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TERRAIN CHARACTERIZATION AND EVALUATION: AN EXAMPLE FROM EASTERN MELVILLE ISLAND

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TERRAIN CHARACTERIZATION AND EVALUATION: AN EXAMPLE FROM EASTERN MELVILLE ISLAND

Abstract

This paper explains the methodology of an integrated (interdisciplinary) 1: 125 000 scale mapping project on eastern Melville Island and describes the style of data presentation used in Geological Survey of Canada Open File 252 (Barnett et al., *1975a) which includes photomosaic maps accompanied by expanded legends. The legend is organized to show geological, geomorphological, botanical, and some wildlife data. These data appear in the upper part of the expanded legend. In the lower part they are interpreted and converted into simple numerical evaluations suitable for aspects of land-use management.*

The data are arranged into a hierarchy with three levels of detail identified as Landscape Type (regional), Geobotanical Facies (intermediate), and Terrain Units (local).

Each sedimentary bedrock formation has a distinctive morphological development with associated suites of landforms and vegetation. The combinations of attributes which make each Landscape Type distinctive are set out in a matrix. The particular significance of veneers, the marine limit, vegetation, and ground ice is explained. The basis for evaluation of trafficability and sensitivity, and the potential utility of integrated mapping for wildlife studies is outlined. Guidelines for nonspecialist users are set in nontechnical language.

Résumé

Cette étude explique les méthodes adoptées pour exécuter un projet intégré de cartographie à l'échelle au 1/125 000 (projet inter-disciplinaire) sur l'est de l'île Melville et décrit la présentation des données adoptée dans le Dossier public 252 de la Commission géologique du Canada (Barnett et al., *1975a), qui comporte des cartes faites à partir de mosaïques photographiques accompagnées de légendes détaillées. Cette légende est conçue pour présenter des données géologiques, géomorphologiques et botaniques, ainsi que des données sur la nature à l'état sauvage. Ces données figurent dans la partie supérieure de la légende détaillée. Dans la partie inférieure, elles sont interprétées et converties en estimations chiffrées simples qui conviennent à divers aspects de la gestion de l'utilisation des terrains.*

Les données sont organisées hiérarchiquement et réparties suivant trois niveaux: types de paysage (niveau régional), faciès géobotanique (niveau intermédiaire), et unités de terrain (niveau local).

Chaque formation de roche en place sédimentaire a subi une évolution morphologique distincte à laquelle sont associées des suites correspondantes de formes de terrain et de végétation. Le jeu des caractéristiques distinctives de chaque type de paysage est présenté dans une matrice. La signification particulière des placages, des limites marines, de la végétation et de la glace dans le sol est expliquée. Les auteurs exposent aussi les bases qui permettent d'évaluer la capacité des sols à subir le passage de véhicules et leur sensibilité et ils traitent de l'utilité potentielle de la cartographie intégrée pour les études de la nature à l'état sauvage. Des directives pour l'utilisateur non spécialisé sont présentées dans un langage non technique.

TERRAIN CHARACTERIZATION AND EVALUATION: AN EXAMPLE FROM EASTERN MELVILLE ISLAND

INTRODUCTION

Purpose

This paper explains an integrated mapping scheme and method of data presentation devised for eastern Melville Island (Barnett *et al.*, 1975a, 1975b) which is believed to be readily applicable to the islands of the Sverdrup Basin and possibly farther afield.

Landscape Types are characterized by environmental variables arranged in a matrix. The essential elements of the Landscape Types also are shown diagrammatically as suites of landforms. Applied geomorphological and botanical relationships discerned from eastern Melville Island are presented and discussed. The last section provides some general principles suitable for land-use management set out in nontechnical language; these principles do not cover all conditions that may be encountered but refer primarily to summer conditions.

In 1973 a pilot field project integrating mapping of several disciplines concerned with land use in the Arctic Islands was initiated on eastern Melville Island (Barnett and Dredge, 1974). This was a response to a general concern for future environmental management and in particular the potential routing of a natural gas pipeline in the Arctic Islands. Extensive terrain data were required, and because trenching was a potential major activity, subsurface information also was needed. The objectives of the pilot project were (1) to integrate data gathering of three agencies concerned with the environment (Geological Survey of Canada, Canadian Wildlife Service, and Forest Management Institute) and (2) to produce an interdisciplinary mapping system in a form that would permit ready storage and retrieval of data. This approach was a planned contrast to the separate and parallel studies that each discipline conducted in the Mackenzie Valley Pipeline Corridor a few years earlier.

An essential element of terrain characterization is to identify regional differences that are significant to the intended users. A diversity of users complicates, and perhaps dilutes, this process.

A variety of potential users was considered, from those concerned with pipeline route selection to those who might be concerned with potential muskoxen habitat. This anticipated need for a variety of information at levels of detail ranging from general terrain characterization to specific local data led to the development of a three-level hierarchy for data presentation. Ranking of information is implicit in a hierarchical format, and in this case the ranks indicate degrees of generalization of the data so that the user has a choice of the level of detail.

Mapping was done on 1:60 000 scale airphotos, and final boundary lines were transferred to a 20 per cent screened 1:125 000 scale airphoto mosaic base (Fig. 1). Extrapolation from sampled sites to those areas not visited involved extensive airphoto interpretation.

Acknowledgments

Several organizations and many persons contributed to the data collection. Initially these included Geological Survey of Canada, Canadian Wildlife Service (Eastern Region), and Forest Management Institute; co-ordination was in association with Environmental-Social Program, Northern Pipelines (ESP-NP). Field equipment largely was supplied by Energy, Mines and Resources, and substantial logistic support was provided by Polar Continental Shelf Project.

In the formative stages of the project Dr. J. G. Fyles offered considerable advice which is hereby gratefully acknowledged. Dr. H. J. Dirschl (ESP-NP) maintained liaison concerning possible application of this work to pipeline-related concerns, provided administrative assistance involving both clerical and technical aspects, and kindly arranged for substantial working space for the compilation phase.

The field assistance of M. Cooper, I. S. Hotzel, M. F. Nixon, D. W. Van Eyk, and R. V. Young is gratefully acknowledged. C. T. Carmody and E. J. Edmonds provided cheerful compilation assistance.

The writers appreciate the involvement of Don Thomas and Lynda Prevett, both of the Canadian Wildlife Service, in the pilot project and now understand some of their difficulties in attempting to delineate the wildlife habitat of fauna whose eating habits are not yet fully understood. The paper has benefited from numerous discussions with D. A. Hodgson of mapping problems and also from his critical review of the manuscript.

Eastern Melville Island

The study area totals about 6000 square miles (15 500 km^2) from 74°55' to 76°50'N and 105°20' to 110°30'W (Fig. 1). It encompasses two major geomorphic provinces: the gently flexured, poorly lithified strata forming the escarpments and central plateau of the Sabine Peninsula, and the more resistant folded strata forming the extensive sandstone plateau to the south and east. Eastern Melville Island is an area of moderate relief, rising to 1300 feet (400 m) maximum at an anticlinal structure east of Weatherall Bay.

Much of the surface material of eastern Melville Island consists of a weathered mantle derived largely from the underlying bedrock. This condition, coupled with the relative scarcity of glacial materials, makes the composition and degree of lithification of the bedrock of considerable significance in this area.

A variety of bedrock types occurs on eastern Melville Island, including sandstones, limestones, shales, and evaporites. Locally extensive alluvial accumulations are present as well. The entire area has been glaciated. Residual, thin, southern provenance till with igneous cobbles and boulders is widespread. These glacial deposits occur generally on high ground and are associated with an early Pleistocene glacial episode.

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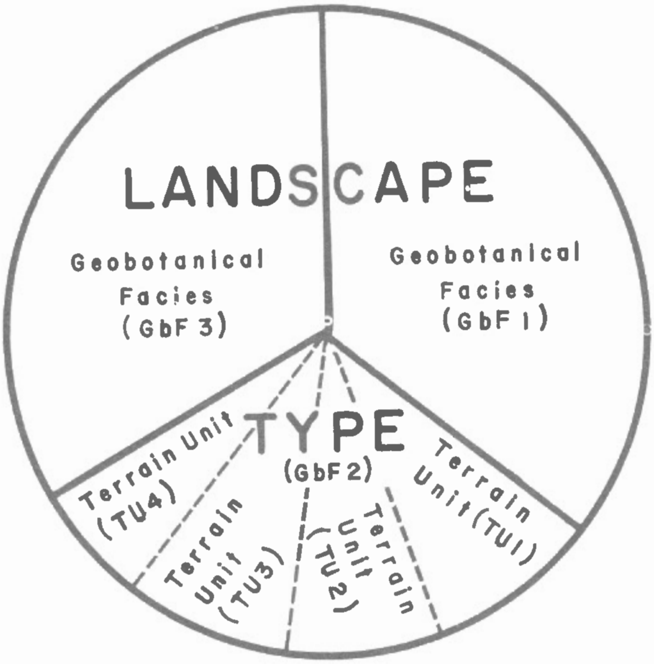


Figure 2. Schematic representation of the spatial relationships and boundary depiction of units at the three levels of the hierarchy.

Till from late Wisconsin glacial activity is rare except locally on the south coast as the Winter Harbour moraine (Fyles, 1967). Despite this, a discontinuous veneer of marine sediment and landforms associated with postglacial marine overlap indicate that the area has rebounded since late-glacial time, with maximum emergence (110 m) in the central section of the east coast south of Towson Point.

The 'summer' (generally snow-free season) climate is cool, cloudy, and often foggy with low, sporadic precipitation. Extensive snow cover often is present well into June; frost can occur at any time. The mean summer temperature is about 5°C. The growing season is short despite 24 hours of daylight. Coastal temperatures are lowered by adjacent sea ice. Open sea is restricted to the southeastern shore, but even here this is intermittent due to drifting ice. Except for very narrow shore leads, Hecla and Griper Bay remains frozen. Permafrost is continuous beneath the landmass of Melville Island. Maximum thaw depths of the active layer, which occur in mid to late August, are usually 60 to 70 cm and only rarely reach one metre. Maximum thaw depths in wet, moss-covered areas are 10 to 30 cm.

Dominant plant cover, especially in well vegetated areas, commonly consists of mosses, liverworts, and lichens. Cryptogamic species far outnumber vascular species. About 120 vascular species grow on eastern Melville Island, but usually the vascular plant component of a community is small, generally only a dozen common species, with an additional 35 species occurring relatively frequently. Dwarf shrubs are present but are not common components of most plant communities. Plant community composition and per cent cover vary considerably over short distances. The richest communities commonly are located near coasts. Uplands are less well vegetated, yet they too vary in composition and per cent cover over short distances. Although comparatively low in diversity and per cent cover, vascular plants such as grasses, sedges, herbs, and willow provide forage for herbivores.

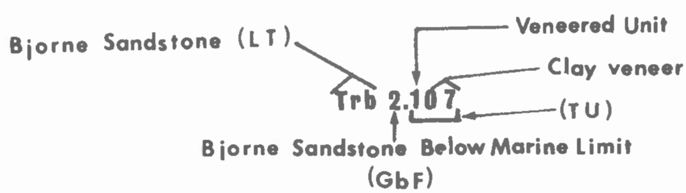
A variety of herbivores is found on eastern Melville Island. Local breeding and staging areas are used by numerous waterfowl (brant, snow geese, old squaw, and eider), shorebirds, passerines, and raptors. Muskoxen usually are found near the coast, but caribou are more widely ranging. Currently both species number several hundred. Polar bears, foxes, wolves, and lemmings also have been observed.

ORGANIZATION OF THE MAPPING SYSTEM

Introduction

Three levels of map-units were prepared for eleven 1: 125 000 scale airphoto mosaic maps; boundaries for each map-unit level are depicted by different weights and styles of line. The hierarchy was developed by division of each regional unit, Landscape Type (LT), into intermediate units, Geobotanical* Facies (GbF), with further subdivision into more detailed units, Terrain Units (TU), such that the sum of all units at each level completely occupies the area of the next higher level (shown diagrammatically in Fig. 2).

Each map-unit is identified by an alpha-numeric code. Landscape Type units are identified by a letter code conforming to geologic convention for the underlying bedrock. The following numeral identifies the Geobotanical Facies, and the succeeding three place decimal number identifies the Terrain Unit. An annotated example of this code is as follows:



By adopting this alpha-numeric format the system is adaptable to other environments, allowing additional units to be added easily to any level. The format is suitable for automatic data processing.

Expanded explanatory legends following the hierarchical format (Fig. 3) were developed for the photomosaic maps. Significant environmental variables – morphology and relief, drainage, surface materials, and vegetation – are discussed at the three levels of detail for each Landscape Type. The degree of recent utilization of the terrain by birds and mammals was estimated for each level and also is included in the legend. An example of the legend for Bjorne Sandstone (Trb) is given in Figure 4.

* The term "geobotanical" refers to a combination of geological and botanical attributes. It is not meant to imply that one discipline is more significant than the other.

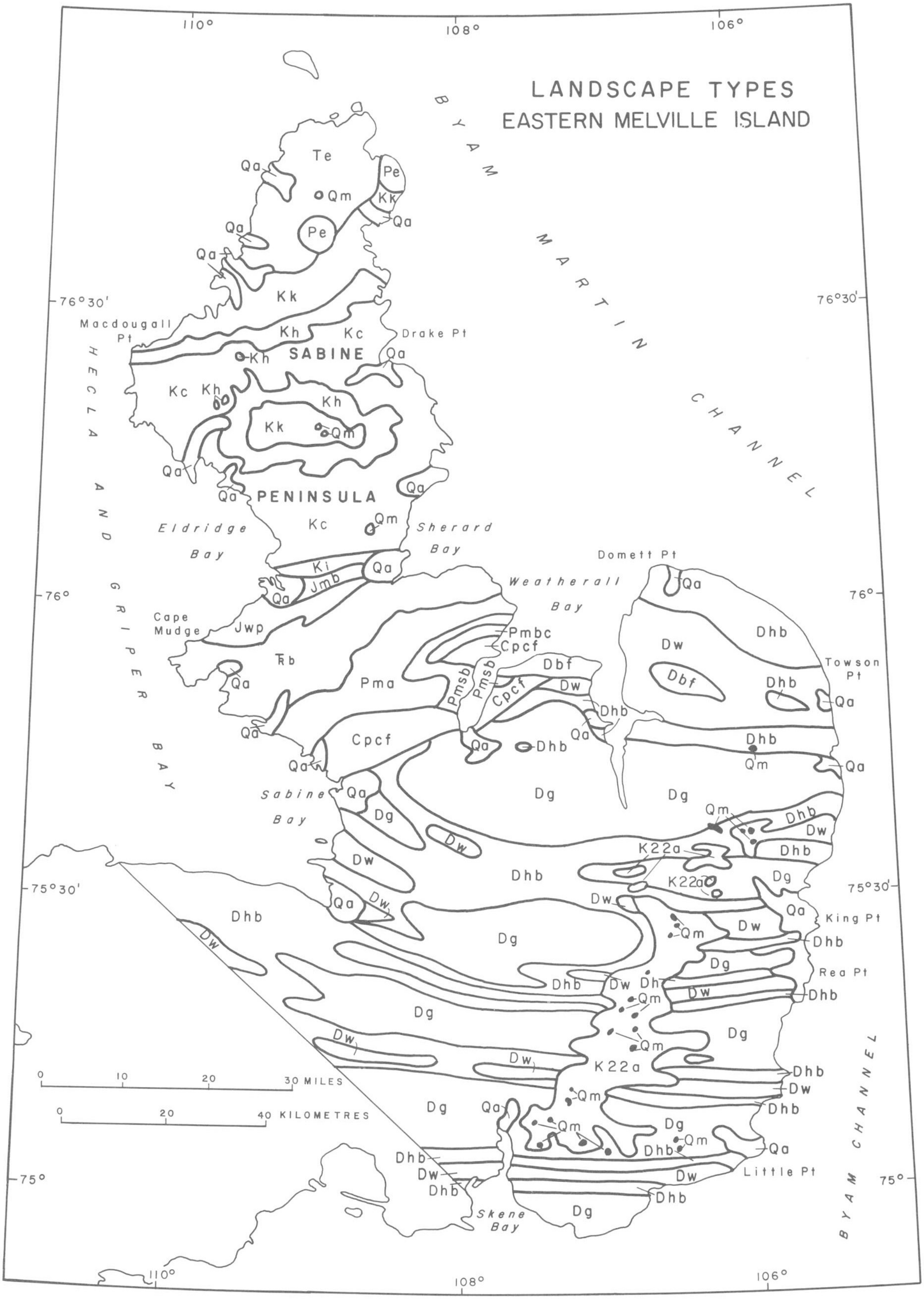


Figure 5. Distribution of the 21 Landscape Types on eastern Melville Island.

An encyclopedic text following the legend format and carrying an entry for each alpha-numeric address on the maps is available in Barnett *et al.* (1975a). The text augments the legend, amplifies information at the Terrain Unit level, and gives easy and rapid access to detailed information. A summary evaluation appears at the end of each Geobotanical Facies section of the text, and it also highlights special conditions for selected Terrain Units.

Landscape Type

Landscape Type units represent the greatest degree of generalization of the data. Twenty-one Landscape Types were identified (Fig. 5) and described (Fig. 3). Landscape Types are named after the corresponding geological formation. The use of the portion of the code designating geologic age has no direct significance although a general trend to decreased competence with youth is apparent. The boundaries commonly correspond to bedrock formation boundaries because the landscape is dominated by geological structure and the materials by weathered bedrock. In many cases, bedrock contacts are conspicuous (Fig. 6) marking not only changes in materials, but changes in grain size, colour, morphology, drainage, and vegetation. Combinations of these attributes provide a natural breakdown of the landscape at a regional scale and are shown on the photomosaics by a heavy solid line. In some places bedrock is masked only by thin till or by a discontinuous veneer of marine sediments at lower elevations. Commonly, vegetation is rooted directly into the bedrock or weathered mantle,

Figure 6. Oblique aerial photograph looking west across the sandstone upland immediately west of Rea Point. In the middle ground a belt of landscape designated K22a is visible, developed on materials resting on the three Devonian sandstones Dg, Dhb, and Dw. (NAPL T419L-169)

and changes in bedrock are reflected by changes in vegetation per cent cover or vegetation community composition or both.

Areas where major accumulations of alluvium have been derived from a variety of bedrock formations are designated as a Landscape Type (Qa), because their texture, morphology, vegetation, and reactive properties commonly differ considerably from those of adjacent terrain. Minor deposits of alluvium derived from only one bedrock formation, however, are treated at the intermediate (GbF) level, because these accumulations exhibit many of the properties of the parent bedrock type.

Geobotanical Facies

Within each Landscape Type up to six intermediate natural subdivisions, termed Geobotanical Facies, occur (Fig. 3). These subdivisions recur within Landscape Types and also from one Landscape Type to another where diagnostic parameters repeat. For example, the Griper Debris Mantled Upland is present in different areas of the Griper Bay Sandstone Landscape Type (Dg 4.), but in addition there are other debris mantled uplands in other Landscape Types (Dhb, Dw, and Dbf). This subdivision at the intermediate level is based on a variety of criteria. Variations in lithofacies in many places are obvious because bedrock is commonly close to the surface. Other criteria include chemical composition, grain size, competence, colour, morphology, and the effects of marine transgression. These distinctions commonly are accompanied or reflected by changes in vegetation – community composition and cover or both – and therefore make natural boundaries.

Geobotanical Facies are delineated on the maps by thin solid lines and are represented by a single number preceding a decimal point. Geobotanical Facies 'Alluvium' is always coded '1. xxx', and other GbF units and numbers follow in general sequence from sea level upward.

In devising a convenient name for individual Geobotanical Facies, one or two of the more distinctive attributes were selected, for example, the 'Slump Prone Facies' of the Canyon Fiord Sandstone (Cpcf 4.). This name is not intended to imply that the designated attributes were the sole criteria for the subdivision. Bjorne Sandstone (Trb) above marine limit (AML) is divided into two Geobotanical Facies, '*Vegetated* Bjorne Sandstone AML' and '*Unvegetated* Bjorne Sandstone AML'. These attributes are so distinct (Fig. 7) that Tozer and Thorsteinsson (1964, p. 112) mentioned them in their description of the bedrock. The differences between the two also extend to colour, subtle change in grain size, drainage development, and soil moisture, but the botanical differences are immediately striking. Despite these medium scale differences, the similarities which unify these two facies within the Bjorne Sandstone Landscape Type should not be overlooked: both facies exhibit a rounded scarp and dip slope morphology developed on a moderately competent, generally medium grained quartzose sandstone. The nomenclature adopted for the Geobotanical Facies was designed to enhance recognition of one or more of their prominent aspects but has the disadvantage of suggesting to the casual reader an inconsistent basis for Landscape Type subdivision. Thus in a multivariate analyses of terrain similar units may be expected to have a variety of descriptive names, depending upon the purpose of the mapping.

The marine limit is used as a GbF boundary; it marks the uppermost limit of recognizable evidence for postglacial marine submergence and is delineated by a dotted line rather than a thin solid line. The effects of the marine episode are both widespread and significant in the Arctic Islands, but usually are subtle in expression at an intermediate scale. Below marine limit (BML), which reaches 110 m. a. s. l. on eastern Melville Island, marine processes have reworked the surface materials, resulting in deposition in some areas and erosion in others, but despite this the influence of underlying bedrock commonly is still apparent. On eastern Melville Island the depositional changes are probably more significant than the erosional ones. The veneer of marine sediments has altered the compositional and behavioural properties of the original surface materials, has produced an enriched environment for plant growth, and in many places has muted the microrelief. Nevertheless this accumulation of marine sediment is thin and discontinuous; bedrock is never far from the surface. In some places the marine influence is identifiable only by detailed site investigation or may not be apparent at all; at these places the boundary has been interpolated, for although there may be little visible evidence of it, some subtle changes probably occur across the marine limit.

Above marine limit (AML) subaerial processes presumably have been continuously active longer in this zone than in the zone below marine limit.

Terrain Units

Forty-nine distinctive types of Terrain Unit were recognized. These units recur throughout eastern Melville Island; none is unique. The basis for subdividing the Geobotanical Facies into Terrain Units, which focus on detailed changes in the landscape, is based on complex criteria such as: micromorphology, soil moisture, surface material veneers, plant communities and coverage, degree of dissection, and slope.

The name of each unit focuses on one or more distinguishing attributes, but, as with Geobotanical Facies, these selected attributes are not the sole criteria for establishing the unit, but rather are convenient descriptors. Terrain Units are outlined by a dashed line on the maps.

Each Terrain Unit is assigned a three digit number following the decimal point that separates it from the Geobotanical Facies numeral. In the legend the Terrain Units have been grouped into three classes (Fig. 3): landforms and localized deposits (. 0xx); veneered units (. 1xx); and geobotanical patterns (. 2xx). The first class is subdivided further into: fluvial units (. 00x); coastal units (. 02x); periglacial units (. 04x); glacial units (. 06x); bedrock-controlled units (. 08x); and localized deposits (. 09x).

Table 1.

Characterization matrix of Landscape Types of Eastern Melville Island.

LT	Morphology	Relief (relative absolute)	Surface drainage	Surface materials	Vegetation*	Ground-ice contents (Engineering soil classification)	Trafficability rating** (0-1-2)	Sensitivity rating*** (1-5)	Degree of lithification	Relative effect of marine inundation (per cent affected)	Weathering products
Qa	Terraced	Low 70 m	Well	Silt-sand (alluvial-deltaic)	1 monocot/ 3 monocot (± *Salix*)	Moderate; ML, SU, SW/SF Sands, or silts of low plasticity	1	2/5	Unlithified	High 100%	Sands, locally silts
Qm	Upland residual	Low 15 m	Well	Gravel	1 saxifrage	Low; GP Gravel-sand mixture	0/2	1	Unlithified	Nil 0%	Dirty gravel
Te	Lowland	Low 80 m	Moderate/ well	Sand-silt (nonmarine)	1 grass/ 3 grass	Low; Variable Uniform sand to silty clay	0	2/3	Unlithified to poorly lithified	Low, locally moderate 80%	Medium sands, locally silts
Kk	Upland	High 150 m	Well	Silt	1 lichens/ 1 monocot	High; ML, CL Silt and clay of low plasticity	1	4	Poorly lithified	Moderate to high 50%	Tinkling shale platelets and pebble rubble
Kh	Benchland	Medium 55 m	Moderate	Sand (nonmarine)	1 saxifrage	Low; SF Silty sand	0	3	Moderately lithified	Moderate 48%	Angular hematite pebble rubble
Kc	Lowland	Low 150 m	Poor	Silt	3 grass (+ saxifrage)	High; MI/CI Silts and clays of intermediate plasticity	1/2	5	Poorly, locally moderately lithified	High 71%	Silty clay, sticky when wet
K22a	Flat upland residual	Low 35 m	Well/poor	Sand/silt	1 saxifrage/ 1 grass	Low; SF/MI Silty sands or silt	0/1	3	Poorly lithified	Nil 0%	Sands/silts
Ki	Lowland	Low 60 m	Well	Sand (nonmarine)	1 monocot-saxifrage	Low; SU Uniform sand	0	2	Moderately lithified	Moderate to high 95%	Medium sand
Jmb	Minor escarpment	Medium 105 m	Moderate	Sand (marine)	3 *Carex-Luzula*	Low; SF Silty sand	0	2	Moderately lithified	High 90%	Fine sand
Jwp	Lowland	Low 124 m	Poor	Fine sand (marine-nonmarine)	3 *Carex-Luzula*	Low; SF Silty sand	0	2	Moderately lithified	High 88%	Fine sand
Trb	Scarp and vale	High 240 m	Well	Medium sand	1 saxifrage	Low; SF/SU	0	1	Lithified	High 49%	Angular hematite rubble to medium sand

Pma	Escarpment	High 220 m	Well / moderate	Calcareous sand (marine)	1 saxifrage/ 2 saxifrage	Moderate; M/SF Sand with fines	1	3	Lithified	High 25%	Angular bioclastic rubble
Pmsb	Minor escarpment	Medium 90 m	Well	Sand (nonmarine)	1 saxifrage	Low; SF/ML Silty sands, and silts of low plasticity	0/1	2	Lithified	Moderate 32%	Angular pebbles
Pmbc	Minor escarpment	Medium 190 m	Well	Sandy limestone (marine)	1 saxifrage-grass	Low; GW/GC Well graded gravels, locally with clay	0/1	2	Lithified	Very low 42%	Angular rubble
Cpcf	Diverse	Medium 235 m	Moderate	Silt-fine sand	1 *Puccinellia*-saxifrage	Moderate; SF/CL Silty sand, and clay of low plasticity	0/1	3	Variable	Low to moderate 56%	Sandy fines
Pe	Diapir	High 255 m	Well	Gypsum, limestone, shale, gabbro	nil	Low?; GC Sand and gravelly sand	2	3	Variable	Low 2%	Gypsum rubble
Dg	Plateau	High 225 m	Moderate/ poor	Sand (largely nonmarine)	1 *Rhacomitrium*-*Alectoria*/ 3 *Carex*-*Luzula*	Low; Variable Sands and gravels containing fines	1	2/3	Lithified	Moderate 22%	Felsenmeer and fine sand
Dhb	Dissected plateau	High 215 m	Well	Sand (nonmarine)	1 saxifrage-*Luzula*	Moderate GC/SW Graded sands with gravels	1	1/2	Lithified	Low to moderate 28%	Felsenmeer and sand
Dw	Plateau	High 255 m	Variable	Sand (marine-nonmarine)	1 *Rhacomitrium*-*Alectoria*/ 3 *Luzula*	Low; BC/SF Silty sands or boulders and cobbles	1	3	Lithified	Moderate Locally high 23%	Felsenmeer and fine sand
Dbf	Dissected upland	High 385 m	Well/ poor	Limestone	nil	Low; BC Boulders and cobbles	1/2	1	Lithified	Very low 13%	Angular rubble
S	Hill	High 215 m	Well	Dolomite	nil	Low; BC Boulders and cobbles	2	1	Lithified	Very low 13%	Rubble

The matrix portrays the variables characterized by ratings. A horizontal line is used to separate attributes which differ topographically, and an oblique line denotes an areal separation.

* Ratings for vegetation cover are: 1 - sparse, 0-20%; 2 - moderate, 20-70%; and 3 - dense, 70-100%. The dominant or co-dominant vascular component is shown.

** Ratings for trafficability increase in difficulty from 0 to 2.

*** Ratings for sensitivity increase from 1 to 5.

An individual Terrain Unit type can recur within different Geobotanical Facies and Landscape Types. The similarities of these units are primarily patterns recognized from aerial photographs and surface character, but considerable differences of some attributes may occur. For example, tundra ponds (.040) are groups of shallow water-filled depressions, irrespective of Landscape Type, but those developed on coarse sands and substrates commonly have dominant sedge and willow components, whereas those developed on fine grained materials lack sedge and willow components and are commonly grass dominated. As a further illustration, each of the geobotanical patterns (.2xx) may be developed on a variety of substrates with differing degrees of lithification and differing vegetation associations. For example, the Terrain Unit .202 (poorly vegetated, moderately dissected bedrock) occurs within Eureka Sound Sands (Te), Bjorne Sandstone (Trb), and Griper Sandstone (Dg). Each of these Terrain Units appears as a poorly vegetated (less than 20 per cent cover), moderately dissected area, exhibiting typical slope values between 10 and 20 degrees, whose primary lithologic characteristics are determined from the Landscape Type designator. In the first example, Te 5.202 designates a poorly lithified silty unit with a less than 1 per cent grass barrens. Yet in the example of Trb 4.202, a medium sand with a lag gravel surface, the vegetation consists of a less than 1 per cent saxifrage barrens. In contrast Dg 4.202, a debris mantled upland, carries a less than 5 per cent *Rhacomitrium-Alectoria* barrens.

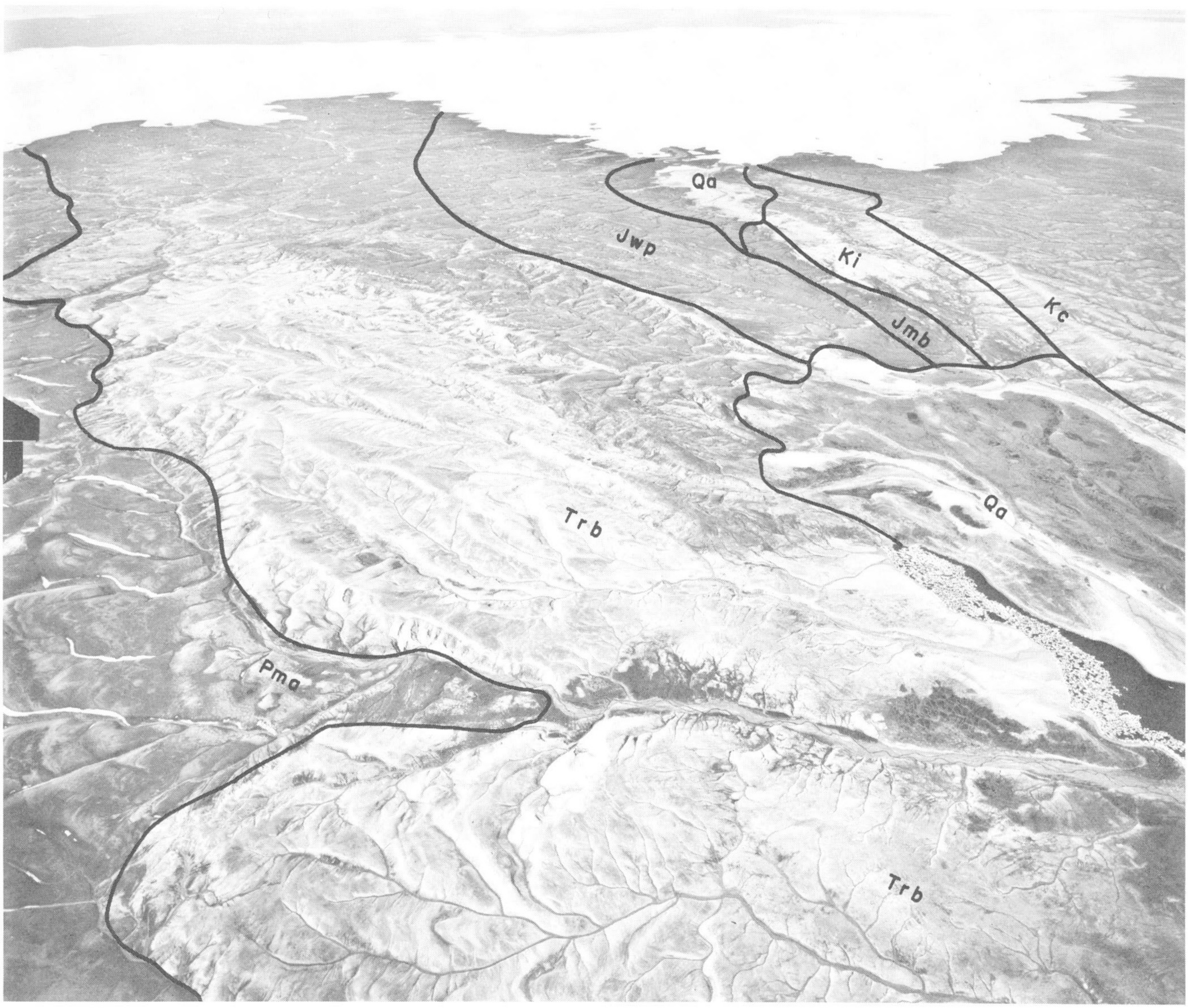


Figure 7. Oblique aerial photograph looking west across southern Sabine Peninsula showing seven Landscape Types. The strong tonal contrast within the Bjorne Sandstone (Trb) is a Geobotanical Facies change between vegetated (dark) and unvegetated (light) terrain. (NAPL T417L-42)

At the Terrain Unit level, the inclusion of the smallest unit (ca. 500 m length) was limited to one which had some assumed practical importance. For example, a small deposit of sand and gravel would be shown, but a lightly dissected zone of the same size in a generally moderately dissected unit may not be delineated.

Summary Evaluation of Terrain Conditions

The second goal of the project was to evaluate terrain conditions. This required 1) identifying information which might be required by a range of potential users, 2) identifying the terrain attributes which describe this information, 3) selecting the type and format of presentation of data to be collected, and 4) making the actual evaluation. Three aspects were evaluated: ground ice and engineering properties, trafficability, and sensitivity to both overland travel and trenching. The evaluation involved assessing field data, particularly direct and indirect evidence for ground ice. Terrain performance was noted at sites already disturbed. This latter evaluation was restricted largely to extensively travelled areas and drill sites associated with exploration. Natural and man-induced gullying (Figs. 8 and 9) was observed in order to evaluate probable trenching performance. The ratings for trafficability and sensitivity are outlined in Figure 3.

Ground ice and engineering properties. These were treated as an evaluation since the total amount of data was small and required substantial interpolation and extrapolation. Ground ice was singled out as an important variable in terrain performance because soil moisture conditions are critical to the behaviour of surface materials. Evaluation of ground ice was based on the following information in various combinations: 1) shallow coring (<3 m) with SIPRE or Winkie drills; 2) cautious collective evaluation of drill logs for seismic shotholes (single drill logs are generally considered unreliable but regional trends sometimes are discernible from multiple seismic lines); 3) observation of natural exposures either from slumping or stream cuts; and 4) examination of morphological evidence such as polygons, thermokarst, or flow slides. Much of the data, and thus the evaluation, is largely qualitative. Quantitative ice-content data were obtained from shallow cores taken at approximately 200 sites. Ice contents are expressed as water equivalents (*see* Barnett *et al.*, 1975a). Values should be treated as approximate indicators of ice content in the unit, but they may not necessarily be representative of the unit as a whole.

Soils were classified according to the Unified Soil Classification System enabling further geotechnical properties to be derived from charts (Road Research Laboratory, 1952). Shear strength measurements were performed using a field vane shear apparatus in fine grained materials.

Figure 8. Gullying of north-facing Christopher (Kc) slope close to Drake Point gas well which blew out (1969-70). The initiating trigger was a single pass of a caterpillar tractor (probably D-8 or D-9) during the summer 1969 or 1970. The gullies are active during snowmelt, and erosion was still continuing in 1973. (GSC-168280)

Trafficability. Trafficability is defined as the summary evaluation of ease with which overland vehicles may traverse an area, taking into account slope, dissection, surface roughness, surface material, and vegetation. Trafficability was assessed primarily for 'summer' conditions, but the encyclopedic text also offers the writers' opinion on any major differences in winter conditions. Gradient, bearing strength, and surface roughness were considered in establishing the ratings. The three classes of trafficability (0, 1, 2) are evaluations of the degree of difficulty with which a conventional tracked vehicle could travel across an area; the ratings do not involve a value judgment of whether travel would be environmentally desirable. As an extreme hypothetical example, a nesting ground of a rare and endangered species of bird on gently undulating, firm terrain would be rated 0 for trafficability, i.e. minimum difficulty.

Sensitivity. Sensitivity is defined here as a summary evaluation of the resistance of the natural environment to man's impact. The higher the sensitivity, the smaller the trigger necessary to create visible change, usually considered to be deleterious (Barnett *et al.*, 1975a). This definition, therefore, covers the physical properties of the surface materials as well as the vegetation.

This complex assessment of sensitivity was based on measured and observed properties, such as grain size and slope, on estimates of ground-ice type and amount, on the seasonal variability of soil moisture, and on the consequences of disturbing vegetation cover. The occurrence of heavy rain (arbitrarily defined as one half inch (≈1 cm) or more in 24 hours) was recognized as a major variable which could be measured easily and which would increase sensitivity everywhere, although not to the same degree.

Sensitivity to travel was assessed on the basis of tracked vehicle use in 'summer'. Since identical vehicles could produce differing degrees of disturbance on the same terrain due to differing driving techniques, the evaluation is a best-estimate relative rating with common types of predicted response listed in Figure 3.

To date no major trenching has taken place on eastern Melville Island; therefore predictions of performance of trench walls exposed to above freezing temperatures are even more difficult than for vehicle travel. Where competent rocks occur at or within a few centimetres of the surface, trench wall stability is probably of little concern, but ice content and stability on thawing are considered in the evaluation of poorly lithified rock and unconsolidated materials. Because sensitivity to trenching is also in large part moisture dependent, spring thaw, the presence of semi-permanent snowbeds, and the effects of heavy rain were considered in this rating.

Trenching in winter could present different environmental problems not dealt with here.

Figure 9. Low-level aerial view looking northwest at Sherard Bay showing effects of multiple summer use of moderately ice-rich, well vegetated terrain. The headward erosion of the gully can be rapid; a rate of 1 metre per day was measured following a heavy summer rainfall. (GSC-18763)

DISTINCTIVE CHARACTERISTICS OF LANDSCAPE TYPES OF EASTERN MELVILLE ISLAND

Introduction

A summary of the distinctive characteristics of the 21 Landscape Types (Fig. 5) follows. More detailed information on the Geobotanical Facies and Terrain Unit levels is presented in the text of GSC Open File 252 (Barnett *et al.*, 1975a).

Bedrock plays a major role in determining the character of the landscape. Evidence is presented in this section to summarize components that combine to form the landscape.

Suites of Landforms

The landforms of eastern Melville Island are mainly a reflection of geological structure and lithology. They retain little evidence of glacial action. Each bedrock type tends to form either an upland or a lowland, rounded or angular topography, but not to the exclusion of other aspects. Therefore the Landscape Type map-unit does not typify a single landform but rather the dominant landforms of a characteristic suite. Schematic cross-sections of suites of landforms developed on the 21 Landscape Types are shown in Figure 10. These cross-sections show the essential elements of morphology and density and typical distribution of vegetation.

The nature of the parent material, whether sandstone, shale, limestone, evaporite, or residual glacial diamicton, has a major influence on landform development in eastern Melville Island. Each reacts differently to erosive processes and gives rise to characteristic landforms. The limestones and evaporite domes form the highest ground and exhibit strong relief. The sandstones underlie more moderate uplands, and shales underlie lowlands. Glacial diamicton occupies a characteristic upland topographic position as scattered residuals. These basic distinctions are modified further by the degree of lithification, tectonic and erosional history, and differences in the environment of deposition.

The degree of lithification of sandstones is varied – Devonian sandstones (Dg, Dhb, and Dw) are better lithified than those of Cretaceous age (Kh, Ki), and those of intermediate age (Jwp, Cpcf) generally show an intermediate degree of lithification. The Tertiary Eureka Sound and Quaternary alluvial sands are unlithified. The lesser the degree of lithification of sandstones, the lower the terrain elevation.

Tectonic history also has influenced morphology. The contrast between Paleozoic and younger sandstones is particularly pronounced. The older rocks have been intensely folded, uplifted, and then planed leaving a plateau landscape which was subsequently deeply incised. The degree of incision is greatest in the Hecla Sandstone and least in the Griper Sandstone. The younger sandstones, however, have been flexed but not planed. Subsequent erosion has left scarp and dip slope topography (Fig. 11) with the main drainage as shallow dip slope streams.

The depositional environment of the sediments determined the fundamental properties which had a marked effect on the development of Landscape Types. Marine and nonmarine sandstones of similar age, for instance, have different chemical compositions. Differences in vegetation cover and type probably reflect the availabilitty of different plant nutrients. On the Hecla Sandstone (Dhb), a white highly siliceous nonmarine sandstone, vegetation consists of an extremely sparse saxifrage barrens; however, large tracts of Hecla Sandstone are unvegetated. On the Weatherall Sandstone (Dw) (marine), which has a greater percentage of feldspar and glauconitic minerals, *Luzula*-based communities are common, and unvegetated tracts are rare.

The Alluvium Landscape Type (Qa) is characterized by sequences of deltas up to the postglacial marine limit. From this level they prograde towards present sea level in a series of terraces which are commonly moderately dissected by either ice-wedge polygon troughs or snowmelt gullies or both. Present rivers in the Qa map-unit are characteristically braided within broad shallow channels. Channel fills are notable as their composition is primarily sand size and smaller; gravel and pebble size materials are usually absent.

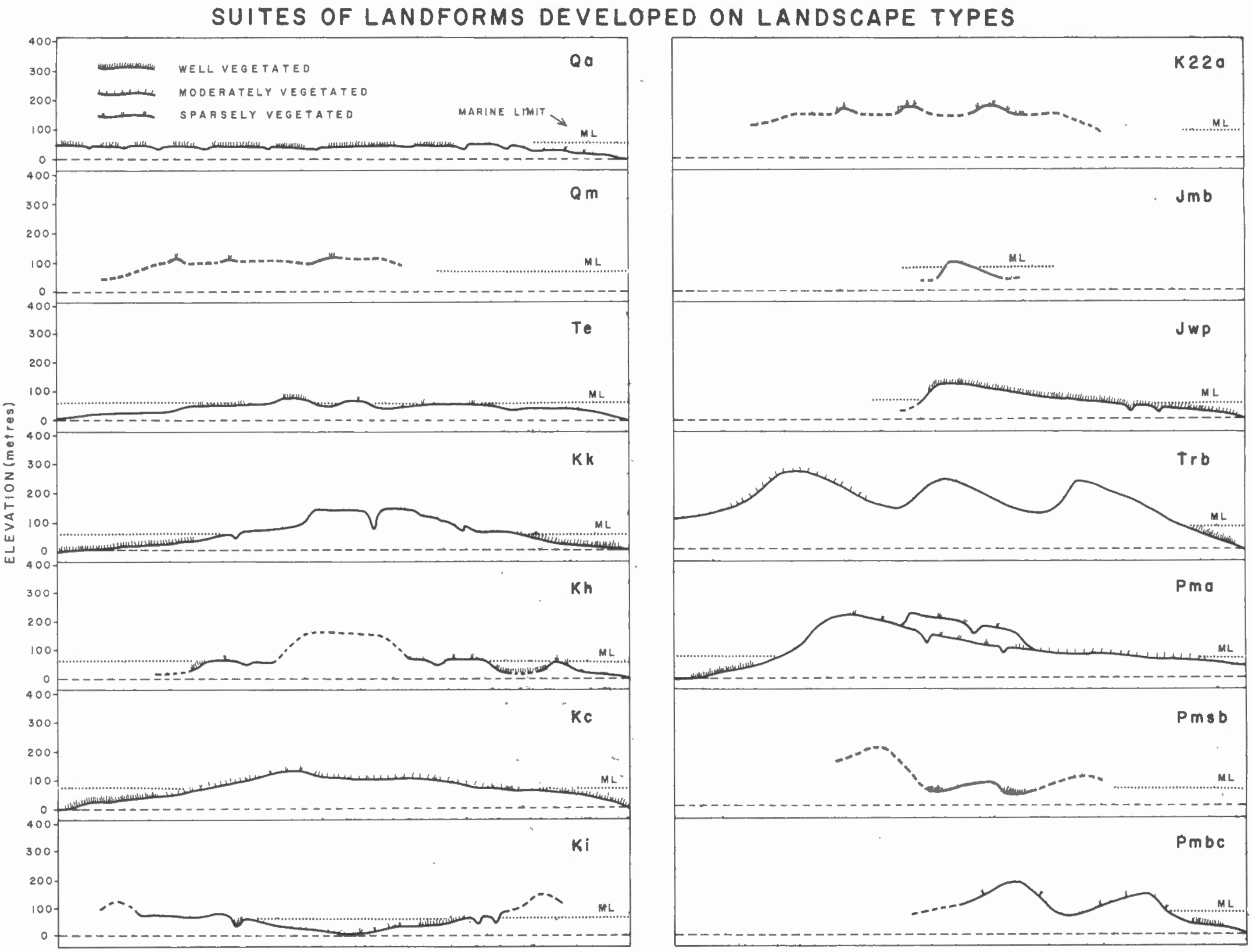
Characterization Matrix

Morphology and vegetation as typified in Figure 10 are two of the visually most distinctive characteristics of the landscape. Table 1 outlines these and additional basic characteristics which together comprise the 21 Landscape Types. This matrix summarizes the environmental variables which appear on the expanded legends of Open File 252 (Barnett *et al.*, 1975a). No two Landscape Types are alike, and the degrees of difference vary. A difference between Landscape Types identified in the matrix may be of direct value to one user and of no particular concern to another. For example, the evaluation of trafficability would have little relevance for the wildlife biologist concerned with birds, but it would be of considerable interest to the geologist planning a seismic program using tracked vehicles.

Degree of lithification, relative effect of marine inundation, and weathering product have been added to those variables listed in Open File 252; lithification, although inherent in the evaluations, was not listed in Open File 252. Table 1 rates the Landscape Type rock as unlithified, poorly or moderately lithified, or lithified. The relative effect of marine inundation is qualitatively ranked from nil to high, and the per cent of the area so affected is listed. Weathering products are listed to indicate the character of only the upper few centimetres. This is distinct from the texture of surface materials which describes the upper metre or more from drill sites.

In general every Landscape Type has been reduced to a dominant characterization in each entry in the matrix, but in some cases more than one descriptor is required to avoid the possibility of misleading the reader. For example a Landscape Type may have two Geobotanical Facies with contrasting vegetation components for which a mean value would be misleading.

Figure 10.



DISCUSSIONS AND CONCLUSIONS

Systems of Terrain Analysis: Adopting a Position

Two review papers (Mabbutt, 1968; Wright, 1972) examine the principles underlying the approaches used by several national groups to what they term land classification. Both authors concluded that a parametric approach is a desirable goal, but both agree that such is not realistically attainable for large areas at a reconnaissance level and particularly not for 'integrated surveys' (Wright, 1972, p. 362).

Both reviews carry sections outlining the merits of the 'integrated' approach, which was the position the present writers began from. Mabbutt (1968, p. 16) outlined the essentials of the integrated approach to terrain characterization:

> The differentiation of land is based on landscape character which may be a response to one or more of a group of factors... no land attribute can really be understood in isolation; in a degree it must express the interaction of all factors, on ecosystematic lines. Most important of all conceptually, however superficial the criteria chosen to recognize and define the land components, the landscape approach aims at discovering the causes of differentiation. The more fundamental the bases of mapping, the greater likelihood that the divisions drawn will be significant, not merely for easily read properties,

but for changes in the terrain that are more difficult to discern. Nevertheless, Wright (1972, p. 351) concluded that the integrated approach is not amenable to classification in a strict sense, and hence the present writers have adopted the term 'characterization' to reflect this condition. Precise definitions of units are impractical because of the multidisciplinary, commonly qualitative information used in their formulation. This condition reflects not only the reconnaissance nature of the exercise, but the gradational changes of some land attributes, and the change of importance of these attributes both spatially and with the level of detail under consideration.

Figure 10. (cont.)

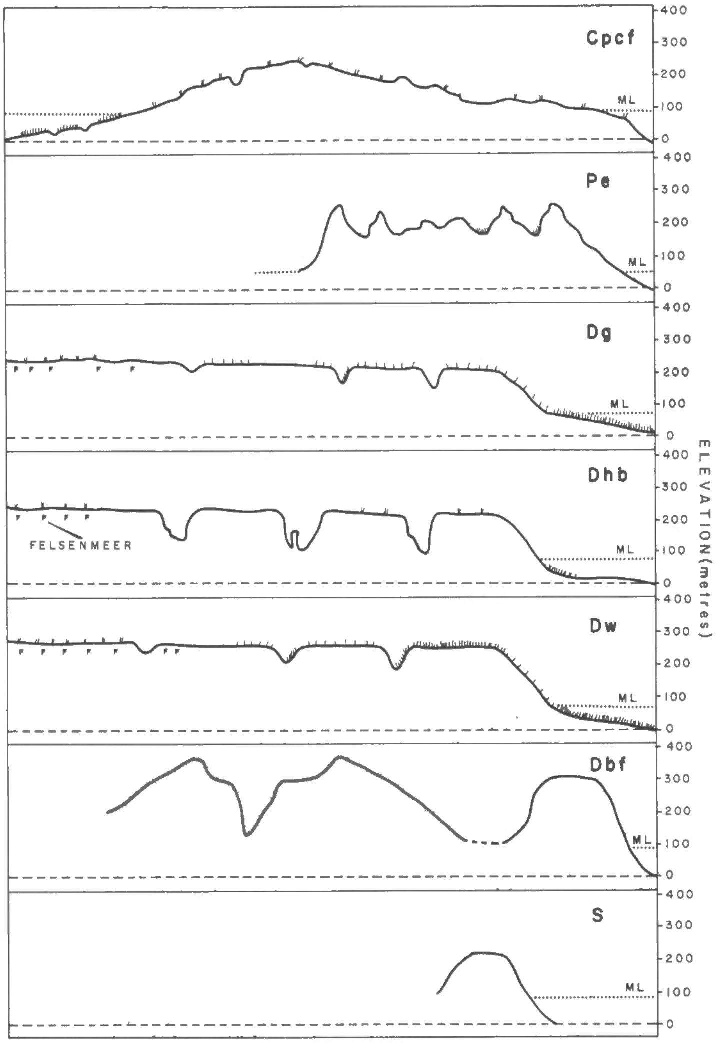


Figure 10.

The characteristic schematic morphology with relief is shown to scale. Vegetation cover and distribution also is depicted.

Boundary Definition

A multidisciplinary approach to terrain characterization refines the precision of boundary location and heightens the perception of such boundaries as natural divisions of the landscape. Such a multivariate approach however also makes a rational basis for boundary location more difficult to define in rigorous terms. In a study of the Peace-Athabasca Delta, Dirschl *et al.* (1974) apparently reached similar conclusions: "An agglomerative, multivariate classification proved fairly successful in identifying major permutations of land facets and vegetation types". What is apparent for Melville Island is that it is impractical to use a separate discipline to define each level of the hierarchy.

One of the strengths of the mapping system is that a user with a specific focus, such as pipeline planning or wildlife management, can readily extract information from pertinent sections. A map showing only one or two attributes could be derived as a clerical operation, using the same map-unit boundaries. This system, which produced boundaries acceptable to, and understood by, different disciplines is a positive contribution of the integrated approach to landscape characterization; in other areas where single discipline studies have subdivided the terrain, boundaries have rarely been coincident.

Significance of Geologic History

Differing morphologies, degrees of dissection, textures, and composition distinguish the Landscape Types which have been delimited. All these parameters reflect aspects of geologic history. Geologic age has significance for terrain characterization in two ways. Firstly, the degree of lithification influences the rate of erosion. The writers conclude that for sandstones, the older the sandstone the greater the degree of lithification and therefore the greater the resistance to erosion and also resistance to the adverse effects of trenching and vehicle travel. Secondly, tectonic activities have had major influences on the topography by determining the attitude and elevation of the strata being eroded. The older materials have been subjected to more folding and faulting than those of younger age.

It was shown earlier that the environment of deposition was a primary determinant of rock type, grain size, and chemical composition and that these factors affected morphology, behavioural characteristics, and nutrient availability for vegetation growth.

It also was shown that marine and nonmarine sandstones of similar age had different properties, reflecting their environment of deposition; Cretaceous shales (Kc and Kk) also have different characteristics which are probably related to details of their environments of deposition, but the exact cause has not been identified. Kanguk Shale (Kk), underlying uplands, is deeply gullied and preferentially weathers into fissile shaly platelets. By contrast Christopher Shale (Kc), underlying lowlands, weathers to mud and is characterized by a shallow dendritic drainage pattern and an abundance of thaw flow slides. The Christopher materials have a higher plasticity than those of the Kanguk; this difference may be the result of preferential development of authigenic clay minerals of the Christopher Shale. Preliminary X-ray diffraction, however, indicates that if the differences are due to clay mineralogy, they are not readily identifiable.

Alluvium

Alluvium on eastern Melville Island possesses textural characteristics related to adjacent bedrock lithologies and is not composed of homogeneous sand and gravel deposits. Alluvial accumulations are classed into 3 groups on the basis of grain size: silt, fine sand, and medium to coarse sand. One of the most striking occurrences is the extremely fine grained alluvium which is present in areas of shaly bedrock.

Alluvium (Qa) derived from shaly rock types has a peculiar morphological expression. The deposits form long digitate deltas with broad levees on each side of the stream. Yazoo streams in places flow parallel to the main incised stream behind the levees. These deltas, which extend from near the marine limit, developed during marine regression. The digitate form probably results from very rapid deposition of snowmelt sediment load, protection of newly deposited alluvium from submarine and littoral erosion by persistent sea ice, and from rapid flocculation of the fines in a marine environment.

Veneers

Veneers are defined by the writers as surficial deposits which are less than 2 m thick. In many places veneers are considerably less than 2 m thick but change the surface character sufficiently that they must be taken into account. They generally have different physical properties from the underlying substrate, although, for marine veneers on Cretaceous shales, the nature of this difference is difficult to detect. Veneers are treated in the mapping system as modifiers of the Landscape Type parent materials as active cryoturbation tends to mix the two materials. An example of coding at the Terrain Unit level for veneers is Trb x.1xx where the .1 denotes veneer and the succeeding xx identifies the type.

Vegetation type and per cent cover are affected by the distribution and properties of the veneers. Veneers are also important in the evaluation of terrain disturbance caused by travel. Because of its limited thickness, however, trenching operations will penetrate veneers into the subjacent bedrock. The prediction of terrain behaviour resulting from trenching therefore requires additional consideration of the properties of the underlying material.

A variety of veneers occur on eastern Melville Island; those identified are discontinuous marine, till, rubble, sand and gravel, clay, and undifferentiated veneers.

Significance of the Marine Limit

Marine processes have altered the micromorphology of Landscape Types below the marine limit by tending to smooth out small topographic irregularities. One result is considerable alteration of drainage pattern detail. Drainage changes are most striking in the Christopher Landscape Type, where the distinctive pattern of dendritic drainage is masked by a veneer below the marine limit. Soil moisture contents tend to be higher below the marine limit because of a slightly higher proportion of fines in the marine veneer, the alteration in drainage pattern, and lower slope angles. Beach ridges also have been preserved in some areas below marine limit but are not common. Beaches, with intervening swales, are best preserved on sandstones. The poorly drained swales generally support greater amounts of vegetation than the ridges. Use of swales by wildlife is locally important as ponds and sedge meadows offer bird habitat; muskoxen appear preferentially to frequent some of these areas.

High-centre polygons with well developed troughs are significant features associated with the marine limit although isolated patches of polygons occur throughout the area. Linear fields of large, high-centre polygons consistently are located just below the marine limit as defined by the elevation of highest beach ridges, driftwood, shells, or textural changes of a less distinctive nature. High-centre polygons, therefore, can be a means of interpolating the marine limit where other criteria are lacking. In addition, since they are easily visible on airphotos at 1:60 000 scale, and possibly at much smaller scales, they can aid in delimiting the marine limit by remote sensing means.

Because high-centre polygons commonly are bounded by substantial ice wedges, trenching generally should be avoided along such a zone immediately below the marine limit.

There appears to be a greater potential for slope instability below the marine limit than above. In areas underlain by sensitive marine shales, shallow thaw flow slides are more prevalent below the marine limit than above. These occurrences probably are related primarily to soil moisture contents. Analyses of core samples indicate that water contents of both frozen and unfrozen soils from areas below marine limit tend to be 4 to 6 per cent higher than those from sites above marine limit. These higher moisture contents in the frozen soil indicate that the veneer of marine deposits has affected soil moisture contents, although the increased moisture content in the unfrozen soil partially may be a result of the migration of water to lower topographic positions.

The presence of a marine veneer commonly has a marked effect on vegetation. The change from plant communities found rooted in weathered bedrock to those found on the marine veneer overlying the same bedrock can be striking in terms of composition, density, or both (e.g. from a very sparse saxifrage barrens (less than 2 per cent cover) to dense sedge- and *Salix*-based communities). The most diverse vascular plant assemblages and densest communities occur below marine limit on areas with a marine veneer. In summer these areas are used considerably by waterfowl, muskoxen, and to a lesser extent, caribou. The distribution of these major animal populations generally is associated with vegetated areas below marine limit.

Vegetation

The integrated mapping approach facilitated the understanding of the striking relationship between plant community composition and cover and the nature of surficial materials, especially composition, texture, soil moisture regime, and topographic expression.

Figure 11. Oblique aerial photograph looking west across the west arm of Weatherall Bay. Several scarp and dip landscapes are easily seen: Bjorne Sandstone (Trb), Assistance Sandstone (Pma), Belcher Channel Limestone (Pmbc). The fault-bounded Blue Fiord Limestone (Dbf) is prominent in the foreground. (NAPL T419R-199)

Although there are only a small number of vascular plant species, their distribution is important in delineating wildlife habitat. They are also the easiest plant component to recognize. A dozen vascular plant species are ubiquitous; however, the dominance of species varies, and absence can be as significant as presence.

Three basic community types grow on eastern Melville Island: 1) sparse barrens vegetation with the lower stratum absent; 2) communities with a discontinuous lower stratum of moss or patina or both and an upper stratum of monocots or dicots or both; and 3) communities with a dense lower stratum of moss or patina or both, with monocots of varying densities rooted within it. An extreme hydric type occurs locally with a submerged moss mat and emergent monocots. There are also localized special communities such as those associated with snowbed vegetation and those around animal burrows and dens.

Plant cover follows an "all or nothing" pattern. Most areas are practically devoid of vegetation (less than 20 per cent cover) or are well vegetated (cover greater than 75 per cent). This pattern seems to be related directly to the availability of nutrients and soil moisture.

Although this general pattern of plant cover is valid for eastern Melville Island, in detail the composition of the communities varies with the type of surface materials. Even plants in extremely poorly vegetated Landscape Types show definite affinities for certain materials. Saxifrage (especially *S. oppositifolia*) barrens are common on nonmarine sandstones such as the Hassel or the Bjorne, on calcareous sandstones such as the Assistance, and on some gravels and coarse tills. Other plants associated with the saxifrages vary in distribution with surface materials or elevation or both. In places *Papaver* is a local co-dominant; in other areas *Luzula* or *Draba* can be a significant component. Other sandstones, such as Mould Bay Sandstone, support *Luzula*-dominated tussock barrens. On shales different barrens occur usually graminae-based. *Alopecurus* barrens are most common but occasionally *Puccinellia* barrens occur. *Cyperaceae* and *Juncaceae* are extremely rare. Number and diversity of dicots are low. On the Kanguk Paper Shale Upland (Kk 4.) a lichen barrens is found which is nearly devoid of vascular plants. Extensive sandstone felsenmeers commonly have a *Rhacomitrium-Alectoria ochroleuca* barrens vegetation in the interstices of boulders. On small areas of till below marine limit *Dryas-Salix* barrens occur.

Better vegetated communities also show definite trends in composition. Fine grained substrates – silts, shales and fine grained alluvium – have grasses as the major constituent; Carices, *Eriophorum* and *Luzula* are absent. On fine grained sands, the communities are commonly a mixture of grasses and Carices (usually *C. stans*). On coarser grained sands, Carices and *Eriophorum* are most common. *Salix* is rare on the fine sands, more common on medium to coarse grained materials, and is generally absent from silts and clays. *Pleuropogon* may occur as an emergent in ponds on any of these substrates.

Because of this relationship of surface materials to plant community composition and coverage, vegetation is often of assistance in accurately locating terrain boundaries – from detecting marine veneer, till veneer, silt deposits, to changes in lithofacies. Vegetation-materials relationships established in the field assist in airphoto interpretation of areas of eastern Melville Island not sampled.

Although a definite relationship exists between dense vegetation and the presence of abundant soil moisture, the converse is not always true; some wet areas are devoid of vegetation. Neither is there a simple relationship between vegetation and ice content as asserted by Babb and Bliss (1974); many sparsely vegetated or nonvegetated areas have high ice content.

Ground Ice

Ground ice occurs in all Landscape Types of eastern Melville Island. As such it is an important near-surface material because of its potential for extreme local disturbance due to its variability in character and amount and its temperature dependence. The following tentative conclusions can be reached based on more than 150 cores and a collective, but cautious assessment of seismic shothole logs: 1) The better lithified the rock, generally the lower the ground-ice content. 2) Well lithified coarse grained rocks generally have low ice contents, but where ice does occur it generally forms massive accumulations either as wedges or thick lenses. 3) Fine grained rocks that are poorly lithified generally show more ground ice, but preferentially in a finely laminated or dispersed, crystalline form. 4) In locally ice-rich materials, irrespective of grain size, amounts of excess ice may be similar although the form may differ.

Difficulties occur in such generalizations based on limited data. For example, the fine grained Kanguk paper shale (Kk 4.) contains massive ice, at least locally. The form of the ice here may be a function of the weathering product, which is shaly platelets of greater than sand size rather than the silt size of the primary constituents. Absolute amounts of ice may also vary with topographic position and aspect, but the variability within sample sites apparently commonly exceeds the variability between sites. A number of short papers recently have appeared which suggest simple relationships between ground ice and vegetation on the basis of limited field evidence (Babb and Bliss, 1974; Price *et al.*, 1974). For example, Babb and Bliss (p. 235) implied that ground-ice amount and vegetation cover are directly and simply related. A partial relationship probably holds, but areas of eastern Melville Island that lack vegetation cover are known to have substantial ground ice (e. g. Kanguk Paper Shale Upland).

Trafficability

Generally little or no difficulty for vehicle travel is predicted in all but five of the Landscape Types. Of these five, two (Pe and S) have high gradients and rate 2 (most difficult) throughout, but are small in area.

Of the remaining three, Dbf and Qm have very difficult tracts because of steep gradients but have other portions which are much less difficult to traverse. For the Christopher Shale (Kc), the restriction relates to wet conditions during which bearing strength is sufficiently low to cause difficulty.

The assigning of a rating to a map-unit does not preclude the occurrence of small areas of terrain which present more severe problems than suggested by the overall rating. Such areas generally can be avoided by short detours or careful route planning.

Although the rating is for summer 'average' conditions, the occurrence of summer precipitation generally will lower bearing strengths of poorly lithified materials. In winter soil moisture is not a problem, but the bearing strength of snow may be critically low particularly in closely dissected terrain where depressions initially may fill with low-density snow.

The degree of lithification influences some aspects of trafficability – well lithified terrain poses no bearing strength limitations but may have adverse effects on travel by supporting high gradient slopes or the development of felsenmeer. Poorly lithified terrain may pose bearing strength problems (depending upon grain size and soil moisture) and generally exhibits lower slope angles. It also may exhibit surface roughness difficulties from hummocks that form on fine grained surface materials.

Although vegetation does not play a direct role in affecting trafficability, it has a more prominent role in the assessment of sensitivity of the surface.

Sensitivity

Sensitivity to travel is lower in winter than in summer because of the protective effects of snow cover and below freezing temperatures. In winter locally exposed vegetation may be an exception to this rule because it would be brittle and easily damaged by tracks of vehicles.

The summer thermal regime leads to high moisture contents in the active layer. When such conditions prevail and vehicles traverse the area, lowered bearing strength may lead to furrowing or churning of the surface. If vegetation, sufficiently dense to act as an insulating cover, is partially stripped by vehicle movement, then further thawing will ensue and additional water will be released. If excess pore water pressures develop, still further lowering of bearing strength will result and free water flow could lead to rilling or gullying even on gentle slopes.

Where a tracked vehicle crosses well vegetated terrain, the vegetation may only be compacted if the binding properties of the plants are sufficient to prevent shearing; in this case, water diverted into the track depression probably would fail to dislodge the vegetation mat. If the vegetation is sheared, drainage may cause soil erosion and plants may die either through direct physical damage or the drying out of the surface layer or both. The soil moisture balance may be critical for community composition in well vegetated terrain; disturbances in these areas, such as deliberate or inadvertent draining of ponds or impounding of water, could lead to changes in vegetation composition in a few years.

One of the more dramatic effects of disturbance occurs when any change accelerates processes, such as when a massive ice wedge is exposed and gullying proceeds rapidly for at least two or three summers; several examples of rapid gullying have been observed (Fig. 9). Although such an event does not affect a large area, the rapidity and intensity of the process could be detrimental to a fixed facility such as an airstrip, pipeline, or compressor station.

Trenching depth for a buried pipeline was anticipated to be of the order of 3 m; therefore in summer at least the lower two-thirds of the trench would expose permafrost. Prolonged exposure to above freezing temperatures would lead to trench wall instability in ice-rich unlithified materials. Where lithified materials containing some ground ice occur, drainage would be a lesser problem.

Utility of Maps for Wildlife Studies

An integrated approach permits delineation and understanding of relationships between vegetation and substrate and thus provides a sound basis for assessment of wildlife habitat. This type of data, therefore, could assist in the study of herbivore habitat and help explain the distribution of animals because it demonstrates relationships between vegetation distribution, composition, and per cent cover (non of which vary uniformly) and topographic expression, moisture content, and surface materials. Where an airborne animal census is planned, census lines can be located to correspond to better vegetated areas, and areas with little vegetation or with unsuitable vegetation can be ignored. Alternatively if a uniform grid approach is used for the census, insights into the distributions could become apparent from terrain maps. Tundra ponds and lakes are of special interest to those studying waterfowl, but not all lake margins carry the same type of vegetation; therefore prediction of waterfowl use could be made based on the vegetation component.

SOME GUIDELINES FOR NONSPECIALIST USERS

This section presents some conclusions from the field work in nontechnical language in order to supply useful information to as many users as possible. Regulatory personnel who may have little or no geological or botanical training should find material of value for their tasks. The writers welcome and encourage comments and criticism of this or any of the preceding sections.

For summer travel on eastern Melville Island, some general principles are listed to minimize difficulties for vehicle operators and regulatory personnel and to minimize disturbance of the environment. The guidelines set out principles to assist in choosing the best oute given a range of alternatives. Obviously circumstances will occur when less-than-best routes are necessary.

1) Stay on high ground because streams are smaller, the surface is drier, there is less vegetation, and there are fewer animals.

2) Stay on dry ground; there is less possibility of vehicles sinking in.

3) Ground that is nearly free of vegetation with very few plants, perhaps growing only among rocks, generally is drier and therefore is better for travel.

4) Stay on sandstones or limestones because less possibility exists of vehicles sinking in.

5) Climb or descend steep slopes at an oblique angle to limit soil erosion.

6) Rubble-covered ground (boulder fields), although stable, offers slow bone-jarring travel and often leads to mechanical breakdowns.

7) Avoid areas with numerous small ponds as vehicles tend to sink into the wet and soft surrounding ground.

8) Avoid 'grassy' coastal areas and ponds; these are commonly important grazing areas for waterfowl, muskoxen, and caribou. If the turf is disturbed, ice in the soil may melt to the extent that on a later trip a vehicle may sink in.

9) If the ground becomes very wet or standing water appears in many areas after heavy or prolonged rainfall, travel should be delayed for at least 24 and preferably 48 hours after the rain ends to minimize the possibility of surface disturbance and vehicles sinking and perhaps becoming stuck.

For trenching:

1) avoid areas with large 'tundra polygons' because the soil is ice-rich and thawing will lead to collapse of the trench walls;

2) given a choice, trench coarser sandstone and limestone materials and avoid shales; the coarser materials are more stable;

3) avoid areas with numerous ponds as they may indicate ice-rich soil which will collapse on thawing; and

4) avoid areas where soil slumps and land slips are present because they indicate unstable soil conditions.

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