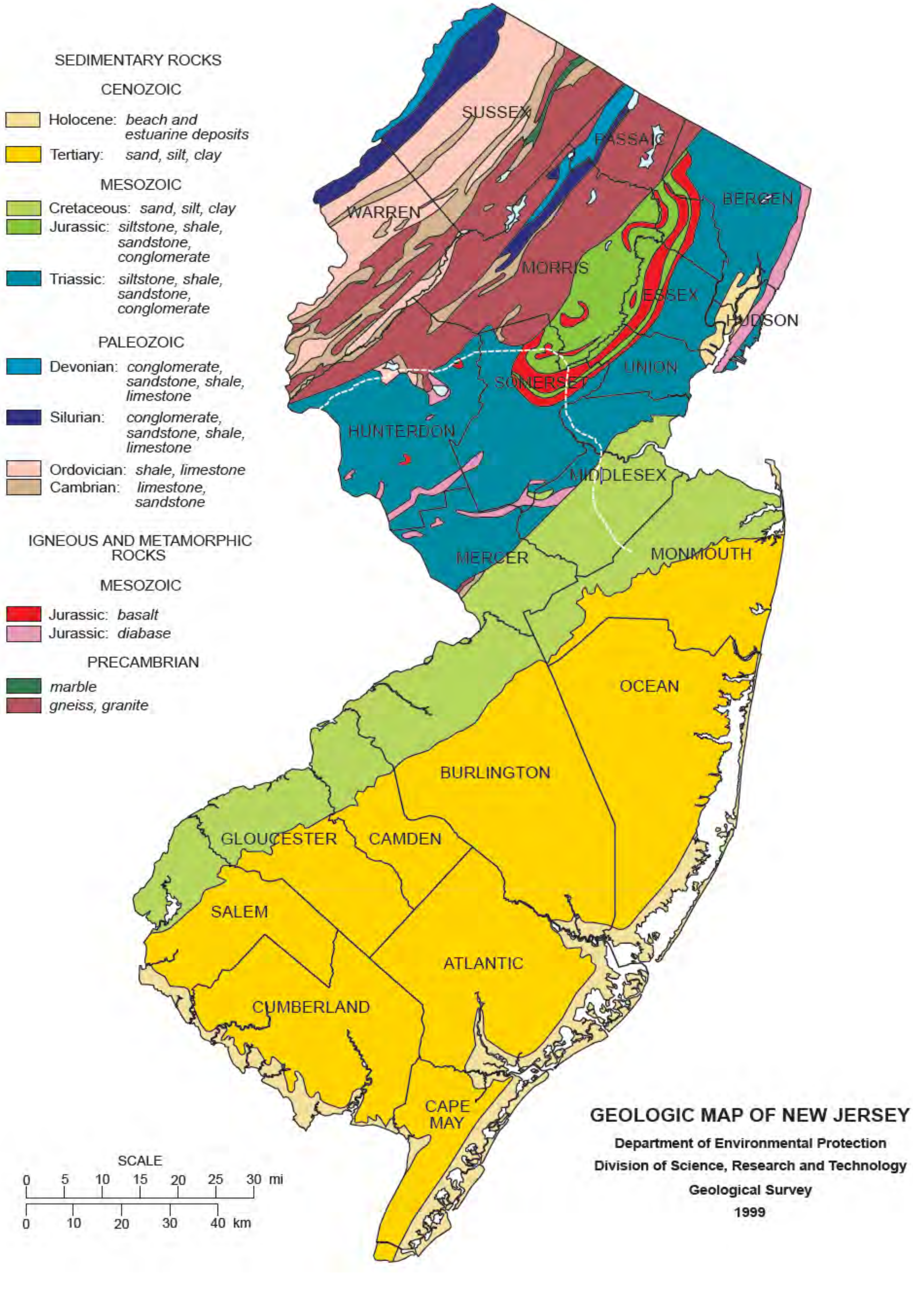
Note – colors used for stratigraphic units are different.

https://geology.rutgers.edu/rutgers-core-repository/newark-basin
https://www.ldeo.columbia.edu/~polsen/nbcp/nbcp.html

Big Changes in the Triassic!

The Newark Basin is just one of a series of Triassic rift basins associated with the Central Atlantic Magmatic Province (CAMP)) along the east Coast of North America, northwestern Africa, and north central South America.




SEDIMENTARY ROCKS
CENOZOIC
Holocene: beach and estuarine deposits
Tertiary: sand, silt, clay
MESOZOIC
Cretaceous: sand, silt, clay
Jurassic: siltstone, shale, sandstone, conglomerate
Triassic: siltstone, shale, sandstone, conglomerate
PALEOZOIC
Devonian: conglomerate, sandstone, shale, limestone
Silurian: conglomerate, sandstone, shale, limestone
Ordovician: shale, limestone
Cambrian: limestone, sandstone
IGNEOUS AND METAMORPHIC ROCKS
MESOZOIC
Jurassic: basalt
Jurassic: diabase
PRECAMBRIAN
marble
gneiss, granite
SUSSEX
PASSAIC
WARREN
BERGEN
MORRIS
ESSEX
HUDSON
UNION
SOMERSET
HUNTERDON
MIDDLESEX
MERCER
MONMOUTH
OCEAN
BURLINGTON
GLOUCESTER
CAMDEN
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
SCALE
0 5 10 15 20 25 30 mi
0 10 20 30 40 km
GEOLOGIC MAP OF NEW JERSEY
Department of Environmental Protection
Division of Science, Research and Technology
Geological Survey
1999

For an area of its size, New Jersey has a uniquely diverse and interesting geology. The state can be divided into four regions, known as physiographic provinces, which have distinctive rocks and landforms.

The **Valley and Ridge** Province is underlain by faulted and folded sedimentary layers of sandstone, shale, and limestone that range in age from Cambrian to Devonian (570 to 345 million years old). These rocks originated as sand, mud, and lime sediment deposited in former seas and floodplains. During Ordovician time (approximately 450 million years ago) and again during Pennsylvanian and Permian time (approximately 300 million years ago) the rocks were deformed by compression into folds and thrust along faults. As a result of the deformation, the originally flat sedimentary layers were tilted and now outcrop as linear belts.

Alternation of belts of erosion-resistant sandstone and easily-eroded shale and limestone creates the long, parallel northeast-southwest trending ridges and valleys characteristic of this province. Resistant sandstone and siltstone layers underlie Kittatinny Mountain and Walpack Ridge; shale and limestone underlie the valley of Flat Brook, the Delaware Valley upstream from the Delaware Water Gap, and the broad valley between Kittatinny Mountain and the Highlands to the east.

The limestone is quarried for construction material and cement aggregate. Some of the limestone units yield large quantities of ground water. The shales and sandstones and some limestone units are generally less productive aquifers.

On the eastern edge of the Valley and Ridge Province, along a line from Franklin through Andover to the Delaware River just north of Phillipsburg, an irregular escarpment averaging 500 feet in height marks the boundary of the **Highlands** Province. The Highlands are underlain predominantly by granite, gneiss, and small amounts of marble of Precambrian age. These rocks, the oldest in New Jersey, were formed between 1.3 billion and 750 million years ago by melting and recrystallization of sedimentary rocks that were deeply buried, subjected to high pressure and temperature, and intensely deformed. The Precambrian rocks are interrupted by several elongate northeast-southwest trending belts of folded Paleozoic sedimentary rocks equivalent to the rocks of the Valley and Ridge Province.

The granites and gneisses are resistant to erosion and create a hilly upland dissected by the deep, steep-sided valleys of major streams. The belts of sedimentary rock form long, parallel ridges and valleys (for example, Bearfort Mountain, Long Valley, and the Musconetcong Valley) that extend through the province.

The Highlands contain magnetite iron ore deposits that formerly supplied an industry of national importance. A valuable and mineralogically unique zinc ore in the Franklin Marble at Ogdensburg was also mined. In places the rocks of the Highlands are quarried for crushed stone. The Precambrian rocks are generally unproductive aquifers except where they are fractured or weathered. The more productive aquifers of the region are the glacial deposits and some of the Paleozoic sedimentary rocks.

Rocks of the **Piedmont** Province are separated from the rocks of the Highlands Province by a series of major faults, including the Ramapo Fault. The more resistant gneisses and granites on the upthrown northwest side of the faults make a prominent escarpment, 200 to 800 feet in height, extending from Mahwah through Boonton and Morristown to Gladstone, and from there westward in an irregular line to the Delaware River near Milford.

South and east of this escarpment, interbedded sandstone, shale, conglomerate, basalt, and diabase of the Piedmont Province underlie a broad lowland interrupted by long, generally northeast-southwest trending ridges and uplands. The rocks of the Piedmont are of Late Triassic and Early Jurassic age (230 to 190 million years old). They rest on a large, elongate crustal block that dropped downward in the initial stages of the opening of the Atlantic Ocean — one of a series of such blocks in eastern North America. These down-dropped blocks formed valleys known as rift basins. Sediment eroded from adjacent uplands was deposited along rivers and in lakes within the basins. These sediments became compacted and cemented to form conglomerate, sandstone, siltstone, and shale. They commonly have a distinctive reddish-brown color.

In the course of rifting, the rock layers of the Piedmont became tilted northwestward, gently folded, and cut by several major faults. Volcanic activity was also associated with the rifting, as indicated by the basalt and diabase interlayered with the sandstone and shale. Diabase is a rock formed by the cooling of magma at some depth in the crust; basalt is formed by cooling of an identical magma that has been extruded onto the surface as lava. Both basalt and diabase are more resistant to erosion than the enclosing sandstone and shale and therefore they form ridges and uplands. The Palisades, Rocky Hill, Sourland Mountain, and Cushetunk Mountain are underlain by diabase layers. The Watchung Mountains, Long Hill, and Hook Mountain are underlain by basalt layers. Valleys and lowlands between these ridges are underlain by shale and sandstone.

The basalt and diabase are extensively quarried for crushed stone. In the past, "brownstone" was widely quarried from sandstone units. Also, minor quantities of copper were extracted from sandstone and shale associated with the diabase and basalt. The basalt and diabase generally are poor aquifers but the sedimentary rocks are, in places, capable of yielding large quantities of water.

Southeast of a line roughly between Carteret and Trenton, unconsolidated sediments of the **Coastal Plain** Province overlap rocks of the Piedmont Province. These sediments, which range in age from Cretaceous to Miocene (135 to 5.3 million years old), dip toward the coast and extend beneath the Atlantic Ocean to the edge of the Continental Shelf. The Coastal Plain sediments thicken southeastward from a featheredge along the northwestern margin of the province to approximately 4,500 feet near Atlantic City to a maximum of more than 40,000 feet in the area of the Baltimore Canyon Trough, 50 miles offshore from Atlantic City. The sediments consist of layers of sand, silt and clay deposited alternately in deltaic and marine environments as sea level fluctuated during Cretaceous and Tertiary time. These layers of sediment outcrop in irregular bands that trend northeast-southwest. Wide areas of the Coastal Plain are covered by a thin veneer of Late Tertiary and Quaternary sand and gravel deposited by rivers.

The topography of the Coastal Plain generally is flat to very gently undulating. However, erosion-resistant gravel or iron-cemented sediment underlie upland areas and isolated hills, such as the Atlantic Highlands, Telegraph Hill, Mount Holly, and Arneys Mount.

Coastal Plain sediments have been mined in the past for bog iron, glass sand, foundry sand, ceramic and brick clay, the mineral glauconite for use in fertilizer, and titanium from the mineral ilmenite in sand deposits. Today the Coastal Plain sediments continue to supply glass sand and are extensively mined for sand and gravel construction material. The sand formations are productive aquifers and important ground water reservoirs.

Within each of these physiographic provinces there have been major changes during the past two million years. In this time New Jersey has undergone three glaciations. The last glacier (the late Wiconsinan advance) began to melt back from its maximum extent approximately 20,000 years ago. North of the limit of the last glaciation much of the surface is covered by glacial deposits. Upland areas in this region are thinly draped with till, an unsorted mixture of sand, clay and boulders deposited directly from the glacier. Valleys and lowlands are filled with up to 350 feet of sand and gravel deposited from glacial meltwater and silt and clay that settled in glacial lakes. The sand and gravel deposits are important sources of construction material, and productive aquifers are found where sand and gravel occur in buried or filled valleys. South of the limit of Wisconsinan glaciation, there are discontinuous patches of till from older glaciations. These deposits occur on uplands and are found as far south as the Somerville area.

During each glaciation, sea level dropped as water from the oceans was transferred to ice sheets. Rivers extended and deepened their valleys to conform to the lower sea levels. When the ice sheets melted, sea level rose, flooding the deepened valleys and establishing new shorelines. The present configuration of the coast is the result of the rapid post-glacial rise in sea level, which slowed approximately 6,000 years ago. Many of the estuaries along the coast are the drowned lower reaches of former river valleys. To the east of the mainland, barrier islands were formed, and continue to be shaped, by erosion and deposition of beach sand by waves and currents. Mud and sand transported by rivers and from offshore is gradually filling the bays and estuaries between the mainland and the barrier islands, creating extensive wetlands.

GEO203 Local Geology Field trip – worksheet

For your own use – it will not be collected or graded but will be the basis of what will.

Stop 1 **Stockton fm**

Washington Rd, just uphill from Lake Carnegie

1. Rock type(s)? Compositional and textural observations.

3. Interpretation of environment of formation; cite evidence.

4. Weathering characteristics? Is this a resistant or non-resistant unit?

5. Layering? If so, it's orientation?

5. Relative age of formation compared to other formations on the trip. Cite critical evidence.

5. Place/find stop on cross-section and map.

6. Other notes

GEO203 Local Geology Field trip – worksheet

For your own use – it will not be collected or graded but will be the basis of what will.

Stop 2 **Passaic fm**

Princeton Professional Offices, Mt. Lucas Rd

1. Rock type(s)? Compositional and textural observations.

3. Interpretation of environment of formation; cite evidence.

4. Weathering characteristics? Is this a resistant or non-resistant unit?

5. Layering? If so, it's orientation?

5. Relative age of formation compared to other formations on the trip. Cite critical evidence.

5. Place/find stop on cross-section and map.

6. Other notes

GEO203 Local Geology Field trip – worksheet

For your own use – it will not be collected or graded but will be the basis of what will.

Stop 3 **Passaic and Rocky Hill fms**

Herrontown WOODS

1. Rock type(s)? Compositional and textural observations.

3. Interpretation of environment of formation; cite evidence.

4. Weathering characteristics? Is this a resistant or non-resistant unit?

5. Layering? If so, it's orientation?

5. Relative age of formation compared to other formations on the trip. Cite critical evidence.

5. Place/find stop on cross-section and map.

6. Other notes

GEO203 Local Geology Field trip – worksheet

For your own use – it will not be collected or graded but will be the basis of what will.

Stop 4 **Passaic fm**

Rt 539 north of Frenchtown

1. Rock type(s)? Compositional and textural observations.

3. Interpretation of environment of formation; cite evidence.

4. Weathering characteristics? Is this a resistant or non-resistant unit?

5. Layering? If so, it's orientation?

5. Relative age of formation compared to other formations on the trip. Cite critical evidence.

5. Place/find stop on cross-section and map.

6. Other notes

GEO203 Local Geology Field trip – worksheet

For your own use – it will not be collected or graded but will be the basis of what will.

Stop 5 **Passaic and Highlands fms**

Rt 611 south of Riegelsville, PA

1. Rock type(s)? Compositional and textural observations.

3. Interpretation of environment of formation; cite evidence.

4. Weathering characteristics? Is this a resistant or non-resistant unit?

5. Layering? If so, it's orientation?

5. Relative age of formation compared to other formations on the trip. Cite critical evidence.

5. Place/find stop on cross-section and map.

6. Other notes