Vegetation-geology-climate relationships of western Melville Island, District of Franklin

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Abstract

Both surficial geology and climate closely control plant assemblages on western Melville Island. Vegetation falls into two broad categories: calciphilous communities on weakly to moderately alkaline substrates, and acetophilic communities on acidic substrates. Superimposed on this lithological control is the control imposed by climate. The region is subdivided into five bioclimate zones including a newly defined one – Zone 0 – unvegetated areas recently emerged from under neoglacial ice and snow.

An unusually vegetation-rich zone (Zone 4) covers a significant area of western Melville Island, making it the richest area of the central and western Queen Elizabeth Islands, comparable to the flora and communities in the Fosheim Peninsula region of Ellesmere Island. This zone may represent a disjunct of Mid Arctic vegetation into the region generally considered to be High Arctic.

Résumé

La géologie des formations en surface et le climat contrôlent étroitement les association végétales dans l'ouest de l'île Melville. La végétation dans cette région se répartit en deux grands groupes: des communautés calciphiles sur des substrats faiblement à modérément alcalins et des communautés acidophiles sur des substrats acides. Au contrôle lithologique s'ajoute le contrôle climatique. On divise la région en cinq zones bioclimatiques dont une zone nouvellement définie, soit la zone 0; il s'agit d'une zone sans végétation qui a récemment émergé de la glace et de la neige néo-glaciaires.

Une zone exceptionnellement riche en végétation (zone 4) couvre une grande superficie de la partie ouest de l'île Melville, faisant de cette dernière la région la plus riche du centre et de l'ouest des îles de la Reine-Élisabeth, comparable par sa flore et ses communautés à la presqu'île Fosheim dans l'île d'Ellesmere. Cette zone peut être considérée comme un îlot isolé de végétation de l'Arctique moyen dans la région généralement considérée comme appartenant à l'extrême Arctique.

Introduction

Reconnaissance studies carried out on western Melville Island (Fig. 86.1) during the summers of 1984 and 1985 confirm the strong geological and elevational controls on the distribution of plant communities expected in a High Arctic environment (Edlund, 1983a). The landscape is dominated by plateaus and folded uplands, up to 776 m a.s.l., developed on relatively resistant Paleozoic clastic and carbonate rocks, whereas in the northern sector, lowlands and low cuestas occur on younger, generally recessive clastic sediments.

Geological control of vegetation

There is minimal soil development in this region, therefore the vascular plants root directly in the weathered rock which is the dominant surficial material. The chemistry of the bedrock therefore exerts a major influence on the vegetation. Most Quaternary surficial materials are locally derived, except at Bailey Point and Cape Hoare (Hodgson et al., 1984) and at Comfort Cove (D.A. Hodgson, personal communication, 1985) where a silty clay calacreous till was deposited by Late Pleistocene glaciers of continental origin. The strong correlation between vegetation and surface materials of Melville Island was first observed by Tozer and Thorsteinsson (1964). This study further refines their observations.

Preliminary pH studies show that the surficial materials can be grouped into two broad categories (Fig. 86.2), according to the types of plant communities they support (Fig. 86.3): (1) those with an alkaline pH, with calciphilic (lime-loving) vegetation and (2) those with an acidic pH, with accompanying acetophilic (acid-loving) or pH-indifferent vegetation. Near neutral soils show some overlap of both acid- and lime-loving species. Although the dominant and common species differ between these two broad divisions, the growth forms of the plants concerned are similar (dwarf shrubs, grass-like, herbaceous, lichen or moss).

Six subdivisions of the substrate, based on the degree of acidity/alkalinity and texture of the surficial materials, are shown in Table 86.1. Most materials are moderately to well drained, therefore the tundra and barrens vegetation dominate. Only on the silty clay till at Bailey Point is there extensive wetland vegetation. Accompanying vegetation is also described.

The densest and most diverse vegetation occurs on several members of the Ibbett Bay Formation found in the Canrobert Hills, which are recessive, black fissile shales that weather into thin, platy fragments. They are weakly to moderately alkaline, and moderately to well drained. At lower elevations these materials support dense, continuous dwarf shrub (**Dryas** and willow)-legume tundra and dwarf shrub-grass tundra, on all stabilized surfaces. At high elevations, grasses and purple saxifrage (herbaceous species) dominate.

Fluvial deposits (sand and silt) derived primarily from the Canyon Fiord Formation at the head of McCormick Inlet, also support dense and diverse calciphilous dwarf shrub-legume and dwarf shrub-grass tundra and barrens, although the parent formation is itself rather poorly vegetated. The lack of vegetation on weathered Canyon Fiord Formation may be due primarily to the instability of its surfaces.

The richest vegetation on weakly to moderately acidic surficial materials consists of willow-**Luzula** tundra, local arctic heather heathland, and **Luzula**-tundra, with a general absence of calciphilous species. The rubbly felsenmeer produced on the lower member of Hecla Bay Formation sandstone, although also weakly acidic, is too coarse for the rooting of vascular plants. Instead, cryptogamic (moss and lichen) communities are found, with crustose lichens on exposed rock facets, and mats of **Rhacomitrium** sp. moss, carpeting the sheltered junctions of boulders.

The poorest vegetation, both in species diversity and density of vascular plant cover, occurs in two general regions, the northern half of the Sproule Peninsula and Cape Grassy, and at elevations above 250-300 m on the plateaus and rolling hills. There the vascular plant species are entirely herbaceous, with purple saxifrage commonly dominant on the alkaline terrain and **Luzula** on the acidic ones. Wetlands are dominated by only grass species; sedges are absent.

Some materials do not support plant growth. Both the nearly pure carbonates of the Canrobert Formation and a Paleozoic carbonate inlier along Kitson River are devoid of plant life. These carbonate surfaces may weather too rapidly for crustose lichen attachment, and the fines lack sufficient other plant nutrients to buffer the overwhelming amounts of calcium and magnesium and thus are toxic.

The siliceous chert gravel facies of the Ibbett Bay Formation does not weather as rapidly as the carbonates and does support crustose lichen and **Rhacomitrium** moss communities.

Influence of climate on vegetation

In addition to the lithological control on plant communities, climate, probably through variations in summer warmth and the length of growing season, influences the diversity, abundance, and dominance of plant species and communities. This control cuts across lithological boundaries and shows a strong elevational trend and a weaker latitudinal trend, as was noted in the central Queen Elizabeth Islands (Edlund, 1983a).

Bioclimatic zones in this region (Fig. 86.3) are: Zone 1, with less than 35 vascular plant species, all of which are herbaceous; Zone 2 also dominated by herbaceous species, but an increase in diversity to between 35 and 60 vascular plant species, including the presence of sedges and woody plants; Zone 3, with woody species and sedges the dominant vascular plants and diversity between 60 and 100; and Zone 4 which is

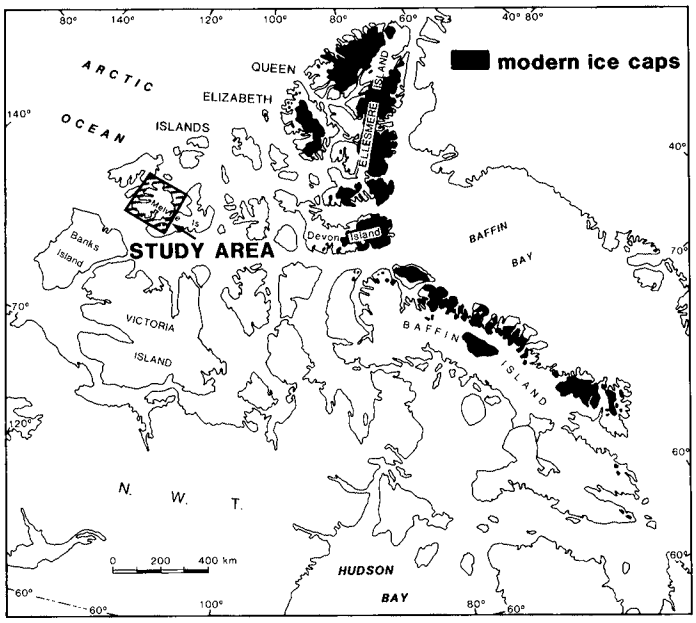

Figure 86.1. Location of study area, western Melville Island.

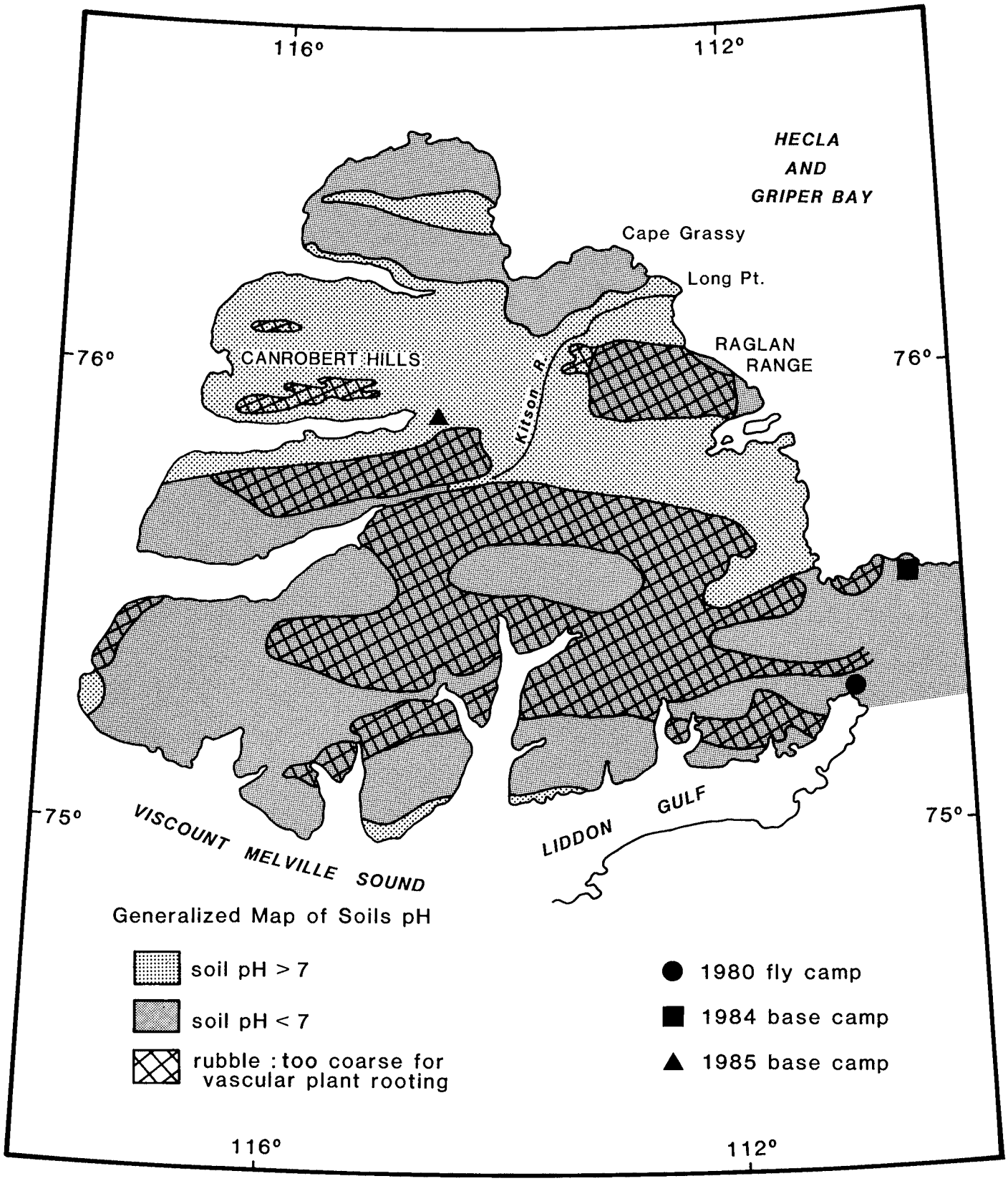

Figure 86.2. Generalized map of soil pH, western Melville Island.

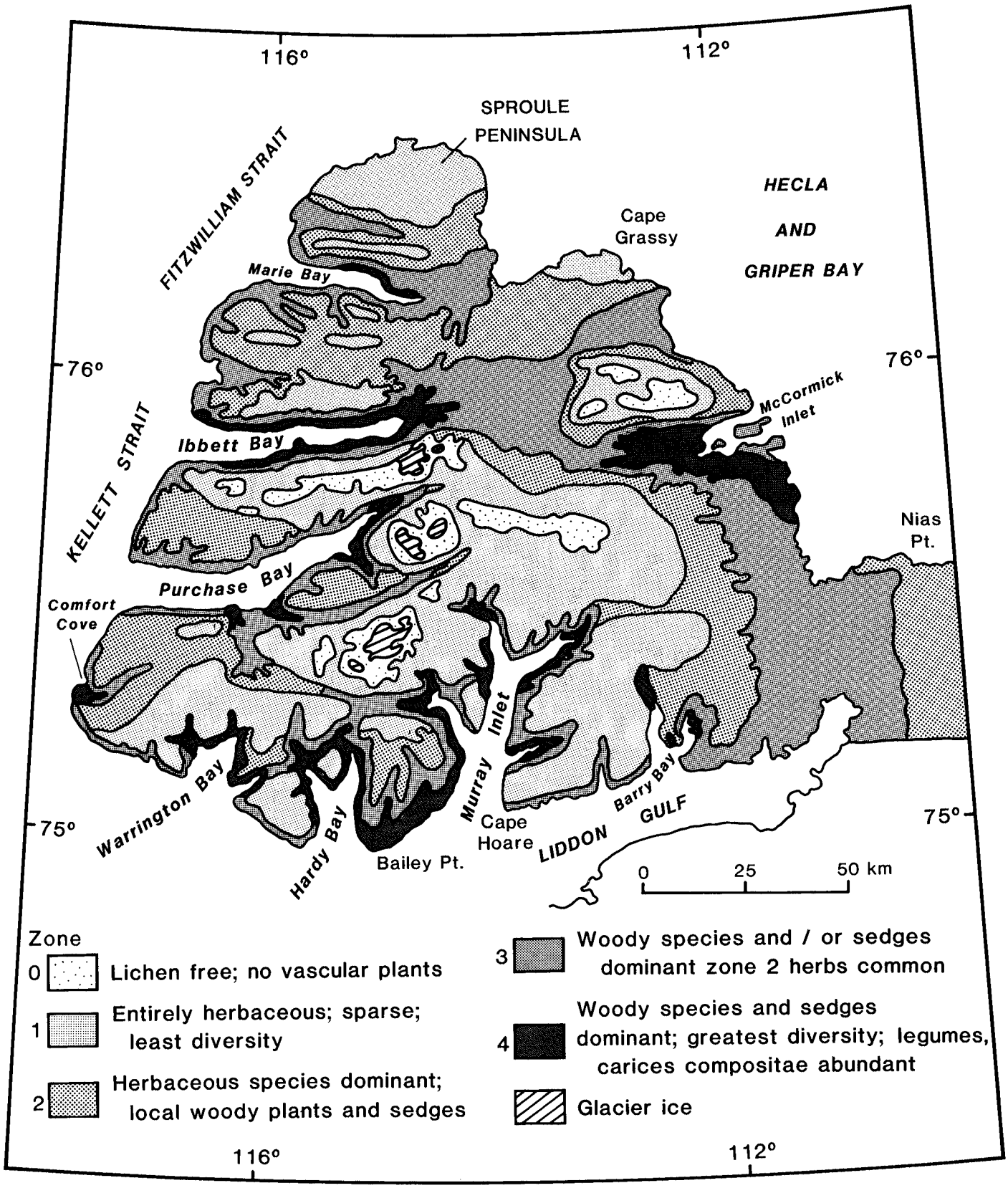

Figure 86.3. Bioclimatic zones of western Melville Island.

also dominated by woody species, including local heath, and sedges and has the greatest diversity of 120-125 or more vascular plant species.

All four bioclimatic zones described for the central Queen Elizabeth Islands occur on western Melville Island. On central and southern Melville Island (Edlund, 1982a, 1983a) the zone (Zone 4) of greatest density and diversity (>100 vascular plant species) is limited to a narrow strip along the southern coast and along the southern shore of western Liddon Gulf.

Zone 4

On western Melville Island Zone 4 occurs in valleys along the north side of Liddon Gulf and Viscount Melville Sound as well as along shores and sheltered valleys in the central part, a much more extensive coverage than predicted by Edlund (1983a). On weakly to moderately alkaline materials in this zone woody species, particularly **Dryas** (Arctic Avens) and **Salix arctica** (dwarf willow), dominate with the diameter of some willow clumps reaching more than 1 m. Common herbaceous associates include the legumes **Astragalus alpinus** (alpine milk-vetch) and **Oxytropis arctica**; other more southerly herbs **Geum Rossii**; a variety of compositae (Daisy family) including **Senecio congestus, Arnica alpina, Erigeron eriocephalus, E. compositus, Antennaria** sp.; **Crepis nana** (dwarf hawks beard), **Petasites frigidus** (Lapland butterbur), and four or five **Taraxacum** (dandelion) species; and local occurrences of the sedges **Carex nardina** and **C. rupestris** and grasses such as **Festuca rubra, F. baffinensis, Trisetum spicatum,** and **Agropyron violaceum**. Communities on acidic substrates include dense mats of **Salix arctica** and local heath of **Cassiope tetragona** (arctic white heather). Common herbaceous associates include **Luzula confusa** (northern woodrush), **L. nivalis,** and **Hierochloe alpina** and **Potentilla hyparctica,** and **Stellaria longipes.**

Wetlands in Zone 4 are dense with sedge and grass species: **Carex aquatalis** var. **stans; Eriophorum triste** and **E. scheuchzeri** (cotton grasses), and grasses **Arctagrostis latifolia, Dupontia Fisheri, Alopecurus alpinus,** and **Hierochloe pauciflora.** Dwarf woody species also occur on mossy hummocks in the wetlands.

Pond emergents include **Arctophila fulva,** a grass which locally fills shallow ponds, **Pleuropogon sabinei** (semaphore grass), **Caltha palustris** (marsh marigold), and tiny buttercups such as **Ranunculus hyperboreus** and **R. gmelini.** Halophytic (salt-loving) species along the ocean shore and in brackish lagoons include locally dense turfs of **Puccinellia phryganodes** (goose grass) and **Stellaria humifusa,** as well as unexpected occurrences of **Carex ursina** and **C. maritima.** An as yet unidentified caespitose Saxifrage was also found in tidal zones.

Zone 3

Zone 3, the more common "rich" zone of the High Arctic (60-100 vascular species) occurs up to 150 m a.s.l. It is also dominated by woody plant species and sedges as in Zone 4 but the diversity and per cent cover are less. Willow and arctic avens are common on weakly to moderately alkaline materials, but legumes, common in Zone 4, are rare and **Saxifraga oppositifolia** (purple saxifrage) and **Alopecurus alpinus** are common associates instead. On acidic materials **Cassiope** is restricted and generally absent. The Compositae family includes only **Petasites frigidus** and **Taraxacum** species. **Pleuropogon Sabinei** and **Ranunculus hyperboreus** are the common marsh emergents. Halophytes include only turfs of **Puccinellia phryganodes** and **Stellaria humifusa.**

Zone 2

In Zone 2 sedges and woody species are no longer dominant but are still present. It is dominated by herbaceous species, generally those that were common associates in Zone 3. Diversity (35-60 species) and per cent cover of vascular plant species decrease (generally less than 10% cover). Sedges and cotton grasses are rare; arctic heather, Compositae, and Leguminosae are absent. Purple saxifrage generally dominates on weakly to moderately alkaline materials, with grasses, generally **Alopecurus** and **Colpodium,** on the siltier aspects. Areas of acidic coarse sand to silt are dominated by **Luzula** (wood rush) species, with **Potentilla hyparctica** as a common associate; grasses, cruciferae, and **Papaver** (arctic poppy) occur on siltier sites. Vascular plants in wetlands are almost entirely dominated by grass species, particularly **Alopecurus** and **Dupontia,** with **Pleuropogon** as an occasional marsh emergent.

On western Melville Island Zone 2 vegetation occurs along the north coast and on the uplands and parts of the southern and central plateau, at elevations of ca. 150-200+ m a.s.l.

Zone 1

Zone 1, which has the most impoverished vegetation in the central Queen Elizabeth Islands, occurs primarily on the plateaus at elevations of generally more than 350 m a.s.l. This zone is entirely herbaceous and/or cryptogamic. There are generally less than 35 vascular plant species, and in places there is no clear dominance. There are no woody species sedges, compositae, or vascular cryptogams present in this zone. Vascular plant cover is generally less than 5 per cent. In some places communities are entirely cryptogamic.

Zone 0

Observations on western Melville Island indicate that another High Arctic bioclimatic zone is present. Zone 0 delineates areas that are devoid of vegetation due to its recent exposure from under ice and snow, rather than for reasons of toxic chemistry, lack of plant nutrients, or rapid weathering of the surficial materials. This zone covers several thousand square kilometres on the highest plateau surfaces of western Melville Island (ca. 500-700 m a.s.l., Edlund, 1985), as well as locally around the edges of permanent snowbanks otherwise lying in Zone 1 and rarely Zone 2.

Floristics

Most plant species observed on western Melville Island have already been reported from other parts of Melville Island (Porsild, 1955, 1964; Cody et al., 1976; Porsild and Cody, 1980; Edlund, in preparation); however, a few unreported species were found during fieldwork. One surprise was the occurrence of species of moss **Sphagnum subsecundum** in small wet meadows at 180 m a.s.l. near the east arm of Murray Inlet and again on the west side of Warrington Bay. **Sphagnum** is generally considered to be a species of the boreal bogs and rarely appears in the Low Arctic. It has not been included in modern flora in the High Arctic. The detection of modern **Sphagnum** on Melville Island may help to explain the seemingly anomalous occurrence of high levels of **Sphagnum** pollen from ice cores from a Melville Island ice cap (J. Bourgeois, personal communication, 1985).

Table 86.1. General types of substrates and accompanying vegetation, western Melville Island

SUBSTRATE CHEMISTRY AND TEXTURE	BIOCLIMATIC ZONES AND VEGETATION
ALKALINE MATERIALS (pH > 7.2)	CALCIPHILOUS VEGETATION
WEAKLY TO MODERATELY ALKALINE SILT, MINOR CLAY Includes Cape DeBray and Christopher formations; parts of Griper Bay, Weatherall Bay, Ibbett Bay, Blackley, Kitson River, Cape Phillips, Cape Fortune, and Canyon Fiord formations; silty calcareous till; Quaternary deposits derived from the above.	ZONES 4 and 3: Dwarf willow and arctic avens dominant; cover 10-50%; grasses, sedges, legumes, **Potentilla**, crucifers, purple saxifrage, composites common associates; sedge dominated wetlands. ZONES 2 and 1: grasses and/or purple saxifrage, herbs dominant; cover 2-10%; crucifers, Caryophyllaceae poppy, saxifrages common associates; grass dominated wetlands; no apparent dominant in some places.
WEAKLY TO MODERATELY ALKALINE SAND AND GRAVEL Gravel includes platy fissile shale fragments from Ibbett Bay, Cape DeBray, Kitson River, and Blackley formations; sand and gravel from Canyon Fiord, Trold Fiord, Assistance Bay and parts of Wilkie Point, Beverley Inlet formations; Quaternary deposits derived from the above.	ZONES 4 and 3: Arctic avens, and to a lesser extent, dwarf willow dominate; cover 10-50%; legumes, dryland sedges, grasses, composites, purple saxifrage common associates; sedge dominated wetlands. ZONES 2 and 1: Purple saxifrage dominant; cover 2-10%; grass dominated wetlands; no apparent dominant in some places.
STRONGLY ALKALINE FINES, GRAVEL, AND RUBBLE Parts of Cape Phillips, Thumb Mountain, Canrobert formations; Silurian carbonate inlier along Kitson River.	ZONES 4, 3, 2, and 1: Not vegetated
ACIDIC MATERIALS (pH 6.8-5.0)	ACETOPHILIC AND pH-INDIFFERENT VEGETATION
WEAKLY TO MODERATELY ACIDIC SILT AND/OR CLAY Local Weatherall Bay, Griper Bay, Beverley Inlet, Christopher formations; Kanguk Formation.	ZONES 4 and 3: Dominated by dwarf willow; cover 10-50%; grasses, particularly goose grass, foxtail grass Caryophyllaceae common associates; sedge dominated wetlands; arctic white heather locally dominant in Zone 4. ZONES 2 and 1: Dominated by grasses (foxtail grass, Colpodium, Phippsia); cover 1-10%; Caryophyllaceae and poppy common associates; grass dominated wetlands.
WEAKLY TO MODERATELY ACIDIC SAND AND GRAVEL Includes platy, fissile shale of Blackley and Weatherall Bay formations, Parry Island Group, and sand of Hecla Bay, Bjorne, Isachsen, Wilkie Point, Hassel formations, and local Quaternary deposits, and till and fluvial deposits derived from these formations.	ZONES 4 and 3: Dwarf willow dominated; cover 10-50%; arctic white heather locally dominant in Zone 4; common associates: woodrush, **Potentilla**, holy grass; sedge dominated wetlands; local **Sphagnum** moss. ZONES 2 and 1: woodrush and grass dominated; cover 1-10%; **Potentilla, Stellaria** common associates; grass dominated wetlands; no apparent dominants in some places.
NON ALKALINE GRAVEL AND RUBBLE WITH FEW FINES Includes upper member of Hecla Bay sandstone formation; local sandstone facies of Hecla Bay and Beverly Inlet formations; siliceous chert of Ibbett Bay Formation.	ZONES 4, 3, 2 and 1: Crustose and foliose lichens on exposed boulder facets; **Rhacomitrium** moss-lichen mats over sheltered rubble and in junctions of boulders.

A few vascular plant species new to Melville Island were also found: the halophytes **Carex maritima** and **Carex ursina**; the grass **Deschampsia pumila**; a possibly new **Festuca** sp. (S.G. Aiken, personal communication, 1985) and calciphilic species **Kobresia myosuroides, Antennaria canescens**; and the wintergreen **Pyrola grandiflora**, and dandelion **T. pumilum**. A nonflowering **Polemonium**, possibly **P. acutiflorum**, not previously reported from the Arctic Islands, occurred on several poorly drained organic deposits on extreme western Melville Island. All new species occurred in bioclimatic Zones 3 and 4 where summer temperatures are warmest.

Discussion

The diverse plant communities found in Zone 4 are more akin to plant assemblages farther south rather than to those of the central High Arctic. The calciphilous dwarf shrub-legume tundra communities at Ibbett Bay, McCormick Inlet, and Liddon Gulf have their counterpart in the broad zone of calcareous deposits of the Mid Arctic, on Banks Island (Vincent and Edlund, 1978) and Victoria Island (Edlund, 1983b). Similarly the dwarf shrub-heath tundra communities are comparable to Mid Arctic communities on acidic Precambrian Shield granites and gneisses of northern District of Keewatin (Edlund, 1982b) and Baffin Island.

Zone 4 seems to represent the sporadic occurrence of Mid Arctic vegetation in the western Queen Elizabeth Islands. The similarities between Zone 4 and Mid Arctic vegetation (National Atlas of Canada, 1971) in plant community common associates, colonizing species wetlands composition, emergent marsh species, and halophytes is striking. A difference between Zone 4 vegetation on western Melville Island and vegetation of the Mid Arctic is the absence in Zone 4 of woody species capable of erect and semi-erect shrub growth form, such as **Salix alaxensis, S. niphoclada**, and **S. lanata** var. **Richardsonii**. In the Mid Arctic, these woody species have adopted a prostrate growth form, similar to that of the genetically dwarfed, prostrate shrub **Salix arctica**; in the Low Arctic, however, these willow rise from 30 cm to 1 m or more above the ground.

The presence of Zone 4 vegetation in the Queen Elizabeth Islands is not restricted to southern and western Melville Island. Similar plant assemblages occur on the lowlands and sheltered slopes and valleys of Axel Heiberg and Ellesmere islands, up to at least 80°N (Waterston and Waterston, 1972). In the mountainous eastern Queen Elizabeth Islands, this seeming vegetation anomaly reflects a climate anomaly – the rain shadow effect. Major mountain ranges provide a barrier to low cloud moving in from the Arctic Ocean, thus many lowlands and valleys receive more direct sunlight than the low lying Queen Elizabeth Islands. This is illustrated best by a comparison of mean daily temperatures for July in several parts of the Queen Elizabeth Islands: Eureka (80°N), surrounded by mountains, has a mean daily July temperature of 5.4°C, whereas Isachsen (78°47'N) on low-lying Ellef Ringnes Island, has a mean daily July temperature of 3.2°C; Resolute (74°43'N), Cornwallis Island, 4.1°C; Rea Point (75°21'N), eastern Melville Island, 4.1°C; and Mould Bay (76°14'N), Prince Patrick Island, 3.1°C (Atmospheric Environment Service, 1975). The ridges and plateaus of western Melville Island may function as orographic barriers to southward moving systems off the Arctic Ocean in similar fashion to the mountainous eastern Queen Elizabeth Islands.

Along the north shore of Murray Inlet, Liddon Gulf some of the densest and most diverse heath and vegetation occur on small coastal plateaus at 150-180 m a.s.l., above the level of coastal fog and thus receiving more sunlight than the coastal strip.

The black shales and mudstones found in the Canrobert Hills, particularly where the Ibbett Bay Formation outcrops, support the most luxurious vegetation growth on Melville Island. No doubt several factors contribute to the richness of the vegetation there, including the occurrence of a wide range of plant nutrients and a source of carbon in the weathered rock. But so, too, the colour of the weathered rock may raise the temperature; the black, unvegetated, steep, unstable upper slopes and ridge tops absorb solar radiation and radiate it, to a much greater degree than the adjacent buff, grey, and white carbonate formations. The observations that vegetation on the black shales flowered and set seed 1-3 weeks earlier than on most of the rest of the island supports this hypothesis; temperatures recorded at the surface of the black shales were 7°C or more above the air temperature whereas temperatures on grey and light brown materials were less than 2°C above air temperature.

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