

T. Lori Stewart. CARBONATE PETROLOGY AND SEDIMENTOLOGY OF THE MIOCENE PUNGO RIVER FORMATION, ONSLOW BAY, NORTH CAROLINA CONTINENTAL SHELF. (Under the direction of Dr. Stanley R. Riggs) Department of Geology, December 1985.

The Pungo River Formation in Onslow Bay, North Carolina is predominantly a siliciclastic sediment sequence with variable amounts of authigenic and diagenetic minerals including carbonates. Based on examination of 14 of the 16 outcropping Pungo River seismic units, the dominant carbonate component is carbonate mud (low-Mg calcite, dolomite, or a mixture of the two). Calcareous fossils are the next most abundant carbonate component. Calcite cements are a very minor component and are only locally abundant.

Four patterns of carbonate sedimentation occur in the Pungo River Formation in Onslow Bay. 1) Cyclic carbonate sediments overlying noncarbonate lithologies and deposited as a couplet during the same fourth-order sea-level cycle are common. Biomicrosparites which grade into phosphorites of seismic unit FPF-1 represent deposition during a fourth-order sea-level maximum when warm Gulf Stream waters flooded the shelf. Calcite-cemented sandstone of BBF-2 grades down section into unindurated quartz sand. Unindurated, muddy, barnacle-rich sands represent fourth-order sea-level regressions. These types of carbonate cap rocks conform to the idealized lithic cycle of the Riggs model of Neogene sedimentation (1984).

2) Sediments of the AF seismic sequence are largely carbonates in northern Onslow Bay and siliciclastics in central Onslow Bay.

Carbonate content in each fourth-order seismic unit increases up section from AF-1 to AF-4. AF-1 in northern Onslow Bay represents mid to outer shelf sedimentation. AF-2 and AF-3 contain a predominantly reworked fossil assemblage. AF-4 is a barnacle hash, representing formation on shelf edge hardgrounds and deposition off the shelf edge.

3) Sparse fossils and minor carbonate mud occur disseminated in all predominantly noncarbonate lithologies. The major source of calcareous mud is probably from bio-mechanical degradation of larger carbonate grains, primarily shell material.

4) Predominantly carbonate beds interbedded with noncarbonate lithologies include: moldic microsparite which probably represents the carbonate cap on FPF-1 in northern Onslow Bay; moldic microsparite in BBF-1 which may be similar in origin to the carbonate cap of unit C in the Aurora Area; and echinoid-foraminiferal biosparites in FPF-6, which probably formed by winnowing of the fines by marine currents such as Gulf Stream eddies.

Diagenetic carbonates (calcite cements and dolomite) and silicates (opal-CT, microcrystalline quartz, and clinoptilolite) exhibit vertical diagenetic profiles in some cores. Where carbonate sediments are abundant, effects of fresh water calcite cementation decrease down section. Because syntaxial cement on echinoids is precipitated faster than rim cements on other fossils, it is a good indicator of the degree of diagenesis undergone by sediments. Dolomite abundance and distribution are sporadic, perhaps reflecting presence or absence of sulfate reducing bacteria in the sediment. Local chert nodule formation is related to abundance of siliceous fossils and to permeability barriers within the sediments.

CARBONATE PETROLOGY AND SEDIMENTOLOGY
OF THE MIOCENE PUNGO RIVER FORMATION,
ONslow BAY, NORTH CAROLINA CONTINENTAL SHELF

A Thesis
Presented to
the Faculty of the Department of Geology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Geology

by
T. Lori Stewart
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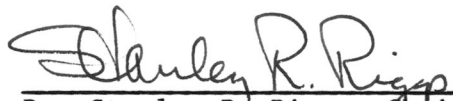
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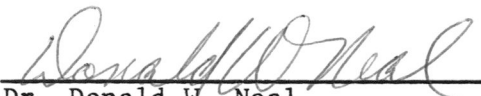
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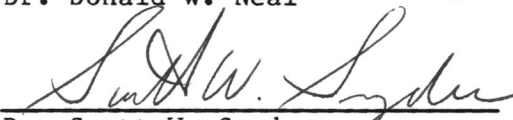
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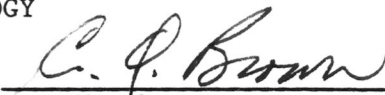

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To my parents, I dedicate this thesis. Their love and support have made it possible for me to complete my tenure as a graduate student at ECU.

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INTRODUCTION

The Miocene Pungo River Formation is part of a southeast-dipping sediment wedge that thickens seaward and underlies the coastal plain and continental shelf of North Carolina. An economically important sedimentary phosphorite deposit, it correlates with the Hawthorn Formation of Florida, Georgia, and South Carolina (Riggs, 1984). Gibson (1967) correlated molluscs and benthic foraminifers of the Pungo River Formation in the Aurora Area with those of the Calvert Formation, the basal portion of the Chesapeake Group, in Virginia and Maryland.

The Calvert-Pungo River-Hawthorn complex of the southeastern United States Atlantic coastal plain and continental shelf contains an anomalous sequence of authigenic sediments (Riggs, 1984). Phosphate occurs throughout the Miocene section from North Carolina to Florida. Diatoms increase northward until diatomites are developed in Virginia. The southern half of the southeastern Atlantic coastal region contains abundant palygorskite and sepiolite (Weaver and Beck, 1977), while the northern half contains abundant clinoptilolite (Rooney and Kerr, 1967) and glauconite (Riggs, 1984).

The study area is located in Onslow Bay, an area of approximately 10,000 km², on the southeastern North Carolina continental shelf between Cape Lookout and Cape Fear (Fig. 1). Pungo River sediments crop out across an area 40 km wide by 150 km long, thicken from 0 m at their updip erosional limit to over 500 meters at the shelf edge, and dip gently to the east and southeast (Riggs and others, 1985). In Onslow Bay, the Pungo River Formation unconformably overlies moldic biomicrites

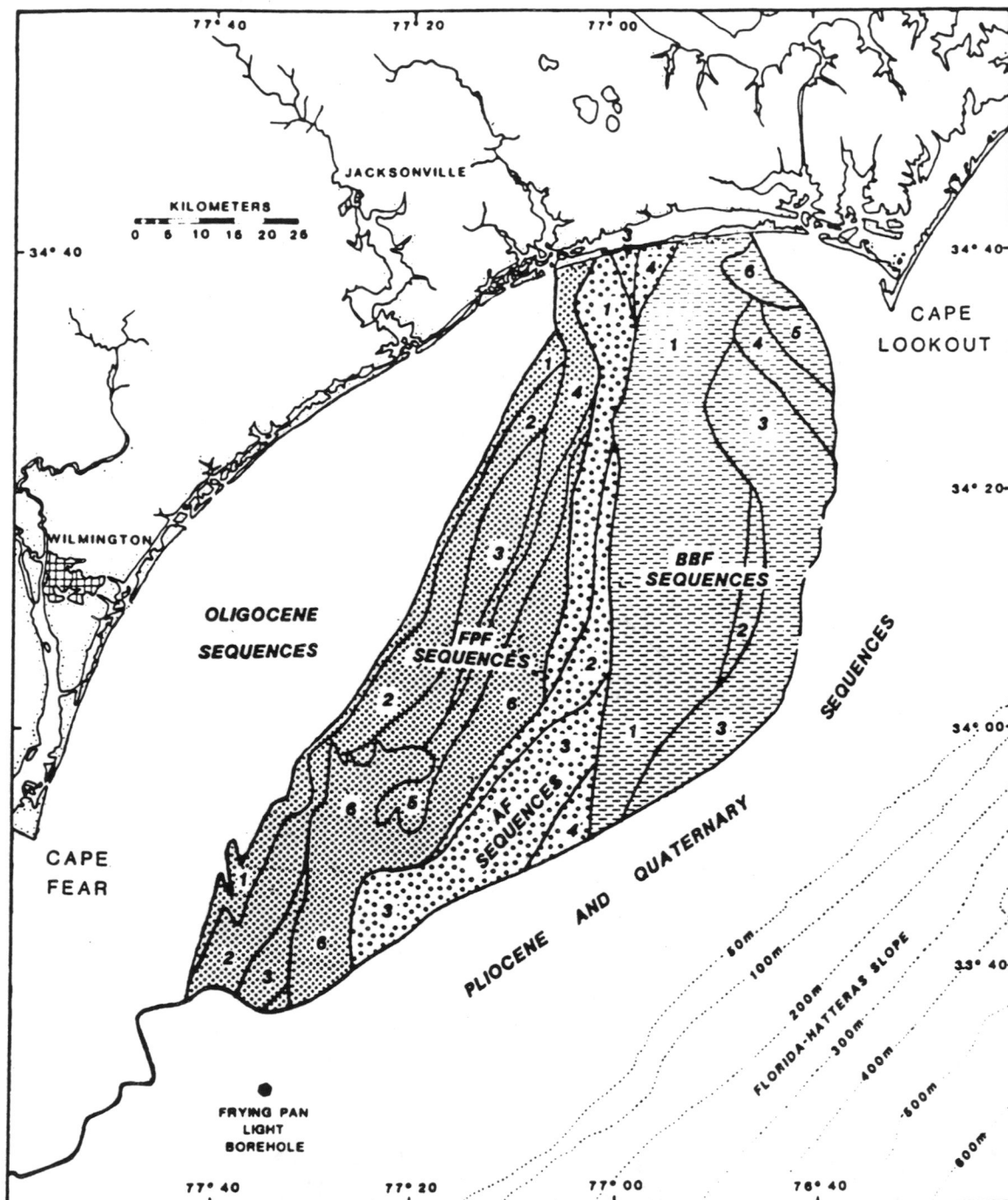


Figure 1. Geologic map showing the subcrop pattern of seismic sequences in Onslow Bay, North Carolina continental shelf (from Riggs and others, 1985).

and calcarenites of the Oligocene Belgrade Formation and calcareous quartz sands of the lower Miocene Silverdale Formation (Baum and others, 1979; Lewis, 1981; S.W.P. Snyder, 1982). The Pungo River Formation is unconformably overlain by Pliocene and Quaternary sediments.

This study is part of a larger investigation on phosphatic sediment genesis along the Mid-Atlantic continental margin funded by the National Science Foundation and coordinated by S.R. Riggs. Other studies address the seismic stratigraphy, biostratigraphy, paleoecology, lithostratigraphy, clay mineralogy, phosphate petrology, and geochemistry of the Pungo River Formation.

This study examines Pungo River carbonate sediments in Onslow Bay, using Riggs' (1984) depositional model for Neogene phosphates of the southeastern United States as a frame of reference. The model relates a systematic change in sedimentation regimes to sea-level and paleoceanographic changes caused by multiple glacial cycles. An idealized cyclical sequence of sediments produced in response to each sea-level cycle would be predominantly siliciclastic sands at the base, grade upward into phosphatic sands, and culminate in carbonates. This model is discussed in greater detail in a later section.

THE NORTH CAROLINA MIOCENE

Structural Setting

Tertiary sedimentation in North and South Carolina was controlled by the Mid-Carolina Platform High (Fig. 2), a topographic high upon the Carolina Platform, which extends from central Onslow Bay, North Carolina to Cape Romain, South Carolina (S.W.P. Snyder, 1982; S.W.P. Snyder and others, 1983). The Carolina Platform is a structural block of pre-Jurassic crust on the trailing continental margin of North America and extends from the Baltimore Canyon Trough to the Southeast Georgia Embayment (Klitgord and Behrendt, 1979; Popenoe, 1983).

Neogene sediments of North Carolina were deposited on the northeast flank of the Mid-Carolina Platform High. The Cape Lookout High (S.W.P. Snyder, 1982; Riggs and others, 1985), an east-west trending topographic high, divided this area into two embayments: Aurora Embayment, in which the Aurora Phosphate District is located, and Onslow Embayment, in which my study area is located (Fig. 3). Pungo River sediments in the Aurora Area are currently being mined for phosphate.

The western updip limit of Pungo River sediments in the Aurora Area coincides with a north-south hinge line discussed by Brown and others (1972) and Miller (1971, 1982). This same north-south line, seismically traced into Onslow Bay, is an ancient erosional scarp with up to 25 meters of relief (S.W.P. Snyder, 1982; S.W.P. Snyder, and others, 1982, 1983), where it is called the White Oak Lineament. Pungo River sediments thicken abruptly from 20 to 40+ m at the White Oak Lineament and continue to thicken rapidly downdip to 500+ m in the subsurface at

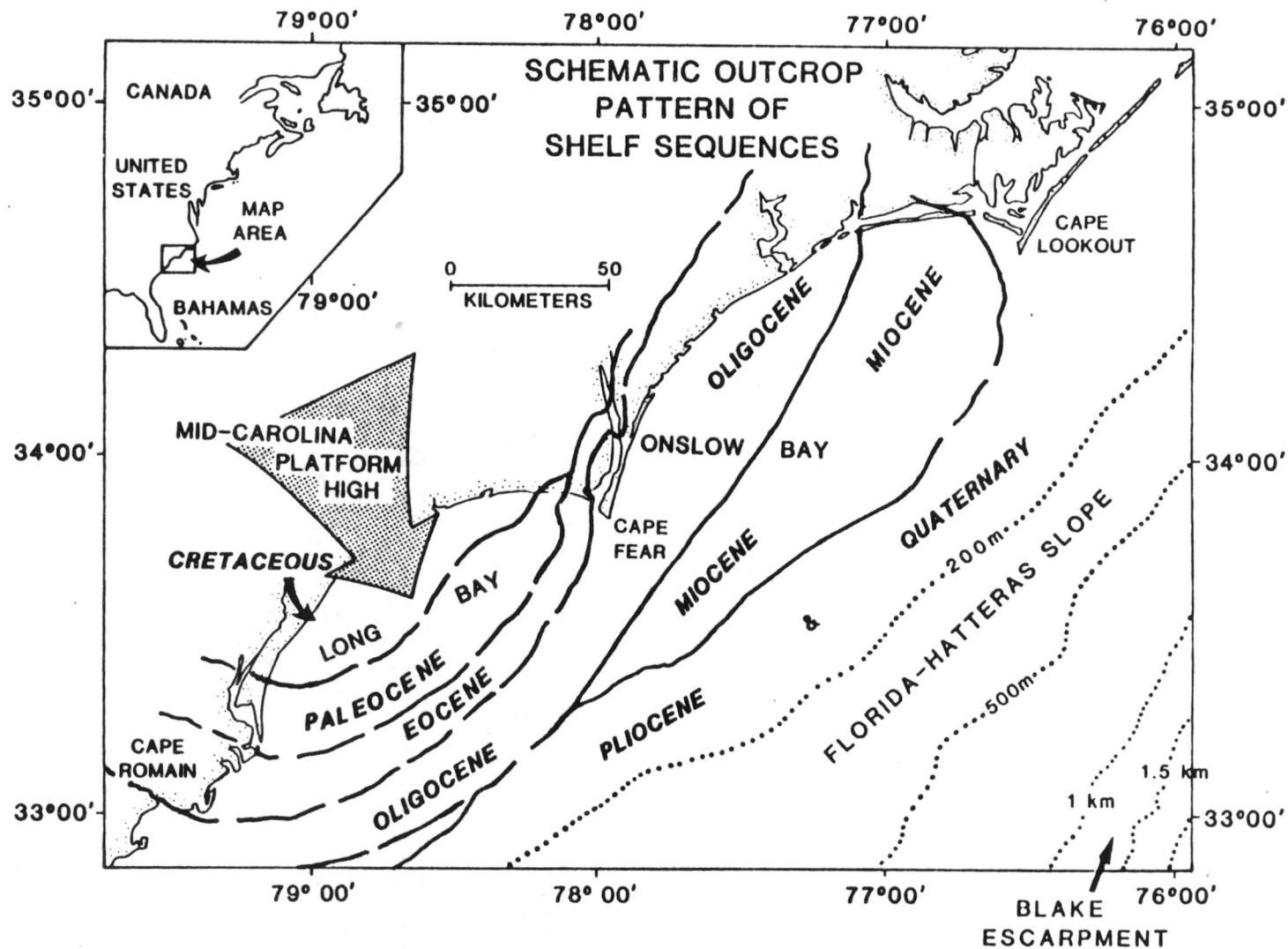


Figure 2. Geologic map showing the location of the Mid-Carolina Platform High and the outcrop pattern of Cretaceous and Tertiary sediments (from S.W.P. Snyder, 1982).

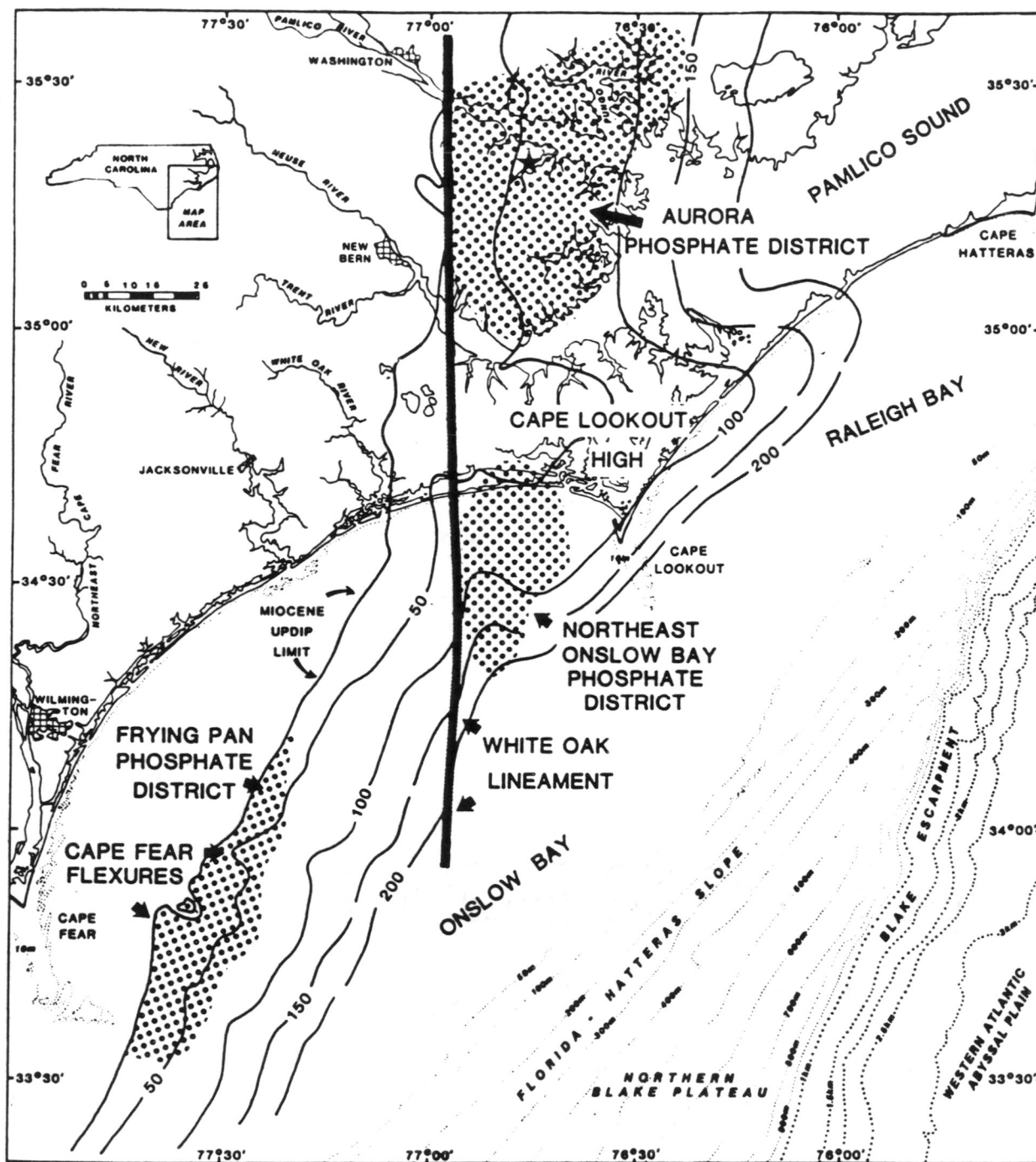


Figure 3. Structural contour map on the base of the Pungo River Formation and the Miocene phosphate districts of the southeastern North Carolina continental margin (from Riggs and others, 1985). The ★ represents the location of active phosphate mining.

the shelf edge (Riggs and others, 1985). The Pungo River Formation subcrops beneath surficial veneers of Pliocene and Quaternary sediments throughout most of Onslow Bay (Fig. 2).

Stratigraphy

Coastal Plain

Phosphatic sediments of the Pungo River Formation have been extensively studied since Brown (1958) first noted them in Beaufort County, North Carolina. Kimrey (1964) named the formation and described the type section from a core near the Pungo River in the vicinity of Belhaven, Beaufort County, North Carolina. He defined the formation as a series of interbedded phosphatic sands, silts, and clays, diatomaceous clays, and phosphatic limestones. Regional studies by Kimrey (1965), Miller (1971, 1982), and Brown and others (1972) demonstrated that Pungo River sediments occur throughout Aurora Embayment. Other investigators who have studied phosphatic sediments of the Aurora Embayment area include Leutze (1968), Potluri (1971), Katrosh (1981), Scarborough (1981), Riggs and others (1982b), Katrosh and S.W. Snyder (1982), Scarborough and others (1982), S.W.P. Snyder and others (1982), Siedlecki (1984), and Allen (1985). Geochemical studies of Aurora Area phosphate include those by Ellington (1984), Dolfi (1983), Indorf (1982), and Tobiassen (1982).

Riggs and others (1982b) recognized four cyclic sediment sequences in the Pungo River Formation of the Aurora Area (Fig. 4). Siliciclastic

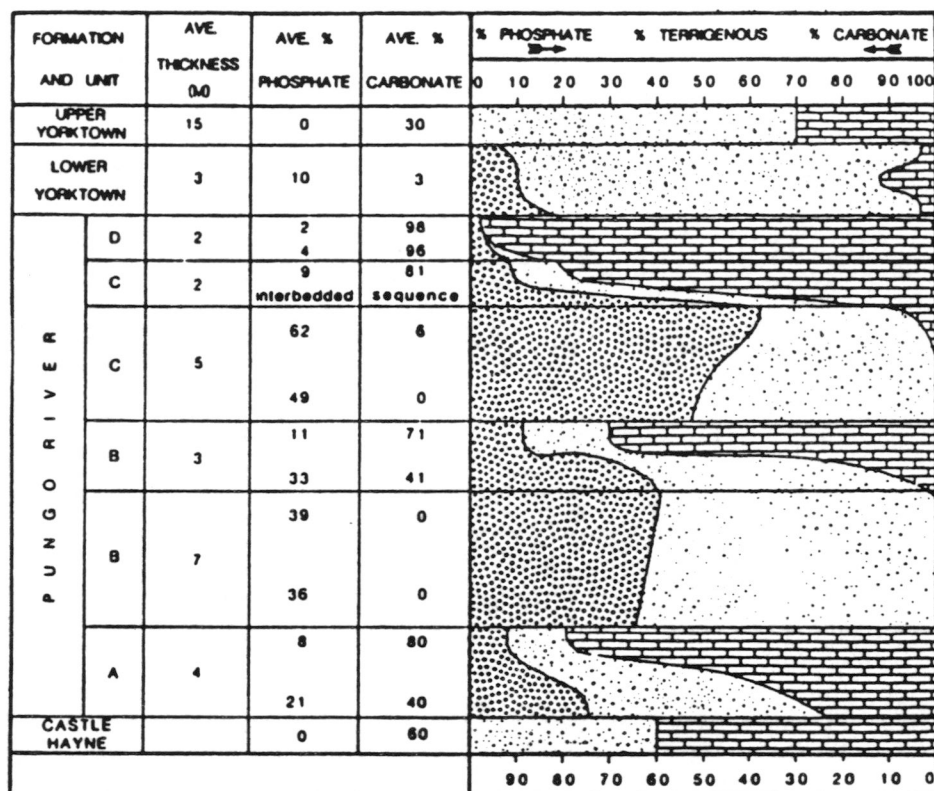


Figure 4. Average concentrations of phosphate, terrigenous (siliciclastic), and carbonate sediments from cores in the Aurora Area, N.C. (from Riggs and others, 1982b).

components decrease upward within units A, B, and C. Phosphate correspondingly increases upward within each unit, and then decreases within the overlying carbonate sediments. Carbonate increases upward gradually or through increasing interbeds and culminates in a predominantly carbonate sediment. The carbonate sediment capping unit C contains a diverse, warm temperate to subtropical, molluscan fauna (J. Carter, pers. comm. to S.R. Riggs). An unconformity, separating each carbonate from siliciclastic sediment of the overlying unit, is denoted by an indurated carbonate surface containing a rock-boring infauna, molds produced by dissolution of shells within the carbonate sediments, and infilling of the extensive bore-hole system by overlying sediments.

Based on foraminifers and molluscs, Gibson (1967) suggested water depths of 100 to 200 m for phosphate formation in units A, B, and C, and 70 to 100 m for associated carbonate cap rocks. Katrosh and S.W. Snyder (1982) and S.W. Snyder and others (1982) state that units A and B contain inner to middle shelf foraminiferal assemblages predominated by Buliminella elegantissima, a species that flourishes in areas with a high nutrient supply. Riggs and others (1982b) and Riggs (1984) suggest that the phosphorite sands of units A and B probably represent upwelling conditions, cold and somewhat toxic at the sediment-water interface. More diverse species assemblages occur within the carbonate caps, suggesting the restoration of more normal marine conditions during deposition of carbonates (S.W. Snyder and others, 1982; Riggs and others, 1982b).

Unit D contains a thin basal phosphatic sediment which rapidly grades into a very fossiliferous dolosilt containing abundant bryozoans

and barnacles. Scarborough and others (1982) traced unit D laterally into a bryozoan-barnacle hash with less than 20% calcareous mud in the central portion of the Aurora Embayment. Miller (1971) attributed this facies change to secondary dolomitization by movement of Mg-bearing groundwaters through an original micrite matrix. Rooney and Kerr (1967) attributed dolomite in the Aurora Area to dolomitization of limestones by hypersaline brines, a process called seepage refluxion by Adams and Rhodes (1960). Gibson (1967) stated unit D formed at depths of less than 70 meters.

Units C and D contain benthic foraminiferal assemblages indicating middle to outer shelf environments (Katrosh and S.W. Snyder, 1982). Foraminifers are more abundant and diverse than in units A and B, and are interpreted to represent a change from nutrient-rich to more normal marine waters, a marine transgression, or a combination of the two (Katrosh and S.W. Snyder, 1982).

Continental Shelf

Pilkey and co-workers first noted phosphate from surface sediments in the central part of Onslow Bay (Pilkey and Luternauer, 1967; Luternauer and Pilkey, 1967). Meisburger (1979), during a seismic and vibracore survey to locate beach replenishment sands on the inner continental shelf of southern North Carolina, encountered Pungo River sediments in two vibracores 11 km south of Bogue Banks in northern Onslow Bay. Steele (1980) found phosphatic sands underlying Pleistocene barrier island sediments in the Bogue Banks area. Blackwelder and others (1982) dredged middle Miocene moldic calcareous quartz sandstones

(similar to limestones which alternate with phosphorite sands in the Aurora Area) in northern and central Onslow Bay. They also stated that Miocene rocks dredged in northeastern Onslow Bay are among the youngest rock units in the Pungo River Formation, and may be in part be early late Miocene, correlative to the Eastover Formation in Virginia.

Five research cruises have been conducted by S.R. Riggs from May 1980 to May 1983. Vibracoring of seismic sequences defined by high resolution profiling during these cruises has shown that Pungo River sediments occur as far south as Frying Pan Shoals (Lewis, 1981; Lewis and others, 1982; Snyder, S.W.P., 1982; Riggs and others, 1982a, 1985). Waters (1983) and Waters and S.W. Snyder (in press) studied the abundant foraminifers in southern Onslow Bay.

The Pungo River Formation in Onslow Bay consists of three third-order seismic sequences, separated by regional unconformities (S.W.P. Snyder, 1982; Snyder and others, 1982), deposited during third-order coastal onlap cycles that are part of the Miocene second-order supercycle (Fig. 5). Third-order sequences consist of more numerous, fourth-order seismic sequences separated by local unconformities (S.W.P. Snyder, 1982; S.W.P. Snyder and others, 1982). Figure 1 shows the northeast-southwest subcrop pattern of 16 of these sequences.

The oldest third-order seismic sequence is the FPF sequence of late Burdigalian age (late early Miocene). It is composed of six fourth-order seismic units labeled FPF-1 to FPF-6 from oldest to youngest. In the Frying Pan Area, units FPF-1 and FPF-2 correlate with planktonic foraminiferal Zone N6, and unit FPF-6 with Zone N7 (Waters,

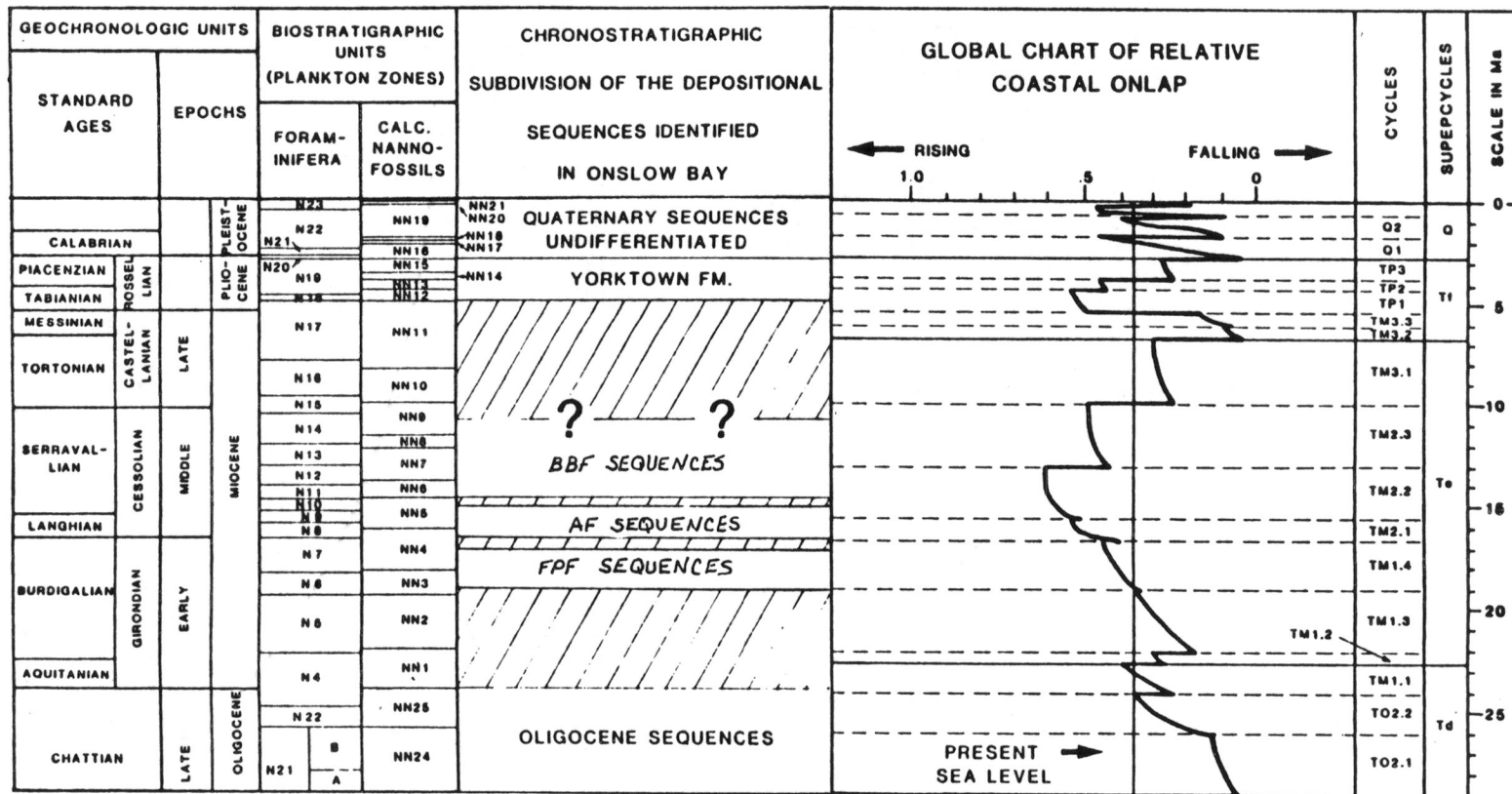


Figure 5. Chart showing the relationship of seismic sequences present in Onslow Bay (modified from S.W.P. Snyder, 1982) to relative global sea-level (from Vail and Mitchum, 1979).

1983). Steinmetz (in S.W.P. Snyder, 1982) assigned FPF-4 to calcareous nanofossil Zone NN4. In seismic profile, FPF-1 through FPF-5 form a series of low dipping units, while FPF-6 has the morphology of a large channel (Fig. 6). This channel is filled with marine sediments (Waters, 1983) and has been interpreted to be a product of erosion and deposition by a spin-off eddy of the Gulf Stream.

The overlying third-order seismic sequence, which is Langhian (early middle Miocene) in age, is referred to as the AF sequence. It has been divided into four fourth-order seismic units, AF-1 to AF-4. These units have been dated by Steinmetz as nanofossil Zones NN4-NN5 (in S.W.P. Snyder, 1982). Moore (in prep.) has assigned AF-3 to planktonic foraminiferal Zone N9. Units C and D of the Pungo River Formation in the Aurora Area appear to be correlative with the AF seismic sequence in Onslow Bay (Katrosh and S.W. Snyder, 1982; Gibson, 1983). In seismic profile, the AF sequence thickens abruptly from 20 m to 40+ m at the White Oak Lineament, where it forms a series of prograding clinoforms (Fig. 7).

The youngest third-order seismic sequence, the BBF sequence, is Serravallian age (middle middle Miocene) on the basis of Steinmetz's nanofossil date of Zone NN6 its the lower part (in S.W.P. Snyder, 1982). Moore and S.W. Snyder (1985) assigned BBF sediments to planktonic foraminiferal Zones N11-N14. This sequence is divided into six fourth-order seismic units (BBF-1 to BBF-6) on Figure 1, but additional seismic units have been recognized in the subsurface by S.W.P. Snyder (1982). The BBF sequence displays complex patterns suggesting extensive cut and fill of preceding units (see Fig. 10 in Riggs and others, 1985).

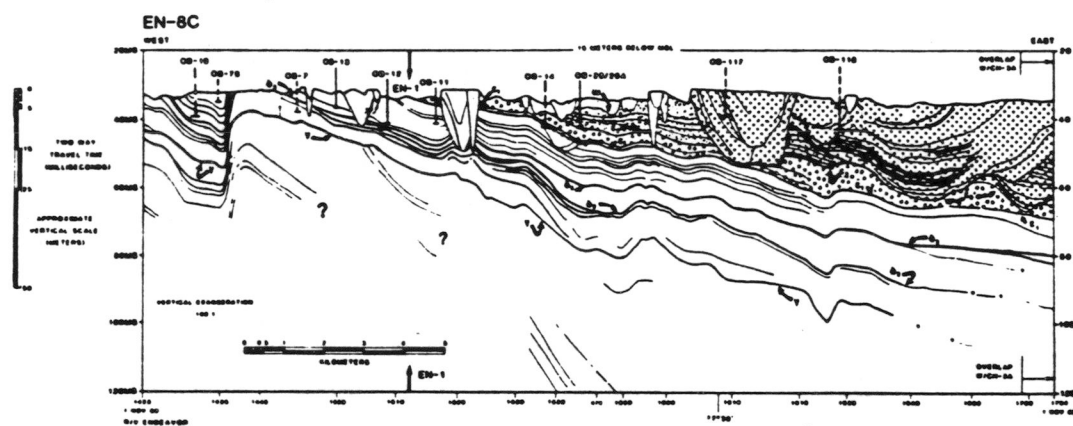


Figure 6. West-east interpreted seismic profile in the Frying Pan Area of southern Onslow Bay (from Riggs and others, 1985). Location of this profile is shown in Figure 8.

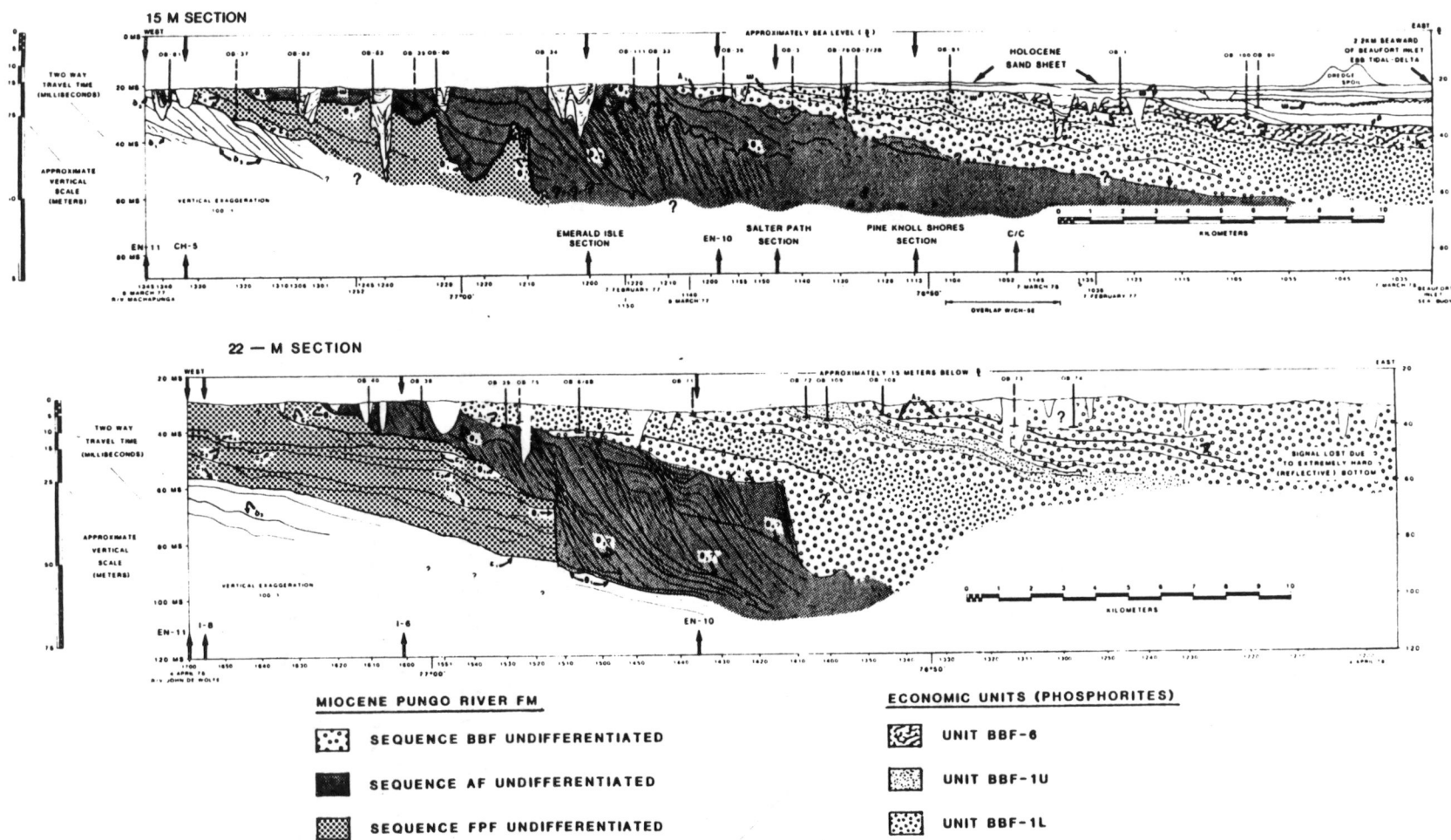


Figure 7. West-east interpreted seismic profiles in northern Onslow Bay (from Riggs and others, 1985). Location of these profiles is shown in Figure 8.

Riggs (1984) hypothesized that the 17 or more fourth-order seismic units were each characterized by some variation of an idealized vertical sequence (siliciclastics, to phosphate and associated authigenic sediments, to carbonates). Each cycle was deposited during transgressions with a frequency between 100,000 and 1,000,000 years. Regressions subsequent to the deposition of each unit may have resulted in erosion and diagenetic alteration of all or part of each deposit, with diagenesis decreasing down section (Riggs, 1984; Riggs and others, 1983, 1984).

Lewis (1981), in a preliminary study of the Pungo River Formation in Onslow Bay, described three informal depositional sequences in northern Onslow Bay: quartz sand, biorudite, and phosphatic sand. He defined two lithofacies within the biorudite: barnacle biorudite and bioclastic dolosilt. He also recognized five lithofacies in southern Onslow Bay: phosphorite sand, quartz phosphorite sand, phosphorite quartz sand, sandy mud, and mud. Table 1 summarizes the types and percentages of carbonate Lewis found in the Pungo River Formation in Onslow Bay. Allen (1985) analyzed eight dolomite samples from Onslow Bay for carbon and oxygen isotopes. To date, no detailed descriptive work has been done with Pungo River carbonate sediments recovered by vibracoring in Onslow Bay.

SEISMIC UNIT(S)	LEWIS' UNIT	LEWIS' FACIES	AVG. % FOSSILS	DOMINANT FOSSILS	DESCRIPTION OF CARBONATE MUD
BBF 1-6	D	Phosphatic Mud	5	bivalves barnacles echinoids foraminifers	minor silt- sized dolomite
AF-4	E	Dry Bioclastic Dolosilt	22	barnacles	dolosilt (74%)
AF-4	E	Barnacle Biorudite	63	barnacles	dolomite mud at base grading upward into calcite mud (30%)
AF 1+2, FPF 1-6	F	Quartz Sand	13	barnacles	90% of silt is dolomite and clay
FPF-3	G	Mud	9	foraminifers	dolosilt to dolo- silty clay (86%)
FPF-2	H	Sandy Mud	15	foraminifers	none described
FPF-1	I	Phosphorite Quartz Sand	23	foraminifers	none described
FPF-1	J	Quartz Phos- phorite Sand	5	foraminifers	none described
FPF-1	K	Phosphorite Sand	5	foraminifers	none described

Table 1. Summary of the Pungo River carbonate sediments described by Lewis (1981).

OBJECTIVES

The primary objective of this study is to describe the carbonate petrology and sedimentology of the Pungo River Formation in Onslow Bay. More specifically, sub-objectives are:

- 1) to describe the types of carbonate sediments, determine their spatial distribution, and establish their relationship with other mineral components (i.e., phosphate and siliciclastic sediments) within the formation;
- 2) to interpret the environment of deposition and diagenetic history of the carbonate sediments; and
- 3) to test Riggs' (1984) model of cyclic sediment deposition against observed vertical and lateral facies relationships of the carbonate sediments.

METHODS OF INVESTIGATION

Sampling

Of 144 vibracores (9 m maximum length) recovered in Onslow Bay during research cruises from 1980 to 1983, 60 were used in this study (Fig. 8). These cores were selected to provide the best possible vertical and lateral coverage through each seismic unit. Table 2 summarizes the cores and samples studied.

Textural Analysis

For textural analysis, the Miocene portion of each core was sampled approximately every 2.0 m or at changes in lithology, whichever came first. One hundred forty-seven samples were dried, weighed, and wet sieved through a 4.0 phi sieve (230 mesh). Mud was saved for insoluble residue and x-ray diffraction analyses. The sand fraction was then dried, weighed, and rotapped at a 0.5 phi interval. Each 0.5 phi fraction was weighed. Individual and cumulative weight percentiles were calculated for each sample and are presented in Appendix D.

Reflected Light Microscopy

Each sample used for textural analysis was also examined for fossil and mineralogical components using reflected light microscopy. Each 0.5 phi fraction was point counted (300 counts) to determine the volume % of

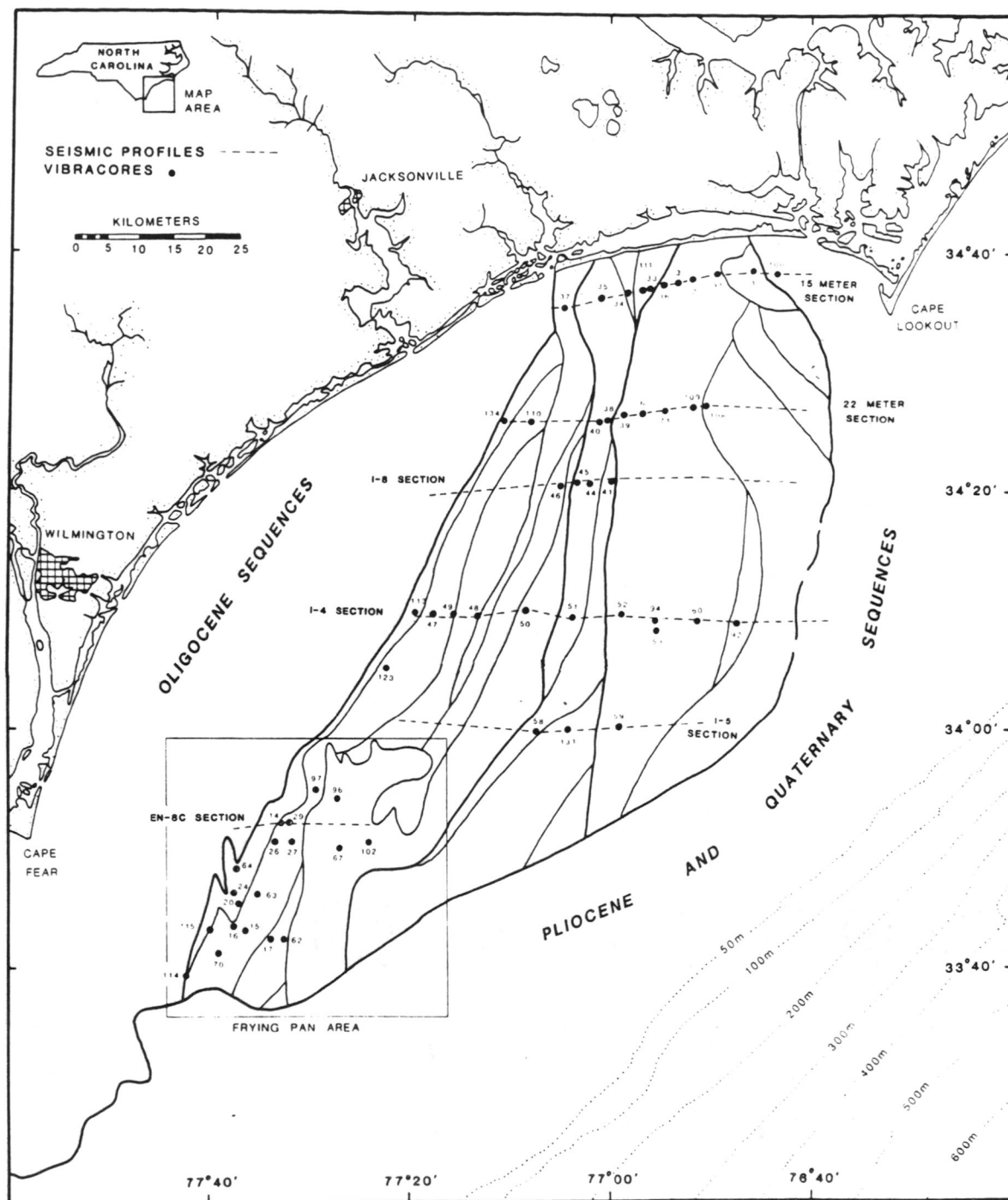


Figure 8. Map of Onslow Bay showing location of vibracores used in this study and seismic profiles discussed in text.

50/5.75-6.00	FPF-5		x	x	x	x	97/6.50-6.75	FPF-2		x	x			
50/8.25-8.50	FPF-5		x	x	x	x	100/8.60-8.70	BBF-6		x	x	x	x	
51/2.00-2.25	AF-1		x	x	x	x	102/7.00-7.25	FPF-6	x					
51/5.00-5.25	AF-1		x	x		x	102/7.75-8.00	FPF-6	x					
51/8.00-8.25	AF-1		x	x			108/1.75-2.00	BBF-3	x					
52/3.75-4.00	BBF-1		x	x	x	x	108/2.25-3.00	BBF-3	x					
53/1.50-1.75	BBF-1	x	x	x			108/2.75-3.00	BBF-3		x	x	x	x	
53/3.75-4.00	BBF-1		x	x	x	x	108/3.75-4.00	BBF-3		x	x	x	x	
53/5.50-5.75	BBF-1	x					108/5.00-5.25	BBF-3	x	x	x	x	x	
53/5.90-6.00	BBF-1	x					109/1.50-1.75	BBF-1		x	x	x	x	
53/6.00-6.25	BBF-1		x	x	x	x	109/3.00-3.25	BBF-1		x	x	x	x	
58/2.25-2.50	AF-2		x	x	x	x	109/4.50-4.75	BBF-1		x	x	x	x	
58/4.25-4.50	AF-2		x	x	x	x	109/5.75-6.00	BBF-1		x	x	x	x	
58/6.25-6.50	AF-1		x	x	x	x	110/1.00-1.25	FPF-2		x	x	x	x	
58/7.40-7.50	AF-1	x					110/4.64-4.75	FPF-2		x	x	x	x	
58/8.25-8.50	AF-1		x	x	x	x	111/0.25-0.50	AF-4	x					
59/6.50-6.75	BBF-1		x	x	x	x	111/0.50-0.75	AF-4		x	x	x	x	
59/7.75-8.00	BBF-1		x	x	x	x	111/2.50-2.75	AF-4		x	x	x	x	
60/1.50-1.75	BBF-1		x	x			111/4.10-4.20	AF-4	x					
60/4.00-4.25	BBF-1		x	x			111/4.25-4.50	AF-4		x	x	x	x	
60/6.25-6.50	BBF-1		x	x			111/4.75-5.51	AF-4	x					
62/3.75-4.00	FPF-3		x	x	x	x	111/5.50-5.75	AF-4		x	x	x	x	
62/5.50-5.75	FPF-3		x	x	x	x	111/6.25-6.50	AF-4		x	x	x	x	
63/0.75-1.00	FPF-2		x	x	x	x	111/7.50-7.75	AF-4		x	x	x	x	
63/2.00-2.25	FPF-2		x	x			111/8.00-8.25	AF-4		x	x	x	x	
64/0.75-1.00	FPF-1	x					113/0.50-0.75	FPF-1		x	x	x	x	
64/1.75-2.00	FPF-1	x					113/1.50-1.75	FPF-1		x	x	x	x	
64/2.75-3.00	FPF-1	x					114/2.10-2.20	FPF-1	x					
64/3.50-3.73	FPF-1		x	x			114/5.75-6.00	FPF-1		x	x	x	x	
64/5.75-6.00	FPF-1		x	x			114/7.50-7.75	FPF-1	x	x	x	x	x	
64/6.25-6.36	FPF-1	x					115/1.50-1.75	FPF-1	x					
64/6.37	FPF-1	x					115/2.50-2.75	FPF-1	x					
67/3.50-3.75	FPF-6		x	x	x	x	115/3.00-3.25	FPF-1	x					
67/6.50-6.75	FPF-6		x	x			115/4.25-4.50	FPF-1	x					
70/1.50-1.75	FPF-2		x	x	x	x	115/4.75-5.51	FPF-1	x					
71/0.50-0.75	BBF-1		x	x	x	x	115/5.00-5.25	FPF-1		x	x	x	x	
91/3.50-3.75	BBF-1		x	x	x	x	115/5.50-5.75	FPF-1		x	x	x	x	
91/5.50-5.75	BBF-1		x	x	x	x	115/7.00-7.25	FPF-1		x	x	x	x	
92/3.25-3.50	BBF-2	x					123/2.00-2.25	FPF-2	x					
92/3.50-3.75	BBF-2	x					123/6.45-6.55	FPF-2	x					
92/4.00-4.25	BBF-2		x	x	x	x	131/3.00-3.25	AF-3	x					
92/5.50-5.75	BBF-2		x	x	x	x	131/3.75-4.00	AF-3		x	x	x	x	
94/1.00-1.25	BBF-1	x					131/4.75-5.00	AF-3		x	x	x	x	
94/1.50-2.00	BBF-1	x					131/5.75-6.00	AF-3		x	x	x	x	
96/1.50-1.75	FPF-6		x	x	x	x	131/6.34-6.44	AF-3	x					
96/3.50-3.75	FPF-6		x	x	x	x	134/0.25-0.50	FPF-1	x					
96/5.50-5.75	FPF-6		x	x	x	x								
97/0.50-0.75	FPF-2		x	x										
97/2.50-2.75	FPF-2		x	x										
97/4.50-4.75	FPF-2		x	x										

Table 2 (continued). Summarization of sample analyses.

50/5.75-6.00	FPF-5		x	x	x	x	97/6.50-6.75	FPF-2		x	x		
50/8.25-8.50	FPF-5		x	x	x	x	100/8.60-8.70	BBF-6		x	x	x	x
51/2.00-2.25	AF-1		x	x	x	x	102/7.00-7.25	FPF-6	x				
51/5.00-5.25	AF-1		x	x		x	102/7.75-8.00	FPF-6	x				
51/8.00-8.25	AF-1		x	x			108/1.75-2.00	BBF-3	x				
52/3.75-4.00	BBF-1		x	x	x	x	108/2.25-3.00	BBF-3	x				
53/1.50-1.75	BBF-1	x	x	x			108/2.75-3.00	BBF-3		x	x	x	x
53/3.75-4.00	BBF-1		x	x	x	x	108/3.75-4.00	BBF-3		x	x	x	x
53/5.50-5.75	BBF-1	x					108/5.00-5.25	BBF-3	x	x	x	x	x
53/5.90-6.00	BBF-1	x					109/1.50-1.75	BBF-1		x	x	x	x
53/6.00-6.25	BBF-1		x	x	x	x	109/3.00-3.25	BBF-1		x	x	x	x
58/2.25-2.50	AF-2		x	x	x	x	109/4.50-4.75	BBF-1		x	x	x	x
58/4.25-4.50	AF-2		x	x	x	x	109/5.75-6.00	BBF-1		x	x	x	x
58/6.25-6.50	AF-1		x	x	x	x	110/1.00-1.25	FPF-2		x	x	x	x
58/7.40-7.50	AF-1	x					110/4.64-4.75	FPF-2		x	x	x	x
58/8.25-8.50	AF-1		x	x	x	x	111/0.25-0.50	AF-4	x				
59/6.50-6.75	BBF-1		x	x	x	x	111/0.50-0.75	AF-4		x	x	x	x
59/7.75-8.00	BBF-1		x	x	x	x	111/2.50-2.75	AF-4		x	x	x	x
60/1.50-1.75	BBF-1		x	x			111/4.10-4.20	AF-4	x				
60/4.00-4.25	BBF-1		x	x			111/4.25-4.50	AF-4		x	x	x	x
60/6.25-6.50	BBF-1		x	x			111/4.75-5.51	AF-4	x				
62/3.75-4.00	FPF-3		x	x	x	x	111/5.50-5.75	AF-4		x	x	x	x
62/5.50-5.75	FPF-3		x	x	x	x	111/6.25-6.50	AF-4		x	x	x	x
63/0.75-1.00	FPF-2		x	x	x	x	111/7.50-7.75	AF-4		x	x	x	x
63/2.00-2.25	FPF-2		x	x			111/8.00-8.25	AF-4		x	x	x	x
64/0.75-1.00	FPF-1	x					113/0.50-0.75	FPF-1		x	x	x	x
64/1.75-2.00	FPF-1	x					113/1.50-1.75	FPF-1		x	x	x	x
64/2.75-3.00	FPF-1	x					114/2.10-2.20	FPF-1	x				
64/3.50-3.73	FPF-1		x	x			114/5.75-6.00	FPF-1		x	x	x	x
64/5.75-6.00	FPF-1		x	x			114/7.50-7.75	FPF-1	x	x	x	x	x
64/6.25-6.36	FPF-1	x					115/1.50-1.75	FPF-1	x				
64/6.37	FPF-1	x					115/2.50-2.75	FPF-1	x				
67/3.50-3.75	FPF-6		x	x	x	x	115/3.00-3.25	FPF-1	x				
67/6.50-6.75	FPF-6		x	x			115/4.25-4.50	FPF-1	x				
70/1.50-1.75	FPF-2		x	x	x	x	115/4.75-5.51	FPF-1	x				
71/0.50-0.75	BBF-1		x	x	x	x	115/5.00-5.25	FPF-1		x	x	x	x
91/3.50-3.75	BBF-1		x	x	x	x	115/5.50-5.75	FPF-1		x	x	x	x
91/5.50-5.75	BBF-1		x	x	x	x	115/7.00-7.25	FPF-1		x	x	x	x
92/3.25-3.50	BBF-2	x					123/2.00-2.25	FPF-2	x				
92/3.50-3.75	BBF-2	x					123/6.45-6.55	FPF-2	x				
92/4.00-4.25	BBF-2		x	x	x	x	131/3.00-3.25	AF-3	x				
92/5.50-5.75	BBF-2		x	x	x	x	131/3.75-4.00	AF-3		x	x	x	x
94/1.00-1.25	BBF-1	x					131/4.75-5.00	AF-3		x	x	x	x
94/1.50-2.00	BBF-1	x					131/5.75-6.00	AF-3		x	x	x	x
96/1.50-1.75	FPF-6		x	x	x	x	131/6.34-6.44	AF-3	x				
96/3.50-3.75	FPF-6		x	x	x	x	134/0.25-0.50	FPF-1	x				
96/5.50-5.75	FPF-6		x	x	x	x							
97/0.50-0.75	FPF-2		x	x									
97/2.50-2.75	FPF-2		x	x									
97/4.50-4.75	FPF-2		x	x									

Table 2 (continued). Summarization of sample analyses.

fossils and mineralogical components in that size range. The sample was then described in terms of fossil preservation and authigenic mineralization.

Percentages of each compositional element in the total sediment for each sample were calculated by: 1) multiplying the % of each component in each 0.5 phi fraction by the weight % of that phi fraction, and 2) totaling these numbers for each sample. This data was generated using SAS (Statistical Analysis System) and the results are presented in Appendix A.

Insoluble Residue Analysis

The mud fraction of each sample saved during wet sieving was divided into two splits. The split used for insoluble residue analysis was first dried and weighed. Dilute hydrochloric acid (10% HCl) was added to each sample until calcite was dissolved. Each sample was then heated to 75°C to dissolve any remaining dolomite. Spent acid was then decanted. Samples were washed in distilled water and filtered. Filters with insoluble residues were dried in an oven at 50°C, after which they were weighed. Percentages of insoluble residues and carbonate in the mud fraction were calculated. These figures were then recalculated in terms of the total sediment. Appendix B contains these results.

X-ray Diffractometry

X-ray diffractometry was done on a GE-700 Diffractometer with nickel filtered copper K-alpha radiation using standard x-ray techniques. Three types of samples were x-rayed: bulk mud fraction to determine the presence or absence of calcite and dolomite, dolomite concentrates, and chert nodules.

The second split of the mud fraction was used to determine the presence or absence of calcite and dolomite in the mud fraction. However, calcite or dolomite must constitute approximately 5% or more of the sample to produce peaks on diffractograms. Appendix B shows the results of this study.

Dolomite concentrates were x-rayed at $1^{\circ}2\theta$ per minute to accurately determine dolomite peak positions. Chert nodules were x-rayed to determine the variety of silica present in the nodules. The results of these two studies are discussed in the sections on dolomite and silicification, respectively.

Thin Section Analysis

Forty-six thin sections were prepared from indurated and semi-indurated Pungo River sediments to study diagenetic features not observable in the unconsolidated sediments. Semi-indurated sediments were impregnated with Hillquist epoxy to prevent plucking of grains while grinding and polishing. Thirteen non-lithified sediment samples were commercially vacuum impregnated to observe structures and features

were commercially vacuum impregnated to observe structures and features not observable in reflected light microscopy. Cover glasses were not affixed to thin sections to permit later x-ray diffractometry.

Each thin section was stained for calcite, dolomite, and ferroan dolomite according to the procedure of Katz and Friedman (1965). This procedure stains calcite red, dolomite blue, and ferroan dolomite does not stain. Each section was then point counted (300 counts) to determine mineralogy and fossil content. These results are recorded in Appendix C.

Scanning Electron Microscopy

Portions of chert nodules, selected dolomite rhombs, and fossils were examined with an ISI-40 Scanning Electron Microscope to observe surface textures of diagenetic features.

PETROLOGY

Both reflected light and petrographic microscopy were used to identify constituents of the Pungo River Formation in Onslow Bay. Table 3 summarizes the average abundance and Table 4 summarizes the range of abundances of the fossil and mineral constituents in each seismic unit. Unless otherwise stated, all abundances are expressed as percentages of the total sediment. Tables 3 and 4 are based on point counts of sediment by reflected light microscopy (Appendix A). Constituents are individually discussed below.

Depositional Components

Carbonate Allochems

Carbonate allochems in the Pungo River Formation include fossils, ooids, superficial ooids, and peloids. Ooids, superficial ooids, and peloids are rare. Fossils constitute up to 82% of the total sediment. Calcareous fossils are diverse in the Pungo River Formation (Table 3); however, only barnacles, molluscs, foraminifers, and echinoids are common. Many authors (Horowitz and Potter, 1971; Milliman, 1974; Bathurst, 1975; Scholle, 1978; Flugel, 1982) have published descriptions and thin section photomicrographs of the ultrastructure of the common fossils; therefore, they need not be repeated here.

Arthropods. Barnacles, the most abundant allochems in most Pungo River sediments (Table 3), compose up to 70.3% of the sediment (Appendix

Seismic Unit	# of Samp	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Cher	Diat	Rads	Spic	Skel	Phos	Glau	Opaq	Oth	Qtz	Matr
BBF-6	6	0.1	tr	0	0.4	0	1.2	0	0.3	tr	1.0	0	0	0	0	2.8	6.6	0.1	tr	tr	62.0	25.5
BBF-3	3	0.5	11.5	0.1	0.7	tr	1.6	0.1	3.0	5.0	0	0	0	0	0	0.2	tr	tr	0	0	19.9	57.4
BBF-2	2	0.2	tr	0	0.1	0	tr	0	0.6	0.4	0	0	0	0	0	tr	tr	0	tr	0	88.7	10.0
BBF-1	27	0.4	0.9	tr	0.2	tr	0.4	tr	0.3	0.2	0.1	0	tr	0	0	1.9	5.0	0.2	tr	tr	48.6	41.5
AF-4	14	9.3	32.4	4.6	0.8	tr	0.6	0.1	5.6	4.6	0.2	0	0	0	tr	tr	0.1	0	tr	0.1	1.2	40.4
AF-3	5	6.5	13.2	1.1	4.5	0.1	1.0	0.2	8.3	4.1	tr	0	0	0	0	tr	0.3	tr	0.1	0	28.8	31.8
AF-2	4	1.4	15.8	0.1	1.1	0	3.6	1.3	4.4	5.9	0	0	0	0	0	0.2	0.3	0.1	0	0	32.4	33.5
AF-1	20	0.9	1.7	0.1	1.2	0.2	0.9	0.1	2.4	0.8	tr	tr	0.2	tr	tr	0.2	0.6	tr	tr	tr	49.4	41.1
FPF-6	9	1.0	5.1	0.2	6.9	tr	5.5	3.5	5.9	1.2	tr	0	0	0	0	0.7	0.6	tr	tr	0	39.9	29.6
FPF-5	7	2.1	6.3	0.2	2.0	tr	0.7	0.2	3.7	0.9	tr	0	0.1	0	tr	0.3	0.3	tr	tr	0	42.6	40.5
FPF-4	3	19.8	3.0	0	0.1	tr	0.1	0	0.3	tr	0	0	0	0	0	0.5	tr	tr	0	0	65.8	10.4
FPF-3	7	0.1	0.3	tr	0.5	tr	1.6	0.1	1.2	1.4	tr	0.2	tr	0.1	tr	0.2	0.5	tr	0.2	tr	32.4	61.0
FPF-2	24	0.1	tr	tr	0.1	tr	1.9	0.9	0.3	0.3	tr	0.2	0.2	tr	tr	0.7	1.1	tr	tr	0.2	26.0	67.9
FPF-1	16	0.3	2.1	0.5	0.4	tr	12.1	3.0	1.0	0.4	0.1	tr	0	0	0	3.2	13.8	0	tr	0	23.4	39.8

Table 3. Average composition (in % of the total sediment) of samples studied from each Pungo River seismic sequence in Onslow Bay. (Moll = molluscs; Barn = barnacles; Bry = bryozoans; Ech = echinoids; Ost = ostracods; Bf = benthic foraminifers; Pf = planktonic foraminifers; Carb = unidentifiable carbonate fragments; Spar = calcite cement; Dolo = dolomite; Cher = chert; Diat = diatoms; Rads = radiolarians; Spic = spicules; Skel = skeletal phosphate; Phos = nonskeletal phosphate; Glau = glauconite; Opaq = opaques; Oth = others; Qtz = siliciclastic sand; Matr = matrix.)

Seismic Unit	# of Samp	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Cher	Diat	Rads	Sptc	Skel	Phos	Glau	Opaq	Oth	Qtz	Matr
BBF-6	6	0	0	0	tr	0	tr	0	tr	0	0.2	0	0	0	0	0.1	tr	0	0	0	53.5	17.5
		0.3	tr	0	1.6	0	3.7	0	0.6	0.1	2.4	0	0	0	0	4.7	10.5	0.2	tr	0.4	67.0	44.4
BBF-3	3	0.3	6.6	0.1	0.4	0	1.3	0	1.8	tr	0	0	0	0	0	tr	tr	0	0	0	10.9	39.5
		0.7	18.7	0.2	1.0	0.1	1.7	0.2	5.0	9.3	0	0	0	0	0	0.3	tr	tr	0	0	27.6	77.8
BBF-2	2	0.1	0	0	0.1	0	tr	0	0	0	0	0	0	0	0	tr	tr	0	0	0	83.9	6.0
		0.4	tr	0	0.1	0	tr	0	1.2	0.8	0	0	0	0	0	tr	tr	0	tr	0	93.4	13.9
BBF-1	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	tr	0	0	0	6.1	19.2
		3.8	15.3	0.2	2.8	0.2	4.9	0.1	6.0	2.9	0.8	0	0.1	0	0	6.4	22.2	1.6	tr	0.3	71.6	92.2
AF-4	14	0	4.3	0	0	0	tr	0	1.3	0	0	0	0	0	0	tr	tr	0	tr	tr	0.1	18.3
		20.6	65.6	12.4	3.8	0.4	2.1	0.5	10.5	38.2	1.7	0	0	0	tr	tr	0.3	0	0.1	1.1	4.1	60.1
AF-3	5	0.4	3.0	0.5	2.4	0	0.2	0.1	3.2	0	0	0	0	0	0	0	0	0	0	0	14.3	28.8
		10.9	26.9	1.6	6.9	0.4	2.1	0.7	11.1	7.9	tr	0	0	0	0	tr	0.7	tr	0.2	0	36.7	36.5
AF-2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0	0	0	2.7	4.8
		4.0	41.9	0.4	2.2	0	12.5	4.6	13.3	22.4	0	0	0	0	0	0.5	0.6	0.3	0	0	94.5	97.3
AF-1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	2.8
		7.1	18.9	0.9	1.8	3.4	11.0	1.0	10.8	7.9	0.5	0.8	2.5	tr	tr	1.0	3.1	tr	tr	0.2	94.8	97.2
FPF-6	9	0	0	0	1.6	0	0.4	0.1	0	0	0	0	0	0	0	0	0	0	0	0	8.7	12.6
		4.4	27.5	0.8	13.6	0.2	10.4	13.7	22.8	6.9	0.2	0	0	0	0	1.1	1.1	tr	tr	0	68.9	49.9
FPF-5	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0	0	3.6	11.6
		8.3	31.6	1.0	6.9	0.1	2.6	0.6	14.8	4.4	0.2	0	0.5	0	tr	1.4	0.8	tr	0.2	0	88.0	95.8
FPF-4	3	0.3	tr	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	38.8	10.2
		46.2	4.8	0	0.2	tr	0.2	0	0.9	tr	0	0	0	0	0	0.9	tr	0.1	0	0	88.1	10.7
FPF-3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	tr	0	0	0	0.5	10.4
		0.6	1.5	0.1	1.7	0.1	6.4	0.4	5.6	10.0	tr	1.5	0.1	0.2	0.1	0.9	1.6	tr	1.1	0.1	78.6	99.2
FPF-2	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0	0	0	tr	8.8
		1.2	0.1	0.2	0.5	tr	19.1	0.9	2.9	4.3	0.3	5.1	2.4	0.2	0.3	3.2	9.1	0.2	tr	3.2	66.3	99.9
FPF-1	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	1.3	0	0	0	7.3	19.1
		2.7	25.4	4.7	2.8	0.1	29.7	7.2	4.3	5.3	1.0	tr	0	0	0	6.9	36.9	0	tr	0	61.7	64.7

Table 4. Range in composition (in % of the total sediment) of samples studied from each Pungo River seismic sequence in Onslow Bay. The upper number for each seismic sequence represents the minimum value and the lower number represents the maximum value. See Table 3 for abbreviations of components.

C). They are disarticulated in all but one sample. Barnacle plates have characteristic shapes and a hollow appearance due to the presence of longitudinal tubes and ribs. Compartmental plates are concave, whereas opercular plates are triangular (Plates 1 and 2). Plates are easily recognized petrographically by their grainy, microcrystalline texture and numerous longitudinal tubes (Plates 3 and 4). Large fragments of barnacle plates are usually poorly laminated in thin section; thus, smaller fragments may be totally nonlaminated. Barnacles may be misidentified as molluscs in thin section because of their laminations (Milliman, 1974). Molluscs, however, usually have well defined laminations within a two-layer shell. Barnacles may also be misidentified as bryozoans because longitudinal and transverse sections through barnacle plates often look similar to zooecia in bryozoan fronds. The principal distinguishing aspect is the fibrous ultrastructure of bryozoans compared to the grainy ultrastructure of barnacles.

Ostracods occur in trace amounts throughout most Pungo River sediments (Table 3). They are most abundant in core OB-35 at 7.75-8.00 m where they constitute 3.4% of the total sediment (Table 4). Both smooth shelled and highly ornamented forms are found, but smooth shelled varieties are most abundant (Plate 5).

Portions of crab claws (decapods) are often present as trace constituents in barnacle hashes but are generally absent elsewhere. They are found in seismic units FPF-1, AF-3, AF-4, BBF-1, and BBF-3 (cores OB-33, OB-71, OB-108, OB-111, OB-115, and OB-131). Plate 4 shows a cross section through a crab claw.



Plate 1. FPF-1 washed sediment. Opercular (O) and compartmental (C) barnacle plates and echinoid (E) plate with partial syntaxial cement overgrowth. Core OB-45, 1.00-1.25m. (reflected light, 12x)

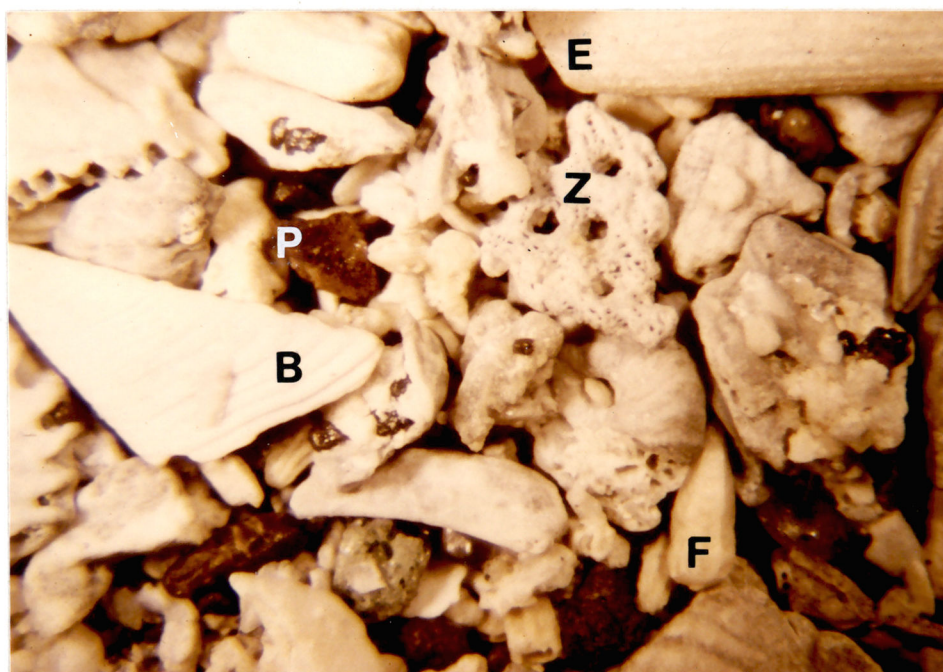


Plate 2. FPF-1 washed sediment. Barnacles (B), bryozoans (Z), echinoid spines (E), foraminifers (F), and fish bones (P) are present. Core OB-115, 5.00-5.25m. (reflected light, 12x)

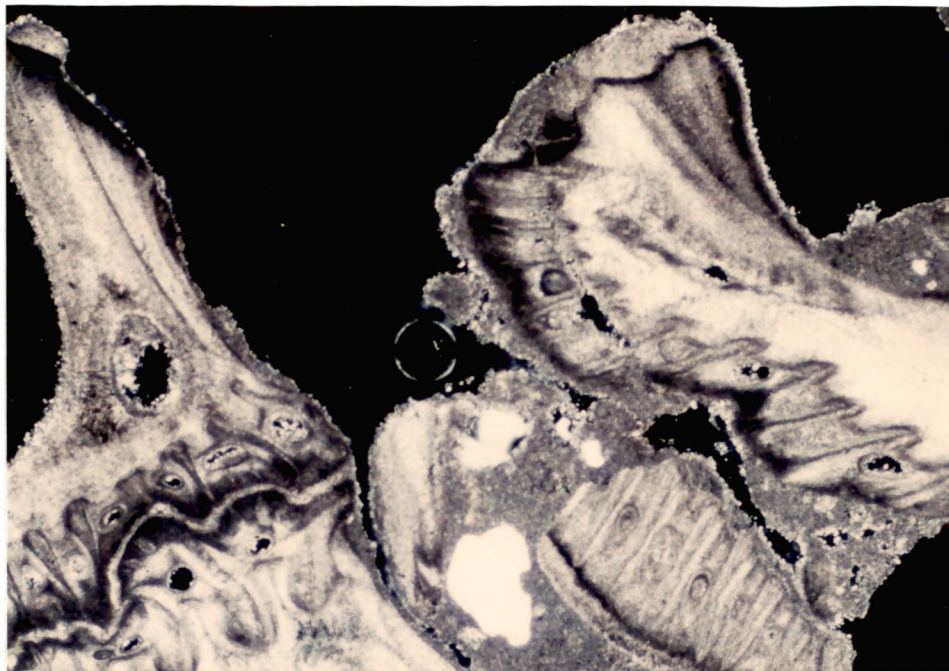


Plate 3. Barnacle plates. Notice the isopachous cement lining the intraparticle pores in the plates. Microspar is also present at the bottom center of the photograph. Core OB-33, 2.50-2.75m. (crossed nicols, 25x)

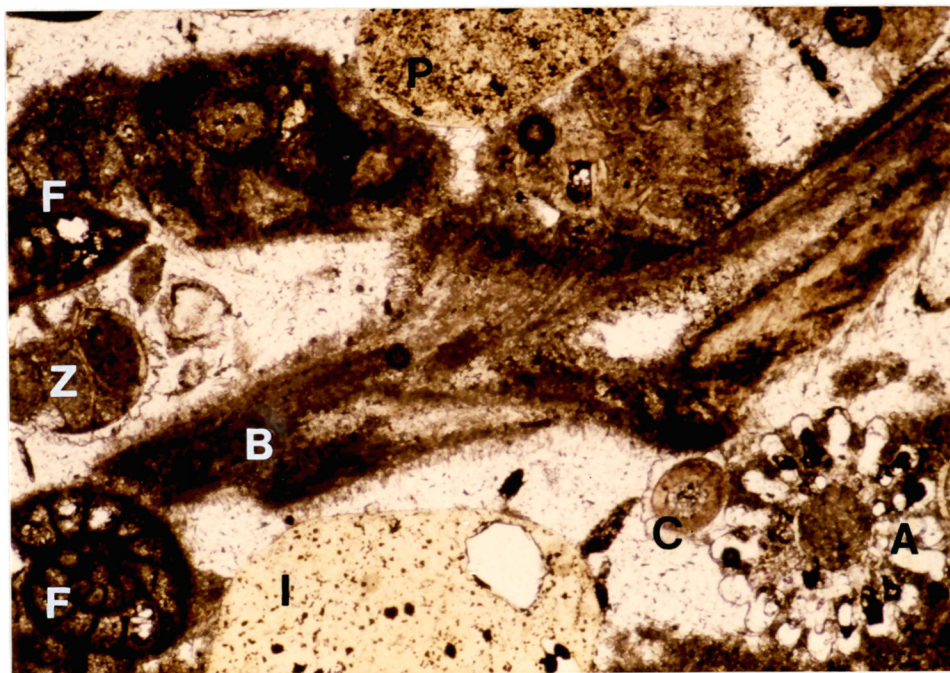


Plate 4. Carbonate cap rock on FPF-1 showing benthic foraminifers (F), barnacle (B), dasycladacean algae (A), crustacean (C), bryozoan (Z), pelletal phosphate (P), intraclastic phosphate (I), and isopachous cement coating most of the fossils. The clear area between allochems is epoxy. Core OB-115, 2.50-2.75m. (transmitted light, 25x)

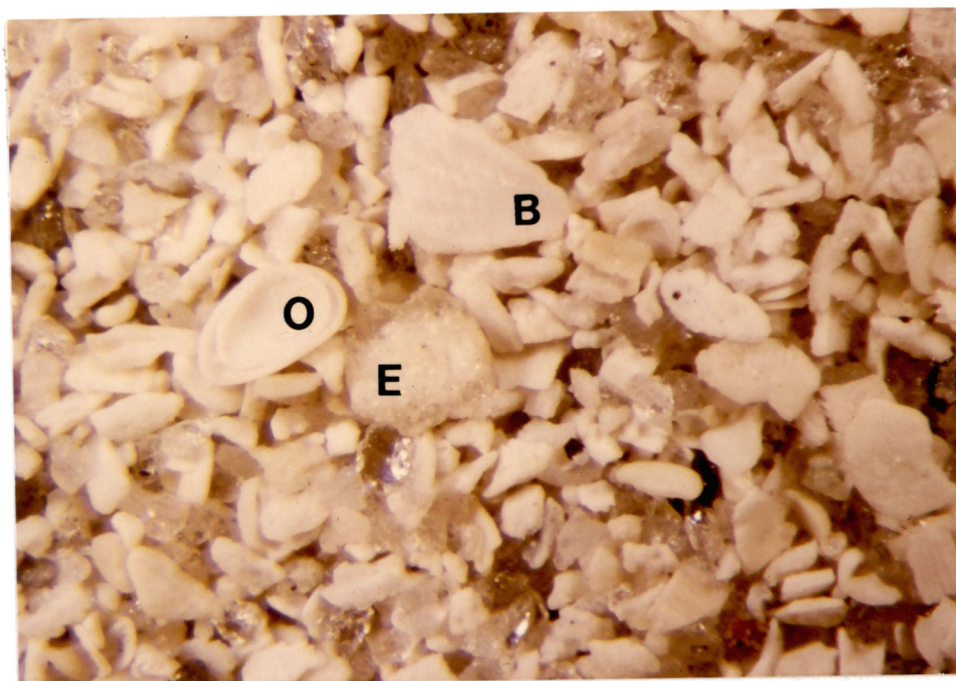


Plate 5. Washed sediment of AF-1. Ostracods (O), bivalves (B), and echinoids (E) are shown. The echinoid has a thick syntaxial cement overgrowth (E). Core OB-35, 5.25-5.00m. (reflected light, 12x)

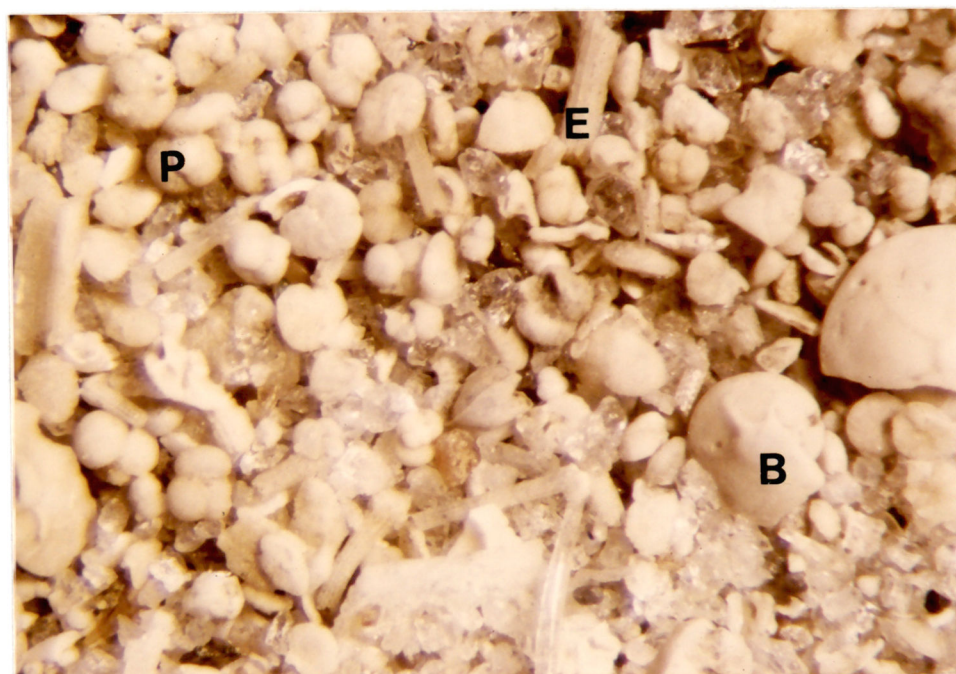


Plate 6. Washed sediment of FPF-6. Abundant planktonic foraminifers (PF), benthic foraminifers (BF), and echinoid spines (E) are illustrated. Core OB-96, 3.50-3.75m. (reflected light, 12x)

Molluscs. Most samples throughout each Pungo River seismic sequence contain bivalve shell fragments (Plate 5). They range in abundance from 0% to 46.2% of the total sediment (Table 4). The AF sequence generally contains more bivalve fragments than either the BBF or FPF sequences (Table 3).

Gastropods are rare to absent in all but one core (OB-131) where they constitute up to 1.4% of the total sediment. They have been included with bivalves for statistical purposes.

Echinoderms. Echinoderms are represented by fragmented echinoid spines and plates (Plates 1, 2, 5, and 6). Though present in all seismic sequences, they are most abundant in seismic unit FPF-6 where they compose up to 13.6% of the total sediment (Appendix C). Average abundances range from 0.1% to 6.9% of the total sediment (Table 3).

Preservation of echinoids ranges from perfectly preserved, through all stages of syntaxial cement overgrowths, to the total encasement of fine sand-sized echinoid fragments by syntaxial cement that forms doubly terminated calcite crystals. Echinoid preservation is discussed in more detail in the diagenesis section.

Foraminifers. Benthic and planktonic foraminifers are present in most Pungo River seismic units (Plates 4 and 6). Average abundance of benthic foraminifers ranges from less than 1% to 12.1% of the total sediment, while planktonic foraminifers range from 0% to 5.5%.

Preservation of foraminifers varies within each seismic sequence.

This will be discussed in more detail in the lithologic descriptions of each seismic sequence.

Bryozoans. Bryozoans occur frequently and compose an average of up to 4.7% of the total sediment. They are generally more abundant where barnacles are abundant; elsewhere, they are rare to absent (Table 3). Bryozoans are represented by fragments of branching, encrusting, and beehive-shaped forms (Plate 2).

Algae. Dasycladacean algae were noted in thin section as trace constituents only in the carbonate-rich part of seismic unit FPF-1 (Plate 4). Coralline red algae (Plate 7) were seen as trace constituents in seismic units FPF-1, FPF-2, AF-3, and AF-4 (cores OB-63, OB-111, OB-114, OB-115, and OB-131).

Brachiopods. Three recrystallized terebratulid brachiopods were found in seismic unit FPF-1 in the southernmost part of Onslow Bay (core OB-114, 7.50-7.75 m). They were most likely eroded from older sediments, probably from the Castle Hayne Formation (Eocene) where they are common. Evidence for reworking is the highly recrystallized nature of these shells in a sediment containing well preserved planktonic foraminifers, which are among the first organisms to be diagenetically altered.

Coated grains. Ooids are rare to absent throughout the Pungo River Formation. They were seen in thin section only in seismic unit FPF-1,

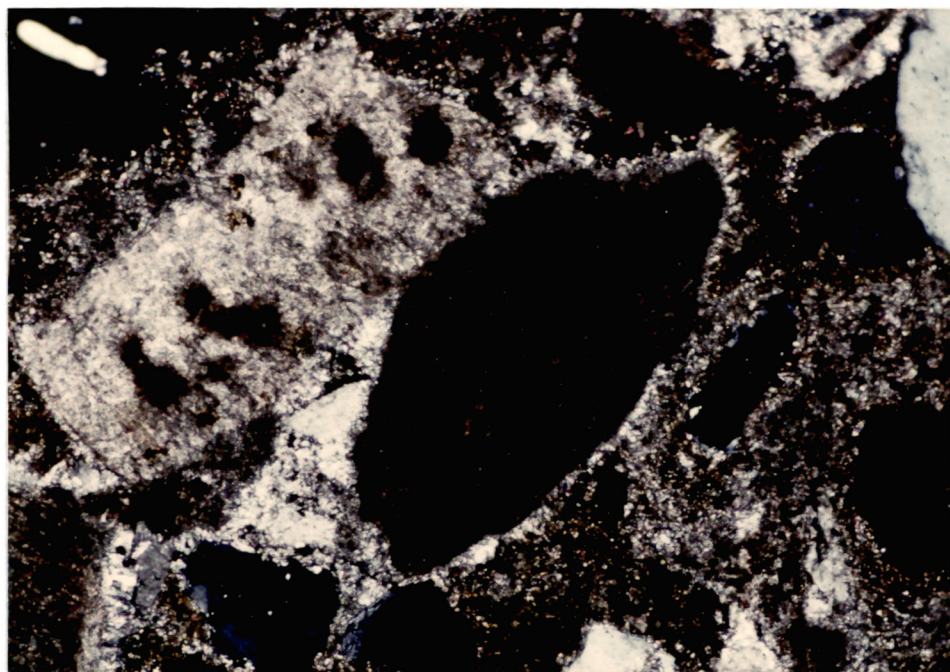


Plate 7. Coralline red algae. Core OB-115, 2.50-2.75m.
(crossed nicols, 25x)

in core OB-64 at 2.75 m below sediment surface where they compose less than 1% of the sediment. Superficial ooids are calcite coated, medium to coarse sand-sized, quartz grains and are usually a pale gray color. They are found in central Onslow Bay in seismic sequences FPF-2, FPF-3, FPF-5, and AF-1, but they never exceed 1% in abundance.

Peloids are present in abundances of less than 4% as determined in thin section. They are only present where barnacles are abundant and their microstructure is grainy like that of the barnacles. This suggests most of that the peloids are small, rounded, unlaminate fragments of barnacles.

Others. Point counts of sieved samples becomes more difficult with decreasing grain size. Poor preservation and/or transportation may destroy shell microstructure and surface texture so that many grains cannot be identified. These make up the majority of unidentifiable carbonate grains. Coralline red algae, dasycladacean algae, crab claws, terebratulid brachiopods, coated grains, and peloids are all present in such small amounts that they were included with unidentifiable carbonate grains for statistical purposes.

Siliceous Allochems

Several types of siliceous organisms are present in the Pungo River Formation. Diatoms (Plate 8) are most abundant (Table 3); sand-sized specimens constitute up to 2.5% of the total sediment (Table 4). Reported diatom concentrations are probably lower than true abundances because most species are smaller than 63 microns. Diatomaceous muds

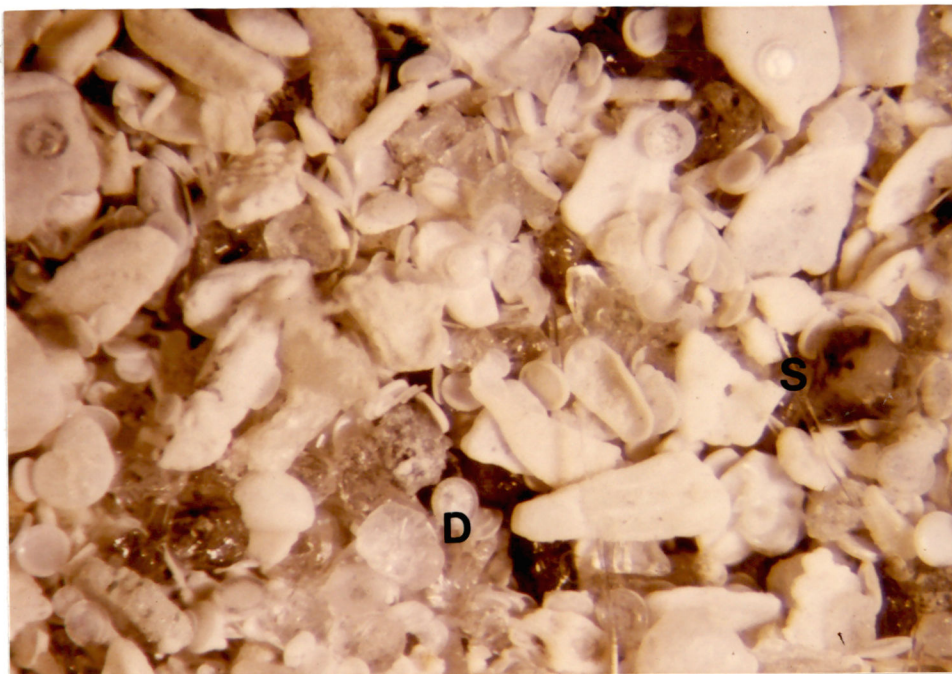


Plate 8. Washed sediment of AF-1. Notice the abundant diatoms (D) and siliceous sponge spicules (S). Also present are mollusc fragments, benthic foraminifers, and ostracods. Core OB-34, 6.00-6.25m. (reflected light, 12x)

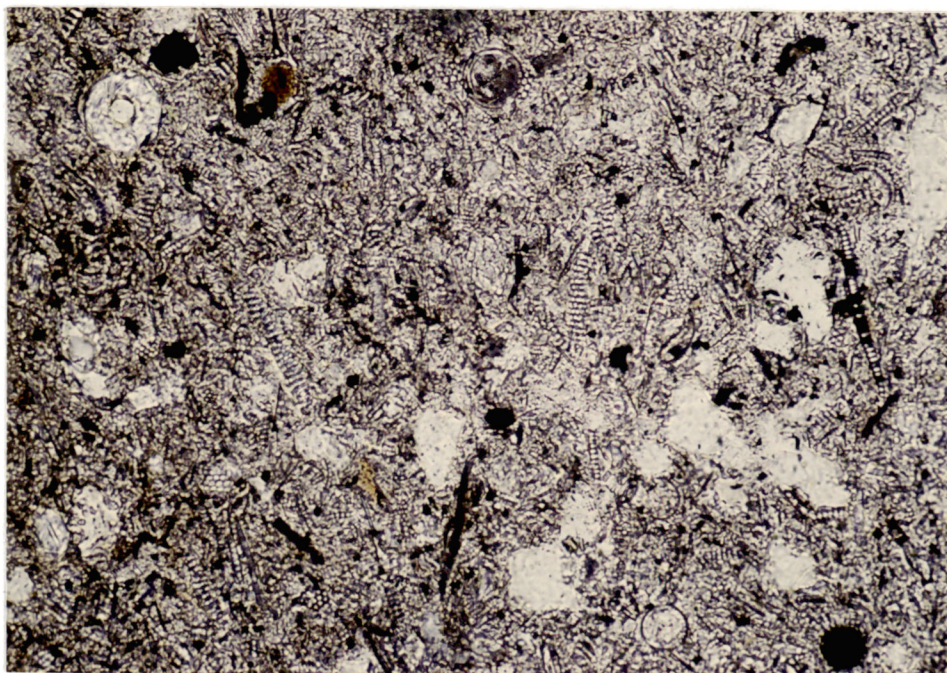


Plate 9. Diatomaceous mud. Core OB-17, 3.00-3.25m. (transmitted light, 160x)

were identified in thin section (Plate 9) in cores OB-17 and OB-47. Radiolarians and siliceous sponge spicules occur in association with diatoms (Table 3). Both monaxon and branching siliceous spicules are found with monaxon varieties being the most abundant (Plate 8). Siliceous organisms are generally associated with fine grained, dominantly siliciclastic sediments. An exception is in core OB-34 (seismic unit AF-1) where the greatest diversity of siliceous and carbonate secreting organisms is found.

Phosphate Allochems

Phosphate allochems were separated into skeletal and nonskeletal varieties to determine their abundances. Skeletal phosphate occurs as fish bones (Plate 2) and teeth, small sharks teeth, and fragments of the inarticulate brachiopod Lingula. Due to its relative scarcity, brachiopod material was included with vertebrate material as the skeletal phosphate component for statistical purposes. Skeletal phosphate content ranges from 0% to 6.9% of the total sediment. It is most abundant in seismic units FPF-1, BBF-1, and BBF-6. Elsewhere, average skeletal phosphate content is less than 1% (Table 3).

Intraclastic and pelletal phosphate grains (Plate 4) were combined as the nonskeletal phosphate component. No attempt was made to determine the individual percentages of these grain types. Nonskeletal phosphate content in ranges between 0% and 36.9% of the total sediment (Table 4). Phosphate is most abundant in seismic units FPF-1, BBF-1, and BBF-6. In the other seismic units, average phosphate content is less than 2% (Table 3).

Glauconite

Glauconite is present as a trace constituent in both sieved samples and thin section (Table 3). Identified by its bright to dark green color, round to subangular grains occur in the coarse silt to fine sand size fraction.

Siliciclastic Sands

Quartz is the most abundant type of siliciclastic sand present in the Pungo River Formation of Onslow Bay. Minor amounts of muscovite, plagioclase feldspar, microcline, and accessory minerals are combined with quartz as the siliciclastic component for statistical purposes.

Matrix

Matrix, as used here, encompasses all materials finer than 63 microns and includes micrite, microspar, clay minerals, clinoptilolite laths, silt-sized quartz, and most diatoms and dolomite present in the Pungo River Formation. Clinoptilolite and dolomite are discussed in the diagenesis section. Micrite is very rare in thin section; most of the carbonate mud is in the size range of microspar and is discussed in the diagenesis section. Lyle (1984) identified the following clay minerals in the Pungo River Formation in Onslow Bay: montmorillonite, illite, chamosite, and sepiolite.

Diagenetic Components

Introduction

Diagenesis refers to all chemical, physical, and biological changes which take place in sediments after their initial deposition excluding metamorphism. It includes such diverse processes as compaction, micritization, cementation, mineral transformations, recrystallization, dissolution, authigenic mineralization, grain to grain pressure solution, stylolitization, and annealing of fractures. The type and extent of diagenesis is controlled by a variety of factors including composition, porosity, and permeability of the sediments, composition of the pore waters, time, temperature, and pressure. Because these factors are so complex, many aspects of diagenesis are poorly understood. The terms early and late diagenesis, rather vague phrases used to describe the relative timing of diagenetic events, are related more to changes in pore water composition and burial depth than to actual time.

Diagenetic components within the Pungo River Formation include calcite cements, dolomite, authigenic silica, and zeolites. Calcite cements, dolomite, and authigenic silica are described from thin section. Zeolites are described only from reflected light microscopy. Table 5 shows the relative abundance of diagenetic components described from thin sections (summarized from Appendix C), which were mostly from carbonates due to the focus of this thesis. Relative timing of diagenesis is discussed in each section on diagenetic components.

Sample	Area	Spar	Micr	Matr	Dolo	Cher	Chal	Foss	Oth	Qtz
BBF-3										
108-1.75	22m	6.0	46.0	0.0	0.0	0.0	0.0	15.3	0.3	32.3
108-2.25	22m	1.3	45.7	0.0	0.0	0.0	0.0	26.3	0.0	26.7
108-5.00	22m	0.0	58.1	0.0	0.0	0.0	0.0	12.9	0.0	29.1
BBF-2										
92-3.25	I-4	20.5	20.9	0.0	0.0	0.0	0.0	4.3	3.6	50.8
92-3.50	I-4	18.4	10.0	0.0	0.0	0.0	0.0	1.2	2.8	67.7
BBF-1										
94-1.00	I-4	8.3	72.0	0.0	0.0	0.0	0.0	3.3	4.0	12.3
94-1.50	I-4	11.1	63.0	0.0	0.0	0.0	0.0	0.0	5.9	20.0
53-1.50	I-4	0.0	73.7	0.0	0.0	0.0	0.0	2.7	5.3	18.3
53-5.50	I-4	0.7	58.3	0.0	0.0	0.0	0.0	2.7	10.7	27.7
53-5.90	I-4	6.7	81.3	0.0	0.0	0.0	0.0	0.0	3.3	8.7
AF-4										
3-8.75	15m	0.0	48.3	0.0	0.0	0.0	0.0	51.3	0.0	0.0
33-2.50	15m	0.4	18.0	0.0	0.0	0.0	0.0	80.6	0.0	0.0
33-3.25	15m	0.0	16.3	0.0	4.0	0.0	0.0	78.3	0.0	1.3
33-4.00	15m	0.0	32.6	0.0	11.7	0.0	0.0	54.8	0.0	1.0
33-5.25	15m	0.0	39.6	0.0	0.0	0.0	0.0	55.6	0.0	4.7
33-6.40	15m	0.0	0.0	50.3	4.7	0.0	0.0	40.2	1.2	3.5
33-8.00	15m	0.0	55.0	0.0	0.3	0.0	0.0	40.0	2.0	2.7
111-0.25	15m	0.0	53.0	0.0	0.0	0.0	0.0	43.0	1.0	3.0
111-4.10	15m	0.0	68.0	0.0	0.0	0.0	0.0	27.7	0.3	4.0
111-4.75	15m	0.3	45.0	0.0	0.0	0.0	0.0	51.9	0.0	2.7
AF-3										
34-2.00	15m	2.7	41.3	0.0	0.0	0.0	0.0	22.4	0.7	24.0
131-3.00	I-5	0.0	76.0	0.0	0.0	0.0	0.0	16.7	1.0	6.3
131-6.34	I-5	5.3	55.8	0.0	0.0	0.0	0.0	28.2	1.0	9.7
AF-2										
38-0.50	22m	0.0	3.0	0.0	0.3	0.0	0.0	79.0	6.3	11.3
58-7.40	I-5	0.0	0.0	0.0	0.0	0.0	32.7	0.0	1.3	65.9
AF-1										
35-4.10	15m	0.0	0.0	0.0	5.3	58.9	13.7	7.9	1.3	12.8
35-6.75	15m	0.0	61.7	0.0	6.3	0.0	0.0	16.6	0.3	14.0
35-7.25	15m	0.0	0.0	0.0	4.7	68.7	2.7	12.7	0.0	11.3

Sample	Area	Spar	Micr	Matr	Dolo	Cher	Chal	Foss	Oth	Qtz
AF-1										
35-8.00	15m	0.0	0.0	0.0	7.0	66.0	7.7	9.0	0.3	10.0
38-7.25	22m	0.0	0.0	0.0	0.0	99.3	0.7	0.0	0.0	0.0
44-5.90	22m	0.0	0.0	0.0	0.0	99.0	0.7	0.0	0.0	0.3
FPF-6										
102-7.00	FP	11.7	0.0	4.0	0.0	0.0	0.0	72.7	0.7	10.9
102-7.75	FP	24.0	1.0	8.0	0.0	0.0	0.0	57.1	0.9	9.3
FPF-3										
17-3.00	FP	0.0	0.0	64.7	17.3	0.0	0.0	8.0	2.4	7.7
FPF-2										
47-0.00	I-4	0.0	0.0	55.4	12.9	0.0	0.0	0.0	8.9	22.7
47-7.25	I-4	0.0	0.0	80.9	0.0	0.0	0.0	0.0	2.6	16.4
123-2.00	---	0.0	0.0	0.0	11.7	63.0	0.0	0.0	0.0	25.3
123-5.07	---	0.0	0.0	0.0	4.5	27.5	0.5	0.0	5.0	62.5
123-6.74	---	0.0	0.0	0.0	15.2	36.4	0.8	0.0	3.2	44.4
29B-2.75	FP	0.0	0.0	29.3	0.0	0.0	0.0	24.3	6.7	36.4
29B-6.75	FP	0.0	0.0	46.0	0.0	0.0	0.0	16.3	17.7	20.0
FPF-1										
134-0.00	22m	7.1	47.2	0.0	0.0	0.0	0.0	8.4	1.3	35.9
14-3.75	FP	0.0	0.0	38.7	0.3	0.0	0.0	8.7	30.3	22.0
20-0.50	FP	4.0	43.6	0.0	1.4	0.0	0.0	41.3	4.0	5.7
24-1.25	FP	0.0	0.0	26.3	0.0	0.0	0.0	1.0	68.4	4.3
24-1.67	FP	0.0	27.7	0.0	0.0	0.0	0.0	1.0	45.3	26.0
64-0.75	FP	1.3	43.6	0.0	0.0	0.0	0.0	42.0	2.5	10.5
64-1.75	FP	0.3	50.2	0.0	0.0	0.0	0.0	40.9	1.5	7.1
64-2.75	FP	0.0	68.8	0.0	0.0	0.0	0.3	20.6	2.1	8.2
64-6.00	FP	4.7	52.1	0.0	0.0	0.0	1.3	16.2	0.0	25.4
64-6.25	FP	0.0	32.8	0.0	0.0	0.0	0.3	27.2	0.6	39.1
64-6.37	FP	1.7	79.2	0.0	0.0	0.0	0.0	1.2	0.0	17.9
114-2.10	FP	2.3	56.3	0.0	0.0	0.0	0.0	38.0	0.0	3.3
114-7.75	FP	0.7	62.2	0.0	0.0	0.0	0.0	7.0	0.6	29.4
115-1.50	FP	1.3	36.8	0.0	0.0	0.0	0.0	59.5	0.9	1.6
115-2.50	FP	1.1	45.4	0.0	0.0	0.0	0.0	44.5	2.8	6.2
115-3.00	FP	1.5	44.3	0.0	0.0	0.0	0.0	43.3	5.9	5.3
115-4.25	FP	2.8	34.8	0.0	0.0	0.0	0.0	45.6	8.8	8.2
115-4.75	FP	1.7	36.4	0.0	0.0	0.0	0.0	39.9	8.4	13.2

Table 5. Summarization of thin section point counts to show abundances of diagenetic components (from Appendix C). Components are shown in % of total sediment. (Sample = core-top depth of sample; Area = seismic profile or Frying Pan (FP) Area; Spar = calcite cement; Micr = microspar; Matr = matrix; Dolo = dolomite; Cher = microcrystalline quartz; Chal = chalcedony; Foss = fossils; Oth = phosphate, glauconite, and pyrite; Qtz = siliciclastic sand.)

Calcite cements

Calcite cements are classified on the basis of crystal morphology, size, and orientation. The following varieties of calcite cement are found in Pungo River sediments in Onslow Bay: radial rim cements, syntaxial cement, pore filling cement, and microspar. Radial rim cements, syntaxial cement, and pore filling cement are combined in point count data as the sparry calcite cement component. The following discussion of calcite cements is based on thin section descriptions of crystal morphology, without support from any microprobe data.

Radial Rim Cements. Radial rim cements are those in which calcite crystals radiate into existing pore spaces. The original mineralogy of these cements may have been aragonite, high-Mg calcite, or low-Mg calcite; however, they are now entirely low-Mg calcite, as determined by staining techniques.

Isopachous and prismatic radial rim cements occur in the Pungo River Formation. The predominant type is isopachous cement. In the Pungo River Formation radial rim cements coat carbonate grain surfaces almost exclusively; however, echinoid fragments are never covered by radial rim cements.

Isopachous rim cement is a thin (15-30um) rind of roughly uniform length calcite crystals which are oriented normal to the host grain surface (Plates 4 and 10). Isopachous cement is a first generation cement which lines interparticle and intraparticle primary pore spaces. Crystal shape may be bladed, prismatic, equant, or fibrous. The dominant crystal forms are bladed and prismatic. Fibrous isopachous

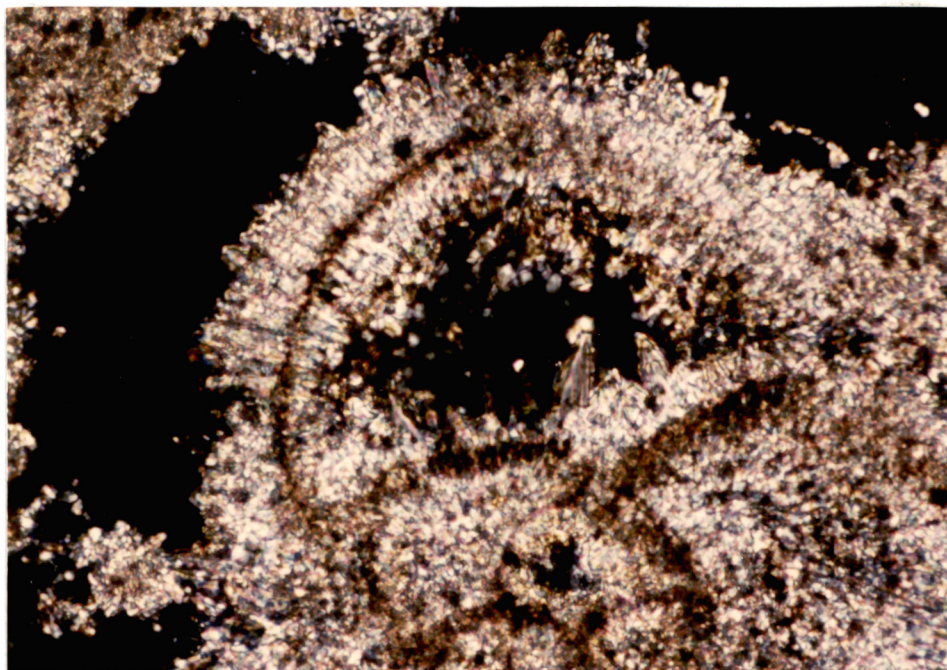


Plate 10. Isopachous rim cement (prismatic crystal shape) on a planktonic foraminifer. Core OB-102, 7.00-7.25m. (crossed nicols, 160x)

cement rarely occurs as intraparticle cement lining tubes in barnacle plates.

Prismatic rim cement, also called dog-tooth cement (Flügel, 1982), does not have a uniform crystal length and is usually larger than isopachous cement, up to about 60 μm long. Prismatic cement is found both as a first generation cement lining interparticle and intraparticle primary pore spaces and as a second generation cement lining secondary moldic pore spaces.

Isopachous cement is usually considered to be indicative of early marine diagenesis (Longman, 1980). Prismatic cement is usually indicative of fresh water phreatic diagenesis, but has been found in beach rocks and marine sediments (Longman, 1980; Flügel, 1982). Where prismatic cement is found with isopachous cement lining primary pore space in the Pungo River Formation it probably is of marine origin. Where prismatic cement is found lining moldic secondary pore space it is associated with blocky calcite cement and is most likely of fresh water phreatic origin.

Syntaxial Cement. Syntaxial cement is a sparry calcite rim cement which forms in optical and crystallographic continuity with host grains. It commonly surrounds echinoderm fragments; however, it has been found on corals, molluscs, and foraminifers (Burgess, 1979). Echinoderm plates and spines are either single crystals of calcite or are composed of numerous minute crystals all with the same orientation (Towe, 1967). The c-axis in echinoid fragments is parallel to the length of spines and is generally normal to plate surfaces (Bathurst, 1971). Growth of

syntaxial cement is much faster along the c-axis than in any other direction (Evamy and Shearman, 1965, 1969).

Syntaxial cement is common in Pungo River sediments and usually surrounds echinoid fragments (Plate 11). It is volumetrically most abundant in echinoid-foraminiferal biosparites of seismic unit FPF-6 where it composes approximately 18% of the total sediment.

Because much of the Pungo River Formation is unindurated, the sequential development of syntaxial cements can be easily studied with scanning electron microscopy. Plate 12 shows a fragment of a well preserved echinoid plate. Early growth of syntaxial cement begins as many small calcite crystals form along the top surface of an echinoid plate (Plate 13); canals in the echinoid plate are not infilled. Further growth of the cement consolidates many small crystals into a few large calcite crystals, accompanied by partial infilling of canals. Porosity of the echinoid fragment is still relatively high at this point (Plate 14). As cement continues to be added, surfaces parallel to the plate are encased in a thick layer of calcite while surfaces normal to the plate are encased in a thin layer (Plate 5).

Syntaxial cement generally is believed to precipitate in fresh water phreatic environments (Land, 1970; Longman, 1980). It may also be an early marine cement, as evidenced by marine borings in the cement (Burgess, 1979); however, evidence for a marine origin is not present in the Pungo River Formation.

Pore Filling Cements. Pore filling cement is second generation sparry calcite which occludes primary interparticle and secondary moldic

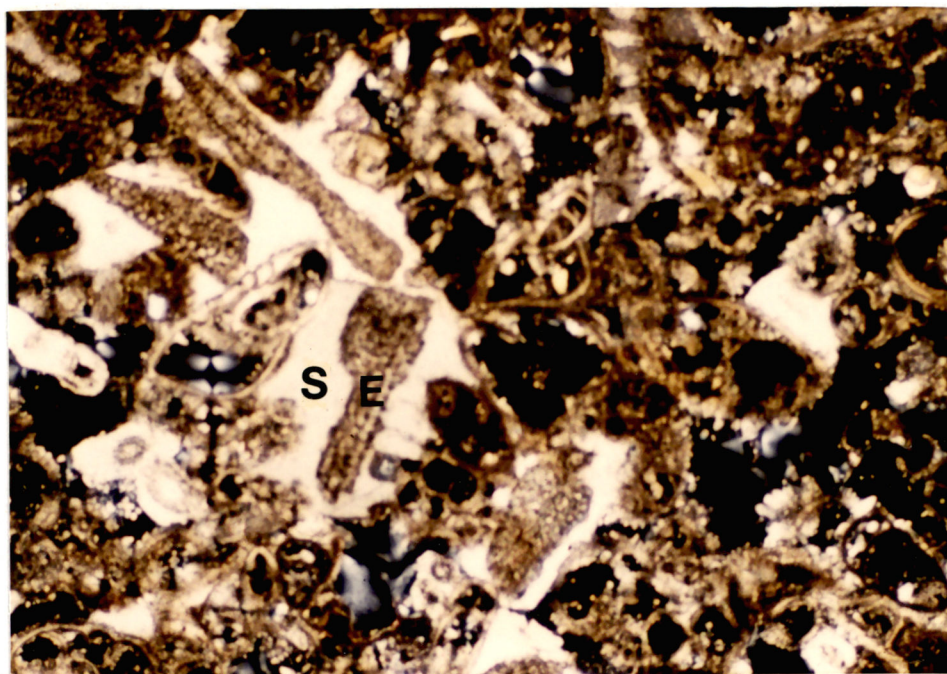


Plate 11. Syntaxial cement overgrowths (S) on echinoid fragments (E). Chambered fossils are foraminifers. Core OB-102, 7.00-7.25m. (crossed nicols, 25x)

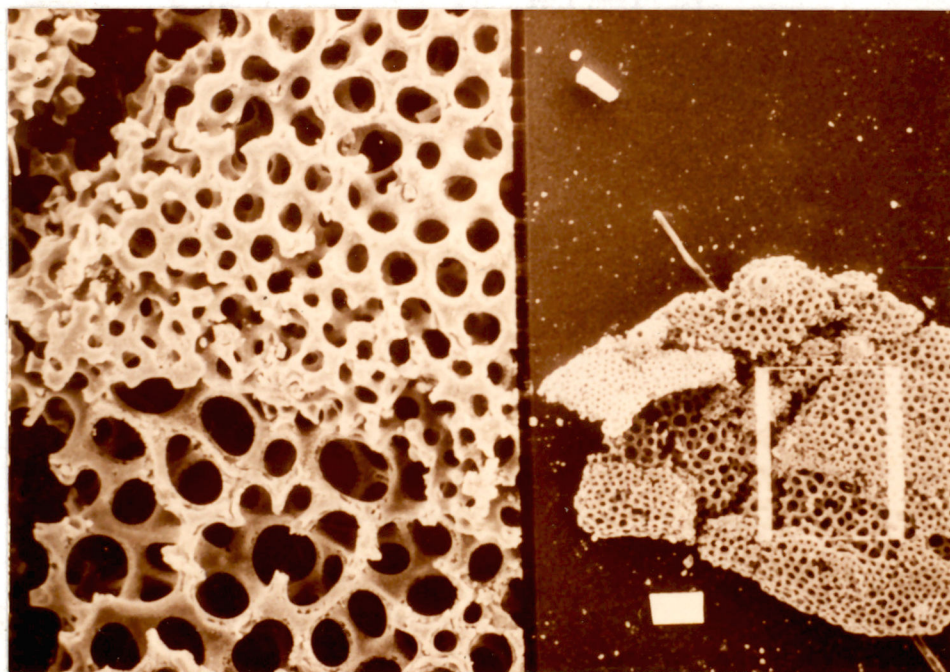


Plate 12. Well preserved echinoid plate fragment. The right side is 150x magnification; the left side is a 10x magnification of the boxed area on the right side. Notice the open, spongy texture of the echinoid plate. (SEM photomicrograph)

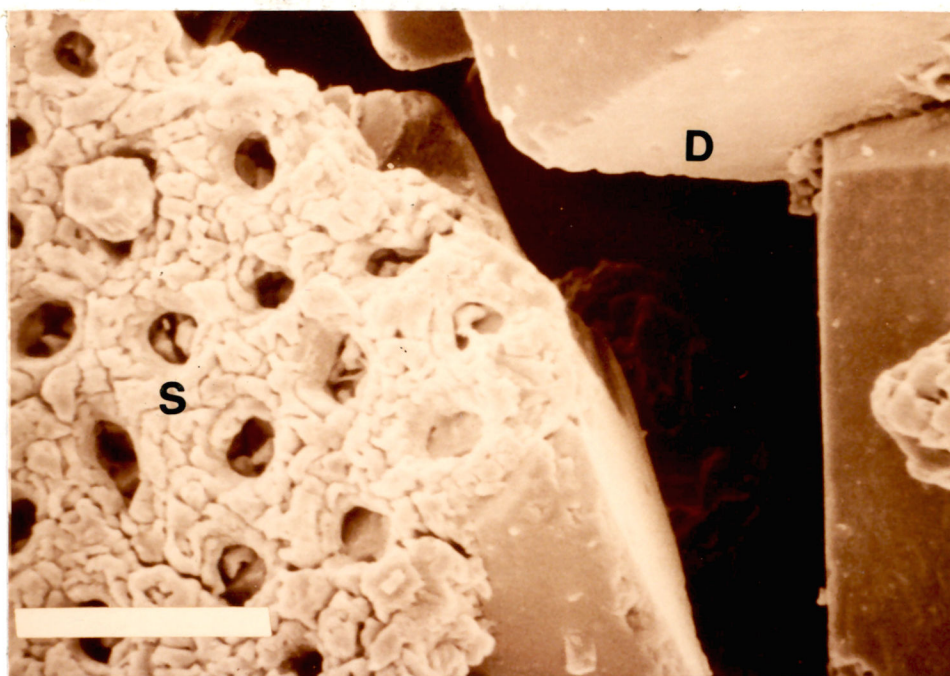


Plate 13. Early stage syntaxial cement overgrowth (S) on echinoid plate fragment. Large straight edged crystals are dolomite rhombs (D). (SEM photomicrograph, 1500x)

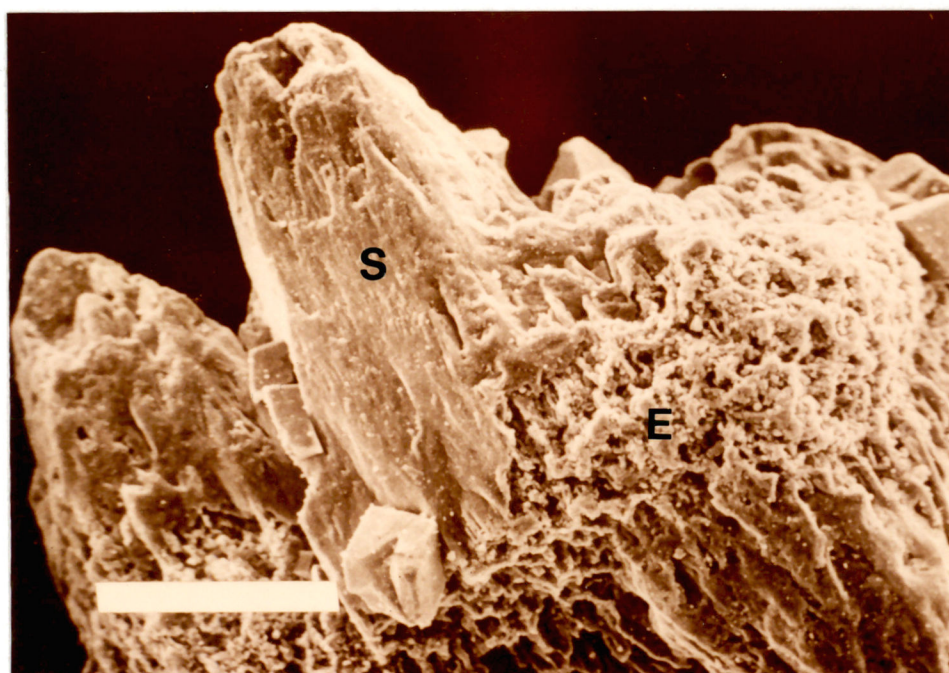


Plate 14. Later stage syntaxial overgrowth (S) on echinoid plate fragment (E). The open, spongy structure of the echinoid plate has been obliterated by syntaxial cement. Notice how the large calcite crystals are growing perpendicular to the plate surface. (SEM photomicrograph, 150x)

porosity. Two varieties of pore filling cement, blocky and drusy, occur in Pungo River sediments. Blocky cement is the predominant pore filling cement.

Blocky cement crystals are greater than 30um in length, subequant to equant in shape, and anhedral to subhedral in form. Where pore space is relatively large, crystal size increases to the center of the pore. Blocky cement occurs in two Pungo River lithologies. In moldic microsparites it partially to totally occludes moldic secondary porosity (Plate 15); contact between blocky cement and prismatic cement, which often lines the molds, is abrupt. In calcite cemented quartz sandstone (seismic unit BBF-2, core OB-92) blocky cement is gradational with microspar and occasionally with drusy cement.

Drusy cement (Plate 16), in which crystals are also larger than 30um in length, is gradational with radial rim cement. Crystal size increases away from pore walls. Drusy cement occurs only in calcite cemented quartz sandstones in interparticle pore spaces between fossils.

Loucks (1977) suggested that increasing crystal size of pore filling cement toward the center of pores is indicative of fresh water cementation. Blocky cement has been interpreted by Longman (1980) to be indicative of a fresh water phreatic diagenetic environment. Pore fluids with Mg/Ca ratios of 1:1 or less indicate a fresh water diagenetic environment and have been shown to form blocky calcite cement (Folk, 1974; Folk and Land, 1975).

Microspar. Microspar is characterized by equant, subhedral to euhedral, calcite crystals with a generally accepted lower size limit of

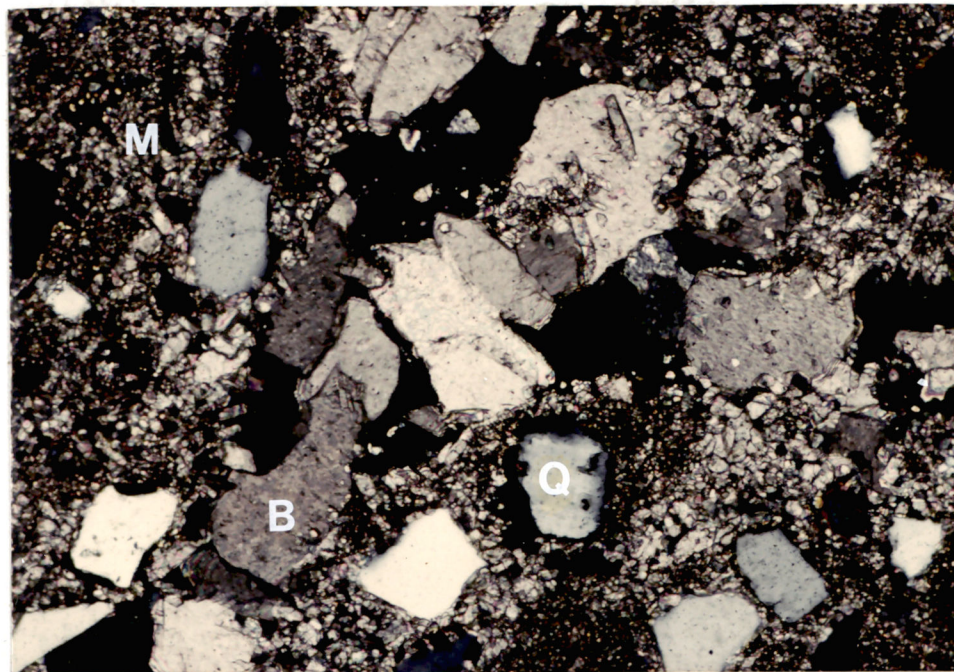


Plate 15. Blocky pore filling cement (B) and microspar (M) in moldic microsparite. Remaining void space in the mold is black. Quartz (Q) is white to blue, subangular to subrounded grains. Core OB-94, 1.00-1.25m. (crossed nicols, 160x)

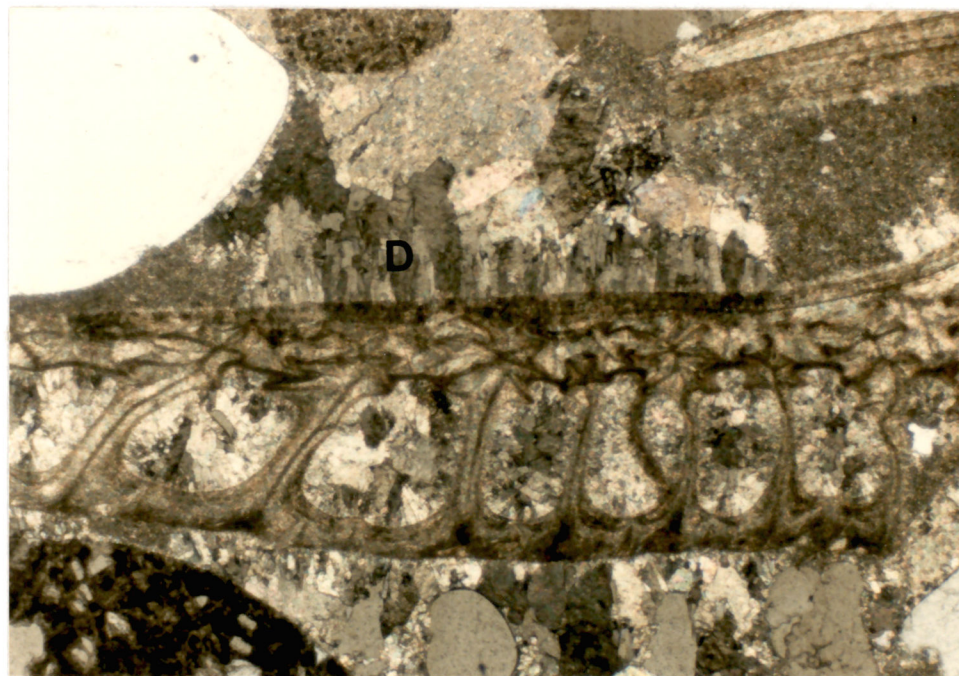


Plate 16. Drusy cement (D) on barnacle plate. Core OB-92, 3.25-3.50m. (crossed nicols, 25x)

4um, but an upper limit that is still debated. Folk (1959, 1965) suggested an upper size limit of 10um. Leighton and Pendexter (1962) believed microspar should include equidimensional calcite crystals up to 30um and Bossellini (1964) used a size range of 4-30um for his micrite II. The latter is used in this study as the size range of microspar.

Microspar is abundant where Pungo River carbonate sediments are partially lithified (Plate 15). Where it is mixed with clays and other matrix materials, microspar occurs in smaller concentrations. This may, in part, be an artifact of sampling because most thin sections used for this study are in partially lithified sediment, while the majority of Pungo River carbonate sediments in Onslow Bay are unconsolidated.

Two methods of microspar formation have been suggested in the literature. Folk (1974) suggested that when aragonite or high-Mg calcite mud inverts to low-Mg calcite, Mg ions expelled from the mud form a "cage" around the 2-3um calcite crystals. Magnesium ions inhibit further growth of the micrite. Removal of Mg ions by fresh water flushing, dolomitization, or absorption of Mg by clay minerals results in increased calcite crystal growth. This two step process of lime mud inversion and later crystal growth, known as aggrading neomorphism, is the generally accepted mode of microspar formation (Folk, 1959, 1965).

SEM studies of aragonite-dominated lime muds show that aragonite laths are calcitized during one period of neomorphism, resulting in the co-occurrence of micrite and microspar (Lasemi and Sandberg, 1984). Mixed crystal sizes do not necessarily mean that micrite has been neomorphosed to microspar.

Because microspar in the Pungo River Formation occurs with other

calcite cements which indicate a fresh water phreatic environment, it probably formed via fresh water flushing.

Dolomite

Dolomite in the Pungo River Formation is present as matrix-supported euhedral rhombic crystals or aggregates of rhombs. According to the dolomite textural classification system of Gregg and Sibley (1984), Pungo River dolomite is idiotopic-P (matrix supported euhedral rhombs with a porphyrotopic texture). Pungo River dolomite rhombs range in size from 5 to 120 μm in diameter and those in the fine sand-sized fraction compose up to 2.4% of the total sediment. However, dolomite is most abundant in the mud fraction. X-ray diffractometry and insoluble residue analyses show that dolomitic mud constitutes up to 50.8% of the total sediment (Appendix B).

Dolomite in the FPF and BBF seismic sequences has even, plane surfaces (Plates 17 and 18). In the AF sequence, rhombs are pitted and have uneven surfaces (Plates 19 and 20). Edges of rhombs in the AF sequence are not rounded, which argues against a detrital origin. Allen (1985) described the uneven surfaces as "flame-like" textures, similar to those described by Weaver and Beck (1977) in Miocene sediments of the Atlantic Coastal Plain. She stated that pitting of dolomite rhombs was caused by dissolution of a calcium carbonate precursor, rather than dolomite dissolution. I believe the pitting and uneven surface textures are due to dolomite dissolution because calcareous fossils in this sequence appear only slightly etched.

Most sand and coarse silt-sized dolomite rhombs in the Pungo River

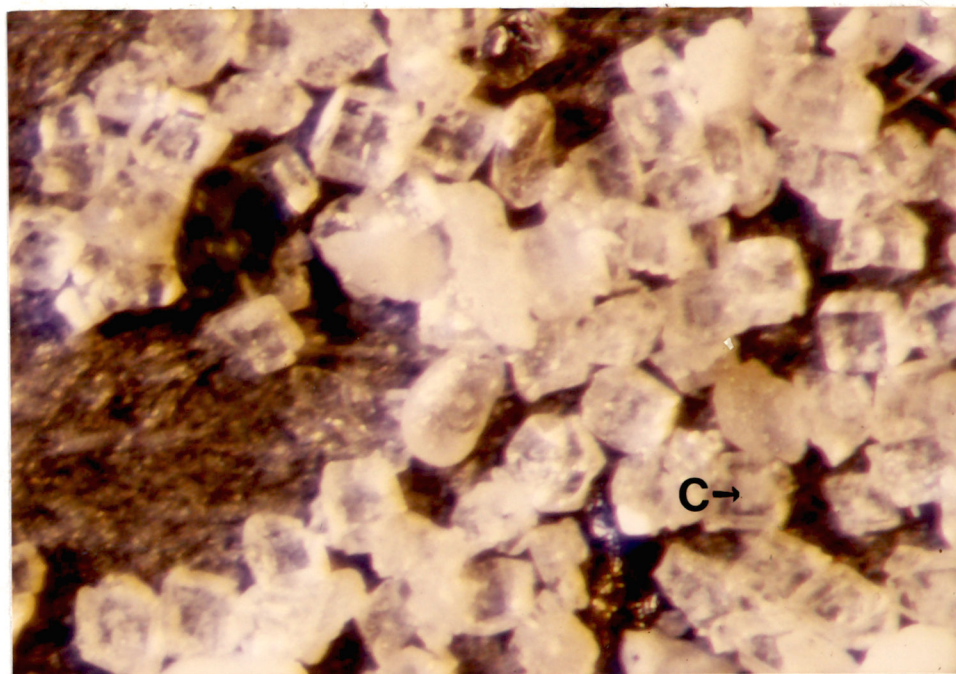


Plate 17. Washed sample of euhedral dolomite rhombs in the BBF sequence. Core OB-1, 4.50-4.75m. Notice opaque white cores (C) in rhombs. (reflected light, 50x)



Plate 18. Euhedral dolomite rhombs in the BBF sequence. Notice the plane, even surfaces of the rhombs. Core OB-1, 4.50-4.75m. (SEM photomicrograph, 1000x)

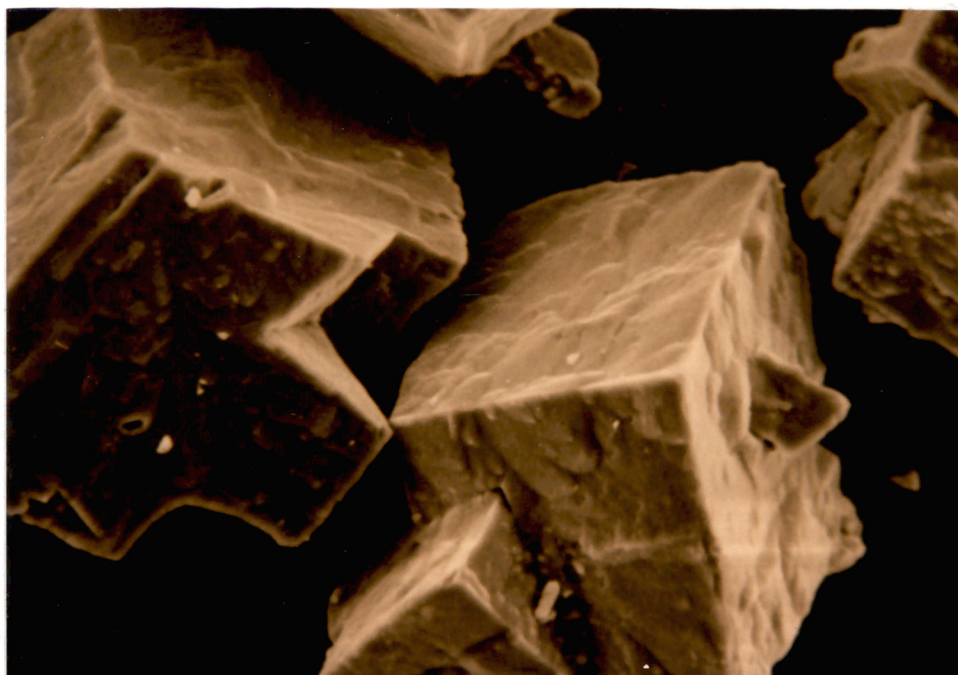


Plate 19. Dolomite rhombs in the AF sequence. Notice the uneven surface texture and dissolution pitting. Core OB-33, 4.50-4.75m. (SEM photomicrograph, 2000x)

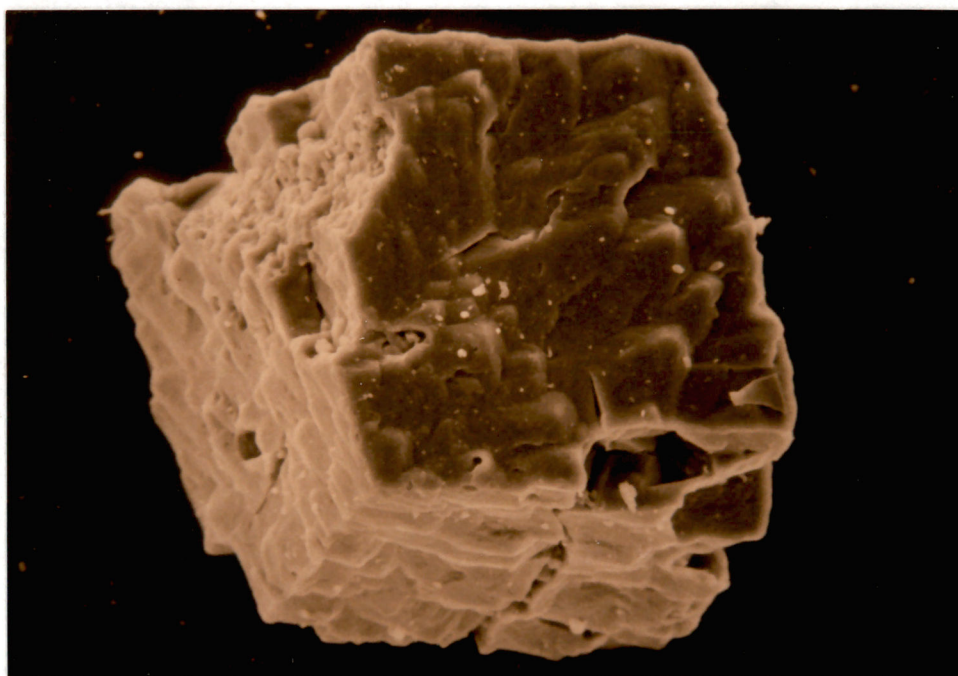


Plate 20. Dolomite rhomb in the AF sequence illustrating "flame-texture" produced by dissolution. Core OB-33, 4.50-4.75m. (SEM photomicrograph, 2000x)

Formation have an opaque white, roughly spherical core that is about one-fourth the size of the enclosing rhomb. The core is surrounded by clear, colorless dolomite (Plate 17). These rhombs are not zoned, nor are they hollow when viewed in thin section. However, dolomites in chert nodules of core OB-123 (seismic unit FPF-2) are well zoned (Plate 21) with a core that has a "spongy" texture; a few of these cores are partially to almost totally hollow. SEM studies of dolomite in chert nodules in the AF sequence indicate a few of the rhombs are hollow (Plate 22).

Dolomite occurrence in the Pungo River Formation is sporadic (Table 6). In some cores dolomite increases up-section, in some it decreases up-section, and in others there is no recognizable trend. This may reflect the actual occurrence of dolomite, or it could be an artifact of the sampling interval or the methods used to estimate dolomite abundance. Thin section point counts of dolomite in some lithologies are not possible because of the fine grained nature of the dolomite. Because most of the dolomite is mud-sized, quantitative x-ray diffractometry using standards is needed to determine the true abundance and distribution of this dolomite.

Composition of Pungo River dolomites was measured by three methods: x-ray diffractometry, staining for ferroan dolomites, and microprobe analysis. Comparison to x-ray diffraction peak positions of ferroan dolomite (ankerite) shows that Pungo River dolomite matches closely (Table 7). Thin sections were stained by the method of Katz and Friedman (1965) to detect iron. Ferroan dolomite, which generally has about 1/3 of its Mg replaced by Fe, stains blue; iron-poor dolomite does

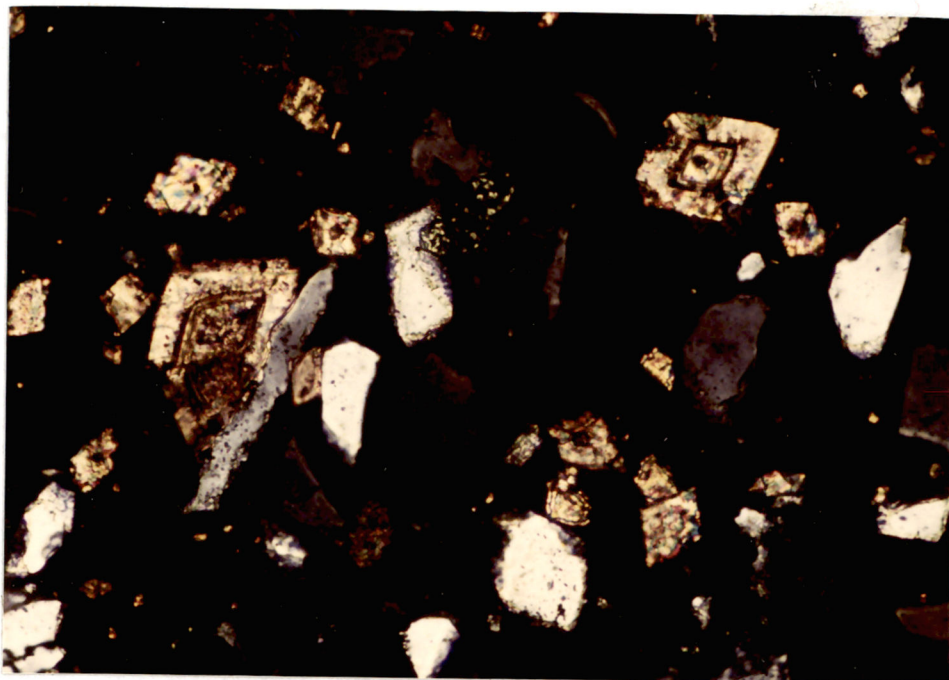


Plate 21. Zoned dolomite in chert nodule. Core OB-123, 6.74m.
(crossed nicols, 160x)



Plate 22. Hollow dolomite in chert nodule. Core OB-35, 8.00m.
(SEM photomicrograph, 1500x)

Core	Dolomite			Core	Dolomite		
Depth (m)	Sand	Matrix	X-ray	Depth (m)	Sand	Matrix	X-ray
<u>OB-1</u>				<u>OB-16</u>			
4.50	1.6	15.6	C+D	1.50	tr	5.8	D
5.25	2.4	--	-	5.50	0	8.2	D
5.75	0.7	11.1	C+D				
6.50	0.2	9.0	C+D	<u>OB-91</u>			
8.00	0.7	3.7	C+D	3.50	0.8	8.6	C+D
				5.50	0.6	6.4	C+D
<u>OB-111</u>				<u>OB-35</u>			
0.50	0.1	17.9	C+D	2.75	0.1	37.9	C+D
2.50	1.7	43.1	C+D	5.25	0.1	36.8	C+D
4.25	0	25.0	C	7.75	0.2	34.1	C+D
5.50	0	37.3	C				
6.25	0	22.9	C	<u>OB-38</u>			
7.50	0	37.4	C	3.50	0.5	22.8	D
8.00	0	13.0	C	6.50	tr	27.7	D
				8.75	0	2.2	D
<u>OB-27</u>				<u>OB-49</u>			
1.0	0	5.1	N	1.75	0	16.2	D
3.0	0	10.3	C	4.75	0	9.2	D
5.0	0	15.7	C	7.75	0	8.9	D
7.0	0	16.4	C+D				

Table 6. The % of dolomite in the sand fraction (Sand), % of carbonate mud (Matrix), and x-ray determinations of the type of carbonate (C = calcite; D = dolomite; N = none) in the matrix (X-ray) are shown for a representative group of samples. Dolomite can increase up section, down section, or have any distribution.

Dolomite			Ankerite			Pungo River dolomite		
2 θ	d(A)	I	2 θ	d(A)	I	2 θ	d(A)	I
30.975	2.886	100	30.975	2.886	100	31.00	2.89	100
51.150	1.786	30	50.350	1.812	6	50.35	1.81	9
51.300	1.781	30	50.950	1.792	6	50.80	1.80	5
41.175	2.192	30	41.025	2.199	6	41.15	2.20	4
50.600	1.804	20						
45.000	2.015	15	44.875	2.020	3	44.95	2.02	3
	1.389	15		1.391	1			
33.575	2.670	10	33.375	2.685	3			
37.400	2.405	10	37.300	2.411	3	37.40	2.41	1
59.850	1.545	10	59.725	1.548	2			
	1.431	10		1.436	1			

Table 7. Major superstructure reflections of dolomite, ankerite, and Pungo River dolomite arranged in order of decreasing intensity of Pungo River dolomite. Peak positions of dolomite and ankerite are from Howie and Broadhurst (1958). Intensity has been recalculated to 100%.

not stain. Pungo River dolomite did not stain, which suggests it is not iron-rich. Microprobe analyses of dolomite rhombs from seismic unit BBF-6 (core OB-1) show no iron enrichment, but instead indicate a calcium-rich dolomite (Table 8).

Hurlbut and Klein (1977) stated that sedimentary dolomite generally deviates from its stoichiometric formula of $\text{CaMg}(\text{CO}_3)_2$ with Ca:Mg ratios of 47.5:52.5 to 58.0:42.0. Dolomite in seismic unit BBF-6 has a high Ca:Mg ratio (Ca:Mg = 57:41) indicating that it is a nonstoichiometric, calcium-rich dolomite.

Stoichiometric dolomite is largely from deeply buried sediments and metamorphic rocks (Land, 1983). Most dolomites contain excess calcium and lack the degree of ordering of Ca and Mg in their structure characterized by stoichiometric dolomite (Goldsmith and Graf, 1958; Goldsmith and others, 1962; Lumsden and Chimahusky, 1980). Calcium-rich, nonstoichiometric dolomite has been called protodolomite in belief that it is a precursor to stoichiometric dolomite (Graf and Goldsmith, 1956; Gaines, 1977). Attenuated superstructure reflections (weakened x-ray peaks) in x-ray diffractograms has been cited as proof that dolomite is disordered. Reeder (1983) stated that if these nonstoichiometric dolomites do, in fact, have superstructure reflections, then they are dolomites and should be called dolomite; if they do not have superstructure reflections, they are not dolomites. Land (1980) suggested that the term protodolomite be dropped because most dolomites are nonstoichiometric. Allen (1985) stated that Pungo River dolomites have attenuated superstructure reflections. X-ray diffractograms included in her study show superstructure reflections from 20° to

GRAIN	SAMPLE	AREA	CaO	MgO	FeO	MnO	Na ₂ O	Al ₂ O ₃	SiO ₂	K ₂ O	TiO ₂
1	D41A	C	34.807	17.538	0.003	0.000	0.027	0.000	0.018	0.001	0.000
1	D41B	R	33.943	16.907	0.000	0.047	0.011	0.000	0.359	0.020	0.000
1	D41C	R	35.367	18.227	0.104	0.017	0.045	0.039	0.038	0.024	0.000
2	D42A	C	36.089	17.641	0.000	0.017	0.067	0.000	0.000	0.033	0.000
2	D42B	R	33.801	16.907	0.000	0.010	0.036	0.078	0.129	0.025	0.050
2	D42C	R	33.896	17.382	0.023	0.000	0.065	0.000	0.029	0.021	0.051
3	D43A	C	33.085	18.350	0.710	0.000	0.093	0.171	0.796	0.088	0.009
3	D43B	R	37.764	19.556	0.000	0.000	0.058	0.000	0.070	0.000	0.060
4	D44A	C	33.561	17.769	0.022	0.044	0.052	0.000	0.100	0.008	0.025
AVERAGE OF CENTERS			34.386	17.825	0.184	0.015	0.060	0.043	0.229	0.033	0.002
AVERAGE OF RIMS			34.954	17.796	0.025	0.015	0.043	0.023	0.125	0.018	0.032
AVERAGE			34.701	17.809	0.096	0.015	0.050	0.032	0.171	0.024	0.022
Stoichiometric Dolomite			30.411	21.857							

Table 8. Microprobe analyses of dolomite from core OB-1 (seismic unit BBF-6) by S.R. Riggs on 2/14/84. Oxides are in weight %. (Area = area of analysis of dolomite: C - center; R - rim.)

50°2 θ for bulk sediment samples (not dolomite concentrates). Continuing x-ray diffractograms until 52°2 θ reveals that a couplet of x-ray peaks indicative of dolomite is not present, but a couplet indicative of ferroan dolomite is present (Fig. 9).

Dolomite crystal shape is dependent on the temperature at which it formed. Gregg and Sibley (1984) suggested that at a "critical roughening temperature" (CRT) of between 50° and 100°C dolomite will form anhedral rather than euhedral crystals. They also stated that calcium-rich dolomite may have a lower CRT due to substitution of Ca for Mg. Pungo River dolomite is calcium-rich and euhedral, which suggests that it formed at temperatures below 50°C.

Oxygen isotope analyses of Pungo River dolomites from Onslow Bay and the Aurora Area indicate formation in marine pore waters at temperatures of 4° to 13°C (Allen, 1985). Carbon isotope analyses indicate that most of its carbon is from an inorganic calcium carbonate precursor (Allen, 1985). Low concentrations of Sr, Fe, Mn, and Zn within the dolomite indicate dolomite formation during shallow burial in marine pore waters (Allen, 1985). Baker and Kastner (1981) showed that, at concentrations as low as 5% of its seawater value, $(\text{SO}_4)^{2-}$ inhibits dolomitization of calcite. Bacterial sulfate reduction occurs 0.01 to 10 m below the sediment-water interface (Pisciotta and Mahoney, 1981), enhancing dolomite formation by removing dissolved $(\text{SO}_4)^{2-}$, producing alkalinity, and causing the formation and exchange of NH_4^+ for Mg^{2+} from opaline silica (opal-A) (Baker and Kastner, 1981). This information indicates that Pungo River dolomite formed from an inorganic calcium carbonate

precursor in the marine environment during early diagenesis after bacterial sulfate reduction, possibly within centimeters of the sea floor (Allen and Baker, 1984; Allen, 1985). This interpretation also helps explain the sporadic occurrence of the dolomites. Where bacterial sulfate reduction has not removed enough $(\text{SO}_4)^{2-}$ from the sediments, possibly due to a scarcity of organic sediment or to rapid sedimentation, dolomite formation could be inhibited which could result in a dolomite distribution that has no relationship to other diagenetic profiles.

Silicification

Replacement of pre-existing sediment and void filling by authigenic silica are the processes involved in silicification. The silica classification of Folk and Pittman (1971) is used to describe varieties of silica in silicified Pungo River sediments. Megaquartz comprises crystals greater than 20um in diameter and those of microquartz are less than 20um. Microquartz is further divided into chalcedony (fibrous) and microcrystalline quartz (equant).

Three patterns of silicification in Pungo River sediments of Onslow Bay include: 1) chert nodules, 2) chalcedonic cement, and 3) selective replacement of fossils. These types of silicification are interrelated and will not be divided into separate headings.

Three lithologically different types of chert nodules occur in Pungo River sediments. Characteristics common to all three include a central portion which reflects an original detrital sand grain mineralogy that is similar to the surrounding sediments. The outer

surface of the nodules is the color of the surrounding sediments and is cemented predominantly by calcite cement.

Type 1 chert nodules are present in seismic unit AF-1, core OB-35 (Plate 23). The center of these nodules is gray with a dull or matte surface texture where cryptocrystalline silica has totally replaced carbonate mud in the sediment. Microcrystalline quartz has replaced calcareous fossils (foraminifers, molluscs, barnacles, echinoids, and ostracods) and calcite rim cements present associated with them (Plates 24 and 25). The shapes of fossils and carbonate cements are mimicked by microcrystalline quartz, making identification easy. Microcrystalline quartz has replaced the central portion of barnacle plates, leaving a micritic rim surrounding the microquartz. Voids are often lined with chalcedony (Plate 26). Detrital quartz composes 11.4% of the nodules and unreplaced fossils constitute another 9.7%. Two sizes of dolomite rhombs are present in Type 1 nodules. Larger rhombs, which constitute 5.8% of the nodules, average 80um in diameter, and have opaque rounded cores approximately 20um in diameter. Smaller rhombs are 10 to 20um in diameter and do not appear to have a core. The latter could not be point counted because of their small size, but constitute approximately 35% of the nodules. Silicification of fossils is most intense near the center of nodules and generally decreases outward. A thin transition zone, 1-2 mm thick, is present between the silicified portion of the nodules and the outer calcite-cemented surface. In thin section this transition zone is cloudy and slightly opaque, and it appears to be where clay in the sediment was expelled from the portion of the nodule being silicified (Plate 27).



Plate 23. Chert nodule from seismic unit AF-1. The gray central area of the nodule is the silicified part; the white outer rim is calcite cemented, dominantly unreplaced carbonate sediment. Core OB-35, 8.00m.

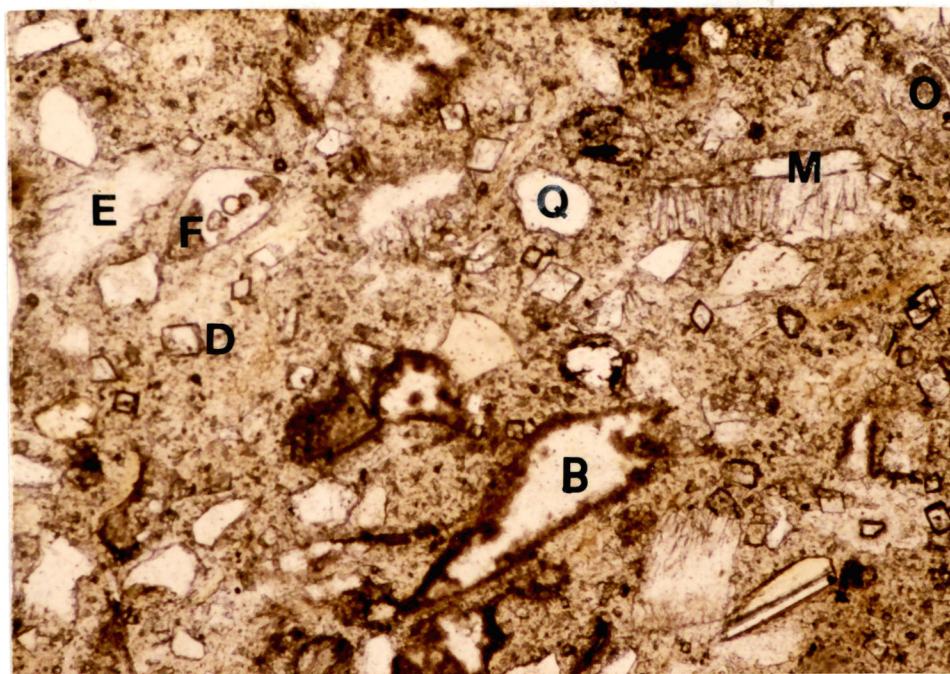


Plate 24. Photomicrograph of chert. Fossils include barnacles (B), ostracods (C), foraminifers (F), molluscs (M), and echinoids (E). Dolomite (D) and subangular to subrounded quartz (Q) is also present. Core OB-35, 8.00m. (transmitted light, 160x)

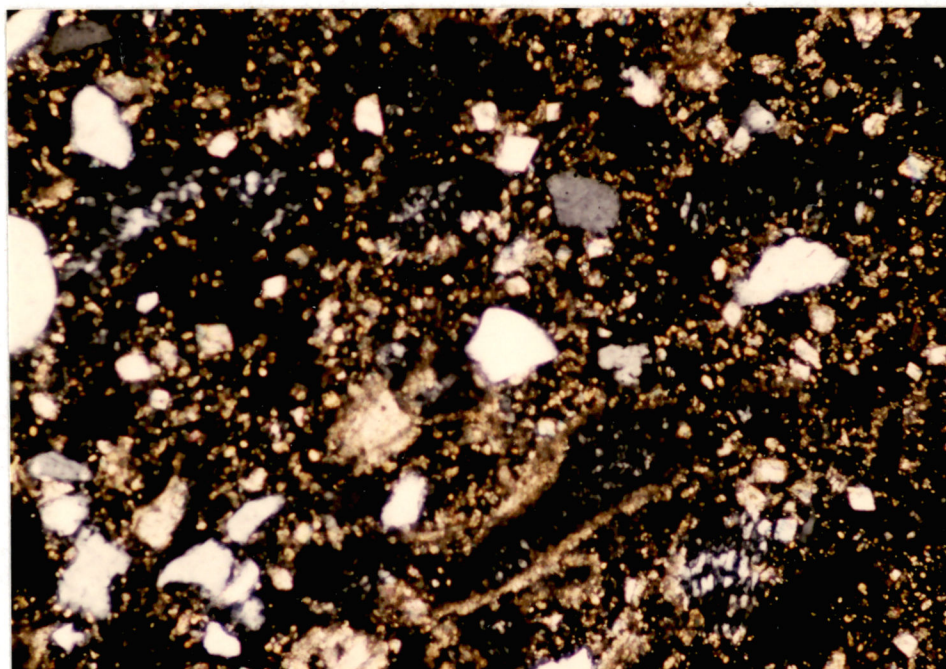


Plate 25. Photomicrograph of chert. Same field of view as Plate 24. Almost all fossils and calcium carbonate cements are silicified whereas dolomite rhombs are not replaced. (cross nicols, 160x)

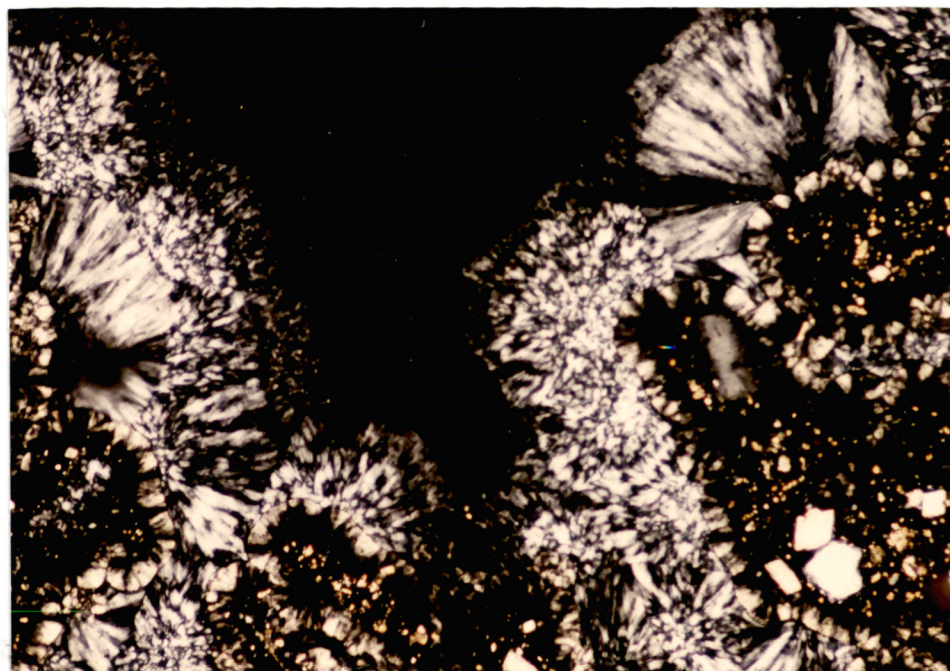


Plate 26. Chalcedony lining a void in chert nodule. Core OB-35, 8.00m. (crossed nicols, 160x)

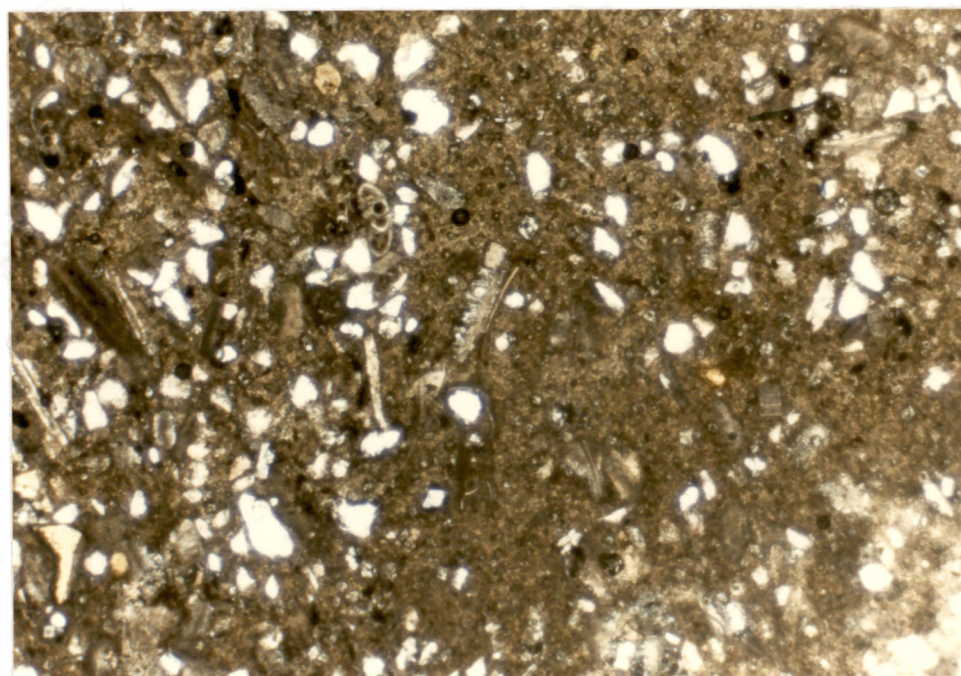


Plate 27. Clay-rich transition between zone of intense silicification and carbonate cemented sediment. Core OB-35, 8.00m. (transmitted light, 25x)

Type 2 chert nodules are found in cores OB-38, OB-40, and OB-44 in seismic unit AF-1 and in core OB-47 in unit FPF-2. The centers of these nodules are gray with a glossy appearance. Detrital quartz is very sparse (0.3%) and calcareous fossils are nonexistent. Dolomite is very fine-grained, averaging 10um in diameter and ranging in size from 5 to 40um. Again, dolomite is too fine grained to be point counted, but constitutes approximately 40% of the nodules. Small voids are lined by chalcedony and filled with microcrystalline quartz. Type 2 nodules also have a thin, clay-rich transistion zone between the intensely silicified central part and the calcite-cemented outer surface.

Core OB-123 in seismic sequence FPF-2 contains many large Type 3 chert nodules averaging approximately 8cm by 3cm. Sedimentary structures such as burrows and bedding were very well preserved during silicification (Plate 28). Silicification appears to have paralleled bedding, probably due to permeability between bedding planes. The nodules contain abundant detrital quartz (44.1%), glauconite (1.3%), and well zoned dolomite (10.5%) (Plate 21). Most dolomite rhombs contain a core that appears to be dolomite with a spongy texture. In a few of the largest rhombs, the spongy core has been partially to almost totally dissolved. Fossils are not present in the nodules. A sharp textural and mineralogical change occurs at the contact between the central part of the chert nodule and the outer rim (Plate 29). The predominant component of the rim is fine (20um) dolomite, with lesser concentrations of what appears to be clay which was expelled from the central part of the nodules. Detrital quartz concentration in the rim drops off to about 2%.



Plate 28. Chert nodule showing bedding preserved by silicification. Core OB-123, 5.00-5.25m. Nodule is 7cm long.

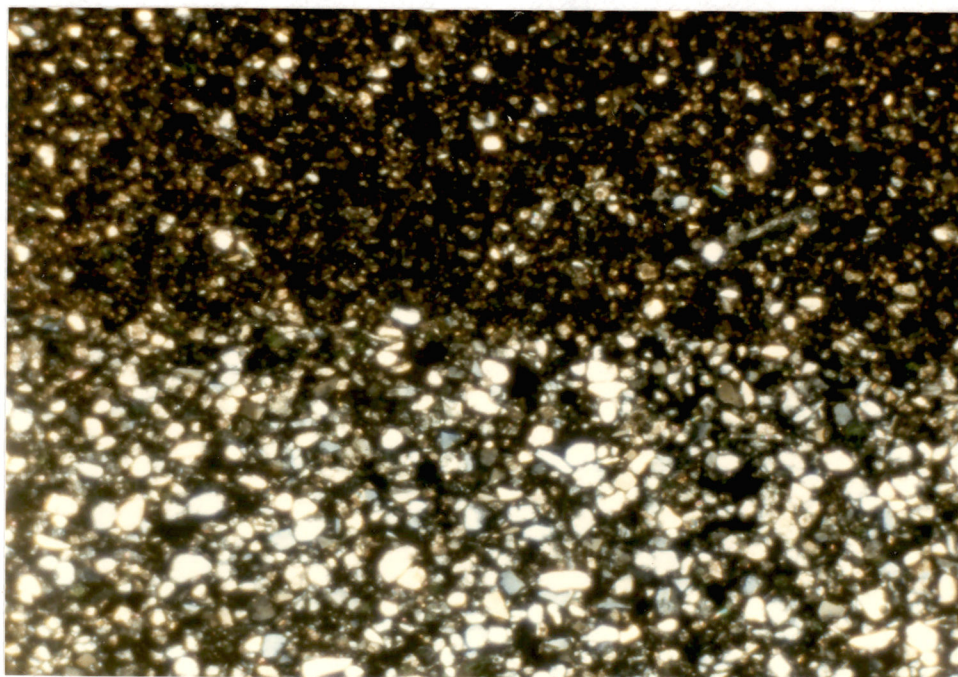


Plate 29. Contact between area of intense silicification and rim of chert nodule showing the sharp mineralogical and textural change. Core OB-123, 6.74m. (crossed nicols, 25x)

X-ray diffractometry of the chert nodules shows the silica to be opal-CT with minor quartz. The quartz probably detrital and authigenic because both detrital quartz and microquartz occur in the nodules. Scanning electron microscopy of the nodules shows the presence of opal-CT lepispheres (Plates 30 and 31) and spaghetti-like structures that appear to have some degree of crystallinity (Plate 32).

Chalcedony is the cementing agent in quartz sandstone (Plate 33) located in core OB-58 at 7.40 m (seismic unit AF-2). It comprises 32.7% of the rock volume. Chalcedonic fibers average 25 μ m long and line all pore spaces. Remaining pore space is filled by either botryoidal chalcedony or microcrystalline quartz. Diagenetic silica appears to have almost totally replaced an original carbonate matrix. In the few areas where any carbonate is left, very minor dolomite and a few partially replaced barnacle plates are present. The central part of the barnacle plates is replaced by microcrystalline quartz and is surrounded by an unreplaced micritic rim in the outer portions.

In core OB-34 at 2.00 m (seismic unit AF-3) echinoids are partially replaced by chalcedony not associated with chert nodules or void lining cements. This chalcedony has only replaced the central portion of echinoid plates and spines.

Potential sources of silica for Pungo River silica authigenesis include diagenesis of volcanic glass and biogenic material. Marine waters contain an average of 3 ppm Si (Anikouchine and Sternberg, 1981) and are undersaturated with respect to silica (Reich and von Rad, 1979). Therefore, marine pore waters have to be enriched by some outside source for authigenic silica to form.

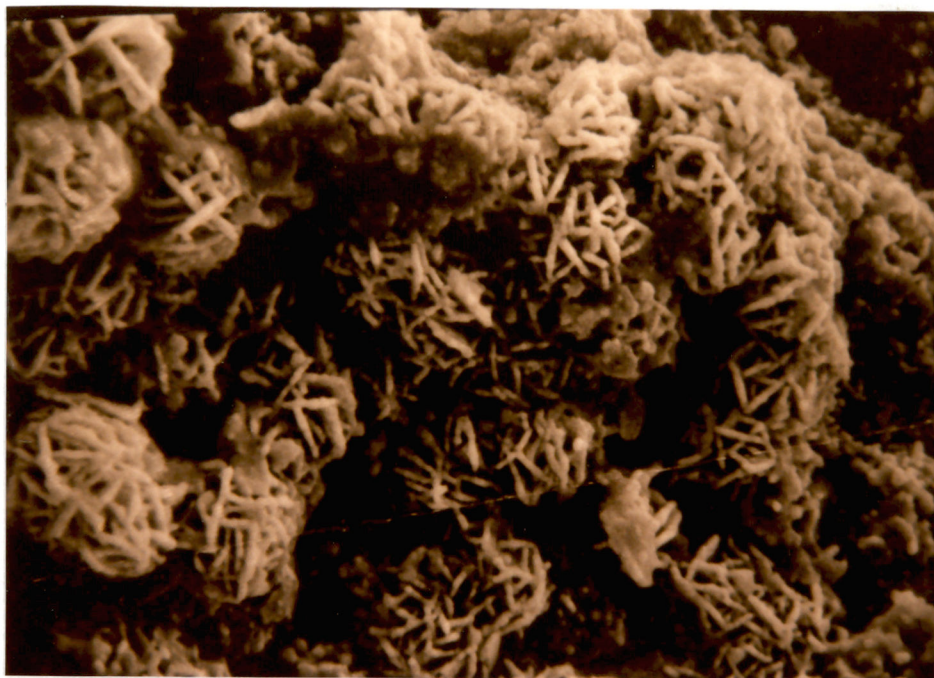


Plate 30. Lepispheres in chert nodule. Core OB-35, 8.00m.
(SEM photomicrograph, 5000x)

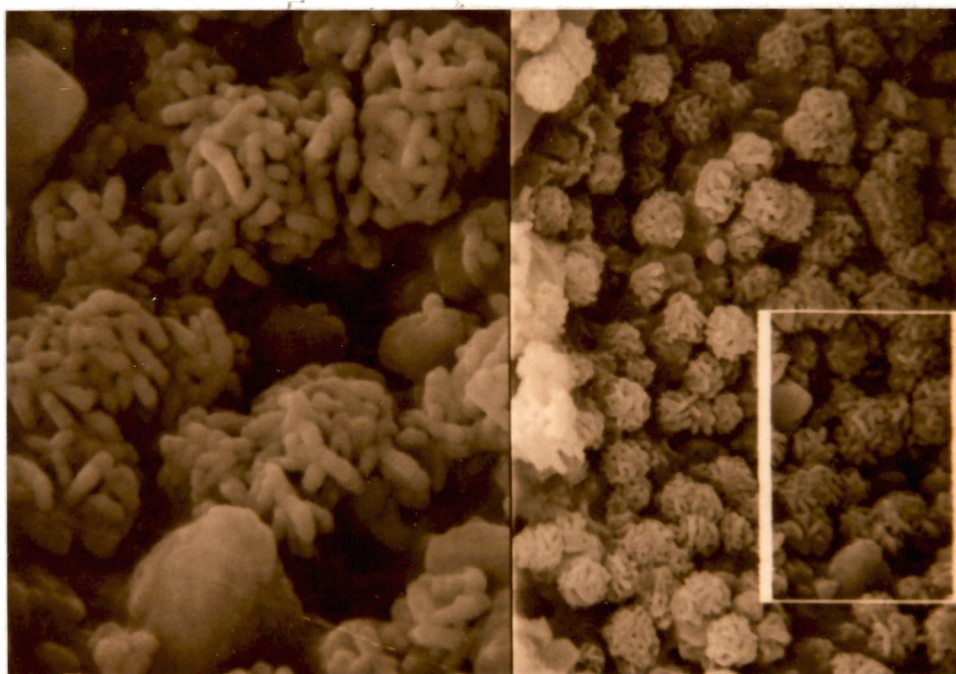


Plate 31. Lepispheres in chert nodule. Core OB-35, 8.00m.
(SEM photomicrograph, 5000x)

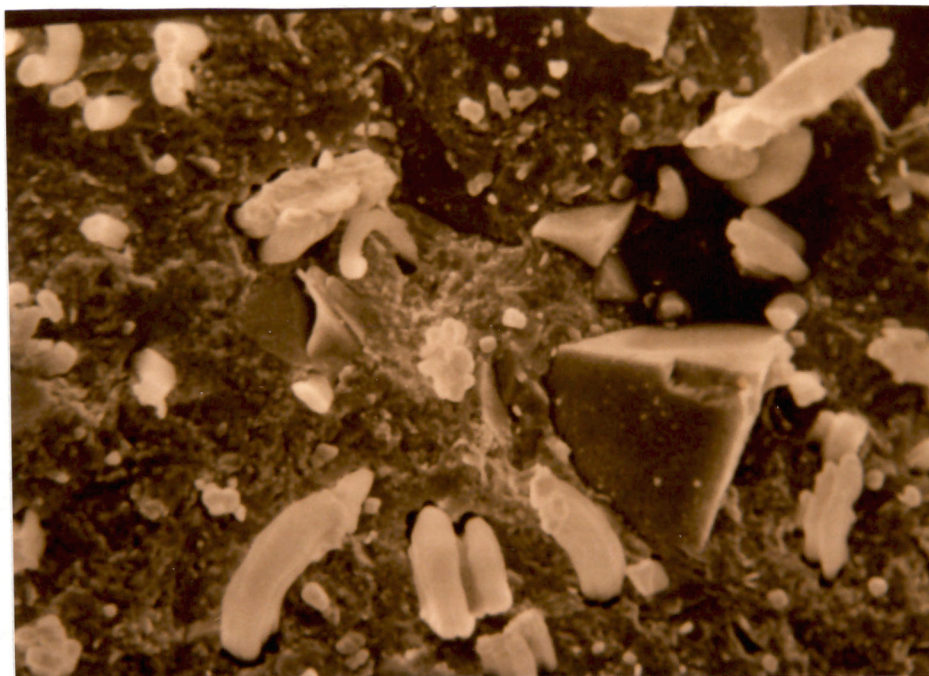


Plate 32. Spagetti-like structures in chert nodule. Notice the euhedral dolomite rhomb floating in the cryptocrystalline silica. Core OB-35, 8.00m. (SEM photomicrograph, 4000x)

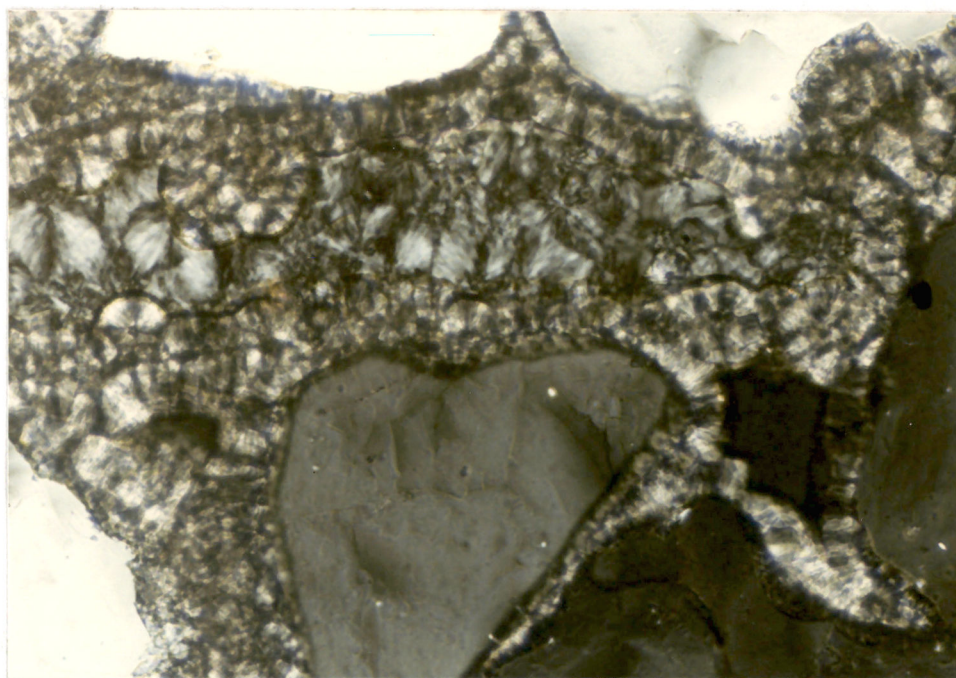


Plate 33. Chalcedonic cement in quartz sandstone. Core OB-58, 7.40m. (crossed nicols, 160x)

Volcanic glass has been postulated to be the source of silica in zeolites at Aurora (Rooney and Kerr, 1964). However, no volcanic glass has been found in the Pungo River Formation, either by Rooney and Kerr (1964) in the Aurora Area or by Lyle (1984) or this study in Onslow Bay. If volcanic glass had ever been present, it already has been altered beyond recognition.

Biogenic silica has been widely documented as a source of silica in deep sea cherts. Diatoms are often abundant in the mud fraction of the Pungo River Formation (Plate 8). The presence of unaltered diatoms, radiolarians, and siliceous sponge spicules in sediment above and below zones of silicification in the Pungo River Formation suggests that biogenic silica was a source of authigenic silica. Sand-sized siliceous microfossils in core OB-47 (seismic unit FPF-2) decrease sharply in abundance above a zone of chert nodules (Fig. 9). Most diatoms and radiolarians are silt-sized or smaller and their abundances in the mud fraction have not yet been carefully charted.

Siliceous organisms fix silica as a highly disordered, nearly amorphous, hydrous silica termed opal-A by Jones and Segnit (1971) and cover their shells with an organic coating. Upon death the organic coating decays, exposing the shells to ocean water where dissolution begins (Lewin, 1961). Siliceous biogenic material that makes it into the sediment column generally goes through a maturation process from opal-A (siliceous ooze) to opal-CT (porcellanite) and ultimately to quartz (chert). Opal-CT is a disordered alpha-cristobalite with some tridymite stacking (Jones and Segnit, 1971). It occurs as 5-10um lepispheres and is the type of silica found in most Cenozoic and some

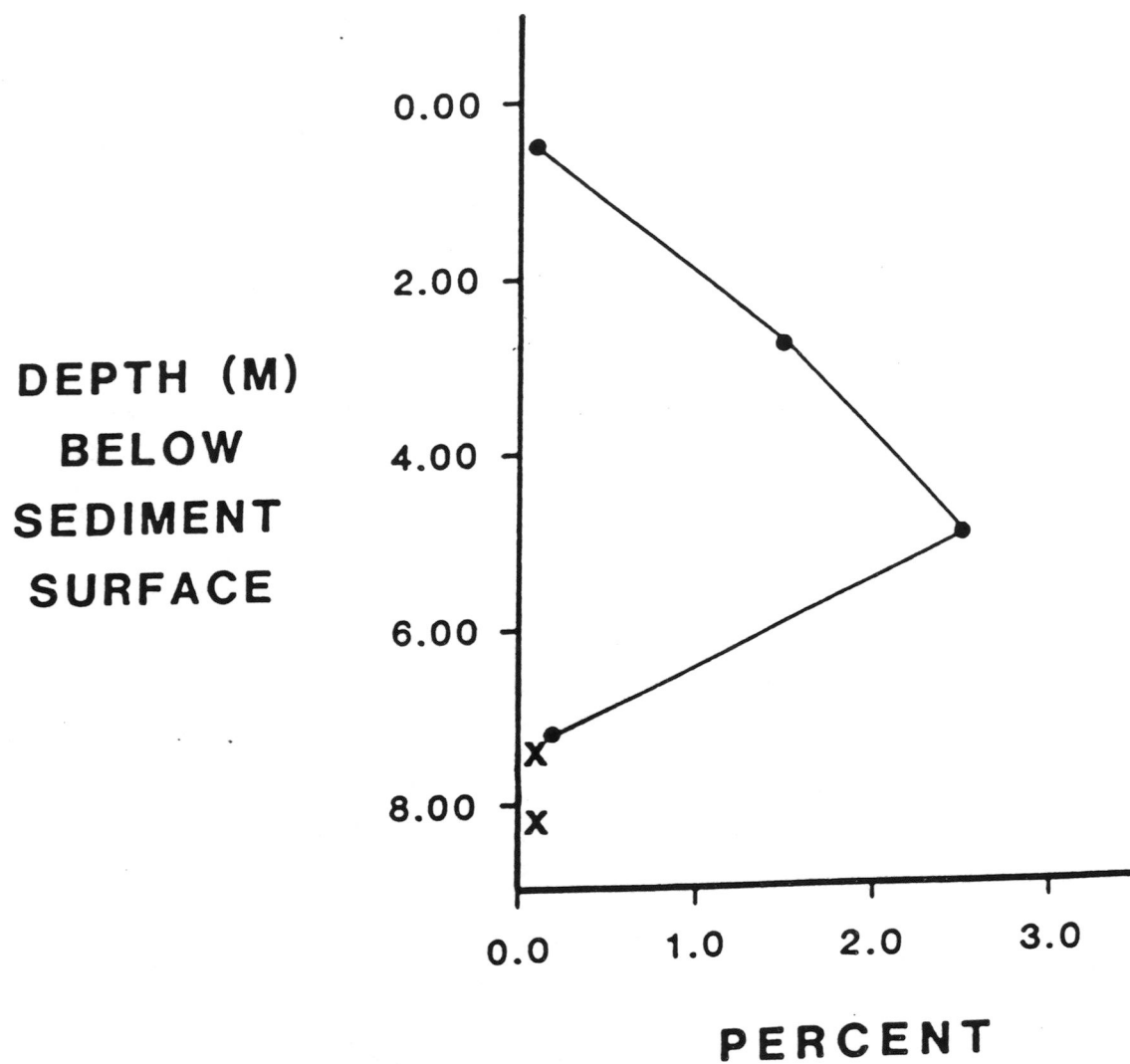


Figure 9. Vertical distribution of sand-size siliceous fossils and chert nodules in FPF-2 (core OB-47). Abundance of siliceous fossils indicated by dots; presence of chert nodules indicated by X.

Mesozoic cherts. Opal-CT lepispheres can be seen in Pungo River cherts (Plates 32 and 33), which are actually "porcellanites" because opal-CT is the predominant type of silica present in the nodules.

Kastner and others (1977) found that transformation of opal-A to opal-CT is faster in pure carbonates than in clayey sediments. This may be one reason why all of the biogenic silica in Pungo River sediments has not been redeposited as authigenic silica. Alkaline conditions are necessary for opal-CT formation (Kastner and others, 1977). Dissolution of carbonates provides alkalinity. As the silicification front moves through the sediment, carbonate is lost to dissolution (Wise and Weaver, 1974). Clays are expelled from the silicified zone and are concentrated along the outside of the silicification front (Lancelot, 1973). Some of the carbonate is reprecipitated beyond the silicification front, cementing the carbonate rock (Wise and Weaver, 1974). This appears to be the mechanism by which Pungo River chert nodules, "floating" in unindurated carbonate sediment, have developed indurated calcium carbonate rinds underlain by clay-rich transition zones.

Zeolites

The zeolite, clinoptilolite, has been found in Pungo River sediments in the Aurora Area (Rooney and Kerr, 1964) and Onslow Bay (Lyle, 1984; Snyder and others, 1984; this study). Lyle (1984) noted that clinoptilolite occurs in the BBF seismic sequence as single euhedral lath-shaped crystals with a broken edge. He suggested reworking of previously deposited zeolites to account for the broken edges of these fine silt-sized crystals.

Foraminiferal tests in unit FPF-2 are usually partially to totally filled with euhedral clinoptilolite crystals and minor pyrite framboids (Plate 34) which have overgrown clinoptilolite crystals (L. Moretz, pers. comm.). Cores OB-27, 63, and 70 show the best examples of zeolite-filled internal molds of foraminifers (Plate 35). No opal-CT lepispheres have been seen associated with the clinoptilolite in foraminifers.

Clinoptilolite occurs in the Atlantic Ocean more frequently with siliceous organisms than with volcanic material (Reich and von Rad, 1979). Common associations are: clinoptilolite with opal-CT in pelagic clays and hemipelagic carbonaceous marls and shales (von Rad and Rosch, 1974); poorly preserved euhedral clinoptilolite and opal-CT lepispheres on the internal walls of radiolarian tests (Berger and von Rad, 1979); euhedral, and less commonly, massive clinoptilolite filling foraminiferal tests after formation of early diagenetic calcite and opal-CT lepispheres (Reich and von Rad, 1979). Reich and von Rad (1979) state that authigenic clinoptilolite can form in sediments if 1) there is a sufficient supply of aluminum, alkali, and alkali-earth ions available and 2) the pore waters are undersaturated with silica with respect to opal-CT. Low silica conditions can occur after precipitation of opal-CT and before opal-CT formation. Negative Eh and pH associated with organic-rich sediments also appears to favor clinoptilolite formation (von Rad and Rosch, 1974).

Known clinoptilolite associations and modes of formation favor a biogenic source of silica for Pungo River zeolites. No siliceous organisms are present in unit FPF-2 where clinoptilolite is found in the

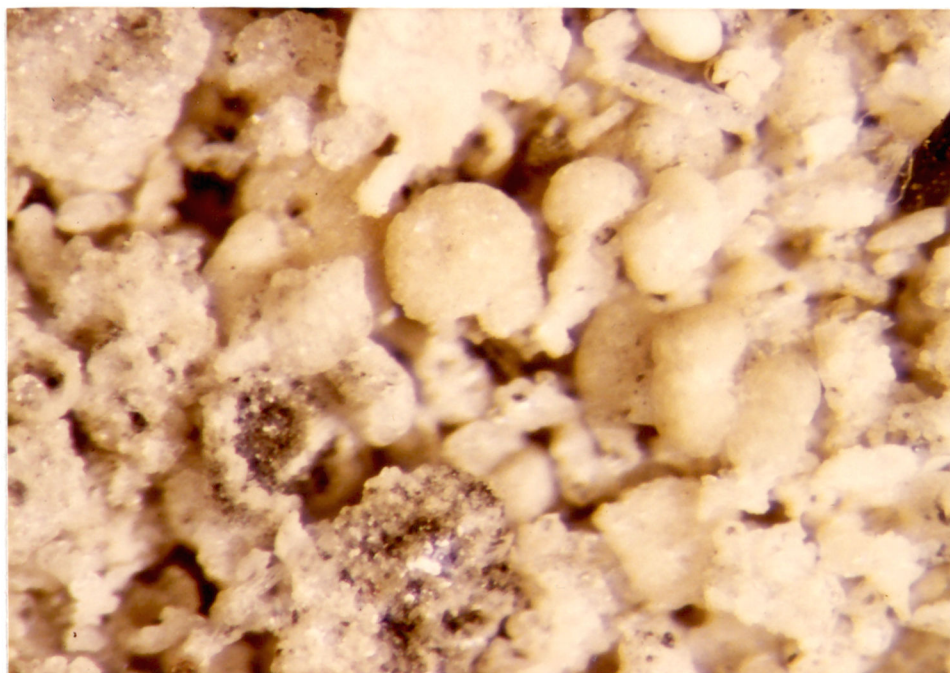


Plate 34. Clinoptilolite filled internal molds of foraminifers. Core OB-27, 1.00-1.25m. (reflected light, 25x)



Plate 35. Clinoptilolite internal mold of a benthic foraminifer (Lenticulina). Core OB-27, 1.75-2.00m. Photo courtesy of Walter Hale. (SEM photomicrograph, 112x)

Frying Pan Area, but are present elsewhere in FPF-2. These sediments are organic-rich, with 2 to 4% organic carbon in the total sediment in core OB-63 (S.R. Riggs, unpub. data). Because no opal-CT lepispheres are associated with the clinoptilolite, it probably formed in sediments with fewer siliceous organisms than those associated with chert. Sodium could have been supplied by marine pore waters while potassium, calcium, and aluminum were supplied by clays. The organic-rich sediments probably caused low Eh and pH conditions to exist. Foraminifers were probably buried while clinoptilolite was growing so that pore waters were poorly oxygenated. Oxygen in the pore waters may have been mostly removed by zeolites, resulting in later growth of pyrite.

Summary

Pungo River sediments show a variety of diagenetic components which have been produced by early marine and fresh water phreatic diagenesis. An interpretation of the relative timing of Pungo River diagenetic processes is summarized in Figure 10. The type and extent of diagenesis in each lithology will be discussed in the description of each seismic sequence.

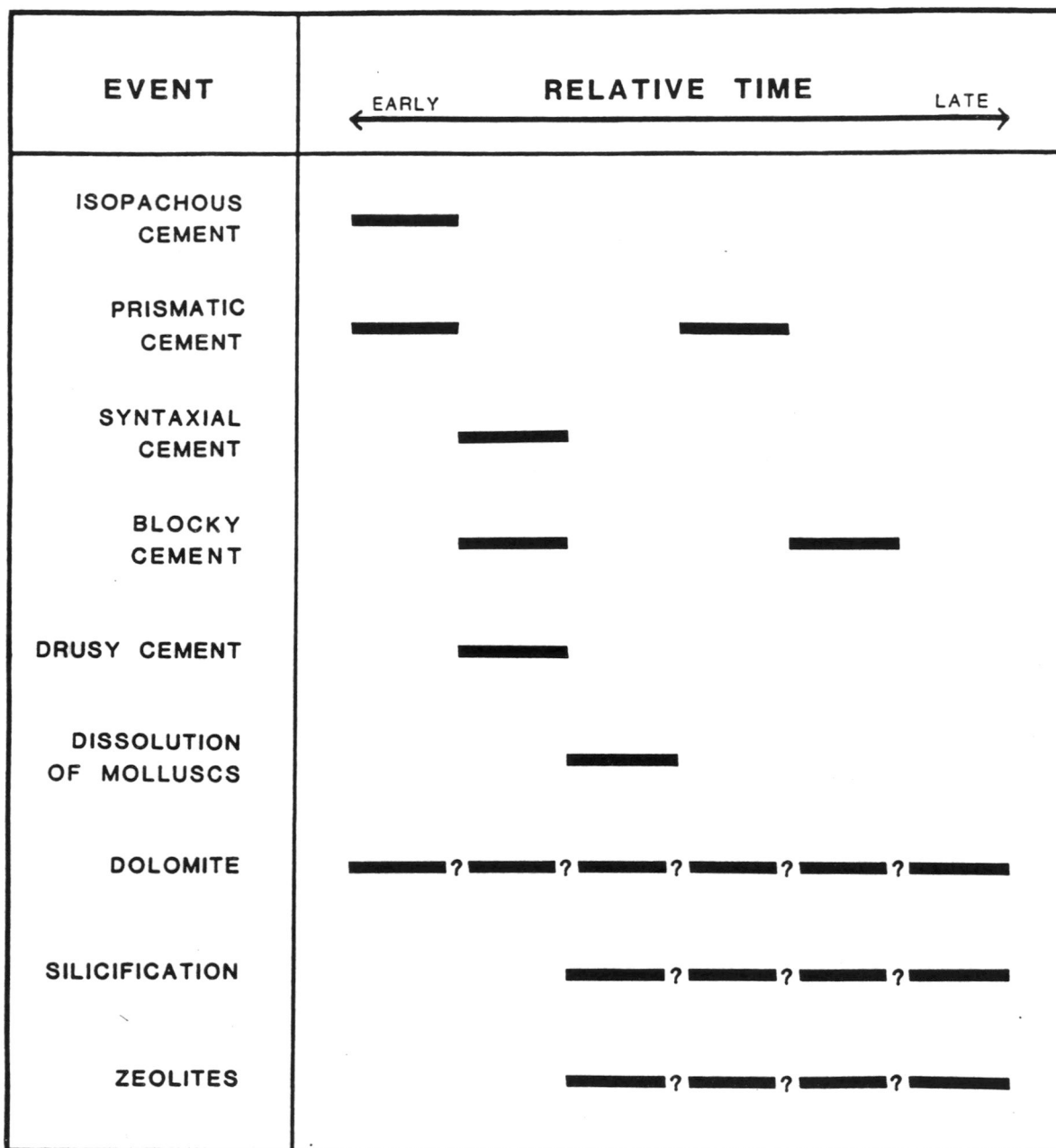


Figure 10. Relative timing of diagenetic events in the Pungo River Formation. Uncertainty of timing is indicated by ?.

LITHOLOGIC DESCRIPTIONS

FPF Sequence

The FPF sequence was deposited during the late Burdigalian (Waters, 1983). Thickness of this sequence ranges from 0 meters at its erosional updip truncation to more than 70 meters in the subsurface (S.W.P. Snyder, 1982). Snyder divided the FPF sequence into six smaller seismic units labeled FPF-1 to FPF-6 from oldest to youngest (Fig. 1).

Table 9 summarizes the average abundance of mineralogical and faunal components in each seismic unit from north to south in Onslow Bay (15m profile; 22m profile; profiles I-8, I-4, I-5; and Frying Pan (FP) Area). Figure 8 locates each seismic unit, all relevant seismic profiles, and the FP area. Average abundance and distribution of the major mineralogical components (carbonate, phosphate, silica, siliciclastic sand and mud) are summarized in Table 10. All data in Tables 9 and 10 is compiled from reflected light microscopy and insoluble residue data (Appendices A and B) except for FPF-1 on the 22m profile (Table 10) which is from thin section data (Appendix C).

Seismic unit FPF-1

Seismic unit FPF-1 was cored along the 22m profile, I-4, and in the Frying Pan Area. The lithology of core OB-134, located on the 22m seismic profile, is a slightly fossiliferous (8.4%), quartz-rich (35.9%), microsparite. It is well indurated and moldic where bivalves have been leached away. Body fossils include barnacles (3.6%), echinoids (2.9%), foraminifers (1.3%), and bivalves (0.6%). No dolomite

Seismic Unit	FPF-1			FPF-2			FPF-3		FPF-4	FPF-5		FPF-6	
Area # of Samples	22m 1	I-4 3	FP 13	22m 2	I-4 7	FP 15	I-4 3	FP 4	15m 3	I-8 3	I-4 4	I-8 4	FP 5
Molluscs	0.6	tr	0.3	0.8	tr	0.1	0.2	tr	19.8	0.3	3.4	2.1	0.1
Barnacles	3.6	tr	2.6	0.1	tr	tr	0.7	tr	3.0	10.6	3.0	11.3	0.1
Bryozoans	0	tr	0.7	tr	tr	tr	tr	tr	0	0.2	0.3	0.5	tr
Echinoids	2.9	0	0.5	0.4	0.1	tr	1.1	tr	0.1	2.3	1.8	5.9	7.7
Ostracods	0	0	tr	tr	0	0	0.1	0	tr	tr	0	0	0.1
B. Forams	1.0	0	14.8	0.1	tr	3.0	1.0	2.0	0.1	0.9	0.6	1.4	8.7
P. Forams	0.3	0	3.7	0.6	tr	1.4	0.2	0.1	0	0.1	0.2	0.3	6.1
Carbonate	0	tr	1.2	0.6	0.1	0.5	2.7	tr	0.3	4.9	2.7	4.9	6.7
Spar	7.1	tr	0.4	0	tr	0.5	3.4	tr	tr	tr	1.6	0.5	1.7
Dolomite	0	0	0.1	0	0	tr	0	tr	0	0.1	0	0.1	0
Chert	0	0	tr	0	0.7	0	0.5	0	0	0	0	0	0
Diatoms	0	0	0	0	0.6	tr	0	tr	0	0	0.1	0	0
Radiolaria	0	0	0	0	tr	tr	0	0.2	0	0	0	0	0
Spicules	0	0	0	0	tr	tr	0	0.1	0	0	tr	0	0
Skel Phos	0	1.5	3.5	0.6	0.3	0.9	0.4	0.1	0.5	0.5	0.2	0.3	1.0
Phosphate	0.3	3.1	16.3	tr	0.4	1.5	0.9	0.3	tr	0.2	0.6	0.5	0.6
Glauconite	0	0	0	0	tr	tr	tr	0	tr	0	tr	tr	0
Opalines	1.0	0	tr	0	tr	tr	0.4	0	0	0.1	tr	tr	0
Other	0	0	tr	0.1	tr	0.3	0	tr	0	0	0	0	0
Qtz Sand	35.9	47.5	17.8	74.1	33.8	16.0	71.3	3.3	65.8	59.5	30.0	45.2	35.6
Insol Mud	0	31.9	19.5	20.5	48.3	64.1	11.8	75.2	6.3	17.1	38.6	7.0	17.3
Carb Mud	47.2	15.9	18.5	2.1	15.5	11.8	5.5	18.7	4.1	3.4	17.0	20.0	14.3
TOTALS	99.9	99.9	99.9	100.0	99.8	100.1	100.1	100.0	100.0	100.2	100.1	100.0	100.0

Table 9. Summary of abundance and distribution of all mineralogical and faunal components (in % of total sediment) in the FPF seismic units. All numbers are based on reflected light microscopy and insoluble residue data (Appendices A and B) except for data on FPF-1 along the 22m profile which is from Appendix C. (Carbonate = unidentifiable carbonate fragments; Spar = calcite cement; Qtz Sand = siliciclastic sand; Insol Mud = insoluble mud; Carb Mud = carbonate mud.)

	Seismic Unit	FPF-1			FPF-2			FPF-3		FPF-4	FPF-5		FPF-6	
	Area # of Samples	22m 1	I-4 3	FP 13	22m 2	I-4 7	FP 15	I-4 3	FP 4	15m 3	I-8 3	I-4 4	I-8 4	FP 5
CARBONATE CONSTITUENTS	Fossils	8.4	tr	23.8	2.6	0.2	5.0	6.0	2.1	23.3	19.3	12.0	26.4	29.5
	Spar	7.1	tr	0.4	0	tr	0.5	3.4	tr	tr	tr	1.6	0.5	1.7
	Dolomite	0	0	0.1	0	0	tr	0	tr	0	0.1	0	0.1	0
	Carb Mud	47.2	15.9	18.5	2.1	15.5	11.8	5.5	18.7	4.1	3.4	17.0	20.0	14.3
MAJOR CONSTITUENTS	Carbonate	62.7	15.9	42.8	4.7	15.7	17.3	14.9	20.8	27.4	22.8	30.6	47.0	45.5
	Silica	0	0	tr	0	1.3	tr	0.5	0.3	0	0	0.1	0	0
	Phosphate	0.3	4.6	19.8	0.6	0.7	2.4	1.3	0.4	0.5	0.7	0.8	0.8	1.6
	Others	1.0	0	tr	0.1	tr	0.3	0.4	tr	0	0.1	tr	tr	0
	Qtz Sand	35.9	47.5	17.8	74.1	33.8	16.0	71.3	3.3	65.8	59.5	30.0	45.2	35.6
	Insol Mud	0	31.9	19.5	20.5	48.3	64.1	11.8	75.2	6.3	17.1	38.6	7.0	17.3
	TOTALS	99.9	99.9	99.9	100.0	99.8	100.1	100.2	100.0	100.0	100.2	100.1	100.0	100.0

Table 10. Summary from Table 9 of abundance and distribution of major mineralogical components (in % of total sediment) in FPF seismic units. (Spar = calcite cement; Qtz Sand = siliciclastic sand; Insol Mud = insoluble mud; Carb Mud = carbonate mud.)

is present.

In central Onslow Bay along seismic profile I-4, unit FPF-1 is a phosphatic (4.6%), muddy (47.8%), quartz sand (Table 6). Carbonate is present only as 15.9% calcite mud and as trace percentage of bivalves, barnacles, and bryozoans.

In the Frying Pan Area, FPF-1 grades up-section from a quartz-rich (17.8%), foraminiferal (18.5%), muddy (38.0%), phosphorite (Table 9) to a phosphatic (3.6%), quartz-rich (6.9%), fossiliferous (41.6%) biomicrosparite (Table 11). In core OB-115, the most extensively sampled of all Frying Pan FPF-1 cores, fossils and matrix increase up-section while siliciclastic sand and phosphate decrease (Fig. 11).

The basal part of unit FPF-1 in the Frying Pan Area contains an average of 18.5% carbonate mud in the form of calcite or calcite with dolomite. Dolomite averages 0.1% in the very fine sand fraction. Predominant fossils are benthic foraminifers (14.8%), planktonic foraminifers (3.7%), and barnacles (2.6%). All barnacles and most bryozoans are rounded, stained gray, and appear to have been transported. Foraminifers and echinoids are well preserved and appear not to have undergone transportation. Plate 2 shows the washed sand fraction of basal FPF-1 (core OB-115).

The biomicrosparite "cap" contains a diverse assemblage of fossils including barnacles (13.7%), bryozoans (8.3%), bivalves (8.3%), echinoids (5.3%), and benthic foraminifers (2.2%). Planktonic foraminifers, ostracods, crab claws, dasycladacean and coralline algae are present in abundances of less than 0.3% (Table 11). Plate 4 is a thin section through the carbonate cap in core OB-115.

Sample	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Alg	Carb	Spar	Mic	Phos	Oth	Qtz
20-0.50	4.9	18.1	2.0	4.3	0.3	0.8	0	0.3	10.6	4.0	43.6	3.7	1.7	5.7
64-0.75	9.6	19.4	4.8	4.1	0.3	1.3	0.3	0	2.2	1.3	43.6	2.5	0	10.5
64-1.75	9.6	9.6	13.0	4.6	0.3	1.9	0	0	1.9	0.3	50.2	1.5	0	7.1
64-2.75	4.8	4.1	0	4.1	0	4.1	0.7	0	2.8	0	68.8	1.4	1.0	8.2
114-2.10	8.7	10.0	6.0	8.0	0	1.3	0	0	4.0	2.3	56.3	0	0	3.3
115-1.50	10.7	13.9	23.7	6.0	0	4.0	0.3	0	0.9	1.3	36.8	0.9	0	1.6
115-2.50	11.4	10.8	13.3	2.2	0.3	4.0	0.3	0	2.2	1.1	45.4	2.8	0	6.2
115-3.00	11.5	9.0	8.7	7.4	0.6	1.5	0	0.3	4.3	1.5	44.3	5.9	0	5.3
115-4.25	8.2	23.1	3.8	6.0	0.3	1.3	0.3	0.4	2.2	2.8	34.8	8.8	0	8.2
115-4.75	4.0	19.0	7.7	6.6	0	2.2	0.4	0	0	1.7	36.4	8.4	0	13.2
Average	8.3	13.7	8.3	5.3	0.2	2.2	0.2	0.1	3.1	1.6	46.0	3.6	0.3	6.9

Table 11. Average composition (in % of the total sediment) of carbonate cap rocks from seismic sequence FPF-1. (Moll = molluscs; Barn = barnacles; Bry = bryozoans; Ech = echinoids; Ost = ostracods; Bf = benthic foraminifers; Pf = planktonic foraminifers; Alg = algae; Carb = unidentifiable carbonate fragments; Spar = calcite cement; Mic = microspar; Phos = phosphate; Oth = other authigenic minerals; Qtz = siliciclastic sand.)

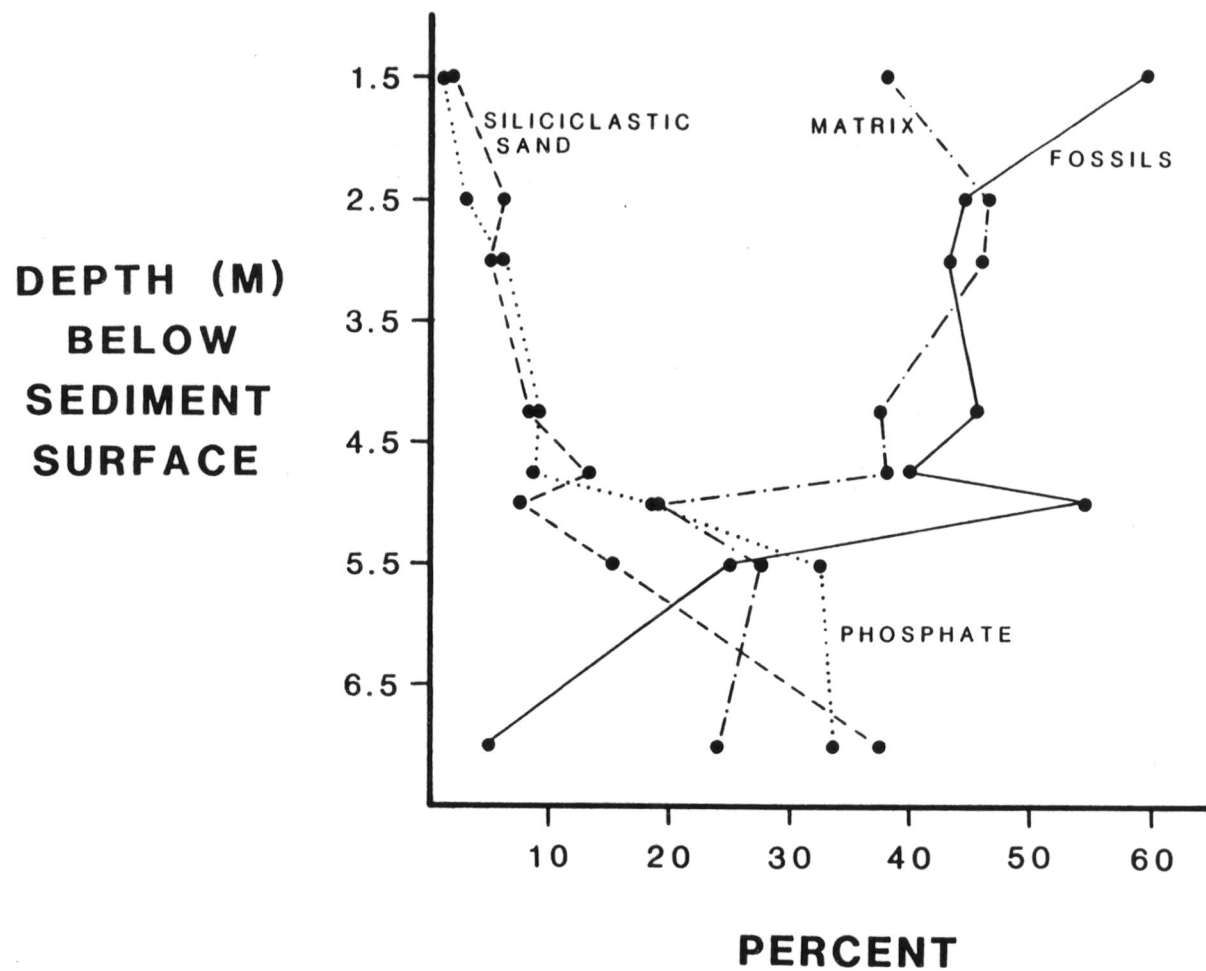


Figure 11. Vertical distribution of major mineralogical components in FPF-1 (core OB-115).

The age of the carbonate cap on FPF-1 is controversial. I interpret it to be Miocene for two reasons: 1) the contact between the biomicrosparite and underlying phosphorite in core OB-115 is gradational over a vertical area of approximately 30cm, and 2) the same benthic foraminiferal assemblage is present above and below the gradational contact.

Figures 12 and 13 show the relative abundance and distribution of the carbonate and siliciclastic components laterally within the FPF-1 seismic sequence, excluding the carbonate cap rocks on FPF-1. Carbonate mud and fossils show an inverse relationship with siliciclastic sand and insoluble mud. Notice that only the biomicrosparite cap on Frying Pan phosphorites and the microsparite along the 22m profile are really carbonate sediments (contain more than 50% total carbonate).

Seismic unit FPF-2

Seismic unit FPF-2 was cored in several parts of Onslow Bay. The Miocene section of core OB-110 located on the 22m profile in northern Onslow Bay is a slightly fossiliferous (2.6%), muddy (22.6%), quartz sand. Carbonate mud (2.1%) is present only as calcite. Bivalves (0.8%) and echinoids (0.4%) are the predominant fossils and are very well preserved.

In central part of Onslow Bay (seismic profile I-4) FPF-2 is a quartz-rich (33.8%), mud. Calcareous fossils are present as less than 0.3% of the total sediment. Dolomite (15.5%) is present in the mud but is not seen in the sand fraction. Sand-sized siliceous fossils constitute 0.2% of the total sediment and are most likely more abundant

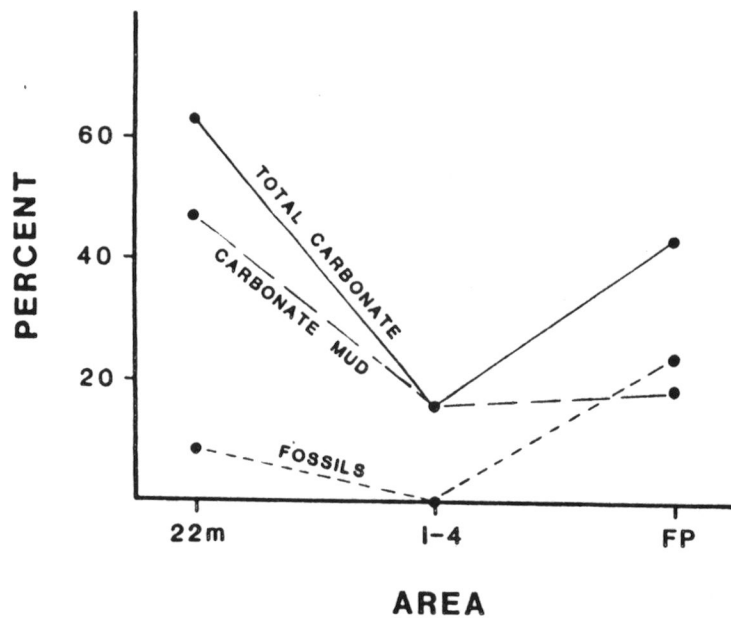


Figure 12. Lateral distribution, from north (22m) to south (FP), of carbonate components in FPF-1.

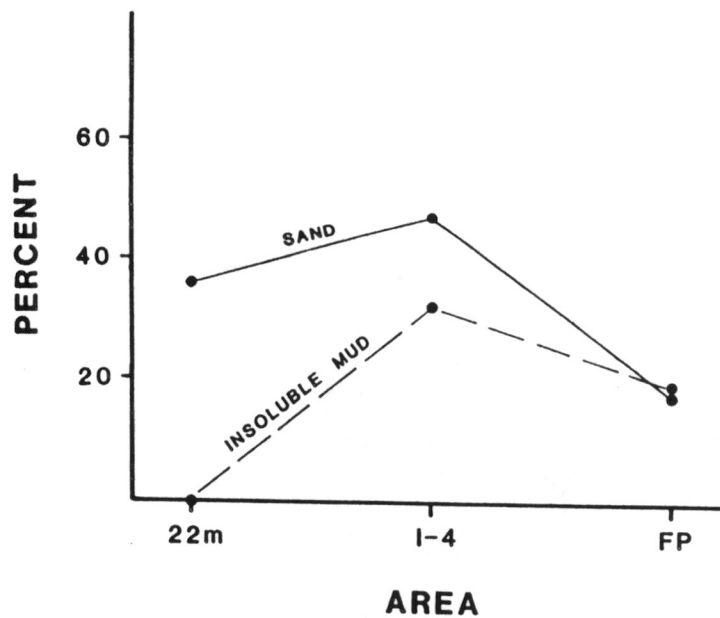


Figure 13. Lateral distribution, from north (22m) to south (FP), of siliciclastic components in FPF-1.

in the mud fraction because most diatoms, radiolarians, and sponge spicules are smaller than 63um. Chert nodules are also present in core OB-47. A sharp decrease in siliceous fossils found in the sand-fraction above chert nodules in OB-47 (Fig. 9) and supports the theory of a biogenic silica source for chert nodule formation.

FPF-2 in the Frying Pan Area is a phosphatic (2.4%), foraminiferal (4.4%), quartz-rich (16.0%), mud. Calcite and dolomite are both present as carbonate mud (11.8%). Another 0.3% of the total sediment is composed of clinoptilolite as sand-sized internal molds of planktonic and benthic foraminifers. In cores OB-27, 63, and 70 (Plates 34 and 35) clinoptilolite is present in almost all foraminiferal chambers. Foraminifers are very well preserved in the bottom of core OB-27 but have undergone increasing dissolution up-section, until at the top of the core foraminifers are nearly all destroyed and sediments are dominated by internal molds (Fig. 14).

Total carbonate content in FPF-2 increases slightly from northern to southern Onslow Bay (Fig. 15). Insoluble mud also increases from the 22m profile to the Frying Pan Area (Fig. 16) while siliciclastic sand decreases. Calcareous fossils and carbonate mud show an inverse relationship with each other (Fig. 15).

Seismic unit FPF-3

In central Onslow Bay FPF-3 is a slightly phosphatic (1.3%), slightly fossiliferous (6.0%), muddy (17.3%), quartz sand. Predominant fossils include echinoids (1.1%), benthic foraminifers (1.0%), and barnacles (0.7%). Carbonate mud (5.5%) consists of dolomite and calcite.

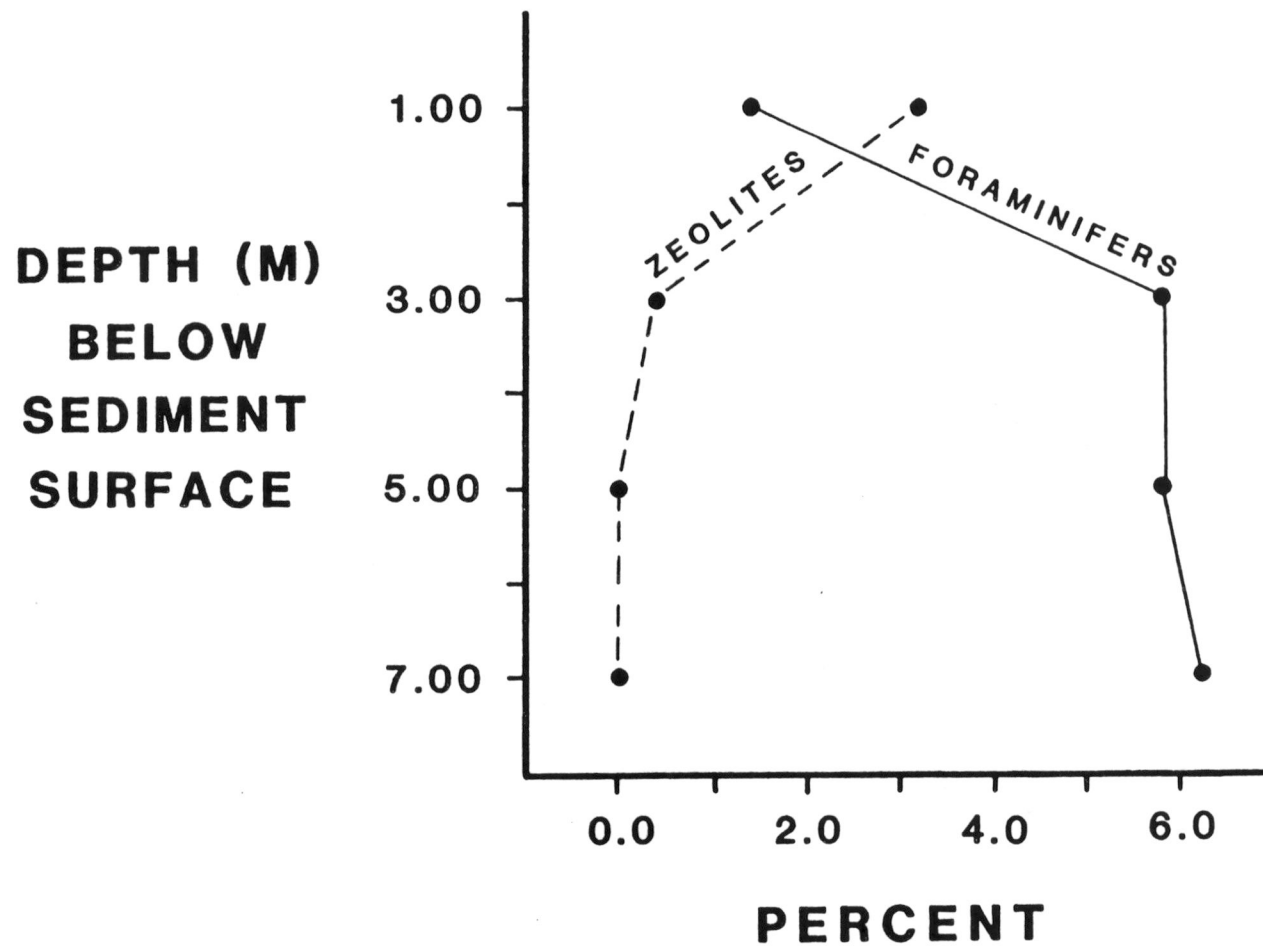


Figure 14. Vertical distribution of zeolites and foraminifers in FPF-2 (core OB-27).

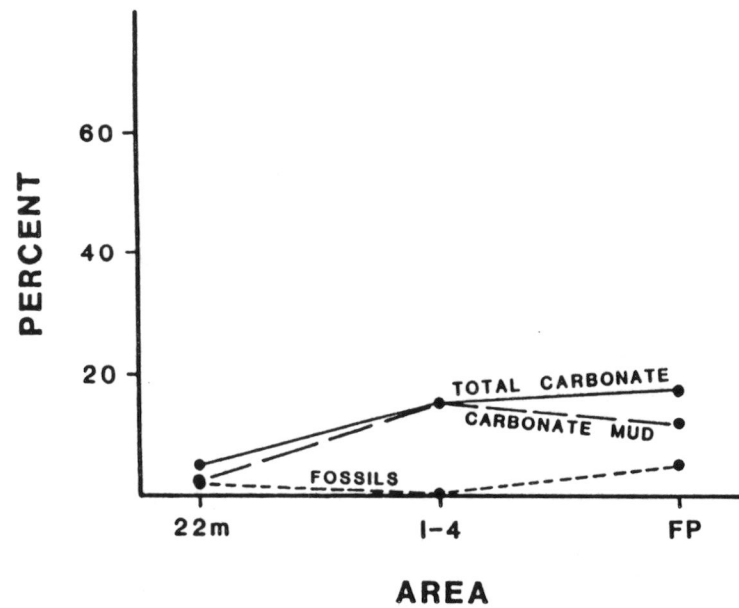


Figure 15. Lateral distribution, from north (22m) to south (FP), of carbonate components in FPF-2.

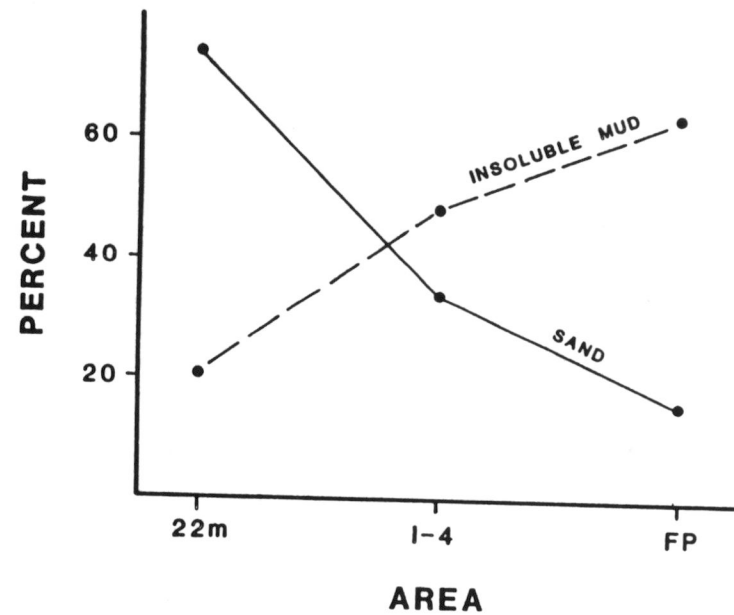


Figure 16. Lateral distribution, from north (22m) to south (FP), of siliciclastic components in FPF-2.

FPF-3 in the Frying Pan Area is a mud containing very minor phosphate (0.4%) and quartz sand (3.7%). Sand-sized radiolarians, siliceous sponge spicules, and diatoms constitute 0.2% of the total sediment. The mud is probably diatomaceous because abundant diatoms were noted in thin section from core OB-17 at 3.00 m (Plate 9). Benthic foraminifers (2.0%) are the predominant calcareous fossils and only trace percentages of other fossils are present. The zeolite, clinoptilolite, partially fills foraminiferal chambers. Carbonate mud (18.7%) is present as dolomite or dolomite with calcite. In the one thin section made of this lithology silt-sized dolomite rhombs constitute 17.3% of the sediment. Dolomite in FPF-3 is pale yellow compared to the clear dolomite in other sediments.

Total carbonate content in FPF-3 is about the same from seismic profile I-8 and the Frying Pan Area (Fig. 17). Calcareous fossils and siliciclastic sands decrease while insoluble mud and carbonate mud increase from central to southern Onslow Bay (Figs. 17 and 18).

Seismic unit FPF-4

FPF-4, cored only in northern Onslow Bay along the 15m profile, has an average composition of muddy (10.4%), fossiliferous (23.3%), quartz sand. Carbonate in the mud fraction is present only as calcite (4.1%). The predominant fossils are bivalves (19.8%); barnacles (3.0%) are secondary. All of the fossils are very well preserved.

Seismic unit FPF-5

FPF-5, cored along seismic profile I-8, is a fossiliferous (19.3%), muddy (20.5%), quartz sand. Carbonate mud (3.4%) is present but is not

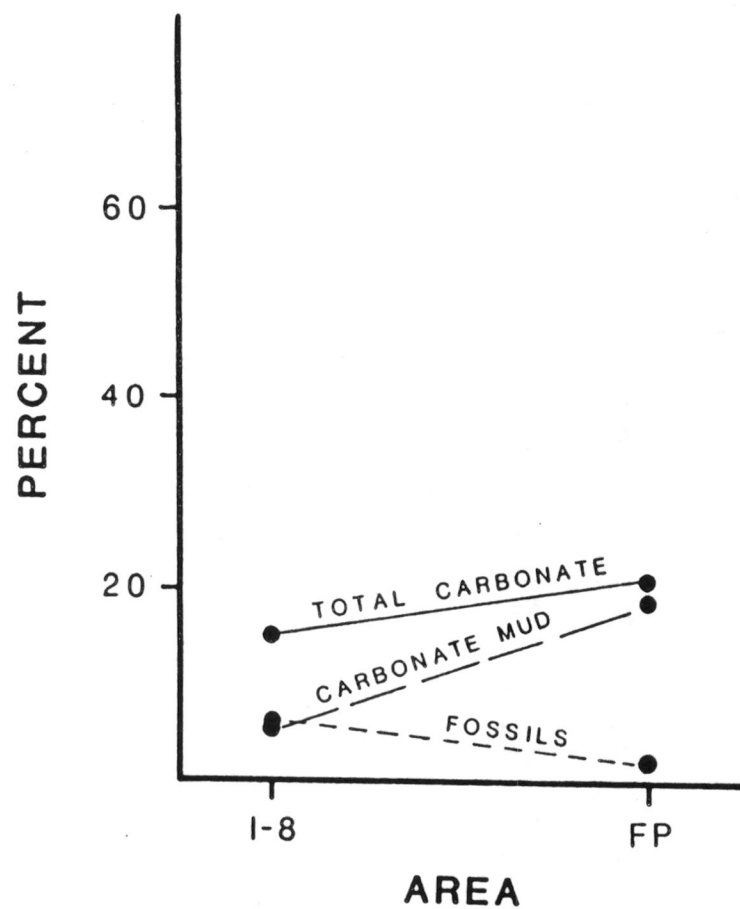


Figure 17. Lateral distribution, from north (I-8) to south (FP), of carbonate components in FPF-3.

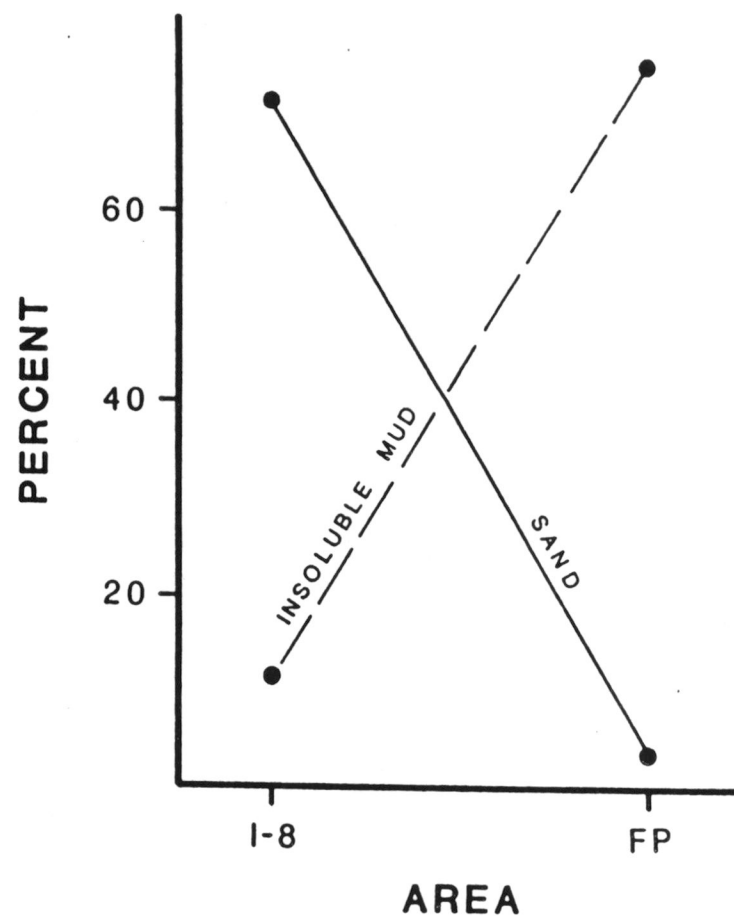


Figure 18. Lateral distribution, from north (I-8) to south (FP), of siliciclastic components in FPF-3.

abundant enough to produce x-ray diffraction peaks. Predominant fossils are barnacles (10.6%) and echinoids (2.3%). Dolomite (0.1%) is present in the very fine sand and coarse silt fractions and can be seen partially encased by syntaxial cement on echinoid fragments.

Along seismic profile I-4, core OB-50 penetrated FPF-5, a fossiliferous (12.0%), quartz-rich (30.0%), mud. Calcite and dolomite are present in the mud fraction (17.0%). Molluscs (3.4%), barnacles (3.0%), and echinoids (1.8%) are the major fossil components. Diatoms, radiolarians, and siliceous sponge spicules are present in the bottom part of the core. Zeolites are present in foraminiferal chambers at the bottom of the core.

Total percent carbonate in FPF-5 increases slightly from seismic profile I-8 to I-4 (Fig. 19). Fossils and siliciclastic sand both decrease while both insoluble mud and carbonate mud increase from I-8 to I-4 (Figs. 19 and 20).

Seismic unit FPF-6

Along seismic profile I-8 in central Onslow Bay, FPF-6 consists of fossiliferous (26.4%), muddy (27.0%), quartz sand. Predominant fossils are barnacles (11.3%), echinoids (5.9%), bivalves (2.1%), foraminifers (1.7%), and bryozoans (0.5%). Dolomite and calcite are both present in the mud-sized carbonate fraction (20.0%).

In the Frying Pan Area, FPF-6 is a fossiliferous (31.2%), muddy (31.6%), quartz sand. The mud-sized carbonate fraction (14.3%) is composed of both calcite and dolomite. Predominant fossils include benthic foraminifers (8.7%), echinoids (7.7%), and planktonic

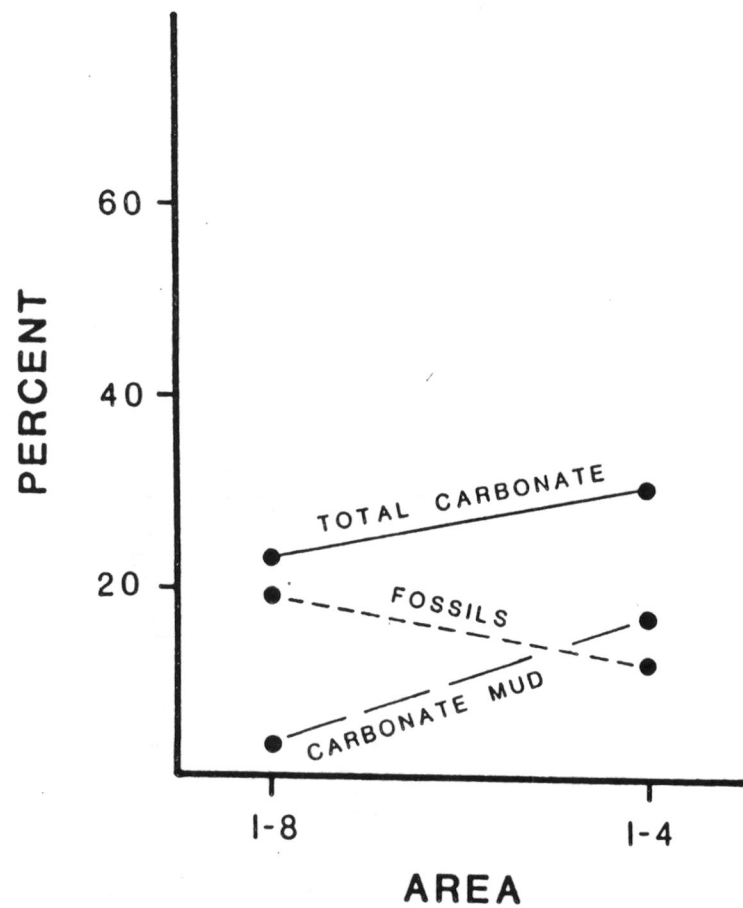


Figure 19. Lateral distribution, from north (I-8) to south (I-4), of carbonate components in FPF-5.

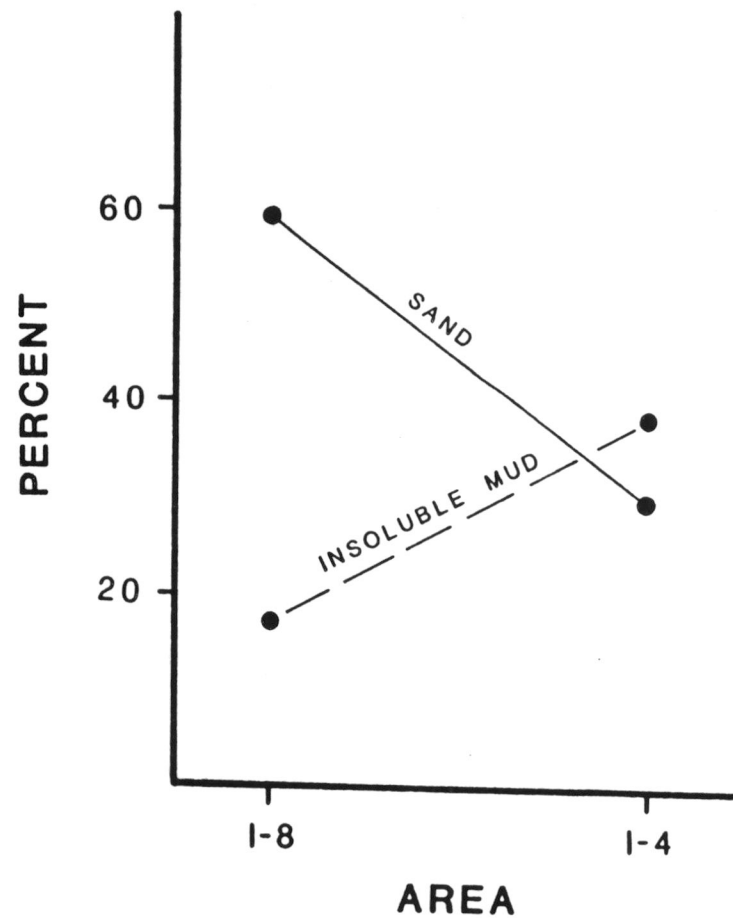


Figure 20. Lateral distribution, from north (I-8) to south (I-4), of siliciclastic components in FPF-5.

foraminifers (6.1%) (Plate 6). Foraminifers have partial internal molds of loosely packed clinoptilolite crystals. Zeolites are present in the center of echinoid spines, either replacing calcite or precipitating within the spongy spine structure, in core OB-96 at 5.50 m. The more poorly preserved the echinoid spines, the more zeolites are present.

Also in FPF-6 in the Frying Pan Area, core OB-102 has two beds of echinoid-foraminiferal biosparite (Plate 11), 10cm and 5cm thick at 7.00 m and 7.75 m, respectively. Biosparite beds are in sharp contact with the overlying and underlying sediment. Benthic foraminifers (31.2%), planktonic foraminifers (22.2%), and echinoids (8.3%) are the predominant fossils, with lesser abundances of molluscs (1.7%), barnacles (1.5%), and ostracods (0.2%). Foraminifers are unabraded and unbroken, suggesting no transportation. These biosparites are well cemented by syntaxial cement from the echinoids and radial rim cements on the other fossils. Noncarbonate mud is sparse (6.0%), as is microspar (0.5%).

Figures 21 and 22 show the lateral distribution of carbonate and siliciclastic components in seismic unit FPF-6. Fossils and carbonate mud show an inverse relationship as do siliciclastic sand and insoluble mud. Total carbonate content remains almost constant.

Summary

The FPF sequence is predominated by siliciclastic sedimentation and authigenic mineralization. Total carbonate content in each of the FPF seismic units generally increases slightly toward the Frying Pan Area of Onslow Bay (Fig. 23). Sharp variation of carbonate content of FPF-1

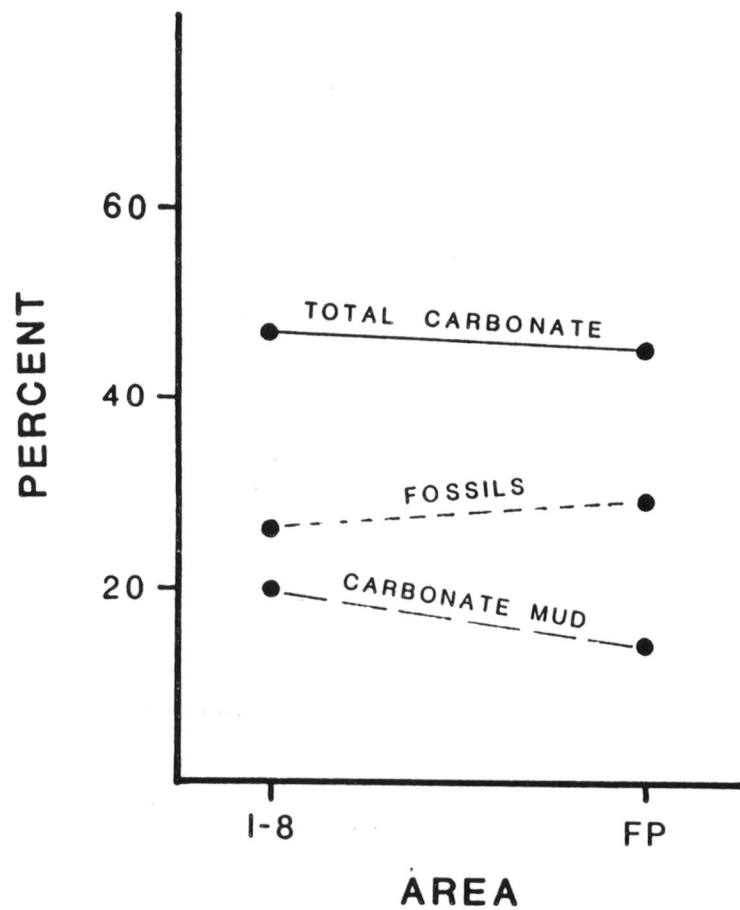


Figure 21. Lateral distribution, from north (I-8) to south (FP), of carbonate components in FPF-6.

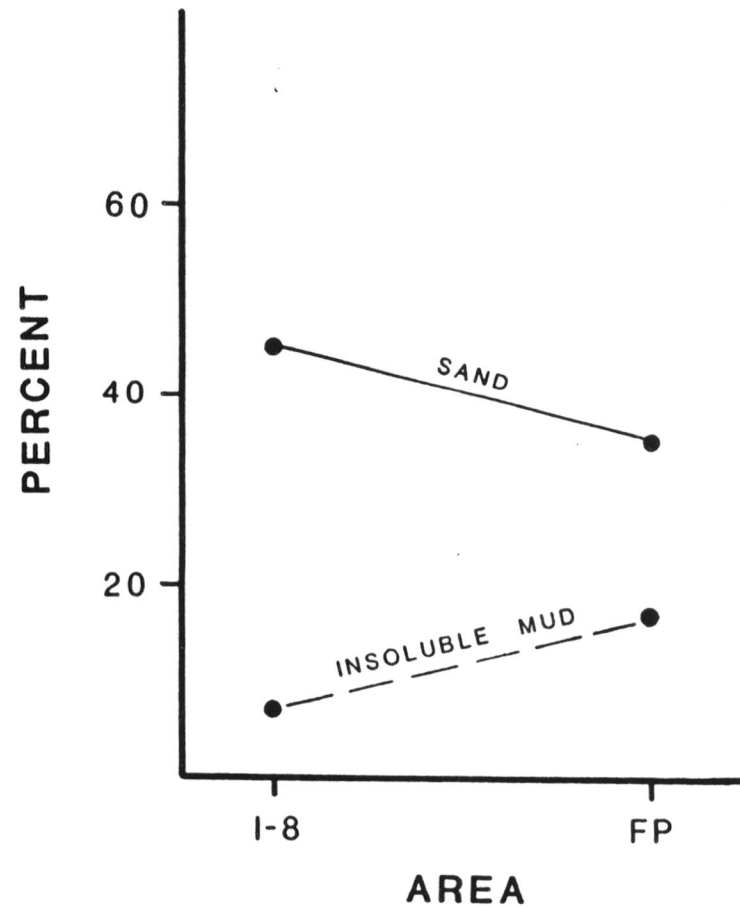


Figure 22. Lateral distribution, from north (I-8) to south (FP), of siliciclastic components in FPF-6.

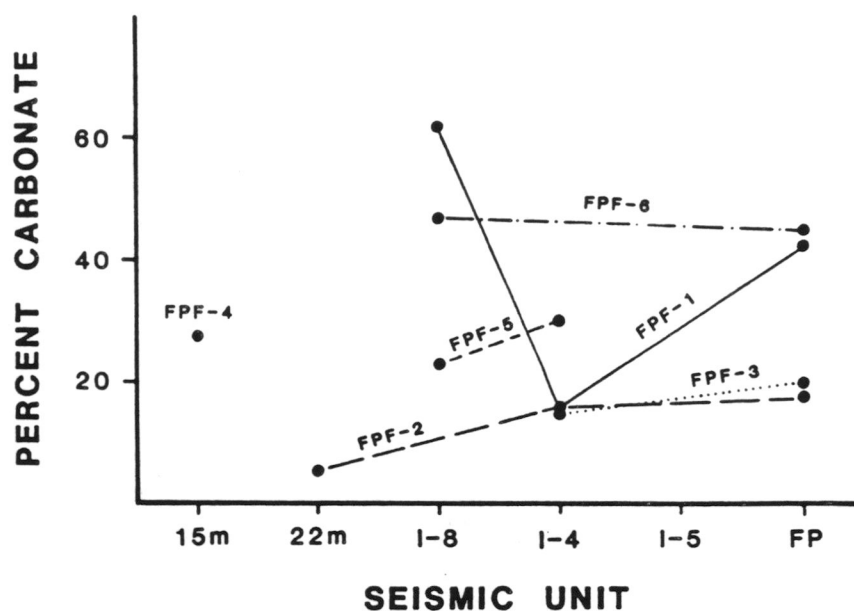


Figure 23. Lateral distribution of carbonate components in each FPF seismic unit.

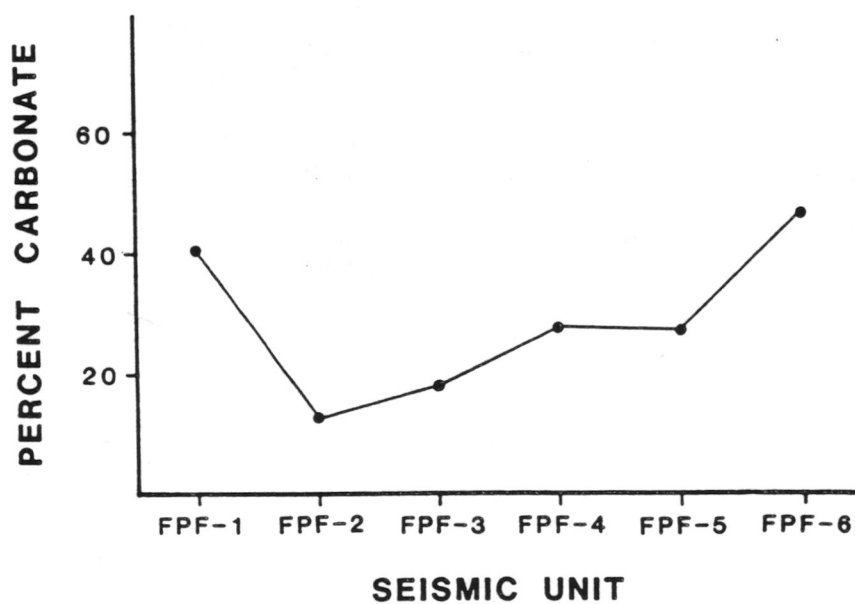


Figure 24. Average carbonate content of the FPF sequence.

might reflect the carbonate cap was sampled along the 22m profile, whereas along seismic profile I-4 the basal siliciclastic facies was sampled. Figure 24 shows the relative abundance of carbonate sediments in each FPF seismic unit. Carbonate sediment decreases from FPF-1 to FPF-2 but increases from FPF-2 to FPF-6. The overall lithology of FPF seismic units contains less than 50% carbonate.

AF Sequence

The AF seismic sequence in Onslow Bay was deposited during the Langhian (Moore, in prep.; Steinmetz in S.W.P. Snyder, 1982). It ranges in thickness from 0 m at its erosional updip truncation to over 250 m at the edge of the continental shelf (S.W.P. Snyder, 1982). The AF sequence thickens abruptly from 20 m to 40 m across an erosional scarp, the White Oak Lineament, with over 25 meters of relief in northern Onslow Bay (Fig. 6). Seismic data suggest that the AF sequence is characterized by prograding clinoforms, a pattern indicating offshore transportation and deposition of shelf edge sediments (S.W.P. Snyder, 1982).

Fourth-order seismic units that compose the AF sequence are labeled AF-1 to AF-4 from oldest to youngest (Fig. 1). Sediments of the AF sequence were cored only in northern and central Onslow Bay. Average abundance of mineralogical and faunal components in each seismic unit for all relevant seismic profiles (15m, 22m, I-8, I-4, and I-5; see Figure 8 for location map) are presented in Table 12. Average abundance and distribution of major mineralogical components (carbonate, phosphate, silica, siliciclastic sand, and mud) are summarized in Table 13. Tables 12 and 13 are compiled from reflected light microscopy and insoluble residue data (Appendices A and B).

Seismic unit AF-1

In northern Onslow Bay (along the 15m profile) AF-1 is a quartz-rich (12.5%), fossiliferous (22.4%), carbonate mud. Total carbonate content in this unit averages 55.5%. Only 0.1% of the total

Seismic Unit	AF-1					AF-2		AF-3		AF-4
Profile # of Samples	15m 6	22m 4	I-8 5	I-4 3	I-5 2	22m 2	I-5 2	15m 2	I-5 3	15m 14
Molluscs	2.4	tr	0.7	tr	tr	2.7	tr	1.4	9.8	9.3
Barnacles	5.4	tr	0.1	tr	tr	31.6	tr	24.4	5.7	32.4
Bryozoans	0.5	0	tr	0	0	0.2	0	0.6	1.5	4.6
Echinoids	3.6	tr	0.1	0.3	tr	2.1	0.1	6.3	3.4	0.8
Ostracods	0.8	0	0	0	0	0	0	0.2	0	tr
B. Forams	3.1	tr	tr	tr	tr	7.2	0	1.1	0.9	0.6
P. Forams	0.4	0	tr	0	0	2.5	0	0.4	0.1	0.1
Carbonate	6.2	tr	1.7	0.4	tr	8.8	tr	6.1	9.8	5.6
Spar	tr	1.9	0.8	0.7	0.8	11.8	0	4.0	4.3	4.6
Dolomite	0.1	0.1	tr	0	0	0	0	tr	0	0.2
Chert	tr	0.2	0	0	0	0	0	0	0	0
Diatoms	0.7	0	0	0	0	0	0	0	0	0
Radiolaria	tr	0	0	0	0	0	0	0	0	0
Spicules	tr	0	tr	0	0	0	0	0	0	tr
Skel Phos	0.2	0.4	0.1	0.5	tr	0.3	0.1	tr	tr	tr
Phosphate	0.2	0.6	0.3	1.8	0.5	0.4	0.1	0.5	0.1	0.1
Glauconite	tr	tr	0	0	0	0.2	0	tr	0	0
Opaques	tr	tr	tr	0	0	0	0	0.1	0	tr
Other	tr	tr	tr	tr	0	0	0	0	0	0.1
Qtz Sand	12.5	54.7	61.6	68.0	91.7	16.2	48.6	22.1	33.2	1.2
Insol Mud	30.7	13.6	15.8	20.3	5.1	7.8	36.4	7.5	8.5	8.1
Carb Mud	33.0	28.4	18.5	7.8	1.8	8.2	14.7	25.4	22.7	32.3
TOTALS	99.8	99.9	99.7	99.8	99.9	100.0	100.0	100.1	100.0	100.0

Table 12. Summary of abundance and distribution of all mineralogical and faunal components (in % of total sediment) in the AF seismic units. All numbers are based on reflected light microscopy and insoluble residue data (Appendices A and B). (Carbonate = unidentifiable carbonate fragments; Spar = calcite cement; Qtz Sand = siliciclastic sand; Insol Mud = insoluble mud; Carb Mud = carbonate mud.)

	Seismic Unit	AF-1					AF-2		AF-3		AF-4
	Profile # of Samples	15m 6	22m 4	I-8 5	I-4 3	I-5 2	22m 2	I-5 2	15m 2	I-5 3	15m 14
CARBONATE CONSTITUENTS	Fossils	22.4	tr	2.6	0.7	tr	55.1	0.1	40.5	31.2	53.4
	Spar	tr	1.9	0.8	0.7	0.8	11.8	0	4.0	4.3	4.6
	Dolomite	0.1	0.1	tr	0	0	0	0	tr	0	0.2
	Carb Mud	33.0	28.4	18.5	7.8	1.8	8.2	14.7	25.4	22.7	32.3
MAJOR CONSTITUENTS	Carbonate	55.5	30.4	21.9	9.2	2.6	75.1	14.8	69.9	58.2	90.5
	Silica	0.7	0.2	tr	0	0	0	0	0	0	tr
	Phosphate	0.4	1.0	0.4	2.3	0.5	0.7	0.2	0.5	0.1	0.1
	Others	tr	tr	tr	tr	0	0.2	0	0.1	0	0.1
	Qtz Sand	12.5	54.7	61.6	68.0	91.7	16.2	48.6	22.1	33.2	1.2
	Insol Mud	30.7	13.6	15.8	20.3	5.1	7.8	36.4	7.5	8.5	8.1
	TOTALS	99.8	99.9	99.7	99.8	99.9	100.0	100.0	100.1	100.0	100.0

Table 13. Summary from Table 12 of abundance and distribution of major mineralogical components (in % of total sediment) in AF seismic units. (Spar = calcite cement; Qtz Sand = siliciclastic sand; Insol Mud = insoluble mud; Carb Mud = carbonate mud.)

sediment is sand-sized dolomite. Both calcite and dolomite are present in the mud fraction (33.0%). A diverse assemblage of fossils including barnacles (5.4%), echinoids (3.6%), foraminifers (3.5%), molluscs (2.4%), smooth and ornamented ostracods (0.8%), and bryozoans (0.5%) are present (Plates 5 and 8). A small percentage of the fossils, particularly some of the echinoids and barnacles, appear to be reworked. Most echinoids are moderately well preserved, but a few are almost totally covered by syntaxial cement overgrowths. Most barnacles are also well preserved, but a small number are stained grey, have glauconite- and pyrite-filled tubes, and display rounded edges.

Portions of seismic unit AF-1 (core OB-34) along the 15m profile also contain a diverse assemblage of siliceous fossils including diatoms (sand-sized specimens comprising 0.7% of the total sediment), radiolarians, and siliceous sponge spicules. Chert nodules, described in the section on silicification, are also present in core OB-35.

Mild dissolution appears to have affected carbonate sediments of AF-1 along the 15m profile. In reflected light, most calcareous fossils are slightly leached. Dolomite is pitted and has a rough surface texture.

AF-1 from the 22m profile is a muddy (42.0%), quartz sand. Fossils are extremely scarce (less than 1% of the total sediment). Carbonate mud (28.4%) occurs only as dolomite. Chert nodules are also present in cores OB-38 and OB-40 and are described in the section on silicification.

AF-1 along seismic profile I-8 is a muddy (34.3%), quartz sand. Calcareous sand is predominantly carbonate grains (1.7%), unidentifiable

due to the fragmental and abraded nature of the grains. The predominate identifiable fossils are molluscs (0.7%). Carbonate mud (18.5%) is present as either calcite or dolomite.

In central Onslow Bay (seismic profile I-4), AF-1 is a muddy (28.1%), quartz sand. Fossils are rare (0.7%). Carbonate mud (7.8%) is present only as dolomite; no dolomite occurs in the sand fraction.

Along seismic profile I-5, AF-1 is a slightly muddy (6.9%), quartz sand. Fossils are present in trace percents. Carbonate mud is rare (1.8%) and composed only of dolomite.

The combined abundance of carbonate mud and calcareous fossils in seismic unit AF-1 decreases from northern to central Onslow Bay (Fig. 25). Dolomite is present in the mud fraction in all but 3 samples of AF-1. Siliciclastic sands and insoluble mud increase southward (Fig. 26).

Seismic unit AF-2

AF-2 is a muddy (16.0%), quartz-rich (16.2%), carbonate sand along the 22m profile. Barnacles are the most abundant fossil group, comprising 31.6% of the total sediment, with less abundant benthic and planktonic foraminifers (9.7%), molluscs (2.7%), echinoids (2.1%), and bryozoans (0.2%). Total carbonate content averages 75.1%. Carbonate in the mud fraction (8.2%) consists of both calcite and dolomite.

Fossils and total carbonate content of unit AF-2 decrease toward central Onslow Bay (Fig. 27) while siliciclastic sands and insoluble mud increase (Fig. 28). The southern facies of AF-2 is a quartz-rich (48.6%), mud. Total carbonate content, mostly in the form of calcite or

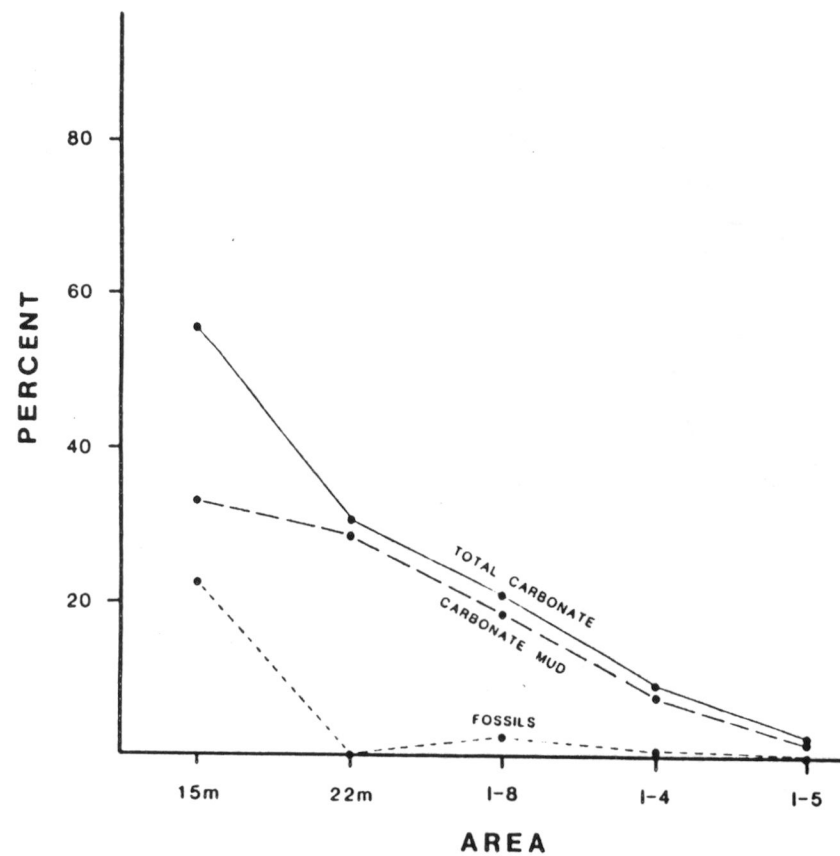


Figure 25. Lateral distribution, from north (15m) to south (I-5), of carbonate components in AF-1.

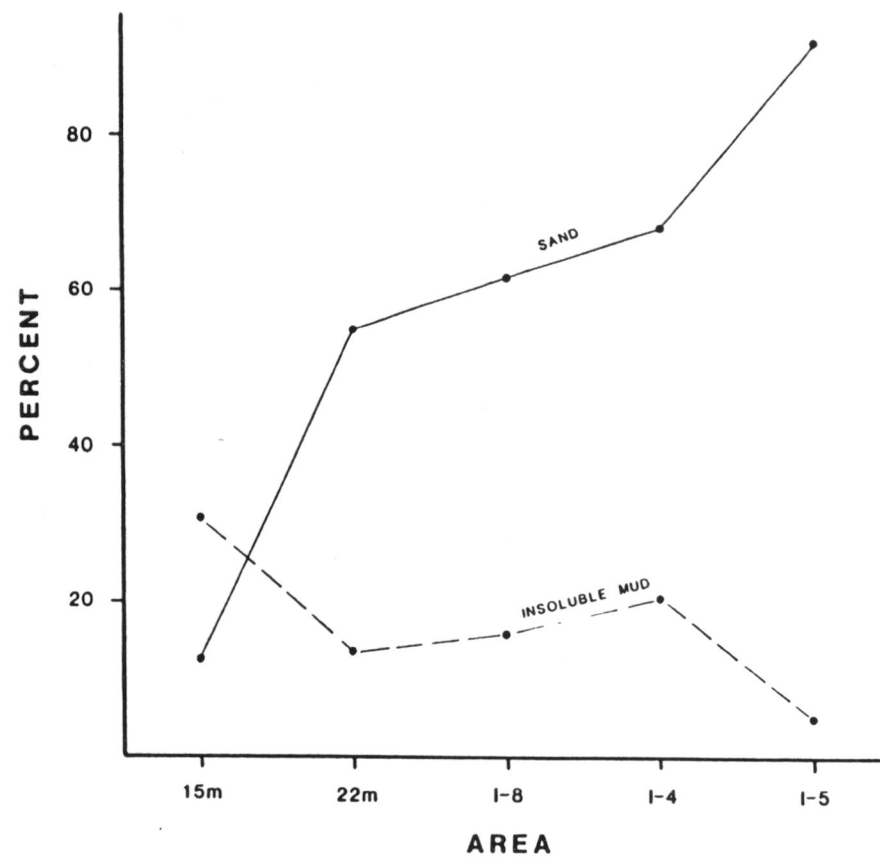


Figure 26. Lateral distribution, from north (15m) to south (I-5), of siliciclastic components in AF-1.

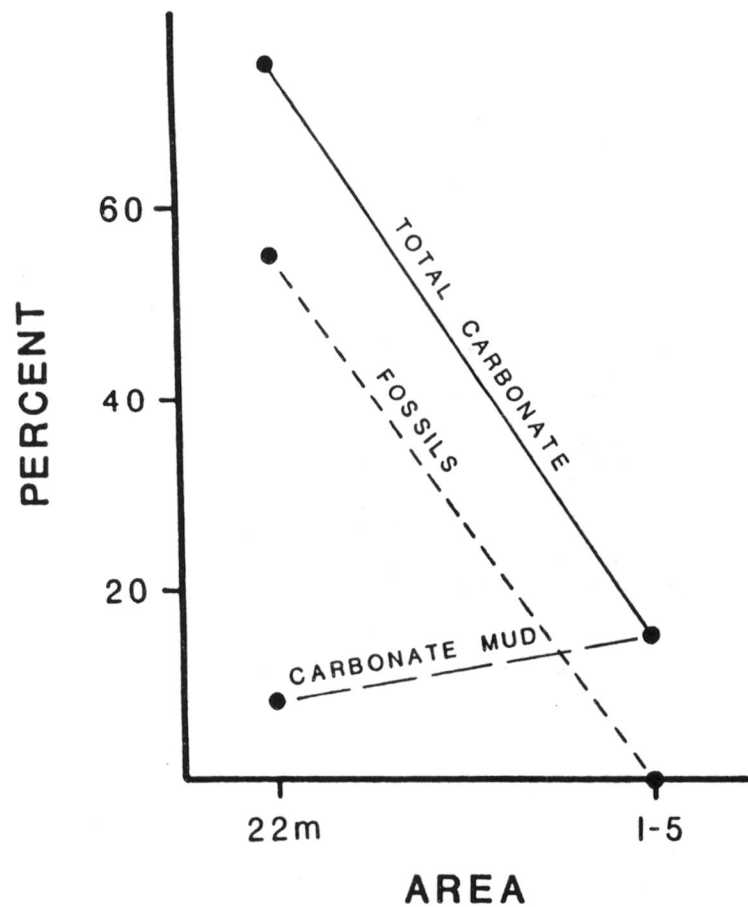


Figure 27. Lateral distribution, from north (22m) to south (I-5), of carbonate components in AF-2.

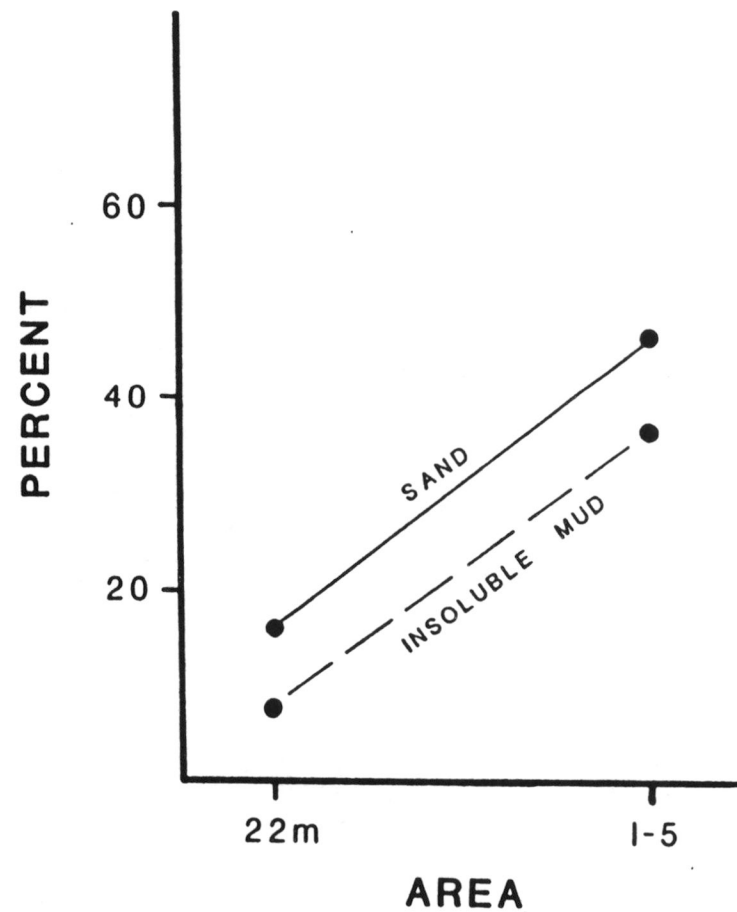


Figure 28. Lateral distribution, from north (22m) to south (I-5), of siliciclastic components in AF-2.

dolomite mud, is only 14.8%.

Seismic unit AF-3

Seismic unit AF-3 in northern Onslow Bay (along the 15m profile) is a quartz-rich (22.1%), muddy (32.9%), carbonate sand. Barnacles (24.4%) and echinoids (6.3%) are the predominant fossils. Carbonate mud (25.4%) is present as calcite with dolomite. Dolomite also occurs in trace amounts as very fine sand-sized rhombs.

AF-3 in central Onslow Bay (along seismic profile I-5) is a quartz-rich (33.2%), muddy (31.2%), carbonate sand. Molluscs (9.8%) are the predominant fossils with less abundant barnacles (5.7%) and echinoids (3.4%). Carbonate mud (22.7%) is present as calcite with dolomite at the top of core OB-131.

Fossils, carbonate mud, and total carbonate content decrease slightly from the 15m profile to I-5 (Fig. 29). Siliciclastic sands and insoluble mud increase slightly (Fig. 30).

Seismic unit AF-4

Seismic unit AF-4 was cored only along the 15m profile (northern Onslow Bay). It is a muddy (40.4%), carbonate sand. Predominant fossils are barnacles (32.4%), bivalves (9.3%), and bryozoans (4.6%). Echinoids, benthic and planktonic foraminifers, and ostracods each average less than 1% of the total sediment. A small percentage of the barnacles appear to be reworked; they are rounded, stained grey, and have pyrite or glauconite in pore spaces.

Dolomite (0.2% of the total sediment) occurs in the very fine sand fraction and in the mud fraction as euhedral, silt-sized crystals that

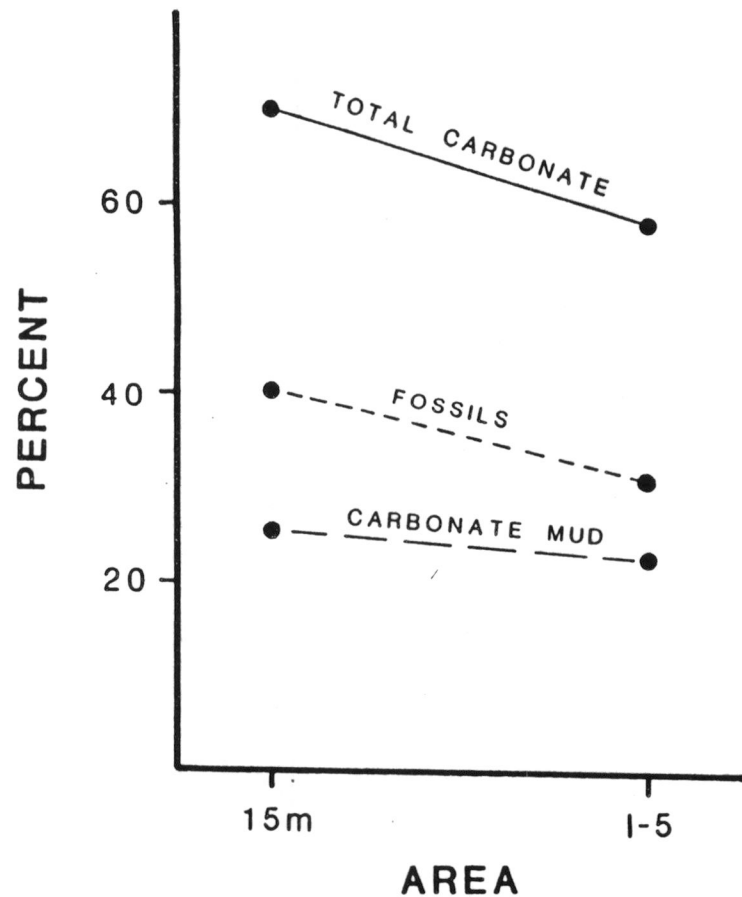


Figure 29. Lateral distribution, from north (15m) to south (I-5), of carbonate components in AF-3.

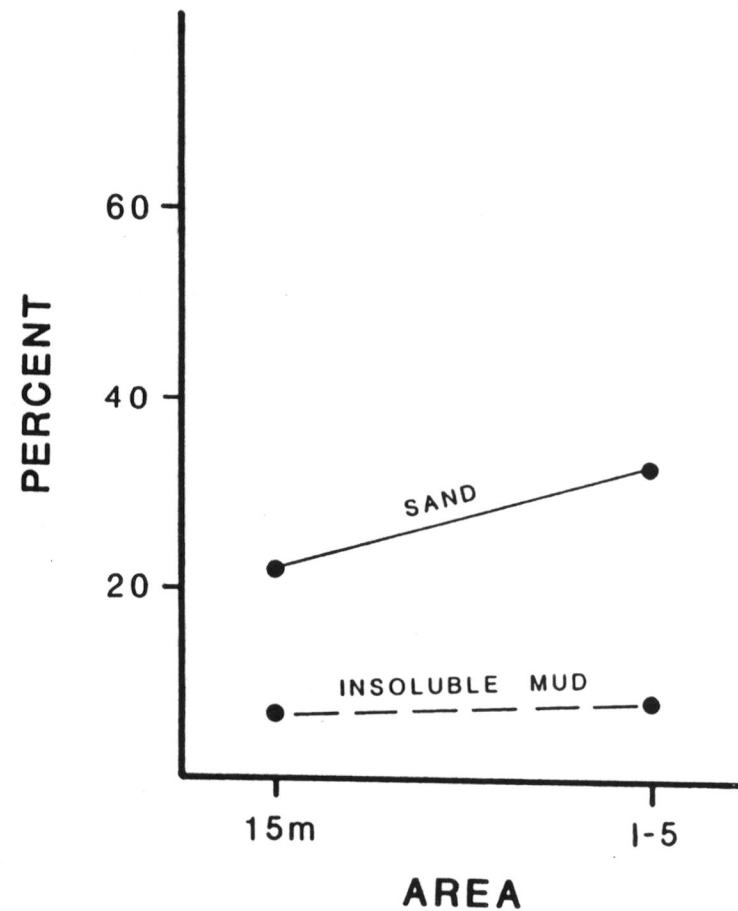


Figure 30. Lateral distribution, from north (15m) to south (I-5), of siliciclastic components in AF-3.

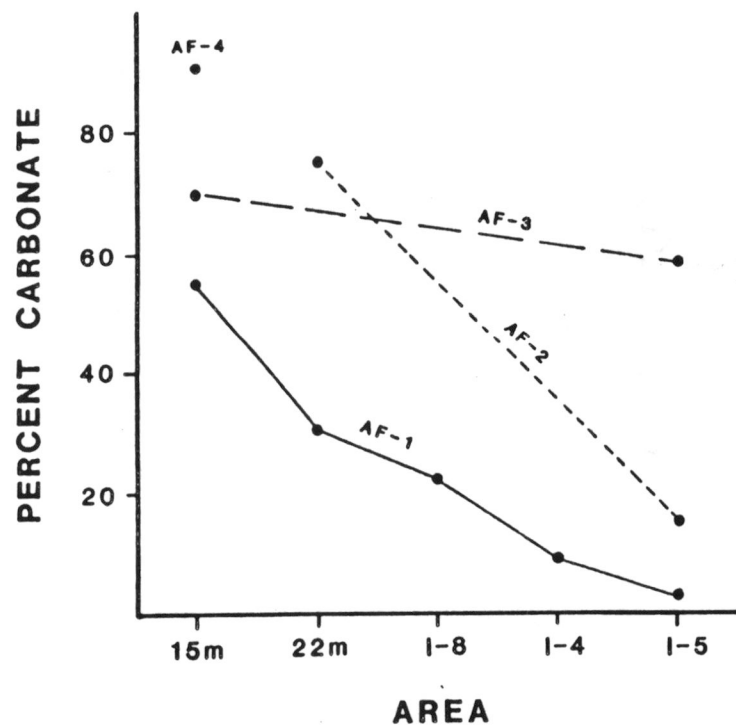


Figure 31. Lateral distribution of carbonate components in each AF seismic unit.

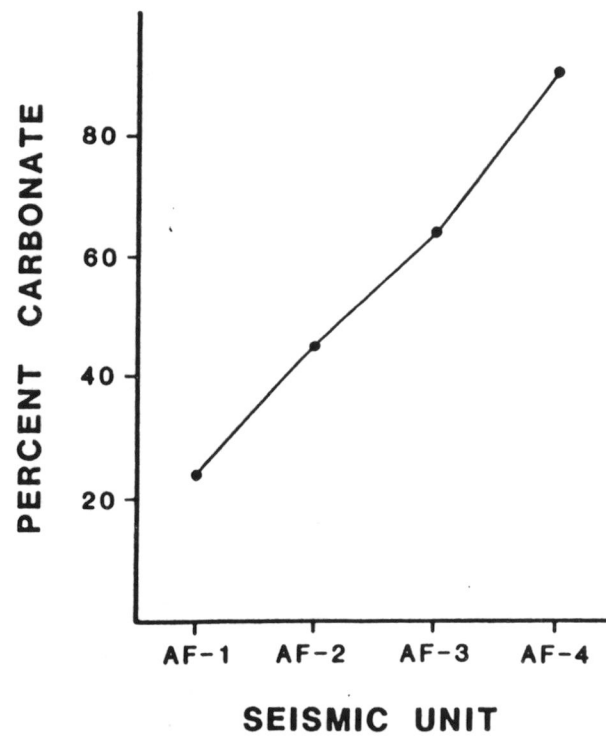


Figure 32. Average carbonate content of the AF sequence.

BBF Sequence

The BBF sequence was deposited during the Serravallian (S.W. Snyder, unpub. data; Steinmetz, unpub. data). In Onslow Bay it ranges from 0 m at its erosional updip truncation to more than 200 m in subsurface (S.W.P. Snyder, 1982). The BBF seismic sequence is divided into 6 fourth-order units labeled BBF-1 to BBF-6 from oldest to youngest (Fig. 1). Seismic unit BBF-1 may actually be a composite of several seismic units (S.W.P. Snyder, 1982). Riggs and others (1985) subdivided BBF-1 into 5 lithologic units based upon patterns of the major mineralogical components.

The BBF sequence crops out only in northern and central Onslow Bay where it is predominantly siliciclastic sediments. Seismic units BBF-4 and BBF-5 were not vibracored. The average abundance of mineralogical and faunal components in each seismic unit for each area of Onslow Bay (15m profile; 22m profile; profiles I-8, I-4, and I-5; see Figure 8 for location map) are presented in Table 14. Table 15 summarizes the average abundance and distribution of major mineralogical components (carbonate, phosphate, silica, siliciclastic sand, and mud). Tables 14 and 15 are compiled from reflected light microscopy and insoluble residue data (Appendices A and B).

Seismic unit BBF-1

BBF-1 is the most thoroughly sampled of the BBF seismic units. It crops out in northern and central Onslow Bay. Nine samples in cores from the 15m profile revealed two lithologies. The lower one (Lithology I), from cores OB-2B, 3, and 36, is a muddy (43.9%), quartz-rich

Seismic Unit	BBF-1								BBF-2	BBF-3	BBF-6	
Profile Lithology # # Samples	15m		22m			I-4		I-5		I-4	22m	15m
	I 5	II 4	I 4	II 2	III 3	I 1	II 6	I 1	II 1	2	3	6
Molluscs	0.1	tr	tr	1.9	0.2	0.1	0.5	3.8	tr	0.2	0.5	0.1
Barnacles	0	0	tr	7.7	0.1	tr	1.4	0.7	tr	tr	11.5	tr
Bryozoans	0	0	0	0	0	tr	tr	tr	0	0	0.1	0
Echinoids	tr	tr	0	1.5	0.2	0	0.2	0.4	0.6	0.1	0.7	0.4
Ostracods	0	0	0	0.1	0	0	tr	0.1	tr	0	tr	0
B. Forams	tr	0.6	0	2.9	0.3	0	0.2	1.0	0.6	tr	1.6	1.2
P. Forams	0	0	0	0	0	0	0	0	0.1	0	0.1	0
Carbonate	tr	tr	tr	0.2	0.1	0	0.3	0.2	6.0	0.6	3.0	0.3
Spar	0.5	0	0	0	0.1	0.1	0.2	tr	2.9	0.4	5.0	tr
Dolomite	0	0.5	0	0.1	tr	0	0	0	0	0	0	1.0
Chert	0	0	0	0	0	0	0	0	0	0	0	0
Diatoms	0	0	0	0.1	0	0	tr	0	0	0	0	0
Radiolaria	0	0	0	0	0	0	0	0	0	0	0	0
Spicules	0	0	0	0	0	0	0	0	0	0	0	0
Skel Phos	3.9	1.8	0.8	1.5	2.8	0.1	2.3	0.6	0.2	tr	0.2	2.8
Phosphate	9.1	4.1	2.3	1.5	3.7	tr	8.4	0.5	tr	tr	tr	6.6
Glauconite	0	1.0	tr	0.1	0.1	0	0.1	0.3	0	0	tr	0.1
Opagues	0	0	0	0	0	tr	tr	0	0	tr	0	tr
Other	0	0	0	0	0	0	tr	0.3	tr	0	0	tr
Qtz Sand	43.9	66.3	49.3	28.0	63.0	7.4	49.9	72.7	6.1	88.7	19.9	62.0
Insol Mud	39.9	17.8	43.4	25.9	23.6	45.9	25.8	12.2	61.4	4.6	29.0	12.2
Carb Mud	2.8	7.9	4.3	28.5	5.7	46.3	10.7	7.1	22.0	5.4	28.4	13.3
TOTALS	100.2	100.0	100.1	100.0	99.9	99.9	99.8	99.9	99.9	100.0	100.0	99.9

Table 14. Summary of abundance and distribution of all mineralogical and faunal components (in % of total sediment) in the BBF seismic units. All numbers are based on reflected light microscopy and insoluble residue data (Appendices A and B). (Carbonate = unidentifiable carbonate fragments; Spar = calcite cement; Qtz Sand = siliciclastic sand; Insol Mud = insoluble mud; Carb Mud = carbonate mud.)

	Seismic Unit										BBF-2	BBF-3	BBF-6
	BBF-1												
	Profile	15m		22m			I-4		I-5		I-4	22m	15m
	Lithology #	I	II	I	II	III	I	II	I	II			
	# of Samples	5	4	4	2	3	1	6	1	1	2	3	6
CARBONATE CONSTITUENTS	Fossils	0.1	0.6	tr	14.0	0.9	0.1	2.7	6.6	7.3	1.0	17.5	2.0
	Spar	0.5	0	0	0	0.1	0.1	0.2	tr	2.9	0.4	5.0	tr
	Dolomite	0	0.5	0	0.1	tr	0	0	0	0	0	0	1.0
	Carb Mud	2.8	7.9	4.3	28.5	5.7	46.3	10.7	7.1	22.0	5.4	28.4	13.3
MAJOR CONSTITUENTS	Carbonate	3.4	9.0	4.3	42.6	6.7	46.5	13.6	13.7	32.2	6.8	50.9	16.3
	Silica	0	0	0	0.1	0	0	tr	0	0	0	0	0
	Phosphate	13.0	5.9	3.1	3.0	6.5	0.1	10.7	1.1	0.2	tr	0.2	9.4
	Others	0	1.0	tr	0.1	0.1	tr	0.1	0.6	tr	tr	0	0.1
	Qtz Sand	43.9	66.3	49.3	28.0	63.0	7.4	49.9	72.7	6.1	88.7	19.9	62.0
	Insol Mud	39.9	17.8	43.4	25.9	23.6	45.9	25.8	12.2	61.4	4.6	29.0	12.2
	TOTALS	100.2	100.0	100.1	99.7	99.9	99.9	100.1	100.3	99.9	100.1	100.0	100.0

Table 15. Summary from Table 14 of abundance and distribution of major mineralogical components (in % of total sediment) in BBF seismic units. (Spar = calcite cement; Qtz Sand = siliciclastic sand; Insol Mud = insoluble mud; Carb Mud = carbonate mud.)

(46.4%), phosphorite sand. Phosphate grains (11.1%) are predominantly intraclastic and pelletal. The only fossils present are bivalves (0.1%), and traces of echinoids and benthic foraminifers. Carbonate mud (2.8%) is too rare for its mineralogy to be determined by x-ray diffractometry. The upper lithology (Lithology II), present in cores OB-2 and OB-91, is a phosphatic (5.9%), muddy (23.7%), quartz sand. Benthic foraminifers are slightly more abundant (0.6%), with trace percentages of bivalves and echinoids. Dolomite is present in the fine sand fraction (0.5%) and in the carbonate mud fraction (7.9%) mixed with calcite.

Along the 22m profile, three BBF-1 lithologies were sampled. The lowermost lithology (Lithology I), from cores OB-6 and OB-39, is a muddy (47.7%), quartz sand. Fossils consist of trace percentages of bivalves and barnacles. Carbonate mud (4.3%) is a minor constituent and its mineralogy could not be identified by x-ray diffractometry. Lithology II occurs in core OB-71 and at the bottom of OB-109. It is a fossiliferous (14.0%), quartz-rich (28.0%), mud. Carbonate mud (28.5%) consists of both calcite and dolomite. Fossils include barnacles (7.7%), benthic foraminifers (2.9%), bivalves (1.9%), echinoids (1.5%), and ostracods (0.1%). The uppermost lithology (Lithology III), found in the upper three samples of core OB-109, is a phosphatic (6.5%), muddy (29.3%), quartz sand. Fossils average 0.9% of the total sediment and include benthic foraminifers, echinoids, bivalves, and barnacles. Carbonate mud (5.7%) is also present. Dolomite was identified on only one of the three x-ray diffractograms.

Two lithologies were sampled in BBF-1 along seismic profile I-4.

The lowermost lithology (Lithology I), present in core OB-52, is a quartz-rich (7.3%), dolomitic (46.3%) mud. Fossils are almost nonexistent (0.1%). Dolomite is present only in the mud fraction.

The upper BBF-1 lithology (Lithology II), from cores OB-53 and OB-60, is a muddy (36.5%), quartz-rich (49.9%), phosphorite sand. Carbonate mud (10.7%) is present as calcite. Fossils consist of barnacles (1.4%), bivalves (0.5%), echinoids (0.2%), benthic foraminifers (0.2%), and trace percentages of bryozoans and ostracods. Three 1-3cm thick laminae of moldic microsparite are present in cores OB-53 and OB-60. Laminae are phosphatic (4.1%), quartz-rich (13.6%), and in sharp contact with the overlying and underlying sediment. The first stage of cementation was growth of isopachous cement within intraparticle pore spaces in barnacle plates. Neomorphism of micrite to microspar fully cemented the sediment. Later, dissolution of mollusc fragments produced secondary moldic porosity, which was then partially occluded by blocky pore filling cement.

Two samples from the BBF-1 section of core OB-59, located on seismic profile I-5, have very different lithologies. The stratigraphically lower lithology (Lithology I) is a slightly fossiliferous (6.6%), muddy (19.3%), quartz sand. Carbonate mud (7.1%) consists of a mixture of calcite and dolomite. Predominant fossils are bivalves (3.8%) and benthic foraminifers (1.0%). The upper lithology (Lithology II) is a quartz-rich (6.1%), slightly fossiliferous (7.3%), mud. Most fossils (6.0%) are unidentifiable because of fragmentation and extensive growth of calcite cement. Echinoids (0.6%) and benthic foraminifers (0.6%) are the predominant identifiable fossils. Both

calcite and dolomite are present in the carbonate mud (22.0%).

Figures 33 and 34 show carbonate and siliciclastic components in seismic unit BBF-1. These graphs show that: 1) all BBF-1 sediments are siliciclastic; 2) carbonate content of BBF-1 increases from northern to central Onslow Bay; 3) relative carbonate content increases upsection in most seismic profiles; and 4) most carbonate in BBF-1 is found in the mud fraction.

Seismic unit BBF-2

Unit BBF-2 was cored only in central Onslow Bay along seismic line I-4 (core OB-92). A calcite cemented sandstone occurs at the top of the Miocene section in this core. Calcite cementation decreases down section, accompanied by a corresponding increase in quartz sand (Fig. 35). A small percentage of the components are insoluble clay and fossils, which consist of barnacles, bivalves, and echinoids. The fossils decrease slightly in concentration down section, with a corresponding increase in clays.

Initial cementation was by interparticle and intraparticle isopachous cement on fossils. Second generation calcite cements are drusy and blocky pore filling cements. Drusy cement is gradational with isopachous cement, filling in remaining intraparticle pore space and sheltered areas between fossils. Blocky pore filling cement, which fills in the remaining interparticle pore spaces, is the most abundant type. Crystal size increases from grain surfaces into pore spaces, grading into patches of microspar. Later dissolution of a few large molluscs left molds which are not filled in by a second stage of pore

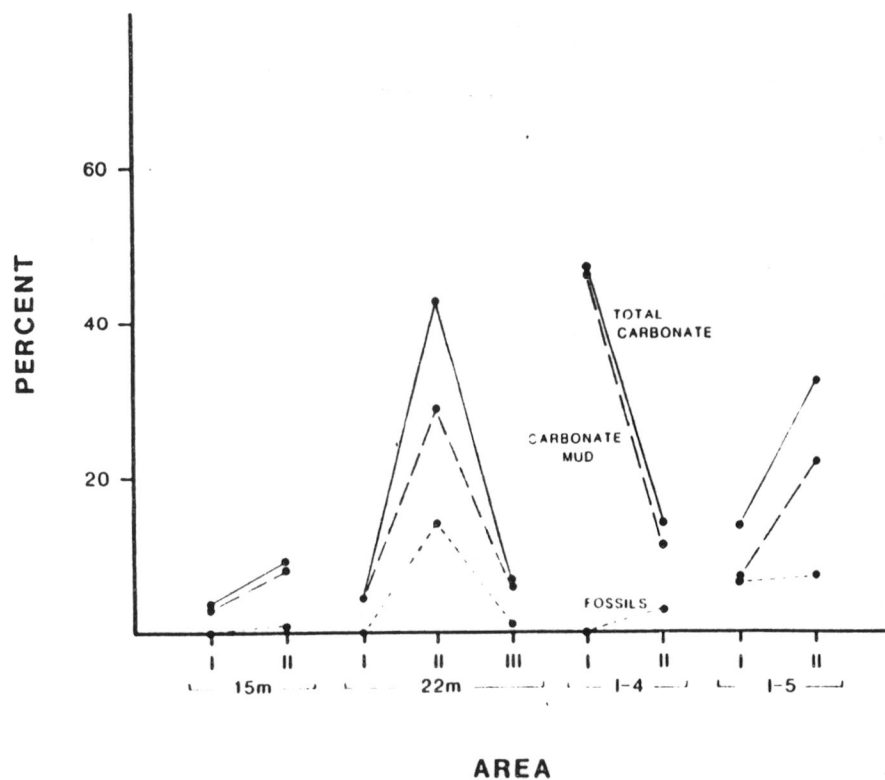


Figure 33. Lateral distribution, from north (15m) to south (I-5), of carbonate components in BBF-1.

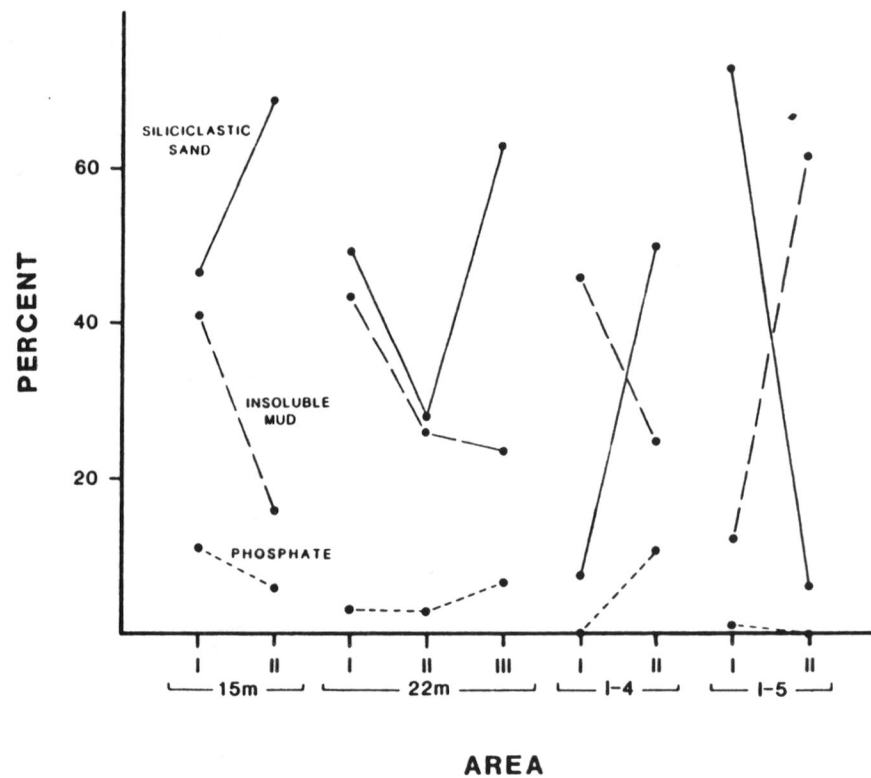


Figure 34. Lateral distribution, from north (15m) to south (I-5), of siliciclastic and phosphatic components in BBF-1.

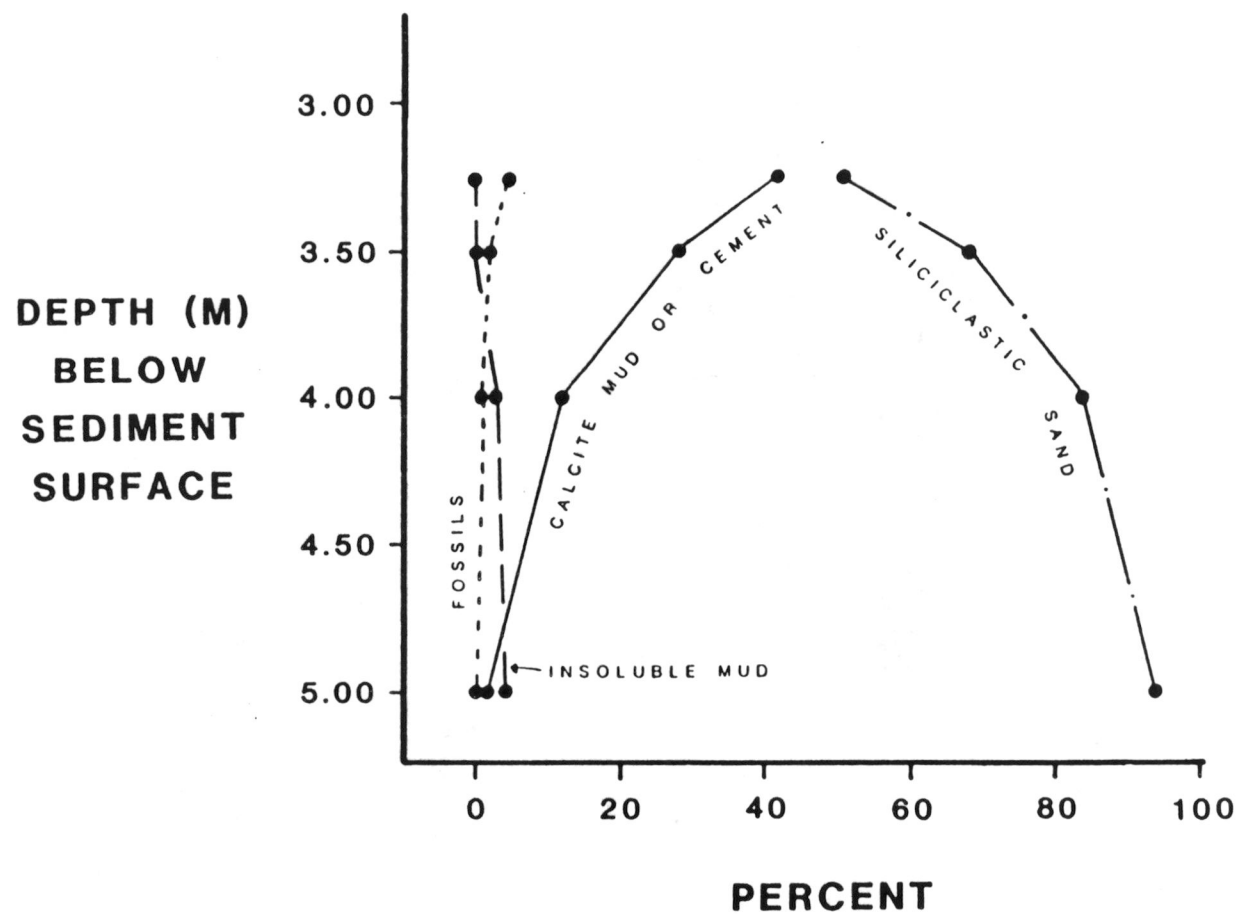


Figure 35. Vertical distribution of carbonate and siliciclastic components in BBF-2 (core OB-92). The Miocene portion of this core begins at 3.00 meters.

filling cement.

Seismic unit BBF-3

BBF-3, cored only along the 22m profile (core OB-108), is a fossiliferous (17.5%), quartz-rich (19.9%), mud. Both calcite and dolomite are present in the mud fraction (28.4%). Predominant fossils are barnacles (11.5%) and benthic foraminifers (1.6%). Total carbonate content averages 50.9%.

Two 20cm thick beds of quartz-rich (29.5%), moldic biomicrosparticle are present at the top of the Miocene section in core OB-108 and are in sharp contact with the surrounding unlithified sediment. The first stage of cementation is an isopachous cement lining interparticle and intraparticle pore spaces around fossils. Second generation drusy and blocky pore filling cement partially filled remaining intraparticle pore spaces, and micrite neomorphosed to microspar, filling in remaining interparticle pore space. Later dissolution of mollusc fragments left secondary moldic porosity which remained unfilled.

Seismic unit BBF-6

BBF-6 crops out only in northern Onslow Bay and was cored along the 15m profile. Here it is a phosphatic (9.4%), muddy (25.5%), quartz sand. Total carbonate content averages 16.3%. Benthic foraminifers (1.2%) and echinoids (0.4%) are the predominant fossils. Carbonate mud (13.3%) occurs as both calcite and dolomite. Dolomite (1.0%) also is present in the fine and very fine sand fractions, but it shows no stratigraphic trend.

DISCUSSION

Four patterns of carbonate sedimentation are present in the Pungo River Formation in Onslow Bay: 1) cyclic carbonate sediments overlying noncarbonate lithologies and deposited as a couplet during the same sea-level cycle; 2) barnacle-rich, relatively pure carbonate sediments deposited throughout each fourth-order sea-level cycle of the AF seismic sequence; 3) sparse fossils and minor carbonate mud disseminated in noncarbonate lithologies; and 4) thin carbonate laminae interbedded with noncarbonate lithologies.

Cyclic Patterns of Carbonate Sedimentation

Carbonate sediments gradationally overlie siliciclastics and other lithologies. Each gradational noncarbonate-carbonate sediment sequence was deposited during one fourth-order sea-level cycle. Carbonate sediments in the Pungo River Formation in Onslow Bay include: 1) those that fit the idealized cycle of Riggs (1984), and 2) barnacle-rich carbonates associated with hardgrounds.

Carbonates Associated with the Idealized Cycle of Riggs

Riggs (1984) proposed a model to explain the origin, distribution, and cyclic nature of Neogene sediments on the southeastern U.S. Atlantic continental margin. Major climatic changes cause multiple cycles of glaciation and deglaciation, and resulting sea-level fluctuations, along with climate, control sedimentation. During glacial maxima, semi-arid conditions result in sparse vegetation and streams carry large sediment loads. As climate becomes warmer and more humid, vegetation increases

and sediment load decreases in streams carrying finer siliciclastic materials. With rising sea level, the Gulf Stream moves towards and begins to interact with the continental shelf. Upwelling occurs where bathymetric contours diverge on the downstream side of topographic and structural highs which interact with the Gulf Stream. Cold upwelling waters supply nutrients for organic production and subsequent phosphate mineralization. Carbonates are produced during glacial minima and sea-level maxima when warm Gulf Stream waters flow across the continental shelf.

Theoretically, each Pungo River seismic unit in Onslow Bay is a product of a sea-level cycle and should consist of an idealized cyclical sediment sequence (siliciclastic sediment at the base, increasing phosphate and associated authigenic sediments up section, culminating in carbonates) or some variation on this theme (Riggs, 1984). However, erosional processes during each lowstand may have locally removed part or all of any preceding sediment sequence. Where preserved, the upper carbonates should be most extensively affected by diagenesis and the degree of diagenesis should decrease down section. This model is summarized in Table 16. This model is documented by sediments in Onslow Bay where the cap rocks are of several different carbonate lithologies.

One distinct lithology occurs in seismic unit FPF-1 in the Frying Pan Area (cores OB-20, 64, and 115). The age of these cap rocks is controversial, as discussed in the description of FPF-1. Carbonates are biomicrosparites which overlie and grade into phosphorite sands (Fig. 11). They contain a diverse fossil assemblage consisting of barnacles, bryozoans, bivalves, echinoids, benthic and planktonic foraminifers,

Sea-level Associated with:	Climate, Fauna, and Vegetation	Gulf Stream (GS) Dynamics	Sedimentation Patterns and Processes
early-mid stage transgression	moderating climate; cool water fauna; increasing vegetation	GS migrates west; topographic upwelling and frontal eddies begin	fine-grained terrigenous sediment deposited on inner part of shelf; phosphate deposited around nose of topographic feature; carbonate inter- bedded with phosphate on outer shelf
mid-late stage transgression	moderating climate	GS continues west- ward migration; upwelling increases	phosphate sedimentation increases and migrates further onto shelf; terrigenous sedimentation decreases; carbonates limited to outer shelf
sea-level maximum	interglacial; warm, humid climate; heavy vegetation; subtropical fauna	upper portion of GS spills onto shelf	carbonate depositional regime; reworking of previously deposited phosphates; terrigenous sedimentation reduced to a minimum
sea-level minimum	glacial maximum; cold, semi-arid; decreased vegetation	GS forced eastward beginning of oceanic overturn	erosion of previously deposited sediments; nondeposition and exposure diagenetically alters sediments; increase in terrigenous sedimentation thick phosphorite pavements form; these are torn up to produce intraclast pebbles which dominate the lower facies of each cycle

Table 16. Neogene sedimentation model for the southeastern United States (Riggs, 1984).

ostracods, coralline algae, decapods, serpulid worms, and coralline and dasycladacean algae. This abundant and diverse fauna and flora indicate open shelf conditions and warm temperate to subtropical waters.

Waters (1983) found that phosphorites in FPF-1 are predominated by benthic foraminiferal taxa indicative of mid to outer shelf, nutrient-rich, oxygen-poor conditions produced by upwelling. The phosphorites grade upward into warm water assemblages of the carbonate cap rocks. These carbonates appear to mark the end of a fourth-order sea-level transgression when warm Gulf Stream waters flooded the continental shelf.

A second carbonate lithology forms the cap rock of seismic unit BBF-2 (core OB-92). It is actually a slightly fossiliferous (4.3%), calcite cemented (41.4%), quartz sandstone (total carbonate content of 45.7%) which grades downward into an unindurated quartz sand with 1.9% carbonate (Fig. 34). The upper part of the section has undergone cementation by blocky pore filling cement and dissolution of bivalves. This type of carbonate cap rock also fits Riggs' (1984) model of Neogene sedimentation because both carbonate content and diagenesis decrease down section.

Barnacle-rich Carbonates

A third lithology, consisting of barnacle-rich carbonate sediments, occurs as an upper facies in the depositional sequence. These appear to be regional developments that represent a variation on the idealized cycle of Riggs (1984). Discussion of these barnacle-rich carbonates in the Pungo River Formation in Onslow Bay must begin with a brief

consideration of their ecology.

Barnacle Ecology. Pungo River barnacles are true barnacles belonging to Order Thoracica in the Class Crustacea, Subclass Cirripedia.

Barnacles present in the Pungo River Formation in Onslow Bay are all balanomorphs and include Megabalanus sp. in the BBF sequence, Balanus imitator in the AF sequence and seismic units FPF-3 through FPF-6, and an unidentified form (similar to Balanus amphitrites present in the Pleistocene Wacamaw Formation) in FPF-1 (V.A. Zullo, pers. comm.). The majority of the the barnacles in FPF-1 appear to be reworked; they are fragmented, have rounded edges, and are stained grey. Barnacles in the BBF sequence are a warmer water taxa than those in FPF and AF sequences (Zullo, pers. comm.). This correlates well with the sea-level curve of Vail and Mitchum (1979) which shows a sea-level maximum during the Serravallian (Fig. 5).

The shells of balanomorph barnacles consist of 12 plates, eight outer compartmental plates attached to a basal disc, and four inner opercular plates (Newman and others, 1969; Zullo, 1979), composed of low-Mg calcite (Milliman, 1974). Barnacles are epibenthic filter feeders that require a hard substrate for attachment. They are most common in the intertidal zone which is best suited for their filter feeding lifestyle, but they do occur in neritic waters where there are ample currents. They can live in many marine environments but are more abundant in subtropical to temperate waters. Growth of barnacles is faster in warmer waters; however, they are not common on tropical shelves (Milliman, 1974) possibly due to grazing fish that scrape the

substrate and remove barnacle larvae (Newman, 1960) or to competition with corals which predominate the epibenthic fauna. In Woods Hole, Massachusetts and Monterey Bay, California the life span of balanomorph barnacles is only about a year (Grave, 1933; Smith and Haederbie, 1969). Shell accretion is rapid, 15 to 30 mm/year (Pequegnat and Fredericks, 1967; Smith and Haederbie, 1969). Because barnacles are short lived, gregarious organisms that produce 12 relatively large calcite plates per individual, their disarticulated plates are an important carbonate component of sediments in subtropical and temperate environments.

Barnacles, though present since the Silurian (Newman and others, 1969), have been common sediment components only since the Cretaceous. Wilson (1975) and Flugel (1982) did not include barnacles in their standard carbonate microfacies, perhaps because very little paleoecological work has been done on them. Therefore, barnacles are generally considered less useful for paleoecological interpretations than many other fossil groups.

Inner Shelf Deposits. Barnacle-rich carbonates which cap seismic units FPF-5 and FPF-6 (cores OB-45 and OB-46) are unindurated and consist of abundant (29.5%) barnacle plates, with lesser abundances of echinoids (6.3%) and benthic foraminifers (2.2%). Carbonate mud (34.6%), quartz sand (7.0%), and insoluble matrix (6.8%) are other major components present in these sediments. Total carbonate content averages 86.3% of the total sediment. Barnacles are well preserved and appear to have undergone little transportation.

Carbonates similar to those in FPF-5 and FPF-6 occur in seismic

units BBF-1 and BBF-3 (in the base of core OB-109 and throughout the Miocene section in core OB-108, respectively). Barnacles (12.4%) are less abundant and occur with benthic foraminifers (2.4%), molluscs (1.3%), and echinoids (1.2%). Quartz sand (21.6%) and insoluble matrix (26.8%) are higher than in the FPF barnacle-rich sediments while carbonate mud content is lower (27.1%). Total carbonate content averages 50.8% of the total sediment. Barnacle-rich carbonates in core OB-109 are at the base of the core and could represent the end of a fourth-order sea-level cycle because: 1) sediments in cores stratigraphically lower in BBF-1 are siliciclastics, 2) sediments in the upper part of core OB-109 are siliciclastics, and 3) BBF-1 may actually contain three seismic/lithologic units (S.W.P. Snyder and others, 1983; Riggs and others, 1985). The composition of barnacle cap rocks in the Pungo River Formation in Onslow Bay is summarized in Table 17.

Riggs' (1984) model can be related to the presence and distribution of barnacle beds which overlie siliciclastic sediments in the Pungo River Formation. Regression during fourth-order eustatic sea-level cycles results in submarine or subaerial exposure of previously deposited sediments and formation of hardgrounds. Barnacles attach to these hardgrounds on the inner shelf. If there is an adequate sediment supply, rising sea level buries the barnacles, which remain articulated and attached to the hardground, during the next transgressive cycle (Fig. 36). Such a scenario can be observed on top of seismic unit FPF-1 (core OB-132).

During a regression, barnacles growing on hardgrounds are disarticulated by current action and accumulate on top of sediments

Sample	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Phos	Oth	Qtz	Matr
FPF-6														
45-1.00	0.5	27.5	0.5	5.6	0.0	1.7	0.1	9.8	0.0	0.2	0.5	0.0	8.7	44.9
FPF-5														
46-0.75	0.6	31.6	0.5	6.9	0.1	2.6	0.3	14.8	0.0	0.2	0.1	0.2	5.2	36.9
BBF-3														
108-2.75	0.4	6.6	0.2	0.4	0.1	1.7	0.0	1.8	tr	0.0	0.2	tr	10.9	77.8
108-3.7	0.7	18.7	0.1	1.0	0.0	1.3	0.0	5.0	5.8	0.0	0.3	0.0	27.6	39.5
108-5.00	0.3	9.3	0.1	0.6	0.0	1.7	0.2	2.2	9.3	0.0	0.2	0.0	21.2	54.9
BBF-1														
109-5.75	3.8	15.3	0.0	2.8	0.2	4.9	0.0	0.4	0.0	0.0	2.7	0.1	26.6	43.2

Table 17. Composition of barnacle cap rocks. (Sample = core-depth (m); Moll = molluscs; Barn = barnacles; Bry = bryozoans; Ech = echinoids; Bf = benthic foraminifers; Pf = planktonic foraminifers; Carb = unidentifiable carbonate fragments; Spar = calcite cement; Dolo = dolomite; Phos = phosphate; Oth = other authigenic minerals; Qtz = siliciclastic sand; Matr = matrix.)

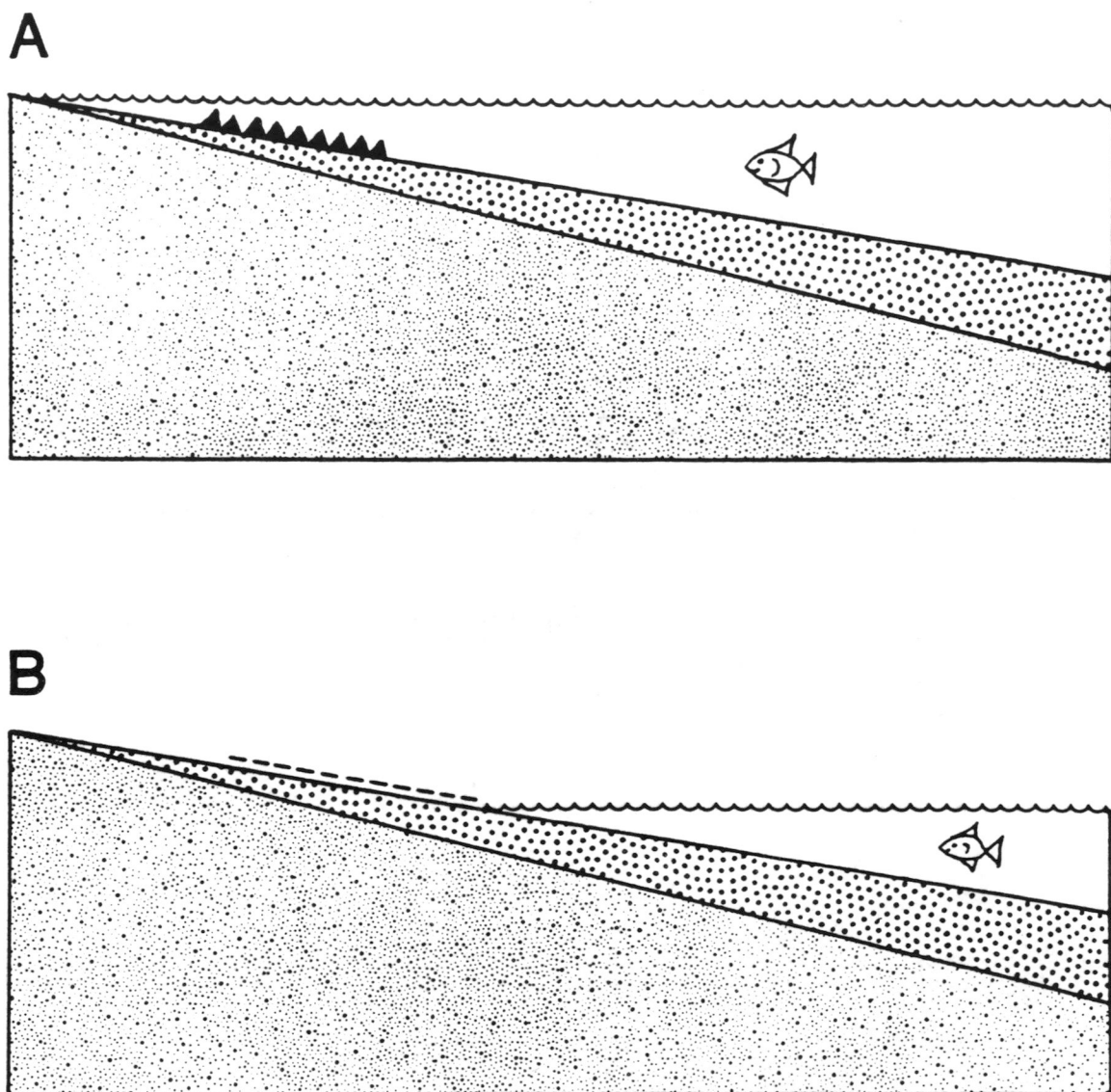


Figure 36. Deposition and preservation of barnacles during a transgression. A. Barnacles (triangles) grow on hardgrounds formed on top of sediments deposited during previous sea-level cycles (fine stipple pattern). B. With rising sea-level, sediments deposited during the current fourth-order cycle (coarse stipple pattern) bury the barnacles articulated and attached to the hardground.

which were deposited during the previous transgression (Fig. 37). If barnacles continue to establish themselves down the shelf at the rate of regression, an extensive layer of disarticulated barnacle plates will overlie much of the previously deposited sediment. If the barnacles can not keep up with the regression, then localized zones of plates will occur nearshore but will be absent further offshore. Disarticulated barnacles occur as cap rocks on noncarbonate lithologies in seismic units FPF-5, FPF-6, BBF-1, and BBF-3 (cores OB-46, OB-45, OB-109, and OB-108, respectively). I believe these carbonates represent the regressive phase of their respective depositional cycles.

Outer Shelf-Slope Deposits. The AF third-order seismic sequence is the only one which is predominated by carbonate sedimentation (greater than 50% carbonate) through each fourth-order seismic unit. Average carbonate content increases up section and toward northern Onslow Bay (Fig. 23).

Seismic unit AF-1 is a quartz-rich (12.5%), fossiliferous (22.4%), carbonate mud in northern Onslow Bay (the 15m profile). It contains a diverse assemblage of calcareous and siliceous fossils including barnacles, echinoids, benthic and planktonic foraminifers, molluscs, ostracods, bryozoans, diatoms, radiolarians, and siliceous sponge spicules. All diatoms seen in the sand fraction are centrics (round), the majority of which are planktonic. Low individual abundances and high diversity of organisms in AF-1 indicates deposition on an open shelf, probably mid to outer shelf based on the abundance of planktonic foraminifers, centric diatoms, and radiolarians.

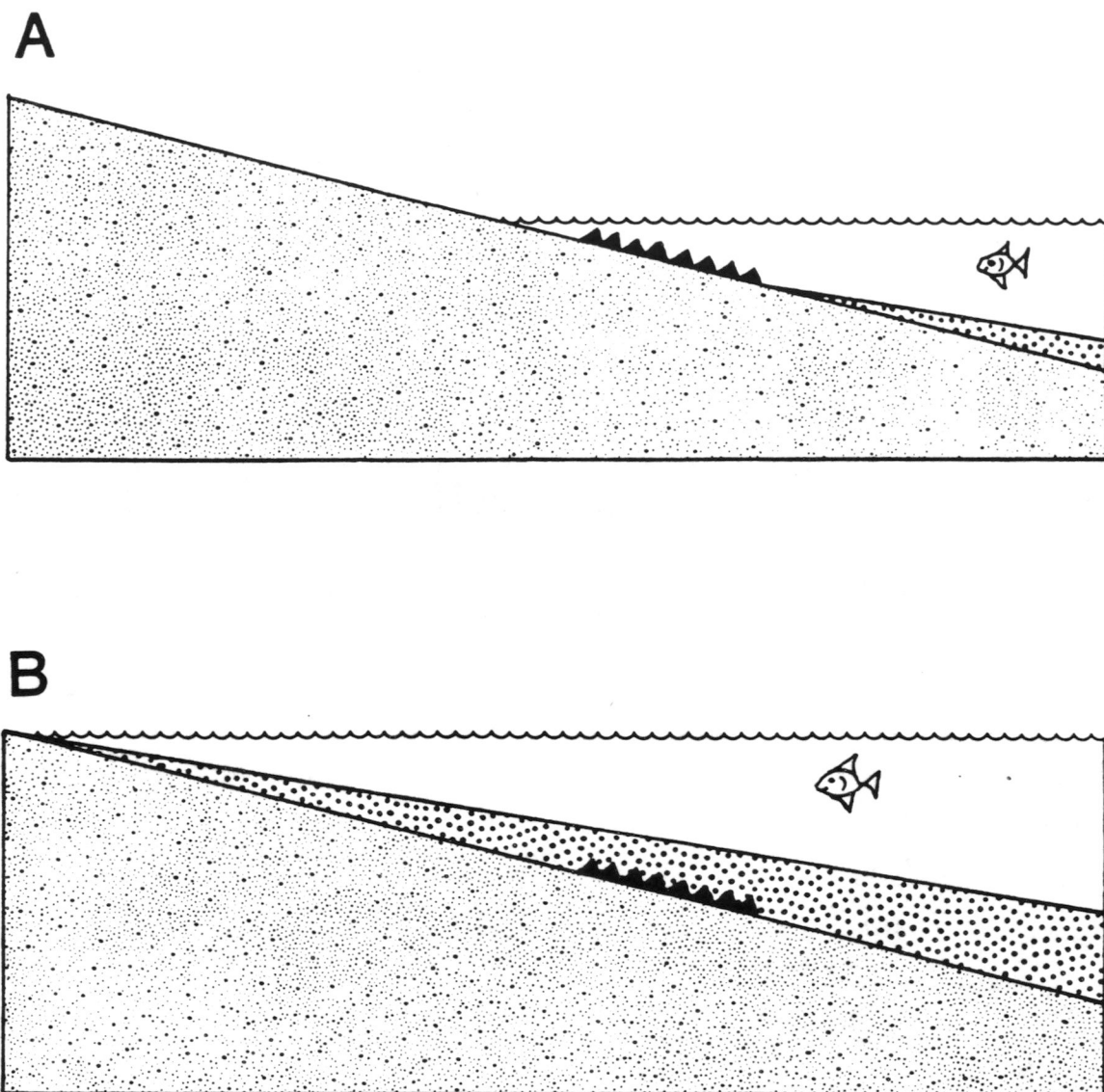


Figure 37. Deposition and preservation of barnacles during a regression. A. Barnacles (triangles) grow on hardgrounds formed on top of sediments deposited during the current fourth-order sea-level cycle (coarse stipple pattern). B. Current activity caused by regression disarticulates barnacles and scatter their plates (dashed line) over sediment deposited during the current fourth-order cycle.

Seismic units AF-2 and AF-3 contain similar quartz-rich, muddy carbonate sands in northern Onslow Bay (Table 13). Barnacles constitute more than 24% of the sediment. Echinoids, foraminifers, and molluscs contribute another 9-15% to the sands (Table 14). Other fossils are relatively rare (less than 1%). Unit AF-3 also is a quartz-rich, muddy carbonate sand in central Onslow Bay; however, barnacles are not as abundant (5.7%), and molluscs (9.8%), echinoids (3.4%), and bryozoans (1.5%) are more abundant. More than 80% of the fossils in AF-2 and AF-3 are poorly preserved. Barnacles, molluscs, and bryozoans are stained grey and have bored and abraded surfaces. Borings are often filled with glauconite or pyrite. Most echinoids are overgrown by calcite cement. Many of the more coarsely perforate foraminifers are covered by a thin coat of calcite cement. Few moderately to well preserved echinoid fragments and planktonic and benthic foraminifers are present. Poorly preserved fossils are interpreted as transported and probably reworked, while well preserved specimens probably accumulated during that particular sea-level cycle. Open shelf conditions are indicated by this assemblage of fossils; however, the majority appear to be reworked. Benthic foraminifers of AF-3 in central Onslow Bay indicate a mid to outer shelf environment (Moore, in prep.).

Seismic unit AF-4 is a muddy (40.4%), carbonate sand. Most of the mud is carbonate (Table 12). Barnacles are the predominant fossils, with less abundant bivalves and bryozoans. Some of the barnacles appear to have been transported or possibly recycled from older sediment sequences. These barnacles have rounded edges and abraded surface ornamentation, are stained light grey, and contain borings often filled

with glauconite or pyrite. The percentage of stained and rounded barnacles increases upward from about 5% at the base to about 40% at the top of AF-4. Remaining barnacles lack stain, and exhibit only minor rounding of edges and little destruction of surface ornamentation. AF-4 sediments differ from other barnacle-rich Pungo River sediments in Onslow Bay because of the abundance of bryozoans. Echinoids are a relatively minor component in AF-4, but constitute a larger percentage of other barnacle-rich sediments.

Milliman (1974) found that the major epibenthic carbonate producers on the modern continental shelf of the eastern United States and Canada are barnacles. Most are associated with the algal ridge system and other rocky areas at the shelf break. Barnacle-rich sediments are rare on most other shelves, with the exception of the coast of Ireland, Alaska, and eastern Africa. Bryozoans and coralline algae are the predominant epibenthic fauna and flora on remaining non-tropical shelves (Milliman, 1974, 1977).

S.W.P. Snyder (1982) interpreted the White Oak Lineament as the paleo-shelf edge during the Langhian. All AF seismic units appear to have been deposited over the White Oak Lineament as a series of prograding clinoforms; the same type of seismic pattern occurs in modern sediments being deposited on the slope beyond the shelf break (A.C. Hine, pers. comm.). Sediments in AF-4 dip more steeply than those in AF-1, AF-2, or AF-3 (Fig. 7).

The greater predominance of barnacles, with lesser abundances of bivalves and bryozoans, in seismic unit AF-4 indicates deposition under conditions different from those of AF-1 through AF-3. AF-4

barnacle-rich sediments probably formed on hardgrounds along the shelf edge, were disarticulated, and redeposited as clinoform beds over the shelf break.

Carbonates in Noncarbonate Lithologies

Disseminated Carbonates

Some calcareous fossils and carbonate mud are present in nearly all noncarbonate lithologies examined. The most common fossils in noncarbonate lithologies are echinoids, bivalves, and benthic foraminifers, all calcareous organisms that lived in a predominantly siliciclastic marine environment. Barnacles, bryozoans, and ostracods are relatively rare in noncarbonate lithologies.

Siliceous fossils are often present in very fine grained siliciclastic sediments where calcareous fossils are rare to absent (Figs. 38 and 39). The only exception to this is in core OB-34 (seismic unit AF-1) where a diverse assemblage of both calcareous and siliceous fossils are present in the sand.

The source of most carbonate mud in "normal" carbonate environments is from disarticulation of green algae (i.e., Penicillus) which contribute aragonite needles to the sediment. Green algae that contribute carbonate to the sand fraction in subtropical to tropical carbonate environments include dasycladaceans and the codiacean algae Halimeda. Dasycladacean algae occurs in only trace percentages in the carbonate cap rocks of FPF-1. Molnia and Pilkey (1972) and Crowson (1980) stated that most modern carbonate mud in Onslow Bay is derived from bio-mechanical degradation of larger carbonate grains. This also

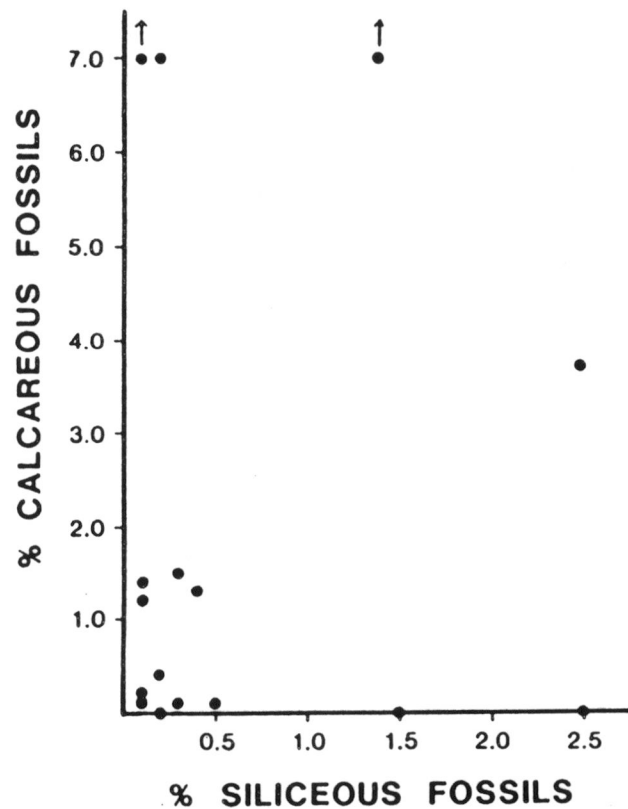


Figure 38. Sand-size siliceous vs. calcareous fossils showing the predominance of siliceous fossils where calcareous fossils are rare.

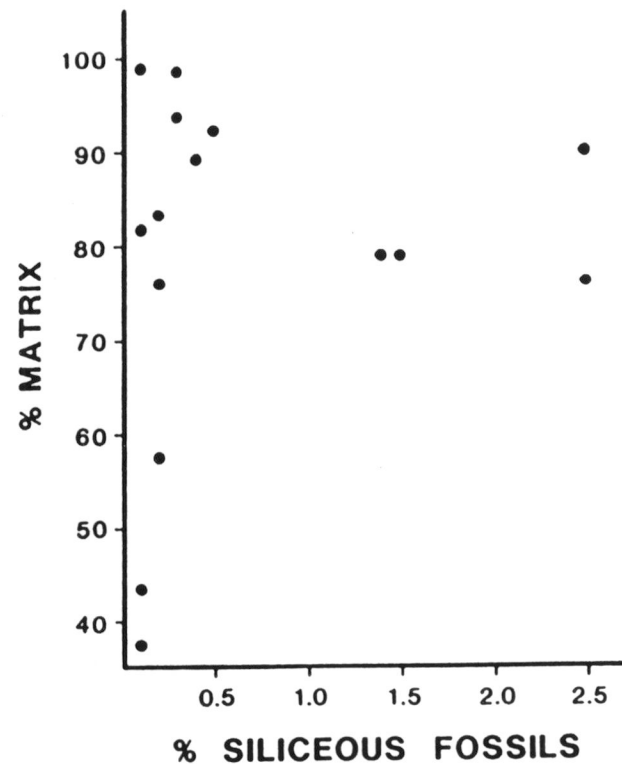


Figure 39. Sand-size siliceous fossils vs. matrix showing the predominance of siliceous fossils in very muddy sediments.

is the most likely source for most calcite mud in the Pungo River Formation in Onslow Bay, especially in sediments that are predominantly muds with a high insoluble content. Loaf-shaped, 10-30um calcite crystals, which Folk (1965) calls psuedospar, were seen in thin sections of muds from seismic unit FPF-2. Calcareous fossils are the only other calcite present in these muds. Folk believes that psuedospar is of neomorphic origin; however, Bathurst (1975) believes most of Folk's loaf-shaped crystals may be formed by the breakdown of skeletal material. Because there is a lack of micrite and microspar which, if present, might suggest a neomorphic origin, a skeletal origin is favored for loaf-shaped crystals where clays and other insoluble matrix material are abundant.

Interbedded Carbonates

Interbedded carbonates are those in which indurated carbonate laminae overlie and are overlain by noncarbonate lithologies. Two types of interbedded carbonate sediments were seen: echinoid-foraminiferal biosparite and moldic microsparite.

Echinoid-foraminiferal Biosparite. Two beds, 5cm and 10cm thick, of echinoid-foraminiferal biosparite (Plate 12) occur in seismic unit FPF-6 (core OB-102) in the Frying Pan Area. These biosparites are well washed (only 6% mud) and are predominated by benthic foraminifers (31.2%), planktonic foraminifers (22.2%), and echinoids (8.3%). In thin section, the foraminifers do not appear to be broken or abraded nor are the fossils laminated. Biosparites have sharp contacts with the overlying

and underlying sediment.

The lithology of the noncarbonate portion of FPF-6 in the Frying Pan Area is a fossiliferous (29.5%), muddy (31.6%), quartz sand. Predominant fossils are benthic foraminifers (8.7%), planktonic foraminifers (6.1%), and echinoids (7.7%). FPF-6 contains a foraminiferal fauna indicative of well oxygenated, open marine, mid to outer shelf conditions; planktonic to benthic foraminiferal ratios are about 1:1 (Waters, 1983). The seismic pattern of FPF-6 in the Frying Pan Area is a series of large-scale channels (Fig. 6) which are interpreted to be the product Gulf Stream activities.

Based on the state of preservation of foraminifers in the biosparites, the minor amount of fine grained sediment, the lack of bedding of the fossils, the similar species composition of faunas in the biosparites to those in overlying and underlying sediment, and the large-scale channeled seismic pattern of FPF-6 (Fig. 6), the biosparites probably formed as a lag deposit via winnowing of the fines by moderately low energy, current activity such as meander eddies of the Gulf Stream. I believe the fines were winnowed by currents rather than by wave agitation and transportation because the fossils are not abraded or bedded.

Moldic microsparites. Moldic microsparites were found in seismic units FPF-1 and BBF-1 (cores OB-134, 53, and 94). Table 18 summarizes the composition of the moldic microsparites. They are well cemented by microsparite (65.9%) and contain few body fossils (2.9%). About 5% moldic porosity is present due to dissolution of bivalve fragments.

Sample	Moll	Barn	Ech	For	Spar	Micr	Phos	Oth	Qtz
53-5.90	0.0	0.0	0.0	0.0	6.7	81.3	2.7	0.6	8.7
94-1.00	0.0	3.3	0.0	0.0	8.3	72.0	3.7	0.3	12.3
94-1.50	0.0	0.0	0.0	0.0	11.1	63.0	5.9	0.0	20.0
134-0.00	0.6	3.6	2.9	1.3	7.1	47.2	0.3	1.0	35.9
Average	0.2	1.7	0.7	0.3	8.3	65.9	3.2	0.5	19.2

Table 18. Composition of moldic microsparites. (Sample = core-depth (m); Moll = molluscs; Barn = barnacles; Ech = echinoids; For = foraminifers; Spar = calcite cement; Micr = microspar; Phos = phosphate; Oth = others; Qtz = siliciclastic sand.)

Quartz is a common component, averaging 19.2%.

Moldic microsparite within seismic unit FPF-2 crops out on the sea floor along the 22m profile (core OB-134). The relationship of the microsparite with underlying sediments is unclear because the rock was too hard to vibracore (only 0.5 m was recovered). However, the 22m seismic profile suggests it may be the carbonate cap rock of seismic unit FPF-1.

In seismic unit BBF-1 (cores OB-53 and OB-94), three laminae of microsparite are interbedded with quartz-rich (49.9%), phosphorite sand. The laminae are 1-3cm thick and in sharp contact with overlying and underlying sediments. Thin section analyses indicate that the laminae are indurated by microspar. Surrounding unindurated phosphorite sand also contains carbonate mud which has neomorphosed to microspar but is not indurated because microspar is a minor component and is mixed with abundant (25.8%) clays. These thin carbonate laminae resemble the cap rock of "unit C" of the Pungo River Formation in the Aurora Area (Riggs and others, 1982b). They may indicate the beginning of an increase of carbonate upsection but better core control will be necessary to document this interpretation.

SUMMARY

1. Four patterns of carbonate sedimentation occur in the Pungo River Formation in Onslow Bay: 1) cyclic carbonate sediments overlying noncarbonate lithologies which were deposited as a couplet during the same sea-level cycle (carbonate caps); 2) barnacle-rich, relatively pure carbonate sediments of seismic sequence AF which were deposited continuously during each fourth-order sea-level cycle of the Langhian; 3) thin carbonate laminae interbedded with noncarbonate lithologies; and 4) disseminated sparse fossils and carbonate mud in noncarbonate lithologies. The total carbonate content of the Pungo River Formation in Onslow Bay is summarized in Figure 40. The distribution of carbonate mud and calcareous faunal assemblages in Pungo River sediments are shown in Figures 41 and 42, respectively.

2. Two types of carbonate cap rocks are present in the Pungo River Formation in Onslow Bay: a) those that fit Riggs' (1984) model of Neogene sedimentation, and b) barnacle-rich carbonates which could represent a variation of the idealized lithic cycle in Riggs' model.

Two varieties of carbonate cap rocks which fit Riggs' (1984) model occur in Pungo River sediments in Onslow Bay. Seismic unit FPF-1 in the Frying Pan Area has a biomicrosparite cap that overlies and grades into phosphorites. It contains a diverse fauna and flora of barnacles, bryozoans, bivalves, echinoids, benthic and planktonic foraminifers, ostracods, decapods, and coralline and dasycladacean algae. This assemblage indicates open shelf conditions and warm temperate to

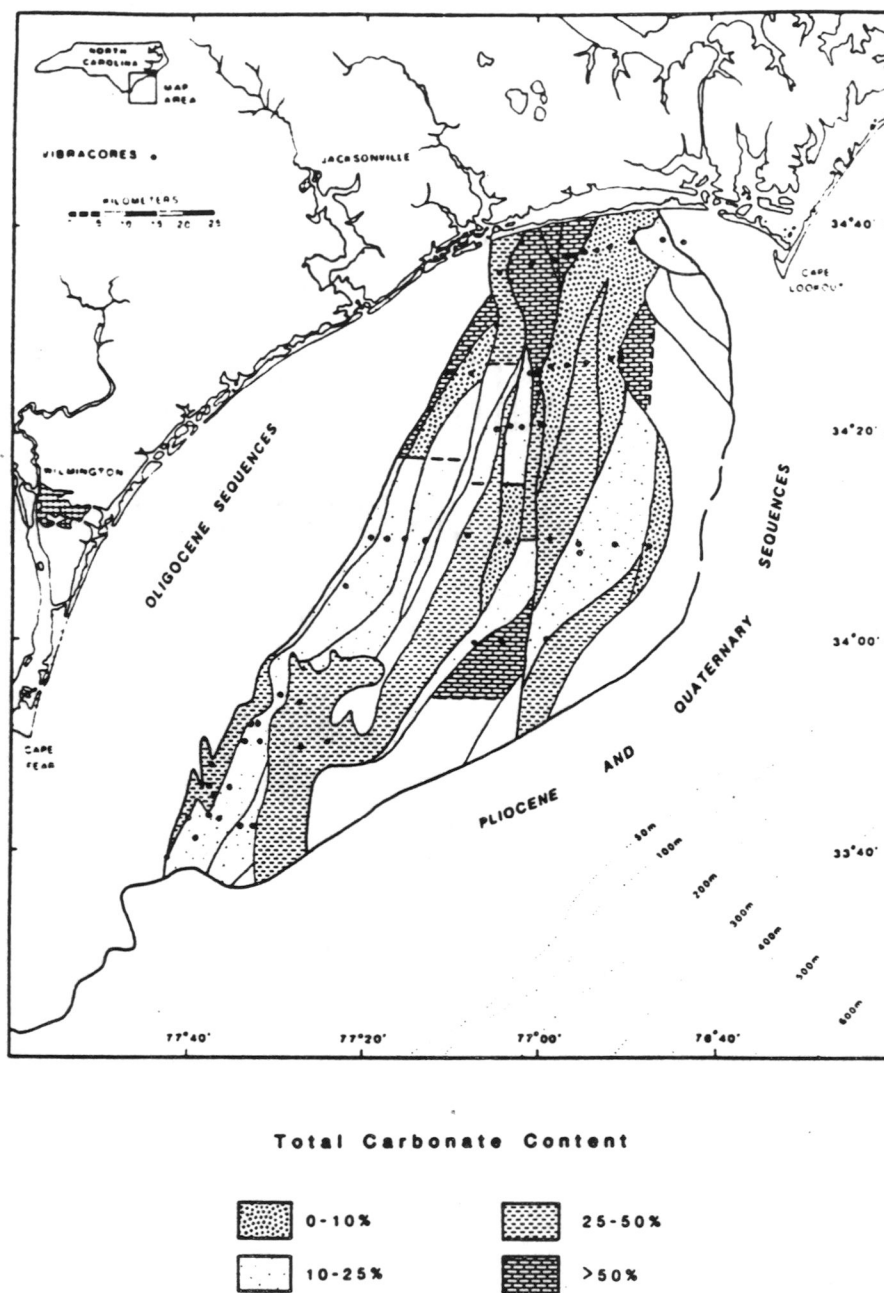


Figure 40. Map of the Pungo River Formation showing the distribution of carbonate sediments.

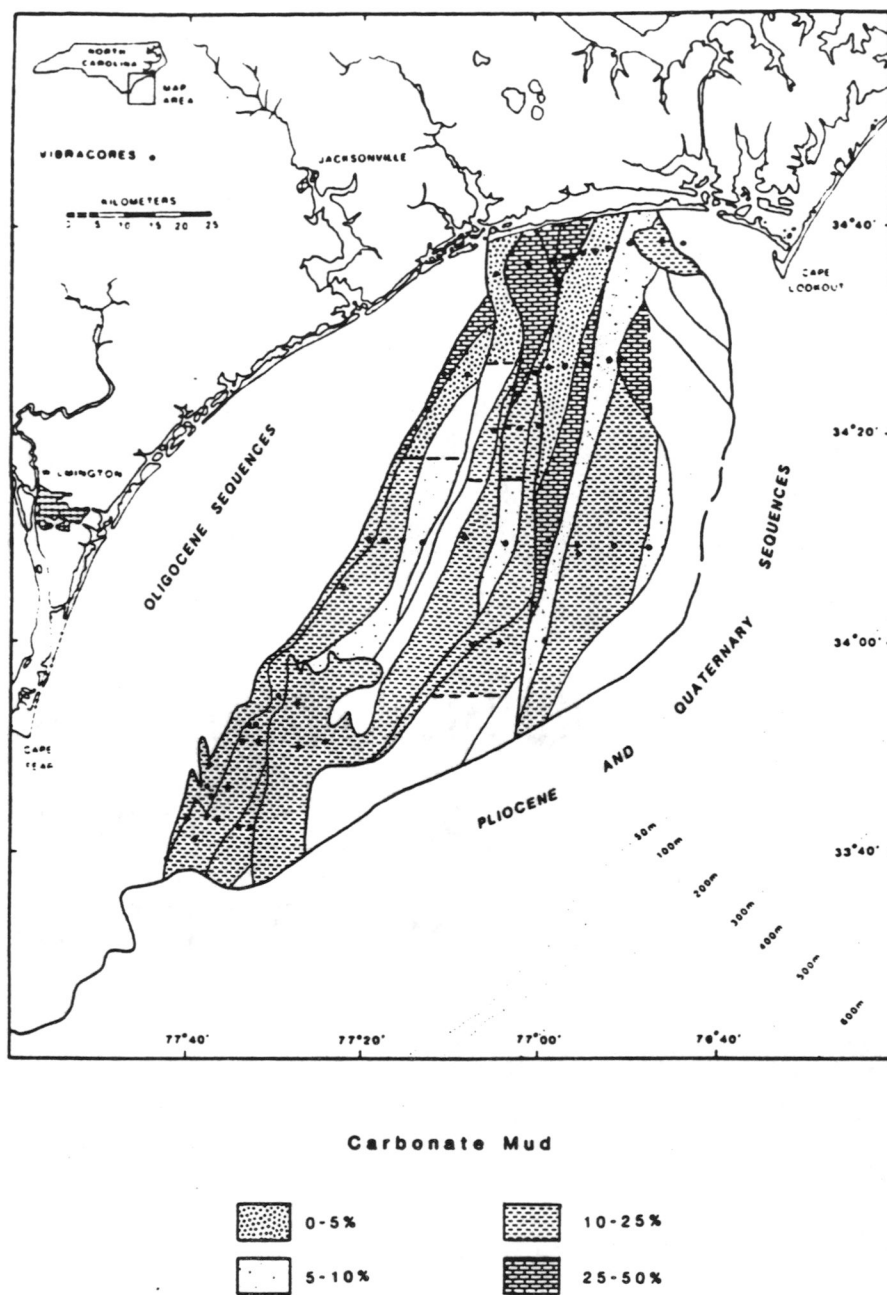
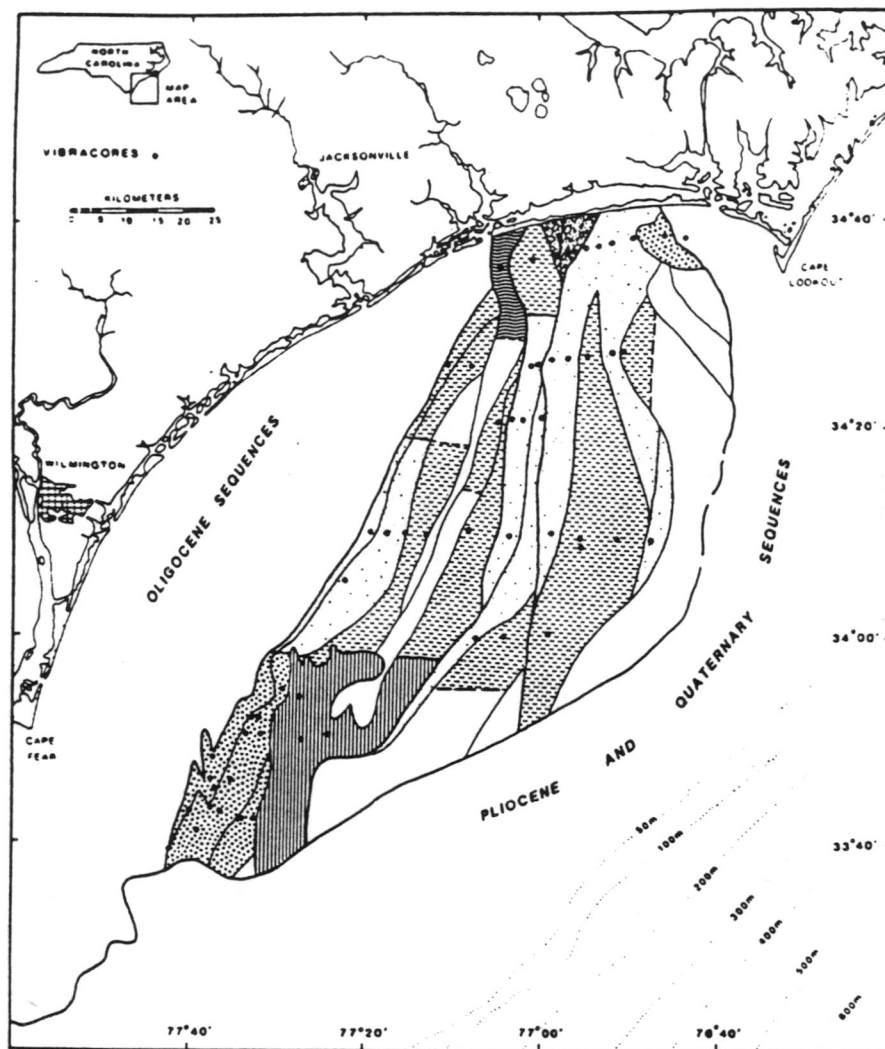


Figure 41. Map of the Pungo River Formation showing the distribution of carbonate mud.



Calcareous Fossil Assemblages

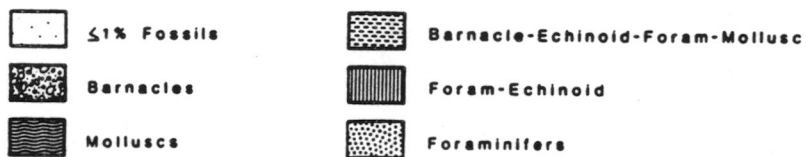


Figure 42. Map of the Pungo River Formation showing the distribution of calcareous fossil assemblages.

subtropical waters. The second "carbonate" cap rock is calcite cemented sandstone of seismic unit BBF-2. Total carbonate content and effects of diagenesis decrease down section.

Barnacle-rich carbonate sediments consisting mostly of barnacles, with minor echinoids and molluscs, probably were formed on the inner shelf. These carbonate sediments were probably deposited during fourth-order sea-level regressions during which the barnacles were disarticulated and scattered over the top of previously deposited siliciclastic sediment.

3. The AF seismic sequence is predominated by carbonate sediments in the northern part of Onslow Bay; siliciclastics decrease upsection and increase toward central Onslow Bay. Sediments of unit AF-1 in northern Onslow Bay contain a diverse assemblage of calcareous and siliceous fossils including molluscs, barnacles, echinoids, bryozoans, ostracods, benthic and planktonic foraminifers, diatoms, radiolarians, and siliceous sponge spicules. This assemblage indicates open shelf conditions, probably mid to outer shelf. AF-2 and AF-3 both contain largely reworked fossil assemblages. AF-4, predominated by barnacles and bryozoans, is interpreted as outer shelf to upper slope deposition.

4. Two types of interbedded carbonate lithologies occur in Pungo River sediments in Onslow Bay: 1) echinoid-foraminiferal biosparite and 2) moldic microsparite. Echinoid-foraminiferal biosparites of seismic unit FPF-6 are probably formed via winnowing of the fines by Gulf Stream eddy currents. Moldic microsparite crops out on the sea floor along the 22m

profile and is interpreted as the carbonate cap rock on FPF-1 in northern Onslow Bay. Seismic unit BBF-1 contains three moldic microsparite laminae which are interbedded with quartz-rich phosphorite sand. These laminae are similar to the carbonates in "unit C" of the Pungo River Formation in the Aurora Area and they may indicate the beginning of increased carbonate deposition.

5. The most common fossils in noncarbonate lithologies of Pungo River sediments in Onslow Bay are echinoids, bivalves, and benthic foraminifers. Barnacles, bryozoans, and ostracods constitute a small percentage of these sediments.

6. The source of carbonate mud in the Pungo River Formation is largely from bio-mechanical degradation of larger carbonate grains, primarily shell material.

7. Vertical diagenetic profiles are exhibited by some, but not all, of the cores studied. This may be due to the sampling interval used, the actual distribution of different diagenetic components, the effects of multiple diagenetic processes, or a combination of these factors. More detailed work at a close sample interval needs to be done with cores that have a thick Miocene section to determine the details and extent of diagenetic alteration.

Where carbonate sediments are abundant, affects of fresh water calcite cementation decrease down section. Syntaxial cement on echinoids seems to be a good indicator of the degree of diagenesis

undergone by sediments because it appears to be precipitated faster than rim cements on other fossils.

The occurrence of early diagenetic dolomite in the Pungo River Formation appears to be sporadic. This may be attributable to the presence or absence of sulfate reducing bacteria within the sediment.

Silica authigenesis appears to be related to concentration of siliceous fossils and permeability barriers within the sediment which would explain the preservation of diatoms in parts of the sediment column and their dissolution in other parts.

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Appendix A.

Reflected light microscopy data

Appendix A. Reflected light microscopy data.

This data is arranged first by seismic unit, then by seismic profile or area (refer to Figure 8 for the location of the seismic profiles). Each series of cores in the same seismic unit are then arranged by location from east to west. Area FP is the Frying Pan Area; cores in this area are listed numerically.

The following data is presented in volume % of the total sediment. The method by which this was determined is described in detail in the Methods of Investigation section. The headings are abbreviated as follows:

Sample	= Core-Top depth of sample (m)
Moll	= Molluscs
Barn	= Barnacles
Bry	= Bryozoans
Ech	= Echinoids
Ost	= Ostracods
Bf	= Benthic foraminifers
Pf	= Planktonic foraminifers
Carb	= Unidentifiable carbonate grains
Spar	= Calcite cement
Dolo	= Dolomite
Cher	= Chert
Diat	= Diatoms
Rad	= Radiolarians
Spic	= Spicules
Skel	= Skeletal phosphate grains
Phos	= Pelletal and intraclastic phosphate grains
Glau	= Glauconite
Opaq	= Opaques
Oth	= Other minerals (zeolites and gypsum)
Qtz	= Siliciclastic sand
Matr	= Matrix

Sample	Area	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Cher	Diat	Rad	Spic	Skel	Phos	Glau	Opaq	Oth	Qtz	Matr
BBF-6																						
100-8.60	15m	tr	tr	0.0	0.6	0.0	tr	0.0	0.6	0.1	0.2	0.0	0.0	0.0	0.0	0.1	tr	0.0	tr	0.4	53.5	44.4
1-4.50	15m	0.3	tr	0.0	1.1	0.0	2.0	0.0	0.4	0.0	1.6	0.0	0.0	0.0	0.0	2.8	8.4	0.1	0.0	0.0	62.1	21.3
1-5.25	15m	0.0	0.0	0.0	0.4	0.0	3.7	0.0	0.4	0.0	2.4	0.0	0.0	0.0	0.0	2.7	6.4	0.2	0.0	0.0	60.2	23.6
1-5.75	15m	0.2	0.0	0.0	tr	0.0	0.6	0.0	0.1	0.0	0.7	0.0	0.0	0.0	0.0	3.0	5.6	0.1	0.0	0.0	63.7	26.1
1-6.50	15m	tr	tr	0.0	0.1	0.0	0.5	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	4.7	8.5	0.1	0.0	0.0	65.6	20.1
1-8.00	15m	0.0	tr	0.0	tr	0.0	0.6	0.0	tr	0.0	0.7	0.0	0.0	0.0	0.0	3.5	10.5	0.2	0.0	0.0	67.0	17.5
BBF-3																						
108-2.75	22m	0.4	6.6	0.2	0.4	0.1	1.7	0.0	1.8	tr	0.0	0.0	0.0	0.0	0.0	0.2	tr	tr	0.0	0.0	10.9	77.8
108-3.75	22m	0.7	18.7	0.1	1.0	0.0	1.3	0.0	5.0	5.8	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	27.6	39.5
108-5.00	22m	0.3	9.3	0.1	0.6	0.0	1.7	0.2	2.2	9.3	0.0	0.0	0.0	0.0	0.0	0.2	tr	0.0	0.0	0.0	21.2	54.9
BBF-2																						
92-4.00	I-4	0.1	tr	0.0	0.1	0.0	tr	0.0	1.2	0.8	0.0	0.0	0.0	0.0	0.0	tr	tr	0.0	0.0	0.0	83.9	13.9
92-5.50	I-4	0.4	0.0	0.0	0.1	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	tr	0.0	tr	0.0	93.4	6.0
BBF-1																						
91-3.50	15m	tr	0.0	0.0	tr	0.0	0.9	0.0	tr	0.0	0.8	0.0	0.0	0.0	0.0	2.9	7.4	1.6	0.0	0.0	66.9	19.4
91-5.50	15m	0.0	0.0	0.0	tr	0.0	0.9	0.0	tr	0.0	0.6	0.0	0.0	0.0	0.0	1.3	2.6	1.1	0.0	0.0	71.6	21.9
2-3.50	15m	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.1	1.2	0.0	0.0	67.6	27.0
2-6.50	15m	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.0	1.5	4.4	0.0	0.0	0.0	59.0	34.5
2B-6.50	15m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	3.4	10.1	0.0	0.0	0.0	50.4	35.1
3-1.50	15m	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	4.5	0.0	0.0	0.0	16.8	76.8
3-4.00	15m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	3.5	11.7	0.0	0.0	0.0	45.6	39.2
3-6.50	15m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	12.6	0.0	0.0	0.0	46.5	36.3
36-2.00	15m	0.3	0.0	0.0	tr	0.0	tr	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.3	6.6	0.0	0.0	0.0	60.1	30.5
109-1.50	22m	0.3	0.2	0.0	0.0	0.0	0.4	0.0	tr	0.0	tr	0.0	0.0	0.0	0.0	2.7	4.3	tr	0.0	0.0	65.7	26.3
109-3.00	22m	0.2	0.0	0.0	0.5	0.0	0.6	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	2.8	4.0	0.1	0.0	0.0	62.8	28.9
109-4.50	22m	0.2	0.0	0.0	0.0	0.0	tr	0.0	0.2	0.2	tr	0.0	0.0	0.0	0.0	2.8	2.8	0.3	0.0	0.0	60.6	32.8
109-5.75	22m	3.8	15.3	0.0	2.8	0.2	4.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.1	0.1	0.0	0.0	26.6	43.2
71-0.50	22m	0.1	tr	0.0	0.1	0.0	1.0	0.0	tr	0.0	0.2	0.0	0.1	0.0	0.0	1.4	1.9	0.1	0.0	0.0	29.4	65.6
6-2.00	22m	tr	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.7	0.0	0.0	0.0	50.7	45.9
6-5.00	22m	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.6	0.1	0.0	0.0	49.0	48.2
39-2.00	22m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.1	0.0	0.0	0.0	49.9	47.7
39-5.00	22m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.9	0.0	0.0	0.0	47.4	48.6
60-1.50	I-4	0.1	2.6	0.0	tr	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.0	66.1	30.1
60-4.00	I-4	0.1	2.0	0.0	tr	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.4	0.0	0.0	0.0	42.9	52.5
60-6.25	I-4	0.3	1.1	0.0	0.4	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	4.2	0.0	0.0	0.0	49.3	43.4
53-1.50	I-4	0.4	0.7	0.0	0.1	0.0	0.4	0.0	tr	0.0	0.0	0.0	tr	0.0	0.0	1.4	7.6	0.0	0.0	0.0	52.0	37.3
53-3.75	I-4	0.2	0.6	0.0	tr	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	22.2	0.3	0.0	tr	45.9	24.0
53-6.00	I-4	1.7	1.7	0.2	0.9	0.0	0.3	0.0	1.4	1.1	0.0	0.0	0.0	0.0	0.0	3.9	14.2	0.2	0.0	0.0	42.9	31.5
52-3.75	I-4	0.1	tr	tr	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	tr	0.0	tr	0.0	7.4	92.2
59-6.50	I-5	tr	tr	0.0	0.6	tr	0.6	0.1	6.0	2.9	0.0	0.0	0.0	0.0	0.0	0.2	tr	0.0	0.0	tr	6.1	83.4
59-7.75	I-5	3.8	0.7	tr	0.4	0.1	1.0	0.0	0.2	tr	0.0	0.0	0.0	0.0	0.0	0.6	0.5	0.3	0.0	0.3	72.7	19.2

Sample	Area	Holl	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Cher	Diat	Rad	Spic	Skel	Phos	Glau	Opaq	Oth	Qtz	Matr
AF-4																						
3-8.75	15m	1.9	49.0	0.5	0.7	0.0	0.4	tr	3.7	4.3	tr	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	39.1
36-5.00	15m	0.0	4.3	0.0	tr	0.0	2.1	0.3	1.3	0.0	0.7	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.1	91.1
33-0.50	15m	20.6	42.5	0.7	0.0	0.0	0.1	tr	8.8	0.3	tr	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.1	26.9
33-2.50	15m	10.3	65.6	3.0	tr	tr	tr	tr	1.5	1.1	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.3	18.3
33-4.50	15m	9.3	27.6	12.4	1.2	tr	0.5	tr	9.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.1	0.0	0.8	38.2
33-6.50	15m	7.0	18.6	8.5	2.1	0.4	1.5	0.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.3	0.0	0.0	1.1	2.9	55.5
33-8.75	15m	2.3	46.4	2.6	3.8	tr	0.9	0.2	6.1	1.9	0.0	0.0	0.0	0.0	0.0	tr	0.2	0.0	0.1	0.0	1.7	33.7
111-0.50	15m	15.3	13.4	5.6	0.1	0.0	tr	tr	6.0	38.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	tr	1.4	19.8
111-2.50	15m	15.1	28.0	3.2	0.5	tr	0.2	0.0	3.1	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.6	47.7
111-4.25	15m	3.0	42.8	7.3	0.4	0.0	0.3	0.0	10.5	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	4.1	27.4
111-5.50	15m	9.5	17.5	7.4	0.6	0.2	1.4	0.2	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.7	55.5
111-6.25	15m	9.8	39.4	5.6	0.5	tr	0.5	tr	4.4	10.9	0.0	0.0	0.0	0.0	0.0	tr	tr	0.0	tr	0.0	1.3	27.4
111-7.50	15m	9.8	12.4	5.8	0.7	0.0	1.0	0.3	8.5	0.0	0.0	0.0	0.0	0.0	tr	tr	0.1	0.0	0.0	0.0	1.4	60.1
111-8.00	15m	16.6	44.9	2.1	0.3	0.0	0.1	tr	5.6	2.8	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.1	0.0	2.0	25.6
AF-3																						
34-2.00	15m	0.4	21.9	0.7	5.6	0.0	0.2	0.1	3.2	7.9	0.0	0.0	0.0	0.0	0.0	tr	0.7	0.0	0.2	0.0	29.9	29.2
35-1.25	15m	2.5	26.9	0.5	6.9	0.4	2.1	0.7	9.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.3	tr	0.1	0.0	14.3	36.5
131-3.75	I-5	10.9	3.0	1.3	3.4	0.0	0.8	0.1	8.7	7.3	0.0	0.0	0.0	0.0	0.0	tr	0.2	0.0	0.0	0.0	30.3	33.9
131-4.75	I-5	8.4	7.8	1.6	4.3	0.0	1.1	0.2	9.7	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	32.6	30.8
131-5.75	I-5	10.1	6.3	1.5	2.4	0.0	0.7	0.1	11.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.7	28.8
AF-2																						
39-8.40	22m	4.0	41.9	0.4	2.2	0.0	1.8	0.5	4.2	1.2	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.2	0.0	0.0	29.1	13.3
38-0.50	22m	1.4	21.3	0.0	2.1	0.0	12.5	4.6	13.3	22.4	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.0	3.3	18.7
58-2.25	I-5	tr	0.1	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	94.5	4.8
58-4.25	I-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	2.7	97.3
AF-1																						
34-4.00	15m	0.1	4.2	0.3	1.7	0.0	0.5	0.2	3.4	tr	tr	0.0	1.4	tr	tr	0.0	tr	0.0	tr	0.0	9.3	78.9
34-6.00	15m	0.1	1.8	0.1	0.5	0.1	0.2	0.1	0.8	0.0	0.0	0.0	2.5	tr	tr	tr	0.0	0.0	0.0	tr	3.8	90.0
34-8.00	15m	0.7	18.9	0.9	6.3	0.5	0.9	0.2	6.6	0.0	tr	0.0	0.1	0.0	0.0	0.0	0.2	tr	0.0	0.0	26.3	38.5
35-2.75	15m	0.2	3.1	0.3	8.1	0.4	3.2	0.5	10.8	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.0	0.0	12.2	60.3
35-5.25	15m	6.0	3.4	0.6	3.2	0.4	2.6	0.4	7.6	tr	0.1	tr	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	13.7	61.5
35-7.75	15m	7.1	1.1	0.5	1.9	3.4	11.0	1.0	8.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	9.7	55.5
38-3.50	22m	tr	0.0	0.0	tr	0.0	0.0	0.0	tr	tr	0.5	0.0	0.0	0.0	0.0	0.4	0.6	0.0	0.0	0.0	68.7	29.8
38-6.50	22m	0.0	0.0	0.0	tr	0.0	0.0	0.0	tr	7.5	tr	0.8	0.0	0.0	0.0	0.0	0.2	0.0	tr	0.0	28.6	62.8
38-8.75	22m	tr	tr	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.6	tr	0.0	0.0	94.6	2.8
40-8.00	22m	tr	tr	0.0	0.0	0.0	tr	0.0	tr	0.0	tr	0.0	0.0	0.0	0.0	0.3	0.1	0.0	tr	0.2	26.7	72.6
41-2.50	I-8	3.4	0.3	0.2	0.4	0.0	tr	tr	4.2	tr	tr	0.0	0.0	0.0	tr	0.4	0.1	0.0	tr	tr	78.6	12.2
41-4.75	I-8	tr	tr	tr	tr	0.0	tr	0.0	4.1	1.9	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	tr	0.0	83.4	10.4
41-7.00	I-8	0.2	0.1	0.0	tr	0.0	0.0	0.0	0.4	2.3	0.0	0.0	0.0	0.0	0.0	tr	1.1	0.0	tr	0.0	86.9	8.8
44-2.00	I-8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	tr	tr	0.1	0.0	0.0	tr	2.5	97.2
44-5.00	I-8	0.0	0.0	0.0	tr	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.2	0.2	0.0	0.0	0.0	56.5	43.1

Sample	Area	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Cher	Diat	Rad	Spic	Skel	Phos	Glau	Opaq	Oth	Qtz	Matr
AF-1																						
51-2.00	I-4	tr	0.0	0.0	0.3	0.0	tr	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.5	3.1	0.0	0.0	0.0	73.8	20.1
51-5.00	I-4	0.0	tr	0.0	0.1	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.7	0.0	0.0	0.0	69.9	26.8
51-8.00	I-4	tr	0.1	0.0	0.6	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.0	0.0	tr	60.4	37.4
58-6.25	I-5	0.1	tr	0.0	0.0	0.0	tr	0.0	tr	0.1	0.0	0.0	0.0	0.0	0.0	tr	0.4	0.0	0.0	0.0	94.8	4.6
58-8.25	I-5	tr	tr	0.0	tr	0.0	0.0	0.0	0.1	1.5	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.0	0.0	88.5	9.2
FPF-6																						
45-1.00	I-8	0.5	27.5	0.5	5.6	0.0	1.7	0.1	9.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	8.7	44.9
45-3.00	I-8	0.2	3.9	0.8	13.6	0.0	2.9	0.6	2.6	1.1	0.0	0.0	0.0	0.0	0.0	0.4	0.9	tr	0.0	0.0	50.1	22.9
45-4.00	I-8	4.4	5.7	0.8	2.9	0.0	0.4	0.1	2.8	0.7	0.0	0.0	0.0	0.0	0.0	0.9	0.8	0.0	0.0	0.0	52.9	27.5
45-5.50	I-8	3.1	8.2	tr	1.6	0.0	0.7	0.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	tr	0.0	68.9	12.6
67-3.50	FP	tr	0.0	0.0	8.3	tr	8.8	13.7	3.7	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.8	0.0	0.0	0.0	39.5	23.6
67-6.50	FP	0.0	0.0	0.0	8.3	0.2	7.5	7.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4	0.0	0.0	0.0	43.6	30.2
96-1.50	FP	0.4	0.4	tr	11.8	0.2	10.4	4.9	22.8	6.9	0.0	0.0	0.0	0.0	0.0	1.1	0.3	0.0	0.0	0.0	16.9	23.9
96-3.50	FP	0.0	tr	0.0	6.0	tr	8.9	3.6	5.4	tr	0.0	0.0	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.0	43.4	30.6
96-5.50	FP	0.0	tr	0.0	4.0	0.0	8.1	1.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	34.8	49.9
FPF-5																						
46-0.75	I-8	0.6	31.6	0.5	6.9	0.1	2.6	0.3	14.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	5.2	36.9
46-2.50	I-8	0.2	0.2	tr	0.0	0.0	tr	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	tr	0.0	0.0	0.0	85.3	13.0
46-5.50	I-8	tr	0.1	0.0	tr	0.0	tr	0.0	tr	tr	0.0	0.0	0.0	0.0	0.0	tr	0.1	0.0	tr	0.0	88.0	11.6
50-2.50	I-4	8.3	8.4	1.0	4.5	0.0	0.9	0.6	6.7	4.4	0.0	0.0	0.0	0.0	0.0	0.1	0.7	tr	tr	0.0	44.4	19.9
50-3.25	I-4	5.3	3.7	0.0	2.7	0.0	1.5	0.3	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.0	0.0	0.0	65.2	14.1
50-5.75	I-4	0.0	tr	0.0	0.1	0.0	tr	0.0	tr	0.0	0.0	0.0	tr	0.0	0.0	0.1	0.4	0.0	0.0	0.0	3.6	95.8
50-8.25	I-4	0.0	0.0	0.0	tr	0.0	0.0	tr	0.1	0.0	0.0	0.0	0.5	0.0	tr	0.1	0.3	0.0	0.0	0.0	6.6	92.4
FPF-4																						
37-3.00	15m	0.3	tr	0.0	0.2	tr	0.2	0.0	tr	tr	0.0	0.0	0.0	0.0	0.0	0.9	tr	0.0	0.0	0.0	88.1	10.2
37-6.00	15m	12.8	4.8	0.0	0.0	0.0	0.0	0.0	0.9	tr	0.0	0.0	0.0	0.0	0.0	0.2	tr	0.0	0.0	0.0	70.5	10.7
37-7.50	15m	46.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	38.8	10.3
FPF-3																						
48-2.00	I-4	0.6	0.5	0.1	1.7	0.1	0.3	0.1	2.6	0.1	0.0	0.0	0.0	0.0	0.0	0.2	1.0	tr	0.0	0.0	78.6	14.2
48-5.00	I-4	0.1	1.5	tr	1.5	0.1	2.8	0.4	5.6	tr	0.0	0.0	0.0	0.0	0.0	0.9	1.6	0.0	1.1	0.0	74.0	10.4
48-7.75	I-4	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1.5	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	61.2	27.2
17-3.25	FP	0.0	0.0	0.0	tr	0.0	1.5	tr	0.0	0.0	tr	0.0	tr	0.2	0.1	0.2	0.6	0.0	0.0	0.0	3.4	93.9
17-5.50	FP	tr	tr	0.0	0.2	0.0	6.4	0.4	0.0	tr	0.0	0.0	0.0	0.2	tr	0.3	0.5	0.0	0.0	0.1	8.2	83.6
62-3.75	FP	tr	tr	tr	tr	0.0	0.1	tr	tr	0.0	0.0	0.0	tr	0.1	tr	tr	tr	0.0	0.0	0.0	0.5	99.2
62-5.50	FP	tr	0.0	tr	0.0	0.0	0.1	tr	tr	0.0	0.0	0.0	0.1	0.1	0.1	tr	tr	0.0	0.0	0.0	0.9	98.7
FPF-2																						
110-1.00	22m	0.4	tr	0.0	0.5	0.0	0.1	0.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	tr	87.8	8.8
110-4.64	22m	1.2	0.1	tr	0.3	tr	0.2	0.9	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.1	tr	0.0	0.0	0.2	60.5	36.4

Sample	Area	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Carb	Spar	Dolo	Cher	Diat	Rad	Spic	Skel	Phos	Glau	Opaq	Oth	Qtz	Matr
FPF-2																						
49-1.75	I-4	tr	tr	0.0	tr	0.0	tr	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.0	0.0	0.0	66.3	32.4
49-4.75	I-4	0.0	tr	0.0	0.4	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.4	0.7	0.1	0.0	0.0	40.9	57.4
49-7.75	I-4	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.9	tr	0.0	0.0	0.1	0.0	0.0	0.7	0.6	0.0	tr	0.0	54.2	43.6
47-0.50	I-4	0.1	0.1	tr	tr	0.0	0.0	0.0	tr	tr	0.0	0.0	0.1	tr	0.0	0.1	0.1	0.0	0.0	0.0	17.2	82.2
47-2.75	I-4	tr	0.0	0.0	0.0	0.0	tr	0.0	tr	0.0	0.0	0.0	1.3	0.2	0.0	0.1	0.1	0.0	0.0	tr	19.3	79.0
47-5.00	I-4	0.0	tr	0.0	tr	0.0	tr	tr	tr	0.0	0.0	0.0	2.4	tr	0.1	tr	0.4	0.1	tr	0.0	20.7	76.1
47-7.25	I-4	tr	tr	tr	tr	0.0	tr	tr	tr	0.2	0.0	5.1	0.1	0.1	tr	0.4	0.3	0.0	0.0	0.2	17.8	75.8
15-0.25	FP	tr	tr	tr	tr	0.0	0.6	0.0	0.3	0.0	0.1	0.0	0.0	0.1	0.3	0.7	0.4	0.0	0.0	0.0	7.9	89.6
15-1.75	FP	tr	tr	0.0	0.0	0.0	tr	0.0	tr	tr	0.1	0.0	0.0	0.0	0.0	0.6	0.9	0.0	0.0	0.0	8.2	90.0
16-1.50	FP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	tr	tr	tr	0.0	0.0	0.0	0.0	0.1	99.9
16-5.50	FP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	tr	tr	tr	tr	0.0	0.0	0.0	0.0	tr	99.9
27-1.00	FP	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	3.2	0.7	94.7
27-3.00	FP	tr	0.0	0.0	tr	0.0	3.1	2.7	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	1.2	92.4
27-5.00	FP	tr	0.0	tr	tr	0.0	5.1	0.5	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.0	1.3	0.0	0.0	tr	16.8	73.3
27-7.00	FP	0.0	tr	tr	0.0	0.0	6.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	2.1	3.4	0.2	0.0	0.0	33.2	54.7
63-0.75	FP	tr	tr	0.0	0.0	0.0	10.6	10.7	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	1.3	75.9
63-2.00	FP	1.1	0.1	0.2	0.2	0.0	19.1	6.2	2.9	4.3	0.0	0.0	0.0	0.0	0.0	2.8	9.1	0.0	0.0	0.0	3.9	49.9
70-1.50	FP	tr	0.0	0.0	0.0	0.0	tr	tr	tr	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.4	2.5	96.4
97-0.50	FP	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.2	tr	0.0	0.0	0.0	0.0	0.0	2.1	2.9	0.0	tr	0.0	45.3	49.4
97-2.50	FP	tr	tr	0.0	0.0	0.0	tr	tr	0.0	tr	0.0	0.0	0.0	0.0	0.0	3.2	1.4	0.0	0.0	tr	56.0	39.3
97-4.50	FP	0.0	0.0	0.0	0.0	0.0	tr	tr	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.8	0.0	0.0	tr	31.7	66.2
97-6.50	FP	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.8	0.0	0.0	0.0	31.4	66.3
FPF-1																						
47-8.50	I-4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.0	1.3	0.0	0.0	0.0	32.8	64.7
113-0.50	I-4	tr	tr	tr	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	1.8	6.2	0.0	0.0	0.0	48.0	43.9
113-1.50	I-4	tr	tr	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	1.8	1.7	0.0	0.0	0.0	61.7	34.7
14-1.00	FP	tr	0.0	tr	0.8	tr	23.2	5.8	0.0	tr	0.0	tr	0.0	0.0	0.0	1.7	3.8	0.0	0.0	0.0	18.7	46.1
14-2.75	FP	0.0	0.0	0.0	0.8	0.0	10.8	4.4	0.0	tr	0.0	0.0	0.0	0.0	0.0	4.8	25.5	0.0	0.0	0.0	20.5	33.3
20-1.50	FP	0.3	0.6	0.2	0.3	0.0	18.3	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.1	0.0	0.0	0.0	10.4	58.5
20-3.75	FP	0.0	tr	0.0	0.1	0.0	13.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	16.1	0.0	0.0	0.0	17.2	49.6
20-6.00	FP	tr	0.0	0.0	0.1	0.0	22.6	7.0	2.1	0.1	0.0	0.0	0.0	0.0	0.0	2.2	15.3	0.0	0.0	0.0	17.0	33.7
26-0.50	FP	tr	tr	0.0	0.3	0.0	19.1	5.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.7	8.6	0.0	0.0	0.0	20.2	42.7
64-3.50	FP	tr	5.1	3.3	0.6	0.1	8.9	0.8	3.8	tr	0.0	0.0	0.0	0.0	0.0	3.2	14.0	0.0	0.0	0.0	17.5	42.6
64-5.75	FP	0.0	tr	0.0	0.1	0.0	6.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	36.9	0.0	0.0	0.0	19.2	28.7
114-5.75	FP	tr	tr	0.0	0.1	0.0	29.7	7.2	2.5	tr	1.0	0.0	0.0	0.0	0.0	2.4	2.6	0.0	tr	0.0	7.3	47.0
114-7.50	FP	0.1	tr	0.0	0.1	tr	15.2	0.9	0.5	0.1	0.1	0.0	0.0	0.0	0.0	4.1	14.4	0.0	0.0	0.0	23.3	41.1
115-5.00	FP	2.7	25.4	4.7	2.8	0.0	7.8	1.4	4.3	5.3	0.0	0.0	0.0	0.0	0.0	3.6	15.0	0.0	0.0	0.0	7.8	19.1
115-5.50	FP	0.2	2.3	0.4	0.2	0.0	14.5	4.5	2.8	tr	0.0	0.0	0.0	0.0	0.0	4.0	28.4	0.0	0.0	0.0	15.2	27.5
115-7.00	FP	1.0	0.0	0.0	tr	0.0	3.2	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4.3	29.3	0.0	0.0	0.0	37.5	24.0

Appendix B.

Insoluble residue and x-ray diffraction data

Appendix B. Insoluble residue and x-ray diffraction data.

This data is arranged first by seismic unit, then by seismic profile or area (refer to Figure 8 for the location of the seismic profiles). Each series of cores in the same seismic unit are then arranged by location from east to west. Area FP is the Frying Pan Area; cores in this area are listed numerically.

Total weight % of matrix in the sediment was determined by wet sieving. Insoluble residue analysis resulted in the determination of weight % of insolubles and carbonate in the matrix and the weight % of mud-sized insolubles and carbonate in the total sediment. Presence (P) and absence (A) of calcite and dolomite were determined by x-ray diffractometry of a split of the mud fraction. It is important to remember, however, that when only a few percent of a mineral are present in the sample being x-rayed that peaks for that mineral may be very weak or not show up at all. These methods are described in detail in the Methods of Investigation section.

Core-Top Depth of Sample (m)	Area	Total weight % of matrix in the sediment	Weight % insolubles in matrix	Weight % carbonate in matrix	Weight % mud-sized insolubles in total sediment	Weight % mud-sized carbonate in total sediment	Calcite	Dolomite
BBF-6								
100-8.60	15m	44.4	20.7	79.3	9.2	35.2	P	P
1-4.50	15m	21.3	27.0	73.0	5.8	15.6	P	P
1-5.75	15m	26.1	57.6	42.4	15.0	11.1	P	P
1-6.50	15m	20.1	55.1	44.9	11.1	9.0	P	P
1-8.00	15m	17.5	79.1	20.9	13.8	3.7	P	P
BBF-3								
108-2.75	22m	77.8	70.6	29.4	54.9	22.9	P	P
108-3.75	22m	39.5	40.7	59.3	16.1	23.4	P	P
108-5.00	22m	54.9	40.3	59.7	22.2	32.8	P	P
BBF-2								
92-4.00	I-4	13.9	16.1	83.9	2.2	11.7	P	A
92-5.50	I-4	6.0	76.7	23.3	4.6	1.4	P	A
BBF-1								
91-3.50	15m	19.4	55.5	44.5	10.7	8.6	P	P
91-5.50	15m	21.9	70.8	29.2	15.5	6.4	P	P
2-3.50	15m	27.0	81.8	18.2	22.1	4.9	P	A
2-6.50	15m	34.5	-	-	-	-	P	P
2B-6.50	15m	35.1	90.6	9.4	31.8	3.3	A	A
3-6.50	15m	36.3	94.8	5.2	34.4	1.9	A	A
36-2.00	15m	30.5	95.1	4.9	29.0	1.5	A	A
109-1.50	22m	26.3	79.6	20.4	21.0	5.3	A	P
109-3.00	22m	28.9	86.0	14.0	24.9	4.0	A	A
109-4.50	22m	32.8	75.7	24.3	24.9	8.0	A	A
109-5.75	22m	43.2	32.1	67.9	13.9	29.3	P	P
71-0.50	22m	65.6	63.2	36.8	41.4	24.1	P	P
6-2.00	22m	45.9	92.1	7.9	42.3	3.6	A	A
6-5.00	22m	48.2	87.2	12.8	42.0	6.2	A	A
39-2.00	22m	47.7	91.1	8.9	43.4	4.2	A	A
39-5.00	22m	48.6	93.1	6.9	45.2	3.4	A	A
60-1.50	I-4	30.1	84.8	15.2	25.5	4.6	A	A
53-3.75	I-4	24.0	65.7	34.3	15.8	8.2	A	A
53-6.00	I-4	31.5	61.2	38.8	19.3	12.2	P	A
52-3.75	I-4	92.2	49.8	50.2	45.9	46.3	A	P
59-6.50	I-5	83.4	73.6	26.4	61.4	22.0	P	P
59-7.75	I-5	19.2	63.2	36.8	12.2	7.1	P	P

Core-Top Depth of Sample (m)	Area	Total weight % of matrix in the sediment	Weight % insolubles in matrix	Weight % carbonate in matrix	Weight % mud-sized insolubles in total sediment	Weight % mud-sized carbonate in total sediment	Calcite	Dolomite
AF-4								
3-8.75	15m	39.1	22.5	77.5	8.8	30.3	P	P
36-5.00	15m	91.1	16.2	83.8	14.7	76.4	P	P
33-0.50	15m	26.9	7.7	92.3	2.1	24.8	P	P
33-2.50	15m	18.3	5.0	95.0	0.9	17.3	P	P
33-4.50	15m	38.1	10.8	89.2	4.1	34.0	P	P
33-6.50	15m	55.3	36.5	63.5	20.2	35.1	P	P
33-8.75	15m	33.7	17.9	82.1	6.0	27.7	P	A
111-0.50	15m	19.8	9.5	90.5	1.9	17.9	P	P
111-2.50	15m	47.7	9.6	90.4	4.6	43.1	P	P
111-4.25	15m	27.4	8.9	91.1	2.4	25.0	P	A
111-5.50	15m	55.5	32.8	67.2	18.2	37.3	P	A
111-6.25	15m	27.4	16.6	83.4	4.5	22.9	P	A
111-7.50	15m	60.1	37.7	62.3	22.6	37.4	P	A
111-8.00	15m	25.6	49.4	50.6	12.6	13.0	P	A
AF-3								
35-1.25	15m	36.5	22.9	77.1	8.4	28.1	P	P
131-3.75	I-5	33.9	22.9	77.1	7.8	26.1	P	P
131-4.75	I-5	30.8	29.1	70.9	9.0	21.9	P	A
131-5.75	I-5	28.8	30.3	69.7	8.7	20.0	P	A
AF-2								
39-8.40	22m	13.3	55.0	45.0	7.3	6.0	P	P
38-0.50	22m	18.7	42.0	58.0	7.8	10.8	P	P
58-2.25	I-5	4.8	61.5	38.5	3.0	1.8	P	A
58-4.25	I-5	97.3	81.0	19.0	78.8	18.4	A	P
AF-1								
34-6.00	15m	90.0	76.9	23.1	69.2	20.8	P	P
35-2.75	15m	60.3	37.1	62.9	22.4	37.9	P	P
35-5.25	15m	61.5	40.2	59.8	24.7	36.8	P	P
35-7.75	15m	55.5	38.6	61.4	21.4	34.1	P	P
38-3.50	22m	29.8	23.6	76.4	7.0	22.8	A	P
38-6.50	22m	62.8	55.8	44.2	35.0	27.7	A	P
38-8.75	22m	2.8	20.2	79.8	0.6	2.2	A	P
40-8.00	22m	72.6	30.0	70.0	21.8	50.8	A	P
41-2.50	I-8	12.2	44.8	55.2	5.5	6.7	P	P

Core-Top Depth of Sample (m)	Area	Total weight % of matrix in the sediment	Weight % insolubles in matrix	Weight % carbonate in matrix	Weight % mud-sized insolubles in total sediment	Weight % mud-sized carbonate in total sediment	Calcite	Dolomite
AF-1								
41-4.75	I-8	10.4	30.2	69.8	3.1	7.3	P	A
41-7.00	I-8	8.8	30.1	69.9	2.7	6.1	P	A
44-2.00	I-8	97.2	67.1	32.9	65.3	31.9	A	P
44-5.00	I-8	43.1	58.0	42.0	25.0	18.1	A	P
51-2.00	I-4	20.1	72.3	27.7	14.6	5.6	A	A
51-5.00	I-4	37.4	-	-	-	-	A	P
58-6.25	I-5	4.6	68.1	31.9	3.1	1.5	A	P
58-8.25	I-5	9.2	78.5	21.5	7.2	2.0	A	P
FPF-6								
45-1.00	I-8	44.9	15.5	84.5	7.0	37.9	P	P
45-3.00	I-8	22.9	26.2	73.8	6.0	16.9	P	P
45-4.00	I-8	27.5	35.7	64.3	9.8	17.7	P	A
67-3.50	FP	23.6	50.6	49.4	11.9	11.7	P	A
96-1.50	FP	23.9	31.5	68.5	7.5	16.4	P	A
96-3.50	FP	30.4	61.0	39.0	18.6	11.9	P	P
96-5.50	FP	41.1	75.7	24.3	37.8	12.1	P	P
FPF-5								
46-2.50	I-8	13.0	83.2	16.8	10.8	2.2	A	A
50-3.25	FP	14.1	46.4	53.6	6.5	7.6	P	A
50-5.75	FP	95.8	81.3	18.7	77.8	17.9	A	P
50-8.25	FP	92.4	80.5	19.5	74.4	18.0	P	P
FPF-4								
37-3.00	15m	10.2	79.8	20.2	8.1	2.1	P	A
37-6.00	15m	10.7	66.2	33.8	7.1	3.6	P	A
37-7.50	15m	10.3	36.0	64.0	3.7	6.6	A	A
FPF-3								
48-2.00	I-4	14.2	51.7	48.3	7.3	6.9	P	P
48-7.75	I-4	27.2	85.2	14.8	23.2	4.0	A	P
17-3.25	FP	93.9	87.8	12.2	82.4	11.5	P	P
17-5.50	FP	83.6	40.9	59.1	34.2	49.4	P	P
62-3.75	FP	99.2	96.9	3.2	96.1	3.1	A	P
62-5.50	FP	98.7	94.8	5.2	93.6	5.1	A	P

Core-Top Depth of Sample (m)	Area	Total weight % of matrix in the sediment	Weight % insolubles in matrix	Weight % carbonate in matrix	Weight % mud-sized insolubles in total sediment	Weight % mud-sized carbonate in total sediment	Calcite	Dolomite
FPF-2								
110-1.00	22m	8.8	88.6	11.4	7.8	1.0	P	A
110-4.64	22m	36.4	92.4	7.6	33.6	2.8	A	A
49-1.75	I-4	32.4	49.7	50.3	16.1	16.2	A	P
49-4.75	I-4	57.4	84.0	16.0	48.2	9.2	A	P
49-7.75	I-4	43.6	79.5	20.5	34.7	8.9	A	P
47-0.50	I-4	82.2	88.3	11.7	72.6	9.6	A	P
47-7.25	I-4	75.8	76.9	23.1	58.3	17.5	A	P
15-0.50	FP	89.6	77.0	23.0	68.9	20.6	P	P
15-1.75	FP	90.0	90.8	9.2	81.7	8.3	A	P
16-1.50	FP	99.9	94.3	5.7	94.1	5.8	A	P
16-5.50	FP	99.9	91.8	8.2	91.7	8.2	A	P
27-1.00	FP	94.7	94.6	5.4	89.5	5.1	A	A
27-3.00	FP	92.4	88.8	11.2	82.0	10.3	P	A
27-5.00	FP	73.3	78.6	21.4	57.6	15.7	P	A
27-7.00	FP	54.7	70.0	30.0	38.3	16.4	P	P
63-0.75	FP	75.9	80.8	19.2	61.3	14.5	P	A
70-1.50	FP	96.4	78.4	21.6	75.6	20.8	A	P
FPF-1								
47-8.50	I-4	64.7	78.3	21.7	50.7	14.0	A	P
113-0.50	I-4	43.9	54.8	45.2	24.0	19.9	A	P
113-1.50	I-4	34.7	67.0	33.0	23.2	11.5	A	P
114-5.75	FP	47.0	82.8	17.2	38.9	8.1	P	P
114-7.50	FP	41.1	47.6	52.4	19.6	21.5	P	P
115-5.00	FP	19.1	17.7	82.3	3.4	15.7	P	A
115-5.50	FP	27.5	48.6	51.4	13.4	14.1	P	A
115-7.00	FP	24.0	59.4	40.6	14.3	9.7	P	A

Appendix C.

Thin section point count data

Appendix C. Thin section point count data.

This data is arranged first by seismic unit, then by seismic profile or area (refer to Figure 8 for the location of the seismic profiles). Each series of cores in the same seismic unit are then arranged by location from east to west. Area FP is the Frying Pan Area; cores in this area are listed numerically. Core OB-123 is located approximately midway between seismic profile I-4 and I-5.

The following data is presented in volume % of the total sediment and is based on 300 point counts per slide. The headings are abbreviated as follows:

Sample	= Core-Top depth of sample (m)
Moll	= Molluscs
Barn	= Barnacles
Bry	= Bryozoans
Ech	= Echinoids
Ost	= Ostracods
Bf	= Benthic foraminifers
Pf	= Planktonic foraminifers
Alg	= Calcareous algae
Carb	= Unidentifiable carbonate grains
Spar	= Calcite cement
Micr	= Microspar
Matr	= Matrix
Dolo	= Dolomite
Cher	= Microcrystalline quartz
Chal	= Chalcedony
Phos	= Phosphate grains
Glau	= Glauconite
Opaq	= Opaques
Qtz	= Siliciclastic sand

Sample	Area	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Alg	Carb	Spar	Micr	Matr	Dolo	Cher	Chal	Phos	Glau	Opaq	Qtz
BBF-3																				
108-1.75	22m	0.3	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	46.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	32.3
108-2.25	22m	0.0	25.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	45.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7
108-5.00	22m	0.0	11.8	0.0	0.4	0.0	0.7	0.0	0.0	0.0	0.0	58.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
BBF-2																				
92-3.25	I-4	1.4	2.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	20.5	20.9	0.0	0.0	0.0	0.0	3.6	0.0	0.0	50.8
92-3.50	I-4	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.4	10.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	67.7
BBF-1																				
94-1.00	I-4	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	72.0	0.0	0.0	0.0	0.0	3.7	0.3	0.0	12.3
94-1.50	I-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	63.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	20.0
53-1.50	I-4	1.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.7	0.0	0.0	0.0	0.0	5.3	0.0	0.0	18.3
53-5.50	I-4	1.0	0.7	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.7	58.3	0.0	0.0	0.0	0.0	10.4	0.3	0.0	27.7
53-5.90	I-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	81.3	0.0	0.0	0.0	0.0	2.7	0.3	0.3	8.7
AF-4																				
3-8.75	15m	3.3	46.3	1.7	0.0	0.0	0.0	0.3	0.0	0.0	0.0	48.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33-2.50	15m	5.4	76.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33-3.25	15m	6.0	70.3	0.0	1.3	0.0	0.7	0.0	0.0	0.0	0.0	16.3	0.0	4.0	0.0	0.0	0.0	0.0	0.0	1.3
33-4.00	15m	9.7	22.0	21.7	0.7	0.0	0.7	0.0	0.0	0.0	0.0	32.6	0.0	11.7	0.0	0.0	0.0	0.0	0.0	1.0
33-5.25	15m	6.3	45.3	3.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	39.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
33-6.40	15m	12.6	7.9	3.1	0.9	1.3	2.8	0.3	0.0	11.3	0.0	0.0	50.3	4.7	0.0	0.0	0.9	0.3	0.0	3.5
33-8.00	15m	4.0	12.3	7.7	1.3	1.0	3.0	0.0	0.0	10.7	0.0	55.0	0.0	0.3	0.0	0.0	2.0	0.0	0.0	2.7
111-0.25	15m	14.7	23.3	4.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	53.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	3.0
111-4.10	15m	4.3	20.7	0.7	1.0	0.0	0.0	0.0	0.0	1.0	0.0	68.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	4.0
111-4.75	15m	4.3	44.3	3.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
AF-3																				
34-2.00	15m	2.3	16.0	0.7	1.7	0.0	0.0	0.0	0.0	1.7	2.7	41.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	24.0
131-3.00	I-5	1.0	3.0	7.0	2.0	0.0	1.0	0.0	0.0	2.7	0.0	76.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	6.3
131-6.34	I-5	2.6	14.3	4.7	4.7	0.3	1.3	0.0	0.0	0.3	5.3	55.8	0.0	0.0	0.0	0.0	1.0	0.0	0.0	9.7
AF-2																				
38-0.50	22m	7.3	37.3	0.0	1.0	0.0	22.1	9.3	0.0	2.0	0.0	3.0	0.0	0.3	0.0	0.0	1.3	5.0	0.0	11.3
58-7.40	I-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.7	1.3	0.0	0.0	65.9
AF-1																				
35-SEM	15m	0.9	0.0	0.0	0.4	0.0	1.3	1.8	0.0	3.5	0.0	0.0	0.0	5.3	58.9	13.7	1.3	0.0	0.0	12.8
35-6.75	15m	3.3	0.0	0.0	1.0	0.0	4.0	0.0	0.0	9.3	0.0	61.7	0.0	6.3	0.0	0.0	0.3	0.0	0.0	14.0
35-7.25	15m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.0	0.0	0.0	4.7	68.7	2.7	0.0	0.0	0.0	11.3
35-8.00	15m	2.0	0.0	0.0	1.3	0.0	0.7	0.7	0.0	4.3	0.0	0.0	0.0	7.0	66.0	7.7	0.0	0.0	0.3	10.0
38-7.25	22m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.3	0.7	0.0	0.0	0.0	0.0
44-5.90	22m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.0	0.7	0.0	0.0	0.0	0.3

Sample	Area	Moll	Barn	Bry	Ech	Ost	Bf	Pf	Alg	Carb	Spar	Micr	Matr	Dolo	Cher	Chal	Phos	Glau	Opaq	Qtz
FPF-6																				
102-7.00	FP	3.0	0.0	0.0	5.3	0.0	34.7	29.7	0.0	0.0	11.7	0.0	4.0	0.0	0.0	0.0	0.7	0.0	0.0	10.9
102-7.75	FP	0.3	3.0	0.0	11.3	0.3	27.6	14.6	0.0	0.0	24.0	1.0	8.0	0.0	0.0	0.0	0.6	0.0	0.3	9.3
FPF-3																				
17-3.00	FP	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	64.7	17.3	0.0	0.0	1.7	0.0	0.7	7.7
FPF-2																				
47-0.00	I-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.4	12.9	0.0	0.0	6.9	1.7	0.3	22.7
47-7.25	I-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.9	0.0	0.0	0.0	2.3	0.3	0.0	16.4
123-2.00	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	63.0	0.0	0.0	0.0	0.0	25.3
123-5.07	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	27.5	0.5	3.0	2.0	0.0	62.5
123-6.74	---	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2	36.4	0.8	1.2	2.0	0.0	44.4
29B-2.75	FP	0.0	0.0	0.0	1.0	0.0	17.3	6.0	0.0	3.3	0.0	0.0	29.3	0.0	0.0	0.0	6.7	0.0	0.0	36.4
29B-6.75	FP	0.7	0.0	0.0	0.0	0.0	10.3	2.3	0.0	3.0	0.0	0.0	46.0	0.0	0.0	0.0	17.7	0.0	0.0	20.0
FPF-1																				
134-0.00	22m	0.6	3.6	0.0	2.9	0.0	1.0	0.3	0.0	0.0	7.1	47.2	0.0	0.0	0.0	0.0	0.3	0.0	1.0	35.9
14-3.75	FP	0.0	0.0	0.0	0.0	0.0	6.7	2.0	0.0	0.0	0.0	0.0	38.7	0.3	0.0	0.0	30.3	0.0	0.0	22.0
20-0.50	FP	4.9	18.1	2.0	4.3	0.3	0.8	0.0	0.3	10.6	4.0	43.6	0.0	1.4	0.0	0.0	3.7	0.0	0.3	5.7
24-1.25	FP	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	26.3	0.0	0.0	0.0	68.4	0.0	0.0	4.3
24-1.67	FP	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	27.7	0.0	0.0	0.0	0.0	45.0	0.0	0.3	26.0
64-0.75	FP	9.6	19.4	4.8	4.1	0.3	1.3	0.3	0.0	2.2	1.3	43.6	0.0	0.0	0.0	0.0	2.5	0.0	0.0	10.5
64-1.75	FP	9.6	9.6	13.0	4.6	0.3	1.9	0.0	0.0	1.9	0.3	50.2	0.0	0.0	0.0	0.0	1.5	0.0	0.0	7.1
64-2.75	FP	4.8	4.1	0.0	4.1	0.0	4.1	0.7	0.0	2.8	0.0	68.8	0.0	0.0	0.0	0.3	1.4	0.0	0.7	8.2
64-6.00	FP	0.3	6.0	0.0	2.3	0.0	3.3	0.0	0.0	4.3	4.7	52.1	0.0	0.0	0.0	1.3	0.0	0.0	0.0	25.4
64-6.25	FP	4.7	9.2	2.4	2.9	0.6	1.8	0.3	0.9	4.4	0.0	32.8	0.0	0.0	0.0	0.3	0.3	0.0	0.3	39.1
64-6.37	FP	0.0	0.0	0.0	0.6	0.0	0.6	0.0	0.0	0.0	1.7	79.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9
114-2.10	FP	8.7	10.0	6.0	8.0	0.0	1.3	0.0	0.0	4.0	2.3	56.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
114-7.75	FP	0.3	3.7	0.0	1.3	0.0	0.7	0.0	0.0	1.0	0.7	62.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	29.4
115-1.50	FP	10.7	13.9	23.7	6.0	0.0	4.0	0.3	0.0	0.9	1.3	36.8	0.0	0.0	0.0	0.0	0.9	0.0	0.0	1.6
115-2.50	FP	11.4	10.8	13.3	2.2	0.3	4.0	0.3	0.0	2.2	1.1	45.4	0.0	0.0	0.0	0.0	2.8	0.0	0.0	6.2
115-3.00	FP	11.5	9.0	8.7	7.4	0.6	1.5	0.0	0.3	4.3	1.5	44.3	0.0	0.0	0.0	0.0	5.9	0.0	0.0	5.3
115-4.25	FP	8.2	23.1	3.8	6.0	0.3	1.3	0.3	0.4	2.2	2.8	34.8	0.0	0.0	0.0	0.0	8.8	0.0	0.0	8.2
115-4.75	FP	4.0	19.0	7.7	6.6	0.0	2.2	0.4	0.0	0.0	1.7	36.4	0.0	0.0	0.0	0.0	8.4	0.0	0.0	13.2

Appendix D.
Textural data

Appendix D. Textural data.

This data is arranged numerically and is presented in weight % of the total sediment. Samples are numbered in the following manner: Core number-Depth in meters below the sediment surface. Individual % (Ind. %) and cumulative % (Cum. %) are given for each 0.5 phi sand and gravel fraction up to -2.0 phi. The mud fraction is all material finer than 63um.

Grain Size mm phi	Sample 1-4.50		Sample 1-5.25		Sample 1-5.75		Sample 1-6.50		Sample 1-8.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	0	0	0	0	0	0	0	0
2.83 -1.5	0	0	0	0	0	0	0.07	0.07	0	0
2.00 -1.0	0.04	0.04	0	0	0	0	0.08	0.15	0.04	0.04
1.41 -0.5	0.08	0.12	0	0	0.05	0.05	0.09	0.24	0.08	0.12
1.00 0.0	0.09	0.21	0.12	0.12	0.18	0.24	0.33	0.58	0.40	0.52
0.71 0.5	0.59	0.80	0.93	1.05	0.86	1.09	1.29	1.87	2.48	3.00
0.50 1.0	3.54	4.34	3.98	5.03	3.82	4.91	5.33	7.20	6.27	9.27
0.35 1.5	8.30	12.64	7.66	12.69	6.96	11.87	9.69	16.89	9.50	18.77
0.25 2.0	12.18	24.82	11.75	24.44	10.52	22.39	13.58	30.47	14.75	33.52
0.177 2.5	25.52	50.34	25.78	50.22	26.63	49.02	28.74	59.21	32.77	66.29
0.125 3.0	23.34	73.68	20.43	70.65	19.58	68.60	18.11	77.32	17.01	83.30
0.088 3.5	3.32	77.00	4.07	74.73	3.79	72.39	2.01	79.33	2.56	85.86
0.0625 4.0	1.68	78.68	2.01	76.74	1.48	73.87	0.60	79.92	1.24	87.10
Mud >4.0	21.32	100	23.27	100	26.13	100	20.08	100	12.90	100

Grain Size mm phi	Sample 2-3.50		Sample 2-6.50		Sample 2B-6.50		Sample 3-1.50		Sample 3-4.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	0	0	0.83	0.83	0	0	0	0
2.83 -1.5	0	0	0.24	0.24	0	0.83	0	0	0.16	0.16
2.00 -1.0	0.11	0.11	1.06	1.30	0.03	0.86	0	0	0.30	0.46
1.41 -0.5	0.10	0.21	1.41	2.71	0.02	0.88	0.16	0.16	0.47	0.93
1.00 0.0	0.25	0.26	1.78	4.49	0.14	1.02	0.18	0.34	0.64	1.57
0.71 0.5	0.36	0.82	2.17	6.66	3.02	4.04	0.51	0.85	1.80	3.37
0.50 1.0	0.55	1.36	1.63	8.29	10.84	14.88	1.37	2.22	3.05	6.42
0.35 1.5	0.68	2.04	1.56	9.85	18.75	33.63	2.88	5.10	5.68	12.10
0.25 2.0	0.83	2.87	1.87	11.72	18.45	52.08	5.17	10.27	15.10	27.20
0.177 2.5	2.06	4.93	2.17	13.89	6.10	58.18	3.02	13.30	20.28	47.48
0.125 3.0	10.39	15.32	6.59	20.48	1.06	59.24	1.76	15.06	8.46	55.94
0.088 3.5	40.58	55.90	24.42	44.91	1.29	60.53	6.72	21.78	3.17	59.11
0.0625 4.0	19.04	74.94	22.88	67.79	4.86	65.39	3.41	25.19	10.45	69.56
Mud >4.0	25.06	100	32.21	100	34.61	100	74.81	100	30.44	100

Grain Size mm phi	Sample 3-6.50		Sample 3-8.75		Sample 6-2.00		Sample 6-5.00		Sample 14-1.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0	0
2.83	-1.5	0	0	6.15	6.15	0	0	0	0	0
2.00	-1.0	1.17	1.17	2.01	8.16	0	0	0	0	0
1.41	-0.5	0.63	1.80	5.32	13.48	0.13	0.13	0.03	0.03	0.13
1.00	0.0	0.79	2.59	8.79	22.26	0.24	0.37	0.06	0.09	0.20
0.71	0.5	2.60	5.19	11.56	33.83	0.49	0.86	0.13	0.22	0.41
0.50	1.0	3.89	9.09	10.13	43.95	1.31	2.16	0.49	0.71	0.90
0.35	1.5	6.18	15.27	6.44	50.40	3.07	5.23	1.61	2.32	2.49
0.25	2.0	11.58	26.85	3.65	54.04	6.90	12.13	4.19	6.51	6.50
0.177	2.5	9.77	36.62	2.19	56.23	9.84	21.97	6.28	12.80	7.33
0.125	3.0	5.52	42.14	1.90	58.13	4.75	26.72	4.56	17.36	11.01
0.088	3.5	3.67	45.80	1.70	59.83	9.47	36.19	13.38	30.74	17.01
0.0625	4.0	17.86	63.66	1.03	60.85	17.96	54.14	21.05	51.78	18.26
Mud	>4.0	36.34	100	39.15	100	45.86	100	48.22	100	39.90

Grain Size mm phi	Sample 14-2.75		Sample 15-0.25		Sample 15-1.75		Sample 16-1.50		Sample 16-5.50	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0	0
2.83	-1.5	0.27	0.27	0	0	0	0	0	0	0
2.00	-1.0	0	0.27	0	0	0.12	0	0	0	0
1.41	-0.5	0.05	0.32	0	0	0.02	0.14	0	0	0
1.00	0.0	0.16	0.48	0.09	0.09	0.02	0.16	0	0	0
0.71	0.5	0.31	0.79	0.09	0.18	0.05	0.21	0	0	0
0.50	1.0	0.73	1.52	0.10	0.28	0.12	0.33	0	0	0
0.35	1.5	1.54	3.07	0.12	0.40	0.20	0.53	0	0	0
0.25	2.0	6.68	9.75	0.18	0.58	0.21	0.74	0	0	0
0.177	2.5	13.96	23.71	0.26	0.84	0.24	0.98	0	0	0
0.125	3.0	18.38	42.09	0.32	1.16	0.24	1.22	0	0	0
0.088	3.5	14.31	56.40	1.59	2.75	1.02	2.24	0	0	0
0.0625	4.0	10.80	67.20	7.69	10.44	7.76	10.00	0.15	0.15	0.12
Mud	>4.0	32.80	100	89.56	100	90.00	100	99.85	100	99.88

Grain Size mm phi	Sample 17-3.25		Sample 17-5.50		Sample 20-1.50		Sample 20-3.75		Sample 20-6.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0	0
2.83	-1.5	0	0	0	0	0	0	0	0.18	0.18
2.00	-1.0	0	0	0	0.16	0.16	0	0	0	0.18
1.41	-0.5	0	0	0.04	0.04	0.21	0.37	0	0.03	0.22
1.00	0.0	0	0	0.04	0.08	0.32	0.69	0.07	0.07	0.30
0.71	0.5	0.02	0.02	0.05	0.13	0.64	1.33	0.18	0.25	0.47
0.50	1.0	0.04	0.06	0.17	0.30	1.43	2.76	0.49	0.74	0.90
0.35	1.5	0.23	0.29	1.33	1.63	4.14	6.90	1.24	1.99	2.45
0.25	2.0	0.31	0.60	1.56	3.19	4.22	11.12	2.58	4.57	6.03
0.177	2.5	0.39	1.00	1.15	4.34	6.27	17.39	7.28	11.85	16.07
0.125	3.0	0.42	1.42	0.94	5.28	7.94	25.33	18.53	30.39	43.52
0.088	3.5	1.30	2.72	2.39	7.67	5.65	30.98	11.37	41.76	59.92
0.0625	4.0	3.34	6.06	8.76	16.43	10.52	41.51	8.66	50.42	66.37
Mud	>4.0	93.94	100	83.57	100	58.49	100	49.58	100	33.63

Grain Size mm phi	Sample 26-0.50		Sample 27-1.00		Sample 27-3.00		Sample 27-5.00		Sample 27-7.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0	0
2.83	-1.5	0	0	0	0	0	0	0	0	0
2.00	-1.0	0	0	0	0	0	0.29	0.29	0.54	0.54
1.41	-0.5	0.08	0.08	0.11	0.11	0	0.05	0.34	0.18	0.72
1.00	0.0	0.09	0.17	0.08	0.19	0	0.14	0.48	0.22	0.94
0.71	0.5	0.35	0.52	0.07	0.26	0.02	0.02	0.19	0.67	1.21
0.50	1.0	0.73	1.25	0.07	0.33	0.08	0.10	0.45	1.12	1.68
0.35	1.5	2.26	3.51	0.12	0.45	1.06	1.16	1.32	2.44	3.16
0.25	2.0	6.01	9.52	0.21	0.66	0.86	2.02	1.14	3.58	4.47
0.177	2.5	10.18	19.70	0.31	0.97	1.17	3.19	1.02	4.60	5.93
0.125	3.0	8.68	28.38	0.43	1.39	1.13	4.32	1.53	6.13	9.18
0.088	3.5	11.28	39.66	1.13	2.52	1.33	5.65	8.94	15.07	29.40
0.0625	4.0	17.64	57.30	2.81	5.33	1.97	7.62	11.62	26.69	45.27
Mud	>4.0	42.70	100	94.67	100	92.38	100	73.31	100	54.73

Grain mm	Size phi	Sample 33-0.50		Sample 33-2.50		Sample 33-4.50		Sample 33-6.50		Sample 33-8.75	
		Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	12.41	12.41	6.47	6.47	8.91	8.91	0	0	6.60	6.60
2.83	-1.5	4.94	17.35	2.87	9.34	2.16	11.07	0	0	7.88	14.48
2.00	-1.0	6.71	24.06	6.02	15.36	3.43	14.49	2.62	2.62	10.46	24.94
1.41	-0.5	9.53	33.59	13.45	28.81	6.52	21.01	1.32	3.94	10.11	35.05
1.00	0.0	8.80	42.39	15.85	44.66	5.64	26.65	1.21	5.16	5.07	40.12
0.71	0.5	9.57	51.96	16.01	60.67	6.12	32.76	2.33	7.49	3.54	43.66
0.50	1.0	7.28	59.24	10.95	71.62	5.13	37.89	3.78	11.27	2.85	46.51
0.35	1.5	5.40	64.64	5.19	76.81	6.28	44.17	5.64	16.91	3.61	50.12
0.25	2.0	3.45	68.09	2.34	79.15	7.95	52.12	8.42	25.33	5.28	55.40
0.177	2.5	1.80	69.90	1.12	80.27	4.23	56.36	6.31	31.64	3.95	59.35
0.125	3.0	1.48	71.38	0.75	81.02	2.37	58.73	5.02	36.66	2.86	62.21
0.088	3.5	0.99	72.36	0.46	81.48	1.64	60.37	4.81	41.47	2.15	64.36
0.0625	4.0	0.75	73.11	0.25	81.73	1.54	61.91	3.27	44.74	1.91	66.27
Mud	>4.0	26.89	100	18.27	100	38.09	100	55.26	100	33.73	100

Grain Size mm phi	Sample 34-2.00		Sample 34-4.00		Sample 34-6.00		Sample 34-8.00		Sample 35-1.25	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0.49	0.49
2.83	-1.5	0.55	0.55	0	0	0	0.44	0.44	0.64	1.13
2.00	-1.0	1.23	1.78	0	0	0	0.32	0.76	2.50	3.63
1.41	-0.5	2.36	4.14	0.06	0.06	0	0.86	1.62	4.74	8.37
1.00	0.0	3.10	7.24	0.12	0.18	0.04	1.12	2.74	3.78	12.15
0.71	0.5	5.50	12.74	0.41	0.59	0.13	2.43	5.17	3.43	15.58
0.50	1.0	6.78	19.52	0.98	1.57	0.30	3.41	8.58	1.93	17.51
0.35	1.5	10.80	30.32	2.80	4.37	0.81	6.67	15.25	2.15	19.65
0.25	2.0	20.66	50.98	8.09	12.46	2.55	15.41	30.66	6.46	26.11
0.177	2.5	14.79	65.77	5.32	17.78	2.72	19.80	50.45	18.37	44.48
0.125	3.0	3.81	69.58	2.01	19.79	1.42	8.63	59.08	13.93	58.41
0.088	3.5	0.60	70.18	0.95	20.74	0.89	1.53	60.61	3.08	61.49
0.0625	4.0	0.60	70.78	1.09	21.83	1.17	1.17	61.78	2.05	63.55
Mud	>4.0	29.22	100	78.17	100	89.98	38.22	100	36.45	100

Grain Size mm phi	Sample 35-2.75		Sample 35-5.25		Sample 35-7.75		Sample 36-2.00		Sample 36-5.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0	0
2.83	-1.5	0.07	0.07	0	0	0	0.21	0.21	0.13	0.13
2.00	-1.0	0	0.07	0	0	0	0.39	0.60	0.17	0.30
1.41	-0.5	0.10	0.17	0.06	0.06	0	0.24	0.84	0.59	0.89
1.00	0.0	0.12	0.29	0.04	0.10	0	0.39	1.23	0.81	1.70
0.71	0.5	0.17	0.46	0.06	0.16	0.05	1.24	2.47	0.91	2.61
0.50	1.0	0.19	0.65	0.06	0.22	0.11	6.59	9.06	0.72	3.33
0.35	1.5	0.43	1.08	0.32	0.54	0.48	16.26	25.32	0.61	3.94
0.25	2.0	1.87	2.95	1.73	2.27	3.03	23.46	48.78	0.59	4.53
0.177	2.5	5.85	8.79	8.48	10.74	9.36	12.71	61.49	0.62	5.15
0.125	3.0	11.79	20.59	18.04	28.78	15.09	1.90	63.39	0.98	6.13
0.088	3.5	9.44	30.02	6.50	35.27	7.78	1.03	64.42	1.26	7.39
0.0625	4.0	11.42	41.45	3.26	38.54	8.62	5.35	69.77	1.47	8.86
Mud	>4.0	58.55	100	61.46	100	55.48	30.23	100	91.14	100

Grain mm	Size phi	Sample 37-3.00		Sample 37-6.00		Sample 37-7.50		Sample 38-0.50		Sample 38-3.50	
		Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	12.81	12.81	30.34	30.34	16.55	16.55	0	0
2.83	-1.5	0.09	0.09	1.47	14.28	5.46	35.80	0	16.55	0	0
2.00	-1.0	0.02	0.11	0.91	15.19	3.45	39.26	0.23	16.78	0	0
1.41	-0.5	0.07	0.18	0.88	16.07	2.92	42.18	0	16.78	0	0
1.00	0.0	0.09	0.27	0.72	16.79	2.08	44.26	0.13	16.91	0	0
0.71	0.5	0.41	0.68	0.80	17.59	1.80	46.06	0.58	17.49	0	0
0.50	1.0	0.92	1.61	1.23	18.81	1.71	47.76	2.93	20.42	0.10	0.10
0.35	1.5	2.03	3.64	1.33	20.14	1.44	49.20	10.38	30.80	3.90	4.00
0.25	2.0	3.20	6.84	2.91	23.05	1.86	51.06	21.99	52.79	27.38	31.38
0.177	2.5	17.34	24.17	12.33	35.38	7.14	58.19	19.18	71.97	29.36	60.74
0.125	3.0	46.29	70.46	24.93	60.31	25.33	83.53	6.65	78.63	8.79	69.53
0.088	3.5	16.56	87.02	26.60	86.91	5.22	88.75	2.04	80.67	0.06	69.58
0.0625	4.0	2.77	89.79	2.35	89.26	0.94	89.69	0.65	81.32	0.62	70.20
Mud	>4.0	10.21	100	10.74	100	10.31	100	18.68	100	29.80	100

Grain Size mm phi	Sample 38-6.50		Sample 38-8.75		Sample 39-2.00		Sample 39-5.00		Sample 39-8.40	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	5.11	5.11	0	0	0	0	0	0.20	0.20
2.83	-1.5	0.60	5.71	0	0	0	0	0	0.58	0.78
2.00	-1.0	0.44	6.15	0	0	0.03	0.03	1.31	0.87	1.65
1.41	-0.5	0.36	6.51	0	0	0.04	0.07	0.17	2.15	3.80
1.00	0.0	0.25	6.76	0	0	0.15	0.22	0.41	4.18	7.98
0.71	0.5	0.19	6.94	0.01	0.01	0.36	0.58	1.01	6.90	14.88
0.50	1.0	0.16	7.11	0.08	0.09	1.16	1.74	3.06	13.84	28.72
0.35	1.5	1.90	9.01	4.59	4.68	2.55	4.29	6.12	23.16	51.88
0.25	2.0	11.34	20.35	44.57	49.25	4.77	9.06	8.25	20.31	72.19
0.177	2.5	11.55	31.90	42.79	92.04	6.89	15.95	10.29	9.01	81.20
0.125	3.0	4.61	36.51	5.02	97.06	3.99	19.94	5.25	3.13	84.33
0.088	3.5	0.47	36.98	0.14	97.20	15.87	35.81	6.00	1.39	85.72
0.0625	4.0	0.27	37.25	0.01	97.21	16.53	52.34	9.53	1.03	86.75
Mud	>4.0	62.75	100	2.79	100	47.66	100	48.59	13.25	100

Grain Size mm phi	Sample 40-8.00		Sample 41-2.50		Sample 41-4.75		Sample 41-7.00		Sample 44-2.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0.59	0.59	0.50	0.50	2.20	0	0
2.83	-1.5	0	0	0.32	0.91	0.34	0.84	0	0	0
2.00	-1.0	0.08	0.08	0.75	1.66	0.04	0.88	0	0	0
1.41	-0.5	0.08	0.16	0.49	2.15	0.32	1.20	0	0	0
1.00	0.0	0	0.16	0.58	2.73	0.29	1.49	0.03	0	0
0.71	0.5	0.01	0.17	1.32	4.05	0.93	2.42	0.17	0	0
0.50	1.0	0.11	0.28	3.89	7.94	3.70	6.12	1.95	0	0
0.35	1.5	2.03	2.31	8.75	16.69	12.07	18.19	11.68	0	0
0.25	2.0	9.30	11.61	27.15	43.84	36.41	54.60	37.21	0	0
0.177	2.5	11.54	23.15	33.65	77.49	26.93	81.53	31.18	0	0
0.125	3.0	3.88	27.03	9.40	86.89	6.10	87.63	5.79	0	0
0.088	3.5	0.24	27.27	0.74	87.63	1.25	88.88	0.69	0	0
0.0625	4.0	0.13	27.40	0.21	87.85	0.72	89.60	0.30	2.76	2.76
Mud	>4.0	72.60	100	12.15	100	10.40	100	8.81	97.24	100

Grain Size mm phi	Sample 44-5.00		Sample 45-1.00		Sample 45-3.00		Sample 45-4.00		Sample 45-5.50	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0.89	0.89	0	0	0.14	0.14
2.83	-1.5	0	0	0.63	0.63	0.59	1.48	0.74	0.74	1.10
2.00	-1.0	0	0	2.24	2.87	1.85	3.33	0.96	1.70	2.79
1.41	-0.5	0	0	4.46	7.33	1.96	5.29	1.47	3.17	6.00
1.00	0.0	0	0	4.03	11.36	2.14	7.43	1.52	4.69	8.64
0.71	0.5	0.01	0.01	3.74	15.09	2.42	9.85	2.44	7.13	12.18
0.50	1.0	0.02	0.03	2.96	18.05	5.41	15.26	4.89	12.01	20.97
0.35	1.5	0.04	0.07	3.90	21.95	13.12	28.37	14.88	26.89	41.65
0.25	2.0	0.85	0.92	5.70	27.65	22.02	50.39	24.95	51.84	70.56
0.177	2.5	13.92	14.84	8.46	36.11	16.38	66.77	12.87	64.71	81.87
0.125	3.0	37.67	52.51	13.43	59.54	7.65	74.42	5.22	69.94	85.71
0.088	3.5	3.70	56.21	3.75	53.29	1.68	76.10	1.69	71.63	86.81
0.0625	4.0	0.73	56.94	1.83	55.13	0.99	77.09	0.89	72.52	87.50
Mud	>4.0	43.06	100	44.87	100	22.91	100	27.48	100	12.50

Grain Size mm phi	Sample 46-0.75		Sample 46-2.50		Sample 46-5.50		Sample 47-0.50		Sample 47-2.75	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0.57	0.57	0	0	0	0	0	0	0
2.83	-1.5	1.43	2.00	0.13	0.13	0.09	0.09	0	0	0
2.00	-1.0	3.33	5.33	0.09	0.22	0.08	0.17	0	0	0
1.41	-0.5	6.18	11.52	0.07	0.29	0.42	0.58	0	0	0
1.00	0.0	4.31	15.83	0.06	0.35	0.77	1.35	0.04	0.04	0
0.71	0.5	4.89	20.72	0.13	0.38	2.48	3.83	0.02	0.06	0.01
0.50	1.0	3.44	24.16	0.61	1.08	13.19	17.02	0.03	0.09	0.01
0.35	1.5	3.79	27.95	2.68	3.76	38.35	55.37	0.13	0.22	0.01
0.25	2.0	5.69	33.64	32.07	35.83	21.71	77.08	0.47	0.69	0.02
0.177	2.5	9.94	43.58	44.84	80.67	7.45	84.53	0.84	1.53	0.06
0.125	3.0	13.98	57.56	5.90	86.58	3.29	87.82	2.03	3.56	1.67
0.088	3.5	3.66	61.22	0.30	86.88	0.92	88.74	7.96	11.52	9.84
0.0625	4.0	1.87	63.09	0.10	86.98	0.42	89.16	6.24	17.76	9.37
Mud	>4.0	36.01	100	13.02	100	10.84	100	82.24	100	79.01

Grain Size mm phi	Sample 47-5.00		Sample 47-7.25		Sample 47-8.50		Sample 48-2.00		Sample 48-5.00	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	4.98	4.98	0	0	0.20	0.20	0	0
2.83 -1.5	0	0	0	4.98	0	0	0.29	0.49	0	0
2.00 -1.0	0.03	0.03	0.16	5.14	0	0	0.17	0.66	0.08	0.08
1.41 -0.5	0.02	0.05	0.14	5.28	0.05	0.05	0.21	0.87	0.10	0.18
1.00 0.0	0.01	0.06	0.06	5.35	0.07	0.12	0.27	1.14	0.09	0.27
0.71 0.5	0.01	0.07	0.05	5.40	0.08	0.21	0.43	1.57	0.17	0.44
0.50 1.0	0.01	0.08	0.03	5.43	0.09	0.30	0.83	2.40	0.25	0.69
0.35 1.5	0.02	0.10	0.02	5.45	0.14	0.44	1.30	3.70	0.47	1.16
0.25 2.0	0.03	0.13	0.02	5.47	0.22	0.66	1.82	5.53	1.08	2.24
0.177 2.5	0.11	0.24	0.04	5.51	0.42	1.08	11.67	17.20	14.67	16.91
0.125 3.0	2.59	2.83	1.12	6.63	3.12	4.20	52.80	70.00	58.27	75.18
0.088 3.5	10.90	13.72	9.49	16.12	21.32	25.52	13.85	83.85	12.74	87.92
0.0625 4.0	10.58	24.30	8.08	24.20	9.74	35.26	2.08	85.92	2.13	90.05
Mud >4.0	75.70	100	75.80	100	64.74	100	14.08	100	9.95	100

Grain Size mm phi	Sample 48-7.75		Sample 49-1.75		Sample 49-4.75		Sample 49-7.75		Sample 50-2.50	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0.40	0.40	0	0	0	0	0	0	9.18	9.18
2.83 -1.5	0	0.40	0	0	0	0	0	0	5.15	14.33
2.00 -1.0	0.21	0.61	0	0	0	0	0	0	3.80	18.13
1.41 -0.5	0.35	0.96	0	0	0	0	0	0	3.73	21.86
1.00 0.0	0.38	1.34	0	0	0	0	0.01	0.01	2.56	24.43
0.71 0.5	0.59	1.93	0	0	0	0	0.01	0.02	3.54	27.97
0.50 1.0	0.96	2.89	0.02	0.02	0	0	0.01	0.02	4.47	32.44
0.35 1.5	1.34	4.23	0.02	0.04	0.01	0.01	0.02	0.04	9.10	41.54
0.25 2.0	2.04	6.27	0.05	0.09	0.01	0.02	0.05	0.09	17.30	58.84
0.177 2.5	6.78	13.05	0.37	0.46	0.13	0.15	0.31	0.40	14.94	73.78
0.125 3.0	32.18	45.23	9.77	10.23	5.25	5.40	7.65	8.05	5.07	78.05
0.088 3.5	21.96	67.19	41.75	51.98	21.57	26.97	27.14	35.19	0.82	79.67
0.0625 4.0	5.64	72.83	15.67	67.65	15.65	42.62	21.32	56.51	0.41	80.08
Mud >4.0	27.17	100	32.35	100	57.38	100	43.49	100	19.92	100

Grain Size mm phi	Sample 50-3.25 Ind. % Cum. %	Sample 50-5.75 Ind. % Cum. %	Sample 50-8.25 Ind. % Cum. %	Sample 51-2.00 Ind. % Cum. %	Sample 51-5.00 Ind. % Cum. %
4.00 -2.0	4.52 4.52	0 0	0 0	2.12 2.12	0 0
2.83 -1.5	2.66 7.18	0 0	0 0	0 2.12	0 0
2.00 -1.0	1.98 9.16	0 0	0 0	0 2.12	0 0
1.41 -0.5	2.29 11.45	0 0	0 0	0.02 2.14	0 0
1.00 0.0	1.41 12.86	0 0	0 0	0.02 2.16	0.02 0.02
0.71 0.5	1.57 14.43	0.01 0.01	0 0	0.02 2.18	0.10 0.12
0.50 1.0	2.99 17.42	0.02 0.03	0.01 0.01	0.12 2.30	0.31 0.43
0.35 1.5	9.72 27.14	0.04 0.07	0.01 0.02	0.90 3.20	1.56 1.99
0.25 2.0	23.67 50.81	0.10 0.17	0.04 0.06	10.97 14.17	8.66 10.65
0.177 2.5	23.14 73.95	0.46 0.63	0.78 0.84	38.89 53.07	29.43 40.08
0.125 3.0	10.31 84.26	1.91 2.54	3.35 4.19	22.56 75.63	26.89 66.97
0.088 3.5	1.23 85.49	1.05 3.59	1.84 6.03	2.97 78.60	4.62 71.59
0.0625 4.0	0.41 85.90	0.64 4.23	1.56 7.59	1.26 79.86	1.59 73.18
Mud >4.0	14.10 100	95.77 100	92.41 100	20.14 100	26.82 100

Grain Size mm phi	Sample 51-8.00 Ind. % Cum. %	Sample 52-3.75 Ind. % Cum. %	Sample 53-1.50 Ind. % Cum. %	Sample 53-3.75 Ind. % Cum. %	Sample 53-6.00 Ind. % Cum. %
4.00 -2.0	0 0	0 0	0.34 0.34	0 0	0.85 0.85
2.83 -1.5	0 0	0 0	0.22 0.56	0 0	0.51 1.36
2.00 -1.0	0 0	0.09 0.09	0.35 0.91	0.56 0.56	0.83 2.19
1.41 -0.5	0 0	0.05 0.14	1.18 2.09	0.23 0.79	1.06 3.25
1.00 0.0	0 0	0.02 0.16	2.00 2.09	0.38 1.17	1.04 4.29
0.71 0.5	0.13 0.13	0.07 0.23	5.23 9.32	1.55 2.72	2.31 6.60
0.50 1.0	0.56 0.69	0.10 0.33	10.91 20.23	3.26 5.98	5.02 11.62
0.35 1.5	3.12 3.81	0.15 0.48	15.44 35.67	4.99 10.96	7.74 19.36
0.25 2.0	13.41 17.22	0.12 0.60	12.40 48.07	8.83 19.79	10.07 29.44
0.177 2.5	21.12 38.34	0.25 0.85	8.35 56.42	18.65 38.44	14.49 43.93
0.125 3.0	13.55 51.89	1.32 2.17	4.36 60.78	25.29 63.73	15.86 59.79
0.088 3.5	7.78 59.67	2.20 4.36	1.22 62.00	9.75 73.48	6.77 66.56
0.0625 4.0	2.90 62.57	3.42 7.78	0.92 62.92	2.52 76.00	3.08 69.64
Mud >4.0	37.43 100	92.22 100	37.08 100	24.00 100	30.36 100

Grain Size mm phi	Sample 58-2.25 Ind. % Cum. %	Sample 58-4.25 Ind. % Cum. %	Sample 58-6.25 Ind. % Cum. %	Sample 58-8.25 Ind. % Cum. %	Sample 59-6.50 Ind. % Cum. %
4.00 -2.0	0 0	0 0	0 0	1.18 1.18	0.25 0.25
2.83 -1.5	0 0	0 0	0 0	0 1.18	0.74 0.99
2.00 -1.0	0.15 0.15	0 0	0 0	0.20 1.38	0.23 1.22
1.41 -0.5	0.03 0.18	0 0	0.07 0.07	0.01 1.39	0.12 1.34
1.00 0.0	0.29 0.47	0 0	0.06 0.13	0.04 1.42	0.09 1.43
0.71 0.5	1.25 1.71	0 0	0.13 0.26	0.05 1.47	0.04 1.47
0.50 1.0	3.60 5.31	0 0	0.52 0.78	0.23 1.70	0.03 1.50
0.35 1.5	6.37 11.68	0 0	5.99 6.77	4.24 5.94	0.04 1.54
0.25 2.0	36.43 48.11	0 0	56.45 63.22	34.24 40.18	0.09 1.63
0.177 2.5	39.65 87.76	0 0	38.71 91.93	44.54 84.72	0.25 1.88
0.125 3.0	6.12 94.37	0 0	3.03 94.96	5.67 90.39	1.27 3.15
0.088 3.5	0.61 94.98	0 0	0.35 95.31	0.30 90.69	6.06 9.21
0.0625 4.0	0.22 95.20	2.75 2.75	0.13 95.44	0.09 90.78	7.36 16.57
Mud >4.0	4.80 100	97.25 100	4.56 100	9.22 100	83.43 100

Grain Size mm phi	Sample 59-7.75 Ind. % Cum. %	Sample 60-1.50 Ind. % Cum. %	Sample 60-4.00 Ind. % Cum. %	Sample 60-6.25 Ind. % Cum. %	Sample 62-3.75 Ind. % Cum. %
4.00 -2.0	0 0	0.84 0.84	0.22 0.22	0.19 0.19	0 0
2.83 -1.5	0.09 0.09	0.87 1.71	0.10 0.32	0.14 0.33	0 0
2.00 -1.0	0.09 0.18	0.35 2.06	0.48 0.80	0.09 0.42	0 0
1.41 -0.5	0.21 0.39	0.29 2.35	0.36 1.16	0.44 0.86	0 0
1.00 0.0	0.32 0.72	0.21 2.56	1.03 2.19	3.05 3.91	0 0
0.71 0.5	0.42 1.14	0.79 3.36	3.47 5.66	14.77 18.68	0 0
0.50 1.0	1.13 2.27	1.50 4.86	4.85 10.51	17.98 36.65	0.04 0.04
0.35 1.5	6.89 9.16	1.18 6.04	2.99 13.50	8.68 45.33	0.02 0.06
0.25 2.0	21.30 30.45	3.77 9.81	3.60 17.10	4.06 49.39	0.01 0.07
0.177 2.5	23.00 53.45	24.67 34.48	13.87 30.98	3.85 53.24	0.03 0.10
0.125 3.0	21.93 75.38	29.69 64.17	12.69 43.67	1.74 54.98	0.07 0.17
0.088 3.5	4.37 79.75	3.46 67.63	1.98 45.65	0.66 55.64	0.17 0.34
0.0625 4.0	1.00 80.75	2.28 69.91	1.88 47.53	0.99 56.63	0.42 0.76
Mud >4.0	19.25 100	30.09 100	52.47 100	43.37 100	99.24 100

Grain Size mm phi	Sample 62-5.50		Sample 63-0.75		Sample 63-2.00		Sample 64-3.50		Sample 64-5.75	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	0	0	1.70	1.70	0.63	0.63	0	0
2.83 -1.5	0	0	0	0	1.13	2.83	0.44	1.07	0	0
2.00 -1.0	0	0	0	0	1.89	4.72	0.71	1.78	0.05	0.05
1.41 -0.5	0	0	0	0	2.52	7.24	0.81	2.59	0.07	0.12
1.00 0.0	0	0	0.10	0.10	1.84	9.09	0.74	3.33	0.12	0.24
0.71 0.5	0	0	0.07	0.17	2.09	11.18	0.74	4.07	0.26	0.50
0.50 1.0	0	0	0.54	0.71	2.37	13.55	0.91	4.98	0.45	0.95
0.35 1.5	0	0	3.75	4.46	5.85	19.40	1.98	6.95	1.02	1.97
0.25 2.0	0.01	0.01	3.70	8.16	5.45	24.85	5.23	12.18	4.24	6.21
0.177 2.5	0.03	0.04	5.14	13.30	6.76	31.61	11.91	24.09	14.05	20.26
0.125 3.0	0.06	0.10	4.44	17.74	8.95	40.56	16.55	40.65	32.34	52.60
0.088 3.5	0.22	0.32	3.13	20.87	4.98	45.54	8.37	49.02	14.11	66.71
0.0625 4.0	0.99	1.31	3.26	24.13	4.54	50.08	8.39	57.41	4.57	71.28
Mud >4.0	98.69	100	75.87	100	49.92	100	42.59	100	28.72	100

Grain Size mm phi	Sample 67-3.50		Sample 67-6.50		Sample 70-1.50		Sample 71-0.50		Sample 91-3.50	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	0	0	0	0	0	0	0	0
2.83 -1.5	0	0	0	0	0.05	0.05	0	0	0	0
2.00 -1.0	0	0	0	0	0	0.05	0	0	0	0
1.41 -0.5	0	0	0	0	0.06	0.11	0	0	0.04	0.04
1.00 0.0	0.03	0.03	0	0	0.05	0.16	0.73	0.73	0.27	0.31
0.71 0.5	0.07	0.10	0.01	0.01	0.02	0.18	1.34	2.07	2.92	3.23
0.50 1.0	0.44	0.54	0.06	0.07	0.03	0.21	2.13	4.20	7.90	11.13
0.35 1.5	1.51	2.04	0.25	0.32	0.07	0.28	2.39	6.59	6.40	17.53
0.25 2.0	4.39	6.43	0.83	1.15	0.16	0.44	3.38	9.97	6.14	23.67
0.177 2.5	7.29	13.72	2.30	3.45	0.33	0.77	8.00	17.97	15.65	39.32
0.125 3.0	15.25	28.97	9.07	12.52	0.18	0.95	11.90	29.87	25.66	64.98
0.088 3.5	37.59	66.56	35.70	48.22	0.33	1.28	2.92	32.79	11.89	76.87
0.0625 4.0	11.08	77.65	21.62	69.84	2.41	3.69	1.65	34.45	3.77	80.64
Mud >4.0	22.35	100	30.16	100	96.31	100	65.55	100	19.36	100

Grain Size mm phi	Sample 100-8.60		Sample 108-2.75		Sample 108-3.75		Sample 108-5.00		Sample 109-1.50	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	0	0	0	0	5.01	5.01	0	0
2.83 -1.5	0	0	0	0	0	0	0	5.01	0	0
2.00 -1.0	0	0	1.54	1.54	3.83	3.83	1.84	6.85	0.27	0.27
1.41 -0.5	0.05	0.05	0.44	1.98	1.84	5.67	0.88	7.73	0.52	0.79
1.00 0.0	0.13	0.18	0.36	2.34	2.12	7.79	1.00	8.73	0.84	1.63
0.71 0.5	0.16	0.34	0.24	2.58	1.94	9.72	1.15	9.88	2.13	3.76
0.50 1.0	0.11	0.45	0.22	2.81	1.78	11.50	1.30	11.18	4.80	8.56
0.35 1.5	0.09	0.54	0.31	3.12	2.58	14.08	1.83	13.01	7.70	16.26
0.25 2.0	0.50	1.04	1.93	5.05	11.58	25.66	5.98	18.99	14.29	30.55
0.177 2.5	5.53	6.56	5.52	10.57	22.30	47.96	9.10	28.09	26.09	56.64
0.125 3.0	38.13	44.69	7.25	17.82	9.28	57.24	11.10	39.19	14.18	70.82
0.088 3.5	10.10	54.79	2.70	20.52	2.25	59.49	3.90	43.09	1.97	72.78
0.0625 4.0	0.80	55.59	1.70	22.22	1.05	60.55	1.96	45.06	0.87	73.65
Mud >4.0	44.01	100	77.78	100	39.45	100	54.94	100	26.35	100

Grain Size mm phi	Sample 109-3.00		Sample 109-4.50		Sample 109-5.75		Sample 110-1.00		Sample 110-4.64	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	0	0	0	0	0	0	0	0
2.83 -1.5	0	0	0	0	0	0	0	0	0	0
2.00 -1.0	0.16	0.16	0.20	0.20	6.16	6.16	0	0	0.04	0.04
1.41 -0.5	0.12	0.28	0.46	0.66	2.84	9.00	0.11	0.11	0.05	0.09
1.00 0.0	0.36	0.64	0.54	1.20	2.43	11.43	0.27	0.38	0.11	0.20
0.71 0.5	1.03	1.67	1.09	2.29	2.11	13.54	0.64	1.02	0.08	0.28
0.50 1.0	3.77	5.44	2.18	4.47	1.92	15.46	1.40	2.43	0.08	0.36
0.35 1.5	6.63	12.07	3.44	7.91	2.26	17.72	1.79	4.22	0.07	0.43
0.25 2.0	9.11	21.18	6.41	14.32	3.84	21.56	1.86	6.08	0.18	0.61
0.177 2.5	20.04	41.22	16.87	31.19	10.63	32.19	4.31	10.39	0.55	1.16
0.125 3.0	25.98	67.20	25.91	57.10	17.30	49.49	36.43	46.82	6.05	7.21
0.088 3.5	3.29	70.49	8.20	65.30	5.75	55.24	39.14	85.96	31.00	38.21
0.0625 4.0	0.61	71.10	1.86	67.16	1.59	56.83	5.21	91.17	25.39	63.60
Mud >4.0	28.90	100	32.84	100	43.17	100	8.83	100	36.40	100

Grain mm	Size phi	Sample 91-5.50		Sample 92-4.00		Sample 92-5.50		Sample 96-1.50		Sample 96-3.50	
		Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0.25	0.25	0.04	0.04	1.56	1.56	0	0
2.83	-1.5	0	0	0	0.25	0	0.04	0	1.56	0	0
2.00	-1.0	0	0	0.09	0.34	0.02	0.06	0.62	2.18	0	0
1.41	-0.5	0.03	0.03	0.18	0.52	0.04	0.10	0.40	2.58	0	0
1.00	0.0	0.06	0.09	3.04	3.56	1.89	1.99	0.80	3.38	0	0
0.71	0.5	0.19	0.28	12.81	16.37	10.77	12.76	1.52	4.90	0.09	0.09
0.50	1.0	0.39	0.67	39.06	55.43	38.55	51.31	2.52	7.42	0.28	0.37
0.35	1.5	0.43	1.10	24.09	79.52	40.11	91.42	3.12	10.54	0.61	0.98
0.25	2.0	0.43	1.53	1.88	81.40	1.60	93.02	5.18	15.72	1.86	2.84
0.177	2.5	1.52	3.05	1.15	82.55	0.39	93.41	11.56	27.28	4.97	7.81
0.125	3.0	10.20	13.25	1.48	84.03	0.31	93.72	27.31	54.59	13.31	21.12
0.088	3.5	46.64	59.89	1.26	85.29	0.16	93.88	17.66	72.25	32.40	53.53
0.0625	4.0	18.35	78.24	0.77	86.06	0.10	93.98	3.82	76.07	16.05	69.58
Mud	>4.0	21.76	100	13.94	100	6.02	100	23.93	100	30.42	100

Grain mm	Size phi	Sample 96-5.50		Sample 97-0.50		Sample 97-2.50		Sample 97-4.50		Sample 97-6.50	
		Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	0	0	0	0	0	0	0	0
2.83	-1.5	0	0	0	0	0	0	0	0	0	0
2.00	-1.0	0	0	0.03	0.03	0	0	0	0	0	0
1.41	-0.5	0.01	0.01	0.14	0.17	0.05	0.05	0.03	0.03	0	0
1.00	0.0	0.05	0.06	0.21	0.38	0.07	0.12	0.01	0.04	0	0
0.71	0.5	0.12	0.18	0.29	0.67	0.09	0.21	0.02	0.06	0.01	0.01
0.50	1.0	0.28	0.46	0.33	1.00	0.15	0.36	0.04	0.10	0.02	0.03
0.35	1.5	0.59	1.05	0.40	1.40	0.21	0.57	0.04	0.14	0.02	0.05
0.25	2.0	1.48	2.53	0.59	1.99	0.33	0.90	0.06	0.20	0.05	0.10
0.177	2.5	3.07	5.60	1.01	3.00	0.93	1.83	0.15	0.35	0.23	0.33
0.125	3.0	7.65	13.25	6.65	9.65	8.05	9.88	1.24	1.59	4.21	4.54
0.088	3.5	24.57	37.82	19.95	29.60	30.59	40.48	13.93	15.52	17.33	21.87
0.0625	4.0	21.05	58.87	21.00	50.60	20.26	60.74	18.28	33.80	11.82	33.69
Mud	>4.0	41.13	100	49.40	100	39.26	100	66.20	100	66.31	100

Grain Size mm phi	Sample 111-0.50		Sample 111-2.50		Sample 111-4.25		Sample 111-5.50		Sample 111-6.25	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	49.61	49.61	10.05	10.05	2.32	2.32	0.26	0.26	11.48	11.48
2.83 -1.5	3.04	52.65	2.51	12.56	0.96	3.28	1.31	1.57	6.36	17.84
2.00 -1.0	2.88	55.53	4.22	16.78	3.04	6.32	0.97	2.54	7.04	24.88
1.41 -0.5	3.23	58.75	5.90	22.68	5.35	11.67	1.48	4.02	8.65	33.53
1.00 0.0	3.03	61.78	5.41	28.09	7.72	19.39	1.40	5.42	8.36	41.88
0.71 0.5	3.58	65.36	4.50	32.59	10.21	29.60	3.11	8.53	6.84	48.72
0.50 1.0	3.91	69.27	3.88	36.47	12.20	41.80	4.61	13.14	4.92	53.64
0.35 1.5	3.83	73.10	3.85	40.32	12.44	54.24	5.76	18.90	4.00	57.64
0.25 2.0	2.97	76.07	4.62	44.94	9.40	63.64	6.67	25.57	4.35	61.99
0.177 2.5	1.50	76.07	2.59	47.53	3.77	67.41	6.30	31.87	4.06	66.05
0.125 3.0	1.29	78.87	1.22	48.75	2.46	69.87	5.54	37.41	2.97	69.02
0.088 3.5	0.82	79.68	1.06	49.81	1.74	71.61	4.12	41.53	2.13	71.15
0.0625 4.0	0.57	80.25	2.53	52.34	0.98	72.59	2.98	44.51	1.40	72.56
Mud >4.0	19.75	100	47.66	100	24.41	100	55.49	100	27.44	100

Grain Size mm phi	Sample 111-7.50		Sample 111-8.00		Sample 113-0.50		Sample 113-1.50		Sample 114-5.75	
	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00 -2.0	0	0	17.51	17.51	0	0	0	0	0	0
2.83 -1.5	0	0	7.93	25.44	0	0	0	0	0	0
2.00 -1.0	4.49	4.49	10.34	35.78	0.07	0.07	0	0	0	0
1.41 -0.5	2.52	7.01	10.86	46.64	0.07	0.14	0	0	0.09	0.09
1.00 0.0	2.06	9.07	8.22	54.87	0.12	0.26	0.08	0.08	0.20	0.29
0.71 0.5	2.02	11.09	5.67	60.54	0.24	0.50	0.10	0.18	0.45	0.74
0.50 1.0	1.99	13.08	3.61	64.15	0.40	0.90	0.24	0.42	1.65	2.39
0.35 1.5	2.59	15.67	2.71	66.85	0.50	1.40	0.32	0.74	5.19	7.58
0.25 2.0	4.73	20.40	2.72	69.57	0.92	2.32	0.53	1.27	6.43	14.01
0.177 2.5	5.99	26.39	1.82	71.39	1.30	3.62	0.92	2.19	12.29	26.30
0.125 3.0	5.91	32.30	1.22	72.61	4.58	8.20	4.59	6.77	17.07	43.37
0.088 3.5	4.47	36.77	1.07	73.68	33.44	41.64	38.76	45.53	5.15	48.52
0.0625 4.0	3.16	39.93	0.74	74.42	14.45	56.09	19.79	65.32	4.46	52.99
Mud >4.0	60.07	100	25.58	100	43.91	100	34.68	100	47.01	100

Grain mm	Size phi	Sample 114-7.50		Sample 115-5.00		Sample 115-5.50		Sample 115-7.00	
		Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	0	0	8.59	8.59	0.91	0.91	0.40	0.40
2.83	-1.5	0	0	4.09	12.68	0.34	1.25	0	0.40
2.00	-1.0	0.24	0.24	4.87	17.55	0.34	1.60	0.38	0.78
1.41	-0.5	0.10	0.34	5.51	23.06	0.62	2.22	0.18	0.96
1.00	0.0	0.18	0.52	4.09	27.15	0.72	2.94	0.23	1.19
0.71	0.5	0.50	1.02	4.31	31.46	0.86	3.80	0.49	1.68
0.50	1.0	1.00	2.02	4.37	35.83	1.24	5.04	1.00	2.68
0.35	1.5	2.28	4.30	5.43	41.26	2.69	7.73	2.09	4.77
0.25	2.0	5.35	9.65	9.07	50.33	7.37	15.10	6.04	10.81
0.177	2.5	14.73	24.37	13.53	63.86	18.09	33.19	14.18	24.99
0.125	3.0	25.71	50.08	12.78	76.64	29.21	62.40	26.98	51.97
0.088	3.5	5.41	55.50	3.09	79.73	7.69	70.09	17.99	69.96
0.0625	4.0	3.36	58.86	1.19	80.91	2.44	72.53	6.04	76.00
Mud	>4.0	41.14	100	19.09	100	27.47	100	24.00	100

Grain mm	Size phi	Sample 131-3.75		Sample 131-4.75		Sample 131-5.75	
		Ind. %	Cum. %	Ind. %	Cum. %	Ind. %	Cum. %
4.00	-2.0	2.29	2.29	1.07	1.07	0	0
2.83	-1.5	0	2.29	0	1.07	0	0
2.00	-1.0	4.17	6.46	2.39	3.46	5.32	5.32
1.41	-0.5	4.51	10.97	2.77	6.23	3.64	8.96
1.00	0.0	4.28	15.25	3.24	9.46	4.65	13.61
0.71	0.5	4.61	19.86	4.78	14.24	5.18	18.79
0.50	1.0	5.52	25.38	6.21	20.45	6.65	25.44
0.35	1.5	6.62	32.00	7.64	28.09	6.08	31.52
0.25	2.0	9.12	41.12	10.22	38.30	9.91	41.43
0.177	2.5	9.01	50.13	13.88	52.18	13.25	54.68
0.125	3.0	11.17	61.30	11.72	63.90	11.09	65.77
0.088	3.5	3.32	64.62	3.67	67.57	3.77	69.54
0.0625	4.0	1.47	66.08	1.59	69.16	1.70	71.24
Mud	>4.0	33.92	100	30.84	100	28.76	100