A Coast for All Seasons

A Naturalist's Guide to the Coast of South Carolina

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2 ORIGIN OF THE COAST

Once upon a time at the spot where the authors of this book have a mountain house in western North Carolina, in place of the now serene Blue Ridge Mountains, stood a stark, snow-capped mountain chain as high as the modern Himalayas. Eventually, that high mountain range was eroded, and, in the process, provided the bulk of the sediment that now comprises the Coastal Plain of South Carolina, including the light gray sand on the beaches. Unraveling the long history of how the present coastline originated has fascinated geologists for many decades. The story is rather complicated, and there are still many unanswered questions regarding details, such as the exact age and timing of the different geological episodes. However, the following brief listing of this chain of events, based on a variety of sources (sciencedaily.com; earthquakes.usgs.gov; news.softpedia.com; sciencedaily.com; geology.er.usgs.gov; Glen, 1975; and Hatcher, 2005), provides a general introduction to the subject. See also the time line in Figure 2.

There is still some question about the exact timing of all this, but conventional wisdom has it that about 400 million years ago, there were two main land masses separated by the Rheic Ocean. In the south sat **Gondwana**, a supercontinent consisting of South America, Africa, India, Australia, and Antarctica, and in the north sat **Laurasia**, made up of North America, Greenland, Europe, and part of Asia. There is still some dispute about the exact makeup of these two landmasses.

[NOTE: In the winter of 1964/65, co-author Hayes led a geological expedition in Antarctica to examine a sequence of sedimentary rocks called the Beacon Sandstone of Permian age (around 250 million years old). These rocks were very similar to other Permian units in South Africa and India, containing huge petrified trees that grew in tropical forests, among other artifacts. The correlation of these very similar sandstones by the geologists at that time was supporting evidence for the original makeup of the supercontinent Gondwana. Those studies also documented the eventual wandering of the fragment of that original continent now known as the separate continent of Antarctica from warmer climes near the equator to the vicinity of the present south pole.]

Around 300 million years ago, during the Carboniferous Period of the Paleozoic Era (see geological time scale in Table 1), these two landmasses collided to form a single large continent called **Pangaea** (see Figure 3A). In the process, the Appalachian Mountains were formed (Dietz and Holden, 1970). These mountains are said by some to have been as high as the Himalayas and by others at least as high as the modern Rocky Mountains. During this time interval, the ancient igneous and metamorphic rocks that presently underlie the

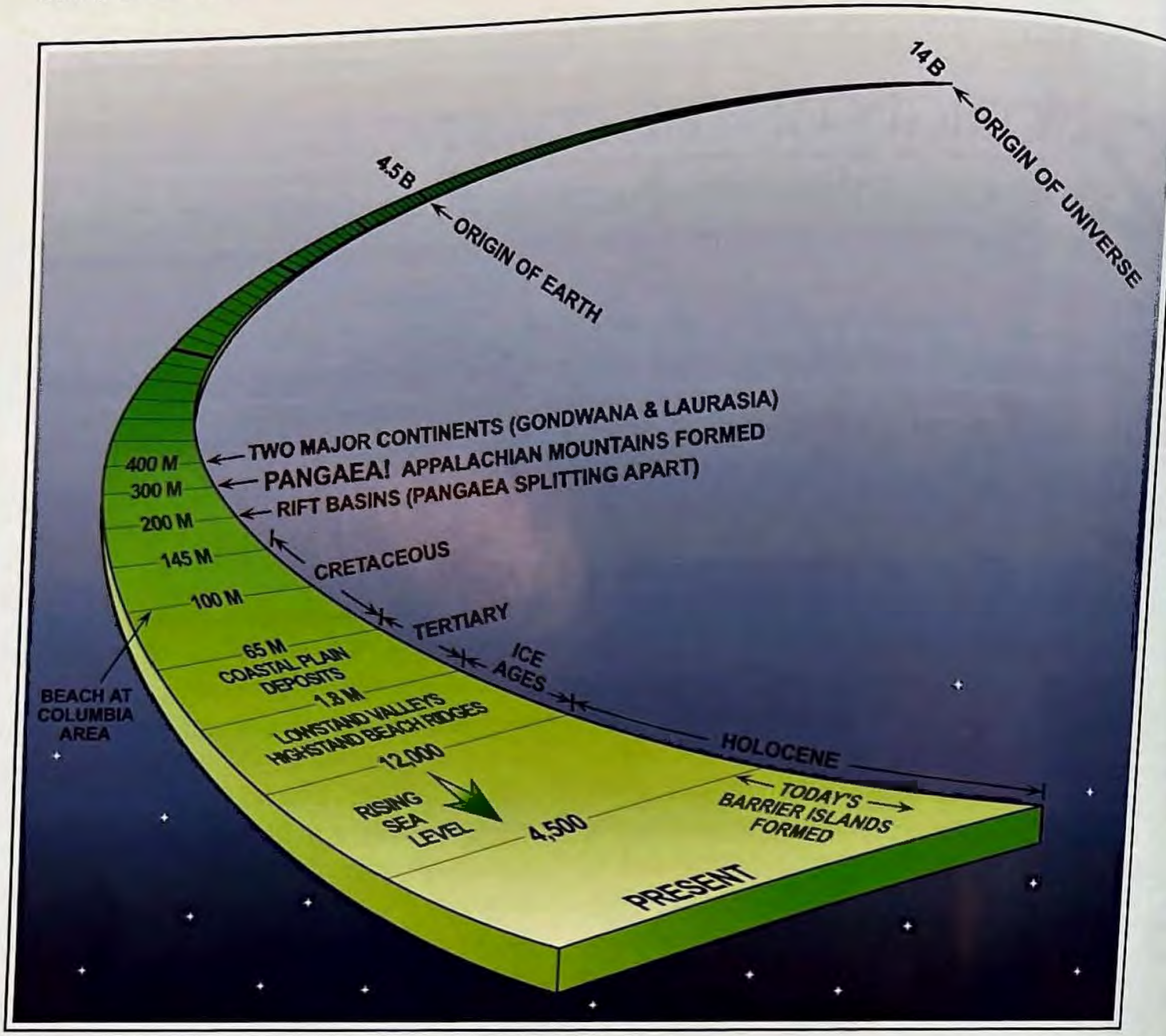

FIGURE 2. Time line for origin of the coast of South Carolina. See Table 1 for nomenclature and timing of the geological events.

sediments and sedimentary rocks of the South Carolina Coastal Plain were intensely folded and faulted.

[NOTE: The three major classes of rocks – igneous, sedimentary, and metamorphic – were first defined by the pioneering Scottish geologist James Hutton in the mid 1700s. He recognized a class of rocks called **igneous rocks** that crystallized from an extremely hot molten mass of material (magma) that was formed as if by fire (*ignis* = fire). One class of igneous rocks, which includes granite, develops by slow cooling of the molten mass at great depths within the earth's crust. As a result of the slow cooling, large crystals of individual minerals form that can be as much as an inch or so in diameter. These minerals, typically including feldspar and quartz, eventually coalesce to form a rock mass, which may later be pushed up to the earth's surface by mountain building processes. A second class of igneous rocks, called volcanic rocks (e.g., basalt and rhyolite), crystallize rapidly as a result of molten lava being extruded suddenly onto the earth's surface. The crystals of these minerals that form so rapidly are, for the most part, too small to be seen

TABLE 1. Geologic time. Time intervals are listed in millions of years before the present (from numerous sources).

Era/Period/Epoch			Time (Million yr ago)
Cenozoic era "Recent Life"	Quarternary period	Holocene epoch	0.012-0
		Pleistocene epoch	1.8-0.012
	Tertiary period	Pliocene epoch	6-1.8
		Miocene epoch	26-6
		Oligocene epoch	38-26
		Eocene epoch	55-38
		Paleocene epoch	65-55
Mesozoic era	Cretaceous period		145-65
	Jurassic period		205-145
	Triassic period		250-205
Paleozoic era	Permian period		290-250
	Carboniferous (Mississippian/Pennsylvanian) period		355-290
	Devonian period		410-355
	Silurian period		438-410
	Ordovician period		505-438
	Cambrian period		545-505
Precambrian	**Proterozoic era**		1500-545
	Archaeozoic (Archean) era		4500-1500

by the naked eye. On the other hand, **sedimentary rocks** are most commonly formed by weathering and erosion of preexisting rocks on the earth's surface. This process creates sediment that can be transported by water, or wind in some cases, to be deposited in large masses on river deltas, beaches, and so on. Once deposited, these most commonly sand-sized sediments may become buried where they are consolidated by chemical cementation and other processes. The most abundant sedimentary rocks formed by this process are called sandstones. Limestones, which are also sedimentary rocks, usually develop in marine waters by a combination of chemical precipitation and accumulation of the hard parts of some marine organisms, such as sea shells. The third class, **metamorphic rocks,** results from dramatic changes in igneous and sedimentary rocks affected by heat, pressure, and water that usually results in a more compact and more crystalline condition. These changes usually take place at significant depths below the earth's surface. Examples of metamorphic rocks include: 1) slate, derived from a sedimentary rock called shale (originally composed of silt and clay); 2) marble, derived from limestones; and 3) gneiss, a banded, micaceous rock typically derived from granite.]

Between 225-190 million years ago, during the Triassic Period, the major land mass of Pangaea started to split apart along the old collision zones. This pulling apart created some **rift basins** in parts of the area now known as the eastern United States similar to the ones presently occurring in south-central Africa. These rift valleys filled with sediments eroded from the uplifted blocks along the rift margins. Some of the most noteworthy of these Triassic Rift Basins occur in Massachusetts and North Carolina. However, the map in Figure 4 shows the presence of one of these rifts along the South Carolina/Georgia border (the South Georgia Rift). The sedimentary rocks in the South Georgia Rift are the oldest sedimentary rocks that have not been metamorphosed (i.e., changed dramatically

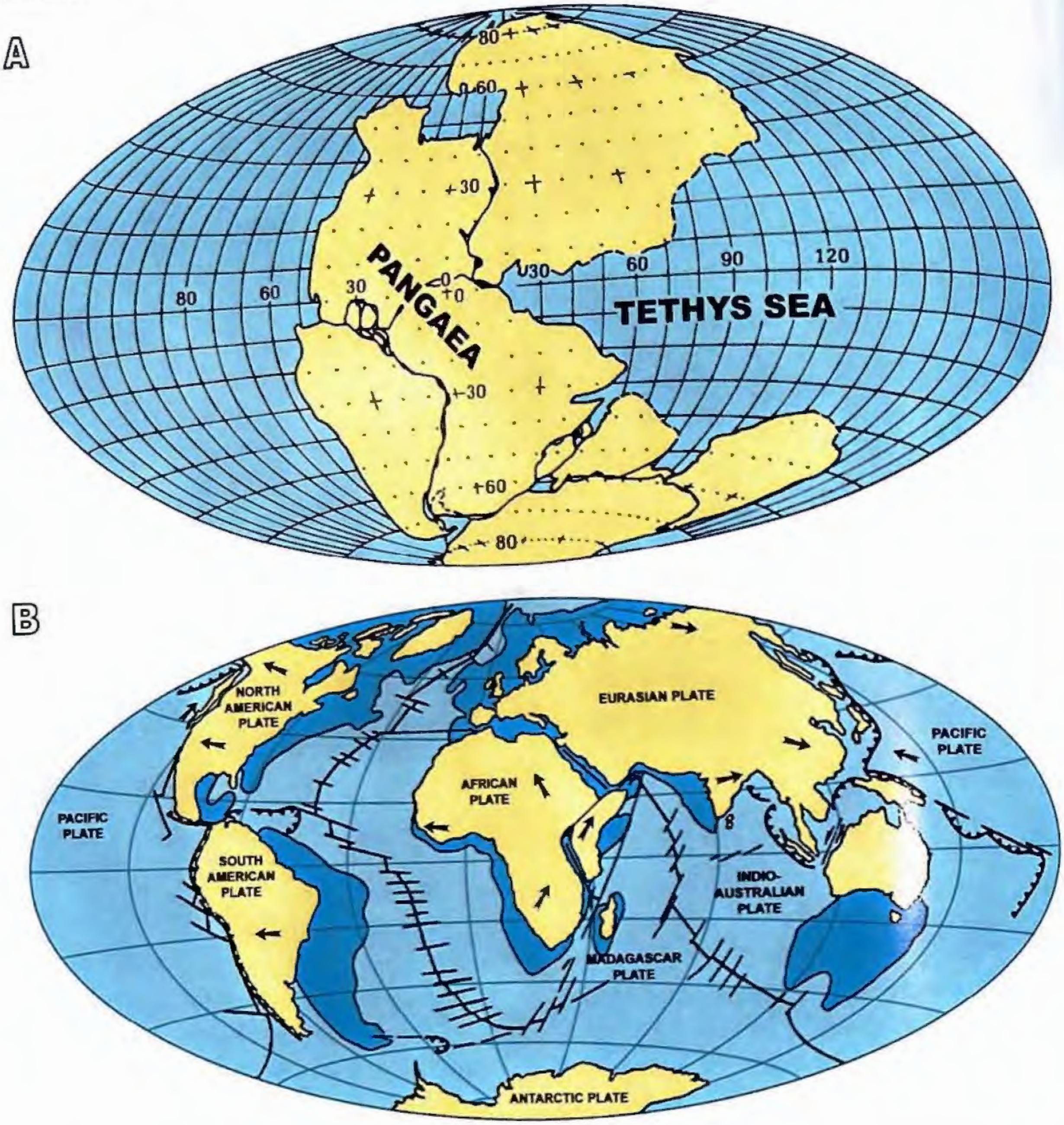

FIGURE 3. Two of the basic elements in the geological history of South Carolina as we now know it. (A) Outline of all the continents that assembled to form **Pangaea**, a universal landmass as it existed at the end of the Permian Period (Table 1) around 250 million years ago [as defined by Dietz and Holden, (1970); modified after Glen (1975: Figure 8.8)]. (B) The major continents in their present position. Arrows indicate the directions the different land masses have moved since they first started "drifting apart" around 200 million years ago. The blue "shadows" represent previous locations of the continents as they moved along.

by high heat and pressure) in the state of South Carolina.

Around 100 million years or so ago as the continents continued to drift apart (see Figure 3B, which shows the final product of this drifting), a huge arm of the world ocean, called the **Cretaceous Seaway,** covered much of what is now North America, extending north to south through the

FIGURE 4. Coastline of the southeastern United States, illustrating the major bend in the shoreline known as the Georgia Bight. Some of the principal tectonic elements, the Cape Fear Arch to the north and the Ocala Uplift to the south, as well as the South Georgia Rift (of Triassic age; Table 1), are shown. Tectonic elements delineated by LeGrand (1961).

middle of the continent. All of the present United States south of the southern edge of the Appalachian Mountains was flooded by this large sea, which extended to the east into the ocean being created by the continents drifting apart. As shown in Figure 5, during the Late Cretaceous, the shoreline was near where Columbia, South Carolina is now located. The Cretaceous sedimentary rocks in South Carolina were deposited in this ancient sea, containing fossils of oysters and other marine animals, as well as dinosaur teeth and bones washed from the shore. These sediments can be seen today on the surface in a relatively narrow band at the upper edge of the coastal plain, and they achieve thicknesses of

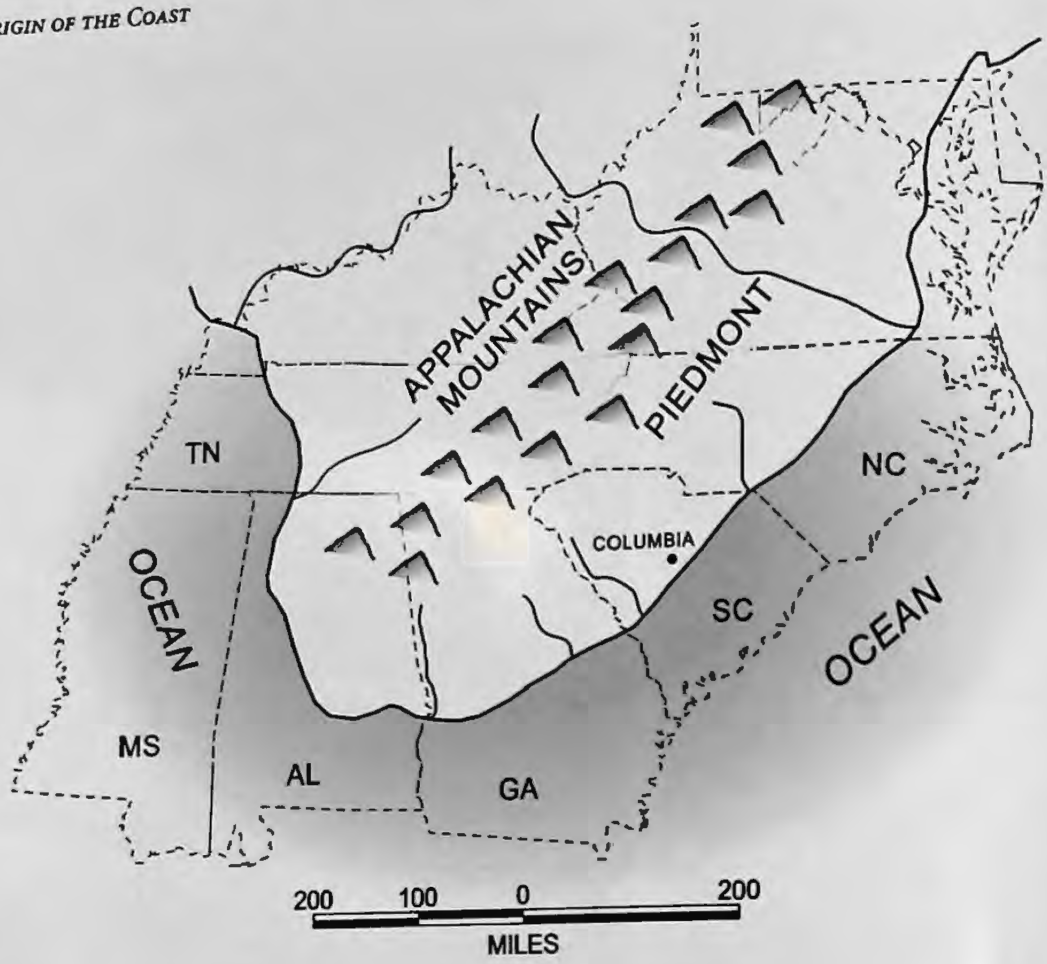

FIGURE 5. Approximate location of the Cretaceous Seaway in the eastern United States around one hund··d million years ago. The shoreline of the Seaway was located near the present town of Columbia, South Carolina. Modified after D. T. King, Jr.

several hundred feet at depth in the lower coastal plain (Figure 6). These sedimentary rocks are important ground-water aquifers throughout the coastal plain.

During the **Tertiary Period** (between 65 and 1.8 million years ago) the **Coastal Plain** of the region we know as South Carolina was transgressed (flooded) and exposed several times. That span of time is described succinctly on the paleoportal.org web site as follows: *Erosion of the Appalachian Mountains supplied much of the material that makes up the Tertiary rocks of South Carolina. Fossils from these rocks indicate that the climate of the Early Tertiary (Paleocene and Early Eocene) was warm and tropical. Worldwide cooling events generated a more moderate climate for South Carolina during the Late Eocene. But by the Middle Tertiary (Oligocene), the climate began to warm again, as evidenced by fossils of whales and large crocodiles. Various marine and terrestrial fossils show that the climate was tropical to subtropical, much like modern Florida, by the Late Tertiary (Pliocene).* Tertiary rocks, which are predominately sandstones and shales, but do contain some significant limestone deposits, are exposed at the surface over much of the Middle and Upper Coastal Plain. They also achieve thicknesses of several hundred feet at depth in the Lower Coastal Plain (Figure 6). Depositional environments ranged from deltas and other shoreline deposits to offshore limestones.

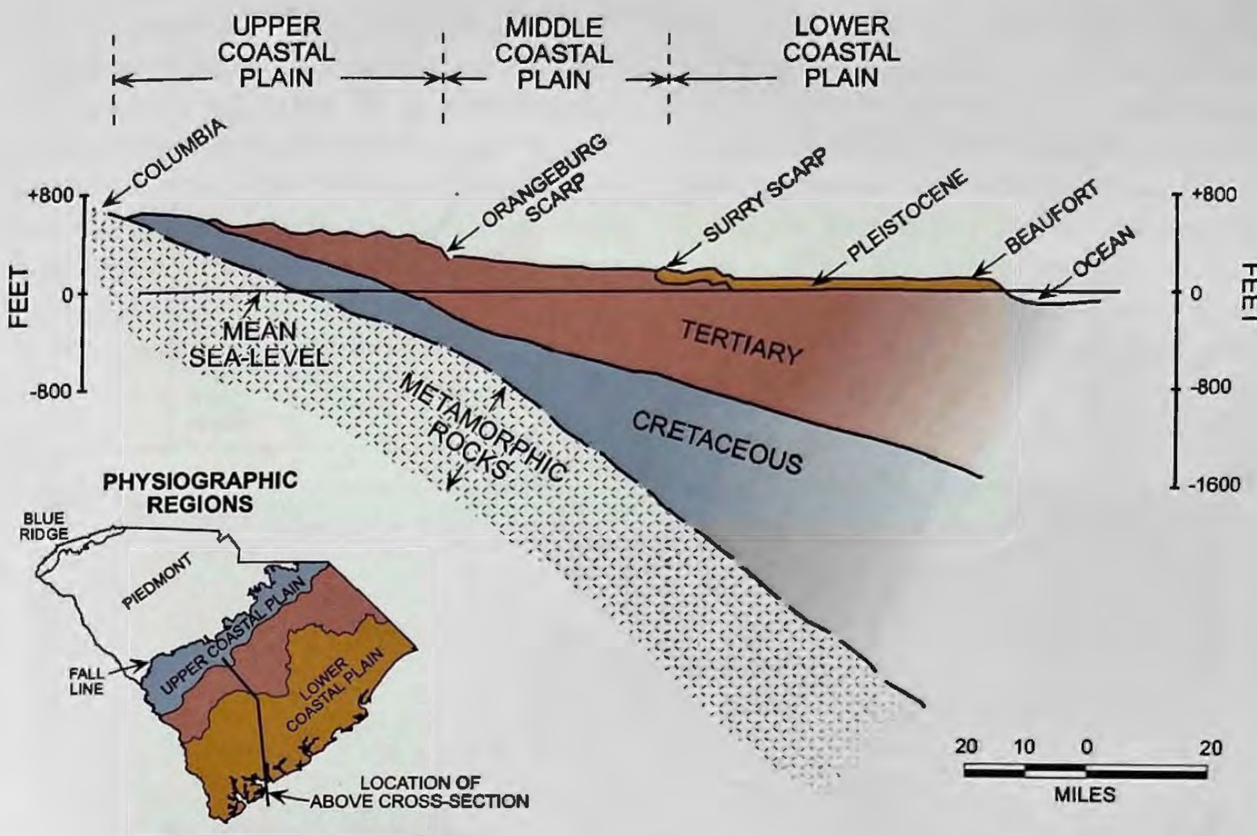

FIGURE 6. General cross-section of the sedimentary rocks and sediments that underlie the Coastal Plain Physiographic Province of South Carolina. Location of the three physiographic provinces in the state is shown in the lower left. The Lower Coastal Plain is characterized by a relatively flat surface underlain by Pleistocene sediments. The Middle and Upper Coastal Plain, which are underlain by surficial outcrops of Tertiary and Cretaceous rocks and sediments, show considerably more topographic relief than the Lower Coastal Plain. These older sedimentary rocks abut against the igneous and metamorphic rocks of the Piedmont Province along the fall line (see Figure 1). Highly modified after Colquhoun et al. (1983).

A major change in climate that initiated the beginning of the Ice Ages (the **Pleistocene Epoch**) occurred around 1.8 million years ago. The Pleistocene Epoch ended around 10-16,000 years ago, when the last of the major glaciations ceased. Within the Pleistocene Epoch, four major glacial events occurred, during which time ice covered large areas of the North American continent (as far south as the Ohio River in the eastern United States). The approximate median peak times for these glacial events, expressed in years before the present (B.P.), were: 650,000 for the Nebraskan glaciation; 450,000 for the Kansan; 150,000 for the Illinois; and 60,000 for the Wisconsin. During each of these glaciations, sea level dropped to significantly lower levels than it is today; during the last glaciation period it was 350 feet lower! When sea level was lower, during what is referred to as **lowstands**, the rivers along the east coast carved deep valleys across the coastal plain and out onto the present continental shelf. The location of these valleys on the coastal plain of the Georgia Bight is shown in Figure 7. The glaciations were separated by warming periods, called interglacials, when sea level rose. During these warming periods, the highest sea levels were higher than it is today, with each succeeding interglacial having lower and lower **highstands**. Sea level during the last interglacial, the Sangamon (peak around 120,000 years B.P.), stood around 10 to 12 feet higher than it is today.

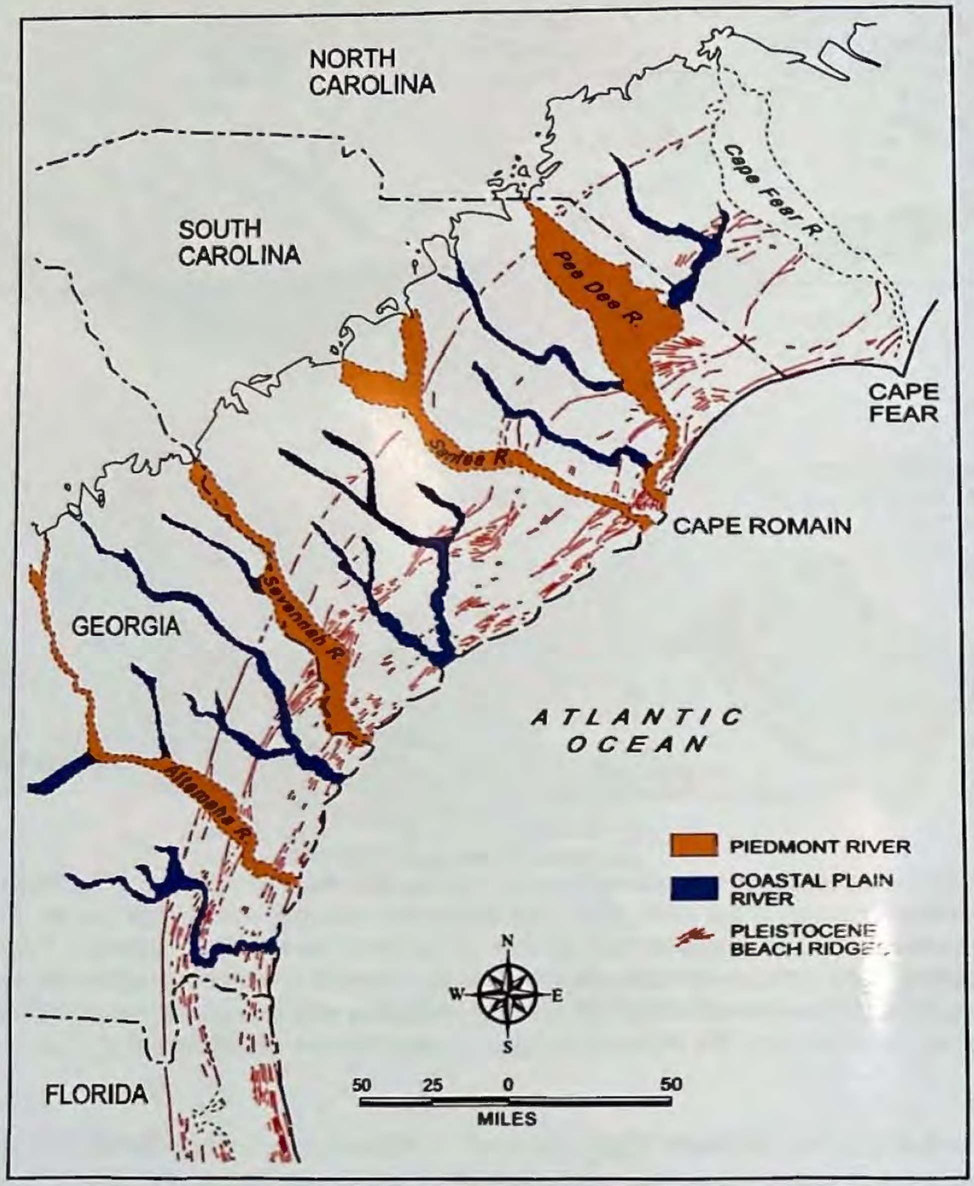

FIGURE 7. Lowstand valleys of the coastal plains of South Carolina and Georgia. The valleys were carved when sea level was lowered during the major glaciations of the Pleistocene Epoch. The bulk of the flood plains that now occupy these valleys were formed during the last major rise in sea level, which started about 12,000 years ago. The valleys of the four piedmont, or red-water, rivers (Pee Dee, Santee, Savannah, and Altamaha), are shown in orange, and those of the major coastal plain, or black-water, rivers are shown in blue. The red lines indicate the position of beach ridges or erosional scarps formed when highstands of sea level occurred between the major glaciations. Highly modified after Winker and Howard (1977).

During these highstands, waves eroded scarps and deposited linear beach ridges inland of the present shoreline. The old beach ridges, shown in red on Figure 7, extend inland as far as 40 miles. Note the zones of parallel beach ridges several miles wide formed during the Sangamon interglacial, that are located only a short distance landward of much of the present shoreline. Pleistocene sediments blanket the Lower Coastal Plain (Figure 6), which is very flat. During some of the lowstand episodes, the actual shoreline was near or at the edge of the present continental shelf, a distance of 60-70 miles from the present shore. Also, during episodes when sea level was relatively constant for a while during its covering and uncovering of the continental shelf, coastal features such as river deltas and barrier-island complexes were deposited; remnants of them are still present on the continental shelf. Such events have created a very complex topography of the shelf (see Figure 8).

The major ice-melting episode that started about 10-16,000 years ago marked the beginning of the **Holocene Epoch** at which time sea level was approximately 350 feet below its present position. A considerable amount of research on this topic is still underway, and the exact dates involved are subject to change as more data are produced. Without any doubt, however, as the melting proceeded, sea level rose rapidly, as much as 2 feet/century, reaching near its present level in South Carolina around **4,500**

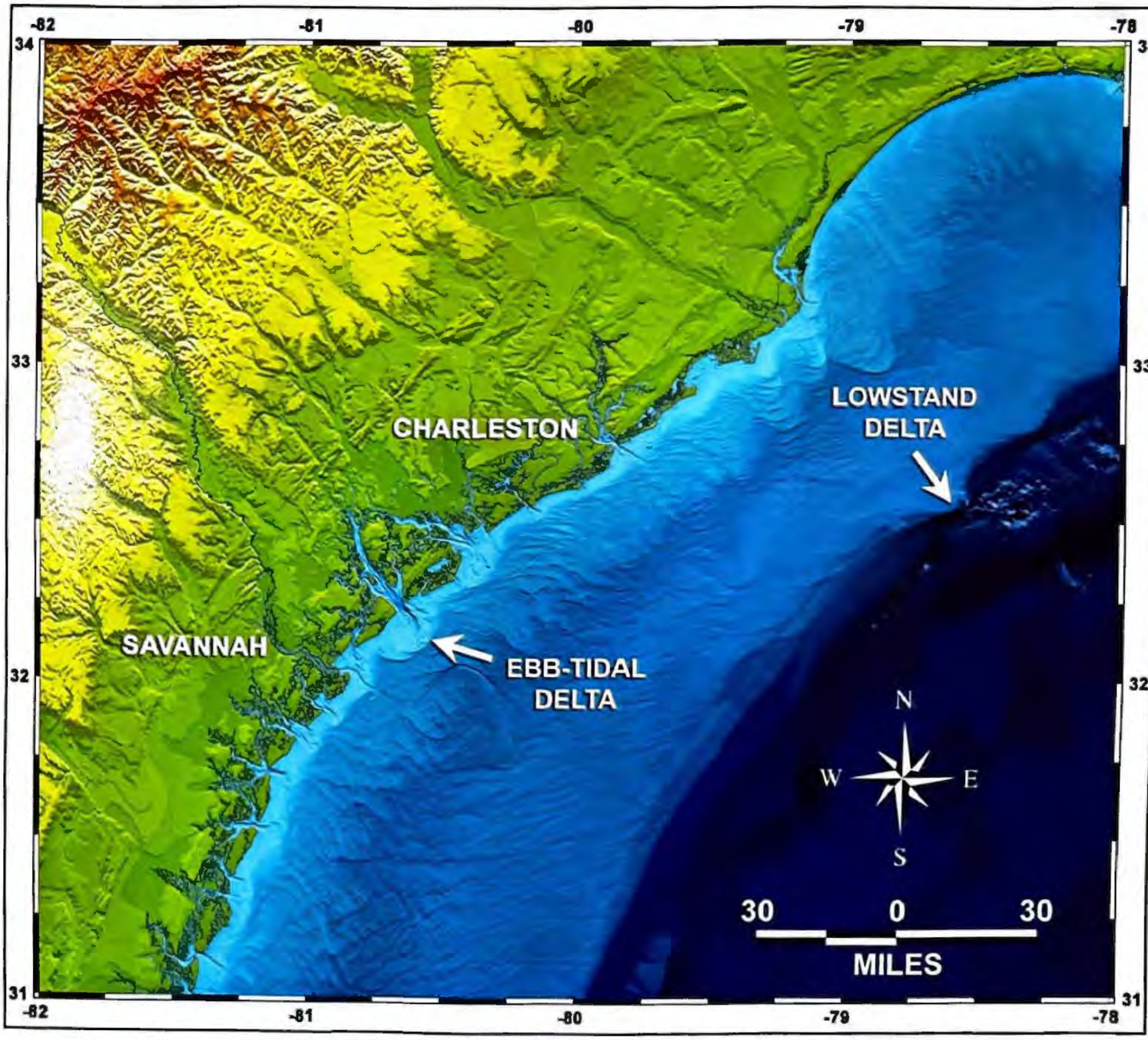

FIGURE 8. Bathymetry of the continental shelf off the South Carolina and Georgia shorelines. Note the lowstand delta at the edge of the continental shelf (arrow), as well as the numerous relict deltas further landward on the shelf, off the present mouths of the Santee and Pee Dee Rivers. The massive ebb-tidal delta off Port Royal Sound (arrow) is also clearly shown. From the National Geophysical Data Center (Coastal Relief Model).

B.P. (the exact date is somewhat in question). Since a near **stillstand** that occurred at that time (4,500 B.P.), the bulk of the major Holocene landforms on the coast (e.g., deltas and barrier islands) have formed. However, as shown in Figure 9, there have been several minor sea-level fluctuations, up to four feet or so, in the past 4,500 years. The remainder of this book mostly concerns features formed during that last, relatively **short time interval**.

This long evolution has left a final imprint on the state of South Carolina, which consists of the three major physiographic provinces shown in Figure 6. Just a sliver of the **Blue Ridge Province** occurs in the extreme northwest portion of the state. This

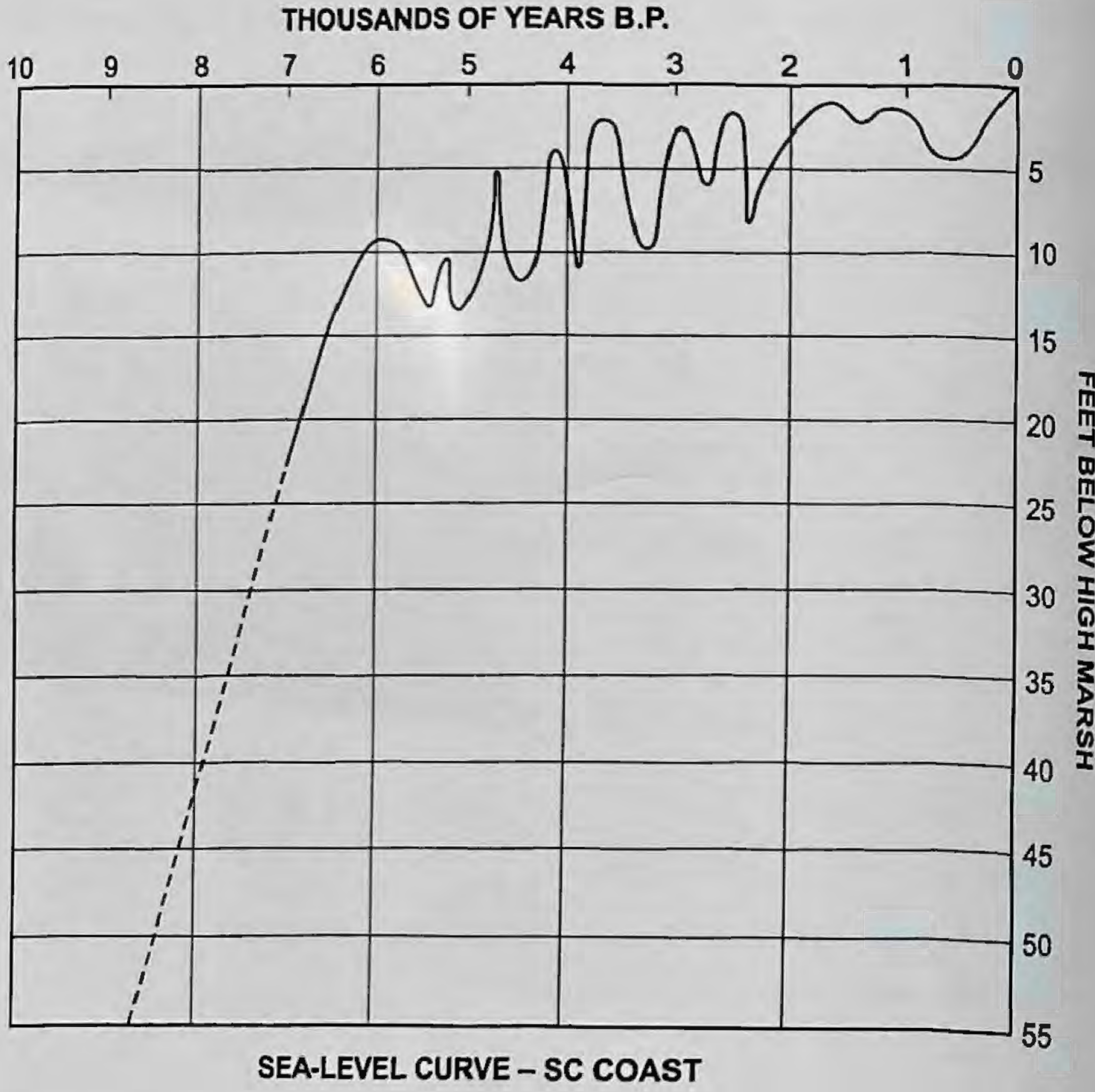

FIGURE 9. Changes in sea level along the South Carolina coast over the past 6,000 years, based on detailed, combined archeological and stratigraphical research (after Colquhoun and Brooks, 1986). The dashed extension of the curve is our approximation. A similar curve was derived for the Georgia coast by DePratter and Howard (1980), but DePratter (pers. comm.) indicates that this curve needs some upgrading. Therefore, some changes are probably in order. Nevertheless, some of the lows in the curve between 2,000 and 4,000 years before present have had a significant effect on the evolution of the barrier islands in the Georgia Bight.

mountainous region has elevations ranging from 1,000 feet in the foothills to 3,554 feet at Sassafras Mountain, the highest point in South Carolina. The Blue Ridge Mountains of South Carolina are but a small portion of the Appalachian Mountain system. The Blue Ridge Province is bordered on the south by the **Piedmont Province.** Piedmont is derived from a French word meaning "foot of the mountains." This Province consists of a 100-mile-wide belt between the Blue Ridge and Coastal Plain Provinces. The fault line called the Brevard Zone separates the Piedmont from the Blue Ridge. The rock types in the Piedmont are primarily metamorphic, mainly schists, gneisses, and slates, and some granite igneous rocks that intruded into cracks and joints in the existing rock about 200 million years ago. The **Coastal Plain Province**, which has already been discussed in some detail, covers more than half of the state. The Upper and Middle Coastal Plain has some relief with hills scattered here and there; but the Lower Coastal Plain, with its surface sediments of Pleistocene age, is nearly flat and featureless.

The **climate** of the three physiographic provinces is summarized briefly below:

- The whole state has a **humid subtropical climate**, with an average precipitation in the coastal plain of about 49 inches/year.
- There is more rainfall in the Blue Ridge Province, with up to 80 inches/year.
- Regional rainfall related to the passage of large fronts is common in the winter months, whereas rainfall in the summer is usually associated with thunderstorms.
- The average January temperatures range from 50 degrees along the coast to 38 degrees in the mountains. Average July temperatures are 81 degrees along the coast and 71 degrees in the mountains.