I.5. THE ICE FACTOR IN MUSKEG

N. W. Radforth

INTRODUCTION

Perhaps because of engineering and scientific experience in the north, the presence of ice as a component in northern terrain is being viewed with increasing attention. Sometimes the ice factor is an aid in engineering application because it affords increased strength and cohesion in terrain that would be otherwise too weak to bear specified traffic. On the other hand, the high amplitudes of unevenness of the ice-surface, the differentials in the deterioration rates incurred in melting and the variation in structure of ice usually provide secondary barriers to successful off-road mobility. Also, now that foundation designers are better able to cope with the permafrost factor, the importance of seasonal frost conditions is coming to the fore.

The author has been associated particularly with disclosing and identifying ice phenomena in organic terrain. In one account (4) emphasis was placed on the suggestion that subsurface ice constitution in organic terrain was related to biological factors in frozen peat and its living cover. In another paper (2) an attempt was made to relate subsurface ice conditions (using contour pattern type) to the system of reference used in classifying organic terrain. Also, some consideration has been given to the importance of ice as a palaeoecological and physiographic factor influencing the development or evolution of organic terrain (1).

In each of these cases, emphasis was given to the development of either principles or hypothetical reasoning. Much research remains to be done before the phenomena involved can be fully accounted for and explained.

The main object of the present account is to reassess the accrued information pertaining to the ice factor in muskeg in order to give special consideration to the seasonal factor.

THE MECHANICS OF ACCUMULATION OF ICE

It is now generally known that organic terrain may be found in which ice occurs when no ice exists in the surrounding mineral terrain. This condition was noticed in Parry Sound District in Ontario at least as early as the first week in April 1962. This is not likely to occur the next year. Ice was not always present in all the organic terrain of the District even this year. When present, it differed as to thickness, shape of the local mass, depth of the mass from the surface of the terrain, quality of the ice and amount. It showed variation in the contour of its surface. Differences in melting rates were apparent. One might wonder whether this complexity can ever be accounted for. It is important that it should be if prediction of terrain conditions is an objective in terrain interpretation.

The problem becomes considerably more complicated when the geographic entity involved is not merely a Provincial District such as Parry Sound, but is instead half a continent. The reason is no doubt wider environmental influence. How this affects complication is a matter for examination.

In northern North America, because of permafrost, ice persists at the base of the peat - the fossilized component of the organic terrain. Where this condition is found, the ice may remain indefinitely, or it may disappear at the end of one summer. At the end of the summer when freezing temperatures commence, new ice forms at the top of the peat and eventually persists and deepens. In time, top ice and basal ice meet and the entire organic overburden is then frozen until the following early summer.

There are therefore three conditions of ice formation associated with the temporal factor; ice which is permanent, produced as an element of the permanently frozen condition (permafrost), ice which is temporary, which lasts more than a year and which is apparently caused in part by the permafrost condition, and finally, ice which comes and goes with seasons within the year. Because the three conditions have separate implications for biological, structural and mechanical relations in organic terrain, the author and his associates have given them different names. The permanent kind of condition (N.B. not the ice itself) is permafrost. The temporary condition which outlasts a year is climafrost. The third condition, the seasonal one, is called active frost.

For obvious reasons it will not always be possible to distinguish between these conditions through the manifestation of mode of ice formation. The temporal factor makes the condition elusive. To claim that climafrost is active frost, as indeed the author has done (4), is not at all wrong if the inference alludes to the ice rather than to the condition, for climafrost ice is undoubtedly active. On the other hand, the genetic meaning and distinction that active frost and climafrost convey is not exemplified in the claim unless the inference is appreciated.

DISTRIBUTION OF ICE FORMATIONS

Northern North America perhaps lacks geographic precision in the author's present connotation. Those who are concerned with the ice factor and with frost temperatures in the terrain, often use the southern limit of the permafrost as a means of separating north from south. The usefulness of this arbitrary method cannot be denied. It becomes troublesome only when one tries to locate the southern limit, and the southern limit is most significant for the engineer and the ecologist.

Near Wabowden, Manitoba, thought to be south of the limit of permafrost (7), John Stewart, an associate working under the author's direction, found active frost which outlasted the summer of 1960 - clearly climafrost. Lest the reader should assume that the presence of this ice arose out of the undetected existence of permafrost, the writer must advise that, beneath the ice mass, temperatures higher than 0°C existed for as far down as the observer could probe.

Thus, climafrost ice does not depend necessarily upon permafrost for its existence. How far south of the permafrost it exists is a matter for study and exploration. Beyond its southern limit, active frost, on the basis of the temporal factor, remains as the sole ice-forming condition and is found in muskeg well south of the United States boundary.

In randomly chosen samples of organic terrain, the average depth-to-ice (18 to 20 inches in August) is no greater at the Wabowden area than it is about twenty miles south of Churchill, Manitoba. Indeed, right at Churchill, soundings showed that it was more usual to find the ice surface about 10 inches further down. Thus, the presence of permafrost is not necessarily a criterion of less rapid recession of the ice surface.

Although climate has its influence on ice formation and persistence, the phenomenon of large isolated ice masses shows that the climatic factor, though primary, is not the only factor governing the control of ice formation. Whatever the localized secondary factor may be it is present in many places, at Hay River, N.W.T. and Wabowden, Manitoba, for example, where climafrost is common; or at Prince Rupert, B.C., Edson, Alberta, on an axis commencing 40 miles north of Kapuskasing, south through Parry Sound and terminating near Dundas, Ontario, at Huntingdon, P.Q. and into the Atlantic Provinces. At the latter locations, the feature can be demonstrated in terms of isolated active frost, in many instances well into the summer months.

ICE-FORM

The subsurface ice-form patterns reported elsewhere (1) by the author are partly in the nature of micro-patterns of ice topography. Several of them contribute a macro-effect when considered over a wide expanse of landscape.

Polygons contribute to a fissured contour (Fig. 2). In the early part of the summer, the ice surfaces within the polygons are flat. Later they become concave and the irregularity of contours over a traverse is enhanced. Although it is reasonable that polygons should appear south of the permafrost limit, there is as yet no knowledge whether the ice form in climafrost and active frost conditions is similar to that in permafrost country.

Perforations (loc. cit.) in active and climafrost ice, and invaginations in permafrost ice provide another kind of subsurface conformation. This is a common kind of feature and occurs both north and south of the permafrost limit.

Ice knolls (Figures 1 and 4) have also been recorded elsewhere. Collectively they form still another common kind of subsurface topography. They are prevalent in the islands of the Canadian arctic archipelago and are just as common in southern confined muskeg.

There are other aspects of contours on subsurface ice which have no direct relationship to specified micro-features. North or south of the permafrost limit raised ice masses occur in both regular and irregular peat plateaux (Figure 11) (2). Sometimes the top of the ice mass is 8 to 10 feet higher than the top of the surrounding ice. Also, there are the ice-forms that arise as a result of the effect of secondary geomorphic aspects in the organic terrain and others that occur through the action of water (1). It is questionable whether these can be defined as forms as yet because conformation is highly variable and somewhat fortuitous.

Elsewhere, the writer has noted that ice is a factor in controlling the topography of organic terrain (loc. cit.). It is perhaps more obvious that the reverse may also occur. In any case, when drainage ensues (Figure 14) ice erosion follows.

INSTABILITY OF ICE CONFORMATION

The temporal effect, the availability of water and inherent variability in ice-form and structure, combine with the climatic factor to make subsurface ice conformation evolve. Upon this, annual change is rhythmically superimposed. Accordingly, imponded arrangements may change and shallow ponds may migrate and change in size.

Also, the process of melting is on a differential basis as the results in Tables I and II illustrate. The amount and rate of melt varied from one station to another. All the readings were taken within the peat. The same situation occurred at the Lamprey site (Table II).

TABLE I

Differential melt in seasonal ice-surface shown by depth-to-ice measurements; Mile 472.5, near Hudson Bay Railway south of Churchill, Manitoba (1949).

	Depth-to-ice (inches) at 9 locations								
	1	2	3	4	5	6	7	8	9
July 9	12	10½	11½	10	9½	10	10½	8½	9½
July 22	12	10½	14½	12	10½	11½	13½	8½	13
Aug. 11	18	16	18	15	14	15	16	12	15
Aug. 27	20	18½	20	18	15	17½	19	13½	17½
Sept. 6	22	20	22	18	16	19	19	14	18
Sept. 15	22½	19	25	20	18	16	20½	15½	21

Inspection of the measurements in the tables shows that the subsurface ice contour profile is different for each date in the traverse connecting the locations. It is not surprising therefore that the areas of free water in the muskeg are constantly changing in position even within a season. Also, ponding pattern (Figure 15), shape and size of ponds would understandably vary from year to year.

ICE AND AIR FORM PATTERN

Certain type patterns predominate as one examines organic terrain from the air. Attributes of the ground have different emphasis as elements of pattern, depending upon the altitude at which inspection is made. This principle has been explained elsewhere (2,3). At 30,000 feet the Air Form Patterns have been designated as Marbloid, Terrazzoid, Reticuloid, Stipploid and Dermatoid (6).

For obvious reasons, especially when most areas of Canada have been photographed from 30,000 feet, it would be useful to know what the ice relations are with reference to the Air Form Patterns.

Marbloid

In Marbloid, because of ice knolling, ice contour of the type depicted in the diagram (Figure 1), is universally common. The polygoid condition is much less common but more prevalent than for other air form patterns. Raised ice masses with eroded edges are extensive and basic to any configuration that arises secondarily, viz., ice ridges from coalescing knolls.

TABLE II

Differential melt in seasonal ice-surface shown by depth-to-ice measurements; Mile 477, near the Hudson Bay Railway south of Churchill, Manitoba (1949).

	Depth-to-ice (inches) at 13 locations												
	1	2	3	4	5	6	7	8	9	10	11	12	13
July 6	26	18½	10	10	10	10	9	8	13	10	13	14½	18½
July 22	36	25	14½	10½	11	11½	13	11	15½	14	17½	21	25
Aug. 11	41	31	22	15	17	14½	15	13½	18	15	25	22½	29
Aug. 27	48½	45½	28	20	18	17	17	18	22½	19	29½	25	35
Sept. 6	46	49	33	23½	19	17½	19	19	26	21	33	46	47
Sept. 15	62	49½	35	24	19½	18	19	19	25	20	34	47	51

The depth to ice is less on the whole for Marbloid than for other air form patterns. Where there is permafrost the shallow depth persists into mid-September as compared with mid-July for active frost.

Marbloid is not confined to regions of permafrost and climafrost ice. Figure 9 shows an area of permafrost and climafrost ice; Figure 6, an area with permafrost-free climafrost ice; Figure 7, an area with active frost ice. On the other hand, Marbloid is very infrequent where active frost alone occurs, much more frequent where permafrost-free climafrost occurs and of highest frequency in permafrost country. From this it might be construed that the ice conditions noted as prevailing for Marbloid are distributed accordingly. Apart from the fact that the polygoid ice configuration has not been studied south of the permafrost limit, the inference would be valid.

Terrazzoid

The ice conditions described for Marbloid occur for Terrazzoid in less exaggerated fashion but in separated areas and with the polygoid feature seldom arising. In the organic terrain adjoining these areas, the frequent ice-form is the highly perforated condition. Figure 12 shows the surface of the terrain.

Active frost ice alone and climafrost and permafrost may occur in Terrazzoid but in climafrost country Terrazzoid is less common than Marbloid.

Reticuloid

Both the knoll and polygoid conditions are rare in Reticuloid although knolls sometimes appear when the reticulations are coarse.

Within the reticulations, the amplitude of change in the depth to ice is high and irregular. Walking is difficult because one moment one foot may be submerged to ankle depth whereas the other foot, a pace away, may sink three feet down with only the hips to check the subsidence.

Beyond the reticulations, ice recedes from the surface rapidly. The conformation produced resembles that shown elsewhere (4), and ponding ensues. The ice at the edges of reticulations usually recedes sharply leaving an almost vertical bank (steep pond margin) unless the reticulations are very broad in which case the ice-surface is less steep and conforms roughly to the slope of the pond margin (2).

The ice conditions described are similar for active climafrost and permafrost country. In the latter, the permafrost ice is found well below the level of the organic overburden, and in the reticulations usually it is likewise within the mineral sublayer. So far as the writer knows, the same applies for climafrost although exceptions may almost certainly be expected to occur (e.g. near Hay River, N.W.T.).

Stipploid

Ice-knolling is common in Stipploid but the knolls are in patches of up to 20 or 30 knolls per traverse across each patch. Neither polygoid nor perforated ice-forms have been found. Erosional patterns, mostly dendritic, are very common and there is great variability in the depth to ice.

In northern Canada, residual ice occurs in Stipploid well into the onset of seasonal frost in the permafrost country. Because this ice is at different depths in different years and occasionally recedes to the lower limit of the organic matter, the author is of the opinion that it is all climafrost ice rather than permafrost ice. South of the permafrost limit climafrost and active frost ice both appear (e.g. Wabowden vicinity).

In the south, where Stipploid is as common as Marbloid is in the north, the ice forms are similarly complex and with marked differentials as to melt (e.g. near Kapuskasing, Ontario).

When snowfall is heavy, it may occur that no ice arises in Stipploid (e.g. Parry Sound District, 1962) whereas it may, and usually does, form in Dermatoid.

Dermatoid

Ice-knolling is common and continuous in Dermatoid (Figure 4). The polygoid condition occurs but is rare. Perforated ice is very common, the condition being similar to that found in the reticulations of Reticuloid but on an extensive and continuous scale (Figure 13). Where this condition is extreme, "shifting" ponds arise in the course of ice recession (Figure 15) but this condition has been noted to date only in permafrost country.

Erosional features (Figure 14) are common (more so than for Stipploid) and are variable but not as abruptly so as with Stipploid. Although erosion is common, it is not usually dendritic and leads to impPonding. Ponds, which are a feature in the Dermatoid south of the permafrost limit are permanent, occur with less frequency and usually have steeper (more abrupt) banks than their counterparts in permafrost country (e.g. Peace River in Alberta, Prince Rupert, B.C. and Newfoundland). Where the banks are steep, the ice-contour conforms.

Both north and south of the permafrost limit hummocking (Figure 3) (2) is common in Dermatoid and this is associated with perforated ice.

ICE-FORM AND VEGETAL COVER

The author has reported elsewhere (4) on subsurface ice with specific reference to muskeg cover. Although the work and reporting in this field is still generally incomplete, emphasis here has been placed on the importance of a single cover class designated earlier by the writer as Cover Class H (2).

Normally, Cover Classes are not defined on the basis of species composition but on morphological features (loc. cit.). Thus Classes A and B both may be constituted of Picea and Larix but they fall within different characteristic ranges of stature when referred to in the sense of Class. In Class H it happens that the structural attributes on which the Class is designated are such that they can only apply to species of lichen. Therefore Class H as it appears in formulae (loc. cit.) designating muskeg cover always connotes lichens.

The cover formulae which recur in the permafrost region frequently are: H, HE, HEI, EH, HEB, EHB and BEH. Their frequencies diminish in the order listed but it must be appreciated that H, the pure Cover Class, usually shares the cover with another class unless the unit of cover is small, say, the size of a metre quadrator less. Therefore H will seldom be referred to as occurring alone wherever large ice-masses are concerned.

The literature already demonstrates that the H factor in cover formulae applies generally in the north (2) and that it arises in association with Classes E, I and B. It has never been explained however, that these associations usually occur where high-table ice-form is established (Marbloid and Terrazzoid) where ice-knolls persist and frequently where polygons occur.

For low-table ice the H factor does not show, e.g., the vegetal cover for the background terrain of Terrazzoid or northern Dermatoid. If the H factor appears in northern Stipploid again there is a high ice-table present though usually not so high as for the Marbloid condition.

Sometimes Classes E and I gain prominence in the cover formulae. When this occurs, irregularities in the ice contour of the raised table are prominent and there is marked erratic micro-relief in both the terrain surface and the ice contour beneath.

The only exception where no high ice-table arises and when the H factor is prominent is where the organic layer is only two or three inches deep and, in these circumstances, the layer thins to zero as, for instance, when an esker or old beach line intervenes across the organic terrain.

Beneath the lichenaceous cover moss exists invariably, sometimes Sphagnum often Hypnum. This constituent predominates in the peat if the cover formula is HE. Thus it appears that the H Class of cover is carried up as a thin layer as the moss grows beneath it. Often through the summer the lichenaceous layer is dry and crisp. Possibly this is why it is never important as a fossilized component of the peat - no water, no fossilization. The H factor is therefore only a symbol designating the presence of a high ice-table, etc. The preservation of low ground temperatures to preserve the ice through summer periods of high atmospheric temperature must be attributed to the living and fossilized moss and the associated components. Doubtless the lichen and the moss are mutually beneficial and biotically compatible. It is reasonable to conclude that this vegetal relationship ultimately controls the formation and maintenance of the conditions producing high ice-table. At Great Whale River, P.Q., at Winisk, Ontario, at Baker Lake, N.W.T., and from the air, across the arctic archipelago one can observe this ice phenomenon arising on scale which diminishes toward the north. It is easy to detect the H factor from the air at any altitude. It appears in summer as a grey to yellow-green mantle (Figure 9); south of Great Slave Lake, N.W.T. (Figure 6) and west of Musgravetown, Newfoundland (Figure 7). The H factor shows white, and the presence or absence of the factor is easy to detect.

It has been observed on a flight commencing near Dawson Creek, B.C., and proceeding north to Fort Nelson, B.C., that the H factor comes into sharp prominence about two-thirds of the distance to Fort Nelson.

A flight from Axel Heiberg Island, southwest to Banks Island and on to Whitehorse, Y.T., revealed HE plateaux south of the snow line beyond Franklin Bay near Horizon R at the end of May 1961. On this traverse the H factor was encountered to within about 25 miles of Whitehorse, Y.T.

On a third flight from Whitehorse to the Edmonton area the H factor reappeared about fifty miles from Fort Nelson.

During the flight northwards from Winnipeg to Churchill the H factor appears about fifty miles northeast of Norway House and becomes plentiful. This region is at about the same latitude as Wabowden, about two hundred miles to the west at which the H factor is also known to occur but where EH is more plentiful than HE.

Finally, the H factor occurs south of Winisk, Ontario on the Hudson Bay coast as observed on a flight from Moosonee, Ontario.

Where a traverse is made in the direction of prevalence of the H factor, Class H is usually first noticed as BEH with H constituting slightly more than 25% of the cover. Within twenty miles in the direction of greater concentration of H, all the formulae involving Class H (loc. cit. p. 11) will have appeared but in reverse sequence. Thus H quickly displaces E as the dominant cover. This phenomenon can be conveniently demonstrated in a flight traverse from Winnipeg, Man. to Churchill.

THE H FACTOR AND THE SOUTHERN LIMIT OF PERMAFROST

An analysis of the positions of initial occurrence of HE shows an approximate coincidence with the southern limit of the permafrost condition. The degree of prevalence of Class H in a secondary position in formulae designating the cover condition to the south of the limit suggests the presence of permafrost-free climafrost (e.g. Wabowden, Man.).

Confirmatory evidence supporting this theory can only be supplied by field inspection. The writer hopes that pertinent data will accumulate during future exploration and invites assistance.

If the theory is substantiated, no doubt there will be important exceptions. One has already appeared. In the Marbloid near Hay River (Figures 5 and 6) and in that near Churchill (Figures 9 and 10), the former in climafrost and the latter in combined climafrost and permafrost country, the situation conforms to the theory. It is assumed on current knowledge however, that in Newfoundland there is neither permafrost nor climafrost ice, despite the presence of the H factor, in significant enough amounts to suggest occurrence of climafrost ice. Although the writer has not had the opportunity to check this example in the field, examination of the ice conditions elsewhere in Newfoundland supports the exception. The climate prevailing in Newfoundland provides strong continuous winds in the summer. Where active frost ice occurs, drying action above it is rapid and persistent. Resulting surficial drought encourages formation of lichens just as it did near Churchill and Hay River. In the latter situations, the drying was slower and the agent was high temperature, not wind.

SUMMARY DISCUSSION

A full accounting for the ice factor in organic terrain will not be expected in this paper for it is too large a topic and in any case it is not yet possible to provide all the evidence and reasoning that comparative analyses require. The information herewith already suggests that perhaps more important than climate are geomorphology and vegetal cover in accounting for ice occurrence and behaviour.

Peat structure if woody and coarse and with many woody erratics harbours much pure ice distributed generally. Woody fibrous peats of a finer texture also contain ice masses but here they are smaller and more numerous than in coarser peats. Where woody and non-woody fibrous components associate, ice masses are often in the form of thin perforated sheets less than a quarter of an inch thick. Where this occurs, the bulk of the peat is incorporated within the ice to interrupt the peat-free laminae. Finally, where granular peats freeze, peat and ice are inseparable.

It will be acceptable to the reader that each ice-peat association as broadly described above will have its own mechanical properties. Frozen peats are sometimes friable, sometimes rubbery and highly elastic. Were it not for the irregularity of contour, generally, frozen peat offers an ideal bearing strength notably resistant to shear and penetration and affords good traction. Construction upon it or within it will be difficult, however, unless the kind of peat-ice mixture is identified and its properties determined. This difficulty is exclusive of that suggested by occurrence of the various subsurface ice micro- and macro-patterns and characteristic differential melt, the order of which would seem to be predictable.

Whether active climafrost or permafrost ice is involved, in engineering development and scientific study, they are each indicative of dynamic states. In organic terrain, active and climafrost ice are more significant because they are more prevalent. Permafrost ice, although inherently static, is inevitably overlain by climafrost which for foundations must be regarded as unstable. The author wishes to emphasize the dynamic concept because of its importance to development in the subarctic and arctic. Long into the summer, the ice factor keeps most of Canada's 500,000 square miles of organic terrain in subtle motion from day to day. The engineering implications of this are obvious. Drainage problems alone, as an example, require special imaginative treatment. In frozen peat in the Prince Rupert area, where woody erratics in the peat are often massive logs one foot and more in diameter occurring at all levels in peat, many 30 to 50 feet thick, the heat conductivity phenomena suggest physical relations that differ from those in the land of "shifting" ponds.

To the academically inclined, there is perhaps need for some supplementary nomenclature. To speak and write of active frost ice, climafrost ice and permafrost ice, each of which is important in its own right, is cumbersome. Why not actakeg, climakeg and the already coined permakeg? Icekeg would serve as an all inclusive expression. Permakeg would then be icekeg but icekeg would not necessarily be permafrost.

The conditions which produce the ice should also be defined as presently named, thus:

Permafrost is a frozen condition existing indefinitely within terrain. Climafrost is a frozen condition existing temporarily but for more than one year within the terrain. Active frost is a frozen condition existing temporarily within the terrain for less than a year.

In this paper too little attention has been directed to the ice factor in confined organic terrain such as is found commonly in the Canadian Shield. Here, Dermatoid and Stipploid are important. Although the ice conditions described for these air form patterns can be expected to be fixed, their distribution will have certain characteristics imposed by reason of the basic geomorphic control that the kettle-hole-like "vessel" imposes on the muskeg it contains. This is a subject for another related account.

ACKNOWLEDGEMENTS

The author acknowledges gratefully the financial and professional support he has received from the National Research Council and the Geophysics Section, Defence Research Board for this and related work.

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Discussion

T. A. Harwood commented that it is important to realize the changes that take place in permafrost. Permafrost is a temperature condition and perennially frozen material does not necessarily contain ice. A distribution map of permafrost in Canada, showing thickness and temperatures of the ground, similar to the one already available for the U.S.S.R., is required. There is a problem of nomenclature here because ground remaining frozen for one or two years can be considered as permafrost. These local variations are caused by micro-climatic changes and variations in vegetation. For construction, each site must be assessed individually. The southern fringe area of the permafrost region is the most difficult for construction and this is where northern development is taking place first. Finally, it must be remembered that permafrost is "perennially frozen ground" not "permanently frozen ground". The author reiterated the usefulness of the "climafrost" concept. In his opinion, there are three types of frozen material associated with the time factor. Firstly, there is the permanent kind of condition which lasts indefinitely called permafrost; secondly, there is the temporary condition which outlasts one year called climafrost; thirdly, there is the seasonal condition called active frost.

J. L. Charles observed that ponds in the tundra beside the Hudson Bay Railroad have been noticeably enlarged through the transmission of heat.

J. A. Pihlainen emphasized that permafrost is defined strictly on a temperature basis. There is no need for the term "climafrost" because it denotes a perennially frozen condition of the ground and therefore can be considered as permafrost.

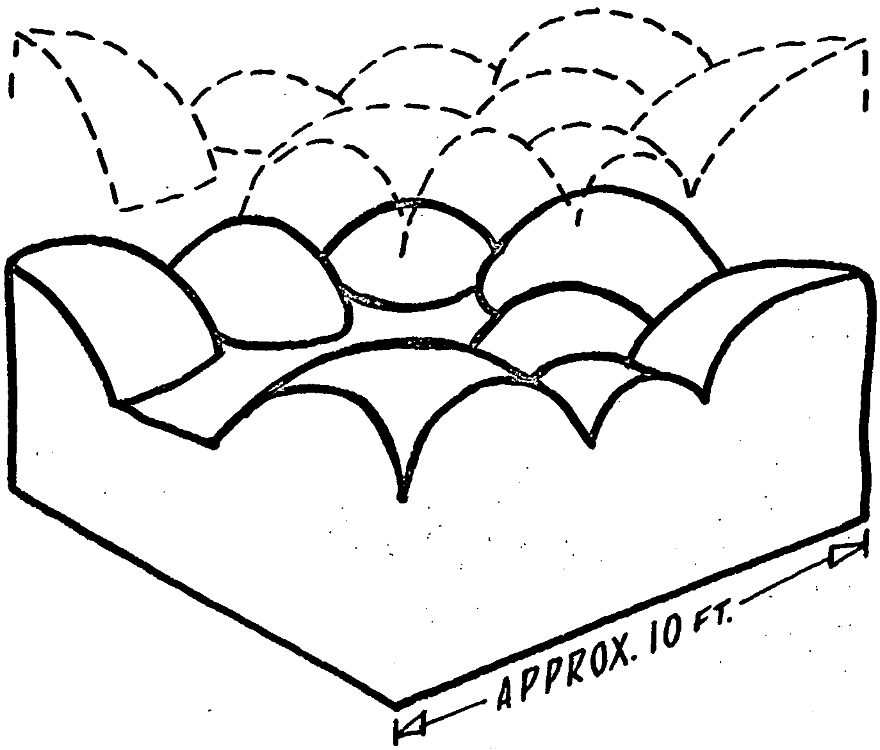

Fig. 1 Diagram showing conformation of ice-surface caused by ice-knolls, a condition common in Marbloid and Stipploid.

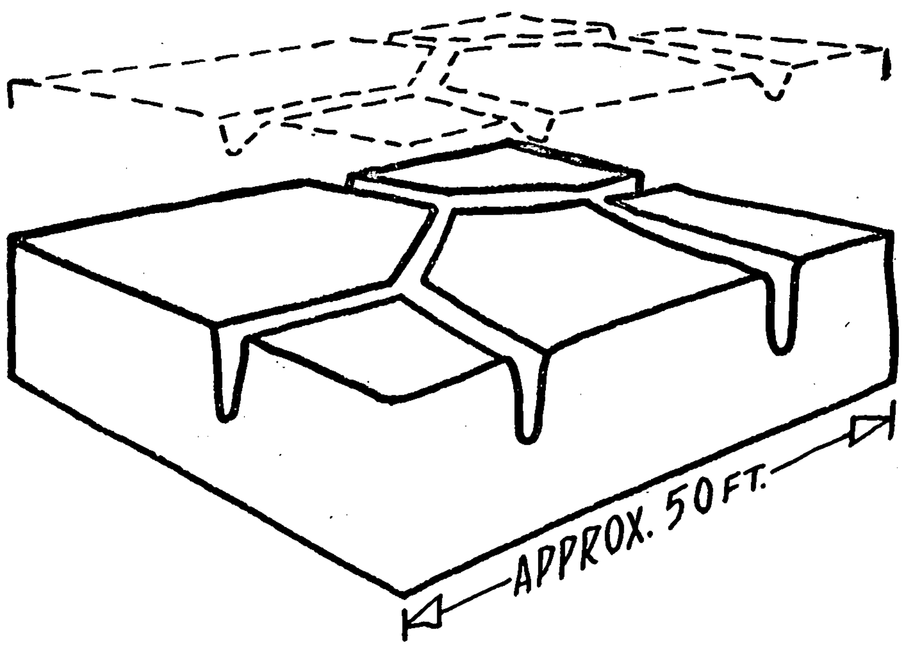

Fig. 2 Diagram showing conformation of ice-surface caused by closed polygons, a condition common in Climafrost of Marbloid.

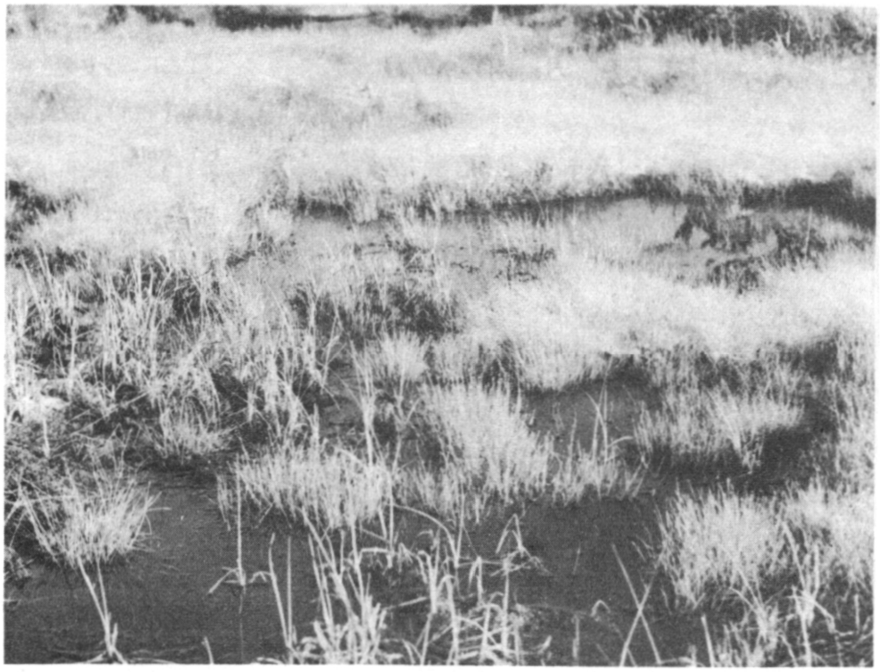

Fig. 3 A photograph showing hummocking ('a') (cf. Fig. 4, mounds ('b')) where perforations occur in active frost of Dermatoid and Reticuloid.

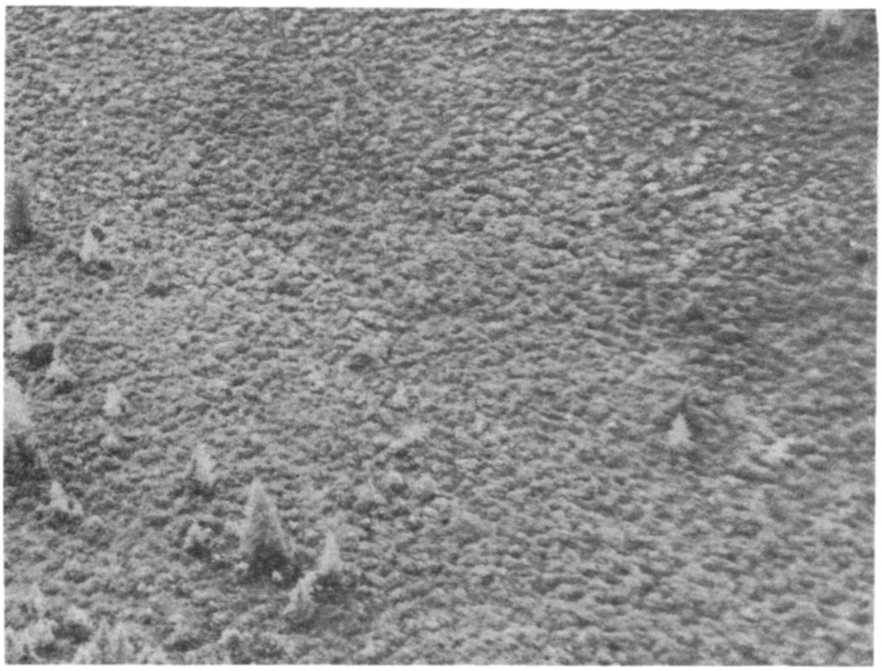

Fig. 4 An association of mounds ('b') (distinct from hummocks ('a') in which ice knolls occur.

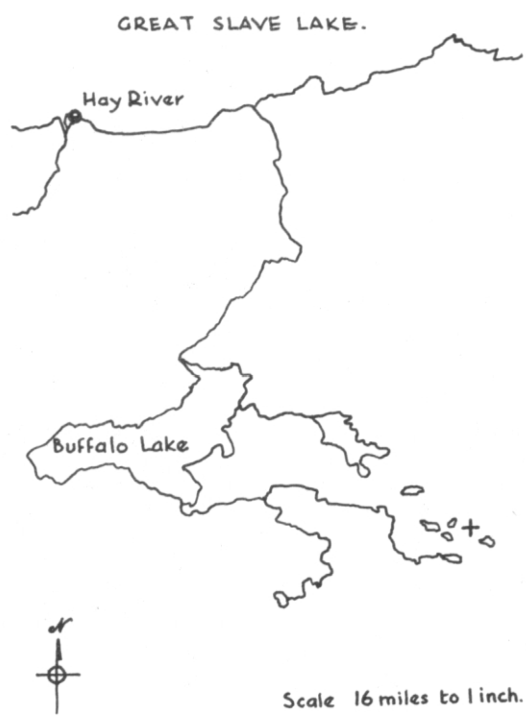

Fig. 5 Map of region south of Great Slave Lake, N. W. T. showing the location of the terrain of which the air photograph Fig. 6 was taken.

Fig. 6 Marbloid near the southern fringe of permafrost where climafrost conditions are common. Light tone marks "H" factor. Scale 1": 1 mile.

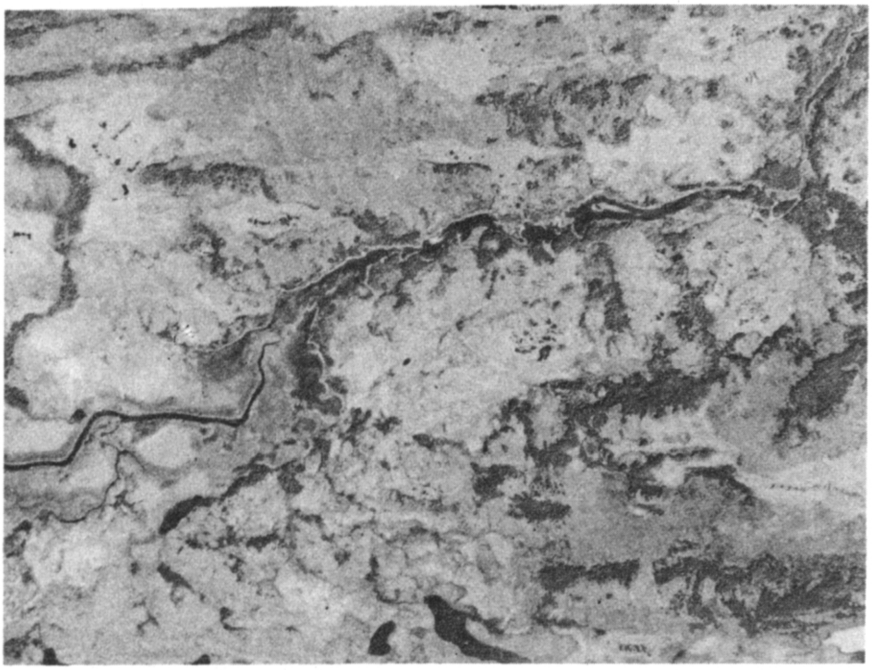

Fig. 7 Marbloid in permafrost-free organic terrain of Newfoundland. Light tone marks "H" factor. Scale 1": 1 mile.

Fig. 8 Map of region west of Musgrave Town, Newfoundland showing the location of the terrain of which the air photograph Fig. 7 was taken.

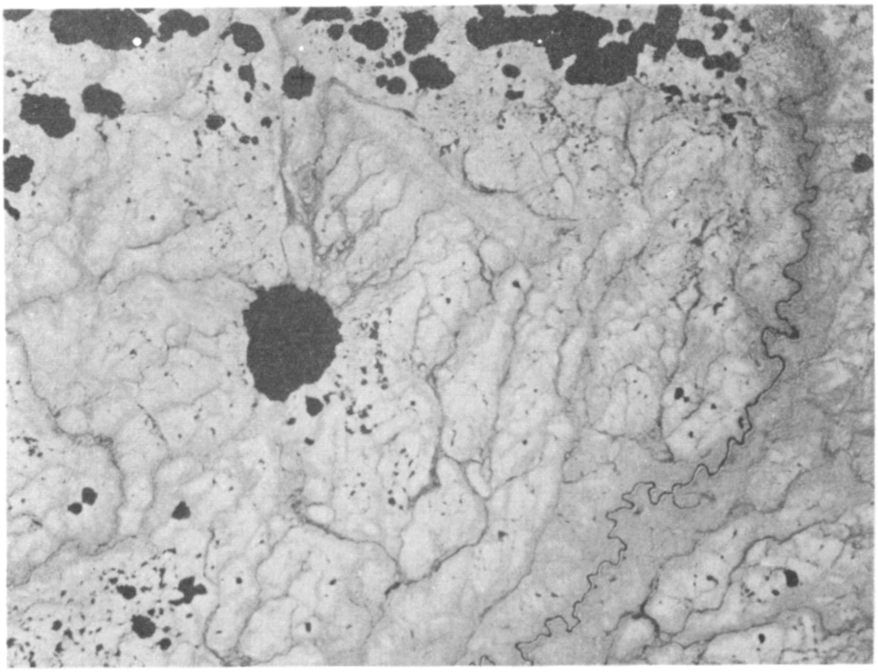

Fig. 9 Marbloid in permafrost area of organic terrain near Fort Churchill, Manitoba. Light tone marks "H" factor. Scale 1": 1 mile.

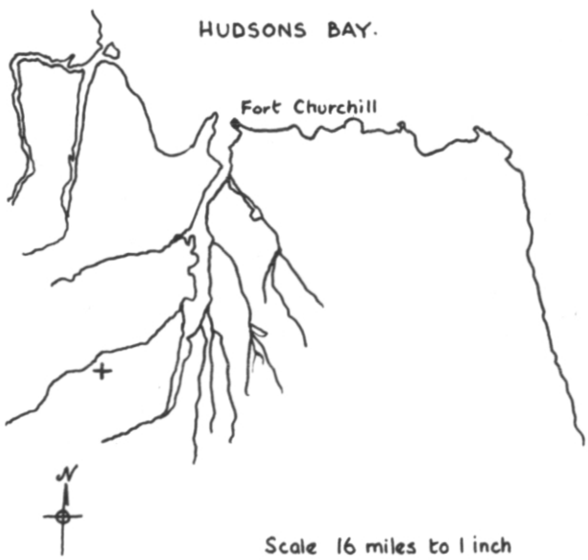

Fig. 10: Map of region east of Fort Churchill, Manitoba showing the location of the terrain of which the air photograph Fig. 9 was taken.

Fig. 11 An irregular peat plateau in which high table ice occurs.

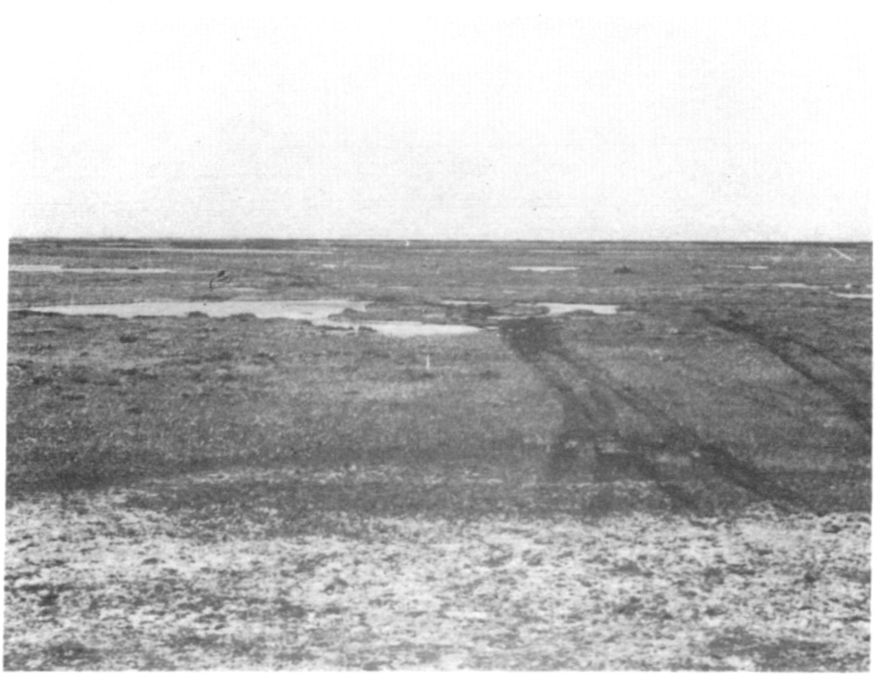

Fig. 12 Depressions in Terrazzoid in which low table, usually active, ice occurs with irregular borders.

Fig. 13 Depressions in Reticuloid in which, south of the permafrost, low table seasonal ice occurs with regular boundaries.

Fig. 14 Ice erosion caused by summer drainage - a condition common in Dermatoid.

Fig. 15 "Shifting Ponds" - a phenomenon encouraged by Climafrost in permafrost country.