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ANNOTATED BIBLIOGRAPHY OF PERMAFROST—VEGETATION—WILDLIFE—LANDFORM RELATIONSHIPS

by

Patricia Roberts-Pichette

Résumé en français

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FOREWORD

Within the Canadian Forestry Service, the Forest Management Institute, Ottawa, and the Northern Forest Research Centre at Edmonton are conducting surveys and studies of the vegetation and vegetation-land relationships in the Mackenzie Valley Corridor. The Forest Management Institute has the task of mapping the current vegetation types, initially on about 30,000 square miles, using aerial photography and limited field sampling within a two-year period. The Northern Forest Research Centre, in collaboration with the Geological Survey of Canada, is determining the relationship of vegetation to surficial deposits, soil moisture, and permafrost; studies are also being made of the effects of disturbance on the most common vegetation-land complexes and on those most sensitive to disturbance. All of these studies are part of the program being undertaken by most agencies of Environment Canada to determine the ecological relationships and the impact of economic development on the total environment in this area.

The vegetation-land-soil moisture-permafrost relationships are of paramount importance in construction activities and on the impact of these activities on the biophysical environment. Information on previous studies of this nature conducted by either Canadian or foreign investigators was not readily available in any organized fashion. Therefore, the Forest Management Institute entered into a contract with Dr. Patricia Roberts-Pichette, a well-qualified plant ecologist, for a literature review to make existing information more readily available to all organizations concerned with vegetation relationship in the northern areas.

On the basis of the literature review, Dr. Roberts-Pichette has drawn some preliminary conclusions concerning the environmental impact of a possible pipeline and associated transportation facilities within the corridor area. The opinions expressed are those of the author and do not necessarily agree with the views of the Canadian

Forestry Service, which will be available after the conclusion of field studies and analysis of the data collected during 1971 and 1972.

A. Bickerstaff
Director
Forest Management Institute

ABSTRACT

This bibliography contains almost 500 titles chiefly from post 1945 North American, European and USSR literature on the arctic and sub-arctic regions of the world. Although concerned primarily with land sensitivity in the north, titles of taxonomic, ecological, geological, geographical, meteorological and permafrost studies and reviews have been included. Quotations have been selected to give special emphasis to the ecological problems resulting from man's increased activities in the North and also to the accumulating of information on how to repair, reduce or circumvent environmental damage.

RESUME

Cette bibliographie regroupe environ 500 titres de publications ayant trait aux régions arctiques et sub-arctiques, parues la plupart depuis 1945 en Amérique du Nord, en Europe et en Union Soviétique. L'orientation principale est axée sur la susceptibilité des terrains dans le nord. On trouvera également des références concernant la taxonomie, l'écologie, la géologie, la géographie, la météorologie et le pergélisol.

Les citations ont été choisies afin de souligner d'une part l'importance des problèmes écologiques qui résultent des activités de plus en plus nombreuses de l'homme dans le nord et d'autre part de l'information sans cesse grandissante traitant des moyens de prévenir, de réduire ou de diminuer les dommages causés au milieu.

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INTRODUCTION

Scope and Organization of the Study

This bibliography was commissioned by the Forest Management Institute, Canadian Forestry Service, Environment Canada, and represents a four-month search of the literature published, except in a few instances, since 1945. Information has been obtained from a variety of sources but the very latest information, mostly acquired by private companies and individuals, has sometimes been hard to obtain – chiefly because the 1971 field season results have not been completely analyzed. Some titles could not be obtained in translation or on short notice, and where this has happened, information has been taken from Arctic Bibliography, Biological Abstracts, or Cold Regions Research Engineering Laboratory Report 12, as noted. Annotations from the Arctic Bibliography are reprinted by permission of the Arctic Institute of North America. In some cases, information has not been obtainable from these sources and the title only is listed.

It should be noted that only translated titles of articles from USSR literature have been used. In some cases, this may lead to confusion

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as not all translators interpret a given title in the same way. Sources of translated articles can be found by consulting the Translation Bureau of the National Science Library. Time has not allowed complete documentation, and sources of translated articles have been included when known.

Most of the abbreviations used follow the "Word-Abbreviation List", 1971 edition, of the National Clearinghouse for Periodical Title Word Abbreviations. Copies may be purchased from the National Clearinghouse for Periodical Title Word Abbreviations, c/o Chemical Abstracts Service, University Post Office, Columbus, Ohio 43210.

Miss Carol Barton, of the reference section of the Department of the Environment Library, has been of invaluable assistance in obtaining material by inter-library loan. Thanks are also due to Dr. L.C. Bliss, University of Alberta, Edmonton, who has also been most helpful in obtaining material.

At the end of the bibliography are the summaries of the ALUR (Arctic Land Use Research, Canada Department of Indian Affairs and Northern Development) 1970 and 1971 studies, as well as the Environmental Protection Board (sponsored by the Gas Arctic Systems Study Group) Interim Reports No. 1, 1971. They are presented together in this way because most of them were not available when the rest of the material had been assembled, and it seemed advisable to keep together all of this information, which is primarily concerned with environmental damage and rehabilitation.

Although concerned primarily with land sensitivity, this bibliography also contains titles of taxonomic, ecological, geological, geographical, meteorological and permafrost studies and reviews. This basic material is necessary for an understanding of patterns of recovery following disturbance. Unfortunately, very few revegetation studies following disturbance of the vegetation mat have been undertaken until very recently and literature reports are very scattered for North America prior to about 1967. Since then, a great many studies have been initiated but the results have not always been readily available or have not yet been published. Thus, some references to unpublished material are included.

References to material from the USSR are much more extensive but most of the papers have not been translated.

Two reports which may be of use to persons interested in studies by Federal agencies and currently underway in the Canadian Arctic are:

"1971-72 and 1972-73 northern pipeline — related studies by Environment Canada" compiled by the Mackenzie Valley Working Group, Environment Canada, which is part of the interdepartmental annual report available through the office of the Environment — Social Programme, Northern Pipelines; and "Environmental studies in North-Western Canada, with special reference to Mackenzie Valley Pipelines" compiled by Dr. R.M. Strang of the Canadian Forestry Service.

A companion volume to the former report is being prepared which will contain preliminary conclusions related to environmental-social concerns and will pinpoint areas of critical concern or in need of further critical study.

General Impressions From the Literature

The overall impression one gains from the more recent literature is that, if reasonable care is taken, the arctic tundra and other communities are not nearly as sensitive to damage as once thought. Since fine-grained soils are apparently always wet they are subject to severe frost disturbance if the vegetation mat is broken and the thermal balance is altered. On well-drained soils, scars resulting from disturbance may be visible for many years or decades, even though revegetated quite quickly. Very little information has been obtained on the result of stream bed and bank disturbance at stream crossings and what effects gravel removal or extra silt loads may have on fish or other aquatic populations.

Another aspect of concern is the possibility of change in drainage patterns due to the often unpredictable enlargement of temporary ponds, lakes or drainage channels created over permafrost, especially if massive ground ice or icy sediments are present in or near the banks.

The siting of pumping stations becomes of major concern, especially if large quantities of water vapour or other chemical emissions are produced. The nature of the meteorological conditions are such that ice fogs and local deposition of exhaust chemicals could be excessive especially if pumping stations are sited in valleys. Some workers are concerned with the effects of noise, especially on the caribou.

There seems to be little doubt that a pipeline can be built through the Mackenzie corridor, with all its attendant facilities, without major disruption to the land-based animals and plants and to the land itself, provided appropriate (and usually expensive) precautions are taken.

Some Specific Questions

The contract specified certain questions on which to concentrate. Insofar as it has been possible to find the answers from the available literature, the results follow:

Question 1: To what extent does vegetation and raw humus protect the ground from thermal erosion?

Wet silty and clayey soils are the ones most subject to frost action while well-drained soils are not greatly disturbed by it. The former soils support the heavy organic matter and vegetation mats, while the latter are likely to have a much thinner (and often shrubby) vegetation mat.

The important insulating layers are the ground vegetation (particularly mosses and lichens) and the underlying peat. There are reports that the removal of trees and shrubs, provided the ground vegetation mat is not broken, has no adverse effect on the underlying permafrost. Preliminary North American experiments and some work from the USSR indicates that perhaps the peat layers themselves are the most important insulators and that the living bryophyte and lichen mat can be removed with only a small increase to the depth of the permafrost table. Work in North America, Europe and the USSR has indicated the feasibility of building roads, runways, buildings, etc. after a gravel pad has been placed over an unbroken vegetation mat. For heated buildings, of course, a ventilation area between the floor and the gravel pad is necessary to preserve the thermal balance.

Question 2: Of what value are the vegetation types as indicators of permafrost?

No general answer can be given. All workers consider a thorough knowledge of the local area imperative before reliance can be placed in vegetation types as indicators of permafrost. In the zone of discontinuous and sporadic permafrost it appears that certain vegetation patterns — heights of trees, absence of certain species, particular combinations of species, wetness of area, etc. can all be used as evidence for the presence or absence of permafrost in a given area, but a set of criteria for one locality cannot necessarily be transferred to another. The scalloped banks of rivers and the presence of thaw lakes and sinks are also indicators of permafrost. In the areas of continuous permafrost, there is no way of predicting the presence, amount, or depth of massive ground ice from vegetation or other surface patterns. In clay and silty soils the quantity of water in the form of ice crystals and/or massive ground ice, may be very great.

Question 3: What are some specific unfavourable (or favourable) effects of removing or disturbing vegetation on sites underlain by permafrost?

Unfavourable effects basically are the initiation of thermokarst (melting of ice below the soil surface) in its various forms, producing extensive slumping, mud flows, slides, hummocky terrain, thaw lakes, etc. The amount and type depends on the water content of the soil. In very wet areas quagmires may be the result. On the other hand, the favourable effects (depending on land-use requirements) can be important, again depending on the site. The lowering of the permafrost table allows better plant growth, deeper rooting and more volume for root growth. In local home gardens or agricultural stations, in the continuous permafrost zones of the world, lowering of the permafrost table has led to important crop increases. Again, the ice content of the soil determines whether or not hummocky terrain will develop, as has happened at some agricultural stations. Special ground preparations in areas of permafrost have allowed USSR investigators to plant trees further north in the tundra than has previously been possible.

Evidence seems to be accumulating that the total removal of the ground moss mat, particularly sphagnum moss mats, and underlying peat, is extremely important in the satisfactory regeneration of white and black spruce where they occur on permafrost, and in the establishment and maintenance of a conventionally productive forest. Fire, which is so disastrous to communities with reindeer lichen mats, appears to be the main initiator of succession on soils suitable for forests (i.e. not those soils which are thin and stony, very wet, or composed of raw humus over bedrock). Evidence points to fire (completely removing humus and exposing mineral soil) or occasional flooding (on alluvial bars) as preventing the invasion of sphagnum mosses under softwoods, with the consequent rise in the permafrost table and eventual stagnation of the forest. It is important to recognize that reindeer lichen sites are not necessarily those that support sphagnum, though the two are frequently interfingered.

Question 4: What plant succession can be expected following disturbance of given vegetation types?

This question has not yet been fully answered. In general, it appears that the severity, area and time of the disturbance determines the general succession. On lightly disturbed tundra, such as produced by tracked vehicles making one or two passes, sedge communities regenerate rapidly from undamaged underground parts; shrub tundra recovery is slower from sprouts. In both types, invasion from surrounding undisturbed areas begins fairly quickly. In severely disturbed areas, a whole new succession cycle may be initiated, once thermokarst development has ceased, from invading species rare or uncommon on surrounding undisturbed sites. Where disturbance is continuous, e.g., gullying and flow-sliding, revegetation may be inhibited or prevented. After fire or flooding, various successions may be initiated, depending on the availability of seed, the site, and the severity of damage.

Question 5: How rapidly will various conditions recover from the type of disturbances which are likely to occur during pipeline construction?

Again, very little information is available though it is accumulating. Certain grasses can be seeded, which grow very rapidly, with good soil stabilization but they do not develop an insulating mat as do the bryophytes, and this insulating mat is very important for permanency. Willows and alders have also been used, but so far no results have been reported. Severely disturbed permafrost areas of fine-grained soils with high ice content will be very slow to recover but with reasonable precaution and effort, drastic disturbance of such sites should not occur.

Further problems are likely to occur if revegetation above a buried, hot pipeline is projected. Use of gravel berms and gravel insulation over the pipeline will result in excess aridity of the fill which may prevent eventual revegetation with native species. Many of the grasses presently under trial appear to be attractive food sources for rodents and large herbivorous mammals, and the rights-of-way appear to be used by migrating caribou. Thus, stabilization by exotic grasses may be very precarious.

There is still some controversy over the effects of winter damage caused by the construction and use of temporary ice, packed snow, and graded winter roads on sedge communities and on shrub communities. The former two winter-road types appear to be less damaging than the latter provided (1) the active layer is frozen to the permafrost before construction, and (2) the roads are not used after thaw sets in. The ice roads appear to be least damaging, since the method of construction preserves the microtopography in hummocky terrain. All methods of construction may cause damage because of the retarded growth of species under packed snow or ice. On the other hand, shrubs appear to be much more subject to severe damage in winter because of their brittle nature when frozen. In the high arctic at least, there is evidence that summer use of vehicles on the upland shrub-tundra is not destructive, as the shrubs are very resilient.

Question 6: Are some vegetation types more sensitive to disturbance than others?

Generally speaking, shrub and lichen communities are more sensitive to disturbance than grass and sedge communities if recovery rate is indicative of sensitivity. The former communities have very slow growth rates and are therefore slower than grasses and sedges to recover. However, the severity and season of the damage are usually more important in determining the rate of recovery than the vegetation type.

Question 7: How can an adequate insulating mat of vegetation be preserved during construction, or, if disturbed, replaced following construction?

In general, a gravel pad over the insulating unbroken vegetation mat appears the best principle. Failing this, winter activities are generally less harmful than summer ones — though this does not necessarily apply in areas of well-drained soils with a deep permafrost table. Adequate precautions should be taken with tracked vehicles: they should not climb slopes at a steep angle, preferably they should not use grouser bars which can be very damaging, and the loads should be carefully calculated for the type of terrain over which they are crossing. Suggestions have been made that temporary winter roads should only be used one (or two) seasons and that every following season a new parallel road be used — the reason: less harm will occur to any particular right-of-way if it is only used one season. However, there is always the criticism that aesthetic problems are created even though recovery and regrowth of the vegetation is rapid. This is a matter of scale! In certain types of terrain, some evidence is accumulating that corridors only should be used, without construction of a road.

In answering the question on how to replace a vegetation mat following construction, several ideas have been put forward (*see also* Question 5). As yet there has not been very much experimentation, but pressed peat mats, wood chips, fibre and bark may be used as insulating material and may have considerable merit especially as a rooting medium. All of these have a good water holding capacity, but aridity may still be a problem over a buried hot pipeline. Another solution may be the use of bitumen or polystyrene under pressure to obtain temporary or semipermanent stabilization. The use of riprap and wire grids may be the only solution under some circumstances.

Question 8: Of what influence is the wildlife on the arctic habitat and to what degree will pipeline construction disturb their activities?

The native animal populations of the arctic and subarctic may have considerable influence on the vegetation and land. The activities of microtine rodents are vital for the health of the tundra. Their four-year cycles allow a buildup and utilization of vital soil nutrients. The larger animals do not have a very great effect on the tundra, except where they have been herded together under situations controlled by man. Caribou trails crisscross the tundra but these apparently cause no extensive damage. Certain water fowl and the caribou can congregate at the edge of water bodies and do local, perhaps temporary damage to the vegetation. How important this is in the total picture is uncertain, but it does not appear to be very great. Burrowing and den-producing animals choose well-drained sites and have considerable effect in further lowering the permafrost table and allowing abundant growth of species often rare in the adjacent tundra. There appears to be more information on this subject in USSR literature than in North American. The pingos and palsas in the tundra can be important denning sites of fox or mink, observation posts for birds, and also the habitat for a particular species of vole. Evidence of the disruption of caribou migration trails by pipeline, seismic lines, power line rights-of-way, etc. does not appear to be accumulating. In fact, there is some evidence that the caribou will use rights-of-way where possible in their migration and some companies appear more concerned about damage that the caribou may do to the pipeline, rather than problems the pipeline may cause the caribou.

It will probably be necessary to impose strict regulations for the control of fire arms and thus of hunting in the Far North since the populations of large mammals will become more and more vulnerable to human interference.

Studies which should provide more complete answers to many of the foregoing questions are currently under way in the North and are the particular concern of both the ALUR programme and the Environmental Protection Board. Time is required before more definitive answers can be found for revegetation problems because of the slow growth of northern species, but temporary solutions are being tested which may provide the necessary stop gap.

ANNOTATED BIBLIOGRAPHY ALPHABETICALLY BY AUTHOR

1. ADAMS, R.S. and R. ELLIS. 1960. Some physical and chemical changes in the soil brought about by saturation with natural gas. Soil Sci., Am. Proc. 24:41-44.

From author's abstract: "Severe chemical and physical changes may occur in soils saturated with natural gas. Plant growth may be retarded or completely eliminated."

Four gas-saturated field sites and the adjacent normal soils were studied physically and chemically.

"Physical determinations at the two most severely affected sites revealed some increase in water retention and total porosity with a corresponding decrease in bulk density. ...The disturbed Fe-Mn [both increased] relationships may be one of the major factors accounting for the frequently observed detrimental influence of gas-saturated soils on vegetative growth. The change in water retention was not considered injurious to plants."

2. ALEXANDROVA, Vera D. 1958. Some regularities in the distribution of the vegetation in the arctic tundra. Problems of the North 1:189-204. (Transl. from Russian by Nat. Res. Counc. Can. 1960.) (This paper is a reprint of the translation of this article appearing in Arctic 13:147-162, 1960 by permission.)

The zonation of vegetation in the islands of Novaya Zemlya are described and detailed comparisons are given between these islands and other areas of the arctic Soviet Union.

The author quotes an article by Gorodkov (1916) concerning the arctic tundra sub-zone and with which she agrees. The features are as follows: "(1) absence of shrub communities due to the severity of the climate, the short growing period, and the extreme variation in the depth of the snow cover; (2) the occurrence of *Dryas*-moss communities on the sufficiently-drained clayey soils, which are, however, replaced over large areas by barren polygon tundra, especially in situations exposed to intense wind action and with consequently very thin snow cover; (3) the occupation of a large part of the area by arctic bogs, chiefly sedge-moss marshes; (4) the small differences between the vegetation of the uplands and that of river valleys, due to the short periods of inundation in the latter and the shallowness of the active layer."

3. ALEXANDROVA, Vera D. 1970. The vegetation of the tundra zones in the U.S.S.R. and data about its productivity. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:93-114.

   The zonal subdivision in the tundra regions of the U.S.S.R. is described and data given on whole plant biomass as well as on aerial and underground parts for each zone.

4. ALLINGTON, Kathleen R. 1961. The bogs of central Labrador — Ungava; an examination of their physical characteristics. Geogr. Ann. 43:401-417.

   This paper is concerned with the recognition (from aerial photographs) of bogs by their physiographic properties. Four main types are recognized:

   1. string bogs; 1a. string bogs with trees;
   2. closed string bogs; 2a. closed string bogs with trees;
   3. sedge meadow;
   4. bog forest; 4a. black spruce muskeg; 4b. tamarack swamp (fen).

   There is a long discussion on bog formation, climax and string bog formation. There is no permafrost in bogs of this area.

5. ANDREEV, V.N. 1954. The advance of tree vegetation into the tundra in connection with the protective properties of tree

plantation in the North. (Transl. Russian Title.) Bot. Zh. 39(1):28-47.

Arctic Bibliography 33265: "Contains a study of melioration of tundra by the introduction of woody vegetation, with historical remarks, notes on the causes of the absence of forests and destruction of trees in tundra. The possibility of woody vegetation expanding northward is discussed and observations offered on the growth of trees in tundra, the method of protective forest belts and their influence on the soil and climate of northern regions. The study is based on experiments carried out in Kola Peninsula, Arkhangel'sk province and in northern Siberia: Igarka, Berezovo, Taymyr Peninsula and the Tiksi region in Yakutia."

6. ANDREEV, V.N. 1954. The growth of forage lichens and the methods for their regulation. Akad. Nauk. SSSR. Bot. Inst. Trudy Series III, Geobot. 9:11-74.

Arctic Bibliography 33264: "Contains a study of growth increase of common arctic lichens, mostly species of *Cladonia*, in consideration of their nutritional value for reindeer. Topics discussed include history of the problem; characteristics of podetial growth; methodics of study of growth and renewal; effect of environment on growth, means of regulating and speeding up growth, etc."

7. ANNERSTEN, L.J. 1964. Investigations of permafrost in the vicinity of Knob Lake, 1961-62. Permafrost studies in Central Labrador — Ungava. I.B. Bird, ed. McGill Subarctic Res. Pap. 16:51-137.

A basic reference paper on permafrost studies.

"It is concluded that the snow cover must be a permafrost-controlling factor in the area. Variations in snow cover cause temperature variations in the soil far greater than those resulting from vegetation cover. Provisionally, it is established that a snow depth of 40 cm or less is critical for

maintaining permafrost conditions...It is concluded that the effect of exposure upon the thermal regime of the ground is of great importance, but it must be one of the most difficult to estimate qualitatively. The direction of the exposure has certainly a direct effect upon the ground surface mean temperature, but there is no evidence that this would affect this temperature by more than about 0.5°C. Where the permafrost is a marginal feature, this is, however, of importance for the permafrost distribution.

"The secondary effects of the exposure must be regarded as more important for the thermal regime, mainly because of their decisive influence upon the snow cover.

"Very exposed areas have block fields or rock deserts which are due probably to extreme winter ground temperatures. Patterned ground, referred to as sorted and non-sorted stone circles by Washburn (1950), is suggested to be an indirect evidence of the presence of permafrost. For limited areas, determinations of the critical height of local relief as a measure of the amount of exposure are valuable in permafrost studies."

8. ANNERSTEN, L.J. 1964. Background for the Knob Lake permafrost studies. Permafrost studies in Central Labrador — Ungava. J.B. Bird, ed. McGill Subarctic Res. Pap. 16. 2 p.

A generalized literature review of permafrost and also of vegetation around Knob Lake. A useful map of vegetation zones is included.

"A characteristic feature in the vegetation cover is the high percentage of burnt areas and according to Fraser (1956) about 35 to 40 per cent of the forest has been burnt in in the last 40 years. Due to short growing seasons the regeneration of the areas is very slow and a recovery to a new Lichen Woodland Forest might not be established until after 90 to 100 years (Fraser, 1956)."

9. ANONYMOUS. 1970. Arctic pipelining for 16,000 miles at $750,000 a mile. Eng. Contract Rec. July, 1970. 83(7):34-36.

From: U.S. Army Cold Regions Res. Eng. Lab. (CRREL) Rep. 12. 25(1) 1971. CRREL 25-585. "Permafrost Distribution, Ecology, Cold Weather Construction Drilling, Canada — NWT — Mackenzie River, Pipelines, Economics."

10. BAKER, Jennifer M. 1970. The effects of oils on plants. Environ. Pollut. 1:27-44.

Author's abstract: "Oils vary in their toxicity according to the content of low-boiling compounds, unsaturated compounds, aromatics and acids. The higher the concentration of these constituents, the more toxic the oil. After penetrating into a plant, the oil may travel in the intercellular spaces and possibly also in the vascular system. Cell membranes are damaged by penetration of hydrocarbon molecules, leading to leakage of cell contents, and oil may enter the cells. Oils reduce transpiration rate, probably by blocking stomata and intercellular spaces. This may also be the reason for the reduction of photosynthesis which occurs, though there are other possible explanations of this — such as disruption of chloroplast membranes and inhibition caused by accumulation of end-products. The effects of oils on respiration are variable, but an increase of respiration rate often occurs, possibly due to mitochondrial damage resulting in an "uncoupling" effect. Oils inhibit translocation probably by physical interference. The severity of the above effects depends on the constituents and amount of the oil, on the environmental conditions, and on the species of plant involved."

11. BAKER, Jennifer M. 1971. Seasonal effects of oil pollution on salt marsh vegetation. Oikos 22:106-110.

Author's abstract: "Salt marsh transects near Pembroke, S.W. Wales, were experimentally sprayed with fresh Kuwait crude

oil at different times of year and recovery measured..... There was little long term vegetative damage [although oiled leaves die] to most perennial species.... Flower density measurements... showed marked reduction of flowering can occur if plants are oiled when flower buds are developing. Flowers, if oiled rarely produce seeds. Oiling of seeds during winter may reduce germination in spring.."

12. BALDWIN, W.K.W. 1953. List of plants collected on Prince Charles and Air Force Islands in Foxe Basin, N.W.T. Nat. Mus. Can. Bull. 128:143-153.

Descriptions of the islands as well as the species lists are presented.

"Although the islands were generally well covered with vegetation, chiefly characteristic wet meadows of grass and sedge, there was little variety of habitat."

13. BALDWIN, W.K.W. 1953. Botanical investigations in the Reindeer-Nueltin Lakes area, Manitoba. Nat. Mus. Can. Bull. 128:110-142.

This paper contains a complete catalogue of collections in the area. Brief descriptions of the major communities are given. General character — Canadian Shield — Precambrian rocks. Much swamp and muskeg and many inland lakes with no apparent outlets are present.

Major Plant Communities: Forest — mixed black spruce, birch and jack pine, evidence of fire and jack pine regeneration. White spruce, aspen and balsam poplar rarely and widely scattered.

Muskegs — Common between marsh and black spruce forest and in "dreary level stretches of country".

Mention is also made of marshes, aquatic vegetation, vegetation of river and lake shores and rock cliffs.

In southern Nueltin Lake vicinity, the trees are

mainly on sides of eskers, etc.

14. BANFIELD, A.W.F. 1960. Distribution of the barren ground grizzly bear in northern Canada. Contrib. Zool., 1958. Nat. Mus. Can. Bull. 166. p. 47-59.

A chronological listing of sightings of the barren ground grizzly, together with location and other information. Maps are included.

Data, with reference to total range and preferred foods are discussed.

15. BARANOV, I. Ya. 1959. Geographical distribution of seasonally frozen ground and permafrost. Principles of Geocryology. Part I:193-219. (Transl. from Russian by Nat. Res. Counc. Can., Tech. Transl. 1121. 1964.)

Discusses the world-wide distribution of frozen ground. Contains an extensive bibliography of Russian papers and a few European and North American papers.

16. BARASHKOVA, E.A. 1963. Accelerated restoration of fodder lichen resources with the aid of growth stimulators. Problems of the North 7:149-160. (Transl. from Russian by Nat. Res. Counc. Can. 1964.)

The results of various treatments of *Cladonia* species of lichen with various growth substances are reported. Substances were used singly and in combination. "On the basis of our data, it can be concluded that there is a direct relationship between growth increment and the area occupied by the algae component. In those experiments where considerable growth increment was observed, the area occupied by the algae component increased correspondingly." Substances used included thiamine, 2,4-D, gibberillic acid plus various other chemicals.

17. BARASHKOVA, E.A. 1970. Photosynthesis in fruticose lichens *Cladonia alpestris* (L.) Rabh. and *C. rangiferina* (L.) Web. in

the Taimyr Peninsula. Bot. Zh. 55(2):284-292.

Biological Abstracts 1971. 83331: "Photosynthesis of *Cladonia alpestris* and *C. rangiferina* was studied under the arctic conditions of the Taimyr National District on the watershed plateau in the dwarf birch-lichen tundra. Data on the intensity of photosynthesis obtained monthly by use of radioactive carbon in July (polar day) August (white night) and September (twilight night) showed that in the morning and evening hours it was more intense than during the day. Both species photosynthesized during night hours of the polar day period. In *C. alpestris* the intensity reached its highest daily level in July at 3:00 a.m. The intensity depends on air temperature and moisture. With relatively low air temperature and lichen moisture content CO_2 uptake speeds up. Drying of the lichens is related with increases in light. The reason for high CO_2 uptake in the dark is still not clear. Possibly at high concentrations of CO_2 the reversible process of CO_2 exchange in plants is increased. It is undoubtedly connected with the symbiotic nature of the plant. To determine seasonal changes in photosynthesis the intensity was studied in *C. rangiferina* in Norilske during May (polar day), March (day and night) and August (twilight nights) for six concentrations of CO_2, 0.05 - 2 per cent. Differences in intensity of assimilation and proportion of absorption in the dark and light were noted."

18. BAY, C.E., G.W. WUNNECKE and O.E. HAYS. 1952. Frost penetration into soils as influenced by depth of snow, vegetative cover, and air temperature. Amer. Geophys. Union Trans. 33:541-546.

Concerns experiments on cultivated soils at Madison, Wisconsin.

19. BECKEL, Dorothy K.B. 1958. A pilot study of caribou summer range (calving ground), Kaminuriak, N.W.T. by means of air photo

interpretation and analysis. Can. Dep. N. Affairs Nat. Res. 13 p. (typescript).

The vegetation is described in relation to soil drainage and four general vegetation groups are delineated. Trees are very rare or absent, and dwarf birch is the largest shrub. Lichen cover is extensive on well-drained uplands.

20. BECKEL, Dorothy K.B. 1958. A pilot study of caribou winter range, Brochet, Manitoba, by means of air photo analysis and interpretation. Can. Dep. N. Affairs Nat. Res. 41 p. (typescript).

By means of aerial photography and analysis with ground checks, the vegetation of Brochet is described. Much emphasis is put on recognition of burns and determination of the ages of the burns. Information is also included on the park-like areas.

21. BENNINGHOFF, W.S. 1950. Use of aerial photographs in mapping vegetation and surficial geology in subarctic regions. Photogramm. Eng. 16:428-429.

"It is common knowledge now that the recent or present occurrence of permafrost...is manifested by polygonal patterns in soils and vegetation and by sink holes...in unconsolidated materials. More subtle permafrost indicators on aerial photographs are the trees of "drunken forests". Fallen trees and freshly cut vertical banks of lake shores indicate the progressive thawing of permanently frozen ground at the margins. In areas with permafrost cover, the vegetative cover, acting as an insulator, is as important as the soil type and drainage in determining the depth of the seasonally thawed layer above the permafrost."

22. BENNINGHOFF, W.S. 1952. Interaction of vegetation and soil frost phenomena. Arctic 5:34-44.

A general discussion of the reciprocal relationships

between vegetation and soil frost.

Influence of soil frost on plants: 1) Depth of rooting is shallow and species are often subject to windthrow. 2) Soil drainage is altered by the presence of frost by (a) inhibiting lateral movement of soil water and downward percolation; (b) release of water by thawing may produce water-logged conditions; (c) thawing may provide water in relatively dry areas; (d) plants may be subjected to severe water loss when the roots are encased in frozen ground. 3) Soil surfaces are often not colonized because of severe soil stirring, etc. by frost action. 4) Thawing of ground containing unevenly distributed ice bodies results in differential settling of the surface. This changes the minor relief forms and thus changes the physical environment for the vegetation of the site. Elsewhere, sites for vegetation are destroyed by progressive thawing of permafrost. 5) Lake margins in areas of high permafrost tables are particularly subject to caving and destruction of the bank vegetation. It has been calculated that the mean rate of shore retreat is from 2.3 to 7.5 in per year in river valleys of eastern Alaska. There seems to be a cyclical filling and draining of these lakes.

"All of these frost processes in the soils demonstrate fundamental features of the severe frost climate environment: instability of the surface and consequent transcience of site conditions."

Influence of plants on soil frost: 1) "Plants affect soil frost phenomena most significantly through control of the thermal regime of the soils... Erosion and thawing by a meandering stream cause the permafrost table to retreat far below the stream bottom level, but it rises under deposits on the slip-off side (Péwé 1947). The permafrost table rises several feet more in the new alluvium during maturation of the initial balsam poplar forest and rises still more as that forest is replaced by a dense stand of white spruce." 2) "Vegetation shields the soil from maximum penetration of heat by shading, by decreasing air circulation, by retaining moisture in and just above the soil, and by intercepting rain, and perhaps from evaporation of moisture on plant surfaces... Mosses [are most important here, they] have a low thermal conductivity, especially when dry, but also have a high water-holding capacity and are strongly hydroscopic." 3) The rate of thawing of frozen ground is greatly increased by removal of moss carpets, thick turf and surface peat. Sumgin (1937), reported "that accumulations of vegetable matter are effective insulators in periods of thaw and good conductors when they are frozen in the water-saturated condition...

"During periods of thaw a greater amount of heat is transferred through water-saturated peat into the underlying soil than through dry peat. Furthermore, when water-saturated peat is frozen, heat is transferred from the soil into the air in quantities four times as great as in thaw periods. Essentially similar properties are recognized in living and dead moss carpets and other accumulations of vegetable matter, although certain factors, such as water-absorbing capacity, vary with different component materials...

"Although vegetation dominantly favours the accumulation of cold reserve in the ground, it also contributes to the opposite effect... Tumel (1940), recognized the effect of vegetation impeding ground cooling during the night when air temperatures are lower. The retention of snow by vegetation is important as the thermal conductivity of snow is very low, usually lower than that of dry peat, and the snow cover therefore exerts great influence on the intensity and depth of seasonal freezing of ground.

"Plant roots and underground stems...serve as organs binding and anchoring the turf and upper soil layers and may show remarkable resilience against frost action. [They] hold the turf wall together on the front scarp of turf-banked terraces, and anchoring roots hold back great heavy mats of turf and sod on slopes with unstable soils. Hopkins and Sigafoos (1951) observed on the Seward Peninsula that the anchoring effect of roots, along with the insulating effects of plants and their dead parts, decreased frost disturbance in tundra." Thaw sinks can be initiated by uprooting and disturbances of roots of larger plants over a high permafrost table.

"Frost in the soil and the associated vegetation cover thus exerts dynamic influence upon each other. In many situations this interaction engenders cyclic changes, especially prominent in vegetation-permafrost relations...

"Clearing of land has a beneficial influence on the thermal regime of the upper layers of soil during the warm months of the year. However, changes in the water relations may result, and should be anticipated... After [clearing and] one or two years of cultivation, both deleterious and beneficial effects of permafrost on the growth of annual plants become negligible, because the permafrost table retreats beyond the reach of the roots of most annual plants. Nevertheless, the effects of permafrost on drainage and subsidence of ground persist as long as permafrost is present within a few tens of feet of the surface."

It should be recognized that "in places the influence of frost activity on vegetation is so strong that distinct plant communities are regularly associated with a particular type of frost feature. Plant communities in such places, must be described, mapped and managed on the basis of their physical environment...

"Plant succession in temperate regions tends to establish more mesophytic conditions in which drainage relations are less extreme. But in regions of severe frost climate, plants commonly generate conditions of extreme lack of drainage and greatly intensified soil frost; in short, the plants frequently destroy the very environmental conditions that favour their growth. Disturbances to vegetation such as burning and clearing in severe frost climate regions do much more than initiate plant succession that will culminate in the return of the original type of stand. Because of soil frost changes following disturbance, the affected surface and the local environment may be so greatly modified that entirely different communities occupy the site for unknown periods of time."

23. BENNINGHOFF, W.S. 1965. Relationships between vegetation and frost in soils. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci.-Nat. Res. Counc. Wash. Publ. 1287:9-13.

The vegetation-soil thermal regime is redefined and some approaches are suggested that may assist in understanding the processes that couple these phenomena.

"Where the surface mean annual temperature is not more than 2° or 3°C below 0°C, the kind and condition of the vegetation cover will be critical to the development and duration of permafrost, but where the surface mean annual temperature is more than several degrees below 0°C, the vegetation cover exercises little control. Vegetation does exert an influence, however, on the occurrence, extent and effects of seasonal frost in the upper layers of soil, wherever the climate will produce such freezing."

24. BENSON, C.S. 1969. The role of air pollution in arctic planning and development. The Polar Rec. 14:783-790.

A discussion of the vulnerability to pollution of the exceptionally stable air masses of the arctic, especially over valley bottoms, from coal smoke and gases, specific toxicants, smog, or ice fog (which occurs whenever air at -35°C or colder is calm and accompanied by a continuing source of water vapour). An underestimate of water vapour production in Fairbanks is

more than 4000 tons/day of which most comes from power plant cooling waters (64%) and coal (power plants) (19%). In the north, ice fog is the most important form of air pollution.

25. BERGERUD, A.T. 1971. The role of the environment in the aggregation, movement and disturbance behaviour of caribou. Int. Symp. Ungulate Behaviour November, 1971. Calgary, Alta.

26. BESCHEL, R.E. 1961. Botany; and some remarks on the history of vegetation and glacierization. Jacobsen-McGill Arctic Research Expedition to Axel Heiberg Island. B.S. Müller, ed. McGill Univ., Montreal. Prelim. Rep. 1959-1960. p. 179-199.

A list of plants collected from Axel Heiberg Island, vegetation pattern descriptions, some soil information, and preliminary vegetation history and lichen dating are included in this paper.

27. BESCHEL, R.E. 1963. Observations on the time factor in interactions of permafrost and vegetation. First Can. Conf. Permafrost Proc. Nat. Res. Counc. Can., Ass. Comm. Soil Snow Mech. Tech. Memo. 76:43-56.

Evidence for the greater reliability of rock-colonizing lichens for dating ice-free surfaces over species of other plants colonizing soil is discussed.

From summary: "Frequently, vegetation provides useful time indications and can be used through dendrochonology or lichenometry for a better understanding of the processes. Rock surfaces are colonized very slowly but the succession on soil is a much less reliable time indicator as great changes in the total cover of plants can occur within a few years, while the same patterns of incomplete cover may last for centuries under the limiting conditions of the arctic environment. Local differences of the environment persist over long periods and the vegetation is not able to change the environment towards more

mesic conditions. Contrarily, differences in the environment may be accentuated through the vegetation. Trends towards a climax cannot be observed in regions with permafrost."

28. BESCHEL, R.E. 1965. Hummocks and their vegetation in the high Arctic. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287:13-19.

The origins of hummocks are described as well as their associated vegetation types on Axel Heiberg and Ellesmere Islands.

29. BILLINGS, W.D. and H.A. MOONEY. 1968. The ecology of arctic and alpine plants. Biol. Rev. 43:481-529.

A comprehensive review of the current information on adaptation of plants to the low temperatures and other stresses of arctic and alpine environments. Reference is made to the importance of vegetative reproduction in the arctic.

An extensive bibliography is included.

30. BLACK, R.F. and W.L. BARKSDALE. 1949. Oriented lakes of northern Alaska. J. Geol. 57:105-118.

This paper is largely theoretical, concerning origins of Alaskan oriented lakes and comparisons with other similar systems, but contains the following information:

Vegetation: "The entire coastal plain is treeless, prairie-like tundra region, characteristic of the arctic and sub-arctic zones. It is covered with a thick mat of vegetation composed of a mixture of lichens, mosses, grasses, sedges, shrubs, and other plants. Small prostrate shrubs are rare along the coast, but are more abundant inland. Willows are particularly common along the protected banks of the largest streams, though they rarely grow as high as 10 feet. Evergreen or large deciduous trees are absent...

"All surficial deposits and the bedrock to a depth of several hundred feet under the arctic slope are permanently frozen...

"All the oriented lakes are being modified by wind, vegetation, and permafrost...

"In contrast to the enlarging effects of thawing of permafrost and subsequent wave erosion, vegetation, (commonly *Coledium fulvum*), in shallow parts of the lakes tends to reduce and finally to eliminate wave erosion, to fill in parts of the lake with plant material, to insulate and protect permafrost from thawing and caving, and to aid in the building-up of permafrost."

31. BLACK, R.F. 1952. Polygonal patterns and ground conditions from aerial photographs. Photogramm. Eng. 8:123-134.

This paper is a summary of the theories on polygons up to this date.

<u>Conclusion</u>: "Considerable caution must be exercised to avoid over-generalizations in interpreting polygons. Only when their origin is clearly understood in any particular locality can they be useful in correctly interpreting present and past earth conditions and in properly evaluating land for agriculture, engineering projects and other purposes." An extensive bibliography on polygons is included in this paper.

32. BLACK, R.F. 1954. Permafrost. A Review. Geol. Soc. Amer. Bull. 65:839-856.

This paper discusses various aspects of genesis and degradation of permafrost and the effects of such phenomena on soil. Its biological significance is not well covered but "the widespread distribution of the frog in the discontinuous and sporadic zones of permafrost demonstrates that low ground temperatures, except perhaps locally, do not necessarily follow periods of low air temperatures, because the frog does not survive body temperatures below about -5°C (Robert Hamilton, 1949, *oral communication.*)"

An extensive bibliography up to 1954 is included.

From author's abstract: "Permafrost is as much as 2,000 feet thick in Siberia and 1,300 feet thick in Alaska, where its minimum temperature is -12°C and -10°C respectively...

"Permafrost results when the net heat balance of the surface of the earth over a period of several years produces a temperature continuously below 0°C... Freezing of the mantle completely eliminates ground water movement, preserves organic remains indefinitely, reduces or prevents mass movements within the frozen material, and promotes frost action in the overlying active layer."

Genesis: "Although the general thesis [of the genesis of permafrost, whether fossil or formed recently,] is relatively simple, it is extremely complex in detail. Some of the primary factors in the heat exchange are 1) climatic — solar radiation, atmospheric radiation, counter-radiation, air temperatures, wind, humidity, cloudiness and precipitation; 2) chemical and physical characteristics of the ground — distribution, types, and textures of material, heat capacities, thermal conductivities, thermal diffusivities, and horizontal and vertical thermal gradients; and 3) the changing interface between the ground and atmosphere — the active layer, surface water, snow, vegetation, and their albedo (reflectivity). The factors in (3) commonly are more important than in the others in the heat exchange... Areas in which the average annual air temperature is several degrees below 0°C may be free of permafrost; conversely, areas with average annual air temperatures above 0°C may contain sporadic permafrost in equilibrium with the climate (Muller, 1952). These conditions may be brought about by the fact that a thick, dry active layer covered with dry mosses and very thick, light snow provides excellent insulation; conversely, a thin, wet, active layer with little or no vegetation and with thin, dense snow, freezes quickly and becomes an excellent conductor. The interface changes markedly from low to high altitudes and latitudes and so do the winter climatic factors... Areas subject to periodic winter thaws may have lower ground temperatures than areas of continuous cold because the insulating effect of snow is lost on melting and re-freezing...

Geologic Significance: "...The active layer is commonly supersaturated, so that mass movements, frost heaving, frost thrusting, frost stirring and frost splitting are commonplace. Patterned ground, involutions, solifluction phenomena, block fields and other micro-features result...

"Thawing of permafrost containing much ice commonly results in pits, ponds, and lakes on level ground and slumps and earthflows on sloping ground. Pressures up to 30,000 lb per sq in may be attained in freezing of ice, and hydrostatic pressure may be transmitted long distances. Injection of saturated soils into cracks of frozen ground or into thawed ground, formation of ice laccoliths and other small mounds, and surface icings commonly result from hydrostatic pressure produced by freezing of water trapped between permafrost and the downward freezing active layer (the *cryostatic* process of Washburn, 1950). Pingos are large mounds resulting from hydrostatic pressure during regrowth of permafrost into thawed basins in permafrost under drained lakes."

33. BLISS, L.C. and J.E. CANTLON. 1957. Succession on river alluvium in northern Alaska. Am. Midland Natur. 58:452-469.

The apparent successional relationships of the vegetation along rivers on the Arctic slope of Alaska are described with particular reference to the Colville River near Umiat. Four stages are recognized: 1) Pioneer (perennial herb), 2) Vigorous willow, 3) Deteriorating willow, 4) Alder-willow-heath.

Later these types give way to one of the several tundra types which are not dependent on the river. Continuous permafrost underlies this part of Alaska.

34. BLISS, L.C. 1970. Oil and the ecology of the Arctic. Trans. Roy. Soc. Can. Ser. 4, 8:361-372.

A general paper which points out and discusses problems associated with oil exploration, production and delivery in and from the Arctic, particularly in relation to vegetation, permafrost, wildlife, transport, oil and air pollution. The author is optimistic that co-operation among industry, university and government agencies is occurring while there is still time.

35. BLISS, L.C. 1970. Primary production within arctic tundra ecosystems. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:77-85.

A review paper, but presents some results from current studies in Alaska and the Yukon. Refers to some problems of revegetation following fire or other disturbances.

36. BLISS, L.C. 1971. Devon Island, Canada, High-Arctic Ecosystem. Biol. Conserv. 2:229-231.

An outline of studies under investigation on Devon Island together with the names of the chief investigators. No results are included.

37. BLISS, L.C. and J.A. TEERI. 1971. Devon Island Programs, 1970. Arctic 24:65-68.

The Truelove Lowland is described to provide background information on the habitat and an outline of the types of investigations on plants, animals, soils, and microorganisms, as well as their interrelationships and reactions to human manipulation of their environment is presented.

38. BLISS, L.C. and R.W. WEIN. 1971. Changes to the active layer caused by surface disturbance. Permafrost — Active Layer Seminar Proc., Vancouver. R.J.E. Brown, ed. Nat. Res. Counc. Can. (in press).

39. BLISS, L.C. and R.W. WEIN. 1972. Plant community responses to disturbances in the Western Canadian Arctic. Can. J. Bot. 50:1097-1109.

Tundra Fires: "Two forest-tundra and two tundra burns [2 and 3 years old] have been studied in Alaska and the Inuvik area. At all 4 sites, fire removed all of the litter, some of the peat, but only charred the *Eriophorum vaginatum* subsp. *spissum* tussocks. All woody species and lichens were consumed while most mosses were scorched and killed. Plant recovery data expressed as percent plant cover showed that most original woody species were recovering from latent stem and rhizome buds. While seedlings of *Eriophorum vaginatum* subsp. *spissum* were common the first one or two years, survival [of the seedlings] was extremely low. Species showing the most regrowth the first year included *E. vaginatum* subsp. *spissum* and *Ledum palustre* subsp. *decumbens*. Of the cryptogams only *Polytrichum juniperinum* regrew after the fire though *Marchartia polymorpha* was an important soil colonizer in some localized wet areas.

"Plant production in the tundra site burned one year earlier was 75% of that on the control plots. In one of the sites burned two years earlier annual plant production was greater than the controls due to the high production of *Arctagrostis latifolia* var. *latifolia* and *Calamagrostis canadensis*; minor species in adjacent unburned areas.

"This rapid regrowth of plant cover and annual production is related to changes in the thermal and nutrient budgets following fire....

"Further studies will be needed to determine whether the pattern of regrowth is similar in other tundra plant communities. If it is, then fires may have a rejuvenating effect in arctic vegetation as they do in other temperate region biomes."

Crude Oil: "Crude oil spills were initiated in 1970 on replicated [three, 4 x 4m] plots at the 3 main study sites using Norman Wells crude... Oil was poured directly on the vegetation in relatively flat areas but only in inter-boil areas (to simulate a moving oil mass) where raised frost boils were prevalent.

"As expected, within hours of application, living tissue had a water-soaked appearance and after a few days, all leaf tissue was dry. By August *E. vaginatum* subsp. *spissum*, *Ledum palustre* subsp. *decumbens* and *Carex bigelowii* showed some regrowth in those plots treated in June. No regrowth was evident in the July-treated plots in fall. In late June 1971, plant regrowth was evident in all plots but the data indicated that oil spilled on wet sedge and cottongrass tussock communities was more detrimental than in those dominated by low shrubs. There has been no regrowth of lichens and mosses in any of the treatments. There was little evidence of plant regrowth in those plots treated in October (20 cm snow present) as opposed to June and July treatment (ca. 1-3% vs. 10-20%)." No clear pattern of changes in active layer depths has emerged. Studies of microbial activities in oil vs. untreated soil cores indicate 10X increase at 3-5°C in the laboratory and therefore that native bacteria and fungi can utilize oil as an energy source.

Surface Disturbance, Seismic Lines: The history of the improvement of seismic technology in preventing vegetation damage is outlined. In 1970 replicated samples were taken on parallel undisturbed terrain and disturbed (varying dates starting in 1965) terrain.

"In dwarf, shrub-sedge-heath hummock communities that dominate much of the Tuktoyaktuk Peninsular, plant cover, including attached standing dead was only 36% (mostly grasses) and the active layer was 153% greater on the summer bulldozed 1965 lines compared with controls. Other sections of this and other seismic lines in the same plant communities have a plant cover of 30-50%. On winter cut lines of 1967 through the same communities, plant cover averaged 57% and the active layer was only 42% deeper than the adjacent control line.

"Plants and litter provide approximately 100% cover on control lines....

"Seismic lines (1969) through *Carex bigelowii* and *C. variflora* dominated communities at Atkinson Point showed no increase in depth of the active layer with a 5% increase in bare ground. These are wetter soils than those near Tuktoyaktuk...

"Where seismic lines run through open grown *Picea glauca* and *Alnus crispa* subsp. *crispa* or through *Salix glauca* subsp. *acutifolia*, *S. phylicifolia* subsp. *planifolia*, *Alnus crispa* subsp. *crispa* shrub lands on the Mackenzie River Delta bare soil predominates the first year. Plant recovery will be more rapid for extensive rhizomes and root stalks remain in the soil...

"The data to date indicate that wherever viable roots and rhizomes of shrubs, sedges and grasses remain in the disturbed soil, a 30-50% recovery in natural plant cover will occur in 3-5 years with subsidence restricted to sites of high ice content. Where subsidence of 0.5-2m has occurred, natural or man-induced revegetation will take place on the new surface but to date there is little indication that immediate reseeding can prevent ground ice melt and subsidence."

Winter Roads: "Compacted snow roads in the delta do relatively little damage. In upland areas where dwarf salix, birch and heaths predominate, bare soil changes from 0% in controls to 100% in road centres. Little more site degradation occurred after 2 seasons use than one, except where mineral soil was exposed."

Seismic Lines and Roads in the High Arctic: "Summer seismic and haul roads rarely cause damage on upland fine gravels, sands and silts except for rutting in June and early July because there are so few plant communities but at lower elevations on dark silty soils with wet land peats and a complete cover of mosses, grasses, sedges and forbs effects are comparable to effects in the Delta. These communities provide the food for Peary Caribou and Muskox herds.

"Active layer measurements in mid-July showed that in sandy and gravelly uplands little increase (0-5%) occurred with surface disturbance. In silty soils with scattered herbs and lichens and in lowland sites with grasses, sedges and mosses, the active layer was typically 15-30% deeper in rutted sites. In contrast with the Delta and Alaska these ruts seldom result in massive ice melt and surface subsidence... Preliminary work in 8 northern Arctic Islands indicates that surface rutting and scraping in most areas is less detrimental biologically than in much of the Low Arctic."

Establishment of introduced species for stabilization of berms etc. indicates that phosphorus alone or with nitrogen improves growth over nitrogen alone. It is noted that seeds must be sown on peat or mulches added to counteract rapid drying of mineral soils in summer.

40. BLISS, L.C. and R.W. WEIN. 1972. Ecological problems associated with Arctic oil and gas development. Pap. presented Can. Pipeline Res. Conf. Ottawa. (in press). m.s. 30 p. mimeo.

Essentially a review of the results of work done by the authors and their associates over the past few years in the Arctic. The implications of this research as related to difficult engineering projects are discussed. Greater details are given in papers presented in the authors' 1971 ALUR reports.

41. BLISS, L.C. 1972. Preliminary report, Devon Island Research 1971. 13 p. mimeo.

Research was concentrated on meadows and raised beach ridges. "Foliose and fruticose lichens nearly double the rates of evaporation compared with bare soil while there was little difference in evaporation comparing a crustose lichen surface with bare ground. Evaporation rates from lichen covers are much greater than those with flowering plants. At the meadow site evaporation from a moss surface was greater than from open water. In both sites it appears that lichens and mosses provide little if any resistance to water loss in contrast with vascular plants...

"Sedges and grasses are the principal plants utilized by muskox... it appears that the lowland receives more intensive winter and spring grazing when the ground is snow covered than it does in summer...

"The manipulatory studies show that with the addition of fertilizer, some species respond more rapidly than others (*Salix arctica*, *Alopecurus alpinus*, and *Arctagrostis latifolia*)...

"Depth of the active layer measurements show that with surface disturbance, the active layer seldom increases more than 10 to 15% and in many places, no significant increase results. With surface scraping, thaw of ice-rich lenses is initiated but relatively few sites of slumpage or subsidence were observed in the other islands."

Information on the other aspects of the studies (biomass production, soils, meteorology, nitrogen fixation, invertebrates, and decomposition) are also given.

42. BÖCHER, T.W. 1949. Climate, soil and lakes in continental west Greenland in relation to plant life. Medd. om Grønland. 147(2). 61 p.

Information on the climate and detailed physical and

chemical analyses of soils and lakes are presented, along with descriptions of the associated vegetation. Many of the lakes and soils are saline.

43. BÖCHER, T.W. 1954. Oceanic and continental vegetational complexes in southwest Greenland. Medd. om Grønland. 148(1). 336 p.

Detailed information on the two types of vegetational complexes are given. Ecological information on associations and individual species in relation to environmental requirements are detailed. The paper is profusely illustrated and has an extensive bibliography.

44. BÖCHER, T.W., K. HOLMEN and K. JAKOBSEN. 1968. The flora of Greenland. Haase and Son. Copenhagen. 312 p.

45. BOGDANETS, Iu. I. 1970. Vegetation effect on thawing rate of frozen ground. (Transl. Russian title). Merzlotney issled. 10:223-226.

From: U.S. Army Cold Regions Res. Eng. Lab. (CRREL) Rep. 12. 25(1) 1971. CRREL 25-3811. "Snow cover effect, Permafrost thickness, Thawing, Vegetation, Active layer thickness."

46. BONNLANDER, B. and G.M. MAJOR-MAROTHY. 1964. Permafrost and ground temperature observations, 1957. Permafrost studies in Central Labrador. J.B. Bird, ed. McGill Subarctic Res. Pap. 16:33-50.

Five cover types are recognized:

(a) spruce forest (little or no permafrost),
(b) forest transition (some permafrost),
(c) lichen heath tundra (permafrost),
(d) lichen heath regeneration (burned-over, now with lichen only, little or no permafrost),
(e) bog and swamp (no permafrost).

"Permafrost is more likely to be found in the exposed hill-ridges with shallow snow cover than in the valley slopes or bottoms."

47. BRASSARD, G.R. 1965. Botany. In Operation Tanquary: Prelim. Rep. 1964. p. 43-47. G. Hattersley-Smith, *et al.* Can. Def. Res. Bd.: Rep. D Phys. R (G) Hazen.

An outline of the preliminary bryological and vascular plant survey and some information on phenology at Tanquary Ford, Ellesmere Island.

48. BRASSARD, G.R. 1968. The plant habitats of the Tanquary Camp area, Ellesmere Island, N.W.T. Can. Dep. Nat. Def., Def. Res. Bd. Oper. Tanquary. Geophys. Hazen 32. Ottawa. 11 p.

Classification of the plant habitats (13) by wetness, slope, overall plant cover, size of substrate material, and stability in the vicinity of Tanquary Camp. Each habitat is described in detail, with comments on vegetation, local distribution and variability. Photographs of most habitats are included.

49. BRASSARD, G.R. and R.E. LONGTON. 1969. Botanical studies in Northern Ellesmere Island in 1967: A preliminary report. Can. Dep. Nat. Def., Def. Res. Bd. Oper. Hazen, Geophys. 38. 9 p.

An outline of botanical studies (chiefly taxonomic) in three localities in northern Ellesmere Island. Notes on growth and reproduction studies on mosses are included.

50. BRITTON, M.E. 1957. Vegetation of the arctic tundra. Arctic Biology. H.P. Hansen, ed. 18th Colloq., Oregon State Coll. p. 67-130.

A detailed review of botanical aspects of the arctic, (including other aspects of the environment) which affect the development of vegetation.

Detailed descriptions of plant communities of the various physiographic provinces, based primarily on Spetzman (1951) and including personal observations from unpublished data and manuscripts, are given. Polygonal and other patterned ground and vegetation relationships are discussed thoroughly, as well as succession on various bare surfaces including those caused by frost action.

An extensive bibliography is included.

51. BRITTON, M.E. (ed.) 1964. Arctic Biology. Bioscience 14(5):9-51.

A general and somewhat abbreviated review of the research in the American Arctic undertaken by various agencies up to 1964.

52. BROWN, J., W. RICKARD and D. VIETOR. 1969. The effect of disturbance on permafrost terrain. U.S. Army Corps Eng., Cold Regions Res. Eng. Lab. (CRREL) Spec. Rep. 138. 9 p.

Conclusions: "... Essentially, any disturbance which eliminates or greatly reduces plant growth will result in an increased thaw. If the vegetative cover is physically damaged and mineral soil is exposed the increased thaw will be accompanied by erosion. A twofold increase in thaw after shearing the tundra vegetation was observed on carefully controlled experimental plots. The same increase was observed on mulched plots. Removal of vegetation by fire also results in an increased [up to <60%] thaw. These increases are caused by the absorption of more energy into the soil through the darker surface cover. Establishment of new...growth following damage will undoubtedly slow the rate of permafrost degradation... It is recommended that all vegetation or restoration studies of tundra measure thaw penetration under revegetated and controlled unvegetated sites to determine the magnitude of these differences."

53. BROWN, J. and W. RICKARD. 1969. The thawing of soils associated with *Eriophorum* tussocks. U.S. Army Cold Regions Res. Eng. Lab. (CRREL) Intern. Rep. 61. 94 p.

54. BROWN, J. 1971. U.S. Tundra Biome Program: The Barrow word model. Tundra Biome Working Meeting on Analysis of Ecosystems,

September, 1970. p. 174-177. O.W. Heal, ed. Int. Biol. Program (IBP) Tundra Biome Steering Comm., London, Engl.

This article outlines the effects of the 3-to-5-year large amplitude population cycles of the brown lemming and their importance for the vegetation.

"The most conspicuous feature of the consumer compartment of the ecosystem is the 3-to-5-year population cycles of large amplitude in the brown lemming, (*Lemnus trimucronatus*), the dominant herbivore. Numbers of lemmings vary from about one to 250 per ha. Insect herbivores are uncommon and other vertebrate herbivores which may be important at other tundra sites are here uncommon (other species of microtine rodent, caribou, geese) or absent (ground squirrels). In the absence of other significant herbivores, variation in lemming density results directly in variation in the grazing process. When lemmings are scarce, vegetation accumulates as standing dead in the plant canopy. As the lemming population builds in the winter and spring preceding the high, much of the vegetation is cut. Only a relatively small amount is consumed; most is converted directly to litter. The litter may be re-distributed during spring melt-off being removed from raised areas and concentrated in lower areas, ponds, and polygon troughs. This also produces a pulse of organic matter entering the saprovore-based food chain. When lemmings are abundant, snowy owls and pomarine jaegers breed in large numbers, and least weasels increased markedly in abundance. In other years these predators are scarce or absent. Ermine and both arctic and red foxes are present, especially in lemming-high years, but are never abundant."

From another part of the paper — "On all terrestrial sites, but particularly in the wetter meso-sites, production is directly influenced by the slow decay of unclipped, standing dead material. It is hypothesized that the availability of nutrients to plants for growth is modulated by the lemming population through accumulation and storage of certain elements (nitrogen, potassium, phosphorus) in, and their ultimate release from faecal and other dead organic matter. The lemmings, by clipping the slowly decomposing standing dead [material] hasten nutrient release as the newly fallen litter decomposes faster than the standing dead."

55. BROWN, J., F.A. PITELKA and H.N. COULOMBE. 1970. Structure and function of the Tundra Ecosystem at Barrow, Alaska. Productivity Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16: 41-64.

An outline of the Tundra Biome Program at Barrow, Alaska. A word model of the ecosystem, development of synthesis and modelling, and a description of vegetation, geographic, climatic and thermal regimes, geomorphology, and surface and subsurface geology of the Barrow region are presented.

56. BROWN, R.J.E. and G.H. JOHNSTON. 1964. Permafrost and related engineering problems. Endeavour 23(89):66-72.

The most important features of permafrost with engineering construction significance are given as:

1. the great sensitivity of permafrost to thermal changes,
2. the relative impermeability of permafrost to moisture,
3. the high ice content of fine-grained and organic soils containing permafrost.

Various suggestions are given for conserving the frozen condition.

"The thickness of permafrost...is determined by the close and complex interaction of a large number of climatic and terrain factors, the most important of which are air temperature, relief (slope and aspect), vegetation, drainage, snow cover and soil type." The factors which affect permafrost also determine the thickness of the active layer.

There is a relationship between mean annual air and mean annual ground temperatures, with mean annual air temperature being about 2 to 5°C less than the mean annual ground temperature and averaging about 3°C less. E.g., Resolute, N.W.T. (continuous zone) mean annual air temperature is -16.1°C and mean annual ground temperature is -12.8°C; Thompson, Manitoba (discontinuous zone) mean annual air temperature is -4°C and mean annual ground temperature is 0.5°C.

"Over a long period of time a change in mean annual air temperature can result in a significant change in the extent and thickness of permafrost. Geothermal gradients from about 1°C per 20 m to 1°C per 60 m — depending to some degree on the type of soil or rock — have been observed. A change of 1°C in mean annual air temperature could result, over a long period of time, in a change of 1°C in the mean annual ground temperature. This would cause a change in permafrost thickness of approximately 20 to 160 m."

Relief: In the discontinuous zone, south-facing slopes usually have no permafrost while it is present on north-facing slopes; in the continuous zone it appears thicker and the active layer thinner on north-facing slopes.

Vegetation provides "resistance to heat flow by conduction. By transpiration, it draws water from the soil, which is thus depleted of heat held by water. Furthermore, the process of evaporation (including that due to transpiration) withdraws heat from the surrounding atmosphere and from incident solar radiation. In the present context, mosses and lichens are particularly significant. Mosses are strongly hygroscopic, but can lose moisture rapidly and in large quantities. Lichens, however, have very dry surfaces at all times, even when the lower layers near the soil are very wet; possibly they protect the soil against heat gain more by an insulating process than by one of evaporative cooling. It is possible, however, that rapid evaporation or diffusion exchange of water vapor from the wet basal layer to the atmosphere above the lichen may contribute to low soil temperatures and a high permafrost table. The underlying peat formed from the accumulation of decomposed vegetation, also influences the heat transfer between the atmosphere and the soil beneath.

"Snow cover influences heat transfer between the air and the ground and hence affects the distribution of permafrost. The snow-fall regime and the time that snow lies on the ground are critical factors. A heavy fall of snow in autumn and early winter will inhibit winter frost penetration and the formation of permafrost. On the other hand, a thick snow cover that persists on the ground in spring will delay thawing of the underlying frozen ground." Talik (unfrozen zone) almost always exists beneath lakes and other bodies of water which do not freeze to the bottom in winter.

"Bare rock and soil have considerable influence on the temperature of the ground because of their ability to reflect solar radiation. Reflectivity values in the range of 12 to 15 per cent for rock and 15 to 30 per cent for tilled soil have been observed. There will also be different evaporation rates and intakes of precipitation.

"In the southern fringe most permafrost is confined to peat bogs. The thermal properties of the peat are to a great extent responsible for its formation in this type of terrain and changes in the extent of permafrost is also largely dependent on changes in the thermal properties of the peat. The mechanisms which caused the formation of permafrost in these bogs are associated with variations in the heat exchange at the surface of the moss and peat. When dry, peat has a low thermal conductivity equal to that of snow (i.e. about 0.00017 cal/cm$^{\circ}$C/sec). Peat can absorb large quantities of water; when wet, its thermal conductivity is greatly increased. Unsaturated peat has a conductivity of about 0.0007 cal/cm^{o}C/sec... When frozen, its thermal conductivity is many times that of dry peat and approaches the value for ice; saturated frozen peat has a conductivity of about 0.0056 cal/cm^{o}C/sec. During the summer, a thin surface layer of dry peat having a low thermal conductivity prevents warming of the underlying soil. During the cold part of the year, the peat is saturated from the surface, and when it freezes, its thermal conductivity greatly increases. Because of this, the amount of heat transferred in winter from the ground to the atmosphere through the frozen ice-saturated peat is greater than the amount transmitted in the opposite direction in summer through the layer of dry peat and underlying wet peat. A considerable quantity of heat is also used during the warm period to melt the ice and to warm and evaporate the water. The net result is a loss of heat, and conditions conducive to the formation of permafrost.

"This thermal mechanism does not cause the permafrost to increase in thickness indefinitely. Rather, a quasi-equilibrium is reached whereby the downward frost penetration is balanced by heat transfer from the unfrozen ground below. The thermal sensitivity of this permafrost is vividly demonstrated by its rapid thawing when the overlying moss and peat layers are removed."

This applies to the southern fringe. "Further north the thermal properties of peat and other terrain feature assume a relatively minor role and the thermal properties of the ground as a whole, together with climate, become dominant. Variations in thermal properties such as conductivity, diffusivity, and specific heat affect the rate of permafrost accumulation. For example, the thermal conductivity of silt is about one-half that of coarse-grained soils and several times that of rock. Variation in thermal properties alone will not, however, necessarily result in differences in permafrost thickness within a particular area...

"Three features of permafrost are significant in engineering construction: 1) Permafrost is particularly sensitive to thermal change. Any natural or man-made change in the environmental conditions, however slight, will greatly affect the delicate natural thermal equilibrium. 2) Permafrost is relatively impermeable to moisture. Drainage is vital, therefore, because all movement of water occurs above the permafrost, in northern areas, surface water is conspicuous despite the generally low precipitation. If natural drainage is impeded or proper drainage structures not provided, construction operations can be seriously complicated by intensified frost action during the winter and accelerated thawing during the summer. 3) The ice content of the frozen ground is a most important consideration. Solid rock, gravel and sand, usually contain little or no ice at temperatures below $0^{\circ}C$ and few difficulties are encountered in building on these materials. Most problems arise with fine-grained materials and organic materials such as peat, which usually have extremely high ice contents and are susceptible to frost action. As long as water remains frozen in such soils, the ice binds the individual particles together to produce a material of considerable strength; when thawed, however, these soils change to a soft slurry with little or no strength. All forms of ice layers or lenses, ranging from hairline sizes to several meters in thickness — can occur within the same material. In silty soils, for example, the volume of ice may be as much as six times that of soil...

<u>Engineering Considerations</u>: "Perennial freezing can be neglected when engineering works are sited on well-drained, coarse-grained soils or bedrock... In the zone of continuous permafrost, particularly where fine-grained soils with high ice content are encountered, every effort must be made to preserve

the frozen condition. In the discontinuous zone,...frozen material [may be removed and replaced] with well-drained material, not susceptible to frost action."

Ventilation or insulation is needed to preserve the frozen condition on the fine-grained ice-rich materials. On suitable sites, buildings may be put on stilts to give sufficient ventilation. Normally highways, airstrips and railways need insulation. "Normally fill methods are used throughout and disturbance of the surface cover is kept to a minimum. Cuts through hills are avoided where possible. Proper drainage must be provided to prevent accumulation of water."

57. BROWN, R.J.E. 1965. Some observations on the influence of climatic and terrain features on permafrost at Norman Wells, N.W.T., Canada. Can. J. Earth Sci. 2:15-31.

Results of meteorological studies from instrumentation under and over five types of vegetation growing in the Norman Wells region are described. "The depth of thaw under moss and lichen was less than in areas supporting other types of plant growth. Ground temperatures in the thawed layer and in the permafrost showed the same characteristics, being lower in the moss and lichen areas."

58. BROWN, R.J.E. 1965. Influence of vegetation on permafrost. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287:20-25.

"In the northern part of the tundra the vegetation has little influence on permafrost because it is sparse and the vegetative period lasts less than two months. It causes local variations in depth of thaw and helps impede erosion. The destruction of the vegetation accelerates thawing only slightly.

"In the southern part of the tundra, vegetation becomes more abundant, peat mantles part of the surface and attains thicknesses of several feet in some basins. The main influence of the vegetation is on the depth of thaw. If vegetation is removed, the depth of thaw will increase; erosion will increase and thermokarst will develop if thawing proceeds at different rates over an area or if there are local differences in the ice content of the frozen ground.

"In forest tundra, vegetation mass is greater than in the tundra, and the rate of accumulation of organic matter is higher. Extensive peat bogs form and water basins are encroached by vegetation and permafrost forms. Woody and brush vegetation grow which accumulate snow, leading to higher permafrost temperatures than in the tundra. If the vegetation is removed, the depth of thaw increases and this is counteracted to some extent by lower snow accumulation and a decrease in permafrost temperatures.

"The maximum development of vegetation occurs in the taiga. Here vegetation has its greatest influence on permafrost even in very small localized areas, causing variations in its extent, depth of thaw and ground temperatures. Frequent forest fires cause variations in the occurrence and thickness of permafrost over short distances in the taiga.

'Mass, density, height and influence of vegetation, and rate of accumulation of organic matter are less in the steppe than in the taiga, but depth of permafrost is greater."

The author concludes that "some mechanisms add heat to the ground, others facilitate heat loss... Some add heat at one time and contribute to heat loss at another time. Influences of vegetation are almost all reversible depending on the conditions under which they occur." The precise measurement of the factors is probably impossible and probably all factors are not known so that prediction of effects by changing various factors is impossible. "The best solution appears to be to measure obvious effects of vegetation, such as depth of thaw, temperatures, extent of thickness of permafrost which are manifestations of net heat gains and heat losses to the ground, and relate these to variations in environmental components. The same permafrost conditions may occur in two adjacent areas, but the combination of vegetation and other factors producing two similar sets of permafrost conditions may be quite different.

59. BROWN, R.J.E. 1965. Relation between mean annual air and ground temperatures in the permafrost region of Canada. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287:241-246.

A discussion of mean annual air and ground temperature relationships which may be used in predicting permafrost, but which are not yet entirely reliable due to the influence of other climatic and terrain factors.

Influence of terrain and other climatic factors. "The difference between mean annual air and ground temperatures, and variations in this difference from place to place are caused by climatic factors other than air temperature in combination with surface and sub-surface terrain factors. The complex energy exchange regime of the ground surface, which is influenced by these factors, is such that the mean annual ground temperature is several degrees warmer than the mean annual air temperature. Factors which seem particularly influential are net radiation, vegetation, snow cover, and ground thermal properties, that vary with time; other factors include relief, slope and orientation and surface and sub-surface drainage.

"The difference between mean annual air and ground temperatures can be explained in part by the fact that the ground surface is heated by solar radiation during the day to a much higher temperature than the air above. This excess heating more than balances the cooling of the ground surface by radiation during the night. Snow cover contributes to this situation by insulating the soil from the cold air above.

"It is suggested that the difference between mean annual air and ground temperatures would be greater in interior, continental localities, than in maritime locations because of the greater snowfall and accumulation in the former areas.

"Variations in net-radiation, vegetation, snow cover, and other factors contribute to observed differences in the thickness and temperature of permafrost in neighbouring areas of the continuous zone having similar mean annual air temperatures; they also help explain the patchy occurrence of permafrost at a particular location in the southern fringe of the permafrost region...."

Relation between air and ground temperatures: "The question arises again as to what is the maximum mean annual air temperature at which permafrost can exist. Permafrost, albeit only a few feet thick, is found at Keg River, Alberta, which has a mean annual air temperature of 31°F. It does not occur in the vicinity of Fort Vermilion, Alberta (28.2°F) nor at Fort Smith, N.W.T. (26.2°F), nor even at the experimental farm at Fort Simpson, N.W.T. (25.0°F). Clearly, vegetation plays a dominant role in this situation. Permafrost at Keg River is confined to a few small scattered spruce-sphagnum peat bogs. No such bogs occur in the Fort Vermilion area. Permafrost exists also in similar bogs in the Fort Smith and Fort Simpson areas.

"The origin of permafrost in these bogs, particularly in Keg River, could be attributed to one or more of the following causes: (a) It could be a remnant from the cooler climatic regime of the Pleistocene; (b) It could be short-lived permafrost of perhaps several decades' duration which formed as a result of slightly lower air temperatures than those prevailing at present; and (c) It could be short-lived, as in the second case, but formed as the result of terrain changes, such as snow cover or drainage which were conducive to initiation of permafrost without a change in mean annual air temperature.

"In all three cases the permafrost is protected by moss and peat cover; it would probably disappear and not re-form if this cover were removed."

60. BROWN, R.J.E. 1966. Permafrost, climafrost and the muskeg H factor. Eleventh Muskeg Res. Conf. Proc. Nat. Res. Counc. Can., Assoc. Comm. Geotech. Res. Tech. Memo 87:159-178.

This paper is a criticism of the use of the Radforth term "climafrost" and the use of the muskeg H factor (25 per cent cover by lichens on muskeg) as an indicator of the southern limit of permafrost.

Brown disputes the use of both terms, considers 30°F mean annual air temperature isotherm a better index. He has seen all combinations of lichens, permafrost and muskeg. He points out that "plant species may be excluded which in fact are significant indicators of ground thermal conditions". For example, there are bogs with lichen but no permafrost; the moisture content of the peat is sufficiently low to allow lichen growth but too high for permafrost. The ground cover includes remnants of pool vegetation — grasses and marsh sedges — which predominated before the encroachment of sphagnum and lichen. These remnants survive because the site is still sufficiently moist; it is too moist for permafrost but sufficiently dry for lichen. The grass and sedge comprise less than 25 per cent of the total cover and thus are excluded from the Radforth muskeg classification. In these situations, however, these plants are the key indicators of the permafrost conditons...

"Permafrost will form and persist in a peat bog regardless of the presence of lichen as long as the moss and peat are not disturbed. The lichen may be burned off and regenerated several times during the duration of the permafrost. At Chesel Lake, Manitoba, a fire in a peat bog burned the lichen and charred the top one inch of sphagnum. The underlying sphagnum and peat were not disturbed, and the depth of the permafrost table remained unchanged. At Inuvik, N.W.T. the removal of trees and brush did not alter the depth of the permafrost table as long as the moss and peat were not disturbed (Pihlainen, 1962). The permafrost and its environment are both dynamic systems but we rarely see the changes with time except in the case of fire."

61. BROWN, R.J.E. 1968. Occurrence of permafrost in Canadian peatlands. Int. Peat Congr. Proc. Quebec, Can. p. 18-23.

This paper discusses the distribution of peatlands and its relationship with permafrost in Canada. "In the southern fringe of the discontinuous zone, permafrost occurs in scattered islands a few square metres to several hectares in size and is confined mainly to peatlands. In the northern part of the discontinuous zone, and in the continuous zone, permafrost is found in other types of terrain but peat is an important factor in determining the thickness of the active layer." Most of the information concerns peatlands in the discontinuous zone because the highest concentration of peatlands occurs in the discontinuous zone and "the occurrence of permafrost in the discontinuous zone is complicated by its patchy distribution...".

Air photo interpretation of permafrost in peatlands: "The recognition on aerial photographs of permafrost occurrences in peatlands is possible where distinctive patterns exist. The largest and most distinctive permafrost features in the southern fringe of the discontinuous zone are peat plateaus and palsas... Where peat micro-relief features are absent, the existence of permafrost can only be inferred in relation to visible terrain factors such as drainage. These terrain relationships have to be considered in the broad framework of climate and location of the area in the permafrost region. For example, it is very unlikely that permafrost will be found in wet peatlands in the southern fringe of the discontinuous zone. Its occurrence is quite probable in similar terrain conditions in the northern portion of the discontinuous zone, and in the continuous permafrost zone it will invariably exist."

The author then goes on to describe the origin and development of peat plateaus and palsas, and variations in the concentration of peatlands in the Canadian physiographic regions.

62. BROWN, R.J.E. 1968. Permafrost investigations in Northern Ontario and N.E. Manitoba. Nat. Res. Counc. Can. 10465. Div. Build. Res. Tech. Pap. 291. 39 p. plus appendices.

A detailed survey of permafrost occurrence in the delineated area was done to map the areas of permafrost and relate its distribution to the various environmental factors. Plant species were not found satisfactory as permafrost indicators. Permafrost is not found where water lies at or near the ground surface, but is found in drier plateaus and palsas of bogs of the Hudson Bay Lowland and Precambrian Shield. It was not found in high areas.

63. BROWN, R.J.E. 1968. Permafrost investigations in British Columbia and Yukon Territory. Nat. Res. Counc. 9762. Div. Build. Res. Tech. Pap. 253. 55 p. plus appendices.

A detailed survey of permafrost in the delineated area was done to map the areas of permafrost and relate its distribution to various environmental factors. In general "south of the 30°F isotherm permafrost occurrence is rare, between 30°-25°F isotherms, permafrost is patchy and restricted [to patches in peat bogs, heavily shaded areas and in some north facing slopes]. North of the 25°F isotherm permafrost is widespread. In mountainous regions the same changes occur with increase in elevation."

64. BROWN, R.J.E. 1969. Factors influencing discontinuous permafrost in Canada. The Periglacial Environment :- Past and present. T.L. Péwé, ed. McGill - Queen's University Press, Montreal. p. 11-53.

Most of this material is contained in Brown's book Permafrost in Canada. 1970.

65. BROWN, R.J.E. 1970. Permafrost in Canada. Univ. Toronto Press. 234 p.

This review of permafrost in Canada, concerns primarily the effects of permafrost on present and future northern development. Much of the information has already been published as individual papers by Brown.

In the section on the nature of permafrost and the subsection on surface features, Brown indicates that polygons occur in many forms and sizes furnishing a pattern that is widespread throughout the cold regions. "The existence of permafrost is not essential for their formation, but the largest ones are found in the permafrost region. They are particularly well developed in the continuous zone where ice-wedge tundra polygons, both raised-centre and depressed-centre, are widespread." Circles, both sorted and non-sorted, form above permafrost but permafrost is not essential.

"Solifluction strips, lobes and scars can be noted where soil is moving slowly downslope under the combined forces of frost action, gravity, and fluid flow. Frost boils are also a common pattern caused by intense frost action in the active layer which bring fine-grained soil to the surface in concentrated circular deposits."

Pingos are the most spectacular landforms associated with permafrost. Two types classified according to origin have been described. In the continuous zone on flat, poorly-drained terrain such as old lake bottoms or river deltas, where water in the underlying thaw basins is forced towards the surface by the surrounding aggrading permafrost, closed-system pingos occur. Open-system pingos occur in the discontinuous zone where ground water in unfrozen zones between permafrost layers is forced to the surface and an ice mass accumulates.

"Surface features associated with permafrost in the discontinuous zone are less numerous and distinctive than in the continuous zone. Low hills or knolls of perennially frozen peat, about 10 feet or less in height, designated by the Swedish term "palsa", occur as permafrost islands in peatlands and peat bogs. They form by the combined action of peat accumulation and ice segregation in the underlying mineral soil. These mounds grow and coalesce to form ridges and plateaus which form distinctive ground surface patterns particularly widespread in the northern part of the discontinuous zone...

"The thawing of permafrost also forms distinctive land forms, both in the discontinuous and continuous zones. "Thermokarst" is the term used for uneven land subsidence caused by the melting of ground ice... Beaded streams are particularly prevalent in the continuous zone where blocks of massive ground ice melt in the stream bed forming enlargements along its course. The thawing of ice wedges of polygonal ground gives a distinctive pattern of regular hillocks termed "baydzherakhi" (cemetary mounds) in the USSR. Massive slumps may occur on the hillsides where large masses of ground ice are exposed to melting by the disturbance of the surface vegetation. Disturbance of the surface vegetation by man in areas of ground ice concentration can also cause slumping on flat terrain."

Climate: "Present knowledge of the southern limit of permafrost indicates that it coincides roughly with the 30°F mean annual air isotherm.,, Southward [of the 30°F] permafrost occurrences are rare and small in size because the climate is too warm. Between the 30°F and 25°F mean annual air isotherms, permafrost is restricted mainly to the drier portions of peatlands and peat bogs because of the special insulating properties of peat. Scattered bodies of permafrost may also occur on some north-facing slopes and in some heavily shaded areas." (As an average there is a value of 6°F between the mean annual ground temperature and the mean annual air temperature.)

Terrain: "The broad pattern of permafrost distribution is determined by climate but terrain conditions are responsible for local variations. In the discontinuous zone variations in terrain conditions are responsible for patchy occurrence of permafrost, size of permafrost islands, depth to the permafrost table, and thickness of permafrost. In the continuous zone, the thermal properties of the peat and other terrain factors assume a relatively minor role and the thermal properties of the ground as a whole, together with the climate, become dominant. Terrain factors that affect permafrost conditions include relief, vegetation, drainage, snow cover, fire, soil and rock type, and glacier ice. In its turn, permafrost influences the terrain". (Each of these conditions are then discussed in turn.)

Vegetation: "The most obvious effect of vegetation is its role of shielding the permafrost from solar heat. This protection is provided mainly by the insulating properties of the widespread moss and peat cover. Removal or even disturbance of this surface cover causes degradation of the underlying permafrost. In the discontinuous zone this may result in the disappearance of bodies of permafrost. In the continuous zone the permafrost table will be lowered. The predominance of moss and peat in protecting the permafrost from atmospheric heat is demonstrated by the fact that little change occurs in the depth of permafrost table when trees and brush are removed provided the moss and peat are not disturbed. A fire may burn trees, brush, and even the surface of the moss, without altering the underlying permafrost." The usefulness of wood chips as insulating material is mentioned.

"The occurrence of permafrost in peatlands in the southern part of the discontinuous zone appears to be related to changes in the thermal conductivity of the peat through the year. Single trees or forests may also affect permafrost distribution because of shading and reducing the snow cover in winter.

"Permafrost also forms an impermeable layer which impedes downward drainage leading to a decline in aeration and impoverishment of nutritive substances because of the weakening of the activity of micro-organisms."

Drainage: "In the discontinuous zone, the existence of permafrost is inhibited in poorly-drained areas."

Snow: Snow in the discontinuous zone can create the difference between the existence and absence of permafrost. "Studies at Schefferville, Quebec, indicated that snow cover is a dominant factor in controlling permafrost distribution at that site. (Annersten, 1964). Variations in snow cover caused temperature variations greater than those resulting from the vegetation cover. It was postulated that the snow depth of about 16 in could be regarded as the critical snow depth for permafrost to survive. Beneath a greater depth either no permafrost existed or a degrading condition prevailed."

Fire: "The degree of influence of a fire on the permafrost depends on the condition of the vegetation and the rate of burning. A fire may move rapidly through an area burning trees but only charring the top surface of the ground vegetation. Palsas and peat plateaus have been observed in the Hudson Bay Lowland and Northwestern Manitoba where the trees have been burned and the surface of the moss and lichen charred by fire. Below a depth of one inch this vegetation layer was untouched, its insulating effect on the underlying permafrost unaltered from nearby unaffected areas which did not catch fire...

"If dry conditions have prevailed in an area for some time prior to a fire, considerable change in the permafrost may occur. For example, a fire began on August 11, 1968 in the vicinity of Inuvik, N.W.T., located in the forested part of the continuous permafrost zone. Summer rainfall had been unusually light and even the normally moist moss cover was dry. The fire swept through the flat lands and hillsides with such intensity that even frost mounds, which occur extensively throughout the area, were denuded of all vegetation. The removal of the insulating surface cover exposed the ice-laden, perennially frozen soils to thawing. Water from melting ground ice on the fire-bared hillsides northeast of Inuvik were released in sufficient quantities to cause considerable thermal erosion during the remainder of the thawing season to mid-September. Fire breaks were bulldozed to the permafrost table. In less than one month, water courses several feet wide had eroded 18 in into the ice-laden permafrost. In the following summers deeper thawing and thermal erosion of the permafrost will continue, because of the absence of the surface vegetation. The permafrost table will eventually stabilize as a new thermal equilibrium is reached and the vegetation gradually regenerates but the effects of the fire will be felt for many years...

"Permafrost occurs in the five physiographic regions, the Canadian Shield, Hudson Bay Lowland, Interior Plains, Western Cordillera and Arctic Archipelago." There follows here a brief description of the soils and permafrost characteristics as well as related engineering considerations.

In the chapters on engineering, buildings, services and so on, are descriptions of works which have succeeded in their object and also of works that have not succeeded and where permafrost has thawed and karst topography has developed.

Transportation: Pipelines - "One consideration is the distribution of permafrost. In the discontinuous zone, permafrost is patchy and its temperature is close to $32^{\circ}F$. In the continuous zone, permafrost occurs everywhere beneath the ground surface and its temperature is several degrees below $32^{\circ}F$. Detailed site investigations will be required along the proposed pipeline route to assess the soils and permafrost conditions.

This is particularly vital in the discontinuous zone where the pipeline will pass through both permafrost and non-permafrost areas. Here, it will be necessary to design for the properties of the soils in the frozen state and also in the thawed state, where permafrost does not occur or where it may thaw as a result of construction and operation of the line."

Notes from the rest of the section: A pipeline buried in the ground has an annual temperature range of about 40°F, above ground a range of about 150°F. Under such fluctuations there can be large volume changes in the pipe as well as viscosity changes in the oil. If a pipe were buried in the active layer it would be subjected to annual freezing and thawing and severe frost heaving in fine-grained soils. If a pipe were laid in the permafrost, then the problem of excavation becomes major as well as the possibility of considerable settlement should the permafrost thaw, particularly in areas of high ice concentrations. "One proposed method, which is receiving favourable consideration, is to build a road, along the pipeline route. A second nearby embankment parallel to the road would carry the pipe and be sufficiently wide to accommodate construction and maintenance equipment. The pipe would be placed along one side of the embankment and gravel banked up around it. The permafrost table would rise into the embankment making it stable and the gravel would protect the pipe from the large annual fluctuations in air temperature. One problem with this method is to locate the tremendous quantities of gravel and other borrow material required to build the road and pipe embankment. The third method, that of suspending it above ground, involves the construction of trestle-like structures to support the line. This arrangement would accommodate movements of the pipe caused by expansion and contraction through the year. It would also eliminate the problems caused by ground volume changes due to frost heaving, but the large temperature fluctuations would impose the problems caused by viscosity of oil at low temperatures. Effective insulation of the suspended line would be difficult. This method would eliminate the problems caused by ground volume changes due to frost action. However, the supporting structures would have to be very stable, perhaps installed on piles embedded in the permafrost, and spaced to carry the heavy large diameter pipe."

Roads - "The most difficult construction problems caused by permafrost were encountered northwest of Whitehorse. During the initial construction engineers with no previous experience in permafrost areas tried to ditch a considerable stretch of the highway and encountered difficulties. In some places the road sank 10 to 15 feet as the permafrost was thawed by heat penetration through the ditches. The permafrost table lay only one to two feet beneath the ground surface in the undisturbed areas and the right-of-way was easy to clear because of the shallow tree roots. After clearing, the topsoil was stripped and attempts were made to grade the road. As fast as the insulating vegetation cover was removed, the ground thawed, creating a morass that became worse the more it was worked. As a remedy, the vegetation was left in place and a layer of brush and timbers 4 to 5 feet thick was added. Gravel fill was then placed on top by end dumping."

Air fields - "In the late 1940's an attempt was made to construct a strip at Aklavik in the Mackenzie River Delta, where adverse soils and permafrost conditions exist. A bulldozer was used to strip the vegetation and thaw soil down to the permafrost table. In a very short time, the perennially frozen, ice-laden silts thawed, turning the stripped area into a quagmire... This area was never used as an airfield and the initial mistake of stripping the surface could only have been rectified by placing a tremendous quantity of coarse-grained soil over the area and allowing the permafrost regime to be re-established...

"At the town of Inuvik...a special design was used for the air strip... The trees were cut by hand and laid on the ground after which a minimum of eight feet of crushed dolomitic limestone fill from a nearby quarry was placed on the undisturbed ground surface. Temperature measurements in and beneath the fill ten years after construction reveal that the permafrost was aggraded to the original ground surface and even into the fill. No difficulties attributable to permafrost or any other cause have been encountered and the air strip has performed and is in excellent condition."

Pipelines - "Imperial Oil constructed an experimental four-inch pipeline at Inuvik adjacent to the main access road between the town and the airport. Right-of-way clearing in August 1967 began with hand brushing of the trees followed by stripping of the surface by bulldozer down to the permafrost. The trees were piled and many years later put through a chipper for use as surface insulating material. Working conditions were muddy during line laying because of thawing of the permafrost. Surface vegetation removed by stripping was pushed back over the line in irregular piles by bulldozer following installation of the pipe.

"Surface conditions were investigated one year later to assess the disturbance to the permafrost caused by installation of the line. Disturbance of the working surface on either side of the line caused ground settlements of one to one and one-half feet and the underlying permafrost table dropped two to three feet below its original position. A considerable amount of water collected in these areas from melting of the large quantities of ice in the top layers of the permafrost. Much less degradation of the permafrost had occurred beneath the line itself, particularly sections covered with wood chips. These preliminary observations indicate the large-scale thermal erosion which can result from disturbing permafrost containing large quantities of ground ice, and the effectiveness of insulation such as wood chips, in protecting the permafrost. Future experiments include pumping oil through the line to test its performance and the effects of an operating line on the permafrost."

Potential developments: Northwest Territories oil - "Another critical problem in oil exploration, which will require careful consideration as it increases in the Arctic, is the thermal erosion of seismograph lines bulldozed across the tundra through areas of high ground ice content. Such difficulties have arisen in the Tuktoyaktuk and Fort McPherson areas (Watmore, 1969). In the former area surface vegetation and soils were peeled back by bulldozer in October, 1965 to a width of more than 14 feet and a depth of approximately 10 in leaving a relatively smooth firm surface near the permafrost table on which geophones could be placed. Three years later, thawing and settlement of the exposed permafrost produced a lengthy ditch-like depression exceeding a depth of 6 feet in places where ground ice content was particularly high. On the Peel Plateau near Fort McPherson a gulley developed along a cutline which reached a width of 23 feet and a depth of 8 feet on one location in four years. This gulley extended up a 3 per cent slope. Snow accumulation in the gulley accentuated spring runoff, which hastened erosion, and a steady flow of water from melting ground ice occurred even during dry periods in summer."

Agriculture: In the Canadian north very little agriculture has been carried out. Some experiments have shown that with continual cultivation over a number of years, the permafrost table recedes. Some crops have been quite successful on a limited garden basis. In Alaska and in the USSR widespread agriculture has been hampered to some extent by the development of thermokarst features. Much more work is still needed before satisfactory agriculture is carried out in the Canadian Arctic.

66. BROWN, R.J.E. 1970. Permafrost as an ecological factor in the subarctic. Ecology of the Subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 129-140.

This paper elaborates further on the interrelationships of permafrost and vegetation and the effects of other factors — fire, succession, water basin encroachment, drainage, snowfall regime, snow accumulation — may have on these interrelationships.

Drainage: "Water greatly influences the distribution and thermal regime of permafrost. In the discontinuous zone, the existence of permafrost is inhibited in poorly-drained areas. Precipitation influences the depth of soil and soil temperatures (Shvetsov and Zaporozhtseva, 1963). First, the amount of moisture in the soil immediately before it freezes in the autumn determines the ice content and depth of soil the following summer. Second, the moisture content of the soil surface and the infiltration of atmospheric water influence the heat transfer to the frozen soil during the thaw period. Moving water is an effective erosive agent of perennially frozen soils. There is almost always an unfrozen zone beneath water bodies that does not freeze to the bottom. The extent of this thawed zone varies with a large number of factors — area and depth of water body, water temperature, thickness of winter ice and snow cover, general hydrology, and composition and history of accumulation of bottom sediments." Permafrost is thinner at the shore than inland as a result of the thermal influence of the ocean.

Snow cover: "Snow cover influences the heat transfer between the air and the ground and hence affects the distribution of permafrost. The snowfall regime and the length of time the snow lies on the ground are critical factors. A heavy fall of snow in the autumn and early winter inhibits winter frost penetration. On the other hand, a thick snow cover that persists on the ground in the spring delays thawing of the underlying ground. The relation between these two situations determines the net affect of snow cover on the ground thermal regime. In the discontinuous zone, particularly in the southern fringe, it can be a critical factor in the formation and existence of permafrost. In both Western and Eastern hemispheres, the thickest permafrost in the southern fringe of the permafrost region occurs in palsas on which snow cover is thin, because of their exposure to wind... In the discontinuous zone, snow cover influences the thickness of the active layer."

The ground thermal regime can be influenced by snow cover as has been demonstrated at Shefferville and also at Norilsk, USSR. At Norilsk, with a mean annual air temperature of -8.4°C, air temperature influence on heat emission from the ground can be prevented by a snow cover of 1.5 meters.

Conclusion: "...Changes in vegetation caused by fire, climatic succession, encroachment in water basins, or by the permafrost itself all have pronounced local effect. The regime of the fall and accumulation of snow influences the ground thermal regime. The geothermal gradient also affects the ground thermal regime. It varies in different types of soil and rock, with changes in geological structure and with time.

"Thus the environment in which permafrost exists is a complex dynamic system, the product of past and present climate and terrain features, which are in turn influenced by the permafrost. The thermal sensitivity of permafrost is such that even small changes in climate and/or terràin will produce changes in the extent, thickness, and temperature of the permafrost. The interactions of permafrost and other factors in the Sub-arctic are varied and very complex. Even a slight change in one factor produces a change in one or several other factors."

67. BROWN, R.J.E. 1972. Characteristics of the active layer in permafrost regions of Canada. Permafrost — Active Layer Seminar Proc. Vancouver. R.J.E. Brown, ed. Nat. Res. Counc. Can. (in press).

68. BROWN, R.J.E. 1972. Permafrost investigations in Quebec and Labrador. Nat. Res. Counc. Can., Div. Build. Res. Tech. Pap. Ser. (in press).

69. BROWN, R.J.E. 1972. Some aspects of air photo interpretation of permafrost in Canada. Air photo Interpretation. J.D. Parry, ed. Methuen. (in press).

70. BROWN, R.J.E. 1972. Permafrost in the Canadian Arctic Archipelago. Ann. Geomorph. Special issue sponsored by the Periglacial Committee of the Int. Geogr. Union.

This is a compilation of all presently known information on permafrost of the Canadian Arctic Archipelago. More information was available than expected, but all of it was very scattered.

71. BROWN, R.J.E. and G.P. WILLIAMS. 1972. The freezing of peatland. Nat. Res. Counc. Can., Div. Build. Res. Tech. Pap. Ser. (in press).

Concerns the patterns of seasonal freezing in peatlands in temperate and permafrost regions (Mer Bleu, Ottawa and Thompson, Manitoba).

72. BROWN, R.J.E. 1973. Effects of climate and terrain on permafrost. Proc. 2nd Int. Permafrost Conf. Yakusk 1973. (in preparation).

Concerns: Ground temperature measurements in similar types of terrain in 3 different places: Thompson, Yellowknife and Devon Is., the distribution of permafrost and the differences in permafrost temperatures.

73. BROWN, W.G., G.H. JOHNSON and R.J.E. BROWN. 1964. Comparison of observed and calculated ground temperatures with permafrost distribution under a northern lake. Can. Geotech. J. 1:147-154.

Author's abstract: 'Making use of limited ground temperature measurements in the neighbourhood of a small, shallow

[900 feet diameter, 6 feet deep] lake near Inuvik, N.W.T., it was possible with the help of an electronic computer to estimate the entire thermal regime under and about the lake. The results indicated a completely unfrozen zone of roughly hourglass shape directly under the lake. Field borings under the lake [240 feet] and adjacent to it supported this theoretical finding."

74. BRYAN, K. 1946. Cryopedology — the study of frozen ground and intensive frost action with suggestions on nomenclature. Am. J. Sci. 244:622-642.

A review of the various processes and phenomena of cryopedology and the current terminology, particularly as used in Europe. Suggestions are made for the use of terms derived from Latin and Greek and a list is given of the suggested new terms with definitions (and equivalents).

75. BÜDEL, J. 1970. Denudation and river erosion in the "zone of pronounced valley formation" on south-east Spitsbergen. Ecology of the Subarctic Regions: I. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 115-117.

This paper discusses the geomorphic role of rivers.

Erosion: "The greater part of the island of south-east Spitsbergen consists of ice-free, almost vegetationless plateaus, 250 to 400 meters above sea level. The steeper parts of the slopes of these plateaus have gradients of 30 to 35°; channel wash predominates here. Erosion works by a combination of sheet wash and solifluction on the rather gentle, convex upper slopes and the also gentle, concave lower slopes. The two processes take place within the uppermost 20 to 30 cm., where the ground freezes only seasonally; 400 m of permafrost lie below that level.

"The surface of the seasonally frozen ground shows frost structures in the form of striped ground. These are the result of a combination of sixteen different processes. Even with the same bed-rock and gradient, there may occur different kinds of striped ground according to the position on the convex upper slopes or the concave lower slopes, respectively. This is because sheet wash dominates over solifluction on the upper slopes, whereas the effect of the solifluction is predominant on the lower slopes. The annual speed of solifluction was accurately measured on slopes with all gradients. During the 15,000 years of the postglacial period, 6 m of ground have been removed by all these denudation processes on upper slopes with a gradient of 6°; steep slopes of more than 35° have retreated 15 m at most. The same occurred on the concave lower slopes although here it is the result of pronounced down-cutting of the rivers. These results of measurement allow us to estimate more accurately the amount of debris entering the rivers in early summer every year.

Lateral erosion: "The rivers of the sub-polar zone are able to transport the entire load even when precipitation is small. This takes place during the flood period of spring thaw. Almost the entire amount of winter precipitation melts at the same time and runs off in the form of a high flood, which lasts several weeks. Loss by evaporation is extraordinarily small., A complete cover of vegetation with high water consumption is almost absent. Striped ground and rills on the slopes feed the melt water straight down into the valleys and, what is more important, there is no seepage as permafrost lies below. Thus the rivers and the extraordinary run-off coefficient is necessary to transport the entire load, to cause intense lateral erosion, and to form the wide valley bottoms. It often occurs that river beds are already 60-150 m wide after a course of only 6-10 km.

Down-cutting and headward erosion: "In tropical and sub-tropical climates river erosion has two effects: (a) it loosens the solid rock and disintegrates it into such small pieces that these can be carried away, and (b) it slowly abrades the solid rock below using the course material as tools. This is an extremely slow process, because each outcrop of hard rock is an element of resistance. All these phenomena result in longitudinal profiles with many kickpoints often even with water falls, especially outcrops of resistant rock causing a kickpoint.

"In the sub-arctic region the permafrost is not even interrupted beneath the rivers. The entire upper layers consist of parts of ground ice; the solid rock in and between these parts is already completely shattered. The 0.5 to 1 m thick upper zone of the permafrost is the so-called "ice rind" (German - *Eisrinde*). In this uppermost zone of the permafrost the temperature change from summer to winter results in a great change in volume. The ice contracts and thus disintegrates the solid rock, when temperatures are low in winter. The resulting fissures become filled with ice, which expands in summer with the temperatures rising to almost 0°C. The solid rock beneath the ice rind consequently is completely disintegrated and ready to be carried away. The river's task is only to melt the ground and add the debris to its load. It is therefore able to carry it away immediately. This means that the most difficult role of river erosion has already taken place within the ice rind."

76. BURNS, J.J. 1964. Pingos in the Yukon-Kuskokwim Delta, Alaska; Their plant succession and use by mink. Arctic 17: 203-210.

Pingos are described together with their vegetation and succession. *Calamagrostis canadensis* is a very important coloniser, with *Spiraea beauverdiana* becoming an important species after the stability of the pingo increases and a higher amount of organic matter is incorporated into the soil. The eventual succession is to tundra on the more stable and protected areas, but the grass remains dominant in those areas subject to disturbance. Notes are included on mink den sites on pingos.

77. BURT, G.A. 1971. Travel on thawed tundra. Symposium on Cold Regions Eng. Proc. College Univ. Alaska. p. 296-319.

From: U.S. Army Cold Regions Res. Eng. Lab (CRREL) Rep. 12. 25(1). 1971. CRREL 25-4162. "Human Factors, Tundra Soils, Trafficability, Thaw Depth, Motor Vehicles, Active Layer, Tundra Vegetation."

78. CARTHY, J.D. and D.R. ARTHUR. 1968. The biological effects of oil pollution on littoral communities. Field Studies, Suppl. Vol. 2. 198 p.

This volume contains the proceedings of a symposium held in Wales and covers a very wide range of aspects of the subject. Most of the papers concern the littoral communities around the British Isles and none concern the Arctic directly. A very extensive bibliography is included.

79. CHERNOV, Yu. I. 1964. Relation between the soil fauna and sod and vegetation in certain types of tundra. Problems of the North 8:273-286. (Transl. from Russian by Nat. Res. Counc., Can. 1964).

These studies were conducted in the true tundra zone of Andreev. Several different community types were investigated. At the sites studied, the formation and succession of the animal populations in the tundra soils were attempted. Descriptions of the soils, the plants associated with them, as well as the invertebrates are included.

80. CHURCHILL, E.D. 1955. Phytosociological and environmental characteristics of some plant communities in the Umiat region of Alaska. Ecology 36:606-627.

Investigations of plant communities in the Umiat area of Alaska are reported. Eighty stands were analyzed and after analysis five types of communities were recognized: "1) Dwarf shrub heath; 2) Frost-scar collective type; 3) *Salix* type; 4) *Alnus crispa* type, and 5) *Carex aquatilis*-marsh type."

In the Umiat area "between the Brooks Range and Barrow, Alaska,...the...gently rolling hills [are covered] with a dense vegetation, generally 6 to 12 inches high consisting of dwarf heath shrubs, dwarf birches and willow, intermingled with herbaceous species and, in places, alders and willow from 3 to 8 feet high... Permanently frozen ground underlies the area at usually shallow depths.

"Aerial photographs were found to be useful in differentiating, delineating, and selecting stands for detailed analysis, since differences were more readily detected on aerial photographs than on the ground."

81. CHURCHILL, E.D. and H.C. HANSON. 1958. The concept of climax in arctic and alpine vegetation. Bot. Rev. 24:127-191.

Plant communities in relationship to habitats and environmental gradients are discussed. Examples of similar communities of widespread distribution through the arctic are given. Types and rates of community changes are discussed in reviewing concepts of "climax" and "succession".

The authors prefer the idea of widespread climax with internal, usually cyclic, variation.

A very large bibliography of arctic and alpine vegetation studies is presented.

82. CISLER, W.L. and S.B. BECHTEL. 1970. Russian Trip. Mimeo.

This contains a description of pipeline and road building methods and problems around Yakutsk, Viliusk and Lena. No information is given on plants or on vegetation.

83. COCHRANE, G.R. and J.S. ROWE. 1969. Fire in the tundra at Rankin Inlet, N.W.T. Annu. Tall Timbers Fire Ecol. Conf. Proc. April 10-11. p. 61-74.

Summary: Fires do occur in the Canadian tundra and their traces were observed on a variety of topographic sites. They burn readily downwind but are easily halted by physical obstacles in an upwind direction.

"Burning is selective, reflecting fuel differences in the vegetation and habitat moistness. *Alectoria* lichen communities burn readily and evenly. *Cetraria* lichen communities burn less easily, while mixed lichen-and-heath communities burn irregularly according to type and quantity of fuel. Apparently Labrador tea and ground birch are particularly flammable and burn fiercely [and deeply].

"Growth and regeneration of lichens and heaths following fire seems to be slow. *Hierochloe alpina* is an important early colonizer of dry, sandy and stony burned areas. Its dominance in a locality, especially if banded alternately with sparsely vegetated moss-peat areas, strongly suggests earlier fire influences."

Other Notes: The depths to which mosses burn depend on the site moisture content at the time of the burn. Burning did not appear to occur in tightly packed, turf-forming *Dryas* communities or on solifluction slopes. "Field observations suggest that the fires moved downwind easily but back fires were stopped by minor obstacles. Low embankments, frost fissures, rock outcrops and even gaps in the vegetation cover provided effective barriers to the advance of fire in an upwind direction."

84. CODY, W.J. 1965. Plants of the Mackenzie River Delta and reindeer grazing preserve. Can. Dep. Agr., Plant Res. Inst. 56 p.

A brief account of the history of plant collecting in the Mackenzie area is presented as well as a description of the physical geography and vegetation. An account of succession after a fire at Burnt Lake is detailed as follows:

"On 18 July, 1957, observations were made at Burnt Lake, 68°52'N, 30°05'W, an area which was burned in 1954. On a slope leading down to the lake, the scattered trees of *Picea mariana*, six to eight feet apart were all or nearly all dead. Shrubs were killed to ground level, but apparently most of the roots survived as new growth was observed at the surface of the ground. The lichens and mosses had been completely or almost completely burned away. With the removal of the protective layer of humus, the permafrost had receded to a depth of sixteen or more inches in some hollows. The recession of the ice of the permafrost under the parts where there was little or no insulating humus had caused the ground to sink in those spots so that the whole terrain had become very hummocky.

"New growth from the live roots of shrubs was as follows:

Salix sp. Up to 3 feet, but mostly 18 inches i.e. still below the old growth limit.

Betula glandulosa Up to 15 in., somewhat spreading (the old branches were burned off to 4-in. dead stubs.)

Rosa bourgeauiana 6 in.

Ledum palustre var. *decumbens* To 4 in.

Vaccinium vitis-idaea var. *minus* One to 1½ inches.

The following plants had invaded the area:

Calamagrostis sp. This species had grown up all over the burnt area, and in some places formed quite dense stands.

Equisetum arvense Scattered throughout the area.

Epilobium angustifolium An occasional patch of fireweed, measuring up to a square yard was noted.

"In crevices and on sides of the hollows some mosses and hepatics had returned. The most noticeable of these Bryophytes was *Marchantia polymorpha*. Only one lichen, *Cetraria nivalis*, a small "broad-leaved" yellowish species, was noted as having returned.

"This area was visited on 8 July, 1963. At a distance, the slopes leading down to the lake appeared quite green from a mixture of vegetation. *Ledum palustre* var. *decumbens* was very common and up to eight inches in height. *Betula glandulosa* was frequent and up to two feet high. *Rosa bourgeauiana* had grown up to one foot in height. *Salix glauca* had many lower shoots to eighteen inches, but showed some winter kill. *Vaccinium vitis-*

idaea var. *minus* was a very common prostrate plant. *Empetrum nigrum* var. *hermaphroditicum* occurred frequently. *Petasites frigidus*, *Equisetum arvense*, *Eriophorum vaginatum*, *Epilobium angustifilium*, *Calamagrostis* sp., *Arctostaphylos rubra*, *Pedicularis labradorica* and *Rubus chamaemorus* appeared occasionally. Sticks of *Picea mariana* to six feet in height were scattered; a few of them had green tops and were producing cones, which appeared to have good seed. The hummocks throughout this area were very hard and dry. There was some very short green moss in the hollows, a few patches of a very dry, unhealthy-looking reindeer lichen, and a trace of *Cetraria* on the hummocks. In spite of the green appearance of the area, there were still large hard black spaces on the ground between the shrubs and other plants.

"Nine years after the fire the shrubs, grasses, sedges and other forms seemed to be returning fairly well. The recovery of the cryptoganic flora was almost negligible. Since the reindeer subsist for the most part on lichens during the winter months it is apparent that it will be many years before these burnt regions will have a lichen flora sufficient to provide them with food."

A discussion is presented on reindeer grazing with a description of overgrazed terrain on Summer Island. "The main herd of several thousand reindeer was confined to this island for a number of years...*Salix glauca* shrubs had been browsed back badly and many were dead or nearly so; shrubs that had been a foot high had only two or three inches of new growth from the base and bore no signs of the previous year's growth. Steeper slopes were dominated by *Dryas integrifolia* and *Cassiope tetragona*, neither of which is palatable to reindeer. Here the effects of the sharp cutting hoofs of the reindeer were readily observed. Low areas and meadows were almost entirely lacking in *Eriophorum vaginatum*, a major part of the reindeer's summer diet. There were large areas where old tussocks of this plant were quite numerous, but these mounds had been taken over by small *Salix* sp., *Cassiope tetragrona*, *Calamagrostis* sp., *Carex lugens*, *Dryas integrifolia* and other small forms to the near exclusion of the *Eriophorum*. Overgrazing in this area has certainly changed the composition of the flora and it may be many years before the former balance of species is regained."

The author notes that grasses, sedges and willows recover fairly quickly from grazing (not overgrazing) and that mushrooms and *Pedicularis lanata*, though not common, are avidly eaten by reindeer.

An annotated list of species is included.

85. CODY, W.J. 1971. A phytogeographical study of the floras of the continental Northwest Territories and Yukon. Nature Can. 98:145-158.

Author's abstract: "The vascular flora of the Continental Northwest Territories and Yukon are analysed; 11.2 % of the Continental N.W.T. flora is considered to be endemic to boreal and arctic N.A. as compared to about 9% for the Yukon. These endemic species are examined for relationships in distributions. Botanical studies in the region are considered to be still in their beginnings."

86. CORDONE, A.J. and D. KELLEY. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish Game 47(2):189-228.

Most of this extensive review concerns work done on salmon and trout streams. While adult fish can apparently survive high concentrations of silt, "deposition of sediments on the bottom of the stream will reduce survival of eggs and alevins, reduce aquatic insect fauna, and destroy needed shelter. There can scarcely be any doubt that prolonged turbidity of any great degree is also harmful." Probably erosion is of greater importance in increasing silt deposition than spectacular discharges from gravel-washing or mining operations.

87. CRUM, H. and P. KALLIO. 1966. Bryophytes of Labrador and Ungava. Contrib. to Botany IV. p. 87-101. Nat. Mus. Can., Bull. 216.

A report on 27 liverworts, 14 *Sphagna* and 144 mosses chiefly collected from Goose Bay, Shefferville, and Churchill Falls areas.

88. DADYKIN, V.P. 1950. Water regime and nutrition of plants on cold soils. (Transl. of Russian title.) Dokl. Akad. Nauk. SSSR. 70(6):1073-1076.

Translation available from:

Senior Information Officer CSIRO.
314 Albert St.,
East Melbourne Australia, Ref. 1517.

Arctic Bibliography 28653: "Contains summary of results of experimental study of transpiration and nutrition: the transpiration of the plants under changing soil temperature is indicated...; the influence of low temperature of the nutritive solution on the growth of barley and oat sprouts is also shown... It is concluded that low temperature causes poor assimilation of nitrogen by plants and the retardation of their growth."

89. DADYKIN, V.P. 1950. On the biological peculiarities of the plants of cold soils. (Transl. of Russian title.) Priroda 5:21-29.

Arctic Bibliography 28651: "Three types of plants growing in permafrost regions are differentiated according to soil penetration of the root systems. Field experiments in permafrost were made (in 1947 and 1948) at 67°27'N with eleven wild-growing (trees, shrubs, herbs) and cultivated (oats, barley, potatoes) plants. The active layer measured 2-3m. The temperatures in the higher soil horizons were -0.5° to -0.8°C, seldom lower than -1.5°. Roots of cloudberry, sedge and horsetail were found to penetrate into the frozen ground to a depth of

90 cm and remain viable. These tests tend to indicate that various plants in permafrost regions utilized different ways of adaptation to low soil temperatures. The result of root penetration of oats and potatoes in frozen ground and harvest yields are tabulated. Tests showed that the value of transpiration decreased under low temperatures and osmosis increased. Results of similar laboratory studies are given."

90. DADYKIN, V.P. 1952. Peculiarities of plant behaviour in cold soils. (Transl. of Russian title.) Akad. Nauk. SSSR. Inst. Merzlotoved. 279 p.

Arctic Bibliography 28654: "Basic work on the relationship of permafrost to agriculture in arctic regions. The biological importance of permanently frozen ground and the history of the agrobiological study of permafrost are outlined. Agriculture is claimed to have expanded northward during the Soviet regime from 63-65°N to 69°N in European USSR and to 71°N in Siberia. Salient factors of plant development in cold soils are discussed, such as loss of sun heat for melting of the ground ice, excessive humidity in the section of soil overlying permafrost, low nitrification of cold soils, etc. The root systems of wild-growing and cultivated plants (trees, shrubs, vegetables, grain crops, grasses etc.) water regime of plants, peculiar features of root function and growth, and plant development are dealt with. The chief factor in the slow development of such plants is not the "physiological dryness" of such soils, but difficulties in the assimilation of nitrogen. This can be relieved by the spraying of plants with a nitrogen-containing solution."

91. DADYKIN, V.P. 1958. Plant physiological research problems in the extreme north. Problems of the North 1. p. 205-216 (Transl. from Russian by Nat. Res. Counc. Can. 1960).

A review of physiological aspects of cold on the growth of plants. Evidence is presented that the rate of synthetic processes in the roots is slowed by cold, rather than the rate of supply of nutrients to the roots. Preliminary experiments have shown that massive doses of nutrients (nitrogen, phosphorus and potassium) to the soil can overcome adverse effects of cold and that perhaps increased dosages of trace elements may also be effective.

Critical work performed by this author has indicated the invalidity of the theory of physiological aridity of cold soils. Part of the experimental method was to use wheat, oats and barley and transfer the plants from warm conditions into a temperature of about 5°C and back, meanwhile measuring the intensity of transpiration. These experiments with periodical cooling of the roots did not show any alteration in transpiration intensity.

"Since the retarded growth of plants under cold soil conditions cannot be explained by the Schimper theory of physiological aridity, it was necessary to look for other causes inhibiting plant growth under these conditions. Experiments carried out in the artificially created conditions of a controlled temperature growth installation,...which made it possible to sustain a low temperature in the soil while maintaining a normal temperature above it, and applying the method of "isolated temperatures", enabled us to ascertain that the effect of low temperature of the soil on assimilation by the plant of various nutrients differs, depending on the nutrient. Plant growth is retarded most with the supply of nitrogen coming from the cold environment....[We were forced] to confine ourselves to short-term, (12 to 14-day) experiments. Under the conditions of the short-term experiments with seedlings it has been found that the assimilation of phosphorus and potassium from cold solutions has little relationship to the temperature. The isolated temperature method has lately been somewhat improved.

Instead of the small-capacity containers, square glass containers of 3-litre capacity installed side by side are used. One of them is immersed in a cooling tank, and the other remains outside the tank. The seedling is secured in a curved glass tube. This arrangement of containers makes the changing of nutrient solutions possible and permits the experiments to be carried through until the plants mature. The growing of the plants to maturity has revealed a difference in the assimilation of phosphorus and potassium from a cold solution... Plants receiving "cold" phosphorus began in the second half of the growth stage to lag considerably behind those plants which were receiving "cold" postassium...

"The chemical analyses of plants grown under various thermal conditions of the root zone have shown that low temperature does not so much hinder the supply of nitrogen to the roots as it influences the synthetic processes taking place in them...

"Experience has shown that vegetation in the north develops considerably better if the soil contains an overdose of nutrients. Our preliminary experiments in plant growth have shown that at low soil temperatures (about 1 to 2°C) the optimum is something about five times the usual concentration of Knop solution...

"It is stated in an announcement by A.I. Korovin (1954) that the author has found that increasing the dosage of phosphorus by 2 to 3 times in comparison with the nitrogen dosage is advantageous for the purpose of overcoming the detrimental influence of cold soils on plants, since it shortens the duration of the period of growth of cereals by 7 to 10 days and increases the yield of grain.

"A.I. Korovin has determined empirically that the greatest reduction of the period of growth and the greatest increase of grain yield is attained when the respective proportions of nitrogen, phosphorus and potassium are $1:3:\frac{1}{2}$. The author has termed this ratio of nutrient components the "northern dosage...

"Another way of overcoming the negative influence of low soil temperature must be looked for in the application of trace fertilizers, which act as catalysts in facilitating the assimilation of the basic nutrients of cold soils. The possibility of influencing plant growth in this manner was demonstrated by us in principle in 1952."

It is suggested that foliar feeding of nitrogen is also a method of overcoming the problem of nitrogen in cold soils. Already some highly encouraging results have been obtained.

Tyrtikov (1951 and 1954) has "established a close connection between the intensity of growth of the surface roots of larch, spruce, pine and birch with the temperature of air and soil. The most intense growth of roots occurred during the warmest weeks. During dry periods of the summer, however, a part of roots slows down or stops growing in the midst of the growing period and resumes growth only after precipitation and adequate moistening of the soil." Further, Tyrtikov has shown experimentally that "the deeper the roots were located [in the cold soil] the slower they grew, showing less accretion and less ramification. [The conclusion is] that the principle factor determining root growth and ramification is the temperature regime of the soil." Thus, root growth inhibition in "a low soil temperature reduces the development of the underground organs as a whole,...exerting an injurious influence on the development of trees" and this is, presumably, one of the most important reasons for treelessness in the tundra.

92. DAHL, E. 1950. Studies in the macrolichen flora of South West Greenland. Medd. om Grønland. Bd. 150 Nr 2. 176 p.

Descriptions, distributions and chemical reactions of 198 macrolichens are presented.

93. DAHL, E. 1956. Mountain vegetation in south Norway and its relation to the environment. Norske vindenskapes-acad. i Oslo. 1. Math-Natur. Kl. Skr. 3:1-374.

This very detailed paper describes the vegetation patterns of Rondane, a group of mountains in southern Norway. Snow cover, depth and duration appear to be of primary importance in community distribution. Succession is discussed, and it appears, that with the possible exception of some communities on dry habitats cyclic successions are a general feature of the area. The last section of the paper lists the species with remarks on their distribution and ecology. Some very interesting observations are included.

In the section on the ecology of the vegetation in Rondane, the author says "the main results of the investigations may be summarized thus: (1) differences in amount of snow cover in winter and duration of snow cover in spring and summer are most important in the vegetation in Rondane. Zonations due to differences in amount and duration of snow cover are summarized. (2) The pattern of snow accumulation is very constant from year to year. It is shown in communities that are restricted to localities with little snow cover in winter and also to communities requiring good snow cover in winter and there are specific differences between the different communities. The low-alpine belt, another community type, grows in localities with late snow cover. (3) Meteorological measurements show that a cover of snow is an efficient protection against severe frosts in winter. (4) The meteorological observations show that the soil temperatures are much influenced by snow cover, exposure, and vegetation cover. Widely different microclimates occur within short distances. The soil surface temperatures are on an average higher than those of the free atmosphere due to the effect of snow cover and possibly the radiation-insulation balance in alpine communities."

<u>Solifluction</u>: Measurements of solifluction were carried out over a number of years. Results indicate that those localities with a marked soil profile, e.g. a podzol profile, apparently do not have active solifluction because (a) the profile takes a considerable time to develop, and (b) the profile is destroyed by active solifluction.

"Solifluction occurs in some years, while the soils are apparently stable in other years." In active solifluction areas buried humus is commonly found. Fluid mass movement of soil may be common in some areas.

Crude measurements of solifluction were taken and there were indications that certain groups of species are more tolerant of solifluction than others.

"In localities with active solifluction a growth of hepatics is commonly found covering the soil like a blanket. When the underlying soil is moving the blanket is folded in a characteristic pattern, forming ridges or elongated hummocks oriented transversely to the direction of the flow. Where solifluction is more active, the mat of hepatics is broken and the vegetation becomes patchy, with much bare soil. In still more active areas the vegetation cover may be completely destroyed."

A list of species considered indicator species in relation to solifluction is given. It should be noted that many of these species are common in Canada.

"Two main types of solifluction are recognized, the amorphous and the structured solifluction. The former is always associated with deep snow and the areas are not exposed to severe winter frosts, while the latter depends upon the absence of snow cover." (Structured solifluction is associated with polygons or with stony earth circles.)

"When solifluction takes place minerals are brought from underground to the surface of the soil. The result is a flush action. The importance of this may be clearly seen in

Abisko. In the birch forests, a podzol profile which carries a meagre type of vegetation with *Vaccinium myrtillus* and *Deschampsia flexuosa* is commonly found. In open areas of the birch forest, polygon formation takes place, and in these places a very rich calcicolous vegetation with *Rhododendron lapponicum, Carex microglochin, Chamaeorchis alpina, Astragalus frigidus, etc.* is found."

In the section on drainage, a great deal of information is presented showing the reasons for the patterning of vegetation in relation to water and its states during both summer and winter. Detailed work is also presented on the distribution of plants in relation to parent rock and to the pH preference of the species. Then the species groupings are discussed in relationship to soil type.

A discussion on succession is prefaced by a discussion of the various schools of ecological thought. Dahl points out that the importance of unequal snow cover in winter is a fundamental ecological factor. "It is an every-day fact that in areas with a considerable snow cover the snow-beds are stable from year to year. Though communities on dry land are very stable under present conditions, and successional concepts are of limited value, mire vegetation is different. [Mire in this terminology refers primarily to peatlands and the origin of the water in those peatlands.] The accumulation of peat through plant activity changes the environment and results in autogenic successions. That such successions have taken place and still take place has been amply demonstrated by the presence of buried peat not now growing on the surface." In Finland a comparison of maps taken at different times (Cajander, 1913) shows that mires have expanded recently at the expense of dry land (paludification). Dahl gives a hypothetical generalized scheme of succession in the poor fen and rich fen series but points out that he can give no indication of speed of the successions or whether the trend is progressive or regressive or cyclic. The last section of this paper lists the species with remarks on their distribution and ecology.

94. DANILOV, D.N. 1958. Den sites of the arctic fox (*Alopex Lagopus*) in the east part of Bol'shezemel'skaya tundra. Problems of the North 2:223-229. (Transl. from Russian by Nat. Res. Counc. Can. 1961.)

Detailed descriptions of the sites of dens of the Arctic fox are given. Changes in vegetation which occur as a result of fox activity are described, and it is noted that den sites can usually be located from the air.

The region under study lies at 69°N and 64°40'E, about 40 to 60 km. from the Kara Sea.

"Geomorphologically, this territory is a rolling till plain in which is encised the broad valley of the rivers Kara and Sibircha-Yakha. The mean monthly air temperature in July, 1956 was 4.5°C. The frost-free period rarely lasts as long as 60 days. The high permafrost level has a strong influence on the thermal regime of the soil and on vegetation. Scrub and moss tundra is prevalent on well-drained sectors, while the depressions are covered by sedge and moss bogs. Forty-one arctic fox dens were investigated."

The physical characteristics of the den sites were studied, and on Vegetation on the den sites, the author had this to say: "In old dens with a large number of burrows, the arctic fox renews and clears annually only some of the exits, near which small mounds of freshly thrown-up earth accumulate. The ground around the other exits, which the animal does not use, usually becomes thickly overgrown with herbacious vegetation... The dark green of this tall and dense growth stands out sharply against the greyish-brown background of the tundra. In many instances, dens that are occupied can be recognized at a great distance from the general character of the vegetation and the presence of yellow patches of sand thrown up by the foxes... A tall, herbacious growth, distinct in colour against the surrounding background, does not develop at every den... One more characteristic feature should be mentioned: dens are usually situated in the immediate proximity of willow thickets. A willow thicket provides good cover for the young, sheltering them both from predators and from bad weather, which is particularly important during the first days they are on their own. According to the measurements...the velocity of the wind in a dense willow thicket is 20 times less than what it is in open places. These thickets also have a bird fauna... An increased density of microtine rodents is noticeable at the edge of the thickets. The presence of willow shrubbery nearby increases the available supply of food at a den site."

Other interesting aspects of den site location indicate that the dens were usually situated on slopes 2/3 of the way up and facing towards water.

95. DANSEREAU, P. and F. SEGADAS-VIANNA. 1952. Ecological study of the peat bogs of eastern North America. 1. Structure and evolution of vegetation. Can. J. Bot. 30:490-520.

The results of very full investigations of bogs in the Laurentian region of Quebec and Ontario are presented. These are bogs which have been developed within the Boreal forest zone. Thus, permafrost is not considered nor discussed. Details are given of all the bog communities and the successional patterns.

96. DANSEREAU, P. 1954. Studies on central Baffin Island. 1. Bray Island. Vegetatio. 5:329-339.

The vegetation and flora of Bray Island, a low-lying island of low ridges, fresh-water lakes and marshland, are described and catalogued. Ecological information is included.

97. DAVIDSSON, I. 1946. Notes on the vegetation of Árskógsströnd,

North Iceland. Acta Natur. Islandica 1(4). 20 p.

The vegetation types of Árskógsströnd are described and compared with those of Mýrdalur in the south.

98. DAY, J.H. and A. LEAHEY. 1957. Reconnaissance soil survey of the Slave River lowland in the N.W.T. of Canada. Can. Dep. Agr. Ottawa. 44 p.

Mineral soils in the permafrost zone tend to have a more dense and luxurious ground vegetation and a thicker moss cover than the lowland soils free of permafrost. The depth to permafrost is six inches to two feet, and is influenced by the depth of moss cover, soil texture, topographic position and summer precipitation. In burned-over areas the permafrost disappears and the soil surface becomes irregular or humpy due to subsidence caused by melting of buried ice blocks. Two indicators of permafrost are considered fairly reliable: scalloped appearance of slumped river banks on aerial photographs and the absence of *Populus tremuloides*, which is abundant in the non-permafrost areas.

Very general vegetation descriptions are given. Detailed descriptions of soil profiles are presented.

99. DAY, J.H. 1962. Reconnaissance soil survey of the Takhini and Dezadeash Valleys, Yukon Territory. Can. Dep. Agr. Res. Br. 78 p.

This report deals with soils in valleys in the south-western corner of the Yukon Territory. Brief descriptions of the vegetation is presented, and within each soil type a brief indication of the predominant vegetation type is given.

100. DAY, J.H. 1964. Characteristics of soils of the Hazen Camp area, northern Ellesmere Island, N.W.T. Can. Dep. Nat. Def., Def. Res. Bd. Operat. Hazen D Phys. R(G) Hazen 24. Ottawa. 14 p.

This paper records morphological characteristics, some

chemical characteristics and the classification of soils at a number of sites in the Lake Hazen campsite area. Dominant plant species and vegetation cover are recorded for each site. Photographs of the sites and soil profiles are included.

101. DAY, J.H. and H.M. RICE. 1964. The characteristics of some permafrost soils in the Mackenzie Valley, N.W.T. Arctic 17:223-236.

"This study was undertaken to investigate the characteristics of soils in a permafrost region under different types of vegetation. The Lower Mackenzie River Valley is within the area of continuous permafrost and both tundra and boreal forest regions are readily accessible from the river. This paper describes soils in three localities, each with a different vegetation, the morphological, chemical, physical and mineralogical characteristics of a number of soil profiles, and the effect of permafrost and vegetation on soil development. The tundra locality at Reindeer Depot is situated on the east channel of the Mackenzie Delta at 68°42'N, 134°07'W; the tundra-boreal forest transition locality at Inuvik is also on the east channel, about 30 miles south of Reindeer Depot at 68°21'N, 133°41'W, and the boreal forest locality at Norman Wells on the Mackenzie River lies about 280 miles southeast of Inuvik at 66°42'N, 126°51'W. Only slight differences in climate between them were found."

<u>Reindeer Depot</u>. 1. <u>Vegetation</u>: "The Reindeer Depot area has been assigned to the forest-tundra section but the sites sampled are more representative of the tundra. The vegetation forms a nearly continuous mat. Only an occasional willow, 1 to 2 feet high is present; along water courses, and in basins protected from the wind alder, 6 to 8 feet tall forms fairly dense stands... The vegetation is low and sparse on top of each knoll and some are bare. In the troughs the vegetation is higher and denser; there the main species are mosses and

labrador tea. In the peat polygon areas, labrador tea is dominant, with reindeer moss, mountain cranberry, and dwarf birch on the raised centre and grasses in the troughs."

2. Surficial geology and permafrost: "Fine-textured glacial till covers the area to depths of three to four feet.... The active layer is thin [6 in] under the troughs and thick [24 in] under the knolls, so that its basal face is a mirror image of the ground surface."

Inuvik. 1. Vegetation: "The forest-tundra transition is a continuous cover formed by various species including black spruce, birch, alder. The continuous ground cover includes *Vaccinium vitis-idaea, Ledum palustris, Hylocomium splendens, etc.* The ground cover is low and sparse on the top of each knoll, higher and denser in the troughs." (The microtopography at Inuvik is rather similar to that at Reindeer Depot, but less rough.)

2. Surficial geology and permafrost: Again, fine-textured glacial till is present at Inuvik. A radio carbon date of 8000-plus years for peat near the present river level at Inuvik shows that the sea level was not higher than at present. "In late August the depth of thaw ranged from 18 to 30 in for clayey mineral soils with peaty cover to 51 in for gravelly soil with peaty cover."

Norman Wells. 1. Vegetation: "The vegetation is typical of boreal regions (Rowe 1959)."

2. Surficial geology and permafrost: "The ground was frozen [July 27] at depths of 2 feet under organic soils, 3 feet under mineral soils on inland sites with tree-moss cover, and at more than 4 feet on the terrace adjacent to the river bank under trees and sparse ground cover."

There is no extensive discussion of the effects of permafrost on the soil or on the vegetation. The soils that were sampled have been assigned to various soil types both in

the Canadian system of classification, and the seventh approximation (U.S.D.A., 1960).

102. DAY, J.H. 1966. Reconnaissance soil survey of the Liard River Valley, N.W.T. Can. Dep. Agr., Res. Br. 71 p.

A brief description of the vegetation of the area is given and a table with the vegetation types in the recent flood plains is also given, including species of the tree layer, underwood layer, shrub layer, and herb layer.

103. DAY, J.H. 1968. Soils at the Upper Mackenzie River area, N.W.T. Can. Dep. Agr. Res. Br. 77 p.

This report includes "the lands west of Hay River in a wide band around the west end of Great Slave Lake and down the Mackenzie River to Green Island. The area is part of the Great Slave Lake Plain". The area is forested. A brief description of the vegetation is given as well as a map of forest types of the area. Brown wooded soils cover 30.3% of the area, Organic soils 24.3%, Gleysols 21.5% while all other types cover less than 10%. About 47% of the soils are poorly drained.

104. DENNIS, T.G. and P.L. JOHNSON. 1970. Shoot and rhizome-root standing crops of tundra vegetation at Barrow, Alaska. Arctic Alpine Res. 2:253-266.

This paper provides evidence that growth of aboveground plant parts is more severely reduced than that of belowground parts, hence confirming USSR studies that permafrost does not appear to be the primary factor limiting growth.

105. DOBBS, C.E. 1939. The vegetation of Cape Napier, Spitzbergen. J. Ecol. 27:126-148.

Detailed information is presented on the following communities:

1. *Dryas* "fjaeldmark" on shingle

2. saltmarsh on tidal mud flats
3. wet tundra on silted areas above tidal limits.

There are no extensive barrens at Cape Napier.

106. DOROGOSTAISKAIA, E.V. 1959. The algal flora in the "spotted tundras" of the far north of the USSR. (Transl. Russian title). Bot. Zh. 44(3):312-321.

Arctic Bibliography 57722: "Contains some notes on methods of study, and a systematic annotated list of terrestrial algae collected in the spotted tundra soils around Tiksi in Yakutia. A discussion of this algal flora, as to its taxonomic composition, distribution and abundance, relation to similar vegetation in other regions, etc. follows."

107. DOROGOSTAISKAIA, E.V. 1959. On the succession of the vegetation in relation to thermokarst in northern Yakutsk. (Transl. Russian title). Izv. Sib. Otd. AN S.S.S.R. (Bull. Siberian Div. Acad. Sci. S.S.S.R.), Novosibirsk. 12:91-100.

Arctic Bibliography 57723: "Presents the author's observations in the tundra of Bykovskiy Peninsula (75°N.129°E.) in the Lena Delta. The upper strata are formed of frozen alluvial deposits mixed with blocks and vertical wedges of fossil ice, all covered with a thin layer of peat. Melting of fossil ice, due to a warming trend in climate, leaves mounds of alluvial deposits called in Yakut "baidzharakhi", each separated from the others by sink holes. Five stages of formation followed by a period of degradation, are distinguished, and patterns of each stage were observed in a valley of the peninsula. The plant succession (lichens, moss and grass) with change of distribution, temperature, humidity and physical properties of soil were studied; observational results are reported in detail and discussed. The mound formation is said to require two to three decades; degradation by weathering and solifluction is more rapid."

108. DOROGOSTAISKAYI, E.V. 1963. A tentative characterization of the ruderal and weed plants of the Town of Vorkuta and its environs. (Transl. Russian title.) Bot. Zh. 48(7):1015-1021.

Arctic Bibliography 78346: "Discusses the general character of the ambient vegetation and its dominant species; changes in it produced by man: plants in over-moist and moist localities; forms on vacant levels alongside roadsides, and railways and on dunghills; plants in cultivated soils. A final section deals with introduced plants, over one hundred."

109. DOROGOSTAISKAIA, E.V. and I.V. IGNATENKA. 1964. Symposium on the forest tundra. (Transl. Russian title). Geograf. o-vo SSSR. Izv. 96(5):445-448.

Arctic Bibliography 86606: Reviews this symposium of 9-15 Dec. 1963 in Leningrad. English translation available as TT 65-64602 from National Technical Information Service, Operations Division, Springfield, Virginia 22151.

110. DOROGOSTAISKAIA, E.V. and L.N. NOVICHKOVA-IVANOVA. 1967. Changes in algal flora of tundra soils resulting from their reclamation. (Transl. Russian title). Bot. Zh. 52:461-468. (English summary given).

Arctic Bibliography 94948: Studies of virgin and cultivated soils of the vicinity of Vorkuta. From the former, 23 species of algae are recorded with Protococcaceae and Volvocaceae prevailing. Cultivated soils contained 45 species with prevalence of filamentous chlorophyceae.

111. DOUGLAS, L.A. and J.C.F. TEDROW. 1959. Organic matter decomposition rates in Arctic soils. Soil Sci. 88:305-312.

Soils studied in 1957 were Arctic brown, upland tundra, half-bog under a very wet environment, and comparatively well-drained organic matter from the top of a peaty, high-centre polygon, using the Warburg microrespirometer in the laboratory

and evolved-CO_2 techniques in the field. A decomposition rate of 1050 lbs. organic matter/acre/year in the 1-0 inch layer of the Arctic Brown soil was estimated "but, due to the discontinuous nature of the organic mat, the amount decomposed on an acre basis probably approximated half of this value." The rate of decomposition of organic matter in the Arctic Brown soil mineral horizon (0-4 in depth) was ca, 300 lbs./acre/year; in the upland tundra ca 840 lbs/acre/year; the half bog ca 1700 lbs/acre/year and the high-centre peaty polygon ca 600 lbs/acre/year.

112. DOWNES, J.A. 1964. Arctic insects and their environment. Can. Entomol. 96:279-307.

A discussion on the characteristics of the arctic environment and their influence on insects. "The most important features are the low temperature, the low annual heat budget, the severe and often variable weather and continuous daylight of the growing season." The most numerous group is the Diptera, especially the Chironomidae. Of interest is that the main groups of insects present in the Arctic pass the predominant part of their life cycle in soil, water or as external parasites of warm-blooded mammals. Aspects of life-cycle, nutrition and reasons for lack of diversity of insect species are discussed.

113. DREW, J.V., J.C.F. TEDROW, R.E. SHANKS and J.J. KORANDA. 1958. Rate and depth of thaw in arctic soils. Amer. Geophys. Union Trans. 39:697-701.

Author's abstract: "Measurements at Point Barrow, Alaska, indicate that rate and depth of thaw in arctic soils are highly related to soil type. Arctic brown soil thawed earlier in the spring, thawed to a greater depth, and froze earlier in the fall than did the adjacent, poorly-drained areas. During 1956, arctic brown soil thawed to a maximum depth of 40 in, while the depth of thaw in the nearby tundra soil approximated 18 in. Diurnal near-surface temperature amplitude was greater in the arctic brown than the adjacent, poorly-drained areas. The willow-lichen-moss complex was the dominant vegetation with the arctic brown soil, while in the tundra soil, it consisted mainly of *Dupontia-Carex-Eriophorum scheuchzeri*. Other vegetation units in relation to soils are given." The work was done on a transect basis.

114. DREW, J.V. and J.C.F. TEDROW. 1962. Arctic soil classification and patterned ground. Arctic 15:109-116.

This paper gives a table of the relationships of patterned ground to the major genetic soils of northern Alaska. Some expected vegetation patterns are also included.

115. DREW, J.V. and R.E. SHANKS. 1965. Landscape relationships of soils and vegetation in the forest-tundra ecotone, Upper Firth River Valley, Alaska-Canada. Ecol. Monogr. 35:285-306.

This paper contains a very full description of plant communities in the Upper Firth River Valley, which contains outliers of white spruce. Diagrams and descriptions of the plant communities of this Valley in the area of the United States-Canada border are given in detail.

"Essentially, all of the country rock in the vicinity consists of limestones. Soils in the valley basin are commonly alkaline and are formed largely in residuum derived from limestone on mountain summits or slopes, and in alluvium derived from limestone on valley terraces. Strongly acid soils occur, however, in certain bog meadow areas and on the bedrock terraces. A frozen layer occurs within two feet of the surface in most of the poorly-drained soils." The areas which had permafrost include the peaty, high-centre polygons, which had a frozen layer at a depth of 21 in, upland tussock tundra, which had a frozen layer at 20 in, the sedge meadow terrace, which had a frozen layer at 20 in, the calcarious bog meadow area, which had a frozen layer at 25 in, and the non-calcarious bog meadow and strangmoor, which had a frozen layer at 21 in. The alpine tundra did not show any freezing down to a depth of 20 in, but excavation below this was impossible. A full discussion of the relationships of soil and tundra vegetation in the Firth River Basin is given. The authors summarize: "In general, the distribution of tundra vegetation on the major landscape units of the Firth River Basin is associated with gradients in the land surface, age, soil drainage, snow cover, and soil reaction, although vegetation mosaics frequently occur in the poorly drained units in association with micro-relief."

116. DRURY, W.H., Jr. 1956. Bog flats and physiographic processes in the Upper Kuskokwin River region, Alaska. Harvard Univ. Contrib. Gray Herb. 178. 130 p.

Detailed information is presented on the bogs and related vegetation in the upper Kuskokwim River region in Alaska. In the discussions it becomes quite clear that the author does not think in terms of succession, but rather in terms of cycles in explaining the bog to white spruce to black spruce to bog communities. He does not see any evidence of climax in the accepted sense.

Summary: "The present climate and vegetation produce a water-logged condition on the fine-grained, alluvial areas of the Upper Kuskokwim River region of Alaska. Under sphagnum-black spruce vegetation, peat accumulates on the surface, and the underlying ground becomes frozen and remains so for a number of years. Quaking bogs form by colonization of ponds, by swamping the low areas, [in this instance, "swamping" and "paludification" are equivalent terms], or by thawing into the frozen ground". (The thaw may be started by a break in the moss cover, e.g. "can be caused by a fire, a tree blow-down, the bursting of a frost-built hummock or pingo, a well-used game trail, or bear's meat cache, the bank of a small brook, or the water that collects in sphagnum mosses invading the forest by the swamping process."). "They expand by thawing in many cases and coalesce, leaving islands covered with sphagnum-black spruce forest. The building-up of peat and the appearance of the perennially frozen ground set the stage for the lowering of the surface by thawing at the margins of the advancing quaking bogs. The antagonistic processes of thawing and of rebuilding of peat combine into a physiographic process molding the terrain of the alluvial lowlands. The cycle of the replacement of forest by bogs, and subsequent reforestation is now going on and can have gone on in the past without change in climate. Cycles of bog formation and reforestation during a period of stream aggradation of fine-grained materials or of loess deposition are adequate to explain the formation of muck... The studies indicate both the persistance of bogs during periods of climatic change and the continuation of change in bog-to-forest relations in the lowlands under constant climatic conditions. The formation of peat bogs as described depends upon the luxuriant growth of sphagnum moss, which is much more abundant in forested than in tundra regions."

A useful glossary is included with European and North American equivalents for certain types of marsh and bog structures. A long bibliography is included.

117. DRURY, W.H. Jr. 1962. Patterned ground and vegetation on southern Bylot Island, N.W.T., Canada. Harvard Univ. Contrib. Gray Herb. 190. 111 p.

A very detailed account of vegetation and geological processes producing patterned ground on this northern island. Primary factors controlling vegetation are discussed.

118. DUNBAR, M.J. 1968. Ecological development in polar regions: A study in evolution. Prentice Hall, Inc., Englewood Cliffs, N.J. 119 p.

Discusses changes since the late Pliocene, which have affected arctic and antarctic ecosystems. Points out that temperature adaptation is not the basic problem — more likely highly oscillating nutrient supply for plants and food for animals. Concerned mainly with marine environments.

119. DUNBAR, M.J. 1970. The scientific importance of the circumpolar region and its flora and fauna. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:71-77.

Discusses whether arctic ecosystems are climax or successional. The author contends they are successional. Utilizes marine biota and differences between the Arctic and Antarctic as evidence.

120. DURNO, S.E. 1961. Evidence regarding the rate of peat growth. J. Ecol. 49:347-351.

Work done in Scotland: dating by pollen analysis was used and rates of growth of peat was expressed in cm/100 yrs.

121. ELLIS, D.V. 1962. Observation on the distribution and ecology of some arctic fish. Arctic 15:179-189.

An annotated list of fish collected from areas extending from Coppermine to Frobisher Bay. Some information on environmental conditions are given. Both marine and freshwater species were collected.

122. ELLIS, R., Jr. and R.S. ADAMS, Jr. 1961. Contamination of soils by petroleum hydrocarbons. Advan. Agron. 13:192-216.

Among the aspects discussed are:

1. Enhancement of microbiological activity in the soil following contamination with oil.
2. Loss of structure, deflocculation, and consequent increased erosion potential occurring in severely

contaminated soils. "The large increase in organic matter increases the water-holding capacity of contaminated soils."

3. Elimination of plant growth for a period is usual on severely contaminated soils as a result of "reducing conditions and increase of exchangeable Mn. to toxic levels during the decomposition and assimilation processes," as well as displacement of soil air by natural gas. Cultivation and aeration can aid in returning the soil to its normal oxidation state.
4. After a period of time soils contaminated with oil often produce better growth than neighbouring uncontaminated soils. The reasons for this are not totally clear yet, but increased nitrogen and water could be partly responsible.

123. ERIKSSON, O. 1970. Current investigations into reindeer grazing in northern Sweden. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:155-159.

This paper discusses areas of conflict between reindeer breeders and others in the course of herding reindeer. Areas of particular concern are forest regeneration, burning, road building, lake level regulation and tourism.

Research is being conducted on lichen growth rates. Increases in *Stereocaulon* sp. are believed to indicate overgrazing.

"The reindeer breeding region in Sweden covers an area of about 165,000 sq. km. (not counting the large lakes) and consists of bare mountains and subalpine birch woodland and coniferous forest land from about latitude 69°N down to latitude 62°N...

"In the pine forests, which form the most important winter grazing grounds, there are occasional conflicts between the interests of reindeer breeding and those of forestry. The reindeer is believed to cause damage to seedlings, when digging into snow in order to get at ground vegetation. The stems and twigs of small, frozen pine saplings may then be accidentally snapped off. On the other hand, the reindeer breeders maintain that the large clearings produced in northern forestry operations result in drifting snow producing hard, wind-packed drifts which make it more or less impossible for reindeer to dig down to the ground. Ice crusts (Sw. *skare*) are also considered to form on the snow surface more in clearings than in the forest.

"Opinions are divided as to the value of controlled burning of the clearings, which is carried out periodically. The Lapps maintain that it damages the lichens for a long time afterwards, while the forestry people consider that the increased growth of grass after burning probably compensates for this loss. The regulation of levels of lakes, the expansion of tourism and the building of roads are examples of other activities which sometime result in considerable difficulties for the reindeer breeder."

Growth and succession studies on lichens in test areas where reindeer were excluded, were constructed within appropriate grazing areas. "In these test areas experiments are being made to determine the growth rate of *Cladonia* species as well as that of different *Stereocaulon* species. [It is believed that increases in this species indicates overgrazing.] The growth in length is determined by photographing marked individual lichens at close quarters at regular intervals of time. Special attention is being devoted to the effect of the intensity of grazing on the growth rate. Attempts are being made to simulate grazing by cutting off portions of individual lichens...

"In a couple of areas in which the lichen cover is somewhat thicker, parts of the lichen cover have been loosened and placed in low, perforated plastic boxes, with an area of about 600 sq. cm., which makes it possible to study the annual growth in weight. The lichens are saturated with distilled water before each weighing."

124. EINARSSON, E. 1970. Plant ecology and succession in some nunataks in the Vatnajökull glacier in south-east Iceland. Ecology of the Subarctic regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 247-256.

This paper discusses the succession on nunataks which became free of ice in the 1930's and later. The plant colonization of these areas seems to start within two years after the melting of the ice. This seems to be about a year later than observed in other areas of Iceland and in northern Sweden. The nunataks however, are isolated by the surrounding ice from areas with vegetation, whereas the areas in Iceland and northern Sweden are moraines in front of retreating glaciers. The distance from one nunatak to the mountains in the east is 9 km, and the distance to the mountains in the west is 8 km. The distance between the nunatak and the edge of the glacier is about 5 km and the distance between the two nunataks studied is only 1 km. Therefore, there seem to be many opportunities for plant dispersal from these areas to the recent nunataks. The author is of the opinion the diaspores are probably windborn or blown along the surface of the ice to the new nunataks. Even whole plant specimens, mostly grasses, with roots and leaves, have been found lying on the surface of the ice far from the nunataks and the edges of the glacier. Grass species seem to be the pioneer plants in such areas accompanied by some few species of mosses. Lichens and fungi seem to invade at a later stage. Exposure to wind, snow cover, and radiation of the sun seems to influence greatly the establishment of vegetation cover. In the established vegetation, the pioneer vascular plants do not play any important role. It is worthy of note that the nunataks are almost entirely covered by moraines and in most parts the soil is very sparse, mostly coarse soil with some clay found between the boulders.

125. EMBLETON, C. and C.A.M. KING. 1968. Glacial and periglacial geomorphology. E. Arnold (publ.) Ltd. Engl. 608 p.

This book contains a two-chapter review of frozen and patterned ground phenomena.

126. FEUSTEL, I.C., A. DUTILLY and M.S. ANDERSON. 1939. Properties of soils from North American Arctic regions. Soil Sci. 48:183-199.

This paper contains a table of soil sample locations and also mentions the species or plant groups at the sample sites. Soils were mainly regosols or lithosols without horizon development, although some peats were sampled. Analyses included: pH, mechanical analyses, total ash, N, organic C, analysis on ash from ignition and colloids analysis. Not all analyses were carried out on all samples.

127. FINNIE, R. 1947. The epic of Canol. Can. Geogr. J. 34:136-138.

Popular account of the building of the Canol pipeline and road.

128. FORMOZOV, A.N. 1946. The snow cover in the life of mammals and birds of the USSR. Mosk, obshchest. ispyt. prirody. Mater. K. poznaniu fauny i flory SSSR Otdel. zool. n.s. 5(20). 141 p.

Arctic Bibliography 21870: "The physical properties and biological influences of snow cover are discussed. Data are presented on the depth and duration of the snow cover in tundra, forest steppe, desert and mountain areas of the USSR. The effect of snow cover on the habits of mammals and birds is

analysed in an attempt to apply the data for the improvement of living conditions for man in the far north"-SIPRE. The animals' mobility, hunt for food, hibernation are dealt with, as well as distribution and migration of certain mammals including reindeer, and the role of snow cover in the history of development of Quaternary fauna.

129. FRASER, M.E. 1956. The lichen woodlands of the Knob Lake area of Quebec-Labrador. McGill Subarctic Res. Pap. 1. Montreal. 28 p.

Descriptions of the communities are given. They are considered ecotonal between tundra and boreal forest. Succession after fire is described.

130. FRASER, J.K. 1959. Freeze-thaw frequencies and mechanical weathering in Canada. Arctic 12:40-53.

The importance of this paper is that it shows that mechanical weathering of rocks is not primarily a result of the lower temperatures or the freeze-thaw frequency but the result of the "absence of a concealing and insulating mantle of snow and vegetation in the north, and is therefore a secondary effect of the climatic factors of low precipitation and low mean annual temperatures."

131. FROST, R.E. 1950. Permafrost. Eng. Bull. Purdue Univ. Ser. 71:101-111.

This short paper is mainly concerned with engineering aspects of permafrost in the Arctic.

"Three types of frozen soils exist in the arctic and subarctic: the upper soils, the active layers, which represent materials which go through annual cycles of freezing and thawing; the subsoils, dry frozen, in which the soil mass contains no ice but is rendered consolidated merely because the temperature is below freezing; and the subsoils, detrimentally frozen,

in which the material contains a large percentage of ice in the forms of lenses, wedges, veins, or large masses of ground ice...

"A delicate balance exists between permafrost, soil, and the protective insulation. Once the protective insulation has been destroyed or even slightly disturbed the sun's heat penetrates and thaw results. To illustrate the delicacy of this balance, the constant use of a game trail by rabbits is sufficient to produce a thaw. One field investigation of such a trail showed that the soils in the trail had thawed to 36 in while three feet on either side of the trail (in the undisturbed area) the normal thaw was 18 in. The root systems of the trees cannot penetrate the frozen soils and the differences in depth of thaw had affected the root system and the trees were pulled inward towards the thaw area...

"All soils are not frozen detrimentally; those which are frozen, vary in the degree and type of permafrost. Those soils which are well-drained internally and are elevated topographically are rarely frozen. Gravels, sands, and some sand and gravel mixtures may be dry frozen. Fine-textured soils such as silts and silty clays are detrimentally frozen. In freezing, these soils permit the accumulation of ice crystals. This is accompanied by a large volume change...When such soils thaw because of the removal of the insulating moss, or the heat of a building, or the construction of a runway, the soil-ice mixture decreases in volume and the supporting power is lost...

"Although the complete details of permafrost patterns have not been worked out, sufficient data is available at present to indicate that the extremely poor soil areas and the very good [soil] areas can be identified by means of aerial photographs. Extensive field work with air photos in hand is showing that areas of detrimental and non-detrimental permafrost can be identified from the aerial photographs and that soil textures can be predicted."

132. FROST, R.E., J.H. McLERRAN and R.D. LEIGHTY. 1965. Photo interpretation in the Arctic and Sub-Arctic. Permafrost Intl. Conf. Proc. 1963. Nat. Acad. Sci., Nat., Res. Counc. Wash. Publ. 1287: 343-348.

This paper concerns the use of aerial photos in interpretation of land form and suitability for engineering projects.

To give information to the engineer...."The following basic principles are necessary for successful analysis of air photos: Air photos record landscape patterns which show the results of relationships between the origin, composition, dynamic factors of physical development and land use.

"Air photo patterns are repetitive and the information content can be extended from area to area only if the origin, composition, and dynamic landscape development are repetitive. The elements of the natural landscape pattern are landform, drainage, erosion, tones, vegetation, land use, and features indigenous to the area.

"The elements of the pattern of cultural development of the landscape are related to such basic urban or rural functions or both, as residential, industrial, governmental, institutional, recreational, municipal services, and facilities, and the transportation-communication net which binds them together."

133. GAS ARCTIC SYSTEMS STUDY GROUP, Sponsor. 1971. Field Programmes, 1971. Environ. Prot. Bd. n.p.

This outlines the projects in wildlife and waterfowl, fishery, vegetation and revegetation studies attempted in the summer of 1971.

134. GAS ARCTIC SYSTEMS. 1971. Gas pipeline research in the arctic environment. Gas Arctic Syst. Study Group. 20 p.

A brochure with excellent photographs describing the test facilities at Prudhoe Bay, Norman Wells, and Nordegg and the Channel study.

135. GILL, D. 1971. Vegetation and environment in the Mackenzie River Delta, NWT — A study in subarctic ecology. Ph.D. dissertation, Dep. Geog. Univ. B.C.

136. GILL, D. 1971. Damming the Mackenzie: a theoretical assessment of the long-term influence of river impoundment on the ecology of the Mackenzie River Delta. Peace-Athabaska Delta Symp. Proc. Univ. Alberta, Edmonton. p. 204-222.

Basic results of damming would be to control flow and accelerate succession to peatland communities.

137. GLADKOV, N.A. 1958. The birds of arctic Yukutia (Tiksi Bay). Problems of the North. 2:177-202. (Transl. from Russian by Nat. Res. Counc. Can. 1961.)

The importance of a town dumpsite in providing suitable nesting sites for birds and mice otherwise unknown in the tundra is described. Mention is also made of unfavourable effects of man on the nesting habits of such species as ptarmigan, geese and ducks.

This dump consists of "discarded wooden shipping containers, such as barrels and especially boxes and crates, tin cans and broken glassware, coils of towing cable, fragments of boats, bricks, etc., which are dumped in this place." The dump has a higher than normal concentration of nesting species, and a few species not known elsewhere in the nearby tundra.

"The fact suggests that a specific fauna of the settlement landscape, one that has a clearly defined zonal character, is gradually evolving in the tundra. In the tundra, as in the rigorous desert conditions of Soviet Central Asia, man is creating biotopes more favourable for bird life, and is thus enriching fauna...

"As far as mammals are concerned, we may mention the invasion of the settlement by the domestic mouse, an immigrant that has become an integral part of the fauna of the settled

landscape in many geographical zones of this region. Until recently the domestic mouse was unknown anywhere in the Siberian northland, from the Yenisei River to the Chukchi Peninsula, while at the present time, as we found out, it is common both in Tiksi itself, and on the dump. Since we observed mice even before the navigation season, they must have wintered safely in these parts.

"When speaking of the favourable influence of man on bird fauna of the tundra, one must not forget also the adverse influence, which is rather sharply reflected in the direct destruction by man of some bird species. It is quite probable that on the sites investigated by us the ptarmigan did not nest owing to the dense human population of the bay, and the large number of hunters there. Perhaps this also is part of the reason why neither geese nor ducks nest in these parts."

138. GORODKOV, B.N. 1935. Vegetation of the tundra zone in the USSR. (Transl. Russian title). Izd-vo Akad. Nauk. SSSR. 141 p.

Arctic Bibliography 5993: "Contains notes on extent and climate of the tundra zone; a detailed description of plant associations and other characteristics of the various types of tundras; an index to plant species discussed in the text, and a bibliography."

139. GORODKOV, B.N. 1944. Tundras of the Ob-Yenisei Watershed. (Transl. Russian title). Sovet. Bot. 3:3-20; 4-5:20-31.

Arctic Bibliography 5995: "Contains results of the study of tundras of Gydan Peninsula between Yenisei and Ob'-Taz Bays...carried out by Gydan Expedition...in 1927. Special attention is given to succession of tundra plant associations and analyses of various zones of tundra vegetation."

140. GRAVE, N.A. and I.A. NEKRASOV. 1961. Some observations on thermokarst in the vicinity of the settlement of Anadyr. Problems

of the North 4:165-172. (Transl. from Russian by Nat. Res. Counc. Can. 1962.)

This paper describes changes in the tundra as a result of human activity between 1935 and 1953. Diagrams are given of the site in 1936 and 1953, showing the degradation that has taken place after extensive tractor movement on part of the experimental area., Adjacent tundra, undamaged by vehicles, has remained unchanged. Beneath the tundra which is rather wet, there are large ice lenses which have known orientation. In the badly damaged area not only was the vegetation cover completely destroyed but the peat layer was badly damaged and it is here that thermokarst began to develop rapidly. "This process was especially vigorous in sections where deep tracks served as channels for numerous small creeks.

"During the relatively dry summer periods, the newly formed shallow gullies are partly filled by soil creep from the surrounding slopes. During the rainy periods, however, they become deeper again and the melting of the ice sets in. As a result, the tundra becomes almost completely covered by gullies, holes and lakes...Comparison of [the two sketch] maps shows that a well-defined gully has been formed in recent years in the central part of the site, on the terrace of the left bank of Malkii Creek. In 1946 instead of a gully there was a deep rut along which water flowed during the warm seasons. In 1951, when the gully became much deeper, the creek uncovered some ground ice. From that time on, the rate of the development of the gully became much faster...

"At present, a small creek flows along the gully on the experimental site during the entire summer; it is fed by surface waters. During the rainy season the water level of the creek rises sharply. In addition to this gully, a whole system of small lakes is being formed here in recent years. The largest ...reaches 60 cm [in depth] in places. Its bottom almost everywhere consists of a thin, peaty mass. A leg will sink into it to a depth of 25 to 30 cm, where it encounters the frozen layer. Slope of the lakeshore is gradually becoming more gentle. As a rule, smaller lakes in this region dry up during the dry summer period.

"A section of tundra devoid of vegetation cover stretches east...and west...of the gully. The sub-layer of peat in this section has been completely destroyed. The surface here has been plowed up by tractors — deep ruts, sink holes and numerous small lakes up to 15 sq m in area may be seen everywhere.

"In the meantime, the adjoining section of the tundra, which is hardly ever disturbed by tractors, has remained undamaged. The surface has retained the appearance of hummocky tundra and there are no sink holes, gullies, or lakes.

"As a result of the disturbed conditions on the experimental site, the depth of summer thaw and the temperature regime in the upper rock strata have been altered...

"The data given show clearly that in this region thermokarst is developing not only in places where the cover of moss and cotton grass has been badly disturbed, but also where the peat layer has been damaged, resulting in the formation of sink holes and deep ruts with temporary water streams. At present, such disturbances to the natural conditions are due entirely to human activities."

141. GREEN, G.W., A.H. LACHENBRUCH and M.C. BREWER. 1960. Some thermal effects of a roadway on permafrost. U.S. Geol. Surv. Prof. Pap. 400-B. p. B141-B144.

The effects of a roadway on the thermal regime of the ground are described. The depth of thaw under the road is much greater than neighbouring undisturbed sites. In summer, roadways are generally warmer and in winter cooler than the

surrounding ground. Roadways are highly sensitive to changes in air temperature. Reduction of moisture content results in less time to thaw to a given depth and hence in anomalously warm seasons the deep thaw is accentuated.

142. GRIGGS, R.F. 1934. The problems of Arctic vegetation. J. Wash. Acad. Sci. 24:153-175.

This is a theoretical paper on the problems of defining plant communities in the arctic. The plant groupings are considered as merely an admixture of whatever arrives. No descriptions are given of vegetation — the author believes that frost action is the main cause of the problems.

143. GRODZINSKI, W. 1971. Food consumption of small mammals in the Alaskan taiga forest. Ann. Zool. Fenn. 8:133-136.

From the author's abstract: "In a white spruce forest (*Picea glauca*) both primary and net production and the numbers of small mammals were estimated...In different years small mammals may consume 3 to 47% of their potential food supply in the taiga forest, which is proportionately higher than in other woodlands."

144. HANNA, G.D. 1963. Oil seepages on the Arctic Coastal Plain, Alaska. Occas. pap., San Francisco, Calif. Acad. Sci. No. 38. 18 p.

A review of the information available on the history, position, human use and bones of trapped animals, at oil seepages on the Arctic Slope.

145. HANSEN, H.P. 1952. Postglacial forests in the Grande Prairie-Lesser Slave Lake region of Alberta, Canada. Ecology 33:31-40.

Concerns the use of pollen profiles in reconstructing forest types.

146. HANSEN, H.P. 1953. Postglacial forests in the Yukon Territory and Alaska. Am. J. Sci. 251:505-542.

Postglacial forests as revealed by pollen analysis of peats from the Yukon and Alaska are described. Distribution of various species is discussed.

147. HANSON, H.C. 1950. Vegetation and soil profiles in some solifluction and mound areas in Alaska. Ecology 31:606-630.

Detailed analyses are given of vegetation and soil profiles on several solifluction and mound (hummock) areas in Alaska. The vegetation in these areas was dense and consisted mostly of sedges with the most important species being *Carex bigelowii* and other important sedges were *Eriophorum vaginatum*, *E. angustifolium*, plus several other species of *Carex*, mosses, particularly *Hypnaceae* and sometimes *Sphagnum*. Species of *Salix*, *Vaccinium* and *Ledum* were common. In the areas studied the invasion of plants into bare areas caused by various denudation processes appeared rapid, by vegetative means rather than by seeds.

"Factors influencing solifluction and mound formation and mound movement are degree of slope, direction of slope, abundance of water, at least during part of the year, upper ground horizons saturated with water, a fine silt or clay horizon below the saturated layer which has flow qualities, forces arising from freezing and thawing, an underlying layer of frozen ground or other hard material, and the presence of obstacles, such as boulders, ridges, or vegetation."

148. HANSON, H.C. 1951. Characteristics of some grassland, marsh and other plant communities in western Alaska. Ecol. Monogr. 21: 317-378.

Detailed lists of species and soil descriptions are given for various communities from Kodiac Island north to

Kotzebue and Big Delta, and comparisons are made with areas in Norway and elsewhere. Permafrost occurrences are mentioned. The dwarf heath-lichen communities with general occurrence on gravelly or stony land is important for winter caribou and reindeer fodder.

149. HANSON, H.C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other arctic regions. Ecology 34:111-140.

Information on the revegetation of denuded areas (usually produced by frost action) by species from the surrounding vegetation is included. The author notes that such information is very scarce.

From the summary: "A preliminary classification of the vegetation of northwestern Alaska is presented. It contains six major physiognomic classes and 22 types...The types occupying the largest land areas are the cottongrass-sedge-dwarf shrub-heath complex, sedge marshes, alpine *Dryas*, dwarf shrub, willow shrub, birch shrub, and white spruce-shrubs.

"The important factors influencing the development, maintenance or changes in the species composition within the types are soil moisture, mineral and organic composition of the soil, soil texture, soil reaction, depth to which the soil thaws during the summer, freezing and thawing processes in the soil, (congeliturbation), drainage conditions, depth and duration of snow cover, exposure to wind, biotic influences such as grazing and trampling by reindeer and other animals, rodent activities, plant competition, and various man-caused influences such as burning, drainage, flooding, earth-moving, etc...

"This classification has been found useful in making aerial surveys of lichen range suitable for grazing during the winter by reindeer. The various types are valuable in indicating soil conditions such as depth to perennial frost, kind of surface and subsurface materials, and moisture and drainage conditions. As a result, the classification is of value when surveys are made for locating roadways, camp sites, landing fields, etc."

150. HARE, F.K. 1968. The Arctic. Quart. J. Roy. Meteorol. Soc. 94: 439-459.

A review paper of the climatology of the arctic and its influence on vegetation zones, land ice and the relationships of the Arctic seas to the energy balance.

151. HARE, F.K. 1970. The tundra environment. Roy. Soc. Can. Trans. Ser. 4., 8:393-399.

The climate of the tundra is described in thermal terms as one "where the annual net radiation income is between 0 and 15 Kly, and where mid-summer means daily air temperatures are roughly... 3 - 10°C...

"Powerful inversions cover the tundra and boreal forest most of the winter and some of the summer.... [Whatever their nature] the arctic airstreams have a much lower capacity to remove atmospheric contaminants by turbulent diffusion than do most airstreams. They are hence vulnerable to pollution by smoke sources.

"The best known examples...are the ice fogs of winter in the towns of the Northwest...other towns...built in these areas...will be prone to this hazard." e.g. Fairbanks is "one of the most polluted places on earth...

"This inability of the winter atmosphere to disperse pollutants is more than simply a nuisance to town dwellers. There is also the question of fall-out. Evidence is accumulating that effluent substances, and such poisons as lead and arsenic, tend to be precipitated or deposited close in to the emmitting site, so one visualizes a sort of metamorphic aureole of contaminated soil, vegetation and surface water gradually

ringing northern towns." Speculations on possible long range effects are also presented.

152. HARINGTON, C.R., A.H. MacPHERSON and J.P. KELSALL. 1962. The barren ground grizzly bear in Northern Canada. Arctic 15: 294-298.

An outline of the distribution of the barren ground grizzly bear and other notes from records concerning the animal.

153. HARPER, F. 1963. Caribou and eskimos. Int. Union Conserv. Nature (IUCN) Bull. 1:6-7.

Contains information on $Sr.^{90}$ fallout.

154. HARWOOD, T.A. 1965. Dew line site selection and exploration. Permafrost Intl. Conf. Proc. 1963. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287:359-363.

This paper records that few problems were experienced (except for some frost action damage) at the DEW Line stations. Bad permafrost areas were identified using air photos and avoided during construction.

Conclusions: "The DEW line was built in haste and with great urgency; therefore it was considered by the contractors and engineers acceptable to take risks. With this in mind, possible permafrost problems became rather secondary considerations, the primary consideration being location of buildings and, in particular, towers with regard to the overall requirements of the line, and the alignment and approaches to airstrips.

"Study of air photos showed where bad permafrost conditions might be expected and avoided; but generally the instructions were to disregard soil conditions, accepting the principle that if problems did arise they could be rectified after the Line was in operation. The facts support this procedure, for so far as is known, only one station experienced

damage from frost action (not permafrost), while on one or two airstrips some slump later occurred, and this was quickly corrected. Special procedures were taken in designing tower foundations to prevent misalignment, and again, so far as is known, no problems followed.

"The siting of these stations could, therefore, be called a purely pragmatic approach to permafrost. It was there, it had to be dealt with, and it was dealt with in the classic manner — by using thick gravel pads or piles. One thing is certain: Permafrost did not slow up site surveys or construction.

"It must be realized, however, that, in all cases, building trains were light, and for the remaining facilities there were very few units that were heated or had foundation problems that could not be rectified by adding more gravel."

155. HARWOOD, T.A. 1969. Some possible problems with pipelines in permafrost regions. Third Can. Conf. Permafrost Proc. Nat. Res. Counc. Can., Ass. Comm. Geotech. Res., Tech. Memo. 96: 79-84.

A summary of the effects of the 3 possible solutions to building a pipeline in permafrost areas are presented:

1. a road with the pipeline along one side covered with fill and appropriate insulation;
2. lay the pipe in a trench in the active layer or in permafrost;
3. lay the pipeline on piles and insulate it.

Of the three, the first is considered most feasible but much work still remains to be done before feasibility is proven.

156. HEAL, O.W. ed. 1971. International Biological Programme, Tundra Biome. Working meeting on analyses of ecosystems Kevo, Finland. September 1970. Tundra Biome Steering Comm., London, Engl. 297 p.

Background information on the I.B.P. tundra projects is presented. Contains a table of studies of human manipulation of the tundra. Canadian studies include effects of: fertilizing; plant and soil removal; crude oil in forest, heath-tussock and sedge communities; fire in tussock communities. No results are presented here.

157. HEILMAN, P.E. 1966. Change in distribution and availability of nitrogen with forest succession on north slopes in Interior Alaska. Ecology 47:825-831.

Evidence is presented of increasing nitrogen deficiency in trees associated with sphagnum build-up on the forest floor, the decreasing depth to the permafrost table and the bulk of the soil nitrogen being in the lowest, coldest layers. Soils under colonizing birch have nitrogen in the upper, warmer layers and the suggestion is made that fire may initiate changes in nitrogen distribution in the soil.

Author's abstract: "Forest succession on north slopes in interior Alaska results in the development of sphagnum bogs on sites formerly occupied by productive forest. This process is one of gradual deterioration of site associated with the accumulation of moss layers on the forest floor. Advancing succession is accompanied by an increasing nitrogen deficiency in black spruce trees. Black spruce growing on the sphagnum bogs are extremely nitrogen deficient. As the moss layers thicken, the soils become increasingly cold with permafrost rising to within as little as 15 in. of the surface of the sphagnum soils. Examination of the depth distribution of nitrogen revealed very small quantities of nitrogen in the upper and warmer portions of these profiles, with the bulk of the nitrogen located in the very cold and latest to thaw, lower layers.

"In contrast, in the soils under birch [*B. papyrifera* colonizing burned areas - almost no organic surface layer] most of the nitrogen was located in the warmest upper layers. Under these conditions, much higher rates of mineralization of soil nitrogen must be obtained. These results show why burning, although changing many factors including volatilization of an undetermined amount of nitrogen, may lead to a large increase in available nitrogen because of the change in depth distribution of the nitrogen in the soil."

158. HEILMAN, P.E. 1968. Relationship of availability of phosphorus and cations to forest succession and bog formation in interior Alaska. Ecology 49:331-336.

<u>Author's abstract</u>: "Concentrations of phosphorus, potassium, calcium, magnesium, manganese, and zinc in black spruce foliage were examined in relation to forest succession on north slopes in interior Alaska. Decline in levels of phosphorus and potassium in the foliage corresponds with rapid decline in forest productivity. Levels of phosphorus and, to a lesser extent, potassium in foliage appear to be deficient on sphagnum soils. Magnesium levels show a slight decrease, but do not fall below deficiency status even on deeper sphagnum soils. Calcium, manganese and zinc show no relationship to forest succession and are at adequate levels in all stages. Concentrations of available phosphorus and exchangeable cations in the soils show no differences between soils corresponding to those found in nutrient levels in the foliage. However, total quantities of phosphorus, potassium, and magnesium, in available and exchangeable forms are consistently lower in sphagnum soils. Also, the depth distribution of these nutrients on a volume basis differs among soils: in sphagnum they are located at deeper depths, while on mineral soils they are concentrated in surface

layers. This distribution difference and the increasing coldness of the soil as moss accumulates appear to be sufficient to reduce the availability of these nutrients.

"Radio-carbon dates showed that 18-28 in (41-71 cm) of sphagnum peat, weighing 270,000-510,000 Kg/ha had accumulated in less than 185 years. The average annual increase of 1,500-2,800 Kg/ha indicates that, in spite of low growth of trees on sphagnum soils, total productivity in dry weight is appreciable."

Conclusions: "Results from this investigation indicate that declining availability of nutrients is a primary factor in reducing productivity of forests with advancing succession on north slopes of interior Alaska. The significant drop to deficiency states of nitrogen, phosphorus and potassium in the foliage of black spruce even before sphagnum mosses have become established, testifies to the importance of this declining availability even in the early stages of succession ... "

159. HENSHAW, J. 1968. The activities of the wintering caribou in Northwestern Alaska in relation to weather and snow conditions. Int. J. Biometeorol. 12:21-27.

Describes in detail the habits of wintering caribou and their behavioural characteristics. Snow morphology plays a strong role in controlling their behaviour.

Migrations of caribou (*R. tarandus*) from winter range along the Kobuk River to the summer range north of the Brooks Range water sheds lasted from April to June, and reverse migrations started in late August and were finished by late November.

Caribou generally preferred open (i.e. non-forested) sites where snow was shallower and hence food easier to obtain. "The animals conserved energy by occupying wind-

shadowed locations during storms [lying down] and by changing territories and feeding intensively during calm periods. It is postulated that numbers of caribou may be controlled by the morphology of the snow cover since they exhibited strong selection against snow criteria inappropriate to specific activities essential to their viability ... would not dig for food where snow cover was more than 70 cm thick."

They change behavioural patterns in winter - do not range in a random fashion as in summer, but "displayed consistant responses to variables of the physical environment."

160. HILL, R.M. 1971. The Arctic environment and petroleum pipelines. The Musk-ox. Publ. 9:35-41.

A general account of the Arctic environment, permafrost, flora and fauna. An outline of the various changes to be expected from the pipelines is given, as well as the environmental challenges to be met when they are built.

161. HIRVONEN, R.P. 1968. Report on the forest conditions in the Lower Liard River Basin, Yukon/NWT. Can. Dep. For. Rural Develop., For. Manage. Inst., N. Surv. Rep. 3. 14 p. plus appendices.

This report gives a general description of the forests of the Lower Liard River Basin, which are predominantly white spruce or spruce mixedwood composition. Forest inventory maps are included for the area which was surveyed. Much of the area has been burned.

162. HOCK, R.J. 1956. Alaskan zoogeography and Alaskan amphibia. Fourth Alaskan Sci. Cont. Proc. p. 201-206.

Quoted by Péwé (1957) concerning the distribution of frogs.

163. HOK, J.R. 1969. A reconnaissance of tractor trails and related phenomena on the North Slope of Alaska. U.S. Dep.

Int., Bur. Land Manage. 66 p. 76 photographs.

A description of damage and progress in restabilization of tundra, disturbed by tracked vehicle trails of known history is presented.

It soon became apparent that although "weasels" and "bombardiers" were used in oil exploration, extreme scarcity of their recognizable tracks indicates that they do not generally cause long-lasting disturbances. Caterpillar-type tractors often cause marked changes in the ground surface. "The single most important variable in determining what changes will occur ... is the season during which the operation was conducted ... [in summer] degree of blading, substrate water content and degree of slope interact to such a degree that it is difficult to discuss one without discussing the others. This close relationship is evident when one considers that the degree to which the surface is disrupted determines the change in heat balance between air and substrate; the substrate in turn responds according to its composition until a new equilibrium is attained; but if slope permits the products of the thawing process to be continually carried away, exposing new frozen material, no new balance can be established." Example of trails crossing poorly drained areas show banks still slumping 7-10 years after initial disturbance with no sign of stabilization. Photographs are presented illustrating various combinations of the above factors.

"Trails which were made during winter, while the ground was frozen, pose a different problem than those which were created by summer travel. Changes along winter haul routes, although more subtle than the effects of running a tractor across semi-solid ground, were nonetheless evident ... Probably two major methods of construction for winter haul roads should be considered:

1. those in which snow and surface irregularities are bladed away for use by heavy trucks;
2. those in which snow is packed and smoothed for use by tractor-drawn sleds.

"When observed during the summer, this type of road [constructed by the first method] generally consisted of a main track of black soggy, exposed peat from which living vegetation has been worn away. A margin of dead vegetation extended some 10 to 20 feet on either side of the main track. Old Navy trails [made prior to 1953] made of packed snow generally did not break the tundra surface. These trails almost invariably followed the most gently contoured course which was available ... The vegetation in these winter sled trails was not scraped or worn away, but was killed and had not fully recovered by the time of observation ...

"It is interesting to note ... [on a bladed winter trail] that the areas immediately adjacent to the actual roadbed, presumably where snow was heaped and packed while keeping the road open, have the same appearance as the snow-packed trail beds. The cause ... is probably a combination of mechanical pressure and shortened growing season (due to late melting of the packed areas) ...

"The most certain means for limiting damage to North Slope environment seems to be prevention rather than rehabilitation. In conclusion it may be said that once a decision is reached to proceed with surface movement of heavy equipment, one thing should be recognized: any marks, once made, will probably last for an indeterminate period of time; the nature and extent of these marks will depend upon the manner in which the operation is planned and carried out."

164. HOLLOWAY, C.W. 1970. Threatened Vertebrates in northern circumpolar regions. Productivity and conservation in

Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:175-192.

This paper discusses the threatened vertebrates of the Arctic and postulates that two main factors control the survival of the species: 1) overexploitation of the species and 2) modification of the environment. Of these, the first is by far the most important. However, discussion on the modification of the species environment indicates the following. "Vibe ... is of the opinion that climatic fluctuations have exercised a greater effect on Arctic wildlife populations than is generally appreciated. In particular, he suggests that depletion of many of the marine mammals during the present century may have resulted, not from over-exploitation, but from the decline in the production of plankton, following retreat of the sea ice."

Human modification of the environment is likely to be more rapid in the future as Arctic resources are developed.

"Threatened Arctic vertebrates have undoubtedly been affected by man's modification of their environment but, for the most part, the changes have occurred outside the Arctic. Migratory routes and wintering grounds of most Arctic breeding birds have been affected by land development and, in the northern zones of the boreal forest, Caribou wintering grounds have been destroyed by fire." On the subject of the introduction of Reindeer, the author goes on to say: "Largely as a result of poor management, domestic Reindeer have caused overgrazing both in Alaska and in Scandinavia ... It would be unreasonable to condemn all domestications of wild animals and their husbandry in the Arctic. Nevertheless, the tundra is a very fragile environment and, under some conditions, intelligent management of wild herbivores without domestication might produce an equally satisfactory return from a wider variety of sources, and would certainly create fewer problems for the conservation of the habitat ....

"In the future the greatest threats to the Arctic environment are likely to arise from large scale development associated with hydro-electric schemes and mineral exploitation. Exploration and drilling for oil will probably have the widest impact. Sedimentary rock formations, which are potential sites for the discovery of petroleum, occur over much of the Soviet Arctic, the western third of the American mainland Arctic and the northwestern region of the Canadian Archipelago. In July 1968, the discovery of an oil field, which may be one of the world's largest, at Prudhoe Bay, Alaska, was announced. The speed with which oil and gas exploration has since spread across the Mackenzie River Delta and into the Canadian Archipelago has been phenomenal.

"The variety and magnitude of the problems posed by oil booms in the Arctic for the conservation of species are equally staggering. Human disturbance, damage to soil and vegetation by traffic and fire hazards will be increased. Construction of road and rail routes for oil will make extraction of other resources economically feasible. Pipe lines stetching over vast distances could obstruct wildlife migration routes. Oil pollution, both on land and at sea may create special problems in the Arctic. Low temperature of the sea might inhibit breakdown of oil by micro-organisms and proximity of ice packs to the shore could reduce its dispersal."

Three basic needs must be met:

"1) Survey and reservation of representative samples of biotopes,

2) Continued and expanded ecological research,

3) Co-ordination of research and management effort ..."

165. HOLMES, G.W., Helen L. FOSTER and D.M. HOPKINS. 1965. Distribution and age of pingos of interior Alaska. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci-Nat. Res. Counc. Wash. p. 88-93.

Classification, distribution, origin, development and degeneration of pingos are described in this paper.

A symmetrical pingo in the upper Tanana area (63° 55' N, 144°33' W) in the zone of discontinuous permafrost in Alaska was "covered by a mature stand of aspen, birch and spruce and surrounded by scrubby muskeg vegetation. "A cratered pingo at 63°45' N, 144°12' W, has "a mature birch forest on its flanks, a circular pond in the crater and muskeg vegetation in the valley floor around it ... 'McKinley Creek (65°09' N, 150°20' W) pingo is an unusually broad, low mound, with vegetation concentrically zoned, grading inward from wet-ground plants around its margin to a birch-willow-heath assemblage on its well-drained summit ...

"No pingos were reported from upland tundra on hill or mountain summits here, but many exist on muskegs and bogs within the boreal forest. Of 170 pingos whose vegetational environment is known, 61% are in forested areas, 34% in areas of shrubby muskeg vegetation and 5% in treeless bogs."

Conclusions: "Closed-system pingos have not been recognized in interior Alaska and probably are not present there. Thus far they have been reported only from areas of continuous permafrost having mean annual air temperatures of 12° to 22° F. Within these areas, they are confined specifically by certain hydrological and edaphic conditions, as shown by Müller; these conditions are mostly commonly met in shallow or drained lake basins.

"Open-system pingos are abundant in the discontinuous permafrost zone of interior Alaska in areas having mean annual air temperatures of 22° to 28° F; they are rare in the continuous permafrost zone, but have been reported in East Greenland where the mean annual air temperature is about 14° F. Within interior Alaska, open-system pingos are confined to areas where the following hydrologic and edaphic conditions exist: a) a thick layer of unconsolidated sediments mantling a sloping surface; ground perennially frozen to depths of the order of 100 feet; b) an aquifer present beneath the perennially frozen sediments through which ground water flows to the pingo site.

"Open-system pingos of central Alaska are of diverse ages; new ones have formed continuously during the last several thousand years. Thus, they did not result from any known single recent climatic fluctuation in central Alaska.

"Although no pingos of Pleistocene age are known, they could have formed in periglacial interior Alaska. Open-system pingos, and possibly also closed-system pingos, pass through a sequence of developmental and degenerative stages, eventually becoming lakes with uneven, raised shores. Possibly some of the hundreds of small lakes in the valleys of the Yukon-Tanana upland, sometimes regarded as thaw lakes, may be very old pingo craters."

166. HOLOWAYCHUK, N., J.H. PETRO, H.R. FINNEY, R.S. FARNHAM and P.L. GERSPER. 1966. Soils of the Ogotoruk Creek Watershed. Environment of the Cape Thompson Region, Alaska. N.J. Wilimovsky and J.N. Wolfe, ed. p. 221-273. U.S. Atomic Energy Comm., Div. Tech. Inf.

Morphology, physical and chemical properties of the soils are described and discussed. The soils are classified into 19 taxonomic classes. A table of equivalents of Great Soil Groups and Great Groups and Subgroups is presented. The most extensive soils are derived from or influenced by mud-stone and graywacke materials and are strongly or very strongly acid soils.

167. HOPKINS, D.M. 1949. Thaw lakes and thaw sinks in the Imuruk Lake area, Seward Peninsula, Alaska. J. Geol. 57:119-131.

Certain lakes and depressions in the Imuruk Lake area, are ascribed to subsidence following the thawing of perennially frozen ground. The mechanisms of formation are described.

"Some of the most spectacular examples of subsidence due to excessive thaw result from the disruption of the tundra mat by human activities. During 1945, a gentle, hill slope had been crossed repeatedly by a Caterpillar tractor. When first examined in 1948, the route of the tractor was marked by long, swampy furrows, indented 3 to 12 in in the tundra. Later in the summer, a series of sink holes, 3 to 5 feet deep, connected by subterranean water courses, was discovered beneath the tracks in areas where the tractor had travelled directly upslope. Still later, the routes of the connecting caverns had collapsed, and the course of the tractor was marked by narrow gullies 3 to 4 feet deep."

It should be noted that the soils in this area are composed of 5 to 20 feet of uniform, fine-grained residuum, scattered boulders lying on the soil surface, and increasing in abundance at depth. 'Masses of clear ice constitute a major component of areas of peat and frozen, fine-grained soils in the Imuruk Lake region." Most of the ice occurs as horizontal lenses or vertical wedges. "Areas mantled with deep residual soil commonly are covered with a dense mat of peat-forming tundra vegetation, including *Eriophorum vaginatum*, various shrubs and heaths, and *Sphagnum* mosses. The dense, interlocking mat of living and dead vegetation constitutes an effective insulator, beneath which summer thaw penetrates only 1 to 3 feet. Beneath areas of bare soil, however, seasonal thaw extends to depths ranging from 3 to 10 feet."

Thaw lakes: "In the Imuruk Lake area, thaw lakes originate in areas of locally deep thaw, which can be initiated in any of the following ways: 1) by disruption of the vegetal cover by frost heaving. Some of the resulting, bare soil areas subside sufficiently upon thawing to collect small pools of water beneath which thawing is further accelerated. (2) By accelerated thaw beneath pools occupying intersections of ice-wedge polygons. These polygons in the soil are reflected at the surface by shallow, swampy trenches. The intersections of the trenches commonly are marked by shallow pools of standing water. (3) By accelerated thaw beneath pools in small streams. The smaller streams flow in indistinct, vegetation-choked channels. Obstruction of the channels by especially luxurient vegetation or by small mounds raised by differential frost-heaving dams small pools beneath which rapid thawing and subsidence takes place.

"The recognition of thaw features in the field and on aerial photographs is useful in engineering and in water-supply studies. Considerable subsidence can be expected in areas in which thaw lakes, sinks, or depressions are present if the surface vegetal mat is disturbed or if the ground is heated beneath poorly insulated buildings. Thaw sinks indicate the presence of thawed zones in a permeable substratum in which some supply of ground water can be expected."

168. HOPKINS, D.M. and R.S. SIGAFOOS. 1951. Frost action and vegetation patterns on Seward Peninsula, Alaska. U.S. Geol. Surv. Bull. 974-C. 100 p.

Cryopedologic terrain features are described in detail together with their probable relationship to vegetation, methods of origin and course of development. These features are found on various poorly drained areas and where perennially frozen ground is present at 3 feet or less. All start from frost scars which may be initiated in several ways including burrowing animals and grazing reindeer. This paper is considered by some to be the definitive work on caespitose tussocks.

Author's abstract: "Cottongrass tussocks, frost scars, peat rings, tussock rings and groups, and tussock-birch-heath polygons in the Imuruk Lake area, Seward Peninsula, Alaska, are products of the interaction of congeliturbation (frost churning) and vegetation development. These cryopedologic features are found on poorly drained areas on summits, slopes of less than 10°, and lowlands where silty mineral soil is present beneath a cover of peat or turf less than 3 feet thick. Perennially frozen ground is present at depths of 3 feet or less.

"The tussock is a ball-like tufted plant form characteristic of certain grasses and sedges found in swampy areas. Differential frost heaving increases the height of tussocks of cottongrass (*Eriophorum vaginatum* subsp. *spissum*) by lifting the plant above the soil surface during the autumn freezing cycle. Frost scars are areas of bare soil resulting from disruption of the vegetative cover by local intense frost heaving.

"Peat rings, tussock rings, and tussock groups consist of vegetation patterns associated with widely spaced mounds of mineral soil projecting through otherwise continuous layers of peat or turf. Tussock-birch-heat polygons consist of closely spaced mounds of mineral soil separated by channels filled with peat. The peat rings, tussock rings, tussock groups, and vegetation polygons represent stages in several developmental series, all of which start with frost scars as the initial form. The final features of these developmental series are the result of congeliturbation, a process which is effective chiefly during the fall freezing cycle and which is modified by the development of the vegetation ...

"The concept of a "climax" vegetation must be modified when applied to tundra vegetation. Disturbance of the substratum occurs repeatedly, and all stages of plant succession exist on unstable surfaces. The vegetation ... represents an equilibrium assemblage adjusted to the climate in which it exists but differs from a "climax" assemblage in that bare areas and areas covered by pioneer plants are intimately mixed among areas covered by assemblages representing the highest stage in the succession ...

"Recognition on aerial photographs of the cryopedologic features described above will assist in the interpretation of terrain conditions."

In the main body of the paper discussion on perennial frozen ground and frost action and congeliturbation and instability of the soil surface is well covered. In the section on vegetation the wet tundra is organized into several vegetation patterns: tussock-birch-heath vegetation, with or without a sedge sod, and willow and birch thickets.

"These plant communities are clear-cut and can be defined in space and correlated with factors in the environment. The three factors most closely correlated with the distribution of the communities are drainage conditions, depth to perennially frozen ground, and the intensity and character of congeliturbation. These in turn are determined, in part, by topography, type of soil, and the character of the vegetation. Each type of vegetation, however, is found locally within the area dominated by another type."

Cryopedologic features are discussed in detail. In the frost-scars section it is noted that their areas originate in a variety of ways. "Burrowing mammals can destroy the stems and roots of plants and probably are effective in initiating a break in the turf, which can be enlarged by congeliturbation. Close grazing by reindeer is an important factor in breaking turf in some localities ... From the air, reindeer corrals near Teller, Alaska, can be distinguished from the surrounding tundra by the presence of closely spaced frost scars in the corrals as contrasted with their absence or relative scarcity in adjoining ungrazed tundra. Cotton-grass tussocks overturned by frost heaving are found locally; the area can become the nucleus of a growing frost scar. In areas mantled with a continuous layer of peat or turf, the surface cover can be broken during the autumn freezing cycle by intense dilation of the underlying mineral soil in spots where the peat is relatively thin, in exceptionally wet spots, or in spots swept bare of snow by the wind following an early snowfall ...

"Once formed, frost scars tend to be self perpetuating." Discussion then follows on succession of vegetation on the scars. As a general rule, colonization occurs by the species which surround the scar. Colonization of the scars is a slow process. Shifts in the balance of plant growth versus congeliturbation result in advances or net losses in the progress of colonization. "Variations from year to year in the number and sharpness of diurnal freeze-thaw cycles probably are reflected by general regional growth or decay of frost scars ... In summary, colonization of frost scars by vegetation appears favoured by an early sudden freeze-up with previous nocturnal frosts and by an early snowfall, especially if it occurs before final freeze-up."

Discussion continues on the formation of tussocks, peat rings, ridges and tussock rings and tussock groups, as well as tussock-birch-heath polygons.

"Recognition of the cryopedologic features described here is useful to the photo interpreter in predicting trafficability and foundation problems ... Peat rings, tussock rings, and tussock groups generally cannot be distinguished from one another ... but these three features can be distinguished from tussock-birch-heath polygons or stripes. [That is on aerial photographs with a scale of 1:10,000 or larger]. The presence of any of these features indicates the probable presence of fine-grained soil in which perennially frozen ground is present at a shallow depth. The thickness of peat at the surface and the moisture conditions of the surface can be estimated if the polygons can be distinguished from the rings. Maximum degree of slope can be estimated from the degree of elongation of the features."

169. HOPKINS, D.M., T.N.V. KARLSTROM and OTHERS. 1955. Permafrost and ground water in Alaska. U.S. Geol. Surv. Prof. Pap. 264-F. 146 p.

A summary at the present knowledge of permafrost and ground water conditions in representative areas at Alaska.

"Assessment of permafrost conditions is aided by recognition on aerial photographs of positive and negative indicators such as certain plant associations, polygonal micro-relief patterns, surface features produced by local thawing of permafrost, pingos, and hydrologic phenomena such as flood-plain icings. Individual indicators are found to be ambiguous to varying extents ... With rare exceptions, no single feature recognizable on aerial photographs can be taken as an infallible indication of the presence or absence of permafrost ...

'The following tabulation indicated the minimum depth

depth to permafrost, if it is present, beneath some vegetation assemblages that are widespread in Alaska."

Tall willows on flood plains	8 feet
Pure stands of mature aspen or white birch	4 feet
Mixed willow, alder and white birch	3-4 feet
Pure stands of balsam poplar	3-4 feet
Mixed white spruce and balsam poplar	3 feet
Pure stands of white spruce	2-3 feet
Mixed stands of white birch and white spruce	2-3 feet
Mixed white and black spruce	1-2 feet
Black spruce in wet tundra or muskeg	1 foot

170. HULTÉN, E. 1958. The amphi-atlantic plants and their phyto-geographical connections. Kungl. Svenska Vetenskapsakadem. Handl. Fjarde. Serien. Band 7. Nr.1. Almqvist and Wiksell, Stockholm. 340 p.

This work concerns the distribution of those plant species which occur on both sides of the Atlantic Ocean but are absent from the Pacific area. Distribution maps are given for each species.

171. HULTÉN, E. 1962. The Circumpolar Plants I. Vascular cryptogams, conifers, monocotyledons. Almqvist and Wiksell, Stockholm.

Each plant species is mapped and taxonomic and distributional notes accompany it. There are no keys.

172. HULTÉN, E. 1968. Flora of Alaska and neighbouring territories. Stanford Univ. Press, Stanford, Calif. 1008 p.

This is a manual of the vascular plants of the region, containing keys, distribution maps and notes on habitats. The introduction discusses general ecology, geology, history of plant collection and taxonomic aspects of the area.

173. HULTEN, E. 1970. The Circumpolar Plants II. Dicotyledons. Kungl. Svenska Vetenskapsakadem. Handl. Fjärde Serien. Band 13. Nr.1. Almqvist and Wiksell, Stockholm. 463 p.

This work is a continuation of the author's 1962 work.

174. HURD, L.G. 1971. Pipelines, people and pingos. Paper presented to the Canadian Gas Association Annual Meeting in Jasper. Mimeo 16 p.

The research and feasibility studies of the Northwest Study Group are outlined and include pipeline design studies and ecological studies among others.

"[The Arctic] Test Facility, located on the west bank of the Mackenzie River between Fort Good Hope and Norman Wells is a $3.5 million undertaking. In operation since early March [1971] it consists of 2,500 feet of 48-in diameter pipe through which compressed air, used to simulate natural gas, is circulated at varying controlled temperatures. It is primarily intended to evaluate the concept of pipelining refrigerated gas, and will provide valuable data on stability of gas pipelines in permafrost ... stability on different types of foundations ... effects of a pipeline on various forms of surface cover; *etc.*

"Wildlife studies are intended to define possible effects of construction and operation of a gas pipeline upon wildlife and the means of avoiding or minimizing any problems.

"Major wildlife programs include our study of the Porcupine caribou herd in the northern Yukon and a study of fur-bearers along various alternative routes ...

"We have found ... that the Porcupine herd is nearly twice as large as previously estimated ... between 60,000 and 65,000 [this number has since been revised and the population is considered to be in the neighbourhood of 70,000 (Northwest

Project Study Group Summary Status Report July 30, 1971)] animals, compared with previous estimates of 35,000 ...

"Caribou made considerable use of winter roads and seismic lines en route to the north slope and favouring the easier walking provided by cut-lines. Herds sometimes moved west along a seismic line for a few miles before they turned northward again. Wolves followed the Caribou herds closely — preying on them throughout the migration.

"Five Barren Ground grizzly bear dens have been discovered ... the first time dens have been recorded."

Among the conclusions the author states: "Our studies to date provide continuing confirmation that the pipeline can be built and operated with ample protection to safeguard the northern ecology and wildlife."

175. HUSSEY, K.M. and R.W. MICHELSON. 1966. Tundra relief features near Point Barrow, Alaska. Arctic 19:162-184.

Author's abstract: "The distribution of minor tundra relief patterns shows that topography plays a leading part in their development. In extensive areas of very low relief, local expression may well exceed the regional range. Aside from the initial relief, the greatest deviations from a flat surface in the Barrow area are related to the growth or thaw of ground ice. This leads to such features as high- and low-centred polygons, ice-wedge troughs, ice-cored mounds and thaw basins of all sizes. The genesis of most of these features has been determined. However, it has been questioned that the basins could have been formed by thaw. Specimens of the frozen ground were collected and analyzed to determine their relative ice content. The values were extrapolated, and it was found that even the largest basins can be true thermokarst features."

176. HUSTICH, I. 1951. The Lichen woodlands in Labrador and their importance as winter pastures for domesticated reindeer. Acta Geogr. 12(1) 48 p.

A survey of the lichen woodlands of Labrador with comparisons of similar types in other parts of the world. Included are discussions on the ecology of lichen woodlands and lichen regeneration.

177. HUSTICH, I. 1953. The boreal limits of conifers. Arctic 6:149-162.

This paper is a theoretical paper on the tree limit in the Arctic regions of the world. The discussion concerns the amplitude of the coniferous species as well as raising the question as to why certain coniferous species are at the tree limit in certain parts of the Arctic and other species in other parts.

178. HUSTICH, I. 1970. On the study of the ecology of subarctic vegetation. Ecology of the Subarctic Regions: 1 Ecology and Conservation Helsinki Symp. Proc. 1966. UNESCO. p. 235-240.

Not an applicable paper: raises a number of general theoretical questions.

179. IVANOVSKI, A.I. 1963. Transformation of nature and ways of developing agriculture in the Far North. Problems of the North. 7:1-19. (Transl. from Russian by Nat. Res. Counc. Can. 1964).

Contains information on crops and crop fields in the far north, methods of transformation of Arctic soils for agricultural crops and suggested crops for various areas.

"The harmful effects of permafrost on the growth and development of plants can be combatted by thermal improvement methods. The principal ones are as follows: holding back snow in autumn with removal of snow in spring; development of

protective strips of forest and bush; steaming of fields; harrowing of fields; sowing of winter crops; timely mulching, ridging and rowing of crops etc.".

Information is also presented on the production of fields and meadows in the tundra which differ little from those of more southern zones.

180. JAHN, A. 1970. Soil movements under the influence of freezing. Ecology of the Subarctic Regions: 1 Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 119-123.

This paper describes the movements of soil due to vertical water migration and its freezing to form segregation ice in the upper soil horizons and the effects of these movements on plants, particularly plant roots.

"The soil movement we are discussing is due to a vertical migration of water and its freezing in the form of segregation ice in the upper soil horizons. We are faced here with one type of soil movement. It is of supreme importance from the ecological standpoint since it produces major changes in the soil structure. Thus in the soil, a whole network is developed of thin horizontal and vertical fissures which are subsequently filled with ice (ice layers and ice lenses). The formation of these structures is most detrimental to plant roots. The sorting out of materials is a simultaneous concomitant of the soil movement. This process is also harmful to soil stability. The upfreezing causes stones to break through a fine-grained soil mass. The shifting of materials in the soil makes it difficult for plants to take root. We can easily find the places where the processes of soil movement and sorting out are alive. In such places the soil surface presents bare spots completely stripped of vegetation cover.

"As soon as the processes of soil movement and sorting out decline, there follows a rapid succession of plant growth. Patterned ground is soon furnished with the uniform vegetation cover.

"Apparently there exists an interdependence between the soil movement due to frost and the absence of vegetation cover. It is not only that soil movement prevents the growth of vegetation: conversely, a fully developed vegetation cover can successfully protect the soil against the action of frost. That is why in places where there occurs a cover of turf and peat, only non-sorted fissure forms (tundra polygons) are found in the absence of patterned ground (sorted circles).

"Another type of soil swelling, those related to so-called injection ice, are formed here. Contrary to the soil movements described above, injection ice causes an abrupt rise of a soil hummock. In this way are formed such forms as bugors with ice cores, and forms known in Canada and Alaska as pingos, while in Siberia they are called *bulkhunyakhy*. An ice lens under turf, mostly at the fissure outlet, lifts upwards the surface soil horizon. This is a single movement, unlike the movements connected with segregation ice. The melting of an ice lens causes a negative movement, i.e. the sinking of the soil surface. A sink hole form then results ...

"The ... types of soil movement in the Arctic and Subarctic conditions may further be classified according to their impact on vegetation cover. Without doubt, rhythmical seasonal movements that is annual up-heaving and sinking of the soil surface, appear to be most detrimental. They are destructive to vegetation because they constantly loosen (disjoint) the soil and produce cracks, in addition to the process of upfreezing of stones (mechanical sorting). In places where violent rhythmical movements occur there is no vegetation cover or else the existing cover fails to produce certain species.

"In principal, single movements are not noxious to vegetation. Luxuriantly overgrown hillocks of palsen and pingos are of common occurrence. Still, these movements weaken the soil (cracks) and frequently leave it unprotected to destructive action of other factors such as, for example, wind and water operating on exposed hillocks."

181. JEFFREY, W.W. 1961. Notes on plant occurrence along Lower Liard River, N.W.T. Contri. to Bot. 1959. Nat. Mus. Can., Bull. 171:32-115.

The area is segregated into 4 topographic divisions and the vegetation into 13 forest types and 6 brulé and shrub types. Each vegetation type is described in detail. Species invading a seismic line are listed and the author suggests that these and/or those invading brulé can be expected on disturbed sites in the Lower Mackenzie.

From author's abstract: "Theme of the paper is plant occurrence. Brief attention is given to the physiography of the study area, which is segregated into 4 topographic divisions: (1) Mackenzie mountains, (2) Mackenzie lowlands, (3) Older flood plains and terraces, and (4) recent flood plains. The vegetation is subdivided into a total of 24 vegetation types, of which 13 are forests and 6 are brulé and shrub types."

Fire is considered to have been exceedingly important in the development of the vegetation. The term "brulé" applies to areas burned-over within approximately 30 years prior to investigation, whose vegetation has not yet attained pole size.

Notes from the various sorts of brulé: "All brulé examined in the Mackenzie lowlands were on upland soils. Floristically, these stations appeared to be distinct from those of brulé in flood plains and terraces. The primary species is *Populus tremuloides*."

On the older flood plains and terraces, brulé appeared to be divisible into 2 classes, based upon the dominance of either *Calamagrostis canadensis* or *Equisetum pratense* in the herb layer. *Populus tremuloides*, two species of *Salix* and *Betula papyrifera* were the primary species in the main storey inhabiting the brulé.

"The brulé of the recent flood plains are interesting in that their flora differs considerably from that of other areas. Notably, they contain species which are most abundant and vigorous in the forest and shrub types of this topographic division, and, in addition, the proportion of *Populus tremuloides* is much reduced in comparison to the other land types." The primary species appear to be *Populus balsamifera*, *Salix bebbiana*, *Betula papyrifera*, *Alnus incana*.

A long list of species is also given from a seismic line near Fort Liard.

182. JEFFREY, W.W. 1961. Origin and structure of some white spruce stands on the Lower Peace River.. Can. Dep. For., For. Res. Br. Tech. Note 103. 20 p.

This paper largely is composed of summaries of other work done in the area. "The spruce forest is believed largely to have arisen following fire, with wind-fall and vegetational change as other modes of origin. A high proportion of stands, presently immature, have a fire history. Undisturbed vegetational change (primary succession) has possibly been of relatively greater importance in older stands. The forest is composed primarily of regular, even-aged stands, though in places some degree of irregularity does exist."

183. JEFFREY, W.W. 1964. Forest types along the Lower Liard River, N.W.T. Can. Dep. For. Publ. 1035. 103 p.

Thirty-eight forest, 6 brulé and 3 shrub vegetation types are described in detail and another 8 are mentioned. The vegetation of the brulés, occurrence of soil frost and the behaviour of tree species are discussed.

From author's abstract: "Main purpose is preparation of a forest typology for the Lower Liard River area. Units segregated are abstractions based upon the recurrence of similar combinations of environment (essentially topography and soil), and vegetation (forest cover and lesser vegetation). The bases of the typology are discussed and a total of 47 types (38 forest types, 6 brulé types and 3 shrub types) are given treatment in detail. Another 8 types receive mention only ...

"Following the description of the ecosystem-types, processes of physiographic-vegetational change in the recent flood plain are discussed. The utility of plant species as indicators of ecosystem types, use of the typology in forest management, vegetation of brulés, occurrence of soil frost and the behaviour of tree species also receive discussion."

184. JOHNSON, A.W. 1965. Plant ecology in permafrost areas. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci-Nat. Res. Counc. Wash. Publ. 1287:25-30.

An outline of permafrost-vegetation interrelationships is given and the vegetation types, mostly low Arctic, at Ogotoruk Creek Valley described. Details of permafrost effects on the plant ecology of the Valley are given. The most important of the vegetation types describes are the *Dryas* mats, sedge-meadow tussock and *Carex*.

185. JOHNSON, A.W., L.A. VIERECK, R.E. JOHNSON and H. MELCHIOR. 1966. Vegetation and flora. Environment of the Cape Thompson Region, Alaska. N.J. Wilimovsky and J.N. Wolfe, ed. p. 277-354. U.S. Atomic Energy Comm., Div. Tech. Inf.

Eight vegetation types are recognized: *Eriophorum* tussock; *Dryas* fell-field; *Eriophorum-Carex* wet meadow; *Eriophorum-Carex* solifluction slope; ericaceous shrub polygon; *Dryas* step and stripe; *Carex bigelowii* high-centre polygon; and saline meadow. Other highly variable and diverse plant communities were also recognized, but could not be aggregated into types. Descriptions of each type are presented together with associated species, soils, slope, etc. It was noted that the arctic ground squirrel produced noticeable effects on the vegetation, especially locally in spring and fall when searching for roots of *Dryas octopetala*. Soil erosion is likely to follow. The squirrels are most active in "the *Dryas* fell-field, *Dryas* step and stripe type and ecotone communities along stream banks ... Studies suggest that vegetation changes result primarily from burrow construction and feeding activities. The activities of the squirrel associated with the formation and use of the burrow affect plant distribution in the following ways: the soil-deposit piles that result from burrow construction cover existing vegetation, and squirrel excrement mixed with the newly exposed soil provides an ideal situation for germination and growth of many species, especially grasses, sedges, and rushes. Because these plants do not ordinarily occur in the undisturbed vegetation surrounding the burrow, they are highly conspicuous as they grow densely on the burrow excavation piles. With time and continued use, willows and other shrubs may grow densely on the burrow system, the important species here being *Salix pulchra* and *S. glauca*. Once established these plants may persist ... for long periods of time even if the ground squirrels abandon the site." An annotated list of the vascular plants is included as well as a list of collected bryophytes and lichens.

186. JOHNSON, F. and H.M. RAUP. 1964. Investigations in Southwest Yukon. Papers at the Robert S. Peabody Foundation for Archeology 6, (1). 488 p.

Within this book are sections with generalized descriptions of the vegetation - forests, grasslands and mountain tundra - in the Dezadeash and Shakwak Valleys.

187. JOHNSON, P.L. and T.C. VOGEL. 1966. Vegetation of the Yukon Flats Region, Alaska. U.S. Army, Corps Eng. Cold Reg. Res. Eng. Lab. (CRREL) Res. Rep. 209. 51 p.

Arctic Bibliography 96479: "Reports a 1963-65 study of the vegetation and ecology of this region by aerial photography and selected ground data from 43 sample sites. The method of sample analyses is explained and the results tabulated and discussed. The volumes of standing crop and tree profiles for various species and sites are given. Mosaics of various imagery (panchromatic, radar, thermal) and transects are analysed. Details of riparian and bog succession are discussed. At present the forests of this region are of little economic value, but this may change with rapidly expanding need for wood pulp, fibre and chips. Three kinds of vegetation type maps are presented and appendices list trees by species and soil sample data."

188. JOHNSON, P.L. 1970. Arctic plants, ecosystems and strategies. Arctic 22:341-355.

Succession: "The phenomenon [of succession] is poorly understood for tundra ecosystems. Fragmentary evidence is accumulating that succession does occur as new habitats are colonized ... (Bliss and Cantlon, 1957; Britton 1957; Vierick 1966) or in response to freeze-thaw activity in tundra terrain (Benninghoff 1952; Hopkins and Sigafoos 1951; Sigafoos 1952; Johnson and Billings 1962;

Proll 1958). We know little about the rates of vegetative recovery or succession in various types of tundra. There are observations at Barrow that suggest re-invasion of some upland vehicle trails within five years. There are other examples of irreversible destruction of tundra in which albedo is lowered from an average of 20% to 10% or lower, and the heat coefficient is altered so that thermokarst processes are activated and shallow ponds replace meadows." (It is unfortunate that there are no references to these latter studies given in the paper.)

Arrays in space-vegetation assemblages: "Studies at Cape Thompson et al. 1966, showed the relations of the principle plant communities to relief, soil type and permafrost.

"Attempts statistically to correlate vegetation type with parameters of the atmosphere or lithosphere in local areas generally produce positive correlations with thaw depth and soil moisture but inconsistent results with other variables. Recent studies have attempted to examine conflicts in relationships ..., but simple relationships do not yet exist."

A table of physiographic habitats and ecological communities of the Arctic coastal plain tundra in Alaska is given.

189. JOHNSON, P.L. 1970. Remote sensing as an ecological tool. Ecology of the Subarctic Regions 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO p. 169-187.

This paper concerns use of remote sensing techniques for obtaining vegetation information, but contains the following: Sub-Arctic Vegetation Patterns: "In interior Alaska an extreme continental climate prevails in the northern tension zone of tree growth. A very complicated vegetation mosaic is the result of a long history of fire superimposed on alluvium deposited by ancient and recent river meanders. The present vegetation pattern is a mixture of forest, shrub, and herbaceous stands in various stages of plant succession. The stability of the pattern appears proportional to the interaction between: a) The stability of the frost table and the resulting drainage condition; b) The elapsed time since the last fire or flood disturbance and the intensity of the burn or duration of the flood; c) The age of the organic or mineral substrate which is usually a function of topographic position."

190. JOHNSTON, G.H., R.J.E. BROWN and D.N. PICKERSGILL. 1963. Permafrost investigations at Thompson, Manitoba. Nat. Res. Counc. Ottawa, Can. Div. Building Res. Terrain Stud. Tech. Pap. 158. 51 p.

This paper deals with the occurrence and distribution of permafrost at the town of Thompson, which is near the southern boundary of discontinuous permafrost. Generally "the permafrost, which is only a few feet thick and has temperatures close to 32° F, frequently contains a considerable quantity of moisture in the form of ice and may, upon thawing, lose much of its supporting strength, resulting in large settlements and even failure of various structures erected upon it ...

"Given a particular climatic regime that is conducive to the existence of permafrost, ... it is the thermal characteristics or properties of the various surface and sub-surface terrain features operating singly and in combination that control the local variation in permafrost conditions. Surface features include snow cover, relief, surface drainage and vegetation; sub-surface features include soil and sub-surface drainage ...

"... It is apparent ... that most of the permafrost encountered at Thompson occurs in the sloping transition zones between the areas of relatively high elevations and good drainage, and the areas of relatively low elevation and poor drainage. This includes the narrow transition zone at the edge of the spruce "islands" within the low areas. Examples of permafrost located between the high and low areas are numerous ...

"From information obtained, ... it appears that the occurrence of permafrost at Thompson may be arbitrarily divided into two categories based on the thickness of the permafrost bodies - those less than 15 feet and those greater ... There is no apparent relation between permafrost thickness and existing terrain features. This suggests that the variations are a reflection of previous environmental conditions not evident at present. The heavier concentrations of ice were noted to occur at the greater depths."

The effect of various terrain features on permafrost occurrence follow:

Snow cover: ... "The snowfall regime and duration of snow on the ground are both critical aspects ... a heavy fall of snow in the fall and early winter will inhibit winter frost penetration and the formation of permafrost. On the other hand, a thick snow cover that persists on the ground in spring will delay the thawing of the underlying frozen ground ... There may be significant differences in snow cover between the densely forested areas and the more sparsely treed areas, which contribute to the variable occurrence of permafrost. Many additional and systematic observations of snow cover properties and depths through the winter are required at Thompson, however, before any specific relationships can be established between this feature and the distribution of individual permafrost islands.

Relief: 'The relief appears to be a significant feature affecting the distribution of permaforst. Most of the permafrost bodies are located either in broad, gently sloping transition zones between high and low areas or in narrow, more steeply sloping transition zones around spruce "islands" within the low areas. In keeping with the general influence of relief on surface and sub-surface drainage, it appears that the transition zones have sufficient slope for moderate drainage of water. Lack of such drainage, e.g. ponding of water, would result in the thawing of the underlying permafrost. On the other hand, the slopes are not too steep to be excessively drained and therefore have sufficient water for the growth of sphagnum moss, which appears to be an important feature associated with the presence of permafrost (and also ice lensing)." There is also a discussion here on the importance of slope orientation, i.e. north vs. south.

"Variations in elevation of even a few feet may cause minute but sufficient differences in air temperature which would affect the ground temperature regime. Air movement between high and low areas, such as the drainage of cold air at night from a high area downslope to a low area, is a micro-climatic feature associated with relief which may be significant ...

Drainage: "The occurrence and movement of surface and sub-subsurface water exerts an important influence on the thermal regime of the ground and is conditioned by the relief, vegetation and soil. Because of the heat storage capacity of water, its movement from one area to another signifies the transfer of thermal energy from one point to another, and the existence of water at any given location indicates an excess of thermal energy there. Moving or standing water such as occurs in the low areas below the transition zones, inhibits the formation and preservation of permafrost. It is probable that in this fringe area a change in drainage conditions in a permafrost area producing an increase of water would, in time, no doubt result in thawing of the permafrost. Water movement may be affected also by the sphagnum moss. It is suspected that the sphagnum moss is able to wick moisture upslope from the low areas and the upper limit of the moss on the transition zones may mark the uppermost elevation to which water can be transported in this manner.

Soils: "The role of the soil, particularly with respect to its effect on moisture movement, is not well understood ....

Vegetation: "The vegetation is undoubtedly an extremely significant feature affecting the distribution of permafrost and its characteristics are greatly influenced by relief, drainage and soils. A permafrost or non-permafrost condition may result from the interaction of vegetation, relief, and drainage components of the terrain, which produce a certain ground thermal situation.

"At Thompson 2 types of vegetation can generally be used as fairly reliable indicators of a permafrost condition. The presence of sphagnum moss and/or stunted, sparse to moderately dense spruce growth has been found to be nearly always associated with permafrost - *provided that reasonably well-drained conditions exist.* This qualification is most important. The converse is not true, however, because permafrost is also found under other types of moss and tree cover.

"The density and height of trees are important aspects of the vegetation influencing the near ground surface wind velocities. Wind speeds are much lower in areas of dense growth than in areas having stunted, scattered trees or no trees. The movement of air represents the transfer of heat from one area to another. In the high areas, tree growth is high and fairly dense and probably results in low wind velocities. In the low areas and transition zones, the trees are shorter and scattered and there are numerous open areas which permit higher wind speeds and thus the movement of more heat away from these areas per unit time than from the high areas. Therefore, the possibility of slightly lower air temperatures and ground temperatures, because of higher wind speeds, is greater than in the high areas.

"The interrelation of vegetation and permafrost can be summed up briefly in a statement for each type of area. In the high areas, there is no sphagnum moss because of the good drainage which allows the growth of birch, poplar, jack pine and large spruce, and there is no permafrost. In the low areas, there is thick sphagnum moss and stunted spruce because of the poor drainage, but there is no permafrost because of the excess water. In the transition zones: sphagnum moss grows because there is enough water to support it; spruce is the main tree species but is stunted because drainage is only moderate; and permafrost can exist because there is not too much water to thaw it. The spruce "islands" are too wet for birch, poplar and jack pine, but not as wet as the low areas resulting in dense but stunted spruce growth and permafrost around their edges."

Anomalous permafrost occurrences: There appears to be at Thompson certain locations where permafrost is present but does not fit into the general pattern, that is, does not occur in transition zones. "It appears that the permafrost in these areas may be associated with certain transition zone characteristics, slope orientation, moss type, slope and drainage."

Conclusion: "Permafrost may exist in one particular area because of an insulating cover of sphagnum moss, in another because of certain soil and moisture conditions, and in another because it is located on a north-facing slope. In all of these cases, the existence of permafrost is very precarious as evidenced by the proximity of its temperature to 32^{o} F. Over a sufficiently long period of time, even a very small change in any one terrain feature affecting the occurrence of permafrost can appreciably alter the thermal regime and therefore the permafrost conditions."

191. JONES, Mary Jane. ed. 1969. Mackenzie Delta Bibliography. Can. Dep. Indian Aff. N. Develop., N. Sci. Res. Group. Ottawa. 119 p.

An annotated bibliography, largely drawn from Arctic Bibliography, but containing information from other sources. Covers information on all aspects of the Mackenzie River Delta. 478 items.

192. KACHURIN, S.P. 1962. Is the development of thermokarst always indicative of a recession of the permafrost table? Data on the Principles of the Study of Frozen Zones in the Earth Crust. Issue II. Transl. from Russian by Nat. Res. Counc. Can., Tech. Transl. 1006:25-32.

The author says no. He points out that "one of the basic conditions for the development of thermokarst features is the presence of ground ice layers, lenses or inclusions in the upper permafrost strata, preserved under the influence of the vegetation cover, the topography and other local conditions ... While thermokarst features develop in the northern part of the permafrost zone, permafrost is also forming there in soils that are no longer under water (for instance in newly formed sandbanks and islands), and in this case thermal conditions in the subsoils do not contribute to the development of thermokarst features, which result from other causes, such as frost fissures, erosion, solifluction, etc. In the southern areas of the permafrost zone, in which thermokarst features are widespread there is no new development of permafrost (with rare exceptions). The central areas of the permafrost zone occupy the medium position in this respect.

"In most instances the initial development of thermokarst is due to the activities of man (ploughing and fire etc.). It is also possible for ground ice to melt in natural conditions, causing ground settlement without a recession of permafrost, for instance when the depth of [seasonal] thawing increases. This latter effect takes place when the continentality of climate becomes more marked ..."

Thus "The fact that thermokarst features are present in a given topography cannot serve as a reliable and sufficient indication that permafrost recession is taking place in present day climatic conditions. In addition to the presence of thermokarst features it is essential to have other data on hand in order to determine whether permafrost recession is in progress. Among the most important data required are those on the thermal regime in subsoils within and beyond the immediate area of development of thermokarst features, information on the influence of man, etc.

"Only when several factors point to a change of thermal conditions in the subsoil towards a temperature increase is it possible to conclude that a natural permafrost recession is taking place, and that this phenomenon is not due to the interference of man, which often serves as the first jolt in the initial stage of the process."

193. KARAVAYEVA, N.A., I.A. SOKOLOV, T.A. SOKOLOVA and V.O. TARGUL'YAN. 1965. Peculiarities of soil formation in the tundra taiga frozen regions of Eastern Siberia and the Far East. Soviet Soil Sci. 7:756-766.

This paper is concerned, in part with whether, cold, of itself, is important in pedologic processes and concludes that the depth to the permafrost table during the warm period (which itself is dependent on climatic conditions and the lithological and geomorphological order) has the most influence on soil formation.

Conclusions: "1) Permafrost has a considerable influence on soil formation, principally in the excessively wet soils of clay loam (and finer-textured) particle-size composition. The factor which has the greatest influence on soil formation within this group of soils is the depth of occurrence of the permafrost table during the warm period depending both upon causes of a lithological and geomorphological order and upon climatic conditions. These soils with specific frozen properties are zonal, genetically independent. 2) Under the conditions of a cold, excessively moist climate, but on easily water-permeable materials we are unable to establish in the soils any specific frozen properties. Their features are determined by the characteristics of the warm period and have much in common with the features of soils on similar materials of non-permafrost taiga-tundra regions. 3) Podzolic soils and soils with a brown non-differentiated profile are distinguished within the soil group without any specific influence of permafrost. 4) Podzolic soils have several specific properties associated with their formation on massive-crystalline and coarse textured parent materials. 5) The non-podzolization of soils with a brown non-differentiated profile is associated with the extreme attenuation of podzol forming process for a number of reasons. 6) Soils with a podzolic and brown non-differentiated profile together with the supra permafrost gley soils are zonal, genetically independent soils."

194. KATZ, N.J. 1926. Sphagnum bogs at Central Russia: phytosociology, ecology and succession. J. Ecol. 14:177-202.

This paper gives a very full description of the ecology of species and communities of sphagnum bogs, and transition bogs. Further information is given on the vegetation of sphagnum and transition bogs in relation to drainage, extraction of peat, and fires. Apparently in this area there is no permafrost, as there is no mention of it in the paper. The bibliography has 16 items.

195. KAY, K. 1968. A look at the future of hazardous contaminants of the circumpolar environment. Arch. Environ. Health 17:653-661.

Potential and actual health problems in circumpolar regions from biological (sewage) chemical (domestic, agricultural and industrial) and radionuclide wastes are discussed with examples. Meteorological problems with the attendant hazard of local fall-out of aerial pollutants at toxic concentrations, and/or their long-distance transport are presented. Antagonistic or potentiating reactions of certain chemicals with one another, which may be increased by increased exposure to low temperatures, are also discussed.

196. KAYLL, A.J. 1968. The role of fire in the boreal forest of Canada. Can. Dep. For. Rural Develop., Petawawa For. Exp. Sta. Inform. Rep. PS-X-7. 15 p.

A general discussion of the beneficial effects of fire in the boreal forest. Includes an extensive bibliography.

197. KELLOG, C.E. and I.J. NYGARD. 1951. Exploratory study of the principal soil groups of Alaska. U.S. Dep. Agr., Agr. Monogr. 7. 138 p.

In the section on permafrost, the importance of the insulating properties of vegetation are emphasized. Other aspects of permafrost are discussed, thawing of ground ice, clearing for agriculture, depth of active layer etc.

"Near the southern margin of permafrost areas important local variations are related to cover and aspect. South-facing slopes, for example, may not have permafrost, or under them it may lie at far greater depths than on nearby north-facing slopes. A cover of thin forest, shrubs, or mosses protects the land, insulates it, and as a result the upper part of the soil that thaws in summer is shallower than on similar places barren of vegetation. Even packing of the moss in animal trails or roadways reduces the insulation of the organic covering and causes deeper thawing. Commonly, in the forests, trees lean toward roadways, trails and the water of thaw lakes because of the greater melting and settling under the less protected surfaces ...

"Some smooth slopes with permafrost beneath have become choppy and hilly - too rough for cultivation - a decade or so after clearing. Without the protective cover of the shrubs and mosses, the uneven permafrost gradually melted, along with huge lenses of ice that developed during the freezing process. On some slopes, breaks or sinkholes have developed that have grown into gullies. Superficially, these look like ordinary erosion-produced gullies, except that little or no sediment flows from them ...

"The depth to which a soil over permafrost thaws in summer depends upon the cover and the physical characteristics of the material, as well as upon the climate. Trees, shrubs and especially mosses protect the soil against thawing. Other things being equal, soils rich in clay are thawed less deeply than sandy soils."

198. KELSALL, J.P. 1968. The migratory barren-ground Caribou of Canada. Can. Dep. Indian Aff. N. Develop., Can. Wild. Serv. 340 p.

This book concerns the ecology of the barren-ground caribou. Various aspects of the vegetation of its ranges are throughly discussed and information on fire, overgrazing, migration trails, preferred food species, nutrition values of these species, revegetation and succession is included.

From Chapter VIII Range Management: "The Canadian tundra is not subject to extensive damage by fire - the major damaging factor is on winter ranges. Although dry, lichen-covered tundra will burn readily, the heterogeneous nature of the vegetation prevents widespread fires ...

"Overgrazing of tundra is frequently noted in small areas particularly where caribou congregate frequently, such as river crossings and the shores of lakes that lie on regular migration routes. The damage done to vegetation often appears to be due as much to trampling as to overgrazing. The vegetation on a few tundra areas is probably permanently depressed because of the frequent presence of caribou ...

"Deeply worn trails and sand blow-outs at some points along the north shore of Aberdeen Lake are caused by caribou ...

"It has frequently been observed that for every square mile of caribou-damaged tundra there are tens of thousands of square miles which show little or no evidence of use. During the summer, caribou utilize the fresh annual growth of grasses, sedges and shrubs in preference to the slow-growing lichens which form their winter diet. Even superficial examination of such heavily used summer ranges as the Thelon River valley and the Bathurst Inlet coastal plains shows that favoured food plants are abundant and thriving even at points of heaviest use ...

"If the condition of tundra ranges causes no concern, the condition of the forested ranges provides the reverse situation. [Damage by fire to forested winter ranges is discussed fully]. The prevalence and continued increase in size of fires has worried all who have studied caribou. The preferred winter range of barren-ground caribou is the lichen-rich portions of the northern boreal forests. The spruce-lichen and jack pine-lichen forest associations are the most inflammable of all. Huge blocks of such forest have never been afforded any protection from fire. Fires are exceptionally damaging in many places because there has been a minimum of soil development over a rocky substrate. In many places an intense fire removes soil as well as trees, undoing in a few minutes thousands of years of vegetative development. In other areas, where modified soils remain after fire, re-establishment of lichen growth adequate for winter grazing requires from 20 to over 120 years. While forest-fire damage may or may not have contributed substantially to the caribou decline, there is no doubt that an increasing population would be severely restricted by damaged winter habitat."

199. KERFOOT, D.E. 1969. Geomorphology and permafrost conditions of Garry Island, N.W.T. Ph.D. Thesis, Dep. Geog. Univ. B.C. 308 p.

200. KERSHAW, K.A. 1962. Quantitative ecological studies from Landmannahellir, Iceland. I. *Eriophorum angustifolium*. J. Ecol. 50:163-169.

Summary: 1. "Circular patches of *Eriophorum angustifolium* invading a *Carex rariflora* association have been investigated with reference to the well-marked 'advancing front' and 'hinterland' that was present, 2) Performance data (leaf length, leaf width, tip length, leaf length/tip ratio) are given for a transect running across the circle of *Eriophorum*. 3) The density of associated species has been investigated and it is shown that there is an inverse relationship between the density of *Salix herbacaea* and the density and performance (leaf length) of *Eriophorum*. 4) It

is concluded that not only does performance vary with age but that an individual with a high level of performance also has a greater competitive ability. Such a variation of competitive ability will impose a pattern on some at least, of the associated species.

201. KERSHAW, K.A. 1962. Quantitative ecological studies from Landmannahellir, Iceland. II. The rhizome behaviour of *Carex bigelowii* and *Calamagrostis neglecta*. J. Ecol. 50:171-179.

From the Summary: 2. "There is a marked clumping of tillers in both species, rhizomes running for some distance before turning up closely adjacent to previously established tillers and producing aerial shoots which contribute to the enlargement of the clump. 3. Several areas of *Calamagrostis* are described and in all cases the behavior is consistent, the clumps often being only 1.5 cm in diameter. 4. The mechanism of this phenomenon is obscure, a 'nutritional gradient' theory being as likely as a 'chemical attraction' theory. 5. The results are discussed in relation to cyclic phases and vegetational pattern."

202. KILBURN, P.D. 1965. Floras of the tundras. Natur. Hist. August-September. p. 54-59.

Concerns the floras of alpine tundras of the Colorado Rockies.

203. KIL'DYUSHEVSKII, I.D. 1964. On the ecology of mosses — dominants of the plant cover in the north. Problems of the North 8:85-89. (Transl. from Russian by Nat. Res. Counc. Can. 1965).

This short paper gives a little information on the ecology of the more dominant species of mosses in the north. It is, however, rather sketchy.

204. KLEIN, D.R. 1970. Tundra Ranges north at the boreal forest. J. Range Manage. 23:8-14.

Information on lichens, their ecology and value as related to caribou and reindeer ranges is presented. Fire damage to the ranges is seen as a major factor in the reduction of caribou populations in Alaska and Canada.

"Fire has been a factor in the destruction of large expanses of caribou winter range in Canada and Alaska and has been associated with the alarming reductions of caribou in Canada in the 1950's and previously in Alaska ...

"Lichens grow notoriously slow and recovery from grazing or from range fires is, therefore, much longer than it is for sedges or other tundra plants. Since re-establishment of lichens takes place from the living parts of the plants that remain, fire can be particularly destructive to lichen range if all living parts of the lichen are burned ... Virgin lichen range can yield as much as 3000 lbs. per acre of forage if complete cropping of the lichens is allowed, but under such grazing practices 30-50 years is required for recovery before the areas can be regrazed. If only top cropping is permitted, approximately 45% of the living portion of the lichens can be removed and the rotation cycle can be reduced to 3-5 years ...

"Lichens form a major portion of the winter forage for caribou and reindeer and have characteristis quite unlike more conventional forage species. They are of high energy value [especially starch but low in protein] and the native grazers are specially adapted physiologically to use them. But lichens are extremely slow growing, subject to damage from trampling and readily destroyed by fire."

205. KLEIN, D.R. 1970. The impact of oil development in Alaska. (A photo essay.) Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:209-243.

This paper is actually a series of photographs taken mainly during July and August 1969 to show characteristics of the terrain of the north slope, activities associated with oil development, and environmental problems resulting from man's activities in the north. Among the photographs of man-made damage are the following: Tundra vegetation damage caused by tracked or wheeled vehicles used during spring and summer which induced permafrost thaw, soil erosion and permanent scars; tundra scarring adjacent to a drilling operation with eroding, bulldozed ditches carrying silt-laden waters into adjacent clear streams; improper road construction with permafrost thawing inducing slumping and caving of the road and adjacent tundra.

Numerous photographs show various forms of waste on land and water.

It is noted that pingos are often used as an elevated platform for seismic survey work. This concentration of human activity may seriously affect the arctic fox which shows a preference for pingos as den sites.

The giant flying crane and hovercraft may be satisfactory travel alternatives over tundra under conditions when vegetation disturbance can occur.

Air pollution can become a problem at Fairbanks from refinery operations.

Photographs are also presented showing results of using winter haul roads after the spring thaw has set in. Rutted appearances and associated thawing of the underlying permafrost is the result of such practices. When this occurs extensive repair is required before the road can again be put into use (winter use) and it is expected degradation of the permafrost will occur in the future.

Problems of this sort can be avoided by timely closing of the road to traffic before spring thaw begins.

206. KLEIN, D.R. 1971. Reaction of reindeer to obstructions and disturbances. Science 17:393-395.

The Scandinavian experience may aid in anticipating problems with caribou. It has been demonstrated that railways and highways may disrupt migration patterns, but there is evidence that the physical condition of wild and domesticated reindeer determines their ability to adapt to changes in their environment and to adjust to disturbances. When the animals are in a poor physical condition, seasonal migrations are easily disrupted and traditional ranges may be abandoned. On the other hand, ranges normally avoided may be used in such circumstances. Alteration of light, moisture and wind conditions of the forest, such as occurs by clearing powerline rights-of-way is a deterrent to reindeer movement.

The trucking of thousands of reindeer from summer to winter ranges because of lack of grazing along migration routes has disrupted the normal migration behaviour pattern, and increased the number of animals failing to follow the spring migrations to summer ranges. It is suggested that the problem is caused by the disruption of the social structure of reindeer populations.

207. KLYUKIN, N.K. 1963. Questions related to ameliorating the climate by influencing the snow cover. Problems of the North 7:67-90. (Transl. from Russian by Nat. Res. Counc. Can., 1964).

This paper has a large bibliography on aspects of snow. Methods for early evaporation of snow in certain areas to decrease soil moisture, the retention of snow in other areas to increase soil moisture, and the methods most likely to be effective are discussed.

From the Summary: "In order to improve the moisture regime in the saturated and boggy soils of regions of heavy snow it is possible to utilize snow amelioration measures directed towards intensifying the evaporation of the snow cover, mainly by breaking it up and blackening its surface. This results in a several times higher rate of evaporation. With a considerable increase in the evaporation of the snow, up to 15-25% of the total annual precipitation can be withdrawn from the moisture balance sheet of the soil. In addition to this, more moisture can be withdrawn from the soil by intensive evaporation from its surface in spring (given the early disappearance of the snow cover) and by not permitting the seepage of the moisture that condenses in the snow cover during the late spring ...

"This method is especially suitable under conditions of flat relief and poor drainage, where drying is extremely difficult, particularly in the West Siberian Plain ...

"A substantial reduction in the intake of moisture in saturated and boggy ground over considerable areas will help to expand the areas covered by productive forests, where timber growth will be 4-5 times greater than in bog forests, will convert the bogging process into a grassing one, and will enable new acreages of land to be put into agricultural production. The growth of thick timber and herbaceous vegetation in place of stunted tree stands and mosses, and the agricultural development of the land will in turn increase evaporation and maintain the effect resulting from the snow amelioration.

"Furthermore, the recommended snow amelioration measures indicated will considerably lengthen the snow-free period and enhance the heat supply to the soil. This will result in degradation of the permafrost over wide areas of the North, which will in turn improve the climate."

208. KOROVIN, A.I., Z.F. SYCHEVA, and Z.A. BYSTROVA. 1963. The effect of soil temperature on the amount of various forms of phosphorus

in plants. Soviet Plant Physiol. 10:109-112.

From the summary: "A drop in the temperature of plant roots (potato and wheat), particularly during the initial period of ontogenesis, is accompanied by suppression of phosphorus absorption and incorporation into organic compounds, primarily into the nucleoprotein fractions. There is also a decrease in the amount of organic forms of phosphorus in the leaves. During the initial period of ontogenesis, there is a decrease in phosphatides and organic, acid-soluble phosphorus in the leaves.

209. KORPIJAAKKO, E. and N.W. RADFORTH. 1965. Aerial photographic interpretation of muskeg conditions of the southern limit of permafrost. Eleventh Muskeg Res. Conf. Proc., Nat. Res. Counc. Can., Ass. Comm. Geotech. Res., Tech. Memo. 87:142-151.

Efforts in the development of aerial photographic interpretation to predict subsurface ice conditions in muskeg are presented. "One such indicator [in the prediction of the southern limit of permafrost] may be the muskeg "H-factor", although any direct correlation is difficult to make at the present stage of the investigation."

210. KOSHELEVA, I.T. and L.N. NOVICHKOVA. 1958. The "spotted tundras" of Western Siberia and their algal flora. Bot. Zh. 43(10): 1478-1485.

Arctic Bibliography 52422: "Lists 22 soil algae of the Yamal and Gydan Peninsulas, with data on the chemistry of their substrates: spotted and polygonal tundras. The algae are analysed for their calcium content and grouped according to stability and ecological characteristics. If the soil has a slightly acid reaction on the spotted tundras, yellow-green (Xanthophyta) and green (Chlorococcales) algae predominate, but on slightly alkaline soil, the blue-green algae (Cyanophyta) take the lead."

211. KRAUSE, H.H., S. RIEGER and S.A. WILDE. 1959. Soils and forest growth on different aspects in the Tanana Watershed of Interior Alaska. Ecology 40:492-495.

This short paper describes the differences in vegetation and soil on north and south-facing slopes on the Tanana watershed. These slopes have similar parent material in the soils but there are radical differences in the genetic nature of the soil and of the vegetation cover.

212. KRINSLEY, D.B., W.E. DAVIES, J. RACHLIN and E.G. NEWTON. 1971. Existing environment of natural corridors from Prudhoe Bay, Alaska to Edmonton, Canada. U.S. Dep. Int., Geol. Surv. (Prelim. Rep.) Wash. 104 p.

The information on the various alternative pipeline routes has been compiled from the literature and an extensive bibliography is appended.

The proposed corridors are:

Corridor A: A submarine route from Prudhoe Bay to the Mackenzie Bay to join Corridor B.

Corridor B: An onshore coastal route to the mouth of the Mackenzie River from Prudhoe Bay then south on the west side of the Delta to join Corridor C along the upper Porcupine River.

Corridor C: An inland route southeast through Philip Smith Mts, Old Crow Flats, Richardson Mts, to south of Fort McPherson.

Corridor D: Fort McPherson to Edmonton by the most direct natural route.

Corridor E: Big Delta to Edmonton, generally parallel to the Alaska Highway.

Conclusions: "The conclusions presented here are based solely upon consideration of those elements of the natural environment described in this report.

"If a hot-oil pipeline is considered, Corridor C, the inland route from Prudhoe Bay to Fort McPherson, has naturally occurring physical advantages over the northern coastal Corridors A and B as the environment most favourable for construction. For road or railroad transport, however, the onshore coastal Corridor B has advantages over Corridor C, and the offshore Corridor A is obviously unsuitable.

"In Corridor A, a submarine pipeline would be subject to ice scour and probably to foundation problems related to permafrost. The mountains of Corridor C would be a severe hindrance to construction of a road or railroad but the rugged terrain would be less of a detriment to emplacement of a pipeline than the foundation problems, associated with permafrost, in Corridor B.

"Corridor B, together with Corridor D, which extends on from McPherson to Edmonton, does not encounter any major topographic obstacle nor pass through an area of significant seismic risk. This combined Corridor B-D has drainage and foundation problems related to unstable slopes in Corridor B in the vicinity of the Mackenzie Delta, troublesome clayey soil in Corridor D to the south, and extensive permafrost.

"Siting of the final alinement within Corridor D would be constrained by the transportation mode. To avoid ground ice, a hot-oil pipeline should occupy the higher, better drained, but discontinuous terraces. Abrupt changes in slope would not be critical for this mode. A road or railroad however, would more likely be aligned along continuous low grades without abrupt slope charges, in spite of more ground ice.

"Choice of mode is less critical within Corridor E, from Big Delta to Edmonton, because of the absence of serious topographic obstacles or extensive areas of ground ice.

"Corridor B-D for a road or railroad and C-D for a pipeline have natural advantages over Corridor E. Although Corridor E has considerably less ground ice and less severe drainage and foundation problems than either Corridor B-D or C-D, major problems would be encountered along any corridor between Prudhoe Bag and Big Delta. These include the topographic obstacle of the Brooks Range, extensive permafrost, a major crossing at the Yukon River, and relatively high seismic risk in the Fairbanks area.

213. KROG, HILDUR. 1968. The macrolichens of Alaska. Norsk Polarinst. Skr. Nr. 144:180 p.

Contains keys, distributions, and comments on chemical properties of 326 species of Alaskan lichens (no crustose species are included).

214. KRYUCHKOV, V.V. 1963. The possibilities of afforestation in the southern treed tundras. Problems of the North 7:97-113. (Transl. from Russian by Nat. Res. Counc. Can. 1964).

Theories for treelessness of the north are discussed. The conclusion reached is that "bogging" is the main probable cause.

"F.I. Yatchenko (1955, 1956), in his studies devoted to the creation of protective forest strips in the tundra along the Pechora railroad, writes that the propagation of the forest in the tundra is prevented by a thick moss cover which hinders germination of seeds of arboreal and shrub species and retards the heating of the soil and air. F.I. Yatchenko states that repeated experiments have shown that it is sufficient to remove the moss cover and expose, or so to speak gash, the soil to make grass grow and even willow trees, birches and spruces (1955). The saturation and bogging of the soils, which prevents the germination of tree seeds and severely inhibits tree growth, can be counteracted by improvement with the aid of tractors. 'Planting is carried out in depressions, in furrows made with the P.L.-70 plow. This rids the planted area of excess moisture, and assures better drainage and warming of the furrows' (1955, p. 53). These measures made it possible to develop strips of protective forest in bogged tundra along the Pechora railroad ...

"The moss cover not only plays an important part on the bogging of the tundra, but is also an extremely unfavourable substrate for the germination of seeds and the development of young shoots of arboreal plants. A study by B.A. Tikhomirov (1952) is devoted to the influence of the moss cover on plant life under conditions of the Far North ...

"One of the principal conclusions reached is that the moss cover, while hindering the germination of seeds, nevertheless provides a certain protection from frost and sudden changes in the weather. As a consequence B.A. Tikhomirov suggests 'that in the cultivation of forests in the southern part of the tundra, artificial regulation of the moss cover should be applied' ...

"We shall not dwell on the so-called theory of physiological barrenness of the cold tundra soil since we share the view ... of the untenability of this theory. Incidentally, we do not share the opinion of those authors who think that the geological barrenness of cold soil (moisture cannot be absorbed because of the low soil temperatures) and the winter drying of trees in the Far North (when the soils are frozen and there is a negative temperature) are one and the same thing."

It is noted that "the actual boundaries of the forest fall short of their thermal limits by 3 to 4° C."

215. KRYUCHKOV, V.V. 1968. Soils of the Far North should be conserved. Priroda 12:72-74 (Transl. by G. Belkov and added as an appendix (p. 11-13) to Brown J. et al., 1969).

The author considers that fire in northern forests, contrary to the usual opinion, causes a decrease in the active layer after the first season i.e. after fire (which because of the wet organic matter does not expose mineral soil), increased thaw occurs which together with rain causes super-saturation of the soil. The following year invasion by hygrophytic cotton grasses retards thawing and subsequent replacement by tussock-forming cotton grass continues the trend. Tree seeds do not germinate in these wet cold soils, and hence the treeline recedes and the once forested area is now a pyrogenic tundra.

216. LACATE, D.S., K.W. HORTON and A.W. BLYTH. 1965. Forest conditions on the Lower Peace River. Can. Dep. For. Publ. 1094. 53 p.

This paper contains extensive information on the Peace River Lowlands of Wood Buffalo National Park near the border of Alberta and the Northwest Territories. The information was collected in July, 1957. The forest types on high terrace land, middle terrace land and alluvial land are described. Fire has been important in the forest history of this area.

Distribution of frozen ground is discussed as well as its relation to moss cover. Destruction of the moss cover is considered important to ensure thawing of the ground and the re-establishment of a new stand after logging.

"The influence of the vegetation on the distribution of soil frost is more obvious in the reconnaissance area than is the influence of soil frost on the vegetation. In the recent deposits of alluvium the frozen ground table is very deep - if present at all - under stands of balsam poplar. No moss cover is present under these stands. Frozen ground table seems to rise gradually from these younger areas of the point bar deposits to the older and higher parts where white spruce stands are well established. Here the mosses form a relatively thick layer which protects the underlying ground during the summer thaw period. As spruce stands develop on the alluvial flats, a moss carpet develops under it and the frozen ground table rises too, or is maintained near the surface. A mature stand of white spruce that presently has only one or two feet of unfrozen ground in which to root, did not develop under such conditions. These conditions have progressed as the stand developed.

"During logging the moss mat under the mature spruce stands should be removed or greatly disturbed, not only to aid in the re-establishment of a new stand, but, mainly to ensure the thawing of the frozen ground that is present.

"In the Peace River area, the frozen ground layer is not extremely thick. Hence, removal of the moss layer after cutting could "burn out" the frozen ground completely over a period of several years."

217. LACHENBRUCH, A.H. 1970. Some estimates of the thermal effects of a heated pipeline in permafrost. Geol. Surv. Circ. 632. 23 p.

The computations contained in this circular are approximate but the following quotation indicates some of the effects to be expected.

"A 4-foot pipeline buried 6 feet in permafrost and heated to 80° C (176° F) will thaw a cylindrical region 20 to 30 feet in diameter in a few years in typical permafrost materials. At the end of the second decade of operation, typical thawing depths would be 40 to 50 feet near the southern limit of permafrost and 35 to 40 feet in northern Alaska where permafrost is colder. Except for special materials near the northern end, equilibrium conditions will not be reached and thawing will continue throughout the life of the pipeline, but at a progressively decreasing rate. If the thawed material or water within it flows, these amounts of thawing can be increased several fold. If the pipeline temperature were only 30° C, the depth of thawing would probably be reduced by only 30 or 40 percent. The principal effect of insulating the pipe would be to increase oil temperatures rather than to decrease thawing."

Many engineering aspects inferred above are discussed in greater detail in the paper. The computations are only for pipelines buried in permafrost.

218. LAMBERT, J.D.H. 1968. Ecology and successional trends of tundra plant communities in the low arctic subalpine zone of the Richardson and British Mountains of the Canadian Western Arctic. Ph.D. Thesis, Dep. Bot., Univ. B.C. 164 p.

The vegetation and soils of the low Arctic Subalpine/ Foothill Zone are described in detail and an attempt has been made to determine major environmental factors which control their distribution and development. The work was done in the area surrounding Canoe and Trout Lakes in the Richardson Mountains N.W.T., and British Mountains, Yukon, respectively. Two major vegetation types were distinguished on the basis of snow cover, 1) chionophilous (on east-south facing sheltered slopes with considerable snow accumulation) and 2) chionophobous (dominating ridges, slopes and wetland habitats with little or no snow accumulation).

219. LARSEN, J.A. 1965. The vegetation of the Ennadai Lake area, N.W.T.: Studies in subarctic and arctic bioclimatology. Ecol. Monogr. 35:437-459.

The communities discussed and described in this paper are: low *Carex* meadow, tussock muskeg, black spruce, rock field, and esker (white spruce) communities. These communities stretch from the wettest, that is, the low carex meadows, through communities on intermediate sites to the rock field and esker communities which are upland.

"Of all the communities at Ennadai the tussock muskeg seems to be the most subject to destructive action by frost." Frost action and permafrost are discussed and an example of ice thrusting described in an area without such frost action when first examined.

"Susceptibility to frost action appears to depend upon the presence of collected water at the interface of the vegetative mat and the substratum of sand or glacial till, or perhaps on the upper surface of the permafrost. The formation of ice lenses at this interface in the fall often results in an upheaval of the vegetative mat and destruction of the plant community; exposure of sand or bare peat renders the area available for recolonization. Where the vegetative mat is quite thin, the underlying material is often exposed, and where the peat is of considerable depth, a large area of bare peat remains exposed by the following frost activity ...

"The colonizing species [on the bare peat] constitute the tussock muskeg community..." (e.g. *Ledum decumbens*, *Betula glandulosa*, *Rubus chamaemorus*, *Vaccinium uliginosum*, *V. vitis-*idaea, and procumbent *Salix* species). There is no information on changes in community structure over an extended period of time so successional relationships have not been worked out. However, if such relationships exist in the usual sense, "it is apparent that the tussock muskeg community is subject to repeated disturbance by frost and this community might be one of the more productive sources of information on plant succession in the Arctic." Although not named it should be noted that moss and lichen species have very high frequencies in this community.

"The term tussock is not used here in its most precise sense (a tuft of grass or *Carex*) since the most heavy representation of mosses would make the term hummock equally suitable. The formation consists essentially of hummocks underlying tussocks of sedges and grasses, so admixed as to be inseparable. The surface of the *Sphagnum* is but slightly raised above the level of the intervening lower areas ... *Carex* species and *Eriophorum spissum* are found most frequently between hummocks."

The low *Carex* meadow community very frequently grades "perceptibly into the tussock muskeg community and there is a temptation to interpret this gradient as a very slow progression from *Carex* meadow into tussock muskeg. The inference seems reasonable but additional evidence must be obtained before the conclusion is finally acceptable. Hummocks of *Sphagnum* are found in the *Carex* meadows, which would also tend to support this successional view. In any case, rapid succession is no doubt prevented by surface ice action and by the slow rate of peat accumulation, the latter process being necessary to raise the surface of the vegetative mat sufficiently high above the water level to permit invasion by characteristic tussock muskeg species." Lichen species are only occasionally present on the tops of some of the hummocks.

The summit of eskers has a vegetation "composed largely of species adapted to pioneering on sandy areas under the most adverse environmental conditions. On these sites, the most visible physical process at work is wind erosion, and many examples exist of active removal of sand from beneath the mat of pioneer species, *Empetrum nigrum*, *Arctous alpina*, *Saxifraga tricuspidata*, *Luzula confusa*, *Hierocloe alpina*, and small xerophytic *Carex* species ... Lichen associates collected in the pioneering mat on the esker summit include [several species of *Cladonia*, *Stereocaulon*, *Cetraria*, *Peltigera* etc.].

There are four major spruce communities in the Ennadai Lake area occupying a variety of sites. "Both black and white spruce are present and each is the arboreal dominant on an upland and a lowland site. 1) The upland black spruce community appears in close association with transition zones between tussock muskeg and rock field communities. 2) The lowland black spruce community occurs where water accumulates to some depth at least in spring. 3) White spruce makes up part of the esker summit community at the north end of the lake and a closed white spruce community on the esker at the south end of the lake. 4) A ravine white spruce community is found at the north end of the lake where a small stream runs through and over boulders." It is considered that black spruce reproduction on the upland areas at the north end of the lake must be sporadic. Evidence exists of layering being the chief method of reproduction.

"The presence of the frost lens in accumulated peat beneath the actively growing mosses of the spruce clumps constitutes a problem. That these frost lenses represent not an amelioration of the environment, but quite the opposite, is the conclusion that must be drawn. Benninghoff, 1952, suggests that in these sites spruce actually destroys the environmental conditions that initially permit growth. The relationship of spruce to environment at Ennadai is further elucidated by observations made in an area where a clump had been cut ... some years previously. In these cut areas, no frost lens existed, at a time when the upper surface of the lens was encountered at shallow levels in spruce clumps elsewhere. In this area, no evidence exists that spruce is becoming re-established. This corroborates other observations near treeline further to the east where an isolated stand of spruce destroyed by fire has not regenerated (Ritchie, 1959). Thus it appears that spruce clumps tend to create an environment which is inimical to optimum physiological activity and growth, although obviously not to continued survival ...

"A second topographic formation affording suitable environmental conditions for black spruce is characterized by broad saucer-like depressions found in a few areas adjacent to lakes or streams ... These areas are underlain primarily by sand and are submerged or saturated to the surface during most of the warm season after permafrost has retreated. Clumps of spruce occupy hummocks which are rather regularly distributed over the area ... and retain ice in the central portions at least until mid July ... [In these areas] spruce apparently reproduces by both layering and by seedlings, although the seedlings are found only rarely and usually in sites that appear unfavourable for prolonged survival." White spruce in the area generally appears to be at the edge of its range.

Frost action and Permafrost: "An area of tussock muskeg with no evidence of frost action in 1959 had become severely dissected by the spring of 1961 and contained one unusually large ice lens and numbers of smaller ones. The area was the site of transect number 117 made during 1960, when there was some evidence of having due to frost ...

"The lens and its covering layer of peat and tussock muskeg vegetation extended in 1961 some 7 to 8 feet in height above the level of the surrounding vegetational mat and was cracked down the center permitting inspection of the ice core. This was composed entirely of clear ice, unmixed with soil or vegetative material, resting on the sand substratum and supporting on its surface the layer of peat, mosses, herbs, and herbs that comprise the tussock muskeg mat. Hopkins and Sigafoos (1950) make note of similar features, and point out

that such ice thrusting occurs where a relatively thin layer of peat overlies a sand substratum."

Permafrost temperatures were taken throughout the summer of 1961 in the major plant community types maintained over permafrost. These data reveal rather uniform differences between the various communities. The tussock muskeg had the shallowest active layer followed by the low *Carex* meadow, followed by the rock field and the dry esker slope had the deepest active layer.

220. LARSEN, J.A. 1967. Ecotonal plant communities north of the forest border, Keewatin, N.W.T., Central Canada Stud. Subarctic and Arctic. Bioclimatol. III. Tech. Rep. 32. Univ. Madison, Wis. 16 p.

This paper is concerned with defining the forest-tundra transitional zone in the Keewatin District by the use of the numbers of species. In a northward direction the number of forest species declines and further north the number of northern species, that is, arctic species, increase. In between there is a zone with very few northern or southern species. This is considered to be the forest-tundra transitional zone.

221. LAWRENCE, D.B. 1958. Glaciers and vegetation in southeastern Alaska. Am. Sci. 46:89-122.

Discusses glaciers and describes the successional patterns in Glacier Bay after glacial recession.

222. LAWRENCE, R.D. and J.A. PIHLAINEN. 1963. Permafrost and terrain factors in a tundra mine feasibility study. First Can. Conf. Permafrost Proc. Nat. Res. Counc. Can., Ass. Comm. Soil Snow Mech. Tech. Memo 76:207-214.

Consideration is given to the various factors affecting engineering design. The authors say: "Although

vegetative changes (in species, growth or density) are not normally utilized in construction projects, this type of observation can be of invaluable help during construction ... For example very frequently the natural drainageways may have different or a more dense plant growth ... Such indicators should not be overlooked, especially in the installation of culverts. In addition, low woody shrubs, willows or ground birch, may indicate a relatively deep snow cover. The absence of vegetation may suggest snow-free, windswept areas and potentially intense frost action."

223. LEGGET, R.F. and R.J.E. BROWN. 1956. Rapid desintegration of alluvial-fan material near Aklavik, N.W.T. Geol. Soc. Am. Bull. 67:1715.

This is taken from an abstract of the paper presented at meetings in Minneapolis, 1956.

Test drilling in an alluvial fan invalidated surficial evidence when at least 40 feet of organic silt and no sand or gravel were found. Expected were sandstones and shales of Cretaceous age from adjacent slopes of the Richardson Mts. It was inferred that intense frost action, together with turbulent stream flow and fast annual growth of grasses on the surface of the stream meanders, accelerated the weathering process. "The short growing season leads to rapid decay of this grass cover, which, with the annual layers of stream-bed material, results in the organic silt instead of the more usual muskeg of the North."

224. LEGGET, R.F., H.B. DICKENS and R.J.E. BROWN. 1961. Permafrost investigations in Canada. Geology of the Arctic 2:956-969.

This paper discusses the regulation of the ground thermal regime in permafrost areas and considers that vegetation, snow cover, water (such as lakes or rivers) bare soil and rock are the main types of surfaces that affect it.

On vegetation effects the authors say: "The entire vegetative complex exerts an influence but it is the effect of plant cover such as mosses and lichen that appears to be paramount. The influence of a vegetative cover is not clearly understood but the suggestion that it provides resistance to heat flow by conduction only is almost certainly too simple a view. Vegetation contributes to evapo-transpiration and thus a considerable proportion of the solar radiation received can be rejected in this way without the soil beneath being affected. Mosses are strongly hygroscopic and are capable of losing moisture rapidly and in large quantities. Lichens, however have been found to have extremely dry surfaces at times, even when lower layers near the soil are very wet. It may be that they are able to protect the soil against heat gain more by an insulating rather than an evaporative cooling effect, although some investigations have suggested that low soil temperatures and a high permafrost table are maintained by rapid evaporation at the wet basal layers.

"The effects of rivers are difficult to assess but it has been shown that the moderating influence of rivers on permafrost extended a distance of 100 m from the river bank. Thawed zones generally take the form of an extended trough, the width of which is proportional to the width of the river."

225. LEWIS, F.J. and E.S. DOWDING. 1926. The vegetation and retrogressive changes of peat areas (muskegs) in central Alberta. J. Ecol. 14:317-341.

Although this paper concerns areas near Edmonton and therefore south of the Mackenzie Basin, there are particular interests in the muskegs studied. For example, there appears to be permanently frozen ground 18 inches below the surface in June or July, and "in many of the muskegs in which there is little or no circulation of water, the layers two feet below the surface remain permanently frozen."

Summary: "1) The vegetation, history and retrogressive changes of muskegs in the poplar parkland district of Edmonton are described. 2) *Sphagnum* is tending to disappear and be replaced by vegetation indicating drier conditions and a cessation of peat-formation. 3) These muskegs are formed on fine glacial clay in small basins in moranic regions ... 4) Retrogressions due to fire, dessication and the inflow of springs highly charged with mineral matter, causing the formation of a calcarious lake in a peat basin, are described."

226. LIVEROVSKAYA-KOSHELEVA, I.T. 1964. The problem of thixotropy of soils in the tundra zone. Problems of the North 8:241-255. (Transl. from Russian by Nat. Res. Counc. Can. 1965).

This rather extensive paper concerns the problem of thixotropy in soils of the tundra zone. This phenomenon is a sol-gel relationship where flow is followed by fast spontaneous hardening of soil. Both iron hydroxide films and colloidal silica have been implicated in the phenomena. Results of various investigations are reported in this paper.

227. LOUGHERY, A.G. and J.P. KELSALL. 1970. The ecology and population dynamics of the barren-ground caribou in Canada. Ecology of the Subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 275-280.

Details of the habits of barren-ground caribou are presented. Much of the information is included in Kelsall (1968).

"In north-central Canada barren-ground caribou occupy a range of 750,000 square miles ... Approximately half of the range is tundra and the other half boreal forest or taiga. It is bounded on the west by the Mackenzie River and on the east by Hudson Bay. The Arctic Ocean forms the northern boundary, while the southern limit includes the northern portions of the three Prairie provinces. The range extends through 15 degrees of latitude, from 55^{o} N to 70^{o} N and through a longitudinal range from 82^{o} W to 130^{o} W. From the Mackenzie River Delta in the northwest to the south-eastern range extremity near God's Lake, Manitoba, is a distance of 1,500 miles ...

"Almost all of the tundra and much of the taiga Caribou Range is underlain by Precambrian granitic bedrock. It is a country characterized by low relief and rolling plains. The western and southeastern parts of the winter range are underlain by more recent Palaeozoic sedimentary rocks. Annual precipitation is light, not exceeding 14 in anywhere on the range. However, perennially frozen ground, surface bedrock, and poorly developed drainage contribute to the accumulation of large amounts of surface water. This surface water varies from temporary melt water tundra pools to great river and lake systems. Surface waters constitute 30 percent of the area of the caribou range. Soil formation and plant growth are slow ...

"The barren-ground caribou of the central mainland are both migratory and nomadic. Between the taiga winter range and tundra calving grounds they make long, uninterrupted and directionally orientated movements twice each year. These migratory periods total 3 to 4 months of the year and may cover as much as 400 miles. During the remainder of the year the caribou are nomadic, constantly on the move, and often change direction unpredictably in response to local environmental factors.

"[Although] caribou are seldom evenly distributed on the taiga winter range [they do] prefer specific calving grounds. Year after year they return to certain locations on the central-northern tundra. The calving areas have common characteristics in that they are high, dry, and possess a more rugged relief than the surrounding country. In the central tundra four major calving grounds are known - the Coppermine Mountains, the coastal range of hills on either side of Bathurst Inlet, the elevated plateaus north and south of Beverly Lake, and the rugged granite hills of Central Keewatin south of Chesterfield Inlet ...

"The spring migration normally begins in mid-March ... [and] depending on the snow conditions the animals may remain near tree line from mid-April to mid-May. Bands of 20-200 animals leave the tree line and head for the distant calving grounds 200-300 miles away. Typically, the bands travel in single file following the course of least resistance across chains of frozen, snow covered lakes, eskers or glacial ridges ... Parturition starts by the first of June and ends in late June but most (about 70 percent) of the calves are born between 9 and 15 June. At that time from 10,000 to 50,000 cows are assembled in each of the 4 major calving grounds." It should be noted that the bulls and non-breeding animals do not leave the forest until sometime after the cows have left.

The foods and feeding behaviour of caribou and reindeer appear to be similar throughout the holarctic ranges. The summer of tundra range in northern Canada is apparently more than adequate to support the present caribou population. However, the forests on the taiga or winter range have been so badly damaged by fire as to limit a major increase in caribou numbers.

"On summer tundra ranges caribou move constantly ... On the calving grounds the pregnant females and those with young calves frequent the higher and drier ground. Their diet is more restricted to lichens than is that of the males and non-breeding animals, which seek out lower and greener pastures. These animals feed on the new growth of green grasses and sedges. The phenological progress of preferred foods is as follows: green shoots of cotton grass (*Eriophorum* sp), mid-June; other sedges and grasses, and new leaves of glandular birch (*Betula glandulosa*), 1-10 July; then ground willows (*Salix* sp.) from 10 July. Throughout the summer, lichens of the genera *Cladonia*, *Cetraria* and *Stereocaulon* are eaten as are the leaves of many woody perennials such as *Arctostaphylos*, *Vaccinium*, *Ledum*, *Empetrum*, and *Rhododendron*. Fungi are highly favoured and are actively sought ...

"The winter feeding behaviour of caribou is adapted to obtaining food under snow. At that time most caribou are within the taiga. When snow depth is not great caribou feed on exposed vegetation pawing with their forefeet to expose additional vegetation. As snow depths increase a characteristic feeding behaviour is followed, in which the caribou, using their forelegs alternately, paw crater-like pits through the snow. The animal feeds on the exposed vegetation ... then moves on ... and digs another [pit].

"In the taiga, snow depth, density, hardness, and granulation increase during winter. When critical levels or thresholds are reached in an area, caribou either move on in search of more favourable areas or feed on arboreal lichens (*Usnea* sp. and *Alectoria* sp). They may even move prematurely on to the tundra ...

"Caribou generally feed only once or twice over a section of range each winter ... The above cycle of feeding activity promotes a rotation of winter pastures and ensures that an area of winter range is not overgrazed, an important behaviourable pattern in view of the animals' dependence on slow growing lichens for food.

"Terrestrial lichens form the most important component of the winter food of caribou, amounting to approximately 50% of their diet ... Fructicose lichens of the genus *Cladonia* are the most important. Other genera include *Cetraria, Stereocaulon* and *Peltigera*. The arboreal lichens *Usnea* and *Alectoria* are taken occasionally. A large variety of woody plants, grasses, and sedges are also eaten in winter. These include plants of the genera *Vaccinium, Empetrum, Ledum, Arctostaphylos, Betula, Salix, Picea, Pinus* and *Alnus*. Grasses eaten include the genera *Deschampsia, Festuca, Calamagrostis* and *Poa* and sedge genera *Carex* and *Eriophorum*. Horsetail (*Equisetum* sp) is a highly preferred winter food. The stems of these plants often protrude above the frozen surface of shallow lakes. Caribou paw through snow to reach them, often completely cleaning out a bed of *Equisetum*. This is in marked contrast to the usual more random feeding behaviour."

Scotter, 1964 has "documented the effect of forest fires on reducing both quantity and quality of forage in forests of various age classes [on caribou winter range] .... He demonstrated that the effect of fire destruction of winter range in the last 15 years has increased 3.1 times over the 1840 to 1884 period. Although forests have always been subject to destruction by fire, chiefly caused by lightning, increases in the rate of fire destruction can be attributed to increased human activity resulting from mining and settlement."

228. LUNDQVIST, J. 1962. Patterned ground and related frost phenomena in Sweden. Sweden. Sver. Geol. Unders. Publ. Ser. C, No. 583. Avhandl. och uppsatser. Arsbok 55 (1961) No. 7. 101 p.

Author's abstract: "The paper presents a systematic treatment of the different types of patterned ground and their distribution in Sweden. Information is derived partly from published papers and partly from new observations. The types of patterns discussed are apparent from the list of contents [sorted and non-sorted nets, circles, polygons, steps, stripes, cracks, fields, talus, landslides and mudflows, etc.]. Their regional and vertical distribution is, when possible studied by means of maps and profiles and their different modes of formation discussed. In combination with climatic maps the distribution and possible modes of formation indicate that the climatic conditions allow the formation of most types of patterned ground in most of Sweden. The limitations are mainly caused by edaphic factors. Only in a few cases (non-sorted polygons, palsas, boulder depressions and possibly sorted and non-sorted steps) are the limits of a climatic nature."

An extensive bibliography is included.

229. LUNDQVIST, J. 1966. Patterned ground in Sweden. Permafrost Int. Conf. Proc. Nat. Acad. Sci.-Nat. Res. Counc. Wash. Publ. 1287: 146-149.

"This paper relates horizontal and vertical distribution of different types of patterned ground to climate and other factors affecting frost action in the ground."

The author gives the diagnosis of the various types of patterned ground found in Sweden.

Factors controlling distribution: "Some types (Earth hummocks, mud circles, stone pits, sorted and non-sorted steps), seem to require vegetation. If this is absent, other types are formed under otherwise similar conditions. Solifluction steps and earth hummocks require some vegetation or stone mantle to keep the soil collected in terraces or hummocks and preserve the forms. Some types, such as mud circles, depend entirely on the vetetation in scars where they form ...

"The close relation between patterned ground and vegetation is especially evident in the lower part of the Caledonides. Herbs and shrubs there are rather thick, so patterns formed by sorting processes are found mainly in shallow depressions which are usually covered by water. Autumn is almost the only time they are dry ...

"The water table affects pattern formation in two ways: a) a shallow depth to the water keeps the soil moist and facilitates formation of patterns requiring movements of fines in the soil. b) If the water table emerges at the surface most of the year it also prevents the growth of thick vegetation and thus facilitates formation of patterns requiring absence of vegetation. This is true chiefly for the area above the timber line, where fen growth is very weak. In low and sometimes in high regions, bogs develop in similar positions, and patterned ground does not form ...

"Vegetative protection does not consist of plants alone. The roots probably contribute to ground stability; and the vegetative cover traps snow, thus making a thicker snow cover on the ground ...

"The above conditions were observed and used in classifying patterned ground. They probably result in zonation of the patterned ground, which is often found in Alpine and Sub-Alpine regions.

"Pattern types that develop in the absence of thick vegetation are found at the highest elevation where soil exists. In favourable positions, such as lakeshores, boulder fields, and the like, they may develop even below the timber-line.

"Pattern types that develop in a coherent vegetation cover are absent at high levels because thinning of the vegetation creates a distinct upper limit. At low levels, on the other hand, thicker vegetation protects the ground against frost action, thus setting a lower limit ...

"Except for fossil patterned ground in southern Sweden, all pattern types can probably be formed under present climatic conditions where they are found - even if, in certain instances, they are fossil.

"The Falun, 200 Km northwest of Stockholm supplies a good example. Factory smoke has killed vegetation over a limited area. Not only boulder depressions but also sorted polygons and stripes have formed. This region is situated far from the Caledonides and at a relatively low level where such patterns are not formed generally, except on lakeshores and the like."

230. LUTZ, H.J. 1960. Fire as an ecological factor in the boreal forest at Alaska. J. For. 58:454-460.

A general account on the relationship of Alaska tree species to fire as well as effects of fire on soil.

231. LUTZ, H.J. 1956. Ecological effects of forest fires in the interior of Alaska. U.S. Dep. Agr. Tech. Bull. 1133. 121 p.

This paper is a very detailed discussion of the effects of forest fires in Alaska and includes all aspects of forest fires, the history of the area, the history of forest fires in interior Alaska, effects on trees, succession, soils, hydrology, game, and on economic development. A long bibliography is included.

232. LYNGE, B. and P.F., SCHOLANDER. 1932. 1940. Lichens from North East Greenland. 1 and 11. Skr. om Svalbard og ishavel Nr. 41. 116 p. Nr. 81. 143 p. (bound as a single volume).

These papers include keys and distributions of both macro- and microlichens as well as descriptions of new species. Comparisons are made with the lichen floras of Spitsbergen, Novaya Zemlya and Eastern Siberia.

233. MACKAY, J.R. 1963. Notes on the shoreline recession along the coast of the Yukon Territory. Arctic 16:195-197.

Comparisons using historical and geomorphological evidence with the present form of the coast between Herschel Island and the Mackenzie Delta indicates that recession of relatively great magnitude (exceeding 1 m/year) has taken place in low bluffs of fine-grained sediments with high ice content. Sand and gravel bluffs tend to recede more slowly. In these areas no bedrock is present.

234. MACKAY, J.R. 1963. Origin of the pingos of the Pleistocene Mackenzie Delta area. First Can. Conf. Permafrost Proc. Nat. Res. Counc. Can., Ass. Comm. Soil Snow Mech. Tech. Memo 76: 79-83.

The author suggests that draining lakes may initiate pingo formation and also suggests some pingos now exist which did not at the time of Franklin's expeditions.

235. MACKAY, J.R. 1963. The Mackenzie Delta area, N.W.T. Can. Dep. Mines Tech. Surv., Geogr. Br. Memo 8. 202 p.

This paper presents a very full description of the Delta (map sheet 107 SW National Topographic Series, Port Brabant, scale 8 miles to the inch). Emphasis is on the physical geography. Terrain features, developed as a result of the climate, as well as the regional physical geography, are discussed at length. There are short sections on climate, break-up and freeze-up and vegetation.

Vegetation: "The northern portion of the Mackenzie Delta area is in the tundra, the southern portion in the boreal forest. The boundary zone between tundra and treed areas may be either sharp or transitional. In general, the sequence from north to south is: tundra; tundra with scrub willow and ground birch; scrub willow and ground birch; woodland and tundra with much scrub willow and ground birch; open woodland; and continuous woodland." (A map showing the vegetation regions is included.)

Open Woodland: "Fires have burned over hundreds of square miles of open woodland, woodland tundra and scrub vegetation. Large burnt over areas occur between the Caribou Hills and Kugaluk River. Old and young burnt areas are easily recognizable on air photographs by tonal and textural contrasts and straight-lined vegetation boundaries. Most of the burnt over areas trend northwest-southeast and have apparently burnt to the southeast, being fanned by northwest winds. Fires appear to have burnt most often in treed areas with thick peat. The disruption of the surface cover causes local thickening of the active layer, melting of ground ice, and topsy-turvy blackened trees precariously balanced in a morass of collapsed hummocks."

Peat: "In the tundra, peat deposits are usually associated with tundra polygons ... Thick peat beds comprise the surface matter of high-centred polygons. The peat may contain logs and branches of spruce, willow, and alder interstratified with other organic matter. As an impression, tree and shrub remains are most numerous near the bottoms of the peat bogs."

White spruce is the most abundant tree in the Mackenzie Delta, black spruce is less common.

"The distribution of white spruce is closely associated with flood conditions. Along any given channel cross-section, the lowest altitude of spruce on both banks is nearly the same, being usually within a few inches. The seaward limit of spruce corresponds to a levee height of about 10 feet above sea level. The precise limit is believed due more to edaphic and geomorphic factors of soil, drainage and flooding, than to micro-climatic factors. Exposures in cut banks show that some spruce have survived, by sending out fresh roots, during the time when six or more feet of sediment were deposited and the permafrost surface rose accordingly. If sedimentation is too rapid, the spruce trees die, topple over, and break near ground level. The stumps may, in time, become concentrated near low water level by bank erosion and give the erroneous impression of the exhumation of a buried forest."

236. MACKAY, J.R. 1966. Segregated epigenetic ice and slumps in permafrost, Mackenzie Delta area, N.W.T. Geogr. Bull. Can. 8:59-80.

Author's abstract: "A classification of ground ice applicable to the Mackenzie Delta [with a map] is given, followed by a more detailed discussion of the origin and distribution of segregated ice with emphasis on epigenetic ice. The relationships among the age of sediments, sedimentation, and grain size distribution of soils are considered. Slump exposures of epigenetic segregated ice, mechanism of slumping, water (ice) content of the soil, polycycle slumps and two contrasting slump types are discussed in some detail. Theories for the origin of epigenetic segregated ice are suggested."

237. MACKAY, J.R. 1966. Tundra and taiga. Future Environments of North America. F. Darling and J.P. Milton, ed. Natural History Press, New York. p. 156-171. (Reprinted in: Vegetation, Soils and Wildlife 1969. J.G. Nelson & M.J. Chambers, ed. Process and Method in Canadian Geography. Methuen, Toronto.)

The problems of thermokarst subsidence caused by removal or breaks in protective vegetation by bulldozers, animals, footpaths, logging, fire, etc. are described. Much of the information is taken from earlier publications and thus this paper is a good review of information up to this date.

"The ice-wedges are particularly subject to thermal erosion and upon melting, conical hillocks - the baidzharakhi of Yakutia - are left protruding. Streams which follow an ice-wedge network may become beaded; coasts cut into ice-wedge terrain may have long gullies which work headward by thermal erosion along the wedges; and so forth. Thus, ice-wedge terrain is particularly susceptible to change, whether naturally or artificially induced. Disturbances are also critical in thick sections of fine-grained soils with horizontal or irregularly shaped ice masses. The ice content (percentage of ice to dry soil on a weight basis) may average 100 to 300% for the upper few tens of feet of permafrost in fine-grained sediments. A natural or artificial rupture of the surface cover may therefore initiate ground ice slumps which retreat headward, mainly by melting. Coastal recession and gullying are rapid in such areas. A break in the vegetation cover or a blockage in drainage may be sufficient to create a thaw (thermokarst) topography with depressions and cave-in lakes ... In the taiga, Raup, 1951, has pointed out that forests on actively moving slopes are more or less unstable, root systems may be torn loose from their intimate soil contact, and mortality is high. Such forests are prone to disturbances, both natural and artificial. The frequent sight of tilted or drunken trees is nearly a sure sign of such a disturbance ...

"Man's activities can and do alter the inter-related elements of soil-patterned ground - microrelief.

The establishment of a summer campsite for one or more seasons leaves its mark by disturbed vegetation, which in abandoned eskimo sites is usually recognizable by a more luxuriant growth than in nearby tundra areas (Wiggins and Thomas, 1962). Frequent vehicular traffic, if unconfined to a road, may slice up the tundra with remarkable rapidity, especially where track or wheel furrows concentrate drainage into flow channels. A footpath, used for only one season, may persist virtually unchanged for decades. Regrowth of vegetation is so gradual that a disturbance, such as forest cutting, may be perpetuated nearly unchanged for a century. For instance, the Hudson's Bay Company established Fort Anderson [on the Anderson River, 150 miles east of Inuvik, N.W.T.] in 1861 and abandoned it only five years later in 1866. In the intervening century, revegetation has been minimal, most of the vegetation is still composed of grasses with a few willows. The forest clearing still preserves the original outlines of the stockade."

Fires: "Forest fires, whether ignited by lightning or by man, have devastated thousands of square miles. Even the treeless tundra has not escaped from fires; some peaty terrain has burned or smoldered for months ... In 1954 an area of 820 sq mi of the reindeer winter range area, east of the Mackenzie Delta, was 70-80% burned and rendered useless for grazing (Cody, 1964; Mackay, 1963). Ten years later, the lichen flora had not recovered sufficiently to allow reindeer to graze ... The direct consequences of fires are several. There is, of course, the destruction of standing vegetation, and thus the immediate loss of a resource which may not be renewable for generations; in the Mackenzie Delta area, 500-year old spruce grew to the treeline. Frequently a forest fire consumes organic matter in the upper part of the soil, rendering it sterile for revegetation. A thickening of the active layer is usual as an aftermath of a fire, and if the ice content of the ground is high, thawing tends to produce hummocks, drunken trees, miniature thermokarst features, local ponding, and gullying."

238. MACKAY, J.R. 1967. Permafrost depths, lower Mackenzie Valley, N.W.T. Arctic 20:21-26.

Author's abstract: "Ground temperatures in the Lower Mackenzie Valley have been obtained for seven sites in the 1965 to 1966 period by installing thermistor cables in seismic shot holes drilled for the purpose. From the initial measurements, permafrost thickness is estimated at about 350 feet for Arctic Red River and 400 feet for a site 14 miles west of Fort McPherson. In the south-central part of the MacKenzie Delta, in an area of gradually shifting channels and infilling lakes, the depth is 350 feet, or possibly more. In the distal part of the Delta, where new islands are growing, permafrost is aggrading downwards in the saturated alluvial soils. At four sites within two feet of sea level, permafrost maybe only 60 to 100 feet deep. Here permafrost should continue to aggrade for many centuries more."

239. MACKAY, J.R. 1970. Disturbances to the tundra and forest tundra environment of the western Arctic. Can. Geotech. J. 7:420-432.

Author's abstract: "The more important physical disturbances to the tundra environment are discussed with examples. Thermokarst subsidence, not thermal erosion, is shown to be the dominant result of man-induced disturbances, such as those caused by bull-dozing of seismic lines and fire breaks ... The typical surface disturbance to the tundra results in a deepening of the active layer. Therefore, foreknowledge of the effect of a disturbance on deepening the active layer, together with information on the ice content of the permafrost affected, makes it possible to predict the amount of thermokarst subsidence likely to take place. Three practical examples of three types of ground disturbances are given: fire, ... vegetation trampled and killed by a dog, and seepage ... The effects ... are illustrated and discussed."

240. MACKAY, J.R. 1971. Geomorphic processes, Mackenzie Valley, Arctic Coast, District of Mackenzie. Report of Activities, Part A. April - October 1970. Geol. Surv. Can. pap. 71-1A: 189-190.

Work on pingos has shown that young pingos at two sites have grown 4 and 8 inches respectively in the past year. "Actively growing pingo can probably be recognized by tension cracks, resembling ice-wedges, which cross the pingo and continue onto the exposed lake bottom." Local coastal retreat, as determined by photograph comparison of more than 1,000 feet has occurred in some areas since 1935.

On the Mackenzie River, "ground ice, some 20 feet thick, and lying beneath 5-15 ft. of peat and lake silts, was found about 20 miles downstream from Fort Simpson. Many slumps in sands and silty sands, along the river, have probably occurred as a result of permafrost thaw in the bare vegetation-free banks ... The forest fires of 1968 and 1969 summer seasons have caused extensive slumping of the active layer from mile 610 to mile 900 along the MacKenzie River. Locally, there is badland topography."

241. MACKAY, J.R. 1971. The origin of massive icy beds in permafrost, Western Arctic Coast, Canada. Can. J. Earth Sci. 8:397-422.

Author's abstract: "Massive beds of ground ice [up to 35 m thick] are shown to exist along the Arctic coastal plain east of the Alaska-Yukon boundary for a distance of at least 500 Km ... A theory is presented which suggests that: the ice is of segregation origin; the source of excess water was from the expulsion of ground water during the freezing of sands; and the high pore water pressures, favourable to ice segregation, developed beneath an aggrading impermeable permafrost cover ... Similarities in the origin of pingo ice and massive ice are discussed."

242. MACKENZIE VALLEY PIPE LINE RESEARCH. 1971. Description of Research Project. 7 Dec. 1971. 4 p. mimeo.

Soils research and Inuvik test facility: 'Mackenzie Valley Pipe Line Research invested some 2 million dollars in the construction and operation of an experimental above-ground pipe loop at a site near Inuvik, N.W.T. The site chosen was representative of open tundra found on the North Slope. The top active layer consists generally of a moss and grass blanket approximately 8 inches thick, underlain by about one foot of humus and silt. This spongelike mass contains large quantities of water. Under this is a layer of 7 to 10 feet of silt mixed with ice in the form of ice lenses, crystals, and masses of irregular shapes. The ice content, based on the dry weight of soil, varies from 80 to 300 percent. Underlying the silt is a layer of partially consolidated gravel and sand with small boulders and an ice content of about 30% by weight. Prior to the start of construction, a layer of gravel ranging from 2 to 5 feet in thickness was placed directly over the original ground, to protect the soil and its cover from traffic and construction activity. The test facility is a closed loop of 2,000 feet of 48" pipe, one half constructed above-ground on piles and the remainder installed in a gravel embankment or berm above the original grade. The pipe in the berm was insulated with

2 inches of polyurethane and covered with 2 feet of gravel. The pipe exposed on the piles had 4 inches of insulation under a sheet of aluminum wrapping. Crude oil at 160° F is circulated continuously through the pipe at a rate equivalent to about 700,000 barrels per day. Extensive measurement programs determine the physical movements of the test loop components at different oil temperatures and prevaling weather and soil conditions ...

"At the conclusion of the first summer's operation, thawing of the permafrost under the pile-supported section was, if anything, less than that in normal undisturbed terrain. Under the berm section depths of melt were not significantly different from those in undisturbed ground. Survey measurements showed that the pile-supported section had not moved. A general settlement 3 to 4 inches in the berm section was observed. Most of this settlement was due to melting of snow and ice entrapped in the gravel during construction, compression of the tundra and normal compaction. The mechanical aspects of the loop relative to expansion, contraction and vibration were as predicted.

"It was considered desirable to accelerate melting of the permafrost to obtain wider variation of temperature changes in a shorter time to correlate with predictions from the mathematical model. It was therefore decided to remove the insulation from a 400-foot portion of the pipe at the thin end of the berm and establish three additional cross sections for temperature monitoring in this "modified" section, allowing continued collection of data from the original configuration as well as from the modified section. With more rapid advance of the thaw front, increased settlement of the un-insulated pipe should occur.

"The insulation was removed from the pipe and new instrumentation installed in early October, 1970. The location of the thaw front predicted by the thermal simulation model was checked with the actual observed thaw front location. As of September, 1971, the thaw front had advanced to about 9 feet below grade, and a settlement of about three feet had occurred in the modified section. Settlement of the insulated section had progressed to approximately 10 inches ..."

243. MACPHERSON, A.H. 1965. The barren ground grizzly bear and its survival in Northern Canada. Can. Audubon 27:2-8.

A brief account of the habits of the grizzly bear. A population of 500-1000 is estimated for the N.W.T. Aspects of bear attacks on humans are discussed, as well as the need for protection of the grizzly. The article indicates lack of knowledge of the bear.

244. MACPHERSON, A.H. 1969. The dynamics of Canadian Arctic fox populations. Can. Wildl. Serv. Rep. Ser. 8. 52 p.

Arctic fox populations of N.W.T. from 1958-1964 were studied to attempt to elucidate causes of population fluctuations. Lemmings accounted for up to 90% of their food intake and never less than 50% and were important both summer and winter. Carrion, other animals and plants all contributed to their diet. Years with low lemming populations had low whelp survival and fighting among the whelps also helped reduce survival. "Survival of whelps in the first half year, rather than the number of litters produced in a given year, appeared to be the governing variable in population fluctuations."

Denning areas "were most common in sandy, well-vegetated areas of gentle slope. Places where numerous eskers overlooked broad valleys or river flats seemed best occupied." Surface stability seems important in location - areas with solifluction features contained few dens. No dens were found on talus or boulder fields. Other features appear to be "small accumulation of winter snow, good exposure to the sun in spring, protection from severest winter winds, and elevations above water and frost line." An average life span for a den was estimated to be 330 years. Wolves and grizzly bear may occupy or dig out fox dens and render them unsuitable for fox habitation. Ground squirrels may also occupy dens or parts of them. Occupied dens were never closer than a mile and there was an average density of 1 den in about 14 square miles.

245. MAGNUSSON, A.H. 1951. Lichens from Torne Lappmak. Archiv for Botanik. Bd 2 Nr. 2:45-249.

Although concerning this northern territory of Sweden, the keys cover species distributed much more widely. Detailed descriptions accompany most species along with local distribution notes.

246. MAINI, J.S. 1966. Phytoecological study of sylvotundra of Small Tree Lake, N.W.T. Arctic 19:220-243.

The study area supports a closed *Picea mariana* forest on the lakeshores and hill bottoms while the exposed slopes are treeless. Between, a *Picea mariana* parkland forms the transition. "The large size of trees in the parkland, absence of krumholz zone, and abrupt timber-line due to topography indicate a delicate balance between the vegetation types. Very general information is included in soils and climate.

247. MAKHAEVA, L.V. 1959. Winter pasture management in reindeer farming in Murmansk Oblast. Problems of the North 3:65-76. (Transl. from Russian by Nat. Res. Counc. Can. 1961.)

This paper contains information on the results of grazing of reindeer on lichen pastures. Suggestions are given as to the best management practices.

248. MANNING, T.H., E.O. HÖHN and A.H. MACPHERSON. 1956. The birds of Banks Island. Nat. Mus. Can. Bull. 1943. 144 p.

Observations on the birds of Banks Island in 1952 and 1953 are herein recorded. Very full notes are included in the systematic list.

249. MANTHEI, J. and K. VAN CLEVE. 1971. Revegetation of disturbed tundra and taiga surfaces. 22nd Alaska Sci. Conf. College, Alaska. August 17-19.

250. MAYCOCK, P.F. and B. MATTHEWS. 1966. An arctic forest in the tundra of Northern Ungava, Quebec. Arctic 19:114-144.

A disjunct willow thicket community 32 miles southeast of Deception Bay in Northern Ungava is described.

251. McGROGAN, J.F., A.C. CONDO and J. NEUBAUER. 1971. Tundra restoration: Two-year response study of generic related grass types introduced onto disturbed Prudhoe Bay area tundra. Southwest Alaska Section Regional Meeting, Petroleum Engineers of Aime Anchorage, Alaska. Pap. No. SPE 3249. 5 p. plus appendices.

From the abstract: "A tundra restoration experiment was initiated on disturbed tundra in May 1969 ... Evaluation in late summer 1970 showed red top, creeping red fescue, brome and Canada blue grasses as having survived the severe Arctic winter and growing well."

Although attempts were made to use seed of native species, the unpredictable nature of seed set and maturation precluded its use. Thirteen species of winter-hardy grass strains were eventually used. Test plots covered both gravel and undisturbed tundra, fertilized and unfertilized areas. Early winter survival tests were done by taking cores from the sample plots, embedding them in wet sphagnum and placing them in a controlled environment in March. Results obtained at this time were confirmed by observations in the field in

August. Gibberillic Acid treatment of seeds was also carried out and results indicate that in most cases there was higher initial seed germination, better first year growth and winter survival and lower residual seed germination in the following year.

252. MCKAY, G.A., B.F. FINDLAY, and H.A. THOMPSON. 1970. A climatic perspective of tundra areas. Productivity and Conservation in Northern Circumpolar Lands Proc. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:10-33.

A review of the problems caused by the climate of organisms inhabiting the Arctic.

From the summary: "Both plant and animal life exist precariously, in the tundra mainly by taking refuge in a particular microclimatic area and thereby escaping the rigors of the general climate. The microclimates are in a delicate state of balance, and alteration of this balance either naturally, as in climatic deviation, or unnaturally such as through vegetative modification, may have serious consequences. For example, the alteration of the albedo can upset the energy balance of the soil surface and result in thermokarst conditions. The removal of tall vegetation will result in increased winds and in shallower snow cover, which may significantly change the thermal regime near and in the ground."

253. McTAGGART-COWAN, I. 1948. Waterfowl conditions on the Mackenzie Delta. 1947. Murrelet 29:21-26.

Arctic Bibliography 21297: "Counts of waterfowl made in 1934 (by Porsild) and June - August 1947 (by the author) show only about half as many birds in the recent as in the earlier year. Some field notes on 17 species, description of the delta as habitat and discussion on the decline in waterfowl are presented."

254. MERSHIN, A.P. 1970. Manual for using aerial photographs in soil mapping U.S. Army Materiel Commond. Foreign Science and Technology Centre. Tech. Transl. FSTC-HT-23-732-68. 52 p. AD-708-787.

From: U.S. Army Cold Regions Eng. Lab. (CRREL) Rep. 12. 25(1) 1971. CRREL 25-2554. (Russian entry indexed under CRREL 23-1157).

"Discusses the use of aerial photography in the mapping of soils. Much attention is given to the methods of interpreting soils by their distinctive characteristics in various zones and provinces. The authors also point out that the application of aeromethods in the practice of large-scale soil mapping in the Soviet Union and abroad indicates that the use of materials from aerial survey increases considerably the accuracy of soil mapping, reduces the volume of the field work, cuts down its cost and increases the practical value of soil maps."

255. MICHURIN, L.N. 1967. Wild reindeer and the economy of the far north. Problems of the North. 11:111-123. (Transl. from Russian by Nat. Res. Counc. Can. 1968.)

Discussion in this paper focuses on relationships of wild reindeer with humans, domestic lands, wolves, methods of capture, etc.

256. MOSS, E.H. 1953. Marsh and bog vegetation in N.W. Alberta. Can J. Bot. 31:448-470.

Author's abstract: "Swamp, marsh, wet meadow, saline meadow, *Drepanocladus* bog and *Sphagnum* bog are characterized, and related aquatic vegetation is described briefly. There is a succession from different kinds of swamp and marsh, through wet meadow, to *Agropyron-Carex* grassland and to various wooded communities, and also of marsh, through *Drepanocladus-Carex* bog to *Larix laricina* association. The main bog sere of the region is initiated by some kind of aquatic or marsh phase and passes through *Sphagnum* bog stages to bog forest (*Picea mariana*) climax. Ecological aspects of *Sphagnum* species are considered in relation to succession and a regeneration cycle. Retrogression caused by burning is described for marshes, bogs, and bog forests. Many bogs in the northern part of the region have large mounds and ridges that retain frozen peat below the surface mantle during the summer. The significance of these permafrost areas is discussed." There is little or no information on soils included in this paper.

"The relative effects of burning per se, level of water table, dessication through lack of tree cover, availability of tree seed, etc., in maintaining this kind of open bog is difficult to determine. Tree damage by rabbits also makes for the open bog conditions."

257. MONLUX, A.W., R.J. SCHOEPPEL, C.C. PEARSON, and G.R. WALLER. 1971. The effects of oil field pollutants on vegetation and farm animals. J. Amer. Vet. Med. Ass. 158:1379-1390.

Biological abstracts 52:93326, 1971: "Disease problems in livestock exposed to oilfield pollutants are not difficult to delineate. In the past, oilfield production practices generally contaminated large surface areas; current methods allow for more efficient management by concentrating various oilfield activities. Though the release of water containing moderately high concentrations of salt onto grazing lands adjacent to production causes spectacular damage to vegetation, the same water when ingested by livestock usually will not produce clinical disease. Ingestion of crude oil and lead frequently results in death. The origin of crude oil pollution is usually easily established, but difficulty may be encountered in finding an exact source of contamination by lead. Proper precautions can be taken to minimize the likelihood of all types of pollution."

258. MOZLEY, A. 1937. Frozen ground in the subarctic region and its biological significance. Scottish Geogr. Mag. 53:266

"Page 269- cites Gadow, who belives amphibians cannot live north of the $0^{o}C$ of mean annual air temperature because of underlying permafrost" Quoted by Péwé (1957).

259. MOZESON, D.L., and N.A. UTENKOV. 1958. The extent of our knowledge of the physical geography of the northeastern USSR and the problems of future research. Problems of the North 2:89-115. (Transl. from Russian by Nat. Res. Counc. Can. 1961.)

The extent of knowledge of the area east of the Lena River is limited. Information is presented on the climate, rivers, soils, fauna and flora. Much of the area is a vast lowland all but impossible in the summer. A large bibliography is included.

260. MULLER, S.W. 1947. Permafrost or permanently frozen ground and related engineering problems. J.W. Edwards, Inc. Ann Arbor, Michigan. 231 p.

A basic reference for engineers.

On the subject of thermokarst the author indicates: "the relative intensity of its processes depends on several factors of which the most important are:

1) Composition of the ground. Ground that contains a considerable amount or entirely consists of carbonate, gypsum, anhydrite, rocksalt, and ice is especially susceptible to the thermokarst processes.

2) Structural relations of ground that is susceptible to the thermokarst processes.

3) Climatic factors.

4) Hydrologic and hydrogeologic factors (circulation and regime of surface and ground-waters and their mutual relations).
5) Condition of the soil.
6) Geomorphic factors.
7) Human activity."

261. NATIONAL RESEARCH COUNCIL, Div. Build. Res. September 1971. List of publications on Permafrost and Building in the North memeo. n. p.

This annotated list contains titles of research and technical papers and books as well as technical translations.

262. NEISHTADT, M.I. and M.N. NIKONOV. 1958. The peat deposits of the Yakut, ASSR. Problems of the North 2:131-159. (Transl. from Russian by Nat. Res. Counc. Can. 1961.)

This paper gives a very detailed description (vegetation, stratification, ash content, etc.) of the upland and lowland peat deposits of this area. The interest is related mainly to their potential use for agriculture or for fuel. Two inferences are interesting: 1) In Central Yakut, ASSR, there are almost no peat bogs due, apparently, to extreme dryness, but "many boggy areas are now being formed, apparently as a result of the disappearance of permafrost in these regions." 2) In an area on the Ukulan-Aldan highway, a bog has apparently been recently burned over "as is indicated by presence of charred stumps ... and considerable quantities of *Marchantia polymorpha*."

263. NORTHWEST PROJECT STUDY GROUP. 1971. Description of Activities Paper prepared for the meeting between government representatives and industry study groups.

The vegetation restoration project is outlined.

"The vegetation research program is being viewed in two phases. The first phase is a temporary vegetative cover to retain surface stability and retard thermal degradation due to the disturbance caused by pipeline construction activities. The second phase is the reinvasion of the naturally occurring species to re-establish the former plant community. Studies have been completed examining seismic lines where the vegetation was cleared some years ago. Observations were made of the plants belonging to the former black spruce - muskeg community that have survived the clearing of the line and the growth response of the plants recorded in the severely altered habitat. At the test site, observations were made before and after construction of the cold and cycling loops to ascertain the amount of damage to the tundra occasioned by construction on a winter road surface.

"Four of the buried pipeline sections at the Test Facility were seeded with eighteen species of grasses. Different fertilizer rates were applied in the test plots and comparative measurements have been recorded during the summer. Three of the critical areas being investigated are dry ridges, river banks and side slopes. These plants are being considered as initial binding agents. Specific critical areas have been seeded with willow and alder cuttings to establish shrub cover to bind the deeper soils on these critical slopes. Various types of native grass seeds have been used to evaluate the effectiveness of these species. They are considered to be most valuable in that they require less nutrients and have a natural persistence."

264. NORTHWEST PROJECT STUDY GROUP. 1971. Arctic Test Facility. n.p.

A brochure—outlines the facilities of the Arctic Test Facility at Mountain River and the research being conducted there.

265. NORTHWEST PROJECT STUDY GROUP. 1971. Research and Feasibility Study Summary Status Reports. Dates issued March 1, April 30,

July 30, Sept. 30.

These reports are prepared periodically to indicate the status of the research programmes. Outlines of proposed research, and interim results are presented.

The Summary Status Report of September 30 contains some results of the summer field investigations. Under Environmental Studies information is included on the movements of the Porcupine Caribou herd during northward and southward migrations, and calving estimates (50 calves per 100 cows) for 1971. Beaver and muskrat populations as well as fox denning sites, and grizzly bear activities were surveyed. - "A much closer relationship between the bears and caribou than was previously assumed [is indicated]. Although only two suspected grizzly kills have been observed, the bears are often observed to feed on wolf kills ...

"Comparative trapping of small animals on disturbed and undisturbed sites has been completed. This survey, to determine if there was a shift in the rodent population and hence food supply of carnivorous fur bearers, indicated no significant difference in population distribution".

Fish population surveys, with particular attention to the Arctic grayling, are endeavouring "to determine the seasonal distribution and population size as related to pipeline activity". A similar survey of the bird population, with specific reference to the raptorial species has been completed.

In the Summary Status Report for July 30, The Vegetation Restoration project was outlined:

"Four of the buried pipeline structures the [Arctic] test facility were seeded with eighteen species of grasses. All species germinated and six to eight of the species appear to be doing very well. Three of the critical areas being evaluated are dry ridges, river banks and side slopes. These plants are being considered for use as initial binding agents. Work on the seeding was performed by ARCO chemicals of Fairbanks Alaska. Four more species are being planted on inactive test sections, seismic washouts and other problem areas to determine their value in the initial germination period. Specific critical areas are being prepared for the planting of willow and alder cuttings to establish shrub cover to bind deeper soils on these critical slopes. Various types of native grass seeds have been used to evaluate the effects of these species. They are considered to be most valuable in that they require less nutrients and also have natural persistance".

The September 30 Summary Status Report, mentions that "evaluation of growth rate and response of grass species seeded on buried pipeline sections at the Arctic Test Site has been completed ... Continuous monitoring of the effect of the introduction of exotic species into northern plant communities is being performed." Work on the native *Calamagrostis canadensis* is also being done.

266. PARMELEE, D.F., H.A. STEPHENS AND R.H. SCHMIDT. 1967. The birds of south-eastern Victoria Island and adjacent small islands. Nat. Mus. Can. Bull. 222. 229 p.

A full account of the bird collections of the 1960 and 1962 field seasons based at Cambridge Bay and 1966 at Jenny Lind Island. A general introduction includes information on nesting habitats and climate.

267. PALMER, L.J. and C.H. ROUSE. 1945. Study of the Alaska tundra with reference to its reactions to reindeer and other grazing. U.S. Fish. Wild. Serv. Res. Rep. 10. 48 p.

This is an extensive report, covering a period of up to 14 years, on the recovery rates of various types of disturbance in tundra in Alaska. These types of disturbance were to simulate reindeer disturbance. Permanent quadrats were set up and results were always compared to untampered sites or natural sites and exclusion quadrats.

"In the tundra-lichen types, the range is quick to react to any disturbance. The length of time required for its recovery is directly proportional to the degree of disturbance. Trampling has a greater damaging effect upon lichens than has grazing or even the removal of the plant cover. Disturbance of the lichen cover on a moist site is followed by an almost immediate invasion of vascular plants, chief of which is cotton-sedge (*Eriophorum*). The rate of invasion is in direct proportion to the amount of disturbance. On dry sites, the reduction of lichens through grazing is followed by an accelerated growth of shrubs. The recovery of lichens is more rapid on dry, than on moist, sites...

"In the tundra-sedge type, even moderate grazing tends to retard the vegetation of denuded or badly depleted areas on the drier sites. Summer grazing reduces the quantity of sedges and permits increased growth of browse species. On moist sites, however, the vegetation readily recovers after denudation of an area, an almost pure stand of *Carex* coming in first. Under protection, the density of cover increases and an invasion of grasses seems to follow. One season without protection was sufficient to undo the progress of four years and render the area substantially as it was when the studies were started ...

"The grass-browse type will bear heavy grazing. Following denudation of a plot the recovery to grass is rapid ...

"The heath type is unstable. After denudation of an area the initial invaders were mosses and *Equisetum*. Opening of the stand allows an increase in weeds. The shrubs recover slowly ...

"In the lichen browse type, recovery is rapid under a light cropping but slow under heavy grazing. On this type open herding should be practiced and the range should not be used during the summer and early fall when the lichens are dry and brittle and thus easily destroyed by trampling ...

"Opening of the woodland moss stand allows competition of the mosses with the lichens. In this type, recovery after over-grazing is slow but a recovered stand contains a large proportion of lichens.

"In the alpine-dryas type, recovery after denudation of an area is slow. Invasion is by *Dryas*, weeds, *Carex*, bluegrass, and lichens ...

"On over-grazed browse-lichen tundra, the browse species are the most aggressive in recovery, followed by lichens. It is indicated that complete recovery would require probably 25 years or more. Substantial recovery was noted on over-grazed sedge-weed tundra [moist site] in four years.

"Very slow recovery occurred on denuded browse-grass tundra [dry site] during a four-year period. Invasion by grasses and sedges was most active.

"Further study of the complex nature of the Alaska tundra is needed. The climax association of the Arctic tundra, ordinarily given as *Cladonia-Carex*, is not readily verifiable, the present cover being unstable, although this may be due, in part, to grazing. Disturbance by grazing and fire, accompanied perhaps by climatic changes, has resulted in a general confusion in the plant mixture and occupation. The removal or depletion of the insulating plant cover allows the topsoil to thaw to greater depths and opens the surface to drainage. This, no doubt, contributes largely to alteration of site conditions and causes further vegetative changes. The advance of tree growth on the tundra indicates that the formation is as yet unstabilized.

"The wet tundra seems less stable than the dry tundra. On both, the recovery of lichens from grazing or fire injury is slow, whereas the invasion and re-establishment of vascular plants are rapid. A depleted lichen range under complete protection requires from 20 to 40 years for restoration to the original density and height growth. Moderate grazing by open herding and rotational use, however, will permit sustained utilization of undamaged tundra range ...

"The vegetative types considered are of beach-transition, sand dune and sand spit, grass-browse, wet and dry tundra (including sedge), lichen, heath, woodland, and alpine ... Moderate utilization of the beach-transition, sand dune, and coast-sand spit types tend to stabilize the cover to a composition of grasses and weeds. Such cover produces more platable spring and summer forage than do the browse-lichen and browse-moss associations of the adjoining tundra. Over-grazing opens the stand to an invasion of mosses, reduces the quantity of forage, and exposes the soil to erosion by wind and rain."

268. PEAKER, J.P. 1968. Report on the forest conditions in the Upper Liard River area, Yukon Territory. Can. Dep. For. Rural Develop., For. Manage. Inst. Surv. Rep. 6. 9 p. plus appendices.

This report contains information on the forest trees which are of possible importance on the Upper Liard River. Most important is white spruce. Maps of the forest inventory are included.

269. PEGAU, R.E. 1968. Growth rates of important reindeer forage lichens on the Seward Peninsula, Alaska. Arctic 21:255-259.

Three species, *Cladonia alpestris*, *C. rangiferina* and *C. sylvatica* were investigated. Their average growth rates were higher than in Northern Canada and some areas of the USSR.

Author's abstract: "The average annual linear rates of growth of *Cladonia alpestris*, *C. rangiferian*, and *C. sylvatica* on the Seward Peninsula, Alaska, were determined to be 5.0, 5.3, and 5.4 mm. respectively. These averages are higher than those of northern Canada and some areas in the USSR. *Cladonia rangiferina* reaches the podetium ["stalk"] renewal period in 5.9 years which is almost half the time required by the other two species."

Notes: "Since *C. rangiferina* matures earlier than the other two species ... grazing on ranges in which it predominates should be rotated more often to obtain maximum utilization. If a range land with mature lichens is not grazed, the production of lichens will accumulate as peat and its potential use as forage ... will be lost. Andreev (1954), recommended proper grazing of lichen pastures rather than the use of chemical stimulants to get the maximum growth. He suggests rotating pastures so that reindeer only graze the top third of the lichens, as complete restoration of the lichen crop under these conditions occurs within 3 - 5 years."

270. PEGAU, R.E. 1970. Succession in two enclosures near Unalakleet Alaska. Can. Field. Natur. 84:175-177.

Author's abstract: "Two exclosures established during the 1920's [by Palmer and others, see #267] were re-examined in 1965. In the dwarf shrub-lichen type browse species suppressed recovery of lichens. Full recovery of lichens had not occurred within 33 years. In several disturbed quadrats in the *Dryas* fjeld - field type, recoverage after 36 years was primarily from plants that were already established rather than from new plants."

271. PEIPER, R.E. 1963. Production and chemical composition of Arctic tundra vegetation and their relation to the lemming cycle.

Ph.D. dissertation, Univ. Calif., Berkeley. 95 p.

272. PERCIN, F. de. 1960. Microclimatology of a Subarctic spruce forest and a clearing at Big Delta, Alaska. U.S. Army, Quartermaster Res. Eng. Centre, Environ. Protect. Res. Div. Natick, Mass. Tech. Rep. E.P.-130. 162 p.

Two areas adjacent to each other at Fort Greely, Alaska, were instrumented to point up differences in microclimate between forested and cleared areas in June and December.

273. PEREZ-LLANO, G.A. 1944. Lichens, their biological and economic significance. Bot. Rev. 10:1-65.

An extensive review on all aspects of lichenology up to 1942. Contains a large bibliography.

274. PERSSON, Å. 1964. The vegetation at the margin of the receding glacier Skaftafellsjokull, Southeastern Iceland. Bot. Notiser. 117:323-354.

This paper gives an outline of plant succession over a period of about 60 years following glacier recession. There are comparisons with similar work by other Scandinavians and Europeans. Information is presented on the rate of colonization and species lists are included. Apparently permafrost is absent in this area.

275. PEWE, T.L. 1948. Terrain and permafrost, Galena area, Alaska. U.S. Geol. Surv. Permafrost Program Rep. 7.

Contains a discussion of permafrost and vegetation on the flood plain of the Yukon River.

276. PEWE, T.L. 1957. Permafrost and its effect on life in the north. Arctic Biol. H.P. Hansen, ed. 18th Biol. Colloq., Oregon State Coll. p. 12-25.

A general account of permafrost in the north, particularly around Fairbanks. Includes thermokarst features. Extensive bibliography.

"A well-defined boundary between two vegetation types generally lies near the boundary between slopes underlain by permafrost and permafrost-free slopes. The boundary between black spruce scrub forest on permafrost areas and white spruce-birch-aspen forest on permafrost free slopes is distinct and readily recognized. Generally, permafrost, with or without ice masses, extends a short distance upslope past the line marking the border between these two types of vegetation ...

"Much of the floodplain vegetation is influenced by permafrost. Cottonwood, white spruce, birch and tall willows grow where depth to permafrost is 4 feet or more especially on the slip-off side of streams and on the bars of bar and swale topography. Stunted black spruce and larch grow in parts where depth to permafrost is less than 4 feet. Where the permafrost is within 18 in. of the surface, the ground is wet and treeless, but supports a shrub growth of alder, dwarf birch, Labrador tea, blueberry, cranberry and thick moss and lichen cover ...

"The vegetation cover is instrumental in preserving permafrost; removal of this cover permits the perennially frozen ground to thaw and in many instances, eventually to disappear ...

"Permafrost may exert some distinct influence upon the distribution of amphibians. Mozley (1937) cites Gadow who believes amphibians cannot live north of the $0^{o}C$ of mean annual air temperature because of the underlying permafrost. Studies in Alaska by Hoch (1956) show the frog is found in many parts of permafrost areas of central and southern Alaska, but is has not been reported north of the Brooks Range."

277. PEWE, T.L. (ed.) 1969. The Periglacial environment: past and present. Montreal, McGill-Queen's Univ. Press. 487 p.

Contains papers on various aspects of processes and features in the present periglacial environment as well as "fossil" forms now found in the temperate environment. There is little information on vegetation as related to the features.

278. PEWE, T.L. 1970. Permafrost and vegetation on flood-plains of subarctic rivers (Alaska): a summary. Ecology of the subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 141-142.

Summary: "Flood plains of major rivers in the subarctic can be divided into several clearly marked phases based on drainage patterns and distribution of vegetation. Each phase is a distinct temporary appearance of the surface features produced by a meandering stream during lateral plantation of the valley.

"The vegetation is quite distinctive in each phase of the flood plain because of differences in drainage - in a large part dictated by the presence of, and depth to, the top of the permafrost. The permafrost table gradually rises in the younger to the older phases of the flood plain because on the older surfaces, the mosses are better established and thicker, and act as better insulation. The oldest flood plain surfaces have the highest permafrost table because of the thick, protective moss carpet.

"At least four phases, can be recognized on major flood plains: a) Linear Phase (the youngest), distinct linear lakes, parallel to the river, no integration of drainage, large deciduous trees, permafrost absent or low, no large masses of ground ice; b) Advanced Linear Phase, distinct linear lakes, some segmentation, large coniferous trees, slightly higher permafrost table, no large masses of ground ice; c) Coalescent

Phase, coalescing linear lakes, generally at an angle to the river, coniferous trees, some tundra, high permafrost table, and no large masses of ground ice; d) Scalloped Phase (the oldest), irregularly shaped lakes with scalloped borders, integrated drainage, stunted coniferous trees, much tundra, very high permafrost table, and much ground ice".
Note: Drury (1956) uses this classification.

279. PIHLAINEN, J.A., R.J.E. BROWN and R.F. LEGGET. 1956. Pingo in the Mackenzie Delta, N.W.T. Geol. Soc. Am. Bull. 67:119-1122.

A general reconnaissance survey of a pingo is described. Two test borings were drilled, one in the crater, the other in the outer edge. The pingo was partly vegetated - particularly in the four guts - with a dense thicket of willow and some alder on the east side; this in contrast to the surrounding vegetation of mosses and low grasses. "Parts of all slopes [of the pingo] especially at the tops were devoid of vegetation".

280. PIHLAINEN, J.A. and G.H. JOHNSTON. 1963. Guide to a field descrip- of permafrost. Nat. Res. Counc. Can., Ass. Comm. Soil Snow Mech. Tech. Memo. 79. 21 p.

A guide for engineers to the description of the ice phase in perennially frozen materials.

281. PITELKA, F.A. 1957. Some characteristics of microtine cycles in the Arctic. Arctic Biology H.P. Hansen, ed. 18th Biol. Colloq. Oregon State Coll. p. 153-184.

A detailed review of the Alaska work on lemming and other microtine cycles in the area. Details of microtine - vegetation - predator - large grazing mammals - bird interrelationships are given.

"Evidence on variation and complexity of tundra plant communities, and in particular on the gradient of

change from the Arctic Coast interiorward of itself suggests that populational phenonema easily observed near the coast may not be manifest on the zonal scale ...

"Circumstances in northern Alaska along the coast proper which promote a strong cyclic interaction between herbivore and vegetation are the following: 1) the prevailing low flat terrain is also relatively flat microtopographically - in this respect it contrasts with interior tundra; 2) the vegetation coastally is shorter and more herbaceous than it is in the interior, consisting primarily of grasses and sedges; 3) only one species of herbivore is important coastally - the brown lemming ...

"The cyclic high in *Lemmus* near Barrow in 1956 was found to extend along the coast for about 200 miles and inland to distances of 15-50 miles. There is no indication now that a similar cycle occurs elsewhere on the Arctic Alaskan slope."

The author considers that where more than one species of herbivore (microtine) is important "competition may act to depress their respective populations and hence to depress likelihood of strong fluctuations."

282. PITELKA, F.A. 1970. Ecological studies on the Alaska Arctic slope. Arctic 22:333-340.

This paper points out many of the areas needing study on the Alaskan Arctic Slope.

283. POLLAK, R. 1971. Oil on ice. Sierra Club Bull. 56(1):14-19.

From: U.S. Army Cold Regions Res. Eng. Lab. (CRREL) Rep. 12. 25(1). 1971. CRREL 25-3502: "Arctic environment, Pipelines, Tundra Terrain, Permafrost Preservation."

284. POLUNIN, N. 1934. The vegetation of Akpatok Island. Part 1. J. Ecol. 22:337-395.

The plant communities and habitats are described.

Various sorts of patterned ground are present on the Island and are described in detail.

285. POLUNIN, N. 1935. The vegetation of Akpatok Island. Part II. J. Ecol. 23:161-209.

This paper continues a very full description of the communities, habitats and species composition and a discussion of probable successional relationships. *Sphagnum* is totally absent from the island and there are no real bogs.

286. POLUNIN, N. *et al.* 1948. Botany at the Canadian Eastern Arctic. II. Thallophyta and Bryophyta. Nat. Mus. Can. Bull. 97. 573 p.

A general introduction and summary is given by Polunin. The section on the algae has been done by R.N. Weldent. p. 13-137; on marine phytoplankton by A. Seidenfaden. p. 138-177; on freshwater Diatomeae by R. Ross. p. 178-233; on fungi by D.H. Linder. p. 234-297; on lichens by B. Lynge. p. 298-369; on mosses by W.C. Steere. p. 370-409; and hepatics by N. Polunin. p. 491-512. notes are presented on each of the species recorded, giving information on collection, distribution, taxonomy, etc.

287. POLUNIN, N. 1948. Botany of the Canadian Eastern Arctic. III. Nat. Mus. Can. Bull. 104. 303 p.

This paper gives a very full account of vegetation in the eastern Canadian Arctic, defined as Ellesmere Island south to the western coast of Hudson Bay, northern Quebec and the tip of Labrador. This area is divided into ten major districts. For each of the districts the vegetation is described, both from information of early observers and by information obtained as a result of investigations by the author. Most of these observations are in the form of descriptions of local habitat rather than of vegetation

types. Some attempt is made to define successions. No infromation is given on permafrost depths or on the results of soil frost movements.

288. POLUNIN, N. 1951. The real arctic: suggestions for its delimitation, subdivision and characterization. J. Ecol. 39:308-315.

A theoretical paper concerning the subdivision into sectors of the arctic as well as into arctic vegetational zones. Characteristic species are listed, and characteristic terrain is described in broad, general terms for each of the vegetational zones.

289. POLUNIN, N. 1955. Aspects of arctic botany. Am. Sci. 43:307-322.

A paper dealing generally with the current status of arctic botany, especially theoretical aspects, *e.g.* plant geography, taxonomy, floristics, *etc.*

290. POLUNIN, N. 1959. Circumpolar Arctic flora. Clarendon Press, Oxford. 514 p.

A comprehensive flora of the Arctic which contains geographical distributions, ranges of variation, habitat descriptions and at least one drawing of each species.

291. POLININ, N. 1960. Introduction to plant geography. McGraw-Hill Book Co., Inc. New York, Toronto, London. 640 p.

Chapter 8 - Vegetational types of polar lands and high altitudes (380-422): A summary of information collected by Polunin himself and other writers, on the vegetation of these areas is presented. He uses the terms low-arctic, middle-arctic and high-arctic within the descriptions. Various communities are described and typical species listed. Unfortunately, no bibliography is given.

292. PORSILD, A.E. 1943. Birds of the Mackenzie Delta. Can. Field Natur. 57:19-35.

A record of observations on birds and breeding grounds made in various years from 1927 to 1935.

293. PORSILD, A.E. 1943. Materials for a flora of the continental N.W.T. of Canada. Sargentia 4:1-79.

This is an annotated list of species for part of the Northwest Territories.

294. PORSILD, A.E. 1945. The alpine flora of the east slope of Mackenzie Mountains, N.W.T. Nat. Mus. Can. Bull. 101. Biol. Ser. 30. 35 p.

This report contains a brief description of areas adjacent to the Canol pipeline over the eastern part of the Canol Road from MacMillan Pass to the Mackenzie River. Vegetation types are described and an annotated species list is appended.

295. PORSILD, A.E. 1951. Botany of southeastern Yukon adjacent to the Canol Road. Nat. Mus. Can. Bull. 121. 400 p.

An extensive description of plant communities and vegetation types of the Canol Road. Includes discussions on soils permafrost distribution, succession after fire, *etc.* An extensive annotated catalogue of the flora of the Yukon is included.

296. PORSILD, A.E. 1951. Plant life in the arctic. Can. Geogr. J. 42:121-145.

A general discussion of plants and communities of the Arctic. This paper includes a classification and descriptions of the plant communities. A theoretical discussion of the problems of Arctic botany is presented - mainly on migration patterns since Wisconsin glaciation, lack of endemism, *etc.* It is well illustrated.

297. PORSILD, A.E. 1964. Illustrated flora of the Canadian Arctic Archipelago. 2nd ed. revised. Nat. Mus. Can. Bull. 146. 218 p.

A manual of the 340 vascular plant species as presently known from the Canadian Arctic Archipelago. Notes and distribution mpas are included. An introductory section covers physiography, soils and habitats.

298. PORSILD, A.D. 1966. Contributions to the flora of southwestern Yukon Territory. Contrib. to Bot. 4:1-85. Nat. Mus. Can. Bull. 216.

This paper is primarily a report of significant additions or range extensions to the vascular flora at S.W. Yukon. Ecological notes and taxonomic status of some critical or little-known species are included.

299. PORSILD, A.E. and W.J. CODY. 1968. Checklist of the vascular plants of continental N.W.T., Canada. Can. Dep. Agr., Plant Res. Inst. Ottawa. 102 p.

This checklist for the Northwest Territories contains information from all pertinent publications, mainly since 1947. It is the preliminary step in the organization of the manual of the vascular flora.

300. POTZGER, J.E. and A. COURTEMANCHE. 1955. Permafrost and some characteristics of bogs and vegetation of northern Quebec. Rev. Can. Géogr. 9:109-114.

This paper gives an abbreviated description of vegetation from the air while flying a transect through northern Quebec for the purpose of locating bogs for pollen analysis.

301. PRICE, L.W. 1969. The collapse of solifluction lobes as a factor in vegetating blockfields. Arctic 22:395-402.

<u>Author's abstract</u>: "The development of soil and

vegetation in blockfields through normal processes is very slow. It is surprising, therefore, to find in the Ruby Mountains of southwest Yukon Territory, tongues and islands of vegetation occurring amidst certain blockfields. The collapse of solifluction lobes from upslope is suggested as the mechanism responsible. The lobes pass from the more gentle solifluction slope of the alb onto the steeper slope of the blockfields and eventually become unable to maintain themselves because of: steeper slope, change in composition of vegetation and deeper active layer. Once the lobes do collapse, they flow downslope carrying with them clumps of vegetation, which may become established somewhere along the mud-flow channel or levee. In this way, small outposts of vegetation are created and speed up a process which would otherwise take indeterminately longer."

302. PRICE, L.W. 1971. Vegetation, microtopography and depth of active layer on different exposures in subarctic alpine tundra. Ecology 52:638-647.

From the author's abstract: "Four slopes of different exposures ... but with similar gradients, elevations and rock types were studied in the Yukon. [Descriptions of plant communities are given.] Vegetation was best developed on the southeast-facing slope ... and least on the north-facing slope. Solifluction lobes were present ... and their development largely followed that of [the] vegetation ... [Likewise, the] depth of the active layer generally corresponded to the presence of vegetation and microtopography. [It] was shallowest and most variable on the southeast-facing slope. Plant cover, in general, was more important than exposure in determining the depth of thaw."

303. PRUITT, W.O., Jr. 1957. Observations on the bioclimate of some taiga mammals. Arctic. 10:131-138.

This paper presents the results of an essentially continuous record over a two-year period of the thermal environment of the habitat area of small mammals in the taiga. The report indicates how important snow is in the survival of these organisms in winter. It also indicates the importance to these mammals of the depth of snow and the changes of depth of snow outwards from the bole of a tree.

304. PRUITT, W.O., Jr. 1958. Qali, a taiga snow formation of ecological importance. Ecology 39:169-172.

Snow build-up (qali) in trees (white spruce) causes breakage and opening of a "forest window" setting a successional change in motion allowing the regeneration of white spruce. In the northern taiga, seedlings do not survive in carpets of moss and thus this postulation of the cyclic phenomena ensuring reproduction.

305. PRUITT, W.O., Jr. 1959. Snow as a factor in the winter ecology of the barren-ground caribou. Arctic 12:159-179.

Studies indicate that for survival barren-ground caribou need both open and closed snow. The former type, such as the snow on lakes, is used for resting and escape while the latter, forest snow, is necessary when digging fuding craters.

"The areas of heavy caribou concentration were characterized by snow cover that was quite soft, light, and thin (hardness range of 6.5 to 60 gm/sq cm for forest stations, and 50 to 700 gm/sq cm for lake stations; density range of 0.13 to 0.20 for forest stations and 0.13 to 0.32 for lake stations, thickness range of 19 to 59 cm.) ...

"Caribou appear to have a threshold of sensitivity to the hardness, density and thickness of snow cover. The threshold of hardness sensitivity appears to be approximately

50 gm/sq cm for forest snow and 500 gm/sq cm for lake snow. The density threshold appears to be approximately 0.19 or 0.20 for forest snow and 0.25 or 0.30 for lake snow. The thickness threshold appears to be approximately 60 cm. When these thresholds are exceeded, caribou react by moving until they encounter snow of smaller hardness, density or thicknesses."

306. PRUITT, W.O., Jr. 1966. Ecology of Terrestrial Mammals. Environment of the Cape Thompsom Region, Alaska. N.J. Wilimovsky and J.N. Wolfe, ed. p. 519-564. U.S. Atomic Energy Comm., Div. Tech. Inf.

Twenty-one species of mammals are known to be present, 4 others are considered likely to occur and 3 (*Ovis dalli*, *Ovibus moschatus* and *Lepus othus*) have been extirpated. An annotated species list is presented. Summer and winter observations were made.

The food web of the area is outlined. Microtine rodents, arctic ground squirrel and the barren-ground caribou are the three main herbivores, and the basic support of this fragile web. "The population density and biomass of the small mammals undergo marked changes that are believed parts of cyclic fluctuations but ... are not in phase with fluctuations in other parts of Alaska, and, indeed, changes between parts of the study region itself are not in phase ... Snow data are related to ecological distribution and population dynamics of some of the small mammals."

307. PRUITT, W.O., Jr. 1970. Some aspects of the interrelationships of permafrost and tundra biotic communities. Conference on Productivity and Conservation in Northern Circumpolar Lands Proc. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:33-41.

A review paper on aspects of permafrost-plant community relationships. Thermokarst subsidence as a result of vehicle movements is described for widely separated areas. The conclusions by Tyrtikov (1959) are listed *in toto*.

"Permafrost forms a complex, dynamic system with climatic history, vegetational history, recent climate, present vegetation, substratum, topography, solifluction and animal activity, all interacting. In any one region permafrost regime is the result of a dynamic balance between the above factors and perhaps other, as yet unknown, factors. If any one of the factors changes the permafrost regime shifts. Thus, a change in vegetation through time or a change in substratum through space will undoubtedly result in some detectable change in the permafrost regime ...

"Permafrost has a profound effect on vegetation, particularly tree-like vegetation. Consequently, most distribution maps of permafrost are actually based to a large extent on plant distributions ...

"Next to annual mean air temperature [-1°C mean annual air isotherm roughly is the southern limit of permafrost], snow cover is of most importance to permafrost. Annersten (1964) has shown that the critical thickness of snow cover for permafrost to survive is 40 cm ...

"In general, man's activities in regions with tundra and forest tundra vegetation tend to lessen its effectiveness as insulation of the substrata. Thus, man's activities in these regions act almost invariably to degrade permafrost. Over wide stretches of the Arctic the permafrost is in such delicate balance that even apparently minor disturbances may have profound, even disastrous, consequences. For example, at Kilyivik on the Baldwin Peninsula in western Alaska (66°47'N, 162°35'W) a nearly flat sedge area near the mouth of the creek was disturbed in winter or early spring of 1959 by a large, dual-wheeled vehicle. By summer the ruts were thawing, and by the summer of 1960 were deepening because of the altered thermal regîme of the soil. In the Ogotoruk Valley in northwestern Alaska, which was subjected to intensive traffic in the period 1959-61 by "weasels" and other relatively light, track-laying vehicles especially designed for Arctic use, some of the tracks have now thawed and eroded 10 feet in depth. On the Arctic slope of Alaska trails made by tractor trains during the days of the U.S. Navy oil explorations in the late 1940's have thawed, eroded, and caused gullys 20 or so feet wide, 10 to 15 feet in depth, and many miles long. The potential effects of continuous thermal degradation of frozen substrata, as in the case of a buried, heated pipeline, have been calculated and discussed by Lachenbruch (1970).

"There is almost always an unfrozen zone under water bodies that themselves do not freeze solid annually. Thus, formation of a new water body or increase in size of an already-existing water body, because of damming or flooding will result in degradation of existing permafrost. The resultant settling and thermokarst may be of profound ecological (and economic) importance ...

"Undoubtedly the most direct effect [of permafrost] is upon plants by chilling the soil and retarding general growth. Of course, the vegetation acts in turn, to chill the soil by shielding it from incoming solar radiant energy. Permafrost prevents deep root penetration, so that plants growing above a shallow layer are relatively unstable. On the other hand, permafrost acts as a reservoir of considerable heat and thus acts to damp wide fluctuations of soil temperature."

It should be noted that minerals in the active layer may become exhausted, particularly if the active layer is thin and no replacements are possible from the store immobilized below. Thus, as Pruitt points out, mineral cycling is restricted to the active layer. "Understanding of this problem is compounded by the difficulty of distinguishing between the effect of permafrost and those of the annual freeze.

"In our initial statement we noted that permafrost is not permanent. Thus, its upper boundary is a sensitive indicator of ecological variations and moves upwards or downward. Such pulsations result in widely varying site characteristics of plants. When the plants, particularly trees, have varying health they are subject to wind tipping, qali (the snow that accumulates on branches of trees), breakage and varying growth rates. Such variations combine to produce twisted and stair-step main stems or "drunken forest". Soil heaving related to annual freezing is also an important factor here. On irregular terrain polifluction and downslope mass movements may have significant effects on the biota."

308. PRUITT, W.O., Jr. 1970. Tundra Animals: What is their future? Roy. Soc. Can. Trans. Ser. 4., 8:373-385.

A discussion of the requirements of some of the larger mammals and birds inhabiting the tundra and a plea for the putting into practice of known information for the conservation of the environment of the tundra. Details of the differences in populations of certain animals from pre-European contact to to-day are also given.

309. PRUITT, W.O., Jr. 1970. Some ecological aspects of snow. Ecology of Subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. UNESCO. p. 83-99.

The author discusses the problems of animals which inhabit the snow regions of the north with particular reference to the types of snow found at various times of the year

and to the adaptations of the animals inhabiting the regions all year round.

310. P'YAVCHENKO, N.I. 1963. The drying of bogs as a means of transforming nature and developing the forest resources of the Siberian north. Problems of the North 7:57-66. (Transl. from Russian by Nat. Res. Counc. Can. 1964.)

This theoretical paper is based on reports of results of draining bogs in Scandanavian countries and at a Siberian research centre in an attempt to improve forest growth. No bibliography is included.

311. RADFORTH, N.W. 1963. The ice factor in muskeg. First Can. Conf. Permafrost Nat. Res. Counc. Can., Ass. Comm. Soil, Snow Mech., Tech. Memo. 76:57-78.

Details of ice and air-form pattern are given, as well as some discussion on ice-form and vegetation cover. Photographs are included.

312. RADFORTH, N.W. 1965. Origin and significance of organic terrain features. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci. - Nat. Res. Counc. Wash. Publ. 1287. p. 38-43.

Various aspects of organic terrain formation are discussed. "Though climate above and below contrast markedly, vegetal succession for given kinds of organic terrain remains virtually the same; there has been no evolving to dominants in the course of time, and vastly differing climates are conducive to the establishment of closely related and enduring colonizers growing more than 1500 miles apart." The importance of water (or ice) in the process is emphasized particularly as influencing the various plant colonizers.

313. RAMPTON, V.N. 1971. Quarternary geology, Mackenzie Delta and Arctic coastal plain, District of Mackenzie. Report of

Activities, Part A: April-October 1970. Geol. Surv. Can. Pap. 71-1A: 173-177.

"A preliminary evaluation of data collected [in 1970 and in previous years] suggests that the region can be divided into 13 areas, each having a unique arrangement of surficial deposits and near-surface unconsolidated sediments. In many cases these areas closely coincide with the physiographic regions of the Mackenzie Delta Area as described by Mackay 1963."

The areas are described and outlined on an accompanying map.

314. RAMPTON, V.N. and J.R. MACKAY. 1971. Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richard's Island, and nearby areas, District of Mackenzie. Geol. Surv. Can., Pap. 71-21. 16 p.

Some 5000 shot hole logs were examined and indicate that about 35% at a depth of 40 feet were in either massive ice or icy sediments and that about 70% of the 264 drill holes penetrating massive ice, did so at about 40 feet. In more than 20% of the cases, massive ice was still reported at 100-150 feet.

Practical Considerations: "The presence of large bodies of massive ice and icy sediments under much of the area indicates that construction and development should be undertaken with caution ... Severe disturbances of the active layer on hillslopes that are underlain by massive ice or icy sediment may lead to thermal erosion which would be very difficult to control when the icy material became exposed. If thickening of the active layer, even on level areas, or the introduction of a subsurface heat source (e.g. hot pipeline) resulted in a thaw line intersecting massive ice or icy sediments, extensive thaw and major thermokarst subsidence could result unless preventative measures were taken. In cases where the meltwater would percolate to the surface but would be locally confined, a thermokarst lake would form. If the lake became deeper than winter lake-ice thickness, it would perpetuate melting and further increase the size of the depression. Where the free water from melted icy sediments could not filter to the surface, a slurry would be created which could provide no support to overlying structures. In the case of masses of ice or icy sediments 30 to 40 feet below ground surface, some years would elapse before melting commenced, but melting would be difficult to stop once it had started."

The authors plead for similar studies in areas where alterations to the thermal regime may result from man's activities.

315. RAND, A.L. 1946. List of Yukon birds and those of the Canol Road. Nat. Mus. Can. Bull. 105. 76 p.

A survey of published material and unpublished data of the National Museum and Parks Branch provided the information in this list.

316. RANWELL, D.S. 1968. Lichen mortality due to *Torrey Canyon* oil and decontamination measures. Lichenologist. 3:55-56.

This brief paper indicates that decontamination activities on the supralittoral fringe ocean shore resulted in more serious damage to lichens than the oil itself (which caused patchy damage). "Symptoms of death as a result of oil and emulsifier contamination include loss or change in colour in the thallus and, in the case of crustose species, tendency for the thallus to curl and eventually break away from the rock."

317. RAPP, A. 1970. Some geomorphological processes in cold climates.

Ecology of Subarctic Regions: 1. Ecology and Conservation. 1966. Proc. Helsinki Symp. UNESCO. p. 105-113.

Various frozen ground phenomena are reviewed as well as other geomorphological phenomena. A plea for continuous observations with the use of bench marks, painted lines and photographs is made.

Solifluction slopes often have a close cover of grass which is not broken by a flow of 0-8 cm per year on gradients 10-30^{o}. This flow occurs mainly in the thaw period, spring to early summer, and also during freeze-up in autumn. The author states that "most of the ground above the forest limit is affected by movements caused by frost ... [but] below the forest limit actual solifluction seems to be absent, ... except on open, forest-free patches with sloping ground, silty soil and poor protection from snow and vegetation. Well-drained ground is not affected by frost action to any appreciable extent above or below the forest limit".

The hydrology of sub-arctic rivers is mentioned. "Ice breakup is often a rather sudden and catastrophic event. The ice is then pushed up in high ridges which can cause damage and erosion on the shores (and their vegetation cover) as well as on the river beds." Effects of river bank erosion vary from year to year, resulting in rather intensive erosion and sedimentation in subarctic rivers due to differences in discharges and ice breakup.

318. RAUP, H.M. 1930-31. The vegetation of the Fort Reliance sand-plain. Ann. Carnegie Mus. 20:9-38.

This is a very detailed description of the laying down of new territory and the succession on these new sites. The types of vegetation and successions described are prograding beach, beach lagoon, stream margin and erosion terrace. There is no discussion of soils, but it seems

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1. Hydrological Atlas of Canada - Envir. Canada

2. Progress in Physical Geography Vol 1-6 1977-82

3. Proceedings of a Symposium on the Physical Env. of the Hudson Bay Lowland - Univ of Guelph

4. Dept Land Res. Sci. 1973

page 17-64

4. F 1st Int. Permafrost Conf. Proceedings

likely that there is very little development of a profile. Most of the parent material is sand. Fire has not been a factor during the past 62 years.

319. RAUP, H.M. 1931. The formation of peat ridges on the shores of muskeg lakes in Northern Alberta. Rhodora 33:18-23.

The phenomenon of peat ridge formation is considered to be related to the lowering of lake water levels following glaciation.

320. RAUP, H.M. 1946. Phytogeographic studies in the Athabaska-Great Slave Lake region. II. J. Arnold Arboretum 27:1-85.

Much of this paper is concerned with the vegetation relationships of the species present in the area and their respective origins and rates of migration in relation to climates.

Geological formations are described and some general information on soil is given. Permafrost is present through much of the area studied. The vegetation types of the area include 1. forests, of which bog forests are most abundant (the forest tree species present are white spruce, black spruce, jack pine, balsam fir and lodgepole pine); 2. shore and muskeg vegetation; 3. grassland; 4. lichen-peat and 5. dune-scrub.

"There seems to be a relationship between the ranges of certain trees and the depth to which the ground thaws during the growing season. Sandy soils that thaw deeply will support plants that require a deep tap root, while heavier soils and muskegs in which frost remains near the surface throughout the year preclude the growth of such plants."

321. RAUP, H.M. 1947. The botany of the southwestern Mackenzie. Sargentia 6:1-275.

This is a most exhaustive discussion on the botanical relationships of the flora of the southwestern Mackenzie. The plant communities are described in general, and mention is, made of the presence of fire in the white spruce forests of the areas. The areas particularly studied are around Brintnell Lake and Fort Simpson. Only in one area is there postulation of successions: the flood plain deposits at the west end of Brintnell Lake.

322. RAUP, H.M. 1951. Vegetation and cryoplanation. Ohio J. Sci. 51:105-116.

A review of the problems of the interpretation of vegetation patterns produced by the instability of substrata resulting from frost action.

323. RAUP, H.M. 1965. Turf hummocks in the Mesters Vig District, Northeast Greenland. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci. - Nat. Res. Counc. Wash. Publ. 1287:43-50.

The origin and development (mainly by an erosion process) of turf hummocks, composed primarily of mosses and formed by thin radial proliferation from a central starting point, are discussed in detail. These hummocks are the only type found in the Mesters Vig district and are the most common type in subpolar, alpine and mainly temperate lands. The other type is formed by the proliferation of a single caespitose plant, usually a grass or sedge, and is particularly well developed in western arctic Canada and Alaska.

324. REED, J.C. 1958. Exploration of Naval Petroleum Reserve No. 4 and adjacent Areas of Northern Alaska, 1944-53. U.S. Geol. Surv. Prof. Pap. 301. 192 p.

The drilling and geological explorations of "Pet 4" from 1944-1953 are described in detail and information is provided on the types of equipment used, routes, cargo transported and periods of activity. Thus it provides the basic information for HOK 1969 on the subject of vegetation damage: "Vehicle tracks are likely to remain easily visible for years because of slow recovery of tundra vegetation. Even winter tracks may long be visible because the compacted snow affects the following summer's growth." The problems of summer freighting became increasingly apparent in 1944. "The profusion of lakes and streams made heavy hauling extremely difficult, but an even greater problem was posed by the surface thawing of frozen ground. The tundra surface becomes an untraversable quagmire if torn up by heavy motorized equipment." After that all heavy equipment was moved in winter, preferably over sea ice, but bladed tundra trails were used.

325. REED, J.C. 1970. Effects of oil development in Arctic America. Biol. Conserv. 2:273-277.

Biological Abstracts 52:19693, 1971: "Large and important discoveries of petroleum were made in northern Alaska in 1968. The reserves were estimated then to be perhaps as much as 10 thousand million barrels. Subsequent exploration has shown the resources to be much greater than was estimated earlier. Many problems must be solved before petroleum from northern Alaska reaches the world's markets. These problems are of three types: those related to exploring, developing, and operating under the physical environment of the region; those having to do with people - both the native people and those brought in from lower latitudes, and those concerning the protection of the natural environment. The problems are great, but so also are the reserves of petroleum. To the extent that the problems are not solved, the cost of development of the operation will be higher, the use of people will be expensive and unsatisfactory, and the natural environments will be threatened. The whole effort could be jeopardized on those grounds."

326. REMPEL, A. 1970. Arctic terrain and oil field development. Productivity and Conservation in Northern Circumpolar Lands W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:243-251.

This paper discusses the problems of oil development in the Arctic.

"Land portions of the sedimentary basins in Canada north of latitude 60 degrees comprise about 470,000 square miles. It has been estimated that the development of the oil reserves in this region will require the direct use of 1,350 square miles, or not quite 0.3 per cent of the total. This includes seismic lines, well sites, roads, pipelines, campsites, storage dumps and airfields. About one-third of the land requirement is for seismic work and wildcat wells which is a temporary use, after which a considerable portion will revert to the original state. The effect of this work on Arctic terrain will depend to a large measure on the amount of ice in the permafrost soils. Fine-grained, frozen soils are particularly susceptible to disturbance by natural and artificial forces ... The Norman Wells oilfield, which lies near the southern limit of continuous permafrost, is a good starting point in a discussion of effects of oilfield development on Arctic terrain.

"Despite the 50 years of activity in the Norman Wells area, including the major wartime "crash" development programs of 1943 to 1945, there is now little evidence of terrain degradation in the field. Flowline rights-of-way, well sites and seismic lines have grown back a second cover and a return to stable conditions is quite evident. The area is still within the forested region of the north. Tundra terrain, on the other hand, may be more sensitive to man's intrusion ....

"In most places, however, it is not so sensitive that only one or two passes of a tracked vehicle, even in summer, will necessarily marr the landscape for many decades - unless one puts a blade on the front of the unit and strips away the insulating cover of vegetation; or alternatively, makes many passes over the same trail. A photograph of the small amount of terrain alteration which has resulted from seismic operations, conducted with track vehicles over tundra in the summer of 1963 is presented . The under-lying soils are in a "sensitive" area of generally fine-grained sediments with a high ice content. Another [photograph] in which the surface was unbroken is [also] shown. [Both of these photographs indicate a small depression developing but both depressions are fully vegetated.] During an inspection flight in 1968, a few thousand feet over the area, many of the old lines were no longer visible from the air. These examples are from areas of low relief. Negotiating steep slopes with tracked vehicles fitted with agressive grouser bars can be somewhat more damaging to the terrain. New concepts in track design which show good drawbar characteristics with reduced ground disturbance are currently under test ... Air cushion vehicles have been used with some success on flat tundra terrain. Surface disturbances are slight. Hilly terrain and tree cover preclude the use of this type of craft over a considerable portion of the Canadian Arctic mainland.

"Winter operations of course cause the least ground disturbance. This is the period when heavy loads required for drilling operations are moved." Bulldozed winter seismic lines may be hard to spot from the air but "in some low areas ... the evidence of the previous winter's work may persist. A small amount of subsidence may occur, but generally a recovery of vegetation has been found to be rapid. [A further photographic] example of seismic work in which tundra vegetation was stripped from the underlying permafrost by bulldozers during the summer of 1965 is [given. The 1965 bulldozed line was inspected in 1968 and again in 1969.] It was apparent that most of the subsidence had taken place the first year of exposure. By 1968 as shown [in an accompanying photograph], some natural regeneration of vegetation was evident. There was little evidence of erosion, even on the hillsides. Consequently, siltation of streams should be slight." (The 1969 photograph idicates complete revegetation of the track line.)

"Thermokarst is of special significance in the construction and operation of large diameter pipelines in Arctic terrain. As a result of the observation of bulldozed lines and construction projects in the Arctic and discussions with numerous Arctic experts, Imperial Oil decided to initiate a modest experimental project on stabilization and restoration of disturbed ground in Arctic tundra." Summer bulldozed lines near Tuktoyaktuk and at Inuvik, have been sown to plants such as Crested Wheat, Reed Canary Grass and some have been covered with two-inch layers of sawdust over a peat mound. Generally speaking, good growth has been obtained from both seed sources.

327. RIEGER, S. 1966. Dark well-drained soils of tundra regions in Western Alaska. J. Soil Sci. 17:264-273.

Author's abstract: "Four dark, well-drained soils in tundra areas near the Bering Sea coast of Alaska have similar morphology, but physical and chemical properties reflect those of the parent materials. Three of the soils are extremely acid and in high mountains at lower latitudes, are classified as Cryumbrepts. One, from basic rock, with slight acidity and fairly high base-status is classified as a Cryoboroll. These soils have some characteristics in common with Cryandepts and Cryorthods of adjacent areas, but can be readily distinguished from them in the field."

328. RIGG, G.B. 1940. The development of Sphagnum bogs in North America. Bot. Rev. 6:666-693.

A basic reference on bogs up to 1940.

Information is presented on *Sphagnum*, bog plants, kinds of peat, types of bogs and their development. An extensive bibliography is included.

329. RIKHTER, G.D. 1963. Snow as an ecological factor in plant and animal life in the north. Problems of the North 7:91-96. (Transl. from Russian by Nat. Res. Counc. Can. 1964.)

This paper presents a good summary of the effects of snow on vegetation and individual species of plants. Contrary to its title, there is no discussion on its effects on animals.

330. RITCHIE, J.C. 1957. The vegetation of northern Manitoba. II. A prisere on the Hudson Bay Lowlands. Ecology 38:429-435.

This short paper gives a description of the succession in the Hudson Bay Lowlands. The succession goes from the meadow phase (on freshly exposed flats) to shrub phase to invading forest (*Picea glauca* and *Larix laricina*) to closed forest (*Picea glauca*) to black spruce (*Picea mariana*) open forest (with mound-hollow topography).

Apparently the development of organic matter such as peat under the white spruce and larch forest firstly insulates the ground and thus allow the development of permafrost close to the surface, which, of course, impedes drainage and allows rapid invasion of peat-forming species and, secondly, with the build-up of acid conditions, this allows the entry of further acid-lowing plants including black spruce and does not allow the regeneration of white spruce. Once the mounds have been produced, black spruce invades the higher, drier sections and with an increase in mound size, the white spruce are lost, around the edges. The author refers to the paper by Drury in 1956 and considers the phenomena described similar to those described for the Hudson Bay Lowlands.

331. RITCHIE, J.C. 1959. The vegetation of northern Manitoba. III. Studies in the subarctic. Arctic Inst. N. Am. Tech. Pap. 3. 56 p.

A detailed study of the subarctic vegetation of northern Manitoba. The types include: bogs, muskegs, forests, heaths, etc. Succession stages are described. Fire has played an important role in forest history. Permafrost is present under certain community types. Evidence of over-grazing and trampling by caribou is indicated by the vigorous growth of *Stereocaulon* sp. and repression of *Cladonia* sp. in local areas.

"Permafrost occurs in boulder till substrata at 1.5 to 2 m. in mid-summer and closer to the surface in peat deposits; it was not detected in esker and flood plain deposits." On boulder till permafrost occurs at 1.5 m. below black spruce-lichen forest communities on the slopes of drift hills. Evidence is present in some heaths on certain ridges and low hills now devoid of tree species that previous forest was present (old stumps and upturned roots, indicating probable destruction by fire). On lower slopes of low hills there is some evidence of recolonization by *Picea mariana* - ages up to 28 years.

On muskeg and bog (muskeg has trees, bogs no trees) peat is seldom deeper than 2 m. and usually about 1 m. In summer, the active layer extends 1 to 1.5 m. in depth. Peat overlies the drift. Ground vegetation is dominated by *Sphagnum* forming hummocks, particularly *S. fuscum* and *S. warnostorfianum*. Lichens characteristic of the area are *Icmadophila ericetorum* - "colonizes disturbed peat on sphagnum hummocks" - *Cladonia rangiferina, C. subrangiformis* and *Peltigera aphosa* are common on moss hummocks and larger tufts. In bogs, *Sphagnum* again forms large hummocks which are colonized by various ericaceous shrubs. Many transitions occur between bog and muskeg.

"The instability of soil surfaces maintains a treeless, poorly-developed community, which consists of a mosaic of plant assemblages showing various stages in the process of colonization of bare areas. After a few early pioneer species become established on bare areas, (*Juncus albescens* and *Onocophorus wahlenbergii*) various herbs and shrubs invade to form an open community. In the absence of further disturbance a layer of humus or peat develops and a distinct group of plants dominates the vegetation of the surfaces. Many intermediate stages exist ... and it would appear that an irregular cycle of colonization and destruction is maintained by the instability of the substratum."

Peat deposits: "The surface of the heaths [no trees] is marked by small mounds 0.5 to 1 m. above the surface level and 1 to 2 m. in diameter. The centre of the mounds consists of disturbed peat lacking vegetation, being colonized locally by certain lichens - particularly the crustose *Icmadophila ericetorum*. Throughout the deposits the lower level of the active layer in late summer is 30 to 45 cm. below the surface. It is suggested that these mounds are the result of frost action, by which swelling and heaving disturbs and locally erodes the peat surface, resulting in typical hummocked topography.

"A second frost phenomenon is present on the surface of these deposits - large polygonal patterns. These unsorted polygons are four- to five-sided, 20 to 30 m. in breadth and bounded by fissures in the peat which vary from 50 cm. in depth and 20 cm. in width to one meter in depth and 60 cm. in width. The peat surfaces of the fissure are unstable, being colonized only by certain pioneer species."

Descriptions of colonization patterns on stable surfaces of the heath type are given—mainly ericaceous shrubs, lichens and mosses are the colonizers.

"Exposed peat surfaces are colonized by various lichens and mosses. Raw peat on peat mounds are first colonized by *Icmadophila ericetorum* and various fruticose species [mainly *Cladonia* sp.] appear subsequently." Black spruce is present on peat surfaces only as stunted, shrubby individuals. "It is likely that the high permafrost layer throughout the deposits, due to the insulating influence of the deep blanket of drying peat, inhibits tree growth".

<u>Summary</u>: In this area "the ground cover is dominated by *Stereocaulon paschale* ssp. *evolutoides*, while the chief species of *Cladonia* neither form continuous dominant carpets nor assume the typical stature and luxuriance found in other regions. The probable explanation of this is the intensive local grazing and trampling by caribou repress the *Cladonia* and favour the more vigorous *Stereocaulon*. The latter grows more rapidly than the species of *Cladonia*, and Hustich (1951) suggests that this explains the more rapid invasion by *Stereocaulon* after habitat disturbance. The temporary dominance of *Stereocaulon* in the lichen forests of Finnish Lapland is a common phenomenon and .., [workers] account for this in terms of intensive grazing by reindeer.

It would appear ... that this phenomenon has not been reported previously in North America ... The area of this study lies on the present migration route of the barren ground caribou, and large herds have been seen passing through in spring and autumn."

332. RITCHIE, J.C. 1960. The vegetation of Northern Manitoba. IV. The Caribou Lake Region. Can. J. Bot. 37:185-197.

Author's abstract: "Based on the findings of one season of field work, an account is given of the vegetation and flora (vascular plants) of the immediate vicinity of Caribou Lake in northeast Manitoba. The plant communities are grouped according to physiographic position. Their chorology is presented in the form of a map which was compiled from interpretation of vertical aerial photographs of the area. The appearance of the various vegetation types on the aerial photographs is described.

"The prevalent vegetation of the mesic sites is a tundra community dominated by ericoid shrubs. There is strong evidence that much of this treeless vegetation occupies sites where trees once grew; they have been removed by fires. Recent alluvium bears stands of *Picea glauca* (white spruce) which shows good growth. Shallow, wet peats are covered by black spruce stands with shrubs and mosses, chiefly *Sphagnum*. Deeper peats, usually with shallow active layers, bear heath of sedge-cottongrass tundra."

333. RITCHIE, J.C. 1962. A geobotanical survey of northern Manitoba. Arctic Inst. N. Am. Tech. Pap. 9. 48 p.

"The aim [of this paper] has been to depict with as much accuracy as possible, the spatial arrangements of the vegetational and floristic units of one area. The present account ... attempts this by a detailed, uniformly compiled map of the vegetation of northern Manitoba, together with a summary of the main features of the floristic geography."

334. ROBINSON, J.M. 1965. Permafrost and forestry. Nat. Res. Counc. Can. Tech. memo. 86:132-135.

Arctic Bibliography 91215: "Describes how permafrost is fostered in the northern Boreal forest by acid litter under the trees and subsequent moss; this cover fills with snow and ice in early autumn, conducts ground heat in winter, then dries and insulates the underlying mineral soil against the summer heat, causing permafrost to develop in areas south of the recognized permafrost zone, and discouraging plant growth. Though most permafrost areas are too cold to permit tree growth, exceptions are noted in the lower Mackenzie Valley and Delta, e.g. at Fort MacPherson where spruce grows in a very shallow active layer. Use of fire in the Scandinavian countries to release chemicals in the moss layers and thus promote tree growth is noted. Generally, conditions favouring permafrost lead to forest-site degeneration, even where soil and summer temperatures are suitable for tree growth. In such areas, a layer of litter must be developed to permit warming of upper soil horizons, but prevented from becoming an insulating blanket and fostering permafrost."

335. ROBINSON, J.M. 1971. The deleterious effect of muskeg on the Canadian North. Unpubl. ms. mimeo. 18 p.

The problems of forest growth in areas of "sheet muskeg" (formed under spruce trees in cold climates, with low evapotranspiration) are discussed. The author cites examples, with photographs, of forests with and without muskeg on similar neighbouring sites in the north. He believes that the succession is fire-initated on uplands and flood induced on alluvial flats and that on both site types, if fire is light, or flooding very rare, a sphagnum-ericaceous ground cover develops, ensuring a high permafrost table and rapid stagnation of the softwood forest. Under conditions of periodic flooding or severe burning, the muskeg ground cover either does not develop or is greatly retarded, the permafrost table remains deep, or at least below the top of the mineral soil, and a forest productive of both trees and wildlife develops.

The author discusses briefly the advantages of muskegs, particularly the depression-filling type, producing bogs which ensure moisture reservoirs and the sheet type developed over thin soils or bare rock providing an organic substrate for ground cover. Draining of the former is not feasible and destruction of the latter disastrous.

A plea is made for a method to control sheet muskeg development over productive forest soils without relying on "nature's disaster approach."

336. RØNNING, O.I. 1969. Features of the ecology of some arctic svalbard (Spitsbergen) plant communities. Arctic Alpine Res. 1:29-44.

Author's abstract: "Investigations were made into the ecological factors governing the distribution of plant communities. In particular, temperatures were studied in the root layers of plant communities and in the micro-environment. The results are recorded for day and night and under different weather conditions. The relationship between vegetation, permafrost, and chemical composition of the soil was also investigated. Permafrost is found to be the main factor determining distribution of plant communities through its influence on drainage. The chemical composition of soil is tabulated for two test areas and different *Dryas* communities. A correlation between vegetation an chemical properties of

soil has been attempted, but the need for further investigations is emphasized."

337. ROUSSEAU, J. 1949. Modifications de la surface de la toundra sous l'action d'agents climatiques. Rev. Can. Géogr. 3:43-51.

Frost action phenomena found in Ungava during botanical explorations in 1947 and 1948 are described.

338. ROUSSEAU, J. 1952. Les zones biologique de la péninsule Québec-Labrador et l'Hémiarctique. Can. J. Bot., 30:436-474.

Phytogeographic zones of Ungava-Labrador are delimited and the typical plant assemblages for each zone are described.

339. ROWE, J.S. 1959. Forest Regions of Canada. Can. Dep. N. Affairs Nat. Res. Bull. 123. 71 p.

The basic reference for descriptions of the Canadian forest regions.

340. ROWLAND, L. 1971. Gas Arctic stressing research. Oilweek Sept. 6:25-28.

The facilities and research programmes at Prudhoe Bay and Norman Wells are described. The following notes indicate some of the facilities and research projects.

"The Prudhoe Bay facility consists of 2,000 feet of 48-inch pipe, partly buried in conventional pipeline ditch and partly laid in a shallow ditch with a berm over it. Its location was selected for the worst possible conditions in continuous permafrost with ground temperature well below 32 deg. F. and much of ground consisting of almost pure ice.

"Norman Wells is in the discontinuous permafrost zone...The...test site installation consists of four 120-foot circulatory sections of 48-inch pipe laid in 100-foot right-of-way, and two static loops of 42-inch pipe...Its facility

is set up to test ground consisting generally of ice-rich clay close to 32 deg. F., the most difficult conditions in the Mackenzie Valley. A facility at Nordegg in central Alberta, will test muskeg and wet clay typical of most of the northern Alberta region and adjacent portions of the Northwest Territories...

"A special feature of Prudhoe Bay has been a construction disturbance test which was conducted before the test loop went into operation. An area on one side of the test section was set up with three concentric ovals for tracked vehicle runs over various kinds of surface preparation, from bare tundra to gravel pads, to test the effect of the relative degrees of impact on the terrain.

"Various backfill methods were also used for experimentation. These included a few short sections where subsidence has been allowed to occur to check the extent to which partial exposure of pipe can cause permafrost degradation or regression. The permafrost in this region is 1,200 to 1,500 feet thick.

"At both Prudhoe Bay and Norman Wells there is a soils program to test for moisture content and density, water pore pressure and other data which have a bearing on the effect of the pipeline. Meteorological records are also being kept to relate soil to air temperature...

"In the field of ecology an Environment Protection Board has been formed, whose objectives are to become familiar enough with Arctic ecological systems to estimate the biological costs or benefits of construction and evaluate effects that might result in damage or disruption to major ecological systems; to become familiar enough with the biological and physical environments that pre-construction findings can be used as a basis for post-construction evaluation; to make recommendations for maximum benefit in environmental protection; and to make available the scientific results of its studies as a direct contribution to Northern scientific development...

"Of particular interest to the professional ecologists on the project is the behavior of caribou. Many predictions had been made, without benefit of actual observation, that caribou would not cross a pipeline berm. Within hours of completion of the bermed segment of the test loop, the caribou were walking all over it. Since the installation of a number of test grass plots on the loop area, they have also been nibbling the new grass and generally displaying a curiosity which indicates they have accepted the installation as an interesting new fixture on the landscape.

"Although not determined conclusively yet, there is an indication that the caribou has tunnel vision which deters it from jumping over a vertical obstacle with a height above eye level, such as the test fence which Atlantic Richfield installed, built of snow fencing reinforced with interwoven burlap bags to simulate a solid barrier. A slope appears to offer no problem at all to caribou mobility."

341. RUSSEL, R.S. and P.S. WELLINGTON. 1940. Physiological and ecological studies on an Arctic vegetation. I. The vegetation of Jan Mayen Island. J. Ecol. 28:153-179.

This paper discusses the vegetation of Jan Mayen Island. "The vascular flora...is small, comprising as far as is known only 58 species of vascular plants. Over the greatest part of the Island the vegetation was dominated by mosses or lichens. In limited areas, however, specially favourable conditions permitted the development of closed communities of vascular plants....

"It is concluded that the degree of exposure to wind, nitrogen and water supply and the time of snow retreat are the major factors which determine the distribution of the various types of vegetation." There are 22 vegetation types defined.

342. SALMI, M. 1970. Investigations on palsas in Finnish Lapland. Ecology of the Subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 143-153.

The origin and development of palsas is outlined as well as the vegetation covering the particular palsas studied. In the discussion which followed the presentation of the paper, Pruitt stated: "I am happy to see that a greater understanding of palsas has been reached since these are of biological as well as cryopedological interest. They form an important part of the biological system of the Subarctic. Caribou feed on the palsa lichens since these lichens are usually snow-free. In North America a genus of voles, previously believed to be rare, have been found to be limited markedly to palsas, where they are quite common. Several species of birds nest primarily in palsa trees, the only trees in an expanse of mires.

"Palsas elevate a mass of peat above the general water-soaked level. Here the peat dries and the organic material is made available to the ecosystem where it supports a more varied vegetation than when water soaked. The release of the previously immobilized energy is important for the biological community. Perhaps when we understand the genesis of palsas we could initiate their formation and thus manipulate one aspect of biological productivity in the Subarctic."

343. SAVILE, D.B.O. 1964. General ecology and vascular plants of the Hazen Camp area. Arctic 17:237-256.

The general ecology of the principal habitats (sand, gravel, clay plains and slopes, saline clay, *Dryas* hummocks, *Dryas-Kobresia* tundra, *Dryas-Salix* tundra, deltas, boulder talus, springy slopes, marshes and sedge meadows) are described. The author comments on the general aridity of the area in relation to some of the species. An annotated list of the vascular plants is appended.

344. SCHENK, E. 1966. Origin of string bogs. Permafrost Intl. Conf. Proc. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287: 155-159.

"String bogs are muskegs with undulating surfaces. In Europe they are called Aapa-moor, strang-moor (string bogs) and ringmoore (ring moor). They are widespread in the Boreal, needle-tree forest zone of the hemisphere. Their topography is characterized by lenticular hummocks and depressions, by long and low ridges, and by long and shallow holes or ditches. Both features are covered with distinct plant communities; each is strictly confined to a definite ecological situation that is controlled by the ground water level and water supply. Peat growth and moor structure is determined mainly by the water budget...In the undulating muskegs or Aapa-moors, the differentiation of xerophytic and hydrophytic plant communities is due to ridges and depressions. The question since the end of the last centry has been: 'What causes the configurations of xerophytic and hydrophytic plants in the moors, and what causes these strange patterns in the same peatland?' "

345. SCHENK, E. 1970. Permafrost and frost structures in the subarctic area. Ecology of the Subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 155-158.

Aspects of the formation of patterned ground in the subarctic and its relation to freeze-thaw cycle, pattern size, length of freezing period, temperatures, soil, water, etc. are discussed.

346. SCHULTZ, A.M. 1964. The nutrient-recovery hypothesis for arctic microtine cycles II. Ecosystem variables in relation to arctic-microtine cycles. Grazing in terrestial and marine environments. D.J. Crisp, ed. Oxford, Blackwell. p. 57-67.

Author's abstract: "Correlated with the lemming cycle of northern Alaska, which is one of the best and readily observable features of the tundra, are fluctuations in primary production, forage quality, and decomposition rates. Also, a number of soil properties show year-to-year changes that appear to be linked with the microtine populations. A four-year record of herbage yields, covering one complete lemming cycle, reflects the recovery of plant vigor that takes place from the type of overgrazing during the peak phase of the cycle to the last year of no grazing.

"Chemical composition of green forage involving calcium, phosphorous, and protein varies significantly during a lemming cycle. The change is in the direction of improving quality as the peak phase of the cycle approaches, and of a sharp reduction in quality during and following the decline phase. The variation may be explained partly by botanical composition changes resulting from selective grazing and partly by changes in the available soil nutrient pool.

"In the soil system, important directional changes occur which can be attributed to two lemming activities, grazing and manuring. Grazing decreases the insulating ability of the vegetative cover; two or three years of no grazing allows the insulation to build up again, thus, there is a three- to four-year cycle in depth of the active soil layer. Excreta produced during the "high" years add a sudden dash of available nutrients to the substrate and perhaps modify the decomposer flora quantitatively as well as qualitatively."

347. SCHULTZ, A.M. 1969. A study of an ecosystem: the arctic tundra. The Ecosystem Concept in Natural Resource Management. G.M. van Dyne, ed. Academic Press, N.Y. p. 77-93.

This paper is concerned with the modelling aspect of the arctic tundra using the microtine cycle (as outlined in the author's 1964 paper). The author then theorizes: "Not until a nutritional threshold has been reached can a lemming population build up. But the population does not keep getting bigger and bigger. This would be disastrous to the vegetation. So a deferred-rotation grazing scheme is built into the system. No grazing at all would also be disastrous to the vegetation and to the soil as well. Predators play a role at the time of herbivore decline. Indeed, all parts of the system play a role. It is a homeostatically controlled system."

348. SCHUSTER, R.M., W.C. STEERE, and J.W. THOMSOM. 1959. The terrestrial cryptogams of Northern Ellesmere Island. Nat. Mus. Can. Bull. 164. 132 p.

An annotated list of the hepatics, mosses and lichens from Ellesmere Island. Information on ecology, distribution and early work on crytogams is included.

349. SCOTTER, G.W. 1963. Effects of forest fires on soil properties in Northern Saskatchewan. For. Chron. 39:412-421.

This paper records certain soil changes as the result of fire in forests, but it has little to say about the problems of regeneration on the burned sites. The work was undertaken as part of a much larger study on the problems of barren-ground caribou. The questions of the problem of lichen regeneration is raised and the need for further investigation is emphasized.

350. SCOTTER, G.W. 1963. Growth rates of *Cladonia alpestris*, *C. mitis*, and *C. rangiferina* in the Tolston River area, N.W.T. Can. J.

Bot. 41:1199-1202.

Data is presented on growth rates of *Cladonia alpestris*, *C. mitis* and *C. rangiferina* and it is shown that growth is slower here than in Russia, Newfoundland or northern Saskatchewan.

351. SCOTTER, G.W. 1964. Effects of forest fireson the winter range of barren-ground caribou in Northern Saskatchewan. Wildl. Manage. Bull. Ser. 1, No. 18. 111 p.

Although this paper deals with areas south of the 60th parallel there are some interesting observations on the effects of fire on the forests of that area. The major tree species are black spruce, jack pine, white birch, quaking aspen, tamarack, white spruce, and balsam poplar. "Burning of winter range results in only a temporary reduction in range productivity, with the exception of high-value "reindeer lichens". In northern Saskatchewan a century or more is required for fire-destroyed "reindeer lichens" to reach their former abundance. Annual growth rates of *Cladonia alpestris* and *C. rangiferina* were approximated at 4.1 and 4.9 millimetres, respectively. The two lichens were found infrequently in forests younger than 30 years of age...Arboreal lichens may make substantial contributions to the winter diet of barren-ground caribou, particularly under severe weather conditions...*Alectoria jubata* is thought to be the most important arboreal lichen in the study area".

Forest and forage yield data were obtained from many of the areas studied. Various species of *Equisetum* appeared to be highly preferred winter forage plants. Barren-ground caribou are primarily grazers, "and, except for evergreen species, browse is of limited importance in their winter diet. Only an occasional white birch or willow twig, generally less than $1\frac{1}{2}$ inches in length and 3/16 of an inch in diameter, were found in rumens of 7 barren-ground caribou...

"Lichens are regarded generally as the principal winter food of caribou...In the present study fruticose lichens such as *Cladonia alpestris*, *C. amaurocraea*, *C. mitis*, *C. uncialis*, *C. rangiferina*, were considered of high value."

Forage Production: "Average air dry yield ranged from 290 pounds per acre in the 1 to 10-year class to 942 pounds per acre in the oldest class...Total average productivity was consistently higher with increased age of the tree class...Yields of lichens increased consistently from 5 pounds per acre to 482 pounds per acre. More important than the increase in total lichen yield was the increase of high value lichens [i.e. preferred species]. Average yield of high-value lichens varied from 1 pound per acre in the 1 to 10-year old forest to an average yield of 264 pounds per acre in the class exceeding 120 years of age. Moderate-value lichens reached their highest yield during the 51 to 75-year age class, and low-value lichens obtained dominance in the 11 to 30-year age class. Although there were variations within each age class, lichen abundance was clearly related to maturity of the forest...

"The effects of increased forest fire destruction in recent years, considered in light of yield data, are obvious. Forage available to barren-ground caribou on the winter range is being reduced, both in amount and quality, at the fastest rate within approximately the last 150 years...Theoretically, the average forage yield on recent burns was 290 pounds per acre, or 3,013 tons on the 20,779 acres. A mature black spruce forest, assuming an average production of 942 pounds per acre, would produce 9,787 tons of forage on the same acreage. On the same acreage, the so-called "reindeer lichens" or high-value lichens would produce 2,743 tons of forage in the mature forest and only 10 tons in the 1 to 10-

year old age class."

An extensive section is given on succession following forest fires basically in stages of 1 to 10 years, 11 to 50 years, 50 to 120 years, and 120+ years. There is also considerable discussion on the effect of fire on soil properties. The main effects of fire seem to be a reduction of barren-ground caribou and perhaps a slight increase of moose in upland forests. A moderate increase in black bear populations is found in burnt-over areas because of an excellent source of berries. Fur-bearing animals such as the red squirrel have been eliminated over much of the area. "Squirrel populations were generally noted only in forest stands older than 50 years. Since squirrels are an item in the food chain of marten...and fisher,...populations of both have been adversely affected. Forest fires may also destroy marten habitat...At least one and possibly two fur-bearers, snowshoe hare...and beaver, [seem to increase after fire]."

352. SCOTTER, G.W. 1970. Reindeer husbandry as a land use in Northern Canada. Productivity and Conservation in Northern Circumpolar Lands. Int. Union Conserv. Nature. (IUCN) Publ. n.s. 16:159-168.

A description of the location, physiography and vegetation of the Reindeer Preserve near Inuvik, N.W.T. is given. The justification of maintaining a reindeer herd is questioned now that caribou are increasing in the area.

353. SDOBNIKOV, V.M. 1971. Causes for breaks in breading of Arctic birds. (Transl. Russian title). Zool. Zh. 50(5):734-740.

Biological Abstracts 52:135797. 1971. (Engl. Summ.): "Breaks in breeding of birds feeding on lemmings are related to changes in the population density of the latter. Non-breeding in other birds is often (but not always) due to

negative climatic anomalies which lead to food deficiency, ice and snow, and unfavourable thermal regimes. During short periods of time such breaks in breeding can hardly be periodic, whereas during longer periods of time during solar activity and other climatic anomalies, non-breeding may be periodical."

354. SEMENOV, L.P. 1963. Heat calculation for an oil pipe laid in seasonally frozen ground. (Transl. Russian title). Materialy K Ucheniiû o merzlykh zonakh zemnoǐ kory. 9:38-52 (In Russian).

From Arctic Bibliography 91571: "Discusses the heat effect of pipelines on adjacent ground and methods of calculating it...Pertinent factors such as the coefficient of heat conductivity of the ground, depth of the pipe, its radius, snow cover, etc. are considered, and formulas given for calculating them. These formulas enable one to determine the heat regime of the oil pipe for each season and to decide upon the optimal depth for laying the pipe."

355. SHACKLETTE, H.F. 1963. Influences of the soil on boreal and arctic plant communities. Unpubl. Ph.D. thesis, Univ. Mich.

356. SHELFORD, V.E. 1963. The ecology of North America. Univ. Illinois Press, Urbana. 610 p.

Chapter 7 — The Tundra Biome: gives an outline of the ecology of the arctic with discussion of climate, soils, permafrost, plant communities and animals. Successions are considered and special aspects of the tundra zones discussed. A good introduction to the area with excellent illustrations.

357. SHTRAUSBERG, D.V. 1958. The assimilation of nutritive elements by plants in the polar region under various temperature conditions. Plant Phys. 5:226-232.

Experiments on assimilation of P, Ca and S in relation to air and soil temperatures by oats, rye and cucumbers are described. Reduction of soil temperature decreases P uptake in root-fed roots more than the reduction of air temperature. Foliar application of nutrients seems more effective than soil application at low temperatures.

358. SHVARTS, S.S. 1967. Biological basis of the hunting and trapping industries. Problems of the North 11:1-17. (Transl. from Russian by Nat. Res. Counc. Can. 1968.)

This paper is concerned chiefly with population dynamics of economically useful wildlife resources. Some problems of over-hunting or industrial changes are also considered.

359. SHVETSOV, P.F. and I.V. ZAPOROZHTSEVA. 1963. The recurrent nature and permafrost engineering significance of 2-3 year soil temperature increases in the subarctic. Problems of the Arctic. 7:21-47. (Transl. from Russian by Nat. Res. Counc. Can. 1964.)

Detailed information is presented on temperature fluctuations resulting in deepening of the active layer and consequent failure of buildings, etc. on permafrost, and reasons for the fluctuations.

"The settlement of rock and coal dust and soot [from mining areas and from cities] on the earth's surface means a sharp increase in the ash content of the tundra soil. As a result, mosses are supplanted in the tundra plant associations by other plants, frequently cereals [grasses?]. A moist moss cover, of course, with its large evaporation surface, markedly reduces the heat penetration of the soil by solar rays and mean surface air temperature."

360. SIGAFOOS, R.S. 1950. Some botanical problems in the interpretation of aerial photographs of tundra areas. Photogramm. Eng. 16:429-431.

"As an aid in the study of perennially frozen ground in tundra regions, photographs are of value only so far as the vegetation and micro-relief features indicate the nature of the frozen substrata, and to the extent that the photographic representations of these features can be identified. It cannot be stressed too strongly that in the interpretation of patterns on aerial photographs, a thorough appreciation and understanding of the topography, physiography and vegetation on the ground are of first importance."

361. SIGAFOOS, R.S. 1951. Soil instability in tundra vegetation. Ohio J. Sci. 51:282-298.

Environmental distribution of effects of congeliturbation: "Peat rings, tussock rings, tussock groups, peat mounds, pingos, ground-ice mounds, swales, and some willow thickets develop on the wettest, fine-grained soils that occur on broad, poorly-drained terraces and uplands, gentle slopes, and parts of river flood plains. Swales and thickets occur where surface drainage in summer is concentrated. The remaining features characterize nearly horizontal surfaces, where run-off is extremely slow.

"Tussock-birch-heath polygons, terrace forms, ridges and hollows, and some willow thickets develop on better-drained, fine-grained soils. Tussock-birch-heath polygons form on better-drained interfluves of gently sloping uplands underlain with wet silty soils. They are associated with the features that occur on the wettest soils. Terrace forms develop in shallow deposits of silty soil and rock that mantle well-drained slopes. The soils are generally drier than those in which tussock-birch-heath polygons develop, but are wet locally during part of the thawing season. Some willow thickets grow on better-drained, steep river and lake banks underlain by silty soils. Ridges and hollows form on better-drained areas of river flood plains adjacent to and within willow thickets that line the banks.

"Turf-banked terraces and vegetation stripes form on the best-drained slopes on hills where bedrock is close to the surface and in terrace gravels. Turf-banked terraces form on the more gentle slopes where some fine material has accumulated, and where movement of soil is slow. Vegetation stripes reach their best development on slopes of 30 degrees, upon which movement of platy fragments is rapid and only small quantities of fines have accumulated.

"Thaw lakes and accompanying phenomena are abundant on lowlands and gently rolling uplands underlain by thick, perennially frozen silt.

"An almost infinite number of micro-relief features formed by congeliturbation occur in tundra regions. The effect of unstable soils on vegetation described is typical of much of the tundra vegetation of Seward Peninsula; all habitats with the possible exception of sand dunes, and beaches, exhibit evidence of soil movement. Micro-relief features involving only fine and coarse rock materials are abundant." (Congeliturbation involves the stirring and mixing of soil surface layers in cold climates where freeze and thaw cycles are intense.)

Vegetation patterns with dominant species are described in detail for each micro-relief feature and problems of succession and climax are discussed.

362. SIGAFOOS, R.S. 1952. Frost action as a primary physical factor in tundra plant communities. Ecology. 33:480-487.

The tundra plant communities are described and their development in relation to frost action discussed. "Tundra plant communities are better correlated with the intensity and character of frost action than with the age of the surface...

The ultimate limit of vegetation development is controlled... by the length of time during which environmental factors do not fluctuate beyond the limits of the ecological amplitude of the species...The length of time involved in the destruction of vegetation by frost action and its subsequent regeneration is considerably shorter than is the time involved for other environmental changes...

"Continuous heath and *Dryas* mats...indicate frost action of less intensity because of well-drained soil and are not characteristic of surfaces of varying age. Discontinuous mats indicate intense frost action and they, too, are not characteristic of surfaces of different ages...

"Willow-birch-heath grows on frost-derived rubbley soil, and well-drained glacial deposits of both glaciations. Frost action is slight at sites supporting willow-birch-heath but is still more intense than at sites where nearly continuous heath and *Dryas* mats grow. Soils supporting willow-birch-heath are well-drained, fine-grained materials, five or more feet thick...

"Cottongrass-tussock-birch-heath grows on poorly-drained, silty soils of level or gently sloping surfaces that vary in age...frost action at sites of this community is intense and periods of soil movement occur annually...Sedge sod and willow shrub grow on drainage lines with peat underlying. Detailed examination of this community...failed to reveal any characteristic form or any species unique to stands on older or younger surfaces."

From the summary: "Surfaces that have been exposed for varying periods of time — surfaces recently formed by water and glacial ice — are essentially of the same age because periodic stirring of the surface layers continually exposes new surfaces to plant colonization.

"Four distinct types of vegetation: heath-*Dryas* mat, willow-birch-heath, cottongrass-tussock-birch-heath, and sedge sod and willow shrub, occur on three surfaces of varying age (younger glacial till, older glacial till, and unglaciated surfaces). Willow-birch-heath and sedge sod and willow shrub also grow on flood plain alluvium. The distributon of these types of vegetation can be correlated with different types of micro-relief features that are formed by frost action. Their distribution could not be correlated with other environmental factors that were investigated."

363. SJÖRS, H. 1959. Bogs and fens in the Hudson Bay Lowlands. Arctic, 12:3-19.

Generalized descriptions of the bogs and fens of the Hudson Bay Lowlands are given, and some generalized comparisons with the same sort of terrain in Scandinavia and in northwestern North America are made. Of interest is the similarity of form here in the Hudson Bay Lowlands to the conditions found by Drury in the Upper Kuskoskwim River in Alaska. Although not specifically discussed, it appears that the same cyclic arrangement occurs here as in the area Drury studied.

364. SJÖRS, H. 1961. Forest and peatland at Hawley Lake, Northern Ontario. Contrib. Bot. 1959. Nat. Mus. Can. Bull. 171:1-31.

This paper contains a detailed description of the palsa bogs of the Hawley Lake area in northern Ontario. The probable upbuilding and degrading of the palsas is discussed. Lists of species typical of the palsas and of the wet areas between them are also given. It is to be noted that these palsas are wooded palsas and although containing sphagnum peat, do not have live *Sphagnum*. This has become replaced by various lichens, particularly *Cetraria nivalis*, "a plant characteristic of wind-swept places with deficient snow cover in winter."

365. SJÖRS, H. 1961. Surface patterns in boreal peatland. Endeavour 20:217-224.

In the various areas of the boreal zone, peatlands have particular patterns both inside and outside the permafrost regions. These patterns are described. The author touches on the idea of succession and believes it does not lead to the formation of a stable climax but instead to continued cyclic phenomena.

366. SKAVEN-HAUG, Sv. 1965. Control of frost penetration in Norway. Permafrost Int. Conf. Proc. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287:268-272.

This paper discusses the methods of preventing destructive effects of frost penetration in the soil, e.g. in roads, railways, etc. Two basic methods are described: 1. by prevention of frost penetration into frost-susceptible sub-soil, i.e. by adding layers of frost-resistant materials, or replacement of frost-susceptible by frost-resistant materials; 2. altering the water properties of local soil by addition of chemicals or draining, neither of which is practical at the moment. The first alternative is used in Norway. Pressed peat blocks (1 m long x 0.5 m wide x 0.3 to 0.5 m thick), as well as discarded railway sleepers are being used by the Norwegian State Railway. The former have been used for over thirty-five years without deterioration. The discarded sleepers have also proved satisfactory as a base.

More recently, spruce and pine bark have been used in the same manner as peat and although the blocks weigh more than the peat blocks when laid, the bark blocks are substantially cheaper, particularly as bark is a waste product produced in very large quantities so that storage places are overflowing. In the author's opinion, "bark is useful for road building in cold regions. Under a bearing layer of

moderate thickness 0.2 to 0.4 m of compressed bark provides a frost-proof foundation and also serves as a very satisfactory filter layer against underlying silt."

367. SKOOG, R.O. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Ph.D. thesis, Univ. Calif., Berkeley. 699 p.

368. SKROBOV, V.D. and E.A. SHIROKOVSKAYA. 1967. The role of the arctic fox in improving the vegetation cover of the tundra. Problems of the North 11:123-128. (Transl. from Russian by Nat. Res. Counc. Can. 1968.)

The changes of vegetation which take place around arctic fox dens are described. "Over arctic fox dens, which form a complex system of underground patterns constructed and improved under permafrost conditions by many generations of the animals, a unique patch of vegetation arises and develops, differing sharply from the surrounding tundra." Twelve species of plants, including three species of grasses, apparently make up the unique vegetation of the environs of the dens. It is noted that "the soils beneath [the dens] are devoid of even the slightest of bogging. This is partly due, of course, to the improvement in drainage. In species composition and appearance, the vegetation of the fox dens resembles the tundra meadowlands." Because of the high proportion of fodder grasses, meadow grass and foxtail as well as other species of grass, "the environs of the fox dens are intensively utilized for grazing by reindeer in summer and in migrating seasons during autumn and spring...

"The luxuriance of the vegetation over the arctic fox dens makes them stand out sharply from a great distance...Inhabited dens are distinguished by the yellow patches of sand thrown up when the dens are cleaned.

"Metal probe measurements made by us showed the permafrost table within the boundaries of the fox dens to lie at a depth of 180 cm, that is, at twice the depth outside these boundaries. The lowering of the permafrost table beneath the den is the result of many years' activity on the part of the animals. The thawing of the substrate is associated with the improved ventilation and drainage, on the one hand, and with the large amount of heat produced, especially when several litters are raised in the den (as many as 18 cubs), on the other.

"In addition to loosening, i.e., the purely mechanical effect on the soils, there is also a gradual change in their chemical properties and constitution, owing to the accumulation of excrements and food remains...

"These two factors, in combination, also cause the formation and development of a luxuriant grass cover over the den where otherwise species composition of the tundra vegetation would be impoverished...

"The tundra meadowland is one of the best types of pasture for reindeer, and in some areas is an early spring feeding ground for geese. Even small areas of tundra meadow surrounded by areas of impoverished summer moss and lichen fodder tundras are gladly visited during the course of the summer by reindeer. According to our figures, the pasturing capacity of tundra meadow is up to 20 reindeer per hectare per day, and that with dwarf birch is only 4.5 reindeer per hectare per day, i.e. a little better than one-fifth as large."

369. SLAUGHTER, C.W., R.J. BARNEY and G.M. HANSEN. 1971. Fire in the northern environment — a symposium. Pac. Northwest For. Range Exp. Sta., For. Serv. U.S. Dep. Agr., Portland, Oregon. 275 p.

This symposium was received too late for individual papers to be annotated.

The papers cover a wide range of topics including: the role of fire in the ecology of northern plant communities; the effects of fire on forestry, wildlife, erosion, tourism, soil properties and water relations; effects of various fire control methods and problems of fire prediction.

370. SOPER, J.D. 1941. History, range and home life of the northern Bison. Ecol. Monogr. 11:349-412.

This ecological study of wood buffalo, done in Wood Buffalo National Park is concerned mostly with the habits of the wood buffalo. The author considers that these animals have little effect on the trees or other vegetation.

371. SPETZMAN, L.A. 1951. Plant geography and ecology of the Arctic slopes of Alaska. M.S. thesis, Univ. Minn.

Basis of material presented in Britton, 1957.

372. SPETZMAN, L.A. 1959. Vegetation of the Arctic Slope of Alaska. U.S. Geol. Surv. Prof. Pap. 302-B. 58 p.

The Arctic Slope is described physiographically, and for each of three provinces, topography, rock composition, soil, vegetation and climate are considered. The major plant communities composing the tundra are: 1. niggerhead meadows; 2. wet sedge meaddows; 3. dry upland meadows; 4. flood-plain and cutbank; 5. outcrop and talus; 6. aquatic. Lists of species are given and descriptions include some information on the local variations of the type. Successional changes, mainly for foothill vegetation, are suggested. There are good illustrations.

373. STEERE, W.C. 1958. Bryophyta of arctic America, 7: A collection from the delta region of the Mackenzie River. Bryologist 61: 182-190.

The results of the study of a small collection of

bryophytes by W.J. Cody in the Delta region are detailed. Sites are given and notes, mostly taxonomic, on some of the species are presented.

374. STEVENS, W.E. 1953. The northwestern muskrat of the Mackenzie Delta, N.W.T. 1947-48. Can. Dep. Res. Dev., Can. Wildl. Serv., Wildl. Manage. Bull. Ser. I., 8. 40 p.

The muskrat is economically the most important fur-bearing animal in the Mackenzie Delta. The study was done on a year-round basis, and included two summers. Studies of life history, reproduction, population, habitat, harvesting, etc. were carried out. "Total depth of about 6 feet was found to be nearly optimum for year-long survival [2 feet of ice in winter with 4 feet of water]. Where depths were less, as in the lower delta area, there was danger of lakes freezing solid in winter. In depths of 10 to 14 feet, there were not sufficient food plants to support a normal winter population of muskrats. The severity of the climate is one of the chief factors restricting the density of muskrats in any given locality...It not only governs the amount and kind of plant growth available for food, but also causes freezing-out in otherwise favourable habitats."

375. STOECKLER, E.G. 1952. Trees of Interior Alaska, their significance as soil and permafrost indicators. U.S. Army Corps Eng., Permafrost Div., St. Paul Dist. 25 p.

"The purpose of this paper is to aid soil survey crews in the field...Identification of the eight major species which attain tree size in the permafrost zone in Alaska is made easy by actual photographs illustrating tree form, branching habits, bark, trees and fruit. To aid aerial observers and photo interpreters, a low-altitude, oblique and a stereo pair of each species are included, along with a description of the trees' salient features and air photo pattern ...A brief discussion of the relative value of each of the eight species as an indicator of soil texture, ground water, and permafrost conditions is included."

376. STORK, Adelaide. 1963. Plant immigration in front of retreating glaciers, with examples from the Kebnekajse area, North Sweden. Geogr. Ann. 45:1-22.

This paper concerns plant succession on rock in front of retreating glaciers in an area of Sweden at about 68°N latitude. Although no mention is made of it, apparently there is no permafrost in this area. It is obviously well drained. The first plants to colonize the areas are mosses, particularly species of *Pohlia* and *Bryum*. Among the pioneers (higher plants) are *Trisetum spicatum*, *Poa alpina*, *P. vivipara*, *Cardamine bellidifolia* and *Saxifraga oppositifolia*. "Ten years after deglaciation the cryptogamic under-story covers about 10 to 20 per cent of the surface, whereas the phanerogamous part is rather constant [and small]. By the end of the second decade the vegetation is still of an open character but about 40 per cent of the ground is covered...[Again, most of the ground cover is made up of cryptogams.] After half a century there is a complete covering of mosses and lichens. At this point the flora changes its character in that flowering plants increase very fast in numbers of individuals. After about 150 to 200 years the vegetation is closed. The number of species increases at a steady rate, totalling about 40."

377. SUMMERHAYES, V.S. and C.S. ELTON. 1923. Contributions to the ecology of Spitsbergen and Bear Island. J. Ecol. 11:214-286.

Contains detailed information on the plant communities and on the associated animals — but the animals are not limited to any one plant community.

378. SVATKOV, N.M. 1961. Natural features at Wrangel Island. Problems of the North 4:1-24. (Transl. from Russian by Nat. Res. Counc. Can. 1962).

This island is classified as Arctic desert, which supports mainly bushy lichens, mosses, and herbacious species and has a desert-like appearance. Descriptions are given of the vegetation, the soils and soil formation as well as patterned ground. Of interest in this paper is the report of the effects of lemmings on the vegetation. "By their activity, the lemmings considerably alter the appearance of the tundra. They dig communal burrows in the soil and interconnect them with numerous passages...On the surface of the tundra these areas stand out clearly. The usual vegetation, which consists of mosses, a limited number of herbacious varieties, sedges and dwarf willows, does not normally form a continuous layer of turf; the plant life hugs the ground and turns brown in August. Areas with burrow holes, on the other hand, stand out because of the rich green of the herbaceous cover, which includes many flowering plants, notably forget-me-nots, arctic poppies...and various meadow grasses, and form a continuous cover almost completely absent of mosses and shrubs.

"The formation of micro-depressions may be explained in terms of the improved aeration and warming of soils due to the numerous lemming burrow holes. The increased warming results in the thawing of ground ice, which leads in turn to soil slumping. Burrow digging by arctic foxes in the dry uplands along the river banks of the Akademia tundra region... has little effect on the micro-relief and vegetation cover."

379. SVENSSON, H. 1962. Tundra polygons. Norges Geol. Unders Arsbok. p. 298-327.

Identification of patterned ground from aerial photos is discussed. Most of the patterns are fossil. Vegetation is not discussed.

380. SVENSSON, H. 1970. Frozen ground morphology of northwesternmost Norway. Ecology of the subarctic regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 161-168.

Contains a discussion of frozen ground phenomena, but most of the discussion concerns a palsa, particularly its thermal structure.

381. SWANSTON, D.N. 1970. Mechanics of debris avalanching in shallow till soils of southeastern Alaska. U.S. Dep. Agr., For. Serv. Res. Pap. PNW-102. 17 p.

From a summary of the Pacific Northwest Forest and Range Experimental Station Annual Report for 1970: "Studies indicate a combination of total saturation, slopes with gradients above the natural angle of stability (greater than 34°), and loss of stabilizing effects of anchoring tree roots are the principle causes of debris avalanching in till soils in southeastern Alaska."

382. SYROECHKOVSKII, E.E. and E.V. ROGACHEVA. 1959. New data on the distribution of birds in the Yenisei taiga. Problems of the North 3: 91-98. (Transl. from Russian by Nat. Res. Counc. Can. 1961).

This paper gives the distribution of birds in the Yenisei taiga. The following paragraphs are informative:

"Human activities can cause extensive changes in the landscape, such as the establishment of populated centres with the consequent cutting of clearings in continuous forests and the spread of open, agricultural landscape. Large-scale deforestation in industrial areas and frequent forest fires on the banks of the Yenisei result in a considerable "brightening" of the taiga, owing to the larger areas of second-growth birch and aspen. The northward spread of the tree pipit, jay,

red-tailed shrike, long-tailed tit, wryneck and gray-headed woodpecker may be connected with these changes in the landscape.

"The spread of other species, the typical habitats of which have undergone no substantial change in the Yenisei region, may be due to the warming of the climate which has taken place in Eurasia in the last few decades, and the whole complex of effects of this phenomenon. The greenshank, black woodpecker, tree creeper, whooper swan, common merganser, and possibly whimbrel belong to this category. It is possible that the spread of the species typical of the more open forests is also largely due to climatic changes."

383. SYROECHKOVSKII, E.E. and E.V. ROGACHEVA. 1961. The bird and mammal fauna of the Yenisei forest tundra and the effect of human economic activity on them. Problems of the North 4: 95-106. (Transl. from Russian by Nat. Res. Counc. Can. 1962.)

Of interest here are the changes in fauna of the forest tundra that have taken place as a result of cutting of trees. Basically, there has been an impoverishment of the bird fauna. "The forest and bush species have receded while the tundra species have either been slow in populating the available areas, or have failed to find sustenance on the dry hillsides. Deforestation has had little effect on the small mammals. Only their numbers have been slightly reduced. It is possible that in small, deforested areas where occasional trees and shrubs have survived, the animals have even found somewhat better living conditions, for the forest has been replaced by many low bushes, including berry producers, which were almost non-existent in the forest, and the food base for the animals has improved somewhat. On the other hand, there is less cover for them in the clearings. The animals are more accessible to predators, primarily pigeon hawks, which congregate here in considerably greater numbers than in ordinary tundra districts."

Apparently there is little disturbance of the commercially-hunted animals in this area.

384. TABER, S. 1943. Perennial frozen ground in Alaska: Its origin and history. Geol. Soc. Amer. Bull. 54:1433-1548.

Basic reference paper. A short section is included on vegetation and climate, but the bulk of the paper is concerned with geology and geological processes in cold climates. Frozen ground and ground ice are also discussed. An extensive bibliography is included.

It should be noted that Taber's hypothesis for the growth of ice wedges is now no longer considered tenable.

385. TAMM, C.O. 1954. Some observations on the nutrient turnover in a bog community dominated by *Eriophorum vaginatum* L. Oikos 5: 189-194.

A bog was fertilized with various chemicals and responses measured by the responses of *Eriophorum vaginatum*. Only phosphorus stimulated a strong response as indicated by increased growth and flowering of *E. vaginatum* and greener colour of both field vegetation and stunted pines. Analyses for all the nutrients used were run on vegetation samples.

386. TARNOCAI, C. 1970. Classification of peat landforms in Manitoba. Can. Dep. Agr. Res. Sta., Pedology Unit. Winnipeg. 45 p.

A classification system of peat landforms (bogs and fens) is presented. There are good photographs illustrating the various types and subtypes.

387. TEDROW, J.C.F., J.V. DREW, D.E. HILL, and L.A. DOUGLAS. 1958. Major genetic soils of the arctic slope of Alaska. J. Soil Sci. 9:33-45.

Summary: "The genetic soils of Arctic Alaska can be arranged in a drainage catena. The mature soils on well-drained sites are Arctic Brown and related soils. The tundra profile is an imperfectly-to-poorly-drained catena member. The Bogs, with permafrost, occupy many of the broad, flat, very wet areas. No evidence of a qualitative soil-forming process unique to the Arctic areas is found. Instead, the Arctic tundra is primarily a northern extension of the hydromorphic soils of the forested regions, whereas the Arctic Brown and related soils represent the northern extensions of the podzolic process. The term tundra, when used in connection with zonal great soil groups along with Podzols, Chernozems, Laterites and related soils, is an erroneous one and its use, except for a hydromorphic soil, should be discouraged. The podzolic process on the stable, well-drained sites weakens northward, resulting in the successive development of Podzols [normally with forest vegetation], Minimal Podzols [with either forest or tundra vegetation], Arctic Browns [normally with tundra vegetation but forest may be present in more southern regions], Arctic Browns, shallow phase [tundra vegetation], and finally no soil formation [lichens are scattered throughout]."

388. TEDROW, J.C.F. and H. HARRIES. 1960. Tundra soil in relation to vegetation, permafrost and glaciation. Oikos 11:237-249.

The discussion indicates that soil types grade between forested and tundra areas and one cannot use vegetation to determine the Great Soil Group. The distribution of species at tree line is described, as well as Arctic vegetation, permafrost, glaciation, and soil processes. Includes a good bibliography.

"Tundra as a genetic soil cannot be viewed as a climatic (zonal) soil type nor as a result of a process unique to the arctic regions...The dominant processes operating in the tundra soils can be considered as a type of gleyzation at low temperature. There is some leaching in the surface horizons and saturation of exchangeable bases is usually below the 50 per cent level. Coupled with the pedological processes is a second set of processes associated with frost displacement in the profile. It has been shown that these cryopedologic processes operate but the magnitude and rates remain somewhat indefinite."

389. TEDROW, J.C.F. and J. BROWN. 1962. Soils of the Northern Brooks range, Alaska. Soil Sci. 93:254:261.

"The concept of the weakening soil-forming potential at high Arctic altitudes and its circumpolar implications is discussed." Various soils taken from stable sites on transects from valleys into the higher altitudes of the Brooks Range are described and used as a basis for the discussion.

390. TEDROW, J.C.F. and L.A. DOUGLAS. 1964. Soil investigations on Banks Island. Soil Sci. 98:53-65.

Summary: "Soils of Bank's Island, N.W.T. are predominantly well-drained with many high arctic affinities. Because of the dry, desert-like appearance of most soils, they are designated collectively as *polar desert* rather than *tundra*. Many of the soils have salts accumulated at the surface, and within the well-drained soils pedogenic carbonate accumulation within the solum is a usual occurrence. Chemical, physical and minerological data are given. Soil taxonomy at both the great soil group and soil series levels is discussed."

Some vegetation information is given: "Vegetation is of low stature, and on well-drained and xeric sites is discontinuous, with the soil retaining a mineral character at the surface. In poorly drained sites vegetation exists as a thick carpet of low-growing plants."

391. TEDROW, J.C.F. 1965. Arctic Soils. Permafrost Int. Conf. Proc. 1963. Nat. Acad. Sci. — Nat. Res. Counc. Wash. Publ. 1287: 50-55.

This review contains an outline of the history of soil science in the Arctic and presents a brief description of the soil types present there: bog soils, well-drained soils and lithosols, regosols and rockland, shungite and rendzina soils. Soil processes, climatic gradients, patterned ground and soil maps are discussed and problems needing solution listed. An extensive bibliography is included.

392. TEDROW, J.C.F. 1966. Polar Desert Soils. Soil Sci. Soc. Am. Proc. 30:381-387.

From the author's abstract: "Polar desert soils are sparsely colonized by vascular plants and in many instances the organic component scarcely enters the soil system. Low temperature, relatively dry soil conditions, a desert pavement, mildly acid to alkaline reaction, and salt efflorescences commonly characterize the Polar Desert soils."

393. TEDROW, J.C.F. 1968. Pedogenic gradients of the polar regions. J. Soil Sci. 19:197-204.

The soils of the polar regions are zonally classified as Arctic Brown, Polar Desert and Cold Desert. "Vascular plants form a continuous mat in the Arctic Brown soil zone but within the Polar Desert soil zone are patchy or at times completely lacking. In the Polar Desert soils, algae and diatoms appear to be the main contributors of soil organic matter... Progressing from the northern fringes of forested land, to colder climates, precipitation decreases, organic matter content of the soil decreases, and soil pH values tend to increase...Tundra and Bog soils dominate areally in the main tundra belt but are confined to the local swales and depressions in the high Arctic. Both Tundra and Bog soils tend to have higher pH values as one progresses to colder, drier climates."

394. TENER, J.S. 1965. Muskoxen in Canada. Can. Dep. N. Affairs Nat. Res., Can. Wildl. Serv. Monogr. Ser. 2. 133 p. plus appendices.

A comprehensive review of the present status of the muskox. On the subject of plant species utilization: "While the species prefers certain plants such as willows and grasses, it will also eat sedges, forbs and woody species....It does not associate in large numbers...Muskoxen forage over a much smaller area [than caribou], do not migrate to forested areas for the winter, and occur in widely-scattered small herds. Such behaviour diversifies range utilization."

395. THOMPSON, J.W., C.W. SCOTTER and T. AHTI. 1969. Lichens of the Great Slave Lake Region. The Bryologist 72:137-177.

Three hundred and forty-three species of lichens are reported from this area. Habitat lists and keys to certain local species, as well as some chemical notes, are included.

396. TIKHOMIROV, B.A. 1935. Burning and its effect on the natural food plants of the Soviet Far East. (Transl. Russian Title.) Akad. Nauk. SSSR. Dal'nevostochnyi filial-Trudy 1:159-170.

Arctic Bibliography 48402: "Contains information on the widespread custom of burning the pastures in these regions and its ameliorating value; effect on forest fires and on tree vegetation; adverse effects on lichens and reindeer pasture. The soil absorbed more heat from the sun after the peat cover was destroyed; there was a decrease in moisture content, and the ashes acted as fertilizer. Permafrost, located usually about 50 cm from the surface, retreated to 90 to 100 cm."

397. TIKHOMIROV, B.A. 1937. On the life conditions of earthworms in tundra soils. (Transl. Russian Title.) Priroda 5:52-58.

Arctic Bibliography 32476: "Contains a study of the role of earthworms in soil formation in the tundra zone, carried out in 1935 on the coast of Tiksi Bay (Laptev Sea); with analyses of ten soil samples, their vegetative cover and the quantity of earthworms found; a table of soil temperatures from various arctic regions; and a text map showing the distribution of earthworms in the tundra zones of the USSR."

398. TIKHOMIROV, B.A. On the geographic distribution of pingos ("baĭdzharakh") in northern Eurasia. (Transl. Russian Title.) Priroda 1:51-53.

Arctic Bibliography 32472: "Deals with geographic range of icing mounds or pingos, peculiar hillocks previously described from the coasts of Laptev and East Siberian Seas. The author found them also on Dikson Island, in northern Yakutia and on Taimyr Peninsula, where he observed their formation and development in the period 1937-1947. They occur in regions of fossil ice and permafrost. The increasing intensity of the process of arctic erosion and the recent westward expansion of icing mounds is explained by destruction of plant cover (mosses) and denudation due to solifluction, snow erosion, activity of animals, and man, and to the warming up of the Arctic. The further expansion of icing mounds and their occurrence in nonarctic mountainous regions may be expected."

399. TIKHOMIROV, B.A. 1951. On the role of the wind in distribution of plants in the extreme north. (Transl. Russian title.) Priroda 40(8):23-25.

Arctic Bibliography 26705: "From five experimental plots, each 100 m^2, a 5 cm layer of snow was removed and the contents examined for plant residues. The species to which belong the various seeds, leaves, stems, fruits, etc. that were found, are listed. The evidence indicates that the flora character of the far north is complemented by migrants from the south with the aid of southerly winds. (Especially significant was the find of needles of Siberian spruce (*Picea obovata*) 450 to 500 km north of this tree's northern limits. The role of birds in northern dissemination is also discussed.)"

400. TIKHOMIROV, B.A. 1952. The importance of moss cover in the vegetation of the far north. Bot. Zh. 37:629-638.

Arctic Bibliography 48403: "Characteristics of moss vegetation are discussed to draw attention to its importance in tundra life. Hitherto its negative aspects have been stressed: the moss cover, a poor heat conductor, worsens thermal conditions in summer; its component plants of low nutritional value are a poor source of food for such tundra animals as reindeer, lemmings, some birds, etc. Mosses, however, have a positive role in vascular plant development in the tundra: they protect plants against temperature fluctuations in spring and stabilize ground moisture. Beneath the snow cover, the mosses create hollow spaces with temperature higher than outside, "natural hot-houses" favourable to vascular plant development. These protective and assimilating activities of mosses are positive factors in the life of tundra vegetation, and require further study."

401. TIKHOMIROV, B.A. 1955. The influence of the Ob' lemming (*Lemmus obensis* Brants) on the tundra's vegetative cover. (Transl. Russian title.) Akad. Nauk. SSSR. Doklady. 104(4):650-652.

Arctic Bibliography 42823: "The local abundance of this rodent which lives on certain tundra plants, chiefly *Eriophorum angustifolium* and *Carex stans*, is a factor affecting the vegetation of central and northern Taymyr Peninsula. Also, lemming migration destroys up to 20 per cent of the moss cover, inducing formation of a hilly micro-relief, which leads to less active melting of snow."

402. TIKHOMIROV, B.A. 1956. Some characteristics of the snow cover of the tundra and its influence on the existence of vegetation. (Transl. Russian title.) Akad. Nauk. SSSR. Inst. geogr. Sneg i talye vody. p. 206-239.

Arctic Bibliography 48400: "Study of ecological effects of snow cover upon tundra vegetation based on observations in the Arctic, partly in the Lake Taymyr area during 1947-48. The distribution and physical properties of snow are described and its regulatory influence on the height of plants noted. The corrosive influence of hard snow on plants is counterbalanced by its protective effect, when accumulated, against extreme low temperatures and strong winds. The melting of snow lowers the level of permafrost in the spring and summer, and deposits some nutritive sediments. The snow- and moss-cover help the flowering plants to withstand the rigors of arctic winter and to continue their biochemical and physiological processes. This is partly due to formation of cavities around the plants under the snow, which serve as natural hot-houses. With the advent of spring, the sun's rays reach these plants through the snow and...photosynthesis starts earlier. The suggestion is made of a regulatory function of the melting of snow, creating optimum conditions for the development of tundra vegetation."

403. TIKHOMIROV, B.A. and E.V. DOROGOSTAISKAIA. 1957. Penetration of new plants into the flora of the Arctic in relation to the advancement of agriculture. (Transl. Russian title.) Izv. AN SSSR. ser. biol./News Acad. Sci., Biol. Ser. 5:601-610.

Arctic Bibliography 55438: "Contains a study of introduction by man, of new plants into the Tiksi Bay region (71^{o} 41'N, 129^{o}W). Climatic conditions, precipitation, and length of cultivation of agricultural plants are discussed. Twenty-seven species of introduced plants, collected in 1955 at the Tiksi Agricultural Station are listed, with data on: biological type, locality, date of collection and phenophase, distribution in Yakutia. Special attention is given to weeds. Successful cultivation of cabbage, radish, lettuce, onions in the open, and cucumbers and tomatoes (in hothouses) is claimed."

404. TIKHOMIROV, B.A. 1957. Dynamic phenomena in the vegetation of spotted tundras in the Arctic. (Transl. Russian title.) Bot. Zh. 42(11):1691-1717.

Arctic Bibliography 55432: "Study, based chiefly on investigations in the Central Taymyr Peninsula, of spotted tundras as an element of the natural complex of arctic vegetation, and of their characteristic structural features. At least 6 different types of spotty tundras can be distinguished: *Dryas punctata* and *Cassipe tetragona* and *Carex hyperborea* and miscellaneous green mosses; *Carex hyperborea* and *Dryas punctata* and miscellaneous green mosses; etc. Characteristics of the soil regimes of different parts of such tundras are given. The main types of spotted tundras and features peculiar to their vegetation are discussed and figured. Wind and corrosion of the snow cover are the principal factors contributing to tundra denudation. Regeneration of the vegetation on bare spots of spotted tundra is a slow process, in which cryptogams and bacteria play the leading part. Bacteria come first, followed in turn by algae such as *Stratonostoc commune*, green mosses, liverworts and lichens (listed), and (later) flowering plants. These two processes, the denudation of the tundra and revegetation of bare spots, going on continuously and simultaneously, are the most important phenomena of the dynamics of spotted tundra vegetation."

405. TIKHOMIROV, B.A. 1959. Effect of vegetation on the summer thawing of ground in permafrost regions. (Transl. Russian title.) Mezhduved. soveshch. merzlotoved. 1956. Mater. obshchemu merzlotoved. ...pub. 1959. p. 207-209.

Arctic Bibliography 62086: "Reports on systematic measurements 1947-1949 of thawing depth in the tundra of Central Taymyr. The rate of thawing was insignificant until 10-30 days after snow-melting, it increased by mid-summer, and decreased rapidly toward the end of the season. An inverse relationship between micro-relief and thawing depth was observed. Temperatures of the vegetation surface and at 10-20 cm depth in the ground differed as much as 20-25°C.; some plants continued growing although part of their root system extended below the 0°C level. Thawing depth varied with types and species of vegetation; the minimum depth was observed under sphagnums."

406. TIKHOMIROV, B.A. 1959. Relationship of the animal world and the plant cover of the tundra. Bot. Inst., Acad. Sci. USSR. Moscow and Leningrad. Transl. from Russian by E. Issakoff and T.W. Barry, W.A. Fuller, ed. 83 p.

This paper is a natural history of the tundra. Relationships of invertebrates, soil fauna, rodents (particularly lemmings), birds, reindeer, and predators with vegetation are recorded and the activities of the animals discussed in terms of their effects on vegetation.

Petelka (1970) says this of the paper: "A general review..on animal-vegetation interactions...[It] is heavily descriptive in its content and preoccupied with the elementary fact that plants and animals interact; but it is admirable in its wide sweep of the topic and the degree to which it raises questions and urges teamwork in concentrated study on particular areas."

The bibliography is omitted from the translation and only some of the figures are included.

407. TIKHOMIROV, B.A. 1960. Plantgeographical investigations of the tundra vegetation in the Soviet Union. Can. J. Bot. 38:815-832.

This is a general summary paper of investigations in the Soviet Arctic. A very extensive bibliography of Russian literature is included. The following short quotations indicate areas of more recent Russian interest in the Arctic.

"Of great importance...is the work revealing the peculiar interrelationship between different biological groups in the arctic plant associations. Especially important for the existence of vascular plants and lichens is the role of mosses, (Tikhomirov, 1952). As a number of investigations have shown, there is no doubt about the enormous role played by algae in the formation of vegetation cover on the substrate, particularly on the barren spots so often occurring in the tundra (Kosheleva and Novichkova, 1958; Dorogostayskaya, 1959; and others)...

"Now the main causes for the absence of trees on the tundra are known and on the basis of this, methods of afforestation have been suggested. We have also revealed the present tendency of a northward and vertical expansion of the vegetation."

408. TIKHOMIROV, B.A. 1960. The influence of the long-tailed suslik *Citellus undulatus* on the flora and vegetation of the Chukchi tundra. (Transl. Russian title.) Moskovskoe o-vo ispytatelei prirody. Trudy. 3:277-290.

Arctic Bibliography 92346: "Account of observations in the Bering Sea coast area. The burrowing activity of this ground squirrel produces changes in the habitat, *i.e.* the drainage, nitrification, etc. This leads to changes in the dwarf shrub and mossy vegetation, specified. Around the burrows on the other hand, there develops a new vegetation with forms hitherto not prevalent. The penetration of the animal into the north has apparently conditioned penetration of some more southerly plants."

409. TIKHOMIROV, B.A. 1962. The basic changes in the development of the vegetation of the USSR north in relation to climatic fluctuations and the activity of man. Translations on Land and Marine Biology — USSR. 1963. p. 1-24. U.S. Dep. Com. Off. Tech. Serv., Joint Publ. Res. Serv. (JPRS 18517-OTS 63-21488).

Describes vegetation changes since the Tertiary period in the USSR north. The varying northern forest boundary is discussed.

"Thus, all the investigators referred to are in agreement on the incursion of forests into the tundra not only for individual regions, but everywhere in the tundra zone of the USSR, Scandinavia and North America. Delineation of the present forest boundary to the north in general is determined by cooling following after the warm period in the Holocene and by the subsequent climatic fluctuations, and also by the activity of man, the importance of which in modifying the biogeographical frontiers of the north has until recently been far from adequately taken into account. Over a long period, measured in centuries, and probably in millenia, man wiped out the forest only to his north. In the interrelationships of forest and tundra, man has continually merged on the side of the tundra against the forest. The unsystematic felling of forests along the northern limits of his advance, together with a feeble attempt at reforestation, has led to the formation of forestless, tundra-like, and low-productivity plant communities ("anthropogenic tundra"). Especially destructive toward the trees in the frontier northern forest have been deer, trampling underfoot the young undergrowth during their autumn feeding.

"In addition, it must be noted that in the centuries-long succession of tundra vegetation, the pasturing of deer has played a very essential role. It has been noted that in places where deer congregate and in localities of intemperate pasturing the tundra cover has been replaced by meadow-like groupings...

"The investigations of several biogeographers of the USSR have concluded that the decisive factor in the forestlessness of the tundra is the shortage of seeds from trees inhabiting the Far North, and their low quality, together with the unfavourable conditions for their propagation and for the development of young saplings (frequent spring frosts, low soil temperatures, high level of summer thawing of the "eternal frost", dense moss cover, etc.). From the foregoing it is clear that the forest limit can be considerably advanced into the tundra zone. This requires a uniform supply of the forest-suitable areas with good quality seed of cold-resistant tree strains, the carrying out of measures which promote the growth of their young saplings, and also measures aimed at setting up favourable tree-planting conditions over specific territories of the southern limits of the tundra adjoining the forest...

"From the observations of Tikhomirov and Dorogostayskaya (1957), over a short period of 15 to 20 years the flora of... Yakutia has been supplemented by...27 species...In the Chukotskiye tundras, over approximately the same interval of time... 42 species have become entrenched, through the aid of man. On the Kola peninsula, due to the intensive development of agriculture over the last three to four decades, the number of species of alien weed plants come to 142, and from the local flora 57 species spread into the planting areas...Around settlements and cities of the north cultivated landscapes have arisen...[and] other constituent elements of the biogeocenoses have also changed. Here, for example, we can note the change both of vertebrates — ornithofauna and mammals — as well as invertebrates."

An extensive bibliography is included.

410. TIKHOMIROV, B.A. 1963. Essays in the biology of arctic plants. (Transl. Russian title.) Akad. Nauk. SSSR. 154 p.

Arctic Bibliography 83538: "Deals with the physiological, morphological and ecological aspects of arctic plant life from own long-time work and that of others, mainly Russian. Successive chapters deal with the history of this line of research, beginning in the 18th Century; climatic factors in the life of arctic vegetation; ecological and soil conditions; basic life processes of arctic plants; their morphological peculiarities including roots; thermal factors; specific traits in development; reproduction; coenotic interrelationships of different biological groups, etc. Forms of plant life, including algae, fungi, lichens, and mosses are outlined, and imminent problems in the study of arctic plant biology, considered. The importance of broad, biogeocenotic study is emphasized in the summary. Ca. 350 refs."

411. TUMEL', V.F. 1939. Some changes in the permafrost resulting from the burning of the vegetation. (Transl. Russian title.) Akad. Nauk. SSSR. Komitet po vechnoi merzlote. Trudy. 8:3-80.

Arctic Bibliography 18084: "Contains detailed analyses of temperature change of frozen ground due to the influence of forest fires, which produce chemical changes and subsequent changes in the vegetation. Data on geography, geology and climate of the Zeya valley are given with descriptions of cross-sections in test pits before and after conflagration. The most significant effect is that a new type of vegetation is produced which influences the moisture content and the thermal regime of the ground. Suggestions for the artificial use of forest fires for amelioration of soil are given."

412. TUSSING, A.R., C.W. ROGERS and V. FISCHER. 1971. Alaska Pipeline Report (Advance copy of ms.) Study prepared for: U.S. Dep. Interior, Inst. Soc. Econ. Gov. Res., Univ. Alaska 1SEGR Rep. 31. 130 p. mimeo.

This report deals only with the probable economic impact of the pipeline (including, of course, oil wells and gas fields) on the economy of Alaska.

413. TYRTIKOV, A.P. 1956. The effect of vegetation on perennially frozen soil. Data on the principles of the study of frozen zones in the earth's crust. Issue III: 69-89. Acad. Sci. USSR, V.A. Obruche Inst. Permafrost Stud. Moscow. Transl. from Russian by G. Belkov, M. Howson, and Z. Topchy. Nat. Res. Counc. Can. Tech. Transl. 1088. Ottawa. 1963.

Conclusions: "(1) The effect of vegetation on the temperature and certain other properties of permafrost is highly varied and depends not only on the type of vegetation cover but also on the general climatic conditions. (2) Any type of vegetation cover retards the penetration of heat into the soil during the summer. Under the cover the vegetation the average monthly temperature of the soil at a depth of 15 to 40 cm is frequently 5^{o} to 15^{o} C. lower, and the depth of thawing is less by a factor of 1.5 to 3.0, or more than in areas where vegetation has been removed and where the organic matter in and on the soil has been mineralized. This effect of vegetation increases with the bulk, height and density of the vegetation cover and with the amount of organic matter deposited in and on the soil. The peat layer and the surface cover of vegetable residue frequently retard the penetration of heat into the soil to a much greater extent than the living vegetation. (3)

Any vegetation reduces the heat loss from the soil in the winter. The average monthly winter temperature of the soil under a vegetation cover is as much as 17^{o} C. higher...than in areas where vegetation is absent and the soil contains no organic deposits. (4) By reducing the loss of heat from the soil in the winter and retarding the transfer of heat into the soil in the summer, the vegetation causes either a decrease (by as much as 3^{o} C) or, under certain conditions, an increase (by as much as 2^{o} C) in the (average annual) temperature of the upper layers of permafrost. (5) By decreasing the depth of thawing and preventing the erosion of soil, the vegetation prevents the thawing of ice in perennially frozen soil and is thus highly conducive to the preservation of fossil ice. (6) The removal of the vegetation cover results in the melting of the ice deposits in perennially frozen soil, which is frequently followed by the formation of extensive depressions of the lake-bog type (Alas), gullies, sink holes, and other thermokarst relief features. (7) Choking the lakes and covering the previously bare, dry land, vegetation facilitates the formation of permafrsot in areas where it did not previously exist. (8) When lakes and dry land are covered by organic deposits, permafrost of organic composition is formed (in the upper layers at any rate) that differs fundamentally from perennially frozen mineral soils, especially by its large ice content."

Notes from the body of the paper: "The dry surface organic layer and peat are characterized also by low heat conductivity, which in dry peat is approximately the same as in snow (Sumgin, 1937). The thermal conductivity of wet peat is eight times greater than that of dry peat, and that of frozen peat (containing ice) is 33 times greater...During periods of drought a thin surface layer of dry peat is formed which, because of its low heat conductivity, prevents the heating and the drying of lower layers of soil. Consequently, as the layers of peat accumulate, the soil becomes steadily colder in summer and its tendency to turn into a bog increases...

"Various types of plants and even various plant communities within the same temperal vegetation differ with respect to the rate of deposition of organic matter in the soil and above it;...in forests where sphagnum moss is present the peat layer accumulates much more rapidly than when the surface cover is of green moss. In areas where lichens predominate the peat layer becomes mineralized. In bogs the accumulation of organic matter is particularly rapid. The thickness of the surface organic layer (peat), and consequently the effect on the temperature regime of the topsoil and underlying strata, varies greatly, not only with various types of plant life but even within the same plant community, depending on the stage of its development and usually increasing with age...Moss and lichen covers evaporate a large quantity of water and apparently greatly reduce the temperature of the layer of air above the soil."

This paper is full of references to data illustrating permafrost and vegetation interrelationships, but records the fact that data even in its general aspect are very scant.

414. TYRTIKOV, A.P. 1957. Thermal conditions of the soil in various plant associations in the Igarka region. (Transl. Russian title.) Pochvovedenie 6:35-42.

Arctic Bibliography 55568: "Reports results of an investigation carried out by the author in 1950. The taiga forest soil of the studied area is characterized by low temperature (1.9° - 4.6° C.) during the vegetation period (June 10 - September 10) as compared with the temperature of ploughed soil (10.3°C). This is due to the thick (10-20 cm.) peat horizon covered with mosses and lichens. Removal of moss cover and acceleration of mineralization of organic residues (peat horizon) are suggested as basic means for thermal amelioration of the soils in this area."

415. TYRTIKOV, A.P. 1959. Perennially frozen ground and vegetation. Principles of Geocryology. Part I. General Geocryology. p. 399-421. Transl. from Russian by R.J.E. Brown, Nat. Res. Counc. Can. Tech. Transl. 1163, 1964. 34 p.

This paper is considered by some to be the best available on the subject. Hence the listing of the conclusions in full.

Conclusions: "(1) The main influence of vegetation on the thermal exchange between the lithosphere and the atmosphere, and consequently on the permafrost, is determined by its influence on the moisture regime between the soil and the atmosphere. (2) The life activity of plants resulting in the accumulation of organic matter in the soil and on the soil (forest litter, peaty horizon, peat) leads to an increase in moisture (ice content) of the surface horizons and in this manner exerts considerable influence on the heat exchange between the lithosphere and the atmosphere. (3) Organic matter in the soil and on the soil have less effect on cooling of it in winter (freezing) than on warming (thawing) in summer. (4) The vegetation exerts considerable influence on the heat exchange between the lithosphere and the atmosphere in the following ways: by transpiration, which dries the soil and reduces the temperature of the air near the surface, by reducing evaporation from the soil surface, by trapping precipitation on the surface of the plant, and by condensing moisture from the air. (5) Under the vegetation canopy the intensity of solar radiation is decreased (sometimes by 100 or more times), resulting in less warming of the soil. (6) The vegetation in weakening the force of the wind contributes to the deposition of snow in a porous condition and in some regions to an accumulation of it, which results in a decrease of heat radiation by the soil and sub-soil in winter. (7) The influence of the vegetation on the temperature and certain other properties of the permafrost takes on many forms and tendencies and varies not only in relation to the character of the vegetation cover but also to the general climatic conditions in which it develops. (8) Any vegetative cover retards the warming (thawing) of the soil in summer. Under the vegetative cover the temperature of the soil at a depth of 15 to 40 cm is usually 5 to 15°C (mean monthly) lower and the depth of thaw is 1.5 to 3 times less than in areas from which vegetation has been removed and the organic matter in the soil and on the soil has been mineralized. This influence of the vegetation is the more significant the greater the mass, height, density and the greater the accumulation of plant matter in the soil and on its surface. Dead plant matter (litter, peat) often retards the warming (thawing) of the soil more than a living vegetation cover."

(The author in the body of the paper pointed out that among the various plant species which cover the soil surface the greatest influence on the thawing of the soil is exerted by *Sphagnum* moss. The soil under *Sphagnum* moss, including peat soil, thaws much more slowly than under green moss. Other types of moss and lichen also reduce the thawing of the soil in comparison with areas where soil cover is removed. The removal of moss and lichen cover resulted in an increase of the depth of thaw by 20 to 50 per cent in one area and a 2- to 3-fold increase in thawing in another area. Observations also indicated that peat lying under mosses and lichens often retards thawing of the soil more than the moss and lichen cover itself.)

"(9) Any vegetation cover retards the cooling (freezing) of the soil in winter. Under a vegetation cover the temperature of the soil in winter is higher (sometimes up to 17°C for the mean monthly temperature), than in areas where the vegetation is absent and the soil does not contain organic matter. (10) Vegetation, by impeding the cooling of the soil in winter and the warming of the soil in summer, leads to a lowering (up to 3°C) or in some conditions to an increase (up to 2°C) of the temperature of the upper layers of the permafrost. (11) By decreasing the depth of thaw and retarding soil erosion, the vegetation impedes the melting of ice in the permafrost and is therefore a most important conservation agent of it. (12) The destruction of the vegetation cover causes melting of the ice in the permafrost, which sometimes leads, in these areas, to the formation of vast meadows (Alas), gullies, sink holes, hollows and other thermokarst forms of relief. (13) By filling in lakes and covering dry land, vegetation often contributes to the formation of permafrost in areas where it was absent. (14) In the growing over of lakes, permafrost of organic composition is formed (at least in the upper layers) which differs fundamentally from mineral types (particularly by having a high ice content). (15) The degree and heterogeneity of the influence of vegetation on the permafrost increases along a line from the north of the tundra zone to the taiga in which the maximum is reached and then it decreases in the steppe zone. (16) Permafrost weakens the development and life activity of the sub-surface and above-ground organs of the plants and soil micro-organisms by contributing to the lowering of the temperature, swampiness, the impoverishment of aeration and nutritive substances of the soil (only in very dry areas do they create favourable conditions of moistening of the soil for the growth of plants). This influence is the more significant the closer to the surface of the soil the permafrost is located and may have no effect when the permafrost table is deep. (17) Where permafrost occurs near the surface it contributes to the formation of shallow root systems of plants and reduces the stability of trees against the wind. (18) To a certain degree, plants are capable of overcoming unfavourable influences of permafrost by additional roots and developing a positive thermotropism of the roots, *i.e.* the capacity to grow in the direction of the warmest part of the soil. (19) Permafrost influences the vegetation cover (by disturbing, changing or completely destroying it), by contributing to the formation of various forms of relief (spot medallions, mounds, thermokarst relief forms, landslides, naleds, lakes, etc.). (20) The unfavourable influence of permafrost on the development of vegetation can be completely or partially removed by thermomelioration. [The author describes removal of trees and ploughing of forest sections to create areas suitable for cultivation, or to create meadows in the tundra zone. To improve the growth of the forest in certain regions, the destruction of the moss cover is recommended by the application of toxic chemicals. "This destruction, besides increasing the soil temperature, also increases the mineralization of the peaty horizon of the soil and thus contributes to the improved nourishment of the plants." In one region, observations give evidence of the fact that in areas where there is no moss cover or peaty horizon, the growth of trees in the forests is 10 to 100 times greater than in areas where there is moss cover.] (21) Thermomelioration of the soil can raise considerably the natural output of agricultural areas in permafrost areas and extend agriculture further north in the permafrost region. (22) Vegetation is an indicator of the composition, properties of permafrost and thickness of the seasonally thawed layer and can be successively used (and is partially used) by the compilation of large-scale permafrost maps both from field observations and from aerial photographs."

This paper gives a very full discussion of the points raised in the conclusions. Tables are given to illustrate some of the results described in the conclusions and an extensive bibliography is included.

416. TYRTIKOV, A.P. 1963. Bog vegetation as an indicator of unfrozen deposits in the northern taiga. (Transl. Russian title.) Akad. Nauk. SSSR. Inst. merzlotoved. Mnogoletnemerzley gornye...: 62-70.

Arctic Bibliography 83728: "Analyzes heat exchange and seasonal freeze-thaw in marshland, as exemplified in the Nadym, Igarka and Khantayka regions. Bogs with water cover (to 50 cm) and without it are compared. Presence of surface water has a positive effect on soil heating. The input of heat is greater and losses smaller with, than without water cover. Beneath bogs with surface water, permafrost is absent or much deeper. Such bogs are indicators of unfrozen deposits throughout the northern taiga of Western Siberia."

417. TYRTIKOV, A.P. 1963. Questions concerning the improvement of tree growth conditions in Northwestern Siberia. Problems of the North. 7:135-139 (Transl. from Russian by Nat. Res. Counc. Can. 1964.)

"The destruction of the soil cover and peat layer in sparsely wooded forests results in a soil temperature increase of 6 to 8.5^{o}C at a depth of 20 cm, compared with natural conditions. In addition, the depth of thawing is increased 2 to 2.5 times, and even in the first year after the destruction of the peat layer, it reaches 120 to 150 cm in loamy soils. A gradual thawing of the permafrost occurs in succeeding years, since winter freezing, as a consequence of the considerable snow cover, is usually less than summer thawing. In this way, soil aeration is improved, the activity of micro-organisms is intensified and in cultivated soils its duration may be extended almost a month in comparison with virgin soils...There is also an increase in the volume of soil accessible to the roots, which are now able to draw nutrient substances from the deeper soil layers.

"It follows that the destruction of the moss cover and peat layer leads to an improvement in the entire complex of soil conditions (temperature, water-air regime, nutrient qualities, etc.). The improvement of soil conditions, in turn, leads to an intensification of tree growth. There is already a case on record where the removal of the moss cover around the trees has almost doubled the trunk diameter in comparison with the natural conditions (Andreev, 1954). After burning off a peat layer in the Igarka region, the growth of young trees, both in height and width, increased several times...

"Following the burning of the peat layer in forests and treeless areas in the Igarka region, a grass cover 1 to 2 m in height is developing, which consists of...*Calamagrostis langsdorffii* Trin. It has been shown...that a grass cover does not greatly hinder the warming of the soil."

418. TYRTIKOV, A.P. 1965. Vegetation as an indicator of composition and properties of seasonally frozen, active layer and permanently frozen ground, Igarka District. Transl. publ. in Int. Geol. Rev. 7(2):196-201.

Translator's abstract: "A review of frost conditions under a series of plant associations, which ranges from open-water swamp to dense forest on hummocks presumably generated by frost-heaving in the past, reveals a continuous sub-surface frost series. The frost series ranges from permafrost without active layer beneath open swamp-water to a total lack of permafrost beneath dense conifer-birch forests. The runoff in both extreme environments consists of melted winter precipitation; this is augmented by an active layer of water in the intermediate types of the environment."

This work was done between 1957 and 1959. Soil profiles were studied in detail, as well as annual freeze-thaw cycles and the associated vegetation types. A comprehensive table showing the relationships is presented.

419. TYRTIKOV, A.P. 1967. Dynamics of vegetation changes and development of permafrost of the flood plains in the northern taiga of Western Siberia. (Transl. Russian title.) Moskva Univ. Vestnik 22, ser. 6, biol. pochvoved No. 6:84-90.

Arctic Bibliography 100844: "Reports changes in plant composition in permafrost zones, as well as dwarfism and other physiological alterations in plants, such as pine, produced by the cold taiga environment."

420. TYURDENEV, A.P. and V.N. ANDREEV. 1968. Basic trends in the development of agriculture and other primary industries in the Soviet north. Problems of the North 13:5-52. (Transl. from Russian by Nat. Res. Counc. Can. 1970.)

The advance of the northern boundary of agriculture into the northern taiga and treed tundra is described. "It has been advanced from 65 to 66°N to 68 to 69°N [between 1926 and 1966] and in places to 70 to 72°N [isolated areas in northern Siberia]."

Figures for agricultural yields are given.

421. U.S. ARMY CORPS OF ENGINEERS. Bibliography on cold regions science and technology [continuation of the Bibliography from Snow, Ice and Permafrost Research Establishment (SIPRE)]. Cold Regions Research and Engineering Laboratory (CRREL) Report 12 — a series, 1951 to present.

Excellent bibliography on all aspects of the cold regions. Very comprehensive and up-to-date.

422. U.S. DEPARTMENT OF THE INTERIOR AND THE FEDERAL TASK FORCE ON ALASKAN OIL DEVELOPMENT. 1969. Stipulation for the Trans-Alaska Pipeline System. 34 p.

"Environmental stipulations to be used in conjunction with existing laws and regulations for construction of the 48-inch oil pipeline and related facilities from Prudhoe Bay to Valdez, Alaska."

423. USPENSKI, S.M. 1970. Problems and forms of fauna conservation in the Soviet arctic and sub-arctic. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature. (IUCN) Publ. n.s. 16: 199-207.

A general review of some of the positive and negative effects of human activities on the fauna in the Soviet north, as well as of the problems of conservation.

"Human activity in the arctic and sub-arctic...disturbs the vegetation and soil covers unusually fast. Their ecosystems have an increased vulnerability, which can be explained by the specificity of natural environmental conditions of the northern polar regions as well as the specificity of the influence on them of human economic activities...

"Gradually, as one moves northward, terrestrial vegetation becomes more and more depressed, biological productivity of the land decreases and life is oriented toward water bodies and, in the extreme north, towards the sea...

"The extreme improverishment of the species composition of the fauna and flora results in extreme simplification of connections and relations in the biocenoses of high latitudes, in sharp changes in the picture of animal life, and in sharp changes in animal numbers within species and populations during different years...

"In evaluating the degree of human influence on

nature, particularly on the fauna of the arctic and sub-arctic, we must remember that the great majority of species are nomadic or strictly migratory forms. These animals consequently are experiencing constantly increasing sport and professional hunting pressure, but fall outside the regions where their reserves can be maintained by breeding, such as the densely populated temperate regions further south. Increasing less sharply is an indirect, mostly unfavourable human influence in the regions of the migration and wintering grounds of arctic animals. This is shown, for example, by a limitation of suitable conditions for wintering, due to land reclamation, pollution of waters by oil products, etc." However, not all human activities have been adverse in the USSR arctic and sub-arctic. In some instances, "in spite of rapid growth of industry and population, natural reserves have served as places for the enrichment of natural resources including game animals and these were set aside or formed from the beginning. The situation in primeval regions of the Soviet tundra where wild reindeer live can serve as a clear example of this. In very large areas, particularly in northeastern Siberia in 1920, this species was already considered extinct. Later, however, wild reindeer started to appear again on abandoned pastures on the Chukotskii Peninsula, as well as in several other regions (of course, quite a significant role was played there by general conservation measures)...

"The specificity of the arctic ecosystems, their simplicity and instability, their extreme vulnerability to economic activities, the peculiarities of the geographical distribution of its mobile components naturally emphasize the necessity of a much wider profile of the international-legal protection of the entire natural complex of the arctic, and especially those species the conservation of which exceeds the limit of ability of individual countries."

424. VIBE, C. 1967. Arctic animals in relation to climatic fluctuations. Medd. om Grønland. 170(5). 227 p.

Climatic fluctuations caused, by the changes in relative strengths of the Canadian, East Greenland and Irminger Currents and drift-ice patterns in the Davis Strait (changes which are related to sun-spot activity) are seen as having great influence on the populations of arctic mammals and sea birds. Details of population fluctuations of such animals as polar bear, seal, arctic eider, ptarmigan, whale, fox, musk-ox, etc. in relation to precipitation and drift-ice patterns are presented.

425. VIBE, C. 1970. The arctic ecosystem influence by fluctuation in sun spots and drift ice movement. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16: 115-120.

This paper is basically a summary of the author's 1967 publication on the subject of sun spots, current changes with concomitant changes in seasons (warm and dry *vs.* warm and wet or abundance and lack of ice) and their influence on arctic bird and mammal population fluctuations.

426. VIERECK, L.A. 1965. Relationship of white spruce to lenses of perennially frozen ground, Mount McKinley National Park, Alaska. Arctic 18:262-267.

The stand investigated, "in which the perennial frozen lenses occur, is an open white spruce — sphagnum type, with an appearance more typical of black spruce than white spruce...The ground surface is irregular with many mounds, especially beneath trees. On the drier sites created by these mounds is a thick moss mat...a few scattered lichens... low shrubs of Labrador tea...bog blueberry, and low birch

shrub.

"In the depressions between the trees is a thin cover of mosses,...a few scattered willow shrubs, and a large number of low shrubs and herbs, plus a few sedges. Frost scars, often with standing water, are in all stages of revegetation by sedges and mosses...

"The parent material of the stand consists of at least 1.5 m of silty clay over river gravel...There is no true development of a soil profile in the stand. Because of the impervious nature of the silty clay substrata, water accumulates in the depressions.

"All of the mounds (containing frozen lenses) are covered with a thick moss mat of *Hylocomium splendens* and *Pleurozium schreberi* through which are growing several ericaceous shrub species and bog birch."

Discussion: "Lenses of permafrost appear to form because of some difference in the heat regime of the soil under the trees as compared with that between the trees...Less snow usually accumulates under coniferous trees than in the adjacent area between the trees...The moss layer is thicker on the mounds under the trees than it is in the area between the trees...A thick moss layer is important in maintaining a permafrost layer close to the surface in many areas of the arctic and sub-arctic, where disturbance of the moss layer usually results in a recession of the frozen ground beneath the disturbed area."

Summary: "Perennially frozen mounds have developed under white spruce growing in silty clay. The frozen lens is thought to result from the insulating effect in summer of a thickened moss mat and from soil cooling in winter as a result of a thin snow layer under the trees. The mound is created through expansion of the silty clay caused by incorporation of water into the lens as thin layers of clear ice.

Disturbance of the moss mat results in a melting of the lens, a collapse of the mound, and often the death of the tree. As new trees develop, new mounds and frozen lenses develop in the soil beneath them."

427. VIERECK, L.A. 1966. Plant succession and soil development on gravel outwash of the Muldrow Glacier, Alaska. Ecol. Monogr. 36:181-199.

From the summary: "Plant succession and soil development are described for a series of five stands on glacial outwash adjacent to the McKinley River in an alpine tundra region of the Alaska Range in Mt. McKinley National Park." Estimated ages of the stands are: 1) pioneer 25 to 30 years since available for colonization; 2) about a hundred years; 3) about 150 to 200 years; 4) 200 to 300 years. Based on the estimated time of retreat of the ice at the end of the late Wisconsin Glaciation, the age of the climax stand is estimated to be 5,000 to 9,000 years. "The vegetation development progresses from that of scattered mat plants with isolated willow and *Shepherdia* shrubs, to a closed, grassy meadow interspersed with small but dense clumps of willow shrubs. Birch shrubs and a thick moss mat begin to form under the willow shrubs and eventually replace them. The low shrub birch forms a continuous and even stratum underlain by a thick moss layer of *Hylocomium splendens* and *Pleurozium schreberi*. The final stage, the climax tundra, consists of low shrub birch and ericaceous shrubs interspersed with *Eriophorum vaginatum* tussocks growing through *Sphagnum* and other mosses.

"The soil undergoes progressive changes from the initial coarse gravel outwash through the four successional stands to the climax condition. Surface soil becomes slightly finer in texture with time, probably through the addition of wind-blown material rather than through physical weathering.

Organic material, mostly in the form of decaying mosses, is added in a thick layer at the surface and small amounts are added to a depth of 10 cm in the later succession stages. Nitrogen is added to the soil primarily through nitrogen-fixing organisms associated with legumes, *Dryas* and *Shepherdia*. The pH is altered from 8.0 to 8.4 of the original outwash to 4.4 in the climax tundra soil.

"Due to the insulating effects of the vegetation, especially the thick moss stratum, permafrost has developed or has risen near the surface in the climax stand. The permafrost layer prevents the downward loss of moisture through the soil, creating a wet condition suitable for the development of *Sphagnum* mosses and sedge tussocks." No permafrost was found in the successional stages.

428. VIERECK, L.A. 1970. Forest succession and soil development adjacent to the Chena River in Interior Alaska. Arctic Alpine Res. 2:1-26.

<u>Author's abstract</u>: "Four stands on varying-aged river deposits were compared with a climax stand on a higher and older terrace to show changes in soil and vegetation with time on the flood plain of the Chena River near Fairbanks, Alaska. The stands were a 15-year-old willow stand on a newly-formed gravel bar, a 50-year-old balsam poplar stand, a 120-year-old white spruce stand, a 220-year-old white spruce/black spruce stand, and a climax black spruce/sphagnum stand. The vegetation characteristics of each stand are given.

"Soil temperature and moisture measurements were taken to depths of 150 cm in each of the successional stands for a period of 2 years. In the early successional stands of willow and balsam poplar, the soil froze quicker and deeper, and reached lower temperatures than in later successional stages. In the willow stand, thawing was completed by the

end of May, whereas in the white spruce/black spruce stand, thawing did not begin until the end of May and was never completed — a continuously frozen layer being present at a depth of 40 to 80 cm. The insulating effects of a thick moss layer under the spruce and the deposit of fine river alluvium during flooding account for delayed thawing and colder soil temperatures. The soil moisture regime changes from a xeric situation on the gravel bar to a mesic one in the poplar and white spruce stands to a hydric situation in the climax stand."

429. VIERECK, L.A. 1970. Soil temperatures in river bottom stands in interior Alaska. Ecology of the Subarctic Regions: 1. Ecology and Conservation. Helsinki Symp. Proc. 1966. UNESCO. p. 223-233.

Soil temperatures and depth of freezing were measured in four stages of forest succession adjacent to the Chena River. Differences in soil temperature regimes were related to thickness or organic layers and textures of the parent material (river alluvium).

430. WAGG, J.W. 1964. White spruce regeneration on the Peace and Slave River Lowlands. Can. Dep. For. Publ. 1069. 35 p.

This paper discusses the problems of white spruce regeneration in the Peace and Slave River lowlands and indicates that fire alone is not always sufficient to provide a good seed bed. Where flooding, with alluvial deposition, follows fires much better seed beds are prepared. Information is also given on the behaviour of seedlings on litter, raw humus, feather moss, decayed wood and mineral soil.

431. WALKER, Jennifer. 1970. The influence of man on vegetation at Churchill. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:266-269.

The vegetation types around Churchill are described. It is noted that fire has devastating consequences. At sites disturbed by man but now abandoned, adventive species are gradually disappearing and being replaced by native species. The rates of recolonization of disturbed sites (e.g. track vehicle trails) are not known but studies have been initiated.

432. WALLACE, R.E. 1948. Cave-in lakes in the Nebesna, Chisana and Tanana River Valleys, Eastern Alaska. J. Geol. 56:171-181.

From author's abstract: "Cave-in lakes resulting from ground caving following the thawing of permafrost have developed in areas underlain by fine-grained sediments in...Northeastern Alaska. It is suggested that vegetal cover has an important control over the presence of permafrost and that a cave-in lake is initiated by a break in this cover..."

433. WARD, W.H. and E.C. SEWELL. 1950. Protection of the ground from thermal effects of industrial plant. Geotechnique 2:64-81.

This paper concerns problems in temperate latitudes — particularly problems with the drying effect of brick kilns on the underlying ground (clay).

434. WARREN-WILSON, J. 1952. Vegetation patterns associated with soil movement on Jan Mayen Island. J. Ecol. 42:249-264.

Details are given of the behaviour of frost phenomena and patterning as well as the importance of plants (present or absent) on Jan Mayen Island (350 miles north of Iceland). "The vegetation of the island consists for the most part of a moss mat dominated by *Rhacomitrium lanuginosum* and *R. canescens* in which occur scattered flowering plants. In some places this moss mat covers wide areas without interruption, but frequently it is broken up by areas of bare ground into patches which form strikingly regular patterns, based especially on polygonal, terraced and striped forms...Such patterning is thus encouraged by immature topography, by frequent freeze-thaw activity, and by poor vegetation; all features which are characteristic of Jan Mayen."

435. WARREN-WILSON, J. 1957. Arctic plant growth. Adv. Sci. 53:383-387.

The author summarizes his paper as follows: "The poverty of arctic vegetation results primarily from an extremely low amount of annual growth, which in turn is due both to shortness of the growing season and also the slowness of plant growth even during the brief summer. These low growth rates result from the low temperatures — especially as aggravated by exposure of the plants to cooling winds and, at least at Jan Mayen, from widespread deficiency of nitrogen, which arises through inhibition of soil microbiological activity by low temperatures and the poor supply of organic material."

436. WARREN-WILSON, J. 1959. Notes on wind and its effects in arctic-alpine vegetation. J. Ecol. 47:415-425.

Experiments and observations on the effects of wind in the Cairngorms in Scotland are reported. "It is concluded that the potent effect of wind on arctic-alpine vegetation is generally a result not so much of high wind speed as of special sensitivity of plant growth to wind; and that this sensitivity is due less to drying and more to cooling under temperate conditions...

"Excessive transpiration may kill projecting shoots rarely in summer and more often (at least in the case of shrubs and trees) in winter when the soil is frozen; but the general depression of growth-rates by wind seems not primarily a result of drying, since in summer the plants of most — though not all — arctic-alpine regions have high water status.

"Wind cools foliage, especially in sunny weather, and this effect is unusually marked in arctic-alpine vegetation; it amounted up to 7°C in observations at Cornwallis Island (75°N). Moreover, at low temperatures plant growth becomes especially sensitive to temperature conditions."

437. WASHBURN, A.L. 1950. Patterned ground. Rev. Can. Géogr. 4:1-59.

A thorough description of the various types of patterned ground, followed by a discussion on the various hypotheses of formation. It is suggested that several different phenomena may be responsible. Mention is made of presence or absence of vegetation on the various types of patterned ground.

438. WASHBURN, A.L. 1956. Classification of patterned ground and review of suggested origins. Geol. Soc. Am. Bull. 67:823-866.

This paper is an extension of Washburn, 1950, and includes a review of the suggested origins of patterned ground. A classification is presented and descriptions of the various types of patterned ground are included. The author believes that the various types of patterned ground have an uncertain origin, but that it is polygenetic. He also makes the plea for more research before final ideas can be formulated on patterned ground. A most exhaustive bibliography is included.

439. WATMORE, T.G. 1969. Thermal erosion problems in pipelining. Third Can. Conf. Permafrost Proc. Ass. Comm. Geotech. Res., Nat. Res. Counc. Can. p. 142-162.

Surface damage caused by bulldozing seismograph cutlines prior to freezeup on the Peel Plateau in October 1964, and near Tuktoyaktuk in October, 1965 were inspected in early August and mid-September, 1968. "Photographs taken at the locations...indicate that subsidence through thawing of permafrost (thermokarst) accounts for more surface disfigurement than that through erosion from rain run-off and snow melt." Photographs illustrate the extent of thermokarst, stabilization

and revegetation which has occurred since the cutlines were produced. At Inuvik, a ground fire occurred in August, 1968, which destroyed the surface cover. Marked changes in the topography are expected. Subsidence and permafrost degradation has occurred after building of the experimental pipeline at Inuvik, but where wood chips provide insulation, damage has been less.

440. WATSON, A., N. BAYFIELD and S.A. MOYES. 1970. Research on human pressures on Scottish mountain tundra. Productivity and Conservation in Northern Circumpolar Lands. W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:256-266.

Problems of disruption of tundra vegetation and consequent soil erosion and other problems due to heavy, year-round human traffic around ski tows are discussed. Experiments with various methods of soil stabilization are described, including spraying bitumen with and without seeding, sodding and fertilization.

441. WATSON, D.G., J.J. DAVIS and W.C. HANSON. 1966. Terrestrial Invertebrates. Environment of the Cape Thompson Region, Alaska. N.J. Wilimovsky and J.N. Wolfe, ed. U.S. Atomic Energy Comm., Div. Tech. Inf. p. 565-584.

A species list of terrestrial and freshwater invertebrates is presented. Limited population studies indicated mites and collembolans were the most abundant groups of arthropods. The former were most abundant in the highly organic substrates under *Eriophorum*, *Carex* and *Sphagnum* while the latter were most abundant in the relatively loose well-drained mineral soils under *Dryas* and lichens.

442. WEEDEN, R.B. 1970. Man in Nature: A strategy for Alaskan living. Productivity and Conservation in Northern Circumpolar Lands.

W.A. Fuller and P.G. Kevan, ed. Int. Union Conserv. Nature (IUCN) Publ. n.s. 16:251-256.

In a section headed Petroleum in the New Alaska, the problems are outlined: "Exploration and production activity in the inlet 'that is Cook Inlet and on the Kenai Peninsula gave Alaskans a fairly clear idea of the sorts of problems oil field development brings. The network of thousands of miles of inter-twining tractor trails across marshes, forests and alpine areas jolted people into sharp awareness that even looking for oil causes problems. Strictly enforced regulations helped: anyone who compared the seeded roadsides and "healing cat" trails on the Kenai National Moose Range with the debris and scarring on state lands just outside the Range could see this readily. Air and water pollution came, as inevitably they will. A cloud of smoke is sometimes visible for miles when wasted natural gas is flared from the Inlet's wells. Hundreds of oil spills from tankers, wells, and pipes have been recorded by government agencies. A few big ones have killed ducks or befouled the nets of fishermen (Cook Inlet has an important commercial and recreational salmon fishery). Life in Anchorage has changed, too, with the advent of oilmen and boomers.

"But Anchorage had its growing pains and Kenai its land scarring before oil. Petroleum development simply intensified and added new facets to the problem. It is in the arctic, with its virginal and vulnerable landscape, that the impact of oil is most obvious. The gnawing scars from seemingly harmless trails of construction vehicles, the puzzles of permafrost engineering, the unsuitability of ordinary sanitation techniques, the fantastic longevity and visibility of debris, the oil spills, the huge demand for gravel for camps and airstrips, the question of whether caribou will be frightened and displaced by surface feeder pipes and the general bustle of oil field operations — these are now commonplace topics of conversation in the north. Part of the problem in Alaska today is secrecy of geophysical and other technological data. Should this haste and secrecy be eliminated such wasteful and destructive duplication of seismic lines, shot holes, camps, roads, airstrips, test wells and gravel pits in the arctic could be eliminated."

443. WEIN, R.W. and L.C. BLISS. 1970. The low arctic environment and primary productivity. Thirteenth Muskeg Res. Conf. Proc. Nat. Res. Counc. Can., Ass. Comm. Geotech. Res., Tech. Memo. 99: 109-117.

Data are presented on the productivity of various species of plants and a general description of positive and negative factors which act on arctic plants.

The authors point out that "the rate of plant production will determine the amount of biomoss that the ecosystem will support and will determine the rate of return to relatively stable conditions after man's disturbances...[Therefore] can [plant productivity] be increased to speed the healing of disturbances?...

"Low soil temperature...restricts root growth, and, as a result of low nutrient and water uptake, net productivity will decrease. By lowering the albedo of the soil surface... the active layer will become deeper, [but] thermokarst activity in soils of high ice content and increased evaporation would, in turn, be unsatisfactory. Another point against lowering the soil surface albedo would be that warmer soils would be conducive to organic matter decomposition and the insulating effect of peat layers would become less effective."

444. WEIN, R.W. and L.C. BLISS. 1971. Northern ecosystems and northern development. Can. Mining Metall. Bull. 64:74-76.

An outline of the work being done in the Mackenzie Delta by the authors and their associates. Although no results were presented preliminary studies indicated that:

1) low, wet sedge communities on the High Arctic Islands are just as susceptible to damage as areas in the Low Arctic and summer travel should therefore be regulated as in the Low Arctic;

2) thermal subsidence is widespread under summer travel routes but soil erosion by running water negligible;

3) technological improvement in seismic line construction has occurred since 1965;

4) winter roads should not be used too early in fall or after thaw starts in spring. Lowland travel is preferable to upland because water-saturated soil profiles freeze and compact less than those where mineral soil and peat predominate. Sedges and grasses recover more quickly than woody shrubs.

445. WIGGINS, I.L. 1951. The distribution of vascular plants on polygonal ground near Point Barrow, Alaska. Dudley Herb. Contrib. 4:41-50.

From the summary: "The vegetational cover on four sites representing different stages in the development of "polygonal ground" in a permafrost area...consists of twenty-nine species of flowering plants and several species of mosses and lichens...Although relief is low,...examination reveals... some species confined to faintly drier tops of hummocks and ridges, while others occur only in the central pans or in the ditches separating individual polygons...others are predominantly occupants of intermediate slopes...The [plant] assemblages...are distinct enough to permit recognition of the outlines of each type of microhabitat when shown on aerial photographs..."

446. WIGGINS, I.L. and J.H. THOMAS. 1962. A flora of the Alaskan Arctic Slope. Arctic Inst. N. Am. Spec. Publ. 4. Univ. Toronto Press. 425 p.

In the introduction, habitats are described, including man-made types: campsites, vehicle trails, shot holes and drained lakes. The authors note the "slowness with which disturbances are healed where the growing season is so short, and where relatively slight changes in drainage pattern can have profound consequences."

On the subject of erosion caused by vehicles, the authors record "some of these artificial ditches have changed the drainage of limited areas quite drastically, even bringing about a complete emptying of ponds and small lakes...In 1956 weasel trails not used for 5 years were clearly traceable." An estimate of several centuries is given for tundra recovery around disturbed campsites.

On the effects of animals on the tundra, the following comments are made: "Snowy owls select several observation perches on hummocks, ridges and small irregularities on the tundra. The excreta on and around such roosts add considerable nitrogenous waste to the soil...Plants on these fertilized hummocks are nearly always deeper green than those on nearby but more sterile soil..."

"Moulting waterfowl...consume large quantities of grass and other vegetation, pack denuded soil to a remarkable degree, and add animal wastes to the soil...

"Jaegers...tear up large quantitites of moss, lichens and some of the smaller flowering plants in order to dig lemmings from their shallow burrows. The breaks (2 to 3 yards) the jaegers make in the tundra are not seriously detrimental to the plants, but they are discernable one to three years later...

"Abandoned burrows [of the arctic ground squirrel] are conspicuous for several years because plants colonized slowly...Readily observable stimulation of growth of vegetation occurs at the entrances to burrows. Both improved aeration and enrichment of the soil occur at such sites...

"Severe local erosion can, and at many places does, occur where the caribou have broken the tundra sod on banks above streams and lakes. Their trails criss-cross the tundra, and around many of the shallower ponds and lakes the trampling done by a herd of caribou destroys much vegetation. In some places the surface is almost devoid of plant cover."

447. WILDE, S.A. and H.H. KRAUSE. 1960. Soil-forest types of the Yukon and Tanana Valleys in Sub-arctic Alaska. J. Soil Sci. 11:266-279.

The various soils found in this area of Alaska are described. They include skeletal, alluvial, half-bog, lowmoor peat, tundra-forest and the two following soil types:

Melanized raw-humus soils (sub-arctic forest soils; incipient podzols). "The scarcity of herbaceous plants and the absence of natural spruce regeneration are characteristic of this soil-forest type. The poor regeneration of white spruce on these moss-covered soils casts doubt on the climax nature of this species in the sub-arctic environment. A wide opening of the canopy is likely to cause invasion by *Sphagnum* and black spruce, an association which would preclude the regeneration of white spruce."

Highmoor peat "In the environment of sub-arctic Alaska, highmoors are formed at a wide range of altitudes and not only on elevated plateaus and gentle slopes, but also on slopes approaching 45°, especially of northern and eastern exposures. There is evidence that the invasion of *Sphagnum* mosses often follows removal or heavy thinning of forest stands. To prevent the conversion of productive lands into highmoors may be one of the most important tasks of regional soil conservation and forest management." All the forest soil types studied here are underlain by permafrost. Vegetation descriptions accompany the discussion of each soil type.

448. WILIMOVSKY, N.J. and J.N. WOLFE, ed. 1966. Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission on Environmental Studies for Project Chariot. Oak Ridge, Tenn. 1250 p.

This book is available as PNE-481 from Clearing House for Federal Scientific and Technical Information, Springfield, Va. 22151.

The investigations cover aspects of the land, including geography, geology, permafrost, hydrology, seismic activity, etc., the land — biotic systems and bioenvironment; it includes vegetation and flora, palynology, limnology, fauna, human ecological studies and radioactivity. Individual papers are listed separately in this bibliography.

449. WILLIAMS, P.J. 1961. Climatic factors controlling the distribution of certain frozen ground phenomena. Geogr. Ann. 43:339-347.

Conclusions: (1) "The development of patterned ground and solifluction requiring deep annual frost penetration depends on the nearness of the mean annual (ground) temperature to $0^{o}C$ rather than on the intensity of winter cold. The mean annual air temperature of $+3^{o}C$ is suggested as marking the rough limit of their development. (2) Large-scale solifluction requiring a deep-lying, still-frozen layer in the spring, is restricted to areas with somewhat lower mean annual air temperatures; $+1^{o}C$ is suggested an an approximate limit. If forest is present, this will prevent its development at even lower mean annual air temperatures. (3) The distribution of stony earth circles, a form of patterned ground due to regel-

ation is not closely related to annual frost penetration. The frequency of fluctuation of air temperatures around $0^{o}C$ is generally not a limiting factor, but the absence of snow and of a thick vegetation cover are necessary. (4) Variations in density of occurrence of fossil forms of patterned ground and solifluction are to be related to the period of time during which conditions might have existed for the essentially slow movements of materials involved."

450. WILLIAMSON, F.S.L., M.C. THOMPSON and J.Q. HINES. 1966. Avifaunal investigations. Environment of the Cape Thompson Region, Alaska. N.J. Wilimovsky and N.J. Wolfe, ed. U.S. Atomic Energy Comm., Div. Tech. Inf. p. 437-480.

Species composition, ecological distribution, density, productivity and seasonal movements of bird populations in the Cape Thompson area are presented for the spring and summer months. One hundred and twenty species were recorded; for 65, evidence of breeding was obtained. "The onset of nesting is rapid, and considerable synchrony is manifest in the breeding and molt programmes." Most densely populated areas are the riparian willows with 194 breeding pairs per 100 acres.

451. YOUNG, S.B. 1971. The vascular flora of Saint Lawrence Island with special reference to floristic zonation in the Arctic regions. Contrib. Gray Herb. Harvard Univ. 201:11-115.

An annotated list of 238 vascular plants known to occur on or reported from St. Lawrence Island is presented together with sections on permafrost, soils, vegetation and habitats. The general vegetation is low and generally herbaceous. *Salix pulchra* is the only common shrub, generally less than 1 foot in height. Vegetation varies from complete cover in wet areas to virtually none (except for lichens, etc.) on alpine rock deserts and lava flows. The main vegetation types are: bog and wet tundra; alpine and fell-field; mesic tundra; and aquatic.

The paucity of species on Saint Lawrence led the author to propose a floristic zonation based on the summer temperature regime. The author suggests that based on climatic data, "accurate predictions of the flora of an area can be made [and] conversely, floristic data can be used to indicate the probable summer climatic regime of an area." Anomalous situations can also be explained.

452. YOUNGMAN, P.M. 1968. Notes on mammals of the Southeastern Yukon Territory and adjacent Mackenzie District. Contrib. to Zool. IV. Nat. Mus. Can. Bull. 223:70-86.

An ecological, distributional and taxonomic study of the 41 species of mammals recorded from this area. Most of the collecting sites were on the South Nahanni River and tributaries.

453. ZACH, L.W. 1950. A northern climax forest or muskeg? Ecology 31:304-306.

A note concerning southeastern Alaska and the interrelationships between muskeg and forest.

454. ZASADA, J.C. and R.A. GREGORY. 1969. Regeneration of white spruce. U.S. Dep. Agr. For. Serv. Res. Pap. PNW-79. Pac. N.W. For. Range Exp. Sta., Inst. N. For. Juneau, Alaska.

This is a literature review with an extensive bibliography.

455. ZHURBITSKY, Z.I. and D.V. SHTRAUSBERG. 1954. The effect of temperature on the absorbtion of phosphorus and calcium by plants. (Transl. Russian title.) Dokl. Nauk. Acad. SSSR. 96:1065-1067.

Abstract from Soils and Fertilizers 17:2528.1954.

"The decrease in the availability of P as the temperature of the nutrient solution decreases is greater than the decrease in the availability of Ca and less than the decrease in the availability of N."

456. ZOLTAI, S.C. and C. TARNOCAI. 1971. Properties of a wooded palsa in Northern Manitoba. Arctic Alpine Res. 8:115-129.

Detailed external and internal morphology of a wooded palsa complex, 106 m in diameter, with a maximum height of 224 cm above the water table, is described. Permafrost was mapped in detail — the active layer is shallowest under black spruce islands and deepest in openings, while cumulative depth of snow is greatest in openings and least in dense stands. The basic physical, chemical characteristics of peat and descriptions of the vegetation patterns are included.

The suggestion is made that the formation of this type of palsa (wooded) is different from the formation of the non-wooded Scandinavian palsas. These latter are present only above the tree line.

457. ZOLTAI, S.C. 1971. Perennially frozen peat plateaus in Central Manitoba and Saskatchewan. Can. For. Serv. Dep. Environ., Edmonton. mimeo.

ARCTIC LAND USE RESEARCH (ALUR)

REPORTS 1970-71

458. BLISS, L.C. and R.W. WEIN. 1970. A preliminary report for 1970. Univ. of Alberta Arctic Disturbance Studies. n.p.

This report contains recommendations to industry following studies on rehabilitation of winter roads and seismic lines.

In frozen water-saturated soils of the lowlands, compaction is less than where mineral soils predominate. Sedges of the lowlands recover more quickly than shrubs of the uplands because their underground parts often remain alive.

Summer seismic lines completed before 1965 have been very deleterious to tundra vegetation, may take many years before revegetated and may be invaded by species different from those originally present. Revegetation of winter seismic lines appears to be by those species formerly present.

459. CENTRE DE RECHERCHES SUR L'EAU. 1970. Water Quality, Annual Report. Université Laval, Québec, Can. 43 p.

Investigation of environmental impact of mining operations in the North. Two mines in Yellowknife - Con Mine, Giant Yellowknife were investigated.

There is no evidence of any aquatic botanical or zoological studies so far, although in the section Future Work: water quality criteria for the protection of aquatic species, is listed as requiring study.

460. CENTRE DE RECHERCHES SUR L'EAU. 1971. Ecological zoning at the eastern portion of Northwest Territories. Can. Dep. Indian Aff. N. Develop. N. Econ. Develop. Branch. 93 p. plus appendices.

This report is in 3 sections, each one constituting a volume. The first section by A. Lafond, R. Héroux, and A. Soucy, deals with the general ecology of the 12 zones of the area and their broad delineation. It includes a general indication of the vegetation and soil relationships in each zone. The second section by R. Héroux deals with geomorphological and geological characteristics of the zones. The third section by A. Soucy deals with the hydrology. Each section is profusely illustrated with photographs. Maps are also included.

461. KERFOOT, D.E. 1970. Thermokarst features associated with tundra disturbances resulting from oil exploration activities in the Mackenzie Delta area, N.W.T. Prelim. Rep. Can. Dep. Indian Aff. N. Develop. 13 p.

This preliminary report includes the following tentative conclusions:

"With few exceptions, the reports describing intensive degradation of the tundra landscape in the Mackenzie Delta area are grossly exaggerated. Perhaps this can largely be attributed to the fact that most disturbances appear to be more severe (primarily for aesthetic reasons) when viewed from an aerial vantage point, than is demonstrated by corresponding ground checks. Another contributory factor may represent an over-emphasis of the disturbances associated with 1965 summer seismic lines ...

"The preliminary analyses provided a limited basis for the following tentative conclusions: (1) with the exception of the 1965 summer seismic lines, in which a substantial portion of the active layer was removed during seismic operations, the topographic effects of the lateral ridges ... and the accompanying depression factor ... are of only minor significance. The adoption of a high-blade bulldozer technique is primarily responsible for the fact that, in general, the only material removed during current winter vehicular operations consists of individual tussocks and/or the tops of earth hummocks so that neither relief component is associated with a topographic effect of more than a few centimetres. The major exception to this pattern consists of patchy damage, which was found in association with all types of disturbance, in which there is still a localized, but complete, removal of the surficial organic layer and a resultant exposure of the bare mineral soil to potential thermokarst development. (2) Thermokarst subsidence ... is primarily responsible for the accentuation of the topographic effects accompanying the 1965 summer seismic lines, and the effects were most pronounced where the surface disturbance has exposed networks of ice wedges. ...(3) Erosion due to the action of running water ... following tundra disturbances is seldom of more than minor significance ... Locally, however, a combination of steeper gradients, complete removal of the active layer, and the exposure of sands, which have properties akin to quicksand upon thawing, has led to the erosion of gullies which are several metres deep. (4) Tundra disturbances associated with winter operations are less pronounced than those accompanying similar operations conducted during the summer months. (5) Damage to the tundra vegetation cover is least severe, in terms of per cent reduction of cover and "permanence" in areas of relatively flat, low-lying, moist terrain. (6) Damage to the tundra vegetation cover is most pronounced in areas where there has been a repeated movement of vehicles over the terrain (*e.g.* winter roads) ... (7) In general, it seems that the "sensitivity" of the tundra environment, particularly with respect to the natural regenerative powers of the vegetation cover, has been considerably underestimated."

The author considers there is a need to distinguish between two basic landscape types - the Delta proper and the adjacent tundra areas. "It appears that most of the damage that has occurred in the Delta centres primarily around aesthetic problems since the terrain seems to be "less sensitive" than the adjacent tundra regions." The author also notes that winter roads should be used for one season only and that it is probably "more desirable to create an entirely new winter road and thus a second aesthetic problem, than to risk intensification of the damage that occurs after one season of use". It is further noted that intensity of tundra damage is greatest where seismic lines cut obliquely across a slope.

462. LAMBERT, J.D.H. 1970. Preliminary report on seismic and related disturbances in the Mackenzie Delta region. ALUR 2. Mimeo. 6 p.

"Preliminary findings suggest that surface disturbance is minimal. In areas with accumulated moisture (drainage pathways, low-centered polygons), lines were obvious. However, vegetation regeneration in all but a few cases must be considered good. Sedges ... appeared to be unaffected at the subsurface (root level) and recovered quickly. Willows show obvious signs of damage - broken off at ground level. In 90 per cent of the damaged willows examined, leafy shoots and suckers indicated that full recovery was only a matter of time. Only a few examples of continued damage (lateral erosion, slumping, etc.) were observed on seismic lines. Where such damage has and is occurring further studies should be undertaken ...

"Preliminary findings of the studies and tests undertaken indicate that while seismic lines are obvious from the air and the I.O.L. 1965, summer operations aesthetically displeasing, they are not all unvegetated, eroding strips ... Where minimal surface disturbance has occurred, revegetation is rapid under prevailing environmental conditions. Where surface disturbance is somewhat excessive then revegetation will be slower."

463. MUSKEG RESEARCH INSTITUTE, University of New Brunswick. Tests to define levels of terrain damage by tracked vehicles operating on tundra. Can. Dep. Indian Aff. N. Develop. 32 p. IAND Publ. QS-1119-000-EE-A-10.

This is a report on work done mid-June to September. Various types of vehicles were used in the test sites at Tuktoyaktuk and Tununuk, in the Northwest Territories and Shingle Point, Yukon Territory, including a light-tracked carrier, a light-medium four-tracked carrier, a medium-tracked carrier, a medium-tracked bulldozer, and a heavy four-tracked carrier. For some of the tests the carriers were loaded with various equipment. Tests were run over a pre-determined line on the various sites and up to 100 passes were made in each test. A photographic record was kept after each 20 passes. A supplement to the main program was conducted in northern Alaska near Prudhoe Bay, where a four-tracked, 20-ton carrier and a two-tracked, 8-ton carrier were tested. As well, terrain disturbance was measured after movement around turning circles of 20, 40 and 60-foot diameters.

"In general, the vehicle tracks would commence by breaking branches on woody shrubs and knocking leaves off if these were present. The grouser bars on the tracks then gradually chopped vegetation, flattening it into the ground surface, scuffed the tops of mounds exposing mineral soil, and then flattened the mounds noticeably. This was accompanied by chopping and scattering of vegetation, displacement of soil by the vehicle's weight, and was followed by the grouser bars picking up chunks of peat and scattering them. If traffic was continued, ruts formed along the vehicle's path and deepened until the permafrost table was reached.

"The prevalent terrain conditions and the characteristics of the particular vehicle involved could definitely be related to the response of the terrain to traffic. For the terrain, the moisture content, vegetation composition, and depth to permafrost appeared to be the major controlling factors. High moisture content, often accompanied by vegetation consisting mostly of sedges and depth to permafrost exceeding 10 cm encouraged rapid rut development. On the other hand, dry hillsides were commonly covered with woody shrubs having a rugged root structure and although the shrub stems and branches suffered rapidly, ruts were slower to form under these conditions. In very wet areas the tracks running in open water produced a washing action which splashed peat outside the immediate path of the vehicle and onto the sides or "banks" of the ruts ...

"In responding to damage at the time it is inflicted, rough, dry, shrub-covered slopes are the least sensitive, followed by flat, moist, shrub and sedge-covered areas, then sedge, moss, and lichen-covered depressed centre polygons, and finally the most sensitive very wet sedge-covered areas adjacent to small lakes. It may prove through time that the wet areas will recover more quickly than the dry regions. If this is so, it will have to be taken into account in the final definition of tundra sensitivity."

From conclusions: "Traffic should be avoided in areas where open water is visible on the ground surface. The most influential factor of tracked vehicle design affecting terrain disturbance is weight. Flat tracks having no detent in the centre are beneficial in reducing terrain disturbance. Based on the terrain disturbance classification system ... disturbance level 4 has been selected tentatively as a tolerable maximum disturbance level. Level 4 consists of 10 per cent damage to vegetation and scuffing and flattening of mounds. The effect of season on terrain sensitivity cannot be neglected. Sensitivity appears to be directly related to proximity of frost to the ground surface. A minimum turning radius of 60 stimulated plant growth more than phosphorus alone and potassium had no effect. There was a greater than additive effect in using the three elements together. Removal of all plants in a mesic sedge meadow resulted in decreased albedo, increased long wave reradiation and decreased heat loss by evapotranspiration and convection. The active layer increased by only, 10 to 15%. Where there is little natural plant cover, the active layer typically increased 0 to 15% and only 25 to 50% in wet sedge or grass lowlands with maximum plant cover.

"In sedge or grass meadows the use of track vehicles in summer is as detrimental as in the Low Arctic. In the uplands with sandy soils or fjaeldmark where there is little plant cover (0 to 5%) little biological damage was done in summer with track vehicles. Where surface disturbance has occurred, reinvasion of plants is very slow because seedling establishment is a minor factor.

"Recommendations: (1) The landscape units identified show such a wide diversity of characteristics that the specific area must be known to predict the response to a given disturbance. Land use officers and future researchers should be aware of these differences. (2) In the High Arctic the lowland areas with relatively lush vegetation are a relatively small proportion of the landscape but are extremely important biologically and should be protected whenever possible. (3) Winter seismic operations should be conducted using "mushroom shoes" on the crawler tractor blade to prevent disrupting the ground surface. This results in little modification of the plant surface and increased depth of the active layer. (4) Extreme caution should be exercised in the use of summer seismic operations in the Low Arctic. In the High Arctic the polar deserts once dried out in the summer may permit operations with little biological damage. (5) On winter roads travel in early fall and late spring can be detrimental.

feet for five passes of any tracked vehicle of the types tested results in terrain surface disturbance equal to or less than level 4. Even for disturbance exceeding level 4, considerable vegetative regrowth of all species present is possible immediately following the disturbance, provided the disturbance occurs early in the growing season. Disturbance occurring during the latter third of the growing season results in no significant appearance of vegetative regeneration."

464. MUSKEG RESEARCH INSTITUTE, University of New Brunswick. 1970. Rolligon tundra disturbance tests, Tuktoyaktuk, August, 1970. Rep. to Bechtel Inc. 13 p.

This paper gives the results of vegetation disturbance after using a prototype of the Albee Rolligon on three test sites and with heavy or light loads and making passes from once to 100 times over the site. Although the paper is mainly concerned with the performance of the vehicle, indication is given that observations will be made during the next few years on vegetative regrowth and erosion, which may occur on the sites.

465. UNIVERSITY OF BRITISH COLUMBIA, Dept. of Soil Science. 1970. ALUR-LURE I. Land use research - Final Report. Dep. Indian Aff. N. Develop. 116 p.

Most of the information in this paper concerns soil classification.

"One of the problems observed in clear-cut logging operations is the change in thermal conditions in the soil. Ground ice in the soil at a depth of approximately 20 inches was found commonly in the logged area at the beginning of the summer, as opposed to 12 inches in the unlogged area. At the end of the summer, ice was not found in the unlogged area, but could still be found in places in the logged area.

[This was in the area of Watson Lake.] This relationship was also found in some of the burned areas along the Liard River.

"This may mean that the depth of frost penetration is greater in the logged area due to the lack of thermal insulation offered by the vegetative canopy in the unlogged area. This ice layer could, if severe enough, greatly restrict drainage and promote the formation of a wetter soil, as well as affect regeneration."

Each of the soil series descriptions is accompanied by a brief vegetation description. The main species present in the forest are lodgepole pine, white spruce, black spruce, aspen, balsam poplar. As well, alder, birch, willow and tamarack are common.

466. UNIVERSITY OF SASKATCHEWAN. 1970. Arctic land use research. LURE No. 1 Final Report. Can. Dep. Indian Aff. N. Develop. IAND Publ. No. QS-1120-000-EE-A-10. 85 p.

Forest studies: The area of study in this report is at Watson Lake in the Yukon, with some reconnaissance study near Fort Liard in the Northwest Territories. The ecological information collected concerned flood plain forests on the lowlands and the vegetation on the uplands, both on the Upper Liard. Balsam poplar and white spruce are present on the lowlands and tend to occur in pure even-aged stands. A brief literature review is included on the regeneration of white spruce, and a comparison of the forests of the flood plains of the Peace, Slave, Liard, Mackenzie, Peel, Yukon and Tanana Rivers is included. A discussion follows on the origin of the stands in lowlands, whether or not it's a matter of cyclical primary succession or fire. Many authors are at a loss to explain how the stands came about. Fire and flooding are both considered to be of importance in the starting of the primary or secondary successions. Descriptions are given of the sample plots on the lowlands and on the upland. Tables of species on the forest floor are also given. Sample plots were also laid on unlogged areas and on burned areas, with comparisons made between these and unburned areas in the neighbourhood.

Surface disturbance study: Oil-well sites - several sites of suspened wells were visited. In most, a rectangular area had been bulldozed and the moss cover scraped away. On all the older leases a good growth of foxtail and other similar grasses had occurred.

"Generally, the older leases were found to be in acceptable state. The surface areas had been levelled, the excavations filled, and waste oil was not encountered. There was no obvious evidence of any significant oil spillage. Some debris had been left in the form of discarded drilling bits, casing and protectors, pipe ... fuel drums and ... bags of oil-well cement ...

"The most recent site visited ... was wet [with] the surface layer mud, but this is characteristic of most new drilling sites and in view of the recent, heavy rainfall not unusual. Parts of the camp had not been removed at the time of the visit and the mud pits had not been filled in, so it was assumed that clean-up operations had not yet begun."

Seismic lines - "Limited reconnaissance of seismic cuts in the area east of the Lower Liard River did not indicate the existence of any obvious land use problems ... Herb and shrub regeneration had occurred on most of the line, which was about 3 years old. Aerial reconnaissance over a considerable number of seismic lines in the same area indicated that similar conditions existed throughout the area."

467. UNIVERSITY OF ALBERTA, Dept. Civil Eng. 1970. Land use research ALUR-LURE 1. Verschuren, J.P. and R.H. Cooper. Final Report.

Can. Dep. Indian Aff. N. Develop. IAND Publ. No. QS-1121-000-EE-A-11. 47 p.

This paper is chiefly concerned with a hydrologic classification of the Mackenzie and Yukon Basins. The field work was carried out on the Liard River in the vicinity of Watson Lake and concerned river engineering aspects.

"The stability of the Liard River throughout the study area appears to be heavily dependent on the presence of timber and natural ground cover on the adjacent flood plains. This vegetative cover retards the development of cut-off channels, protects river banks from erosion, and inhibits surface erosion on the flood plains. It also plays an important role in the ground frost regime, which may be relevant to channel bank stability and therefore bank erosion rates.

"In the study reach of the Liard River an absence of silts and clays in the banks and flood plains was noted. This makes the banks and flood plains extremely susceptible to erosion, but it may be a local condition ...

"The anticipated consequences of unrestricted logging or other land use practices involving the removal of timber and ground cover on the flood plain areas include: (1) Increased frequency of channel pattern changes, resulting from cut-off development. (2) Increased rates of channel bank erosion. (3) Erosion and gullying on the flood plain surface, particularly where ground cover is removed. (4) Probable change in river widths and type of channel pattern. (5) A change in the sediment load of the river, resulting in changes in river regime ...

"In the uplands basin, some of the problems that can be expected from land use operations were experienced during installation of the discharge measurement flume. Removal of vegetation for the access road resulted in drainage of the adjacent muskeg areas. This change in ground moisture condition could in turn be expected to have a pronounced effect on the vegetation. Other anticipated effects of vegetation removal include changes in time distribution and volume of run-off, surface erosion, and gullying."

ARCTIC LAND USE RESEARCH

REPORTS 1971-72

468. BLISS, L.C. and R.W. WEIN, ed. 1972. Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta region and the Arctic Islands. Report to ALUR of work done in 1971. 288 p.

This report contains papers by several authors who are listed separately, following this citation.

The following summary and recommendations were written by the editors and cover the main conclusions of the separate authors:

Summary: "The data presented show that one cannot generalize for the Arctic as a whole regarding the summer impact of seismic activity, winter roads, natural and artificial re-seeding success, and the impact of surface disturbance on plant cover and depth of the active layer. Neither can one accurately predict in advance the influence of surface disturbance, seeding response, and required fertilizer levels in upland and lowland sites within a few acres or hectares.

"Based upon aerial photographs, the lower and eastern Mackenzie Delta Region can be divided into five major plant community types. [Most of these types are not unlike those described by Churchill and by Hansen, though the actual species present and their relative abundance are quite often different.] The most extensive is Dwarf Shrub-Heath which occupies 75% of the area in the Caribou Hills, 48% at Eskimo Lakes, 35% at Tuktoyaktuk, and 30% at Tununuk. The next most important type is the Herb-Dwarf Shrub Heath which comprises 23% and 28% of the land at Tununuk Point and Tuktoyaktuk respectively, 9% to 10% at Eskimo Lakes and the Caribou Hills, and is absent in the Atkinson Point areas. The Medium Shrub-Heath type occupies mid-slope positions ... The Herb type [includes] sedge and aquatic communities in lowland wet sites ... [and] lakes comprise 10% of the area in the Caribou Hills, 12% at Eskimo Lakes, 20% at Tununuk Point, 32% at Tuktoyaktuk, and 36% near Atkinson Point.

"Organic soils are more prevalent in lowland areas where low and raised center polygons predominate. Regosols are formed on newly deposited sites (sand dunes, receding lake shores) as at Atkinson Point. Gleysolic soils predominate in the uplands of the Caribou Hills and Tuktoyaktuk areas where Medium Shrub-Heath and Herb-Dwarf Shrub Heath types predominate. Brunisolic soils in the best drained uplands occur at Tununuk Point and the Eskimo Lakes areas and are covered by Dwarf Shrub-Heath communities.

"Regeneration of older summer seismic lines will take many years. The principal species that naturally invade these lines (*Arctagrostis latifolia*, *Calamagrostis canadensis*, *Poa lanata*, *Luzula confusa*, and *Senecio congestus*) were only minor components in the native undisturbed vegetation. In wetter areas, *Arctophila fulva*, *Eriophorum angustifolium*, and *Carex aquatilis* predominate. In these sites and elsewhere where the plant cover was removed, the active layer was generally 60 to 150% deeper by August. With winter seismic activity and the use of "mushroom shoes" there was little surface modification (less than 10%) and the active layer was generally less than 25% deeper by August.

"Winter snow roads destroy nearly all of the above ground plant parts in upland areas dominated by shrubs. Resprouting from underground parts occurs to only a limited degree. In lowland areas where sedges predominate resprouting from underground parts is common and in summer show little effect of the winter operation.

"In both the Low Arctic and High Arctic, low soil temperatures exert the major limitation on plant growth.

Native species respond very significantly to the addition of nitrogen on both peat and mineral soils. Available nitrogen is normally low due to slow release, the result of low soil temperatures which suppress microbial activity. Phosphorus is quite readily available in native soils so that the addition of commercial fertilizer is less influential.

"In contrast, introduced grasses respond more readily to phosphorus alone or in combination with nitrogen than to nitrogen alone. Similar results have been presented for cereals when tested in the Siberian arctic. Tests show that a combination of 100 kg/ha each of nitrogen and phosphorus gives the best results for these introduced grasses on mineral soils and that phosphorus alone is best for organic soils. Seed head production also increased with application of nitrogen and/or phosphorus.

"Of the 16 species tested the first year, only 7 were vigorous the second summer. Of these, timothy, meadow foxtail, and slender wheatgrass provided the best height growth while red fescue, Kentucky bluegrass, and Canada bluegrass gave the best ground cover. Preliminary results indicate that seed mixes may be best with reed canary grass and orchard grass providing good nurse-crops the first year when mixed with some of the above species.

"In the High Arctic plant growth is even slower and plant cover less than in the Low Arctic. Vast areas are either Polar Desert or areas of scattered low herbs. In a few areas, quite lush meadows of sedges, forbs, and mosses predominate and provide a food base for large herbivores.

"High Arctic soils are mostly Regosols. The surface typically dries but the soil at the base of the active layer is moist and in fine-grained soils this promotes surface instability. This is especially common on scraped runways.

"Nitrogen fertilizer applied to native vegetation stimulated plant growth more than phosphorus alone and potassium had no effect. There was a greater than additive effect in using the three elements together. Removal of all plants in a mesic sedge meadow resulted in decreased albedo, increased long wave re-radiation and decreased heat loss by evapotranspiration and convection. The active layer increased by only 10 to 15%. Where there is little natural plant cover, the active layer typically increased 0 to 15% and only 25 to 50% in wet sedge or grass lowlands with maximum plant cover.

"In sedge or grass meadows the use of track vehicles in summer is as detrimental as in the Low Arctic. In the uplands with sandy soils or fjaeldmark where there is little plant cover (0 to 5%) little biological damage was done in summer with track vehicles. Where surface disturbance has occurred, reinvasion of plants is very slow because seedling establishment is a minor factor.

"Recommendations: (1) The landscape units identified show such a wide diversity of characteristics that the specific area must be known to predict the response to a given disturbance. Land use officers and future researchers should be aware of these differences. (2) In the High Arctic the lowland areas with relatively lush vegetation are a relatively small proportion of the landscape but are extremely important biologically and should be protected whenever possible. (3) Winter seismic operations should be conducted using "mushroom shoes" on the crawler tractor blade to prevent disrupting the ground surface. This results in little modification of the plant surface and increased depth of the active layer. (4) Extreme caution should be exercised in the use of summer seismic operations in the Low Arctic. In the High Arctic the polar deserts once dried out in the summer may permit operations with little biological damage. (5) On winter roads travel in early fall and late spring can be detrimental.

Fall damage can occur when the surface has frozen but a thawed layer remains below. In the Low Arctic, keep to the lowland communities and waterways where possible. Frozen saturated soils protect underground plant parts and provide a solid roadway whereas upland shrubs are broken back to ground level. (6) Choose winter road routes, drill sites and landing strips in summer when it is possible to locate coarse textured materials and less sensitive areas. Wherever possible aerial photographs should be used in aiding these decisions. (7) Agronomic species that have shown promise for reseeding are timothy, meadow foxtail, red fescue, Kentucky bluegrass and Canada bluegrass. (8) Seed mixtures containing both species that show good growth the first year and those that are winter hardly will ensure a better ground cover. (9) Seeding should be conducted immediately after the disturbance has occurred and/or as early in the spring as possible. (10) Fertility programs should include both nitrogen and phosphorus fertilizer up to rates of 100 kg/ha (100 lbs/acre). (11) Even though reseeding of disturbed areas is possible, emphasis should be place on preventing damage rather than on restoration after damage. (12) Based upon present information, reseeding of surface disturbed areas in the High Arctic appears to have little potential. A nitrogen and phosphorus fertilizer will stimulate plant growth and may be the only practical approach to increasing plant cover, provided some species have survived."

469. BABB, T.A. 1972. High arctic disturbance studies. Botanical studies of natural and man-modified habitats in the Eastern Mackenzie Delta region and the Arctic islands. L.C. Bliss and R.W. Wein, ed. p. 230-281.

This paper contains results of experiments on a wide variety of sites and subjects.

Summary: 1. "High arctic soils are primarily regosolic, "polar desert soils". During summer months moisture in fine-grained soils near the base of the active layer promotes soil instability, especially when compaction or removal of surface layers results in increased thaw depth. 2. Sixty passes in a mesic meadow community with a light tracked vehicle did not significantly disrupt plant cover or affect the thickness of the active layer. 3. Movement of vehicles and other activities on High Arctic terrain can reduce plant cover 50 to 100 per cent. In polar desert areas, overall effect is small. In protected sites where cover approaches 100 per cent, disturbance has effects similar to those in the Low Arctic. 4. Removal of all vegetation from a mesic meadow community altered the energy budget of the surface. Albedo decreased; long wave reradiation increased, and heat loss by evapotranspiration and convection decreased. Soil heat flux increased by a relatively small amount, and thickness of active layer subsequently increased by 10 to 15 per cent. 5. Thickness of the active layer increases 0 to 50 per cent with surface disturbance of High Arctic soils. The smallest increases are on sparsely vegetated xeric sites and the greatest are in low-lying meadows with 100 per cent plant cover. In very few instances, if any, is thaw depth increased as much as in Low Arctic tundras. 6. Re-invasion of disturbed areas is relatively slow. Efficient seed or bulbil producers are the most rapid re-invaders on mesic or dry sites. In meadow sites, invasion of higher plants is primarily lateral encroachment by rhizomes. There may be physiological limitations to the latter mode of revegetation. 7. Plants in beach ridge and mesic meadow habitats showed increased growth with addition of nitrogen. Phosphorous had a lesser effect, and potassium none. The three elements combined appeared to have a greater additive effect. Because of varying responses by different species, plant community

changes can result from fertilization. 8. Bi-weekly clipping of graminoids on wet meadow plots reduced above-ground dry matter yield by 25 per cent. It is suspected that the depletion of overwintering carbohydrate reserves will result in a greater reduction in subsequent years. 9. Spilled diesel fuel on beach ridge and mesic meadow communities reduced vascular plant cover by as much as 50 per cent. Lichens on the beach ridge appear not to have been affected."

470. CORNS, I.G.W. 1972. Plant communities in the Mackenzie Delta Region. Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta Region and the Arctic Islands. L.C. Bliss and R.W. Wein, ed. p. 4-46.

Summary: "The 75 stands sampled in the Mackenzie Delta Region can be divided into five major types. The most extensive, the Dwarf-Shrub Heath is characteristic of the drier hilltops and gentle slopes of Tununuk Point, Tuktoyaktuk, Caribou Hills and Southern Eskimo Lakes area. It is absent on the flat topography at Atkinson Point.

"The next most extensive type, the Herb-Dwarf Shrub Heath is divided into Sedge Heath, Sedge Cotton-grass Heath, Raised Center Polygon, Lichen Heath and Gravel Deposit Community subgroups. The Herb-Dwarf Shrub Heath Type is, with the exception of the Gravel Deposit Community which occurs on well-drained gravel hills, characteristic of moderately drained flat to very gently sloping areas usually below the Dwarf Shrub Heath in topographic position. The areas listed in decreasing extent of Herb-Dwarf Shrub Heath are Tununuk Point (28.2%), Tuktoyaktuk (22.9%), Eskimo Lakes (9.6%) and Caribou Hills (8.5%).

"The less extensive Medium shrub (*Alnus*) Heath Type generally occupies a midslope position between the Dwarf Shrub Heath and Herb-Dwarf/Shrub Heath Types. It is most abundant

at Eskimo Lakes (26.6%) followed by Tununuk Point (13.6%), Caribou Hills and Tuktoyaktuk (3.6% each) and Atkinson Point (0%).

"The Herb Type, encompassing the Sedge, Aquatic and Sage subgroups, is less extensive than the Medium Shrub Type at Tununuk Point (7.2%), Tuktoyaktuk (4.1%), Caribou Hills and Eskimo Lakes (both less than 1%) but it is the predominant type at Atkinson Point where it accounts for greater than 60% of the surface area. The Sedge and Aquatic subgroups are the most extensive, found in flat low, very wet areas. The Sage subgroup is limited to steep river banks and is not extensive.

"The tall Shrub-Herb Type is restricted to deposited sediments along the river channels, to stream channels and to lake shores. It covers approximately 3% of the surface area at Eskimo Lakes and Caribou Hills, less than 1% at Tununuk Point and Tuktoyaktuk and is absent at Atkinson Point."

471. HAAG, R.W. 1972. Limitations to production in native plant communities in the Mackenzie Delta region. Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta region and the Arctic Islands. L.C. Bliss and R.W. Wein, ed. p. 69-142.

<u>Summary</u>: "From the results of this study, water availability does not appear to be an important limiting factor on production in this area. Poor internal drainage, due to presence of permafrost, and the high water retentive capacity of the soil combined with the melting of the active layer during the growing season, help to maintain a relatively high level of available soil water.

"Directly or indirectly, low soil temperature acting on various components of the ecosystem, appears to exert the major limitation on plant production. Response to nitrogen in both communities (wet sedge meadow and dwarf shrub-heath) including both increased protein content and dry weight production, indicates that the limitation on production by soil nitogen is not a direct result of low temperature. Rather, this is the indirect result of low soil temperature, acting to inhibit decomposition and transformation by the soil microbial population.

"Changes in pigmentation, as well as increased protein content, demonstrate that nitrogen, if available, can be rapidly taken up and metabolized by the plant. The quantity of available soil nitrogen, however, is kept at a low level by low soil temperature.

"Phosphorus metabolism, on the other hand, appears to be directly limited by low soil temperatures in both communities; incorporation of phosphorus into organic compounds is limited in the field. The lack of response to fertilizer addition indicates that the level of available soil phosphorus does not limit growth and production ...

"The high organic content of the surface soil constitutes an efficient means for nutrient cycling. The high cation exchange capacity and water absorbent properties combine to retain nutrients in proximity to the major rooting mass, and combined with a shallow active layer, acts to prevent major leaching."

472. HERNANDEZ, H. 1972. Surficial disturbance and natural recolonization in the Mackenzie Delta Region. Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta region and the Arctic Islands. L.C. Bliss and R.W. Wein, ed. p. 143-174.

Summary and conclusions: "1. Summer operations, especially summer seismic lines, are very deleterious to all tundra communities except for sparsely vegetated, gravelly areas such as eskers and moraines. 2. Revegetation of summer disturbed areas takes many years and initially is not by the common species of adjacent, undistrubed areas. 3. The grasses *Arctagrostis latifolia*, *Calamagrostis canadensis*, and *Poa lanata* appear to be the best pioneers of totally disturbed moist to dryer areas. Also common are *Luzula confusa*, and *Senecio congestus*. 4. Winter operations lead to much less damage than do summer operations, especially in wet areas where sedges predominate. 5. Unless peat is removed, both wetland communities and dry dwarf shrub heath winter disturbed areas regenerate predominantly from undisturbed roots and rhizomes. 6. Almost all disturbances result in a deeper active layer. However, where the peat layer remains intact, this increase is minimal (less than 25%)."

473. JANZ, A. 1972. Soil survey in the Mackenzie Delta region. Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta region and the Arctic Islands. L.C. Bliss and R.W. Wein, ed. p. 47-68.

Summary: "In the survey area [sites at Atkinson Point, Tuktoyaktuk, Tununuk, Eskimo Lakes, Caribou Hills] some plant-soil associations have been defined. Organic soils are often associated with low and raised centre polygon areas. They develop in areas where accumulation of organic matter exceeds decomposition. Regosolic soils are found on recently deposited or exposed parent materials like beach sands or receding lake edges. Sedge-heath and sedge-cottongrass-heath vegetation types are found on these new soils. Most of these associations are found in the Atkinson Point area.

"Gleysolic soils are predominant in the Caribou Hills and Tuktoyaktuk areas. They are associated with alder, cotton-grass, and sedge-heath vegetation types. Birch and willow-heaths are usually found over Brunisolic soils which predominate

in the Tununk Point and Eskimo Lakes areas.

"Several weak podzols are present where soil texture is coarse and drainage is not impeded and precipitation is sufficient for leaching to occur.

"This general classification applies to patterns observed as influenced by macrotopographic variation, and excludes variation due to microtopography."

474. YOUNKIN, W.E. 1972. Revegetation studies of disturbances in the Mackenzie Delta region. Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta region and the Arctic Islands. L.C. Bliss and R.W. Wein, ed. p. 175-229.

Reseeding should be done as early as possible in spring, prior to complete snow melt, or perhaps about time of first snowfall.

Fertilizer trials on 16 introduced grasses indicated that only phosphorus gave good results alone while both lime and nitrogen used alone reduced production below controls. When used in combination with phosphorus, both lime and nitrogen stimulated good growth. Rates of application, 1970; 100 kg/ha Phosphorus, or 100 kg/ha Nitrogen and Phosphorus (N,P). Phosphorus alone was best on organic soils, and the combination best on mineral soils. 1971 trials; 100 kg/ha Nitrogen plus 200 kg/ha Phosphorus (N_1P_2) proved best on both mineral and organic soils, but not much better than (N_1P_1) combination. Fertilizer treatment also increased seed head production, but viability of this seed has not yet been tested.

If ground cover the second year is used as an indicator of success, then red fescue, Kentucky bluegrass and Canada bluegrass were the best species. Although slow to provide cover the first year, they overwinter well and produce a dense, lush cover. Seed mixes would probably be most effective, provided a good "nurse" species is included, because the range of microenvironments can be utilized and a greater number of "strong points" in the species selected can be obtained. No information is yet available on native species and information is needed, particularly on *Arctagrostis latifolia* and *Calamagrostis canadensis*, both of which invade disturbances and become dominants very quickly, although they are not dominant in undisturbed tundra.

475. KERFOOT, D.E. 1972. Tundra disturbance studies in the western Canadian Arctic. 1971. Final Rep. Arctic Land Use Res. for Dep. Indian Aff. and N. Develop. 112 p.

From the summary and recommendations: "The investigations of the sites of winter road operations show that the destruction of the vegetation cover and surface microrelief forms has produced a predictable increase in the thaw depths and ground temperatures beneath the disturbed areas as compared to the adjacent undisturbed terrain. This obliteration of the surface microrelief has also led to more uniformity in the thaw penetrations in the damaged areas ... The field observations suggest that the ice road method of construction is much more effective than the snow packing technique in limiting the level of terrain disturbance ... Data from the quadrat studies in the Shingle Point area indicate that, in comparison to the undisturbed terrain, the re-use of the road produced a relative increase in the thickness of the active layer of almost 27%, which compares with an increase of slightly less than 21% in the winter road which was used for only one year's operations ... In terms of the general appearance of the two winter roads at Shingle Point, however, there is no doubt that these access routes should not be used for more than 2 years' operations. The extreme form of damage exhibited by the winter road at Sitidgi Creek demonstrates what can happen when the surface organic layer is finally destroyed to a point where pronounced thermokarst subsidence is initiated ...

"The investigations of summer seismic lines, from one to nine years old, and those made during an actual summer seismic programme demonstrate conclusively that, in certain areas at least [e.g. Jimmy Lake Area, Parsons Lake area, Richards Island, Caribou Hills, etc.] and with the adoption of suitable operational techniques, the terrain disturbances associated with these operations need not result in any serious damage to the tundra. Indeed, the negligible amount of terrain disturbance revealed in the 1971 seismic operations suggests that there are in fact certain merits in scheduling summer programmes. Most of the disruption of the ground surface was in fact due to a compression of the organic layer and the ability of the terrain to undergo slight deformation in response to weight of the vehicles may produce less damage than the abrasive effects of vehicles on the same terrain when it is frozen solid. Similarly, the supple nature of the vegetative cover, and the shrub layer in particular, in the summer allows it to withstand the passages of vehicles with fewer adverse effects than in the winter months. The on-site investigations also confirmed that, for the most part, the real problem with respect to cross-tundra movement in the summer thaw period is the maximum number of vehicle passes that the ground surface can tolerate before the degree of disturbance begins to exceed acceptable levels ...

"The terrain disturbances associated with 1970-71 winter seismic operations of Gulf Oil Exploration and Production Canada Ltd. and Deminex (Canada) Ltd., on Banks Island are negligible."

The author points out that only limited sample sizes were possible and that pre-disturbance terrain conditions were impossible to establish with accuracy. Almost no information was available regarding operating conditions and types of vehicles involved in the disturbance studies.

The author sets forth tentative recommendations for the resource exploration operation in the tundra regions as derived from results of his research, among which he suggests that no summer seismic work should be permitted on recently burnt-over areas and that summer operations should probably be limited to early summer (e.g. late June and July) to facilitate vegetation recovery. Concentration of heavy traffic in summer within a 33-foot right-of-way should be avoided as the level of disturbance is intimately related to the number of heavy vehicles moving over the same route.

476. LAMBERT, J.D.H. 1971. Botanical changes and terrain modifications resulting from seismic and drilling operations, Mackenzie Delta, N.W.T. Prog. Rep. to ALUR. 8 p. mimeo.

<u>From conclusions</u>: Extended use of winter roads appears to not only destroy the surface vegetation but also the sub-aerial plant stems and rhizomes, thus greatly retarding the rehabilitation of a disturbed area. Species propagated by seeds (grasses and annuals) compete successfully for exposed soil and original species are displaced. No data are included in this report.

477. LAMBERT, J.D.H. 1972. Botanical changes and terrain modifications resulting from seismic and drilling operations, Mackenzie Delta, N.W.T. 1971 Rep. Arctic Land Use Res. for Dep. Indian Aff. N. Develop. 51 p.

The studies concern recovery rates of vegetation damaged during both winter and summer seismic operations and drilling operations. Results are only tentative but indicate that recovery is probably rapid on lightly damaged vegetation but prolonged on severely damaged vegetation, and almost imperceptible on heavily damaged shrub communities.

Studies of vegetation damage after 2-year use of the Gulf Oil winter ice road in the Jimmy Lake area to transport supplies and move a drill rig, indicated that in lightly damaged areas plant composition remained "virtually the same but the percent cover was reduced". Traffic over the winter ice road tended to pulverize the hummock tops with the material remaining in place until the thaw. Thus, since most of the plants are rooted in the sides of the hummocks and therefore not particularly subject to damage, it is believed that ice road construction gives protection to vegetation. Further, since the microtopography is preserved, recovery is expected to be rapid.

Studies of bladed lines at the Sitidgi Creek indicate that because of changes in drainage patterns recovery to the original vegetation will be very long, if it ever occurs. Meantime, a tussock community is expected to develop because of the impeded drainage.

478. LAVKULICH, L.M. 1971. Soils-vegetation-landforms of the Fort Simpson area, N.W.T. Rep. 1971 Land Use Res. to Dep. Indian. Aff. N. Develop. - ALUR Programme. 272 p. plus maps.

The area studied was confined to the southwest district of Mackenzie, west of the sixth meridian.

Soils and organic landforms of the area are described and classified, the former using the Canadian system, the latter using the classification of Tarnocai. General information on associated vegetation is given.

Some relationships between soils, vegetation and ground frost: "Patterns or distribution of vegetation communities and ground frost of the Mackenzie Lowlands are intimately related to the water and temperature regimes of the soil. The flora of the region is typically Boreal in its makeup and in its simplicity, and reflects the harsh macro-climate ..."

Soils of well- to rapidly-drained sandy and gravelly materials: "These coarse materials are of glaciofluvial or fluvial origin and associated landforms include old river terraces, eskers, crevasse fillings, pitted outwash and beach ridges. Degraded Dystric Brunisols predominate and are characterized by low pH (4.5 to 5.5 in the A and B horizons) and low cation exchange capacity and content of exchangeable cations.

"These soils have a low inherent water holding capacity ... will freeze quickly and deeply in the fall but will heat up just as quickly in the spring. Ground frost was not encountered in July ...

"Forests on these sites consisted of jack or lodgepole pine or aspen, depending on forest fire history. An understory of shrub sized white spruce is often observed and indicative of the successional trend. Under pines the shrub and herb layers are sparse and include *Rosa acicularis*, *Shepherdia canadensis*, *Linnaea borealis*, *Cornus canadensis*; the moss layer is moderate, consisting primarily of *Pleurozium schreberi* and *Hylocomium splendens*. A minor but notable cover of lichens (xerophytic) is present. Under aspen the shrub cover is considerably higher".

<u>Soils of moderately well-drained clayey tills and silty glaciolacustrine materials</u>: "These materials are generally associated with a plain landform. The glaciolacustrine plains are gently rolling; till plains are commonly either drumlinized or fluted.

"Whereas the difference in materials is reflected in a differential occurrence of ground frost and differing soil temperatures, vegetation communities on the two materials are virtually identical. The silty lacustrine soils and materials were generally colder in July than the finer-textured tills and ground frost was detected in two silty soils in July ... [while none] was encountered in the clayey till soils ...

""Sirloin" ice and the platy structure it generates was observed most strongly in silty lacustrine materials ... The accumulation of segregated ice lenses in silty material may well lead to increased water content (as ice) and subsequently to slower thawing and heating during the following summer...

"White spruce, aspen, white birch and mixtures of these predominate on these soils, which were classified as Gray Luvisols on the till or Degraded Eutric Brunisols on the lacustrine. The high shrub component is virtually absent under spruce, but increases with an increasing deciduous component and its density is high under aspen. The herb layer is sparse. The very high feathermoss cover (*Hylocomium splendens*) which is invariably found under pure spruce is eliminated under pure aspen, presumably by the mechanical smothering action of the large annual litterfall of aspen.

"The high natural fire frequency of the region, as reflected in the high incidence of young, immature stands, tends to maintain these stands in relatively early successional stages. However, the occasional occurrence of more successionally advanced black spruce stands indicates that black spruce may well be the stable or climax community on moderately well-drained sites."

<u>Imperfectly drained till and glaciolacustrine soils</u>: "Imperfectly drained soils are found in water receiving areas such as the lower sides of drumlins or of undulations in the till or glaciolacustrine plains. Gleyed Orthic Gray Luvisols occur on till but on silty geological materials Gleyed Degraded Brunisols occur due to the lack of clay in the parent material ...

"Vegetation of these imperfectly drained sites is similar to that of moderately well-drained sites. Horsetails (*Equisetum pratense* and *E. scirpoides*) are notable additions to the herb layer. In addition, the height and productivity of aspen and white spruce is higher. Apparently, the favourable water supply offsets the deleterious effects of growing season length resulting from colder soil temperatures. Relatively good quality black spruce is commonly intermixed with the white spruce to varying extents. Balsam poplar, on moderately well-drained sites, is sporadically represented."

Moderately poorly drained soils of till and glaciolacustrine materials: "Moderately poorly drained soils are found on flat to gently sloping areas of the till and glaciolacustrine plains.

"Peaty phase gleysols predominate ... Ground frost was observed at 50 cm at a number of the sites examined.

"The vegetative community consistently observed was of the black spruce-feathermoss type. Poor quality, low density black spruce stands with a dense feathermoss cover of *Hylocomium splendens*, *Ptilium crista-castrensis* and some *Pleurozium schreberi* are characteristic. High shrubs and herbs are minor; low shrubs have a moderately low cover and include *Vaccinium vitis-idaea*. Under openings or more open parts of the stand, lichens including *Cladonia alpestris*, *C. arbuscula* and *C. rangiferina* become established among the feathermoss.

"Somewhat more poorly drained soils of more depressional areas of the plains are associated with either Peaty Gleysols or Turnic Mesisols. The ground water is minerotropic in this type of transitional bog. Tamarack becomes a significant part of the tree cover: *Ledum groenlandicum*, *Betula glandulosa* and *Potentilla fruticosa* appear in the shrub layer: *Carex* sp. often occur in the herb layer, and lichens are denser than in the typical black spruce-feathermoss type due to the higher light intensities under these more open stands. *Sphagnum* sp. and *Aulocomnium palustre* hummocks occur with *Comptothecium* *nitans* mats in moister depressions."

Very poorly and poorly drained mesic and humic organic soils: "These soils which overlie till and glaciolacustrine materials at depth are composed of moderately to well-decomposed organic materials which are saturated to or almost to the surface throughout the year by minerotrophic ground water. These fens may be patterned (*e.g.* net-like or string) with low ridges of organic material as on very gentle slopes and unpatterned on flat areas or horizontal fens. Either form may have numerous ponds of open water.

"The horizontal fens and flanks of the patterned fens support *Carex* - *Drepanocladus* communities. The ridges of somewhat more fibric organic material support *Betula glandulosa* and stunted tamarack. Slightly drier fens are hummocky due to the growth of sphagnum hummock forms and in addition to *Carex* sp. support *Betula glandulosa*, *Ledum groenlandicum*, *Myrica gale*, *Potentilla fruticosa*, *Vaccinium vitis-idaea*, *V. uliginosum* and *Oxycoccus* sp.

"Although the data are limited, temperatures at 20 cm are somewhat higher than with peaty gleysols. The lack of a forest cover may be responsible. However, at 50 cm the July temperatures were at or slightly above $0^{o}C$. the saturated condition of the organic material and concurrent high heat capacity is implicated. The present work did not allow conclusions to be made regarding the performance of ground ice in fens."

Fibric organic soils: "Fibric organic soils are associated with the "peat" plateau and "palsa" landforms which are typically found in the zone of discontinuous permafrost.

"In the Mackenzie Lowlands these bog soils are underlain by permafrost. The active layer water content by volume is of the order of 5% while the permanently frozen peat has a volumetric water content of the order of 80%. Thawing is prevented by the excellent insulating properties of the active layer peat.

"Growth of both the sphagnum moss and the volume of ground ice leads to a raising of the bog surface by several feet. This leads to improved drainage of the bog and rather anomalously, these organic soils by their evolution become better drained. Dissolved oxygen content of the bog water is high and the redox potential indicates oxidizing conditions, so that the soil is in reality imperfectly drained. The sphagnum mosses' requirements for water are met by the wick effect of their long strands of dead tissue.

"In addition, these bog soils are ombrotrophic, in that base cycling and content is low and pH average 3.8.

"Vegetation is typically stunted, very open black spruce forest with *Ledum groenlandicum* and several other ericaceous shrubs dominating the shrub layer; herbs are virtually absent; *Sphagnum* sp. dominate the moss layer and *Cladonia* sp. are well represented in the older, more mature communities. After fire, along with the black spruce seedlings, jack or lodgepole pine becomes established for the first 25 to 35 years of the succession probably as a result of temporarily more minerotrophic conditions due to ashing by the fire of the old vegetation and the upper peat."

From a section on soil temperatures: "... ground water is an important factor influencing the distribution of perennially frozen ground. Because of this, the quality of the water is affected by what happens to the ground ice. Since permafrost is relatively impermeable to moisture, all movement of water takes places above and/or below the permafrost. As a result, permafrost affects plant growth from nutrient considerations as well as the effects of temperature. As was shown previously, the type of material partly governs the temperature of the ground. Therefore, some vegetation species will be more suited to areas that are able to thaw during the summer months. For example, outwash material or river flood plains have very little ice since the material is coarse-textured. On the other hand, fine-grained soils and peat have a high content which undoubtedly affects the vegetation. Also, because they have a high ice content, they are susceptible to frost action".

Vegetation and landscape - Fort Simpson: A discussion is presented on the landforms and associated soils and vegetation. The organic soils are based on the classification of Tarnocai with some modification.

"Vegetation on various drainage divisions of terrain types can be generalized to show indicator significance of species groups ... [and] a number of relationships between ... strata of vegetation and sites. Mixed tree stands characterize moderately well to imperfectly drained mineral soils, while single-species stands are more typical of the dry and wet extremes. Tall shrubs (> 2 m tall and with leaves larger than 2 x 4 cm) are uncommon. They are confined to the better-drained mineral soils and are absent from organic terrain. Medium shrubs (1/2 to 2 m tall with leaves smaller than 2 x 4 cm) are only absent from acid peat (bog) soils; elsewhere they are prominant on mineral soils and on the richer (fen) peats. Dwarf evergreen shrubs less than 1/2 m tall, chiefly members of the heath family, characterize organic terrain and are especially conspicuous after fire. The tall herb and grass stratum common in southern Boreal forests is absent, although fireweed (*Epilobium angustifolium*), horsetail (*Equisetum pratense*) and *Calamagrostis canadensis* occur sporadically. The typical ground cover under forests on mineral soils consists of low evergreen species such as *Pyrola*, *Linnaea* and *Lycopodium* in a mat of green feathermosses.

Dense lichen cover occurs on dry mineral soil and on convex (raised) peat bog surfaces. The *Sphagnum* mosses are confined to poorly drained organic soils". (A summary table of vegetation-mineral-organic soil relationships is presented).

Indicators of frozen ground: (All July measurements). "No ground frost was encountered under vegetation on well-drained and moderately well-drained sites (*i.e.* convex, water shedding surfaces) with one exception [on a lacustrine silt] under a stand of *Picea glauca/Rosa acicularis/Cornus canadensis/Hylocomium splendens*. Further evidence was found that coniferous forests with feathermoss carpets (*Hylocomium*) over lacustrine silt are apt to be frozen late into summer, and perhaps perennially. On less well-drained (imperfectly and moderately poorly drained) silty lacustrine soils, ground frost was encountered in all areas examined ... It is probably safe to conclude that for the Fort Simpson area conifer-covered silt soils are at least capable of harboring persistent ground frost. On the other hand, frozen ground was not encountered (or only rarely) in other mineral materials over the range of drainage from imperfect to moderately poorly drained regardless of vegetation. One conclusion is that aspen forests, and probably mixed forests in which aspen is a component, indicate the absence of perennially frozen ground.

"In organic terrain, peat plateaus covered with an open black spruce-lichen woodland are always frozen. When burned, the lichen and *Sphagnum* at the surface are killed, exposing the peat to weathering, but still the frozen stratum persists at shallow depth. Only in bog hollows does permafrost disappear, and as these depressions fill again with peat the frozen ground returns. It seems to be a matter of moisture; wet (depressed) areas are thawed, dry (elevated) areas are frozen".

The disagreement between Korpijaakko and Radforth and Brown on the use of lichens to indicate the presence of peatland from the air shows the necessity of interpreting *both* vegetation and landform. "It can be stated categorically that in the Fort Simpson area a reflectant lichen cover under sparse black spruce on peat plateaus and slope bogs indicates permafrost. However, a lichen cover under pine on dune ridges indicates no permafrost.

"In fens, the picture is a little less clear ... As a generalization, all convex or elevated forms on organic terrain contain permafrost while concave or depressional forms are ice-free."

Effect of seismic lines on the landscape: "Tree felling and bulldozing along seismic lines on upland mineral soils encourages growth of *Calamagrostis canadensis* and a variety of weedy herbs with windblown seeds such as species of *Senecio/Arnica/Epilobium*. Frozen ground recedes or disappears from imperfectly and moderately poorly drained sites when they are cleared.

"On organic terrain the effects of clearing are quite striking from the air. When the surface vegetation is skinned from fens, they regenerate to luxuriant green stands of sedge (chiefly *Carex aquatilis*), but convex bog surfaces may remain relatively open and unvegetated for at least a decade. After 15 years or so, black spruce seedlings are re-established on dry peat mounds with Labrador tea, hair cap moss (*Polytrichum juniperinum*) and scattered herbs such as fireweed (*Epilobium angustifolium*). Permafrost persists at about the same depth under the disturbed peat as in the adjacent forested peat. Bulldozing of the lower parts of mounds on peat plateaus increases surface wetness. Where much peat is gouged out, pools of water form and cottongrass (*Eriophorum*) with aquatic *Sphagnums* invade. Less wet areas commonly are colonized by *Chamaedaphne calyculata*, *Andromeda polifolia* and consolidating *Sphagnum rubellum*.

479. LAVKULICH, L.M. 1971. Physical environmental studies, Watson Lake vicinity, Yukon Territory. Prelim. Rep. Land Use Res. to Dep. Indian Aff. and N. Develop. - ALUR Programme. 133 p.

"Four watersheds [Moore Creek, milepost 715 Alaska Highway; Spencer Creek, milepost 694, Alaska Highway; #13 Creek, milepost 689, Alaska Highway, and Tom Creek, milepost 25 Ross River Road] were mapped consisting of recognition and appraisal of geologic materials, landforms, soils and vegetative succession." Descriptions of soils and associated vegetation are included.

480. MURRAY, J.M., J.S. ROWE, O.L. SHAW AND D. READ. 1971. University of Saskatchewan, Final Report. Arctic Land Use Res. No. 1. Can. Dep. Indian Aff. N. Develop. 129 p.

The studies were done in the Watson Lake area of the Upper Liard and concerned vegetation, soil, landform surveys.

"The effect of forest removal on soil moisture content ... [is to increase] the soil moisture content on the cleared areas ... due to a reduced evapotranspiration rate." All organic soils in the area have permafrost with an active layer of 15 to 24 inches. At Watson Lake "fire is one of the most important determinants of vegetation cover and local environment."

481. MUSKEG RESEARCH INSTITUTE. 1971. Terrain disturbances by off-road vehicles. Rep. Can. Dep. Indian Aff. N. Develop. 70 p.

Summary and Conclusions:

Observations of 1970 Test Site: "The results revealed to date have been regarded as interim, and the main purpose ... is to provide a documented record of them. It is possible at this time, however, to state some tentative conclusions with respect to long-term effects of vehicle traffic disturbance on tundra. 1. Multi-spectral photo analysis enables various features of terrain disturbance to be identified. These

include vegetation damage and recovery, and exposure of mineral soil. 2. The degree of disturbance can be described in accordance with the tundra disturbance classification system developed in 1970. 3. Any amount of traffic by any vehicle is likely to result in recession of the permafrost table, even though such recession may be only slight. 4. Chance of severe thermokarst resulting from the type of traffic used in the tests is ... almost negligible. This conclusion should be checked through subsequent measurements in future years. 5. There is a direct relationship between vegetative recovery and the season at which the traffic is run. 6. Vegetative recovery also depends on the weight of the vehicle used in the operation. 7. Vegetative recovery rate also depends on the number of passes over the same piece of ground. 8. Formation of deep ruts especially on slopes has the effect of concentrating melt water, which may encourage thermokarst."

Winter seismic operations and tundra disturbance: "1. In spite of the use of shoes on dozer blades, the majority of present tundra disturbance, if not all, is caused by dozer blades scuffing the ground surface. 2. This disturbance might be reduced if the blade shoes were adjusted to give more clearance between the blade and ground surface, leaving six to eight inches covering of snow on the seismic lines and camp moving trails."

Off-road vehicle operations in the Arctic Islands: "1. Summer traffic should perhaps be avoided in low-lying, wet, vegetated areas, if severe surface disturbance is to be avoided. 2. Ruts formed in a majority of locations within the area investigated would likely constitute permanent or at least very long-lasting features of the topography."

Discussion of terrain disturbance on seismic lines in forested areas: "1. Apart from removal of the tree cover, which is a necessary part of the seismic operation in this type of country, there is very little detrimental effect of the seismic operation on the ground surface. 2. It could also be concluded that any traffic on the seismic line following thawing of this low cover in the spring is likely to destroy low vegetation such as sedges and any low shrubs, and if followed at any time during the summer by heavy precipitation, frequent cases of pronounced thermokarst erosion are likely to be encountered."

Vegetation regeneration: "One area near Prudhoe Bay in northern Alaska had had almost a year for recovery following heavy traffic amounting to 10 or 20 passes of medium and heavy vehicles. When viewed from the air, the tracks were visible ... Closer inspection at ground level revealed that vegetation in the tracks was not only darker green but also slightly larger in stature with more plant material in a given area than in adjacent, undisturbed areas. There did not appear to be any subsidence of the permafrost table in such locations."

At Tununuk, inspection in August was made of areas where multi-pass tests were made in June. "Considerable growth of vegetation in ruts is visible ... Sites at Tuktoyaktuk where tests were performed at the end of August displayed virtually no noticeable regrowth by the end of September.

There was some recession of permafrost table but measurements showed the recession to be highly irregular and variable." (Explanation unsure but recession may have been incomplete at time of measurement.)

ENVIRONMENTAL PROTECTION BOARD

Interim Reports No. 1

482. ENVIRONMENTAL PROTECTION BOARD. 1971. Towards an environmental impact assessment of a gas pipeline from Prudhoe Bay, Alaska to Alberta. Interim Rep. No. 1. Sponsored by Gas Arctic Syst. 29 p.

This report summarizes and assesses the material presented in the appendices. Potential causes and effects of environmental damage on wildlife, plants and fish are listed.

"Initial appraisal of the effects on wildlife indicates the possibility of serious effects upon the caribou stocks and the potential for damage to other species. Depending upon the route followed by the pipeline, damage can probably be held to acceptable levels if close attention is paid to restraints that will be specified in detail after further study. The effect on fishes, that may arise through pipeline crossings through stream beds, can probably be maintained within tolerable limits. However, each stream is a separate problem and until details of how much gravel is wanted from individual stream beds is available, the magnitude of the potential effect on the fish population cannot be determined, nor the constraints specified. Revegetation of disturbed areas is possible with adequate plant food and attention to other strictures imposed by time and edaphic conditions."

483. CALEF, G.W. and G.M. LORTIE. 1971. Observations of the Porcupine caribou herd: April 1 - September 22, 1971. Rep. to Environ. Prot. Bd. sponsored by Gas Arctic Syst. Study Group. 45 p. plus Appendices. Appendix I. Wildlife.

Observations on the spring to fall behaviour of the herd is followed by suggestions of possible effects of pipeline construction on the herd. The most important are:

1. Destruction of critical habitat: It was noted that Skoog's work of 1968 (and Kelsall 1968) indicates that "caribou often winter successfully in areas where lichens are scarce, either naturally or through fire damage, even though other areas containing abundant lichens are available, by eating sedges or other forage types which may be highly palatable foods." ,

2. Disturbances to animals on critical ranges (particularly calving areas): Interference at calving time could have serious effects on calf survival. "It is essential to avoid major human activity on the calving grounds at the time of calving, and to avoid altering the habitat in any way which might frighten the caribou into abandoning the calving ground or altering their behaviour."

3. Interference with migrations: Interference with migrations is discussed in detail and "in summary, it is likely that a bermed or buried pipeline would be crossed by caribou in their normal migrations. The construction of an exposed line representing a physical barrier to the animals should be avoided ... Sound without accompanying visual or olfactory stimuli does not seem to greatly frighten caribou."

4. Increased accessibility to caribou by humans will occur and thus, besides increases in the above effects, there will also be increased harvesting.

Already there is increased hunting pressure on the herd from the Dempster highway and with its completion in 1974 hunting pressure will intensify. It is pointed out that "the Dempster Highway will have all the effects on wildlife which have just been described for the pipeline." Therefore, the need for herd management data under increased hunting pressure must be obtained and "access for hunting should not be granted by pipeline companies until an adequate management programme is instigated."

484. CALEF, G.W. and G.M. LORTIE. 1971. Waterfowl surveys. Rep. to Environ. Prot. Bd. sponsored by Gas Arctic Syst. Study Group. 19 p. plus appendices. Appendix I. Wildlife.

Aerial surveys were carried out in little-surveyed areas adjacent to the pipeline corridor over flats, lakes and potholes. All areas supported substantial breeding populations with scaup and scoters comprising over 50 per cent of the tallies. Canada geese were present on the Ramparts River flats but not elsewhere. Cranes were present here and also west of the Arctic Red River. Swans were the most abundant species of waterfowl along the Arctic coast; they were absent from the Ramparts Flats but present in some other areas.

Possible effects of construction on wetlands mainly concern the destruction of staging and nesting areas which often are gravel and sandbars. These areas "must not be "borrowed" for berm fill, and they must be avoided during spring and autumn migrations." Drainage patterns in the important waterfowl population wetland areas should be maintained. If these precautions are taken there should be little effect.

Furbearers have much the same problems as caribou and waterfowl except that fire is very destructive to their populations.

485. SHOTTON, R. 1971. The nature and mechanisms of problems that might arise to fish from pipeline construction activities. Rep. to Environ. Prot. Bd. sponsored by Gas Arctic Syst. Study Group. 251 p. Appendix II. Fish.

River bed removal, increased siltation or turbidity from erosion and runoff are the main factors expected to affect fish populations.

Increased siltation and turbidity smothers and fills interstitial spaces in redds and stream bed gravels, reducing oxygen supply to eggs and alevins, covers food organisms, and clogs gills and opercular cavities of older fish.

"Research on effects of logging indicates that construction of access roads and the resulting changes in drainage they cause are significant factors in fish habitat deterioration. Similar effects from pipeline construction would be increased by the slow rates of recovery of the vegetation in certain areas of the pipeline route."

Details of life histories of fish of the Arctic are presented as far as known, with particular reference to the 0 year class (eggs, alevins and fingerlings), and material relevant to their survival is reviewed.

On the subject of removal of river bed materials, the author has not been able to obtain publications which yield quantitative information on the upstream effects of such removal. Evidence indicates that sediments will be deposited at the site of removal, scour will occur downstream from the site which "will result in a lowering of the bed profile, increasing the slope and, hence, causing drawdown of sediments upstream of the site of the initial removal. In this manner, scour of the river bed upstream of the removal site will occur. Return to equilibrium conditions will depend on rates of sediment transport and the availability of sediments upstream which can replace those removed."

Effects of gravel removal will probably be of much greater significance than the turbidity and siltation caused by trenching of the river for actual pipeline laying, although this would not be true for the smaller rivers and streams.

The increase in siltation and turbidity relative to the time of year and flow rates of the watercourses may reach critical levels for some fish.

Habitat damage caused by logging and access activities is also discussed, especially increased siltation by runoff from access roads, flattening of stream bank vegetation into watercourses and results of accumulation of slash and debris in streams.

An extensive bibliography is included.

486. WEIN, R.W. 1971. Vegetation survey along the proposed gas pipeline route. Peel Plateau to Old Crow Mountains. Rep. to Environ. Prot. Bd. sponsored by Gas Arctic Syst. Study Group. 58 p. Appendix III. Vegetation.

The survey, chiefly in the boreal forest zone included gathering of information on species cover, combustible standing crop and active layer depth and characteristics. Fire was noted as a major environmental factor throughout the area except on rocky summits and riverside communities. Nine major plant communities were recognized which appeared closely related to the moisture regime. Native species showed evidence of colonizing slumps, seismic lines, winter roads and burned areas, but the rates and species were determined by prior conditions, e.g. degree of damage, moisture regime, etc.

487. WEIN, R.W. 1971. Revegetation trials related to the proposed Gas Arctic pipeline. Prelim. Rep. to Environ. Prot. Bd. sponsored by Gas Arctic Syst. Study Group. 49 p. Appendix III. Vegetation.

Revegetation studies using agronomic grasses were initiated at Norman Wells, Inuvik and Prudhoe Bay in 1971 to test: (1) growth over pipeline berms at Norman Wells and Prudhoe Bay; (2) if winter survival is dependent on the time of seeding, i.e. length of growing season; (3) the relationship between fast-growing cereals and perennial grasses; and (4) the reaction of introduced species seeded into undisturbed plant communities. Results indicate that the annual cereal species produced ten times the biomass of perennial species but were particularly susceptible to damage by hungry rodents and birds. Even so, the annual cereals do have potential as soil stabilizers in the seeding year. The agronomic species do germinate in the undisturbed plant communities but survival and/or invasion there has yet to be observed. Nevertheless, invasion by certain weed species has been observed on newly disturbed sites, the species being determined by the nature of the site. Certain native species also show natural invasion into disturbed sites.

The nature of the berms with their differing microsites provide niches for different plant species and differentially affect the growth of individual species.

INDEX

INDEX

INDEX

INDEX