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QUATERNARY GEOLOGY OF THE YUKON COASTAL PLAIN

V.N. RAMPTON

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ERRATUM

GSC Bulletin 317, by V.N. Rampton

p. 23 Figure 19. Glacial features near the limit of Buckland Glaciation east of Firth River including A – abandoned meltwater channels, B – kame terraces, and C – kame deltas. Note the thermokarst depression (D) within the kame deltas. (NAPL A13751-103)

p. 37, paragraph 5, left column, line 4 block slumping, not block sampling.

p. 43 Figure 40. Well drained edge of a fluvial terrace along Firth River Canyon.

Table 14. Stratigraphic summary of pre-Buckland sediments exposed along the Yukon Coastal Plain

Area	Herschel Island	Malcolm Lake to Babbage River	Erosion Surface	Kay Point and southeast	King Point	Sabine Point and northwest	Shingle Point	Walking to Blow rivers
General Stratigraphic Descriptions	Marine clays; possibly contain sequence of freshwater sediments. Vegetation---shrub tundra.	Marine clays		Marine clays; poorly exposed.	Marine clays	Freshwater silts overlain and underlain by marine sediments; ice-wedge casts. Vegetation---forest nearby(?).	?	Interbedded sands, silts, gravels, with peaty beds. Vegetation---tundra, tree line nearby.
	'Mixed' sediments from shallow marine and brackish environments. Vegetation---boreal forest.	Deformed sands and gravels.	? Gravels ? ? ?	Interbedded silt, sand, and gravel with peat beds. Vegetation---forest-tundra and tundra.	Interbedded clay, silt, sand, gravel, and peat. Vegetation---boreal forest, forest-tundra, and shrub tundra.	?	?	Till, oxidized.
							Gravel	Gravel; ice-wedge casts.
							? Gravel and sand, oxidized; ice-wedge casts.	Gravels, oxidized; ice-wedge casts.
	Marine clays						Vegetation---tundra and forest(?).	

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PREFACE

The surficial geology and geomorphology of the Yukon Coastal Plain were first systematically examined by the Geological Survey in 1962. During the following decade, in anticipation of intensive exploration programs by the petroleum industry and the possible construction of oil or gas pipelines and other transportation facilities, the Survey carried out several projects in the region culminating in 1972 in a large field operation which involved surficial mapping, geophysical studies, drilling, stratigraphic studies and a study of river and coastal processes. The author was involved in many of these projects and continued the involvement as a private consultant.

This report synthesizes both Dr. Rampton's observations and those of others. It will assist in establishing the sequence and age of Quaternary deposits and landforms in the northern Yukon which mark the northwestern limit of the North American ice sheet, will provide information invaluable to permafrost and engineering studies and will form a basis for rational planning and land use on the sensitive terrain of the Yukon Coastal Plain.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, February 1979

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QUATERNARY GEOLOGY OF THE YUKON COASTAL PLAIN

Abstract

The Yukon Coastal Plain lies between the British, Barn, and Richardson mountains and the Beaufort Sea; the Mackenzie Delta adjoins the eastern end of the Coastal Plain. Much of the Yukon Coastal Plain consists of an erosion surface or pediment, which also flanks streams in the adjacent hills and mountains.

Most of the Yukon Coastal Plain east of Firth River and the northern edge of the adjacent mountain ranges were glaciated by ice moving west from Mackenzie Valley during the Buckland Glaciation, presumably of early Wisconsin age. The adjacent mountain ranges and most of the Coastal Plain west of Firth River have not been glaciated during the Pleistocene. During deglaciation a major stillstand or readvance, termed the Sabine Phase of the Buckland Glaciation, occurred and constructed a moraine-outwash complex parallel to the coast between Kay Point and Coal Mine Lake. A small part of the Coastal Plain bear Aklavik was glaciated during late Wisconsin time.

A complex of marine, deltaic, fluvial, lacustrine, and terrestrial sediments underlies Buckland till and outwash. Fine-grained sediments of marine and deltaic origin, containing ice-wedge casts, directly under the Buckland till and outwash are thought to be Sangamon or early Wisconsin. Other pre-Buckland sediments are believed to predate the Illinoian. A till is present within the pre-Buckland sequence at the eastern end of the Coastal Plain. Boreal forest, forest-tundra, and shrub tundra covered the Coastal Plain at various times during deposition of the above mentioned sediments.

Post-Buckland time has been marked primarily by alluviation, thermokarst, mass wastage, and the formation of ground ice. Large alluvial fans have formed adjacent to streams west of Firth River and south of Willow River opposite Aklavik. Terraces flank most other streams throughout the area. Ice wedges and epogenetic and aggradational segregated ice are common forms of ground ice. Thermokarst in the form of retrogressive thaw flow slides has formed small and large lacustrine basins; thermokarst was particularly active between 12 000 and 8000 years ago. Creep and solifluction have affected most slopes. Evidence collected indicates that the vegetation and climate of the Coastal Plain have been similar to those of the present throughout much of the post-Buckland time. Cooler and drier conditions may have prevailed during the late Wisconsin maximum; macrofossil evidence and thermokarst activity suggest that the Coastal Plain experienced warmer temperatures between 10 000 and 9000 years ago.

Most of the area is covered by fluvial deposits, both fine and coarse grained; morainic deposits, which commonly are associated with massive ground ice; lacustrine deposits of thermokarst origin; and colluvial deposits where bedrock-controlled slopes prevail. Glaciofluvial deposits, glacially deformed preglacial sediments, and bedrock underlie small areas. Only small areas of eolian, estuarine, and marine deposits have been mapped. Organic deposits blanket most flat to gently sloping, poorly drained terrain.

Résumé

La plaine côtière du Yukon se trouve entre les monts British, les chaînons Barn et Richardson et la mer de Beaufort; le delta du Mackenzie touche à l'extrémité orientale de la plaine côtière. La majeure partie de la plaine du Yukon est une surface d'érosion ou pédiment traversée par les cours d'eau provenant des collines et des montagnes adjacentes.

La presque totalité de la plaine côtière du Yukon à l'est de la rivière Firth et la bordure nord des chaînes de montagnes voisines ont subi l'effet de la glace se déplacant vers l'ouest en provenance de la vallée du Mackenzie pendant la glaciation de Buckland, probablement au début du Wisconsin. Les chaînes de montagnes adjacentes et la majeure partie de la plaine côtière à l'ouest de la rivière Firth n'ont pas été couvertes par les glaciers au Pléistocène. Pendant la déglaciation, une période stable importante suivie d'une poussée, appelée phase de Sabine de la glaciation de Buckland, a édifié un complexe formé d'alluvions proglaciaires et de moraines, parallèle à la côte entre pointe Kay et le lac Cola Mine. Une petite partie de la plaine côtière près d'Aklavik a subi la glaciation à la fin du Wisconsin.

Sous le till et les alluvions proglaciaires de Buckland repose un complexe de sédiments marins, fluviatiles, lacustres et terrestres. On pense que les sédiments à grains fins d'origine marine ou deltaique, contenant des coins de glace, directement sous le till et les sédiments proglaciaires de Buckland, datent du Sangamon ou du début du Wisconsin. On suppose que les autres sédiments pré-Buckland sont antérieurs à l'Illinois. Du till est présent parmi la succession pré-Buckland de l'extrémité orientale de la plaine côtière. Pendant le dépôt des sédiments susmentionnés, la plaine côtière a été couverte à divers moments par la forêt boréale, la forêt-toundra et la toundra arbustive.

Le post-Buckland a été marqué essentiellement par l'alluvionnement, le thermokarst, les mouvements de masse et la ségrégation de glace. De grands cônes alluviaux ont été formés au voisinage des cours d'eau à l'ouest de la rivière Firth et au sud de la rivière Willow en face d'Akalavik. Dans toute la région, des terrasses longent la plupart des cours d'eau. Les coins de glace, les ségrégations de glace épigénique et d'aggradation sont les formes communes de glace retenue dans le sol. Le thermokarst sous forme de glissements dus à l'écoulement régressif pendant le dégel a formé de petits et grands bassins lacustres; le thermokarst fut particulièrement actif il y a de 12 000 à 8000 ans. La plupart des pentes ont subi des phénomènes de reptation et de solifluxion. Les preuves recueillies indiquent que la végétation et le climat de la plaine côtière ont été semblables à ceux d'aujourd'hui pendant la plus grande partie du post-Buckland. Des conditions plus fraîches et plus sèches ont peut-être dominé à la fin du Wisconsin au maximum; les macrofossils et le thermokarst suggèrent que la plaine côtière a eu des températures plus chaudes il y a de 10 000 à 9 000 ans.

La plupart de la région est couverte de dépôts fluviatiles à grains fins et grossiers, de dépôts morainiques fréquemment associés aux grandes ségrégations de glace, de dépôts lacustres qui ont pour origine le thermokarst et de dépôts colluviaux là où les pentes dépendent de la roche en place. La superposition de dépôts glaciofluviatiles, de sédiments préglaciaires déformés par la glaciation et de la roche en place est répartie en petites zones. Il n'y a que de petites zones de dépôts éoliens, d'estuaire et marins qui ont été cartographiées. Des dépôts organiques couvrent la plupart des terrains mal drainés plats et légèrement en pente.

INTRODUCTION

The object of this report is to synthesize the many observations and interpretations made by various investigators between 1962 and 1976 on the surficial geology and geomorphology of the Yukon Coastal Plain and adjacent areas.

The surficial geology and geomorphology of the Yukon Coastal Plain and adjacent areas were first systematically investigated by the Geological Survey of Canada in 1962. Hughes (1972) mapped the surficial geology of much of northern Yukon Territory and adjacent areas of the District of Mackenzie as part of a large reconnaissance survey carried out by Survey geologists, which included all aspects of the geology. Fyles (1966) made stratigraphic observations of Pleistocene sediments along the coast. I spent a short part of summer 1970 in the area in anticipation of intensive exploration programs by oil companies and possible construction of oil or gas pipelines. Surficial geology maps were produced (Rampton, 1970) from data collected by Fyles, Hughes, and the author during 1970. A further series of maps was produced (Rampton, 1974a) following a large field operation in 1972, which involved surficial mapping, shallow geophysics, drilling, stratigraphic studies, and a study of river and coastal processes (McDonald and Lewis, 1973; Rampton, 1973a). During summer 1975 I was employed by Northern Engineering Services Company Ltd. (1976) of Calgary to investigate certain aspects of the Yukon Coastal Plain terrain. Finally, during the fall of 1976, I was part of a team that carried out an inventory of granular materials of the Yukon Coastal Plain (R.M. Hardy and Associates Ltd. and Terrain Analysis and Mapping Services Ltd., 1976).

Samples from a variety of locations were collected during the above studies and forwarded to M. Kuc, formerly of the Geological Survey of Canada; J.V. Matthews, Jr. of the Geological Survey of Canada; J.C. Ritchie of Scarborough College (University of Toronto); and L.D. Delorme of Canada Centre for Inland Waters (Burlington) for paleontological identifications and paleoenvironmental interpretations. Dr. Delorme forwarded select samples to J.E. Hazel and R. Todd of the United States Geological Survey.

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Previous studies

Besides the geomorphic and stratigraphic investigations undertaken by Hughes (1972) and Fyles (1966), numerous other studies and investigations have been carried out that concentrate on either small areas or specific geomorphic features of the Yukon Coastal Plain. O'Neil (1924) briefly described the landforms and Pleistocene stratigraphy along the Yukon coast, specifically at Herschel Island and Kay Point. Mackay (1959) described the deformed Pleistocene stratigraphy at Herschel Island, Kay Point, King Point, and Stokes Point, and related the deformation to the effects of overriding glacier ice. Mackay et al. (1961) described the shallow stratigraphy at Engigstciak, an archeological site east of Firth River and about 30 km south of Herschel Island. Mackay (1963a) analyzed coastal retreat at King Point, Sabine Point, Kay Point, Herschel Island, and near the delta on Running River. McCloy (1970) described levee formation on the Blow River delta. Legget et al. (1966) suggested a model for formation of the alluvial fans west of Aklavik from geomorphic and testhole observations. Naylor et al. (1972) investigated the palynology and molluscs of sediments in sections near Shingle Point, King Point, and on Herschel Island. From stratigraphic observations and radiocarbon dates Mackay et al. (1972) projected the age of permafrost and the glacial chronology of the Coastal Plain. McDonald and Lewis (1973) made detailed investigations of the geomorphology and sedimentologic processes of selected sites along major streams and the coast; this work has been continued by Lewis (1975) and Forbes (1975). Rampton (1974a) briefly described the terrain and possible terrain hazards. Rampton and Dugal (1974) measured rates of slope movement at selected sites on the Coastal Plain and in adjacent hills and mountains. Bouchard (1974) made detailed observations on the surficial deposits, geomorphology, and structural character of Herschel Island. Matthews (1975) conducted a detailed paleoecological study of a late Pleistocene peat sample.

Climate

Climatic parameters for the Yukon Coastal Plain are based on observations at Aklavik and at DEW-line sites at Shingle Point and Komakuk Beach. The climatic data are summarized from Burns (1973). Temperature and precipitation records have been collected at Shingle Point since 1957 and at Komakuk Beach since 1961. At Aklavik, temperature, wind, and precipitation data have been collected during various intervals between 1926 and 1962.

The Yukon Coastal Plain is characterized by a harsh, cold, arctic climate dominated by continental arctic air in the winter and by maritime arctic air in the summer. Winters are long, with most years having 250 days with temperatures below 0°C. Mean daily temperatures range from -11°C at Komakuk Beach to -8.9°C at Aklavik. July mean daily temperatures vary from 7.2°C near Komakuk Beach to 10°C at Aklavik; there is a definite southeasterly trending gradient along the Coastal Plain. Maximum temperatures can exceed 26°C on the Coastal Plain during summer; temperatures greater than 32°C have been recorded at Aklavik. January mean daily temperatures range from -28.9°C at Komakuk Beach to -31.7°C at Aklavik; temperatures are affected somewhat by topography. Extreme minimum temperature generally is about -50°C.

Winds are a dominant element of the climate. In general, wind directions are probably parallel to the coast, but anomalies may arise due to lee or mountain waves, wind flow along valleys, katabatic and land-sea winds. Although winds are more persistent in summer, maximum velocities over 65 km/h usually occur during winter.

Although the Arctic is considered to be an 'arctic desert', the shallow active layer keeps much of the ground relatively wet. Precipitation along the Coastal Plain averages around 13 cm at Komakuk Beach, rising to almost 25 cm at Aklavik; mountainous areas may receive greater amounts. Peculiarly, monthly maximum precipitation in 24 hours commonly exceeds the mean monthly precipitation. Approximately half of the precipitation falls as snow. Maximum snow cover averages about 50 cm on the Coastal Plain, although depths are variable due to drifting. Fog and cloud cover are maximum during the summer and fall, when the adjacent sea is free of ice.

Permafrost

The Yukon Coastal Plain and adjacent areas are located in an area of continuous permafrost. The average ground temperature near the mouth of Babbage River on the Coastal Plain is -8.5 ± 1.5°C, -2.5 ± 1.5°C on the northern part of the MacKenzie Delta, and -3.5 ± 1.5°C on the southern part of the Mackenzie Delta (Mackay, 1975). On the Coastal Plain the thickness of permafrost is probably well in excess of 300 m (cf. Judge, 1973) but is shallower under recently formed landforms such as drained lake basins and the aggrading distal edges of deltas. For example, Mackay (1971) reports the base of permafrost on low distal islands of the Mackenzie Delta as being within 91 m of the surface. Taliks are probably present under major streams, floodplains, drained lake basins, spits, baymouth bars, and any feature where mean annual ground temperatures recently have been decreased.

Active layer thicknesses vary according to deposit characteristics and vegetation cover. Generally, fine-textured soils covered by peat and moss have active layers less than 0.3 m thick, whereas gravels and sands with broken vegetative cover have active layers varying in thickness from less than 1.2 m near the Alaska-Yukon boundary to more than 2.5 m thick in the Richardson Mountains opposite Aklavik (R.M. Hardy and Associates Ltd. and Terrain Analysis and Mapping Services Ltd., 1976). Ice wedges occur in all deposits except floodplains and marine coastal features, where deep active layers prevent their formation. As previously discussed, ground ice is distributed widely throughout the Coastal Plain.

Vegetation

The Yukon Coastal Plain is covered by tundra. Most vegetation types are dominated by sedges; better drained slopes are characterized by "...cottongrass tussock tundra dominated by *Eriophorum vaginatum* and *Carex* species. Shrubs are not lacking in the tussock tundra, but their role is subordinate to the cottongrass" (Welsh and Rigby, 1971). Flat areas commonly are characterized by wet sedge meadows. Willow shrub (predominantly *Salix alaxensis*) is common along streams and sheltered lakeshores.

Although shrub birch (*Betula nana* L. and *B. glandulosa* Michx.) is present over much of the Coastal Plain, it only becomes an important component southeast of King Point. Alder (*Alnus crispa* (Ait.) Pursh) has its northern limit within the coastland, occurring mainly as part of the riparian vegetation on streams near the southwestern edge of the Coastal Plain and southeast of King Point (Matthews, 1975).

The vegetation of the bordering mountains is similar to that of the Coastal Plain, especially on lower slopes and along streams. At higher elevations, however, many areas such as block fields, outcrops, and talus are bare of vegetation or are covered by clumps or strips and patches of *Dryas*, *Empetrum*, *Betula*, and *Carex*. Different rock types support different floras (Welsh and Rigby, 1971). Open spruce woodland occurs on favourable habitats along Firth River and its tributaries (Matthews, 1975) and in some sheltered valleys in the Richardson Mountains (Mackay, 1963b).

Within the map area the vegetation of the Mackenzie Delta consists predominantly of shrubs (dominated by willows and alder) with clumps of scattered poplar in the northern part. South of Shallow Bay, it is covered by a complex of spruce forest interspersed with areas of alder and willow shrubs and sedge flats. Poplar stands also are present (Mackay, 1963b).

PHYSIOGRAPHY

The area considered in this report has been described previously by Bostock (1948, 1970) and lies within parts of his British Mountains, Richardson Mountains, Porcupine or Arctic Plateau, Arctic (Yukon) Coastal Plain, and Mackenzie Delta. Discrepancies between his two classifications evidently resulted from the fact that in his early work (Bostock, 1948) a physiographic description of the northern Cordillera was involved, whereas in his later work (Bostock, 1970) a physiographic description of Canada was attempted. An attempt has been made in Figure 1 to maintain Bostock's basic classifications but also to delineate the physiographic units in more detail according to natural physical boundaries. In addition, Bostock's Arctic (1948) or Porcupine (1970) Plateau has been discarded; mountainous and hilly areas have been integrated into the British and Richardson mountains; planate areas have been integrated into the Yukon Coastal Plain; and a range of hills and mountains lying between Babbage and Blow rivers has been grouped into a unit called the Barn Mountains (Barn Range).

Because of geomorphic complexities within physiographic units, the study area has been divided into physiographic elements to describe the geomorphology more fully. Elements present are mountains, hills, and plains. Hills are individual or clusters of prominences that rise above the surrounding area and generally are less than 370 m from base to summit. Mountains are prominences that exceed the height of hills and generally are characterized by a restrictive summit area, steep slopes, and considerable bare rock. Along the Coastal Plain, hills are rounded with summits below 760 m above sea level (a.s.l.). Major and minor valleys having restricted widths have not been excluded from areas classified as mountains and hills. Plains are extensive areas of comparatively flat, smooth, or gently undulating terrain having few surface irregularities. They may have a considerable slope but are at low elevations relative to adjacent areas. Streams crossing these features may be incised considerably below the general plain surface.

British Mountains and Buckland Hills

Geomorphology and drainage

The British Mountains are the eastern extension of the Brooks Range, which crosses northern Alaska. The British Mountains are highest adjacent to the Alaska-Yukon Boundary between the headwaters of Firth and Malcolm rivers where peaks exceed 1680 m elevation; summit elevations decrease in all directions from this area. Peaks and ridges are generally steep sided and sharp crested, although rounded crests are not uncommon. Most valleys are V-shaped and narrow. Local relief within the British Mountains generally ranges between 460 and 600 m. Although most ridges have a west-northwest or northwest alignment, other orientations are not uncommon.

The Buckland Hills form the northern foothills of the British Mountains. Major ridges also are aligned west-northwest or northwest, but most local relief is between 300 and 460 m, and few hills exceed 760 m in elevation. Ridge crests generally are rounded, slopes less steep, valleys broader, and outcrops less common in the Buckland Hills than in the British Mountains. An east-west trending extension of the Coastal Plain between Firth and Malcolm rivers has been included within the Buckland Hills (Fig. 1).

Although the Buckland Hills merge with the British Mountains to the south, the boundary with the Yukon Coastal Plain to the north is marked by a 120 to 245 m escarpment along most of its length (Fig. 2).

Figure 2

Boundary between British Mountains and Yukon Coastal Plain near the Alaska-Yukon Territory boundary. (GSC-203452)

The drainage pattern within the British Mountains and Buckland Hills is broadly dendritic, although the northwest alignment of some ridges and structures has caused parallel alignment of some streams. Firth and Malcolm rivers are the two major rivers having their source in the British Mountains and form major gaps in the escarpment between the Buckland Hills and the Yukon Coastal Plain.

Bedrock

The British Mountains are the surface expression of the Romanzof Uplift in Canada, a structural feature of Tertiary age (Norris, 1974). Major structures within the Romanzof Uplift are northwest-southeast plunging folds and southwest-dipping reverse faults (Norris, 1973) which account for the northwest alignment of ridges described above.

Most of the British Mountains are underlain by the intensely folded and faulted Precambrian Neruokpuk Formation, consisting of a lower unit of limestone and shale and an upper unit of argillite and lithic sandstone (Norris, 1972). Overlying the Neruokpuk Formation are cherts and quartzite pebble conglomerates of the Kekiktuk Formation; carbonaceous and calcareous shales, grey coaly quartzite, coal, and limestone of the Lisburne Group; mudstone of the Sadlerochit Formation (all Permo-Carboniferous in age); and limestone of the Triassic Shublik Formation, and shale of the Jurassic Kingak Formation. Unconformities exist, and the sequence is not necessarily complete at any one locality (Norris, 1972). Mount Sedgewick is underlain by Devonian(?) porphyritic granite; Late Devonian volcanic agglomerate overlies the Neruokpuk Formation near the Alaska-Yukon Boundary (Norris, 1973).

Barn Mountains

Geomorphology and drainage

The Barn Mountains (Barn Range), which are an eastern extension of the British Mountains, consist of a group of hills and low mountains between Babbage and Blow rivers. Bostock (1948, 1970) previously had included this group of prominences in either his Arctic or Porcupine Plateau physiographic units. The mountains and hills are isolated in clusters by broad valleys and basins that interconnect with the Coastal Plain. Some mountains, such as the group that contains Mount Fitton, have peaks exceeding 1100 m elevation, although most peaks and hill crests do not exceed 915 m elevation; local relief of 460 m is common. Individual peaks and ridges generally are sharp crested (Fig. 3), although some low hills are more subdued and rounded. Ridge crests commonly have curvilinear shapes, reflecting local bedrock structure.

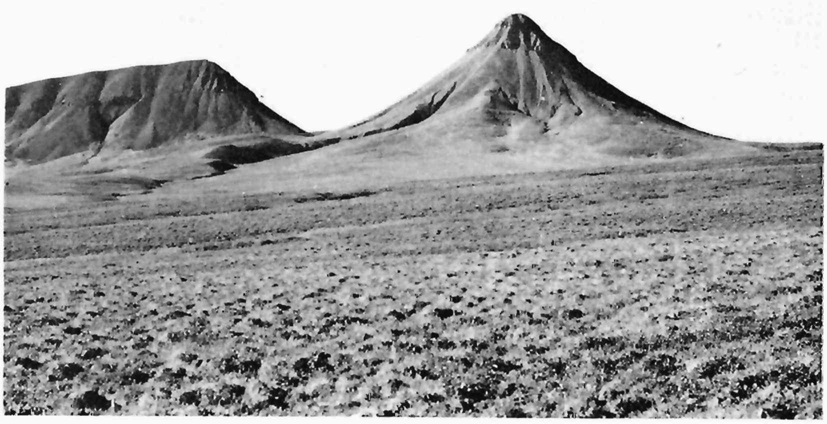

Figure 3

Sharp-crested peaks and ridges in the Barn Mountains. (GSC-203452-A)

Boundaries between mountain groups and the intervening valleys and basins are delineated sharply by escarpments, as is most of the boundary between the Barn Mountains and the Coastal Plain. This boundary, however, is less distinctive than the boundary between the British Mountains and the Yukon Coastal Plain to the west because of the somewhat rolling nature of the Coastal Plain near the Barn Mountains.

Slopes within the Barn Mountains sweep up from valley axes towards the flanking hills and mountains with dramatic steepening at the boundary between valleys and hills. Resistant rock strata have resulted in local, small, rounded ridges and hills in the valleys, with local relief rarely exceeding 50 m elevation.

Within the study area, the Barn Mountains form the headwaters of the southeastern tributaries of Babbage River and the northwestern tributaries of Blow River. A well integrated, dendritic drainage pattern has developed.

Bedrock

The Barn Mountains are the surface reflection of the Barn Uplift (Norris, 1973), the easternmost part of the Romanzof Uplift. Major structures within the Barn Uplift, which are reflected in the geomorphology, are imbricated southwest-dipping thrust faults and open folds with northwest-trending axial tracts (Norris, 1973, 1974). The southeastern edge of the Barn Mountains may coincide with the western edge of the Rapid Creek Fault array, part of the Kaltag Fault, a major Cretaceous fault resulting from the interaction of drifting continental plates (Yorath and Norris, 1975).

Strata present are similar to those in the British Mountains, namely the intensely folded Neruokpuk Formation; chert, conglomerate, quartzite, shale, coal, and limestone of the Carboniferous Kekiktuk and Kyak formations; limestone of the Triassic Shublick Formation; shale of the Jurassic Kingak Formation; and Cretaceous shale and sandstone (Norris, 1972). Devonian porphyritic granite is exposed on Mount Fitton (Norris, 1973).

Richardson Mountains

Geomorphology and drainage

The Richardson Mountains have been described by Bostock (1948, p. 35):

> "The greater part of these mountains presents the aspect of closely spaced hills with smooth profiles, broken only here and there by aligned outcrops of harder strata crowned by scattered crags. For the most part, Richardson Mountains are not more rugged and are lower than the southern foothills of the Rocky Mountains ... and their position adjacent to areas of relatively low relief---Mackenzie Delta, Peel Plateau, Arctic Plateau, and Porcupine Plain---is partly responsible for their being termed mountains."

The northern Richardson Mountains comprise a western fringe of peaks and ridges with no particular orientation, a central part of peaks and hills connected into north-south oriented ridges and broad parallel-aligned valleys, and an eastern fringe of rounded hills with deeply incised streams.

The western fringe is mountainous, with peaks connected by ridges trending in various directions. Local relief is generally 460 m, except along the northern fringe where rounded hills stand only 150 m above valley bottoms. Most valleys are V-shaped and narrow, although a few broad valleys and basins are present. Elevations of peaks and ridges range from 900 m at the southern edge of the mapped area to between 460 and 760 m near their northern edge. Local relief varies from about 460 m in the southern mountainous area to about 150 m in the northern hills.

The central part consists of north-south oriented ridges and intervening parallel, broad valleys. The ridges, reflecting bedrock structure, are commonly asymmetric in profile. In the southeastern corner of the study area many peaks and ridges have broad crests and are mesa-like. Elevation of ridge tops ranges from 1230 to 1530 m along the southwestern edge of the mapped area to around 310 m at the northern edge of the Richardson Mountains. Local relief is as much as 610 m along the southwestern edge of the mapped area. The valley bottoms are characterized by gentle slopes, although they may be rolling and locally hilly due to effects of glaciation or local bedrock structure and lithology. Streams along the axis of these valleys commonly are deeply incised into narrow canyons.

Figure 4. Escarpment between the Mackenzie Delta and Aklavik Range. (GSC-203452-B)

The eastern fringe consists of a narrow belt of rounded ridges, separated by moderatly wide valleys. The entire complex is dissected deeply by steep-sided canyons and gullies. Upland relief does not exceed 250 m, but the canyons, such as that of Willow River, commonly add another 150 m to the relief. Maximum elevations in the eastern fringe of the Richardson Mountains rarely exceed 770 m. The boundary between the Mackenzie Delta and the eastern edge of the Richardson Mountains is formed by a major 460-m-high escarpment called the Aklavik Range (Fig. 4). This ridge and adjacent ridges are little more than high hills, but their extreme elevation above the adjacent Mackenzie Delta gives them an imposing mountainous appearance.

The Richardson Mountains are drained by streams that flow north and northeast, parallel to geomorphic and structural features. Most major streams are incised in narrow canyons. The stream pattern of the minor tributaries is mainly dendritic although it takes on a trellis arrangement in areas of strongly folded, interbedded, resistant and weak strata. Due to the diversionary effects of glaciation on the drainage, a few lakes are present in the east part of the Richardson Mountains.

Bedrock

The northern Richardson Mountains from part of the Aklavik Arch, namely the Cache Creek and Rat uplifts and the Rapid and Canoe depressions (Norris, 1973, 1974). These features are characterized by north and northeasterly trending folds and near vertical faults.

The oldest rocks exposed in the northern Richardson Mountains are Permo-Carboniferous clastics and limestone of the Sadlerochit Formation (Norris, 1973). They are overlain unconformably by Jurassic quartzose sandstone and siltstone and interbedded lower Cretaceous lithic sandstone, shale, and less commonly by ironstone and chert conglomerate (Young, 1972; Norris, 1976).

Yukon Coastal Plain

Geomorphology and drainage

The Yukon Coastal Plain includes all flat and gently sloping land that lies adjacent to the northeastern edge of the British, Barn, and Richardson mountains. Bostock's Arctic (1948) or Porcupine (1970) Plateau and Arctic (1948) or Yukon (1970) Coastal Plain have been combined into this physiographic unit as no clear-cut division exists between the units. They appear to be part of the same geomorphic system, i.e., a plain constructed through erosional and depositional processes but with a common base level---some ancestral form of the Beaufort Sea.

The flat to gently rising surface of the Yukon Coastal Plain can be divided into two parts (Fig. 1): (1) the area fringing the Beaufort Sea, having negligible regional slope but showing minor undulations and (2) the area fringing the mountains to the south, having a gentle coastward slope. Broadly, the coastal fringe corresponds with Bostock's Arctic (1948) or Yukon (1970) Coastal PLain, and the mountain fringe corresponds with his Arctic (1948) or Porcupine (1970) Plateau.

The coastal fringe is underlain by thick unconsolidated deposits, generally more than 60 m thick, although bedrock may be nearer the surface along its inland edge. Typically, west of Firth River the surface is almost flat, and the only relief is due to the incised stream valleys, 3 to 15 m below the surface (Fig. 2), and small thermokarst basins inset 1.5 to 6 m below the general level of the plain. East of Firth River, lakes and ponds of thermokarst origin spot the plain. Local relief rarely exceeds 30 m, and elevations are generally below 60 m except for Herschel Island (maximum elevation near 185 m) and the ridge connecting Kay Point and King Point (maximum near 80 m). The coastal scarp rises from about 9 m near the Alaska-Yukon Boundary to about 30 m near Stokes Point; east of Stokes Point it ranges between 30 and 60 m. Coastal scarps are absent where alluvial fans of major streams, such as Firth and Malcolm rivers, impinge on the Beaufort Sea west of Herschel Island.

The mountain fringe is primarily an erosion surface or pediment that sweeps up to the edge of the mountains and extends into the mountains along major streams. It consists of a narrow strip of land near the Alaska-Yukon Boundary, but widens considerably east of Firth River. The coastward edge of the mountain fringe has a relatively thick cover of unconsolidated deposits, which thins towards the mountain front. In all areas, the coastward slope of the terrain is clearly a reflection of the surface of the underlying erosion surface developed on bedrock.

The mountain fringe of the Coastal Plain is interrupted near the mountain front by rounded bedrock hills and ridges, which are outliers of the mountains to the south. Generally they have a north-south orientation similar to that of major ridges of the mountains to the south. Local relief along the edge and within these hills rarely exceeds 155 m; maximum elevations are generally around 470 m.

The surface of the mountain fringe not only slopes upward to the mountains but also slopes upward to the southeast. For example, the coastward edge of the erosion surface related to the Coastal Plain is below sea level west of Firth River but is near 125 m elevation at the mouth of Big Fish River. Also, the elevation of the base of the escarpment forming the border between the mountains and the Coastal Plain is at about 125 m elevation near Firth River and between 250 and 280 m near Big Fish River. East of Blow River the Coastal Plain takes on a more rolling aspect due to deep stream dissection and broad indistinctive hills in interfluve areas. Whereas Babbage and Running rivers are incised only 30 to 60 m below the surface of the Coastal Plain, Blow River is incised 95 m and Big Fish River is incised as much as 155 m below its surface.

Adjacent to the Mackenzie Delta, just west of Aklavik, a 60- to 125-m-high escarpment separates the main part of the Coastal Plain from a segment bordering the Delta whose surface generally ranges between 60 and 155 m elevation (Fig. 1). This segment is separated from the Mackenzie Delta by a 30 to 60 m rise, whereas near the mouth of Big Fish River the main part of the Coastal Plain is separated from the Mackenzie Delta by a 125-m-high escarpment.

Although the coastal fringe is poorly drained and is spotted by lakes, the mountain fringe is moderately well drained due to its gentle and regionally continuous slope. Locally lakes occupying morainic and thermokarst depressions are present. Most major streams draining the mountains east of Babbage River cross the Coastal Plain in deeply incised canyons and drain adjacent local areas (Fig. 5). In general, these streams flow directly northeastward towards the coast, but some have been deflected northwest and parallel the coast.

Bedrock

The Yukon Coastal Plain is the landward extension of the Beaufort Shelf. Onshore the Beaufort Shelf is underlain by Jurassic and Lower Cretaceous shale and sandstone, commonly quartzose, which are draped over slaty argillite and quartzite of the Neruokpuk Formation west of Firth River (Norris, 1974). Where the Coastal Plain widens east of Firth River, Upper Cretaceous shale, mudstone, sandstone, and conglomerate, and Tertiary sandstone, conglomerate, coal, and shale are widespread (Young, 1975). Structures mirror the styles present in the mountains to the south; northwest trending thrust faults, common in the British Mountains, continue under the Coastal Plain adjacent to the British Mountains; north and northeast trending faults and folds, common in the northern Richardson Mountains, continue under the Coastal Plain adjacent to the Richardson Mountains (Yorath and Norris, 1975).

Norris (1973, 1976) has shown a normal fault paralleling the bedrock escarpment that offsets part of the Coastal Plain west of Aklavik (Fig. 1). The escarpment between the Yukon Coastal Plain and Mackenzie Delta may be related in some way to faults along the western edge of the Delta.

Figure 5. Incised stream and escarpment adjacent to the Mackenzie Delta near the Yukon Territory-Northwest Territories boundary. (GSC-203193-D)

Mackenzie Delta

"The Mackenzie Delta is a flat, near sea-level deltaic plain developed on fine-grained unconsolidated sediments. The delta is 130 miles long and about 40 miles wide, with its long axis trending NNW. Its surface is covered by a maze of lakes and channels" (Rampton, 1974b, p. 5).

Blow River, Big Fish River, Willow River, and minor streams flow out of canyons onto the Mackenzie Delta, integrating into the distributaries on the Delta surface. Large, coalescing, low-angle alluvial fans on the east side of the Mackenzie Delta have been included in this physiographic unit.

Erosion surface

Description

Much of the study area is characterized by an erosion surface or pediment that slopes gently from the mountain front towards the coast. The coastward edge of the erosion surface is covered by thick unconsolidated deposits. As proximity to the mountains increases and the overburden becomes thinner, however, the erosion surface becomes extremely well defined.

Slopes on the erosion surface are relatively gentle if minor surface irregularities are ignored. Generally, it shows a concave profile with slopes less than 1° on the outer part, steepening to 4° to 7° near the escarpment at the inner edge. Erosion surfaces or pediments, which are described in Figure 1 as plains, also are present within the mountains where they are adjacent to a number of streams (Fig. 6). They are best developed within the mountains where softer and more easily eroded rocks are concentrated. Gentler slopes in the intermontane valleys usually range between 2° and 4°; slopes gradually steepen to more than 7° near bordering escarpments where they generally exceed 15°. The transition between the erosion surface and the escarpment takes place over a relatively short lateral distance. Erosion surfaces within the mountains are at relatively high elevations, commonly more than 760 m in the Barn and Richardson mountains.

Away from the mountains, but within the mountain fringe of the Yukon Coastal Plain, ridges and hills stand out above the erosion surface or pediment (Fig. 1).

Modern streams and their associated terraces are incised within the erosion surface (Fig. 6). Secondary relief due to erosion is much greater at the eastern end of the study area where major streams are incised as much as 150 m, whereas near the western edge incision is commonly less than 30 m. In places stream incision and dissection are so great that it is difficult to identify the erosion surface. Secondary relief also is created by depositional landforms associated with glacial materials superimposed upon the erosion surface and by thermokarst and fluvial modifications of these deposits.

As outlined in the description of the Yukon Coastal Plain, it appears that the erosion surface slopes upward to the southeast.

The cover of unconsolidated, but predominantly frozen, sediments on the erosion surface is thinnest on its high, unglaciated parts. Up to 3 m of colluvium of a mixed nature ranging from bouldery rubble to organic clayey silts or gravels, ranging from 1.5 to 15 m thick, overlies eroded bedrock. In the glaciated area 6 to 20 m of glacial and nonglacial sediments commonly overlies the erosion surface, and on parts of the Coastal Plain unconsolidated sediments more than 45 m deep overlie the erosion surface.

Origin and age

A pediment is thought to be a geomorphic unit formed by the parallel retreat of escarpments in areas of semi-arid climate. Basically, processes such as weathering, mass movement, local gullying, and basal sapping continuously erode the face of retreating escarpments. The material produced at the base of the escarpments is weathered and is transported across the pediment surface by creep and sheetwash. The expansion of the pediment continues regardless of the rock type in which the eroding escarpments are developed, although rock type undoubtedly affects the rate of retreat. Similar to stream erosion, pediments develop more rapidly in less resistant rocks such as shale and mudstone, and pediments in mountainous areas generally are underlain by such rock types. The fact that the surfaces of pediments intercept various rock types tilted at different angles, however, indicates that pediments do not owe their existence solely to differential erosion of rock types or to structural control, but to the development of planar erosion by pediplanation or similar processes.

Figure 6

Pediments along the upper reaches of Purkis Creek. A number of terraces visible in the centre of the photograph were formed by Purkis Creek as it eroded a canyon to its present level. (GSC-203452-D)

The exact age of the erosion surface or pediment along the Yukon Coastal Plain is difficult to determine. Hughes (1972) noted similar surfaces throughout much of the northern Yukon and was unable to determine the age or the climatic conditions under which they developed; however, there seems to be little doubt that they were formed under different conditions than prevail today. Flat surfaces underlain by permafrost do not appear conducive to sheetwash. Also, the present stream valleys, which are deeply incised, do not seem to be in equilibrium with the present form of the pediments. Surely the pediments related to some late Tertiary interval when climatic conditions may have been warmer. However, soil profiles showing deep weathering or oxidation have never been noted on pediment surfaces. The erosion surface predates some regional tilting and faulting of tectonic origin as can be evidenced by the northwestward slope of its surface, deep stream incision, and a bedrock escarpment (fault) displacing the surface near the Mackenzie Delta (Fig. 1). The maximum age of formation of the erosion surface is limited by the youngest rocks, the Aklak Member of the Reindeer Formation of Cretaceous or Paleocene age (Young, 1975), that it truncates. All evidence points to a late to middle Tertiary age for the formation of the erosion surface.

QUATERNARY GEOLOGY

The Quaternary stratigraphy, landforms, and history of the Yukon Coastal Plain can be divided conveniently into preglacial, glacial, and postglacial intervals. Although parts of the Coastal Plain may have been glaciated twice, the glaciation (Buckland) that affected most of the Coastal Plain and that is responsible for the formation of most glacial landforms is probably early Wisconsin in age. Sediments deposited and landforms constructed previous to this glaciation, therefore, predate the early Wisconsin; deposits and landforms formed after this glaciation have been designated as postglacial, even though they may date from as early as the mid-Wisconsin.

Pre-Buckland Glaciation

Deposits predating the Buckland Glaciation are best seen in coastal exposures on Herschel Island and along the coast between Roland Bay and the mouth of Eagle Creek; scattered exposures are present along the remainder of the coast and throughout the Coastal Plain (Fig. 7). The most prominent preglacial Quaternary features are the alluvial fans developed on the unglaciated erosion surface (pediment) and altiplanation terraces in the British and Richardson mountains. Both features lie beyond the maximum extent of any glaciation.

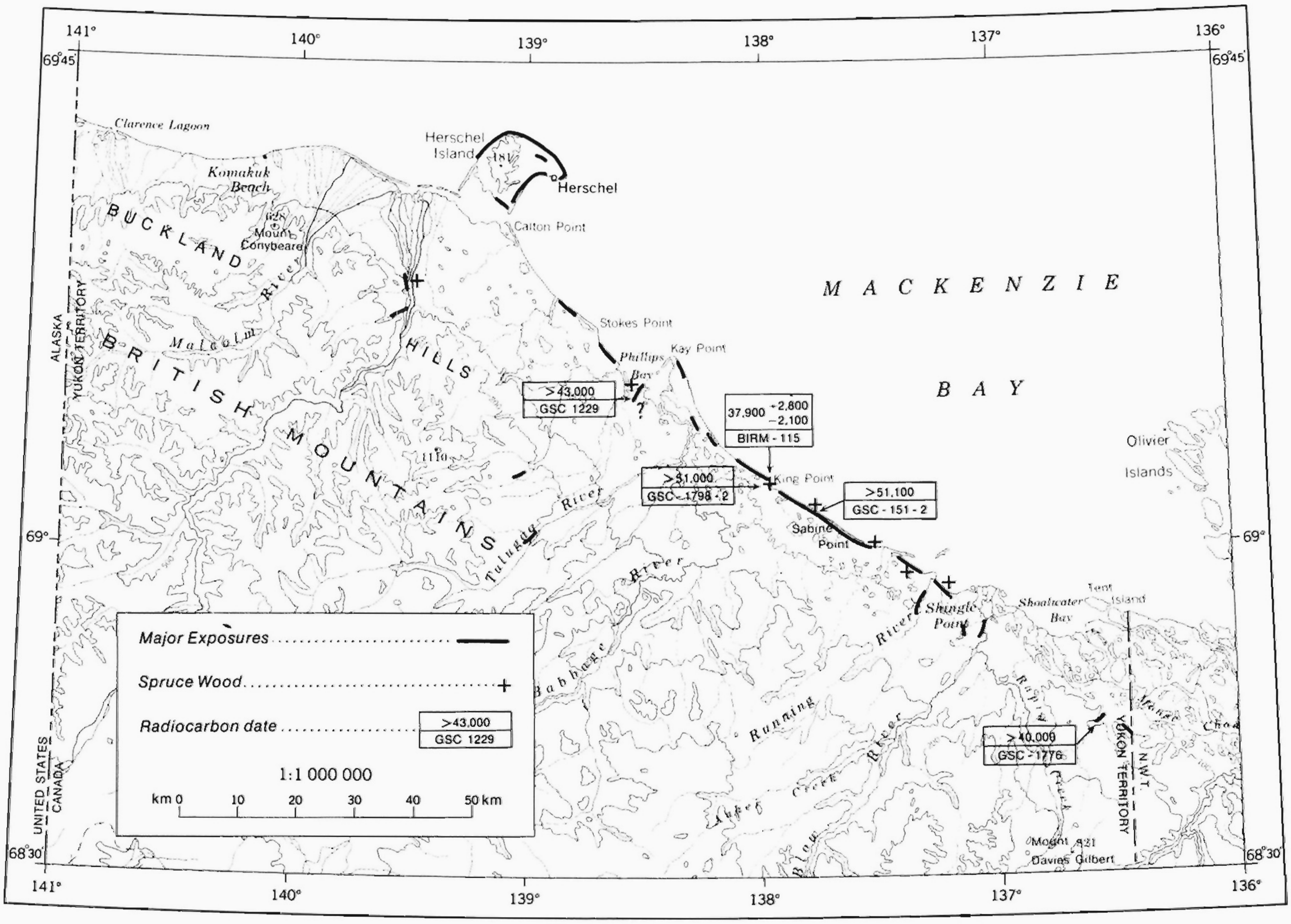

Figure 7. Locations of exposed pre-Buckland sediments, identified spruce wood, and radiocarbon dated material.

Stratigraphy: Malcolm River - Babbage River

Between Roland Bay and the mouth of Crow River 15- to 20-m-high bluffs expose pre-Buckland sediments under a sequence of postglacial lacustrine sediments and till. Some sections examined near the midpoint between Roland Bay and the western end of Stokes Point lagoon indicate that the till in this area is underlain by at least 8 m of dark grey clay and clayey silts. At one locality, marine ostracods and foraminifera were found to be plentiful in the 2 m of clay underlying the till. Lower sediments, where exposed, contain only organic detritus but presumably are also marine. Near the western end of the lagoon at Stokes Point, brownish sands with silty interbeds and rusty gravels, which appear to underlie the marine clays and silts, are exposed above sea level due to uplift of the sediments during glacial deformation. East of Stokes Point, the stratigraphic sequence appears similar in that fine-grained sediments of probable marine origin underlie till.

South of Phillips Bay, slumping makes it difficult to determine the exact position of sand containing gravel interbeds up to 20 cm thick and waterworn twigs and logs. Both Fyles and myself originally reported these sediments to overlie till (Mackay et al., 1972). The contact between the sand and till, however, nowhere was cleanly exposed and thus leaves the exact stratigraphic sequence open to interpretation. Furthermore, shothole logs[1] in the area indicate that fine-grained lacustrine sediments and till at the surface commonly are underlain by gravel and sand. Thus the sand exposed south of Phillips Bay may be pre-Buckland in age.

On the glaciated part of the Coastal Plain the materials underlying tills in retrogressive thaw flow slides were generally either icy sands or silty clays, undoubtedly similar sediments to those exposed along the coast. Shothole logs however indicate a significant amount of subtill gravel south and west of Bloomfield Lake to Firth River.

On the unglaciated erosion surface 6 to 15 m of gravel commonly overlies bedrock, especially between Spring and Crow rivers just beyond the limit of glaciation and west of Firth River. The gravel is generally coarse and contains subangular clasts of local origin. The gravel probably correlates with gravel underlying till in shotholes in adjacent areas. Only at one exposure on Firth River did gravel appear to underlie glacially contorted sediments, but even here the nature of exposure at the time of examination left open the possibility that terrace gravels had been covered by slumped sediments from adjacent terrain. Spruce wood has been identified from contorted pre-Buckland sediments at Firth River and indicates that the area was covered by spruce forest or the tree line was nearby during deposition of the sediments.

Stratigraphy: Kay Point - King Point

Much of the high ridge paralleling the coast between Kay Point and King Point is composed of pre-Buckland sediments that have been deformed and in part elevated to their present position by glacial overriding. From Kay Point to within a few kilometres of King Point most of the sediments are thinly bedded marine clays and silts. Erosion by Babbage River, however, has exposed steeply folded and faulted silt, sand, and gravel in a 60-m-high cliff on the landward side of the ridge. The sequence consists of 3 m of rusty gravel overlying 3.7 m of fine silty sand containing wood, 1 m of sandy silt with much plant detritus and wood, 2.4 m of coarse crossbedded sand, and more than 7.5 m of sandy silt containing woody mats and peaty layers. The sequence is indicative of a deltaic or floodplain environment. A similar sequence, repeated due to faulting, is exposed in a gully about 15 km southeast of Kay Point (Fig. 8; Table 1). Pollen spectra from units B and C of this stratigraphic sequence can be divided into two zones (Fig. 9) which indicate that two different vegetation types covered the landscape during deposition of the two stratigraphic units. During pollen zone "a" the landscape was covered by a forest-tundra or possibly the northern fringe of the boreal forest---certainly the site was south of the tree line. During pollen zone "b" the landscape was covered by tundra vegetation dominated by dwarf birch and sedge with associated heath (J.C. Ritchie, pers. comm., 1976). The climate during deposition of these units appears to have been significantly warmer during pollen zone "a" and similar to today's climate during pollen zone "b".

West of King Point a complex of glacially deformed marine, floodplain, and deltaic sediments is exposed in cliffs for about 1.5 km (Mackay, 1959). The sediments consist of interbedded gravel, sand, silty sand, and clay. Beds of gravel and coarser sand, which contain abundant wood, many pods

Table 1. Stratigraphic sequence shown on the walls of a gully located 15 km southeast of Kay Point (Cooper, 1973)

Unit	Thickness	Lithology
	(m)	
A	3.0	Fine grey sand, silty sand, and yellow-brown sand and gravel; horizontally bedded; laterally varying; thin layers of yellow silty sand and silt, and lenses of wood; rare lenses of peat near the base.
B	0.6 - 3.0	Silt, dark brown to black; horizontally laminated.
C	0.0 - 0.3	Peat.
D	1.2	Pebble gravel; oxidized yellow-brown sand matrix; at one location crossbedded with 0.9-m-thick crossbeds.
E	0.0 - 0.9	Silt, dark brown; horizontally laminated; peaty in places; containing some wood fragments.
F	6.1	Sand, grey; crossbedded; thin layers of yellow sand and thin lenses of wood and gravel; sand finer and crossbeds thinner towards bottom of unit; horizontally layered at bottom.
G	4.6	Silt, brown-grey; horizontally laminated silt; the top 40 cm is dark brown, organic, with pebbles and dark wood fragments.

[1]Shothole logs are drillers' records of materials encountered while drilling holes, from 15 to 60 m deep, to emplace explosives for seismic work. Although not entirely accurate or complete, the logs give some indication of materials being drilled. Generally an experienced geologist can determine those records that contain useful information from those that are extraneous and unreliable.

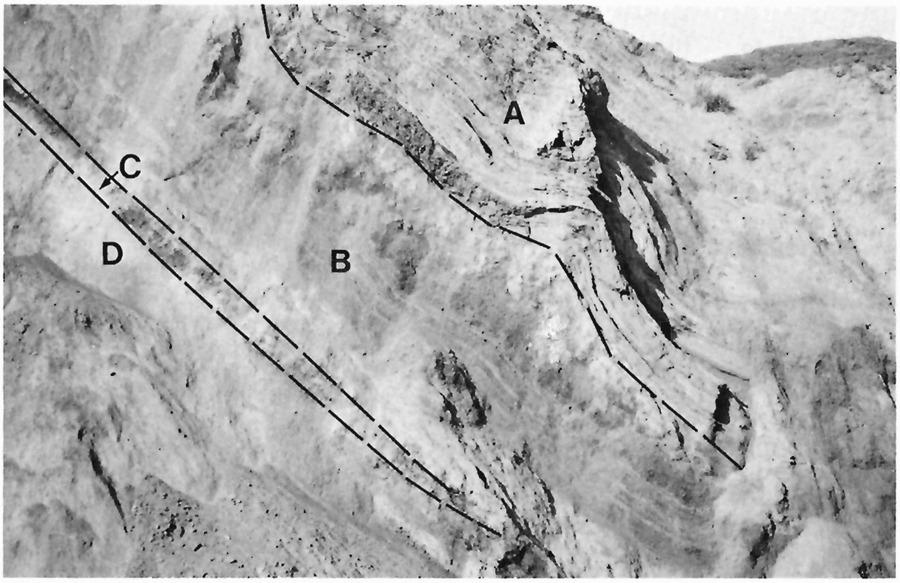

Figure 8

Folded and tilted sediments exposed in a guly 15 km southeast of Kay Point. A---interbedded sand and gravel with discontinuous lens of peat near the base; B---silt; C---peat; D---gravel (see Table 1). (GSC-202580-B)

and lenses of terrestrial peat, and no marine shells or other fossils, are considered to be channel deposits on an alluvial or deltaic plain. Clays containing marine shell fragments and silty sands containing marine ostracods or foraminifera are considered to be marine deposits. Fine sand and silty sand containing no diagnostic fossils but abundant organic detritus are considered to be of deltaic origin.

About 290 m west of the eastern end of the King Point section, in a sequence indicative of a deltaic environment with periodic marine submergence (Table 2), a 7.6-cm-thick bed of well preserved mossy peat that contained well preserved macrofossils and pollen was present. The diversified collection of mosses (Table 3) from the mossy peat bed indicates that bogs having small permanent pools and seasonally submerged areas and hummocks were locally abundant during the deposition of unit D (M. Kuc, pers. comm., 1973). Kuc further believed that the abundance of *Sphagnum* sp. in the collection of identified fossil mosses indicates a 'subarctic environment'. The pollen spectra of this peat indicates a tundra environment, with the tree line within 50 to 100 km of the site (J.C. Ritchie, pers. comm., 1976). The high *Betula* pollen percentage indicates that shrub tundra, dominated by dwarf birch, covered upland areas. Thus during the deposition of the mossy peat bed the climate was slightly warmer than or similar to the climate of today.

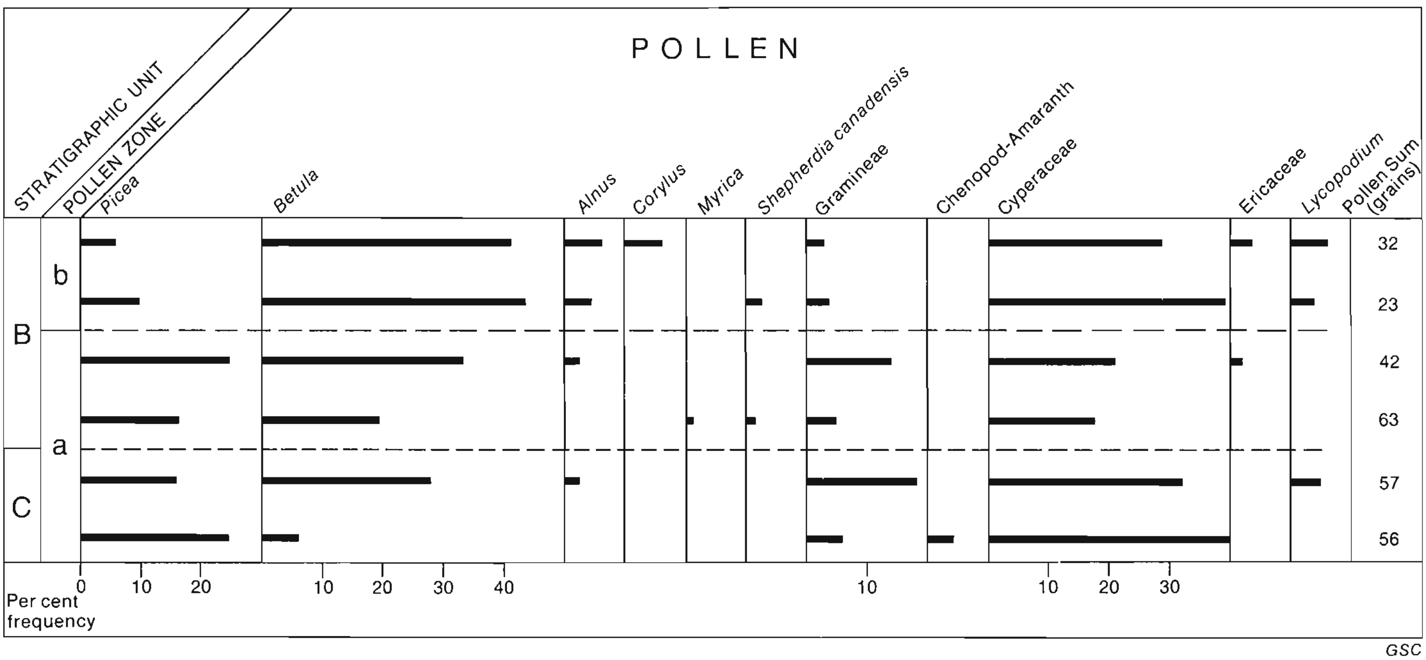

Figure 9. Pollen frequencies in samples from stratigraphic units B and C at an exposure 15 km southeast of Kay Point (see Fig. 8, Table 1). Pollen identified and analyzed by J.C. Ritchie.

Table 2. Stratigraphic sequence at the base of cliffs about 290 m west of King Point

Unit	Thickness	Description
	(m)	
A	---	Covered to top of cliffs.
B	3.0+	Gravel, pebbly; sand interbeds; lenses of woody detritus near base; top of unit covered.
C	2.1	Silt and fine sand, light brown; contains many shell fragments, shells (*Macoma baltica*), and foraminifera.
D	5.5	Silt, clayey; dark brown to black; wood; thin beds of peat and twigs common near base; 1.2 m from base a 7.6-cm-thick bed of mossy peat is present.
E	3.0	Gravel, cobbly; some sandy interbeds; base covered near sea level but appears to be underlain by sand.

*Table 3. Fossil mosses and pollen spectra from a peat bed (unit D, Table 2) in cliffs about 290 m west of King Point**

Mosses:

Sphagnum fuscum	Meesea triquetra
Drepanocladus exannulatus	Calliergon orbicularicordatum
D. exannulatus var. tundrae	C. giganteum
D. revolvens	C. cf. sarmentosum
D. adunus	Cratoneuron curvicaule

Pollen:	Per Cent
Picea	7.8
Betula	35.9
Alnus	2.1
Salix	0.8
Gramineae	2.1
Rosaceae	1.3
Rubus chamaemorous L.	0.4
Cyperaceae	49.0
Ericaceae	0.8
Lycopodium	0.2
Equisetum	0.2

*Mosses identified by M. Kuc; pollen analyzed by J.C. Ritchie, 474 pollen grains counted.

West of the section described above, gravel and sand are the more common sediment types for the next 610 m; sections described in Tables 4 and 5 are typical. Repetition of beds is probably due to thrust faulting and folding caused by overriding glaciers. For example, the angular discordance within the section described in Table 4 (Fig. 10) may represent a fault plane. The lithologies of units 2B, 2D, and 2H as described in Table 5 are similar; however, pollen spectra from units 2B and 2H are dissimilar, and unit 2D was barren of pollen (Fig. 11).

Sediment textures and fossils indicate that sediments in the sections described in Tables 4 and 5 represent a variety of environments. Units composed of gravel probably represent channel deposits on an alluvial or deltaic plain. Fine-grained sediments, the percentage of which increases towards the top of the sections, probably represent floodplain, deltaic, and rarely, shallow marine environments. Marine ostracods and foraminifera in units 1E (Table 4) and 2B (Table 5) certainly favour a marine environment for those units. Samples examined from other fine-grained units contained only organic detritus including a few seeds and insect fragments. Both sections indicate consistent fluctuations in relative sea level.

Pollen spectra from selected beds in the eastern section (Fig. 11) indicate that the landscape probably was covered by northern boreal forest dominated by spruce and birch during deposition of the upper part of the section if pollen spectra from units 1E and 1G are representative, and a forest-tundra vegetation complex during deposition of the lower part of the section if pollen spectra from units 1H and 1J are representative (J.C. Ritchie, pers. comm., 1976). Cones of *Picea glauca* found in unit 1G and 1H and spruce logs identified from similar gravels by the author and others (Naylor et al., 1972) confirm that spruce was growing nearby. Spruce needles, twigs and bark of *Betula glandulosa* and *Salix* sp., fragments of *Carex*, and leaves of *Sphagnum* and *Tomenthypnum nitens* (identified by M. Kuc) support the forest-tundra interpretation of pollen spectra from this unit.

Pollen spectra from selected beds in the western section (Fig. 11, stratigraphic units 2B, 2H, and 2K) indicate a landscape covered by tundra dominated by sedges with the tree line probably fairly close.

A gradual warming probably occurred in the area of the Yukon Coastal Plain during deposition of the beds exposed in the cliffs between sections described in Tables 4 and 5. The consistent eastward dip of strata along these cliffs (Mackay, 1959) indicates that the eastern section (Table 4) postdates the western section (Table 5). Paleoecological studies indicate that the climate was only slightly warmer than that of today during deposition of the western section, whereas it was significantly warmer during deposition of the upper part of the eastern section, when boreal forest covered the landscape.

Towards the western end of the cliffs west of King Point, gravel composing the lower 9 m of sea cliffs is overlain by sand and clayey silt containing marine shells. This sequence suggests that the fluvial and deltaic sediments exposed to the east, closer to King Point, are overlain by marine sediments.

About 4 km west of King Point, steeply dipping (60°N) gravel and sand containing much wood are superimposed on fine-grained sediments in another series of eroding cliffs. This apparent reversal in the stratigraphic sequence relative to the apparent sequence at King Point may be due to faulting and folding of ice-thrust origin.

Stratigraphy: King Point – Shingle Point Spit

Cliffs 3 to 5 km northwest of Sabine Point expose fine-grained pre-Buckland sediments under thick glacial and postglacial sequences. Table 6 is a composite section giving the typical stratigraphic sequences found in cliffs along this part of the coast; units E through H are pre-Buckland in age. The sediments appear primarily to have a freshwater origin, although the upper metre at some localities contains marine

Figure 10. Lower middle part of cliffs approximately 330 m west of King Point. Peaty beds and fine-grained beds are obvious in gravels of units 1H and 1I described in Table 4. Note angular discordance at level of figure. (GSC-203452-E).

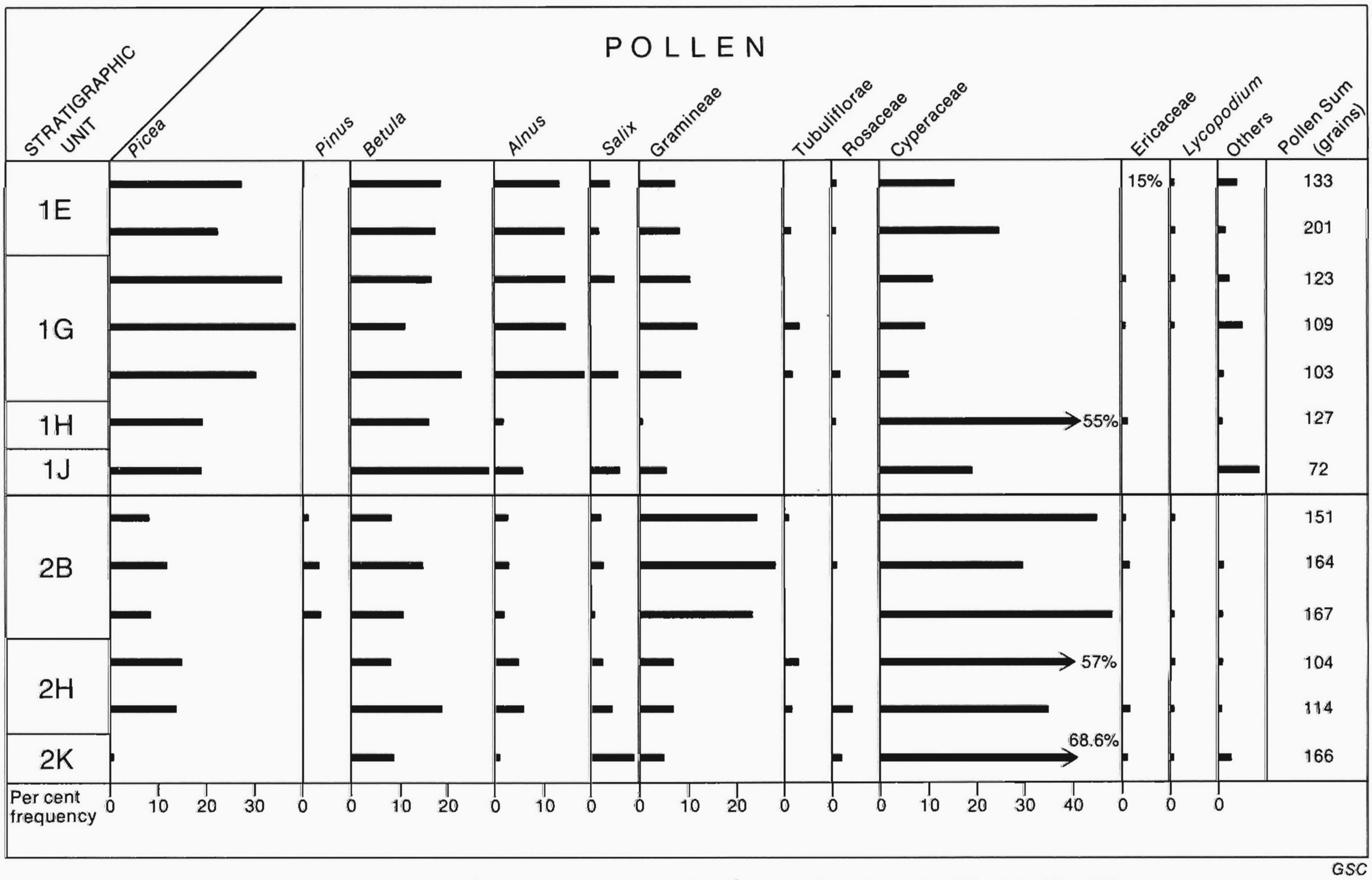

Figure 11. Pollen frequencies in samples from units 1E, 1G, 1H, 1J, 2B, 2H, and 2K at exposures west of King Point (see Tables 4,5). Sampled materials were mainly peaty beds and fine-grained sediments. Pollen identified and analyzed by J.C. Ritchie.

ostracods, foraminifera, and shell fragments. L.D. Delorme (pers. comm., 1974) identified freshwater ostracods (Table 7) from units F, G , and the base of unit E at the section described in Table 6. Similar sequences were noted as far east as Sabine Point, although locally some silty beds along these bluffs also contain marine shells. For example, 10 km southeast of Sabine Point, about 9 m of interbedded fine sand and laminated sand and silt contain peaty lenses, organic detritus, and freshwater ostracods. Driftwood in these sediments at one locality (Fig. 7) was identified as spruce.

Pre-Buckland sediments exposed between Shingle Point spit and King Point probably represent an alluvial or deltaic plain with relative sea level slowly rising towards the end of the interval represented by the sediment. Inland from the coast shothole logs indicate a coarsening of sediment and the probable inland source of sediment. At least one climatic fluctuation occurred during sediment deposition to allow for the formation of ice wedges and their subsequent thaw (Fig. 12). The presence of spruce wood suggests the possibility of spruce in the area, although it may be driftwood from more southern localities.

Stratigraphy: Shingle Point - Blow River

Between Shingle Point spit and the mouth of Running River, interbedded sands and gravels containing interbeds of silt, wood, organic detritus, and rare ice-wedge casts (Fig. 13) occur in the lower part of most cliffs. Although gravel predominates towards the mouth of Running River, sandy beds are present in the lower part of the gravel. At a few localities, it was noted that the lower part of the sequence was intensely iron stained; the discontinuous nature of

Table 4. Stratigraphic sequence in cliffs approximately 330 m west of King Point

Unit	Thickness	Description
	(m)	
1A	4.6	Covered to top of cliff.
1B	9.1	Sand, grey; gravel beds near top; largely covered.
1C	3.0	Gravel, cobbly.
1D	3.0	Covered; dark greyish brown clayey silt (?).
1E	8.5	Sands and silts, dark greyish brown; partially covered; some peaty layers and wood fragments near base of unit; contains marine ostracods and foraminifera.
1F	0.6 - 0.9	Gravel, pebbly, light brown; sandy interbeds.
1G	5.2	Sand, fine, brown; silty towards top of unit; gravel bed near base; two *Picea glauca* cones near base.
1H	7.6	Gravel, pebbly to cobbly; brown; crossbedded in places; sandy interbeds; 0.5-m-thick bed of mixed peat, wood, and gravel present 4.6 m above base of unit; contains spruce cones; 0.6- to 1.5-m-thick wedge of fine-grained sediments at base; spruce(?) logs common.
		Angular discordance
1I	3.0	Gravel, brown; sand interbeds; lenses of woody detritus.
1J	4.6	Sand, fine, grey; silt interbeds.
1K	4.6	Gravel, cobbly, rusty; sand interbeds.
1L	3.0	Covered to sea level.

Table 5. Stratigraphic sequence in cliffs approximately 610 m west of King Point

Unit	Thickness	Description
	(m)	
2A	3.0	Gravel (outwash?).
2B	4.6	Sand, fine, brown; grades to silt below mid-point; wood; contains marine ostracods and forams.
2C	10.7	Gravel; sandy beds; wood common.
2D	8.2	Sand, fine, brown; grades to silt below mid-point; peaty layers near mid-point.
2E	9.1	Gravel, cobbly; sandy interbeds containing wood and organic detritus.
2F	0.9	Sand, brown; lower part cross-bedded; contains much organic detritus.
2G	1.5	Sand and gravel, interbedded.
2H	4.3	Sand, brown; grades to silt below mid-point.
2I	3.0	Sand, orangish brown; cross-bedded; gravel near base.
2J	0.5	Silt, clayey, grey.
2K	12.2	Sand, brown; lenses of organic detritus; highly folded(?); base covered at sea level.

Table 6. Stratigraphic sequence in cliffs approximately 4 km northwest of Sabine Point

Unit	Thickness	Description
	(m)	
A	1.5 - 4.6	Peat; in part slumped.
B	3.0 - 10.7	Silt and clay, grey; peaty layers; rare plant fragments and pebbles scattered throughout.
C	1.5 - 3.0	Mudflow debris, light yellowish brown; jointed; oxidized; pods of peat and organic silt.
D	3.0 - 12.2	Till, clayey, grey; contains 0.3- to 0.6-m-thick layer of sheared clay near mid-point; upper 2.4 m oxidized(?).
E	4.6	Thinly bedded fine sand, silt, and clay.
F	1.5	Clay and silt, grey; very thinly bedded.
G	0.8	Clay, grey; massive; thin peaty bed near base.
H	2.4	Silt and fine sand, grey; thinly bedded; ice-wedge casts containing peat present.
I	1.5	Covered to sea level.

*Table 7. Fossil freshwater ostracods from sections approximately 4 km northwest of Sabine Point (see Table 6)**

Unit	Ostracods
E - base	*Candona rawsoni* Tressler 1957
F - base	*Candona rawsoni* Tressler 1957 *Ilyocypris bradyi* Sars 1890 *Limnocythere liporeticulata* Delorme 1968
G	*Candona rawsoni* Tressler 1957 *Candona acutula* Delorme 1967 *Ilyocypris bradyi* Sars 1890 *Limnocythere liporeticulata* Delorme 1968

*Ostracods identified by L.D. Delorme.

Table 8. Stratigraphic sequence on east bank of Running River, approximately 6.5 km south of its mouth

Unit	Thickness	Description
	(m)	
A	0.6	Sand, silty, peaty beds; post-Buckland.
B	1.5	Gravel, pebbly; Buckland.
C	0.9	Gravel, pebbly; sandy beds; pre-Buckland(?).
D	3.7	Gravel, coarse; foreset beds with peaty beds; contains fossil insects; pre-Buckland.
E	1.5	Till, stony; oxidized in part; pre-Buckland.
F	4.6	Gravel, cobbly; ice-wedge casts near top of unit; pre-Buckland.
G	1.5	Gravel, oxidized; ice-wedge casts; pre-Buckland.
H	7.6	Covered.

*Table 9. Fossil insects from a peaty bed in pre-Buckland sediments along lower Running River (see Table 8)**

Bembidion petrosum Gebler	*Holoboreaphilus nordenskioldi* Makl.
Pterostichus (Cyrobius) spp.	*Tachinus* cf. *T. brevipennis* Sahlb
Pterostichus haematopus Dej.	*Simplocaria* sp.
Amara sp.	Lathridiidae - Genus?
carabid larval fragments	*Chrysomela* sp.
Lathrobium sp.	*Lepidophorus lincaticollis* Kirby
Stenus sp.	Araneae - Genus?
Micralymma cf.	Oribatidae
M. brevilingue Schiødt.	

*Insects identified by J.V. Matthews, Jr.

Figure 12

Ice-wedge cast containing peat developed in pre-Buckland sediments northwest of Sabine Point. See Table 6 for further description of stratigraphic sequence. (GSC-202580-A)

exposure prevented establishing the continuity of the contact between unaltered and iron-stained gravels.

During investigations conducted by Northern Engineering Services Company Ltd. (1976), relevant sections on the banks of Running and Blow rivers were examined briefly. At both sites a till was identified that was believed to lie within the pre-Buckland sequence. The section on Running River (Table 8) lies on a meltwater channel, and the absence of Buckland till is probably due to removal by meltwater erosion. The early age of the till present (unit E, Table 8) is indicated by the fact that the fossil insect assemblage from peat in unit D above the till contained one beetle species *(Bembidion petrosum)*, which is not found as far north today (Table 9; J.V. Matthews, Jr., unpublished Fossil Arthropod Report 76-10). The section on Blow River (Table 10) was not exposed fully nor completely accessible, but the lower till (unit D) was overlain by pre-Buckland fluvial sediments and an equivalent of Buckland till. The extent of the glaciation that deposited the lower till is not clear; however, it may be confined to the eastern end of the Coastal Plain, as the two above mentioned localities are the only ones where till has been noted within the pre-Buckland sequence.

The nature of the gravels underlying the lower tills at the Running River and Blow River sites suggest a correlation between these gravels and gravels exposed between Shingle Point spit and the mouth of Running River. Ice-wedge casts and a lower oxidized unit are common to both sequences. The lower oxidized gravels probably represent an alluvial fan or terrace deposited under conditions cold enough to allow ice wedges to form. Following their deposition, the climate presumably warmed to a point where the ice wedges thawed and the gravels oxidized to depth. Presumably this would require significant degradation of permafrost. Following this warm interval, alluviation continued with fluctuations in climate or local thermal regimes to permit the formation and degradation of ice wedges.

Pre-Buckland sediments overlying the lower till at the Running River and Blow River sites appear to represent floodplain or deltaic environments. Insects found in peat in

Figure 13

Ice-wedge cast containing peat developed in lower part of pre-Buckland gravels between Running River and Shingle Point spit. (GSC-202580-D)

Table 10. Stratigraphic sequence on west bank of Blow River, approximately 6.5 m south of its mouth

Unit	Thickness	Description
	(m)	
A	0.6	Peat and pebbly silt; post-Buckland.
B	1.2 - 2.4	Diamicton; till and reworked till; Buckland.
C	9.1	Interbedded sand, silt, and oxidized gravel; peaty layers containing plant and insect fossils; unit poorly exposed; pre-Buckland.
D	4.6 - 12.2	Till; oxidized; pre-Buckland.
E	not measured	Gravel; oxidized; pre-Buckland.
F	not measured	Gravel; oxidized; pre-Buckland.
G	not measured	Shale to river level.

unit D of the exposure at Running River (Tables 8,9) were either characteristic of riparian habitats or the margins of well vegetated tundra or boreal ponds. One insect, *Bembidion petrosum* Gebler, is thought to be restricted to boreal environments and probably indicates the presence of a boreal forest on the Yukon Coastal Plain, which would be indicative of warmer summers than at present. The oxidization of sediments at the Blow River site (Table 10) and of underlying tills at both sites also indicates a warm climate.

Pre-Buckland sediments similar to those found along Blow River were seen in a retrogressive thaw flow slide on the upland near Coal Mine Lake. Shothole logs on the Yukon Coastal Plain and in many of the broad valleys in the northern Richardson Mountains indicate the presence of similar pre-Buckland sediments.

Stratigraphy: Herschel Island

The stratigraphy of Herschel Island is complicated by intense deformation of the sediments (Mackay, 1959; Bouchard, 1974), the discontinuous nature of exposures, and the lack of good marker beds that can be correlated from site to site.

Bouchard (1974) has separated the sequence into a number of units. Bouchard believed that 1 to more than 10 m of dark grey marine clays, containing a few shells, shell fragments, and pebbles and commonly showing a reticulate joint pattern, comprise the uppermost preglacial unit. Underlying this unit, Bouchard identified 'mixed' sediments, which he interpreted as representing deposition in nearshore (marine) and shoreline (brackish) environments. The mixed sediments were: (1) light grey to brown sand interbedded with silt containing shell fragments, organic detritus, and wood (1 to 9 m thick); (2) brown sand with silt laminae containing shells, shell fragments, organic detritus, twigs, and wood (3.7 to 15.2 m thick); and (3) brown to orange gravel containing shells and woody debris (0.6 to 1.8 m thick). Bouchard identified a lower marine unit of brown and grey silt with sand laminae, ranging from 1.2 m to more than 10 m thick. Bouchard also identified one nonmarine pre-Buckland unit consisting of 0.6 m of peat associated sand and silt in a ravine on the northeast part of Herschel Island. He did not stratigraphically relate this unit to other units. I concur with Bouchard's (1974) divisions.

Along the south coast of Herschel Island, east of Pauline Cove, the stratigraphy is confused by intense deformation, but the general sequence appears to be as follows (from top to bottom): 0 to 6 m of pebbly clayey diamicton; 3 m or more of pebbly gravel; 0.3 to 3 m of grey, thinly bedded fine sand and silty clay; 3 m of brown clayey silt with many shells and a few thin sands interbeds; 12 m or more of brown to grey very thinly bedded sand with a few pebbles and shell fragments near the upper contact. All sediments probably equate with Bouchard's (1974) 'mixed' sediments.

Reconnaissance from the air of the northeastern coast indicates that grey massive clays usually overlie brown 'mixed' sediments. Some sections show grey clay both above and below the brown 'mixed' sediments, but the apparent position of the underlying clay is probably due to folding and faulting of the sedimentary sequence.

About 2.5 km northwest of Collinson Head, 20 m or more of grey silty clay containing some marine shells and a few pebbles overlies 5.2 m of grey to brown thinly bedded sand and silt. The measured thickness of the marine clay must be considered as a maximum thickness as it was not possible to determine if the measured face was perpendicular or inclined to the bedding due to the massive nature of the clay. The sequence is more complicated 1.5 km farther along the coast. From top to bottom it consists of 6 m of thinly bedded brown sand, in part crossbedded; 12 m of partly covered silty clay with rare marine shells; 4.5 m of thinly bedded grey to brown sand and silt; and 3 m of dark grey clay. Whether this sequence is reversed due to deformation or whether the lower units are equivalents of Bouchard's (1974) lower marine unit was not clear.

About 8 km east of the northern tip of Herschel Island a sequence of 'mixed' sediments is exposed. Because of deformation, they are inclined at almost 90°; some repetition of beds may be possible. In the exposure, 12.8 m of interbedded grey clayey silt and sand, commonly thinly bedded, with beds rich in organic detritus and wood fragments and at least one thin gravel bed respectively overlies 5.5 m of sand with silty interbeds; 7.6 cm of peat (organic detritus mainly); 1.2 m of grey sand with thin interbeds of silty clay and organic detritus; 0.9 m of grey clayey silt; 3.7 m of interbedded pebbly gravel and sand with some beds rich in organic detritus; and 0.5 m or more of grey clayey silt.

Near the northern tip of the island, complexly folded and faulted grey marine clays and 'mixed' sediment are exposed. On the face of one sea bluff, 6 m of greyish brown sands with thin silty and organic-rich interbeds and 3 m of thinly bedded clayey silt and sand underlie 12 m of grey massive marine clays containing a few shells. This bluff parallels the axial plane of the overturned fold or thrust fault, which has structurally superimposed the sands and silts over 6 m of the same marine grey clay that they actually underlie. The remainder of the northwest coast is eroded mainly in marine clay.

West of Osborn Point along the southwestern coast of Herschel Island, as much as 10 m of interbedded clay, clayey silt, sand, and gravel are exposed. The fine sediments commonly contain pebbles and laminae of organic detritus and rare shell fragments. The gravel and sand commonly are oxidized. Pebbles are commonly subangular, and no exotic lithologies are present. Clearly this sequence represents a nearshore environment and is part of Bouchard's (1974) 'mixed' unit.

Along the southeast edge of Herschel Island, complexly folded 'mixed' and marine sediments apparently underlie ice-rich marine sediments, which are considered the equivalent of Bouchard's upper dark grey marine clay. The 'mixed' sediments consist mainly of interbedded brown to grey silty clays and fine sands with a few pebbly lenses, thin laminae of organic detritus, wood, and shell fragments. A 1- to 2-m-thick gravel bed overlain by pebbly clay was noted within the 'mixed' sediments at a number of localities. The 'mixed' sediments are up to 20 m thick along this section of the coast. Under the 'mixed' sediments, 6 to 10 m of grey marine clay silt with many shells is present; this unit is probably Bouchard's lower marine unit. The possibility exists, however, that the grey marine clayey silt may owe its relative position to the 'mixed' sediments because of deformation of sedimentary sequences at Herschel Island.

One section of 'mixed' sediments on the northern edge of Thetis Bay was described in detail (Table 11), and samples were collected for paleoecological purposes. Foraminifera from units A through D (Fig. 14) were interpreted by R. Todd (pers. comm., 1973) as indicating "...relatively shallow and nearshore conditions" of an arctic region. Marine ostracods from units B and D indicate a marine environment, and from unit C, a brackish environment (J.E. Hazel, pers. comm., 1973). Hazel believed the identified ostracods to be representative of arctic or subarctic conditions. With the exception of one species, *Rabilimis mirabilis*, all have been found in the Gubik Formation of northern Alaska. Molluscs collected from this same section by Naylor et al. (1972) indicate water conditions similar to those of the present, but pollen spectra suggest the closeness of a spruce woodland or forest. In summary, it appears that deposition of part of the 'mixed' sediments was in shallow marine and brackish waters and that the climate was warmer than that of the present, with trees on nearby land and slightly warmer water temperatures.

On the southern bank of a small valley about 5 km northwest of Collinson Head, a peat bed and associated nonmarine and marine beds are exposed (Table 12). The stratigraphy and fossil foraminifera and ostracods identified in the sediments (Fig. 14) indicate that the sequence represents gradual shoaling of a shallow nearshore marine environment followed by deposition in a shallow pond, presumably on a broad, gently sloping coastal plain. Eventually the pond drained and was covered by shrub tundra dominated by dwarf birch, willows, and sedges, which formed a layer of peat. Table 13 and pollen spectra of four samples from the peat in which *Picea* varied between 2 and 6 per cent, *Betula* between 15 and 30 per cent, *Alnus* between 1 and 6 per cent, *Salix* between 24 and 33 per cent, Gramineae between 6 and 12 per cent, *Artemisia* between 2 and 7 per cent, and Cyperaceae between 24 and 33 per cent (J.C. Ritchie, pers. comm., 1976) confirm this. The site was flooded again, first by fresh water and then by sea water (the upper part of the section is mainly covered).

Table 11. Stratigraphic sequence in bluffs on the north edge of Thetis Bay

Unit	Thickness	Description
	(m)	
A	0.6	Covered; silty.
B	5.2	Interbedded grey to brown sand and silt; contains shell fragments and pebbles.
C	2.4	Thinly interbedded grey to brown clayey silt and silty sand; contains abundant shell fragments and rare cobbles.
D	2.1	Light brownish grey fine sand; contains silt laminae and some shell fragments.
E	0.2	Covered.
F	2.4	Grey, very thinly bedded silt and fine sand.
G	0.9	Covered to sea level.

Table 12. Stratigraphic sequence along a small valley about 5 km northwest of Collinson Head

Unit	Thickness	Description
	(m)	
A	9.1	Covered; clayey silts(?).
B	1.8	Silt; very thinly bedded; laminae of organic material.
C	1.1	Silt, clayey; thin peaty and sandy interbeds.
D	0.2 - 0.8	Peat, woody; moss and plant fragments predominate; wood consists of branches up to 30 cm long and 1.9 cm in diameter.
E	1.5	Sand and silt, grey; thin peaty beds.
F	1.5	Silt, clayey; some pebbles and twigs.
G	2.4	Sand and silt; crossbedded near top of unit; some plant fragments present.
H	15.2	Covered to creek level.

*Table 13. Macrofossils in peat bed located in bluff along a small valley about 5 km northwest of Collinson Head**

Plants	*Mosses*
Salix sp.	*Ditrichum flexicaule*
Betula (dwarf)	*Polytrichym juniperinum*
Dryas integrifolia Vahl	Ditrichaceae
D. sp. cf. *chammisonis* Juz.	*Tomenthypnum nitens*
Potamogeton sp.	*Brachythecium* cf. *trachypodium*
Equisetum sp.	*Hylocomium splendens*

* *Macrofossils identified by M. Kuc.*

Strata deformation and undoubtedly rapid facies changes across a coastal plain complicate stratigraphic correlation but reinforce the general stratigraphic sequence proposed by Bouchard (1974), namely that 'mixed' sediments characterized by sediments of nearshore and shoreline environments are both underlain and overlain by marine deposits. All sediments along the southern edge of the island in which gravel, sand, and organic detritus are a component would seem to belong to the 'mixed' sediments unit. Along the northern coast, sequences containing gravel beds probably can be correlated with the 'mixed' sediments of the southern coast, but it is difficult to determine whether sandier units overlain and underlain by marine clay and silty clay are the equivalent of the 'mixed' sediments or are, in fact, a separate unit within the upper marine clay.

Tentatively, the peat bed and associated sediments exposed 5 km northwest of Collinson Head are considered to be a late emergent phase within the time represented by the upper marine clay. It cannot be ruled out, however, that this sequence belongs to Bouchard's (1974) 'mixed' sediments. During deposition of the peat bed , the vegetation was shrub tundra with a significant proportion of shrub birch, whereas during part of the interval covering deposition of the 'mixed' sediments, it was forest or forest-tundra, with spruce as a major component.

		MARINE OSTRACODS																FORAMINIFERA																FRESHWATER OSTRACODS			
SITE	STRATIGRAPHIC UNIT	Paracyprideis Pseudopunctillata	Eucytheridea Bradii	Acanthocytheris Dunelmensis	Robertsonites cf. R. Logani	Palmanella Limicola	Heterocyprideis Sorbyana	Rabilimis Septentrionalis	R. Mirabilis	Normanicythere Concinella	Pseudocytheretta Teshekpukensis	Cytheropteron cf. Latissimum	Pteroloxa venipuncta	Krithe glacialis	Cytheropteron montrosiene	Cythere? sp.	Candona sp.	Buccella frigida	Cassidulina teretis	Cornuspira involvens	Dentalina baggi	Dentalina frobisherensis	Florilus labradoricus	Elphidiella gorbunovi	Elphidium bartletti	Elphidium clavatum	Elphidium subarcticum	Glandulina laevigata	Oolina melo	Pseudopolymorphina curta	Pyrulina fusiformis	Quinqueloculina akeriana	Virgulina loeblichi	Candona candida	Candona rawsoni	Candona rectangulata	Cytherissa lacustris
Thetis Bay (Table 11)	A	+					+				+								+					+	+		+		+		+	+					
	B	+		+	+		+												+					+	+			+			+	+					
	B	+		+			+												+					+	+							+					
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Inland (Table 12)	B																																	+	+	+	+
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	G	+	+	+			+		+					+					+		+	+		+	+			+			+						

Fossil present ....+

Figure 14. Fossil ostracods and foraminifera found in exposures at Thetis Bay and along a small valley 5 km northwest of Collinson Head. Marine ostracods identified by J.E. Hazel, U.S. Geological Survey; foraminifera by R. Todd, U.S. Geological Survey; and freshwater ostracods by L.D. Delorme, Canada Department of Fisheries and Environment.

Correlation of sections

As can be seen from Table 14, a tentative correlation of strata is possible on the Yukon Coastal Plain in spite of discontinuous exposures, sediment deformation, and lack of detailed paleontological data. The uppermost pre-Buckland sediment exposed along the coast is a sequence of fine-grained sediments primarily of marine origin, although locally at Sabine Point and Herschel Island evidence of a marine regression is present during which freshwater sediments and a peat layer were deposited and ice wedges developed and thawed. The Herschel Island peat indicates that during part of this interval the vegetation was shrub tundra.

At Herschel Island and a number of localities along the coast a sequence of sediments is present that was deposited during a time when the landscape was covered variously by boreal forest, forest-tundra, and shrub tundra. The sediments represent a shallow marine and coastal plain environment at Herschel Island and alluvial, deltaic, and shallow marine environments at Kay Point and King Point. The alluvial sediments overlying an oxidized till in exposures along Blow and Running rivers tentatively have been correlated with similar sediments exposed near Kay Point and King Point.

The till and underlying gravels at the river exposures and gravels exposed along the coast west of Running River are considered unique.

Chronology

If the early Wisconsin age assigned to the Buckland Glaciation is valid (see section on Buckland Glaciation), all pre-Buckland sediments predate the early Wisconsin. At the localities where the contact between early Wisconsin till and the pre-Buckland sediments could be observed, it appeared to be gradual without signs of any weathering or soil horizons. This suggests that the upper pre-Buckland unit at most localities was deposited during the nonglacial interval immediately preceding the early Wisconsin which would make the sediments the equivalent of the Pelukian transgression of Alaska, considered to be Sangamon and early Wisconsin (Hopkins, 1973). Hopkins also noted that Pelukian sedimentary sequences show evidence of mid-unit regression of considerable duration during which ice-wedge casts were formed similar to those noted at Sabine Point (Fig. 12). A radiocarbon date of >51 100 years B.P. (Hughes in Dyck et al., 1966) on organic material from within this unit (Table 15) does not rule out a pre-Wisconsin age.

Lower sedimentary units, excluding the till and underlying gravels along Blow River, probably were deposited during an earlier interglacial or interglacials. The 'mixed' sediments and equivalent units at Kay Point and King Point contain fossils indicative of relatively warm climates. Matthews (1974) has indicated that warm intervals occurred during the pre-Illinoian in western Alaska, and a tentative correlation is suggested. Naylor et al. (1972) collected a sample of wood from near the base of the interbedded gravels and sands near King Point, and it was dated at 37 900 ± 2800 years B.P. As noted by those authors, however, the date is suspect. I concur with their conclusion as the described stratigraphic position of the wood indicates much greater antiquity, and a log identified as *Picea* sp. from about 12 m above sea level near the site examined by Naylor et al. (1972) was dated at >51 000 years B.P. (Table 15).

The age of the lower till along Walking and Blow rivers (Table 14) and sediments underlying it are presumed to predate the pre-Illinoian intervals discussed above.

Alluvial fans

Most of the erosion surface or pediment in the unglaciated part of the study area is covered by alluvial fan gravels, especially near the limit of glaciation flanking Tulugaq (Crow), Spring, and Firth rivers (units Fd, on Map 1503A). The surfaces of the preglacial alluvial fans slope gently towards the coast or valley axes with a slight steepening near the mountain front. The gravels forming the fans are capped by thick ice-rich silts and can only be examined in stream-cut escarpments.

Good exposures of the gravels contained within the alluvial fans are not common. In the few exposures examined, the gravel was generally coarse, crudely stratified, and contained pebbles reflecting local bedrock lithologies. No oxidation zones, wood, or fossils were discovered that might indicate the age of the gravels or the climatic conditions which prevailed during deposition.

The alluvial fans are probably early to middle Quaternary in age because their distal edges appear to be overlain by glacial deposits attributed to the Buckland Glaciation of probable early Wisconsin age. Although no exposures were found to demonstrate this clearly, stratigraphic sequences recorded in shothole logs suggest that the gravels continue under the till where alluvial fans abut against the moraines of the Buckland Glaciation (Fig. 15).

Altiplanation terraces

Altiplanation terraces were noted in two areas: (1) isolated occurrences along the northwestern edge of the Buckland Hills west of Malcolm River and (2) numerous examples near the headwaters of Willow River in the Richardson Mountains.

The isolated occurrences in the Buckland Hills consist of a series of narrow benches with 9- to 18-m-high scarps backing 30- to 60-m-wide benches (Fig. 16) developed on argillites and cherts of the Neruokpuk Formation.

Altiplanation terraces in the Richardson Mountains occur in series with as many as 15 terraces to a series. Each terrace consists of a 6- to 30-m-high scarp and a tread 30 to 150 m across (Fig. 17). The outer edge of the treads is underlain by angular blocky boulders, whereas the inner edge is covered by vegetation. These terraces are developed mainly in resistant quartz sandstones of the Jurassic Bug Creek Formation. Undoubtedly the near horizontal bedding and disintegration characteristics of the Bug Creek sandstone have aided periglacial processes in the formation of altiplanation terraces. Péwé (1975) noted that altiplanation terraces in Alaska were best developed on closely jointed resistant rocks.

Although the exact origin of altiplanation terraces is unknown, they are believed to form through periglacial processes. They generally lie below present and Pleistocene snowlines (Péwé, 1975; Washburn, 1973). Péwé believed that altiplanation terraces in adjacent Alaska were formed during the Pleistocene. All altiplanation terraces located adjacent to the Yukon Coastal Plain lie beyond the limit of the Buckland Glaciation; this distribution suggests that locally active formation of the altiplanation terraces was confined to early Wisconsin or pre-Wisconsin time or both.

Buckland Glaciation

General

At present no evidence exists to indicate that surficial deposits and landforms along the Yukon Coastal Plain and the adjacent mountainous area can be attributed to more than one glaciation of probable early Wisconsin age. The eastern fringe of the Richardson Mountains and southeastern fringe

Table 14. *Stratigraphic summary of pre-Buckland sediments exposed along the Yukon Coastal Plain*

Area	Herschel Island	Malcolm Lake to Babbage River	Erosion Surface	Kay Point and southeast	King Point	Sabine Point and northwest	Shingle Point	Walking to Blow rivers
General Stratigraphic Descriptions	Marine clays; possibly contain sequence of freshwater sediments. Vegetation---shrub tundra.	Marine clays		Marine clays; poorly exposed.	Marine clays	Freshwater silts overlain and underlain by marine sediments; ice-wedge casts. Vegetation---forest nearby(?).	?	Interbedded sands, silts, gravels, with peaty beds. Vegetation---tundra, tree line nearby.
	'Mixed' sediments from shallow marine and brackish environments. Vegetation---boreal forest.	Deformed sands and gravels.	? Gravels ? ?	Interbedded silt, sand, and gravel with peat beds. Vegetation---forest-tundra and tundra.	Interbedded clay, silt, sand, gravel, and peat. Vegetation---boreal forest, forest-tundra, and shrub tundra.		? Gravel ?	Till, oxidized. Gravel; ice-wedge casts.
						?	Gravel and sand, oxidized; ice-wedge casts.	Gravels, oxidized; ice-wedge casts.
	Marine clays						Vegetation---tundra and forest(?). (spans Shingle Point and Walking to Blow rivers)	

Table 15. *Radiocarbon dates on materials associated with pre-Buckland sediments (see Fig. 7 for location map)*

Laboratory Number	Location	Material and site description (reference)	Date (years B.P.)
Birm-115	1.5 km west of King Point; 69° 07'N, 138°01'W	Wood from about 6m above sea level in 33-m-high cliff composed of interbedded sand and gravel (Naylor et al., 1972).	$37\,900 \pm {}^{2800}_{2100}$
GSC-1798-2	1.5 km west of King Point; 69°07'N, 138°01.5'W	Spruce wood from 12 m above sea level in 45-m-high cliff composed of deformed sand and gravel (Lowdon and Blake, 1976).	>51 000
GSC-151-2	5.5 km east of eastern end of spit at King Point; 69°05'N, 137°50'W	Wood and peaty fragments, 0.6 m above sea level in organic silts grading up into stony clay with marine shells and overlain by till (Dyck et al., 1966).	>51 100
GSC-1776	North bank of Hornet Creek, 11 km north-northwest of Coal Mine Lake; 68°44'N, 136°36'W	Compressed *Salix* wood from clayey bed in 1 m of weathered gravel overlying shale and underlying 40 m of gravel (large part of section covered) (Lowdon and Blake, 1976).	>40 000

of the Yukon Coastal Plain, however, probably were covered by late Wisconsin ice. Radiocarbon dates and morainic landforms indicate that east of the Mackenzie Delta, Wisconsin glaciers covered hillslopes to elevations of 300 m just south of Campbell Lake and sloped below sea level between Reindeer Station and the southern end of Richards Island; if the glacier had a similar sloping surface along its western edge, the eastern fringe of the Richardson Mountains and the southeastern fringe of the Coastal Plain to the mouth of Cache Creek probably would have been covered by late Wisconsin ice (Fig. 18).

It is proposed here that the interval during which glaciers covered the Yukon Coastal Plain and adjacent mountainous areas beyond the late Wisconsin limit be called the "Buckland Glaciation" as its limit is clearly defined along the flanks of the Buckland Hills. A stillstand or readvance during deglaciation following the maximum extent of the Buckland Glaciation is indicated by a long morainic ridge and associated outwash features stretching from Kay Point to near Coal Mine Lake (Fig. 18). The author proposes that this readvance or stillstand be called the 'Sabine Phase' of the Buckland Glaciation, as Sabine Point is located opposite the central part of the ridge.

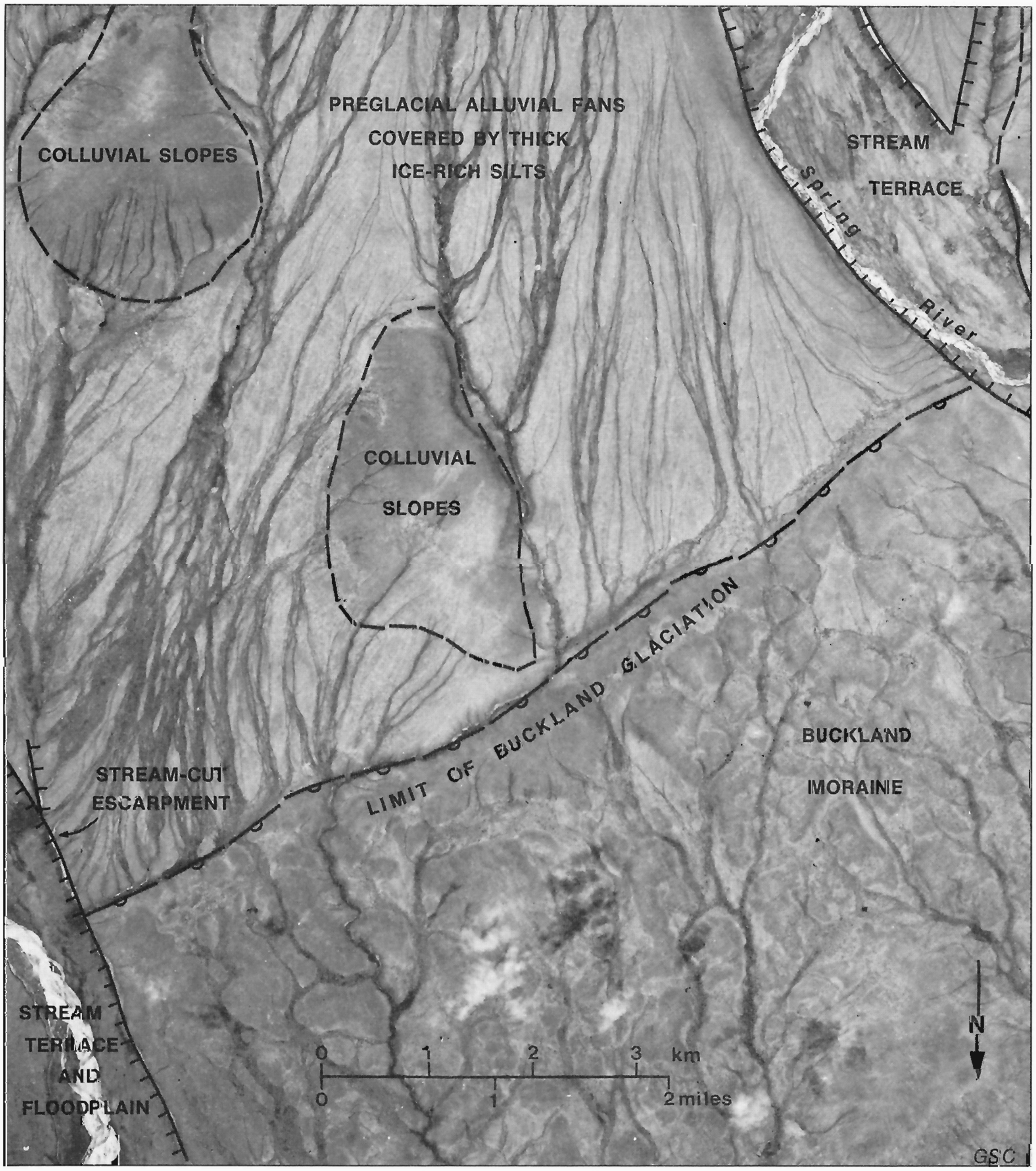

Figure 15. Buckland glacial limit between Spring and Tulugaq (Crow) rivers. (NAPL A24123-129)

Figure 16

Altiplanation terraces along the northern edge of the Buckland Hills. (GSC-203452-F)

Figure 17

Altiplanation terraces in Richardson Mountains near the headwaters of Willow River. (GSC-203452-G)

Limit of glaciation

The limit of Buckland Glaciation can be traced from the Richardson Mountains northwest along the Barn Mountains and Buckland Hills to where it reaches sea level near the mouth of Malcolm River (Fig. 18). The limit is marked by morainic ridges, the maximum extent of morainic topography, kame terraces and fans, meltwater channels, and the local maximum elevation of erratics (Hughes, 1972). The limit is most clearly marked by a morainic ridge between tulugaq (Crow) and Spring rivers (Fig. 15) and by numerous meltwater channels and kame terraces near Firth River (Fig. 19).

The glacial limit shows a gradual slope down to the northwest except for some irregularities where the glacier has advanced southwest along major valleys. The rather abrupt descent of the glacial limit in the northern Richardson Mountains probably does not reflect the slope of the glacier surface over the Mackenzie Delta but rather impedence to flow due to the mountainous topography along its southwestern edge. The rapid descent of the glacier surface north of Herschel Island probably is due to impedence caused by Herschel Island and drawdown effects of the subsea Mackenzie Canyon north of Herschel Island.

Moraines

Much of the area within the limits of the Buckland Glaciation is covered by moraines formed during the glaciation and modified by thermokarst and other periglacial processes. Most moraines show rolling to hummocky topography (Mh, Mm; Map 1503A), but the morphology of some ground moraine (M) primarily reflects slopes of the underlying bedrock. Although pre-Buckland sediments may separate morainal deposits from the underlying bedrock, they do not mask the configuration of bedrock slopes. Ice-thrust moraine (Mr) forms high ridges and hills near the coastline, e.g., Herschel Island.

The morphology of rolling and hummocky moraines appears to be due to thermokarst development rather than primary glacial deposition. A thermokarst origin for depressions within moraines is indicated by the thinness of the morainal deposits relative to intermorainal relief, by cores of ice-rich sediments or ground ice under most hills and ridges, and by sediments of thermokarst origin in depressions. Areas of hummocky moraine and sharper relief appear to be the result of recent thermokarst activity as attested to by active and stabilized retrogressive thaw flow slides in the belt of hummocky moraine south of Shoalwater

Bay. Rolling and hummocky moraine of a similar nature also has been attributed to the presence of massive ice and the effects of thermokarst east of the Mackenzie Delta (Rampton, 1973b; Rampton and Walcott, 1974).

Ground moraine is usually level to gently rolling with broad ridges and swales. On areas underlain by moderately to steeply sloping bedrock, however, surface slopes of ground moraine mirror those of underlying bedrock. In the Richardson Mountains and adjacent Coastal Plain, the major streams are deeply incised, and their small tributaries have eroded headwards into morainic areas, adding to the relief of these areas.

Two major ice-thrust moraines were formed during the Buckland Glaciation---Herschel Island and the ridge paralleling the coast between Kay Point and King Point. The latter feature forms part of the margin of the Sabine Phase of the Buckland Glaciation.

Herschel Island, which rises to nearly 180 m above sea level, consists of sediments ice-thrust by glaciers from under Ptarmigan Bay southeast of Herschel Island. The basin underlying Ptarmigan Bay has a volume approximately that of Herschel Island (Bouchard, 1974; Mackay, 1959). The deformed nature of the sediments is indicated by folds, inclined beds, fault planes, and shear planes exposed along stream cuts and coastal cliffs, and surface ridges and trenches along the northwestern side of the island (Bouchard, 1974). The formation of Herschel Island undoubtedly resulted from the presence of a thick overiding glacier and from high pore-water pressures in unfrozen sediments underlying permafrost (Mackay, 1959; Mathews and Mackay, 1960; Mackay and Mathews, 1964).

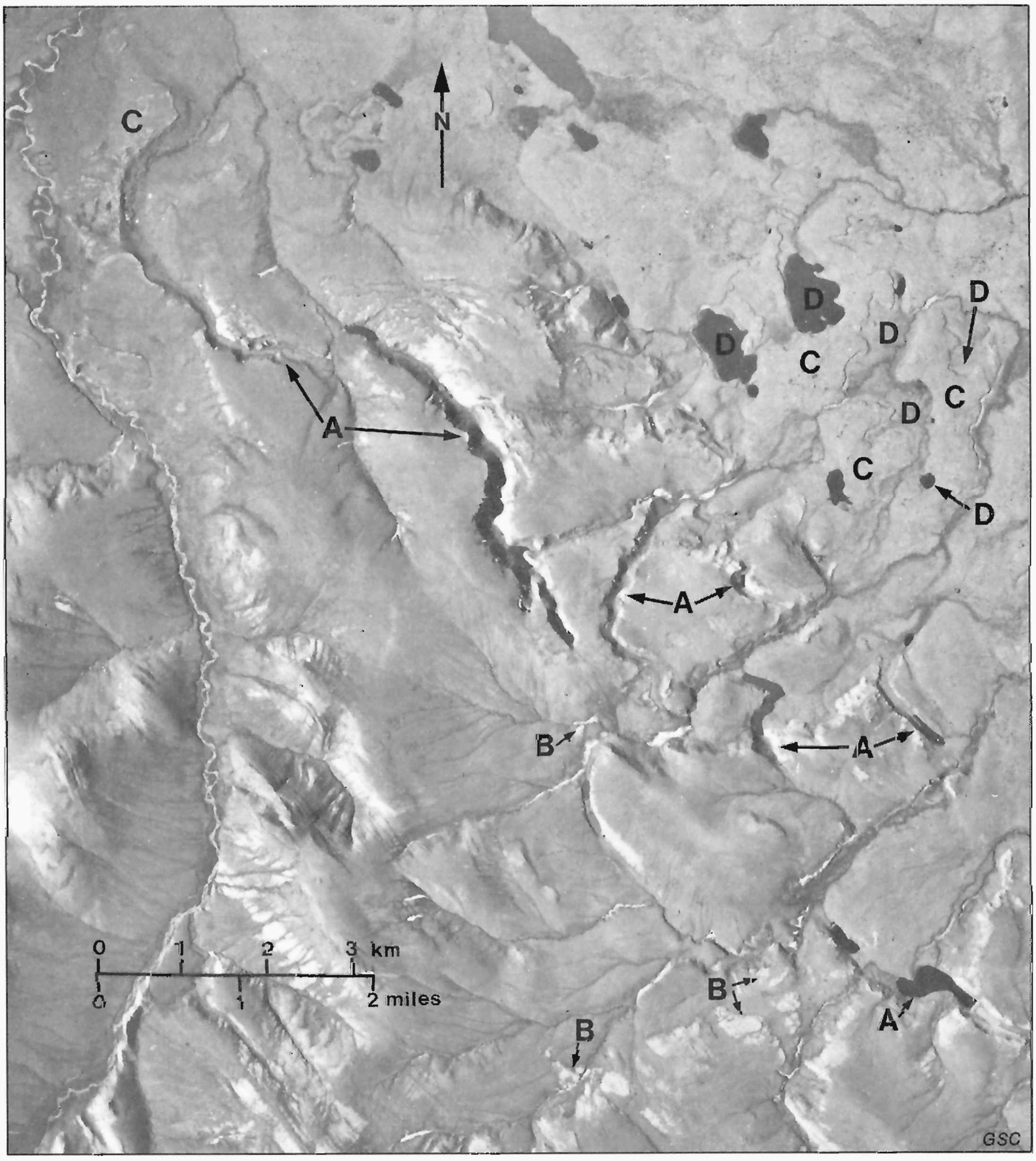

Figure 19. Glacial features near the limit of Buckland Glaciation east of Firth River including abandoned meltwater channels; A---kame terraces; B---and kame deltas; C---Note the thermokarst depression; D---within the kame deltas. (NAPL A13751-103)

The ice-thrust ridge running from Kay Point to King Point also rises well above the surrounding terrain to near 75 m elevation. Faults and folds observed in gullies near the midpoint of the ridge and near King Point indicate "...push to the southwest from an ice front that roughly paralleled the coast, a trend that agrees well with that of the lateral drainage channels. At King Point ... there was apparently a later thrust of sediments from the southeast over those produced by the Kay Point disturbance. These sediments probably came from the depressions forming King Point Harbour" (Mackay, 1959, p. 19). Again, permafrost and high pore-water pressure under the edge of an advancing glacier probably contributed to the formation of the ridge.

Kame deltas and terraces

Kame deltas and terraces (Gk) are concentrated near the limit of the Buckland Glaciation (Map 1503A). Generally they are flat benches perched against mountain and hillslopes or located at the downstream end of meltwater channels cutting across bedrock ridges (Fig. 19). Commonly they have been dissected by meltwater flowing at lower elevations as deglaciation proceeded (Fig. 20). Large kame deltas, such as the kame delta northeast of Purkis Creek, and terraces commonly are hummocky and channelled. The large complex of kame deltas southwest of Roland Bay shows typical channelling (Fig. 19). Although this channelling originally may have been due to meltwater dissection, the presence of ground ice in the kame sediments indicates thermokarst modification.

The large number of kame terraces and deltas adjacent to the limit of Buckland Glaciation is not solely due to meltwater flowing northeast along the southwest edge of the glacier. Undoubtedly streams that flowed out of the Richardson and British mountains and were diverted to the west by glaciers contributed to the formation of kame terraces and deltas.

Valley trains, outwash fans, and outwash plains

Outwash fans (Gf) and plains (Gp) are most common on the coastal fringe (Fig. 1; Map 1503A). Outwash plains formed here because streams that flowed along the southwestern edge of the Buckland glacier encountered lower gradients when they turned northeast across the coastal fringe of the Coastal Plain in front of the retreating glacier. During the late stages of formation of the plains, meltwater streams, which were obviously farther from a source of gravel and sand, locally incised and terraced the outwash plains. Due to their low gradient and poor drainage, the outwash plains commonly are covered by thick, icy, organic deposits, and only well drained areas adjacent to scarps have gravel surfaces.

Valley trains (Gp) and remnants of valley trains occupy a number of broad channels eroded by meltwater. Valley trains have low gradients, are poorly drained, and are covered by organic deposits having many shallow thermokarst lakes. The longest train occupies a broad valley paralleling the limit of the Sabine Phase of the Buckland Glaciation (Map 1503A). This valley train originates just southwest of Coal Mine Lake; remnants are present along the broad valley occupied by Deep Creek and its terraces to the northwest. Parts of the valley train may have been covered by a short-lived glacial lake and have been channelled during lake drainage. The valley train has been dissected by the valleys of major streams, such as Blow and Running rivers, that cross it.

Coalescing outwash fans flank the ridge forming the limit of the Sabine Phase of the Buckland Glaciation over most of its length (Map 1503A). They form a continuous series of benches from Peat Lake to southwest of Sabine Point. Flat areas on these benches are covered by ice-rich silts and peat. The fans were deposited by meltwater flowing southwest off glaciers occupying the area presently covered by Mackenzie Bay. The distal edges of the fans later were eroded by meltwater flowing northwest towards Phillips Bay parallel to the limit of the Sabine Phase of the Buckland Glaciation.

Eskers

Eskers (Gr) were formed both by streams flowing out onto glaciers from the adjoining mountains and by streams flowing parallel to the coast on the glacier surface. One of the largest eskers is located between Blow and Running rivers about 10 km south of Trent Bay (Map 1503A). This esker has a broad surface with numerous hills and depressions; much of the relief may be the result of thermokarst.

Figure 20

Kame terrace and meltwater channels near the limit of Buckland Glaciation west of Firth River. The small lake lies about 12 m below the flat upper surface of the kame terrace. (GSC-203193-G)

Meltwater channels

Most meltwater channels on the Coastal Plain parallel the limit of the Buckland Glaciation. Indeed, many channels are located along the Buckland glacial limit, especially along the Buckland Hills near Firth River (Fig. 19). At high elevations channels generally are eroded in bedrock along the edge of hills and across bedrock ridges; the most spectacular example of the latter is the channel occupied by Hidden Lake (Map 1503A).

Meltwater channels at low elevations on the Coastal Plain generally are eroded in unconsolidated materials. Channels generally parallel the defined limit of the Buckland Glaciation---presumably the edge of the glacier maintained a similar configuration to the limit of glaciation as it slowly retreated to the southeast. During the Sabine Phase of the Buckland Glaciation a broad meltwater channel was formed, paralleling the coast from south of Coal Mine Lake to near the confluence of Trail and Babbage rivers; Rapid Creek, near its mouth, has followed this channel for a number of kilometres. Rapid Creek and other major streams, such as Blow and Running rivers, have downcut to well below the base of this meltwater channel.

Glacial lakes

Undoubtedly some glacial lakes formed in stream valleys that were blocked by Buckland glaciers; however, conclusive field evidence is lacking for such phenomena. Erratics found near Trout Lake likely were ice rafted from the coastward glacial limit in a short-lived glacial lake along this part of Babbage River valley. No other features or deposits, however, were found at this locality that were indicative of a glacial lake. A number of other glacial lakes have been mapped (Gl, Map 1503A) where fine-grained sediments cover valleys near the limit of Buckland Glaciation or where faint traces of beach-like features confirm the possibility of a glacial lake having existed.

A lake covered large areas lying below about 75 m elevation along the lower reaches of Rapid Creek, Blow River, and the large meltwater channel leading northwest towards Jacobs Lake. Fine-grained sediments, 0.6 to 6 m thick, overlying outwash in this area are thought to have been deposited in a lake that formed when the channel was dammed by a slight readvance of the Sabine Phase. This blockage was short lived, and during drainage the sediments were reworked and broad meanders were formed on the surface near the outlet, as can be seen east of Running River. Most of the surface of this lake bed presently is poorly drained and is covered by peat and thermokarst lakes.

Glacial stratigraphy and chronology

Sediments attributed to the Buckland Glaciation usually overlie pre-Buckland sediments or bedrock and underlie a complex of lacustrine deposits, organic silts, and peat.

Till is present in a number of exposures along the Yukon coast between Stokes Point and Shingle Point. Generally where till directly overlies marine sediments, the contact appears relatively gradational with numerous shell fragments present in the lower part of the till. In fact, Mackay et al. (1961) were able to identify marine foraminifera in surficial material, probably till, near the glacial limit east of Firth River. The texture of till overlying coarser textured sediments similarly reflects the texture of these sediments.

Near Sabine Point, at one locality a 0.3-m-thick band of dark grey sheared clay sporadically occurs at the midpoint of the 6- to 12-m-thick pebbly till (Table 6). Perhaps the clay, which is probably marine, represents a short interval between the main phase and the Sabine Phase of the Buckland Glaciation. Coincidentally, the greatest thickness of till presumed to be Buckland in age is present near Sabine Point. Buckland till is generally less than 5 m thick, except where it has a high ice content.

In many localities the till is overlain by materials having a thermokarst origin. Unaltered till commonly is overlain by partially oxidized till containing pods of peat and grading upwards into lacustrine deposits.

Sticky clay, containing large boulders, exposed near sea level at a few localities west of Komakuk Beach likely is glaciomarine in origin and was deposited during the Buckland Glaciation.

The Buckland Glaciation is presumed to be early Wisconsin in age. Subdued morphology of moraines and landforms and radiocarbon dates obtained from materials overlying till on the Coastal Plain and regions adjacent to the eastern edge of the Mackenzie Delta (Mackay et al., 1972) indicate that the Buckland Glaciation predates the late Wisconsin.

Plant fragments and twigs in autochthonous peat in a pond sequence developed on Buckland drift near Stokes Point were dated at 22 400 ± 240 years (GSC-1262, Table 16; Fig. 21). The base of the lacustrine sediments was not exposed so it was not possible to date the oldest sediments in this thermokarst basin. Although the date falls within the late Wisconsin, it certainly predates the late Wisconsin maximum of about 13 000 years B.P. within the Mackenzie Delta area (Rampton, unpublished radiocarbon dates), and as such relegates the Buckland Glaciation to an earlier major glaciation.

The date of >43 000 years (GSC-1229; Table 16) on fragments of waterworn wood from south of Phillips Bay (Fig. 7) is difficult to relate to the Buckland Glaciation as the exact stratigraphic position of the sampled wood is open to question. J.G. Fyles (1966) collected the wood from near the base of a 3-m-thick unit of sand and gravel, which he believed overlay till-like pebbly clay. No continuous section, however, was measured. Similarly, I noted sands and gravels containing waterworn woody fragments at elevations of 3.7 to 9 m above sea level and till at elevations of 3 to 4.5 m above sea level in separate exposures along this part of the coast, but was unable to observe the two units in juxtaposition. The identification of the dated wood as *Picea* sp. indicates either that the sediments are nonglacial and probably predate the Buckland Glaciation or that the sediments are Buckland outwash consisting mainly of reworked pre-Buckland sediments which contained spruce wood. In any event, GSC-1229 cannot be used as positive proof that the Buckland Glaciation predates 43 000 years B.P.

A pre-Wisconsin age for the Buckland Glaciation is not probable because radiocarbon dates on sediments overlying Buckland till or outwash indicate that all major thicknesses of peat and weathering zones on Buckland till or outwash postdate 11 000 years (Table 16) and that no previous warm interval of an interglacial nature has affected sediments deposited during the Buckland Glaciation.

The Sabine Phase of the Buckland Glaciation is believed to have been a stillstand or readvance that occurred within the latter part of the glaciation with no major separation in time between that phase of the Buckland Glaciation when glaciers reached their maximum extent and the Sabine Phase. Basically, the morphology of moraines beyond the glacial limit of the Sabine Phase is similar to the morphology of those within it. Postglacial sediments within depressions also have similar thicknesses on both sides of the Sabine glacial limit. Although the oldest radiocarbon date on thermokarst sediments overlying Sabine drift is 14 000 ± 180 years (GSC-1792; Table 16; Fig. 21), this does not conclusively indicate that a major interval of time separates the Sabine Phase from earlier parts of the Buckland Glaciation; initiation of thermokarst activity was probably a climatically related phenomenon that occurred long after deglaciation of the Coastal Plain (Rampton, 1973a, b).

Table 16. Radiocarbon dates on materials associated with sediments that postdate Buckland Glaciation (see Fig. 21 for location map)

Laboratory Number	Location	Material and Site Description (reference)	Date (years B.P.)
A. GLACIOFLUVIAL OR FLUVIAL			
GSC-1229	South edge of Phillips Bay; 69°15'N, 138°30'W	Fragments of water-worn wood (*Picea* sp.) near base of 3 m of sand and gravel that appears to overlie till in composite section (Lowdon and Blake, 1973).	> 43 000
GSC-1670	Southeast side of Lopez Point on southwestern coast of Herschel Island; 69°33'N, 139°12'W	*Salix* wood from base of peaty layer, 0.6 m from base of 5.5 m of silty and sandy alluvium in a small alluvial fan (Lowdon and Blake, 1976).	3940 ± 150
GSC-1900	East bank of Malcolm River 18.5 km south of its mouth; 69°29'N, 139°57'W	Plant fragments in silty sand 1.5 m from base of 10.5 m of terrace gravels underlying 1.5 m of cover (Lowdon and Blake, 1976).	34 600 ± 1480
GSC-1838	Coastal exposure, about 8 km west of Komakuk Beach; 69°35.5'N, 140°22'W	*Salix* wood from peaty layer of midpoint of 3.7 m of gravel overlain by 1.8 m of organic silt (Lowdon and Blake, 1976).	10 200 ± 120
GSC-1853	Coastal exposure about 3 km west of mouth of Backhouse River; 69°36'N, 140°36'W	*Betula* wood from ice-wedge cast at midpoint of 4.5 m of gravel overlain by 0.5 m of silt (Lowdon and Blake, 1976).	10 900 ± 80
GSC-1881	East bank of Roland Creek; 69°13'N, 139°19'W	Wood fragments from 0.6 m of silty sand with thin peaty layers. Unit overlain by 1 m of gravel and underlain by 4.8 m of gravel (Lowdon and Blake, 1976).	4540 ± 60
BGS-197	Same as BGS-196	Surface peat (Zoltai and Tarnocai, 1975).	10 100 ± 130
GSC-480	Small scarp at Kay Point; 69°17.5'N, 138°23.5'W	Peat from base of ice-wedge cast transecting 3 m of sand and gravel (Lowdon and Blake, 1976).	9710 ± 140
GSC-1872	Coastal scarp about 1.5 km southeast of Kay Point; 69°17'N, 138°22.5'W	Peat from base of ice-wedge cast developed in 2.4 m of glaciofluvial gravel which is overlain by 3 m of sand with peaty lenses and 0.6 m of peat (Lowdon and Blake, 1976).	7170 ± 70
GSC-159	Coastal bluff, 5.5 km east of eastern end of spit at King Point; 69°05'N, 137°50'W	Peat from 5-cm-thick bed, 1.2 m from base of 5.8 m of lacustrine silt overlying till (Dyck and Fyles, 1964).	9510 ± 170
GSC-1792	Coastal bluff about 4 km west of Sabine Point; 69°04.5'N, 137°51'W	Peat from pods in contact zone between 1.5 to 3 m of partly oxidized diamicton and 1.2 to 1.8 m of overlying silt clay with peaty pods at base. Units underlain by till and overlain by 8.5 m of lacustrine clay and silt with peaty beds (Lowdon and Blake, 1976).	14 400 ± 180
GSC-2022	Coastal bluff about 5 km southeast of Sabine Point; 69°02'N, 137°38'W	*Populus* wood from base of 3 m of mudflow debris overlying pre-Buckland sediments (Lowdon and Blake, 1976).	9940 ± 90

B. THERMOKARST AND LACUSTRINE

GSC-1869-2	Coastal exposure, 400 m east of Alaska-Yukon boundary; 69°38'N, 140°59.5'W	Peat from upper part of 1.2 m of clay overlain by 4.5 m of lacustrine silty clay (Lowdon and Blake, 1976).	10 600 ± 260
GSC-1483	Coastal scarp, 1.5 km west of base of Herschel spit on Herschel Island; 69°34'N, 138°58'W	Basal peat from 4.3 m of peat, about 15 m above sea level (Lowdon and Blake, 1976).	9380 ± 170
GSC-506	Exposure at small lake, 1.5 km west of Difficult Creek; 69°26'N, 139°23'W	*Salix* wood from base of 0.6 m of peat overlying stabilized debris flow (Lowdon et al., 1971).	8860 ± 140
GSC-1808	Coastal bluff about 3.5 km east of Roland Bay; 69°22.5'N, 138°52'W	Peat pod in 0.5 m of oxidized bouldery sand overlying more than 0.8 m of till and underlying 4 m of lacustinne clay with many peaty layers (Lowdon and Blake, 1976).	9610 ± 90
GSC-1262	Coastal scarp opposite the western end of a large lagoon west of Stokes Point; 69°22'N, 138°48'W	Fragmented plant remains from midpoint of 1.5 m of fine sand underlying 1.5 m of gravel in lacustrine bench (Lowdon and Blake, 1976).	22 400 ± 240
BGS-196	Coastal Plain; 69°15'N, 138°02'W (exact location unknown, as given co-ordinates are obviously wrong; see Fig. 21)	Surface peat (Zoltai and Tarnocai, 1975).	8260 ± 110

C. SOLIFLUCTION

GSC-1875	Hillslope, 2.7 km west of Purkis Creek; 68°35'N, 137°16'W	Peat from under solifluction lobe, 1.2 m from front of lobe (Lowdon and Blake, 1976).	1160 ± 50
GSC-1790	Hillslope, 2.7 km west of Purkis Creek; 68°35'N, 137°16'W	Peat from under solifluction lobe, 0.6 m from front of lobe (Lowdon and Blake, 1976).	350 ± 50

D. ARCHEOLOGY

I-3911	Shore of small lake, 1.5 km northeast of Trout Lake; 68°50'N, 138°42'W	Charcoal from hearth in Eskimo house-pit (Buckley and Willis, 1972).	260 ± 90
I-4447	Same as I-3911	Charcoal in soil from top of pit hearth (Buckley and Willis, 1972).	4590 ± 110
I-4985A	Same as I-3911	Disseminated charcoal and willow twigs from intermediate and lower levels of large hearth (Buckley and Willis, 1972).	5490 ± 125
P-228	Engigstciak, east of Firth River about 25 km south of its mouth; 69°22'N, 139°30'W	Antler from shallow pit (Mackay et al., 1961).	3250 ± 160

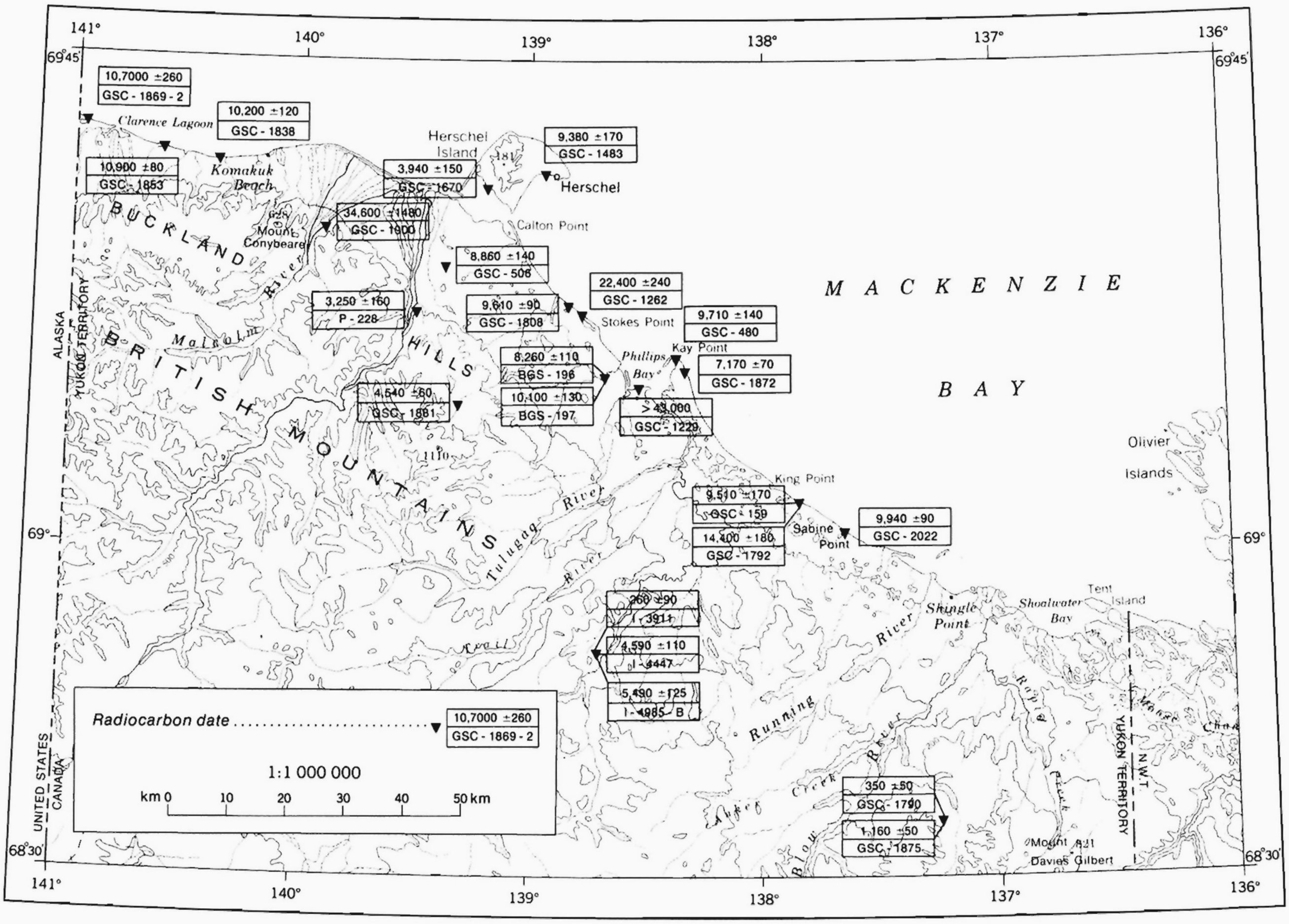

Figure 21. Location of radiocarbon dates from materials postdating the Buckland Glaciation (see Table 16 for further details).

Post-Buckland phenomena

General

Post-Buckland phenomena are generally of a nonglacial origin, the exception being glacial deposits, which are probably late Wisconsin in age, along the eastern edge of the Coastal Plain. The nonglacial phenomena consist mainly of ground ice and associated features, thermokarst, solifluction lobes, fluvial landforms and deposits, and marine beaches, bars, and spits.

Late Wisconsin glacial features

The assignment of some glacial features on the eastern edge of the Coastal Plain to the late Wisconsin is tentative and is based mainly on the identification of morainic ridges and meltwater channels at comparable elevations with late Wisconsin features in adjacent areas. Hughes (1972) has mapped a glacial limit, which he dated as late Wisconsin, along the base of the Mackenzie and Richardson mountains to the south, that descends to less than 300 m just south of the map area. On the east side of the Mackenzie Delta a glacial limit can be traced along the east side of Sitidgi Lake to 275 m above sea level near the southern end of the lake. Glacial features in the hills surrounding Noell Lake indicate that the limit in that vicinity stands at approximately 150 m elevation. The lack of fresh glacial features along the west side of the Caribou Hills and to the north indicates that the late Wisconsin ice sloped rapidly to sea level northwest of Inuvik.

A morainic ridge, kame delta, and meltwater channels north of Willow River directly west of Aklavik mark a major ice marginal position which was near 120 m elevation at Willow River (Fig. 18). North of Willow River subtle changes in morainic morphology and a number of meltwater channels trace a possible ice marginal position that would intercept sea level at the mouth of Cache Creek. This ice marginal position is believed to be the late Wisconsin glacial limit as it mirrors the probable late Wisconsin position on the east side of the Mackenzie Delta.

Ground ice and related phenomena

Ice wedges and epigenetic and aggradational segregated ice in the form of ice lenses and massive ice are common in surficial deposits of the Coastal Plain (Fig. 22). Most ice wedges examined were 0.6 to 1.5 m across at the top and extended 1.2 to 3 m into underlying sediments. Tundra polygons, which include high-centre and low-centre polygons, are the surface expression of ice wedges and are common on most flat areas and gentle slopes (Fig. 23). The diameters of polygons generally range from 6 to 45 m. Although ice wedges are present in morainal deposits, their presence generally is not indicated by polygons (Fig. 24). Evidently, the till composing morainal deposits is mobile enough to fill any trough that may form over a developing ice wedge. Similar sediment movement probably prevents troughs forming over ice wedges on slopes.

Ice wedges probably range in age from that of the underlying material to the present. Theoretically, ice wedges

Figure 22. Ice wedges in lacustrine sediments exposed near Sabine Point. The large ice wedge in the centre of the photograph has an apparent width of about 1.8 m at the top of the exposure. (GSC-203452-H)

should have begun to form in outwash and morainic deposits of early Wisconsin age immediately after deposition of the material. The relative age of an ice wedge can be assessed from the width of the overlying trench which forms the tundra polygon. For example, trenches in early Wisconsin kame terraces and deltas commonly are broad, up to 3 m wide, whereas those in post-Wisconsin alluvium, such as the Firth River alluvial fan and the Stokes Point spit (Fig. 23), are generally less than 0.3 m wide.

Many sediments on the Yukon Coastal Plain contain segregated ice as can be seen in numerous exposures (Fig. 25) and from shothole log data. Rampton (1971) found that "...all clayey and silty materials, this includes morainal deposits, lacustrine deposits, fine-grained alluvium and colluvium, have high contents of ice. Excess ice is even common in thin veneers of fine-grained sediments and organic deposits where they cap bedrock, pediment surfaces, and glaciofluvial and fluvial deposits. Only bedrock, fluvial and glaciofluvial deposits lacking a cover of fine-grained sediments or organic deposits, modern beach deposits, and modern floodplain deposits are relatively free of excess ice." Most excess ice is segregated ice in the form of small lenses or bodies of massive ice.

Most segregated ice in the lower part of the glacial till and in sediments underlying the till probably formed during and immediately following the Buckland Glaciation. Rampton (1973b) believed that much of the massive ice east of the Mackenzie Delta was formed from subglacial water driven to an aggrading permafrost table by the hydraulic gradients caused by glacier ice. Minor folding and faulting in segregated ice of this age probably are due to local differences in the rates of permafrost aggradation and ice formation or deformation due to differential overburden pressures following ice formation (Rampton and Mackay, 1971).

Some concentrations of segregated ice within 1.5 to 3 m of the ground surface are due to permafrost aggradation that has occurred during the last 5000 years (Rampton, 1973b). "Aggradational ice is closely associated with a climatic change, the addition of material onto the ground surface by sedimentation (e.g. alluvial or colluvial), the accumulation of organic matter, and burial from mudflows, slumping, and soil creep" (Mackay, 1972, p. 10).

Isolated lenses of massive ice are present at depth in areas of glacially deformed sediments such as on Herschel Island and along the edge of the coast between Stokes Point and Shingle Point (Rampton, 1971). Bouchard (1974) has observed severely deformed massive ice in preglacial sediments on the northwestern coast of Herschel Island (Fig. 26). Deformed massive ice and similarly deformed pre-Buckland sediments are common in adjacent areas to the east (Mackay and Stager, 1966).

The deformed massive ice in preglacial sediments at Herschel Island and adjacent areas predates the Buckland Glaciation. Bouchard (1974) and Mackay and Stager (1966) believed that the ice developed in the sediments when they were horizontal because optic axes of ice crystals, which generally form parallel to the thermal gradient, are normal to the banding in the ice and the sedimentary bedding. The deformed attitudes of both the ice and the sediments are due to the effects of the Buckland Glaciation as previously discussed. Although evidence indicates that the deformed massive ice originated prior to the Buckland Glaciation, it is not presently possible to date the origin of the massive ice, other than to say it postdates the sediments within which it is contained. Perhaps the massive ice formed when permafrost aggraded immediately prior to the Buckland Glaciation.

Active thermokarst

Active thermokarst proceeds mainly through retrogressive thaw flow slides (Brown and Kupsch, 1974) around the edges of depressions and along the coast (Fig. 23, 25). Icy sediments and massive ice are exposed on a steep slope in the headwall of retrogressive thaw flow slides. As they melt, the sediment and meltwater flow or slide down the headwall to its base where they form a soupy mixture and flow farther downslope on gentle slopes in the form of a mudflow (Fig. 25, 26). Where sediment is not removed from the base of the retrogressive thaw flow slide, it will stabilize at a slope between 2° and 10°. Stabilized retrogressive thaw flow slides can be identified throughout the region (Fig. 23).

Commonly, mudflow debris is deposited in a lake at the base of the flow slide. Continued removal of sediment from the base of the flow slide by wave action and currents allow the retrogressive thaw flow slide to continue its activity and further expand the basin. Some subsidence may occur under lakes as ice at depth continues to thaw under flooded areas.

Thawing of ice wedges is also a form of thermokarst that is occurring continuously on the Yukon Coastal Plain. Although the volume of ice and sediment thawed in individual wedges may be minor compared to the volume thawed in active retrogressive thaw flow slides, the total volume of wedge ice thawed over large areas annually may exceed that

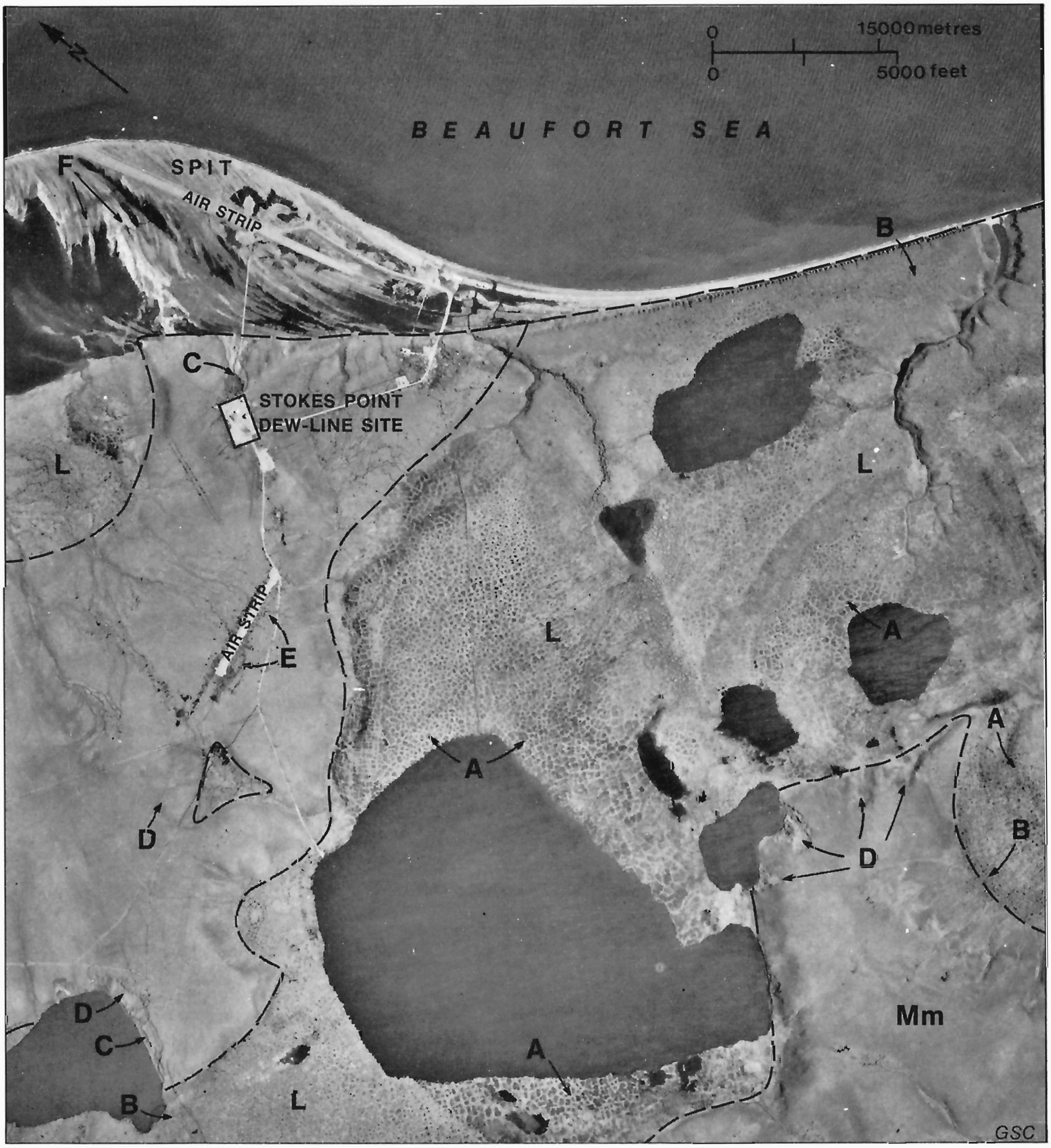

Figure 23. Polygonal ground (A---low centre polygons; B---high centre polygons) developed in peat and lacustrine sediments near Stokes Point DEW-line site. Note active (C) and stabilized (D) retrogressive thaw flow slides, polygons that have developed on rolling moraine (Mm) adjacent to the air strip where the ground cover has been disturbed (E), and ice-wedge trenches (F) on the spit. Lacustrine basins (L) are of thermokarst origin. (NAPL A21923-14)

Figure 24

High centre polygons developed on morainal deposits adjacent to the Stokes Point air strip. Polygons have developed because the vegetation cover has been removed. (GSC-203452-I)

Figure 25

Massive ground ice exposed in a retrogressive thaw flow slide between Sabine Point and King Point. Note the surface of the stabilized debris flow in the foreground. The polycyclic nature of this retrogressive thaw flow slide is due to continued wave erosion at the base. (GSC-203452-J)

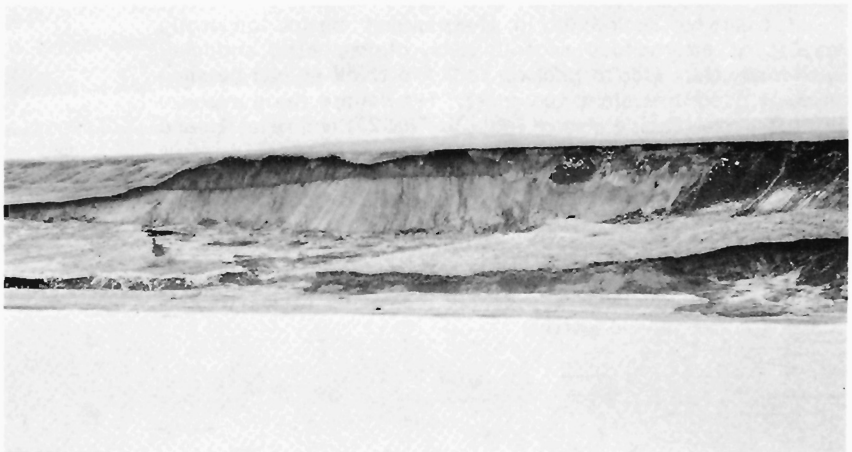

Figure 26

Vertically inclined epi-genetic segregated ice exposed in the headwall of a retrogressive thaw flow slide on the northwestern coast of Herschel Island. The ice is 12 m wide. (GSC-202580-C) amount of ice thawed in retrogressive thaw flow slides over the same area. Thawing of ice wedges results from an increase in annual or summer temperatures at the top of the ice wedge. This may result from (1) ice-wedge growth widening ice-wedge trenches to the point where the tops of ice wedges are exposed to summer temperatures; (2) formation of pools along ice-wedge trenches because of blocked drainage; (3) flooding of areas by lakes; and (4) shifting of stream channels over areas underlain by ice wedges. In areas of thawed ice wedges, polygonal patterns clearly outline the former or thawing ice wedges.

Thermokarst basins

Most basins, both those presently containing lakes and those that have been drained (unit L, Map 1503A) result from thermokarst activity. Active and stabilized retrogressive thaw flow slides can be identified around the periphery of most basins (Fig. 23). Although lacustrine basins of a thermokarst origin are present on fluvial and glaciofluvial landforms, they usually are associated with morainal landforms. This follows from the fact that segregated ice of significant thickness is common within and underlying morainal deposits and that its melting leads to the development of large thermokarst basins. Large thermokarst lake basins cover most of the Coastal Plain at lower elevations west of the glacial limit (Map 1503A).

Lacustrine sediments in thermokarst basins generally consist of interbedded organic silts, clayey silts, and clay with many thin beds of peat up to 0.3 m thick as can be seen in many exposures along the coast. Typical are those exposed in cliffs, near Sabine Point (Table 6; Fig. 27) and near Roland Bay (Table 17). The sediments contain organic detritus including wood fragments, shells, and some ice-wedge casts which are usually associated with peaty layers. West of the glacial limit the basal lacustrine sediments are clayey, and a number of ice-wedge casts are present consisting of small synclines formed by peat and lacustrine sediments (Fig. 28). This latter phenomenon is probably indicative of ice wedges melting under ponded water.

Table 17. Stratigraphic sequence of lacustrine sediments in a thermokarst basin about 3.5 km east of Roland Bay

Unit	Thickness (m)	Description
A	0.30	Peat, sedge, light brown.
B	0.90	Clay, silty, grey; numerous rootlets; small ice lenses.
C	0.03	Peat, fibrous, dark brown.
D	0.80	Clay, silty, grey; small ice lenses.
E	0.03	Peat, mossy, brown; thickens latterly.
F	0.80	Clay, silty, greyish-brown, laminated; thin sandy beds; thin laminae of organic detritus near top.
G	0.09	Peat, fibrous, brown; some water-worn woody fragments; small wedges into unit H (ice-wedge casts?).
H	1.50	Clay, silty, laminated; small plant fragments and rare shell fragments; pebbly near base; some small ice lenses.
I	0.50	Sand, brownish-grey, orange streaks; rare boulder and peat pods; peat dated at 9610 ± 90 (GSC-1808).
J	0.6 - 1.8	Clay, grey; many cobbles; peat stringers in upper part.
K	9.10	Covered, but mainly marine clay.

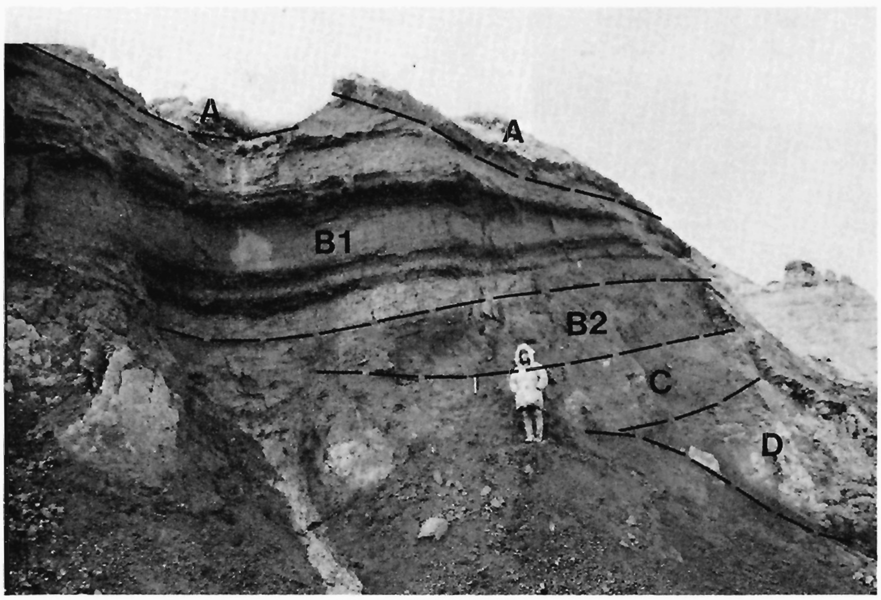

Figure 27

Lacustrine sediments containing numerous peaty layers overlying mudflow debris and till near Sabine Point. A---slumped peat; Bl---lacustrine sediment with peaty layers; B2---lacustrine sediment with plant fragments and small pebbles near base; C---mudflow debris with peat pods; D---till. Peat for radiocarbon date GSC-1792 (14 400 ± 180 years) was obtained from the lower part of unit B2 and the upper part of unit C. (GSC-202580-E)

In some areas underlain by fluvial or glaciofluvial sediments the lower lacustrine sediments in themokarst basins are predominantly sand; typical are sediments in exposures along the south edge of Phillips Bay and southeast of Kay Point. These sediments contain numerous pods and stringers of peat.

In areas underlain by till, slope wash or mudflow debris from retrogressive thaw flow slides commonly can be identified at the base of the lacustrine sediments. Excellent examples are present in exposures near Sabine Point (Table 6; Fig. 27), south of Stokes Point, and near Roland Bay (Table 17) where slope wash debris or diamicton consisting of reworked till and containing pods and lenses of peat underlie lacustrine sediments. Commonly the slope wash and mudflow debris are oxidized, indicating a short period of exposure before submergence by lake waters. In some basins debris flows capping Buckland till or pre-Buckland sediments are overlain directly by peat, which indicates that all thermokarst depressions have not been occupied by ponds or lakes.

Sediments deposited in thermokarst basins overlie a number of different sediment types. Although thermokarst lacustrine sediments west of the glacial limit are believed to overlie marine sediments, east of Clarence Lagoon they commonly overlie alluvial fan gravels. Within the glacial limit, they usually overlie till or, less commonly, outwash, except in areas of glacially deformed sediments where the till is thin, e.g., Herschel Island and the Kay Point - King Point ridge.

Most thermokarst basins are believed to have been actively forming and expanding between 12 000 and 8000 years ago in areas adjacent to the Mackenzie Delta (Rampton, 1973c). Numerous dates on mudflow debris and basal lacustrine sediments support this theory (GSC-1869-2, GSC-506, GSC-1808, GSC-2022; Table 16). GSC-1483 gives a minimum age of 9380 ± 170 years for the formation of a small depression on Herschel Island. Obviously, some depressions formed earlier as evidenced by dates of 22 400 ± 240 years (GSC-1262; Table 16) and 14 400 ± 180 years (GSC-1792; Table 16), and others formed later as evidenced by a date of 7170 ± 70 years (GSC-1872; Table 16) on an ice-wedge cast underlying lacustrine sediments and by depressions that presently are expanding.

Solifluction and frost creep

Solifluction and frost creep undoubtedly affect most slopes of the Yukon Coastal Plain and adjacent mountains. A demonstration of this follows: "...a discontinuous subsurface organic layer, ranging in thickness from less than one inch to several feet, lies close to the permafrost surface throughout extensive areas of the Western Arctic of Canada. Although the organic layers are found in a variety of materials and on gentle to steep slopes, they are best developed in silty to clayey soils on slopes of less then 10°" (Mackay, 1958, p. 1). This buried organic layer is best explained by overriding through frost creep and solifluction of organic material deposited in depressions between hummocks. On slopes where hummocks or depressions do not form, downslope movement is not recorded by a buried organic layer.

Recent studies in the British and Richardson mountains indicate that surface material on vegetation-bare steep slopes moves an average of 2.5 cm per year (Rampton and Dugal, 1974). Steep slopes covered by vegetation commonly show less movement. Movement on steep slopes is due mainly to frost creep rather than to solifluction, which is a more prominent process in moist habitats on gentle slopes covered by vegetation.

Solifluction lobes are common on gentle to moderately steep vegetated slopes, especially near the base of steeper slopes (Fig. 29). This positioning is presumably caused by high moisture contents spawned by the melt of thick snow accumulation and by the occurrence of moderately impermeable sediments on gentle slopes. Even under ideal conditions, solifluction may be local and sporadic because of slight differences in material and moisture regimes. On one solifluction lobe investigated in the northern Richardson Mountains, annual movements of 3.8 to 9 cm were measured on the surface of the lobe, whereas on a lobe investigated in the Buckland Hills no movement was noted on the surface although some turf had slid down the front edge of the solifluction lobe during a period of high rainfall.

Many solifluction lobes presently are characterized by small slumps and gullies along the leading edge. Evidently, the morphology of the lobes and climatic conditions at present favour this manner of local erosion on short steep slopes rather than movement of solifluction lobes en masse.

Figure 28

Ice-wedge cast in lacustrine sediments west of Clarence Lagoon. (GSC-203452-K)

Figure 29. Solifluction lobes and terraces in the northern British Mountains. The small scarp in the foreground is about 1 m high. Note that the solifluction features in the background originate near the base of steeper slopes. (GSC-201831-A)

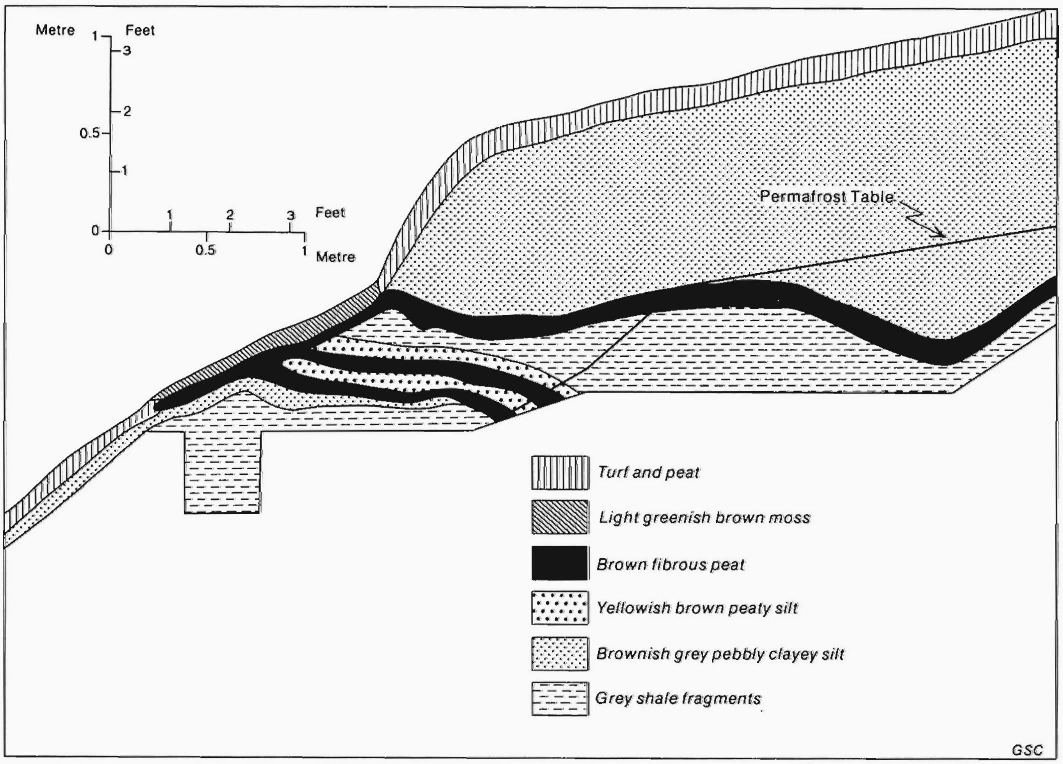

Figure 30. Profile of a solifluction lobe in the northern Richardson Mountains.

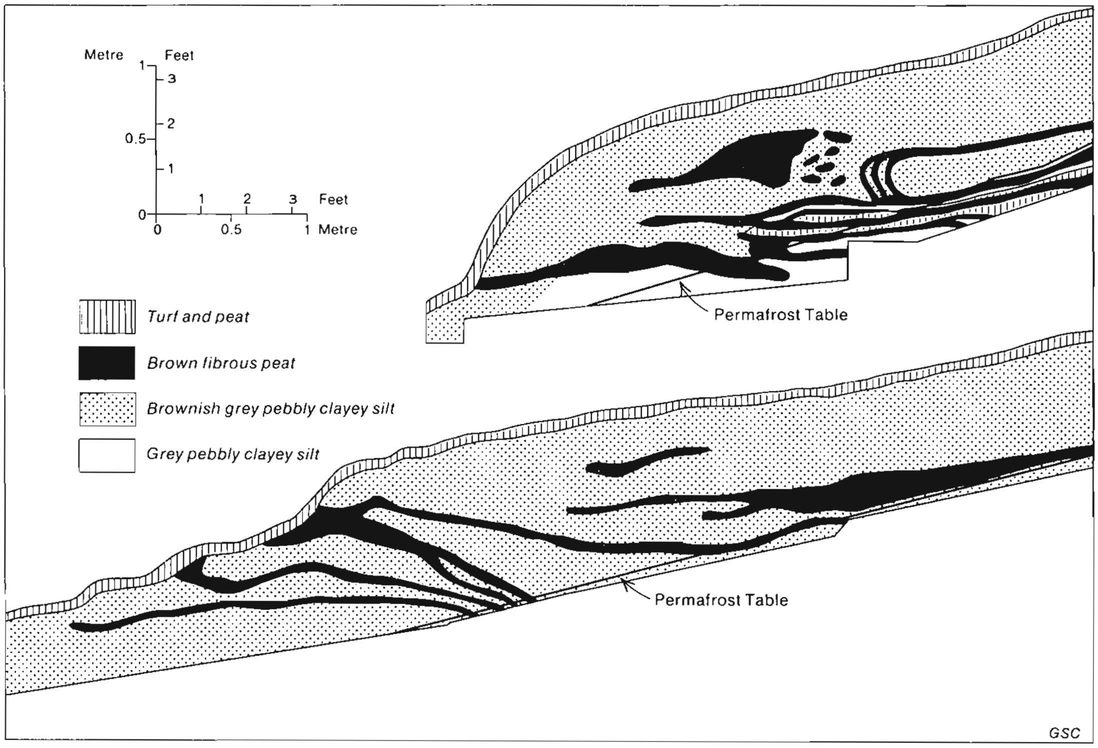

Figure 31. Profiles of typical solifluction lobes in the Buckland Hills west of Firth River.

Trenches dug in a number of solifluction lobes in the area indicate complex soil profiles and possibly multiple mechanisms of movement (Fig. 30, 31). Besides the classical frost creep and flow (solifluction) cited by most authors (e.g., Harris, 1972; Price, 1972), it would appear that some shearing at depth is required to explain structures in Figures 30 and 31. Possibly some structures may be formed by small active layer detachment failures that have been observed in the immediate area (Rampton and Dugal, 1974).

Two radiocarbon dates (GSC-1790, GSC-1875; Table 16) obtained from a buried organic layer under a solifluction lobe in the northern Richardson Mountains indicate that the front of this solifluction lobe has advanced between 0.13 and 0.18 cm per year over the last 300 to 500 years and between 0.06 and 0.10 cm per year in the previous 600 to 900 years. However, movement is probably sporadic with negligible motion during some years and more rapid movement during other years.

Fluvial landforms and deposits

Alluvial fans (unit Ff, Map 1503A) are common phenomenon on the Coastal Plain at the edge of the Buckland Hills west of Firth River and along the eastern flank of the Richardson Mountains south of Willow River. In both areas, stream gradients abruptly decrease at the apex of the fans. Sediment textures are different in each of the above areas; sediments flanking the Buckland Hills are coarse grained, whereas those flanking the Richardson Mountains are fine grained. Texture is a reflection of the erosional maturity of the source area, bedrock lithologies in the source area, and distance of transport of sediments.

Alluvial fans west of Firth River have been terraced, with individual segments standing from 0.5 to more than 6 m above modern floodplains. On some alluvial fans small channels have formed near the base which collect shallow water seeping across the fans through the active layer. Generally, the surface of the fans and the active floodplains of streams crossing them show braided patterns with localized veneers of silt and peat on terraced segments, especially in abandoned channel traces.

Alluvial fans along the Richardson Mountains are not terraced but show faint braided patterns reflecting abandoned and active stream beds and seepage channels. Flow across these fans does not seem to follow any distinct channel except near the apex (Legget et al., 1966). Seepage on the lower part of the fans, however, is concentrated in broad shallow ill-defined channels.

The alluvial fans south of Willow River have formed since the late Wisconsin glaciation, as the area presently covered by the alluvial fans was covered by late Wisconsin ice. Some deposition is still occurring on the alluvial fans (Legget et al., 1966).

Alluvial fans west of Firth River probably have been formed over a long period of time; however, their upper parts and surfaces seem to postdate the late Wisconsin glaciation, as organic material from within the gravel from two exposures west of Firth River was dated as post-Wisconsin. About 8 km west of Komakuk Beach, wood, 1.2 m from the top of gravel in a terrace chronologically equated with nearby alluvial fans, was dated at 10 200 ± 120 years (GSC-1838, Table 16). About 3 km west of the mouth of Backhouse River, wood from an ice-wedge cast, 2.4 m from the top of a 4.5-m-high scarp of gravel, was dated at 10 900 ± 80 years (GSC-1853, Table 16). Alluvial fan surfaces at lower levels are all younger, as both dates relate to upper levels of the alluvial fans. The base of a higher terrace remnant on the east bank of Malcolm River has been dated at 34 600 ± 1480 years (GSC-1900, Table 16). This terrace may only be a remnant of a small alluvial fan deposited by a local tributary of Malcolm River; however, it indicates that the Malcolm River alluvial fan was near its present level during that time interval.

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A small alluvial fan on the south coast of Herschel Island consists of fine-grained sediments having numerous peaty layers and woody fragments. Wood from a peaty layer near its base, and dated at 3940 ± 150 years (GSC-1670, Table 16) indicates the relatively recent origin of the fan. Multiple terraces (Ft) and floodplains (Ftp, Fp) are present along most streams (Map 1503A). High terraces with scarps cut in bedrock are common east of Babbage River, where modern streams are incised deeply in bedrock. The highest terraces along Blow River and its tributaries stand 35 to 55 m above present river level. Intermediate terraces are present but are less common. This phenomenon suggests that the streams cut down from the level of the higher terraces to near the present level at a relatively rapid rate.

Above the mouth of Purkis Creek the highest terraces along Blow River commonly are flanked by benches, which appear to be terraces, that have been glaciated and covered by drift (Fig. 32). This suggests that base level for Blow River was near the level of the highest terraces previous to the Buckland Glaciation. Downcutting was initiated after the retreat of ice (Sabine Phase).

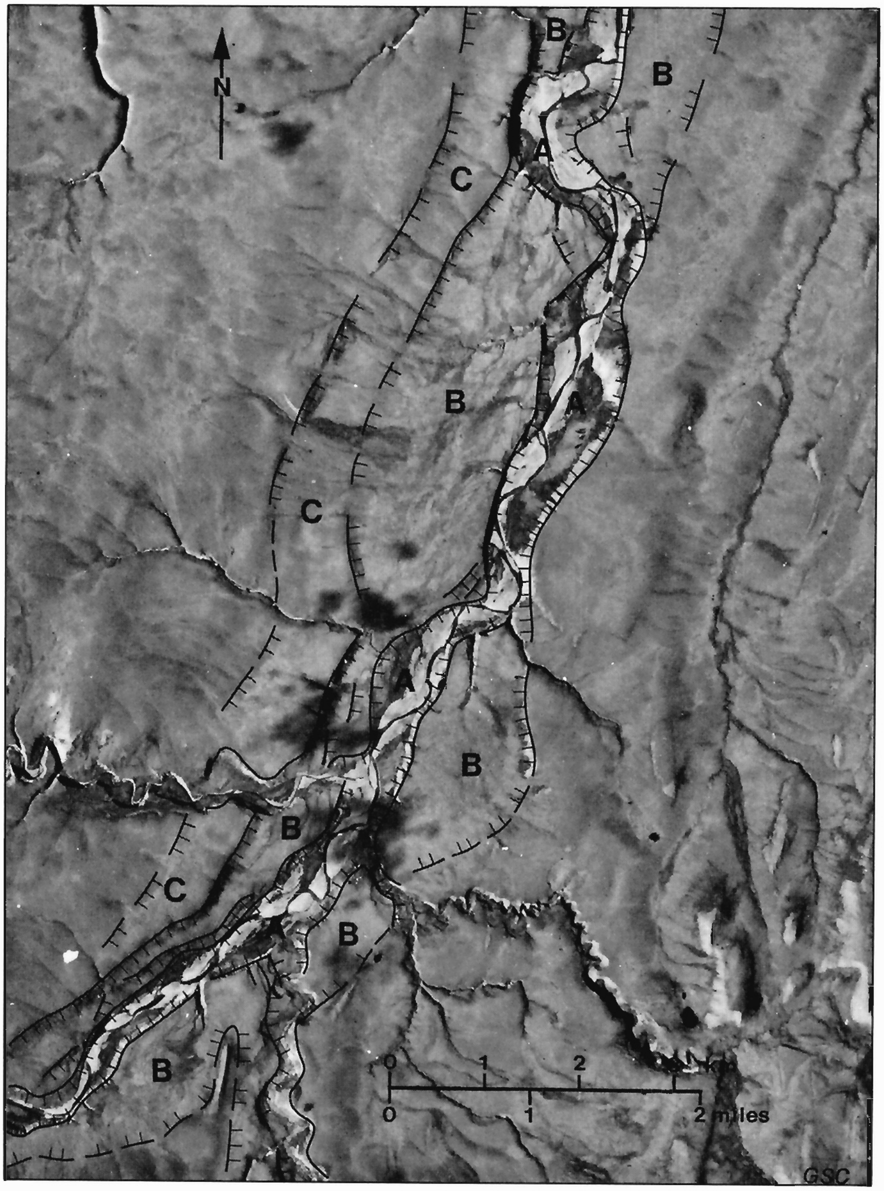

Figure 32. Terraces and floodplain along Blow River upstream from Purkis Creek. The high terraces stand about 35 m above Blow River. A---floodplain and low terraces; B---high terraces; C---high drift-covered terrace. Note that the vegetation-bare floodplain consists mainly of point bars. (NAPL A14451-18)

Figure 33. Braided floodplain of Fish Creek near Komakuk Beach. Note the alluvial fan (A) in the background. (GSC-203193-C)

Low terraces from 0.5 to 12 m above stream level are common in the region (Fig. 32,33). Multiple terrace levels are separated by small scarps. Commonly, low terraces are poorly drained and are covered by overburden.

Downcutting to present floodplain levels may have occurred relatively recently. Wood fragments from 1 m below the crest of a terrace on the upper reaches of Roland Creek were dated at 4540 ± 60 years (GSC-1881, Table 16). Thus, at least locally, present stream levels were reached only within the last 4500 years.

Many floodplains along the Yukon Coastal Plain have active portions that are relatively bare of vegetation. The active floodplains generally consist of braided bar and channel complexes on the western Coastal Plain (Fig. 33) and of large point bars and islands on the eastern Coastal Plain. Only streams flowing in fine-grained deposits, e.g., Deep Creek, have insignificant active floodplains.

Small scarps commonly separate floodplains from low terraces. Generally it is difficult to identify the highest level of flooding and therefore to differentiate floodplains from some low terraces (McDonald and Lewis, 1973). Both floodplains and low terraces have a cover of fine sediment on gravel and sand bases due to overbank flooding. Presently, streams appear to be downcutting slowly, and floodplains progressively become low terraces as their elevation relative to stream level increases. Channel traces commonly can be identified on the surface of low terraces even though they are partially or completely filled with sediment.

Present stream activity consists mainly of scour and redeposition of coarse material on the surface of the floodplain during floods. Bank retreat along local reaches by niching and block sampling of frozen sediments is rapid during the high-water stages. McDonald and Lewis (1973) have studied the modern river environments in detail.

Deep canyons characterize stream valleys of the eastern Coastal Plain. Generally the canyons are 30 to 90 m deep and are broad except where restricted by resistant bedrock. Local erosion of the canyon walls is occurring along all stream valleys.

Marine features

Numerous spits, baymouth bars, and beach ridges (unit mb, Map 1503A) are present along the Beaufort Sea coast (Fig. 34). Most of these features are single ridges, although the distal ends of some spits and baymouth bars consist of multiple recurved ridges (Fig. 23). Generally the crests of spits and baymouth bars are 1 to 2.5 m above sea level. Longshore movement of sand and gravel, mainly from coastal erosion, has caused recent extension of most spits (McDonald and Lewis, 1973) and is presently continuing.

Narrow gravel beaches are common at the base of and just down drift of cliffs containing sand and gravel. Beaches are virtually absent at the base of cliffs consisting of fine-grained sediments. Periodically, coastal escarpments cut in fine-grained sediments containing little ground ice are undercut by thermal niches formed by wave action. This results in block slumping, rapid erosion of material in the blocks, and continued coastal retreat (Fig. 35). Where ground ice is present in the sediments, coastal retreat proceeds through the formation of retrogressive thaw flow slides (Fig. 25). The flow slides are initiated whenever wave action erodes sediment and exposes a major body of ground ice or icy sediment. McDonald and Lewis (1973) have studied the modern coastal environments in detail.

Paleoenvironments

Reconstruction of the vegetation and climate of post-Buckland time is based on macrofossil studies of peat and wood collected for radiocarbon dating, pollen analysis, and macrofossil studies of material in selected exposures, and thermokarst chronology. Sections studied in detail were located east of Roland Bay (Table 17) and near the west end of the Stokes Point lagoon (Table 18). Materials in the section at Stokes Point are believed to date around 22 400 ± 240 years (GSC-1262, Table 16), whereas materials in the section east of Roland Bay postdate 9610 ± 90 years (GSC-1808, Table 16).

Figure 34.
Typical spit near Calton Point south of Herschel Island. Note the large amount of driftwood. (GSC-203193-F)

Figure 35. Block slumping along the north coast of Herschel Island caused by thermal niching. The cliffs are more than 60 m high. (GSC-202261-N)

Interpretation of pollen counts and macrofossils from sediments in the section at Stokes Point (Fig. 36) is complicated by the fact that the enclosing sediments were deposited in a thermokarst lake and contain much redeposited material. Some of the redeposited material undoubtedly is pre-Buckland in age as pre-Buckland sediments are exposed along the edge of the thermokarst basin in cliffs to the west.

Units B and C (Table 18) indicate that fluctuating water levels characterized the late history of the basin, because macrofossils found in unit C are primarily indicative of terrestrial peat accumulation, and the gravel of unit B is indicative of a beach. Macrofossils and ostracods in unit D indicate pond and shoreline environments (J.V. Matthews, Jr., unpublished Fossil Arthropod Report 76-9, Plant Macrofossil Report 76-8).

Table 18. Stratigraphic sequence of sediments in a low bench at the west end of Stokes Point lagoon

Unit	Thickness	Description
	(m)	
A	0.9	Covered; appears to be silty sand with pods of peat.
B	0.9	Gravel, sandy, brown; 5- to 7.6-cm-thick peat layer from the base.
C	0.3	Peat, brown; many identifiable plant fragments and twigs.
D	0.6	Sand, fine, brown to grey; thin peaty beds near base.
E	0.2	Peat, brown, compressed; mainly plant fibres and twigs; equivalent dated by J.G. Fyles at 22 400 ± 240 years (GSC-1262).
F	0.6	Sand, fine, brown; orange mottles; few silty beds and peaty layers and pods; 7.6 to 15 cm gravelly bed at base.
G	0.3	Clay, silty, grey; few twigs, pebbles, and cobbles.
H	3.0	Covered to sea level.

The pollen diagram indicates that the terrain was covered by shrub tundra dominated by dwarf birch (units C and E, Table 18) or by vegetation common to the forest-tundra community (units D and F, Table 18). However, because the sediments of units D and F probably are reworked pre-Buckland sediments, which may have contained significant amounts of *Picea* pollen, and because the pollen sums are small, the interpretation of pollen spectra from units D and E should be viewed with caution. L.D. Delorme (pers. comm., 1976) believes that ostracods in the lower part of unit D indicate mean annual temperatures of -8.5 ± 1.5°C and annual precipitation of between 30 and 38 cm, conditions similar to those of today at the site. It would seem certain that the landscape was covered by shrub tundra during the deposition of unit E around 22 400 years ago, given that the unit is the strata from which the date GSC-1262 was obtained as discussed in the section on glacial stratigraphy and chronology. The presence of the ground beetle *Elaphrus lapponicus*, which generaly is found only near the tree line, indicates that the tree line may have been closer to the site than it is today (J.V. Matthews, Jr., unpublished Fossil Arthropod Report 76-8) and that the local climate may have been slightly warmer 22 400 years ago than the climate is at present.

Macrofossils identified in the peat near Sabine Point on which radiocarbon date GSC-1792 was obtained (Table 19) indicate that the climate around 14 400 years ago was colder and drier than that of the present. Although most identified mosses are wide-ranging, *Crateneuron articum* is present today only in the high arctic and northernmost Alaska, and the complete moss flora is indicative of a xeric site (M. Kuc, pers. comm., 1973). The fossil insects also are indicative of a dry local environment, possibly fell-field since the weevil *Lepidophorus lineaticollis*, fragments of which were numerous, usually is found at dry sites (J.V. Matthews, Jr., unpublished Fossil Arthropod Report 2-72).

By 10 900 years B.P. climatic conditions again ameliorated and were similar to those of today. Matthews (1975) examined macrofossils and pollen from peat associated with *Betula* wood dated at 10 900 ± 80 years B.P. (GSC-1853, Table 16) and concluded that they represented patches of vegetation of a fell-field type growing on a gravel substratum. The insect assemblage also indicated a tundra environment but with the tree line probably as close as that of today.

Macrofossils from a section at Roland Bay (Table 20) are characteristic of either tundra or northern boreal environments (J.V. Matthews, Jr., unpublished Fossil Arthropod Report 76-9, Plant Macrofossil Report 76-8). The absence of spruce, alder, and poplar macrofossils and the presence of dwarf birch, however, suggest that shrub tundra similar to that covering nearby terrain covered the area during deposition of the sediments which postdate 9600 years B.P. A pollen spectrum dominated by *Betula* and Cyperaceae (J.C. Ritchie, pers. comm., 1970) from peat dated at 9380 ± 170 years (GSC-1483, Table 16; Fig. 21) on Herschel Island also indicates shrub tundra containing abundant dwarf birch occupied that site around 9400 years B.P. Although Herschel Island lies within the northern limit of dwarf birch, it is by no means a dominant component of the island vegetation, and *Betula* is probably a minor component of the modern pollen rain. Thus the climate of the Coastal Plain perhaps was warmer around 9400 years ago than it is today to allow for the abundance of dwarf birch on Herschel Island at that time. *Populus* wood dated at 9940 ± 90 years B.P. (GSC-2022, Table 16) from an upland site near Sabine Point, well beyond the present northern limit of *Populus*, also indicates a relatively warm climate during this time interval.

Radiocarbon dates on basal material in thermokarst basins, both on the Yukon Coastal Plain (Table 16) and areas immediately adjacent to the eastern edge of the Mackenzie Delta, also indicate that "...the melting of ground ice became a common phenomena following 12 000 B.P. and reached a maximum between 10 000 and 9000 B.P. Melting was probably initiated at this time because of climatic warming and thickening of the active layer; ice sediments were subjected to temperatures above freezing for the first time" (Rampton, 1973c).

Macrofossils, including *Ranunculus* sp., *Carex* sp., *Betula* cf. *glandulosa*, *Dryas intergrifolia*, *Sphagnum*, and numerous mosses (Table 21), in peat from an ice-wedge cast near Kay Point indicate that shrub tundra containing shrub birch was present at Kay Point around 7000 years B.P. as the peat was dated at 7170 ± 70 years B.P. (GSC-1872, Table 16).

The regional climate of the Coastal Plain cooled between 5500 and 4000 years B.P. as indicated by palynological studies east of the Mackenzie Delta (Ritchie and Hare, 1971). The absence of *Populus* from areas where it grew around 10 000 years B.P. and the relatively slow expansion of thermokarst basins at present indicate that a cooler climate exists today. This may, in part, be due to the present coastal configuration, i.e., the shoreline 9000 to 10 000 years ago was 4 to 15 km north of the present shoreline (Matthews, 1975). Undoubtedly the Beaufort Sea has a cooling effect on summer temperatures.

*Table 19. Fossil mosses and macrofossils identified in peat from near Sabine Point (69 04.5'N, 137 51'W) on which radiocarbon date GSC-1792 was obtained**

Taxon	Frequency
Mosses:	
Distichium sp.	++
Barbula icamadophila	++
Platydictya jungermanioides	++
Hypnum vaucheri	++
Encalypta rhabdocarpa	+
Crateneuron arcticum	+
Bryum sp. - two species	+
Insects:	
Amara alpina Payk.	+
Pterostichus spp.	+
Lepidophorus lineaticollis Kirby	++
Ceutorhynchus sp.	+
Staphylinidae	+
Miridae	+
Lepidoptera - larval mandibles	+
Bibionidae - protibial fragments	++
Miscellaneous diptera puparia	+
Hymenoptera - larval head capsules	++
Plants:	
Dryas integrifolia Vahl. (*identified by M. Kuc*)	+
Carex sp.	+
Ranunculus sp.	+
cf. *Cerastium* sp.	+
Chenopodium sp.	+
Gramineae sp.	+

\+ present
++ abundant

*Mosses identified by M. Kuc; insects and plants identified by J.V. Matthews, Jr.

Table 20. *Fossils from lacustrine sediments exposed near Roland Bay (cf. Table 17)**

Unit	Ostracods	Insects	Plants
A	*Cypria opthalmica*		
B	*Cyclocypris globosa* *Cypria ophthalmica*		
C	*Cypria opthalmica*	Carbidae (Genus?) Dytiscidae (Genus?) *Boreaphilus* sp. Staphylinidae (Alcocharinae)?	*Betula* sp. *Ranunculus trichophyllus* Chaix.
D	*Candona candida* *Cypria ophthalmica* *Cyclocypris globosa* *Cytherissa lacustris*		
E		Dytiscidae (Genus?) *Stenus* sp. *Boreaphilus henningianus* Sahlb. *Olophrum latum* Makl. *Arpendium brunnescens* Sahlb. *Pycnoglypta* sp. *Gymnusa* sp. *Simplocaria* sp. Trichoptera (Genus?)	Gramineae (Genus?) *Carex aquatilis* Wahlenb. *Carex* sp. *Ranunculus trichophyllus* Chaix. *Ranunculus* sp. *Potentilla* sp. *Empetrum nigrum L.* *Hippuris vulgaris L.*
F	*Candona rectangulata* *Cyclocypris globosa* *Cytherissa lacustris*		
G		*Pterostichus (Cryobius) brevicornis* Kirby *Agabus*(?) sp.	*Carex aquatilis* Wahlenb. *Carex* sp. *Salix* sp. *Potentilla palustris L.* *Empetrum nigrum L.* *Ledum* sp. *Vaccinium* sp.
H	*Cypria ophthalmica* *Cytherissa lacustris*	Staphylinidae (Omalinae)? *Olophrum latum* Staphylinidae (Aleocharinae)? *Lepidophorus lineaticollis* Kirby Diptera (Genus?) Chironomidae (Genus?)	*Potamogeton Richardsonii* (Benn.) Rydb. cf. *Poa* *Carex aquatilis* Wahlenb. *Betula* sp. *Ranunculus trichophyllus* Chaix. *Potentilla palustris L.* *Ledum decumbens* (Ait.) Lodd. *Vaccinium Vitis-ideae L.*

* *Ostracods identified by L.D. Delorme; insects and plants identified by J.V. Matthews, Jr.*

Table 21. *Mosses in peat from an ice-wedge cast near Kay Point (GSC-1872)**

Hylocomium splendens	*Drepanocladus exannulatus*
Hygrohypnum sp.	*Dicranum elongatum*
Aulacomnium turgidum	*Brachythecium* sp.
Sphagnym sp.	*Polytrichum alpinum*
Entodon schreberi	*Psylopilum laevigatum*
Bryum sp.	*Leptobryum pyriforme*
Pholia sp.	*Distichium* sp. cf. *inclinatum*

*Mosses identified by M. Kuc.

SURFICIAL DEPOSITS

General

Unconsolidated surficial deposits have been mapped according to their texture and slope. As an aid to further mapping and extrapolation, however, the deposits have been grouped according to their genesis (Fig. 37, 38). The advantages of labelling materials according to genesis are at least threefold: (1) lateral and vertical variations can be predicted for a given genetic category; (2) areas of different texture or slope too small to map, but common to a genetic unit, can be predicted; and (3) in areas where textures have been assigned incorrectly, the correct texture can be assigned once a spot check has identified it.

Genetic groupings used in the area are: (1) C---colluvium; (2) E ---eolian deposits; (3) Є---estuarine deposits; (4) F---fluvial deposits; (5) G---glaciofluvial deposits; (6) L---lacustrine deposits; (7) m---marine deposits; (8) M---morainic deposits; and (9) R---bedrock. Bedrock has been included in order to map the surface of the landscape completely, even though bedrock is not an unconsolidated surficial deposit. Further descriptions are intended only to supplement the extended legend (see Fig. 37, 38).

Generalized thicknesses of unconsolidated materials that can be expected to overlie bedrock are shown in Figure 39. No attempt has been made to show details, such as escarpments along streams where the thickness of unconsolidated material is negligible or other small areas having thicknesses of unconsolidated deposits that are divergent from the surrounding area. Most escarpments and small areas of bedrock can be identified in Figures 37 and 38 which show details of surficial geology.

Depths of materials have been estimated by extrapolating from depths of unconsolidated materials observed in exposures and numerous shothole logs that have been drilled throughout the area. Certain landforms also were interpreted as being indicative of depths of unconsolidated materials. For example, the thickness of unconsolidated deposits underlying alluvial fans on the Coastal Plain is known to be greater than 15 m; the thickness underlying glacial landforms in valleys of the mountains and foothills generally ranges between 1.5 and 20 m; and the thickness underlying colluvial slopes usually is less than 3 m.

The thickest unconsolidated deposits are present under the outer edge of the Coastal Plain, under the Mackenzie Delta, and in small basins mainly along the northeastern edge of the Richardson Mountains. Under the coastal fringe of the Coastal Plain and the Mackenzie Delta, these deposits commonly exceed 60 m thickness. Thicknesses of more than 150 m have been reported from the Mackenzie Delta (Fyles et al., 1972). At Herschel Island, the unconsolidated deposits probably exceed the maximum elevation of the island, nearly 185 m, as is the case along the ridge running from Kay Point to King Point where elvations reach 105 m.

Colluvium

Colluvium occurs on most slopes beyond the limit of glaciation and numerous slopes within the limit of glaciation. Textures of materials in this genetic category are related to the underlying material and range from clay to large boulders.

The unit includes: (1) residuum which has been locally derived from the disintegration and weathering of bedrock; (2) slope deposits moving under the effect of gravity either through solifluction or creep; and (3) accumulations of creep-derived colluvium mixed with alluvium at the base of slopes. Generally, colluvium may have been moved by flowing water, but it has neither been transferred a long distance nor been sorted to any degree by overland flow; however, drillhole data indicate that some layering has developed.

Within the glaciated area, materials on slopes have been mapped as colluvium, even though glacial deposits (till, glaciolacustrine sediments, etc.) may be interbedded with the colluvium. Generally, the entire complex of materials has been subjected to mass wastage.

Grain size analysis of colluvium shows that the content of clasts exceeding 2 mm in diameter can range from nil to more than 90 per cent. In gently sloping areas underlain by less competent rock types, stones generally constitute a small proportion of the colluvium but may comprise up to 15 per cent. In some areas of colluvium underlain by shale, the surface layers are stony because concretions and bedrock fragments tend to accumulate at the surface due to frost action. On steep slopes and in areas where resistant rock types are present, the stone content ranges between 20 and 50 per cent. In areas where resistant rock types, mainly highly indurated sandstones, are dominant, colluvium consists of a coarse, bouldery rubble. Bouldery rubble is particularly common on steep ridge crests and on altiplanation terraces in the Richardson Mountains (Fig. 17).

The organic content of fine-textured colluvium is high. Layers and pods of peat and woody detritus commonly are present, indicating that solifluction has occurred in the past on most slopes. Measurements on a number of slopes in the British and Richardson mountains indicate that movement of 2.5 cm per year is common on steep slopes and 1.5 to 2.0 cm per year on gentle slopes (Rampton and Dugal, 1974).

Colluvium containing substantial amounts of fine-grained sediment has high ice contents. Most fine-grained colluvium contains 30 to 60 per cent excess ice, commonly in the form of ice lenses and veins; layers of ice more than 0.6 m thick may be present. Along the Coastal Plain west of Malcolm River, 2.5 to 3 m of almost pure ice commonly has been found to underlie 0.3 to 0.6 m of organic silty colluvium in drillholes.

Solifluction lobes and bouldery terracettes are periglacial features common to this unit. Terracettes are confined mainly to slopes where stony colluvium predominates. Solifluction lobes are common where fine-grained or poorly sorted colluvium is present and at the base of steep slopes where moisture might accumulate. Active layer detachment failures were noted on some colluvial slopes in the summer of 1973.

Disturbance of the ground cover on slopes underlain by ice colluvium or thick layers of ice would increase vulnerability to thermokarst erosion and gullying. Unless corrective measures are taken, stripping of any insulative surface layer should be avoided, as it will lead to erosion and scarring of the landscape.

Eolian deposits

Recognizable eolian deposits are a rarity on the Coastal Plain. It remains a question, however, whether some of the silt in the silty colluvium, especially in unglaciated areas, is of eolian origin for it is difficult to imagine that the silt has developed solely from disintegration of the underlying or nearby bedrock. As the silt generally has undergone mass movement, however, it has been classified as colluvium.

The few eolian deposits present consists of small dunes on low terraces near the outer edge of the Firth River alluvial fan; the sandy, periodically inundated lower reaches of the alluvial fan are the obvious source of sand. Isolated cliff top dunes are present along the top of stream-cut and wave-cut escarpments. The dunes vary in thickness from about 0.6 m to more than 3 m along the crests of some escarpments. The eolian materials adjacent to the Firth River fan are fine sands, whereas those along crests of escarpments are coarser and commonly contain some pebbles or shale chips. All eolian deposits contain a significant amount of organic material in the form of detritus or peaty layers. Eolian deposits are generally low in ice content.

Estuarine deposits

Within the map area, only a few areas where sediment has been deposited by fresh water during spring floods and by brackish and saline water during storm tides have been mapped as estuarine deposits. This type of deposit, therefore, is confined mainly to the outer edge of actively forming deltas, such as the Mackenzie Delta, Blow River delta, and Babbage River delta (Lewis and Forbes, 1975). The boundary between marine deposits, estuarine deposits, and fluvial deposits is relatively subjective, as it involves a judgment on the amount of deposition under different environmental conditions.

Estuarine sediments are generally a mixture of fine sand, silty sand, and fine sandy silt (McDonald and Lewis, 1973). The sediment generally contains a high percentage of organic detritus with logs and large woody fragments (Lewis and Forbes, 1975). Woody detritus and driftwood are common on the surface of this unit as are pebbly gravels in the form of beaches (McDonald and Lewis, 1973). This unit generally lacks a peat cover because of its youthfulness.

Estuarine deposits probably have ice contents similar to fine-grained fluvial deposits where excess ice contents commonly exceed 10 per cent. Ice occurs as lenses up to and exceeding 15 cm thick (McDonald and Lewis, 1973). Areas mapped as estuarine are usually poorly drained and are subject to frequent inundation during spring floods and storm tides.

Estuarine deposits would be subject to moderate amounts of thermokarst subsidence and possibly thermokarst erosion and gullying if a disturbed area were affected by flooding. Any depression formed, however, gradually would be infilled because of its location in an area of net deposition.

Fluvial deposits

Fluvial deposits include channel, floodplain, terrace, alluvial fan, and deltaic deposits. Fluvial deposits can be divided into two parts on the basis of texture: (1) coarse-grained deposits that have been deposited mainly through channel flow and (2) fine-grained deposits that have been deposited mainly through overbank flooding. The textural divisions do not always correlate with different landforms.

The most extensive areas of fine-grained fluvial deposits are found in the Mackenzie Delta, alluvial fans adjacent to the Aklavik Range, the lower reaches of major rivers such as the Babbage, and the outer fringe of some alluvial fans such as that on Firth River. Most fine-grained fluvial deposits are composed of sand or silty sand. The Mackenzie Delta sediments are predominantly fine sand and silt near its outer edge, although clayey facies are present (Gill, 1972; Mckay, 1963b). McDonald and Lewis (1973) also indicated that silt is the predominant sediment type of the floodplain along the lower reaches of Babbage River. In general, fine-grained materials form the upper part of low terraces and floodplains (McDonald and Lewis, 1973). The lower part of the Firth River alluvial fan is also very sandy. These fine-grained deposits commonly directly overlie coarse-grained fluvial deposits having a channel origin.

Fine-grained fluvial sediments generally have high organic contents. In the Mackenzie Delta, logs, wood fragments, lenses of peat, and organic detritus of variable size are common. Driftwood logs also have been found in the Babbage delta (Forbes, 1975). In floodplains and terraces, organic detritus, layers of peat, twigs, and roots are a common constituent of fine-grained materials. A variable thickness of peat, usually between 0.3 and 2.5 m, covers most low terraces. Fine-grained fluvial deposits have a moderately high content of excess ice as small- to medium-size ice lenses are common throughout the sequence; excess ice contents of 10 to 50 per cent by volume can be expected. McDonald and Lewis (1973) found that excess ice was greater than 10 per cent in fine-grained Babbage River delta sediments. In the Mackenzie Delta, Johnston and Brown (1965) found that ice lenses and veins in a hole drilled near Inuvik were limited to the upper 9 m. Ice wedges are common in fine-grained sediments, as evidenced by polygonal ground on these deposits.

Areas underlain by fine-grained fluvial deposits are poorly drained with numerous small ponds. The centres of low-centre polygons and the trenches outlining the polygons commonly contain standing water. Most deltaic areas and the low terraces also are frequently inundated by floods and storm surges.

Permafrost and excess ice make fine-grained floodplain deposits susceptible to thermal niching and block slumping; stream erosion of a floodplain or a low terrace generaly proceeds through these processes (McDonald and Lewis, 1973).

Disturbance of the surface of floodplains and low terraces usually will bring about thermokarst subsidence. If disturbed locations are close to stream courses or delta channels, thermal erosion and gullying may occur.

The major areas covered by coarse-grained fluvial deposits are the large alluvial fans west of Firth River, most terraces, and those parts of active floodplains periodically subjected to stream flow (Fig. 32, 33). Most stream deposits and alluvial fans in the area are composed of stratified, poorly sorted pebbly gravels with many cobbles and few boulders; sandy beds are present in places. No notable change in the texture of materials, other than a gradual upstream coarsening, has been noted along most terraces and floodplains. The texture of materials in alluvial fans, however, changes rather abruptly to sand near the toes. A veneer of either fine-grained sediment or peat is present on most terrace and alluvial fan surfaces and has been mapped where it exceeds more than 0.6 m in thickness.

Little ice is present in most coarse-grained fluvial sediments except for a few ice wedges. On poorly drained broad flat areas, some thin layers of ice may occur within the upper parts of the gravel and sand. On Malcolm River one small pingo is present, which indicates a local concentration of ice. Fine-grained sediments and peat overlying gravel and sand usually contain excess ice.

Drainage on broad areas of coarse-grained materials is commonly poor with pools of water lying in low areas. A shallow active layer and permeable sediments on alluvial fans encourage near-surface seepage, which often appears as surface water in swales and abandoned channels. Coarse-grained fluvial deposits near escarpments are better drained (Fig. 40). Active floodplains composed of bare gravel or sand bars are subjected to periodic inundation during floods.

Surfaces of coarse-grained fluvial deposits are generally stable upon disturbance except where overlain by fine-grained sediments, in which case disturbance will cause thermokarst subsidence and possibly erosion. Active floodplain surfaces that are frequently bare of water are stable except during floods when movement of material will occur via bed scour or lateral erosion of channel bars. Permafrost and clast imbrication limit the depth and extent of this erosion and sediment movement (McDonald and Lewis, 1973).

Glaciofluvial deposits

Glaciofluvial deposits are locally abundant in the form of outwash plains and fans, valley trains, kames, kame deltas and terraces, and eskers. The most extensive areas of glaciofluvial deposits are found on the flat plain just south of Herschel Island, along the flanks of the Buckland Hills, and on the inland side of the ridge extending along the coast between Shingle Point and Coal Mine Lake.

Figure 40. Well drained edge of a fluvial along Firth River Canyon. (GSC-203452-L)

Most glaciofluvial deposits are poorly sorted pebbly to cobbly gravels with some sandy layers. Some deposits adjacent to the ridge extending southeast from Kay Point are mainly sand. Generally, glaciofluvial deposits along the flanks of the Buckland Hills have high silt contents and high proportions of angular clasts, as they were deposited directly downstream of the bedrock canyons from which they were eroded.

Glaciofluvial deposits generally have low ice contents, although on broad flat areas some ice lenses are common at shallow depth. In places glaciofluvial deposits are underlain by massive ice, especially where they lie directly over sandy pre-Buckland sediments along the ridge extending southeast of Kay Point. Massive ice also has been found under kame deltas and kames along the edge of the Buckland Hills. Broad flat areas commonly are covered by peat or organic silts that generally have high ice contents. Ice wedges are present where glaciofluvial deposits are covered by peat or fine-grained sediments.

Most glaciofluvial deposits are well drained because of their elevated positions, although broad flat areas that are covered by peat can be poorly drained with numerous small pools and water along trenches overlying ice wedges.

Glaciofluvial deposits are generally stable except where a thick cover of icy peat and organic silt is present; here a large amount of thermokarst subsidence could occur if the surface was disturbed. Melting of massive ice also might be initiated if large amounts of gravel were removed from glaciofluvial deposits underlain by massive ice.

Lacustrine deposits

Lacustrine deposits are predominantly of thermokarst origin and occur most commonly in morainic areas. Many of the small areas of lacustrine deposits are not mapped within moraines. A few areas of glaciolacustrine deposits occur near the limit of glaciation and near the mouth of Rapid Creek.

Lacustrine deposits of thermokarst origin include thinly bedded and highly organic silty clay, silt, and silty sand with layers of peat throughout the sequence (Fig. 27; Tables 17, 18). Scattered pebbles and cobbles may be present and commonly are concentrated at the base of lacustrine sequences and in poorly developed beaches. In areas where sand and gravel constitute the surrounding deposits, e.g., glaciofluvial deposits, lacustrine deposits have high sand and gravel contents. Glaciolacustrine deposits are generally clayey or sandy silts with low organic contents.

Lacustrine deposits of thermokarst origin generally range between 3 and 9 m thick. Glaciolacustrine sediments along the lower reaches of Rapid Creek are up to 3.5 m thick. The thickness of deposits along the limit of glaciation is not known.

In most lacustrine sequences excess ice in the form of thin ice lenses, which are most common in upper 1.5 to 3 m, constitutes 5 to 40 per cent of the total volume. Polygonal networks of ice wedges are common in lacustrine sediments and in the peat that overlies them (Fig. 23). Drainage on areas covered by flat lying lacustrine deposits is generally poor; tundra pools are common as is water in the troughs overlying ice wedges.

Lacustrine deposits are susceptible to moderate amounts of thermokarst subsidence: 1.5 to 3 m can be expected on areas stripped of surface vegetation cover. The flatness of the unit will prevent further damage unless disturbance is near a scarp or steep slope, in which case some gullying may develop if drainage was localized along the disturbed ground.

Marine deposits

Two types of marine deposits are present: (1) sand and gravel beaches and spits (Fig. 34) and (2) silty and clayey intertidal deposits. Beaches are present along most coastal escarpments but are narrow, usually less than 15 m wide. Spits up to 150 m wide are present at the distal edge of the Malcolm and Firth rivers alluvial fans and are attached to numerous promontories, for example, Avadlek Spit at the southwest corner of Herschel Island.

Baymouth bars enclose most depressions along the coast and range up to 90 m wide. Intertidal deposits are confined to the landward sides of spits and beaches in relatively flat areas and the distal edges of deltas (Lewis and Forbes, 1974).

Gravel and sand in narrow beaches probably range in thickness between 1 and 2 m, whereas large spits and baymouth bars may be up to 8 m thick (McDonald and Lewis, 1973). Spits, bars, and beaches are composed of fine pebbly gravel or coarse sand. Silty and till-like sediments may be interbedded with sand and gravel under the inland edge of beaches. The deposits may contain driftwood and lenses of woody detritus.

Intertidal deposits are present at the distal edges of most deltas, such as the Babbage River (Forbes, 1975). The largest area of mapped intertidal deposits lies within a shallow depression flanked by a beach just west of the mouth of Babbage River.

Intertidal sediments associated with the deltas are usually silt or sand with patches of gravel, fragments of driftwood, and organic detritus (Forbes, 1975; McDonald and Lewis, 1973). The infilled basin west of Babbage River appears to be composed of organic silt and clay with large amounts of driftwood. Surface morphology suggests stringers of gravel and sand may be present within the finer sediments. Intertidal deposits, where frozen, probably contain some excess ice. A network of ice wedges appears to have developed in the sediments west of Babbage River. Most marine deposits are subject to periodic inundation during storms and high tides.

Morainic deposits

Morainic deposits are common within the glacial limit on the Coastal Plain and in some mountain valleys. Tills on the Coastal Plain generally contain between 5 and 20 per cent stones greater than 2 mm diameter. In areas such as near Shingle Point where till is underlain by gravels, pebble content of the till is commonly higher. However, in other areas where the till is underlain by fine-grained marine deposits that have been incorporated into the till, pebbles are a rarity. Boulders and cobbles are rare in tills, except near ridges of resistant bedrock. The upper 3 m of material mapped as till commonly is debris flow, lacustrine, or colluvial deposits because periglacial processes, including solifluction, mass wastage associated with thermokarst, and the formation of temporary ponds, affect the surface. Colluvial and lacustrine deposits generally resemble the till from which they were derived except that they will contain pods and lenses of organic material and peat, and the lacustrine deposits will be stratified.

Morainic deposits commonly contain between 10 and 40 per cent excess ice with the highest ice contents being present in the upper 1.5 to 3 m. Thick beds of massive ice and icy sediments are common in areas of hummocky and rolling moraine. Generally massive ice and icy sediments are located at the interface between the till and the underlying sediments.

Active layer detachment failures and retrogressive thaw flow slides are common in mountainous areas where steep slopes are common, along sea cliffs, stream banks, and lake shores (Fig. 23, 25). Surface disturbance on slopes steeper than 5° may initiate layer detachment failures, retrogressive thaw flow slides, or thermokarst erosion and gullying; in flatter areas, disturbance will generally result in some thermokarst subsidence.

Organic deposits

Organic deposits are ubiquitous throughout the area and are common in mappable thicknesses on flat, poorly drained areas underlain by almost any other type of material. Even in gently sloping areas, a layer of turf and peat up to 0.5 m thick commonly is present; in poorly drained flatter areas peat is up to 3.5 m thick in places.

Peat in this area is composed primarily of the remnants of mosses or herbaceous plants, with a minor woody component of shrub twigs and roots. Ice content of organic deposits is high, and all organic deposits contain networks of ice wedges. The deposits are usually poorly drained, with numerous small ponds and standing water in trenches over ice wedges. Surface disturbance of organic deposits tends to cause more water to accumulate and thermokarst subsidence to occur.

Glacially Deformed Sediments

Glacially deformed marine clay and silty clay, lacustrine deposits, and fluvial silt, sand, and gravel form the surface materials at Herschel Island and on the ridge extending between Kay Point and King Point. Glacially deformed sediments are actually close to the surface throughout much of the coastal fringe and throughout parts of the mountain fringe of the Coastal Plain.

Most glacially deformed sediments are fine grained but in places consists of sand or gravel. Glacially deformed sediments have a discontinuous veneer of glacial drift or modified drift. In areas mapped as glacially deformed sediments, the upper metre commonly is colluvium as the underlying sediments usually have been modified by solifluction, slumping, or have been reworked due to mudflow activity (Bouchard, 1974).

Glacially deformed sediments commonly do not contain any ground ice at depth, but excess ice is common in the upper 1.5 to 3 m of fine-grained facies. Isolated massive bodies of ice and icy sediment are present at depth in the sediments at a few localities (Bouchard, 1974).

Drainage patterns developed on these deposits usually reflect the structure of the deformed sediments. On Herschel Island, for example, gullies and ridges along the western and northern edge of the island parallel the strike of fault planes and fold axes (Mackay, 1959; Bouchard, 1974). Drainage is moderately good because of relief; however, on flat areas, peat may accumulate or shallow thermokarst ponds may be present on the surface. Active layer detachment failures and retrogressive thaw flow slides are common on steep slopes, and thermal niching and block slumping occur along coastlines exposed to wave erosion (Fig. 35). Disturbance on slopes underlain by icy, fine-grained, glacially deformed sediments undoubtedly would lead to the development of retrogressive thaw flow slides and gullying. Thermokarst subsidence will develop in flat areas, relative to the amount and thickness of excess ice in the underlying sediments.

Bedrock

Bedrock outcrops in the following environments: (1) mountain ridge crests; (2) steep slopes and cliffs in areas of high relief; and (3) steep-walled, stream-cut canyons. The bedrock mapped in the first two environments is covered, in part, by shallow colluvium, generally coarse in nature and of the same lithology as the underlying rock. Rock outcrops are common on the erosion surface east of Babbage River, as stream incision has been greater in this area and has resulted in some dissection of the erosion surface and exhumation of the underlying bedrock.

In the British and Barn mountains, resistant rock types that form most of the outcrop areas are lithic sandstone, cherts, carbonates, and indurated argillites. Where individual beds outcrop over long distances in the Richardson Mountains, the ridge and cliff formers are mainly lithic and quartzose sandstones. In river canyons and ravines a wider range of rock types is exposed, as stream flow can maintain bare surfaces on less competent rock types such as shale and poorly indurated argillites.

Although permanently frozen, most bedrock appears to be free of ground ice other than that filling fractures and cavities within the rock. Small ice lenses are present in weathered shale.

Most rock surfaces are stable, although rockfalls may occur along steep slopes cut in the less competent rock types.

SUMMARY

The Yukon Coastal Plain includes all flat and gently sloping terrain between the British, Barn, and Richardson mountains and the Beaufort Sea. The Coastal Plain can be divided into two areas (Fig. 1): (1) a part fringing the Beaufort Sea having negligible regional slope and underlain by thick unconsolidated deposits, and (2) a part fringing the mountains having a gentle coastward slope and consisting of an erosion surface or pediment. The erosion surface is interrupted by bedrock hills and ridges near the mountain front. The Coastal Plain and erosion surface rise gently to the southeast; the outer edge of the Coastal Plain is separated from the Mackenzie Delta by an escarpment of up to 120 m elevation, and streams at the eastern end of the Coastal Plain are incised in deep canyons. The erosion surface or pediment seems to have been formed during the late or middle Tertiary, as it truncates strata of Paleocene age and is covered by Pleistocene sediments.

The British Mountains consist mainly of steep-sided peaks and ridges separated by V-shaped valleys. Peaks rarely exceed 1680 m elevation, and local relief ranges between 460 and 600 m. The Buckland Hills, which are the northern foothills of the British Mountains, consist of rounded hills to 760 m elevation separated by broad valleys. Ridges and valleys of both physiographic units have northwest alignments reflecting structural control.

The Barn Mountains are a group of low hills and mountains between Babbage and Blow rivers; the mountains generally do not exceed 1100 m elevation, and local relief of 460 m is common. Clusters of mountains and hills commonly are separated by broad valleys and basins.

The Richardson Mountains consist of a western fringe with V-shaped valleys, peak elevations to 900 m, and local relief to 460 m; a central part with structurally controlled, north-south oriented ridges, elevations to 1530 m, and local relief to 610 m; and an eastern fringe consisting mainly of rounded ridges with elevations to 770 m and local relief to 400 m.

Prior to the Buckland Glaciation, which affected most of the Coastal Plain, a complex of marine, deltaic, fluvial, lacustrine, and terrestrial sediments was deposited and is exposed along coastal bluffs and in isolated sections scattered over the Coastal Plain (Table 14). Along the coast west of Shingle Point spit, fine-grained marine, deltaic, and floodplain sediments are most common. Generally, the marine sediments that directly underlie Buckland till and outwash contain a unit of freshwater or terrestrial sediments indicating a short period of emergence. Peat from an ice-wedge cast in this sequence near Sabine Point has been dated at >51 100 years (GSC-151-2, Table 15) and supports the assignment of a Sangamon or early Wisconsin age to these sediments. Macrofossils and pollen from a peat bed on Herschel Island, which may possibly equate with peat near Sabine Point, indicate that the landscape was covered by shrub tundra dominated by dwarf birch during its deposition.

The sedimentary sequence at Herschel Island is complicated by faulting and folding due to glacial overriding; however, it appears that a 'mixed' sediments unit representing nearshore and shoreline environments is wedged between two marine units. The peat and associated freshwater sediments mentioned in the paragraph above are thought to represent a brief period of emergence during deposition of the upper marine unit. Fossils indicate that boreal forest covered the landscape during deposition of part of the 'mixed' sediments unit.

Some 14 km south of Kay Point and at King Point, glacially deformed gravel, sand, silty sand, clay, and a few peat beds attest to deposition on a coastal plain that experienced some fluctuations in sea level. Fossils from these sediments indicate that the landscape was covered by shrub tundra and boreal forest at different time intervals during their deposition. These sediments are believed to be pre-Illinoian in age.

East of Shingle Point spit, gravel and sand are predominant in sections. Nine metres of interbedded sand, silt, and oxidized gravel underlying a diamicton and overlying oxidized till near the mouth of Blow River is thought to correlate with the sediments exposed at King Point. Similarly, gravel overlying partly oxidized till on Running River is thought to correlate with sediments exposed at King Point. The oxidized till in the Blow River and Running River sections and unoxidized and oxidized gravels underlying the till and exposed along the coast east of Shingle Point spit are believed to predate sediments exposed at King Point (Table 15). Gravels underlying the oxidized till contain numerous ice-wedge casts.

Large alluvial fans on pediment surfaces and isolated altiplanation terraces formed during the Pleistocene before the Buckland Glaciation.

Morainic ridges, the maximum extent of morainic topography, kame terraces and fans, meltwater channels, and the local maximum elevation of erratics mark a limit of glaciation on the Yukon Coastal Plain and adjacent mountains that falls from about 910 m near the headwaters of Willow River to near sea level at the mouth of Malcolm River (Fig. 18). During deglaciation a major stillstand or readvance occurred and constructed a moraine-outwash complex parallel to the coast between Kay Point and Coal Mine Lake. The glaciation that covered the Coastal Plain and defined the maximum extent of glaciation has been termed the Buckland Glaciation, and the readvance or stillstand has been termed the Sabine Phase of the Buckland Glaciation.

Rolling to hummocky moraines, and ice-thrust ridges are common glacial features of the Coastal Plain. The moraines owe much of their relief to thermokarst as is indicated by the thinness of morainal deposits relative to intermorainal relief, the presence of ice-rich sediments or ground ice under most hills and ridges, and the presence of sediments of thermokarst origin in depressions. The upper 3 m of material in moraines is commonly debris flow, lacustrine, or colluvial deposits. Colluvial and debris flow deposits have similar textures to the underlying till. Even today, because of high ice contents in till and material underlying till, retrogressive thaw flow slides, which produce debris flow deposits, are common on steep slopes. Herschel Island and the ridge that parallels the coast between Kay Point and King Point and forms part of the margin of the Sabine Phase of the Buckland Glaciation are ice-thrust moraines. They undoubtedly resulted from high pore-water pressures in unfrozen sediments underlying permafrost and the presence of a thick overriding glacier. Isolated bodies of ice and icy sediments are present within the deformed sediments comprising the ice-thrust moraines.

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Kame deltas and terraces are concentrated near the limit of Buckland Glaciation, although individual kames are scattered throughout the Coastal Plain. Isolated eskers, the largest located 10 km south of Trent Bay, also are present. Thermokarst depressions attest to the presence of ground ice in the base or underlying some of these features.

Terraced outwash fans and plains are common on the coastal fringe of the Coastal Plain. Valley trains occupy a number of broad channels eroded by meltwater, the most notable being the channel and valley train originating near Coal Mine Lake and paralleling the limit of the Sabine Phase to near Kay Point. Outwash fans that flank the inland side of the morainic ridge forming the limit of the Sabine Phase of glaciation have had their distal edges eroded by meltwater flowing along this channel. Except for some outwash fans near Kay Point, which are composed of sand, most glaciofluvial deposits consist of gravel.

Small glacial lakes probably formed in stream valleys that were blocked by Buckland glaciers. Also, a glacial lake appears to have covered a large area below 75 m elevation near the confluence of Rapid Creek and Blow River during the Sabine Phase. Glaciolacustrine deposists are generally clayey or sandy silt.

Subdued morphology of moraines, radiocarbon dates obtained from materials overlying till on the Coastal Plain and adjacent regions, and the absence of major thicknesses of peat and weathering zones that predate 11 000 years B.P. all suggest that the Buckland Glaciation is early Wisconsin in age. Most dates from depressions on the Coastal Plain are believed to be related to the initiation of thermokarst activity rather than to deglaciation.

A few glacial moraines and outwash features on the eastern edge of the Coastal Plain below 120 m elevation have been assigned a late Wisconsin age (Fig. 18). This assignment is based on the known levels of the late Wisconsin limit in adjacent areas.

The Yukon Coastal Plain and adjacent areas are underlain by continuous permafrost with ground temperatures of about -8.5°C near Babbage River and between -1° and -5°C on the Mackenzie Delta. Permafrost probably exceeds 300 m in depth on the Coastal Plain with shallower depths under the Mackenzie Delta. The depth of the active layer varies from less than 0.5 m under peat-covered surfaces to more than 2.5 m under bare gravels near Aklavik. Ice wedges and epigenetic and aggradational segregated ice in the form of ice lenses and massive ice are the commonest forms of ground ice on the Coastal Plain. Segregated ice is found in morainal deposits, lacustrine deposits, fine-grained alluvium, colluvium, and organic deposits. Some segregated ice in the deformed sediments of Herschel Island and at other localities probably predates the Buckland Glaciation. Most segregated ice in the base of Buckland sediments and sediments directly underlying them probably formed during deglaciation. Aggradational segregated ice in the upper 3 to 6 m of many units is believed to have formed during climatic cooling over the last 5000 years. Ice wedges may have formed at any time since the deposition of the deposits that contain them.

Thermokarst, both at present and in former times, has proceeded primarily through retrogressive thaw flow slides. Mudflow debris at the base of lacustrine sequences covering much of the Yukon Coastal Plain attests to the importance of retrogressive thaw flow slides in the origin of thermokarst basins. Most thermokarst basins are believed to have been forming actively between 12 000 and 8000 years ago; however, thermokarst basins were forming earlier and continue to form at a much reduced rate at present. The lacustrine sediments in thermokarst basins are usually thinly bedded, highly organic silty clay, silt, and silty sand with peaty layers and scattered pebbles and cobbles. In areas where sand and gravel constitute the surrounding deposits, the lacustrine deposits have similar textures.

Colluvium is present on most slopes beyond the limit of glaciation and numerous slopes within the limit of glaciation. The texture is variable and is related to underlying and upslope materials. It commonly contains high organic contents because of continuous burial of organic material by solifluction. Solifluction lobes and bouldery terracettes are common on colluvial slopes. Measurements on vegetation-bare steep slopes indicated average movement of 2.5 cm per year, primarily by creep. Solifluction appears to be more sporadic with movements of up to 9 cm per year measured on the surface of various lobes. Radiocarbon dates from material below one lobe indicate that it advanced at about 0.15 cm per year over the last 300 to 500 years and at about 0.08 cm per year in the previous 600 to 900 years.

Large terraced alluvial fans composed mainly of gravel are a common phenomenon on the Coastal Plain west of Firth River. The fans likely have been forming over a long period of time, but radiocarbon dates indicate a post-Wisconsin age for their surfaces. Post-Wisconsin alluvial fans also flank the Richardson Mountains south of Willow River, but they are composed mainly of fine-grained sediments.

Multiple terraces and floodplains are present along most streams. Due to the incised nature of the present valleys, the highest terraces are adjacent to streams east of Babbage River. High terraces probably immediately postdate Buckland Glaciation, whereas low terraces may have been formed during the last 4500 years; streams continue to downcut at present. Fluvial deposits are composed mainly of gravel and sand, although low terraces and floodplains may have covers of fine sand and silt with high organic contents. The Mackenzie Delta and other deltas of course consist primarily of fine sand and silt. Active floodplains generally consist of braided bar and channel complexes on the western Coastal Plain and large point bars and islands on the eastern Coastal Plain.

Numerous spits, baymouth bars, and beach ridges are present along the Beaufort Sea coast and consist primarily of sand and gravel. Beaches are absent at the base of cliffs composed of fine-grained sediments that erode through thermal niching or retrogressive thaw flow slides. Minor areas of intertidal deposits, composed mainly of sand and silt with high organic contents, are present near the distal edges of deltas.

Flat to gently sloping areas on deposits of any texture are usually poorly drained because of shallow active layers. Because of this, organic deposits commonly blanket flat to gently sloping terrain.

Fossils obtained to date indicate that the landscape during post-Buckland time has been covered by tundra. Macrofossil studies indicate that shrub tundra was present at Stokes Point around 22 400 years ago with the tree line possibly closer to the site than the present tree line. Macrofossils from an exposure near Sabine Point indicate that around 14 400 years B.P. the area was covered by fell-field or steppe and was colder and drier than at present. Macrofossils, pollen evidence, and thermokarst chronology indicate climatic warming shortly after 11 000 years B.P. Dwarf birch may have been a more dominant component of the coastal vegetation between 11 000 and 7000 years B.P. than at present. *Populus* wood dated at 9940 years was also well north of its present limit. The regional climate probably cooled between 5500 and 4000 years B.P. and has remained relatively static to the present. Sea level and the position of Beaufort coastline may be a partial cause of some climatic fluctuations.

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