Landscape Mapping in the Mackenzie River Valley

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ABSTRACT. Terrain over a wide area of the Mackenzie River valley was evaluated on the basis of vegetation-landform patterns, identifiable in air photographs as landscape units which could be grouped into regions with climatic connotations. From a ground inspection of selected sites, it was shown that each landscape unit comprised a complex of elements characterized by permafrost relationships. An evaluation of the terrain over a much wider area was extrapolated from the air photographs. Vegetation or landform alone did not permit of a satisfactory delineation of regions with climatic connotations, since they were both so diffusely distributed.

RÉSUMÉ. *Elaboration topographique dans la vallée du Fleuve Mackenzie.* Le terrain, sur une large surface de la vallée du Fleuve Mackenzie, a été évalué sur la base de types de végétation-configuration du sol, identifiables sur des photos prises à vol d'oiseau comme unités topographiques regroupables en régions avec des connotations climatiques. A partir d'une inspection des sites choisis sur le terrain, il a été démontré que chaque unité topographique comprenait un complexe d'éléments caractérisés par des relations de pergelisol. Par extrapolation, à partir de photos à vol d'oiseau, on a obtenu une évaluation du terrain sur une échelle beaucoup plus large. Ni la végétation, ni la configuration du sol prises individuellement ne permettaient une délimitation satisfaisante des régions à connotations climatiques, étant donné leur trop diffuse distribution.

РЕЗЮМЕ. *Картирование рельефа долины р.Макензи.* На основе взаимосвязи между растительностью и формой рельефа, выявленной с помощью аэрофотосъемки и показавшей, что отдельные участки могут быть сгруппированы по типу климатических особенностей, была произведена оценка значительной части рельефа долины р.Макензи. Как показало наземное обследование ряда выбранных участков, их ландшафт включал группу элементов с характерными для условий вечной мерзлоты взаимосвязями. С помощью аэрофотографий было сделано экстраполирование на значительно большую территорию. В силу своей разбросанности ни растительность, ни форма рельефа в отдельности не позволяли достаточно хорошо обрисовать районы по типу климатических особенностей.

INTRODUCTION

Extensive land classification interpreted from the observed vegetation and landform relationships has been undertaken in several countries: e.g., in Canada by Hills (1961), and in Australia and New Guinea by the Commonwealth Scientific and Industrial Research Organization (CSIRO 1970, 1973). The aim has been to rapidly identify and classify ecologically different parts of a large land area. The landscape unit generally shown on a map has been the Land System, which is conceived as defining a recurring pattern of landforms, soils and vegetation recognizable in air photographs (Mitchell 1973). Renwick's (in Stewart 1968) assessment of landscape mapping in the Hunter Valley of New South Wales,

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Australia (Story *et al.* 1963) illustrates the general usefulness of this style of survey for regional planning. With practical objectives, landform-vegetation patterns have been mapped extensively in Jordan and neighbouring areas (Mitchell 1973).

The unit of subdivision of the Land System has often been called the Land Facet which, according to Mabbutt (in Stewart 1968) is characterized by an unbroken continuity of internal properties that the Land System cannot have and which, by implication, is based on much more detailed ground inspection. Land Systems can be conveniently grouped into what may be called Land Regions on the basis of selected common attributes. Land Regions, with Land Systems and Land Facets provide a possible three-level stratification for a biophysical land classification.

PHYSIOGRAPHY OF STUDY AREA

The study area encompasses the Mackenzie River valley from southwest of Great Slave Lake at latitude 60°N, northwards to west of Great Bear Lake at latitude 66°N (Fig. 1). Devonian and Cretaceous shales underlie most of the valley lands, giving rise to silty soils. East of the Mackenzie River, isolated plateaus such as Horn Plateau (Fig. 2) are capped by Cretaceous sandstones, and mountains such as the Norman Range (Fig. 3) are formed by Palaeozoic limestones thrust from the west. West of the Mackenzie River, mostly Palaeozoic limestones

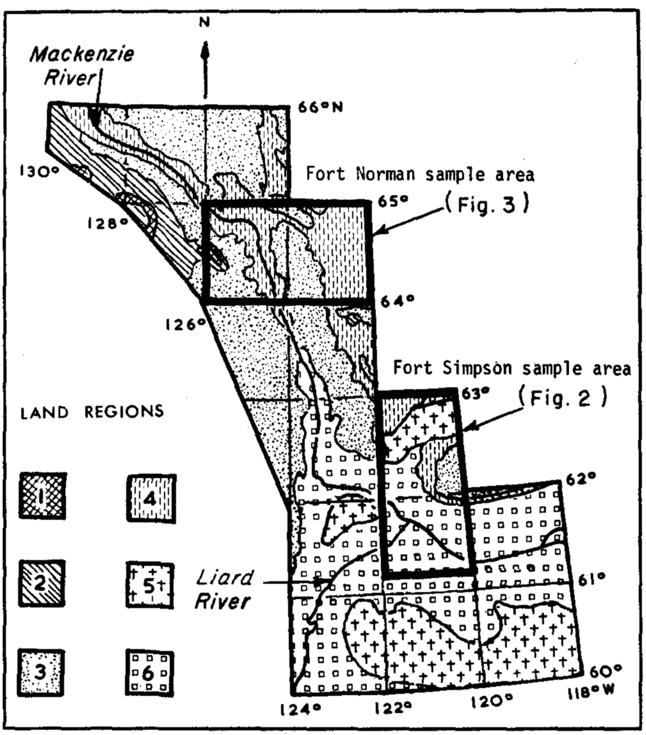


FIG. 1. Grouping of Land Systems within Land Regions.

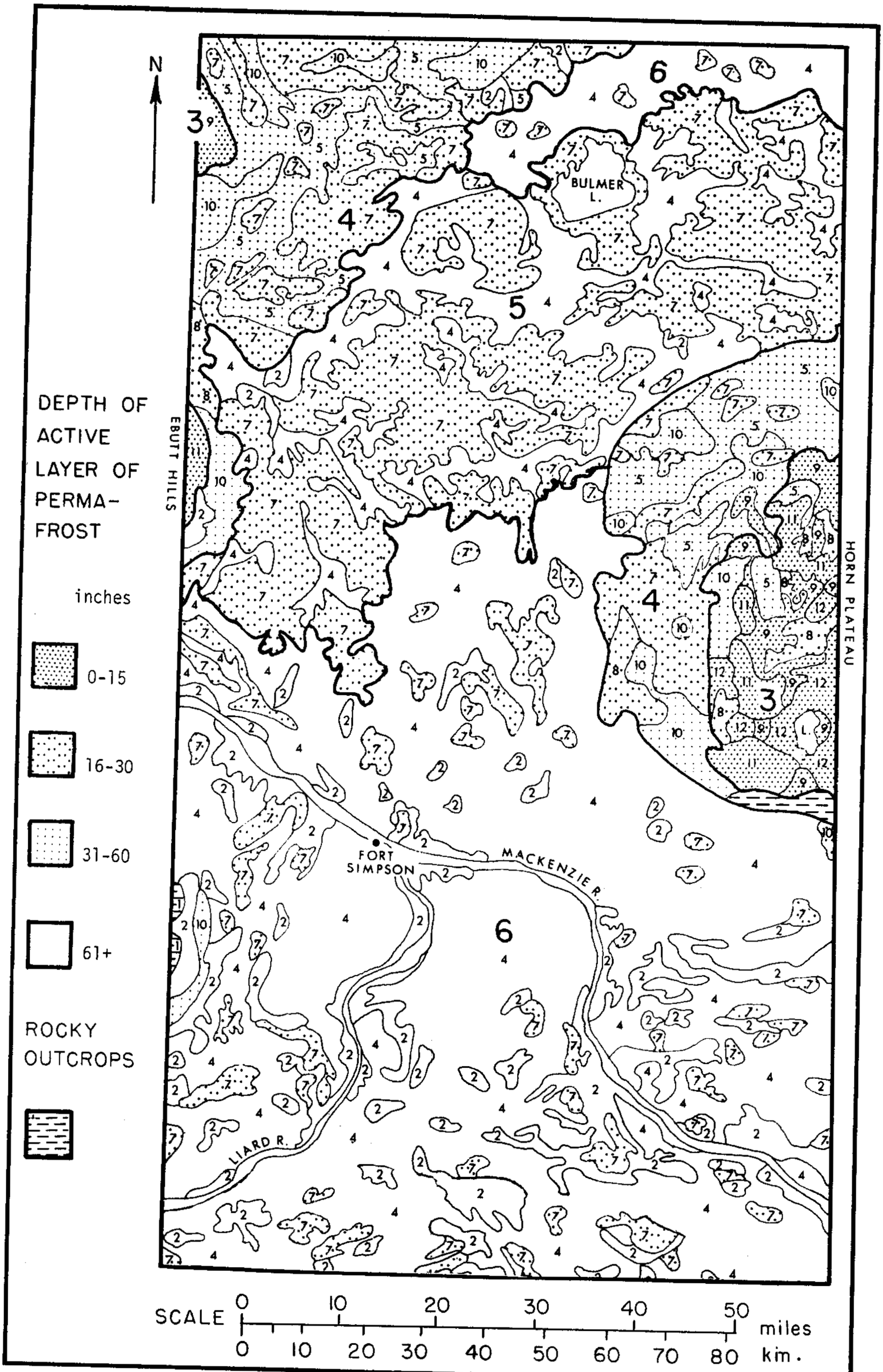
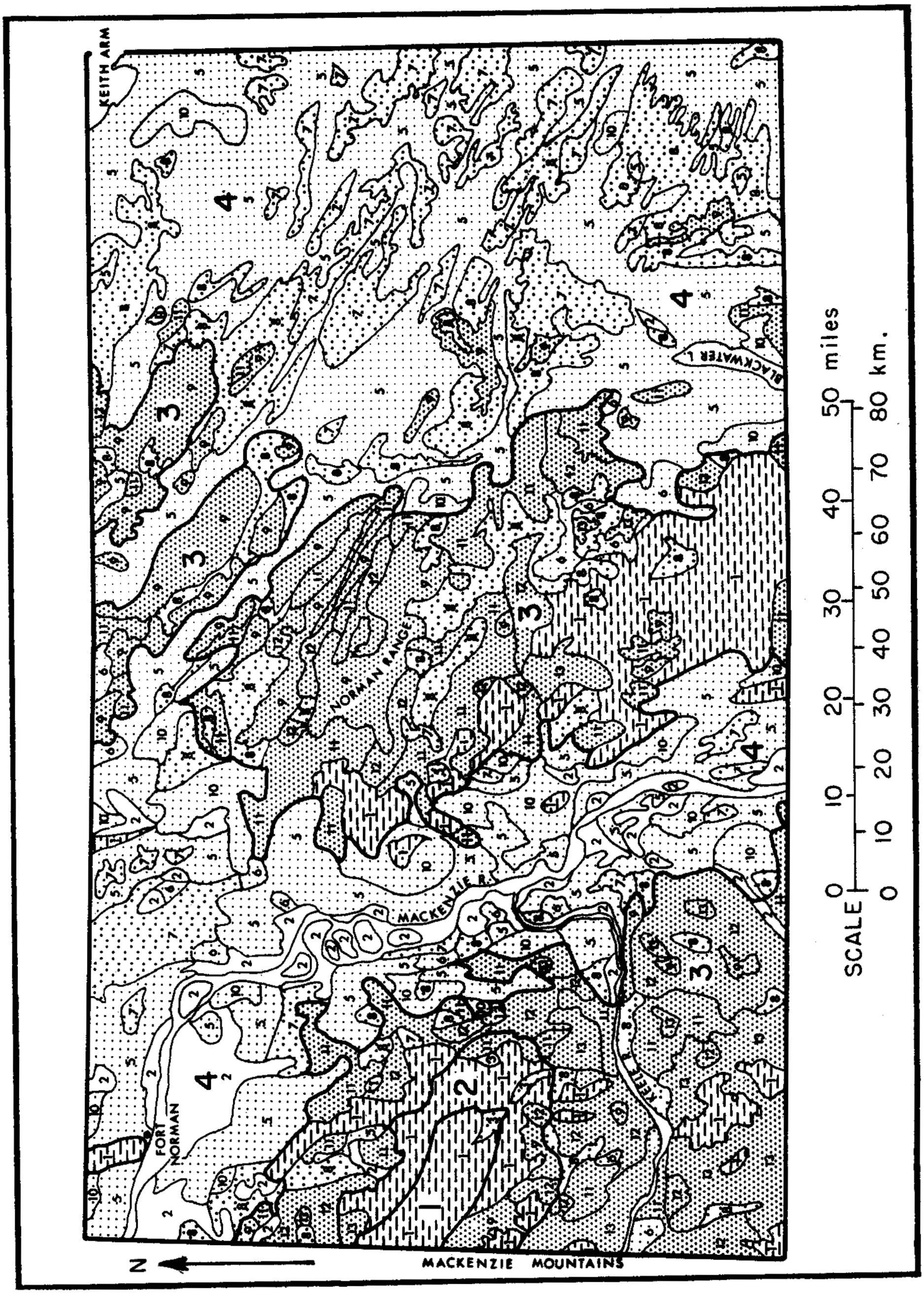

N
DEPTH OF ACTIVE LAYER OF PERMAFROST
inches
0-15
16-30
31-60
61+
ROCKY OUTCROPS
EBUTT HILLS
HORN PLATEAU
BULMER L.
FORT SIMPSON
MACKENZIE R.
LIARD R.
SCALE
0 10 20 30 40 50 miles
0 10 20 30 40 50 60 70 80 km.

FIG. 2 (left). Distribution of Land Systems in the Fort Simpson sample area.

FIG. 3 (below). Distribution of Land Systems in the Fort Norman sample area.



form the Mackenzie Mountains (Fig. 3) which are part of a continuous, north-south mountainous belt. A key to the numbering of the Land Systems represented on Figs. 2 and 3 is provided by Table 1. During the Pleistocene, ice from the Canadian Shield country of ancient metamorphosed and igneous rocks woved westwards and against the Mackenzie Mountains, in retreat depositing a till mantle of variable texture depending upon the local content. Some of this material was distributed as sandy glacio-fluvial or finer-textured lacustrine deposit (Craig 1965).

TABLE 1. Association of similar land systems

	Land system	Description
Linear-patterned slopes	13	Rocky plateaus and finely-lineated slopes with near-surface permafrost.
	12	Gentle, coarsely-lineated slopes with near-surface permafrost.
	11	Moderate, finely-lineated slopes with near-surface permafrost.
	10	Steep, lineated slopes without near-surface permafrost.
Terrazoid-patterned peaty lands	9	Hummocky peat plateaus with lichen and near-surface permafrost.
	8	Hummocky, peaty mineral soils with near-surface permafrost.
	7	Peat plateaus with labrador tea, locally with near-surface permafrost.
Seasonally waterlogged lands	6	Drumlinoid terrain, locally with near-surface permafrost and waterlogged depressions.
	5	Seasonally waterlogged lands with near-surface permafrost.
	4	Seasonally waterlogged lands without near-surface permafrost.
Mineral soils and rock outcrops	3	Freer-drained mineral soils with near-surface permafrost.
	2	Freer-drained mineral soils without near-surface permafrost.
	1	Mountain rock outcrops and screes.

The mean annual precipitation is below 15 inches (38 cm) throughout the Mackenzie River valley, though the precipitation over adjoining highlands exceeds this value. Despite the small precipitation, water movement off the land is retarded by flatness in some places, and the frozen substrate in others, producing extensive waterlogged terrain in summer. Very substantial changes occur in the landscape from south to north, from the discontinuous permafrost zone (Brown 1967), to "outliers" of the continuous permafrost zone formed by mountain ranges and plateaus.

PROCEDURE

During a study of landscape-permafrost relationships in the southern and central Mackenzie River valley there was a need for extensive mapping by extrapolation between widely separated localities of ground inspection. To map the observed changes across such a great area within a reasonable time period required a flexible approach to land classification. Widely distributed vegetation-landform patterns identifiable in air photographs (Fig. 4) were used to define Land Systems, which were used as map units (Figs. 2 and 3). Ground inspection at carefully selected sites allowed characterization of the Land Facets occurring in these Land Systems, and their description in terms of presence or absence of permafrost, and of thickness of the active layer. Since fire disturbs the patterns, inferences had to be made with reference to unburnt areas.

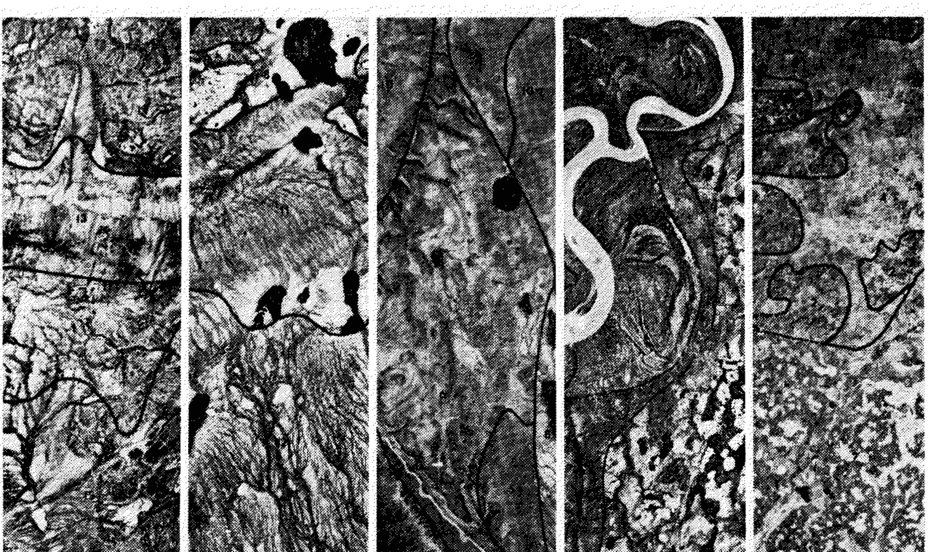


FIG. 4. Vegetation-landform patterns associated with the Land Systems described in Table 7.

Landform, vegetation and soil relationships change with the climate, and an interpretation of these relationships enabled the study to be zoned. It was possible to group the Land Systems into six Land Regions (Fig. 1), each distinguished by a particular combination of those climatic features that could be interpreted from the Land Systems and Land Facets. The selected Fort Simpson (Fig. 2) and Fort Norman (Fig. 3) sample areas illustrate this zonation of the landscape into Land Regions based on the distribution of Land Systems.

RESULTS

The kinds of vegetation which are generally associated with the landform to produce a characteristic pattern identifiable in air photographs include forested land, land with a rich *Sphagnum* cover, or a rich lichen cover, or various combinations of two or three of these elements. Continuously forested lands are mostly freely drained, sometimes imperfectly drained; lands with much *Sphagnum* (and sedges) are surficially waterlogged in the summer; and lands with much lichen in the vegetative cover are usually dry at the surface. Such dryness can arise because the substrate is excessively freely drained (as in podzolized soils on sandy-gravelly sites in the south) or, elsewhere in the study area, it often occurs where the permafrost table is close to the land surface. In places this surficial summer dryness gives the landscape a desiccated appearance, despite the nearness of ice-rich permafrost. In ice-rich permafrost, water must always be present in the frozen substrate as ice in order to maintain the substrate's natural mechanical properties. The land configuration was often dependent on the local relief arising from the surficial drainage distribution over permafrost.

Land System 1 defines areas mostly of bare rock outcrop. Land System 2 occurs on many terraces, river banks, morainal and glacio-fluvial ridges, sites that are better drained than surrounding land. They support the best forest stands in the study area, locally over 100 ft. (30 m) high, usually of white spruce (*Picea glauca* (Moench) Voss), and are associated with rich herbaceous ground flora. Locally, especially over silty lacustrine sediments, ice lenses may be present, though generally frozen substrate does not occur near the land surface. Northwards there is an increasing amount of ice in the substrate, closer to the land surface, associated with an increasing amount of lichen (mostly *Cladonia alpestris* (L.) Rabenh.) in the ground flora beneath a more open forest canopy, representing a transition into Land System 3 (Fig. 4).

On these sites in the south of the study area, podzolization in the soils has produced horizontal layering associated with the redistribution of certain elements characteristic of normal pedogenesis. There is a well-developed, light-toned, sub-surface eluvial layer (Fig. 5). Wright *et al.* (1959) and Day and Rice (1964) have reported the podzolic character of certain soils in the south and central

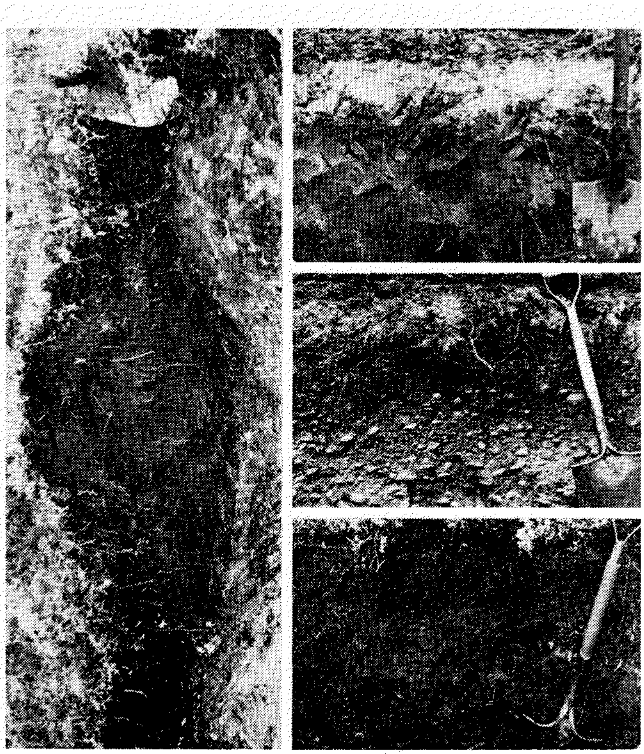


FIG. 5. Soil profiles illustrating from top right (Orthic Dystric Brunisol), downwards and to the left-hand side (Brunisolic Turbic Cryosol), declining podzolization from the south of the study area, northwards, with concomitant increasing cryoturbation, especially at high elevations.

Mackenzie River valley though, as Tedrow (1970) notes, comparisons in this field should be made with caution, as there is considerable ambiguity regarding soil genesis and nomenclature. Northwards, biochemical activity in the soils declines, and the eluvial layer is less distinct.

In northern and high parts of the study area there is an undulating permafrost table, and a mounding of the land surface over depressions in the permafrost (Fig. 5). Cryoturbation within the mineral soil mound is indicated by streams of organic matter (see Pettapiece 1975), from the wedge-shaped crevices defining the mound peripheries, downwards and over the permafrost table — as also described by Mackay (1958), and upwards at the centre of each mound to give a turbulent pattern. Despite this long-term turbulence, both Mackay and Pettapiece consider these structures to have short-term stability. Thus, Orthic Dystric Brunisols in the south have given way in the north to Brunisolic Turbic Cryosols (C.D.A. 1973), or Tundric Cambisols according to the World Classification (C.D.A. 1970). Organic matter within the mound may be ancient (Zoltai and Pettapiece 1973), and wood fragments, leaves, artefacts, bones and charcoal may have been "rolled under" (Tedrow *et al.* 1958), suggesting a continuing, albeit slow, process. In this way the changing character of better-drained ridge and shoulder sites, from soils showing evidence of normal pedogenesis in the south to cryoturbated soils in the north, distinctly reflects the declining mean annual temperature with increasing latitude and elevation.

Seasonally waterlogged, flat lands of Land System 4 are generally peaty Gleysols, or Luvisols where the surficial deposits are thin over calcareous shales. Black spruce (*Picea mariana* (Mill.) BSP.), about 50 ft. (15 m) high, tends to be concentrated on better-drained parts of the landscape such as beach lines and morainal mounds, with extensive areas of *Sphagnum* and sedges in between, locally forming reticulate bogs. In places icy substrate occurs near the land surface, though sub-surface frozen substrate is more widespread in the north of the study area as Land System 4 merges into Land System 5. The presence of near-surface permafrost is often reflected by increased lichen in the ground vegetation (Crampton 1973). Drumlinoid terrain of Land System 6 contains treed mineral soils on mounds, and seasonally waterlogged depressions between, locally with frozen substrate.

In the south of the study area, peat plateaus of Land System 7 support a rich growth of labrador tea (*Ledum palustre* L. spp. *groenlandicum* (Oeder) Hult.), which gives dark tones contrasting with the light-toned depressions often containing summer pools. The permafrost can occur 30 in. (76 cm) below the land surface. In the centre and north of the study area, peat plateaus of Land System 9 support a rich growth of lichen, which gives light tones contrasting with the dark-toned depressions (Fig. 4). Outside of these depressions the permafrost occurs within about 10 in. (25 cm) of the land surface. Land System 8 contains peaty Gleysolic Cryosols, on the higher parts of the landscape showing a hummocky or mounded surface and a permafrost configuration similar to the Brunisolic Turbic Cryosols, though there is no evidence that they are still actively heaving. These soils support stunted black spruce in the south, or white spruce in the north of the study area, about 15 ft. (4.6 m) high and widely spaced.

On slopes a lineated pattern is produced by downslope-oriented runnels separated by low ridges. In the south of the study area, in Land System 10, frozen substrate is local. In the centre and north of the study area, permafrost occurs to within 10 in. (25 cm) of the slope surface. The steeper slopes of Land System 11 have a finely-lineated pattern, whereas the gentler slopes of Land System 12 have a coarsely-lineated pattern of runnels and ridges. In Land System 13 finely-lineated, steep slopes occur with rocky mountain plateaus.

LAND REGIONS

These Land Systems were grouped, according to similarity in the thickness of the active layer (Figs. 2 and 3), to produce Land Regions with climatic connotations (Fig. 1). Land Systems 2 and 4 (Fig. 1) in which the frozen subsoil is sufficiently deep to have little effect on the surface vegetation, are widespread in the central part of the Fort Simpson sample area (Fig. 2), designated Land Region 6. The mineral soils in Land System 2 show the maximum podzolization within the study area. On highlands in the south, and in lowlands around the northwest of Horn Plateau (Fig. 2), peat plateaus of Land System 7 with permafrost at a depth of about 30 in. (76 cm) are intricately patterned with the relatively unfrozen lands of Land System 4, suggesting a cooler climate for Land Region 5 compared with Land Region 6. Around Horn Plateau particularly, and also around Ebutt Hills, between the peat plateaus of Land System 7 the seasonally waterlogged lands of Land System 5 have an active layer 30 in. (76 cm) to 60 in. (152 cm) thick. The overall reduction in thickness of the active layer in the Land Region 4 must reflect a yet cooler climate than in Land Region 5. Similarly, Land Systems 10, 11 and 12, in which the active layer is 15 in. (38 cm) or less in thickness, are widespread on Horn Plateau and the Ebutt Hills, reflecting a still cooler climate at these elevations. Hence, these highlands have been delineated as Land Region 3.

Northwards in Land Region 4, into the eastern Fort Norman sample area (Fig. 3), Land System 8 (with an active layer between 15 in. (38 cm) and 30 in. (76 cm) thick) becomes more extensive, though it continues to have a complex interdigitation with Land Systems 5 and 7. The Norman Range is sharply differentiated from surrounding land by a pronounced increase in the extent of Land Systems 10, 11 and 12, all characterized by a thinner active layer, and so this cooler highland has been separated as Land Region 3, like the Horn Plateau.

Like Great Bear Lake and Great Slave Lake east of the study-area, the Mackenzie River appears to have an ameliorating effect on the climate, judged in terms of the general thickness of the active layer. Land Systems associated with Land Region 4 follow northwards either side of the river. The Mackenzie Mountain foothills are associated with widespread Land Systems 10, 11 and 12, which characterize the cooler climate of Land Region 3. In Land System 13 the active layer is also thinner than 15 in. (38 cm), but this unit tends to be far more common in higher Land Region 2 where, in many places, the till is thin over the rock. At the highest elevations cryoturbated soils are associated with the alpine tundra of Land Region 1.

SUMMARY

The vegetation or the micro-relief on its own did not allow a satisfactory delineation of zones with climatic implications, since each has so diffuse a distribution in the Mackenzie River valley. Each Land System was a complex association of vegetation, microrelief, soils and geomorphology identifiable in air photographs, and each had different permafrost relationships. By combining Land Systems with similar active layer thicknesses within Land Regions, it was possible to define zones with differing climatic characters. Some Land Regions were also defined, in part, by the distribution of podzolized soils (in the south) or cryoturbated soils (in the north and at high elevations).

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