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SURFICIAL GEOLOGY, LOUGHEED ISLAND, NORTHWEST ARCTIC ARCHIPELAGO

Project 760010

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Abstract

The surficial materials on Lougheed Island and adjacent Edmund Walker Island are mainly weathered soft shale and sandstone at high elevations, and a complex of weathered rock, and glaciomarine, marine, deltaic and fluvial sediments over the remaining area. Glacial till, and associated deformation of the soft bedrock, are exposed only in section. The direction of the deforming force, the source of erratics, and alignment of drumlinoid ridges and a possible esker, indicate ice movement from the southeast; the age of the responsible glacial event is not known and may well be pre-late Quaternary. Rapid deposition of glaciomarine, and subsequently marine, sediment was in progress at 10 500 ± 130 years ago, while emergence of at least 90 m has occurred since 10 240 ± 280 years ago. The cause of uplift and the origin of the glaciomarine sediments is suggested to be break-up of an ice sheet to the south, covering at least Bathurst Island 10 500 years ago, and producing floating ice, or even an ice shelf which extended to Lougheed Island; however, latitudinal compressive tectonic forces might also be responsible for uplift.

Introduction

Glacial and glaciomarine deposits found on Lougheed Island have not been reported from adjacent areas of surrounding, larger Queen Elizabeth Islands. This information, derived from a survey of surficial materials, plus confirmation of at least 90 m emergence since the late Quaternary (GSC-356, Table 5.1), introduces data from the northwestern islands into the debate on extent of late Quaternary glacial ice in the Queen Elizabeth Islands. Blake's (1970) concept of the Innuitian Ice Sheet covering much of the islands has been challenged by England (1976) and Boulton (1979), who favour a restricted ice cover. In addition to its significance in regional late Quaternary history, the island is surrounded by a number of offshore gas fields and, if development proceeds, knowledge of surficial materials will be required for engineering and environment studies.

Raised beaches and marine shells were noted by the first recorded visitors to the Findlay Group, which comprises Lougheed and the three smaller islands to the southeast (Stefansson, 1921, p. 544). Fyles (1965) observed landforms of probable glacial origin and measured raised marine deposits, which were plotted on the Glacial Map of Canada (Prest et al., 1968). For this study, Lougheed Island was visited between mid-July and early August, 1979, when, with S.A. Edlund who studied vegetation (Edlund, 1980), traverses were made by Honda A.T.C. and on foot.

Acknowledgments

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Physiography

Lougheed Island (1300 km^2) is elongated north-northwest; the north half rises to a ridge at 130 m a.s.l., whereas the south half comprises low rolling hills rarely rising to 100 m elevation and an extensive lowland in the west. Fluvial dissection locally sharpens relief in all parts of the island. The three islands to the southeast are low, and the largest, Edmund Walker Island, peaks at 135 m a.s.l. The Findlay Group rises from waters at least 150 m deep, except to the southwest where a depth of about 50 m is maintained towards Melville and Cameron islands (Fig. 5.1). Previous studies summarized by Pelletier (1966) suggest that inter-island channels and basins of the Queen Elizabeth Islands are products of a glacially modified fluvial system. However as tectonism is now known to have formed Parry Channel (Kerr, 1980), concurrent rifting might have shaped Lougheed and the other northwest Queen Elizabeth Islands.

Structural Geology

Thick units of soft sandstone alternate with shale in the shallow Lougheed Syncline, the axis of which coincides with the longer axis of the island. Bedrock is described by Balkwill et al. (1977, 1979), and units are outlined on Figure 5.2. Surface characteristics of rock are described under surficial materials in this report.

Drainage and Permafrost

The flow of surface water ceases soon after snowmelt in all but the highest order channels or where perennial snowbanks survive in drainage incisions. Surface water is otherwise restricted to several lakes dammed by coalescing prograding deltas, and to the few areas where thaw-enlarged frost fissures occur.

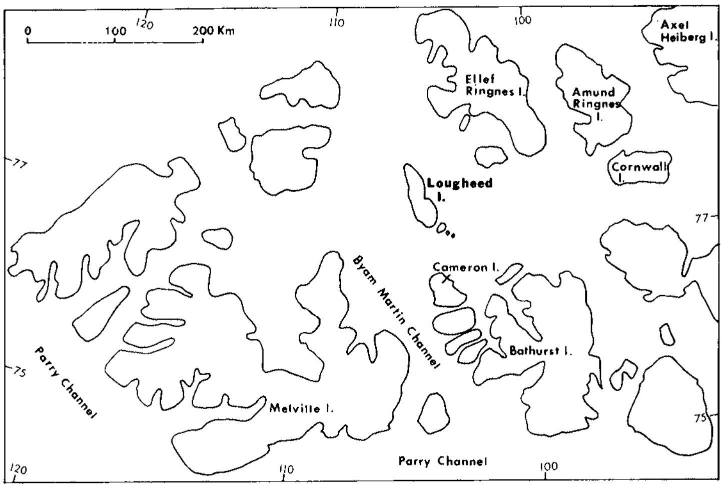


Figure 5.1. *Location map.*

Table 5.1

Radiocarbon dates, Lougheed and Edmund Walker islands

Laboratory no. (Field no.)	Radiocarbon age (years B.P.) corrected (uncorrected)	Material dated	Location	Sample elevation (m)	Geological environment	Significance	Collector	References
I(GSC)-24	8200 ± 180	Marine pelecypods	NE coast Lougheed I., 77°33'N, 105°W	ca. 23-30	Clay in shallow gully	As higher shells uncommon on this coast, sample may not be contaminated by them (see text).	V. Stefansson. Coll. during Canadian Arctic Expedition, 1916; subm. 1959 by J.G. Fyles	Craig and Fyles, 1960, p. 11. Walton et al., 1961, p. 53
GSC-320 (FG-64-113 at site 7/27C)	10 100 ± 150	**Hiatella arctica**	17 km W of C. Rondon, Lougheed I., 77°20'N, 105°07'W	ca. 60	Surface of linear ridge (see text); on glaciomarine sediments?	Maximum age of 60 m water plane on central Lougheed I.	J.G. Fyles, 1964	Lowdon et al., 1967
GSC-356 (FG-64-46d at site 7/19D)	10 240 ± 280	**Hiatella arctica**	E. Edmund Walker I., 77°09'N, 104°02'W	ca. 90	Surface of shale ridge	Maximum age of 90 m water plane on Edmund Walker I.; highest definite late Quaternary shells	J.G.Fyles, 1964	As above
GSC-2928	10 400 ± 260 (10 400 ± 260)	**Hiatella arctica** 15.7g	30 km SSE of C. Ahnighito, Lougheed, I., 77°30'N, 105°36'W	43.5	Near top of 3.5 m marine pelite and glaciomarine sediment exposed in nivation hollow	Indicates rapid rate of sedimentation for 3 m of marine pelite	D.A. Hodgson, 1979	This report
GSC-2986	10 500 ± 130	**Hiatella arctica** 26g	as above	40.5	In stony marine pelite (glaciomarine) over rock, beneath 3 m marine pelite	Minimum age of late Quaternary sea and deposition of glaciomarine sediment	D.A. Hodgson, 1979	This report

Permafrost thickness is >300 m at Pat Bay well site (Fig. 5.2), 17 m a.s.l. and 2 km from the modern shoreline (Judge et al., 1980). This site emerged from marine waters after 8000 years B.P. (I(GSC)-24, Table 5.1; Fig. 5.3), but probably before 5000 years ago. Active layer thickness varies from 10 to 100 cm depending on material and on vegetation type and cover.

No data exist on ground ice. No surface manifestation of ice occurs except possibly as frost fissures, though these may not contain ice wedges owing to the paucity of moisture.

Climate – Wind

Prevailing and strongest winds are from the northwest or north-northwest over much of the northwest Queen Elizabeth Islands (Maxwell, 1981), hence eolian deposits have this alignment. There is a remarkable parallelism on Lougheed Island among bedrock structure trends (and thus topography), glacial ice flow of unknown age, and dominant wind direction, which causes confusion in the air photo interpretation of landforms.

Surficial Deposits

Surface Rock

Material directly derived from underlying bedrock is exposed over 25 per cent of the island (Fig. 5.2). Periglacial weathering, possibly aided by glacial deformation, has reduced the poorly cemented bedrock to constituent particles, dominantly medium to fine sand and silt size, down to a depth of several metres. Probably all surface rock, which includes the highest land, has been washed by marine waters during late Pleistocene and early Holocene high sea levels; hence scattered pockets of marine sediments occur on this unit. A discontinuous lag of clasts related to underlying rock contains scattered erratics of southern provenance (Fyles, 1965).

In vertical section, the contact between bedrock and overlying sediments ranges from abrupt to gradational owing to intermixing by glacial or fluvial processes. Unconsolidated silty shale beds, and to a lesser extent sandstones, are easily confused with Quaternary marine or deltaic sediments, unless Cretaceous macrofauna are present.

The three dominantly sandstone formations described by Balkwill et al. (1977, 1979) are treated as one unit here, whereas the two shale formations, which have dissimilar weathering characteristics, are each considered separately.

Isachsen, Hassel, and Eureka Sound Formations – Sandstone. These formations are composed of weakly cemented carbonaceous sandstone which readily weathers to buff or light grey sand. Scattered resistant cemented beds reinforce areas of highly dissected scarpland. The Hassel Formation, which is the most widely distributed sandstone, contains shale beds.

Christopher Formation – Shale. As on the Ringnes islands, the Christopher Formation underlies rounded hills which form the highest land even though the weathered rock can be highly unstable in the geotechnical sense. Balkwill et al. (1977) described this shale as more silty than the Kanguk Formation; however the weathered rock is more plastic and prone to failures, particularly active layer detachment slides and flows. Stream beds, however, are commonly more stable owing to an armouring of mudstone concretions derived from this formation. As this is the best vegetated and most water-retentive unit, it is the unit most likely to contain substantial ground ice bodies.

Kanguk Formation – Shale. The low lying, acidic, and barren silty terrain is quite unlike the Christopher Formation (cf. Edlund, 1980). Thin sandstone beds reinforce low scarps. Wide shallow channels filled with silty sand are characteristic of terrain dominated by large-scale fluvial processes rather than by mass movement and rills as on Christopher Formation shale.

Quaternary Deposits

Much of Lougheed Island, other than land at high elevations, is covered by Quaternary deposits. With the exception of fluvial deposits and thick marine and deltaic sediments, it proved difficult to identify on air photos materials with different origins. Hence one third of the materials map (Fig. 5.2) is composed of a complex of glacial, glaciomarine, marine, and deltaic sediments, together with areas of rock where drainage is incised, or weathered rock under a discontinuous marine veneer especially near the central west coast.

Glacial Deposits. Till outcrops only in sections found in the southeast and west of the island (Fig. 5.2), and the extent of subcrop is unknown. Carbonate and crystalline erratics, together with striated sandstone clasts, scattered on the surface at all elevations, are either remnants of till or of glaciomarine deposits. A diabase block 4 m across was found 125 m a.s.l. at the northern height of land. Till is best exposed over an area of Kanguk Formation shale and minor sandstone in the extreme southeast of Lougheed Island at about 30 m a.s.l. Here, in up to 1 m of a calcareous, in places pinkish-hued, diamicton the dominant clasts are sandstone but include Paleozoic limestones. The till overlies rock in which the upper few centimetres to metres has commonly been deformed, and in some cases convoluted or even overthrust and sheared, by a compressive force from a southerly direction. Rafts of unconsolidated bedrock up to 50 cm thick and 3 m long are incorporated in the till. Rock exposed in a river cut near the west coast has been sheared to a depth of 3 m by a force from the southeast (Fig. 5.4). Glacial deposits are overlain by a stony marine pelite, in places in conformable contact, elsewhere unconformable. Underlying rock is everywhere too friable or soft to preserve striae.

Glaciofluvial (?) Deposits. An esker-like ridge 1.5 km long, 10 m high, and 25 m a.s.l. at the southeast extremity of Lougheed Island is oriented north-northwest. The surface is composed of sandstone and a few carbonate clasts up to 1.5 m diameter, some striated; the subsurface is dominantly sand or sandy silt. The concentration of surface boulders is unique on the island, and even if reworked by beach processes, deposition by a glacial process is the most plausible origin.

Glaciomarine (?) Deposits. A dark grey or black stony marine pelite up to 3 m thick, and unstructured to faintly stratified, is widespread in the west centre, centre, and southeast of Lougheed Island. The sediment overlies rock or till and commonly grades upwards into stonefree marine pelite. Stones, composing up to 10 per cent of the volume, are chiefly sandstone and less commonly carbonate, and are commonly striated. Contact with underlying rock or till may be abrupt (Fig. 5.5) and in places obviously disconformable. Clasts of poorly consolidated material resembling the underlying rock occur in the pelite. Nevertheless, as fragile and paired marine pelecypods occur at all levels, it is considered that most clasts are dropstones, and not reworked from subjacent deposits. Drifting glacial ice or an ice shelf are likely sources. At a number of localities thin (1-25 cm) lenses or beds of finely stratified sand underlie stony pelite in a conformable manner (Fig. 5.6).

Figure 5.2 *Surficial materials and geology, Lougheed Island.*

LEGEND

5 FLUVIAL DEPOSITS: sand and silt, in active channel zones >200 m wide

4 DELTAIC DEPOSITS: sandy topset beds, planar, generally overlying marine pelite.

3A MARINE PELITE: <2 m thick

3B MARINE PELITE AND DELTAIC DEPOSITS: >2 m thick

2 QUATERNARY UNDIFFERENTIATED: surficial rock; till (minor outcrop); glaciomarine (stony pelite); marine (pelite or silty and sandy littoral deposits); active fluvial channels <200 m wide.

1 SURFICIAL ROCK
A: sandstone (Isachsen, Hassel, and Eureka Sound formations); friable, generally disintegrated to sand.
B: shale (Kanguk Formation), silt, clay, shale fragments; low plasticity.
C: shale (Christopher Formation), silt, clay; moderate plasticity.

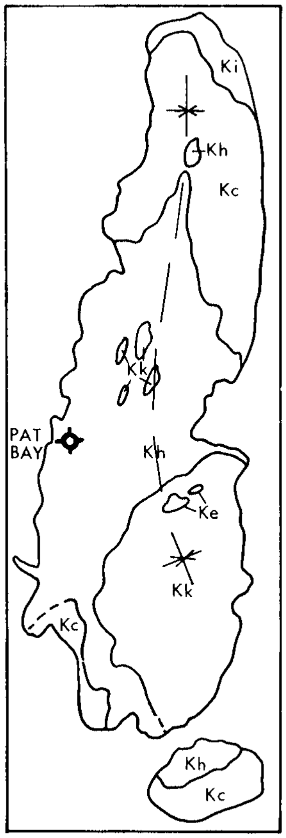
——— – – – ····· Geological boundary (defined, approximate, assumed/transitional)

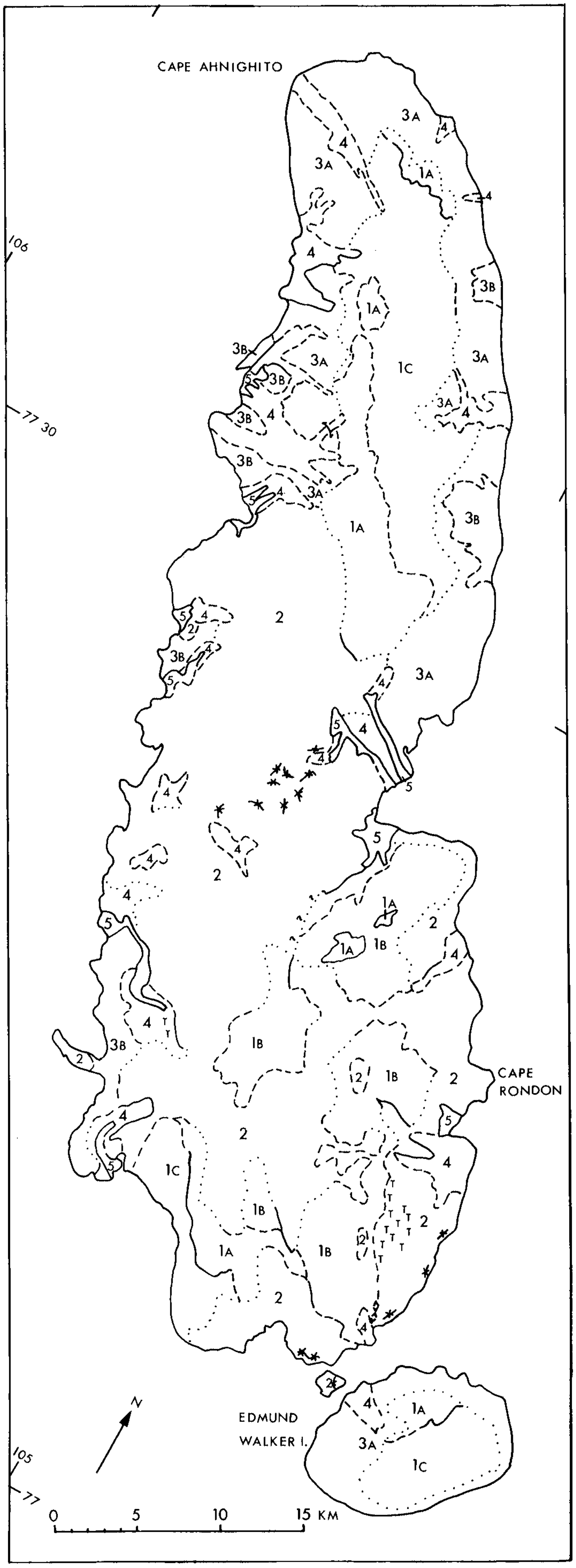
T T T Known till subcrop

<><7 Esker-like ridge

—✕— Raised beach flight (subdued morphology)

GEOLOGY (see inset below)
Ke: Eureka Sound Formation: sandstone
Kk: Kanguk Formation: shale
Kh: Hassel Formation: sandstone
Kc: Christopher Formation: shale
Ki: Isachsen Formation: sandstone





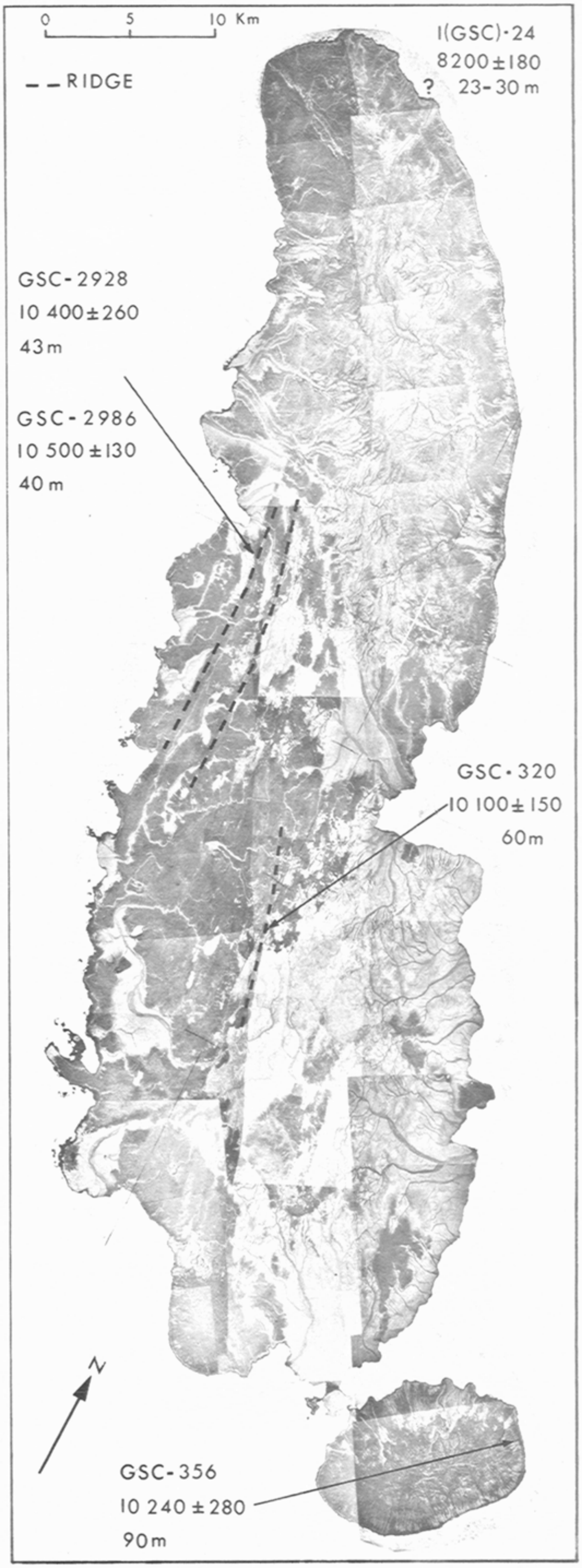


Figure 5.3. *Photomosaic of Lougheed Island showing locations of radiocarbon-dated material. (RE No. 11934 EMR).*

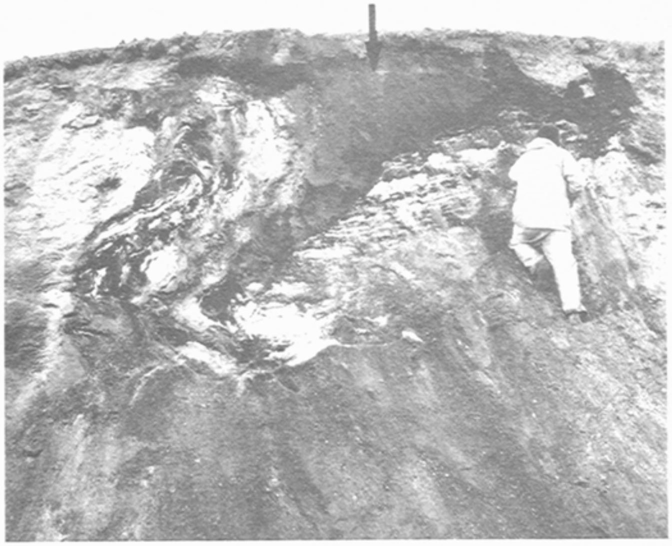


Figure 5.4. *Glacially(?) deformed sandstone and shale overlain by marine pelite (base of marine sediments shown by arrow); north of Pat Bay well site, Lougheed Island (see Fig. 5.2, geology inset). GSC 203754-D*

Figure 5.5. *Large nivation hollow, northwest Lougheed Island, showing marine pelite (black exposures) over Hassel Formation sandstone. The section parallels a drumlinoid ridge, which forms the horizon. Marine pelecypods from the glaciomarine and marine sediments in the section (arrow) dated 10 400 ± 260 years old (GSC-2928) at top and 10 500 ± 130 years (GSC-2986) at bottom. GSC 203754-C*

The thickest sections were observed in stream cuts and nivation hollows on the flanks of three linear ridges, shown in Figure 5.3. Each ridge is at least 15 km long, about 250 m wide, and up to 30 m high (Fig. 5.7) though most of the relief is developed in rock.

Marine Deposits. Inundation by a late Quaternary sea to at least 90 m a.s.l. (see marine shells, GSC 356, 10 240 ± 280 years old, at 90 m on Edmund Walker Island, Table 5.1) left few deposits at high elevation, but below 50 m

Figure 5.6. *Typical contact (arrow) between sandstone, stratified sand, and glaciomarine sediment, grading up to marine sediment shown in the centre of Figure 5.5. GSC 203754-E*

Figure 5.7. *North end of westernmost drumlinoid ridges. Nivation hollow (Fig. 5.5, 5.6) and alignment of ridges shown by arrows. GSC 203754-B*

there is a discontinuous cover. The thickest accumulations (Fig. 5.2) are adjacent to large rivers and are probably bottomset deposits of prograding deltas. Much of the sediment is silt size, even over Hassel Formation sandstone; conversely, sandy littoral sediments, probably derived from fluvial and till deposits, cover coastal areas underlain by the Kanguk Formation in the southeast.

Few beach forms exist, even at the modern shoreline, owing to lack of coarse material and to vigorous ice push which occurs in all but the most protected waters. Modern coastal geology is described by Woodward-Clyde Consultants (1981).

Fluvial and Deltaic Deposits. Most large rivers are prograding, while upstream a wide channel is cutting into the former delta surface. This surface is rarely terraced, for lateral fluctuations of a river mouth are rare on a coast where a near permanent sea ice cover moderates normal coastal processes. A similar fluvial regime in the adjacent Ringnes islands is described in more detail by Hodgson (in press).

Bedloads are dominantly fine sand or silt, except where till, glaciomarine materials, or coarse competent rock are intersected by channels.

Eolian Deposits. The singularity of wind direction aided by low precipitation results in erosion of unvegetated areas. This is well illustrated in Figure 5.3 where sand and silt from wide active river channels have been deposited up to 5 km to the south-southeast (light-toned patches), inhibiting vegetation growth (dark-toned areas), especially in the otherwise well vegetated west-central area. Erosion and deposition take place in thin sheets at any one time, thus no distinctive landforms occur.

Granular Material Sources

Gravel and sand are scarce in Quaternary deposits on Lougheed Island. Gravel covers, but does not appear to core, the esker-like landform in the southeast (Fig. 5.2), and till deposits are thin, bouldery, and generally only outcrop in section. The discontinuous lag gravel on inactive fluvial surfaces and over glaciomarine sediments could be concentrated by dragging. Sandy fluvial deposits are common, but silt content may be high. Bedrock is the best source for aggregate: sand is available as friable quartzose sandstone, and both sandstone and shale units include indurated sandstone beds suitable for riprap.

Late Quaternary Glacial History

Direct Evidence of Glacial Ice

The till described above is exposed at a number of localities in the southern half of Lougheed Island. Sandstone, the dominant clast lithology, outcrops widely on this and surrounding islands, including much of the land area immediately to the south (eastern Melville and northwestern Bathurst islands). Carbonate rocks, which are less commonly present in till, only outcrop in abundance more than 150 km away, particularly to the southeast in central and eastern Bathurst Island. This, and the orientation of glacial deformation, indicate Bathurst Island as the most likely source of the erratics.

No evidence exists of a carapace ice cover on Lougheed Island, and in particular, no meltwater channels are present. Such evidence of late Quaternary age is hardly expected, however, as little or none of the island projected above the late Quaternary sea at its maximum extent (when deglaciation most likely would occur).

Blake (1964) shows drift and till patches on Bathurst Island and on Helena Island – 100 km from southern Lougheed – otherwise the closest clearly identified till deposits are over 200 km distant: till of unknown age on northeast Amund Ringnes Island and on Cornwall Island (Hodgson, in press), and a moraine ca. 10 000 years old on southern Melville Island (Fyles, 1967). Although the till on Lougheed Island is overlain by glaciomarine sediments dated 10 000 to 10 500 years old (though not at a location directly over till), it cannot be inferred that the till is only slightly older as the glaciomarine sediment disconformably overlies till in places and generally overlies rock – not till.

Clasts in glaciomarine sediments are of similar lithologies to the till, except for the few diabase and granitic rocks assumed to originate south of Parry Channel. A minimum age for this sediment has been established from three collections of marine shells made in marine pelite over drumlinoid ridges. From the surface of the most easterly ridge (Fig. 5.3) at 60 m, **Hiatella arctica** valves are 10 100 ± 150 years old (GSC-320, Table 5.1). From a massive nivation hollow in the most westerly ridge (Fig. 5.5, 5.7), **Hiatella arctica** valves were collected near the top and bottom of 3.5 m of pelite, stony near the base, and overlying a rock surface at 40 m a.s.l. (Fig. 5.6). The basal shells (from a rare concentration at this level) are 10 500 ± 130 years old (GSC-2986). Shells are absent in mid-section but common in sandy partings near the top (banks of shells are exposed in the vicinity). **Hiatella arctica** valves from 20 cm below the ground surface and 3 m above GSC-2986 are 10 400 ± 260 years old (GSC-2928), indicating rapid accumulation of the fine grained sediment.

A terrestrial or littoral origin on unglaciated land seems unlikely for the lenses of stratified sand; the necessary subsequent or concurrent transgression should result in poorly or unsorted deposits. Sorted deposits might be expected from submarine currents, possibly at the base of an ice shelf attached to, and fed by, an ice cap or sheet.

The most equivocal landforms are the drumlinoid ridges described above. A structural origin must be considered as they have a similar trend to the low-amplitude, regularly spaced folds described by Balkwill et al. (1977); however ridges both coincide with and slightly diverge from anticlinal and synclinal axes shown by Balkwill et al. (1979). The ridges are sharp-crested whereas the bedrock dips gently, and even appears to be homoclinal beneath one ridge. If they are glacial (or even ice shelf) bedforms, no age can be assigned.

Other equivocal evidence of glaciation comes from Marlowe's (1968) study of bottom sediments within a 50 to 100 km radius of Lougheed Island; to the west of the island he found an upper oxidized unstructured stratum, 6 to 54 cm thick, overlying more structured reduced material in which cyclical laminates resembling varves occurred. The lower layer was equated with restricted water circulation and possible glacial sedimentation at a time of lower sea level. The upper stratum is explained by more open circulation brought about by a rise in sea level. As no datable material was recovered from cores, as no means of comparison exists between rates of sedimentation of Marlowe's cores and the marine pelite on Lougheed Island (note the >3 m deposition on the drumlinoid ridge), and as a record of a rise in sea level has not been found, no correlation of cores with land exposures has been possible.

Indirect Evidence of Glacial Ice

The most plausible explanation to a glacial geologist for the 90 m of emergence which has occurred during the last 10 000 years is disintegration of an overlying or nearby ice sheet, resulting in elastic and viscous crustal responses and removal of gravitational influence on the sea (quantitative values for an arctic area (Somerset Island) are discussed by Dyke (1979)). However as Boulton (1979) questioned the value of postulating an ice sheet on the basis of 'proxy' data, other mechanisms for this uplift suggested by a geophysicist (L.W. Sobczak, personal communication, 1981), will be given. Unfortunately the form of emergence is not known, since the profusion of shells at high elevations and paucity at low elevations makes contamination of younger collections likely unless they are found in situ. Only one sample younger than 10 000 years B.P. has so far been dated: shells from 23 to 30 m a.s.l. are 8200 ± 180 years old (I(GSC)-24).

High seismic activity which occurs below Byam Martin Channel (Basham et al., 1977; Forsyth et al., 1979), latitudinal compressive forces and longitudinal tensional forces which are predicted from four large earthquakes (Hasegawa, 1977), northeast trending mafic dikes which occur within the region (Reford, 1967), and a system of northeast trending faults and northwest trending folds and uplifts which are proposed (Sobczak, in press) may explain an uplift in the short term (10 000 years) of 90 m. In the long term (millions of years), however, general subsidence of many kilometres has been noted (Sweeney, 1977) and possibly up to 17 km (Sobczak, in press). Glacial unloading may have triggered the latitudinal forces in the last 10 000 years and thus have resulted in local uplift occurring subparallel to the north trending Boothia Uplift (Kerr, 1977). Other possible mechanisms for local uplift include diapiric evaporite intrusions, gas hydrate migration, and massive ice growth induced by temperature changes or world-wide sea level changes.

Conclusions

Glaciomarine deposits on Lougheed Island have a minimum age of 10 500 ± 130 years B.P. (GSC-2986). Since this time, some 90 m of emergence has taken place. This uplift can be explained by glacio-isostatic mechanisms following removal of an ice sheet in close proximity at ca. 10 000 years ago or as a result of latitudinal compressive tectonic forces. The nearest late Quaternary ice margin proved by direct evidence is that of the Laurentide Ice Sheet 250 km to the south on southern Melville Island (Fyles, 1967). It is probable that at this time an ice sheet expanded to the sea on Axel Heiberg Island, 250 km east of Lougheed Island, and on western Melville Island, 200 km southwest. None of these is likely to induce much emergence. Blake (1964, Fig. 1) showed by striae, streamlined landforms, and meltwater channels, an undated ice flow radiating from the centre of Bathurst Island. An ice sheet covering Bathurst Island, and contiguous with ice extending to Ellesmere Island (Hodgson, 1978), or even more widespread, might depress Lougheed Island and generate floating ice or an ice shelf extending to or grounding on the island.

The age of till deposits on Lougheed Island has not been established; they may be the result of a late Quaternary glaciation, or may be older.

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