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# A RECONNAISSANCE LANDSCAPE SURVEY IN THE SOUTHERN MACKENZIE RIVER VALLEY

by

C. B. CRAMPTON

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# A RECONNAISSANCE LANDSCAPE SURVEY IN THE SOUTHERN MACKENZIE RIVER VALLEY

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C. B. Crampton*

## INTRODUCTION

The Geological Survey of Canada is mapping surficial deposits in the Mackenzie River valley, a prime concern being the nature of the permafrost, and its distribution, with an important objective being to minimize any damage to the landscape that could be caused by road or pipeline construction. Members of the Canadian Forestry Service have joined this study, chiefly to make an ecological contribution. Composite teams have been established in the northern, lower reaches of the Mackenzie River, and the southern upper reaches. The contribution of the Canadian Forestry Service in an area around Fort Simpson at the confluence of the Liard and Mackenzie Rivers in the southern part of the Mackenzie River valley is described here. (Fig.1).

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* Research Scientist, Northern Forest Research Centre,
Canadian Forestry Service,
Environment Canada,
5320 - 122 Street, Edmonton, Alberta, Canada.

## PHYSIOGRAPHY

The area surveyed occurs in the discontinuous permafrost zone between latitudes 60° and 63°, with an annual precipitation varying from about 15 inches in the south to 13 inches in the north. Lowlands adjoining the rivers, and the plateau-lands of Horn Plateau and Ebbutt Hills in the north (maximum 2,650 ft elevation), and the Cameron Hills in the south (maximum elevation 2,550 ft), are underlain by Cretaceous shales and limestones, mantled with morainal and lacustrine (Craig, 1965) deposits. Where massive Devonian limestones have been thrust into the western part of the area surveyed, there are mountains rising to 4,154 ft elevation which pierce the till mantle. Though the annual precipitation is small, the regional drainage is slow, which leaves an excessive amount of water in the solum. Partially frozen, raised peat plateaus and waterlogged peat flats are extensive in the lowlands during summer, while on undulating plateau-lands continuously frozen peatlands occur on the slopes and in the broad depressions. High forest land is confined to the drier bank or ridge slopes.

## LANDSCAPE CLASSIFICATION

The classification is based on the Biophysical System (Lacate, 1969) with a sequential sub-division from Land Regions, (reflecting climatic zones) into Land Districts, into Land Systems,

though there has been some reorganization of the lower two levels of classification to suit local needs (Fig. 2 and 3). Jack pine (Pinus banksiana Lamb.) accompanies white and black spruce (Picea glauca (Moench) Voss, and Picea mariana (Mill.) BSP.) in the most southerly of the three Land Regions defined, the Trout Lake Land Region 1; trembling aspen (Populus tremuloides Michx.) on the driest sites, with balsam poplar (Populus balsamifera L.) elsewhere in the Fort Simpson Land Region 2; and white birch (Betula papyrifera Marsh.) in the most northerly of Land Regions, the Horn Plateau 3, but scattered pine trees still occur in the Horn Plateau Land Region.

In contrast to the somewhat diffuse distribution of the species, orthic humo-ferric podzols are widespread in the most southerly Trout Lake Land Region, but were not observed anywhere in the most northerly Horn Plateau Land Region, where degraded eutric brunisols are the characteristic soils on drier sites. Degraded dystric brunisols characteristically occur on the drier sites in the Fort Simpson Land Region, though other brunisols and podzols also occur locally. Since the parent materials are mostly sandy, the intensity of podzolization is a reflection of climatic changes from south to north, associated with a declining rainfall and average temperature. These soils profiles become darker as the subsoil becomes less ochreous, and the bleached layer thinner (Fig.4) northwards. Since the soil type cannot be identified in air photographs, it is best correlated with the vegetation.

The breakdown of Land Regions into Land Districts is equated with the different parent materials from place to place. Morainal deposits cover most of the area, though glacial Lake McConnell extended on either side of the Mackenzie River in the Fort Simpson Land Region, and laid a veneer of lacustrine deposits (Craig, 1965). Most parent materials are sandy (in terms of the International System) though morainal and lacustrine deposits have been subdivided into sandy and gravelly facies (respectively, Land Districts 1, 2, 3, and 4). Locally, the sandy facies of the lacustrine deposits consists of very fine sand, grading into coarse silt in which ice accumulates more readily. Gravelly morainal deposits are often associated with a glacio-fluvial origin and gravelly lacustrine deposits with beaches delineating the margins of Lake McConnell.

During post-glacial times some lacustrine sand was redistributed by wind to produce eolian dunes (Land District 5) (Fig.14). Alluvial deposits (Land District 6) adjoins rivers (Fig.5), and in mountainous areas of the Horn Plateau Land Region rock outcrops are extensive (Land District 7) (Fig.8).

The characteristic feature of the Trout Lake Land Region is the great extent (75% of the total area) of sandy morainal till; of the Fort Simpson Land Region, the extent (52% of the total area) of sandy lacustrine deposits; and of the Horn Plateau Land Region, the extent (38% of the total area) of thin till over country rock. Eolian deposits occur only in the Fort Simpson Land Region.

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Land District boundaries were delineated on the basis of surficial geology maps produced by a Geological Survey of Canada team under the direction of Dr. N. W. Rutter.

Land systems are landscape units, or composite units of repeating landforms, vegetation, and soil catenas. One criterion used in defining landscape units was that they should be, wherever possible, identifiable in air photographs, to allow their use outside the area surveyed. Land System elements of the landscape can be arranged into partly continuous and partly discontinuous morphological series, usually from least frozen units as one end-member, to frozen or partially frozen units as the other end-member of each series. For convenience, they are numbered. The use of Radforth's muskeg cover formulae (MacFarlane, 1969) is a useful way of symbolizing the vegetation of the different Land Systems; a method which broadly differentiates as well as describes the vegetative cover, and which may allow useful correlations with other areas. Though cover formulae are intended for peat landscapes, they are also conveniently used for describing freer-drained mineral soils, so giving a comprehensive symbolization of Land Systems as used in this landscape survey.

## DESCRIPTION OF LAND SYSTEMS

### Land Systems 2(AEG), 10(AEH), 1(BE)

This morphological series of forested Land Systems includes mostly mineral soils on slopes. The herbaceous and shrubby ground flora beneath some of the lowland's best forest stands growing in podzols and brunisols occurring within Land System 2(AEG), is replaced by a lichenous

and shrubby ground flora in raw, frozen soils beneath upland forests in Land System 10(AEH). The precipitous, rocky slopes in Land System 1(BE) allow only the formation of regosols supporting dwarfed treed and ericaceous shrub layers.

The three soil and forest associations used to define the Land Regions have been mapped as Land System 2 since they all occur on similar sites; drier alluvial terraces (e.g. Fig.5), valley sides, ridges (Fig.6) (eskers, drumlins, etc.), or slightly elevated sand plains, and all are, more or less, continuously forested. Land System 2 is most extensive on either side of rivers in all Land Regions and Districts; for example, forested, freer-drained lands occupy 54% of Land District 26 in the Fort Simpson Land Region; and 77% of Land District 36 in the Horn Plateau Land Region, both districts being alluvial belts. Conversely, forested freer-drained lands occupy 10% of all of the Trout Lake Land Region in the south, 16% of all of the Fort Simpson Land Region in the centre, and 8% of all of the Horn Plateau Land Region in the north. This is consistent with the greater extent of forested lands on either side of the area's major river, the Mackenzie River in the valley lands of the Fort Simpson Land Region; a lesser extent of forested lands at greater elevations in the Trout Lake Land Region; coupled with greater latitudes in the Horn Plateau Land Region.

As these are the forested lands in the southern Mackenzie River valley, they also have the only reasonably extensive merchantable

stands of timber in the valley. Based on measurements of basal area and tree height and age (Honer, 1967, 1965) the average productivity of white spruce on Land System 2 in the Trout Lake Land Region is 50 merch. $ft^3$ M.A.I./acre; in the Fort Simpson Land Region it is 70, and in the Horn Plateau Land Region it is 40. This is broadly consistent with the stand area relationships already quoted; i.e. the Mackenzie River valley proper, contains the most extensive and most productive stands of merchantable timber in the area. In this same Fort Simpson Land Region, very locally the productivity of trembling aspen and jack pine can attain 80 (though, in many cases at least, aspen forms short-lived fire stands with an understorey of white spruce which will eventually take over and form the long-lived part of the succession). Typically, the spruce stands are tall and open. Old stands up to 200 years of age are most widespread in the Camsell Range section of the Horn Plateau Land Region, whereas few stands in the other two Land Regions exceed 100 years of age, presumably because of frequent fires.

Though white spruce occurs on most drier sites, black spruce often occupies the least fertile and most podzolized sites, and then accompanying jack pine in the Trout Lake Land Region. Normally in the southern Mackenzie River valley, abundant lichen (mostly Cladonia alpestris (L.) Rubenh.) indicates frozen subsoil; the more lichen there is, the nearer is frozen subsoil to the land surface. Very dry sites in Land System 2 are richly covered with lichen, constituting an exception to this otherwise useful generalization since the land is mostly unfrozen near the surface. Frosen ground, often in the form of ice lenses, at

about 6 ft deep is most extensive in lacustrine deposits with the finest textures, sometimes helping to produce landslips on slopes, or in waterlogged subsidence hollows where clearing and exposure of the mineral soil has caused near-surface ice lenses to thaw.

Shreber moss (Pleurozium schreberi (BSG.) Mitt.) is abundant on podzols, whereas shiny moss (Hylocomium splendens (Hedw. (BSG.)) is generally more abundant elsewhere. The comparatively rich herbaceous flora includes bunchberry (Cornus canadensis L.) twinflower (Linnaea borealis L.), maiathemum (Maianthemum canadense Desf.), fireweed (Epilobium angustifolium) and northern bedstraw (Galium boreale L.); the shrub layer wild rose (Rosa acicularis Lindl.), dogwood (Cornus stolonifera Michx.), cowberry (Vaccinium vitis-idaea L.), dwarf raspberry (Rubus pubescens Raf.), squashberry (Viburnum edule Michx.), and most characteristically in all the Land System 2 forest associations, alder species (e.g. Alnus incana (L.) Moench.). The cover class of AEF is a natural expression of this vegetation.

Land System 10 occurs mostly in the mountainous and western portion of the Horn Plateau Land Region, where the morainal veneer is sufficiently thin to show the structure of the underlying country rock, reflected through to the land surface, often giving a quasi-reticulate drainage pattern (Fig.7). Though not important in extent (accounting for only 1.5% of the Land Region), as rock does not often contain ice, the significance of this landscape pattern is that although it is part of the permafrost landscape, ice is probably not deeply developed.

Occurring at great elevations, a herbaceous flora is largely replaced by lichen, which reflects frozen subsoil often within 12 inches of the land surface during summer. This vegetation is symbolized by the cover class of AEH. As the terrain is also rolling, the land can be damaged by careless cutting of seismic lines and roads.

Land System 1 contains steep slopes and rocky outcrops associated with mountains (Fig.8). Bare rock cropping out between areas of thin till occupies the greatest part of the total landscape in the Camsell Range mountain section of the Horn Plateau Land Region (e.g. 74% of Land System 37-1). The forest is open, stunted black spruce, especially at the highest elevations, growing where there are regosols, and associated with a dominantly ericaceous ground flora of labrador tea (Ledum groenlandicum Oeder) and cowberry, giving a cover class of BE. The flora at the highest elevations has a distinctly Alpine character, though this is not sufficiently extensive to justify separate delineation.

Land Systems 4(AEF), 6(AEI), 8(AEH).

This series of Land Systems is characterized by an open, shrubby forest with trees 15 - 30 ft high, growing in peaty (12 to 24 inches thick) soils on slopes showing a lineated drainage pattern. The least frozen slopes around plateau perimeters have peaty rego gleysols and support a sedgey flora in those parts waterlogged in summer. Frozen

slopes on the plateau have peaty cryic gleysols and support a mossy flora on sites surficially wetter, and a lichenous flora on the most continuously frozen sites.

Land System 4 describes land sloping from the uplands and associated with a close, fan-shaped drainage pattern of nearly parallel, shallow runnels in the peaty surface, a lineation oriented downslope (Fig.9). The smallest runnels are about 50 yards apart, and the largest about 600 yards apart. Land System 4 occurs in the Trout Lake and Fort Simpson Land Regions. In the latter, in Land District 27 where thin till occurs over the country rock along the southern periphery of the Horn Plateau, Land System 4 accounts for 59% of the total landscape. Lichen is scattered in pockets, and locally frozen ground occurs at about 4 ft. Most slopes are gentle and much land is waterlogged, supporting a sedge and shrub vegetation beneath black spruce; hence the cover class is AEF.

Land System 6 is, with one minor exception, confined to the northern plateau lands, on gently inclined lower slopes merging down into broad depressions, or on slopes facing prevailing rain-bearing winds (Fig.10), and like Land System 4, is associated with the same lineated drainage pattern. Club-topped, widely spaced black spruce occurs with some lichen on the higher mounds, but with Sphagnum mosses covering the wide runnels and numerous depressions. The ground is frozen at about 2 ft below the land surface, except in and around depressions where the frost is deeper. Labrador tea, shrubby cinquefoil (Potentilla

fruticosa L.) and dwarf birch (Betula glandulosa Michx.) form an open shrub layer with bake-apple (Rubus chamaemorus L.) and shiny moss with the lichen in the ground flora. This cover class is AEI.

It is noteworthy that this and other similarly frozen landscapes so widespread on Horn Plateau in the north of the area surveyed, occur only in the form of a small area of Land System 6 on the cool, north-east facing slopes of the plateau lands south of Trout Lake; in this southern area, upland slopes have Land System 4 on them, indicating less frozen conditions. The effect of the increasing amelioration of the climate with decreasing latitude is greater than the effect of greater elevation.

Land System 8 is entirely confined to the northern plateau lands of the Horn Plateau Land Region, on upper plateau slopes or on slopes protected from the prevailing rain-bearing winds (Fig.11), associated with the lineated drainage pattern described for Land System 4. Lichen grows abundantly beneath club-topped black spruce, with Sphagnum mosses confined mostly to the vicinity of the runnels and the more widely scattered depressions where thick deposits of winter snow accumulate. This gives the landscape a lighter tone from the air compared with the mossy Land System 6 which is darker in appearance. Land Systems 8 and 6 are about equally widespread (30% of Land System 31-8, as compared with 27% of Land System 31-6).

Because of the lichenous surface the albedo is high, which, added to the influence of altitude, latitude, and the effective thermal

insulation of the vegetative mat and organic layer, keeps the ground cool during summer, and frost is encountered during mid-August at 12 inches or less, except around runnels and depressions. The low shrub layer of labrador tea, shrubby cinquefoil, and dwarf birch is often dense and with the black spruce and lichen, gives a cover class of AEH. The association of a frozen subsoil several inches below the land surface and on slopes, however gentle, make this land system one of the most likely units in the area surveyed to be damaged by careless seismic line and road cutting (Fig.12). Stripping the insulating vegetative and the organic cover produces deep summer thawing and, where the ice content is great, erosion of the slurried topsoil and, locally, there are 8 ft deep gullies.

In this manner, Land System 8 is similar to Land System 10 and there is a gradation from one system to the other. The cross-country profile (Fig.13) illustrates Land System 10 occurring on the mountain pleateau tops where the till cover is thinnest and the country rock structure is most likely to be reflected by the land surface configuration. The till cover thickens downslope and tends to obscure the country rock structure, which is replaced by a surface configuration reflecting the slope orientation in the form of a lineated drainage pattern. This lineated drainage pattern is partially represented on the slopes in Land System 10 (Fig.7), and with one system grading into the other, there is always the uncertainty of classification in marginal areas. This relationship explains the same cover class of AEH for each system, and so an affix is necessary to distinguish the two covers: i.e. $AEH^{8}$ for Land System 8, and $AEH^{10}$ for Land System 10.

Land Systems 3(EFI), 7(BEI), 9(BEH).

This morphological series describes waterlogged, lowland flats with sedges and mosses, usually having a low shrub layer, but with a localized tree cover and sometimes showing a diffuse, polygoid drainage pattern, which is better expressed on the frozen upland plateau landscapes. These plateau-lands are shrubby, poorly treed, and mossy in channels and lichenous on the raised centres.

Except on alluvium, waterlogged flatlands of Land System 3 are extensive everywhere in Land Regions Trout Lake and Fort Simpson, especially where there are scattered sand dunes (Fig.14). Though the dunes are elevated and noticeable relief forms they cover a remarkably small part of the total landscape (e.g. only 3% of Land System 25-3 in the Fort Simpson Land Region consists of treed dunes). Coarse-textured, gravelly deposits are associated with more extensive unfrozen flats than the sandy facies, whether morainal (e.g. 64% of gravelly Land System 12-3, as compared with 54% of the sandy Land System 11-3 in the Trout Lake Land Region), or lacustrine (e.g. 77% of gravelly Land System 24-3, as compared with 57% of sandy Land System 23-3 in the Fort Simpson Land Region). The waterlogged and peaty flats of this Land System 3 have on them stunted black spruce, with some tamarack (Larix laricina (Du Roi)(K. Koch), white birch, and balsam poplar; these trees normally cluster on slightly raised and drier parts and often leave the intervening areas mostly barren of large trees (Fig.15). Confining pools in summer, the embankments

of local string bogs may be treed in this manner, though adjoining large areas or remnants of frozen peat the string bogs are normally barren. Sedges, especially the tufted bog-cottongrass (Eriophorum spissum Fern.) characterize these wet flats. Dwarf birch is widespread, locally forming a dense shrub layer. Sphagnum mosses are very widespread on these peaty, so-called "Fenlands". Hence, the cover class if EFI. Though generally unfrozen in summer, local frozen patches of subsoil were observed. Otherwise similar to Land System 2, on treed "Islands" the incidence of frozen ground is greater in Land System 3.

This is a somewhat heterogeneous landscape unit, and it figures in two morphological series, with an area of overlap. A marbloid, or diffuse polygoid appearance can be quite widespread in the lowlands, which links this landscape unit with the polygoid drainage pattern characteristic of the other two members of this morphological series, Land Systems 7 and 9. These latter two systems occur on upland plateaus but, locally, they show within the overall polygoid pattern, the terrazoid appearance of "Rotting" thermokarst topography best seen in the lowland Land System 5 (Fig.18). Locally, a smooth transition can be seen from the terrazoid Land System 5, through string bogs, to Land System 3.

Land System 7 has a mossy and shrubby vegetation similar to that of Land System 6, except that the black spruce is shorter, giving a cover class of BEI. Frozen subsoil generally occurs 2 ft below the

surface of the land, but deeper in depressions and drainage trenches, as in Land System 6. Land System 7 occurs in broad upland depressions, at the base of the long plateau slopes showing a stiploid (lineated) drainage pattern. Troughs delineating the polygoid patterning determine the drainage pattern on the depression flats, individual polygons being up to 600 yards across (Fig.16).

Land System 9 has a lichenous and shrubby vegetation similar to that of Land System 8, except that the black spruce is shorter, giving a cover class of BEH. Except below depressions and drainage trenches, frozen subsoil occurs within 1 ft of the land surface, in summer giving a dry, fluffy, peaty surface more richly lichenous than in any other land system (Fig.17). Compared with other areas, a greater part of the flatlands with a polygonal drainage pattern is frozen to within a few inches of the land surface (29% of Land System 31-9, as compared with 8% of Land System 31-7, both in the Horn Plateau Land Region to which these systems are confined). Land System 9 is best expressed on the raised centres of polygons.

Land Systems 3(EFI), 5(EI).

In this series sedges and mosses on the waterlogged flats give way to frozen, raised peat with a low, dense shrub layer on mounds and moss in depressions.

Land System 3 has already been described. It occurs in juxtaposition with Land System 5. Extensive on lower lands in the Fort

Simpson and Trout Lake Land Regions are areas of frozen, raised peat, mostly barren of trees but with widely scattered, dwarfed, black spruce trees, with some stunted tamarack, jack pine and white birch. Numerous depressions containing summer pools scattered across the peat landscape give the terrain its characteristic terrazoid appearance (Fig.18). Frozen, raised peatland is more extensive in (finer-textured) sandy deposits than in (coarser-textured) gravelly deposits (e.g. 30% of sandy morainal Land System 11-5, as compared with 12% of gravelly morainal Land System 12-5 in the Trout Lake Land Region; or 18% of sandy lacustrine Land System 23-5, as compared with 3% of gravelly lacustrine Land System 24-5 in the Fort Simpson Land Region). In the Fort Simpson Land Region, frozen, raised peatlands are more extensive on the finer-textured (locally coarse silty), lacustrine deposits (i.e. 18% of Land System 23-5) than on morainal deposits (i.e. 7% of Land System 21-5). Great east-west belts of this frozen land occur between the Horn Plateau and the Mackenzie River, terminated abruptly where they abutt against local, gravelly lacustrine deposits. Thin belts of frozen land often occur on the cool and north sides of ridges (Fig.6).

Frozen land is more extensive (covering almost all the area) on the Horn Plateau part of this Land Region than in any other region. Trout Lake Land Region is further south than Horn Plateau, and though locally the Trout Lake Land Region is higher than the Horn Plateau, frozen land is mostly in the form of frozen raised peatlands (totalling one-quarter of the landscape) which are characteristic of the valley-lands further north. This is another effect of the increasing

amelioration of the climate with decreasing latitude at, or at greater than corresponding altitudes.

Labrador tea grows profusely, often dominating the appearance of the land from the air. Scattered clumps of lichen reflect a substrate frozen at about 2 ft depth below the land surface. Shiny moss typically occurs on drier, slightly elevated parts of the peat bog, while Sphagnum mosses are abundant in the depressions. Hence, Land System 5 has a cover class of EI, though in this classification the moss and shrub layers belong to distinctly different parts of the landscape. Dwarf birch, shrubby cinquefoil and cowberry are common shrubs, and horsetails (e.g. Equisetum arvense L.) are widespread. The herbaceous flora is sparse but, characteristically, includes bake-apple.

The higher peat mounds are often split by radiating cracks, in which the frozen ground can be felt by probing. If the centres of these radiating cracks are sufficiently open, thawing produces a pool of water in summer. Water-filled depressions, some large and some small, are scattered across the raised peat area. Cracking and slumping of peat blocks into the depressions produces the very typical dead, or dying trees which lean over and eventually subside into the depressions, implying that these depressions are enlarging and encroaching on the raised peat. Generally, there is a discontinuity between this Land System 5 and Land System 3, though locally there is a transition from raised peat with depressions, larger depressions with frozen, raised peat confined to banks dividing adjoining depressions, less prominent

banks thawed to a greater depth, to a reticulate, polygoid bog, implying at least one origin for string bogs, presumably accompanying the amelioration of the climate during post-glacial times.

## GENERAL CONCLUSIONS

The landscape in the southern Mackenzie River valley between latitudes 60° and 63° in the discontinuous permafrost zone, has been classified with special reference to the state of frost in the ground. The forest cover is normally used to identify climatic zones, but could not be used here because the trees are clustered locally, and the regional distribution pattern of species is diffuse. With declining average annual rainfall and temperatures northwards, there is a declining intensity of podzolization represented by the transition from orthic humo-ferric podzols in the south, to degraded dystric brunisols in the centre, to degraded eutric brunisols on drier bank and ridge slopes in the north of the area surveyed. This is the most suitable characterization of climatic zoning in this particular region. Elsewhere, for example in regions where all mineral soils are frozen, the vegetation may allow a better characterization of climatic zoning.

Merchantable forest stands are confined to freely or imperfectly drained mineral soils on bank or ridge slopes near river tracks. Tree growth can be excellent, but such stands are of limited value because of their isolation. The oldest stands occur in mountain

valleys where the fire risk would be generally less. Forested mineral soils have a rich herbaceous ground flora, whereas sedges characterize the unfrozen waterlogged flats. With the exception of very dry podzol sites, dry, crisp mats of lichen are indicative of a frozen subsoil a few inches below the land surface. Other sites which have a deeper frozen subsoil have Sphagnum mosses intermingled with clumps of lichen, reflect more free water on the land surface. In the shrub layer the wild rose, and especially alder, are characteristic of mineral soils, dwarf birch of waterlogged peat, and labrador tea and shrubby cinquefoil of frozen peat.

Morainal and lacustrine deposits mantle the area, except where mountains produce rocky outcrops. Partially frozen, raised peat and unfrozen waterlogged flats are extensive in the lowlands of the Mackenzie River valley. Frozen land is least extensive in the gravelly glaciofluvial and beach deposits, and most extensive in the siltiest lacustrine deposits. Though mineral soils are generally unfrozen, subsidence-hollows and landslips over ice lenses are most prevalent in fine-textured lacustrine deposits.

Except where rock crops out, all land is frozen on the upland plateaus. Where the morainal mantle is thin, the structure of the country rock is reflected at the land surface by a reticuloid drainage pattern. On slopes this pattern merges into a lineated drainage pattern. Where there are slopes, the frozen landscape is most easily damaged by careless seismic line and road cuts. Removal of vegetative and

organic cover allows deep thawing in summer, and subsequent erosion and gullying, locally to a depth of 8 ft. Rock unusually contains ice, and so land with a reticuloid drainage pattern probably has thinner surficial ice layers than till-mantled land with a lineated drainage pattern, though this till will not be as thick on slopes as it is on the valley flats with a polygoid drainage pattern where, probably, the permafrost layer is thicker than elsewhere. In upland flats most of the land is frozen to within a foot of the surface throughout summer.

Frozen landscapes characteristic of northerly plateau-lands at elevations down to 1,000 ft, occur on the southerly plateau-lands only within one very small area on a cool, north-east facing slope at about 2,000 ft overlooking Trout Lake. Whereas a lineated drainage pattern on slopes is associated with frozen conditions on the northern uplands (Land Systems 6 and 8), on the southern uplands this drainage pattern is associated with frost at 4 ft depth or greater (Land System 4). Frozen, raised peatlands which are characteristic of northern valleylands, are far more widespread on southern plateau-lands. These relationships are an effect of the increasing amelioration of the climate with decreasing latitude at, or at greater than corresponding elevations.

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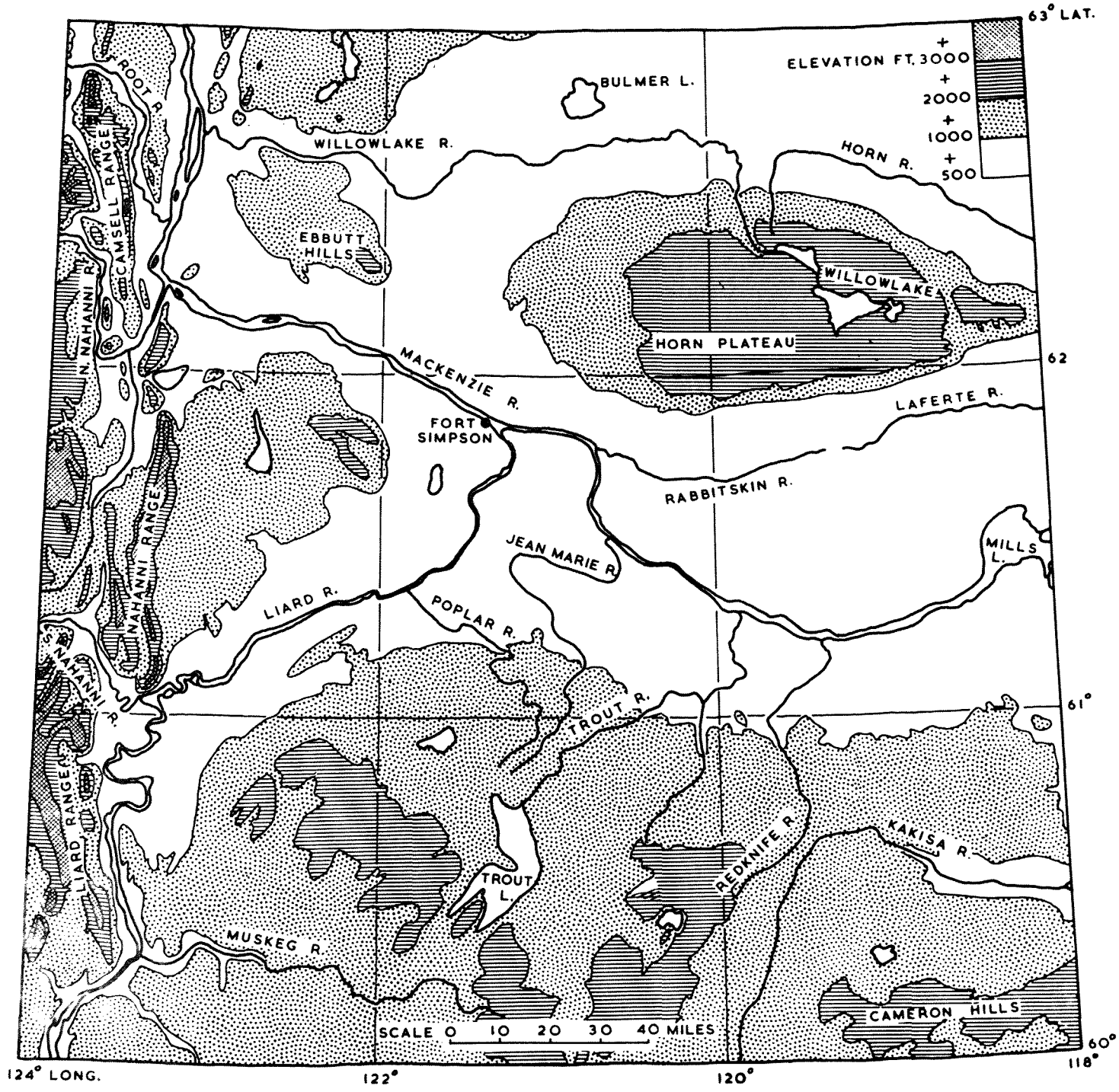
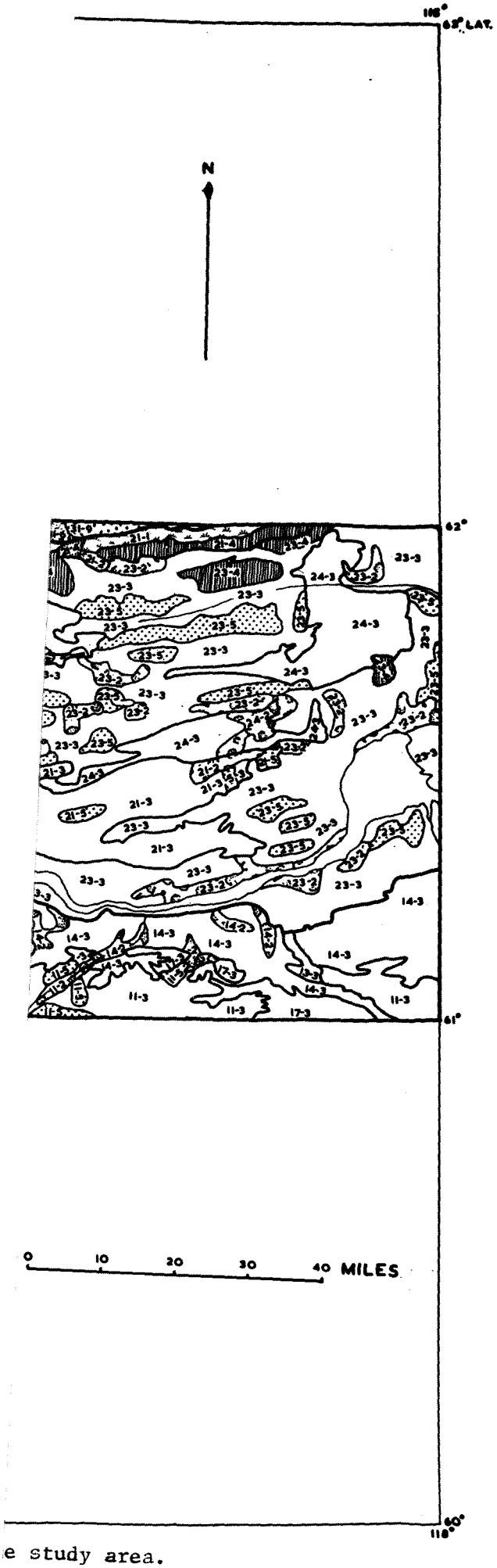



Fig. 1. Topography of the study area.

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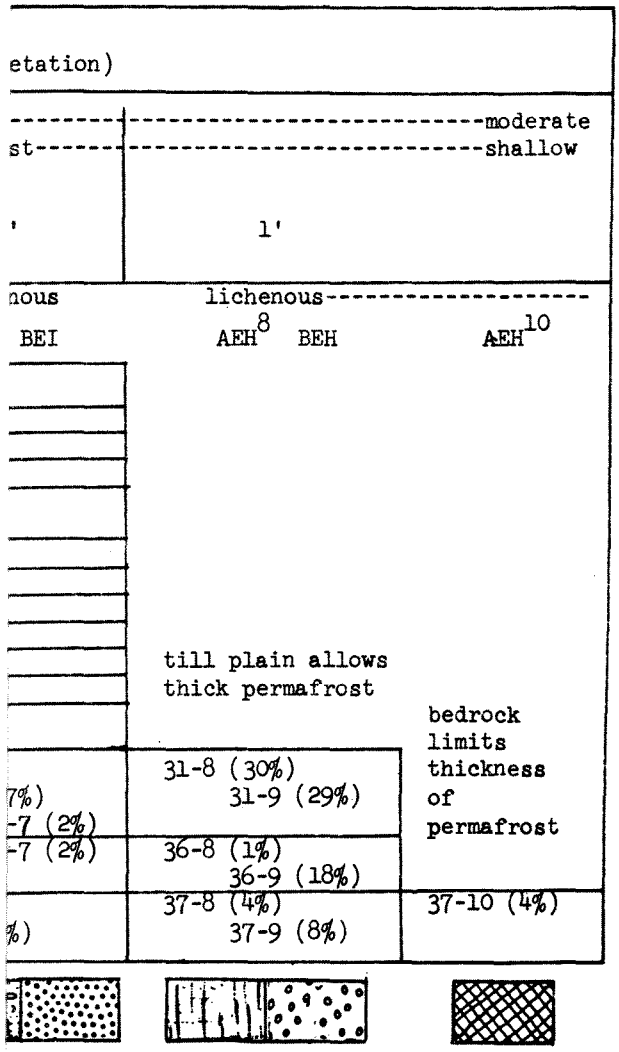


Distribution at increasing elevation or latitude

ate" - where the vegetation, and especially the organic layer is removed to expose the l soil, thawing extends, on average, 36" into the subsoil. The mineral soil becomes ted with water in summer, and mobile on slopes as in Land System 8 with a slope- ed drainage pattern, to produce erosion gullies.

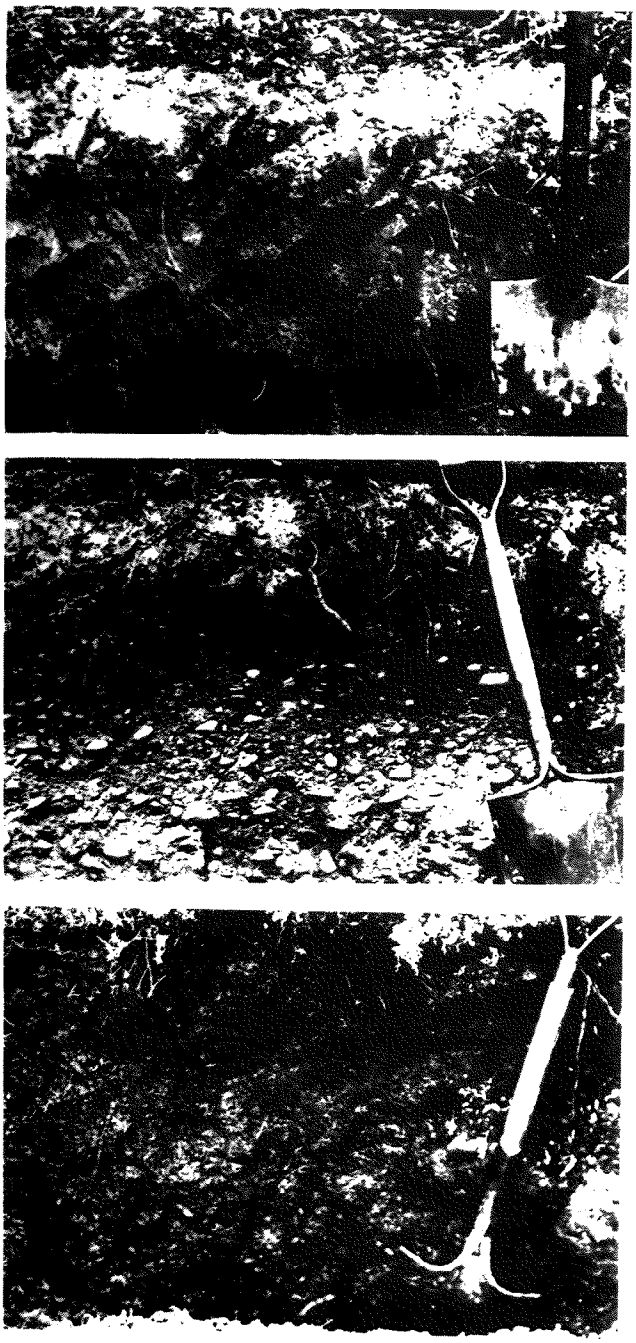

Fig. 4. Soil profiles illustrating decreasing podzolization (decreasing intensity of leaching in the grey, eluvial layer, and decreasing ochreousness or darkening of the illuvial layer) from Land Region 1 in the south (top photograph), through Land Region 2 (central photograph), to Land Region 3 in the north (bottom photograph).

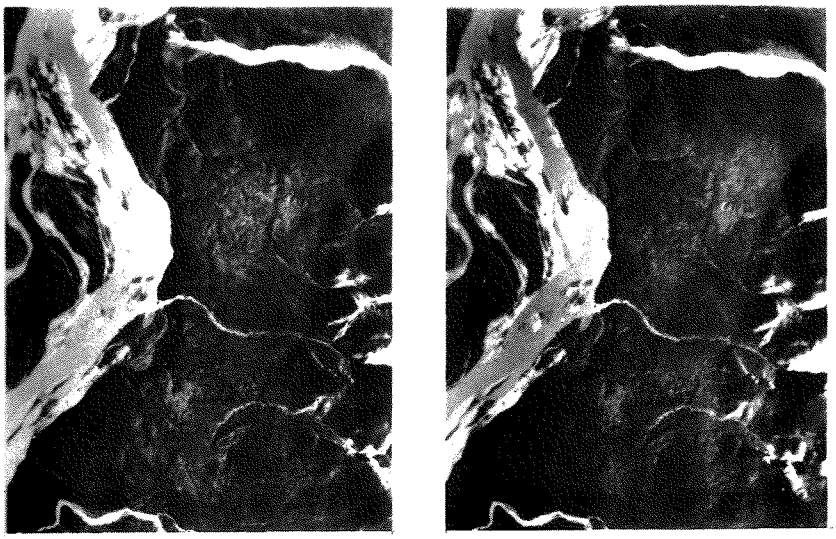

**Fig. 5.** Stereogram of alluvial terraces (parts of air photographs A17624 - 52, 53*).

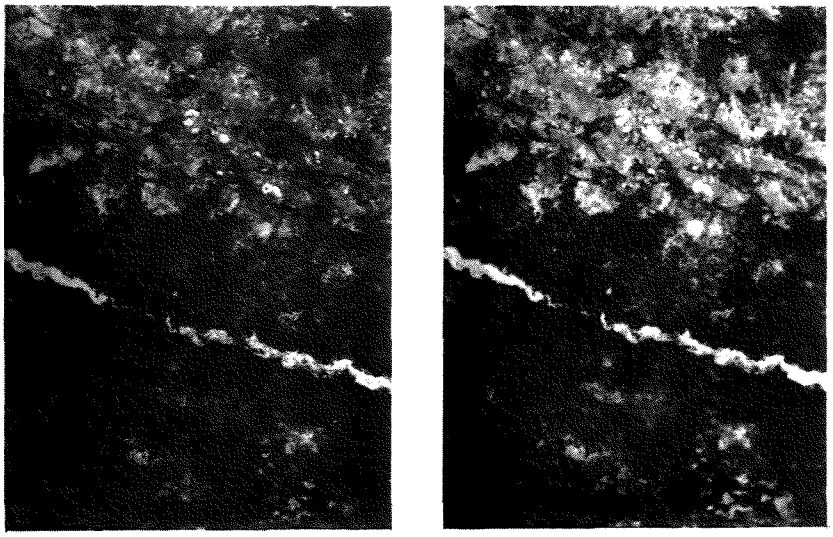

**Fig. 6.** Stereogram of slightly elevated, broad ridge, adjoining frozen and unfrozen flats (parts of air photographs A11029 - 374, 375).

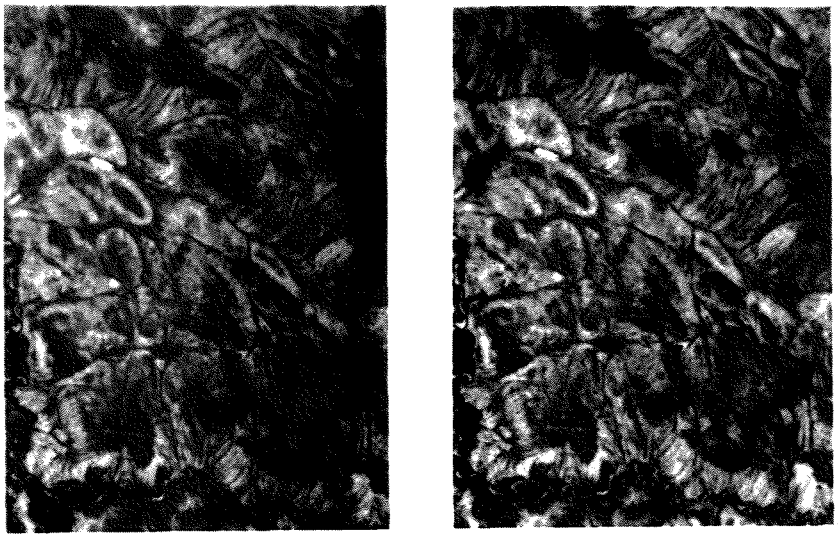

Fig. 7. Stereogram of mountains and flanks with thin till (parts of air photographs A17624 - 45, 46).

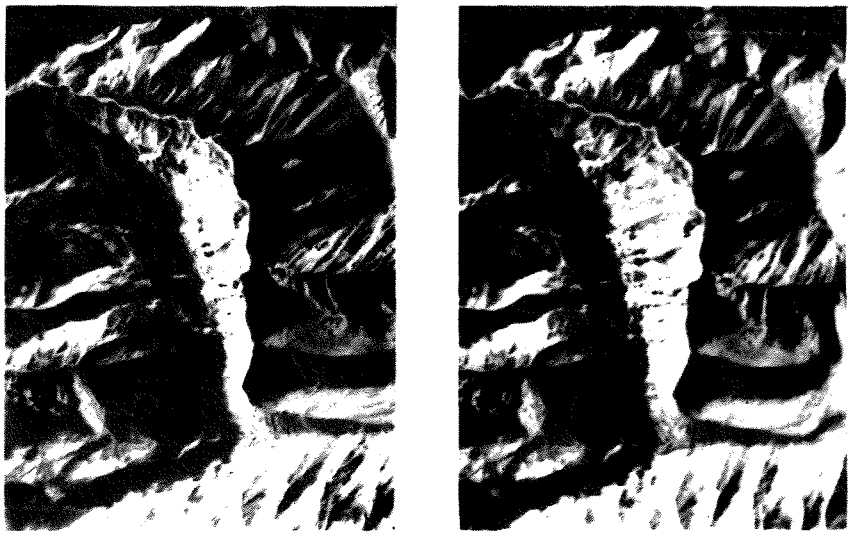

Fig. 8. Stereogram of rocky mountains and precipitous slopes (parts of air photographs A17624 - 53, 54).

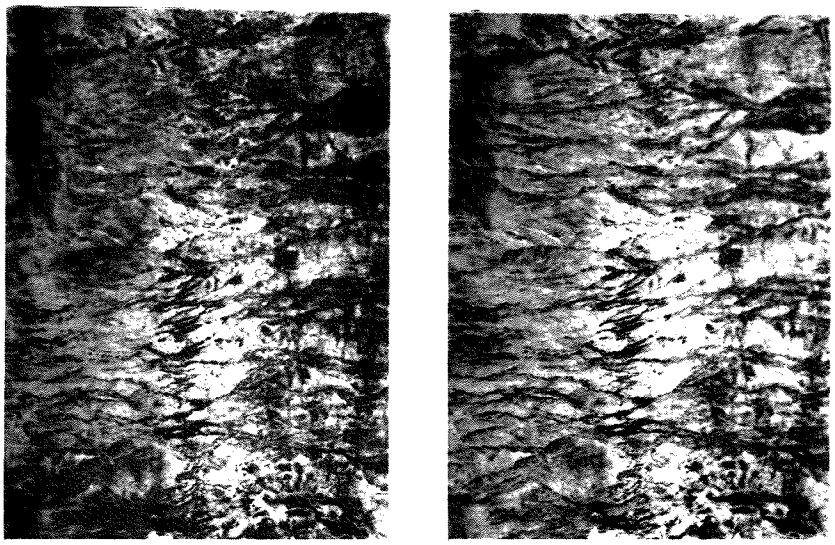

Fig. 9. Stereogram of plateau flanks (parts of air photographs A17430 - 49, 50).

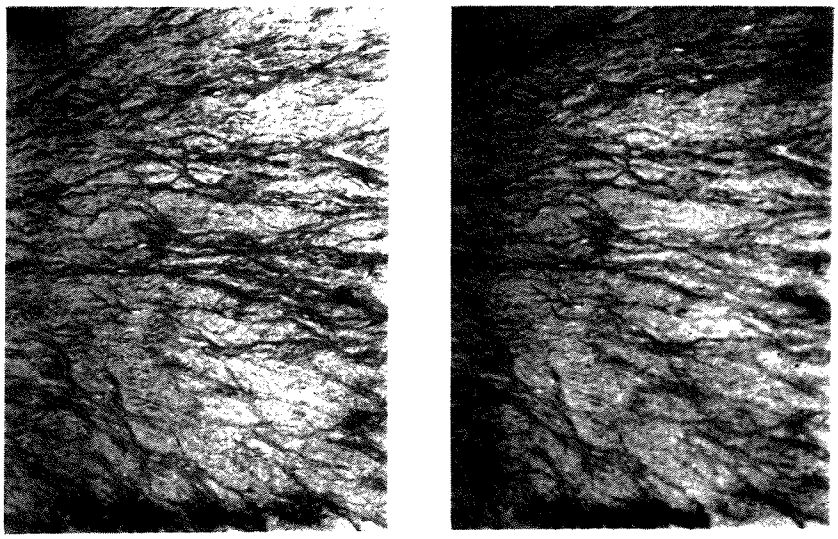

Fig. 10. Stereogram of more gentle, plateau slopes (parts of air photographs A17430 - 94, 95).

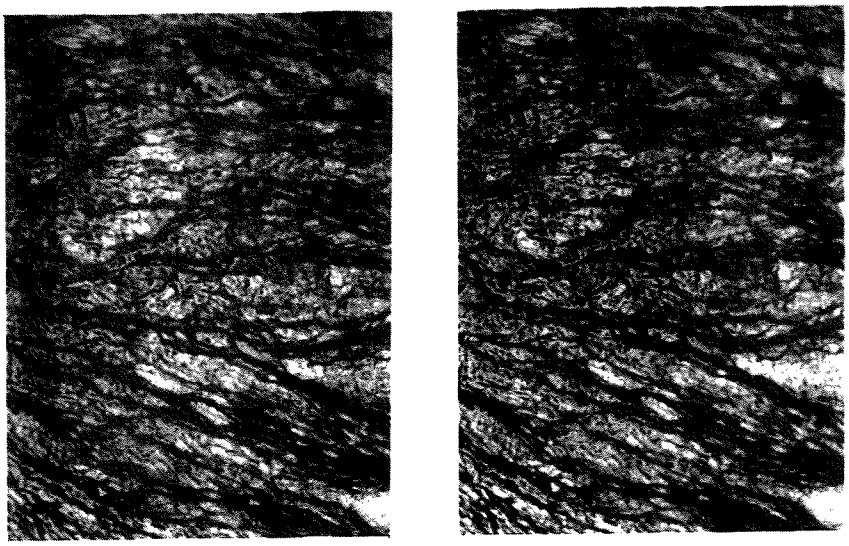

Fig. 11. Stereogram of steeper, plateau slopes (parts of air photographs A17430 - 93, 94).

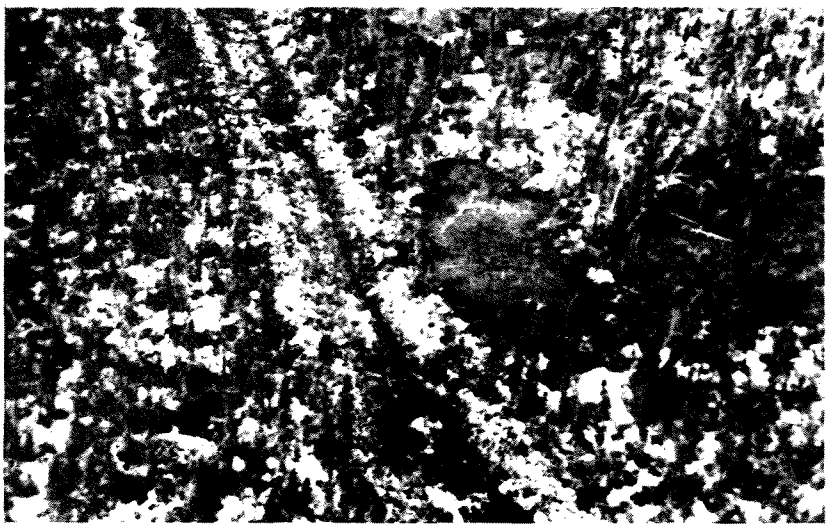

Fig. 12. Early, careless, seismic line cut, showing subsequent 8 ft deep gullying in places where slopes are steeper.

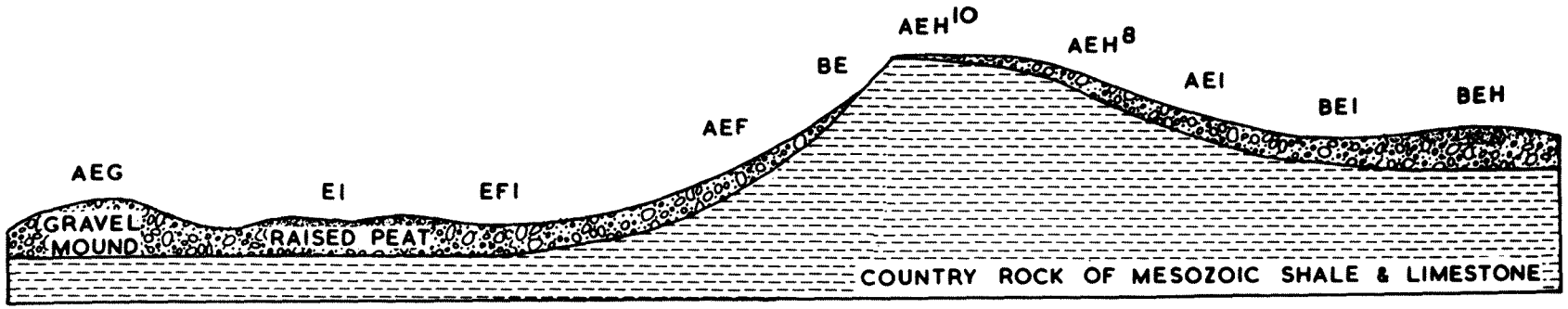


Fig. 13. Diagramatic representation of cross-country profile, illustrating the distribution of different landscape units.

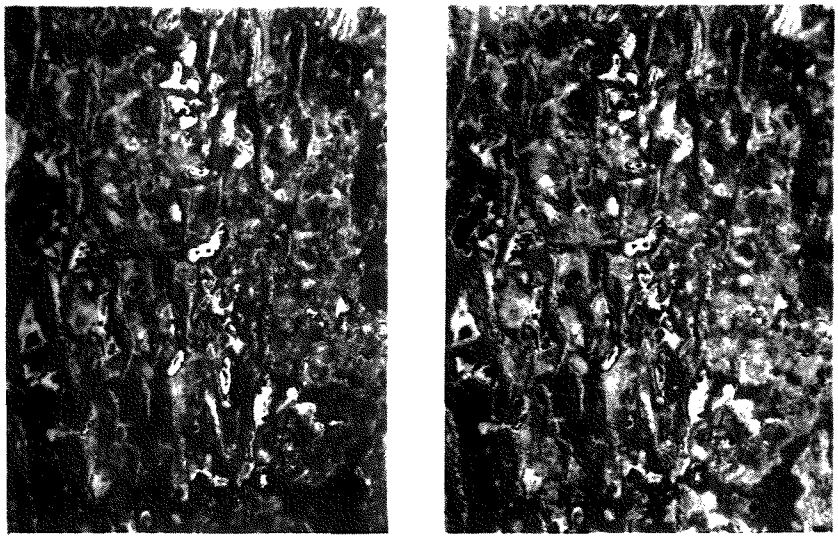

Fig. 14. Stereogram of sand dunes in mostly waterlogged flats (parts of air photographs A11028 - 336-337).

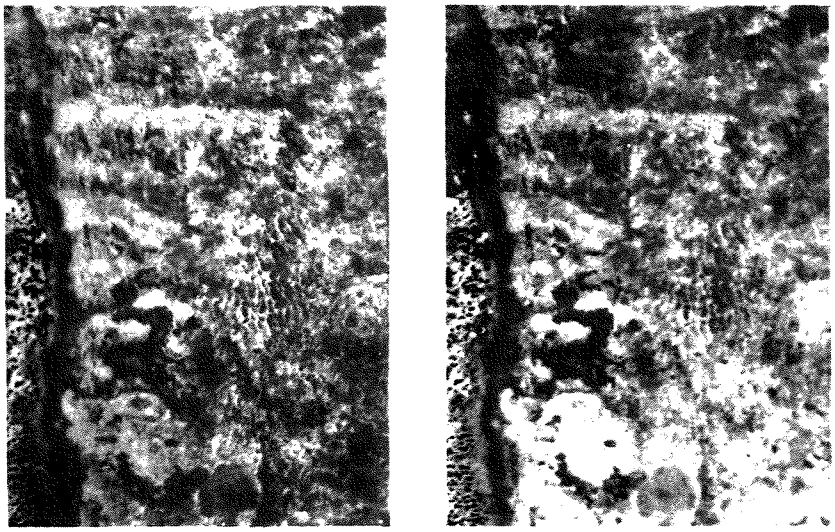

Fig. 15. Stereogram of waterlogged flats with string bogs (parts of air photographs A11378 - 22, 23).

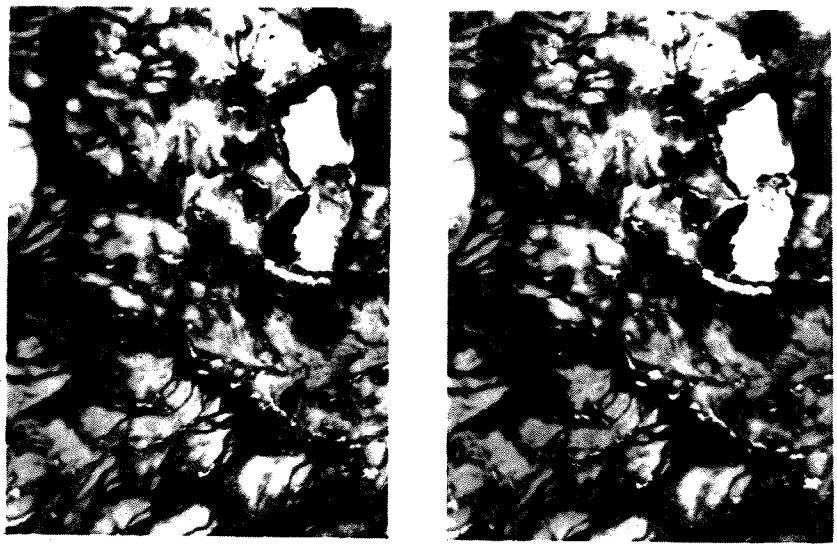

Fig. 16. Stereogram of wetter, plateau flats (parts of air photographs A11342 - 33, 34).

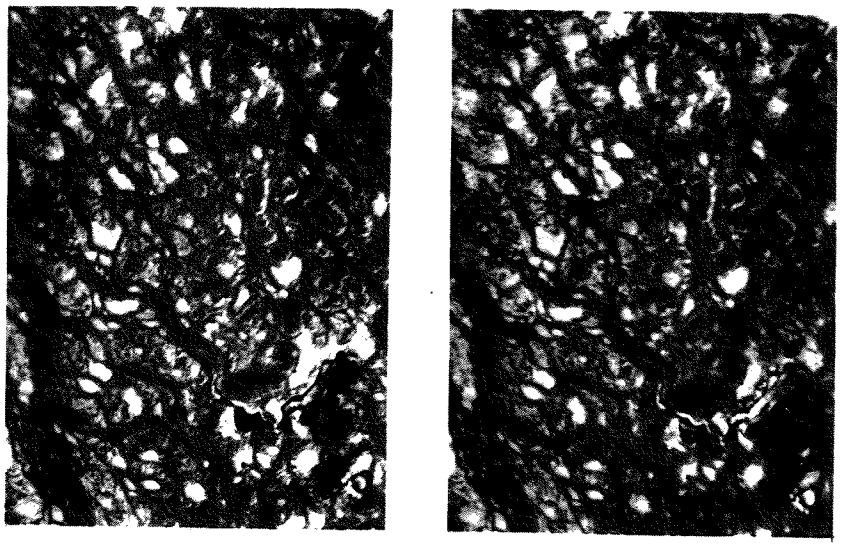

Fig. 17. Stereogram of more frozen, plateau flats (parts of air photographs A11342 - 34, 35).