UNITED STATES DEPARTMENT OF THE INTERIOR

FORAMINIFERA, DIATOMS, AND MOLLUSKS FROM TEST WELLS NEAR ELIZABETH CITY NORTH CAROLINA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 189–G

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Professional Paper 189—G

FORAMINIFERA, DIATOMS, AND MOLLUSKS FROM TEST WELLS NEAR ELIZABETH CITY, NORTH CAROLINA

BY

L. G. HENBEST, K. E. LOHMAN, AND W. C. MANSFIELD

Shorter contributions to general geology, 1937

(Pages 217–227)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1939

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 10 cents

CONTENTS

ILLUSTRATIONS

FORAMINIFERA, DIATOMS, AND MOLLUSKS FROM TEST WELLS NEAR ELIZABETH CITY, NORTH CAROLINA

By L. G. Henbest, K. E. Lohman, and W. C. Mansfield

ABSTRACT

Samples from the beds penetrated by 9 test wells in the vicinity of Elizabeth City, N. C., yielded 84 species and varieties of Foraminifera, 100 species and varieties of diatoms, and 86 species and varieties of mollusks. The maximum depth penetrated was 482 feet in 1 deep drilled well; the other wells were jetted to various depths less than 100 feet. The beds penetrated fall into three groups—(1) marine and brackish-water beds assigned to the Pleistocene; (2) brackish-water beds assigned to the interval from Pliocene to lower Pleistocene; and (3) marine beds assigned to the upper Miocene. The beds in group 1 are correlated with Pleistocene outcrops on the Neuse River below New Bern, N. C., near Beaufort, N. C., about 95 miles to the southwest; those in group 2 with exposures made during excavations in the Dismal Swamp, about 25 miles to the northwest, assigned to the upper Pliocene or lower Pleistocene; and those in group 3 with exposures on the Roanoke River near Hamilton Wharf, N. C., about 65 miles to the southwest, assigned to the upper part of the Yorktown formation, of upper Miocene age. The younger beds were deposited in somewhat brackish water, suggestive of an estuary or lagoon, and the older beds were deposited under a strictly marine environment.

INTRODUCTION

In the fall of 1932 a large number of test wells were put down in the vicinity of Elizabeth City, N. C., under the supervision of S. W. Lohman, of the Geological Survey, for the purpose of determining the possibility of developing a ground-water supply that would be adequate for the needs of the city. The results of this investigation have since been published.[1]

One of these wells was drilled to a depth of 482 feet, and the others were jetted to various depths from 25 to 93 feet. Samples were collected from each well as drilling proceeded and later were shipped to the Geological Survey for examination. A great many of the samples contained either Foraminifera, diatoms, or mollusks, the study of which formed the basis of the present paper.

Figure 28 shows the general location of the Elizabeth City area, and figure 29 shows the location of the wells, which bear the same numbers as were given to them in the report cited above.

We are indebted to Mr. S. W. Lohman for the use of the two figures, for the collection of the samples, and for a considerable amount of data regarding the depths and locations of the wells.

Foraminifera were found in samples from six wells, diatoms from one, and mollusks from eight.

[1] Lohman, S. W., Geology and ground water resources of the Elizabeth City area, North Carolina: Geol. Survey Water-Supply Paper 773-A, 1936.

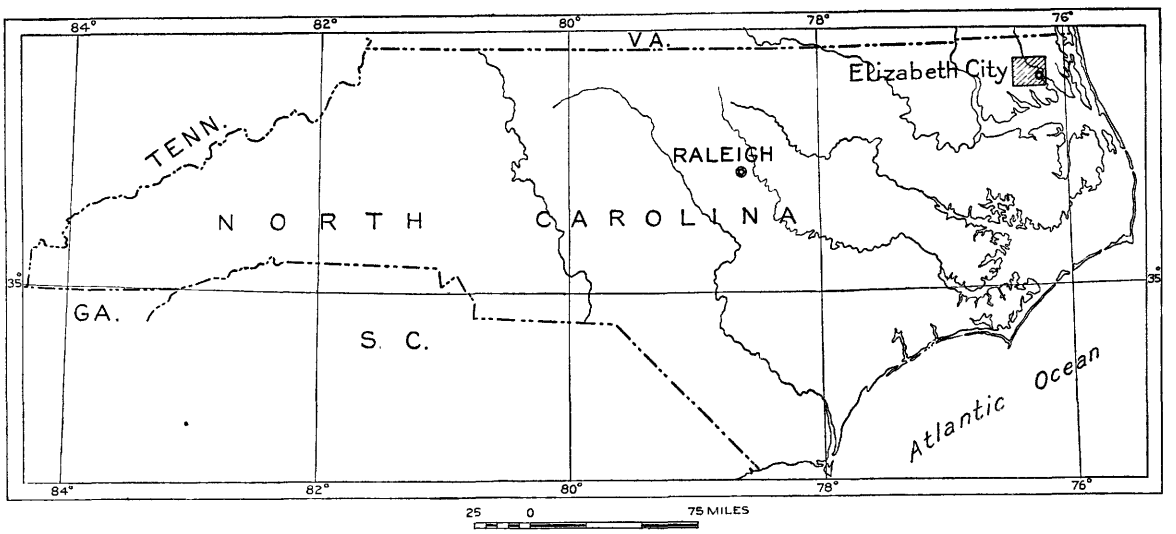

FIGURE 28.—Index map of North Carolina, showing the location of Elizabeth City.

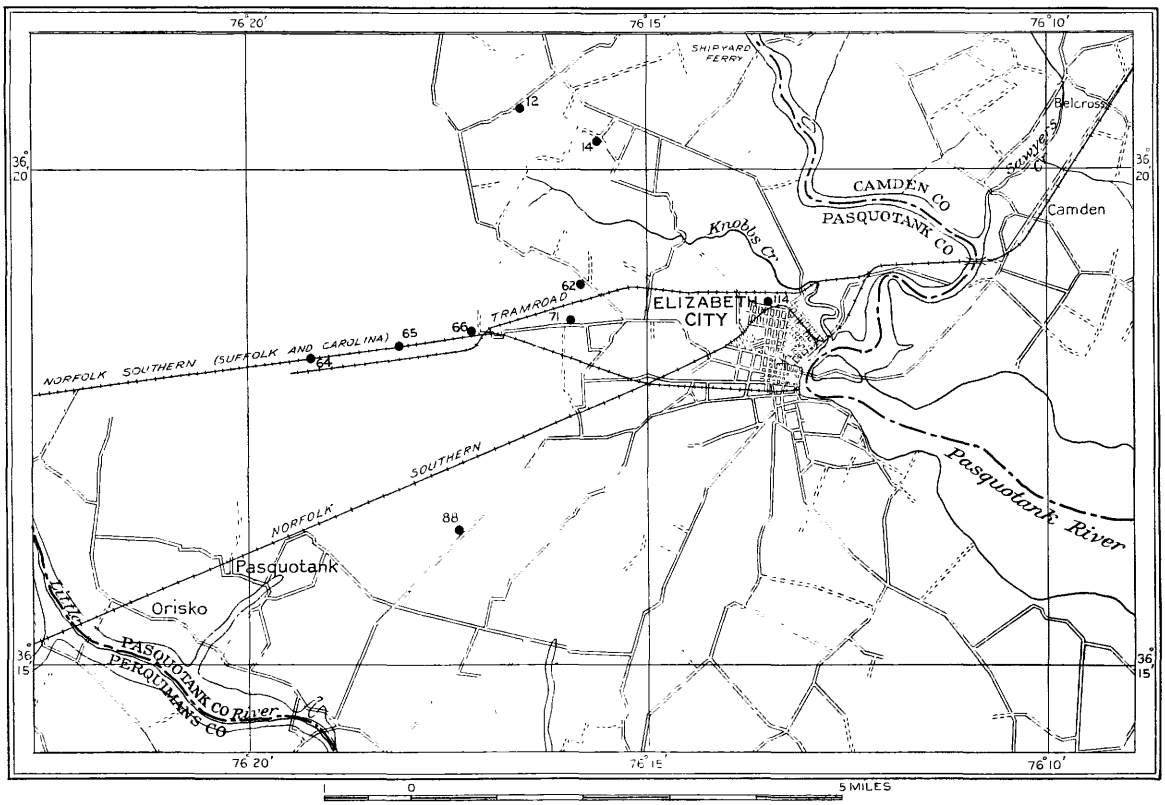

FIGURE 29.—Map of Elizabeth City and vicinity, showing location of test wells.

FORAMINIFERA

By L. G. HENBEST

A few samples of fossiliferous sand and clay from shallow test wells near Elizabeth City, N. C., were submitted to me by S. W. Lohman for age determination. Foraminifera were found in most of the samples, but they were rather sparsely distributed. Fortunately the shells were not filled with secondary mineral matter; so it was possible to concentrate them by flotation with carbon tetrachloride. The concentrates from the lower horizons—depths 50 to 93 feet—contained a varied fauna, which proved to be of Miocene age, probably upper Miocene. This fauna was represented by four samples. The remaining five samples were collected at depths of 12 to 25 feet and contained a less varied fauna of Pliocene or Pleistocene age or more probably a mixture of both.

CORRELATION PROBLEM

The more or less disconnected succession of Miocene, Pliocene, and Pleistocene sedimentary strata on the Atlantic Coastal Plain contain foraminiferal assemblages which have many species in common and cannot be distinguished by pronounced or radical differences. In a general way the historical changes in the assemblages are gradual and involved rather than abrupt; however, certain geographic and stratigraphic differences have been discovered in these faunas by Cushman, Cole, and Ponton, that can be utilized in stratigraphic problems such as the one here treated if a large and varied foraminiferal fauna is recovered.

CHECK LIST OF SPECIES

The list on pages 219 and 220 shows the Foraminifera found in these samples.

In a general way the Foraminifera of the Florida region during and since Miocene time have belonged to a shallow subtropical facies, while those farther north lived in a cooler marine climate. This difference was probably related to general conditions rather than depth of water. Associated with the climatic differences are variations in faunal composition, for some of the elements in the fauna that are conspicuous and characteristic in one region are rare or absent in the other, although the rocks that contain them are of supposedly similar age. This circumstance complicates correlation problems and in several places renders close correlation impossible. The time range of species is confusing at first glance, for many species of the varied, populous fauna of Miocene age have held over into the Pliocene and later time. The Pliocene in turn had a more varied fauna than the succeeding Pleistocene but less varied than the Miocene. Many Pliocene species persisted into the Pleistocene. Accordingly, it is not everywhere

easy to distinguish either Miocene from Pliocene or Pliocene from Pleistocene.

The Foraminifera obtained from wells 65 and 64 at depths of 65 feet and 50 to 55 feet, respectively, are so similar to those obtained at depths of 87 to 93 feet in well 71 that they evidently came from the same formation. The discrepancy in depth is reduced about 30 percent when the dip of the rocks is taken into account. Specimens collected at depths of less than 25 feet evidently belong to a closely related succession of sediments and may be grouped together.

The stratigraphic and geographic distribution of the foraminiferal species are represented in the accompanying table. The table is self-explanatory, but certain of its features deserve comment. Only the fossil assemblage from depths of 50 to 93 feet in wells 64, 65 and 71 contains a Miocene, probably upper Miocene, fauna, although many of the species would fit in a Pliocene fauna. The presence of *Textularia candeiana* D'Orbigny and other species of *Textularia* which are uncommon in the Pliocene; a Miocene variety of *Cancris sagra* (D'Orbigny); *Cibicides americanus* (Cushman),

Foraminifera in samples from test wells near Elizabeth City, N. C.

Well no	71		65	64	14	12	66	65	64	Previous fossil record. Atlantic Coastal Plain		
Depth (feet)	87	93	65	50–55	12–15	20	25	23–25	25	Miocene	Pliocene	Pleistocene
Spiroplectammina? sp			×									
Spiroplectammina gracilis (Muenster)	×									×		
Textularia agglutinans D'Orbigny	×									×		
T. cf. T. agglutinans D'Orbigny		×								×		
T. articulata D'Orbigny		×								×		
T. candeiana D'Orbigny		×	×							×		
T. floridana Cushman				×						×	×	
T. cf. T. gramen D'Orbigny	×		×	×						×	×	
T. mayori Cushman		?								×	×	
Textularia sp		×										
Quinqueloculina flexuosa D'Orbigny					×		×					×
Q. cf. Q. fusca H. B. Brady		×								×	×	
Q. lamarckiana D'Orbigny			?				×			×	×	×
Q. cf. Q. seminula (Linné)	×		×							×	×	
Q. seminula var				×								
Q. contorta D'Orbigny	×									×	×	
Quinqueloculina sp	3 sp.	3 sp.										
Spiroloculina depressa D'Orbigny	?	×								×		
Massilina cf. M. quadrans Cushman and Ponton	×									×		
M. mansfieldi Cushman and Cahill	×		×	×						×		
M. marylandica Cushman and Cahill			×							×		
Sigmoilina sp	×											
Triloculina linneiana D'Orbigny var. caloosahatchensis Cole							×				×	
T. trigonula (Lamarck)					×					×	×	
Pyro sp			×									
Pyro subsphaerica (D'Orbigny)	×	×								×	×	
Articulina sagra D'Orbigny var. miocenica Cushman and Ponton	×									×		
Articulina sp		×									?	
Lagena cf. L. marginato-perforata (Sequenza)				×						×		
L. cf. L. striato-punctata (Parker and Jones)	×									×		
Guttulina austriaca D'Orbigny	×	×	×							×		
G. caudata D'Orbigny					×	×				×	×	
G. lactea (Walker and Jacob) var. earlandi Cushman and Ozawa	×		×			×		×	×	×		
Pyrulina albatrossi Cushman and Ozawa	×		×							×		
Globulina inaequalis Reuss							×			×	?	?
G. inaequalis var. caribaea D'Orbigny							×			×	×	×
Globulina sp						×						
Vertebralina sp	2 sp.	×										
Nonion cf. N. glabrellum Cushman							×			×	×	
N. grateloupi (D'Orbigny)						×				×	×	×
N. grateloupi (Pliocene var.)	×										×	
N. pizarrense Berry	×		×							×		
N. pompilioides (Fichtel and Moll.)					?		×		×	(1)	×	×
Nonion sp					×		×	×				
Nonionella auris (D'Orbigny)	×		×	×						×		
Elphidium sp	2 sp.			4 sp.	×	×		×	2 sp.			
Elphidium fimbriatulum (Cushman) var. advenum (Cushman)			?		×					×	×	×
E. gunteri Cole	×										×	
E. incertum (Williamson)			×	×		?		×	×	×	×	×
E. poeyanum (D'Orbigny)			?			×		×		×	×	×
E. sagrum (D'Orbigny)						×		×		×	×	×
Elphidium? sp			×							×		

[1] Cushman's Miocene specimen is not like the post-Miocene forms in this collection.

Foraminifera in samples from test wells near Elizabeth City, N. C.—Continued

Well no	71		65	64	14	12	66	65	64	Previous fossil record, Atlantic Coastal Plain		
Depth (feet)	87	93	65	50–55	12–15	20	25	23–25	25	Miocene	Pliocene	Pleistocene
Buliminella elegantissima (D'Orbigny)			×	×						×	×	×
Bulimina gracilis? Cushman			×			×				×		
B. marginata D'Orbigny	×									×	×	
Bulimina sp	2 sp.	×	2 sp.		×							
Bolivina cf. B. plicatella Cushman					×		×			×	×	
B. plicatella var. mera Cushman and Ponton		×								×		
B. striatula Cushman							×					×
Virgulina fusiformis Cushman			×							×		
V. cf. V. pontoni Cushman					×					×		
Loxostoma sp					×							
Reussia spinulosa (Reuss)	×									×	×	
Spirillina sp			×									
Discorbis candeiana (D'Orbigny)					×					×		
D. consobrina (D'Orbigny)							×			×		
D. floridana? Cushman						?				×	×	×
D. orbicularis (Terquem)	×	×								×	?	
D. vilardiboana (D'Orbigny) of Cushman, 1930				×						×		
Rotalia sp		×				×						
Rotalia beccarii Linné var. ornata Cushman					×		×	?	×		×	×
R. beccarii var. parkinsoniana (D'Orbigny)			×			×		×	×	×	×	×
R. beccarii var. tepida Cushman						×		×	×		×	×
Cancris sagra (D'Orbigny)[2]			×							×		
Eponides frigida (Cushman) var. calida Cushman and Cole	×	?	?	×	×	×	×		×		×	×
E. mansfieldi Cushman			×							×		
Eponides sp			2 sp.									
Amphistegina lessoni D'Orbigny	×		×							×		
Cibicides americanus (Cushman)		×								×		
C. concentricus (Cushman)	×		×	×						×		
C. lobatulus (Walker and Jacob) var. ornatus (Cushman)	×									×		
Acervulina cf. A. adhaerens Schulze		×								×		
Globigerina sp			3 sp.									
Globigerinoides sp			×									

[2] A primitive Miocene form.

whose range is Oligocene to Miocene; *Massilina mansfieldi* Cushman and Cahill; *M. marylandica* Cushman and Cahill; *Eponides mansfieldi* Cushman; and several others which are rare or absent in the Pliocene gives satisfactory evidence for Miocene age. The appearance of the assemblage as a whole agrees with this conclusion.

The fossils that were derived from the more shallow beds are clearly post-Miocene, but it is not at all easy to decide whether they are Pliocene or Pleistocene. The presence of *Rotalia beccari* Linné var. *ornata* Cushman especially and also of *Eponides frigida* (Cushman) var. *calida* Cushman and Cole is generally considered to be adequate evidence of post-Miocene age. The evidence for choosing between Pliocene and Pleistocene conflicts, as the table indicates. Although a faunal mixture was rather apparent, I was inclined to leave the question indeterminate, with a slight inclination in favor of Pliocene. The specimens from well 14, depth 12 to 15 feet, were shown to Prof. W. Storrs Cole, who agreed with the conclusion that the fauna is mixed, but he was inclined to think that most of the evidence in that sample favored assignment to the lowest Pleistocene.

The known range of *Guttulina lactea* (Walker and Jacob) var. *earlandi* Cushman and Ozawa in the sediments of the Atlantic Coastal Plain is limited to the Miocene, but in the Mediterranean region this variety extends from Miocene to Recent. Inasmuch as careful collecting has failed to disclose this variety in post-Miocene rocks on our Atlantic coast, I am inclined to regard these specimens as erratics wherever they are found in these well samples above the Miocene zone. A similar problem is presented by the occurrence of *Eponides frigida* (Cushman) var. *calida* Cushman and Cole, a characteristic Pliocene and Pleistocene form which was found in the Miocene zone of the Elizabeth City test wells. The methods practiced in drilling these shallow wells make a mixture of this sort easily possible. As the specimens at hand of *Guttulina lactea* var. *earlandi* are fragile and are perfectly preserved, it would appear improbable that they are redeposited fossils.

Fragments of woody tissue and a grass (?) seed were found in test well 64, depth 50 to 55 feet.

BIBLIOGRAPHY

The problems touched upon in this paper are treated more extensively in these selected references:

Cole, W. S., The Pliocene and Pleistocene Foraminifera of Florida: Florida Geol. Survey Bull. 6, 1931.

Cushman, J. A., Some Pliocene and Miocene Foraminifera of the Coastal Plain of the United States: Geol. Survey Bull. 676, 1918.

Cushman, J. A., The Foraminifera of the Choctawhatchee formation of Florida: Florida Geol. Survey Bull. 4, 1930.

Cushman, J. A., and Cahill, E. D., Miocene Foraminifera of the Coastal Plain of the eastern United States: Geol. Survey Prof. Paper 175–A, pp. 1–50, 1933.

Cushman, J. A., and Cole, W. S., Pleistocene Foraminifera from Maryland: Cushman Lab. Foram. Research Contr., vol. 6, pp. 94–100, 1930.

Cushman, J. A., and Ponton, G. M., The Foraminifera of the upper, middle, and part of the lower Miocene of Florida: Florida Geol. Survey Bull. 9, 1932.

DIATOMS

By K. E. Lohman

The deep test well (no. 114) was the only one from which diatoms were obtained. The greater part of the samples consisted of very fine blue-green clay, fine silt, and some medium-coarse sand, in all of which diatoms were present only sparingly. A log of this well is given of page 14 of Water-Supply Paper 773–A. Much washing of the material was necessary, particularly of the fine clays, in order to obtain a sufficient concentration of diatoms for a fairly representative assemblage. Thus, although a total of 101 species and varieties, representing 41 genera, were found, it is believed that prolonged search on larger samples would increase this number.

Diatoms were found in all samples taken at depths between 30 and 75 feet. None were found between 75 and 145 feet, below which they continued to be found to a depth of 330 feet. No diatoms were found in any samples taken at depths between 330 and 482 feet, the bottom of the well.

CHECK LIST OF SPECIES

The accompanying table indicates the distribution and frequency of occurrence of the diatoms at the different depths studied. The right-hand four columns show other significant occurrences of the same species. The relative abundance of the diatoms is indicated by the following symbols, based on the concentrated material: A, abundant; C, common; F, frequent; R, rare; ×, present (used only in reporting work of other authors where relative abundance was not stated).

As all the samples received the same degree of concentration in preparation, the abundances indicated bear a fair relation to one another but have no absolute value.

Diatoms from city test well 114, at Elizabeth City, N. C.

	Pleistocene	Pleistocene to upper Pliocene		Upper Miocene						Horry clay, S. C.	Dismal Swamp, N. C.	Hamilton wharf N. C.
Locality no	1338	1339	1340	1342	1343	1344	1345	1346	1347	2815		237 9
Depth (feet)	30	45	75	145	175	200	250	310	330	------		------
Melosira ambigua (Grunow) Müller		F	R								×	
Melosira sulcata (Ehrenberg) Kützing	A	A	A	F	F	C	C	C	C	C	×	C
Melosira cf. M. undulata var. normanii Arnott		R	R									
Melosira westii Wm. Smith				F	F	F	F	C	C			C
Podosira stelliger (Bailey) Mann		F	F	F	F	F			F	C		F
Endictya robusta (Greville) Hanna and Grant	F										×	
Stephanopyxis turris (Greville and Arnott) Ralfs				F	F	F		F				F
Pseudopyxilla americana (Ehrenberg) Forti				R								
Stephanogonia actinoptychus (Ehrenberg) Grunow								R	R			
Stephanogonia polygona Ehrenberg				R								
Syringidium sp		R										
Omphalotheca sp.				R								
Cyclotella striata (Kützing) Grunow		C	F							C		
Coscinodiscus asteromphalus Ehrenberg			R									R
Coscinodiscus decrescens Grunow			F								×	
Coscinodiscus denarius Schmidt	C	C	F							F		
Coscinodiscus devius Schmidt					R							
Coscinodiscus excentricus Ehrenberg	C	C	F						R	F		
Coscinodiscus heteroporus Ehrenberg		R										
Coscinodiscus kützingii Schmidt		F										
Coscinodiscus lineatus Ehrenberg				R	R							
Coscinodiscus minor Ehrenberg			F									
Coscinodiscus nitidulus Ehrenberg	R											
Coscinodiscus nitidus Gregory	F	R	R							F		
Coscinodiscus oculus-iridis Ehrenberg		C								F		R
Coscinodiscus perforatus Ehrenberg			R									
Coscinodiscus radiatus Ehrenberg	C	F								F	×	F
Coscinodiscus cf. C. rothii (Ehrenberg) Grunow		F										
Coscinodiscus sublineatus Grunow	R											
Coscinodiscus subtilis var. glacialis Grunow		F										
Coscinodiscus woodwardii Eulenstein		R										
Liradiscus cf. L. circularis Hanna		R										

Diatoms from city test well 114, at Elizabeth City, N. C.—Continued

	Pleistocene	Pleistocene to upper Pliocene		Upper Miocene						Horry clay, N. C.	Dismal Swamp, N. C.	Hamilton wharf, N. C.
Locality no	1338	1339	1340	1342	1343	1344	1345	1346	1347	2815		2679
Depth (feet)	30	45	75	145	175	200	250	310	330	------		------
Actinoptychus cf. A. cathedralis Brun				R								
Actinoptychus maculatus Grove and Sturt			R									
Actinoptychus splendens (Shadbolt) Ralfs		F			F	F	F	F	F	R		C
Actinoptychus undulatus Ehrenberg	C	C	F	F	F	F	F	F	F	F	C	C
Aulacodiscus argus (Ehrenberg) Schmidt	R	R		C						F		F
Aulacodiscus rogersii (Bailey) Schmidt			F	F	F	A	A	C	F		F	
Eupodiscus radiatus Bailey		F									X	
Auliscus caelatus Bailey	F										X	
Auliscus stockhardtii Janisch		R										
Pseudauliscus radiatus (Bailey) Rattray		R									X	
Goniothecium rogersii Ehrenberg			R								X	
Hercotheca mammilaris Ehrenberg		R										
Periptera sp		R										
Biddulphia chinensis Greville		R										
Biddulphia rhombus (Ehrenberg) W. Smith	R	C		R						F	X	C
Triceratium favus Ehrenberg	F									F		
Triceratium reticulum Ehrenberg		C	R	F			?		?	F		F
Eunotogramma laevis Grunow	C	F										
Hemidiscus cf. H. simplissimus Hanna and Grant							R					
Rhaphoneis amphiceros Ehrenberg			R	R	F					C		F
Rhaphoneis amphiceros var. rhombica Grunow	C	F	R	R								
Rhaphoneis belgica var. intermedia Grunow	F	R										
Rhaphoneis surirella Ehrenberg				F						R		F
Rhaphoneis surirella var. australis Grunow					R							
Rhaphoneis sp. aff. R. scalaris Ehrenberg					R		R					
Opephora schwartzii (Grunow) Pettit		F	R									
Dimerogramma minor (Gregory) Ralfs		R	R									
Dimerogramma minor var. nana (Gregory) Van Heurck				R								
Synedra sp. aff. S. fimbriatus Castracane				F								
Thalassiotrix longissima Cleve and Grunow				R				R				R
Plagiogramma cf. P. antellarum Cleve	R	R										
Plagiogramma cf. P. inaequale Greville	F	F										
Plagiogramma gregorianum Greville		F	F								X	
Plagiogramma interruptum var. adriatica Grunow			R									
Plagiogramma cf. P. ornatum Greville	F											
Plagiogramma wallichianum Greville		R	R									
Achnanthes subsessilis Kützing		R										
Cocconeis distans Gregory	C	C	F									
Cocconeis japonica Schmidt		R										
Navicula brasiliensis Grunow		R										
Navicula hennedyi W. Smith		R										R
Navicula humerosa var. constricta Cleve		R										
Navicula cf. N. irrorata Greville	R											
Navicula lyra Ehrenberg	F	R					R					
Navicula lyra var. atlantica Schmidt	R											
Navicula lyra var. elliptica Schmidt			R									
Navicula lyra var. signata Schmidt		F										
Navicula monilifera Cleve var. constricta Hustedt		R										
Navicula pennata Schmidt				F	F	F						
Diploneis bombus Ehrenberg		F										
Diploneis elliptica (Kützing) Cleve	R	R	R							R		
Diploneis gemmatula (Grunow) Cleve					R	F	F	R	R			
Diploneis gruendleri (Schmidt) Cleve		F	F	F	F			R	R	R	X	
Diploneis lineata (Donkin) Cleve		R										
Diploneis crabro var. suspecta (Schmidt) Cleve						R						
Trachyneis aspera (Ehrenberg) Cleve				F	F	F	F		F	R		F
Trachyneis aspera var. intermedia Grunow				R								
Caloneis permagna (Bailey) Cleve		R										
Amphora ovalis Kützing			R									
Pleurosigma sp				R								
Campylodiscus echeneis Ehrenberg	R										F	
Nitzschia circumsuta (Bailey) Grunow		R										
Nitzschia granulata Grunow	F	F	R							R		
Nitzschia tryblionella Hantzsch		R								R		

CORRELATIONS

Depth of 30 feet.—The assemblage obtained at a depth of 30 feet indicates marine deposition with a slight brackish-water influence, indicated by the presence in small numbers of such species as *Diploneis elliptica*, *Campylodiscus echeneis*, and *Nitzschia granulata*. The frequent occurrence of *Triceratium favus* at this level is a strong indication of Pleistocene age, probably late Pleistocene, as this species has never been found in older rocks on the Atlantic Coastal Plain. Of the 26 species of diatoms found at the 30-foot depth, 11, including *Triceratium favus*, also occur in the Pleistocene Horry clay near Myrtle Beach, S. C.[2] These are listed in the accompanying table. No definite correlation with the Horry clay is suggested by this comparison. It is merely offered as a check on the Pleistocene age assigned to the bed at a depth of 30 feet in the Elizabeth City well.

Depths of 45 to 75 feet.—The diatom assemblage obtained at depths of 45 to 75 feet represents deposition in marine to somewhat brackish water. Out of a total of 69 species, 11 are now living in fresh or brackish water; the rest are marine. The water was thus more brackish than that indicated by the flora from a depth of 30 feet, and many of the diatoms found here are now living in brackish estuaries. This diatom flora strongly resembles one obtained by Woolman [3] from an excavation that was made for the purpose of widening the Dismal Swamp Canal in 1897–98. The diatoms were determined by C. S. Boyer, who listed 31 species, of which 18 are found in the Elizabeth City well. Of the remaining 13 species not found at Elizabeth City, only 3 are diagnostic, whereas the bulk of those found are important and useful as a means of correlation. Woolman was of the opinion that the diatom assemblage from the Dismal Swamp excavation represented an admixture of reworked Miocene forms with some of uppermost Pliocene or Pleistocene age. This opinion was borne out by the examination of the mollusks from the same horizon, determined by H. A. Pilsbry and C. W. Johnston.[4] Two species of diatoms in Woolman's list, *Actinoptychus heliopelta* Grunow and *Aulacodiscus rogersii* (Bailey) Schmidt, are characteristic of the Calvert formation (middle Miocene) along the Atlantic Coastal Plain, and the first is not known to occur in younger beds. The second is definitely known only from Miocene rocks, although Mann [5] reported it in a dredging off Lower California. As it has never been reported as definitely living, and as Mann gave no information regarding the state of preservation of the diatom in his material, it is possible that the Lower California dredging may represent reworked material, at least insofar as this species is concerned. The Dismal Swamp species that are also present in the well are shown in the accompanying table.

The diatom flora from the well at depths of 45 to 75 feet also shows the mixing of Miocene and later forms noted by Woolman, and his explanation—erosion from nearby Miocene diatom-bearing beds and redeposition—appears to be adequate here.

The absence of *Triceratium favus*, the lower stratigraphic position of this part of the section, and the striking similarity to the Dismal Swamp diatom flora strongly suggest a Pleistocene (probably lower Pleistocene) to upper Pliocene age for these beds.

Depths of 145 to 330 feet.—A marine diatom assemblage of 36 species and varieties was obtained from 6 samples taken at depths between 145 and 330 feet. In addition to 14 species that are present in both the upper and lower beds, 21 species occur in the lower beds only. Their geologic ranges are summarized in the following list:

Recent to upper Miocene	9
Recent to middle Miocene	5
Upper Miocene only	2
Upper and middle Miocene	3
Middle Miocene only	2
	21

The two species in this list whose known range is limited to middle Miocene (Calvert formation), *Pseudopyxilla americana* (Ehrenberg) Forti and *Actinoptychus* cf. *A. cathedralis* Brun, occurred rarely in sample 1342, from a depth of 145 feet. Only a fragment of the *Actinoptychus* was found, and the identification is, as indicated, uncertain. The probability that the beds at depths between 145 and 330 feet are of middle Miocene age is therefore extremely slight, as the two forms mentioned occurred only in the uppermost part of this interval. Negative evidence supporting the determination consists in the absence of a number of species of short geologic range but wide geographic distribution, known only from the middle Miocene of the Atlantic Coastal Plain and the Coast Range in California.

All the other species found in the samples from the interval between 145 and 330 feet are known from rocks of upper Miocene age elsewhere, and five are extinct species known from the upper Miocene only or from both upper and middle Miocene. I have found 14 of

[2] Cooke, C. Wythe, The Pleistocene Horry clay and Pamlico formation near Myrtle Beach, S. C.: Washington Acad. Sci. Jour., vol. 27, no. 1, pp. 1–5, 1937.

[3] Woolman, Lewis, Fossil mollusks and diatoms from the Dismal Swamp, Virginia and North Carolina; Indication of the geological age of the deposit, with notes on the diatoms by C. S. Boyer: Acad. Nat. Sci. Philadelphia Proc., vol. 50 (1898), pp. 414–428, 1899.

[4] Idem, p. 418.

[5] Mann, Albert, and Ricker, P. L., Report on the diatoms of the *Albatross* voyages in the Pacific Ocean, 1888–1904: Contr. U. S. Nat. Herbarium, vol. 10, pt. 5, p. 281, 1907.

the species listed in this interval at two localities on the Roanoke River near Hamilton Wharf, Martin County, N. C. (Geol. Survey diatom localities 2679 and 2680). The diatoms came from a buff to blue-gray silt immediately overlying a bed containing numerous mollusks which W. C. Mansfield[6] correlates with the upper part of the Yorktown formation, of upper Miocene age. The Hamilton Wharf species that occur in the Elizabeth City well are indicated on the extreme right of the table. The examination of the Hamilton Wharf material has not been completed, and it is quite probable that more species common to the two localities will be found.

As a result of the foregoing analysis and comparison the most probable age for the beds represented by the interval between 145 and 330 feet is upper Miocene.

No diatoms were found in any of the samples taken at depths between 330 and 482 feet, the bottom of the well.

MOLLUSKS

By Wendell C. Mansfield

The fossil mollusks were taken at depths between 12 and 93 feet below the surface from eight of the test wells numbered 14, 12, 66, 62, 65, 64, 18, and 114. (See fig. 29.) Most of the specimens are either fragments of shells or immature individuals of larger shells, and some of them can be assigned only to genera or questionably to species. Nearly all the specimens have a dark-gray or nearly black color. Some of the specimens of gastropods have coarse-grained quartz sand in their apertures.

CHARACTER AND AGE

A list of the species occurring at different depths is given in the accompanying table.

Depths of 12 to 30 feet.—Of the mollusks from depths between 12 and 30 feet only *Rangia* sp. was found below the 25-foot level. The fauna is assigned to the Pleistocene and agrees closely with the molluscan fauna from a bed above a cypress-stump bed at Geological Survey station 10896, in a section on the Neuse River 10 miles below New Bern, N. C., and from station 10892, about 10 miles northwest of Beaufort, N. C. (See p. 226.) The faunas from both of these localities I have referred to the Pleistocene, but that from station 10892 was considered a little younger than the one from station 10896.

The following species from the Elizabeth test wells are identical with species from either station 10896 or 10892:

Acteocina canaliculata (Say).
Terebra concava (Say).
Terebra dislocata (Say).
Mangilia cerina (Kurtz and Stimpson).
Alectrion acuta (Say).
Astyris lunata (Say).
Pandora trilineatus Say.
Tellina sayi Dall.
Donax variabilis Say.
Mulinia lateralis Say, thin form.

[6] Oral communication.

At a depth of 30 feet a fragment belonging to the genus *Rangia* was taken. This genus indicates a brackish-water condition at this depth.

Depths of 50 to 55 feet.—The mollusks observed at depths between 50 and 55 feet in the well indicate a change in the character of the fauna. Large specimens of *Corbula inaequalis* Say occur here. The specimens referred to this species are as a rule small in the Pliocene and larger in the Miocene. An exception is to be noted, however, in specimens from station 8167, 3 miles southwest of Riverdale, N. C.; although I have correlated this locality with the Pliocene Croatan sand, the shells of *C. inaequalis* found there are larger than those commonly found in the Pliocene.

The age of the fauna occurring between depths of 50 and 55 feet is believed to be Tertiary and may be no older than Pliocene.

Depths of 65 to 93 feet.—The fauna between depths of 65 and 93 feet, although somewhat similar to that between depths of 50 and 55 feet, carries fragments of *Turritella* aff. *T. alticostata* Conrad that are somewhat similar to shells of this species in the fauna in the upper part of the Yorktown formation at Tar Ferry, N. C. (See below.) *Corbula inaequalis* and *Cyprae olina dacria* Dall (the latter a Miocene and Pliocene species) are also found in this part of the section. The fauna between depths of 65 and 93 feet is in most respects different from the late Yorktown fauna at Tar Ferry, there being only a few species in common. About the only molluscan evidence that the upper Miocene has been reached in the Elizabeth City wells is that afforded by *Turritella* aff. *T. alticostata*. I found no Turritellas like this form in the Croatan sand of the Pliocene.

Summary.—The ages indicated by the mollusks at different depths are summarized below.

Between 12 and 30 feet—Pleistocene.
Between 30 and 50 feet—no specimens.
Between 50 and 55 feet—Tertiary; may be Pliocene.
Between 55 and 65 feet—no specimens.
Between 65 and 93 feet—Tertiary; questionably referred to the upper Miocene.

RELATED FAUNAS IN NORTH CAROLINA AND VIRGINIA

Tar Ferry, N. C.—At Tar Ferry, Wiccacor Creek, about 30 miles nearly west of Elizabeth City, and at Colerain Landing (upper beds), Chowan River, about 30 miles southwest of Elizabeth City, are well-exposed beds carrying late Yorktown faunas comparable in age with the Duplin marl at the Natural Well, N. C., but a little later in time than the upper part of the Yorktown as exposed in the vicinity of Suffolk, Va. A list of the species at Tar Ferry is given by Miller.[7]

Dismal Swamp Canal, N. C.—A collection of fossils was obtained by me from a spoil bank along the Dismal Swamp Canal about 3½ miles south of the Virginia-North Carolina State line and about 16 miles a little

Species of mollusks from test wells in and near Elizabeth City, N. C.

	Pleistocene		Tertiary		
	12–25 feet	30 feet	50–55 feet	65 feet	87–93 feet
Gastropods					
Acteocina canaliculata (Say)	×				
Acteocina canaliculata (Say) var					×
Terebra concava (Say)	×				
Terebra dislocata (Say)	×				
Mangelia cerina (Kurtz and Stimpson)	×				
Olivella mutica (Say)	×				×
Marginella aureocincta Stearns					×
Marginella bella (Conrad)					×
Marginella cf. M. limatula Conrad	×				
Cypraeolina dacria (Dall)					×
Marginella, sp. ind	×				
Alectrion acuta (Say)	×				
Alectrion trivittata (Say)	×				
Alectrion near A. obsoleta (Say)			×		×
Alectrion sp. (fragment)				×	
Astyris lunata (Say)	×			×	
Astyris aff. A. profundi Dall				×	×
Columbella? sp					×
Eupleura caudata (Say)? (fragment)	×				
Urosalpinx aff. U. cinereus (Say)					×
Urosalpinx sp			×		
Epitonium sp. *a*					×
Epitonium sp. *b*				×	
Melanella sp					×
Melanella sp	×				
Turbonilla sp. *a* (apparently 1 sp.)	×				
Turbonilla sp. *b*	×				
Turbonilla sp. *c*				×	×
Pyramidella sp	×				
Odostomia sp	×				
Alabina sp			×		
Seila adamsii (H. C. Lea)	×			?	
Caecum regulare Carpenter					×
Turritella sp. *a* aff. T. alticostata Conrad (fragments)				×	×
Turritella sp. *b* aff. T. alticostata Conrad (fragments)					×
Crepidula fornicata (Linné)	×			×	×
Calyptraea sp					×
Tectonatica pusilla (Say)	×				×
Pelecypods					
Nucula proxima Say				×	×
Nuculana acuta (Conrad)			×	×	×
Yoldia sp					×
Glycymeris americana (Defrance)					×

	Pleistocene		Tertiary		
	12–25 feet	30 feet	50–55 feet	65 feet	87–93 feet
Pelecypods—Continued					
Glycymeris subovata (Say)? (young)				×	×
Arca (probably more than 1 sp.) (young)	×		×	×	×
Ostrea sp. (young)					×
Anomia? sp. (young)	×				
Pecten eboreus Conrad? (fragments)					×
Plicatula sp. (young)				×	×
Crenella aff. C. glandula Totten					×
Pandora trilineata Say	×				
Pandora sp. (fragments)	×			×	
Astarte cf. A. concentrica Conrad (fragment)					×
Astarte sp. (fragment)				×	
Crassinella lunulata (Conrad)	?			×	×
Venericardia perplana Conrad				×	×
Venericardia granulata Say			×		×
Venericardia tridentata Say	×			×	
Chama sp					×
Phacoides trisulcatus (Conrad)			×	×	×
Phacoides multilineatus (Tuomey and Holmes)	×			×	×
Diplodonta, 2 sp.?	×				×
Sportella sp	×				
Sportella constricta (Conrad)	×				
Rochefortia planulata Stimpson	×				
Aligena sp. (young)	×				
Cardium sp. (young)	×				
Callocardia sp					×
Macrocallista sp. (young)	×				
Venus sp. *a* (young)	×		×	×	×
Venus sp. *b* (young)	×		×		
Gemma magna Dall				×	
Tellina aff. T. declivis Conrad					×
Tellina sayi Dall	×				
Donax variabilis Say	×				
Ensis directus Conrad	×		?		
Spisula, 1 or more sp.?	×			×	×
Abra sp			×		
Mulinia lateralis Say	×				
Mulinia congesta Conrad?			×		
Rangia cuneata Gray		×			
Paramya subovata Conrad					×
Corbula inaequalis Say			×		×
Corbula aff. C. cuneata Say				×	
Corbula (Corbula) sp					×
Corbula sp					×
Corbula conracta Say	×				

west of north of Elizabeth City. The following is a list of the species with their geologic ranges:

Marginella limatula Conrad, Miocene to Recent; same as Recent specimens at Smiths Island, Va.
Olivella mutica (Say), Miocene to Recent.
Busycon caricum (Gmelin), more like Pleistocene and Recent forms.
Alectrion trivittata (Say), Pliocene?, Pleistocene, and Recent.
Ilyanassa obsoleta (Say), Pleistocene and Recent.
Urosalpinx cinereus (Say), Pleistocene and Recent.
Vermetus sp.
Crepidula sp.
Polynices duplicatus (Say), Miocene to Recent.
Nucula proxima Say, Miocene to Recent.
Arca (Noetia) limula Conrad, similar to a Pliocene Waccamaw form.
Arca plicatura Conrad var., more nearly like the Pliocene form.
Modiolus sp.
Venericardia tridentata Say (has two or three more ribs than the Recent northern form), probably more nearly like the Pliocene form.
Divaricella quadrisulcata (D'Orbigny), Miocene to Recent.
Cumingia tellinoides (Conrad), Pleistocene and Recent.
Ensis directus Conrad, Miocene to Recent.
Mulinia lateralis Say, Miocene to Recent, a light form and more nearly like Pleistocene and Recent.
Spisula sp. cf. S. procera Solander.
Coral.

Some of the species in this list—*Ilyanassa obsoleta* (Say), *Urosalpinx cinereus* (Say), *Cumingia tellinoides* (Conrad), and perhaps others—appear to have been taken from the Pleistocene, whereas other species—*Arca limula* Conrad, *Arca plicatura* Conrad var., *Venericardia tridentata* Say, and perhaps others—appear to have been taken from the Pliocene. The collection appears, therefore, to be a mechanical mixture of Pliocene and Pleistocene species.

[7] Miller, B. L., The Tertiary formations: North Carolina Geol. and Econ. Survey, vol. 3, pp. 233, 234, 1912.

Nine of the names listed are the same as names listed by Woolman [8] in his "table of species of mollusks dredged from the Dismal Swamp Canal in North Carolina and Virginia." I have not had an opportunity to compare his specimens with mine.

Localities near New Bern and Beaufort, N. C.—Pliocene and Pleistocene faunas found in the outcrops along the Neuse River below New Bern and Pleistocene faunas from ditches 10 miles northwest of Beaufort, N. C., were described in 1927.[9] These localities are about 100 miles nearly south of Elizabeth City.

[8] Woolman, Lewis, Acad. Nat. Sci. Philadelphia Proc., vol. 50, p. 418, 1898.

[9] Mansfield, W. C., Notes on Pleistocene faunas from Maryland and Virginia and Pliocene and Pleistocene faunas from North Carolina: Geol. Survey Prof. Paper 150-F, 1927.

SUMMARY OF RESULTS

Studies of the three classes of fossils have given results that are in fairly close agreement. They are summarized below in tabular form.

Depth (feet)	Foraminifera (wells 12, 14, 64, 65, 66, and 71)	Diatoms (well 114)		Mollusks (wells 12, 14, 18, 62, 64, 65, 66, and 114)	
	Age	Age	Ecology	Age	Ecology
	No Foraminifera.	No diatoms.		No mollusks.	
	Pliocene or Pleistocene.			Pleistocene.	Brackish water.
		Pleistocene.	Marine to brackish water.		
	No Foraminifera.	No diatoms.		No mollusks.	
				Pliocene (?).	Marine.
	Miocene (probably upper).	Pleistocene to upper Pliocene.	Marine to brackish water. Estuarine.	No mollusks.	
				Miocene (probably upper).	Marine.
100	No Foraminifera below 93 feet.	No diatoms.		No mollusks below 93 feet.	
200		Upper Miocene.	Marine.		
300		No diatoms below 330 feet.			

INDEX