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LATE QUATERNARY STRATIGRAPHY AND GEOLOGICAL CHARACTER OF COASTAL AND INNER SHELF SEDIMENTS OF NORTHERN NORTH CAROLINA

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ABSTRACT

The Quaternary stratigraphic section and sedimentary character of the barrier coast and shelf of northern North Carolina was investigated using deep borings and vibracores, grab samples, continuous seismic reflection profiles, sidescan sonar, and self-contained underwater breathing apparatus (SCUBA) observations. Analyses of the cores and the geophysical data show that the Quaternary section is composed of four lithologic units having fairly distinct seismic signatures, mineralogy, and faunal composition. Grab samples and sidescan sonographs reveal that shoreface and shelf sediments are generally of finer grain size and better sorted than the coarse textured beach. Exceptions are the meso-scale shoals, exhibiting relief up to 10 m on the shelf which are composed of medium to coarse shelly sands. Sidescan and SCUBA diver observations show megaripple bedforms overlie about 30 percent of the area, predominantly on the shoal flanks, while smaller scale ripples are very common on the shoreface. The bedform patterns and sediment texture distributions confirm that the transgressive sand sheet is in equilibrium with the modern storm-dominated hydraulic regime.

INTRODUCTION

The study area of northern North Carolina (Fig. 1) consists of the long and continuous Currituck barrier fronted by the smooth concave-up shoreface and a relatively low gradient continental shelf. The area contains both erosional and depositional morphologic elements characteristic of a storm-dominated shelf. The information presented here results from a study of late Pleistocene and Holocene deposits underlying the coast and continental shelf near Duck, North Carolina. The Quaternary stratigraphy and seabed and subbottom characterization presented are based on our interpretations of bathymetric measurements, grab samples, borings and vibracores, continuous seismic reflection profiles, sidescan sonar, and SCUBA observations collected over the past decade at the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center's (CERC) Field Research Facility (FRF).

The results presented are intended to contribute to the general knowledge about the geologic framework, mode of formation, and evolutionary development of the North Carolina coast and other Middle Atlantic barrier coasts, from late Quaternary time to the present.

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TABLE 1

Heavy Minerals in Borings and Cores

Minerals (in %)	Unit B	Unit C	Unit D	Unit E
Zircon	0.11	0.04	-	0.10
Rutile	0.49	0.11	-	0.24
Garnet	5.91	11.38	6.57	12.77
Staurolite	7.17	3.11	2.87	4.15
Kyanite	0.41	0.32	0.24	0.28
Epidote	24.82	10.48	8.33	10.77
Hypersthene	0.19	0.23	0.17	C.80
Sillimanite	0.40	0.12	0.42	0.51
Amphibole	37.96	5.60	74.40	56.89
Tourmaline	3.38	3.45	3.67	5.39
Black Opaque	18.82	13.81	3.22	7.26
Glauconite/0.15 gm	2.90	11.60	56.00	13.80
Mica/0.15 gm	5.00	156.90	53.20	1.80
No. of samples	14	16	10	30

TABLE 2

Foraminifera in Borings and Cores

Species	Unit C	Unit D	Unit E
Ammonia beccarii (Linne)	*tr	*tr	*tr
Buccella hannai (Phleger & Parker)	0.5	1.0	0.3
Cibicides lobatulus (Walker & Jacob)		0.4	
Elphidium excavatum (Terquem)	94.1	91.7	91.5
Elphidium galvestonense (Kornfeld)		0.1	
Elphidium Mexicanum (Kornfeld)			
Elphidium rugulosum (Cushman & Wickenden	*tr	1.3	1.1
Eponides repandum (Fichtel & Moll)	0.4		
Guttulina sp.	*tr	0.8	0.3
Hanzawalia concentrica (Cushman)	*tr	2.7	4.7
Haynesina germanica (Ehrenberg)	0.9	0.4	*tr
Nonionella atlantica Cushman	*tr	0.5	2.0
Poroeponides lateralis (Terquem)	0.1		
Quinqueloculina seminula (Linne)	2.9	0.5	
Quinqueloculina jugosa Cushman	0.2		
Rosalina globularis D'Orbigny	0.8	0.3	
Webbelina concava Williamson	*tr	*tr	
No. of samples	29	10	14

*tr = present in quantities less than 0.10%

Hole (see Fig. 4)	Depth Below MSL	Date (yrs. BP)
Core 1	18.8 m	37,000
Boring D-1	21.6 m	28,000
Boring D-3	21.6 m	32,000

The depositional environment of the peat in boring 3 was determined by pollen analysis to be nonmarine. Analyses of the other samples yielded indeterminate results.

The three C-14 age dates from the peat samples and one age date greater than 37,000 yrs B.P. on shell fragments (Shideler et al. 1972) confirm that Unit B is of late Pleistocene age, likely associated with Sangamon high sea level. Its high epidote and low amphibole content relative to the other sediment units suggest that it may have been derived from different sources.

The next younger lithosome, sedimentary Unit C, is a brown, muddy, very fine sand containing numerous of mollusk shells and foraminifera, and a large mica fraction (Tables 1 and 2). The seismic profiles show the unit is widespread and distinguishable from adjacent units by faint horizontal bedding and by its rather homogeneous character varied only by evidence of paleochannels between shoals A and B (Fig. 5). The size and form of the channels

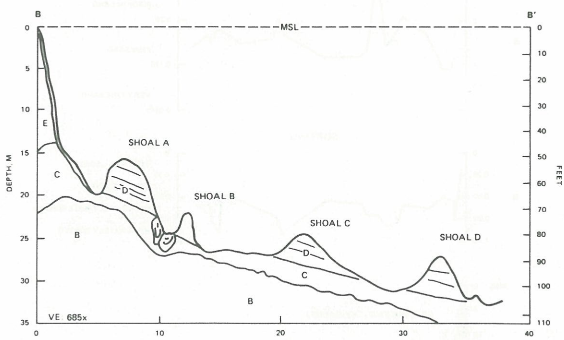

Figure 5. Cross Section of the North Carolina Coast and Shelf from Interpretative Correlations of Seismic and Core Data Along Transect B-B' Shown in Fig. 3

suggest they are of tidal inlet or lagoonal origin. Unit C underlies the entire study area, exhibiting variable thickness from 1 m to 8 m. It crops out at the base of the lower shoreface in a depth range of 12 to 21 m and in swales between the shoals (Fig. 5). The muddy, fine sand textural nature of Unit C, the abundance of mica, and the faunal assemblage suggest a low-energy environment of deposition such as a marsh, or backbarrier lagoon. Two C-14 dates from Shideler et al. (1972) on shells in Unit C suggest a late Wisconsinian or early Holocene age. We interpret Unit C to be a backbarrier deposit which has been overridden by the Currituck barrier during the Holocene transgression. A modern analogue might be the marsh deposits forming in Currituck Sound landward of the barrier.

Unit D, the uppermost unit in the study area comprises surficial shoreface and shelf deposits. Unit D attains its greatest thickness (5 to 8 m) in the prominent shoals (Fig. 5). The seismic data show Unit D is thin (≦1 m) and patchy on the lower shoreface and in swales between the shoals where lagoonal muds and lag sands are exposed. Unit D is most often a shelly, gray to gray-brown, very fine to fine-grained sand, especially on the shoreface; however, light brown, fine to coarse sands, occur in the shoals and in one case, sample 14 on shoal B, there is also granule and pebble size material.

The sediment texture data (Fig. 6) show that in general the shoreface is mantled with gray, moderately well sorted, very fine to fine sand. Patches of muddy sands are common at depths of about 12 to 21 m and often ephemeral according to diver reports over a period of years. Grab sample 11 (near the crest of shoal A) and sample 12 (on the seaward flank of the shoal) contain clean, fine to medium quartz sand with broken shell fragments (Fig. 6). Sample 13, at the seaward toe of shoal A, is considerably finer, containing

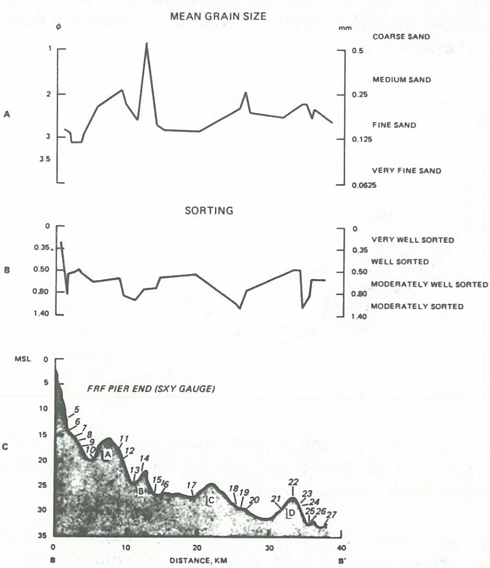

Figure 6. Plots of Mean Diameter and Sorting Across the Shelf Transect B-B' Shown in Fig. 3

muddy fine sand. Sediments at station 14, on the crest of shoal B, contrast greatly with the other samples in transect B-B' (Fig. 6). The crest of shoal B is mantled with a gray-brown, medium to very coarse, quartz sand containing rounded and iron-stained rock fragments. Because the sample is remarkably similar in texture and composition to typical samples from the Currituck barrier, a littoral origin for shoal B is likely. The sample from station 15 at the seaward toe of shoal B is again a characteristic gray fine sand. Samples 16 and 17 show that the sea floor between shoals B and C is also composed of moderately well sorted fine sand. Samples from shoal C are also somewhat coarser and more shelly than average; sample 19 on the seaward flank is the coarsest of the set. This sample is also richer in heavy minerals (21.1 percent) than any other sample along the transect, suggesting a shallow-water nearshore origin for shoal C as well. The seven (21-27) samples seaward of shoal C (Fig. 6) are fine to medium sand, most with shell fragments. Generally, they show that the crest and seaward flanks of shoal D, like the other shoals, are mantled with sands of somewhat larger grain size and slightly lesser sorting than in the adjacent regions.

Microscopic examinations of the grab samples from Unit D show that most of them have a similar composition: the primary constituents are quartz particles and, in some samples, biogenic calcium carbonate. Secondary components make up only a small part of the sediment, but are often important in correlating samples. Also, the secondary components in the grab samples are generally similar in type, but exhibit wide areal variation in frequency.

Heavy mineral distributions were determined for the fine sand size fraction. The common nonopaque heavy minerals present appear in Table 3 as percentages of total nonopaque minerals. The opaque heavy minerals were not identified but were counted as a single class. They are recorded in Table 3 as a percentage of total opaque plus nonopaque heavy minerals.

The heavy mineral contents of 20 of the 22 grab samples range from 1.0 to 5.2 percent by weight. Samples 19 and 20 are anomalous, having 21.1 and 7.7 percent, respectively.

Most of the nonopaque heavy minerals belong to the 10 mineral species listed in Table 3. In the grab samples only five of the mineral types (garnet, staurolite, epidote, amphiboles, and tourmaline) are common. The other heavy minerals, for the most part, either do not occur or occur at less than 2 percent frequency.

A comparison of the frequency of heavy mineral species shows three groups of adjacent samples exhibiting high garnet values and a concomitant decrease in amphiboles. The groups are comprised of (a) samples 13 and 14, (b) 18, 19, and 20, and (c) 24, 25, and 26. There is also a substantially higher percentage of opaque heavy minerals in the three high-garnet content groups than in the other samples.

Although large differences between the grab samples exist in the frequency of certain mineral species, the differences are within the ranges observed in samples from beach transects (Flores and Shideler (1982), and CERC unpublished data) and may reflect selective sorting rather than any change in source. This assumption is supported by the fact that high percentages of garnet and black opaque minerals which are relatively heavy are accompanied by a significant decrease in the lighter amphiboles and, in some cases, tourmaline.

It is uncertain whether the present hydraulic regimen of the inner shelf could be wholly responsible for creating the zonal patterns in heavy mineral distribution observed. It seems just as likely that the zonation could reflect a relict distribution pattern created during the Holocene transgression, that is now being modified by modern processes.

Information on mica abundance in the grab samples appears in Table 3 as a percentage of mica to total nonopaque minerals plus mica. It is the most easily eroded and transported mineral of the grab samples.

TABLE 3

Minerals in ARSLOE Samples

Sample	Water depth (m)	Zircon	Rutile	Garnet	Staurolite	Kyanite	Epidote	Hypersthene	Sillimanite	Amphibole	Tourmaline	% Opaques to non-opaques	% Mica to non-opaques	Glauconite per 0.15 gm	Mean diameter (mm)	% Heavy minerals
AR5	12.0			5.1	5.1	0.0	6.8			76.1	6.8	3.28	68.78	80.00	0.13	1.5
6	14.0			9.8	2.0	0.5	10.2	0.5		69.8	7.3	8.48	29.64	52.06	0.12	1.5
7	15.2			11.0	4.4	0.4	7.0		0.4	72.4	4.4	9.16	18.57	62.14	0.12	4.5
8	16.8			13.3	1.9		7.6			69.5	7.6	20.45	56.79	39.71	0.11	3.9
9	17.4			4.6	1.7	0.6	6.9		0.6	80.0	5.7	1.13	10.71	72.9	0.14	3.3
10	20.7			8.0	3.9		9.0	1.0		69.5	8.7	5.76	0.64	48.8	0.21	1.1
11	18.0		0.3	15.8	2.7	1.6	13.1	1.6	0.3	58.3	6.3	11.57	1.87	24.64	0.26	3.1
12	20.1			17.3	1.3		14.2	0.9		60.4	6.0	16.75	0.31	11.47	0.23	1.2
13	25.6	0.4		30.4	4.8	0.4	6.6	1.3		51.1	3.5	32.73	9.31	35.56	0.17	5.2
14	23.0	1.2	0.3	31.2	9.8	1.2	16.0	1.8		36.2	2.4	56.06		18.21	0.57	1.0
15	27.4			5.7	3.0	1.5	4.6	0.4	0.8	77.9	6.1	5.40	21.26	57.30	0.15	1.5
16	27.4			7.9	3.2		6.4		0.7	75.7	6.1	12.77	16.17	67.5	0.14	5.2
17	28.0			3.1	2.6	0.4	4.8	0.4	0.4	83.7	4.4	0.44	15.30	87.3	0.15	1.9
18	29.9			40.8	5.2	1.4	5.7	2.3	0.3	41.1	2.9	34.03	2.60	35.5	0.20	3.2
19	30.2	1.5	1.1	65.5	4.0	0.4	1.8	1.1		24.0	1.1	49.26	0.36	10.71	0.28	21.1
20	30.5			44.7	1.9	0.2	9.8	0.5		40.4	2.4	20.23	0.48	40.0	0.19	7.7
21	29.6			8.5	3.1	0.6	12.7	1.4	0.3	68.3	5.1	4.59	0.28	25.56	0.18	1.9
22	27.4			11.7	2.3		6.5	0.7	0.3	71.0	7.5	4.06		33.75	0.20	1.9
23	28.3			16.1	5.4	1.5	7.3	1.5		62.0	6.3	27.56	3.76	33.7	0.22	2.0
24	33.8			29.8	2.9		6.1	1.0	0.6	54.5	5.1	16.58	0.95	49.1	0.23	1.9
25	33.2		0.3	23.7	2.7		5.3	0.3	0.3	58.3	9.8	16.95	0.58	51.00	0.18	3.8
26	32.0		0.3	38.1			7.4	3.0		46.3	4.9	19.44	0.27	16.07	0.20	2.5
27	32.9			9.2	0.6	0.3	5.6	3.0	0.6	75.4	5.3	0.12	0.30	16.1	0.17	4.0

Mica appears in relatively high concentrations on the shoreface (Fig. 6 stations 5 through 9), and in the flat seaward of shoal B (Fig. 6 stations 15, 16, and 17), and is relatively sparse across the other parts of the shelf transect. The high values of mica for the shoreface are consistent with a nearshore band of mica abundance reported by Doyle, and others (1968) along the coast between Cape Hatteras and Florida.

Glauconite pellets occur in all of the grab samples and are most abundant in the fine sand size fraction. The glauconite grains range in color from medium green to nearly black, with the darker varieties predominant.

The highly variable frequency of glauconite pellets in the grab samples suggests that they are detrital rather than the product of in situ formation, as the latter process could be expected to produce a more uniform distribution. No pronounced trends occur; however, there is an overall greater abundance on the shoreface and flat between shoals B and C than elsewhere on transect B-B' (Fig. 6). The glauconite content of Unit D is several times higher than that of the other subjacent units (Table 1), suggesting glauconite may be forming under present conditions at places farther seaward on the shelf and moving landward.

Schnitker (1971) investigated foraminifera in the vicinity of transect B-B' (Fig. 6) and found that the fauna were characterized by a high species dominance of Elphidium clavatum Cushman, = Elphidium excavatum (Terquem), throughout the shelf area. Our grab samples are similar in their foraminiferal content, but show some trends in the frequency of secondary species (Table 4). Apart from E. excavatum, the only common species occurring in the samples are Hanzawaia concentrica (Cushman), Quinqueloculina seminula (Linne') and Proteonina atlantica Cushman. Proteonina atlantica is listed separately in Table 4 because their tests usually contain many heavy minerals resulting in a reduced fraction that float during the separation procedure making it necessary to count them in unseparated material. Because of the paucity of foraminifera of all types in the unseparated material, the counts necessarily covered only a small number of specimens; consequently, the listed frequency of P. atlantica to other types is an approximation.

The frequency data in Table 4 suggest there is some detectable zonation of the more common species along the B-B' transect (Fig. 6). Between sample stations 5 and 9, E. excavatum is abundant while H. concentrica and Q. seminula are relatively low and Proteonina atlantica is absent. At stations 10, 11, and 12, there is a decrease in the frequency of E. excavatum and an increase in H. concentrica and Q. seminula. P. atlantica makes its first appearance at station 12.

From station 12 (Fig. 6) to the seaward end of the transect, the frequencies of E. excavatum and P. atlantica are irregular and do not show any pronounced trends but, both H. concentrica and Q. seminula show a relative increase seaward of station 20.

Variations in the foraminiferal assemblage across the shelf transect are for the most part not pronounced. The strongest trend is shown by P. atlantica which is absent inshore of station 11, and generally quite common toward the seaward end of the study area. The only other apparent trend is the small, but important, relative increase in H. concentrica and Q. seminula in shoals A and D.

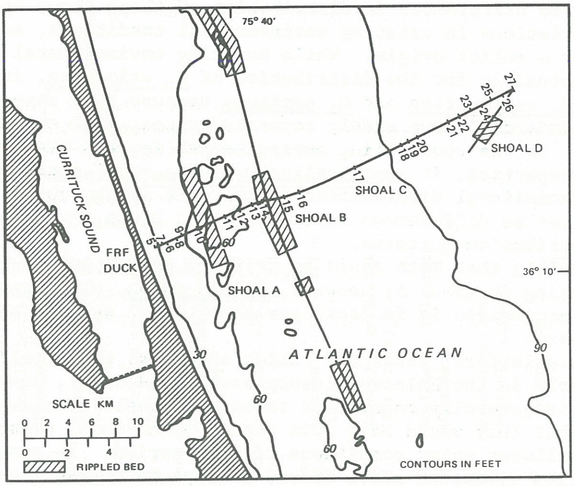

Figure 7. Distribution of Megaripples on the Shelf Surface Based on Sidescan Sonar Observations

The sidescan sonographs from our 1980 survey reveal that sedimentary bedforms of a smaller scale are present over approximately 30 percent of the transect area, shown in (Fig. 7). Most bedforms fit a megaripple size class having fairly straight clearly defined crests that are tens of meters long and spaced 1 to 2 m apart. The distribution of the megaripples appears to be closely related to relief and morphology of the sea floor and sediment grain size. The megaripples are abundant and show the best definition on the seaward flanks of shoal areas where sediment size ranges from medium to coarse sand. The presence of such distinct well defined bedforms indicates that the shoals are subjected to vigorous and regular winnowing by bottom currents. On some shoals, bedform distribution appears patchy with sharp boundaries, probably reflecting grain-size variability at the seabed or bed modification by wave motion. The megaripple crests on most of the transects were oriented from north-south to about N 20° E., generally parallel to the coastline. Their shape and orientation suggest they were formed by some combination of currents and waves. These findings are supported by Green's (1986) work which was based on detailed sidescan coverage in the shoal A region of the study area.

The lack of obvious bedform patterns on the sidescan records from other parts of the study area does not mean smaller and lower relief ripple features are not also present. In fact, SCUBA diver observations of the shoreface at the time of the sidescan surveys revealed that the very fine sand substrate at 10-m depths had well developed ripples with crest spacings of about 10 to 20 cm and heights of 5 to 10 cm. These ripples were not expressed on the sonographs because of the limited resolution of the side scan equipment. The ripple crests observed by

SCUBA divers were generally shore-parallel in response to fair-weather waves.

CONCLUSIONS

The Quaternary section of the coastal and inner shelf deposits near Duck in northern North Carolina are in close agreement with the standard section proposed by Shideler et al. (1972) for Virginia.

Carbon 14 dates on the earliest deposit reached by engineering borings through the Currituck barrier near Duck indicate a late Pleistocene age. The three overlying units are probably of Holocene transgressive age.

The barrier consists of a thick wedge of of medium to coarse sand that probably originated in the latter stages of the transgression by either spit extension from the north or barrier retreat from offshore.

Absence of any overridden backbarrier deposits in the 22-m section underlying the modern beach indicates that the barrier has not retreated shoreward in modern times.

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