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See table of contents

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Mid-Tertiary Stratigraphy of the Continental Slope off Nova Scotia*

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Introduction

Planktonic Foraminifera of Oligocene-Miocene age have been obtained from dredge hauls and cores in submarine canyons and ledges that occur along the continental slope off Nova Scotia (Fig. 1). The stratigraphic section with its mid-Tertiary microfauna was first reported by Bartlett (1967). Bartlett (1968) also discussed some of the characteristic species of planktonic Foraminifera in detail. To date, samples of consolidated Tertiary sediment containing planktonic Foraminifera have been collected in depths as great as 2200 metres along the continental slope.

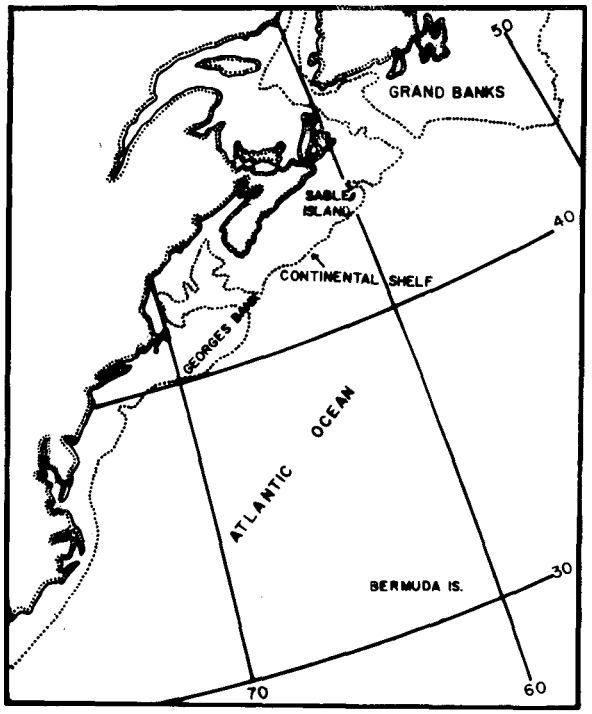

Fig. 1 Location map of Study area. Dotted line indicates outer limit of continental shelf with depth of approximately 187 metres.

Sparker profiles along the sides of the Slope show that persistent, gently-dipping reflecting horizons are present in the subsurface. Continuous reflectors are present at 450, 550, and 650 metres below sea level. Discontinuous reflectors occur in various canyons at lesser depths and appear to represent sturctures within poorly-consolidated or unconsolidated deposits of probable Pleistocene age. Sparker surveys have thus far been unsuccessful in depths greater than 500-600 metres, probably because of the steepness and ruggedness of the canyons below that depth range. The present sparker information, however, suggests that the shelf and sides of the slope are underlain by rock formations which have acoustical discontinuities at vertical spacings comparable to the spacings of topographic ledges and at similar elevations.

The stratigraphic section examined to date extends from the Globigerina opima opima zone to at least the top of the Globorotalia mayeri zone. The major portion of the section extends from the Catapsydrax dissimilis zone through the Globorotalia fohsi sensu lato zone. Eocene and Cretaceous sediments have also been collected as erratics in a few dredge hauls. Particular boundaries cannot be established because of the nature of the samples. Both planktonic and benthonic assemblages are comparable to those described from Trinidad and Venezuela, in particular, and the Caribbean area in general. The similarity of these assemblages with those in the Caribbean area suggests the presence of a proto-Gulf Stream and a warm climatic belt extending from the Caribbean to at least southern Newfoundland (North latitude 46°00') during Oligocene-Miocene time.

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Previous Work

The first of a series of investigations concerning the geological structure of the continental slope was carried out in 1964 by the Geological Survey of Canada and the Bedford Institute. Subsequent investigations by J. I. Marlowe in 1965 and 1966 were centered on the Gully, a large submarine canyon on the continental slope off Nova Scotia. The writer joined Marlowe in 1966 on "CSS HUDSON" and obtained sediment samples which were determined to be of mid to late Tertiary age on the basis of the constituent fauna. Extensive investigations in the general slope area were also conducted by the writer in 1967.

Foraminifera

Benthonics

The mid-Tertiary fauna is composed of diverse benthonic assemblages having predominantly calcareous-hyaline tests. Arenaceous forms are subordinate. The benthonic assemblage consists of 36 genera and 94 species representing the Lenticulina wallacei, Siphogenerina transversa and Marginulinopis basispinosis zones.

The benthonic fauna is comparable to those described from the Agua Salada Group-Venezuela (Renz 1948), the Ecphora, Yoldia and Arca facies of the Choctawhatchee Stage, Florida Panhandle (Puri 1953), the Mio-Oligocene from the Goajira Peninsula, Colombia (Becker & Dusenbury, 1958) the Miocene Foraminifera of the Coastal Plain of the Eastern United States (Cushman & Cahill 1932) and those reported from "The Gully" (Bartlett 1967).

Most samples containing rich benthonic foraminiferal assemblages have diagnostic Miocene Ostracodes. Samples with scattered planktonic and sparse arenaceous benthonic assemblages are characterized by abundant radiolarians and diatoms. These samples also contain abundant fibrous material, and, consequently recognition of minute foraminiferal tests is difficult.

Planktonics

The planktonic population is composed of seven genera and 28 species. Globigerinoides trilobus (s. l.), Globigerinoides bisphericus, Globoquadrina dehiscens dehiscens, Globoquadrina venezuelana, Globorotalia fohsi praefohsi , Globorotalia fohsi peripheroronda, Globorotalia fohsi fohsi, Globorotalia menardii praemenardii and Globigerinatella insueta are dominant planktonic forms (Plates 1, 2, 3). Well defined foraminiferal zones per se cannot be established along the continental slope at present (see Fig. 2). However, precise knowledge of the vertical position of particular samples and the constituent fauna permits a tentative relationship of Scotian Slope faunas with world wide zones. The planktonic fauna best represents the Globigerina ciperoensis ciperoensis - Globorotalia mayeri zones as described by Bolli (1957, 1967). The assemblages are comparable to, and within the Globigerinatella insueta - Globigerinoides trilobus trilobus to the Globorotalia mayeri zones in Venezuela (Blow 1959), and the assemblages described from Brazil (Closs 1967). It is obvious that the planktonic faunas have close affinities to those described from the West Indian region. Their recent counterparts inhabit these waters at the present time.

Comparable assemblages have also been described from Australia (Jenkins 1960), Honshu, Japan (Saito 1963), Mediterranean (Drooger 1960), East Africa (Eames et al 1962), Aquitaine (Jenkins 1966), British Solomons (McTavish 1966) and Egypt (Said and El-Heiny 1967). The Scotian Shelf and Slope Tertiary faunas correspond to the Globigerina woodi to the Globigerina menardii miotumida zone in Australia, the Globigerinita unicava to within the Globorotalia bykovae zones in Japan, and the Globorotalia kugleri to the top of the Globoquadrina altispira zone as defined in the British Solomons. The Globorotalia kugleri - Globoquadrina altispira globosa to the Globorotalia fohsi fohsi zones in Egypt are probably comparable to our present sections. The comparable East African section extends from the G. ampliapertura to the G. cultrata s. s./G. nepenthes zone.

Faunal Succession

The faunal succession is determined with difficulty because of the nature of the samples. Materials examined were obtained from dredge hauls and short sections in cores. First appearances, maximum abundances and faunal extinctions cannot be determined from the present

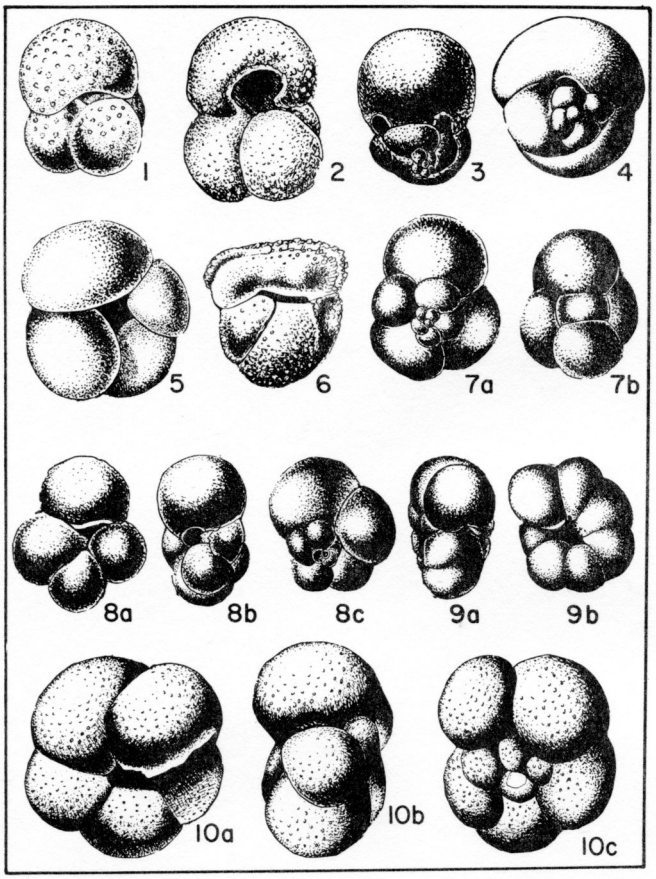

PLATE 1

1. Globigerinoides Trilobus immaturus LeRoy, umbilical view, X100.

2. Globigerinoides Trilobus altiaperturus Bolli, umbilical view, X100.

3. Globigerinoides trilobus trilobus (Reuss), spiral view, X100.

4. Globigerinoides bispherious Todd, spiral view, X75.

5. Globoquadrina venezuelana (Hedberg), ventral view, X75.

6. Globoquadrina dehiscens dehiscens (Chapman, Parr, Collins) ventral view X75.

7a,b. Catapsydrax dissimilis (Cushman & Bermudez), 7a spiral view, 7b ventral view, X100.

8a,b,c. Globigerina ciperoensis angustiumbilicatula Bolli, 8a ventral view, 8b apertural view, 8c spiral view, X200.

9a,b. Globorotalia kugleri Bolli, 9a apertural view, 9b ventral view, X150.

10a,b,c. Globorotalia opima opima Bolli, 10a ventral view, 10b apertural view, 10c dorsal view; X100.

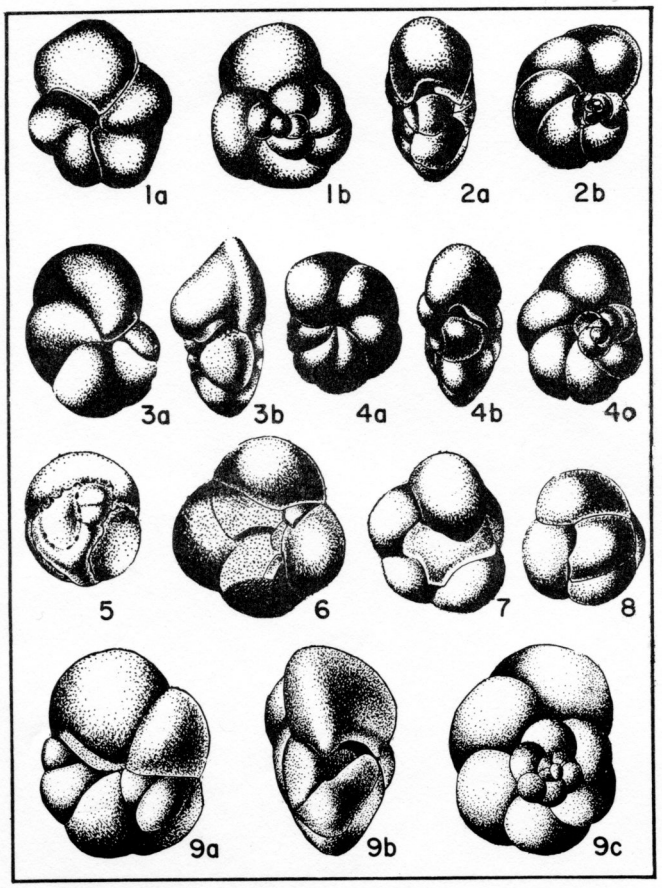

PLATE 2

1a,b. Globorotalia fohsi praefohsi Blow and Banner, 2a,b.
1a ventral view, 1b dorsal view, 2a axial-apertural 2b dorsal view, X100.

3a,b. Globorotalia fohsi fohsi Cushman and Ellisor 3a ventral view, 3b axial-apertural, X100.

4a,b,c. Globorotalia fohsi peripheroronda Blow and Banner, 4a ventral view, 4b axial-apertural, 4c dorsal view, X100.

5. Globigerinatella insueta Cushman and Stainforth, 5 ventral view, X100.

6. Globigerinita naparimaensis Bronnimann, 6 ventral view X200.

7. Catapsydrax stainforthi Bolli, Loeblich and Tappan, 7 ventral view, X150.

8. Catapsydrax dissimilis (Cushman and Bermudez) 8 ventral view, X100.

9a,b,c, Globorotalia fohsi peripheroronda Blow and Banner, 9a ventral view, 9b apertural view, 9c dorsal view, X150.

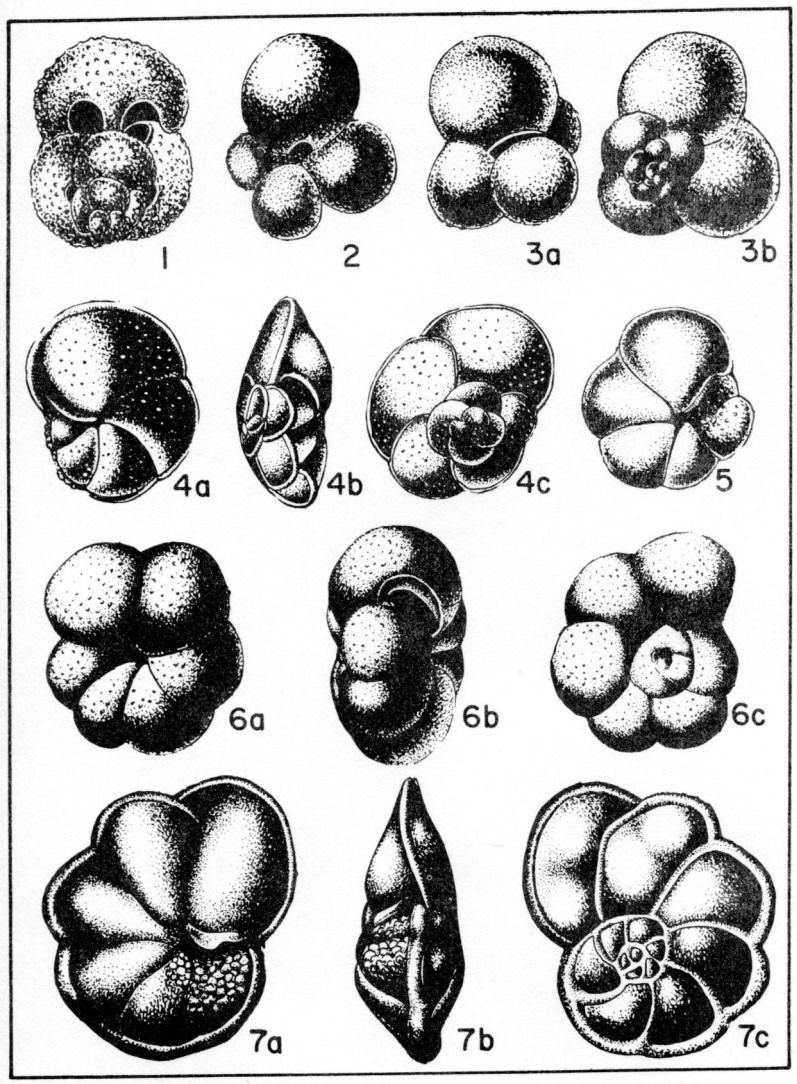

PLATE 3

1. *Globigerinoides ruber* (d'Orbigny) 1. spiral view, X100.

2. Globigerina foliata Bolli, 2 ventral view X100.

3a,b. Globigerina juvenilis Bolli, 3a ventral view, 3b dorsal view, X300.

4a,b,c. Globorotalia archeomenardii Bolli, 4a ventral view, 4b axial-apertural view, 4c dorsal view, X100.

5. Globorotalia menardii praemendardii Cushman and Stainforth, 5 ventral view, X75.

6a,b,c. Globorotalia mayeri Cushman and Ellisor, *6a ventral view, 6b axial-apertural view,* 6c dorsal view, X100.

7a,b,c. Globorotalia fohsi lobata Bermudez, *7a ventral view, 7b axial-apertural view,* 7c dorsal view, X100.

collections. However, sufficient material permits at least partial correlation with well established sections (Fig. 2) such as those described from Trinidad and Venezuela by Bolli (1957), Blow (1959), and Blow and Banner (1966) and with East Africa, (Eames et al 1962).

If one follows Bolli (1957), Eames et al (1962), Berggren (1963), Hofker (1963) and Jenkins (1966), the presence of Globigerina ciperoensis angustiumbilicatula in the slope sediments is indicative of rocks of Oligocene age. Placing the Oligocene-Miocene boundary between the G. opima opima and G. ciperoensis ciperoensis or the Globorotalia kugleri - Catapsydrax dissimilis zones is beyond the scope of the present investigation. Forms resembling G. opima opima and G. ciperoensis ciperoensis have been collected from the same sample.

The appearance of typical specimens of Globigerinoides trilobus altiaperturus with Globorotalia fohsi peripheroronda is indicative of a Lower Burdigalion age. Jenkins (1966) tentatively places the Aquitainian-Burdigalian boundary between the Globorotalia kugleri and Catapsydrax dissimilis zones as defined by Bolli (1967). The association of Globigerinatella insueta and Siphogenerina transversa in the present collections denotes the upper portion of the G. insueta zone. Globigerinoides trilobus (s.l.) and G. bisphericus are dominant forms in the lower part of this zone. Similarly, the association of Globorotalia menardii miotumida, Marginulinopsis basispinosis, and Globorotalia mayeri denotes the upper part of the Globorotalia mayeri zone. Therefore, planktonic assemblages and planktonic - benthonic associations suggest the presence of sediments along the continental slope of at least Chattian to Tortonian age. Recent seismic and core data suggests that a Tertiary-Mesozoic section of 12, 000' - 15, 000' underlies the entire Scotian Shelf, Slope and the Grand Banks area. This material is presently under investigation.

Orbulina universa has not been identified in the present assemblages. This implies that sediments containing this species have not been collected, or that they appeared later (Tortonian) in our region. The presence of Porticulasphera glomerosa glomerosa and well developed Globorotalia fohsi peripheroronoda through Globorotalia fohsi (s.l.) suggests that Orbulina universa is stratigraphically above the horizons collected to date. Furthermore, the dominance of Globigerinoides trilobus (s.l.) and Globigerinoides bisphericus forms in the present collections also indicates [Blow (1956, 1959), Bolli (1957), Findlay (1947), Hornibrook (1958), Jenkins (1958, 1960)] that Orbulina universa lies above this rapidly evolving series.

Paleoecology

The interpretation of depositional environments for the Tertiary off Nova Scotia is based on comparisons with the distribution of Recent assemblages of Foraminifera and encompassing sediment characteristics. Many of the species are still living in the warmer parts of the Atlantic or in West Indian waters. Comparable assemblages are not living in Recent Scotian Shelf-Slope waters.

Consolidated sediments thus far sampled from the Scotian Shelf and Slope consist of siltstone and claystone with minor occurrences of glauconitic and quartzose sandstone. The Oligocene-Miocene section as presented here appears to be composed predominantly of firm, compact clay and siltstone with well-defined, laminar bedding structures. Mica, chlorite and fibrous fragments, plant remains, with concentrated spore and pollen grains are abundant in most samples. The sediment is gray to brown in color and some samples give off an odor of hydrocarbons when disaggregated. Delicate shards of brown glass occur abundantly in the upper part of the section. This zone of shards may later prove to be of considerable significance in the interpretation of regional geological history. Mineral assemblages are immature and do not have the compositional aspect of later glacio-fluvial sediment common in the shelf at the present time.

The benthonic foraminiferal assemblage is composed essentially of forms belonging to the Nodosariidae, Bolivinitidae, Buliminidae, Cibicididae and Rotaliidae. These forms indicate deposition in the Outer Shelf - Upper Slope zones of Phleger (1939-1942) or depths of 200-500 metres (Phleger 1960). The presence of Quinqueloculina and Ammonia suggests that these forms were transported from shallower nearshore depths. The faunal composition is characteristic of Continental Shelf deposition.

It is apparent that most of our present collections lie within the typical Lenticulina wallacei and Siphogenerina transversa benthonic zones as described by Renz (1948). The sediments were laid down in a typically marine open sea environment at medium depths along the Continental Shelf, probably off a warm temperate to sub-tropical coast. There are indications that the fauna was accumulated in depths of 500 to 600 metres. Tertiary sediments landward from the Slope contain predominantly inner-neritic macro and micro faunas in association with prolific spore and pollen assemblages.

The absence or scarcity of calcareous Foraminifera and the presence of deep water (> 600 metres) arenaceous forms in association with prolific radiolarian and diatom assemblages indicate deposition of the constituent sediments at great depths. These sediments are difficult to correlate but occur below the Lenticulina wallacei zone. Globigerina ciperoensis angustiumbilicatula is extremely rare in these sediments.

The presence of Globigerinoides trilobus (s.l.), G. ruber, Globorotalia fohsi (s.l.), Globorotalia fohsi peripheroronda, Catapsydrax dissimilis and G. menardii praemenardii in Scotian Slope sediments is indicative of waters with West Indian characteristics. This situation requires a proto-Gulf Stream or a continuous West Indian connection off Nova Scotia during at least part of the Tertiary. The similarity of both planktonic and benthonic assemblages with those in Trinidad, Venezuela, Colombia, and the Florida Panhandle favours a direct connection. It is plausible that relatively uniform climatic conditions extended from the Caribbean to the Newfoundland Banks (46°00'N) during mid-Tertiary time.

Cool-temperate to boreal planktonics (various species of Globigerina) are subordinate or absent in early and mid-Tertiary sediments but become more prolific and finally dominate through much of the late Tertiary and Pleistocene. Specimens of Globorotalia are dominantly right coiling on the Scotian Shelf and Slope in Miocene sediments and thus support a warmer-

water hypothesis. Consequently, our study indicates that the planktonic faunal boundary , the Globorotalia line (Bandy 1960, 1964, 1966) separating diverse planktonic globorotalids and globigerinids on the south from less diverse globigerinids on the north must be extended to at least 46°00'N. The work of Wiseman and Ovey (1950), Bé (1959, 1960), Bé and Hamlin (1967), Bradshaw (1959), Parker (1960, 1962) and others on the distribution of Recent planktonic Foraminifera has shown that most species are distributed in latitudinal zones. The question arises as to whether similar distribution patterns were in existence during the mid-Tertiary. Planktonic Foraminifera probably had broad patterns of geographic distribution during the mid-Tertiary, however, the latitudinal belts postulated by other workers e. g. (Bandy 1966, Jenkins 1965) were much broader than previously realized.

Fine-grained sediment textures, laminated bedding, plant fragments, and a shelf-depth benthonic fauna all suggest that deposition of Tertiary sediments on the Scotian Slope occurred in a low-energy, outer-shelf environment. Mesozoic and Tertiary sediments collected on the Scotian Shelf represent deposition in the inner neritic zone. The occurrence of a section of these deposits several hundred metres in thickness implies that deposition took place in a subsiding basin. Therefore, there is considerable evidence that a large basin of subsidence may exist along the continental shelf off Nova Scotia. There is also ample indication that the sediments filling this basin are marine in origin and as old as Cretaceous. Furthermore, faunal evidence implies that the sediments underlying the Continental Shelf off Nova Scotia and Newfoundland are a continuation of the Gulf Coast and Atlantic Coastal Plain physiographic province.

Summary

Planktonic and benthonic foraminiferal assemblages in Scotian Slope mid-Tertiary sediments are comparable to those described from Trinidad, Venezuela and Brazil, in particular, and the Caribbean area in general. The similarity of these assemblages with those in the Caribbean area suggests the presence of a warm-water connection and a warm climatic belt extending from the Caribbean to at least southern Newfoundland (North latitude 46 degrees) during mid-Tertiary time. Paleontological, sedimentological and structural evidence implies that the Continental Shelf off Nova Scotia is a continuation of the Gulf Coast and Atlantic Coastal Plain physiographic province.

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