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SURFICIAL GEOLOGY OF THE YARMOUTH-BROWNS BANK MAP-AREA

Georges Drapeau and Lewis H. King

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INTRODUCTION

This report accompanies Chart 4039-G: Surficial Geology of the Yarmouth-Browns Bank Map-Area. It describes the surficial geology of the western part of the Scotian Shelf, from Halifax to Yarmouth. The area described in this report is adjacent to the Halifax-Sable Island map-area (Chart 4040-G) for which King (1970) gave an account of the physiography, the surficial geology, and a brief description of the underlying bedrock geology. The description of the geology provided by King for the Halifax-Sable Island area holds for the whole of the Scotian Shelf and serves as a basic framework for the mapping of the Yarmouth-Browns Bank sheet.

Grateful acknowledgement is made to the Canadian Hydrographic Service for making the echograms available for study, to the ship's company of the CSS KAPUSKASING for co-operation at sea, to B. MacLean for assistance in carring out the program, and to V.F. Coady and D. Clattenburg for technical assistance. The manuscript was critically reviewed by B.R. Pelletier, B. MacLean and D.H. Loring. The map constitutes part of Drapeau's doctorate thesis at Dalhousie University (Drapeau, 1971).

PHYSIOGRAPHY

The Scotian Shelf may be divided into three physiographic zones: an inner zone characterized by a rough topography; a central zone comprising broad depressions that roughly parallel the margin of the inner shelf; and an outer zone consisting of a series of wide, flat banks. The criteria for such a division are apparent on bathymetric charts, particularly on the Canadian Hydrographic Service Chart 801.

The inner shelf is the area that borders Nova Scotia and extends from the shore to a depth of 60 fathoms (110 metres). This region has a uniform width of 15 miles (25 km). The rough topography of the inner shelf bears many similarities to that of the adjacent land area mainly because it is underlain by the same bedrock formations, and has had a similar geological history including periods of subaerial and glacial erosion.

The central shelf covers approximately one third of the map-area. Its prominent physiographic features are the two basins, La Have and Roseway, which are separated by Roseway Bank. The eastern end of the central shelf, in the area of La Have Basin, is approximately 35 miles wide (65 km), whereas at the western end, its width has decreased to 10 miles (18 km). La Have Basin is the largest basin of the map-area, and has an area of 700 square miles (2400 sq. km). The main body of La Have Basin lies between the inner shelf to the north and Sambro Bank to the east. La Have Bank divides the southern part of the basin into a southwest arm which runs more or less parallel to the shelf, and a southeast arm which extends across the shelf in a transverse direction. The floor of the basin is very smooth and reaches a maximum depth of 147 fathoms (269 m). Roseway Basin lies 30 miles (55 km) to the west of La Have Basin. It is separated into a northern and a southern half by the Roseway Basin moraine which forms a ridge on the seafloor. The northern and the southern basins have respective depths of 100 and 90 fathoms (183 and 165 m) and both are approximately 20 miles (37 km) in diameter. Roseway Bank is an isolated low relief feature at the edge of the inner shelf, and separates La Have and Roseway Basins. It is approximately 17 miles (31 km) in diameter and it has a minimum depth of 29 fathoms (53 m).

The outer shelf is an area of high relief which runs parallel with the shelf edge. Within the map-area the outer shelf is composed of two broad more or less flat-top banks that are separated by a shallow depression or saddle which extends from La Have Basin to the edge of the continental shelf. La Have Bank has a somewhat elliptic form, the long axis of which is oriented north-south and is 35 miles (60 km) in length. The bank has an average depth of 45 to 50 fathoms (82 to 91 m). Browns and Baccaro Banks combine to form a flat L-shaped feature that occupies the southwestern corner of the Scotian Shelf for a distance of 70 miles (130 km) along the edge of the shelf. Water depths are very shallow along the northwestern edge of Browns Bank and at one point the Bank is only 16 fathoms deep (29 m).

MAPPING METHODS

The methods of survey used to compile this map are the same as those developed by King (1967a, b, 1970) for mapping the sediments of the Halifax-Sable Island map-area, and were used later by MacLean and King (1972) for the Banquereau and Misaine Bank map-area. Echograms

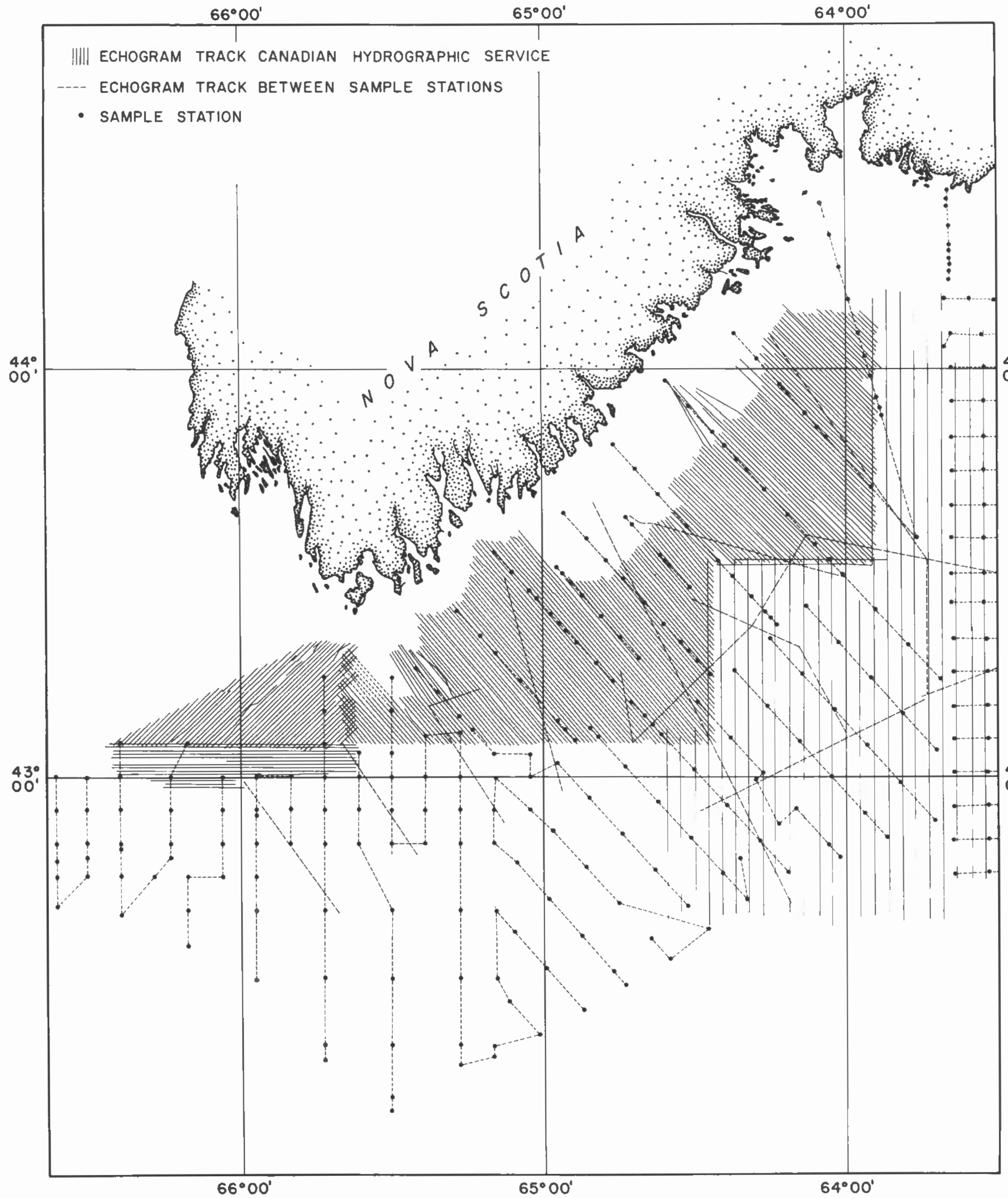

Figure 1. The acoustical and bottom-sampling control across the Yarmouth-Browns Bank Map-area.

TABLE OF FORMATIONS

Era	Period or epoch	Map-unit	Lithology	Thickness, metres
CENOZOIC	Quaternary	Sable Island sand and gravel (8)	Buff to greyish brown, medium to coarse-grained, very well-sorted sand, grading laterally to coarse, sub-rounded, glacial lag gravels; basal transgressive unit.	0-15 (generally thin)
		Time equivalent of map-unit 7.		
		LaHave clay (7)	Very dark greyish brown, loosely-compacted silty clay grading locally to clayey silt	0-20
		May in part be a time equivalent of the upper portions of map-units 5 and 6; mostly younger.		
		Sambro sand (6)	Dark greyish brown, medium- to fine-grained, moderately to well-sorted, sub-littoral sand, grading to sandy gravel or modified till; mainly proglacial.	0-20 (generally a thin veneer)
		Time equivalent of map-unit 5.		
		Emerald silt (5)	Very dark greyish brown, poorly-sorted clayey and sandy silt, some gravel; proglacial.	0-60
		In part a time equivalent of the late drift (map-unit 4): otherwise younger.		
		Scotian Shelf drift (4)	Very dark greyish brown, cohesive, sandy till in ground and end moraines; may include some stratified drift.	0-90
	Disconformity			
	Tertiary	(3)	Semi-compacted bedrock; continuous seismic-reflection profiles suggest poorly-defined bedding and some cross-bedding; prograding at the continental margin.	–
Angular unconformity				
MESOZOIC	Cretaceous	(2)	Semi-compacted to well-compacted bedrock; continuous seismic reflection profiles suggest regular, well-defined bedding and prograding at the continental margin; one dredged sample consisted of buff to light olive grey, sideritic quartz sandstone and arenaceous sideritic carbonate, both in part glauconitic.	–
Angular unconformity				
PALEOZOIC	Cambrian to Devonian	(1)	Undifferentiated basement, probably comprising folded Cambrian and Ordovician quartzite and slate, cut by Devonian granite.	–

obtained by the Canadian Hydrographic Service for charting purposes together with data from bottom samples were systematically used to identify the nature of the bottom sediment as well as to outline the morphology of the sea floor. This approach permitted the production of more precise and detailed maps than would have been possible with mapping methods based only on bottom sample data. Echogram coverage in the surveys undertaken by the Canadian Hydrographic Service is shown in Figure 1. The northern part of the map-area was surveyed along lines spaced at intervals of one-half mile, and situated perpendicular to the major morphological trends. In the southern part, the survey tracks were spaced at two-mile intervals. A geological interpretation of these echograms was compiled on a preliminary map. The area was then surveyed aboard CSS KAPUSKASING in 1967 to obtain additional echograms, bottom samples and continuous seismic-reflection profiles on which to base the final geological interpretation of the area.

BEDROCK GEOLOGY

King (1970) provided evidence to divide the bedrock underlying the Scotian Shelf into three map-units: A)

Map-unit 1: a Paleozoic basement composed of deformed metasediments and granitic batholiths; B) Map-unit 2: a well stratified sequence of sedimentary rocks of Mesozoic age; and C) Map-unit 3: wedges of Cenozoic strata (see cross section in lower left corner of accompanying map).

Map-unit 1: This unit comprises the deformed Cambro-Ordovician metasediments of the Meguma Group and the Devonian granites that outcrop along the seashore between Halifax and Yarmouth. These rocks form an eroded Paleozoic basement that extends for some 25 miles offshore beyond which point it is unconformably overlain by strata of Cretaceous age.

Map-unit 2: This unit comprises rocks of Mesozoic age. Continuous seismic profiles reveal that these rocks occur as a sequence of well-bedded strata that overlie the Paleozoic basement described above. These strata dip very gently to the southeast across much of the Scotian Shelf. The upper limit of map-unit 2 is marked by a well-defined erosional surface.

Map-unit 3: This unit is composed of Tertiary (?) strata, and its recognition within the map-area is based on the interpretation of continuous seismic-reflection data. It comprises the sediments overlying the Cretaceous strata and underlying recognizable Quaternary deposits. The map-unit is characterized on the seismic records by poorly-defined bedding, some cross-bedding, and prograding near the edge of the continental shelf. If the age interpretation of this map-unit is correct, then Tertiary strata unconformably overlie the Mesozoic sequence on the central part of the shelf.

SURFICIAL GEOLOGY

The surficial geology map-units within the Yarmouth-Browns Bank map-area are similar to those described by King (1970) for the Halifax-Sable Island map-area. The sedimentary processes and source areas, as well as the sequence of events that controlled the sedimentation of the surficial sediments, are the same in the two map-areas and consequently the surficial sediments are similar.

The sedimentological history of the unconsolidated sediments of the Scotian Shelf is intimately related to a lower standstill of the sea, at a depth of 63 fathoms (115 m), which took place some 15,000 (Milliman and Emery, 1968) to 19,000 years ago (Curray, 1960). To understand the distribution of sediments on the continental shelf, reference must not be made to the present height of sea level but rather to the lower ancient stand (15,000-19,000 B.P.). At that time, large areas of the shelf were above sea level and consequently exposed to subaerial conditions. The silts and clays now trapped in the deeper basins were ultimately derived from those areas through the action of glacial, fluvial, and marine processes.

The lower standstill of the sea at a depth of 63 fathoms (115 m) was first recognized from surf-cut terraces observed on echograms obtained south of Halifax in the Halifax-Sable Island map-area. Grain-size distributions of the samples obtained from these terraces compare closely with those obtained from present beach sands. Similar beach-type sediments are found at the depth of 63 fathoms (115 m), even in cases where terraces are apparently absent. Terraces generally are not evident on echogram profiles across the Yarmouth-Browns Bank map-area though in many cases a slight change in slope occurs at the 63-fathom (115 m) isobath.

Of particular interest is the presence of an end-moraine system deposited along the Scotian Shelf (King, 1969). The moraine was directly related to the low stand of the sea at 63 fathoms and was laid down as a submarine deposit. If the moraine had been formed above sea level, it would have been destroyed while the sea transgressed from its low stand at a depth of 63 fathoms (115 m) to its present level. Other moraines probably were formed at other elevations and at other times during the Pleistocene Period, but were destroyed by subsequent glaciations or transgressions and regressions of the sea. The mapping of the terminal moraines on the Scotian Shelf is based mainly on their morphological configuration as determined from echograms and confirmed through analysis of continuous seismic-reflection profiles and bottom samples.

The name *Scotian Shelf drift* (map-unit 4) was introduced informally (King, 1970) to describe the unit which includes the morainic material deposited by glaciers as they extended over the continental shelf during the Pleistocene Period. It is a very dark greyish brown, cohesive, poorly-sorted sediment generally containing angular fragments in the pebble, cobble, and boulder range. The unit is dominantly sandy but everywhere contains abundant silt and clay. The gravel fraction of the till was derived from the bedrock exposed in southwestern Nova Scotia and consists mainly of quartzite and slate from the Meguma Group and granite from the Devonian granitic stocks and batholiths.

On the central shelf, the Scotian Shelf drift occurs as a blanket deposit of glacial drift and as a series of end moraines. These moraines occur at depths in excess of 63 fathoms (115 m), for the reasons given above, and reach a maximum depth within the map-area of approximately 130 fathoms. The principal moraines in the Yarmouth-Browns Bank map-area are the Pennant Point and the South Shore moraines. They are well developed features on the northern side of La Have Basin and merge into one large unit along the eastern flank of Roseway Bank. The La Have Basin moraine consists of two lobes in La Have Basin, one of which terminates against Sambro Bank at the eastern side of the basin, and the other lies to the north of La Have

Bank. The Roseway Basin moraine, about 35 miles (65 km) south of Lockeport, forms a ridge which divides Roseway Basin into two sub-basins. It extends westward for a distance of 45 miles (84 km) where it may join with the Fundian Moraine.

On the outer shelf, the Scotian Shelf drift also appears on the continuous seismic profiles as partially filling irregularities on the Tertiary bedrock surface along the bottom of the saddle that separates La Have Bank from Baccaro Bank. This filling is evident along the section D-E of the cross section shown on the map. It has not been established if a blanket of glacial till also underlies the shallower banks. If it had been deposited in these areas it probably would have been undercut and substantially reworked during the transgression of the sea.

The name *Emerald silt* (map-unit 5) was introduced informally (King, 1970) to identify a proglacial unit associated with the marine deposits. Emerald silt is a very dark, greyish-brown, fine-grained, muddy sediment which is generally silty and locally sandy. In the Yarmouth-Browns Bank map-area, the dominant constituent of the unit is silt. It contains less than 10 per cent sand and approximately 25 per cent clay in the eastern portion of the map-area. The proportion of sand increases westward. At the southern extremity of Roseway Basin , the sediments consist of well-sorted, dominantly fine sand, with small quantities of silt.

Continuous seismic profiles show that Emerald silt overlies and interfingers laterally with the Scotian Shelf drift. It is commonly exposed adjacent to the moraines. Because the Emerald silt consists mainly of fine-grained sediments, the most important accumulations are found in the basins where it is partly covered by the La Have clay (map-unit 7).

The boundary relations of the silt with the overlying clay are distinct because of the high degree of acoustical transparency exhibited by the clay. On the seismic profiles, stratification within the silt contrasts distinctly with the underlying drift which is generally devoid of orderly internal structure. The silt and till formations are also readily distinguished by the character of the bottom; a smooth, relatively soft bottom for the silt in constrast to a rough, undulating, somewhat harder bottom for the till.

The seismic profiles show that the Emerald silt has accumulated as a continuous layer in both La Have and Roseway Basins. This unit is almost completely overlain by La Have clay, and crops only as a rim around La Have Basin and the northern half of Roseway Basin. In contrast the Emerald silt in the southern half of Roseway Basin is exposed at the sea floor.

The name *Sambro sand* (map-unit 6) was introduced informally by King (1970) to identify a sublittoral deposit associated with the Pleistocene shoreline. It is believed to be a lateral equivalent of the Emerald silt, and underlies the Sable Island sand and gravel. Map-unit 6a is mainly a dark greyish brown, medium- to fine-grained, quite well-sorted sand. The presence of at least 5 to 10 per cent mud in the samples of this unit is highly significant and it is one of the criteria used to distinguish this unit from the Sable Island sand and gravel (map-unit 8). In some areas gravel becomes an important constituent in Sambro sand (map-unit 6b) and in such instances it is considered to represent a modified till.

The Sambro sand covers a very wide area east of La Have Bank where it extends as far as Emerald Bank in the Halifax-Sable Island map-area. The Sambro sand also occupies the floor of the saddle between La Have and Baccaro Bank. On the southeastern flank of Browns-Baccaro Bank this map-unit forms an 8-mile (15 km) wide band that narrows to a width of 2 miles (4 km) on the southwestern flank of Browns Bank. The Sambro sand also covers most of the area that lies between Browns-Baccaro Bank and the inner shelf. This area was initially occupied by tills that were later transformed to Sambro sand by the action of strong currents along the channel between the inner shelf and the then emerged Browns-Baccaro Bank. Consequently, the Sambro sand in that area is a gravelly sand that forms a thin surficial unit and retains the undulating surface of the original till material.

The name *La Have clay* (map-unit 7) was introduced informally by King (1970) to describe the fine-grained deposits that cover the floors of the basins and depressions on the Scotian Shelf. The unit overlies the Emerald silt and the Scotian Shelf drift, and is a lateral equivalent of the Sable Island sand and gravel. La Have clay is characterized on the echograms by a high degree of acoustical transparency and a smooth surface. The La Have clay is a very dark greyish brown, loosely-compacted, silty clay which locally grades to a clayey silt.

Sediments of this unit accumulated in the topographic depressions of the map-area, principally in La Have and Roseway Basins. The bottom of La Have Basin is almost completely covered with a deposit of La Have clay and the same is true for the northern half of Roseway Basin. However, the clay did not accumulate in the southern half of Roseway Basin. Most of the La Have clay was deposited during the transgression of the sea which followed the retreat of the Pleistocene ice sheet. At that time clay and silt were winnowed from glacial material on the higher banks and deposited in the basins.

The name *Sable Island sand and gravel* (map-unit 8) was introduced informally by King (1970) to describe transgressive basal deposits formed as the sea advanced across the bank areas. During the transgression of the sea the fines were winnowed from the banks and deposited in the adjacent basins. The sand fraction (map-unit 8a) was redistributed within the high energy environment leaving behind lag deposits of gravel (map-unit 8b). The Sable Island sand and gravel unit consists of clean, buff to greyish brown, medium- to coarse-grained, very well sorted sand grading laterally to very coarse gravel with boulders, and intergradations of these lithological types. On the basis of bottom samples, the unit is divided into two major groups: 8a, sand with less than 50 per cent gravel; and 8b, gravel with less than 50 per cent sand.

On the inner shelf, the gravel mode (map-unit 8b) dominates except for the area between Lockeport and Cape Sable where sand is (map-unit 8a) important and forms areas of smooth bottom. On the outer shelf, the whole of La Have Bank and half of Browns-Baccaro Bank are covered with gravel (map-unit 8b). Sand (map-unit 8a) covers the western and southern part of Browns Bank.

When the sheets of the map-areas covering the Scotian Shelf are juxtaposed it becomes apparent that the proportion of gravel increases to the west. Only small patches of gravel appear on Banquereau Bank and Sable Island Bank, but the percentage of gravel increases on Western and Emerald Banks. La Have Bank and most of Baccaro Bank are completely covered with gravel, and Browns Bank is covered with about 50 per cent gravel. The distribution of sand and gravel seems to bear some correlation with present water depths whereby sand accumulation is favored in shallower areas. A recent survey on Browns Bank from a submersible (Drapeau, 1970) has shown that sand waves and megaripples are formed on that bank. Observations *in situ*, as well as estimates of the wave energy in the area, indicate that transport of sand is active in the shallower region of Browns Bank. There is then a dynamic interaction between the sand on the outer banks and the hydrodynamics of that environment.

APPLICATIONS AND AID TO FISHERMEN

The surficial geology maps of the Scotian Shelf serve as a basis of further study in all fields of geology, as well as in many fields of oceanography and ocean engineering. The correlation between bottom roughness and the map-units in this area is similar to that for the Halifax-Sable Island map-area. It is repeated here for the convenience of the reader.

Mud bottoms are always flat and smooth and are represented on the chart by Emerald silt (map-unit 5) and the La Have (map-unit 7).

Sand bottoms are generally flat and smooth and these are represented by the sandy parts of the Sambro sand (map-unit 6a) and the Sable Island sand and gravel (map-unit 8a).

Gravel bottoms are rough but they can be either flat, or hummocky and jagged, and are represented mainly by the Sable Island sand and gravel (map-unit 8b). Rock fragments in the gravel vary in size from very fine gravel (pea-sized grains) to large boulders several feet in diameter. Gravel bottoms on the inner shelf are hummocky and jagged because of the underlying bedrock surface, but those on the central and outer shelf are generally flat.

Gravel bottoms also occur in the Sambro sand (map-unit 6b). They are generally flat and consist of a sand bottom with scattered pebbles and cobbles.

Glacial till of the Scotian Shelf drift (map-unit 4) is a mixture of mud, sand, and gravel. The till has a rough, hummocky surface and would be unsuitable for most fishing operations.

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ERRATA:

The Emerald silt at the southern end of Roseway Basin is improperly labelled at two locations on Chart 4039G as map-unit 5b instead of 5c.