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Eocene and Oligocene Stratigraphy of Southeastern North Carolina

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STRATIGRAPHY OF OUTCROPPING EOCENE AND OLIGOCENE FORMATIONS—COASTAL PLAIN OF THE CAROLINAS

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ABSTRACT

Outcropping Eocene and Oligocene marine deposits in the Carolinas consist largely of carbonate rocks that formed in tropical or subtropical environments. In middle Eocene time, the seas transgressed as far west as the Piedmont and deposited sediments of the Castle Hayne Formation in North Carolina and the Santee Limestone in South Carolina. During late middle Eocene time, the Castle Hayne sea regressed as the Cape Fear arch to the south and the Norfolk arch to the north became positive. No outcropping upper Eocene deposits are now recognized in North Carolina. However, in South Carolina, sediments of the lower part of the Cooper Formation were deposited during the late Eocene, in moderately deep water. During the early Oligocene, substantial erosion of Eocene units apparently took place in the Carolinas. By late Oligocene time, a new transgression deposited sediments of the upper part of the Cooper Formation in South Carolina and the River Bend Formation in North Carolina. In the latest Oligocene, a separate transgressive-regressive cycle deposited sediments of the Edisto Formation in South Carolina and the Belgrade Formation in North Carolina.

INTRODUCTION

The North Carolina and South Carolina depositional basins are separated from each other by the Cape Fear arch, which apparently has been an active feature throughout the Cenozoic. On the crest of the arch, Cretaceous deposits crop out at sea level along the present coastline. Overlapping the eroded surface of Upper Cretaceous and lower Tertiary rocks on the North Carolina Coastal Plain, a middle Eocene (Claibornian) sea transgressed as far west as the Piedmont. A thick sequence of limestone, deposited in this shallow, tropical, marine basin, constitutes the Castle Hayne Formation (Figure 1) and consists largely of well-sorted, locally crossbedded, bryozoan hash. During the late middle Eocene, the Castle Hayne sea regressed as the Cape Fear arch to the south and the Norfolk arch to the north became positive areas relative to adjacent basins. During this regression, sediment comprising an arenaceous molluscan limestone (the Spring Garden Member of the Castle Hayne) was deposited in the Neuse River area.

During the late Eocene (Jacksonian) and much of the early Oligocene (Vicksburian), exposed Eocene carbonate rocks on the Coastal Plain of North Carolina were eroded subaerially, which produced an uneven surface and removed the Castle Hayne entirely in some areas. A middle Oligocene (late Vicksburgian) transgression centered in the area of the Neuse River and persisted through the late Oligocene (Chickasawhayan). Covering less than a tenth of the area overlapped by the Castle Hayne sea, this Oligocene sea was shallow near its perimeter, where crossbedded, barnacle shell-hash limestone is common (River Bend Formation). Uplift of the Coastal Plain at the end of the late Oligocene (Chickasawhayan) again exposed carbonate sequences of the Castle Hayne and newly deposited sediments of the River Bend to subaerial solution and erosion.

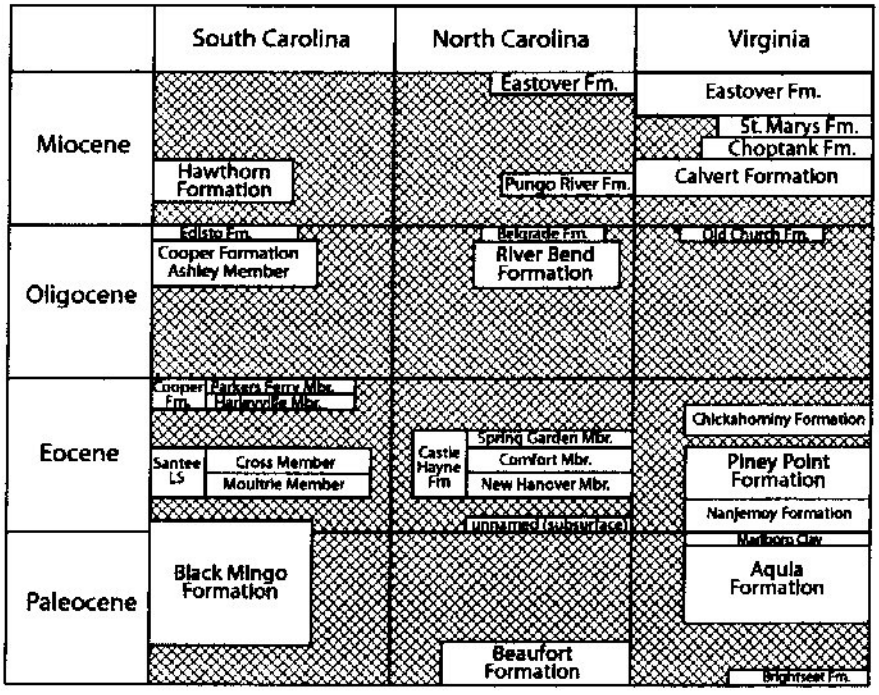

Figure 1. Correlation chart of Paleocene, Eocene, Oligocene, and Miocene stratigraphic units in South Carolina, North Carolina, and Virginia.

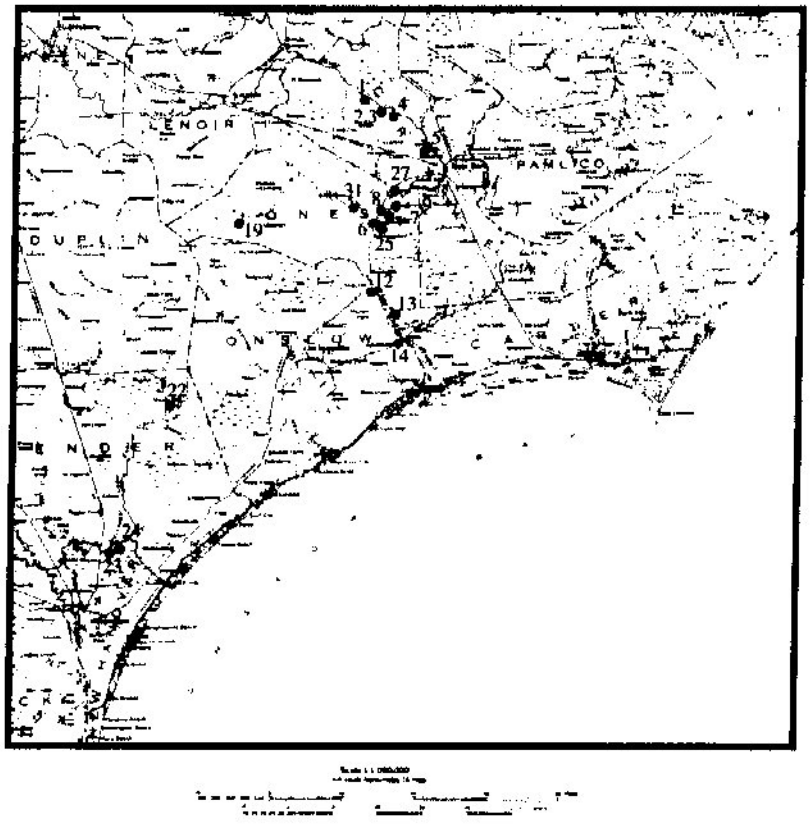

Figure 2. Base map of North Carolina, showing localities illustrated by graphic sections. These and other localities are described in Appendix 1. Fossil lists are given in Appendix 2.

During the latest Oligocene, a small marine embayment evolved in the Jones, Onslow, Carteret, and Craven Counties area. Normal-saline seas overlapped part of the already well-indurated River Bend limestone. Marine currents swept the underlying limestone clear of sediment, and marine mollusks bored the exposed rock substrate. A thin phosphate coating formed on the limestone surface, and marine oysters attached to this substrate. As an offshore bar became prominent, quartz-rich sandy sediment was deposited in the basin. Fossil mollusks indicate that the basin was at first of near-normal salinity. As the barrier prograded seaward, salinities decreased, and groups restricted to normal marine conditions disappeared; the oyster *Crassostrea* thrived in this sand (Pollocksville Member of Belgrade Formation).

During the latest Oligocene, a small marine transgression reworked back-barrier oysters from the Pollocksville member into open marine deposits of the Haywood Landing Member of the Belgrade formation. The Haywood Landing sea did not transgress over the full area covered by Pollocksville sediments; as a result, these marginal marine deposits are preserved on the northern and northwestern perimeter of the Belgrade Formation.

Eocene

Castle Hayne Formation

The Castle Hayne Formation was redefined by Ward *et al.* (1978) because of the ambiguous original description (Miller, 1910, 1912), lack of a type locality, and failure of subsequent studies (Kellum, 1925, 1926); Cooke and MacNeil, 1952; LeGrand and Brown, 1955) to define clearly the limits and various units of the formation. The Castle Hayne was named for limestone near Castle Hayne in New Hanover County. The

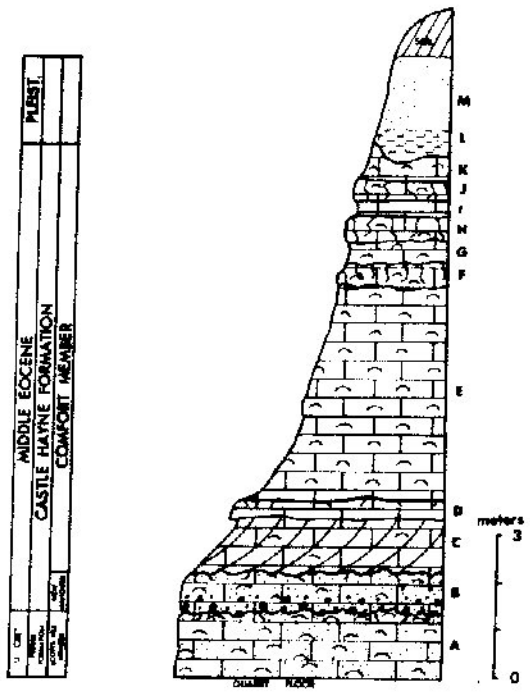

Figure 3. Section at Locality 24. Type locality of Castle Hayne Formation; reference locality of New Hanover and Comfort Members.
M. Sand and clayey sand, tan to orange, filling solution-pocked upper surface of underlying limestone.
L. Clay (residue of dissolved limestone), green, containing glauconite and phosphate near base.
K. Biocalcarenite, tan, soft.
J. Calcarenite, tan, hard, containing burrows filled with fine shells.
I. Biocalcarenite, tan, soft.
H. Calcarenite, tan, hard, containing burrows filled with fine shells.
G. Biocalcarenite, tan, soft.
F. Calcarenite, tan, hard, containing burrows filled with fine shells.
E. Biocalcarenite, yellow gray, fossiliferous, soft and friable; fossils mainly molds of mollusks, some calcitic forms preserved; many bryozoans, glauconitic, limy nodules, indicating possible diastem.
D. Bryozoan, dense micrite, very light gray, fine, some molds, glauconite, phosphate,; upper surface irregular, phosphate coated.
C. Crossbedded, light-gray, fine, bryozoan bio-calcirudite to medium calcarenite in micrite matrix.
B. Lithocalcirudite, sandy, phosphatic, glauconitic, in very light-gray micrite matrix.
A. Molluscan-mold biocalcirudite, light gray, sandy, cemented by calcite spar.

Ideal Cement Co. quarry just east of Castle Hayne, New Hanover County (loc. 24, Figs. 2,3) (see also Appendix 1,2) was designated by Ward *et al.* (1978) as the type locality. The formation was redefined to include three new member: phosphatic lithocalcirudite facies (New Hanover Member), bryozoan and echinioid biocalcarenite facies having micrite matrix (Comfort Member), and siliceous bivalve-mold biocalcirudite facies (Spring Garden Member), Later, Baum *et al.* (1978) described beds in the Castle Hayne as consisting of three facies; these units and their equivalents in this and the report of Ward *et al.* (1978) are: 1) bryozoan biomicrudite—Comfort Member, 2) bryozoan biosparrudite—Comfort Member, 3) phosphate pebble biomicrudite—New Hanover Member

New Hanover Member. The name "New Hanover Member" was proposed for a slightly arenitic, micritic, phosphatic lithocalcirudite consisting of cobble- to pebble-size, sandy calcareous casts, commonly subrounded to well rounded, many of which are coated with phosphate and glauconite. A few quartz pebbles and flat clay chips also are present, together with very fine sand, glauconite, and phosphate in a cream-colored micerite matrix. Common ingredients also are shark and ray teeth, a few worn bones, calcitic mollusks such as *Pecten* and *Ostrea*, echinoids, crabs, and molluscan molds. The member ranges in thickness from 0 to 2 m.

Best exposures of the New Hanover were in three large quarries in the Castle Hayne area (loc. 24, Fig 3; loc. 23, Fig 4—the type locality; loc. 22, Fig 5). The New Hanover is easily delineated from the underlying Peedee Formation, a gray, mold and cast, siliceous limestone of middle Maestrichtian (Late Cretaceous) age. The New Hanover occupies erosional channels in the Peedee. The contact between the two

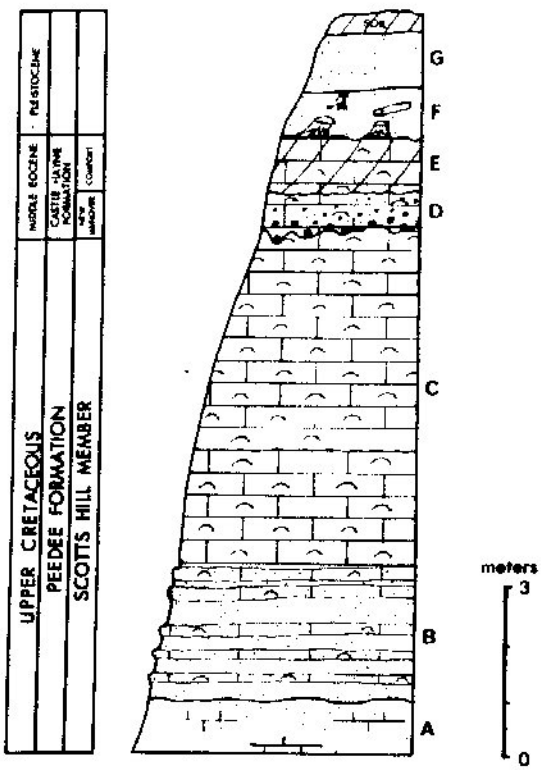

Figure 4. Section at Locality 23. Type locality of New Hanover Member of Castle Hayne Formation; reference section of Comfort Member of Castle Hayne.
G. Sand, tan to orange, coarse to medium, massive.
F. Sand, dark-gray humate, containing logs, roots, stumps.
E. Massive to crossbedded, tan, fine, bryozoan biocalcirudite to tan biomicrite; molluscan molds.
D. Lithocalcirudite, sandy, phosphatic, glauconitic, conglomeratic, coarse, in very light-gray micrite matrix.
C. Molluscan-mold (bivalve) biosparrudite, very sandy.
B. Biosparrudite, alternating with loose quartz arenite.
A. Quartz arenite, unconsolidated.

is sharp, and much conglomeratic material in the New Hanover was derived from the Peedee; clasts in the New Hanover fine upward.

The uneven upper surface of the New Hanover apparently is due to erosion after lithification; it is overlain by the sharply contrasting bryozoan biocalcarenite of the Comfort Member. The two members nowhere are seen to intergrade; they have an

abrupt, uneven contact. Apparently, only a short hiatus separated deposition of New Hanover sediments from those of the overlying unit. The New Hanover contains molluscan molds of nautiloid cephalopods, gastropods, and various bivalve species, many of which also occur in the overlying Comfort Member. The presence of *Cubitostrea sellaeformis* in the New Hanover at locality 23 suggests that this unit is middle Eocene and equivalent to the Lisbon Formation of Alabama.

Comfort Member. The name "Comfort Member" was proposed by Ward *et al.* (1978) for gray to cream-colored, bryozoan-echinoid calcirudite, grading to fine calcarenite, containing small admixtures of fine quartz, detrital and authigenic glauconite, and some detrital phosphate. This member represents several depositional cycles, which begin with medium to fine bryozoan and echinoid fragmental

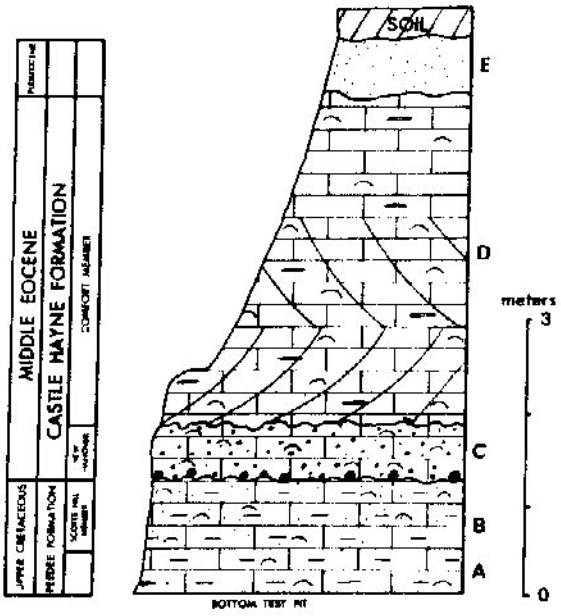

Figure 5. Section at Locality 22. East Coast Limestone Co. quarry.
E. Dark, fine, humate sand.
D. Bryozoan biocalcirudite, very light gray to yellowish gray, medium to fine. Crossbedded near base, becoming massive near top. Consisting mostly of broken bryozoans and echinoderms; recrystallized. Molluscan molds, calcitic pectens, and whole echinoids common.
C. Lithocalcirudite, light gray, sandy, phosphatic, coarse; some molluscan molds. Many pebble to cobble-size, phosphate-coated clasts.
B. Biosparrudite, medium-light gray, sandy; molluscan molds common.
A. Silty sand, calcareous, medium-dark gray; some calcitic macrofossils.

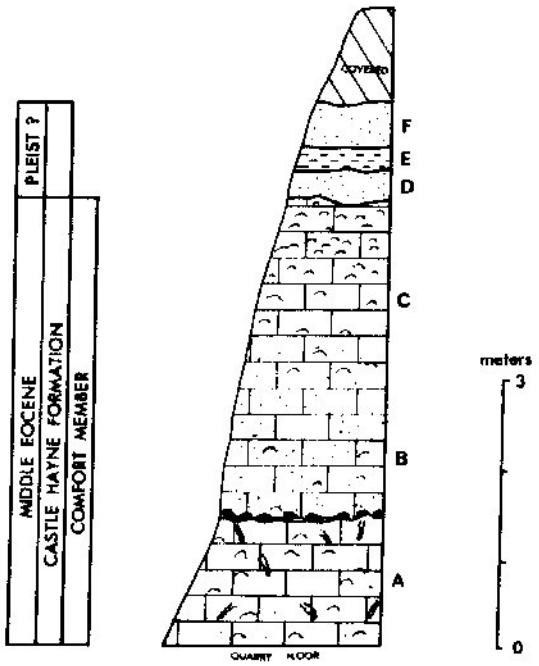

Figure 6. Section at Locality 19. North Carolina Lime Excavating Company Quarry. Type locality of Comfort Member of Castle Hayne Formation.
F. Sand, tan, fine.
E. Clay, dark gray, sticky, soft.
D. Sand, orange, leached; many small molds.
C. Bryozoan and foraminiferal calcarenite, light gray to yellowish gray, medium grained, Abundant pectens, especially near top; small echinoids common. Grades into...
B. Bryozoan biocalcirudite, light gray, fine, slightly glauconitic. Consists mainly of comminuted, sorted bryozoan and echinoid fragments; whole echinoids common, other macrofossils rare; large foraminifers, abundant. Contact below burrowed, marked by rubble of cobble-size, phosphate- and glauconite-coated clasts.
A. Shelly calcarenite, yellowish gray, very glauconitic (5-10%), moderately sandy (very fine, clear, angular). Macrofossils common, abundant in pockets; pectens predominate, echinoids common.

calcirudite and grade upward to fine calcarenite. Glauconite and phosphate pebble concentrations mark breaks in deposition. Under increased energy conditions, deposition resumed, resulting in coarse bryozoan hashes above glauconite and phosphate pebble beds. The Comfort generally is soft and friable, but locally may be cemented by a dense micrite matrix. The North Carolina Lime Excavating Co. quarry at Comfort, Jones County (loc. 19, Fig 6), was designated the type locality. The member is the most widespread of the Castle Hayne units. The best localities are in several quarries (locs. 19, 20, 21, 22, 23, 24).

The Comfort ranges in thickness from approximately 3 m at Maple Hill and Castle Hayne (locs. 22, 23) to at least 10 m at Rose Hill (loc. 20), Magnolia (loc. 21), and Comfort (loc. 19, Fig. 6), and probably accounts for about half of the 260 m of middle Eocene rocks reported by Brown *et al.* (1972) in the subsurface of the Core Sound area. The Comfort unconformably overlies the New Hanover in the southern part of the basin (locs. 22, 23, 24, 28). Below Goldsboro on the Neuse River (loc. 33) and on Moseley Creek (loc. 34), the Comfort overlies sandy, argillaceous sediments of the Beaufort Formation (Paleocene), as it does in the subsurface in the northeast part of the basin. In the more eastern counties, the Comfort directly overlies a sequence of lower Eocene carbonate rocks in the subsurface; to the west, it contains progressively more detrital quartz, consists of limy sandstone in Johnston County (loc. 32), and is considered a nearshore, sandy facies.

The Spring Garden Member overlies the Comfort in the area of the Neuse River from Rock Landing (loc. 2, Fig. 7), to New Bern (loc. 5, Fig. 8), and near Trenton on the Trent River. At Biddle Landing (loc. 1), lower Pliocene shelly sands of the Yorktown

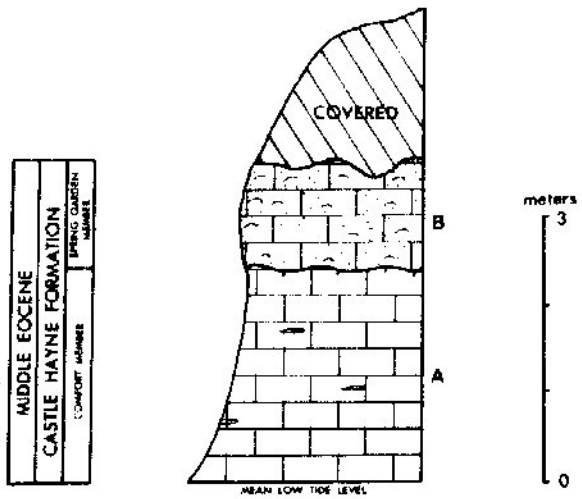

Figure 7. Section at Locality 2. Rock Landing.
B. Dry, sandy, molluscan-mold biocalcirudite in light-gray, micrite matrix; sand-size phosphate very common (5%); molds iron stained and occasionally filled with calcite.
A. Calcarenite, light-yellowish gray; microfossils present; a few sand dollars.

Formation directly and unconformably overlie the Comfort, as it does southward in the basin at Natural Well, Duplin County (loc. 30). On the New River (loc. 29), the Comfort is directly overlain by calcerenite units of the River Bend Formation (Oligocene).

The Comfort Member is Claibornian (late middle Eocene) in age and is equivalent to the Lisbon Formation of Alabama. *Pecten membranosus* Morton, found in both the Santee Limestone and the Comfort, is a senior synonym of *Pecten wautubbeanus* Dall, found in the Claibornian of Alabama. Also common are *Pecten clarkeanus* Aldrich and *Crassatella alta* Conrad, both found only in Claibornian beds in Alabama and elsewhere.

Spring Garden Member. The name "Spring Garden Member" was proposed by Ward *et al.* (1978) for tan to gray arenaceous molluscan-mold biocalcirudite along the Neuse River from Rock Landing (loc. 2, Fig. 7) to New Bern (loc. 5, Fig. 8) in Craven County. This gray, normally

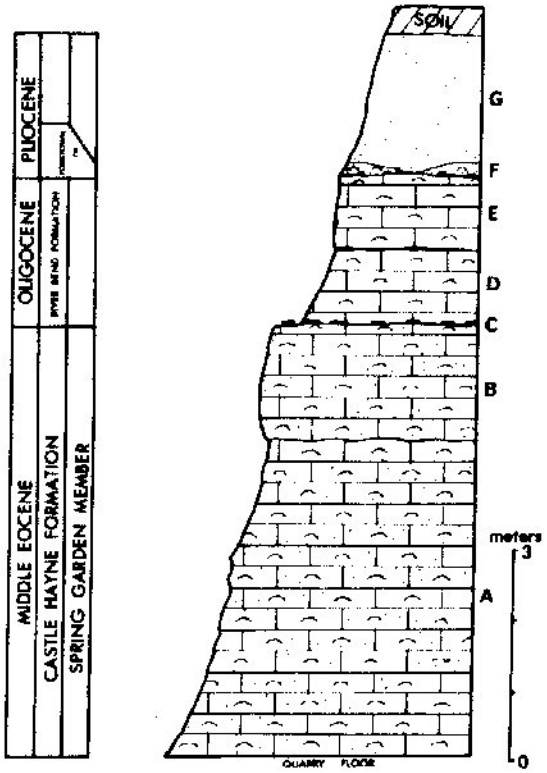

Figure 8. Section at Locality 5. Martin Marietta Co., New Bern quarry. Reference locality of Spring Garden Member of Castle Hayne Formation; reference locality of River Bend Formation.
G. Fine sand, tan to orange, somewhat massive near base, grading to crossbedded sand above.
F. Phosphate-shell bed, tan to orange, sandy; some bones; teeth along contact.
E. Gastropod biocalcirudite, light gray, in micrite matrix; small amounts of very fine sand.
D. Barnacle calcarenite, light-yellowish gray; few small mollusks.
C. Large pycnodontids common, adhering to 6 mm black phosphate coating.
B. Molluscan-mold biocalcirudite, light gray, very sandy, hard, slightly phosphatic; some siliceous infilling; some molds in living position.
A. Molluscan-mold biocalcirudite, light gray, very sandy, moderately hard, slightly phosphatic; some bivalve molds in living position.

siliceous rock is well cemented by sparry calcite. Molluscan bivalve molds are partly or completely filled with calcite, which forms pseudomorphs after the dominant mollusk, *Macrocallista neusensis* (Harris). Fine detrital phosphate is a common

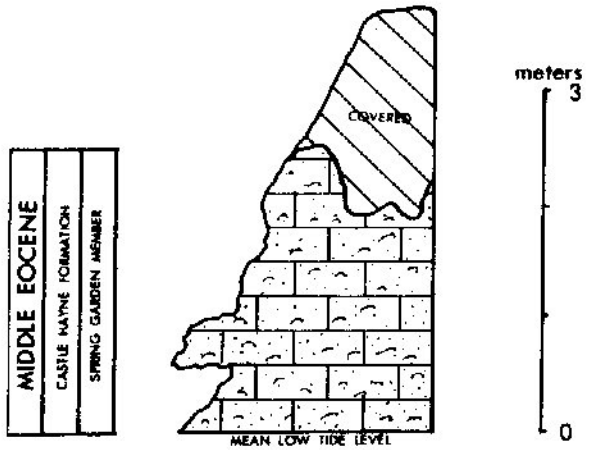

Figure 9. Section at Locality 4. Spring Garden Landing. Type locality of Spring Garden Member of Castle Hayne Formation.
Molluscan-mold biocalcirudite, light gray, very sandy, in micrite matrix; sand-size phosphate common; molds iron stained and commonly partly or completely filled by calcite.

accessory, in amounts as great as 5 to 10 percent. Bivalve shells originally accounted for as much as 50 percent of the rock. Spring Garden Landing (loc. 4, Fig. 9) on the Neuse River, Craven County, a natural exposure of rock as much as 3 m thick, was designated the type locality. The quarry at New Bern (loc. 5), where 6 m of well-indurated sandy limestone is exposed, was designated a supplementary reference locality.

Later, Baum et al. (1978) referred the same beds to the New Bern Formation. The name suggested by Baum is preoccupied by the Newbern Shale (Wilmarth, 1957 and Keroher, 1966). Further, distribution of the New Bern as depicted by Baum *et al.* (1978, Fig. 1) included limestones along the Trent River from Prettyman Landing (loc. 31.Fig. 9) to Pollocksville that are middle to late Oligocene in age and assigned to the River Bend Formation Ward *et al.* (1978) (Trent Formation, in part, of Baum *et al.*, 1978). For these reasons, the name "New Bern Formation" is considered invalid.

The Spring Garden conformably overlies gray calcarenite of the Comfort at Rock Landing (loc.2, Fig. 7), and is exposed

above and below Rock Landing (loc. 3), at Spring Garden Landing (loc. 4, Fig. 9), and at New Bern (loc. 5, Fig. 8). At the quarry in New Bern, the upper surface of the Spring Garden is extremely uneven because of solution and erosion, and is thinly coated by veneer of phosphate upon which Oligocene oysters are attached. Overlying this surface is a tan, barnacle hash in calcarenite matrix of Oligocene age, which ranges up to 2 m in thickness and may be found in molluscan molds and burrows in the top 7 cm of the Spring Garden. Because of erosion and channeling, shelly quartz sand of the Yorktown Formation (lower Pliocene) directly overlies the Spring Garden (middle Eocene) in the center of the pit, whereas on the flanks of the pit, the Yorktown overlies Oligocene calcarenite deposits. Along the Trent River, the Spring Garden overlies the Comfort and crops out intermittently from above Trenton to just below Prettyman Landing (loc. 31, Fig. 10), where it dips below water level. At Prettyman Landing, the Spring Garden is overlain by calcareous molluscan mold, sandy biocalirudite of the River Bend Formation (Oligocene). The contact between the two units, sharply unconformable, is marked by coarse conglomerate at the base of the River Bend.

The Spring Garden represents the latest Claibornian (latest middle Eocene). The molluscan assemblage is dominated by *Macrocallista neusensis* (Harris) [=*Macrocallista perovata* (Conrad)], a common Claibornian form. Also present are *Crassatella alta* Conrad and *Bathytormus protextus* (Conrad), both common in the Gosport Sand of Alabama. Baum *et al.* (1978) cited several diagnostic Claibornian fossils from their "New Bern Formation." Included was *Periarchus lyelli*, which they erroneously cited as an indicator of Jacksonian age; this echinoid occurs in both Jacksonian and Claibornian sediments of the Gulf Coast.

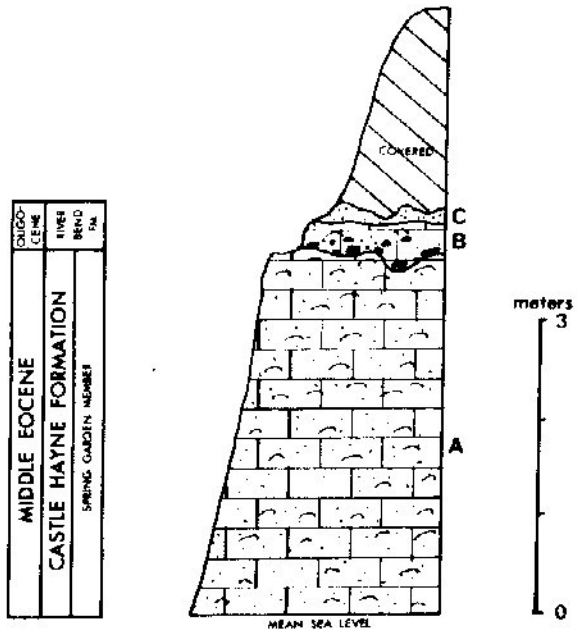

Figure 10. Section at Locality 31. Prettyman Landing.
C. Fine quartz sand; many microfossils.
B. Phosphate-coated conglomerate in calcarenite matrix; weathered, grayish orange; some cobble-size clasts; some barnacles, *Mercenaria* molds common.
A. Very sandy, molluscan-mold biocalcirudite; yellowish gray; molds partially filled with calcite, consist mostly of *Macrocallista neusensis* (Harris).

Oligocene

River Bend Formation

The name "River Bend Formation" was proposed by Ward *et al.* (1978) for a series of limestone beds originally included in the Trent Marl by Miller (1910, 1912) and later in the Castle Hayne by Brown (1955) and LeGrand and Brown (1955). Kellum (1925, 1926) included some of these rocks in his treatment of the Trent and believed them to be equivalent to unconsolidated sandy shell beds at Silverdale (loc. 14 of this report). Because of the resulting confusion, Ward *et al.* (1978) recommended that the name "Trent" be abandoned and that this limestone, which constituted part of the original Trent, be given the name "River Bend Formation," from the River Bend Estates (loc. 27, Fig. 11) on the Trent River, Craven County, the type locality.

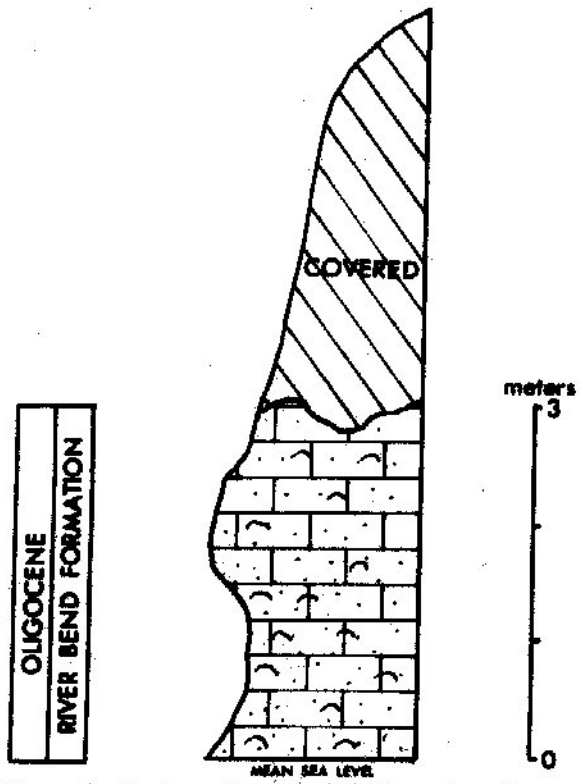

Figure 11. Section at Locality 27. Rhems Landing. Type locality of River Bend Formation. Molluscan-mold biocalcirudite, yellowish gray, indurated but partially friable, very sandy; small amounts of phosphatic sand; molluscan molds mostly *Mercenaria*.

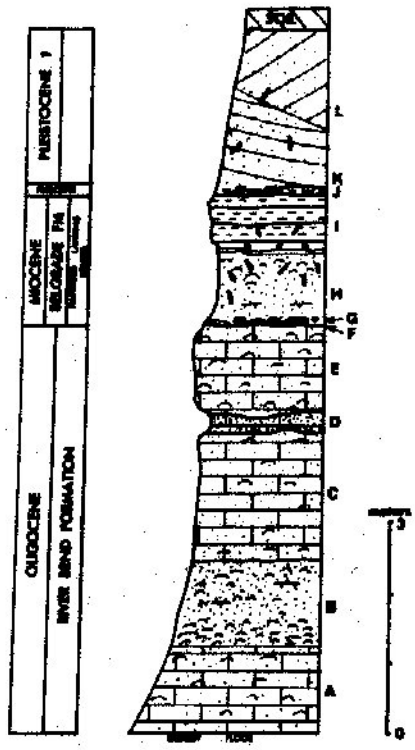

Figure 12. Section at Locality 12. Martin Marietta Company Belgrade Quarry. Type locality of Belgrade Formation; reference locality for Haywood Landing Member.
L. Sand, crossbedded, fine, tan.
K. Discoidal pebble lag on Pliocene surface.
J. Pliocene shell and lag, small pockets.
I. Thinly laminated green clay, interbedded with shell bed below.
H. Shell bed, slightly calcareous, very phosphatic, very sandy, slightly clayey; many preserved mollusks, most water worn; bones, teeth.
G. Oyster beds adhering to phosphate.
F. Phosphate-coated surface, irregular, uneven.
E. Molluscan-mold biocalcirudite, light gray, very sandy, hard, coarse; small amounts of very fine phosphate in micrite matrix. Some molds partially filled with $CaCO_3$. Many large *Mercenaria* molds.
D. Sand, tan, fine, calcareous, friable.
C. Molluscan-mold calcirudite, medium gray, medium grained, in micrite matrix; small amounts (5-10%) very fine quartz sand. Mollusk molds, mostly fragmentary; some preserved *Pecten, Anomia*; many barnacle plates. Grades into...
B. Quartz arenite, light gray, somewhat calcareous, containing abundant preserved *Anomia*; some *Pecten*, barnacles. Grades into...
A. Molluscan-mold calcirudite, tan to light gray, very sandy, crumbly; molds mostly gastropods; *Balanus* common.

Baum *et al.* (1978) chose to retain the name "Trent" in a restricted sense; but they failed to designate a specific type section; citing only a 24-km stretch of the Trent River, Baum *et al.* (p. 13) stated that the Trent could be differentiated from their "New Bern" by the presence of *Mercenaria* in the Trent. However, on their map, they placed rocks from Pollocksville to Prettyman Landing in the "New Bern." These limestones contain abundant *Mercenaria* that first appeared in the Oligocene and are not present in their "New Bern". For these and reasons noted above, we follow the recommendation by Ward *et al.* (1978) that the name "Trent" be discarded.

The River Bend consists of bio-calcarenite, molluscan-mold biocalcirudite,

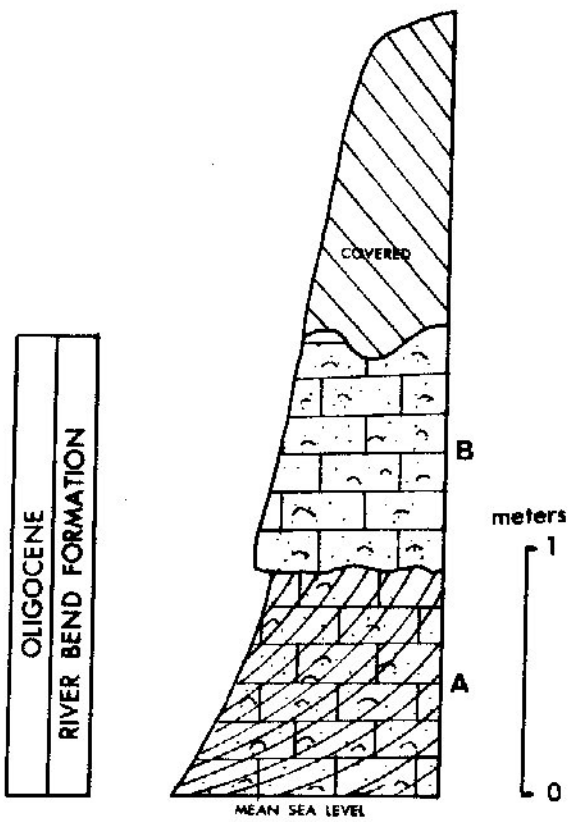

Figure 13. Section at Locality 9. Reference locality of River Bend Formation.
B. Molluscan-mold biocalcirudite, pale-yellowish orange, very sandy. Many large bivalve molds in excellent condition; very hard and indurated.
A. Barnacle-fragment biocalcirudite, grayish orange, slightly sandy, steeply current bedded (45°), somewhat friable and less indurated; bivalve molds common.

arenaceous barnacle hash, and very arenaceous bivalve biocalcirudite. Near its base, in some areas, the River Bend contains little or no quartz sand and consists mainly of barnacle plates and molluscan molds in a fine calcarenite matrix. Toward the center of the basin, in the Trent and White Oak River areas, the River Bend grades upward into a very arenaceous, slightly phosphatic bivalve biocalcirudite. This sandy limestone is lithically similar to the Spring Garden Member of the Castle Hayne, but the two are nowhere in contact. Only the lower calcarenite facies of the River Bend is in

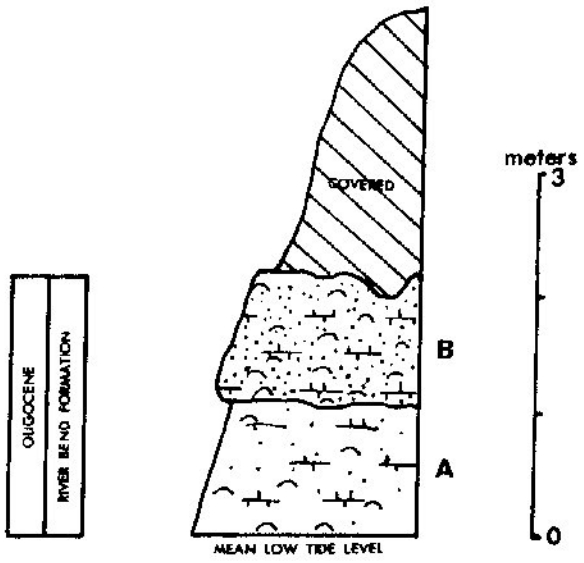

Figure 14. Section at Locality 7. Reference locality of River Bend Formation.
B. Molluscan-mold biocalcirudite, grayish orange, very sandy.
A. Calcirudite, grayish orange, slightly sandy, friable, fine; some small molds; small pectens common (*Pecten trentensis, P. byramensis).*

contact with the Spring Garden, and the two units are easily distinguishable.

The sandy limestone facies of the River Bend was referred to the Trent and Belgrade Formations by Baum *et al.* (1978); the "Belgrade" was considered to be Miocene and equivalent to shelly sand in the Silverdale, Onslow County, area, which they termed the "Silverdale Formation." The units are similar lithically and contain *Mercenaria* and *Balanus* as well as other forms, and are considered to be Chickasawhayan in age. Further, beds assigned to the "Silverdale" by Baum *et al.* clearly unconformably overlie their "Belgrade" (= River Bend; Fig. 12, loc. 12) at the type locality of the "Belgrade." Therefore, their "Belgrade" is not a lateral equivalent of their "Silverdale."

The River Bend occupies the area outlined by Brown *et al.* (1972) as Oligocene; it has maximum thickness of 150 m in the Cape Lookout area. The River Bend is approximately 3 m thick at the New

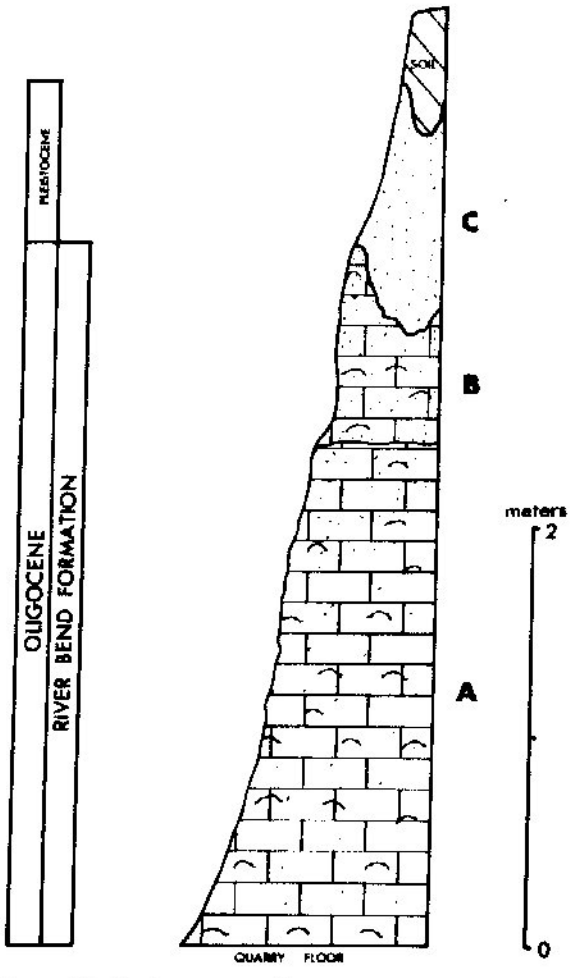

Figure 15. Section at Locality 8.
C. Tan, fine, massive sand.
B. Calcareous sandstone, very firmly cemented, grayish orange.
A. Fine calcirudite, very sandy and indurated near top; many molluscan molds, many *Pecten*.

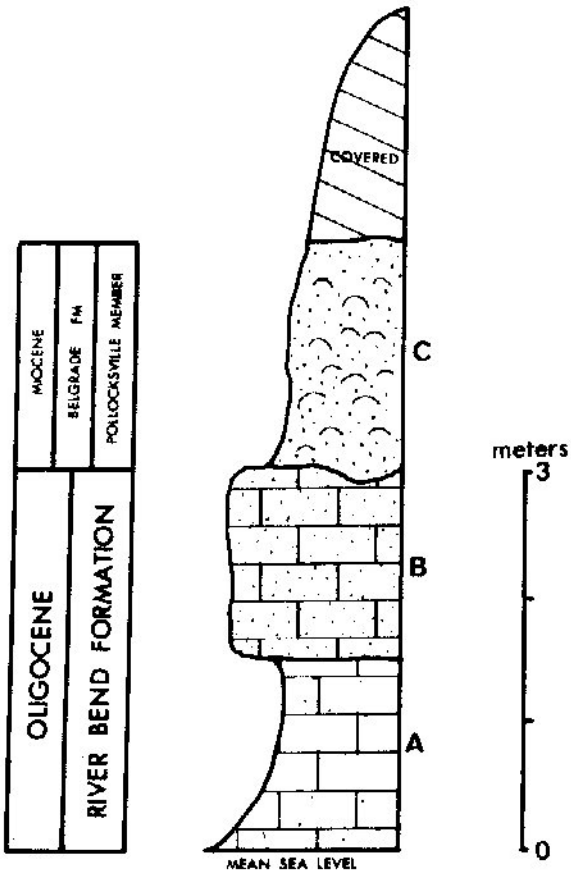

Figure 16. Section at Locality 25.
C. Moderate-yellow, weathered, very sandy oyster bed; fine quartz sand; abundant *Crassostrea*, balanid barnacles common; basal contact uneven and sharp.
B. Yellowish-orange, firmly indurated, molluscan-mold, very sandy, biocalcirudite; *Mercenaria* molds abundant.
A. Yellowish-orange, slightly phosphatic, friable, sandy calcarenite. Many barnacle fragments; *Pecten* common.

Bern quarry (loc. 5, Fig. 8) and is exposed intermittently along the Trent River from New Bern to Prettyman Landing (loc. 31, Fig. 10). Large quarries at Belgrade (loc. 12, Fig. 12) expose 10 m of the very sandy limestone facies. Several small outcrops (locs. 15, 16, 17, 18) on the New River at Camp Lejeune, Onslow County, also are assigned to the formation. Where the River Bend crops out in the area of River Bend Estates, barnacle calcarenite, biocalcirudite, and upper arenitic molluscan-mold biocalcirudite facies may be seen. Exposure there at Rhems Landing (loc. 27, Fig. 11) is the type locality. The west bank of the Trent River 0.5 km below Bells Landing and just below the mouth of Raccoon Creek was designated as a supplementary reference locality (loc. 9, Fig 13). Another supplementary reference locality, the west bank of the Trent River, 0.4 km below the mouth of Clayhill Branch, was selected to demonstrate nonsiliceous lower beds of the formation (loc. 7, Fig. 14). These beds also may be seen at locality 8 (Fig. 15) on the

east bank of the Trent River, 0.4 km below the mouth of the Clayhill Branch. The more arenaceous bivalve-mold facies may be seen at the type locality, in the area of Whitford Landing at River Bend (loc. 26), and on the west bank, 0.4 km below the mouth of Miry Hole Branch (loc. 10), all of the Trent River. An additional locality just below the mouth of Mill Creek on the Trent River (loc. 25, Fig. 16) shows the two lithofacies of the River Bend and the overlying Pollocksville Member of the Belgrade Formation. The River Bend crops out in Onslow, Jones, and Craven Counties, and Oligocene deposits probably referable to the River Bend are present in the subsurface in Carteret, Pamlico, Hyde, and Dare Counties.

The River Bend overlies the Castle Hayne at the New Bern quarry (loc. 5, Fig 8). Here, light-tan, barnacle calcarenite overlies a phosphate and *Pycnodonte* veneer on the sandy Spring Garden Member of the Castle Hayne. The calcarenite is overlain by a molluscan-mold biocalcirudite, also belonging to the River Bend. The contact between the River Bend and Castle Hayne is sharp and uneven; a slight angular unconformity is evident on the southwest wall of the quarry. The unconformable Castle Hayne-River Bend contact also can be seen at Prettyman Landing (loc. 31, Fig. 10) on the Trent River, where the mold and cast biocalcirudite of the River Bend overlies siliceous, very indurated limestone of the Spring Garden Member of the Castle Hayne. The two units are sharply separated by an uneven contact marked by coarse basal conglomerate consisting of clasts as large as cobbles. In the New Bern area, the River Bend dips east and south. The higher, sandier limestone dominates surface outcrops from the River Bend area to Belgrade. Subsequent erosion and solution beveled and cut channels into the indurated upper surface of the River Bend.

Overlying this surface and occupying eroded channels from Pollocksville to Belgrade is a friable, arenaceous *Crassostrea* bed assigned to the Pollocksville Member of the Belgrade Formation (loc. 25, Fig. 16) of Ward *et al.* (1978), not of Baum *et al.*, (1978). To the east, the River Bend is directly overlain by the Haywood Landing Member of the Belgrade Formation, as in the quarry at Belgrade (loc. 12, Fig. 12). Near the mouth of the Trent River at Brice Creek (loc. 11), River Bend carbonate deposits are overlain by upper Miocene (Eastover Fm.) leached, clayey sands. In the quarry at New Bern (loc. 5), the River Bend is overlain partly by shelly sand of the Duplin Formation and partly by tan and orange, leached clean sand, which may represent the Pleistocene in the area.

The River Bend ranges in age from middle Oligocene (late Vicksburgian) to late Oligocene (Chickasawhayan). The presence of *Ficus mississippiensis* Conrad, *Oniscia harpula* Conrad, *Dentalium mississippiensis* Conrad, *Cardium diversum* Conrad, and *Chione imitabilis* (Conrad) in the River Bend at the New Bern quarry (loc. 5) indicates a probable late Vicksburgian age. Calcarenite beds at the pit north of Pollocksville (loc. 8, Fig. 15) on the Trent River also are believed to be late Vicksburgian in age, on the basis of the abundance of *Pecten perplanus byramensis* Gardner. On the basis of ostracodes, Hazel (1977, written comm.) determined that the higher sandy limestone beds of the River Bend are Chickasawhayan. Mollusks in this facies include *Chlamys waynesis* Mansfield, *Anomia taylorensis* Mansfield (=*Anomia ruffini* Conrad), and many venerid species, which indicate a Chickasawhayan age. Also indicative of post-Eocene age are abundant remains of balanid barnacles, which are extremely rare to absent in Eocene deposits on the Atlantic coast. However, in

Vicksburgian sediments, *Hesperibalanus* is extremely common. Baum *et al.* (1978) presented faunal evidence for an Oligocene age for the "Trent Formation" but cited a eustatic sea-level drop in the mid-Oligocene (documented by Vail, 1976) as evidence for an early- to middle-Oligocene age. Lower calcarenitic beds of the River Bend were found by Ward, Lawrence *et al.* (1978) to be late Vicksburgian in age, and specifically, to correlate with the Byram Formation of Mississippi and Alabama. Beds of this age are found in the quarry at New Bern (loc 5) and along the Trent River from New Bern to Pollocksville.

The upper, very sandy beds containing abundant large molds of mollusks, especially venerids, are considered to be of Chickasawhayan age and may be correlated with upper beds of the Cooper Formation in South Carolina (Hazel, 1976), the Ashley Member of the Cooper (Ward *et al.*, 1979), the Suwannee Limestone of Georgia and Florida, and the Chickasawhay Formation and Paynes Hammock Sand of Alabama and Mississippi (Poag, 1975).

Belgrade Formation

Beds assigned by Ward *et al.* (1978) to the Belgrade Formation were not included by Miller (1910, 1912) in his definition of the Trent Marl, but Kellum (1925, 1926) considered them equivalent to beds on the Trent River below Pollocksville. Using mollusks found in the Silverdale area. Kellum concluded that the Trent was early Miocene in age and included rocks now known to be middle Eocene and middle-late Oligocene in that age assignment. Sediments assigned to the Belgrade by Ward *et al.* (1978) represent two distinct and sharply contrasting lithologies. The Belgrade consists typically of a tan, somewhat leached, very arenaceous oyster (*Crassostrea*) bed and a moderately phosphatic (as much as 15%), slightly calcareous, silty, arenaceous shell bed containing a few, thinly laminated olive clays.

The Belgrade crops out from the mouth of the White Oak River to Belgrade, Onslow County, and north to Pollocksville, Jones County. Quarries expose Belgrade beds 3 m thick or more in the vicinity of Silverdale, and small exposures are known along White Oak River and in Croatan National Forest. The Belgrade is named for deposits in the area of Belgrade, Jones County, and is well exposed at the type locality (loc. 12, Fig. 12). Here Baum *et al.* (1978) established their "Belgrade Formation." However, early in 1978, Ward *et al.* (1978) reserved the name "Belgrade Formation" with the U. S. Geological Survey Geologic Names Committee. Rocks included under this name by Baum *et al.* (1978) were placed in the River Bend Formation by Ward *et al.* (1978) and were shown to be Oligocene (Chickasawhayan) in age rather than Miocene, as suggested by Baum *et al.* (1978). The Belgrade Ward *et al.* (1978) overlies the River Bend unconformably, and progressively overlaps older sediments of the River Bend from Belgrade to Pollocksville. The Belgrade is divided into two members—the Pollocksville and the Haywood Landing.

Pollocksville Member. The Pollocksville Member, named by Ward *et al.* (1978), consists of a leached, tan to orange, unconsolidated, very arenaceous *Crassostrea* bed, described by Lawrence (1975). It reaches a maximum thickness of 3 m and crops out from Belgrade to Pollocksville and along the Trent River in that area. Excellent exposures of this bed (4.0 m) crop out at the type locality (loc. 6, Fig. 17). Here the Pollocksville unconformably overlies an uneven and eroded River Bend surface. The River Bend there consists of moderately arenaceous to calcarenitic limestone of Vicksburgian age.

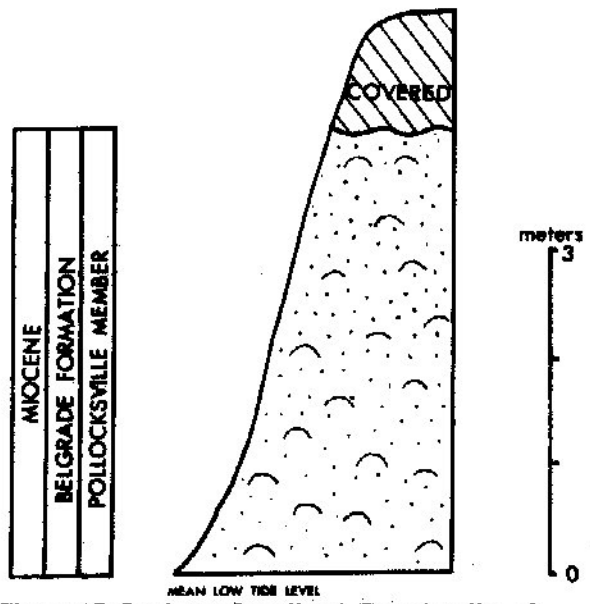

Figure 17. Section at Locality 6. Type locality of Pollocksville Member of Belgrade Formation.

Crassostrea bed, grayish orange, weathered, very sandy; oysters very poorly preserved.

In the vicinity of Belgrade, also, the Pollocksville overlies, and occupies channels in the very hard, eroded upper surface of the River Bend.

The sediments of the Pollocksville were deposited in the late Oligocene. Earliest deposition somewhat preceded that of the Haywood Landing Member, but the two members were, in part, penecontemporaneous. The large fossil assemblage in the Haywood Landing indicates that it and also the Pollocksville are age equivalents of the Tampa Limestone (upper Oligocene) of Florida. Giant oysters of the species found in the Pollocksville are common in the Catahoula Sandstone of Mississippi and Alabama. Although *Crassostrea* is found in upper Chikasawhayan sediments of the River Bend, we believe that oysters of the Pollocksville represent the latest Oligocene appearance of *Crassostrea gigantissima* (Finch).

This bed was termed the "*Crassostrea gigantissima* facies" by Baum *et al.* (1978) and was thought to be younger than, and occupy channels in, their "Silverdale" Formation (=Haywood Landing Member of Ward *et al.*,1978). No localities were mentioned where this relationship could be observed. Oyster beds underlie and grade into the Haywood Landing at the Belgrade quarry (loc. 12, Fig. 12).

Haywood Landing Member. The Haywood Landing Member was named by Ward *et al.* (1978) for unconsolidated, gray to brown, moderately phosphatic, and, in some areas, somewhat calcareous, clayey, very shelly quartz sands. In places, these shells constitute more than 50 percent of the bed and range from leached to excellently preserved material. In the western wall of the quarry at Belgrade (loc. 12, Fig. 12), the sandy shell deposit grades upward into a laminated, olive-green clay. This clay bed has not been traced beyond the quarry, but may represent a quiet lagoonal facies of the Haywood Landing.

The Haywood Landing is approximately 3 m thick at Belgrade, at Haywood Landing (loc. 13, Fig. 18) (the type locality) on the White Oak River, and in borrow pits at Silverdale (loc. 14, Fig. 19). Brown *et al.* (1972) included beds here assigned to the Belgrade in their maps and sections of the Oligocene; in their core section NC-CR-OT-30 (Pl. 26), beds of Haywood Landing lithology are present at the interval of 25.4 m to approximately 57 m , a total thickness of approximately 31 m in this far southeastern section of Craven County. The member occurs in the shallow subsurface in the Bogue and New River Inlet areas.

The Haywood Landing Member was named for a small outcrop (the only known natural outcrop) at Haywood Landing on the White Oak River, its type locality (loc. 13, Fig. 18). A supplementary reference locality is the quarry at Belgrade (loc. 12, Fig. 12). The Haywood Landing apparently overlies limestone of the River Bend Formation in its

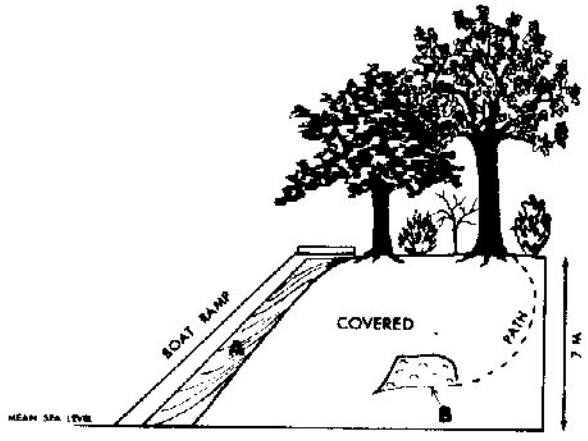

Figure 18. Section at Locality 13. Haywood Landing. Type locality of Haywood Landing Member of Belgrade Formation. Small exposure of shelly sand on otherwise covered, overgrown bank considered to be the type locality because it is only natural outcrop known.
B. Shell bed, tan to orange, sandy; weathered on surface but contains fresher shells several centimeters into exposure; many well-preserved bivalves and gastropods; phosphatic sand throughout.
A. Float broken shells found in cut made for boat ramp.

entire geographic area. However, this relationship is well exposed only in the walls of the Belgrade quarry (loc. 12). In the southeastern wall, the Haywood Landing overlies an oyster-covered, thin phosphatic veneer on the surface of River Bend indurated biocalcirudite beds. In the northwestern corner, a 15-cm thick shelly deposit of Duplin age overlies the olive clay bed of the Haywood Landing. The member is the offshore, open-marine equivalent of the Pollocksville Member and contains a very large molluscan fauna that shares many forms with the Tampa Limestone in Florida.

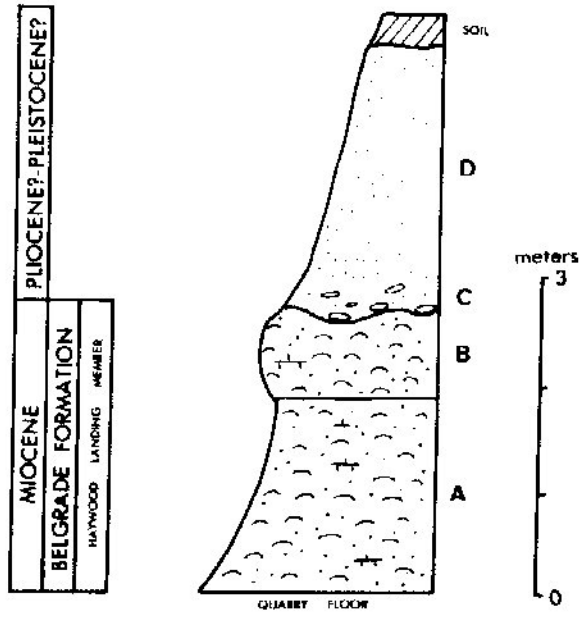

Figure 19. Section at Locality 14. Silverdale Marl Co. quarry; Supplementary type section of Haywood Landing Member of Belgrade Formation.
D. Orange and tan sand, fine to medium, becoming coarser toward base.
C. Lag deposit of pebbles, cobbles, phosphatized bone and teeth.
B. Very sandy shell bed; phosphate sand abundant; many large mollusks; bone of fish, turtle, manatee common; light gray.
A. Very sandy, phosphatic, shell bed; slightly calcareous; small mollusks predominate.

The Haywood Landing is the same age as the Old Church Formation in Virginia. Contrary to the interpretation of Baum *et al.* (1978) the Haywood Landing (their "Silverdale") unconformably overlies, and is not a lateral equivalent of the River Bend (their "Belgrade"). This unconformable relationship can be seen at the Belgrade quarry (Fig. 12).

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APPENDIX 1—LOCALITY REGISTER

1. Biddle Landing, right bank of Neuse River, 3.2 km N of Ft. Barnwell, Craven County, NC
2. 180 m above Rock Landing, mouth of Turkey Quarter Creek, right bank of Neuse River, Craven County, NC (Figure 7).
3. Rock Landing, 4.0 km N of Jasper, right bank of Neuse River, Craven County, NC.
4. Spring Garden Landing, 5.2 km ENE of Jasper, right bank of Neuse River, Craven County, NC (Figure 9).
5. Martin Marietta Company, New Bern Quarry, NW of New Bern, 0.8 km NE of North Carolina 55 on Craven County 1402, Craven County, NC. Top of quarry 5 m above sea level (Figure 8).
6. Left bank of Trent River, next to Seaboard Coastline railroad trestle, Pollocksville, Jones County, NC (Figure 17).
7. Right bank of Trent River, 0.4 km below mouth of Clayhill Branch, Jones County, NC (Figure 14).
8. North Carolina Highway Dept. borrow pit, 4 km NNE of Pollocksville on left bank of Trent River, Jones County, NC (Figure 15).
9. Right bank of Trent River, 0.5 km below mouth of Raccoon Creek, Jones County, NC (Figure 13).
10. Right bank of Trent River, 0.4 km below mouth of Miry Hole Branch, Jones County, NC.
11. Right bank of Trent River, just below mouth of Brice Creek, 1.6 km SW of James City, Craven County, NC.
12. Martin Marietta Company, Belgrade Quarry, just E of intersection of Onslow County 1434 and U.S. 17, Belgrade, NC. Top of quarry approximately 10 m above sea level (Figure 12).
13. Haywood Landing, left bank of White Oak River, 1.2 km below mouth of Holston Creek, Jones County, NC (Figure 18).
14. Silverdale Marl Company Quarry at Silverdale, 0.4 km SE of intersection of Onslow County 1434 and 1442, NC. Top of quarry approximately 8 m above sea level (Figure 19).
15. Right bank of New River at Hines Point, Onslow County, NC.
16. Right bank of New River, 0.8 km above Catfish Point, Onslow County, NC.
17. Right bank of New River, 0.4 km above mouth of Mill Creek, Onslow County, NC.
18. Left bank of New River, 0.4 km below mouth of Goose Creek, Onslow County, NC.
19. North Carolina Lime Excavating Company Quarry, 6.4 km W of Comfort, just N of North Carolina 41,Jones County,NC. Approximately 20 m above sea level (Figure 6).
20. Billy B. Fussel Company, Inc., Quarry, 1.6 km W of Rose Hill on Duplin County 1102, NC.
21. Atlantic Limestone Company Quarry, 4.0 km SSE of Magnolia, just E of North Carolina 117, Duplin County, NC.
22. East Coast Limestone Company Quarry, 2.4 km W of Maple Hill, 1.6 km SW of intersection of North Carolina 53 and 50, Pender County, NC. Approximately 10 m above sea level (Figure 5).

23. Martin Marietta Company Castle Hayne Quarry, 2.8 km E of Castle Hayne, 0.8 km N of New Hanover County 1002, NC Approximately 3 m above sea level (Figure 4).
24. Ideal Cement Comnpany Quarry, 4.0 km E of Castle Hayne, N of New Hanover County 1002 at end of 2023, NC (Figure 3).
25. 0.3 km below mouth of Mill Creek on right bank of Trent River, Jones County, NC (Figure 16).
26. Whitford Landing, right bank of Trent River at River Bend, Jones County, NC.
27. 0.3 km above Rhems Landing, left bank of Trent River, just below River Bend, Craven County, NC (Figure 11).
28. Lanes Ferry Park, right bank of Northeast Cape Fear River, just below North Carolina 210 bridge, Pender County, NC.
29. 03 km below Onslow County 1316 bridge over New River, on left bank, just downstream from small falls over limestones of Comfort Member of Castle Hayne Formation, NC.
30. Natural well, 2.9 km SW of Magnolia, just E of Duplin County 1003, NC.
31. Prettyman Landing, left bank of Trent River, Jones County, NC (Figure 10).
32. Pine Hollow golf course, just E of Wake-Johnston County line, just N of Johnston County 1004, NC.
33. 2 km upstream from North Carolina 111 bridge over Neuse River, on right bank, Wayne County, NC.
34. 0.8 km above North Carolina 55 bridge over Moseley Creek, on both banks, Craven and Lenoir County, NC.

APPENDIX 2—FOSSIL LISTS

Locality 2 (Figure 7). Rock Landing, 180 m above, mouth of Turkey Quarter Creek, right Bank of Neuse River, Craven County, NC.

Bed A. Mollusks: A few eroded small pectens not identifiable. Echinoderms: A few specimens of sand dollar *Scutella*. Foraminifera: Two samples referred to Poag, U.S.G.S., Woods Hole, Mass. with following observations (1976, written comm..): 1) +2 ft above water level—Fair preservation; moderate diversity; few planktics. Main constituents: *Acarinina perclara*—(other planktics not readily identified), *Gyroidinoides octocameratus, Cibicidina blanpiedi, Florilus spissus, "Nonion" mauricensis, Cribrononion preadvena, Alabamina wilcoxensis, Eoepondilla* sp. cf. *hemisphaericus, Cibicidoides lawi,* and *Cibicidoides* sp. Assemblage lacks short-ranged species; most constituents range from late Paleocene into at least middle Eocene. Presence of *C. blanpeidi* without *C. westi* may limit age span to late Paleocene to early Eocene. Assemblage reflects presence of Paleocene beds not far west, from which sediments were reworked in middle Eocene. 2) +6 ft. above water level—Poor preservation; diverse; numerous planktics. Mixed Cretaceous-Tertiary assemblage. Planktic forms predominantly Late Cretaceous, probably Maestrichtian, including: *Heterohelix, Guembelitria, Rugoglobigerina, Globotruncana,* and *Globigerinelloides*. Several unidentifiable small subbotinids represent the Tertiary. *Acarinina* sp. cf. *densa* and *Globigerinatheka*? Sp. each represented by single specimen, are middle Eocene forms. Benthics also mixed Tertiary-Cretaceous forms; Cretaceous representatives include: *Gaudryina* spp., *Pseudovigerina* sp. cf. *plummerae, Vaginulina navarroana,* and *Pulsiphonina prima.* Tertiary benthics, more diverse include: *Cibicidina blanpiedi, Textularia* sp., *Nodosaria* sp., *Buliminella* sp., *Loxostomum* sp., *Lenticulina* sp. cf. *alatolimbatus, Asterigerina* sp., *Anomalina* spp. *Hanzawaia* sp., *Gyroidinoides* sp. cf. *octocameratus, Cibicidoides* sp., *Rosalina* sp. and *Siphonia* sp. These forms generally range through Paleocene and Eocene. The most logical interpretation is that Late Cretaceous assemblages were redeposited into a relatively shallow-water area during middle Eocene. However, additional larger samples are necessary to confirm it. Cretaceous forms in this sample probably were derived from Upper Cretaceous beds not far west of Rock Landing.

Bed. B. Mollusks: Large numbers of molds and casts, a few definitely determined: *Crassatella alta* Conrad, *Macrocallista neusensis* (Harris) = *Macrocallista perovata* (Conrad), *Pecten* sp. cf. *biddleana*? *Kellum, Pycnodonte* sp., and *Fusinus abruptus* Tuomey

Locality 4 (Figure 9). Spring Garden Landing, 5.2 km ENE of Jasper, right bank of Neuse River, Craven County, NC.

Only confidently determinable fossil was bivalve *Macrocallista perovata*

(Conrad), which makes up at least 99% of fauna.

Locality 5 (Figure 2). Martin Marietta Company New Bern Quarry, NW of New Bern, Craven County, NC.

Bed A. Mollusks: *Crassatella alta* Conrad, *Crassatella protexta* Conrad, *Panopea sp.*, *Pholadomya* sp., *Macrocallista neusensis* (Harris) =*M. perovata* (Conrad), which makes up approximately 70% of fauna.

Bed B. Mollusks. *Crassatella alta* Conrad, *Crassatella protexta* Conrad, and *Macrocallista neusensis* (Harris) =*M. perovata* (Conrad), which makes up at least 95% of fauna.

Bed C. None.

Bed D. Consists solely of single layer of marine oyster. *Pycnodonte* sp., attached to phosphate-coated hard grounds of Spring Garden Member.

Bed E. Consists mainly of detached, worn plates of barnacle *Hesperibalanus* sp. Also present, but not abundant are juvenile pectens, one a smooth, nonribbed form and the other a finely ribbed form, as yet considered indeterminate. Ostracodes (Hazel, 1976, written comm.) Indicates Oligocene, possibly Chickasawhayan age.

Bed F. Consists mainly of gastropod molds and casts; bivalves make up only about 20% of fauna. Molds indicate that this was extremely diverse assemblage, but present preservation allows only the following mollusks to be determined with certainty: *Ficus mississippiensis* Conrad, *Turritella* spp., *Oniscia harpula* Conrad, *Cardium diversum* Conrad and *Chione imitabilis* (Conrad). Barnacle *Hesperibalanus* is common. Ostracodes (Hazel, 1976, written comm.) indicate Oligocene age.

Bed G. Typical diverse fauna characteristic of Yorktown Formation. Because of large number of species, only more abundant forms are listed. Mollusks: *Mercenaria rileyi* (Conrad), *Spisula modicella* (Conrad), *Mulinia congesta* (Conrad), *Hemimactra duplinensis* Dall, *Chesacardium acutilacqueatum* (Conrad), *Carditamera arata* (Conrad), *Laevicardum sublineatum* (Conrad), *Plicatula marginata* Say, *Carolinapecten eboreus* (Conrad), *Sectiarca lienosa* (Say), *Costaglycymeris subovata* (Say), *Glycymeris americana* (Defrance), *Turritella* spp. *Fasciolaria elegans* Emmons, and *Busycon* spp. Numerous bryozoans, corals, etc.

Bed H. Apparently unfossiliferous, except for occasional Yorktown fossils reworked in lower part, including cetacean, sea cow, and fish bones.

Locality 6 (Figure 17). Left bank of Trent River, next to Seaboard Coastline Railroad trestle; Pollocksville, Jones County, NC.

Only known macrofossils, both abundant, are *Crassostrea gigantissima* (Finch) and *Balanus* sp. A sample given to Poag for foraminiferal analysis yielded the following (1976, written comm.): Poor preservation (leached and oxidized): low species diversity; no planktics; assemblage consists of small, shallow-water benthic species not strongly diagnostic of stratigraphic age, including: *Buccella* sp. A-rounded periphery, *Buccella* sp. B-keeled periphery, *Buccella* sp. cf. *mansfieldi* -1 specimen, *Bulliminella elegantissima*-1

specimen, *Brizalina* sp.-1 specimen, *Cribrononion* sp. cf. *preadvenum*-few, *Cribrononion* sp. cf *advenum*-1 specimen, and *Cibicidoides* sp. A, B, C,-(rare). *Buccella mansfieldi* s.s. is diagnostic for middle and probably lower Miocene, but specimens in sample seem not to be true *mansfieldi*. Whether they are ecophenotypic variants or are separated by genetic barriers is not clear. Close morphologic resemblance to *Buccella mansfieldi* suggests Miocene rather than Oligocene age, however. Most *Cribrononion* have much smaller central bosses than typical Gulf Coast forms from Chickasawhay and Vicksburg stages, also tending to support a Miocene age.

Locality 7 (Figure 14). Right bank of Trent River, 0.4 km below mouth of Clayhill Branch, Jones County, NC.

Bed A. Mollusks: *Pecten trentensis* Harris, *Pecten perplanus byramensis* Gardner, *Chione* sp., and *Pycnodonte* sp. Bryozoans: Some small specimens present. Arthropods: *Hesperibalanus* common.

Bed B. Mollusks: *Mercenaria* sp., *Chione* sp., *Macrocallista* sp., *Cardium* sp., and *Panopea* sp. Arthropods: *Hesperibalanus* sp. and *Balanus* sp.

Locality 8 (Figure 15). NC Highway Dept. borrow pit, 4.0 km NNE of Pollocksville, on left bank of Trent River, Jones County, NC.

Bed A. Mollusks: *Pecten trentensis* Harris, *Panopea* sp., *Pecten perplanus* Gardner, *Pycnodonte* sp., *Gryphaeostrea* sp., Anomia sp., *Turritella* sp., *Chione* sp., *Semele* sp., and *Cardium* sp. Bryozoans: Small specimens present. Arthropods: barnacle—*Hesperibalanus* sp.; ostracodes (identified by Hazel)—*Paracytheridea toleri* Howe & Law, *Echinocythereis* sp., *Paracytheridea* sp., *Macrocyprina gibsonensis* (Howe & Law), *Cytherelloidea* sp. cf. *C. colata* Poag, *Leguminocythereis* sp. aff. *L. scarabaeus* Howe & Law (=*L. scarabaeus* Brown, 1958; Pooser, 1965), *Hermanites* sp., *Bairdia* sp., and *Actinocythereis* sp. On basis of fauna, Hazel concluded that deposit was late Oligocene.

Bed B. Mollusks: *Mercenaria* sp., *Chione* sp., *Macrocallista* sp., and *Panopea* sp.

Bed C. Nobody fossils apparent. Appears burrowed in some areas.

Locality 12 (Figure 12). Martin Marietta Company Belgrade Quarry, Belgrade, NC.

Bed A. Mollusks: *Chione* sp., *Macrocallista* sp., *Panopea* sp., and *Glycymeris* sp. Arthropods: Very many *Hesperibalanus* sp.

Bed B. Mollusks: *Mercenaria* sp., *Panopea* sp., *Macrocallista* sp., and *Glycymeris* sp.

Locality 20

Bed A. Mollusks: *Mercenaria* sp., *Panopea* sp., *Turritella* sp., and many small indeterminate bivalves. Arthropods: *Balanus* sp., and *Hesperibalanus* sp.

Bed. B. Mollusks: *Anomia ruffini* Conrad (=*A. taylorensis* Mansfield) and *Pecten chickaria* (Mansfield). Arthropods: barnacle—*Balanus* sp; ostracodes (identified by Hazel)—*Leguminocythereis* sp. aff. *L. scarabeus* and several other poorly preserved forms. He concluded age was late Oligocene or Chickasawhayan.

Bed. C. Mollusks: *Anomia ruffini* Conrad, *Pecten chickaria* (Mansfield), and gastropod

steinkerns, common but indeterminate. Arthropods: barnacles—*Balanus* sp. and *Hesperibalanus* sp. ostracodes abundant in pockets.

Bed D. Arthropods: *Balanus* sp.

Bed E. Mollusks: *Mercenaria gardnerae* (Kellum), *Panopea intermedia* Richards, *Modiolus stuckeyi* Richards, *Cardium belgradensis* Richards, *Pecten* sp., *Crassatella mississippiensis* Conrad? *Crassostrea* sp., *Anomia* sp., *Glycymeris* sp., *Macrocallista* sp., *Turritella* sp., *Calyptraea* sp., and *Busycon* sp. Many mollusks show delicate casts of boring sponges, worms, etc. Arthropods: *Balanus* sp.

Bed F. Thin phosphate veneer on surface of Bed E bored in places.

Bed G. Consists of single layer of *Ostrea vaughani* Dall, firmly cemented to phosphate substrate in most present pit area. Some oysters show borings by small mollusks.

Bed H. Mollusks: *Crassostrea gigantissima* (Finch), *Anadara silverdalensis* (Kellum), *Glycymeris anteparilis* Kellum *Astarte onslowensis* Kellum, *Astarte*, sp. nov., *Crassatella silverdalensis* (Kellum) Venericardia *nodifera* Kellum, *Stewartia anodonta* (Say), *Pecten crocus* Cooke, *Carditamera* sp., *Cardium taphrium* Dall, *Donax idoneus* (Conrad) *Venus floridana* Conrad, *Chione* spada Dall, *Mya* sp., *Diadora* sp., *Potamides campanulatus* Heilprin, *Crucibulum* sp., *Sinum imperforatum* Dall, *Rapana vaughani* Mansfield, *Busycon spiniger onslowensis* Kellum, *Fusinus* sp., *Ecphora* sp., *Mercenaria gardnerae* (Kellum), *Chione erecta* (Kellum), *Macrocallista acuminate* Dall, *Barbatia* sp., *Glycymeris* sp., *Mytilus* sp., *Modiolus* sp., *Chama chipolana* Dall, *Cyclocardia* sp. nov., *Cardium* sp., *Donax* sp., *Chione rhodia* Dall, *Corbula* sp., *Diadora* sp., *Turritella indenta* Conrad, *Calyptraea* sp., *Polinices* sp., *Rapana gilletti* Richards, *Murex spinulosa* Hellprin, *Fusinus trentensis* Richards, and *Conus* sp.

Bed I. Contains same mollusks as Bed H in sandy laminae. Green clay examined by W. A. Abbott (S. C. Geol. Sur.) for diatoms, with negative results; Abbot reported presence of pollen.

Bed J. Mollusks: *Mulinia congesta* (Conrad), *Carditamera arata* (Conrad), *Cardita tridentata* Say, *Glycymeris duplinensis* Dall, *Plicatula marginata* Say, *Cardita perpiana* (Conrad), *Chama striata* Emmons, *Corbula* sp., *Olivella* sp., and *Marginella* sp.

Bed K. Some reworked shark teeth and bone, probably derived from Beds H and J.

Bed L. No body fossils but numerous burrows.

Locality 13 (Figure 18). Haywood Landing, left bank of White Oak River, 1.2 mi. below mouth of Holston Creek, Jones County, NC.

Mollusks: *Phacoides* sp., *Anadara silverdalensis* (Kellum), *Astarte* sp., nov., *Venericardia nodifera* Kellum, *Stewartia anodonta* (Say), *Chione erecta* (Kellum), *Cyclocardia* sp. nov., *Donax idoneus* Conrad, *Donax* sp., *Polinices* sp., *Sinum imperforatum* Dall, *Corbula* sp. nov., and *Turritella tampae* Dall.

Locality 14 (Figure 19). Siilverdale Marl Company Quarry, Silverdale, Onslow County, NC.

Bed A. Mollusks: *Astarte onslowensis* Kellum, A. sp. nov., *Venericardia*

nodifera Kellum, *Stewartia anodonta* (Say), *Macrocallista acuminata* Dall, *Corbula* sp., *Calyptraea* sp., *Crucibulum* sp., *Polinices* sp., and *Cyclocardia* sp. nov. Bed contains abundant fauna of micromollusks, most undescribed. Many fish otoliths. Well-preserved microfauna includes many ostracodes and foraminifers. Ostracodes (Hazel, 1976, written comm.) indicate tentative early Miocene age; benthonic foraminifers (Poag, 1976, oral comm.) indicate tentative latest Oligocene age.

Bed B. Mollusks: *Crassostrea gigantissima* (Finch), *Anadara silverdalensis* (Kellum), *Glycymeris* sp., *Crassatella silverdalensis* (Kellum), *Venericardia nodifera* Kellum *Mercenaria gardnerae* (Kellum),*Macroscallista acuminata, Pecten crocus* Cooke, *Carditamera* sp., *Cardium taphrium* Dall, *Chione rhodia* Dall, *Panopea* sp., *Antigona lamellacea* Kellum, *Anomia ruffini* Conrad, *Turritella indenta* Conrad, *Potamides campanualtus* Heilprin, *Crucibulum* sp., *Sinum imperforatum* Dall, *Rapana vaughani* Mansfield, *Murex davisi* Richards, *Busycon spiniger onslowensis* Kellum, *Glycymeris anteparilis* Kellum, *Astarte onslowensis* Kellum, *Astarte* sp., *Stewartia anodonta* (Say), *Chione erecta* Kellum, *Barbatia* sp., *Chama chipolana* Dall, *Cyclocardia* sp., *Venus floridana* Conrad, *Chione spada* Dall, *Corbula* sp., *Plicatula* sp. nov., *Diadora* sp., *Turritella fuerta* Kellum, *Calyptraea* sp., *Polinices* sp., *Rapana gilleti* Richards, *Murex spinulosa* Hellprin, *Murex kellumi* Richards, *Fusinus trentensis* Richards, *Scaphella stromboidella* Kellum, *Conus*, spp., *Lyria carolinensis*, and *Ecphora* sp.

Bed C. Contains bone and teeth derived from Haywood Landing Member and other units, including shark teeth derived from early Pliocene beds.

Bed D. None.

Locality 19 (Figure 6). North Carolina Lime Excavating Company Quarry, 6.4 km W of Comfort, Jones County, NC.

Bed A. Mollusks: *Pecten membranosus* Morton, *Pecten clarkeanus* Aldrich, *Pynonodonte trigonalis* (Conrad), *Pecten* sp., and *Anomia filamentosa* Conrad. Numerous bivalves, including *Arca* sp., *Modiolus* sp., *Mytilus* sp., etc. preserved as external molds on underside of bryozoans; they served as substrate for beginning colony. Gastropods steinkerns common but indeterminable; few small nautiloids present. Bryozoans: Many specimens, mainly encrusting forms. Echinoderms: *Periarchus* sp. Brachiopods: *Terebratula wilmingtonensis* (Lyell & Sowerby). Ostracodes: Assemblage (Hazel, 1976, oral comm..) indicates middle Eocene age.

Bed B. Bryozoans: Mainly fragments that are worn, recrystallized, and current sorted; coarse fragments near base, grading upward into fine calcarenite. Echinoderms: Large forms of *Periarchus* sp. in coarse bryozoan hash. Ostracodes: (Hazel, 1976, personal comm.) Indicates middle Eocene age. Foraminifera: Common, including several large forms common in high-energy environments; not examined by specialist.

Bed C. Mollusks: *Pecten cookei* Kellum and *Pynonodonte trigonalis* (Conrad). Bryozoans: Common,

delicate, but small. Echinoderms: Specimens of *Periarchus* sp. common, although mostly small. Ostracodes: assemblage (Hazel, 1978, written comm.) indicates middle Eocene age, probably late middle Eocene, and includes: *Hazelina conleycreekensis* (Gooch) = *Hermanites collie* (Gooch), *Actinocythereis gosportensis* (Blake), *Cytheretta alexanderi* Blake, *Cytherelloidea* n. sp. *Haplocytheridea* sp. cf. *H. perarcuata* (Ulrich), *Clithrocytheridea garretti* (Howe & Chambers), *"Cushmanidea"* sp. *Cytherella* sp. *Cocaia grigsbyi* (Howe & Chambers), *Opimocythere martini* (Murray & Hussey), *Tringinglymus* n. sp., *A. Kingmaina* n. sp., *Idiocythere washingtonensis* (Swain), and *Loxoconcha* sp.=L. sp. cf. *L. creolensis* Swain.

Bed D. Molds of mollusks, too small and imperfect for identification.

Bed E. None

Bed F. None

Echinoids from middle Eocene at Comfort quarry (P. M. Kier, 1976, written comm.) include: *Echinolampas appendiculata* Emmons, *Maretia subrostrata* (Clark), *Cidaris pratti* Clark, and *Linthia hanoverensis* Kellum.

Locality 22. (Figure 5). East Coast Limestone Company Quarry, 2.4 km W of Maple Hill, Pender County, NC.

Bed A. A few juvenile oysters.

Bed B. Mollusks: *Crassatellites* sp. (Stephenson, 1923, Pl. 48, Fig. 7), *Cardium penderense* Stephenson, and *Ostrea subspatulata* Forbes.

Bed C. Mollusks: *Venericardia* sp. and *Pleurotomaria* sp.

Bed D. Mollusks: *Pecten membranosus* Morton, *Pecten clarkeanus* Aldrich, *Anomia filamentosa* Conrad, and *Pleurotomaria* sp. Many small aragonitic bivalves and gastropods, present as molds and casts, not determinable. Bryozoans: Current-sorted, abraded fragments make up majority of sediment, most in excellent condition, although partially recrystallized. Echinoderms: Kier (1976, written comm..) reported the following: *Echinocyamus parvus* (Emmons)? *Rhyncholampas carolinensis* (Twitchell), *Eurhodia* sp., and *Meoma* sp. nov.

Bed E. None.

Locality 23 (Figure 4). Martin Marietta Company Castle Hayne Quarry, New Hanover County, NC.

Beds A, B. Late Cretaceous, not studied.

Bed. C. Not extensively collected or studied. Some mollusks include: *Cucullaea* sp. *Isognomon* sp., *Inoceramus* sp., *Ostrea subspatulata* Forbes, *Exogyra* sp., *Trigonia* sp., *Pholadomya* sp., *Crassatellites* sp., and *Cardium penderense.*

Bed. D. Mollusks: *Pecten* sp., *Venericardia* sp., *Cubitostrea sellaeformis* (Conrad), *Trachycardium claibornense* (Aldrich), *Cypraea* sp. *Crassatella alta* Conrad, *Crassatella* sp., and *Strombus* sp. Echinoderms: Several well-preserved echinoids, not studied. Arthropods: 2 common species of crab. Vertebrates: Shark and ray teeth common.

Bed E. Mainly current-sorted bryozoan fragments and small pectens.

Bed F. Stumps present, in situ

Bed G. None.

Locality 24 (Figure 3). Ideal Cement Company Quarry, New Hanover County, NC.

Bed A. Mollusks: *Cucullaea* sp., *Ostrea subspatulata* Forbes, *Trigonia* sp., *Cardium penderense* Stephenson, *Inoceramus* sp., *Exogyra* sp., *Pholadomya* sp., and *Crassatellites* sp.

Bed B. Mollusks: *Pecten* sp. and *Venericardia* sp. Vertebrates: Shark and ray teeth common.

Beds C, D. Dominantly current-sorted bryozoan fragments; a few specimens of *Pecten membranosus* Morton.

Bed E. Mollusks: *Pecten membranosus* Morton, *Pynonodonte* sp., *Crassatella alta* Conrad, *Arca* sp., *Pecten* sp., *Spondylus* sp., *Pholadomya* sp., and *Barbatia* sp. Numerous indeterminate nautiloids. Bryozoans: Many specimens, excellently preserved. Echinoderms: (See comments after Bed M). Brachiopods: *Terebratula wilmingtonensis* Lyell & Sowerby.

Beds F-K. Mollusks: *Pecten membranosus* Morton. *Spondylus* sp., *Xenophora* sp., *Crassatella alta* Conrad, *Barbatia* sp., *Fusinus abruptus* Tuomey, and *Crassatella* sp.

Bed L. None.

Bed M. Freshwater bivalves and gastropods found in some areas. Kier (1976, written comm.) reported the following from undifferentiated Eocene limestones at Ideal Cement Co. quarry: *Periarchus lyelli* (Conrad) or *P. rutriformis* Paulson, *Arbacia* n. sp. *Coelopleurus carolinensis* Cooke, *Eurhodia* sp. cf. *E. rugosa* (Ravenel), *Rhyncholampas* sp. cf. *R. conradi* (Conrad), *Echinolampas appendiculata* Emmons, *Linthia hanoverensis* Kellum, *Eupataqua carolinensis* Clark, *Maretia subrostrata* (Clark), and *Cidaris pratti* Clark.

Locality 25 (Figure 16). 0.3 km below mouth of Mill Creek, right bank of Trent River, Jones County, NC.

Bed. A. Mollusks: *Crassostrea gigantissima* (Finch), *Chione* sp., *Pecten trentensis* Harris, and *Pecten waynesis* Mansfield. Arthropods: Many barnacles.

Bed B. Mollusks: *Mercenaria* sp., *Panopea* sp. *Glycymeris* sp., and *Chione* sp.

Bed C. Dominated by abundant large oysters, *Crassostrea gigantissima* (Finch). Barnacles commonly attached to oysters.

Locality 27 (Figure 11). 0.3 km above Rhems Landing, left bank of Trent River, just below River Bend, Craven County, NC.

Mollusks: *Mercenaria* sp., *Panopea* sp., *Chione* sp., *Calyptraea* sp., *Glycymeris* sp., *Macrocallista* sp., *Pecten* sp., and *Turritella* sp. Arthropods: Barnacle fragments common.

Locality 31 (Figure 10). Prettyman Landing, left bank of Trent River, Jones County, NC.

Bed A. Consists mainly of very abundant molds of *Macrocallista neusensis* (Harris)=*M. perovata* (Conrad)

Bed B. Only mollusks recognized were *Mercenaria* and *Crassostrea(?).*

Bed C. No macrofossils seen; fine, clean sand contains abundant foraminifers and ostracodes in places.

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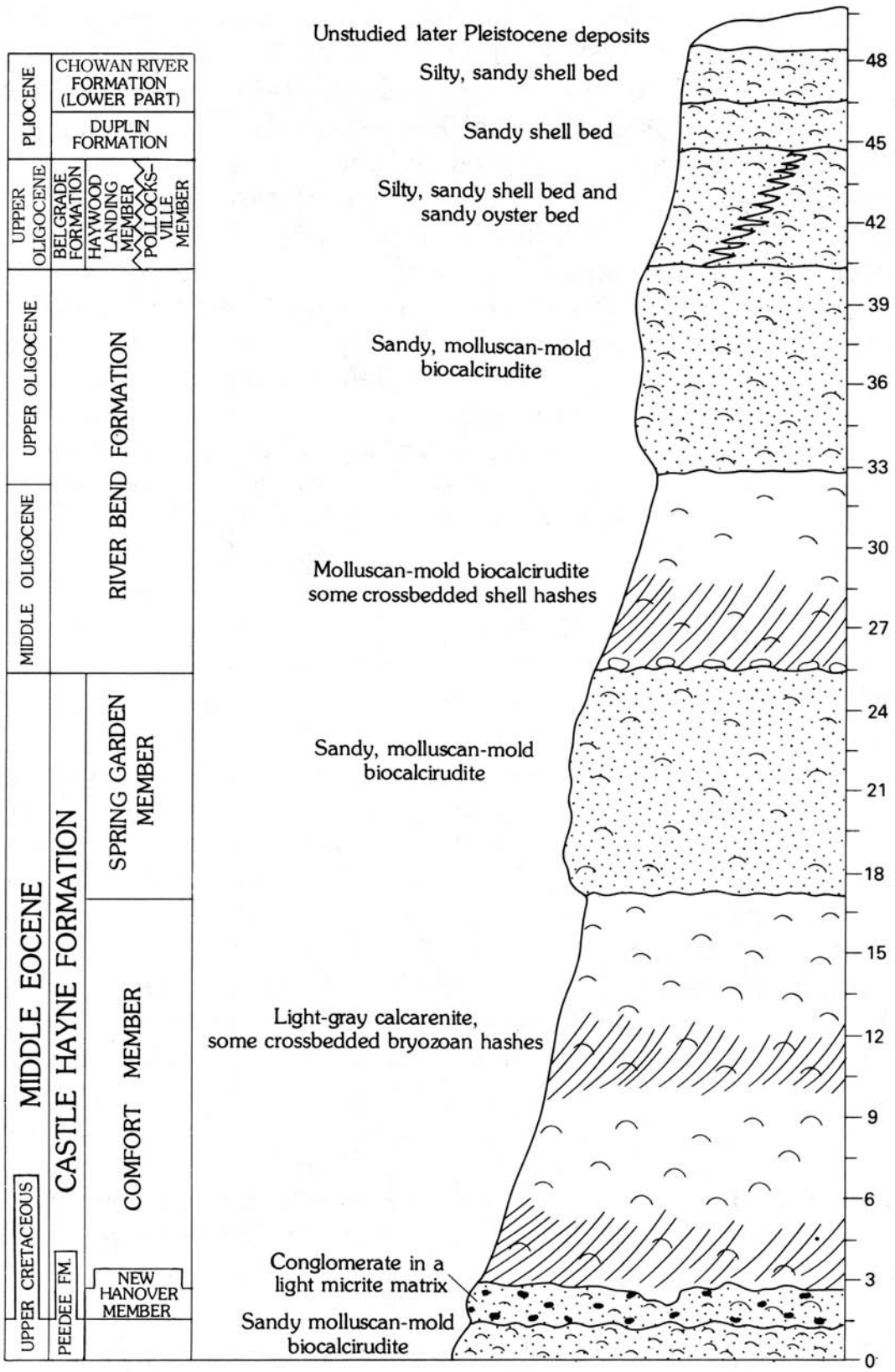

Composite section of outcropping Tertiary formations.