CRETACEOUS MARGINAL MARINE AND FRESHWATER RHIZOPODS FROM CENTRAL NOVA SCOTIA, CANADA

Jennifer Lynne Waringer

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Department of Earth Science
Dalhousie University, Halifax, Nova Scotia
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Dalhousie University

Department of Earth Sciences
Halifax, Nova Scotia
Canada B3H 3J5
(902) 494-2358
FAX (902) 494-6889

DATE 08/04/96

AUTHOR Jennifer L. WARINGER

TITLE Cretaceous Marginal Marine And Freshwater Rhizopods From Central Nova Scotia, Canada.

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Abstract

This study of rhizopod assemblages, from two cores drilled near Shubenacadie, provides evidence for a marine connection to central Nova Scotia during the early Cretaceous. Five different rhizopod assemblages have been documented. They include; Assemblage A, *Ammotium* sp., *Trochammina* sp., and *Difflugia sp.*; Assemblage B, *Ammotium* sp., C*entropyxis aculeata,* and *Difflugia sp; Assemblage C, Ammotium* sp., and *Trochammina* sp; Assemblage D, *Ammotium* sp., *Trochammina* sp., *Miliammina sp.*, and *Difflugia sp.*; and Assemblage E which contains only *Trochammina* sp. Fossil fish vertebrae and pyritised foraminifera were also found.

The paleodepositional environment of Cretaceous sedimentary rocks in the Hants-Colchester lowlands of central N.S. was thought to have been freshwater. However, it appears that the basal section below 140 m for the SHUB94-5 core and below 90 m of the SHUB95-3 core, may actually have been deposited during a marine transgression producing marginal marine strata, which was followed by a fluvial progradation. The barren nature of the upper units of the cores does not allow further interpretation. The poor preservation of the assemblages in the upper units of the core could be attibuted to either the initial lack of rhizopods during deposition of the sediments in a fluvial setting, or may indicate alteration by post-depositional chemical weathering. The marginal marine environment refers to most coastal regions including beaches, marshes, and estuaries. Several lines of evidence that support a marginal marine setting include the discovery of marine foraminifera and thecamoebians, the relatively high abundance of the rhizopods, the pyritised pyrite, and the abundant sedimentary pyrite content.

Comparison of the central Nova Scotian rhizopods and early Cretaceous rhizopods from Alberta, Canada with modern marginal marine genera, reveal that these faunas are typical of salt marsh type environments. These assemblages also have Carboniferous counterparts identified in studies from the Sydney Coalfields, Nova Scotia.

Key words: Shubenacadie, Nova Scotia, early Cretaceous, marginal marine, foraminifera, thecamoebian, rhizopod, sedimentary pyrite, post depositional chemical weathering.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

There has been much speculation about the paleodepositional environment of a large deposit of laterally extensive, Cretaceous sedimentary rocks in central Nova Scotia (N.S.). The material has been interpreted in the past as being predominantly non-marine. Until recently, only microspore data on lignite samples were available. These data were used to confirm that the material was Cretaceous-aged. Pollen analysis can also be useful in determining paleoclimatic conditions but is not convincing as a paleoenvironmental indicator because pollen grains, by nature, are transported from their site of origin. In contrast, foraminifera and thecamoebians are excellent depositional indicators as they are benthic, providing in-situ evidence for different environments.

This micropaleontological honours thesis was designed to determine the paleodepositional environment, using the testate rhizopod assemblages from two cores, of early Cretaceous-aged strata from Shubenacadie, N.S. This project is part of a larger study initiated by the Nova Scotia Department of Natural Resources (NSDNR) and the Geological Survey of Canada (GSC) in 1993. The Central Meguma Mapping Project examines Quaternary and Cretaceous sediment distribution and stratigraphy in the Hants-Colchester Lowlands of central Nova Scotia, using regional mapping, drilling and reflection seismic surveys (Finck *et al.*, 1995a ,b). These studies were concentrated in the Shubenacadie and Musquodoboit valleys where Carboniferous outcrop is almost absent and isolated occurrences of Cretaceous silica sand, lignites and coloured kaolin clay are known (Finck, *et al.*, 1995b). These surveys indicate that Cretaceous sediments underlie much of the younger Quaternary sediment of the Shubenacadie Valley (Finck *et al.*, 1995a). This thesis is the first micropaleontological study to look at rhizopod assemblages in the Cretaceous deposits of onshore central N.S., and the results indicate that there was a marine transgression and subsequent regression with a fluvial progradation during the early Cretaceous period in this area.

The rhizopod assemblages in this thesis originated from the basal units below 140 m and 90 m below surface in the SHUB94-5 core and the SHUB95-3 core, respectively. The upper Units 2 and 3 (Finck et al., 1995a,b) were barren of rhizopod assemblages and did not permit further micropaleontological interpretation of the two cores. The poor preservation of the rhizopods in this study may be due either to the initial lack of rhizopods during deposition or to the alteration by post-depositional chemical weathering that began during the early Tertiary in the Shubenacadie deposits. The presence of thecamoebians and the lack of marls and glauconitic clays suggest a transitional setting (Stea et al., 1996). Several lines of evidence that support a marginal marine setting include the discovery of marine foraminifera, and freshwater or brackish thecamoebians, the relatively high abundance of the rhizopods, pyritised foraminifera, and abundant sedimentary pyrite content.

1.2 Purpose

The purpose of this thesis is two-fold. The first objective is to analyse and document the testate rhizopods in two Cretaceous cores from Shubenacadie, N.S. The organic richness of the lignites, and the silty sand and clay units of the core made them particularly interesting to examine. The second goal was to determine the paleodepositional environment of the area using the rhizopods as indicators.

1.3 Previous Work

Stevenson (1959) noted extensive clay deposits in his geological mapping of the Shubenacadie area. The Nova Scotia Department of Mines and Energy began an extensive mapping and diamond drilling program in the Musquodoboit Valley in 1967. Dates on spores from lignite samples from Elmsvale near middle Musquodoboit indicated an early Cretaceous age, probably pre-Albian (Stevenson, 1959; Stevenson and McGregor, 1963; Lin, 1971; Dickie, 1986). NSDNR undertook a diamond drilling program, the Central Meguma Mapping Project, in this area in 1994. The stratigraphy and sedimentary deposits of the Cretaceous are discussed in chapter 2.

It is helpful to compare the Nova Scotian Cretaceous rhizopod assemblages with marginal marine rhizopod assemblages in Cretaceous deposits from the rest of Canada. A landmark study from southern Alberta (Wall, 1976) documents similar Cretaceous rhizopod assemblages from the marginal marine environment. Wall (1983) also studied rhizopods from the Sverdrup Basin in the Canadian Arctic. Modern marginal marine environments are under investigation by researchers from the Centre for Marine Geology (Dalhousie University, Department of Earth Science). Scott *et al.* (1983) compared Cretaceous to recent marsh foraminifera from Wall's initial study. Medioli *et al.* (1990) studied early Cretaceous thecamoebians from deposits in Alberta. Prior to Wightman et al. (1993) and Thibaudeau (1993), marsh foraminiferal assemblages had not previously been reported from strata older than early Cretaceous, although certain genera are known from the early Paleozoic (Wightman et al., 1993). Thibaudeau (1993) identified taxa from 10 genera of agglutinated foraminifera and 3 genera of arcellacea in upper Pennsylvanian (Westphalian D) coal-bearing strata of the Sydney Mines Formation, Cape Breton Island, N.S.

Wightman *et al.*, (1993, 1994) discovered marginal marine agglutinated foraminifera and thecamoebians from the late Carboniferous cyclothems of coal-bearing rock in the Sydney coalfields of N.S. *Trochammina sp., Ammotium sp., Ammobaculites sp.*, and thecamoebians dominated their various assemblages. Medioli (1995) studied the sequence stratigraphy of the upper Cretaceous to Eocene deposits from the northeastern Pyrenees of Spain, using the rhizopod assemblages present in cores as evidence that the lignites and surrounding sediments are marginal marine deposits.

CHAPTER TWO: GEOLOGICAL BACKGROUND

2.1 Study Area

The study area is located in the Shubenacadie Valley, in the gently rolling Hants-Colchester lowlands, approximately 500 m southeast of the village of Shubenacadie, N.S. (Finck *et al.*, 1994, 1995a,b). Figure 2.1 shows the locations of the drillsites along Highway #102 (Finck *et al.*, 1995a).

Cores SHUB94-5 and SHUB95-3 were used in this study. Drillhole SHUB94-5 was drilled 370 m east of a pit through a large drumlin and penetrated approximately 110 m of Cretaceous sediments (Finck *et al.*, 1995a). SHUB94-5 is the first Cretaceous core examined for rhizopod assemblages from the Shubenacadie area. The top 86 m of SHUB94-5 is missing but is present in the drillhole SHUB94-4. The drillhole SHUB94-4 had to be abandoned due to drilling difficulties. The new hole (SHUB94-5) was drilled a few metres away but recovery began below 86 m, therefore it is considered the continuation of SHUB94-4. The SHUB94-4 core was not examined in this study.

The second core, SHUB95-3, was drilled in 1995, when NSDNR began drilling on the property of Russell Moxsom near the intersection of the Densmore Road and Highway #2 (Finck *et al.*, 1995a).

2.2 General Geology of The Study Area

Unconsolidated coarse- and fine-grained sedimentary rocks in this part of central N.S. span the Mesozoic and Cenozoic eras. Figure 2.2 is a schematic cross-section showing that early Cretaceous sediments crop out as isolated pockets through the overlying Quaternary sediments. The Cretaceous sediments are overlain by Quaternary channel fill deposits of gravel, sand and varved clays ranging in thickness from 13 to 80 m (Stevenson, 1959; Finck *et al.*, 1995b). Three distinct till sheets of Quaternary surface drift overlie the channel fill (Stea *et al.*, 1996).

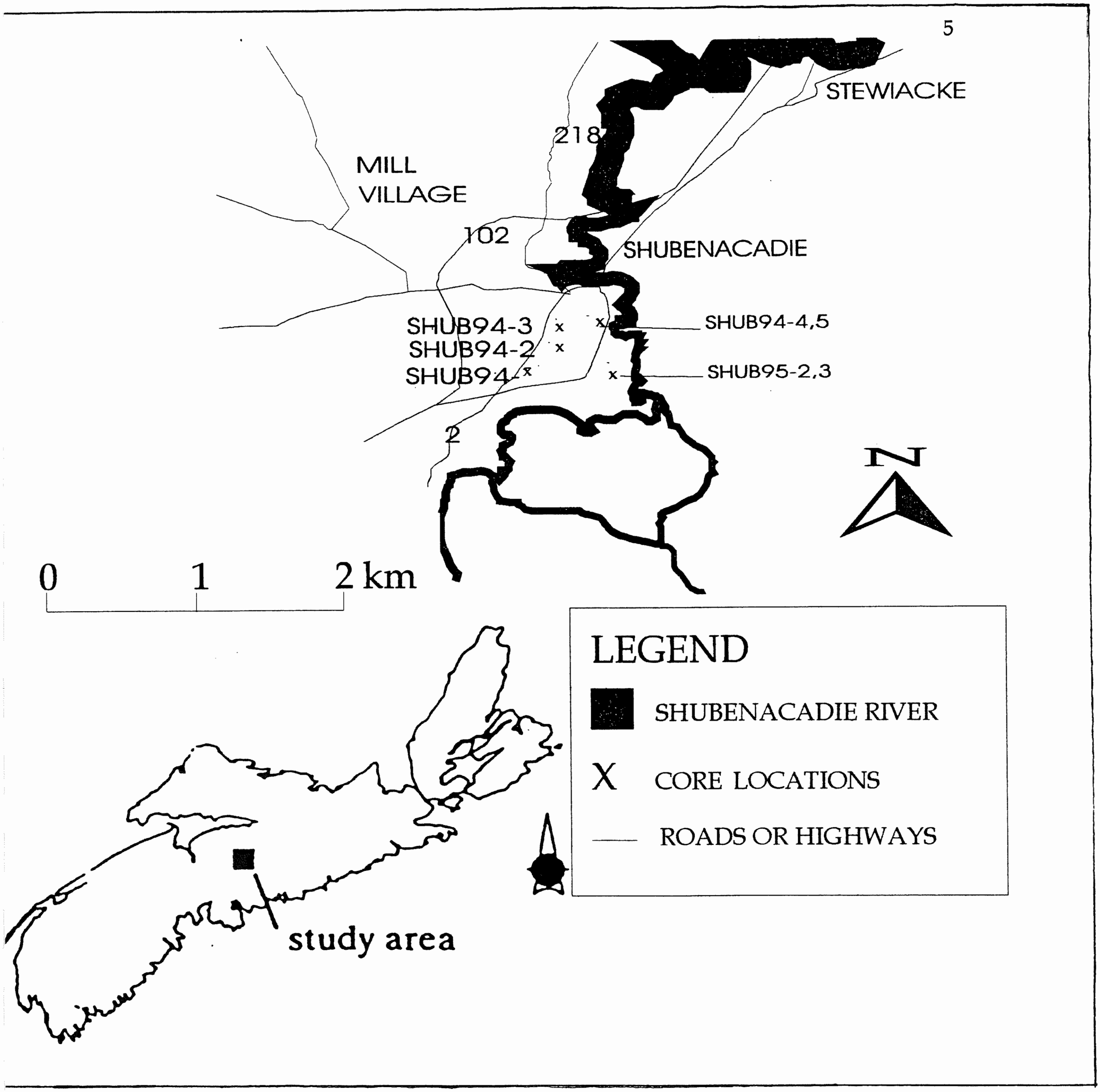


FIGURE 2.1: LOCATION OF THE 1994-95 DRILLHOLES. NOTE THAT THE TWO CORES USED IN THIS STUDY ARE SHUB94-5 AND SHUB95-3

(ALTERED FROM FINCK ET AL., 1995A)

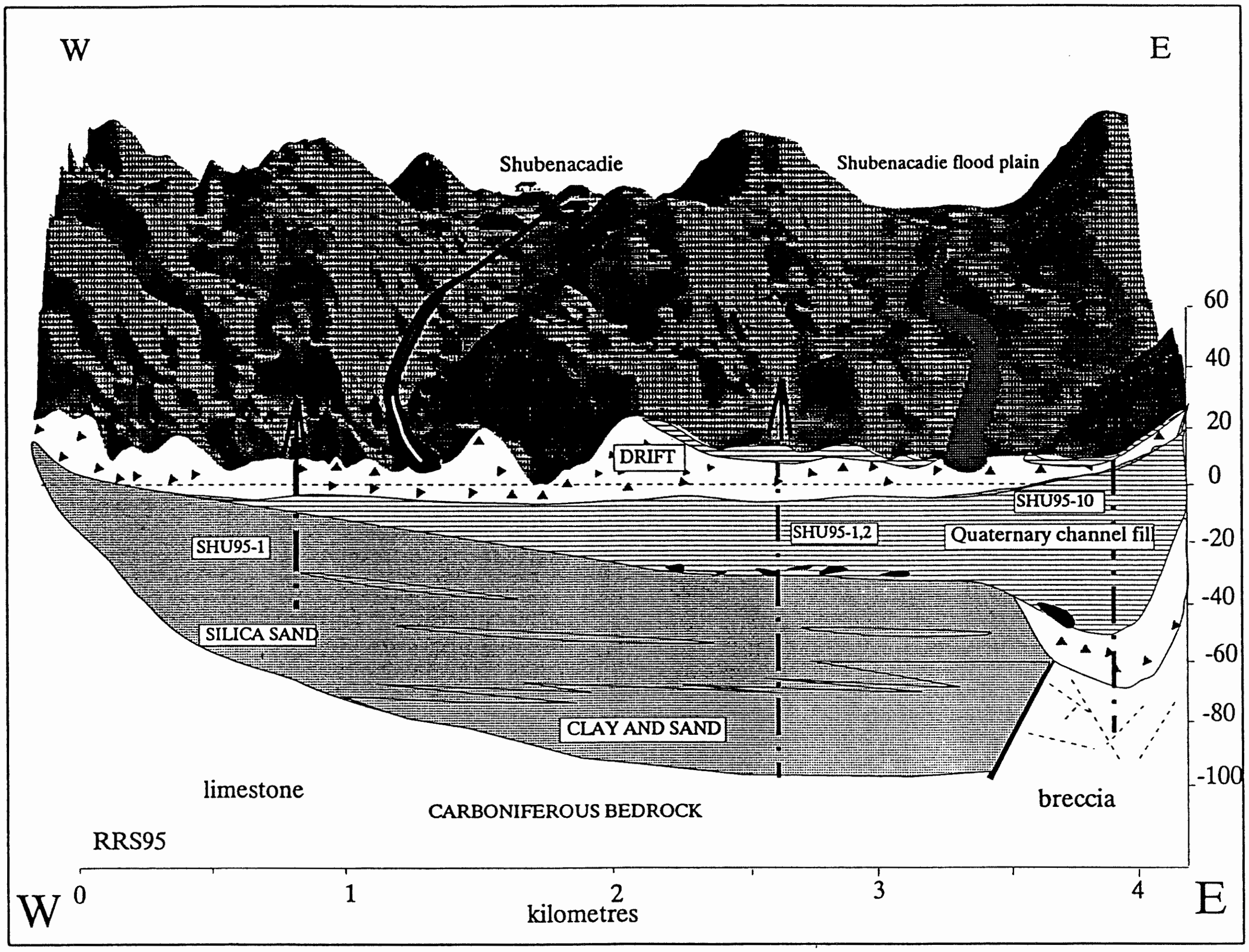


Figure 2.2: A schematic cross-section of the Cretaceous paleovalley below the Densmore and Crombe road seismic line. Thick Cretaceous deposits of silica sand, clay and sand, overlie Carboniferous limestone bedrock. Quaternary channel fill underlie Quaternary drift sheets.
(Altered from Stea *et al.,* 1996)

The Cretaceous sediments exceed 200 m in thickness in some locales and are generally undeformed (Finck *et al.*, 1995a). This region is a broad lowland plain with a relief of less than 50 m, is characterised by southeast-trending drumlins and moraines underlain by Carboniferous and Triassic sedimentary rocks (Stevenson, 1959; Finck *et al.*, 1995a,b; Stea *et al.*, 1996). These early to late Carboniferous strata are composed of evaporite and carbonate rocks interbedded with grey and red clastic sedimentary sequences (Stea *et al.*, 1996). Masked in all but a few other scattered localities, the Windsor limestone bedrock crops out 2-4 km on either side of the Shubenacadie River (Stevenson, 1959; Finck *et al.*, 1995a).

The stratigraphy of the Cretaceous deposits of N.S. is complex and beds are difficult to trace (Dickie, 1986). The original upper surface of the Cretaceous sediments is uneven and as a result is encountered at different levels in the various drillholes (Stevenson, 1959). The NSDNR has correlated between the 5 diamond drill holes of the SHUB94 suite using seismic profiles. Figure 2.3 shows the correlation of 5 cores and their division into eight lithostratigraphic units, including the Carboniferous limestone bedrock, Cretaceous and Quaternary sediments (Stea *et al.*, 1996).

2.3 The Extent of Cretaceous Deposits

Prior to drilling and seismic surveying, the extent of the Shubenacadie Cretaceous deposits was estimated at 0.5 km^2. In total, 18 holes were drilled using traditional diamond-drill methods with HQ and NQ size drill rods. Thirteen drillholes outlined the margins of a Cretaceous sedimentary basin, expanding the extent of known Cretaceous deposits from an area of 0.5 km^2 to an area of approximately 15 km^2 (Finck *et al.*, 1995b). Twenty-four, common depth point, seismic surveys were also conducted to determine the depth to bedrock, the stratigraphy of the Quaternary and Cretaceous strata, and to delineate the form of the valley margins. These surveys carried out cross-sectionally and longitudinally up the valley indicate that the Cretaceous sediments are

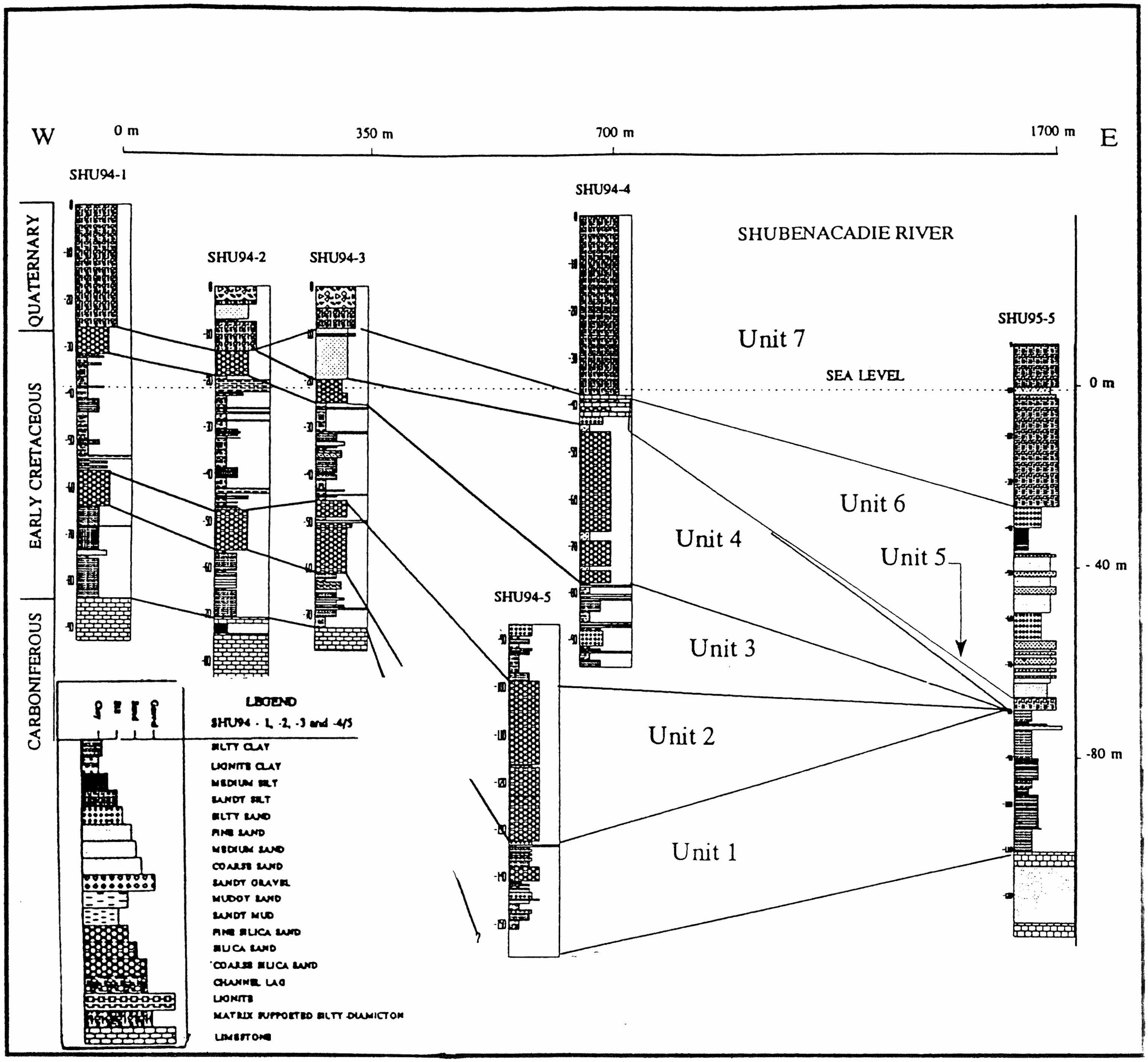


Figure 2.3: Correlation diagram between SHU94-1 to -5 and SHU95-5. The core SHU94-5 was sampled for rhizopod assemblages in this study. Three marine rhizopod assemblages were found in Unit 1 and it is interpreted as a marine transgression. it is inferred that Units 2 and 3 represent fluvial progradation. (Altered from Stea et al., 1996)

laterally extensive and continuous between drillholes (Finck *et al.,* 1995b). Post- Cretaceous erosion, including Quaternary glacial erosion, controlled the present upper surface position and thickness of the Cretaceous deposits (Finck *et al.*, 1995b).

Mean vitrinite reflectance data (R_o) from lignite horizons in Drillhole SHUB94-4/5 range from 0.31 to 0.48 R_o (Finck *et al.,* 1995b). This level of organic maturity indicates burial of about 1 km for geothermal gradients of typical sedimentary basins and heating to temperatures up to 80° C (Finck *et al.,* 1995b). The burial depth of one kilometre implies that the Cretaceous deposits were much thicker, prior to erosion in late Mesozoic-Cenozoic.

Other smaller deposits and occurrences are located in sinkholes and depressions in several regions of N.S. including the Musquodoboit Valley, West India Road and McKay Settlement (Hants County), Stewiacke and Belmont (Colchester County), and Glen Brook (Inverness County) (Dickie, 1986). The NSDNR mapping project has increased the known resources of kaolin clay and glass-grade silica sand from scattered deposits <1 km^2 to large areas of Cretaceous valley fill up to 130 m thick. The silica sand deposits intersected in the Shubenacadie area are up to 99.4 % SiO_2 (Finck *et al.*, 1995b). There is a Jurassic to recent wedge of marine sediment on the continental margin of Nova Scotia, but it is uncertain whether or not the Shubenacadie Cretaceous deposits are related to these strata.

2.4 Structure of the Shubenacadie Basin

The Shubenacadie Basin is separated from the Musquodoboit Basin by a region of Cambro-Ordovican Meguma Group metasedimentary rocks which forms the upland block called the Wittenburg Mountain (Stea *et al.*, 1996). The Cretaceous deposits occur in Windsor-aged, fault-bounded basins, the bottom of which occur at least 100 m below present sea level in Shubenacadie, Musquodoboit and Stewiacke Valleys (Dickie, 1986). The sediments are preserved in regionally extensive basins of greater than 80 km^2 (Finck *et al.,* 1995b).

The steep-walled nature of the valley is shown by the rapid increase in depth to bedrock at its margins (Finck *et al.*, 1995b).

2.5 Lithological Units In The Cores SHUB94-5 And SHUB95-3

The Cretaceous sediments occur as clay- and sand-dominated units in the core SHUB94-5 and SHUB95-3. The clay-dominated units consist of silty clay with repeating cycles of light to dark grey and black, organic-rich clay and lignite (Stea, *et al.*, 1996). The sand-dominated units are characterised by thick, fining-upward sequences of quartzose gravelly-sand and sand, light grey and white clay, with thin lignite horizons (Stea et al., 1996). The sands are dominated by subangular quartz grains with poor sorting (Stea et al., 1996).

The core SHUB94-5, which was sampled for foraminifera, consists of three units described by NSDNR and shown in Fig. 2.3 (Stea et al., 1996). Starting from the base, Unit One consists of alternate layers of (1) organic-rich silty clay with lignite or peat fragments, (2) lignite, and (3) dark to light grey silty clay. The base of Unit 1 is not seen in this core. The other cores from this study area intersected Windsor bedrock at their bases. The fact that this core did not intersect bedrock, probably reflects the varying thickness of strata . Many of the clays appear mottled by bioturbation. These organic-rich clays have high percentages of iron pyrite (Fowler, 1972). This deposit is underlain by Windsor limestone bedrock at depths of > 60 m (Finck *et al*, 1995a).

Unit Two is silica-rich sand in a white to light grey matrix (Finck *et al.*, 1995a). The matrix is kaolinite-rich similar to the clay at Elmsvale, Halifax County (Fowler, 1972). Silica sand and kaolin are two important industrial minerals found in the Cretaceous sediments. The source areas of the kaolinite and silica sand are thought to be weathered crystalline Appalachian and Shield bedrock terranes to the north, with local input of Carboniferous sediments (Stea *et al.*, 1996). There are also opaque minerals such as marcasite, and a large number of plant fragments

(Finck *et al.*, 1995a). This unit is overlain by the basal section of Unit 3 which consists of alternating layers of clay similar to those in Unit 1.

Core SHUB95-2/3 is capped by till and glaciofluvial sand and gravel which overlie Cretaceous silica sand, lignite, organic-rich clay, and channel fill. The core has been correlated with the other cores from the 1995 drilling project and is shown in Figure 2.4. This drillhole has ten lithostratigraphic units within the Quaternary and Cretaceous basin fill and bottoms in limestone bedrock at 109 m (Finck *et al.*, 1995a; Stea *et al.*, 1996). The basal unit which yielded rhizopod assemblages (D and E) and fish fossils was Unit 1. It consists of poorly sorted greyish, silica sand with clasts of whitish to grayish clay ranging in size from 0.25 to 10 cm. The sand contains angular to subrounded quartz grains, with evidence of silica recrystallisation on grain surfaces.

2.6 Dating

The exact age of the Shubenacadie material is still uncertain. There is sufficient palynological data available only to restrict the age to Cretaceous, Barremian to Aptian in age (124 to 113 Ma) but an older age cannot be ruled out (Stea et al., 1996). Table 2.1 compares two different palynological studies carried out on lignite sediments in the Shubenacadie sedimentary deposits. Lignite samples from a pit in Shubenacadie were analyzed for pollen and spores by P. Hacquebard and J. Terasmae of the GSC (Stevenson, 1959). More recently, Stea et al (1996) reported palynological analysis for lignite sediments and clays recovered from Unit 3 drillhole SHUB94-3. Stea et al. (1996) also sampled clays from Unit 1 in SHUB94-3 which produced poorly preserved spores typical of the Visean Windsor Group. The poor preservation of the pollen may suggest the possibility that it was reworked and deposited into younger material. Stevenson (1959) indicated that the microspore study discovered a large amount of well-preserved gymnospermous pollen and spores.

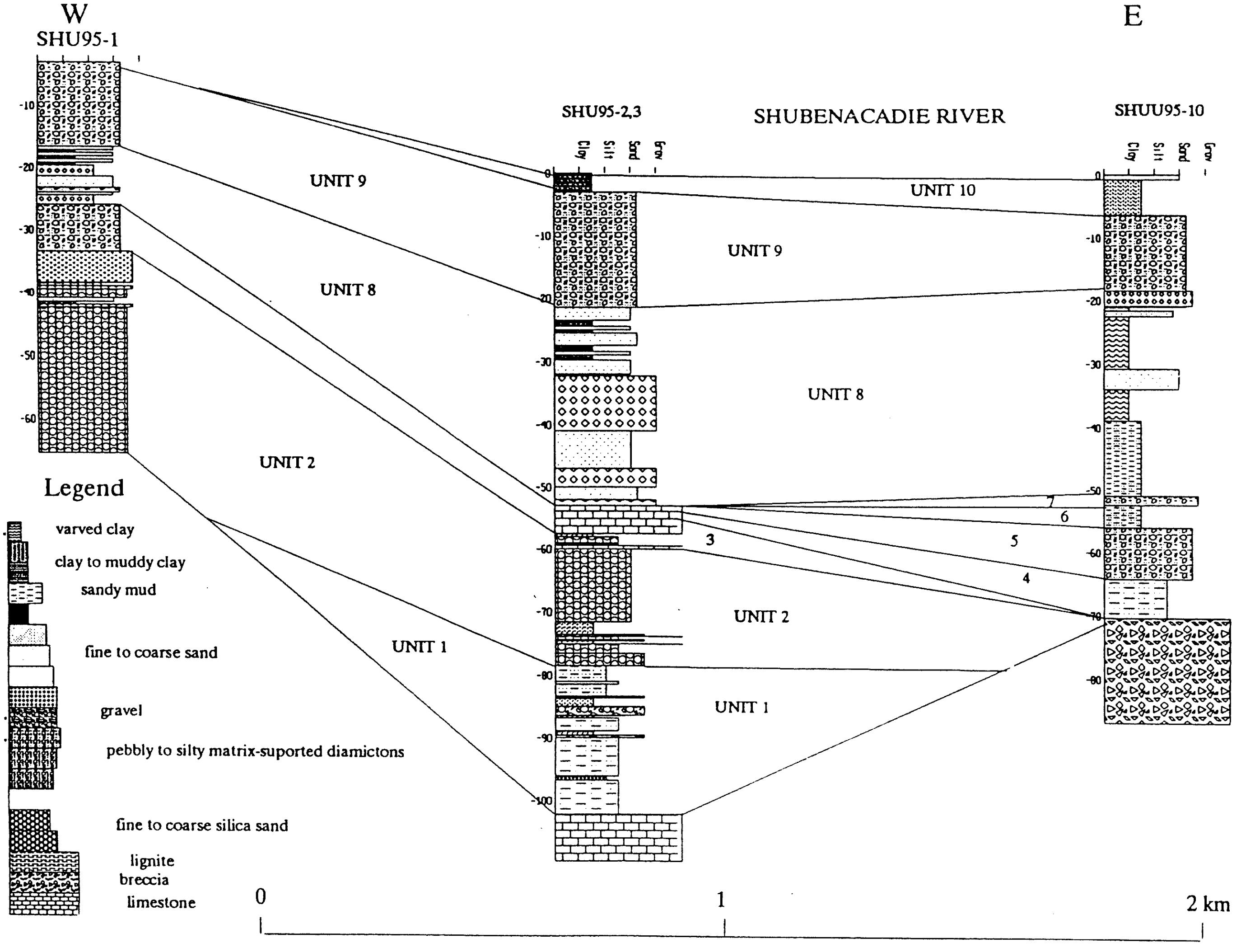


Figure 2.4: Correlation diagram between drillholes SHU95-1, 2/3 and SHU95-10. The core SHU95-3 was examined for rhizopods in this study. The basal section of Unit 1 contained altered fish vertebrae and one rhizopod assemblage.
(Altered from Stea et al., 1996)

TABLE 2.1

Pollen Analysis on a lignite from a Shubenacadie pit (Stevenson,1959)	Pollen Analysis on a lignite from SHUB94-3 core (Stea et al., 1996)
Appendicisporites	Appendicisporites
Cicatricosisporites	Cicatricosisporites purbeckensis
Monosulcites	Concavissimisporites apiverrucosus
Abietineaepollenites	Concavissimisporites granulosus
Schizaeaceae	Concavissimisporites montuosus
Podocarpaceae	Nodosisporites
Cycadophyte	Pilosisporites trichpapillosus
	Rugubivesiculites
	Saxetia elongata

Gymnosperms appeared in the Permian, whereas, angiosperms first appeared in the rock record at approximately 125 Ma in the mid Cretaceous (Raven and Johnson, 1995). Both studies discovered a general lack of angiosperm pollen and this suggests that the material originated before 125 Ma or a pre-Albian age (Stevenson, 1959; Stea et al., 1996). Both studies also indicated that the occurrence of the genus *Appendicisporites* is of special significance, as this genus is only known from the Cretaceous (Stevenson, 1959).

2.7 Climate and Paleolatitude

Two lines of information may be used to infer climatic conditions during the Cretaceous: the paleolatitude of Nova Scotia during the Cretaceous and pollen analysis. Nova Scotia was located within the subtropical to temperate zone between the 30° and 40° latitudes (Owen, 1983).

Warm climatic conditions are supported by the presence of ferns in the Shubenacadie material (Stevenson, 1959). Prolonged conditions of humidity with high rainfall of the Tertiary, would help account for some of the erosion and weathering of these deposits to the present levels (Dickie, 1986).

CHAPTER THREE: METHODS

3.1 Drilling

NSDNR drilled five wire-line diamond-drill holes in 1994. HQ rods were used to drill the surface till, and at 48m the holes were reduced to NQ rods. The HQ rods were left free hanging in the hole, to act as casing for the NQ drill string. The HQ casing traveled down the hole as the NQ drilling progressed. During a drill bit change, the HQ casing in hole SHUB94-4 fell sideways in an area of a sand washout and further attempts at drilling were unsuccessful. The hole was abandoned at 96m. A hole (SHUB94-5) was drilled within a few metres, laterally, to allow drilling to approximately 157 m depth. The core SHUB94-5 is a continuation of the abandoned drillhole of SHUB94-4. Core recovery in SHUB94-5 did not begin at the surface, but at a depth of ~86 m (Finck et al., 1994, 1995a). Core recovery varied widely between units with the highest average recovery achieved in the combined clay, silt and lignite, approximately 85% (Finck et al., 1995a,b).

The second core studied in this thesis (SHUB95-3) was one of three wire line drill holes completed by Logan Geotech. Inc., in 1995, using the above methods (Finck et al., 1995a).

3.2 Sample Collection and Preparation

The sample extraction began with the removal of 20 cc or approximately a 2 cm slice of material from the core. A hammer and chisel were needed for the extraction due to the consolidated nature of the predominantly silty sand and lignite-rich core. Sample preparation involved the soaking and washing of the rock through a $> 63\mu m$ sieve. The washed samples were dried in an oven at low heat (~50°C).

Different drying techniques were explored to ascertain whether or not the poor condition of the foraminifera was due to this stage of preparation. A unit was resampled and sieved, but not dried. The sample was immediately placed in alcohol. Unfortunately, there was little improvement in the quality of preservation of the specimens between the two methods. The best results occurred when the material was sieved and allowed to air dry. It appears that repeated rewetting and drying destroys the fragile foraminiferal tests.

3.3 Extraction

The dry samples were passed through a series of sieves (<500, <212, <180, <125 and <63 microns). This process sorted the sediment into different size fractions, allowing easier examination of the samples. The rhizopods were removed from the samples using a small paint brush, size 84 3/0. The samples were examined under a stereo dissecting scope (40X and 80X).

All picked specimens were placed onto standard cardboard micropaleontological slides. Prior to picking, the slides were coated with gum Tragacanth glue. The glue allows the specimens to stick effectively to the slide, but when water is applied, the rhizopods are easily moved. These Cretaceous aged cores were challenging to work with due to the poor preservation of rhizopods. To avoid further destruction of what remained after sample preparation, handling of specimens had to be kept to a minimum. The majority of foraminiferal specimens presented in this thesis were located in the smaller size fractions (<180 μm and <125 μm) of sieved samples.

3.4 Scanning Electron Microscope (SEM)

Double-sided tape was placed onto a scanning electron microscope (SEM) aluminum stub. The specimens were removed from the micropaleontological slides and placed on the taped stub. The specimens were arranged in rows with the individual specimens spaced equally apart, allowing for easier identification and photography. The mounted specimens were accurately documented with regard to which sample interval they originated from.

The aluminum stub was then vacuum dried and coated with gold/palladium alloy in a Tousimis Samsputter-2a (an automatic sputter-coating apparatus). The coated stub was then placed in the vacuum chamber of a scanning electron microscope (SEM). The SEM used in this study was a Bausch & Lomb ARL Nanolab 2000 model located in the Biology Department of

Dalhousie University. The specimens were viewed and photographed at varying magnifications on the SEM.

3.5 Thin Sections

Due to the poor preservation, few external structures are left. In an effort to determine if the selected specimens had maintained any internal features, thin sections of the foraminifera were made. The foraminifera were mounted on an aluminum SEM stub using crazy glue. The glue was allowed to dry until hard. Then, on a glass plate smeared with graphite grit used in polishing, the specimens on the stub were ground down by hand. Only a low percentage of mounted specimens used in this technique remained on the stub long enough to be thin sectioned, so as a precaution, the best specimens were not used. The stubs were then photographed on the SEM.

3.6 Microprobe Analysis of Pyrite Casts of Foraminifera

Polished grain mounts with selected sulphide casts of foraminifera were analyzed using the microprobe to determine if the sulphide was pyrite, as suspected. Specimens were selected from both cores. A standard glass thin section slide was drilled with several holes into which the selected casts were placed and sealed with balsam glue. The slides were air dried overnight and polished for several days using standard techniques. Many of the specimens were lost during polishing due to their small size. The polished grain mounts were then coated with carbon to make the samples conductive to the beam and placed in the microprobe under vaccum.

The samples were analysed on a JEOL 733 electron microprobe which has four wavelength dispersive spectrometers and an Oxford Link energy dispersive system. The energy dispersive detector system is used for all elements and has a resolution of 137 ev at 5.9 Kev. Each spectrum was used for 40 seconds with an accelerating voltage of 15 Kv and a beam current of 15 nA. The instrument was calibrated using cobalt metal to +/- 0.5% precision at 1 standard deviation. Major elements calibrate to accuracies of +/- 1.5to 2.0%. The probe uses geological standards as controls; in the case of the Shubenacadie sulphide samples, the probe was set up for chalcopyrite. The probe spot on the sample is approximately 1 micron and for each specimen on the grain mount, two locations were sampled. The raw data were corrected using Links ZAF matrix correction program. The results are shown in Appendix A.

CHAPTER 4: RESULTS AND SYSTEMATIC TAXONOMY

4.1 Results

Despite poor preservation in both cores, abundant rhizopods where extracted. Only a few of these specimens were identifiable to the genus level using their morphology. The classification process is further explained in the systematic taxonomy section of this chapter. Three foraminiferal genera and two genera of arcellacea (or thecamoebians, as they are commonly referred to) were identified as far as the genus level, but there was one exception: an excellent thecamoebian specimen *Centropyxis aculeata,* which can be identified to the species level. Naming the species of foraminifera is not possible for the specimens in these cores due to poor preservation, recrystallisation and deformation. The foraminifera identified are *Trochammina sp., Ammotium sp*., and a *Miliammina*-like sp. The thecamoebian genera are *Difflugia sp.* and *Centropyxis aculeata.*

Table 4.1 is a summary of the rhizopod assemblages for the SHUB94-5 samples, and includes other pertinent data such as sampling depth and lithology. The rhizopod assemblages of SHUB94-5 vary within Unit 1. Assemblage A consists of *Trochammina sp., Ammotium sp.* and *Difflugia sp.;* the two thecamoebian genera and *Ammotium sp.* make up assemblage B; and Assemblage C includes *Trochammina sp,* and *Ammotium sp.* From the three assemblages A, B and C, two main trends are apparent. There are repeated associations of the five rhizopod genera in the different samples examined, and all the identifiable (moderately well preserved) specimens occur in Unit 1. Figure 4.1 is a stratigraphic column of SHUB94-5, and it shows the sample locations and the assemblages associated with each sample.

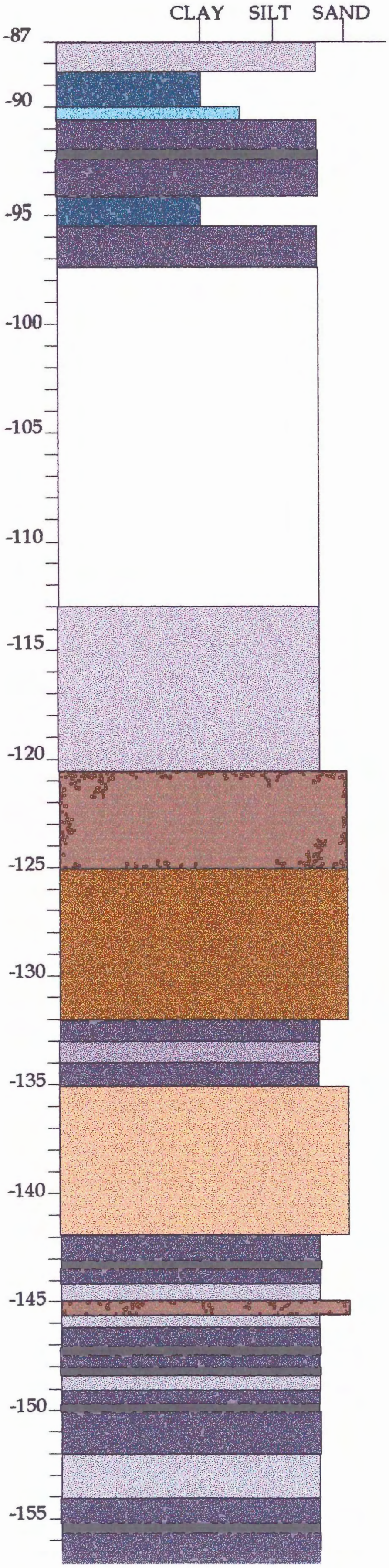
Table 4.2 is a summary of the rhizopods from the 95-3 core. Two different assemblages are referred to as D and E. The richest sample in SHUB95-3 was taken 98.83 m below surface and contains Assemblage D, an assemblage similar to assemblage A but including the foraminiferal

CORE	SAMPLE	DEPTH (M)	LITHOLOGY	UNIT	RHIZOPODS	ASSEMBLAGE
94-NS-SHUB-5	1579-1581	141.93-141.95	Light grey silty sand	1	Trochammina sp. Ammotium sp. Difflugia sp.	A
	2490-2492	154.51-154.53	Grey organic-rich silty sand	1	Trochammina sp Ammotium sp. Difflugia sp.	A
	2576-2578	155.45-155.47	Light grey silty sand	I	Ammotium sp. Centropyxis aculeata Difflugia sp.	B
	2609-2611	155.82-155.47	Dark grey organic-rich silty sand	1	Trochammina sp Ammotium sp.	C
	2644-2646	156.19-156.21	Dark grey organic-rich silty sand	1	Trochammina sp. Ammotium sp. Difflugia sp	A
	2646-2648	156.12-156.14	Dark grey organic-rich silty sand	1	Trochammina sp. Ammotium sp. Difflugia sp.	A

Table 4.1: Rhizopod assemblages in the SHUB 94-5 core. The repeated combinations of the different rhizopods were called assemblages and were assigned a letter for discussion purposes. The table also includes the depth at which the sample was taken and the lithology of the units identified by Finck et al.(1995a.).

Figure 4.1: Stratigraphic column and rhizopod assemblages for SHUB4-5. Three marginal marine assemblages were identified in this core. The assemblages occur in Unit 1 which has been interpreted as a marine transgression.

SHUB94-5 CORE AND RHIZOPOD ASSEMBLAGES



DEPTH TO SAMPLE	SAMPLE NUMBER	ASSEMBLAGES
87.0m	14-16	
87.5m	64-66	PF
89.9	127-129	BN
90.0	140-142	BN
91.0	245-247	PF
95.5	690-692	PF
95.7	715-717	LG
96.6	788-790	LG
96.8	802-804	LG
97.5	838-8340	BN
98.3	874-876	PF
132.7	1260-1262	LG
134.5	1302-1304	LG
141.9	1579-1581	ASSEMBLAGE A
142.1	1600-1602	LG
146.2	1930-1932	LG
147.0	1982-1984	LG
148.0	2106-2108	LG
148.5	2150-2152	BN
148.6	2169-2171	BN
148.7	2174-2176	LG
151.3	2247-2249	LG
151.6	2268-2270	LG
151.9	2294-2296	LG
152.0	2304-2306	LG
154.5	2480-2482	BN
155.2	2490-2492	ASSEMBLAGE A
155.5	2576-2578	ASSEMBLAGE B
155.8	2609-2611	ASSEMBLAGE C
156.1	2646-2648	ASSEMBLAGE A
156.2	2644-2646	ASSEMBLAGE A

LEGEND

▨	DARK GREY ORGANIC-RICH CLAY
▨	LIGHT GREY ORGANIC-RICH SILTY CLAY
☐	WHITE SILTY SAND
▨	LIGHT GREY SILTY SAND
▨	GREY ORGANIC-RICH SILTY SAND
▨	DARK GREY LIGNITE LAYERS
▨	BROWN SULPHUR-RICH COARSE SAND
▨	YELLOW/GREY SULPHUR-RICH SAND
▨	LIGHT GREY SULPHUR-RICH SAND

PF = PEAT FRAGMENTS
LG = LAMINATED LIGNITE FRAGMENTS
BN = BARREN SAMPLE

ASSEMBLAGE A = *Trochammina sp/Ammotium sp/Difflugia sp.*
ASSEMBLAGE B = *Ammotium sp/Centropyxis sp/Difflugia sp.*
ASSEMBLAGE C = *Trochammina sp/Ammotium sp.*

CORES	*SAMPLES*	*DEPTH m*	*LITHOLOGY*	*RHIZOPODS*	*ASSEM-BLAGE*
95-NS-SHUB-3	*94.5 + 9.52*	*94.40-94.42*	*GREY SILTY SAND*	*Trochammina sp.*	*E*
	97.5+1.33-1.35	*98.83-98.85*	*GREY SILTY SAND*	*Trochammina sp.* *Ammotium sp.* *Miliammina sp.* *Difflugia sp.*	*D*
	102.50-102.52	*102.50-102.52*	*LIGHT GREY SILTY SAND*	*Fish vertebrae*	*F*

Table 4.2: Rhizopod assemblages in the SHUB 95-3 core. Different rhizopods occurred in each sample. For discussion purposes each assemblages were assigned a different letter. The table also includes the depth at which the sample was taken, and a brief lithologic description. Note the fish fossils were assigned a letter because they were present with rhizopods too poorly preserved to survive the extraction process.

genus *Miliammina*. Figure 4.2 is a stratigraphic column of SHUB95-3, and it shows the sample locations and the assemblages associated with each sample. The overall poor preservation of the rhizopods in the core did not allow identification of trends, in assemblage composition and succession. Fish fossils were discovered near the base of the SHUB95-3 core, at approximately 102.50 m below surface (Plate 7; Figures 10 and 11). The fish bones or vertebrae are composed of calcium carbonate but have a thin layer of silica over the calcium carbonate. The fish bones reacted slowly to hydrochloric acid (HCl) at first as the thin silica layer with its carbonate matrix began to dissolve. Once the silica layer had been removed, the bone dissolved rapidly and completely within 5 minutes. Rhizopods were also observed in this sample (95-NS-SHUB-3 102.50-1.2.52) but due to their poor preservation, they disintegrated during extraction.

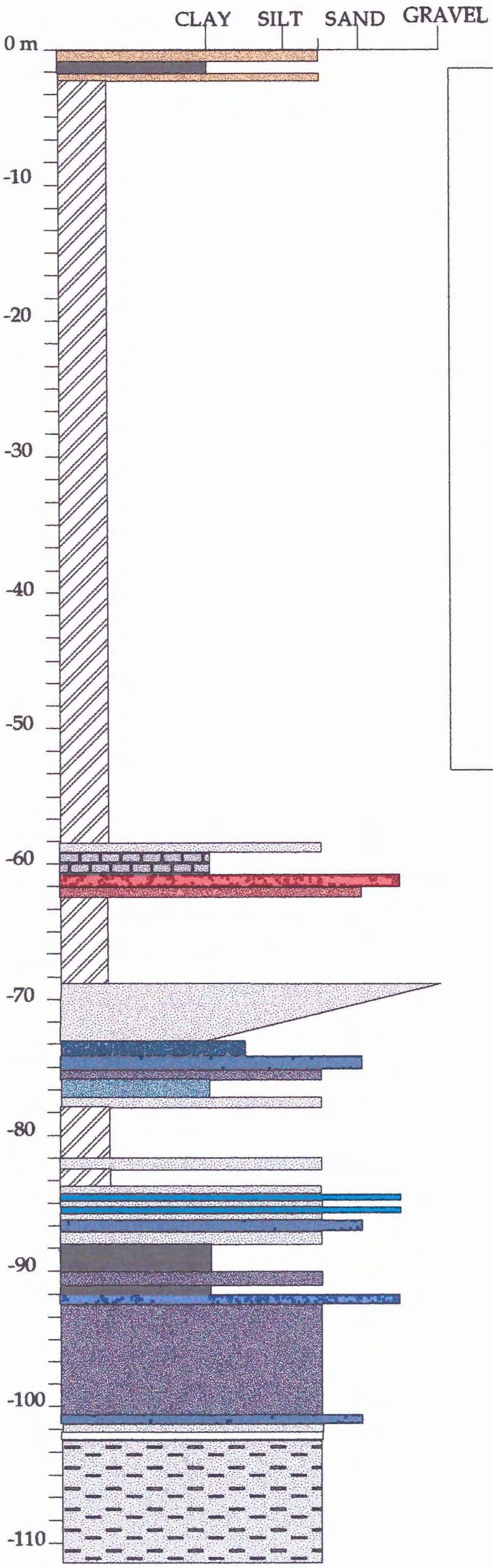
Comparison of the tables 4.1 and 4.2, reveal another trend that involves the lithologic units described in Fig. 2.3. Unit 1 contains the most organic-rich clays and, consequently, was sampled extensively. Figure 4.3 is a photo showing lignite layers in the SHUB94-5 core. Conversely, the top portions of the cores were barren of rhizopods, containing predominantly silty sand. Both Unit 2 and 3 in the 94-5 core are apparently barren of rhizopods. These two units contain clean, white silica sand which is almost 98.9% silica (Finck *et al.*, 1995a,b). All the rhizopods presented in this study are agglutinated forms but their external granular coverings have been stripped off, leaving only their organic inner linings. In some cases, even the lining has been replaced by a very finely crystalline silica.

4.2 Microprobe Analysis Results

The microprobe analysis of sulphide casts of foraminifera from the two cores indicated that the samples were predominantly FeS_2 which may be pyrite or marcasite, with very low amounts of trace elements near the lowest detection limits of the microprobe. SEM

Figure 4.2: Stratigraphic column and rhizopod assemblages for SHUB95-3. Fossil fish vertebrae and two marginal marine assemblages were discovered in the basal section of this core.

SHUB95-3 CORE AND RHIZOPOD ASSEMBLAGES



LEGEND

- ■ LIGNITE LAYER
- ■ GREY SILTY CLAY
- ■ LIGHT GREY CLAY
- ▦ LIGHT GREY LIMESTONE
- ▤ LIGHT GREY LIMESTONE-RICH SILTY SAND
- □ WHITE SILTY SAND
- ▒ LIGHT GREY SILTY SAND
- ■ GREY SILTY SAND
- ■ TAN SILTY SAND
- ■ REDISH-PINK COARSE SAND
- ■ PINK COARSE SAND
- ■ GREY SAND
- ■ LIGHT GREY SAND
- ■ LIGHT GREY SAND AND GRAVEL
- ▨ MISSING CORE

PF = PEAT FRAGMENTS
BN = BARREN SAMPLE
LG = LAMINATED LIGNITE FRAGMENTS

ASSEMBLAGE D = *Trochammina sp/Ammotium sp/Milliammina sp/Difflugia sp.*
ASSEMBLAGE E = *Trochammina sp.*

DEPTH TO SAMPLE (m)	SAMPLE NUMBER	ASSEMBLAGE
72.66	72.66 - 72.68	BN
73.35	73.35 - 73.35	BN
73.60	73.60 - 73.62	BN
74.12	74.12 - 74.14	LG
77.49	74.49 - 74.51	LG
80.70	80.70 - 80.72	PF
83.44	83.44 - 83.46	PF
84.70	84.70-84.72	LG
88.99	88.99 - 89.01	LG
89.40	89.40 - 89.42	LG
90.51	90.51 - 90.53	LG
91.08	91.08 - 91.10	LG
91.50	91.50 - 91.52	LG
93.28	93.28 - 93.30	LG
93.40	93.40 - 93.42	LG
94.40	94.40 - 94.92	ASSEMBLAGE E
95.88	95.88 - 95.90	LG
96.46	96.46 - 96.48	LG
98.83	98.83 - 98.85	ASSEMBLAGE D
102.50	102.50 - 102.52	FISH FOSSILS

Figure 4.3: A photo of interbedded lignite layers and organic-rich silty sand and silty clay layers in the basal section of the SHUB94-5 core. (Photo courtesy of P. Finck and R. Stea)

photomicrographs of two examples of pyrite casts of *Trochammina sp.* are presented in Plate 7, Fig. 12-14. The microprobe results of this section of the study are listed in Appendix A.

4.3 Thin Section Results

To determine if internal structure still remained, thin sections were made of selected foraminifera. Unfortunately, the organic linings of the foraminifera crumbled during thin sectioning, preventing a clear view of the internal structures. A few of the thin sectioned foraminifera from the SHUB94-5 core, despite the crushing of the inner linings, showed the slight impressions of chambers. However, the specimens did not have the relief necessary to make convincing SEM microphotographs.

4.4 Systematic Taxonomy

Systematic taxonomy is the practice of classifying organisms using comparative morphology (Bates and Jackson, 1984). Morphology is the study of the form and structure of organisms or their fossil remains (Bates and Jackson, 1984). The systematic arrangement of genera followed in this thesis uses the classification of Loeblich and Tappan (1964). The classifications are based on the external morphology and test composition. Taxonomy is challenging in circumstances where preservation of fossil material is poor, as in the case of the Shubenacadie rhizopods. Photomicrographs featuring examples of the five different genera of marginal marine rhizopods found in the Cretaceous cores are presented in this chapter, but none are proposed as new species. The figured specimens are located in the Dalhousie University Centre for Marine Geology archive, numbers SHUB94/95-1 to SHUB94/95-5. The following are the systematic taxonomy, the specimen descriptions and the various photomicrograph plates. The format of the plates is designed to provide information on the photos, for example:

Fig. 2: *Ammotium sp.*, 94- NS-SHUB-5 1579-1581, (141.93 m Below Top in light grey silty sand), 14.4 μm. (Stub 5 sp. 37)

The figure number relates to the specimen's arrangement on the plate. The species is identified in italics. The number 94 represents the year the sample was taken; N.S. is an abbreviation for Nova Scotia, and SHUB is short for Shubenacadie, where the cores were taken. The information in the brackets, indicates the sample depth below surface and the lithology of the rock from which it came. The µm reading is shown on photomicrograph in numbers and a scale bar. The numbers in the last brackets are the physical location of the photographed specimen.

Kingdom **PROTISTA**
Phylum **FORAMINIFERA**
Subphylum **SARCODINA** Schmarda, 1871
Class **RHIZOPODEA** von Siebold and von Stannius, 1845
Order **FORAMINIFERA** Eichwald, 1830
Suborder **TEXTULARIINA** Delage and Hérouard, 1896
Superfamily **LITUOLACEA** de Blainville, 1825
Genus **Ammotium** Loeblich and Tappan, 1953

Ammotium sp.
Plate 1; Plate 2, Fig. 1-8.

Description: The plainispiral tests are small sized, lenticular in shape. They have been strongly compressed. The sutures are indistinct. The final chambers tend to uncoil into a tube with a high terminal elliptical apertures located at the last chamber. They have inner linings. Agglutinated material is sparse. The foraminifera are arenaceous casts (composed of sand bound together by cement). Their colour is light brown. The geological range is from the Carboniferous to recent.

Family **TROCHAMMINIDAE** Schwager, 1877
Subfamily **TROCHAMMINIDAE** Schwager, 1877
Genus **Trochammina** Parker and Jones, 1859

Trochammina sp.
Plates 2, Fig. 9 & 10; Plates 3, 4 and 5.

Description: Tests are medium sized and strongly compressed resulting in collapsed chambers. The foraminifera have a trochospiral arrangement in a helicoid spiral with evolute, irregular length chambers. Gently curved sutures are distinct. Their positions indicated by raised light lines generally radiating between darker chambers. Plate 3, Fig. 1-3 and Plate 4, Fig. 7-8, show excellent collapsed chambers.

Specimens have apertures and pores on ventral basal surfaces with well developed lips apparent in selected specimens. Plate 5 show apertures and pores in various locations on the foraminifera.

Umbilical areas are present on the majority of the specimens. Plate 4, Figure 1-6 & 9-12, show excellent umbilical cavities. Star shaped structures in a few of these openings are perhaps umbilical teeth. Plate 5, Fig.4 and 6 show an umbilical plug over the umbilical area. They have inner linings. Agglutinated material is sparse. The foraminifera are arenaceous casts (composed of fine-grained sand bound together by cement). Their colour is light brown. The geological range spans the Carboniferous to recent (Haynes, 1981). Its environmental range consists of the marginal marine zone (Haynes, 1981).

Family **RZEHARKINIDAE** Cushman, 1933
Genus **Miliammina** Heron-Allen & Earland, 1930

*Miliammina sp.*1
Plate 7, Fig.6-9.

Description: The medium sized tests show strong lateral compression. The test have an oval shape with rounded apertures at one end. Multiple pores or tiny apertures cover the test. They are a brown colour. There is not obvious umbilical area present. Agglutinated material is sparse but where present it is fine grained. *Miliammina sp.* has been reported from the Carboniferous to recent. The environmental range is considered to be marginal marine zone (Haynes, 1981).

Subclass **LOBOSIA** Carpenter 1861
Order **ARCELLINIDA** Kent, 1880
Superfamily **ARCELLACEA** Ehrenberg, 1832
Family **CENTROPYXIDAE** Jung, 1942
Genus **Centropyxis** Stein, 1859
Centropyxis aculeata Ehrenberg, 1832

Centropyxis aculeata
Plate 6, Fig. 1, 2.

Description: The test is not as highly organized as the foraminiferida. Its recent analog has an agglutinated body and is saucer-shaped chitinous test. It has a dorsoventral symmetry. It is vertically compressed (Medioli, et al., 1990). Peripheral spines may or may not be present. The apertures are generally variable in outline. The specimen from the Cretaceous core SHUB95-3 has an invaginated aperture on its ventral side, but has sparse agglutinates. It is a brown colour. This species' geological range spans from the Mississippian to Recent. Its environmental range is considered to be fresh and slightly brackish water (Medioli and Scott. 1988).

Order **ARCELLINIDA** Kent, 1880
Superfamily **ARCELLACEA** Ehrenberg, 1832
Family **DIFFLUGIIDAE** Stein, 1859
Genus **Difflugia** LeClerc, 1816

Difflugia sp.
Plate 6, Fig. 3-12; Plate 7, Fig.1-5.

Description: The test shapes are variable including subglobular, flask shaped or cylindroid (Medioli and Scott, 1988). The sac-like tests coil and taper down at the tip. A round aperture is usually located at the end of the tip. There is no obvious umbilical area present. It has been reported from the Mississippian to Recent. Its environmental range is considered to be freshwater.

Fish vertebrae
Plate 7, Fig.10, 11

Description: Unable to identify. They appear to have a coating of silica over a calcium carbonate core.. They have been at least partially recrystallised.

Casts
Plate 7, Fig. 12-14.

Description: The casts resemble the genus *Trochammina sp.* but are not really identifiable. They are composed of FeS_2, which could be either pyrite or marcosite.

PLATE #1: *Ammotium sp.*

Fig. 1: *Ammotium sp.* 94-NS-SHUB-5 2490-2492, (154.51 m below top in grey silty sand), 52.4 µm. (stub 7 sp 7)

Fig. 2: *Ammotium sp* 94-NS-SHUB-5 2490-2492, (154.51 m below top in grey silty sand), 23.6 µm.(Stub 7 sp 7)

Fig. 3: *Ammotium sp.*, 94-NS-SHUB-5 2490-2492, (154.51 m below top in grey silty sand), 70.5 µm. (stub 7 sp 5)

Fig. 4: *Ammotium sp.,* 94-NS-SHUB-5 2490-2492, (154.51 m below top in grey silty sand), 29.2 µm. (Stub 7 sp 5)

Fig. 5: *Ammotium sp.* 94-NS-SHUB-5 2644-2646, (156.19 m below top in dark grey silty sand), 64.2 µm. (Stub 5 sp 17)

Fig. 6: *Ammotium sp.* 94-NS-SHUB-5 2576-2578, (155.45 m below top in light grey silty sand), 83.6 µm.(stub 2 sp 44)

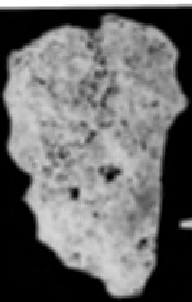
Fig. 7: *Ammotium sp.* 94-NS-SHUB-5 2576-2578, (155.45 m below top in light grey silty sand), 52.4 µm.(stub 2)

Fig. 8: *Ammotium sp.* 94-NS-SHUB-5 2576-2578, (155.45 m below top in light grey silty sand), µm.(stub 2)

Fig. 9: *Ammotium sp.* 94-NS-SHUB-5 1579-1581, (141.93 m below top in light grey silty sand), 44.9 µm. (Stub 5 sp 28)

Fig. 10: *Ammotium sp.* 94-NS-SHUB-5 2490-2492, (154.51 m below top in grey silty sand), 46.2 µm. (Stub 7 sp 6)

Fig. 11: *Ammotium sp.* 94-NS-SHUB-5 2490-2492, (154.51 m below top in grey silty sand), 16.3 µm. (Stub sp 6)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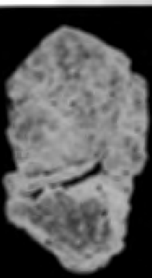
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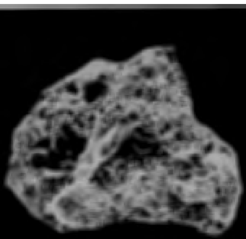
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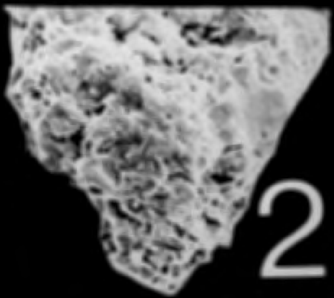
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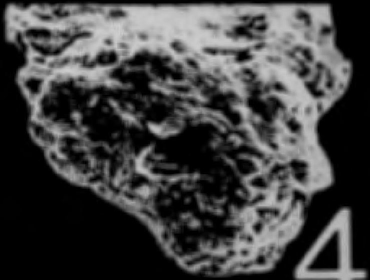
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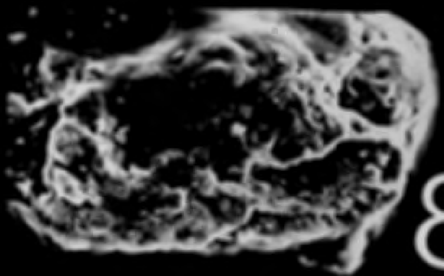
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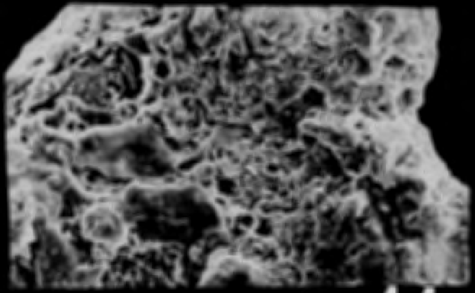
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PLATE #2: *Ammotium sp. and Trochammina sp.*

Fig. 1: *Ammotium sp.* 94-NS-SHUB-5, 2609-2611, 40.0 µm.(Stub 1 sp 15)

Fig. 2: *Ammotium sp.* 94-NS-SHUB-5, 2609-2611, 15.7 µm.(Stub 1 sp 15)

Fig. 3: *Ammotium sp.* 94-NS-SHUB-5, 2609-2611, 16.2 um.(Stub 1 sp 15)

Fig. 4: *Ammotium sp.* 94-NS-SHUB-5, 2609-2611, 11.3 µm.(Stub 1 sp 15)

Fig. 5: *Ammotium sp.* 94-NS-SHUB-5, 1579-1581 (141.93 m below top in light grey silty sand), 55.7 µm.(Stub 2 sp 29)

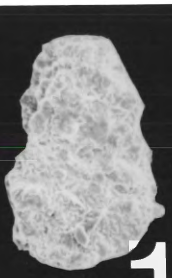
Fig. 6: *Ammotium sp.* 94-NS-SHUB-5, 1579-1581 (141.93 m below top in light grey silty sand), 14.6 µm. (Stub 2 sp 29)

Fig. 7: *Ammotium sp.* 94-NS-SHUB-5, 1579-1581 (141.93 m below top in light grey silty sand), 8.27 µm. (Stub 2 sp 29)

Fig. 8: *Ammotium sp.* 94-NS-SHUB-5, 1579-1581 (141.93 m below top in light grey silty sand), 19.4 µm.(Stub 2 sp 29)

Fig. 9: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 57.1 µm.(Stub 1 con 2 sp 35)

Fig. 10: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 16.0 µm.(Stub 1 con 2 sp 35)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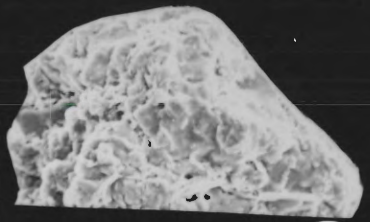
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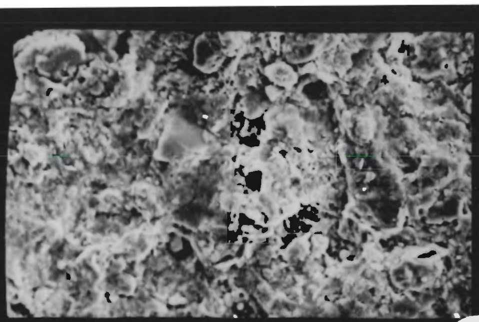
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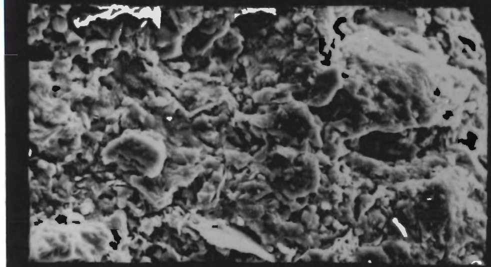
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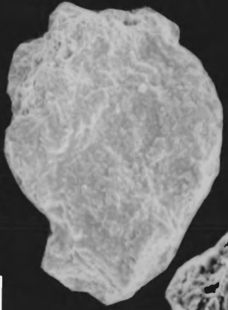
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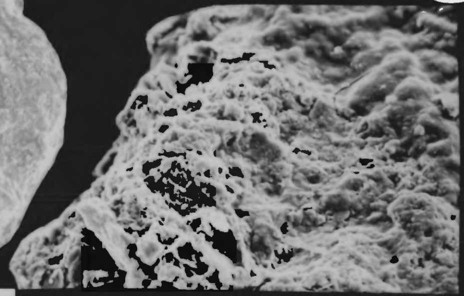
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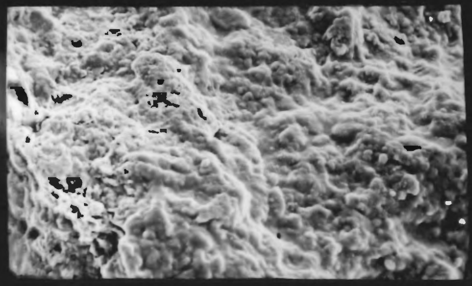
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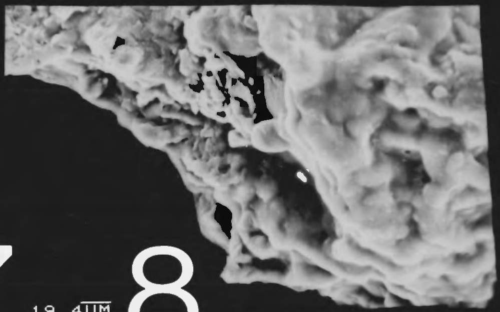
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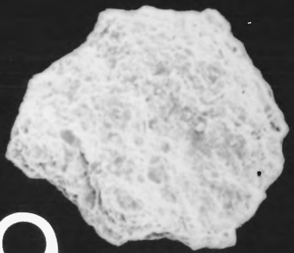
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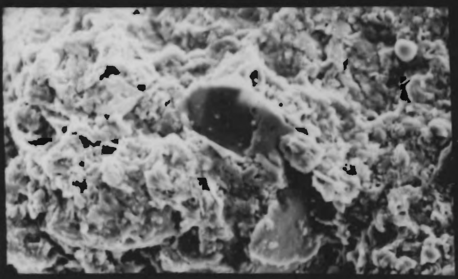
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PLATE #3: *Trochammina sp.*

Fig. 1: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 50.7 µm. (Stub 5 sp20)

Fig. 2.: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand), 20.9 µm. (Stub 5 sp20)

Fig. 3: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 13.3 µm. (Stub 1 con 1 sp 1)

Fig. 4: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 67.1 µm. (Stub 1 con 1 sp1)

Fig. 5: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 46.0 µm. (Stub 5 sp 7)

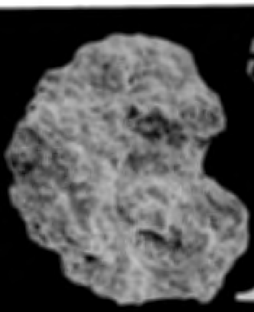
Fig. 6: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 16.3 µm. (Stub 5 sp 7)

Fig. 7: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 22.0 µm. (Stub 1 con 2 sp 47)

Fig. 8: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty. sand), 4.39 µm (Stub 1 con 2 sp 47)

Fig. 9: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty. sand), 47.5 µm (Stub 1 con 2)

Fig. 10: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty. sand), µm (Stub 1 con 2)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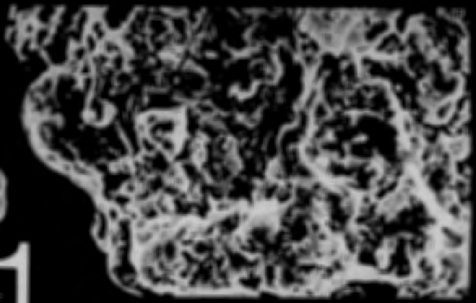
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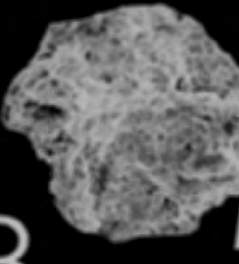
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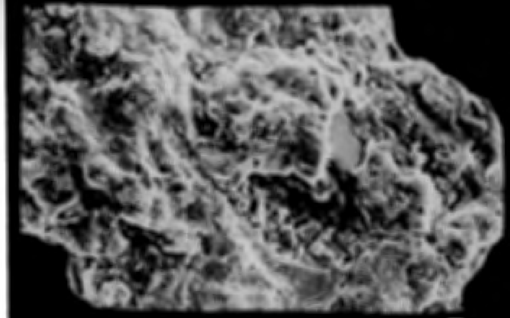
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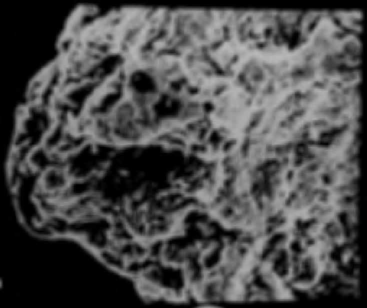
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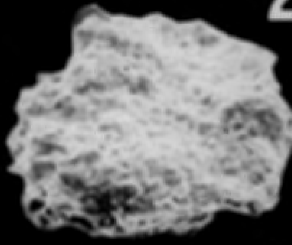
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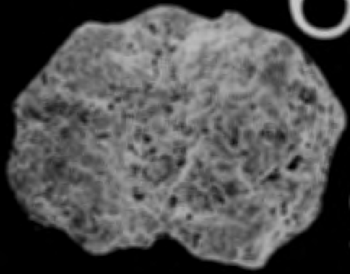
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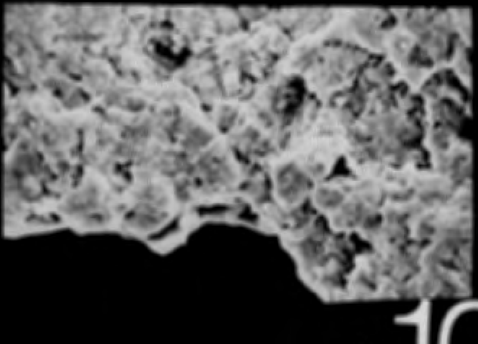
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PLATE #4: *Trochammina sp.*

Fig. 1: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 33.0 µm. (Stub 1 con 2 sp 39)

Fig. 2: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 5.86 µm.(Stub 1 con 2 sp 39)

Fig. 3: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 28.9 µm. (Stub 1 con 2 sp 46)

Fig. 4: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 4.75 µm.(Stub 1 con2 sp 46)

Fig. 5: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 24.2 µm.(Stub 1 con2 sp 38)

Fig. 6: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 9.90 µm.(Stub 1 con2 sp 38)

Fig. 7: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 65.9 µm.(Stub 5 sp 1)

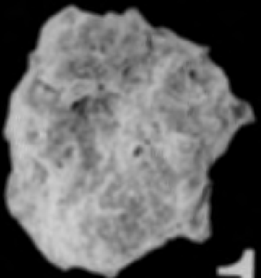
Fig. 8: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 15.2 µm. (Stub 5 sp 1)

Fig. 9: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 7.78 µm.(Stub 1 con2 sp 49)

Fig.10 *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 23.8 µm.(Stub 1 con2 sp 49)

Fig. 11: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 48.2 µm.(Stub 1 con2 sp 33)

Fig.12: *Trochammina sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 7.52 µm.(Stub 1 con2 sp 33)



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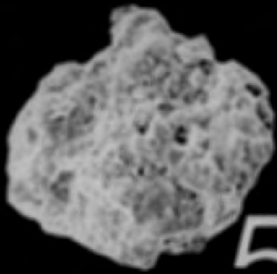

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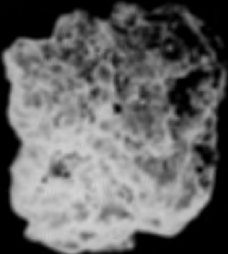

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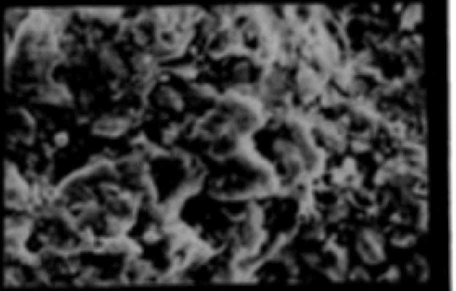

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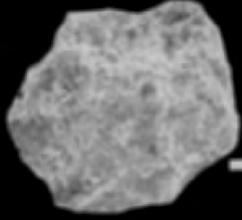

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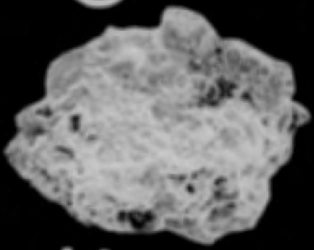

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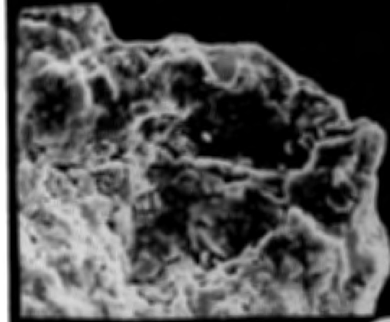

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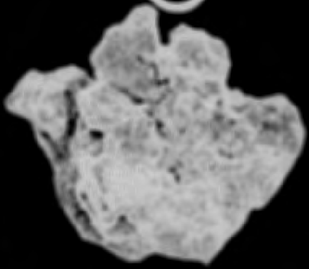

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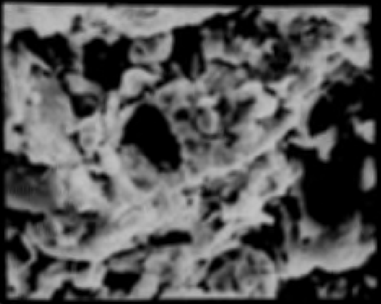

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PLATE # 5: *Trochammina sp.*

Fig. 1: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 46.3 µm. (Stub 1 con 1 sp5)

Fig. 2: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 18.5 µm. (Stub 1 con 1 sp 5)

Fig. 3: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 20.1 µm. (Stub 1 con 1 sp 5)

Fig. 4: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 54.4 µm. (Stub 5 sp 8)

Fig. 5: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 17.4 µm. (Stub 5 sp 8)

Fig. 6: *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in dark grey silty sand) 23.1 um. (Stub 5 sp 8)

Fig. 7: *Trochammina sp.* 95-97.5+1.35-1.33 (98.85 m below top), 57.5 µm. (Stub 3 sp 15)

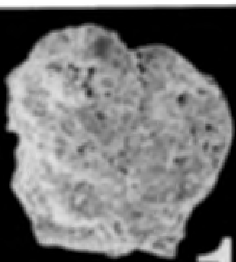
Fig. 8: *Trochammina sp.* 95-NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 17.0 µm. (Stub 3 sp 15)

Fig. 9: *Trochammina sp.* 95-97.5+1.35-1.33 (98.85 m below top), 16.0 µm. (Stub 3 sp 15)

Fig. 10: *Trochammina sp.* 94-NS-SHUB-5, 2609-2611, 32.0 µm.(Stub 1 con 2 sp 35)

Fig. 11: *Trochammina sp.* 94-NS-SHUB-5, 2609-2611, 27.1 µm.(Stub 1 con 2 sp 35)

Fig. 12: *Trochammina sp.* 94-NS-SHUB-5, 2609-2611, 12.8 µm.(Stub 1 con 2 sp 35)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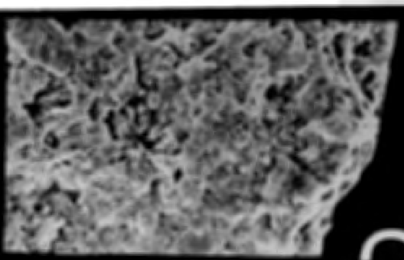
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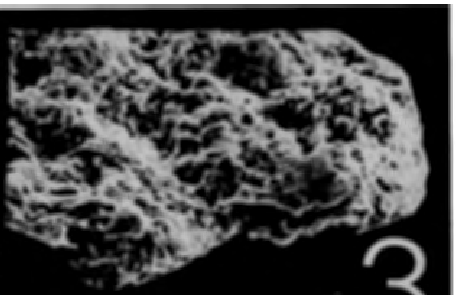
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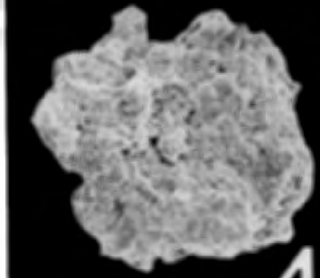
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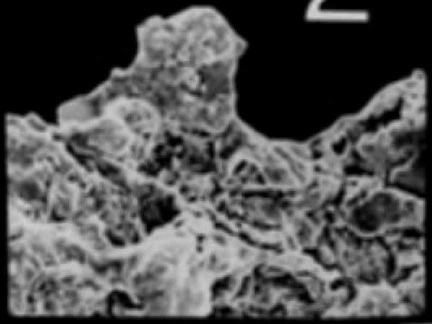
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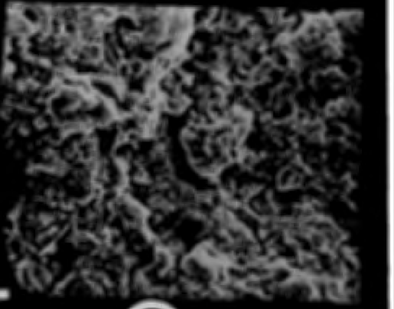
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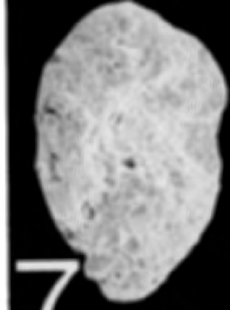
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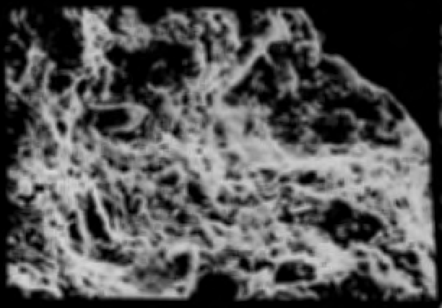
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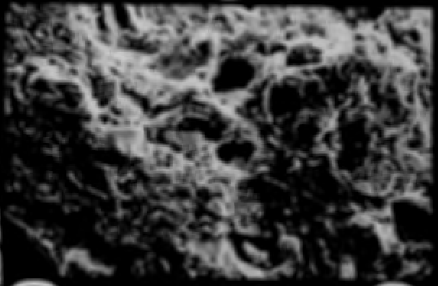
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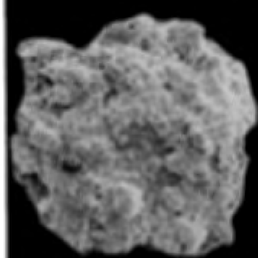
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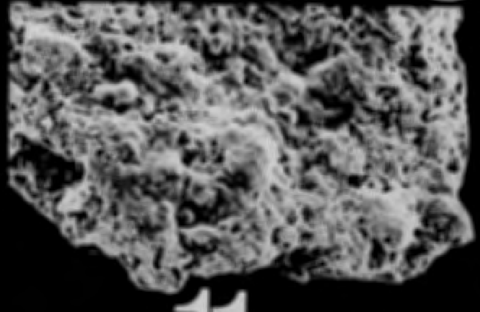
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PLATE #6: Thecamoebians

Fig. 1 :Centropyxis aculeata, 94-NS-SHUB-5, 2576-2578 (155.45 m below top in light grey silty sand) Ventral side, Aperture, 88.0 µm 15. sp, now moved to stub 3)

Fig. 2: Centropyxis aculeata, 94-NS-SHUB-5, 2576-2578 (155.45 m below top in light grey silty sand) dorsal side, 85.9 µm (Stub 3 ph 26. sp.40)

Fig. 3: *Difflugia* 94-NS-SHUB-5, 2490-2492, (154.51 m below top in grey silty sand), 78.6 µm. (Stub 2 sp 32)

Fig. 4: *Difflugia sp.* 94-NS-SHUB-5, 2490-2492, (154.51 m below top in grey silty sand), 8.59 µm. (Stub 2 sp 32)

Fig. 5: *Difflugia sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 51.6 µm.(Stub 1 con2 sp 45)

Fig. 6: *Difflugia sp.* 94-NS-SHUB-5, 2646-2648, (156.12 m below top in dark grey silty sand), 7.29 µm.(Stub 1 con2 sp 45)

Fig. 7: *Difflugia sp.* 95- NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 56.5 µm.(Stub 3 sp 11)

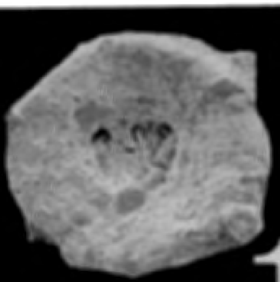
Fig. 8: *Difflugia sp.* 95 NS-SHUB-3 97.5+1.35-1.33 (m below top), 16.6 µm. (Stub 3 sp 11)

Fig. 9: *Difflugia sp.* 94-NS-SHUB-5, 2576-2578 (155.82 m below top in dark grey silty sand),40.3 µm (Stub 7, sp 10)

Fig. 10: *Difflugia sp.* 94-NS-SHUB-5, 2576-2578 (155.82 m below top in dark grey silty sand),24.4 µm (Stub 7, sp 10)

Fig. 11: *Difflugia sp.* 95 NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 102 µm.(Stub 3 sp14)

Fig. 12: *Difflugia sp.* 95 NS-SHUB -3 97.5+1.35-1.33 (98.85 m below top), 41.1 µm.(Stub 3 sp14)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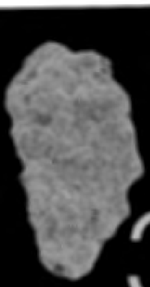
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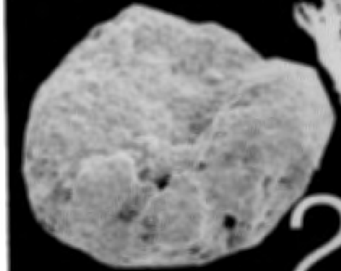
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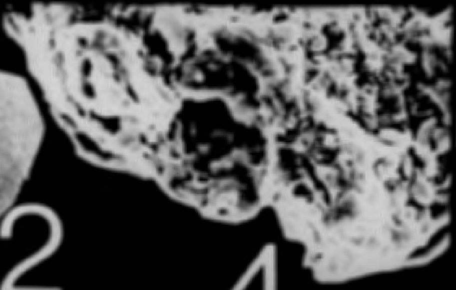
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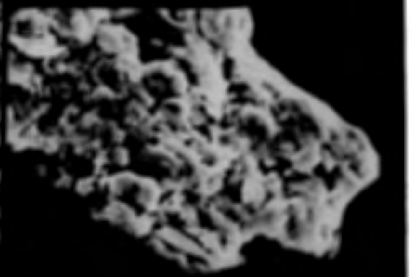
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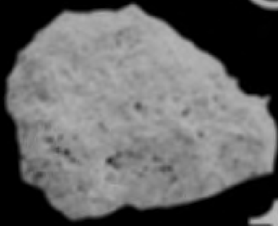
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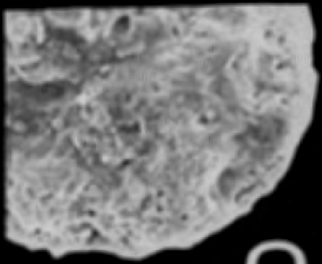
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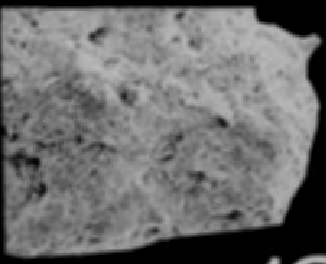
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PLATE #7 : *Difflugia sp., Miliammina sp,* Fish vertebrae and Pyrite casts

Fig. 1: *Difflugia sp.* 94-NS-SHUB-5, 1579-1581 (141.93 m below top in light grey silty sand), 34.0 µm.(Stub 5 sp 36)

Fig. 2 : *Difflugia sp.* 94-NS-SHUB-5, 1579-1581 (141.93 m below top in light grey silty sand), 12.4 µm.(Stub 5 sp 36)

Fig. 3: *Difflugia sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in light grey silty sand), 46.1 µm.(Stub 5 sp 19)

Fig. 4: *Difflugia sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in light grey silty sand), 16.4 µm.(Stub 5 sp 19)

Fig. 5: *Difflugia sp.* 94-NS-SHUB-5, 2576-2578 (155.45 m below top in light grey silty sand) dorsal side, 86.8 µm (Stub2 sp59)

Fig. 6: *Miliammina sp.* 95 NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 82.6 µm.(Stub 3 sp9)

Fig. 7: *Miliammina sp.* 95 NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 62.3 µm.(Stub 3 sp.9)

Fig. 8: *Miliammina sp.* 95 NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 12.4 µm.(Stub 3 sp9)

Fig. 9: *Miliammina sp.* 95 NS-SHUB-3 97.5+1.35-1.33 (98.85 m below top), 4.12 µm.(Stub 3 sp9)

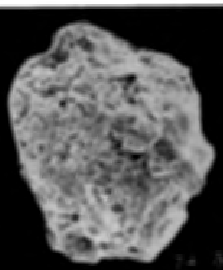
Fig. 10: Fish Vertebrae, 95 NS-SHUB-3 95-102 +0.5-0.52 (102.50 m below top), 134 µm.(Stub 3 sp23)

Fig. 11: Fish Vertebrae, 95 NS-SHUB-3 95-102 +0.5-0.52 (102.50 m below top), 177 µm.(Stub 3 sp17)

Fig. 12: Pyrite cast of *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in light grey silty sand), 52.6 µm.(Stub1 sp29).

Fig. 13 : Pyrite cast of *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in light grey silty sand), 39.4 µm.(Stub1 sp29).

Fig. 14: Pyrite cast of *Trochammina sp.* 94-NS-SHUB-5, 2644-2646, (156.19 m below top in light grey silty sand), 11.0 µm.(Stub1 sp29).



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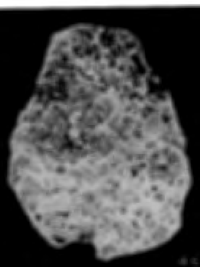

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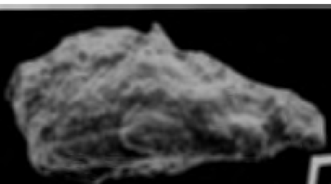

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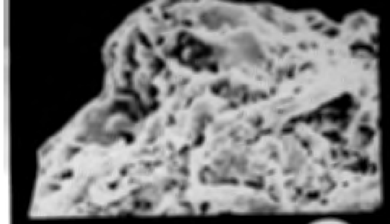

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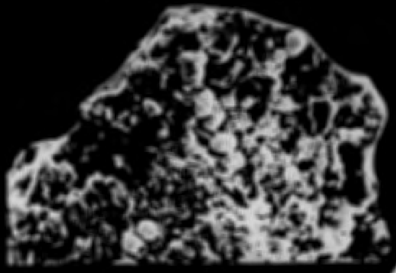

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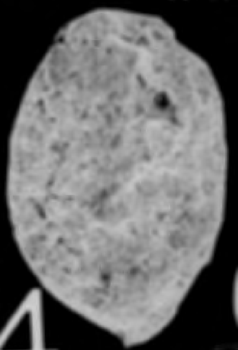

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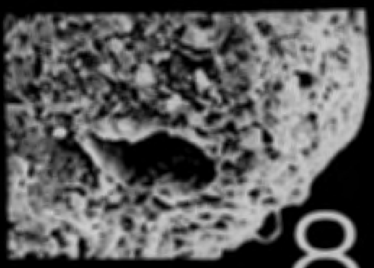

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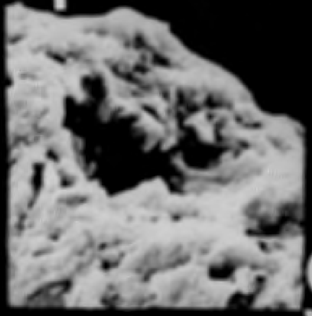

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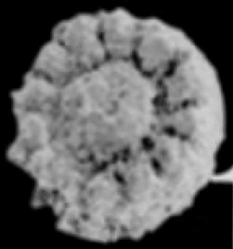

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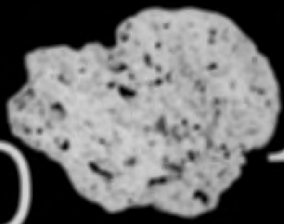

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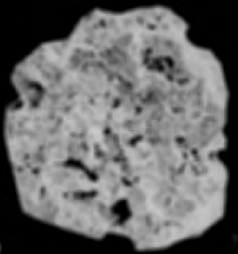

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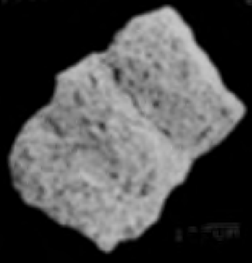

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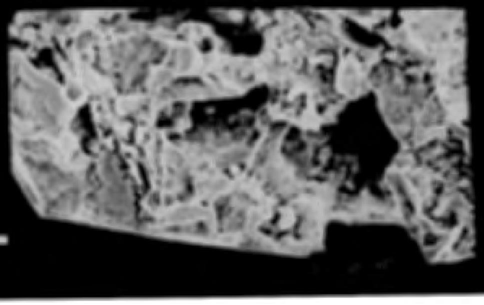

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CHAPTER FIVE: COMPARISON WITH OTHER FOSSIL MARSH FAUNAS

5.1 Comparisons

The genera presented in this thesis are not proposed to be new and have modern counterparts in the present day marginal marine environments. It is common to find mixed assemblages of thecamoebians and foraminifera in modern environments (Scott et al., 1980). The geological range of all the genera in Assemblages A to E appear to be the Carboniferous to Recent. The Cretaceous Shubenacadie samples had large numbers of rhizopods, similar to the high density of rhizopods found modern marsh sediments.

Medioli (1995) studied the rhizopod assemblages of the Upper Cretaceous to Eocene marginal marine deposits of south-central Pyrenees, Spain, and found species of *Trochammina* and *Ammotium*. Medioli's (1995) *Ammotium* sp. from La Pasarela, Spain, are coarsely agglutinated and clearly show the characteristics of the genus. *Ammotium* specimens in the study by Medioli (1995) are similar to those found in the Shubenacadie assemblages A, C and D. The *Trochammina* sp. specimens from Botlana, Isabena Valley and La Pasarela are similar to those found in Shubenacadie assemblages A and B.

Wall's (1976) study from the late Cretaceous Bearpaw-Horseshoe Canyon transition in southern Alberta, Canada, found low-diversity assemblages of agglutinated foraminifera, which suggested a salt marsh environment over that of a lagoon or shallow shelf. Wall (1976) found *Trochammina* sp., *Ammotium sp., Miliammina sp.*, *Verneuilinoides* sp., and *Eggerella* sp. The *Trochammina* sp., *Ammotium sp. and* the *Miliammina sp.,* specimens resemble the foraminifera found in the early Cretaceous deposits of Shubenacadie.

Thibaudeau's (1993) study of agglutinated brackish water foraminifera and arcellaceans from the upper Carboniferous, coal-bearing strata of the Sydney Basin, N.S., identified three rhizopods similar to those found by this author in the Cretaceous aged organic-rich clays of

Shubenacadie. Thibaudeau's (1993) foraminifera, *Ammotium* sp. 2, *Trochammina* sp.1-4., and an arcellacean, *Difflugia* sp. 3, resemble the Shubenacadie early Cretaceous *Ammotium* sp., *Trochammina* sp., and *Difflugia* sp. (a thecamoebian). Thibaudeau's (1993) *Trochammina* sp.1- 4 show sutures, star shaped umbilical areas and apertures with pronounced lips at their edges, similar to those in the Shubenacadie core 94-NS-SHUB-5 assemblages A and B. The *Ammotium* sp. in the Shubenacadie assemblages A, C and D lacked agglutination but showed classic genus characteristics such as sutures, apertures and umbilical areas.

Wightman *et al.,* (1993) studied the paleoecology, paleoenvironment and paleogeographical implications of agglutinated rhizopods from the late Carboniferous Sydney coal field, N. S. Three foraminiferal assemblages were recognized; 1) *Ammobaculites-Ammotium*, (siltstone facies), 2) mixed *Trochammina-Ammobaculites-Ammotium*, and 3) *Trochammina*-dominated assemblage. A thecamoebian assemblage was recognized, with specimens resembling modern *Difflugia, Nebela* and *Centropyxis.*

Scott and Medioli's (1983) study of modern agglutinated rhizopods from Lake Erie reported 8 species of the genus *Difflugia;* 2 species of the genus *Centropyxis; Pontigulasia compressa*; and *Heleopera sphagni.* The *Centropyxis aculeata* specimen found in the Lake Erie paper is similar to the early Cretaceous *Centropyxis aculeata* found in the Shubenacadie assemblage B. Assemblage A in the Shubenacadie cores contains many examples of *Difflugia sp.* which supports the presence of a freshwater influence in the transitional depositional setting.

5.2 Preservation

Despite the need to use multiple processing techniques such as drying, boiling, use of detergents and formic acid treatment, the rhizopod assemblages of the upper Cretaceous to Eocene deposits of south-central Pyrenees, Spain, were generally very well preserved (Medioli ,1995). Conversely, the Shubenacadie material was easily broken down with standard washing and drying techniques but the preservation was poor. The rhizopod assemblages in this thesis originated from the basal units 140 m and 90 m below surface, in the SHUB94-5 core and the SHUB95-3 core, respectively. The marine foraminiferal assemblages in the basal sections of both cores indicate the presence of a marine transgression in the Shubenacadie area during the early Cretaceous. The shift from abundant foraminifera to the barren units in both cores may reflect a regression with a fluvial progradation. The poor preservation of the rhizopods in this study may be due either to the initial lack of rhizopods during deposition or to the post-depositional chemical weathering. Fish fossils from the SHUB95-3 core have undergone alteration, possibly due to either diagenetic or weathering processes which have affected the other fossil remains.

Stea and Fowler (1981) interpreted the depositional environment of the Nova Scotian onshore Cretaceous deposits as being fluvial and commented that the lack of feldspar and phyllitic rock fragments might have been the result of chemical weathering in the source area or post-depositional intrastratal solution (Stea and Fowler, 1981). Dickie (1986) indicated that these deposits retain a primary deltaic sedimentary character except that the sand deposits are 98% SiO_2 and the clay deposits are virtually pure kaolinite. In contrast, the offshore deposits of the same age represent a typical sedimentary sequence of feldspathic sandstone, mudstone, and shale. It is clear that the onshore deposits have undergone a cycle of chemical weathering after their deposition (Dickie, 1986). Dickie (1986) suggested that the weathering began in the early Tertiary.

Wall's (1976) material was well preserved, allowing identification to the genus level. The foraminifera had their agglutination intact, unlike the Shubenacadie specimens which apparently had been stripped of agglutinated covering.

Thibaudeau's (1993) and Wightman *et al.*, (1993) rhizopods were moderately well preserved in the upper Carboniferous, coal-bearing strata of the Sydney Basin. Wightman *et al.*, (1993) assemblages have varying degrees of preservation; for example the mixed *Trochammina-Ammobaculites-Ammotium* had moderate preservation in medium to fine-grained siltstone and clayey siltstone facies. The *Trochammina*-dominated assemblage and the thecamoebians are well preserved in fine-grained siltstone and silty claystone facies.

In summary, the five genera found in the early Cretaceous deposits of Shubenacadie, N.S. are not proposed as new species because the specimens lack diagnostic morphological features required for identification past the genus level. It appears that the genera are slow to evolve and are widespread, occurring in Cretaceous deposits in other parts of Canada, such as in the Western Canada Sedimentary Basin (Haynes, 1981). The preservation of the Nova Scotian material appears to be better than the Carboniferous material which is to be expected because it is younger, but the present specimens are not as well preserved as the material found in Spain or Alberta.

CHAPTER SIX: DISCUSSION

6.1 Discussion

The two goals of this study were to document the rhizopod assemblages in 2 cores and to determine a paleodepositional environment for the large deposits of Cretaceous sedimentary rocks in central N. S. Rhizopods, whether marine or non-marine, are useful for paleodepositional analysis because they are generally benthic and reflect bottom conditions (Scott and Medioli, 1983). Prior to this study, these rocks were thought to have been formed in a freshwater environment. The discovery of marine foraminiferal genera in association with thecamoebian genera indicate that the strata were laid down in a transitional or marginal marine setting, possibly during a marine transgression. In the context of this thesis, the "marginal marine" environment is defined as the area that encompasses most coastal regions influenced by tidal activity; it can be brackish or hypersaline and includes beaches, salt marshes, deltas, and estuaries as the main components. Stea *et al.* (1996) broadly reinterpreted the paleodepositional environment of these Cretaceous deposits as being fluvial/deltaic/estuarine. All 3 of these environments ("fluvial/deltaic/estuarine") are components of a transitional or marginal marine setting. Other supportive lines of evidence for a marginal marine interpretation include the pyritisation of foraminifera, and the large amount of sedimentary pyrite found in the cores studied.

The discovery of agglutinated marine foraminifera in association with freshwater thecamoebians in two sedimentary rock cores from central N. S. raises serious doubts concerning the earlier freshwater interpretation. Five different rhizopod assemblages have been documented. They include; Assemblage A, *Ammotium* sp., *Trochammina* sp. and *Difflugia sp.*; Assemblage B, *Ammotium sp.*, C*entropyxis aculeata* and *Difflugia sp.; Assemblage C, Ammotium* sp., and *Trochammina* sp.; Assemblage D, *Ammotium* sp., *Trochammina* sp. *Miliammina sp.*, and

Difflugia sp. ; and Assemblage E which contains only *Trochammina* sp. Fossil fish vertebrae and pyritised foraminifera were also discovered.

Comparison of the early Cretaceous rhizopod assemblages found in central N.S. with assemblages in modern marginal marine environments, such as salt marshes, reveals a strong similarity. Rhizopods generally occur at relatively high densities. Modern marginal marine environments commonly have mixed assemblages of thecamoebians and foraminifera (Scott et al., 1980). On shelf or upper slope regions agglutinated genera are generally overshadowed by marine calcareous genera, whereas, freshwater environments are dominated by thecamoebian genera. In contrast, the agglutinated forms are capable of withstanding extreme conditions that exist in transitional zones which exclude most genera (Haynes, 1981). Those that can exist there seem to have near-worldwide distribution (Scott and Medioli, 1978). Four of the 5 Cretaceous assemblages contain mixed assemblages of brackish or freshwater thecamoebians and marine foraminifera.

The high density of rhizopods is an important characteristic of modern marsh sediments. The Nova Scotian Cretaceous specimens which occurred in well preserved samples were highly abundant.

The majority of samples, which contained rhizopod assemblages in the SHUB94-5 and SHUB95-3 cores, were deposits rich in lignite fragments and had varying shades of dark grey to black. The black or dark grey colour in these sediments suggest conditions of low oxygen concentrations during deposition and burial. Low oxygen conditions occur in saltmarshes due to heavy demand for available oxygen by decomposing bacteria (Boaden and Seed, 1985).

The pyritised foraminifera in the samples from the basal sections of the SHUB94-5 and SHUB95-3 cores, in addition to the large amounts of pyrite (up to 20% in some samples), could be supporting evidence for a paleodepositional environment rich in sulphate and organic carbon. In particular, there were casts of pyrite in the shape of *Trochammina sp.* It is clear that the foraminifera have been replaced by pyrite. In marine sediments pyrite formation is controlled by organic matter and is high when dissolved sulphate and iron minerals are abundant (Berner, 1984). Berner (1984) indicated that the presence of large quantities of sedimentary pyrite could be useful in determining paleodepositional environment.

Raiswell *et al.* (1983) proposed that pyritisation of fossil material, which is composed of low reactive organic matter, requires unusually high dissolved iron concentrations in porewater. Under sufficient exposure times to this groundwater, even the most refractory iron silicates become pyritised (Raiswell *et al.*, (1983). This theory might explain the poor preservation of rhizopods in the Shubenacadie cores and the alteration of the fish fossils.

6.2 Summary

The rhizopod assemblages documented in this thesis originated from the basal units below 140 m and 90 m below surface, in the SHUB94-5 core and the SHUB95-3 core, respectively. The marine foraminifera assemblages in these basal sections of both cores indicate the presence of a marine transgression in the Shubenacadie area during the early Cretaceous. The shift from abundant foraminifera to the barren units in both cores may reflect a regression with a fluvial progradation. At present, it is difficult to restrict the environment further, except to say that it is a the marginal marine depositional package with possible saltmarsh layers interspersed suggesting a dominance of shallow intertidal type conditions in the basal section of the SHUB94-5 and SHUB95-3 cores.

In summary, the interpretation of an entirely freshwater paleodepositional environment for the early Cretaceous sedimentary rocks in Shubenacadie does not explain the presence of marginal marine rhizopods in the area. Several lines of evidence that support marginal marine conditions include: the rhizopod assemblages; pyritised foraminifera; and the abundant sedimentary pyrite.

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MICROPROBE OF PYRITE CASTS OF FORAMS

*=NOICE

SAMPLE: 94-NS-SHUB 5 2646-2648 #1a

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC%
Fe	45.824	.295	33.176
S	52.740	.168	66.516
As	0.372	.114	.201
Au	0.523	.240*	.107
TOTAL	99.459		100

SAMPLE: 94-NS-SHUB 5 2646-2648 #1b

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	45.399	.294	33.083
S	52.435	.168	66.564
Mn	.262	.076	.194
As	.294	.114*	.160
TOTAL	98.389		100

SAMPLE: 94-NS-SHUB 5 2646-2648 #2a

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	46.290	.296	33.448
S	52.241	.168	65.757
Au	.572	.240*	.117
As	.348	.115	.188
Si	.150	.038*	.216
Cr	.124	.059	.096
Al	.119	.039	.178
TOTAL	99.845		100

SAMPLE: 94-NS -SHUB 5 2646-2648 #2b

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	46.155	.295	33.798
S	51.765	.167	66.035
As	.305	.114*	.166
TOTAL	98.225		100

SAMPLE: 94-NS-SHUB 5 2646-2648 #3a

ELEMENT	*% ELEMENT*	*ST. DEVIATION*	*ATOMIC %*
Fe	*45.521*	*.294*	*33.368*
S	*51.926*	*.167*	*66.308*
Au	*.646*	*.238**	*.134*
As	*.346*	*.113*	*.189*
TOTAL	*98.439*		*100*

SAMPLE: 94-NS-SHUB 5 2646-2648 #3b

ELEMENT	*% ELEMENT*	*ST. DEVIATION*	*ATOMIC %*
Fe	*45.491*	*.294*	*33.569*
S	*51.577*	*.167*	*66.304*
As	*.231*	*.112**	*.127*
TOTAL	*97.299*		*100*

SAMPLE: 94-NS-SHUB 5 2646-2648 #4a

ELEMENT	*% ELEMENT*	*ST. DEVIATION*	*ATOMIC %*
Fe	*45.071*	*.292*	*33.234*
S	*51.385*	*.166*	*66.006*
As	*.310*	*.116**	*.171*
Al	*.200*	*.040*	*.305*
Si	*.194*	*.038*	*.285*
TOTAL	*97.160*		*100*

SAMPLE: 94- NS-SHUB-5 2646-2648

ELEMENT	*% ELEMENT*	*ST. DEVIATION*	*ATOMIC %*
Fe	*38.721*	*.274*	*30.431*
S	*43.663*	*.159*	*59.777*
Si	*5.852*	*.059*	*9.145*
Ca	*.294*	*.042*	*.321*
Al	*.200*	*.040*	*.326*
TOTAL	*88.731*		*100*

CORE 95-NS-SHUB-3

SAMPLE: 95-NS-SHUB-3 97.5+1.35-1.37 #1a

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	46.618	.299	32.969
S	54.163	.170	66.729
Mn	.248	.076	.178
As	.234	.110	.123
TOTAL	101.263		100

SAMPLE: 95-NS-SHUB-3 97.5 +1.35-1.37 #1b

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	46.082	.298	34.560
S	49.833	.164	65.105
Si	.141	.036	.210
As	.225	.105*	.126
TOTAL	96.281		100

SAMPLE:95-NS-SHUB-3 97.5 + 1.35-1.37 #2a

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	47.054	.299	33.075
S	54.401	.170	66.616
Mn	.433	.078	.309
TOTAL	101.887		100

SAMPLE: 95-NS-SHUB-3 97.5 + 1.35-1.37 #2b

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
. Fe	46.959	.300	33.248
S	53.976	.170	66.574
As	.336	.112*	.178
TOTAL	101.272		100

SAMPLE: 95-NS-SHUB-3 97.5 + 1.35-1.37 #3a

ELEMENT	% ELEMENT	ST. DEVIATION	ATOMIC %
Fe	47.359	.301	33.487
S	53.880	.170	66.369
As	.274	.111*	.144
TOTAL	101.513		100