

Biostratigraphic and Lithostratigraphic Correlation of Sedimentary Strata in the Atlantic Coastal Plain

Introduction to the Atlantic Coastal Plain (Please read this page prior to doing the lab)

The **Atlantic Coastal Plain** is the region of flat topography extending from the Atlantic coast inland (westward) to where the underlying bedrock of the Piedmont meets the surface. Eastward, the Atlantic Coastal Plain extends beneath the ocean overlying the continental shelf. The coastal plain consists of very gently eastward dipping layers of sediments that have been accumulating on the margin of North America since the opening of the modern Atlantic Ocean following the breakup of Pangea at the beginning of the Mesozoic. Since the Late Jurassic (about 150 million years ago) the Atlantic Ocean has been depositing layers of sediment on the coastal plain. As sea level has risen and fallen (through transgressions and regressions) sediments have blanketed the coastal plain to different distances inland. During times of high sea level (such as in the Cretaceous and Eocene) layers of sediments were deposited as far inland as Philadelphia and Washington D.C. During times of low sea level inland areas were exposed and unconformities developed as the coastal plain was eroded.

During the 150 million year history of the Atlantic Coastal Plain it has been continuously **subsiding**. Subsidence is caused by two factors: 1) the cooling and thickening of the lithosphere beneath the Atlantic seafloor, which causes it to grow more dense through time and 2) the weight of the overlying sediment layers, both of which cause the crust to sink lower as it isostatically adjusts its buoyancy above the mantle. The coastal plain will continue to subside and accumulate sediments as long as the eastern margin of North America continues to be a **passive margin** (a continental margin that is not currently involved in tectonic subduction or collision).

Because of the generally flat topography of the coastal plain near sea level, there are very few natural exposures of younger coastal plain sediments (mostly these can be seen in bluffs along coastal rivers) and almost no exposures of older sediments. To study the **stratigraphy** (sequence of sedimentary layers) beneath the coastal plain it is necessary to drill down into the subsurface and collect or record the sediments encountered at different depths in a **core** or **well log**. This is an expensive undertaking and only a few widely spaced cores are usually obtained. It is the job of sedimentologists and paleontologists to make **correlations** between localities for which there is stratigraphic information to recreate the regional pattern of strata. Correlation involves identifying which layers in each core are equivalent in age and connected together, as well as locating unconformities (intervals of missing time / strata). The age of different sedimentary layers is usually determined based on the fossil species they contain, although thin, distinctive layers such as bentonites (volcanic ash layers) and shell beds can also be correlated to show equivalent “moments” in time (**event beds**).

Knowing the spatial pattern of sedimentary layers across a region allows geologists to follow the history of sea level change and to compile information from multiple localities to build a more complete understanding of the geological and environmental history of a region. Also, knowing the two and three dimensional pattern of strata is critical for locating economic resources such as mineral deposits, groundwater aquifers and hydrocarbons (oil and natural gas). Being able to make stratigraphic correlations is an important skill in the toolkit of a wide variety of working geologists.

The Correlation Exercise

In this laboratory exercise you will create a **fence diagram** of the Atlantic Coastal Plain by correlating a sequence of **well logs** recorded along a NW–SE transect through coastal North Carolina. A well log is a stratigraphic section obtained by drilling a well into the subsurface and extracting a sequence of rock / sediment samples. The well logs in this exercise are based on actual well logs published by the United States Geological Survey, so you will obtain a realistic cross section of the Atlantic Coastal Plain when the exercise is completed. Because there is so much repetition in the lithologies that make up the different layers (they are mostly alternating sand and mud layers) the **lithostratigraphic correlations** (based on rock type) between well logs must be guided by information provided by **biostratigraphic correlations** (based on fossil content).

Instructions

Follow the directions below carefully and in the order given. What seems like a very complex problem can be successfully completed if you follow directions.

Materials:

Pencils – grey, blue, red, green, and yellow
Transparent tape and / or rubber cement
Scissors

Building the map

1. Assemble stratigraphic sections OT-7 and OT-30 by trimming the bottom of the upper sheet(s) and joining the parts of each column together using rubber cement or backing tape. Try not to apply tape to the front of the diagram as this will make drawing on the diagram difficult.

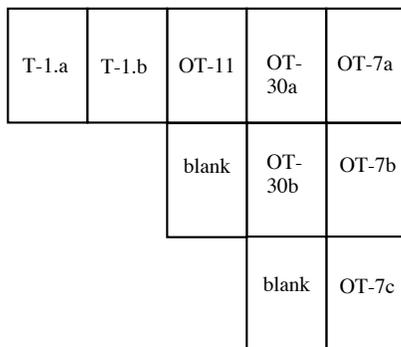


Figure 1. Layout of stratigraphic column sheets.

2. Assemble all stratigraphic sections in the sequence shown on the index map. Leave about 6-8 inches between each section and **align the top of each section to the sea level datum**. Use blank sheets of white paper to fill in squares below columns OT-11 and OT-30 so that you end up with a triangular map (see Figure 1 directly above).
3. Microfossils are often used to determine the age of sediment layers in drill core because hundreds or even thousands of specimens can be obtained from a few grams of sediment. Use the foraminifera index fossils (left side of stratigraphic columns) to identify and label the

age of the strata in the columns using the time unit abbreviations from Table 1. Index species are illustrated and identified in Figure 2 and arrows indicate the stratigraphic range of each species within individual well logs.

Making correlations

Allostratigraphic Correlations – unconformities (intervals of missing time)

1. Using a **red pencil** connect the tops of the stratigraphic columns together with an unconformity line – this is the modern erosional surface (an unconformity in the process of formation).
2. Using a **red pencil** connect the bottom of each stratigraphic column where the lowermost sedimentary layer meets the bedrock **basement** together with an unconformity line. If the basement was not reached by the well run the unconformity line beneath the section.
3. Locate all other unconformities in the sections and mark them on the sections.
 - a. Look for intervals of time not represented by strata (for example, Lower Eocene strata overlain by Lower Miocene strata indicates that the Middle and Upper Eocene and all Oligocene strata are missing). A geologic time chart showing the complete sequence of periods and ages is provided in Table 1.
 - b. One unconformity is marked in the sections by a squiggly line. This represents a distinct surface of exposure and erosion that has been identified by a fossil soil (**paleosol**) in the sequence of strata.
4. Using a **red pencil** correlate all unconformities cutting out the same ages. Note that unconformities will tend to merge together in the landward direction.

Biostratigraphic Correlations – time-equivalent horizons marked by fossil beds

5. Using a **blue pencil** make chronostratigraphic correlations using distinctive shell beds represented by the invertebrate fossils illustrated to the right of the sections.

Lithostratigraphic Correlations – laterally continuous rock layers

6. Using a **grey pencil** lightly make lithostratigraphic correlations between the five sections (be prepared to erase and redraw). Remember to only correlate **between** unconformities. Do not draw any correlations across unconformities (red lines). Also, use the biostratigraphic correlations (blue lines) to guide your lithostratigraphic correlations. Pinch out any layers that do not appear to extend over to the adjoining column. Sandstones will tend to pinch out to the east (into deeper water) whereas mudstones and limestones will tend to pinch out to the west (toward shallower water).
7. Using a **yellow pencil** shade in the sandstone layers between the correlation lines. This will help you better see the pattern of lithologies that you have correlated. When your correlations are complete you can shade in the mud layers with a **green pencil**.

Questions – to be discussed among your group and then answered and submitted individually as well-explained short essays.

- 1.** Why are fossils important for correlating sedimentary strata? In other words, what information do fossils provide that assists in correlating sedimentary layers from locality to locality?

- 2.** What intervals of geologic time were times of major sea level fall (regression)?

- 3.** What intervals of geologic time were times of relative high sea level (transgression) that flooded much of the modern coastal plain?

- 4.** Why does the unconformity formed during the pre-middle Eocene disappear between wells OT-30 and OT-7?

- 5.** Which unconformities appear to be angular unconformities?

- 6.** If you were going to drill for oil or natural gas, where in the subsurface would you drill and why? (Hint: to trap oil you need layers of sandstone capped off by a layer of shale – see your answer to question 5).

- 7.** Why are there sediments currently exposed above sea level on the Atlantic Coastal Plain?

- 8.** Sea level is currently rising at a rate of about 1.5 feet / century. At this rate, approximately how long will it be before the Atlantic Coastal Plain is flooded by the ocean as far inland as locality T-1a?

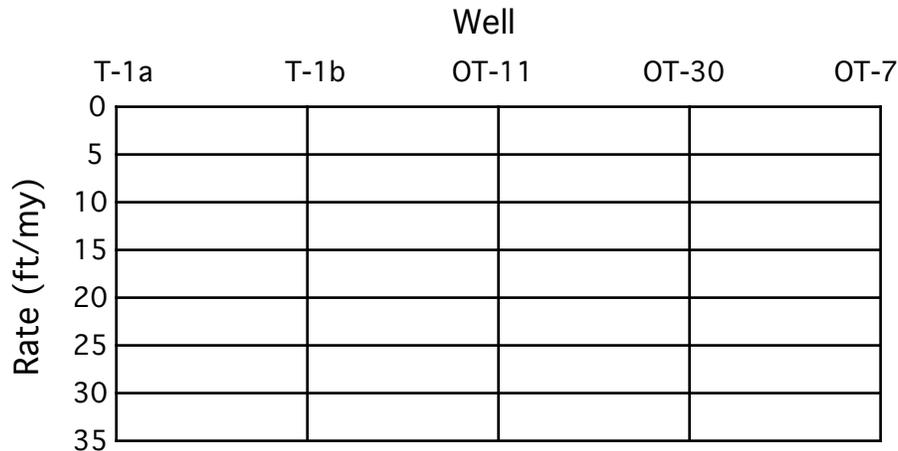
Subsidence Calculations

The rate of subsidence in an area can be calculated by measuring the vertical distance the basement rock has dropped downward over a known interval of time. This distance is equal to the thickness of sediments that have been deposited over the basement since subsidence began. The age of the sediments directly above the basement rock gives the amount of time over which subsidence has been occurring. Dividing the thickness of sediments by the duration of subsidence will yield an average rate of subsidence, which is usually expressed in terms of feet per million years.

1. Calculate the average rate of subsidence at each well location. Measure the thickness of each section using the vertical scale provided with section T1-b. The ages of the strata at the bottom of each well are given below. Thickness / Age = Subsidence Rate (ft / m.y.)

	<u>Age</u>	<u>Thickness</u>	<u>Subsidence Rate</u>
T-1a	85 my		
T-1b	+/- 90 my		
OT-11	135 my		
OT-30	140 my		
OT-7	150 my		

2. Plot subsidence rate vs geographic location on the graph below.



3. Describe how subsidence rate changes going from onshore to offshore. Why are the ages of the oldest (first-deposited) strata different at the bottom of each well?

References

Brown, P.M., Miller, J.A., and Swain, F.M., 1972. Structural and stratigraphic framework and spatial distribution of permeability of the Atlantic Coastal Plain, North Carolina to New York. *United States Geological Survey Professional Paper 796*, 79 pp.

Sundberg, F.A. and Gilinsky, N.L. (eds), 1988. *Historical Geology Laboratory Manual*, Department of Geological Sciences, Virginia Tech.

Abbreviation	Name
Np – Npl	Neogene: Pliocene – Pleistocene
Nm (U)pper (M)iddle (L)ower	Neogene: Miocene
Po	Paleogene: Oligocene
Pe (U)pper (M)iddle (L)ower	Paleogene: Eocene
Pp	Paleogene: Paleocene
Upper K	Upper Cretaceous
Lower K	Lower Cretaceous
Jur	Jurassic

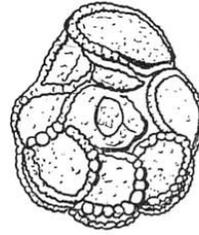
Table 1. Complete sequence of time intervals for the Mesozoic and Cenozoic used in this exercise.



Frondicularia
Jurassic



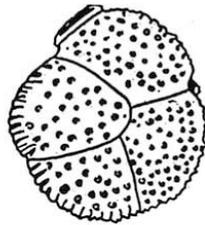
Flabellammina
Lower Cretaceous



Globotruncana
Upper Cretaceous



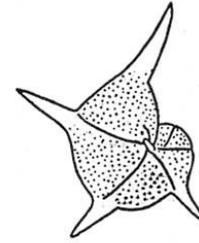
Bulimina
Paleocene



Siphonina
Lower Eocene



Robulus
Middle Eocene



Hantkenina
Upper Eocene



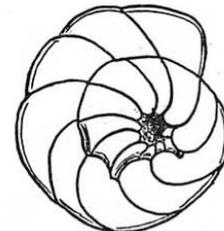
Bifarina
Oligocene



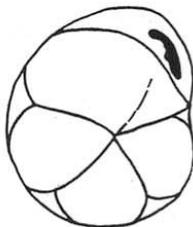
Ellipsonodosaria
Lower Miocene



Bigenerina
Middle Miocene



Amphistegina
Upper Miocene



Cassidulina
Pliocene-Pleistocene

Foraminifera species used for biostratigraphic correlation

Figure 1. Key to oraminifera species used for assigning sediment layers to geological time intervals in this exercise.

