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PINGOS AND PINGO-LIKE FORMS, BANKS ISLAND, WESTERN CANADIAN ARCTIC

Résumé des auteurs

Dans le travail on a décrit un ensemble de collines atteignant plusieurs mètres en hauteur, très nombreuses sur la terrasse inférieure de la rivière de Bernard dans son cours moyen, ainsi que des collines semblables de l'amont de la vallée de Sachs. Les formes étudiées sont les plus souvent rondes ou ovales; certaines d'eux sont allongées et par leur allure se sesemblent aux ozars. La plupart de collines de la région se caractéerisent par une concavité distincte située dans la partie centrale. Comme on a constaté en se basant sur les coupes géologiques, les collines contiennent un noyau de glace couvert partun manteau de graviers, sables et limons atteignant de 1 à 2 mètres d'épaisseur qui certifie en faveur de l'opinion qu'elles représentent les formes du type de pingo. Pourtant elles se distinguent des pingos classiques "Mackenzie" du type fermé par la situation morphologique, dimensions et la forme irrégulière. D'après les auteurs, les formes décrites des vallées de Bernard et de Sachs ont du se développer en résultat de la congélation des taliks qui sans doute ont existé dans les dépôts perméables situés au-dessous des anciens lits fluviaux. Les parties centrales enfoncées, souvent à petit lac àl'intérieur, montrent que les formes se trouvant actuellement dans l'état de la dégradation.

INTRODUCTION

Pingos are intrapermafrost ice cored hills. Similar features in the Soviet Union are termed *bulgunnyakhs* (SOLOVIEV, 1973). From a hydrological point of view, pingos may be of either an open system type, resulting from the freezing of sub- and supra permafrost waters, or of a closed system type, resulting from the freezing of intrapermafrost waters. In general, open system pingos occur in regions of thin and/or discontinuus permafrost, such as interior Alaska (e.g. HOLMES, *et. al.*, 1968), the Yukon Territory of Canada (e.g. HUGHES, 1969), and Greenland (e.g. MULLER, 1959; CRUICKSHANK and COLHOUN, 1965), while closed system pingos are restricted to regions of thick and continuous permafrost.

The most widely studied pingos of the closed system type are found in the Mackenzie Delta region of Canada, where they commonly occur in recently drained lake bottoms (e.g. MACKAY, 1962; 1973). About 1350 pingos exist in the Pleistocene Coastal Plain (e.g. RAMPTON, 1972). Pingos have not been reported with any frequency from the Arctic islands. A few are known to occur on western Victoria

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Island (e.g. WASHBURN, 1947; FYLES, 1963), and a number exist on Prince Patrick Island (e.g. PISSART, 1967).

Recent fieldwork (FRENCH, 1975, 1976) has resulted in the identification of over 100 previously undocumented pingos and pingo-like features on Banks Island. Since Banks Island is totally within the zone of continuous permafrost, these pingos

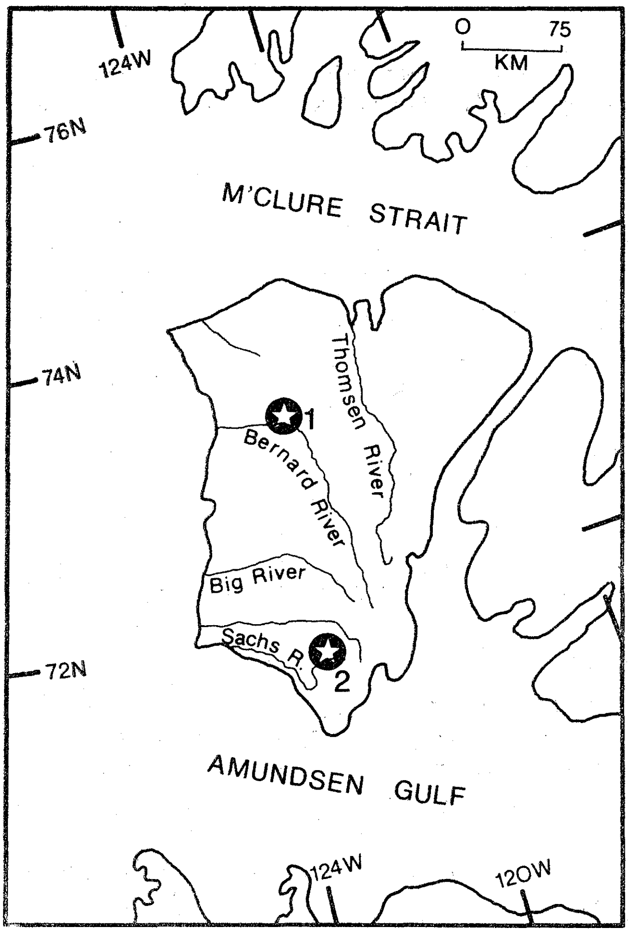


Fig. 1. Location map of Banks Island showing pingo localities mentioned in the text
1. Central Bernard River; 2. Upper Sachs River

are presumably of the closed system type. They differ from classic Mackenzie Delta type pingos mainly in terms of their irregularity of form, their geomorphic settings, and the high proportion of collapsed features. One group, located within the valley of the Thomsen River and its small tributary, the Able Creek, has already been described (PISSART and FRENCH, 1976). In this paper, a number of pingo-like features from two further localities on Banks Island are documented (fig. 1). They illustrate the variety of forms which closed system pingos can assume, and are thought to reflect the distinct fluvial and hydrologic conditions of regions of continuous permafrost and high latitude.

PINGO-LIKE MOUNDS, CENTRAL BERNARD RIVER

(Lat. 73° 23' N, Long. 123°15'W)

A number of partially collapsed mounds and shallow rim-like features occur on a low terrace of the large Bernard River in central Banks Island (fig. 2). They were first identified from the air in 1974 and field investigations were made in June 1975.

A total of thirty one features were mapped, all located within an area of approximately 2.0 km². The terrace on which they occur rises 8.0 m above the level of the present Bernard River. A higher terrace, approximately 20 m above the river, is also present but the features are restricted to the lower terrace. Tundra ponds constitute over 70 per cent of the surface area of both terraces.

The mounds possess little vertical relief, the highest rising only 3.1 m above the level of the terrace. The majority are circular, less than 2.0 m high, and between

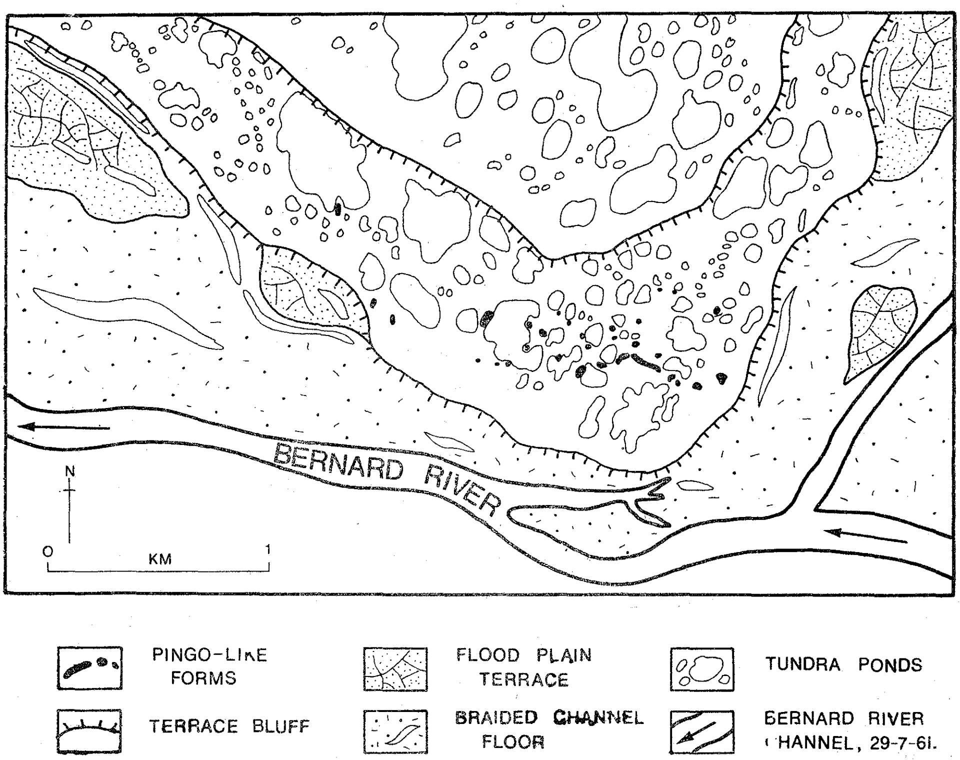


Fig. 2. Sketch map showing location and distribution of the Bernard River pingo-like features
Based upon air photograph A-17564-48 and field investigation

Table I

Dimensions and form characteristics of pingo-like mounds,
Central Bernard River, Banks Island

A — Mounds > 2.0 m high

Mound	Long axis m	Short axis m	Length: Width ratio	Height m	Long axis orientation	Plan*	Morphology
1	46	43	1.1:1.0	3.4	N—S	C	hummocky
2	35	26	1.3:1.0	2.0	E—W	C	flat
5	33	29	1.1:1.0	2.0	E—W	C	depressed centre
7	166	22	7.5:1.0	2.0	E—W/N—S	L	axial depression
8	42	32	1.3:1.0	3.0	E—W	C	depressed centre
17	52	25	2.1:1.0	2.7	N—S	E	depressed centre
24	71	25	2.8:1.0	3.4	N—S	E	depressed centre
29	34	25	1.4:1.0	2.4	N—S	C	depressed centre

B — Mounds < 2.0 m high

Number of mounds	Average dimensions			Plan*		Complex
	Long axis m	Short axis m	Length: Width ratio	Circular	Elongate	
23	21.5	13.4	1.6:1.0	12	10	1

*C — circular (1.5:1.0); E — elongate (1.5:1.0); L — linear (5.0:1.0)

20 and 100 m in diameter. The dimensions of some of the features are given in Table I. Many contain shallow central depressions and some of the smaller features consist solely of a circular or semi circular rampart. Since the terrace is very flat and poorly drained with a near continuous cover of wet tundra vegetation, the features stand out as gravelly, well drained elevations, devoid of vegetation. A few are elongate or complex in form, the latter resulting from the apparent coalescence of several adjacent mounds. One of the features is best regarded as a true linear feature (fig. 5, being over 150 m in length and only 20—30 m in width. This esker-like ridge exhibits a marked angular change in direction, averages 1.5—2.5 m in height above the terrace surface, and possesses a shallow linear depression along the axis of the ridge (fig. 6).

In plan, the mounds exhibit no systematic relationships and appear to be randomly distributed over the terrace. Where mounds are elongate, the long axis orientation appears roughly equally divided between those aligned downvalley and those aligned cross-valley.

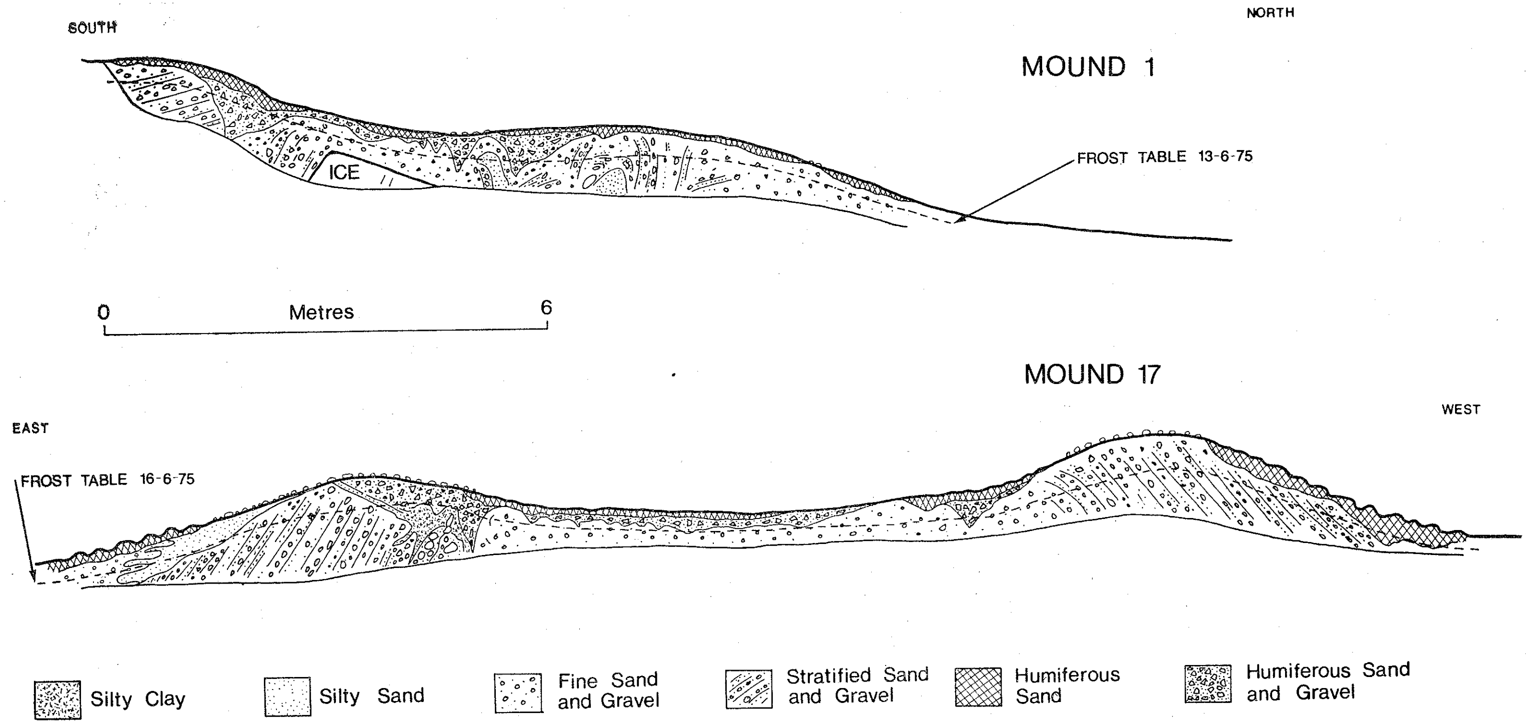


Fig. 3. Diagram illustrating the sections cut in mounds 1 and 17, Central Bernard River

Sections were excavated in the two highest mounds (Nos 1 and 17). These are illustrated in figure 3. In mound no. 1, an ice core, consisting of near-vertically inclined ice layers separated by lines of mineral inclusions, was encountered at a depth of 1.5 m. The junction between the ice core and the overlying sediments was sharp and marked by a thin layer, 1—5 cm thick, of dark grey silty clay. The overlying materials were silty sands and gravels, of a fluvial nature. Towards the top of the mound, these beds dipped inwards towards the centre. Lower down the slope, the bedding appeared more disturbed and near vertical in places. A number of wedge structures, infilled with mineral soil and less than 1.5 m in depth, were also present. In mound no. 17, a complete cross section was excavated. However, no ice core was visible in this section. Instead, the two ramparts were found to be composed of inclined beds of fluvial sands and gravels which dipped in opposite directions. Wedge structures, similar to those observed in the other section, were found to exist at the periphery of the central depression. These observations suggest the mounds to be the result of the growth of an ice core, the updoming of the overlying sediments, and the subsequent partial collapse (i.e. melt) of the features.

The origin of these pingo-like forms can only be hypothesised. The possibility that the mounds are a type of glacial "dead ice" topography can be dismissed since glacial materials are not present on the terrace. The uptilting of the enclosing sediments, the absence of "candled" ice, and the dipping sediment layers within the ice indicate these features are not simple ice mounds or "naledi" (e.g. SHUMSKIJ, 1964, p. 192—5; CHURCH, 1972, p. 101—3). Furthermore their density of occurrence, their elongate forms, and their relatively small dimensions are not typical of mounds normally regarded as pingos. Finally, the features are quite different from, and much larger than, the very small hydrolaccoliths described from southern Banks Island (FRENCH, 1971a) and elsewhere in the Arctic islands (e.g. BIRD, 1967, p. 201—3).

One possible explanation is that the mounds developed following the abandonment of the terrace and the freezing of localised taliks which might have existed in the permeable sediments beneath a braided channel system. Moreover, if bodies of standing water had been left in the deeper parts of the channels and in meander traces, they would have aided in the maintenance, or even growth, of taliks until that time when the water bodies became infilled and permafrost aggradation was able to take place. This type of hypothesis explains the relatively high density and random distribution of the features on the terrace, the linear feature, and the elongate nature of some of the others.

Although no visible morphological evidence of previous channel braiding is present on the terrace, the uplifted sediments which comprise the mounds are entirely compatible with braided channel deposits. Furthermore, in common with the other major rivers which drain the central and western lowlands of Banks Island, the present Bernard River possesses a well developed braided pattern over much of its length. This current response of the river can be attributed to (a) the seasonal discharge variability of the runoff regimes in the high Arctic (CHURCH, 1974, p. 12—15), and (b) the abundance of coarse sediments available for bedload transport.

Photo by H. M. French, 1975

Pl. 1. Oblique air view of large pingo-like mound (No 17; Tab. I), Central Bernard River. Note the section cut across the mound and the presence of other pingo-like mounds in the background

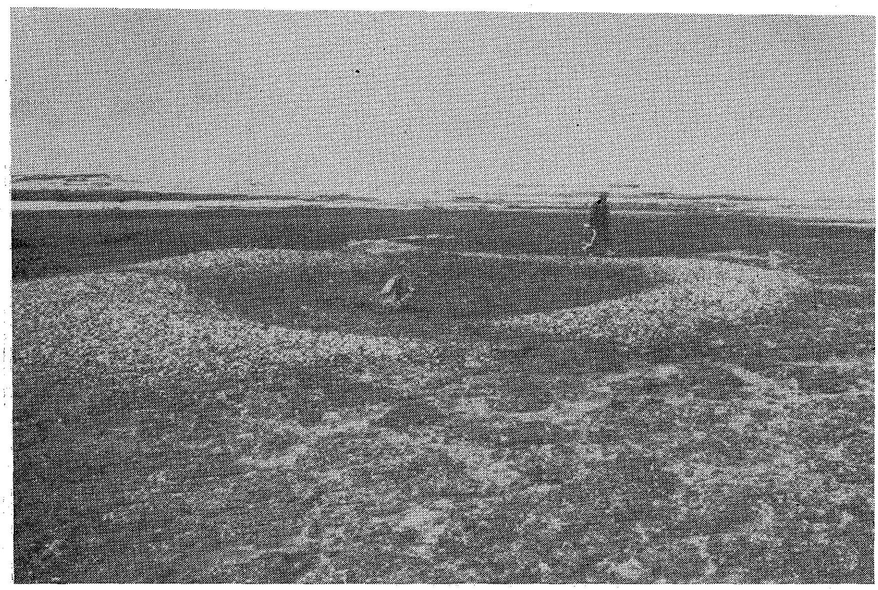
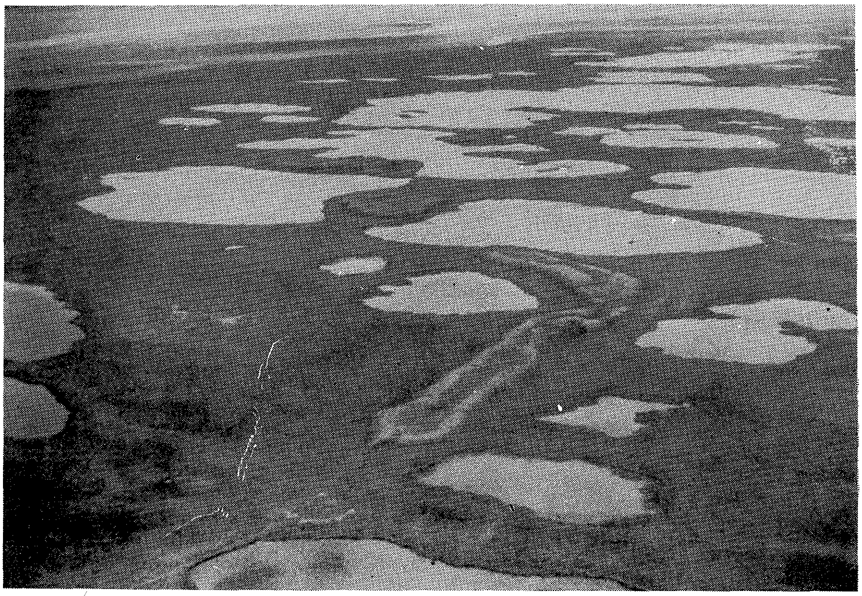


Photo by H. M. French, 1975

Pl. 2. Small collapsed pingo-like feature, Central Bernard River



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Pl. 3. Oblique air view of linear pingo-like ridge, Central Bernard River. At least six other pingo-like forms can be identified in this photograph

Photo by H. M. French, 1975

Pl. 4. Surface morphology of linear pingo shown in Pl. 3

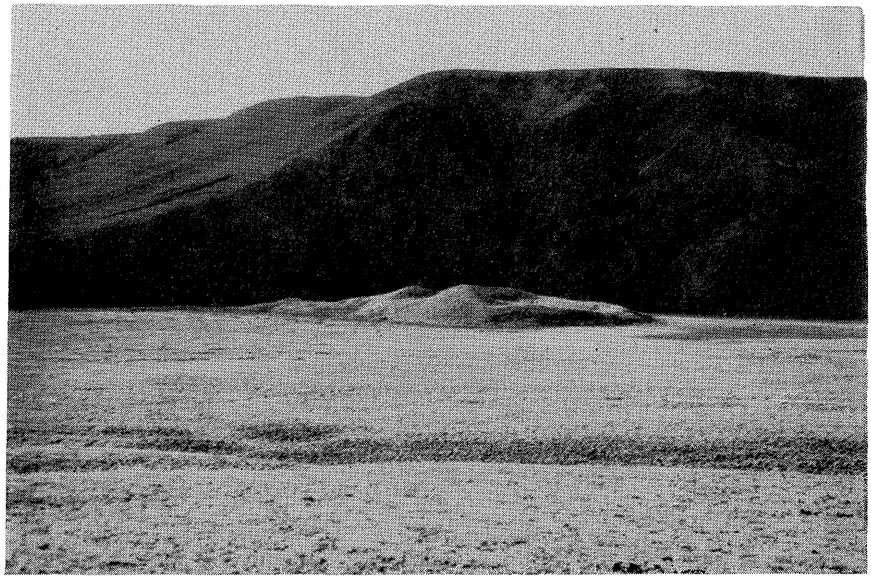

Photo by H. M. French, 1975

Pl. 5. Partially collapsed pingo, Upper Sachs River. A small pond exists in the crater. The pingo is 7.4 m high, and 70 × 110 m in dimensions

Photo by H. M. French, 1975

Pl. 6. Oblique air view of the two pingo-like ridges, Upper Sachs River. The section cut and the pingo illustrated in Pl. 5 are indicated by arrow

Photo by H. M. French, 1975

Pl. 7. Surface morphology of pingo-like ridge, Upper Sachs River, showing shallow linear depressions and hummocky relief

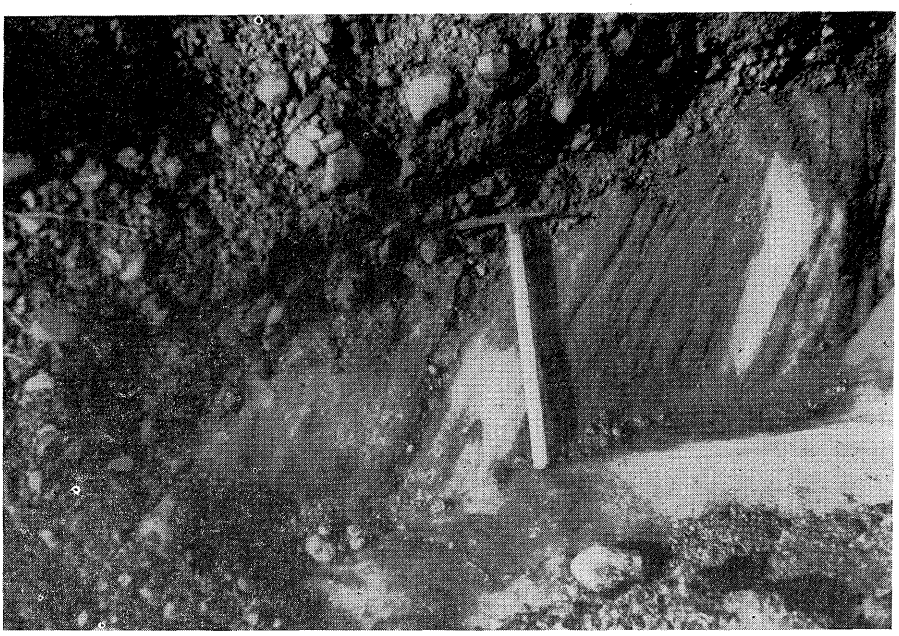

Photo by H. M. French, 1975

Pl. 8. Part of the ice core exposed in the pingo-like ridge, Upper Sachs River, showing steeply inclined layering of the ice and bands of mineral inclusions

The latter results from the unconsolidated nature of the sands and gravels of the Beaufort Formation which underly much of the central and western lowlands of the island (THORSTEINSSON and TOZER, 1962), and the extensive glacial deposits which occur in eastern Banks Island. Thus, each year, large quantities of debris are supplied to the rivers by rapid mass wasting on slopes and lateral bank erosion by rivers. These conditions which are present today were equally, if not more effective in the past when river discharges were greater and the volume of glacial debris available for redistribution was also significantly higher.

PINGO-LIKE RIDGES, UPPER SACHS RIVER

(Lat. 71°47'N, Long. 123°12'W)

Two elongate ridges, aligned downvalley, together with a distinct partially collapsed pingo occur within a small stream valley in the upper headwaters of the Sachs River, in southern Banks Island (fig. 4). The puzzling nature of the ridges and the location of this pingo prompted field investigation in July 1975.

In the vicinity of the features under discussion, the valley is strikingly asymmetrical. The present stream is undercutting the southeast facing slope which forms a steep, unstable escarpment developed within the shales of the Christopher Formation (THORSTEINSSON and TOZER, 1962) and the basal „burut skale" units

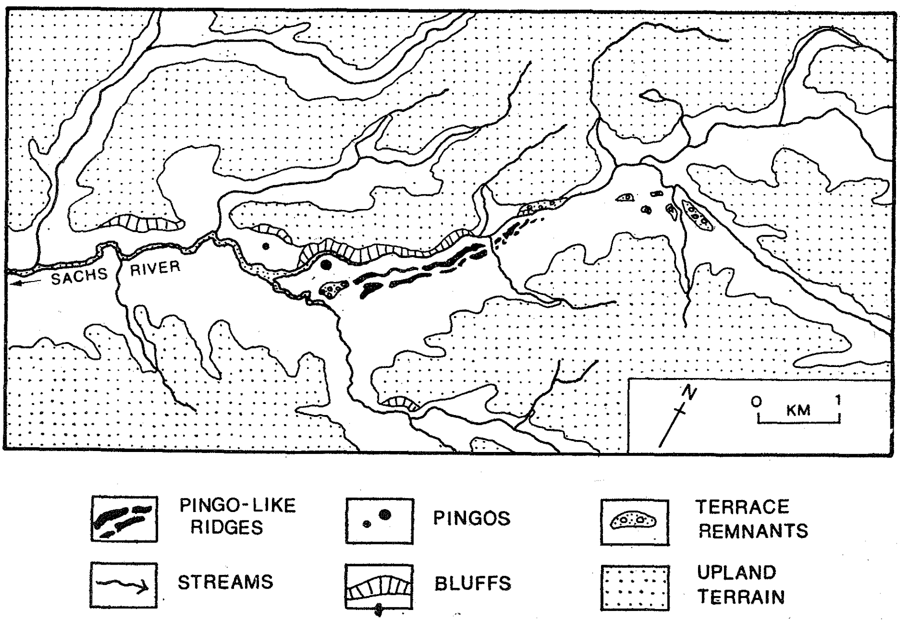

Fig. 4. Sketch map showing location of the pingo-like forms in the headwater valley of the Upper Sachs River, southern Banks Island

Based upon air photograph A-16285-138 and field investigation

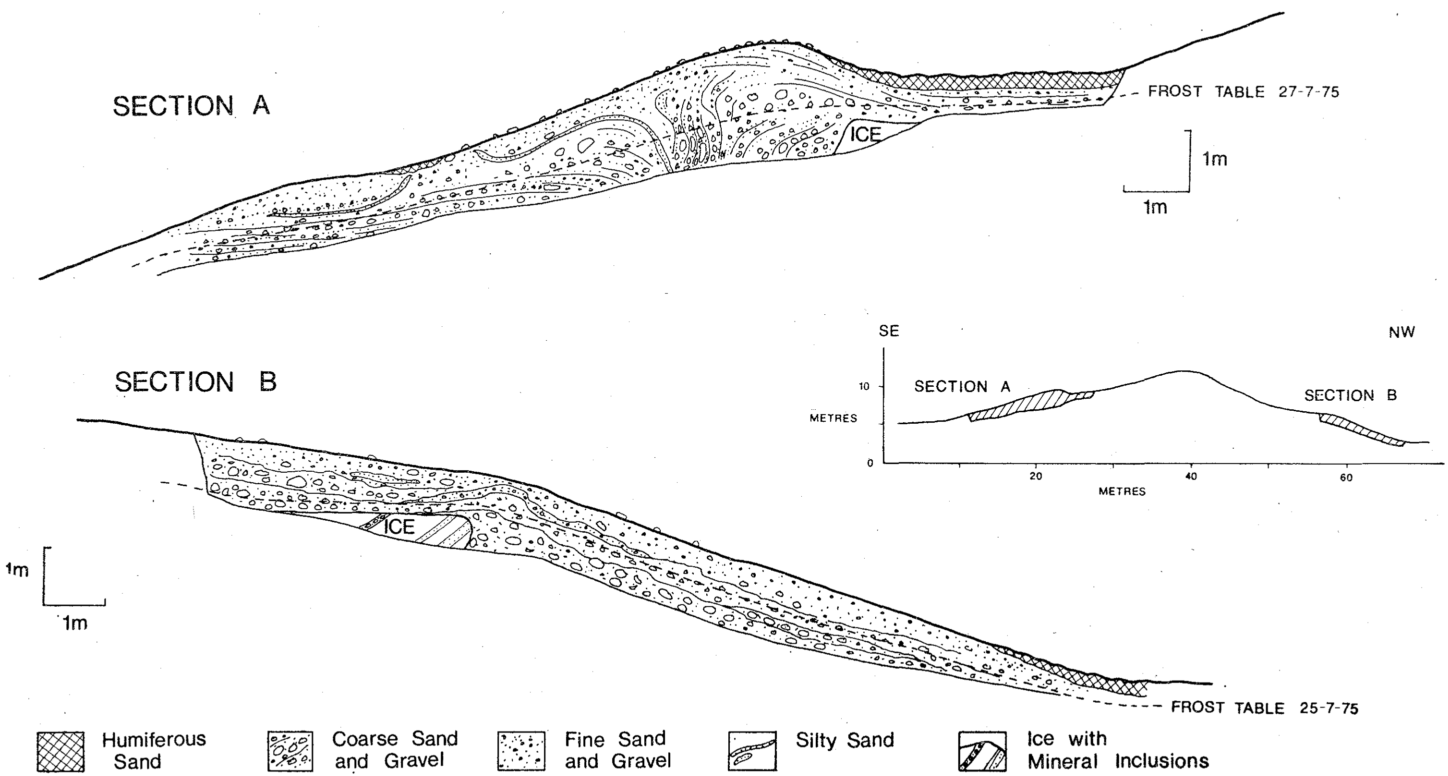

Fig. 5. Diagram illustrating section cut through pingo-like ridge, Upper Sachs River

Location of the section is indicated on Pl. 6

of the Kanguk Formation (1974 Miall,). Downvalley from the pingo, the valley widens, becomes more symmetrical, and assumes an east—west alignment.

The pingo is located within the valley bottom in a depression formed where the present stream has swung laterally to undercut the southeast facing slope of the valley, thus producing an impressive cliff, over 150 m high (pl. 5). The two ridge-like features extend upvalley from the pingo for a distance in excess of 2.5 km. They are approximately parallel to each other, varying from 50—200 m apart, and are located towards the foot of the gentler northwest facing slope (pl. 6). Neither ridge exceeds 10 m in height and each varies in width from between 20 and 200 m. The features possess little vegetation since they are composed at the surface of sands and gravels. Characteristic of both ridges are a number of shallow elongate and irregular depressions which follow the long axes of the ridges (pl. 7). Thus, the ridges give rise to an irregular hummocky relief within the valley and constitute important topographic features.

At first sight, these linear features bear striking resemblance to typical eskers. However, their location towards the bottom of a sharp asymmetrical valley, their near parallel alignment, and the absence of other evidence for recent glacial activity within the valley do not support this interpretation. This conclusion was reinforced when a section was cut through part of the ridge nearest to the valley bottom. The location of this section is indicated in figure 4 and illustrated in figure 5. Two large ice bodies were found to exist at depths of 1.0—1.5 m beneath the depressions on the ridge. The ice possessed steeply dipping bands of mineral inclusions interbedded with layers of pure ice (pl. 8).

The coarse gravels and sands which enclose the ice cores are, however, almost certainly of a glacial origin. They are virtually structureless, heterogeneous in composition, and relatively well rounded and sorted with no cobbles exceeding 40 cm in diameter. Clearly therefore, these gravels are not locally derived from either the Christopher or Kanguk Formations. They seem best interpreted as having deposited by glacial meltwaters which may have utilised this valley at some time in the past when an ice front lay to the east. Remnants of an extensive gravel terrace, which can be traced on air photographs further up the valley, support this interpretation.

The origin of these pingo-like ridges appears linked to the evolution of the valley in which they are located. A mechanism involving the freezing of sub-channel taliks consequent upon the migration of the stream associated with the development of the valley asymmetry seems most logical. It is possible that, following the resumption of normal fluvial activity within the valley, a near continuous talik might have developed in the coarse, permeable gravel infill. The dual nature of the ridges on the gentler slope could then be explained in terms of two successive positions of the stream channel as it migrated to its present position at the foot of the steeper southeast facing slope. The efficiency of lateral stream migration in permafrost terrain and its relation to valley asymmetry has already been described from northwest Banks Island (French, 1971 b).

The proposition that substantial taliks exist beneath streams as small as the one under discussion needs verification, particularly since this small stream certainly freezes to its bottom in winter, and sub-channel taliks are usually associated with much larger rivers. However, recent studies of winter stream flow and river icings in the Mackenzie Valley and Yukon Coastal Plain indicate that flow can be maintained in the permeable sediments beneath the channels of very small streams (e.g. Pipeline Applications Assessment Group, 1974, p. 229—32,310; VAN EVARDINGEN, 1975). In places, these taliks must be continuous since they supply springs which serve as fish over-wintering areas.

Similar taliks may have existed, therefore, beneath the stream channel of this particular tributary valley on Banks Island. Their development was favoured by the permeable nature of the valley infill materials while the progressive lateral movement of the stream led to their freezing and the formation of the pingo-like ridges.

DISCUSSION

Features similar to those described in this paper have not been reported with any frequency from elsewhere in the Western Arctic. However, PISSART (1967, p. 201—14) has described several pingo-like ridges which occur in stream valley situations on Prince Patrick Island, and both PORSILD (1938, p. 47—48), STAGER (1956, p. 15—16), and MACKAY (1963, p. 89—93) mention the existence of linear pingo-like forms which resemble eskers in Alaska and the modern Mackenzie Delta. Some, or all of these features may be of the same origin as that proposed for the Sachs River pingo-like ridges.

The most comparable features to the pingo-like mounds of the Bernard River locality have been reported from northern Norway (SVENSSON, 1964) and from Finnish Lapland (SEPPÄLÄ, 1972). In both case, shallow circular, semi circular and elongate ridges of similar dimensions to those described in this paper have been interpreted as remnants of collapsed pingos. However, both the Lappish and Norwegian forms are believed to have originated as open system pingos and are rather different in origin, therefore, to those of the Bernard River.

Several questions remain unanswered concerning the pingo-like forms described from Banks Island. The age of the features is unknown but, given the dominance of collapsed forms, it seems reasonable to assume that they are inactive. In north central Banks Island, C-14 dating suggests that pingo-like forms located on low terraces within the Thomsen River and Able Creek valleys developed between 3500 and 5000 years B. P. (FRENCH, 1976; PISSART and FRENCH, 1976). This period coincided with the latter part of the climatic amelioration which took place in the western Arctic between 8500 and 4000 years B. P. At that time thaw depths would probably have been greater than today and taliks would have developed in situations where none presently exist. A similar age may be appropriate for the forms described in this paper.

The exact mechanism of growth of the features is also unknown. The pingo-like forms clearly differ in morphology and geomorphic setting from classic Mackenzie Delta type pingos. Wheter the four stage mechanism of pingo growth, as suggested by MACKAY (1973, p. 996—1000), involving a change from pore ice, through segregated ice to injection ice and rupture of the pingo, is applicable to the Banks Island features remains to be determined. Detailed crystallographic and chemical analyses of the ice cores is required.

CONCLUSIONS

The features described in this paper may be regarded as end members of a form spectrum which ranges from small, circular mounds through to large, elongate and linear ridges. These features differ from the much studied Mackenzie Delta type of closed system pingo mainly in terms of their irregularity of form and their geomorphic locations. They are thought to result from the peculiarities of fluvial and hydrological conditions in regions underlain by thick permafrost. The existence of such forms in present periglacial environments may help in the understanding of some of the elongate and complex pingo-like remnants which are found in certain of the Pleistocene mid latitude periglacial environments (e.g. PISSART, 1965; SPARKS, *et al.*, 1972; WATSON and WATSON, 1974).

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