UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

EOLIAN SAND AND INTERBEDDED ORGANIC HORIZONS AT KEALOK CREEK ON THE ARCTIC COASTAL PLAIN OF ALASKA: POSSIBLE REGIONAL IMPLICATIONS

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Menlo Park, California

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature

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INTRODUCTION

Eolian sand has long been recognized as a widespread but minor facies of supposedly dominantly marine sediments of the Gubik Formation of the Arctic Coastal Plain (Smith and Mertie, 1930; Black, 1951 and 1964; O'Sullivan, 1961). Descriptions of eolian landforms of the coastal plain have been published by several authors, including Black (1951), Rickert and Tedrow (1967), and Walker (1967 and 1973). Many of the dunes discussed by these authors are associated with modern floodplains. Black (1951), however, outlined an area of stabilized longitudinal, parabolic, and multicyclic dunes occurring over an area of 12,950 sq km west of the Colville River, which includes the area discussed in this report. Black (1951, p. 93) characterized the dunes as being most abundant on crests of ridges and other topographic irregularities, and pointed out that they are commonly associated with the cut banks of large lakes and streams. He described the longitudinal dunes as generally less than 1,000 m long, but as much as 2,500 m in length and stated that they "...appear to be only a few feet thick, although some may be as much as 10 to 20 feet thick." Field investigations during the summer of 1977 on the Arctic Coastal Plain (Williams and others, 1977) disclosed that, over at least a portion of this area, the ridges upon which the small dunes described by Black are superimposed, and the cut banks associated with the dunes, consist of eolian deposits that comprise the major part of the Gubik Formation.

This report describes a particularly good exposure of thick eolian sand that occurs along Kealok Creek (fig. 1), and discusses possible implications of this exposure and associated landforms for the geomorphic and climatic history of a portion of the Arctic Coastal Plain, and for previous interpretations of features visible on Landsat imagery of this region. The

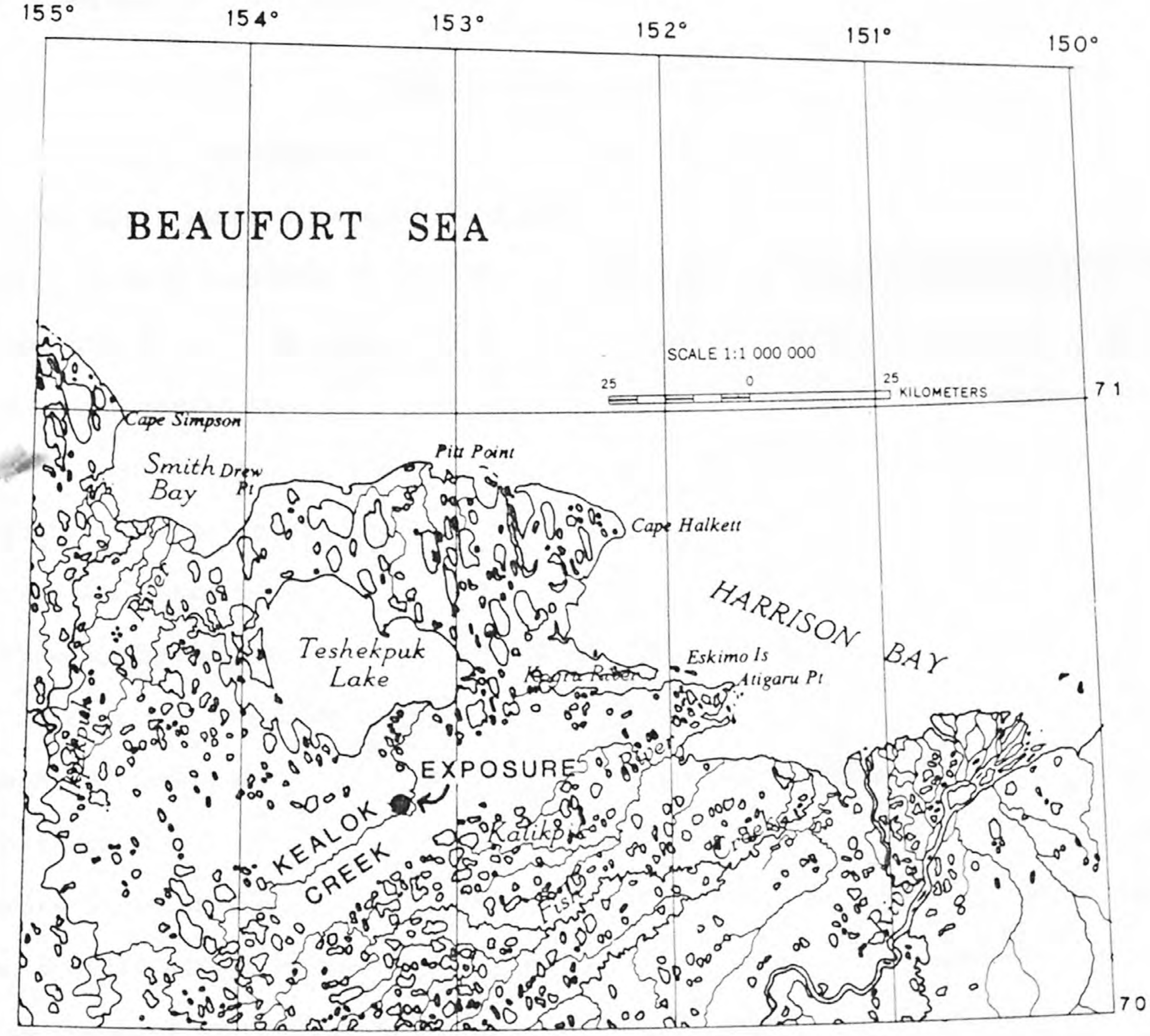


Figure 1. Location of the Kealok Creek exposure (153°12.3'W, 70° 22.3'N, Teshekpuk B-1 quadrangle, T.12N., R.5W., Sec. 29).

interpretations presented herein represent progress to date on one aspect of a continuing field and laboratory investigation of the Quaternary history of a portion of the Arctic Coastal Plain.

KEALOK CREEK LOCALITY

An excellent exposure of sand of the Gubik Formation occurs along Kealok Creek about 8 km south of Teshekpuk Lake (fig. 1). The terrain in this vicinity consists of low, broad, and generally elongate hills that rise from 20 to 30 m above intervening troughs to elevations of from 35 to 50 m, and are aligned in an ENE-~~S~~WSW direction. Thaw lakes are numerous in the troughs, and some of the lake shores cut into the hills to produce bluffs a few meters in height. Kealok Creek is incised from 3 to 10 m below the level of the trough floors. The exposure occurs where the creek turns northward and transects one of the low hills.

From the creek bed to the crest of the hill, 27 m of clean, pebble-free sand and interbedded woody zones and peat beds are exposed (fig. 2). Strong northeasterly winds in places have scoured the bluff revealing well preserved cross-stratification in the lower 17 m of the exposure. Bones of small mammals occur scattered over the surface in this interval, and presumably are lag deposits left after deflation of the bluff face. The remains of marine or fresh water organisms were not observed. The upper 10 m (fig. 3) contains two woody zones and two peat layers that are separated by clean sand and capped by 2.5 m of sand that contains abundant remains of tundra plants. Because the organic horizons are more resistant than the clean sand, they stand out in relief on the bluff face, and form the floors of blowouts that occur along the top of the bluff.

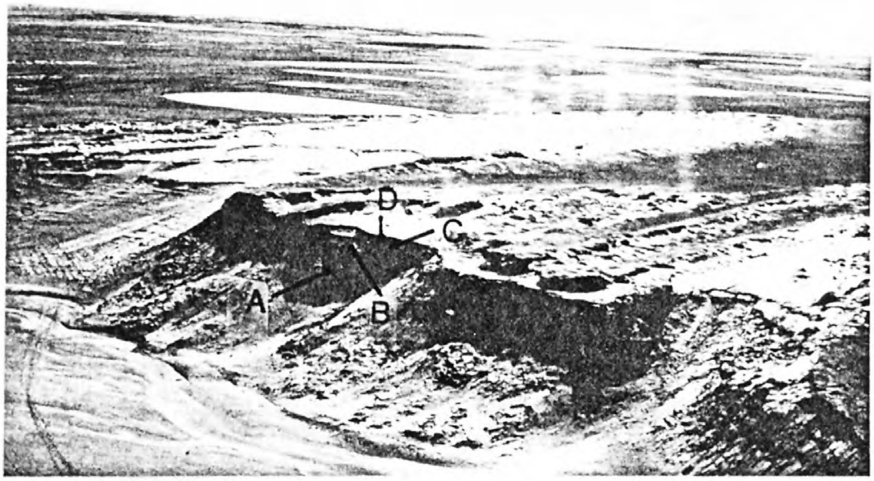


Figure 2. Aerial view of eolian sand and organic horizons exposed along Kealok Creek. The exposure is approximately 27 m in height. Note cross-bedding in the lower part of the clean bluff face on the left. Exhumed organic horizons form the steps in the large blowout and lie in shadow in the central part of the bluff. Positions of sampled organic horizons indicated by letters.

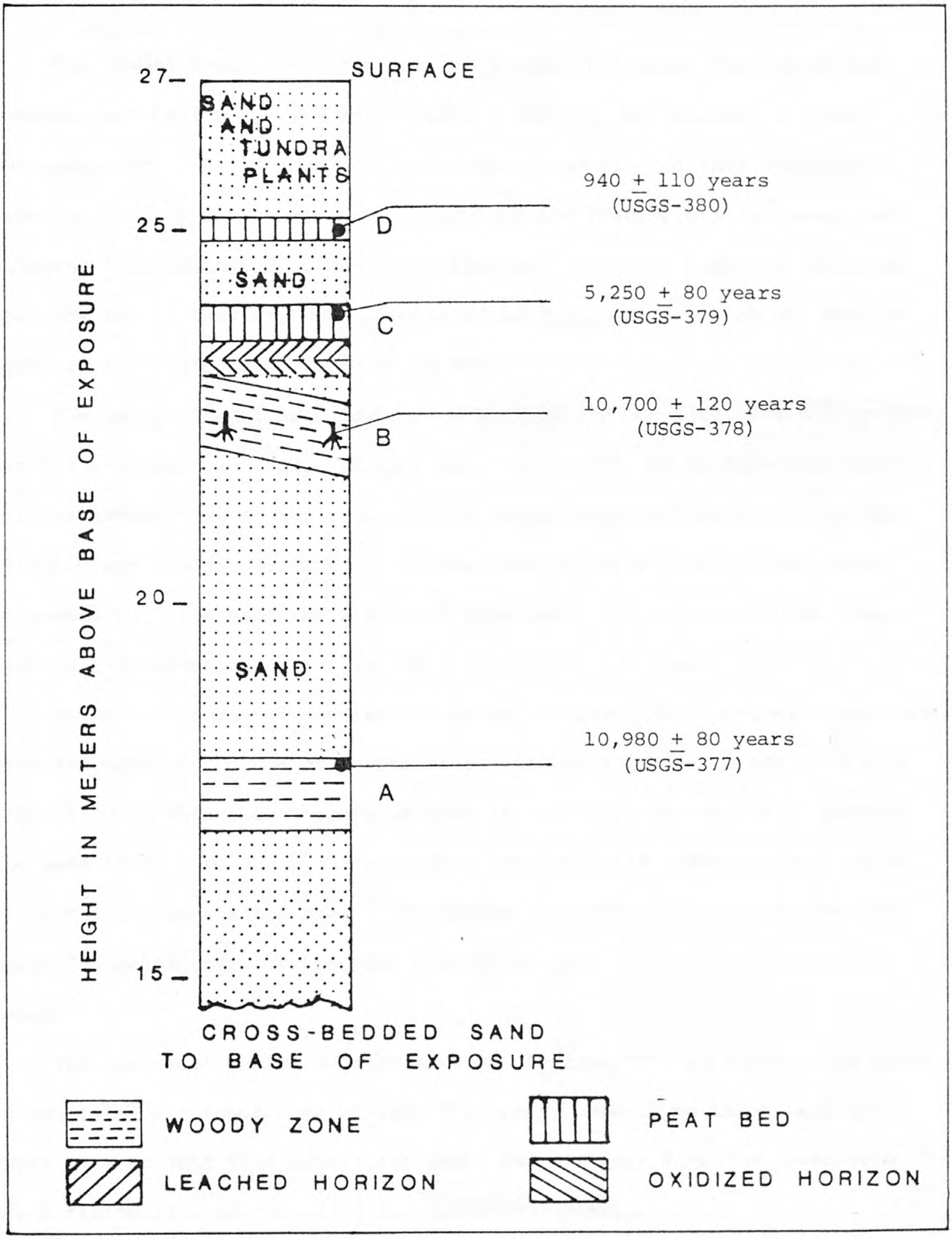


Figure 3. Stratigraphy of the Kealok Creek exposure.

The lowest organic-bearing horizon occurs 10 m below the top of the exposure and is 1 m thick ("A" of figs. 2 and 3). It consists of about 90% sand, but contains abundant horizontal to gently inclined twigs and roots up to 4 cm in diameter which commonly are in discrete horizons, and abundant dark laminae of finer plant remains. One wood fragment collected near the top of this unit was identified as Salix sp. (R. Koeppen, written commun.) and radiocarbon dated at 10,980 ± 80 (USGS-377) years old (table 1).

The second lowest organic-bearing horizon ("B" of figs. 2 and 3) occurs about 4 m above the first, and is 1 to 1.5 m thick. It is like the lower horizon except that it is discontinuous, being truncated in places by the next highest organic horizon. A willow stump 5 cm in diameter was found in growth position near the middle of this unit, and a piece of the stump yielded a radiocarbon age of 10,700 ± 120 (USGS-378) years.

Organic horizon "C" consists of sandy, fibrous, fine peat with scattered wood fragments up to 0.4 cm in diameter. The dark reddish brown (5YR 3/3) peat is 50 cm thick, and occurs as much as 2 m above horizon "B". Beneath the peat is a 25 to 35 cm thick leached zone which is underlain by a 15 to 25 cm thick iron-stained zone. Radiocarbon analysis of a sample from the upper few centimeters of the peat yielded an age of 5,250 ± 80 (USGS-379) years.

The uppermost buried organic horizon (horizon "D") is about 30 cm thick. It consists of a lower zone of very fine peaty sand 15 cm thick, and an upper zone of sand with fibers and small twigs. Peat from the lower zone has a radiocarbon age of 940 ± 110 (USGS-380) years.

Large-scale cross-stratification, terrestrial mammal remains, and the presence of peat beds and woody horizons containing wood in growth position, coupled with the absence of pebbles, which are ubiquitous in fluvial and

Table 1. Radiocarbon ages of organic materials from the Kealok Creek exposure.

HORIZON	MATERIAL	LAB. DESIG.	AGE (years B.P.)
D	Peat	USGS-380	940 ± 110
C	Peat	USGS-379	5,250 ± 80
B	Wood (*Salix sp.*)	USGS-378	10,700 ± 120
A	Wood (*Salix sp.*)	USGS-377	10,980 ± 80

marine facies of the Gubik Formation, and the lack of fresh water or marine faunal or floral remains, indicates that all of the sand in this section is eolian in origin. This hill is thus interpreted as a dune, and other, similar trending ridges in the Kealok Creek vicinity also are interpreted as dunes.

REGIONAL GEOMORPHIC INTERPRETATION

Terrain with the characteristics described above for the Kealok Creek vicinity extends from the southern tip of Teshekpuk Lake southward for 75 km to Price River, and from near the Kogasukruk River westward at least 110 km to beyond the Ikpikpuk River (fig. 4). Black (U.S. Geol. Survey unpub. field notes) recognized ENE-WSW trending hills in this area despite the low relief, gentle slopes and ubiquitous thaw lakes that obscure the pattern. Farther west ENE-SSW trending ridges are especially difficult to detect, but pebble-free sand is widespread and small parabolic dunes are present at least as far as 25 km west of the Meade River (Black, 1951; Williams and others, 1977).

The geomorphic development of this region is of more than local interest because this terrain has been proposed as a terrestrial analog for Martian fretted terrain (Gatto and Anderson, 1975). Linear and curvilinear geomorphic features of this area, including the thaw lake pattern, previously have been attributed to structural control (Rosenfeld and Hussey, 1958; Fischer and Lathram, 1973; Lathram and others, 1973), and, most recently, to tectonism (Maurin and Lathram, 1977).

Structural control of ENE and WNW trending reaches of the Ikpikpuk River was suggested by Rosenfeld and Hussey (1958), and NE-SW trending regional lineations were identified by Fischer and Lathram (1973) on Landsat imagery. Fischer and Lathram (1973, p. 98) noted that, "The lineations are expressed as: (1) straight

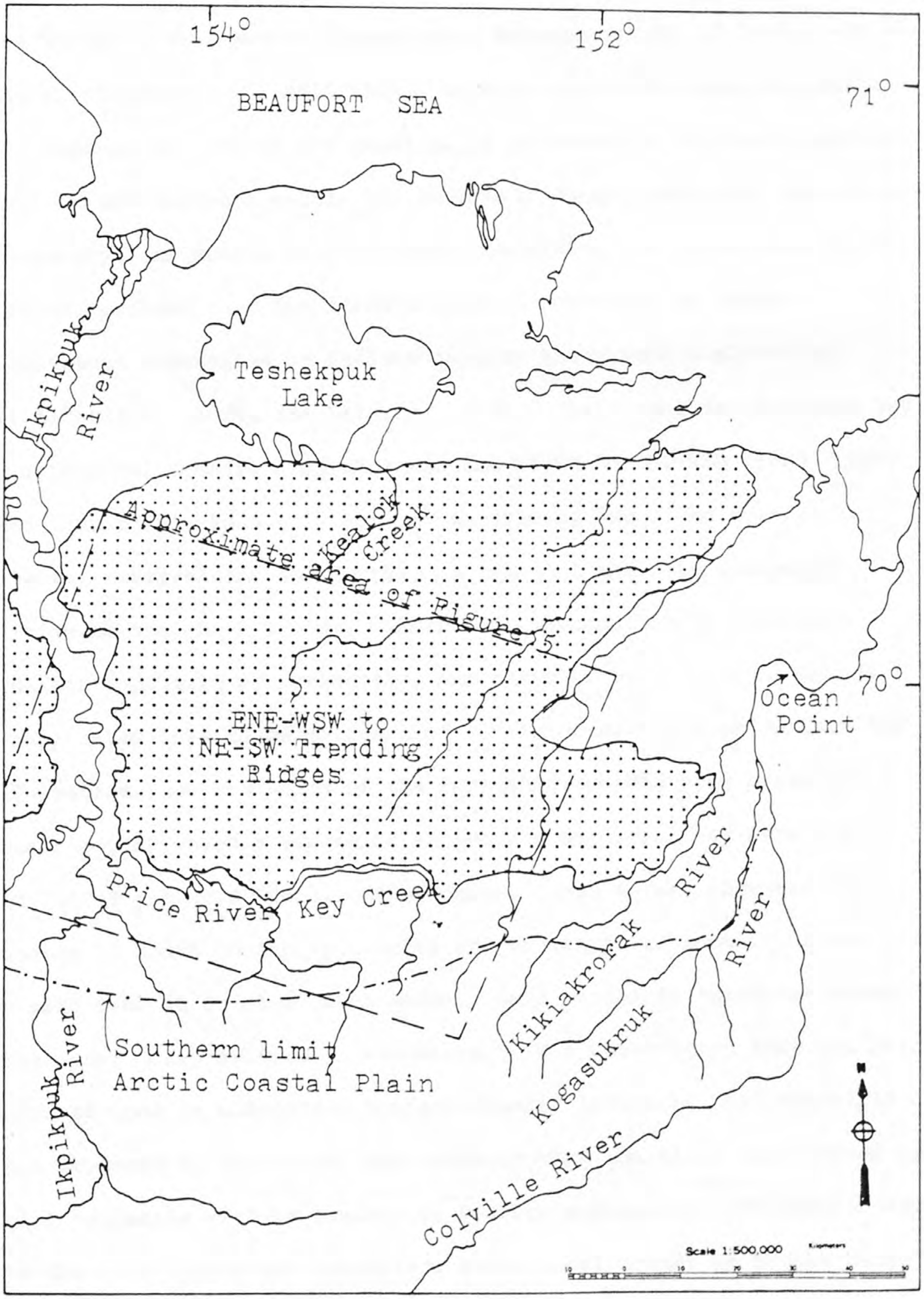


Figure 4. Extent of terrain characterized by ENE-WSW and NE-SW trending ridges.

nearly east-trending alignments of small lakes, of distortions in the shorelines of larger lakes, and of linear areas between groups of lakes; and (2) curvilinear alignments of small lakes, locally enclosing large elliptical areas." Because the trends are parallel or sub-parallel to known geologic structure in the northern margin of the Brooks Range foothills, and to subsurface geophysical trends of the region containing the lineations, Fischer and Lathram proposed that the lineations are controlled by bedrock structure.

Lineations observable on Landsat imagery later were analyzed by several methods by Maurin and Lathram (1977). Their analyses detected two nearly orthogonal trends; a NW-SE trend and NE-SW to ENE-WSW trend. They proposed that both trends are tectonic in origin, but noted that it is possible to interpret the NW-SE trend in terms of the lake elongation. In addition to the above trends, Maurin and Lathram thought that they could detect a pattern of crescentic, and circular or elliptical trends. They interpreted this to be evidence of a "mini-cuesta system" within the Gubik Formation. On the basis of the foregoing trends, they presented a structural map on which a system of anticlines and synclines were drawn.

In 1947 Black (U.S. Geol. Survey unpub. field notes) observed that, "Sand comes in south of Ikpikpuk delta and continues to south. As much as 180 ft sand over 20 ft clay (with sand). Sand varies in thickness according to topography. Clay uniform in elevation." The observation that the hills of sand rest upon an undeformed surface clearly indicates that the hills were not produced by tectonism, and suggests that the hills were formed by surficial processes with no control by bedrock structure. Any parallelism between the sand ridges and subsurface geophysical trends or Brooks Range structural trends must be coincidence.

An instructive image of the area under discussion is reproduced in figure 5. This reproduction is a portion of a Landsat-1 multispectral scanner (MSS), band 7 enhanced image (ID 1237-21353). Geometric corrections and a linear contrast stretch were carried out on the image by the Image Processing Laboratory of the Jet Propulsion Laboratory for the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (Gatto and Anderson, 1975). The image is a winter scene and was obtained under conditions of low sun angle and apparently uniform snow cover. The low sun angle accentuated the hills, which are difficult to discern on other Landsat imagery because of low relief and gentle slopes. Owing to ice and a uniform snow cover, the numerous thaw lakes, which formed an integral part of the black-white discriminatory analyses of Maurin and Lathram (1977), are not visible and thus do not interfere with a visual assessment of the hill patterns. Thaw lake basins, however, are sharply portrayed.

East of the Ikpikpuk River, and north of Price River and Key Creek, the most striking features of the image are abundant ENE-WSW trending ridges up to 20 km in length and 1 km wide. Also apparent are numerous shorter, NE-SW trending ridges. Reference to U.S. Geological Survey topographic maps at a scale of 1:63,360 shows that the ridges range up to 25 m in height.

In order to analyze the ridge pattern, a map of the ridges (fig. 6) was made from the Landsat imagery. Then, the orientation and length was measured of each of the 302 mapped ridges. For each 5 degree increment, beginning at 0 degrees, the total ridge length for ridges with orientations within that increment was computed. For example, the lengths of ridges with orientations within the azimuths 0° to 5° were summed, etc.

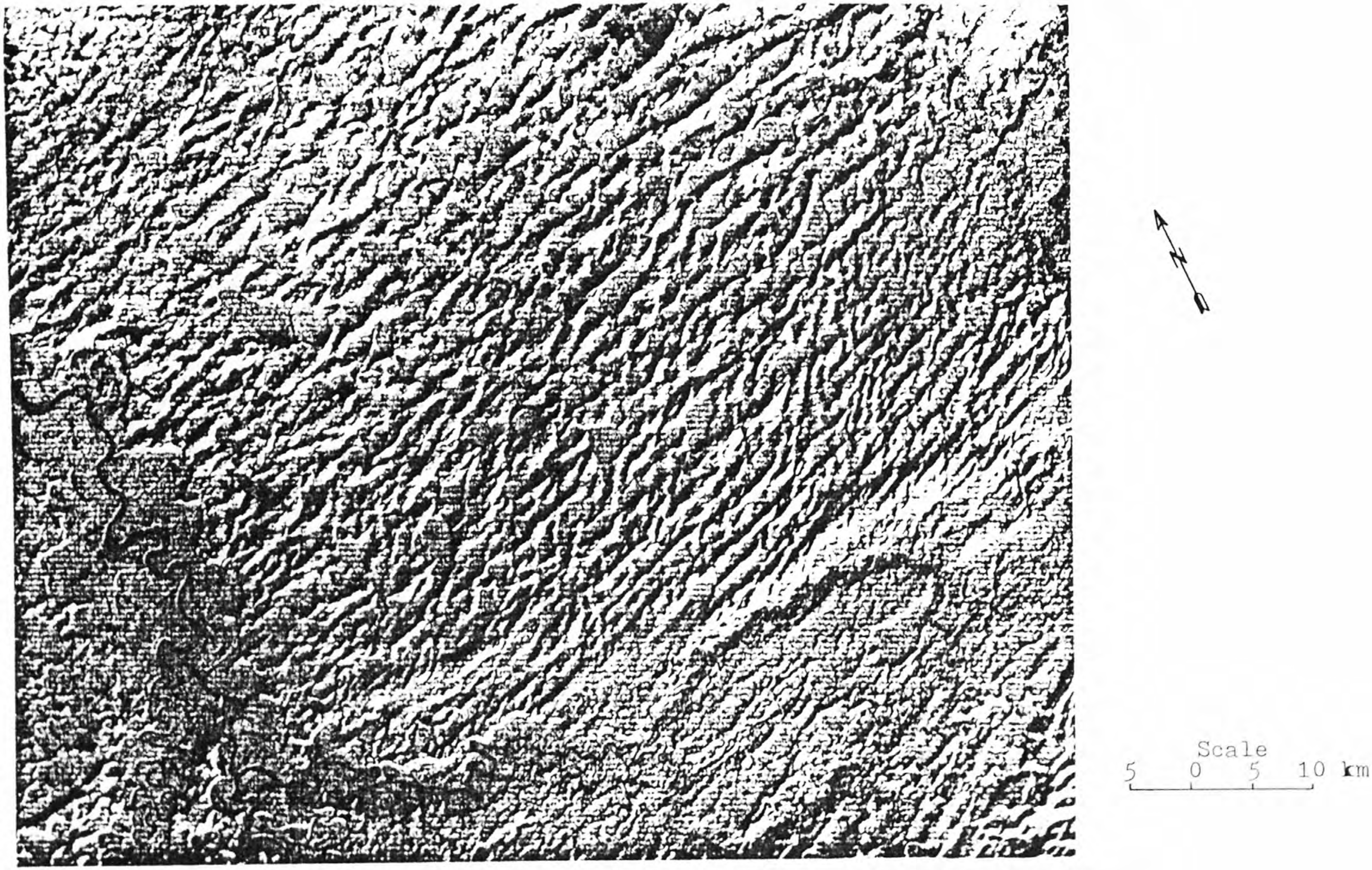


Figure 5. Landsat-1 multispectral scanner (MSS), band 7 image (ID1237-21353) of a portion of the area under discussion (see fig. 4 for location of image and names of rivers).

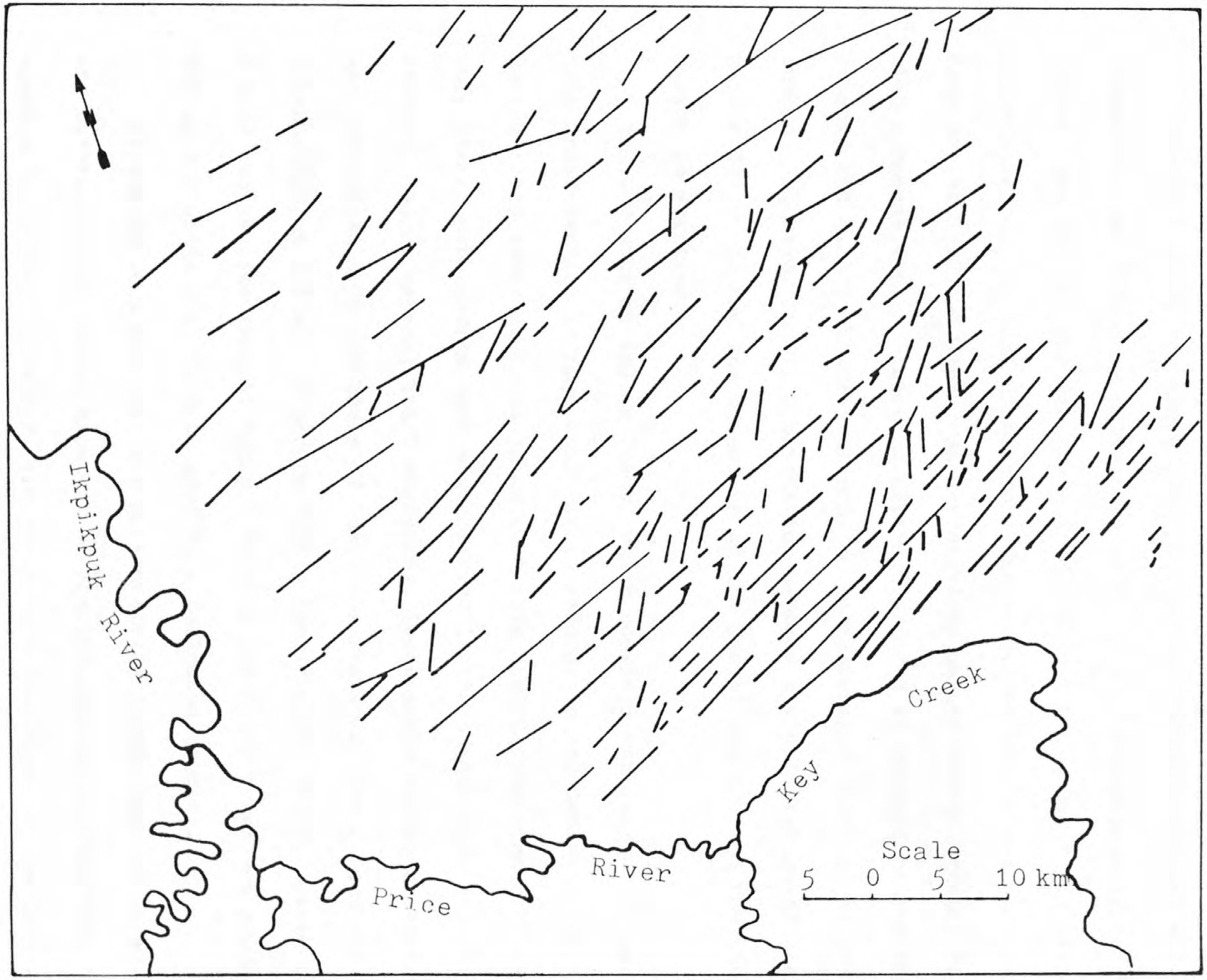


Figure 6. Map of 302 ridges visible in the Landsat image of figure 5.

The results of these summations are given in table 2, and presented as a histogram in figure 7. The dominance of ridges with ENE-WSW orientations is apparent in the histogram.

Figure 8 shows the above data plotted as a polar histogram and presents polar frequency histograms of daily wind directions at Barrow, Alaska, the nearest weather station on the Arctic Coastal Plain with continuous records of wind direction. The frequency histograms were taken from Moritz (1977). Other weather stations on the Arctic Coastal Plain with comparable wind direction data are located at Wainwright and Barter Island, and each indicates easterly to northeasterly winds to be the most common (Selkregg, 1975). Correlation between the orientation of the dominant ridge trend and the direction of the prevailing ENE and WSW winds at Barrow is striking.

The exposure at Kealok Creek, which consists entirely of eolian sand, is a cross-section through a hill that belongs to the dominant ridge trend. During field investigations throughout this area in the summer of 1977, only clean, pebble-free sand was observed in the upper 20 to 30 m of the section, and at several fresh exposures, large-scale eolian cross-bedding was identified. On the basis of these observations, the ridges are interpreted as a field of predominantly longitudinal dunes, formed under a wind regime like that of today. Whether the major trend was produced by ENE or WSW winds will be discussed in a following section.

It should be noted that the northwesterly trend observed by Maurin and Lathram (1977) is not apparent in the orientation of thaw lake basins visible in figure 5. Rather, the occurrence and shape of the thaw lake basins is largely constrained by dunal morphology. Many modern thaw lakes, which are not visible in the image due to ice cover, do, however, exhibit

Table 2. Total ridge length per 5 degree increment of orientation.

Azimuth	Number of Ridges	Total Length (km)
0° to 5°	0	0
6° to 10°	0	0
11° to 15°	0	0
16 to 20	8	18.72
21 to 25	8	19.26
26 to 30	12	26.11
31 to 35	18	33.14
36 to 40	18	41.64
41 to 45	18	41.46
46 to 50	16	47.02
51 to 55	17	47.79
56 to 60	24	87.01
61 to 65	50	155.49
66 to 70	46	191.41
71 to 75	42	158.09
76 to 80	14	81.80
81 to 85	7	40.36
86 to 90	3	20.72
91 to 95	1	7.96
96 to 100	0	0
	302	1017.78

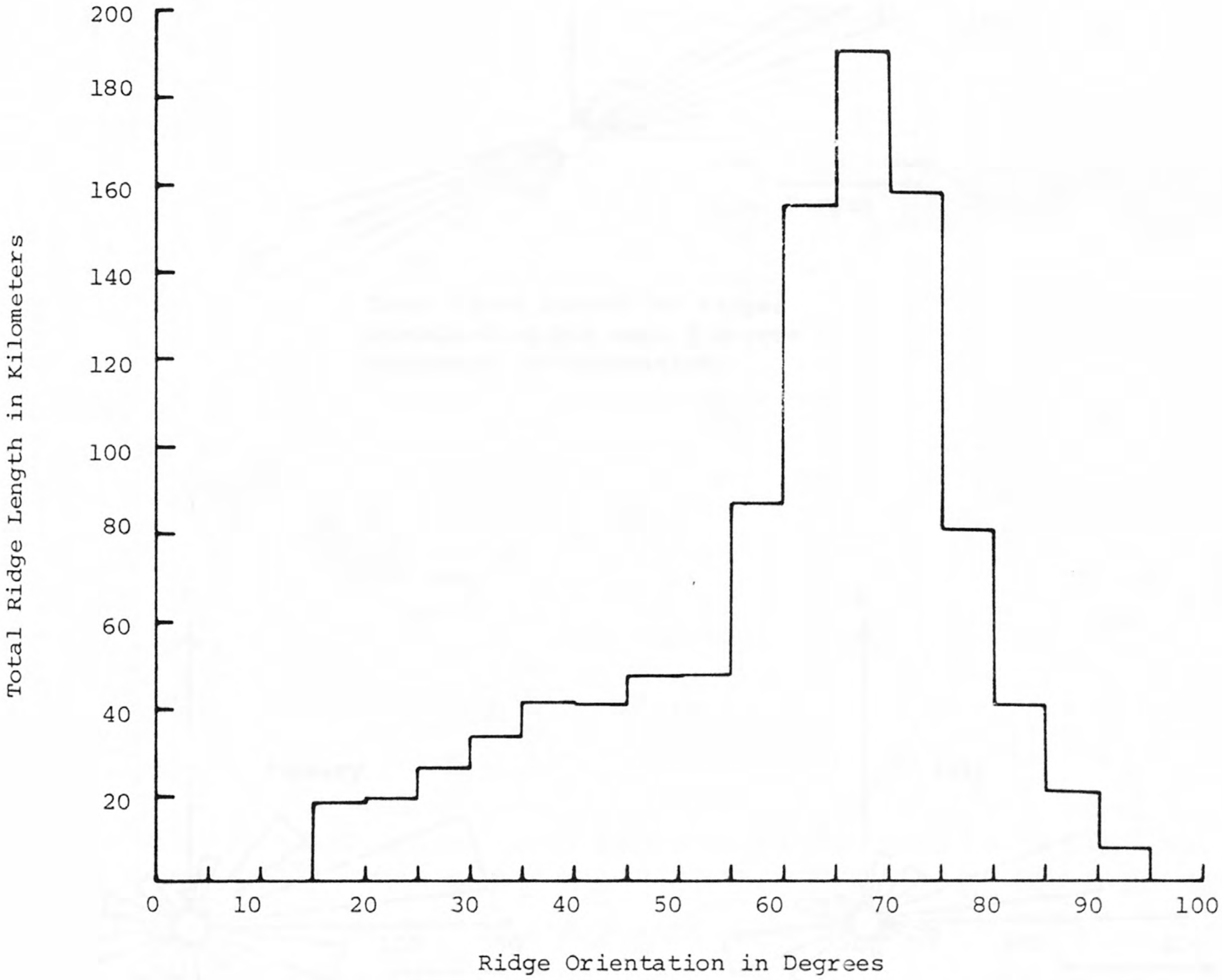
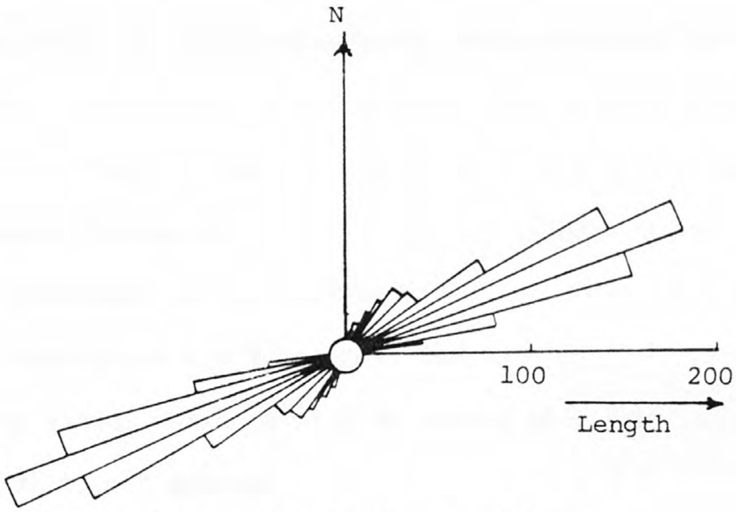
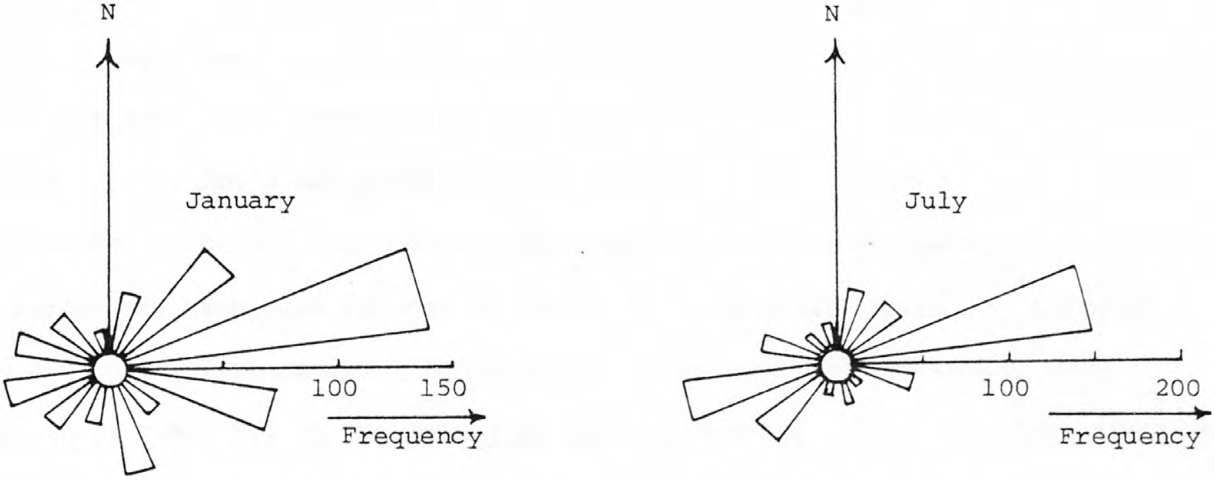


Figure 7. Histogram of ridge length sums. The top of each bar represents the total length of ridges that have orientations within that particular 5 degree increment.



Total ridge length for ridges contained within each 5 degree increment of orientation.



Polar frequency histograms of daily wind directions at Barrow for January and July (from Mortiz, 1977). Derived from 600 daily observations, 1955 through 1974. Length of cell determined by number of daily observations.

Figure 8. Ridge length and orientation in the area of study and wind directions recorded at Barrow, Alaska.

a weak northwesterly elongation (Sellmann and others, 1975), and this is doubtless the cause of the northwesterly trend detected by Maurin and Lathram (1977). Elongation of the modern lakes without elongation of the basins containing them is perhaps explainable by the fact that some of the thaw lake basins visible in figure 5 contain several lakes. Once a lake occupying an interdune trough shrinks or is partially drained, the original topographic constraints are lessened. Then, elongation perpendicular to the prevailing winds, which is part of normal thaw lake development (Carson and Hussey, 1962), can proceed.

DISCUSSION

Radiocarbon dates for the Kealok Creek exposure clearly indicate the following:

(1) 5 m of net accretion of sand about 11,000 years ago;

(2) minor net accretion (about 1 to 2 m) between 11,000 and 5,000 years ago; and

(3) 4 m of net accretion in the past 5,000 years.

These relationships may prove to be of only local significance. Additionally, the record at Kealok Creek may not be complete, because one or more organic horizons may have been removed by deflation, especially during the interval 10,600 to 5,000 years ago. In the light of the regional geomorphic relationships described in the preceding section, however, they allow the interpretations presented below, which provide reasonable working hypotheses of regional landscape development during latest Wisconsinan and Holocene time. These hypotheses can be readily evaluated during field studies this summer and by further radiocarbon dating in the fall and winter.

The Dune Field

Prior to 11,000 years ago, the ridge now transected by Kealok Creek was an active longitudinal dune near the northern edge of a large dune field. By 11,000 years ago, climate had ameliorated enough, or dune activity had subsided enough, or both, to allow at least local growth of willows in the dune field. Kealok Creek and other streams that now originate within the area of stabilized dunes did not exist while the dunes were active.

Sometime between 11,000 and 5,000 years ago, the dune at Kealok Creek was stabilized and the peat of horizon "C" (fig. 3) developed. Leached and oxidized zones beneath the peat suggest that this interval was lengthy. The 5,000 year age is a maximum for cessation of development of the peat, because, if a thin peat represents a considerable interval of time, any sample of the peat will include organic material of a wide age range. A sample from the base of the peat is now at the radiocarbon laboratory and will provide a minimum age for stabilization of this dune.

Thaw lake development doubtless commenced at the onset of dune stabilization. Interdune ponds may have been present while the dunes were active, but a large system of active dunes could not have coexisted with the numerous thaw lakes that now occur. Additionally, thaw lake erosion has cut bluffs into the dune ridges, clearly indicating that thaw lake development postdates the major episode of eolian acitivity.

Drainage development also did not begin until after stabilization of the dunes. Field observations and air photo and map interpretation suggest that the first step in the development of many streams in this area was the formation of drainageways between thaw lakes and subsequent drainage of the lakes. In any case, a major stream like Kealok Creek may have developed slowly. The 5,000 year age for the upper part of the peat of horizon "C" could be interpreted as an indication of the time when Kealok Creek became established close enough to the site for sand to be blown from the floodplain and marginal bluffs and be deposited on the dune ridge. With this interpretation, the upper 4 m of net accretion would have no regional significance, as this interval would merely represent bluff-top accretion.

Alternatively, the 5,000 year date could have regional significance. Because the date occurs within the hypsithermal phase of the Holocene, organic horizon "C" could be interpreted as a hypsithermal soil. Black (1951) proposed that small longitudinal and parabolic dunes which are superimposed upon the dunes described in this report were formed during a warm hypsithermal interval in which the active layer was thicker than now, soil moisture was lower, and blowouts were widespread. Peat formation, on the other hand, would suggest a warm, wet episode in which thaw lake development would presumably have been at its zenith. In this regard, Carson (1968) found that relict regressive strand lines of thaw lakes near Barrow are generally less than 3,500 years old, and reported a date of 4,865 ± 150 (GX0084) years B.P. for a tundra mat buried during a transgressive lake phase. He suggested that maximum lacustrine expansion occurred near the end of the hysithermal, and that the initial period of draining coincided with neoglacial cooling. If this proves to be the case, the small parabolic and longitudinal dunes described by Black may be post-hypsithermal in age. An age of 3,840 ± 140 (I-1004) years reported by Rickert and Tedrow (1967) for an organic horizon buried beneath a small stabilized dune near the Ikpikpuk River may bear upon this, but it is not clear in their report that this dune belongs to the field of stabilized dunes that Black identified.

The 940 year age determination for the uppermost buried peat is equivocal. First, the upper 4 m of the section may have no regional significance, and, second, the peat, where collected, forms the floor of an active blowout and may have been recolonized several times. Thus, the peat could be much older than 940 years.

The time of initiation of the dune field and the duration and number of episodes of dune activity are unknown. The Late Wisconsinan and Holocene history hypothesized above may merely represent the latest episode of activation and stabilization of an ancient dune field.

The Dune-forming Winds

Earlier, it was established that the trend of the major ridges, which are longitudinal dunes, is ENE-WSW. The direction from which the sand came, and thus the direction of the prevailing winds, can be determined by examining the geologic map of Williams and others (1977). On this map, silt believed to be older than the dunes occurs at the surface over an extensive area WSW of the southern part of the dune field. Dunes do not occur on the silt. Southwest of the silt are rocks of the Brooks Range foothills. The sand could thus not have been derived from the southwest, and must therefore have come from the northeast. The most significant dune-forming winds must have been ENE winds like the prevailing winds of the present. A suitable sand source to the northeast is discussed below.

Paleoclimate and Sand Source

The climatic implications of extensive dune development and subsequent stabilization are uncertain. The dune field could be reactivated with the present wind regime simply by destroying the protective tundra vegetation. Several mechanisms for destroying the vegetation can be envisaged:

(1) fire

(2) long-term summer drought with current summer temperatures

(3) long-term increase in summer temperatures with precipitation remaining about the same as at present

(4) prolonged decrease in summer temperatures, coupled with a decrease in precipitation to produce a "polar desert" such as the High Arctic ecological region of the northern Canadian Arctic Islands.

Alternatively, a dune system could develop under the present climate without initial destruction of the tundra vegetation if an adequate source of loose sand were available. It is difficult to conceive, however, of how a suitable sand source could be produced under the present climatic and geographic conditions.

If the dune system does prove to be Late Wisconsinan in age, as suggested by radiocarbon dates for the Kealok Creek exposure, then the most likely conditions under which the dune system developed would be those of item (4) above. Under these conditions, there would be two possible sources for the sand:

(1) sand from the Gubik Formation

(2) the floodplain of the Colville River.

If sand of the Gubik Formation was the source for the dunes, then the area of exposed Gubik sediments east of the dunes and west of the Colville River (fig. 4) would have been a barren plain of deflation during latest Wisconsinan and earliest Holocene time. Inasmuch as the area of Gubik sediments that could serve as a source is considerably smaller than the dune field, deep deflation would be required.

Radiocarbon ages of peat exposed in the bluffs along the Colville River between the Kogasukruk River and Ocean Point (fig. 4) do indeed suggest that vegetation was sparse or lacking on the plain west of the Colville River during at least earliest Holocene time and perhaps for part of the Late Wisconsinan. The upper 2 m of the bluff deposits generally consists of buried peat about 0.5 to 1 m thick, overlain by about 0.5 m of silty sand, which is in turn overlain by as much as 1 m of peat. A radiocarbon analysis of a sample from the center of the buried peat near Ocean Point yielded an age of 8,180 ± 75 (USGS-184) years, and a sample from the base of the upper peat proved to be 2,280 ± 50 (USGS-185) years old. The buried peat rests upon fluvial and marine pebbly sands of the Gubik Formation that were deposited long before the Colville River cut down to its present level. The presence of early Holocene peat resting directly upon these deposits indicates that prior to formation of the peat the surface was either sparsely vegetated or previously existing vegetation was removed by erosion.

Deflation is a likely mechanism for erosion. Deep deflation, however, should have resulted in the development of a pronounced, ventifacted pebble-pavement as sand from the pebbly Gubik deposits was blown away. Such a pebble-pavement has not been observed at the base of the buried peat described above, and an additional sand source thus seems necessary.

During the Late Wisconsinan, the Colville River would have had a broad, barren, braided floodplain because of the high sediment load doubtless contributed by glaciers of the Brooks Range. Sand from exposed bars of the floodplain would have been swept up the Colville bluffs by easterly to northeasterly winds and carried across the plain at the top of the bluffs to accumulate as dunes. This ready supply of loose sand might have protected the Gubik deposits from deep deflation, and certainly would have prevented the growth of abundant vegetation. On this basis, sand from the Colville River floodplain is believed to be the major sand source for the dunes.

Regional Drainage

The presence of the dune field provides a ready explanation for otherwise anomalous drainage of the region. Streams within the dune field predominantly flow either ENE or NE, and these directions are clearly controlled by dune trends. Outside the dune field, Price River and Key Creek (figs. 4 and 5) leave the foothills, flow northward down the regional slope of the coastal plain for 10 km, then turn abruptly west. The westward deflection occurs at the southern edge of the dune field, which indicates that the streams were deflected by formation of the dunes.

Both of the above streams join the Ikpikpuk River, which flows northward and is joined successively by the Titaluk and Oumalik Rivers. The Ikpikpuk River may have been a barrier to dune migration, which would explain the weak development of dune ridges in a portion of the area west of the river. The present northerly course of the river does not reflect control by the dune field.

All of the above streams are incised from 18 to 25 m below the surrounding terrain, and this incision is recorded by a series of well preserved strath terraces that lack large dunes. Because the courses of Price River and Key Creek are controlled by the dune field, river incision post-dates dune field development. If the dune field is Late Wisconsinan in age as suggested by the radiocarbon dates for the Kealok Creek exposure, then the strath terraces would be Holocene in age, and should be datable by radiocarbon.

ACKNOWLEDGMENTS

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REFERENCES CITED

Black, R. F., 1951, Eolian deposits of Alaska: Arctic, v. 4, no. 2, p. 89-111.

_____1964, Gubik formation of Quaternary age in northern Alaska: U.S. Geol. Survey Prof. Paper 302-C, p. 59-91.

Carson, C. E., 1968, Radiocarbon dating of lacustrine strands in Arctic Alaska: Arctic, v. 21, no. 1, p. 12-26.

Carson, C. E., and Hussey, K. M., 1962, The oriented lakes of arctic Alaska: Jour. Geology, v. 70, no. 4, p. 417-439.

Fischer, W. A., and Lathram, E. H., 1973, Concealed structures in Arctic Alaska identified on ERTS-1 imagery: Oil and Gas Jour., v. 71, no. 22, p. 97-102.

Gatto, L. W., and Anderson, D. M., 1975, Alaskan thermokarst terrain and possible Martian analog: Science, v. 188, p. 255-257.

Lathram, E. H., Tailleur, I. L., Patton, W. W., Jr., and Fischer, W. A., 1973, Preliminary geologic application of ERTS-1 imagery in Alaska: Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1, V. II - Summary of Results, p. 31-38.

Maurin, A. F., and Lathram, E. H., 1977, A deeper look at Landsat-1 images of Umiat, Alaska: U.S. Geol. Survey Prof. Paper 1015, p. 213-223.

Moritz, R. E., 1977, On a possible sea-breeze circulation near Barrow, Alaska (correspondence); Arctic and Alpine Research, v. 9, p. 427-431.

O'Sullivan, J. B., 1961, Quaternary geology of the Arctic Coastal Plain, northern Alaska: Dissert. in partial fulfillment of requirements for Ph.D., Iowa State Univ. Sci. and Tech., Ames, Iowa, 191 p.

Rickert, D. A., and Tedrow, J. C. F., 1967, Pedologic investigations of some eolian deposits of northern Alaska: Soil Science, v. 104, p. 250-262.

Rosenfeld, G. A., and Hussey, K. M., 1958, A consideration of the problem of oriented lakes: Proc. Iowa Acad. Sci. 65, p. 279-287.

Selkregg, L. L. (ed.), 1975, Alaska Regional Profiles, Arctic Region: Univ. Alaska Arctic Environmental Inf. and Data Center, p. 19.

Sellmann, P. V., Brown, J., Lewellen, R. I., McKim, H., and Merry, C., 1975, The classification and geomorphic implication of thaw lakes on the arctic coastal plain, Alaska: USAE Cold Regions Research and Eng. Lab., Research Rept. 344, 21 p.

Smith, P. S., and Mertie, J. B., Jr., 1930, Geology and mineral resources of northwestern Alaska: U.S. Geol. Survey bull. 815, 351 p.

U.S. Geological Survey unpublished field notes in the files of Branch of Alaskan Geology, Tech. Data Unit, Menlo Park, CA by R. F. Black (F.N. #2003, p. 90, 1947).

Walker, H. J., 1967, River bank dunes in the Colville Delta, Alaska: Louisiana State Univ. Coastal Studies Bull. 1, p. 7-14.

_____1973, Morphology of the North Slope, p. 49-92, in Britton, M. E., ed., Alaskan Arctic Tundra: Arctic Inst. North America Tech. Paper 25.

Williams, J. R., Yeend, W. E., Carter, L. D., and Hamilton, T. D., 1977, Preliminary surficial deposits map of National Petroleum Reserve-Alaska: U.S. Geol. Survey open-file rept. 77-868, 2 sheets.

[illegible] and Hussey, K. M., 1956, A consideration of the problem of [illegible] lakes: Proc. Iowa Acad. Sci. 63, p. 229-237.

Selkregg, L. L. (ed.), 1975, Alaska Regional Profiles, Arctic Region: Univ. Alaska Arctic Environmental Inf. and Data Center, p. 19.

Sellmann, P. V., Brown, J., Lewellen, R. I., McKim, H., and Merry, C., 19 The classification and geomorphic implication of thaw lakes on the arctic coastal plain, Alaska: U.S. Army Cold Regions Research and Eng. La Research Rept. 344, 21 p.

Smith, P. S., and Mertie, J. B., Jr., 1930, Geology and mineral resources of northwestern Alaska: U.S. Geol. Survey Bull. 815, 351 p.

U.S. Geological Survey unpublished field notes in the files of Branch of Alaskan Geology, Tech. Data Unit, Menlo Park, CA by W. P. Black (F.N. 71003, p. 49; 1947).

Walker, H. J., 1967, River bank dunes in the Colville Delta, Alaska: Louisiana State Univ. Coastal Studies Bull. 1, p. 7-14.

______ 1973, Morphology of the North Slope, p. 49-92, in Britton, M. E., e Alaskan Arctic Tundra: Arctic Inst. North America Tech. Paper 25.

Williams, J. R., Yeend, W. E., Carter, L. D., and Hamilton, T. D., 1977, Preliminary surficial deposits map of National Petroleum Reserve-Alaska: U.S. Geol. Survey open-file rept. 77-868, 2 sheets.