GEOLOGY OF FLORIDA

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PETROLEUM RESTORATION PROGRAM ANNUAL TRAINING – GEOLOGY OF FLORIDA

Presentation Agenda

- Why is it Important?
- Geology Basics.
    - Rock Types.
    - Geologic History.
- Current Geology of Florida.
    - How does this affect us?
    - Aquifers.

WHY IS IT IMPORTANT?

GEOLOGY OF FLORIDA

WHY IS IT IMPORTANT?

Geology can determine a lot about how we proceed with assessment and remediation.

Drilling.

- Geology will determine what kind of drill rig we need to collect soil samples and install monitor wells.
- Depth to water will determine if we need hand augers or a drill rig for soil sample collection.
- Depth to water will also determine what kind of drill rig we can use to install monitor wells.
    - Direct Push Technology (DPT) Rigs with Hollow Stem Auger attachments are generally only used up to 30 feet below land surface (BLS).
    - Areas with stiff clay may require more robust drilling equipment.
    - Areas with limestone or other rock may require use of a sonic drill rig.

Groundwater Sampling.

- Geology will determine how fast the groundwater will recharge, which can affect groundwater sample times and collection of stabilization parameters.
- In some cases, we may encounter perched aquifers due to the presence of clay layers in the subsurface, which will complicate assessment activities.

WHY IS IT IMPORTANT?

Assessment.

- Geology will influence the vertical and horizontal migration of petroleum hydrocarbons.
- Geology will influence which way groundwater flows, especially in areas with a mixed lithology.
- Water will flow faster and preferentially through sandy areas and be blocked by more clayey layers.
- Clay layers can prevent groundwater from migrating deeper underground.
- You must be careful drilling at confining layers not to open a pathway for deeper migration.

There is a potential for background/naturally occurring concentrations of some contaminants of concern.

Remediation.

- Lithology will determine what kind of remediation strategy will work best.
- Depth to groundwater may determine if conventional excavation or large diameter auger excavation is most appropriate.
- Lithology will determine what sloping or sheet piling is required for excavation stability.
- Clay lithology will potentially block fluid and vapor flow, which will limit the effectiveness of injections, air sparge/soil vapor extraction and multi-phase extraction.
- Shallow water tables may limit the use of air sparge/soil vapor extraction due to complications with undesired groundwater extraction or groundwater and sediment being pushed to the surface.

GEOLOGY BASICS

GEOLOGY OF FLORIDA

Igneous Rocks.

Igneous rocks form when hot, molten rock (magma) crystallizes and solidifies. The magma originates deep within the Earth and rises toward the surface near active plate boundaries or hot spots. Igneous rocks are divided into two groups, intrusive or extrusive, depending upon where the molten rock solidifies.

Intrusive and igneous rock forms when magma cools very slowly deep inside the Earth over many thousands or millions of years until it solidifies. Slow cooling means the individual mineral grains have a very long time to grow, so they grow to a relatively large size. Intrusive rocks have a coarse-grained texture.

Extrusive (or volcanic) igneous rock is produced when magma reaches the Earth’s surface and cools there. The magma, called lava when molten rock erupts on the surface, cools and solidifies almost instantly when it is exposed to the relatively cool temperature at the surface. Cooling so quickly means that mineral crystals don't have much time to grow, so these rocks have a very fine-grained or even glassy texture.

Metamorphic Rocks.

Metamorphic rocks started out as some other type of rock (igneous, sedimentary or metamorphic), but have been changed from their original form. Metamorphic rocks form when rocks are subjected to high heat, high pressure, hot mineral-rich fluids or some combination of these factors. Conditions like these are found deep within the Earth or where tectonic plates meet.

The process of metamorphism transforms rocks into denser, more compact rocks. New minerals are created either by rearrangement of mineral components or by reactions with fluids that enter the rocks. Pressure or temperature can even change previously metamorphosed rocks into new types. Metamorphic rocks are often physically altered by folding, compression or stretching. Metamorphic rocks do not get hot enough to melt, or they would become igneous rocks.

In Florida, Igneous and Metamorphic rocks do not occur naturally at the surface but are found in deep wells reaching from 3,500 feet to deeper than 18,000 feet below land surface.

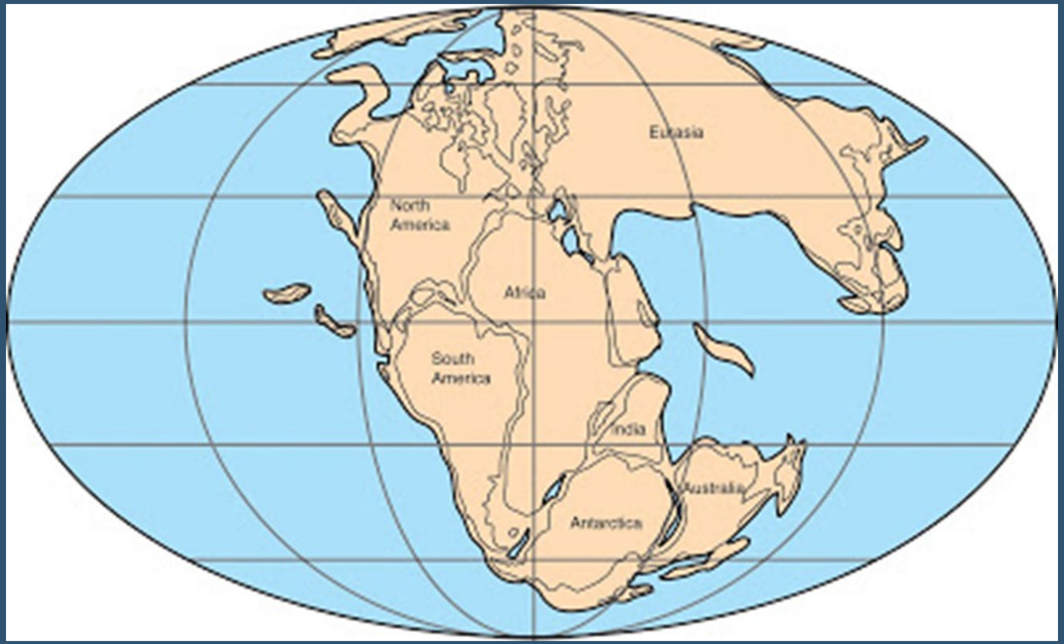
Sedimentary Rocks.

Sedimentary rocks are formed from pieces of pre-existing rocks or organisms. They form from deposits that accumulate on the Earth's surface. Sedimentary rocks often have distinctive layering or bedding.

Clastic sedimentary rocks are made up of pieces (clasts) of pre-existing rocks. These rocks often start as sediments weathered from existing rock and carried in rivers and deposited in lakes and oceans. When buried, the sediments lose water and become cemented to form rock. Clastic sedimentary rocks may have particles ranging in size from microscopic clay to huge boulders and names are based on their clast or grain size.

Biologic sedimentary rocks form when large numbers of living things die. Chert is typically formed from microscopic floating organisms that settle on the ocean floor and are compacted over time. Limestone found in Florida is typically formed by the accumulation of coral and shells in a shallow marine environment.

Common sedimentary rocks in Florida include sandstone, limestone and shale.



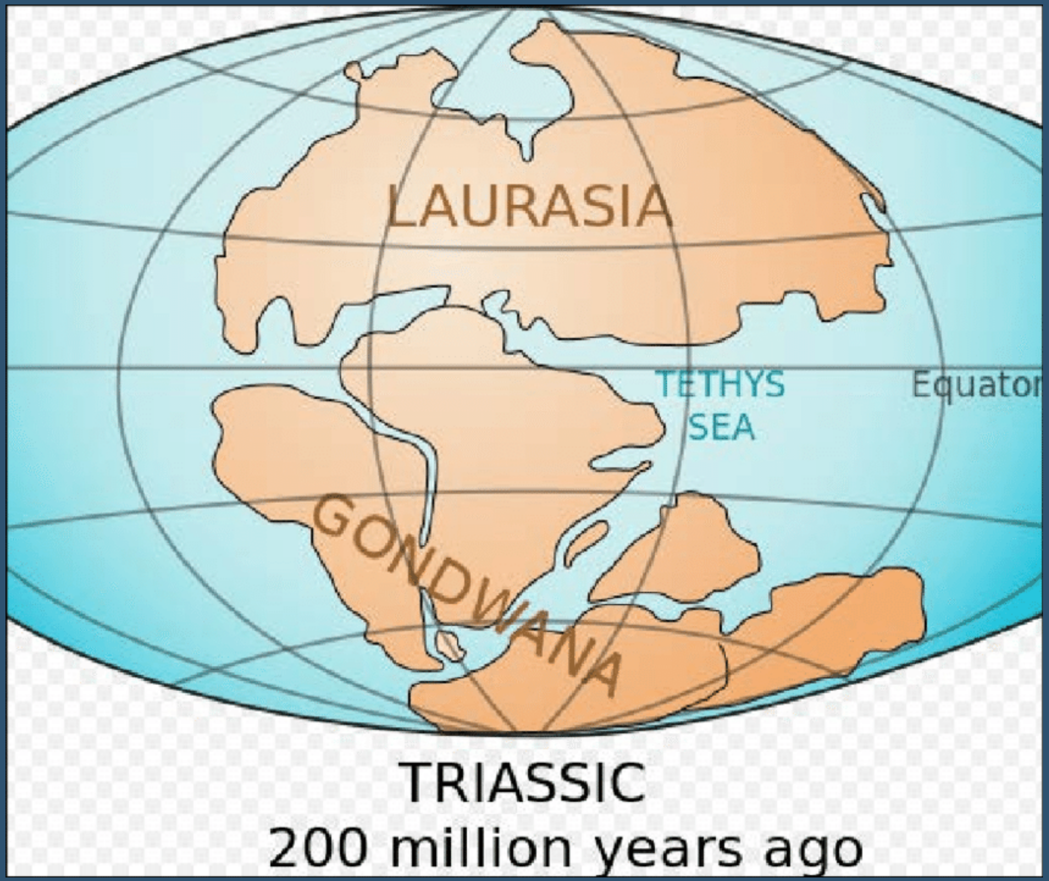
Pangea – 300,000,000 Years Ago.

At one time, most of the modern continents were joined together in one single landmass called Pangea.

Florida was located at the point where the North American, South American and African landmasses were joined together.

The bedrock of Florida is a mixture of rocks from all three continents. The boundary between North American and African landmasses was thought to be in Southern Georgia.

(Pangea) – Pangea Supercontinent, 'Coal formation linked to assembly of supercontinent Pangea', Jan. 21, 2016



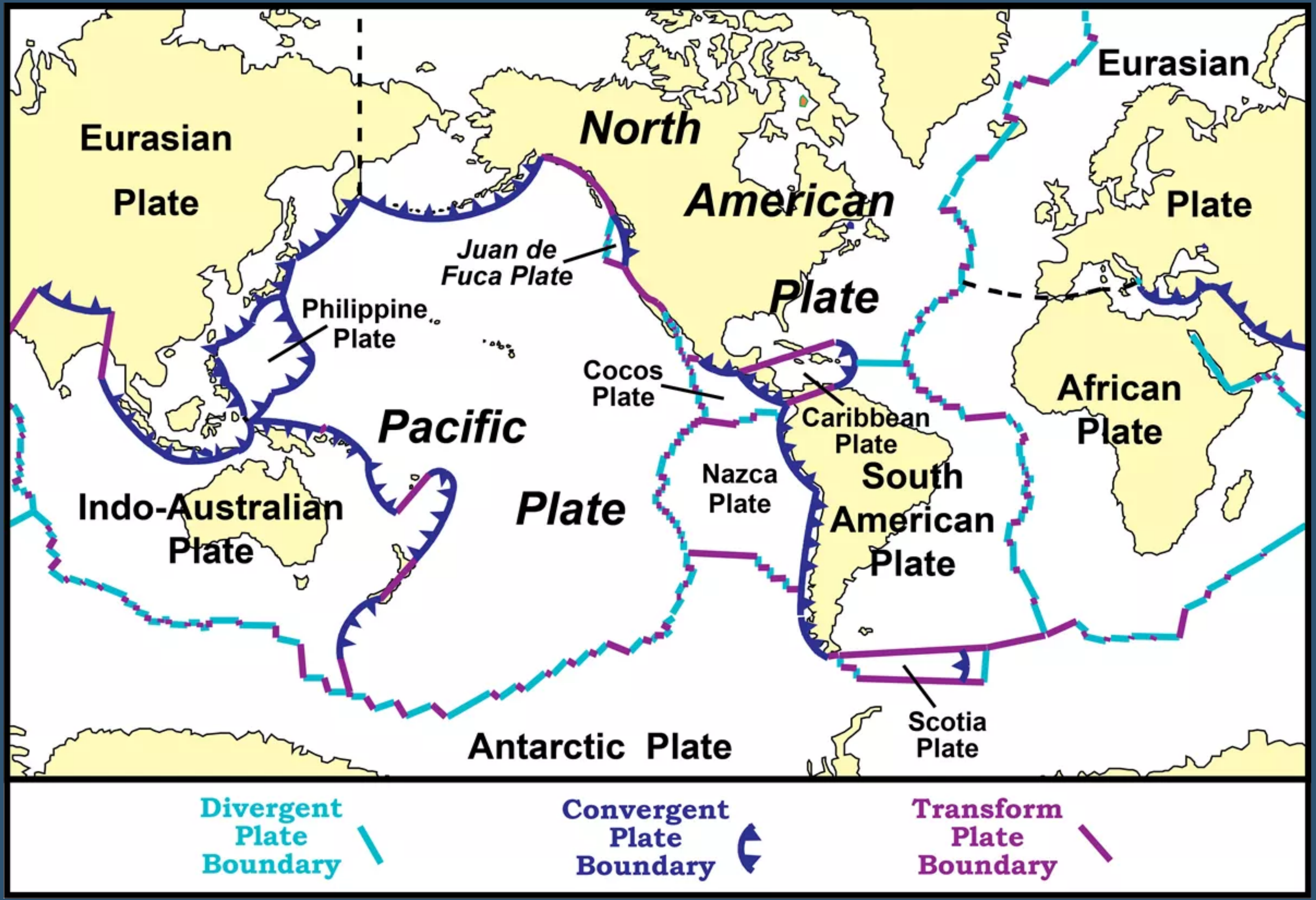
Breakup of Pangea — 200,000,000 Years Ago.

Pangea began to break apart when a three-pronged fissure grew between the North American, South American and African landmasses. These fissures created a volcanic rift zone. The rift zone eventually formed a new ocean basin (the Atlantic) and is still spreading today at the mid ocean ridge.

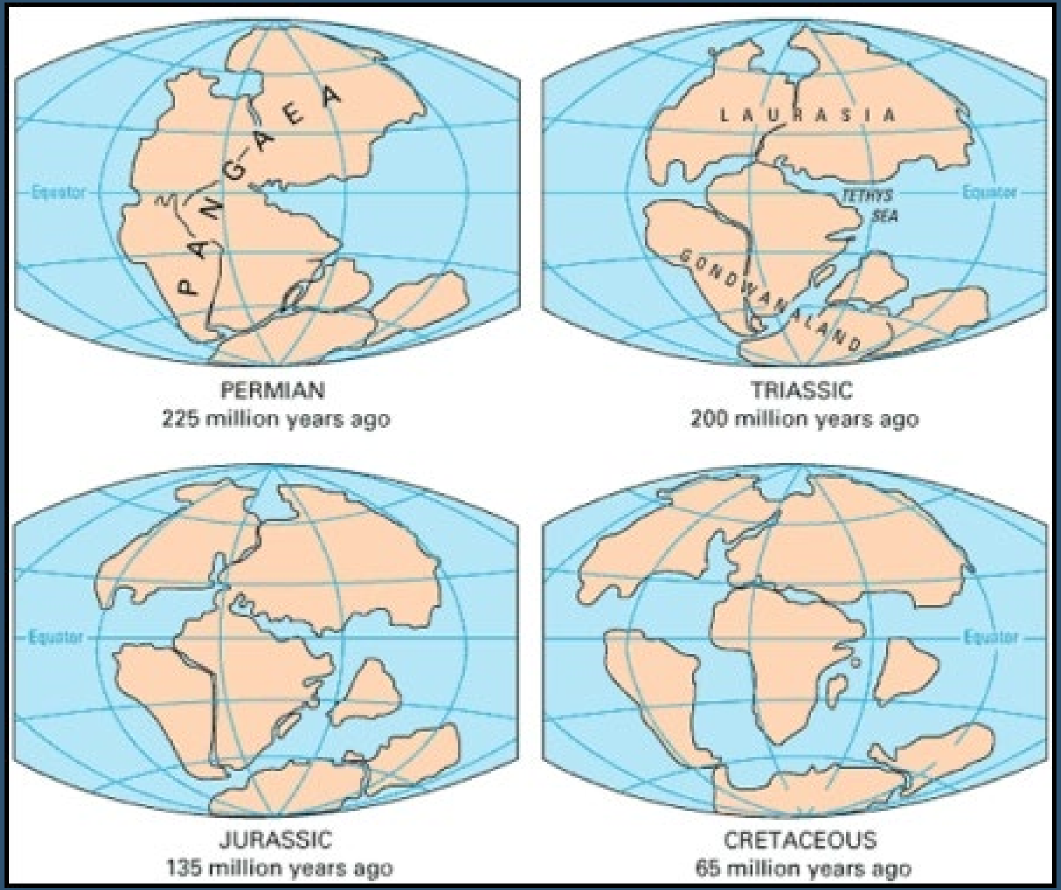
This rifting is the source of the volcanic bedrock deep below the surface in Florida.

(Laurasia-Gondwana) - The continents Laurasia-Gondwana 200 million years ago, United States Geological Survey, Feb. 23, 2006.

GEOLOGY BASICS
GEOLOGIC HISTORY OF FLORIDA



(Fig-1-3-New-Tectonic-Map-x10) — Earth's Tectonic Plates, "Evidence of Plate Motions", National Park Service, February 11, 2020

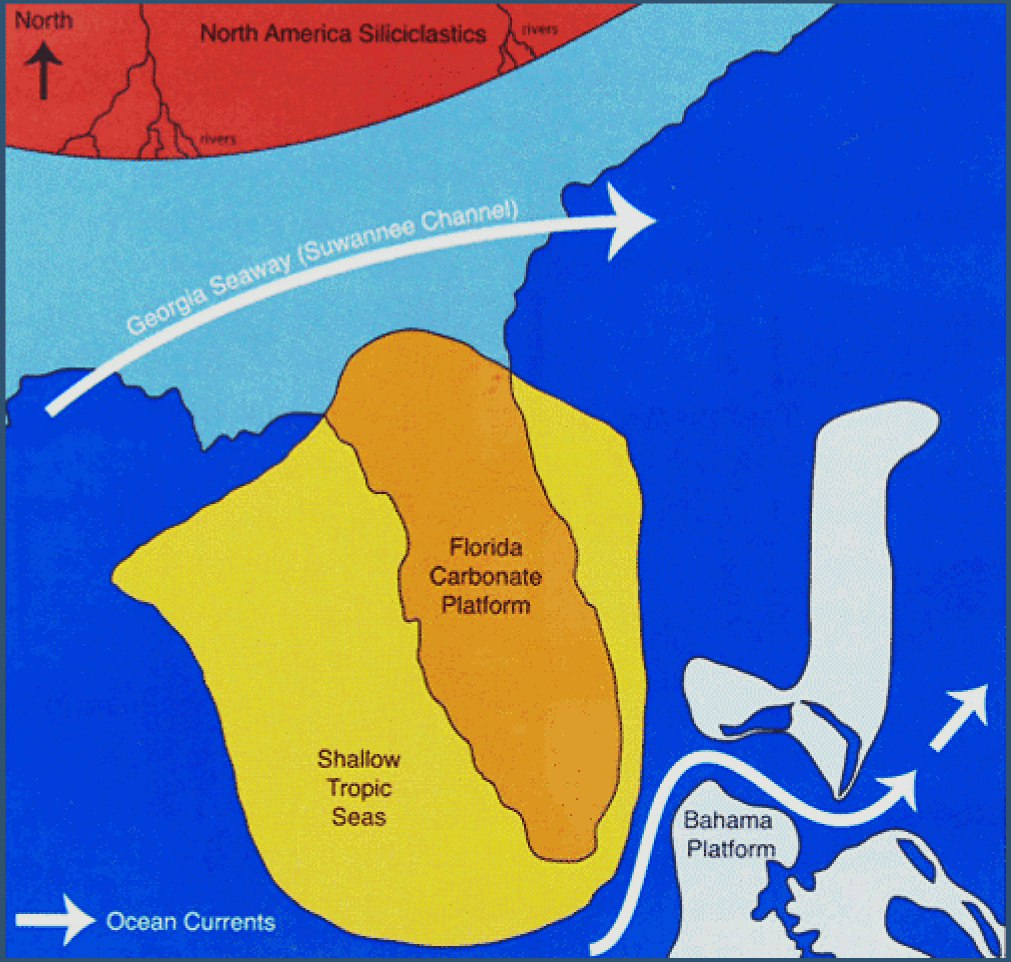


Jurassic and Cretaceous Periods – 200,000,000 to 66,000,000 Years Ago.

As Pangea continued to divide, Florida was located in a shallow ocean basin between the North American and South American landmasses.

The shallow ocean basin where Florida is located continued to fill with organic sediments from shallow marine organisms and eroded material from the North American landmass.

(Pangea to Present) – The breakup of Pangea, 'This Dynamic Earth: The Story of Plate Tectonics.' (Online ed.), United States Geological Survey, Aug. 7, 2012



Cretaceous Period and Paleocene and Eocene Epochs – 145,000,000 to 34,000,000 Years Ago.

When the landmass that would become Florida was attached to the North American continental plate, there was a narrow rift basin between Florida and Georgia/Alabama that created a water channel called the Suwannee Channel or the Georgia Seaway.

The Suwannee Channel isolated the Florida Platform from the siliciclastic sediments eroded from North American mainland.

(Figure 3) - Map of Georgia Seaway, 'Geologic History of Florida.', University Press of Florida, Hine, A.C., 2013

Cretaceous Period and Paleocene and Eocene Epochs ─ 145,000,000 to 34,000,000 Years Ago.

During this time, the Florida Platform was all or mostly submerged under a warm, shallow sea. Sedimentary rocks began to accumulate on the bedrock, primarily carbonate rocks (limestone and dolostone). The carbonate rocks are composed of marine organisms, both plankton and coral reefs, that accumulated and compacted up to three miles thick in places.

We can still find these coral fossils and other shallow marine fossils (shark teeth, ray mouth plates, manatee bones) in the central parts of the state far from the current shoreline.

These carbonate layers are what forms the base of the Floridan Aquifer.

Oligocene Epoch to Now ─ 23,000,000 years ago to present.

Between 34,000,000 and 23,000,000 years ago, Earth entered a global ‘icehouse’ state, and sea level dropped by over 300 feet. Much of the Florida Platform was exposed and erosion and karstification began to act on the carbonate rocks. Land animals began to appear in the fossil record as land bridges are exposed during the lowest sea level elevations.

Between 23,000,000 and 2,600,000 years ago, the Suwannee Channel is completely filled by sediments coming from the eroding Appalachian Mountains, fully connecting the Florida Platform to the rest of North America. Large volumes of clastic sediments begin to flow onto the Florida Platform and at first mix with the carbonate layers and later cover them completely, from north to south.

In general, these clastic sediments are carried by rivers and coastal currents. The smaller particles (silt / clay) can be carried further and are deposited first. As the clay layers build up, the rivers and coastal currents reach farther. Sand and larger particles will then be deposited on top as the land surface rises.

GEOLOGY BASICS

GEOLOGIC HISTORY OF FLORIDA

FLORIDA GEOLOGICAL SURVEY

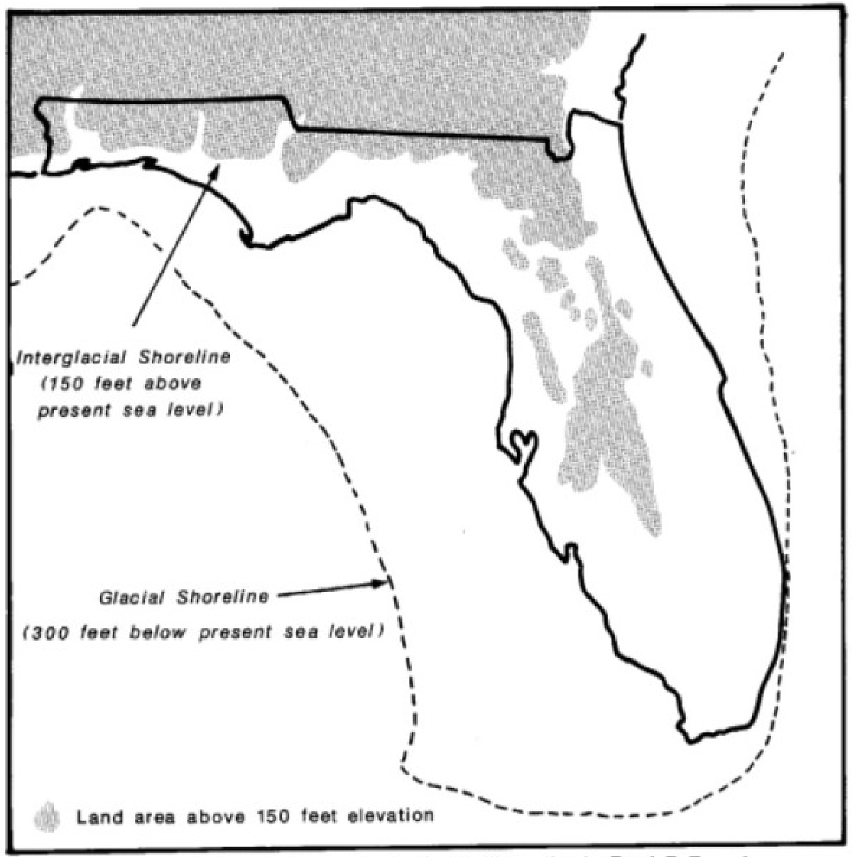
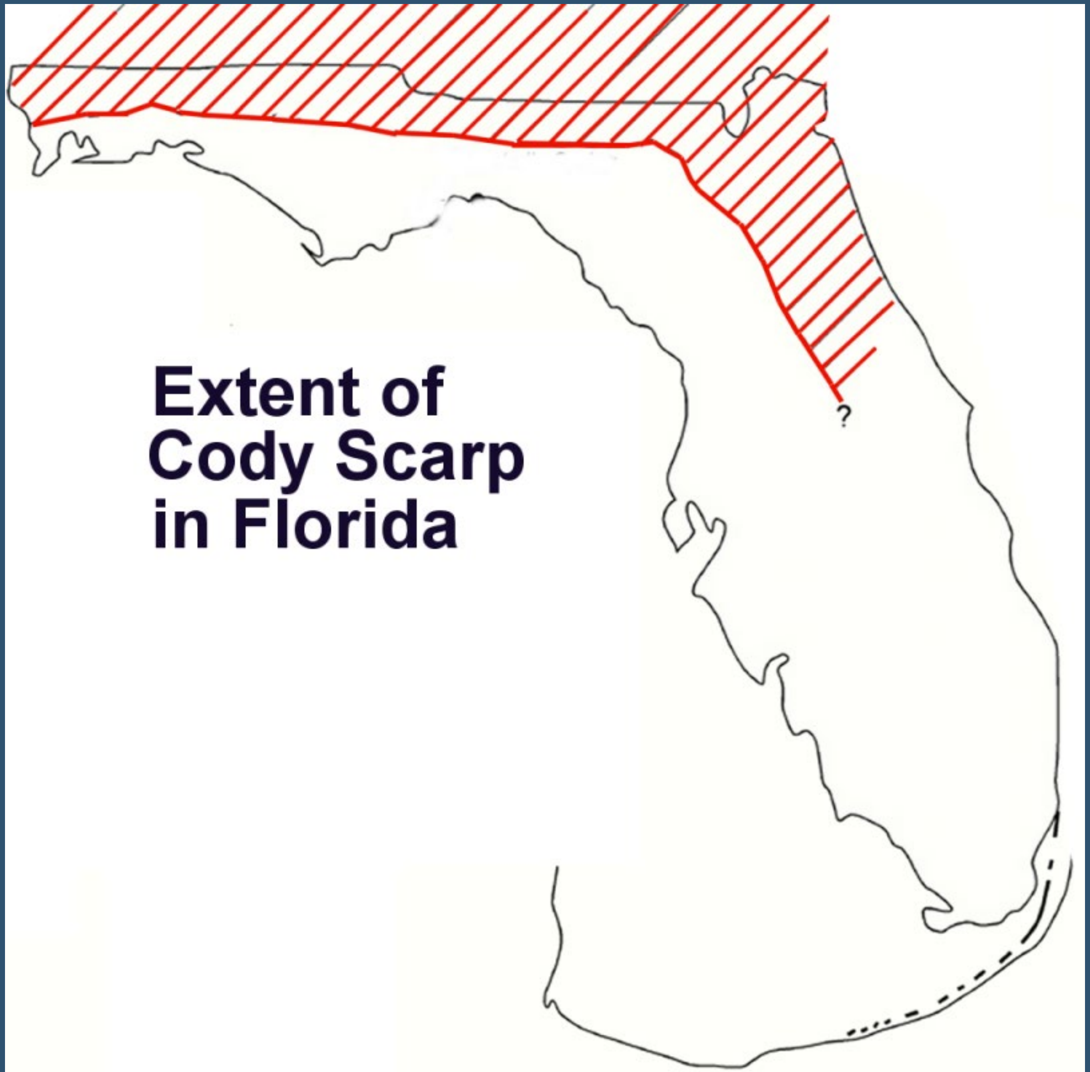


Figure 16. Pleistocene shorelines in Florida. Illustration by Frank R. Rupert.

Oligocene Epoch to Now — 23,000,000 years ago to present.

Pleistocene Ice Ages consisting of four main events between 1,800,000 and 10,000 years ago caused large variations in sea level (400 feet below to 150 feet above current levels). Florida was never covered in glaciers, but the Florida landmass ranges from a narrow peninsula to nearly twice as large as its present size due to the changes in sea level.

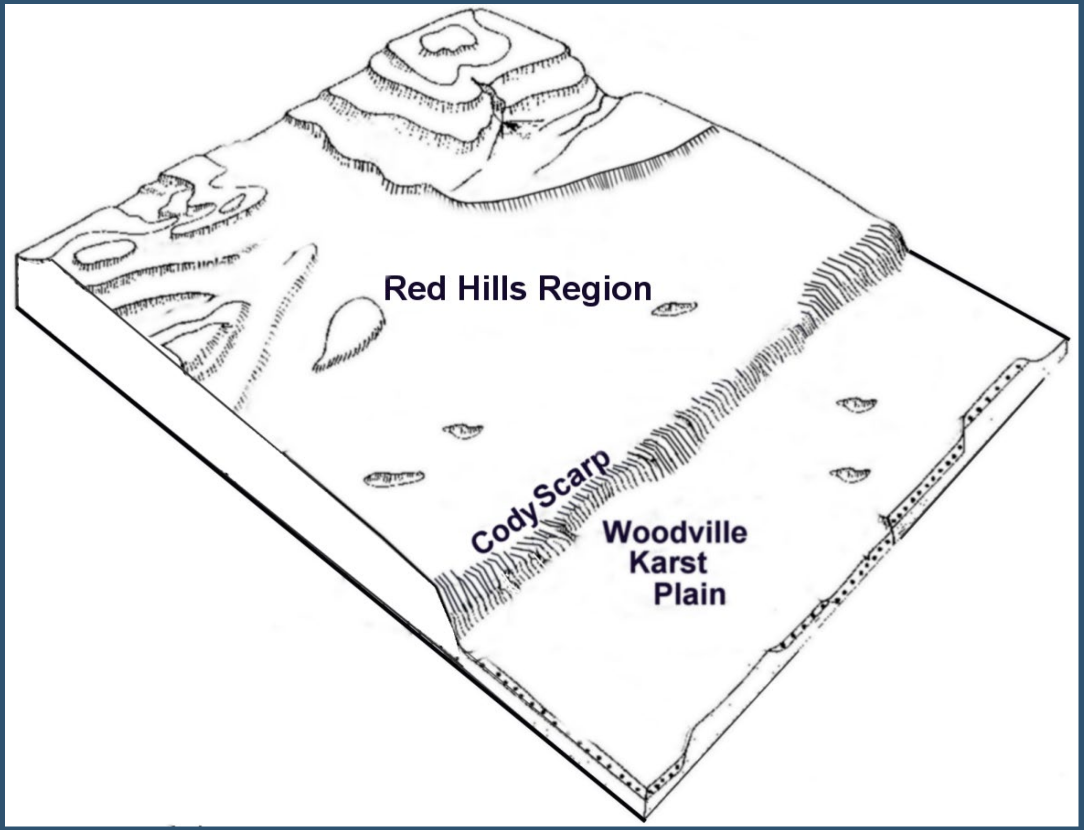


Cody Scarp.

The Cody Escarpment or Cody Scarp is a geomorphologic feature located through the north and central parts of Florida. It was formed from ancient early Pleistocene shorelines of ~1.8 million to 10,000 years before present day during interglacial periods.

When sea level was higher and the Cody Scarp area represented the coastline, the clay confining layer was eroded away by wave action and ocean currents. When sea levels receded to the present-day shoreline, there was a combination of headward erosion by streams as well as the dissolution of carbonate rocks by both streams and groundwater.

(Cody Scarp Extent) – Extent of Cody Scarp In Florida, Wikipedia author Noles1984, Jan. 5, 2008



Cody Scarp.

The Cody Scarp region approximates the transition area between the confined and unconfined Floridan aquifer system. In the Northern Highlands, the Floridan aquifer system is overlain by a thick layer of clay that recharge into the aquifer. To the south and the west of the Cody Scarp, the Floridan aquifer system is generally unconfined in the Gulf Coastal Lowlands. The clay units are generally absent (or very thin where present) in the Gulf Coastal Lowlands and recharge to the Floridan aquifer system is relatively high.

Many rivers that cross the Cody Scarp go underground, and reemerge downstream as a spring.

(Cody Scarp) – Cody Scarp cutaway Diagram, Wikipedia author Noles1984, Jan. 5, 2008

CURRENT GEOLOGY OF FLORIDA

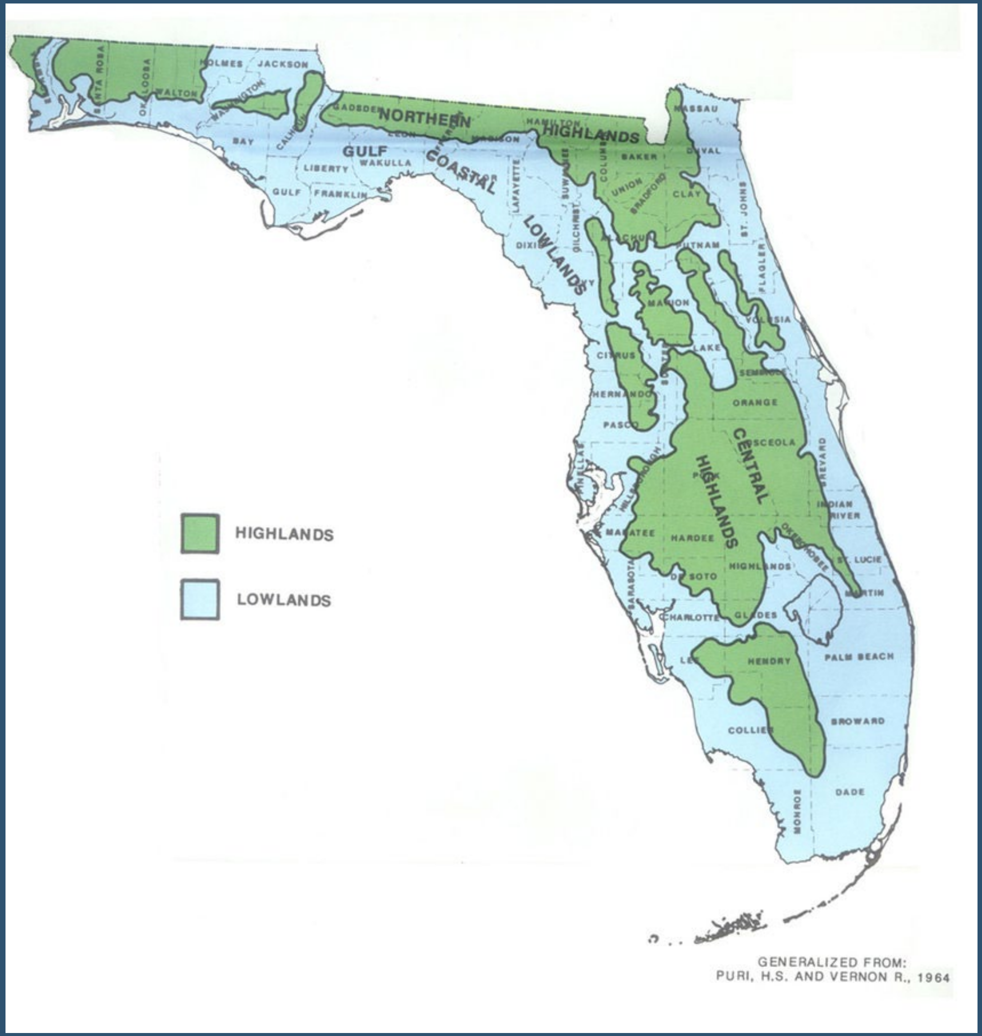
CURRENT GEOLOGY OF FLORIDA

How does this affect us?

The geologic history is what created the lithology, water table elevation, topography and depth to sensitive aquifers you will encounter while drilling or excavating.

(Florida Topographic Map) – Topographic Map of the State of Florida, NGDC Coastal Relief Model completed with ETOPO1 (public domain), Dec. 2008

CURRENT GEOLOGY OF FLORIDA



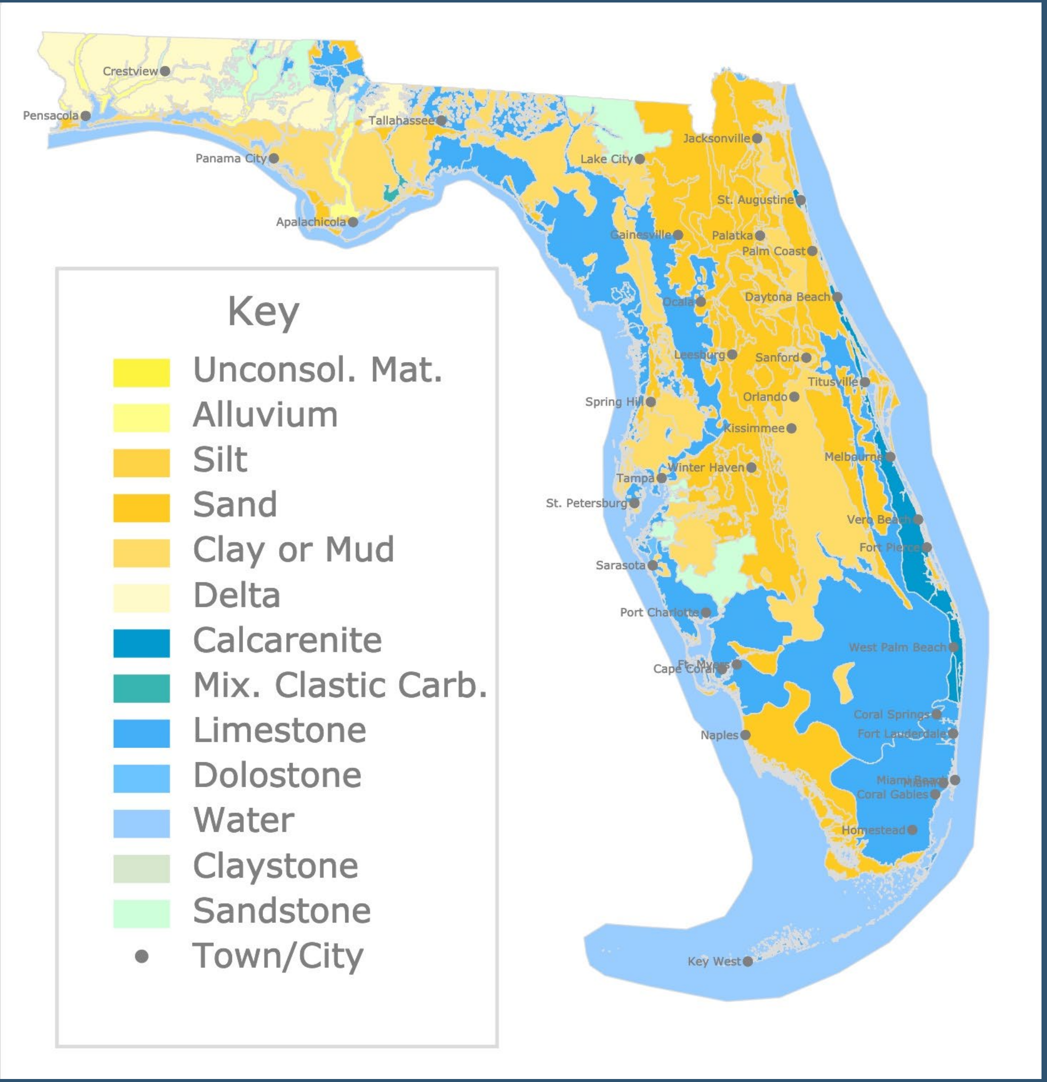
How does this affect us?

Areas along the north and central spine of the state are at a higher elevation than the coastal areas, which are mostly composed of lowlands closer to sea level.

This will affect the depth to groundwater and general lithology of the area.

(Landforms of Florida) – FLGS Map Series No. 112, 'Florida's Geological History', April 2005

CURRENT GEOLOGY OF FLORIDA

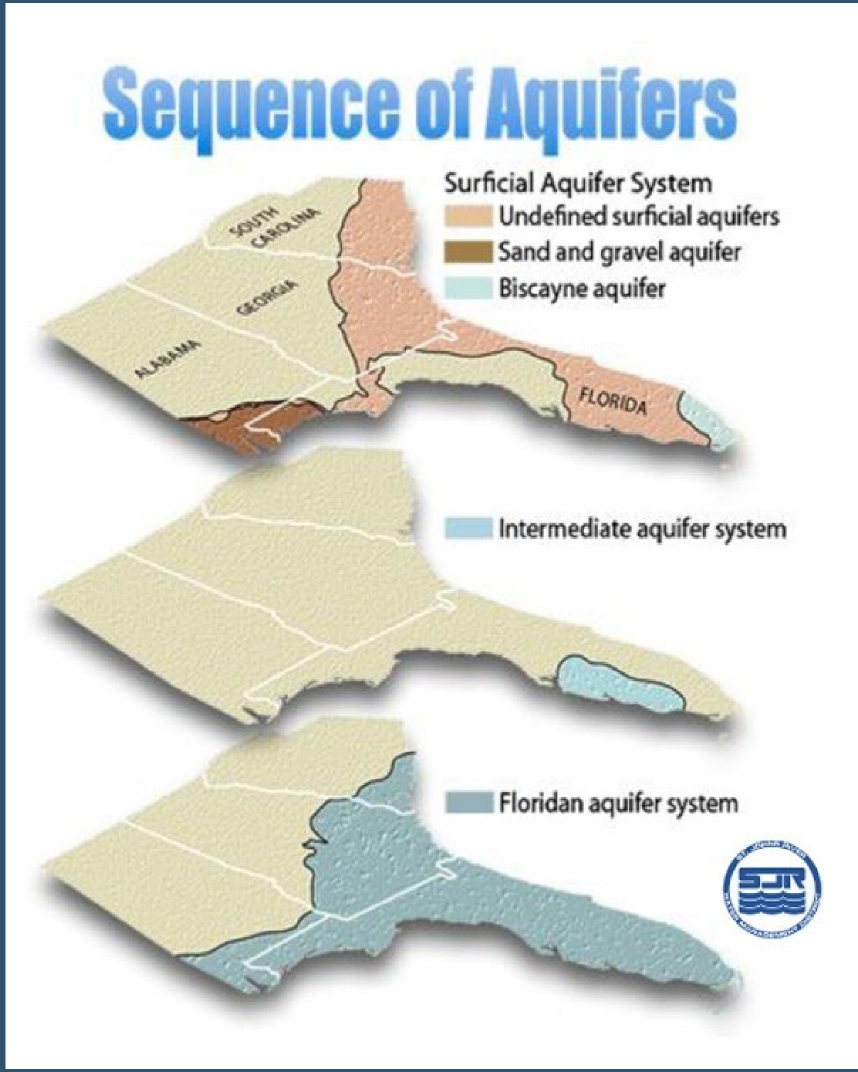


How does this affect us?

At the most general, the lithology in Florida consists of a limestone base, covered by clay layers that intermingle with and transition to sand layers. This can vary by the part of the state you are in. From the northern part of the state the clay and sand layers are thickest, thinning in southern areas until the limestone is beneath only a few feet of sand or exposed at the surface.

(Geologic Map of Florida) – 'Preliminary integrated geologic map databases for the United States', United States Geological Survey, Dec. 2007

CURRENT GEOLOGY OF FLORIDA

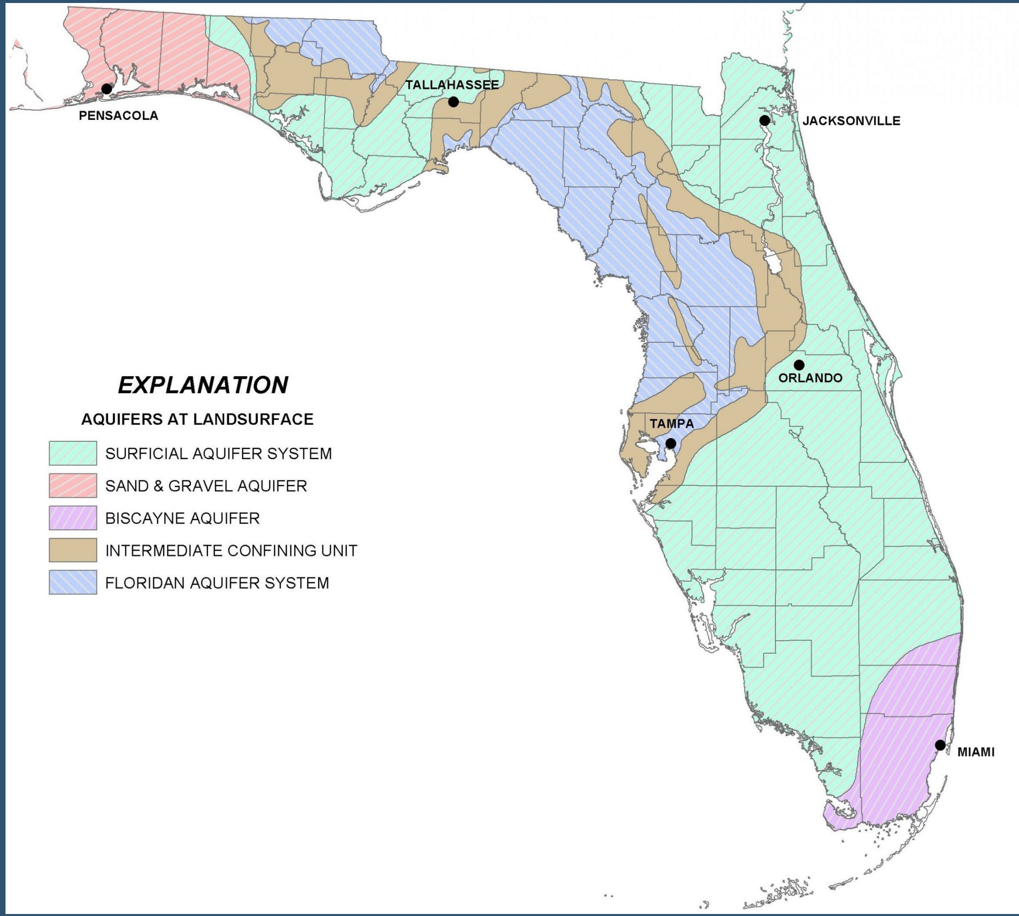


How does this affect us?

Aquifers are classified as either unconfined, semi-confined or confined, depending on the physical conditions under which the water is contained in an aquifer's rocks. Florida has all three types of aquifers in various combinations throughout the state.

The closer the primary aquifer is to the surface, the more impact a petroleum release will have on water supply.

CURRENT GEOLOGY OF FLORIDA



How does this affect us?

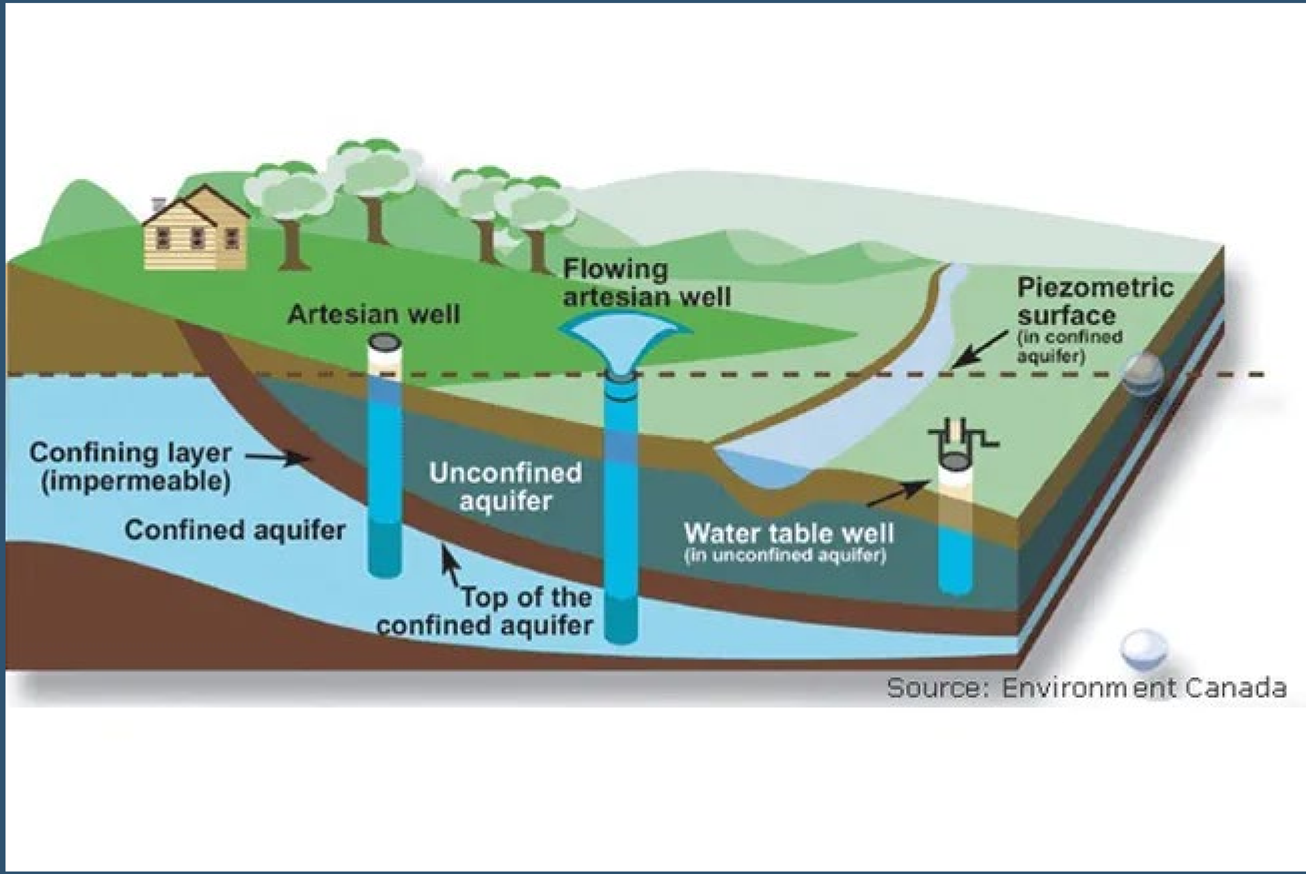
The Floridan aquifer system, which underlies all of Florida, is the main source of potable groundwater for much of the state. However, in the extreme western Panhandle and in South Florida, the Floridan aquifer is either too deep or contains water of higher salinity.

Non-potable wells can be installed in the shallower aquifer and influence plume migration.

(Florida Aquifers) – Map of Aquifers at land surface, Florida Department of Environmental Protection, April 9, 2020

CURRENT GEOLOGY OF FLORIDA

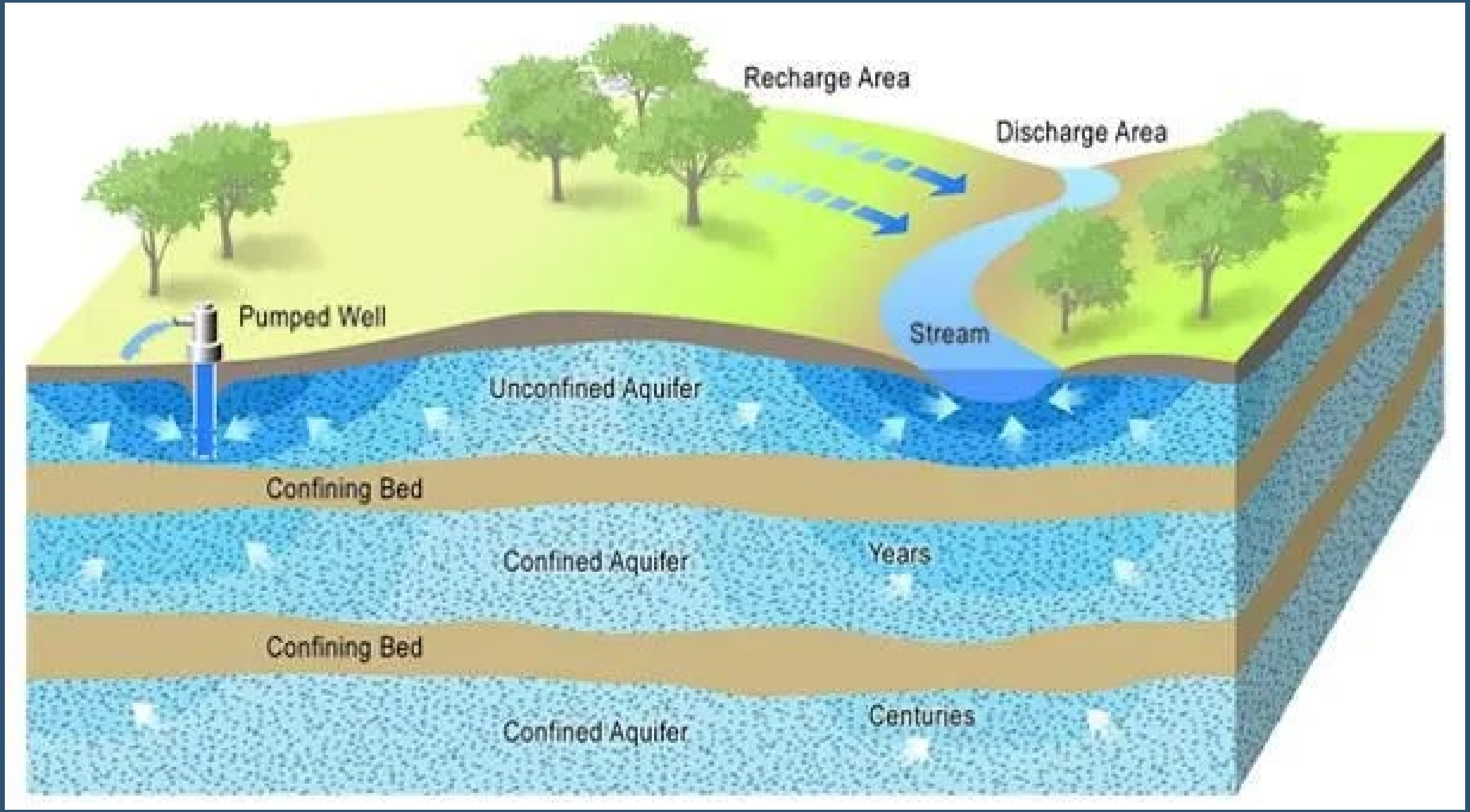
AQUIFERS



(Aquifers and Wells) – Cross-section of confined and unconfined aquifers, ‘Aquifers and Groundwater’, USGS, Oct. 16, 2019, image credit Environment and Climate Change Canada

CURRENT GEOLOGY OF FLORIDA

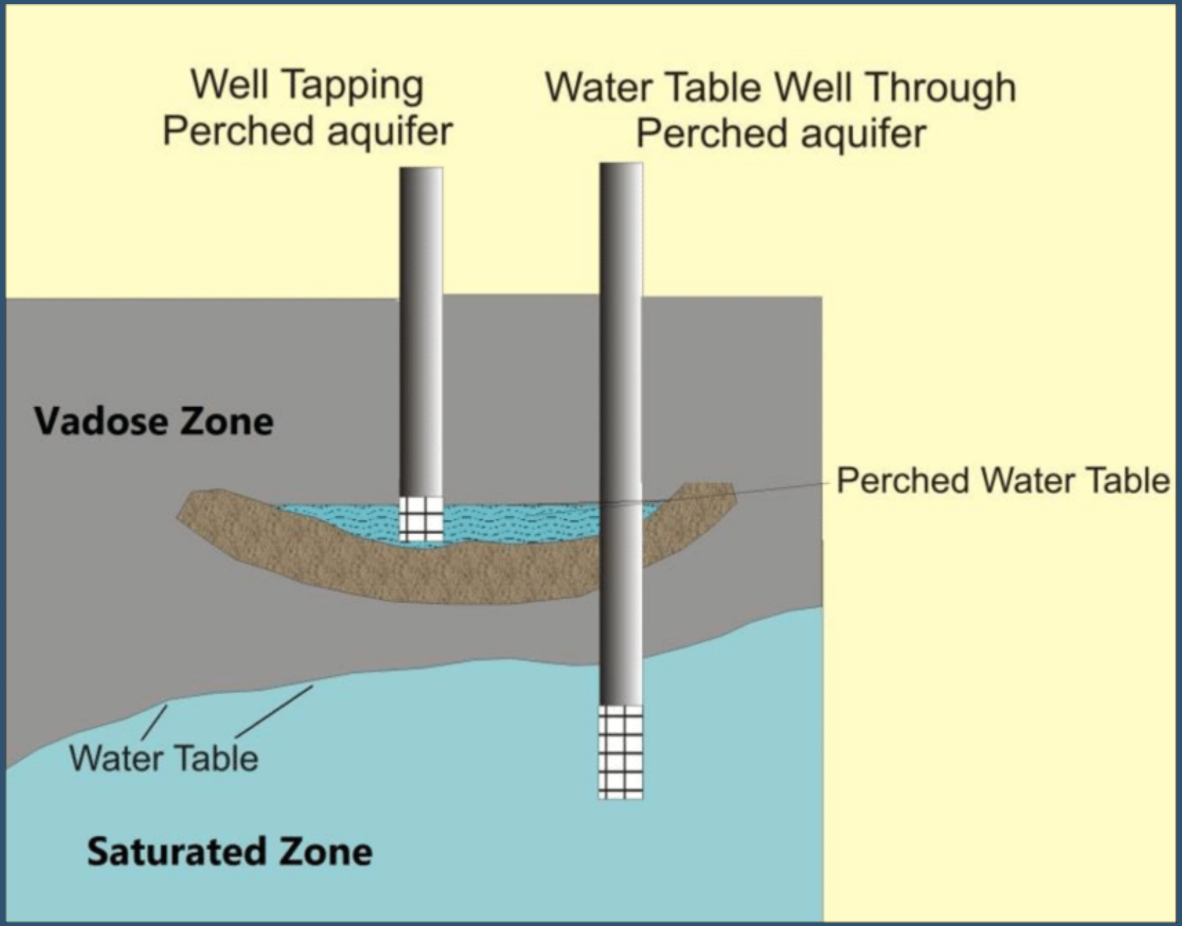
AQUIFERS



(Aquifer Diagram) – Aquifer discharge and recharge, California Department of Water Resources, Nov. 16, 2015

CURRENT GEOLOGY OF FLORIDA

AQUIFERS



(Perched Aquifer) – A schematic drawing of perched aquifer, 'Aquifer Properties', 2017


FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION
QUESTIONS?

THANK YOU

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