

A VEGETATED DUNE FIELD IN CENTRAL ALASKA

By

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SUMMARY

A 4,800 mi² dune field occupies lowlands in central Alaska in a roughly triangular area between the lower Nowitna River, Nenana, and the Alaska Range. The field can be divided into two tracts: (1) the Northwestern Tract, which extends 90 mi west-southwestward from the Tanana River and is separated from the Southeastern Tract by the Kuskokwim Mountains; (2) the Southeastern Tract, which extends southwest from the Tanana River and is 160 mi long and a maximum of 50 mi wide. The Southeastern Tract is subdivided by the Kantishna and Muddy Rivers into eastern, central, and southwestern areas. The field is composed mostly of parabolic and longitudinal dunes that are 10 to 150 ft high, 50 ft to 3 mi long, and 50 to 1,000 ft wide. The dunes are blanketed by loess and forested with birch or aspen; black spruce and muskeg cover the permanently frozen terrain between the dunes.

Sand from many dunes in the Southeastern Tract and from cutbanks of the Kantishna River was sampled; no organic matter, sand wedges, or ice wedges were found, and the sand is generally well sorted, light yellowish gray, and fine grained. It is composed of quartz and chert with some darker rock and mineral grains. Many samples contain a fine-silt-and-clay fraction that causes the distribution curve to be bimodal.

The eastern area in the vicinity of Dune Lake has a sharply defined sand sheet 50 mi long overlain by irregular transverse dunes that in turn are capped by rosettes, small arcuate dunes arranged concentrically in roughly circular groups about 1 mi in diameter. They seem to be caused by a combination of local and regional winds. The central area is the largest in area and in volume of sand and contains a few large transverse dunes as well as parabolic and longitudinal ridges; the southwestern area has only the latter.

Underlying deposits are exposed along the Kantishna River and consist of alluvial sand and silt underlain by gravel. Apparently contemporaneous with the aeolian sand are thick silt deposits on the northeast flanks of Bearpaw Mountain and of Castle Rocks, isolated hills that are southwest of the eastern area and south of the southwestern area of the dune field, respectively.

Shape, orientation, and distribution of the dunes and the silt deposits indicate deposition by wind from the northeast. The source of the sand is undoubtedly the Alaska Range, which furnished alluvium to the north-flowing tributaries of the Tanana River. Dune distribution also suggests a barren landscape near the Tanana River, with scattered clumps of vegetation farther from the source of the sand. Present evidence is consistent with the tentative conclusion that the dunes were deposited in late Wisconsin time.

A proposed agricultural development in some townships west of Nenana will disturb the thin vegetative and soil cover and may reactivate dune movement.

INTRODUCTION

Location

A large dune field in interior Alaska covers southwest-trending lowlands that occupy about 4,800 mi² in a roughly triangular area between the lower Nowitna River, Nenana,

and the Alaska Range (fig. 1). It can be divided into two major tracts separated by the northeastern part of the Kuskokwim Mountains. The Southeastern Tract extends about 160 mi southwestward from the Tanana River and has a maximum width of 50 mi. The Kantishna River drains most of its length, and the southwestern part continues into the basin of the Swift Fork of the Kuskokwim River. The Southeastern Tract is subdivided into an eastern area east of the Kantishna River, a central area west of the Kantishna and north of the Muddy, and a southwestern area to the south of the Muddy River. The Northwestern Tract is nearly 90 mi long and has a maximum width of 30 mi. It extends from the Tanana River west-southwestward to the Nowitna River, which is west of the Fairbanks mapping meridian in the Kateel River meridian area. The Northwestern Tract was not visited on the ground.

Except for one small active blowout at Dune Lake (T. 6 S., R. 12 W., map sheet), the dunes are completely vegetated, and the outline of the dune field as shown on the map is based on the distribution of dune ridges visible on vertical aerial photographs (scale approximately 1:40,000).

Field work

Most of the dune field has been viewed from a small plane, and many dunes in the Southeastern Tract were examined on the ground in 1956. Sections through the dunes exposed in cutbanks of the Kantishna River were examined in 1981.

The dunes first came to the attention of Florence Weber and me shortly after we came to Fairbanks, Alaska, to work for the U.S. Geological Survey Navy Oil Unit. On vacations and weekends we flew our small 2-place plane to Lake Minchumina and elsewhere in the territory and were attracted by the unusual ridged patterns of the terrain between Nenana and the lake. Preliminary study of aerial photographs was followed by a summer of field work in 1956, using a plane on floats for transportation. In 1957, Lake Minchumina became my permanent home, and I have had continuing opportunities to study the winds, weather, and dunes of central Alaska.

Information on dune composition was obtained for the most part from pits dug in the crests of the dunes we visited; that location was chosen so that samples would be comparable from one dune to another and would be relatively unaffected by slumping or other local disturbance. Silt deposits were sampled near the tops of hills for the same reasons. A few pits were nearly 3 ft square and more than 4 ft deep; the rest were about 2 ft square and 2 ft deep, with an additional 5 ft of depth sampled by means of a soil auger. The sediment sequence was measured and described, and samples were taken at various depths to be sieved for grain-size determination (tables 1-7).

Unless designated "K.R.M." for Kateel River meridian, all township and range data refer to the Fairbanks meridian.

Acknowledgments

This study would have been impossible without the help of Florence R. Weber from the U.S. Geological Survey and of my husband, Richard H. Collins, who shared in the geologic field work and in interpreting the data gathered. The interest of Mr. Joseph T. Flakne and other members of the Arctic Institute of North America resulted in some financial support for the early work. More recently, the interest and

encouragement of David M. Hopkins resulted in collection of more field data and the final preparation of this report. Henry Bender and Charles L. Powell II of the U.S. Geological Survey contributed time and effort to making the numerous sieve analyses in 1956 and 1981, respectively. Other geologists and co-workers of the U.S. and State Geological Surveys have also been very helpful, sharing relevant facts and theories on the subject of Alaskan sand dunes. W. M. Geertz of Shell Oil Company loaned the aerial photographs from which figure 2 was derived.

DUNE MORPHOLOGY

The dune field ranges in elevation from 400 ft to nearly 1,200 ft above sea level. Isolated bedrock hills projecting above 1,200 ft are generally free of dunes, although sand ridges cross many lower hills. Most of the dunes are parabolic; individual dunes have arms of unequal length that are slightly convex away from the dune axis. They usually meet at an acute angle to form the southwest end of the dune, although a few dunes have broad U-shaped apices. Individual arms may be less than 50 ft to 3 mi long, 10 to 150 ft high, and 50 to 1,000 ft wide. The sides of the arms slope equally steeply to the northwest and southeast, generally approaching the angle of repose for sand; the southwest slope of the apex is generally somewhat steeper than the sides. A cross section through a typical arm would have the profile of an abrupt, rather steep, rounded hill. In some cases (such as Carlson Lake, T. 13 S., R. 22 W.), the apex of the dune has been breached, leaving a narrow gap between the arms. Examples of small dunes enclosed by the arms of a large parabolic dune are very rare.

Longitudinal (windrift) dunes are less common than parabolic ones, but resemble them very closely except for lacking the accompanying arm. Their long axes parallel the axes of parabolic dunes, and the axes of neighboring dunes are parallel. Although there are slight and gradational variations of a few degrees in the orientation of dune axes from place to place, the axes are remarkably similar throughout each tract, being about southwest in the Southeastern Tract and west-southwest in the Northwestern Tract.

In much of the Northwestern Tract and the north half of the central area, the parabolic dunes overlie large sand ridges that resemble transverse dunes, but that strike north at a 45° angle to the axes of the parabolic dunes. They are described in the section on the central area.

True transverse dunes are rare, and most of them are located near the Tanana River. They may also be present near Dune Lake in association with the unique rosette dunes. The latter, which are described in more detail in the rosette section, are roughly circular groups of small arcuate dunes that top the crests of what appear to be irregular transverse dunes (fig. 2).

DIRECTION OF SAND TRANSPORT

The distribution, size, and shape of the dunes nearly all indicate deposition by a wind from the northeast. The most massive deposits and the transverse dunes are close to the Tanana River, and the dune deposits diminish to scattered small ridges to the southwest. There is commonly a lack of dune-sand deposits on the southwest, wind-shadow side of isolated bedrock hills. The steepest sides of the dunes face southwest, as do the apices of the parabolic dunes.

VEGETATION

A very noticeable feature of the parabolic and longitudinal dunes is the difference in vegetation between the ridges and the interdune areas. The well-drained dune crests support birch, aspen, white spruce, herbs, and shrubs, and lichens are found along crestline animal trails. The interdune areas, both between dunes and between dune arms, are commonly covered with scrubby, small, black spruce and have a muskeg ground cover and permafrost at or near the surface. The contrast is especially striking in the autumn, when leaves of the deciduous trees are gold against the evergreen background.

STRUCTURE AND COMPOSITION

Because the Northwestern Tract was not visited on the ground, discussion in this section applies only to the Southeastern Tract.

The dune sand contains no organic matter or interstitial cementing material; its color, as determined from the Rock-color Chart (Goddard, 1948), is usually a light yellowish gray, and apparently comes from the grains themselves, which are clear, white, or yellowish quartz and chert with some darker grains of chert and other rocks and minerals. Sieve analyses show that most of the sand is well sorted and fine grained. The small fraction below 40 (0.0625 mm) was divided in the dune-crest samples into coarse silt and fine-silt-and-clay fractions; many samples had more of the finest material than of the coarser silt, resulting in bimodal distribution.

Permafrost was absent in every dune crest sampled, and none was visible in any exposures of dune sand in cutbanks of the Kantishna, Toklat, and Foraker Rivers. No ice or sand wedges were noted.

Eastern area

Sand exposed in pit walls in the eastern area was light yellowish gray, uniform, and massive. At the surface of the small blowout dune at Dune Lake the sand is grayish yellow, and in the Toklat River and Kantishna River bluffs it is light yellowish gray. Sand samples from the upper part of the pits are consistently slightly finer grained than those from 4- to 5-ft depths. Horizontally, however, sieve analyses show no clear pattern (table 1). Samples from Dune Lake, the Toklat River, and the bluffs at site 3 are all better sorted (with fine sand dominant) than those from Black Bear and Cabin Lakes farther east. However, these comparisons may not be of great value: the Dune Lake sample is from the surface of the sand, Black Bear and Cabin Lake samples are from depths of 4 to 5 ft below the dune crest, and the Toklat and site 3 samples are from 20 to 100 ft below the surface; the relation of the Toklat and site 3 samples to the dune crests is unknown.

Central area

The only place in this area where crossbedded dune structure is exposed is the large bluff near the mouth of the Kantishna River (T. 2 S., R. 12 W.) called site 6 in this report. This bluff is about 200 ft high and more than a half mile long. The upper 50 ft consists of beds of sand that dip 10° south. The base of this interval has a sharp, horizontal contact with underlying sand beds that dip about 5° south. About 30 ft of the latter are exposed, but the base is covered, and only a few patches of silty sandy material are exposed in the lower part of the bluff. The upper part of site 4 (T. 6 S., R. 15 W., table 2) is probably dune sand, but it is poorly exposed and lacks crossbedding. Sand exposed in the dune-crest pits was massive and uniform except at Kindanina Lake near the Tanana River, where there were horizontal streaks of medium to coarse sand with rare granules, and at Pass Lake at the southwestern end of this area, where there were alternating, gradational beds of fine and very fine sand in beds 0.5 to 1 in. thick. Details are given in table 2.

Sand in this area is light yellowish gray except at Wien Lake, where it is moderate yellowish brown.

Two general trends are noticeable in the sand samples from the central area: (1) as in the eastern area, sand from any one site becomes slightly coarser with depth; (2) the fine-silt-and-clay fraction (0.044 mm) is larger than the coarse-silt fraction (0.0625-0.044 mm), resulting in bimodal distribution in 14 of the 19 samples subdivided in this size range. The proportion of this finest fraction generally increases (except at Pass Lake) with distance from the Tanana River. The greatest amounts are at Wien Lake (21.8 percent) and Duck Lake (26.9 percent); elsewhere the proportion ranges from 0.9 to 8.3 percent. Otherwise, the central, like the eastern area, shows no consistent variations. Kindanina Lake has the coarsest sand, the medium (20) sand slightly outweighing fine (30) sand; fine sand dominated in most of the other samples.

Ikgiza, East Twin, Duck, and Pass Lakes are nearly in a

straight line and range from 5 to 65 mi southwest (in a downwind direction) from the Tanana River. Comparison of sand samples (from approximately the same depth) from pits at each location indicates that sand size decreases slightly from East Twin to Pass Lakes. However, the Iksgiza Lake sample is the finest grained of the four in spite of being, presumably, nearest the source.

Except for samples from Kindanina and Wien Lakes, sand from the central area is generally similar in size range and color to the well-sorted sands from Dune and Grassy Lakes in the eastern area.

Southwestern area

The only exposures of dune sand are in cutbanks along the Foraker River below its junction with the Herron River. One exposure near Foraker Pond is described in table 3. Another exposure 4 mi farther north contains, from southwest to northeast, sand with irregular but generally horizontal bedding, a swale containing muck over similar sand, and, at the highest part of the bank, crossbedded sand. A third cut more than a mile farther north contains coarse to fine sand with irregular and lenticular bedding.

Sand in samples from east of the Foraker River (from pits at Carlson, Billberg, and Gosling Lakes, for instance) generally becomes finer with depth. Except for the Foraker Pond samples, however, sand in samples from west of the Foraker River coarsens with increasing depth. Comparison of samples from depths of 3 to 5 ft across the area (from pits at Beaverlog, Billberg, Gosling, Carlson, Foraker, Doghouse, Cranberry and Shisnana Lakes) showed no trend. Sand in samples from Doghouse and Cranberry Lakes in the west is the coarsest and is the only sand in which the fine to medium ratio is about equal. The finest grain sand is found in samples from Beaverlog, Gosling, and Shisnana Lakes at the east and west ends of the area; the Beaverlog sample has 81.6 percent and the latter two have more than 40 percent of very fine sand, and the cumulative curves from Gosling and Shisnana Lakes are very similar. Except for the Beaverlog Lake sample described above, sand from the Billberg Lake and Foraker Pond samples is the best sorted and is 66.5 percent and 59.4 percent fine grained, respectively; their cumulative curves are also very similar. On the other hand, the sand sample from Carlson Lake is strongly bimodal, and is comprised of 45.6 percent fine sand and 36.6 percent coarse silt (0.0625–0.044 mm). An overlying granule-containing stratum is trimodal, containing 29.8 percent coarse sand (with granules to 0.5 cm), 30.6 percent fine sand, and 21.9 percent coarse silt. Both of these samples are from depths of less than 5 ft below the top of a 25-ft dune and, hence, from sands that are surely windlaid. Layers 1 to 1.7 ft below the surface at Foraker Pond and Cranberry Lake also contain coarse sand and granules (see table 3). Coarse sand layers are also present at slightly greater depths (as deep as 5 ft) in the pit at Carlson Lake and in the Foraker River cutbank.

Samples used in the above comparisons were similar in containing little of the fine-silt-and-clay fraction (0.044 mm). In 25 of the 33 sieve analyses, however, that fraction is larger than the coarse-silt fraction, resulting in a bimodal distribution. In three samples this fraction makes up 24.4 percent, 30.9 percent, and 50.1 percent of the total, probably because they all were collected from just below loess or a soil horizon. The percentage of the fine-silt-and-clay fraction in the rest of the 25 samples is mostly less than 10 percent; the coarse-silt fraction is less than 1 percent in half the samples, less than 8 percent in two of them, and between 2 percent and 4.5 percent in the remainder.

Area comparisons

It is difficult to compare sieve analyses of sand from the southwestern area with those from the central and eastern areas because of the apparently random variability in the southwestern area (fig. 3). Of the seven comparable samples discussed above, only those from Billberg Lake and Foraker Pond, which contain well-sorted, mostly fine grained sand, resemble the typical sands from the other two areas. However, samples from Doghouse and Cranberry Lakes

resemble those from Kindanina Lake in having nearly equal amounts of fine and medium sand. The bimodal distribution, which results from the comparatively large amount of fine silt and clay, seems to be the only characteristic the sieve analyses from this area have in common with sands to the northeast.

DETAILED GEOGRAPHIC DESCRIPTIONS

The Southeastern Tract

The eastern area of the Southeastern Tract is bounded roughly by the Kantishna, Tanana, and Teklanika Rivers and the Totek Hills; there are also a few small patches of dunes north of the Tanana and east of the Teklanika Rivers that may be conveniently included here. The central area, largest of the three, is bounded on the north and east by the Tanana and Kantishna Rivers, on the west by the Kuskokwim Mountains, and on the south by the Roosevelt Hills. The southwestern area is separated from the central area by the Roosevelt Hills and lake-dotted flats drained by the Muddy River, but it continues with the same southwesterly trend past Lake Minchumina to approximately long 153°W.

The eastern area

The lowland in which these dunes occur ranges in elevation from less than 300 ft above sea level along the downstream part of the Tanana River to a maximum height of nearly 700 ft in the rosette area near the southern boundary. The roughly oval area is nearly 50 mi long and approximately half as wide. The north and east edge is a scalloped bluff of varying height that borders the Tanana River flood plain. An inconspicuous and discontinuous bluff, reduced near the Teklanika River to a terrace several feet high, forms the southeast border. Just north of the Totek Hills, a sharp break in slope marks the south edge of the dunes; it is a composite of erosional cutbanks (in some cases shorelines of lakes set into the edge of the sand) and of the southern depositional limit of the sand blanket itself. The southwest corner is defined by bluffs along the lower Toklat River.

The 1,000 mi² of nearly streamless lowland thus enclosed exhibit several types of topography, most of which seem to be developed on sand. The northeastern part of the area has parabolic and longitudinal dunes, some of which are quite inconspicuous; lakes are interspersed among them. A typical ridge on the west side of Cabin Lake (T. 1 S., R. 9 W.) is only 5 ft high. The terrain rises gradually to the south, and south of the latitude of Nenana relief increases somewhat. Parabolic and longitudinal dunes 0.5 mi to nearly 2 mi long are scattered between the southwest-facing steep lee slopes of small individual sand sheets. Ponds are scattered through the area at the base of lee slopes; some have shrunk, and much or all of their former volume has been replaced by marsh.

The northwestern part of the area is occupied by a narrow, keystone-shaped marshy depression about 18 mi long, 4 mi wide at the southwestern end, and more than twice as wide at the northeast end. At an elevation of about 300 ft, it is as low as the flood plain of the Tanana River a few miles to the north. It is underlain in part by flood-plain alluvium (Péwé and others, 1966) and may represent an ancestral lower Kantishna River. Ponds are common, and two large lakes occupy the southwest end. Clumps of spruce mixed with aspen are scattered through the marsh-like flat, apparently marking slightly higher ground. This depression may be a remnant of the original surface on which the sand dunes were deposited; its straight boundaries are longitudinal, southwest-trending dunes about 25 ft high that seem to override both the marshes and the edges of spruce clumps. A small peninsula in the southwest side of Black Bear Lake (T. 3 S., R. 12 W.) contains gravel 2 ft below the surface (F. R. Weber, oral commun., February 1981).

On its southwest edge, the eastern area is truncated by a 150-ft bluff (T. 5 and 6 S., R. 14 W.) cut by the Toklat River in unconsolidated sand. Much of the bluff's slanting surface is covered with vegetation and material slumped from above, but the upper 70 ft of a short north-south exposed section is

crossbedded with dips about 20° to the south. The lower half of the bluff is horizontally bedded.

Southwest of the Toklat River flood plain, an area of more than 1 mi² is covered by dunes that have about the same elevation and orientation as those northeast of the Toklat. This small area is bounded on the east, north, and west by cutbanks bordering the flood plains of the Toklat and Kantishna Rivers; alluvium and small tributaries of the Kantishna River form the southern boundary and also divide the dunes into one large and several smaller groups. Pronounced dune ridges are 5 to 25 ft high and 50 ft to 0.5 mi long. Site 3, a bluff on the Kantishna River (map sheet and table 1), has furnished a section of the sediments underlying this small group of dunes.

Rosettes

Surrounding Dune Lake is a sand sheet about 7 mi long and 5 mi wide that has sharply defined southwest-trending tongues in the southwest part. Dunes that have more relief than any others in the dune field occupy the center of the sheet; associated with them are dunes of a unique shape herein termed "rosettes". A sketch (fig. 2) derived from large-scale aerial photographs illustrates the sand sheet. The rosettes consist of groups of small arcuate dunes ranging from 5 or 6 ft to 30+ ft high and 1,000 ft to 2 mi long; their steepest slopes are on the convex outer sides. They are arranged concentrically, and each arc is concave toward a slightly depressed center, resulting in a pattern like a multi-petalled rose roughly 1 mi across (fig. 4). The rosettes occupy some of the highest terrain in the vicinity, and the total relief between the dunes and interdune ponds (of which Dune Lake is much the largest) is greater than 200 ft. Little of this relief is accounted for by the small arcuate dunes themselves; the overall pattern suggests that they are developed on or near the crests of large, possibly transverse, dunes.

The origin of the rosettes is uncertain, but some topographic clues point toward a possible explanation: (1) their locations suggest that the rosettes developed close to the crests of large transverse dunes that had been deposited by wind from the northeast; (2) the east side of Dune Lake is bordered by large, mostly vegetated dunes, which have crests 100 ft or more above the lake that were the result of wind from the southwest; and (3) the northern rosettes, especially, have larger, more massive arcs on their northern sides. The present wind regime, as observed during many flights across the area in small planes and from snow-drift patterns, consists mostly of (1) strong northeast winds of dry, cold air in winter; (2) less common storm winds from the southwest, mostly in summer; and (3) occasional strong, very local winds from the southeast that blow down the Nenana River canyon from the Alaska Range and that extend to this part of the dune field, but do not reach to other parts of the field. This combination of winds could account for this most unusual localized pattern. Similar small arcuate dunes are present on the crests of large dunes in the northwest part of the central area of the dune field (T. 1 S., R. 17 W., for example); these do not form rosettes because they are all concave to the northeast. This also tends to support the theory that the rosettes are the result of a unique and local wind regime.

The sharp relief, lack of any developed drainage system, and location atop a sharply defined sand sheet suggest that the rosettes are the youngest of any dunes in the field. The only exposed sand in the region occupies two or three small areas on one of the large dunes just east of Dune Lake; in the summer of 1956, blown sand was collecting to the east of grass tufts on the northeast lip of the blowout's steep (33°) west-sloping surface.

North of the Tanana River

East of the Tolovana River and north of the Tanana River is a flat, marshy expanse known as the Minto Flats, much of which is lake covered. East of Swanneck Crossing, at the northernmost curve of the Tanana River, old water-filled meander scars are prominent, becoming fainter to the north. Beyond them, away from the river, are marshy lakes

that range from a few feet to 4 mi long and that have very irregular outlines. Most are narrow, and many show a rough south-southwest orientation. Ten miles north and east of Swanneck Crossing the level surface of the flats is interrupted by a few low aspen- and brush-covered hills that rise as much as 25 ft above the marsh. The hills are mostly 1 mi or so long and about 0.5 mi wide. These gentle elevations have irregular outlines, but are always made up of south-southwest-oriented ridges separated by narrow, shallow swales that lie above the level of the surrounding lowlands. The northeast edges of some hills are abrupt, as though they had been cut by a northwest-trending stream. The hills are judged to be remnants of dunes on the basis of topographic expression; none were visited.

Farther west the lowland is mostly occupied by meander scars and by mud flats on which tributaries and distributaries of both rivers are now depositing alluvium. Within this area of low ground are some lakes and some rather distinct patches of dunes consisting of low hills marked with south-southwest-trending ridges. The largest area is more than 2 mi across, and has some V-shaped dunes that have apices at the south-southwest. The southwest edge of the dunes appears unaffected by subsequent erosion, but the northeast edge has been sharply truncated. A typical dune ridge, located near the east side of this group, borders a bay of Grassy Lake (T. 1 N., R. 10 W.); the ridge is separated from the bay by about 100 ft of grassy marsh. To the northeast, the dune merges with other parallel ridges, but the southwest end is only about 100 ft wide at the base. It rises abruptly from the marsh, attaining a height of about 25 ft along its nearly level crest. A 5-ft pit in the dune crest penetrated a little humus and some loess before encountering sand (table 1). A sample from the bottom of the pit is slightly better sorted and slightly coarser than the upper one, but both are typical dune sand and have sieve analyses similar to those from the Toklat River bluff and Dune Lake.

South of Nenana

Three small groups of dunes are located 2 to 4 mi southeast of Nenana. They are 2 mi or less long and a few 100 ft to 0.75 mi wide, differing more because of accidents of erosion than because of differences in original size. Their present outlines are irregular, but each area is crossed by more or less distinct ridges all oriented in an east-northeast direction. The dunes rise about 25 ft above the lowland surface and support a young birch and aspen forest, in contrast to the stunted black spruce, tamarack, and muskeg of their surroundings. A road cut exposes 5 ft of crossbedded sand; a sand sample from a pit in this dune, taken from 2.5 ft below the surface, is finer grained than sand samples from Grassy Lake and was overlain by 2.1 ft of yellowish-brown silty clay (table 1).

A small 1-mi by 0.5-mi dune-covered surface just west of Nenana is distinctly higher than the flood plain that surrounds it. It is about half way between the main part of the northeast-trending dunes to the west and the east-northeast-trending dunes; its faint ridges parallel the latter.

The central area

The north and northeast edges of this massive sand body are formed by the terraces bordering the south side of the Tanana River flood plain, and much of the southeast edge is the cut bank on the west side of the Kantishna River flood plain. These boundaries are sharp and comparatively straight, but the rest of this area is bounded by very irregular and less distinct edges determined by the effect of topography on the deposition of sand moved by a wind from the northeast.

Near the Tanana River, which here flows roughly northwest, are a few ridges that strike northwest and have steep southwest slopes; these ridges are probably transverse dunes (map sheet, T. 1 N., R. 16 W.; T. 1 S., R. 15 W.; T. 2 S., R. 13 W.). South of these, the dunes form a veritable sea of sand; they have long wave crests as much as 200 ft or more above the troughs. These dunes, too, are asymmetrical and have steep western slopes; the sinuous crests, which strike north-south, appear to be composed of coalesced sides and apices of

parabolic dunes. Many of the crests curve sharply to the northeast at the north end and diminish in height or are overridden by another wave of sand. See T. 3 and 4 S., R. 15 W. for examples. Comparatively small longitudinal dunes superimposed on the gentle windward slopes of the north-south sand ridges southwest; groups of small arcuate dunes that top some of the most prominent, large sand ridges are concave to the northeast and have steep southwest slopes. Undrained depressions at the bases of the massive dunes contain long, narrow marshes or ponds, and some of the western ones are drained by small tributaries of the Zitziana River. The steep lee slopes are covered with grass and scattered birch or aspen; crests support the same trees and a scattering of spruce. Gentle slopes, depressions, and interdune areas are forested with spruce.

Surrounding these massive deposits, except at the north, are longitudinal dunes interspersed with parabolic dunes that have apices to the southwest. Near East and West Twin Lakes and Wien Lake, dunes have encroached on bedrock hills that rise 200 ft or more above the dune-filled lowland to the north and that cast duneless "wind shadows" to the southwest. Farther south beyond this group of hills, the massive dunes are absent; parabolic and longitudinal dunes continue to the Roosevelt Hills, about 40 mi to the southwest. The dunes are 3 to 50 ft high and 100 ft to more than 0.5 mi long.

North-trending dunes

Two small groups of longitudinal and parabolic dunes that strike north-south are located near the Kantishna River in T. 4 S., R. 13 W. and in T. 7 S., R. 16 W. Both groups are on surfaces that are about 30 ft above the river flood plain but 100 ft below the dune-field surface. A series of cut banks (sites 7, 7A, and 5) intersect the surface underlying the northern group of dunes, and the sections exposed are described in table 4.

The southwestern area

This part of the dune field is much smaller than the central area and lacks the massive sand ridges that dominate the latter. The southwestern area occupies a broad, shallow valley southeast of the Kuskokwim Mountains that is about 40 mi long and less than 15 mi wide. Several small outlying areas are separated from the rest of the dunes by channels and flood plains of the present drainage. Parabolic and longitudinal dunes 300 to 3,300 ft long rise as much as 150 ft above the terrain in the northeast and diminish in height to 30 ft or less in the southwest; only a few are found west of 153° W. Numerous lakes fill shallow depressions between dunes and in a few places surround the dune ends, as at Carlson and Billberg Lakes. Lake elevations rise from 660 ft in the northeast to 850 ft in the southwest, as the terrain gradually rises to form part of the regional divide between the Yukon and Kuskokwim River drainages. Most of the lakes have sandy bottoms and the banks are gently sloping except where a dune borders the water. Dune sides slope 29° at Carlson Lake, and the slope of the southwestern nose of the large dune at the east side of that lake is 35°; slopes of other dunes are similar.

Just west of the southwest edge of the dune field on the northeast shore of Spirit Lake (T. 14 S., R. 28 W.) is a group of small blowout dunes emplaced by a wind from the southwest.

The northeast end of the dune field is bordered by a strip of comparatively low land (occupied by Lake Minchumina, innumerable smaller lakes, and the Muddy River) that ranges in elevation from 642 ft (on the 1952 1:63,360-scale McKinley D-5 quadrangle) at the lake to about 625 ft at the southeast end of the lowland. Situated within this strip, about 4 mi east of Lake Minchumina and 0.75 mi northwest of the present edge of the dunes, is Sevenmile Hill. The top of this bedrock knob, at an elevation of 862 ft, is about 175 ft above the adjacent ponds and flats and 55 ft above the crest of the highest dune in the vicinity. In a pit dug at the top of the hill, several ventifacts (dreikanter) were found on the weathered bedrock surface under 1 ft of loess. Two other pits, located down the slope to the east at elevations of 730 ft and 700 ft, exposed 0.4 and 1.8 ft of loess, respectively, on

weathered bedrock. The bottom 0.3 ft of the latter hole did, however, contain a little fine to medium sand in interstices of the angular bedrock fragments, but no ventifacts occurred in these pits or in a second pit dug at the top of the hill. The ventifacts imply passage of blown sand over the top of the hill, but no dune forms are known on or immediately upwind from it. Whether the sand-blasting material has since been removed or whether the loess shaped the ventifacts as it blew by, the ventifacts are witness to the passage of rapidly moving, wind-blown material 100 ft or more above the local terrain.

Higher land surrounds the rest of the area—outliers of the Kuskokwim Mountains, smaller isolated hills, and alluvial deposits of rivers that flow from the Alaska Range.

The Northwestern Tract

The Tanana River flows northwest (see map sheet⁴) from the mouth of the Cosna River to its junction with the Yukon River, and its flood plain marks the northeast edge of the Northwestern Tract of the dune field. This part of the field extends west-southwest to the flood plain of the Nowitna River, some 90 mi away. The northeast edge of what appears to be a massive sand body rises from the flood plain elevation of a little more than 200 ft to a gently undulating surface nearly 600 ft higher. The surface is drained to the north and south by a series of small subparallel streams incised as little as 10 ft to as much as 150 ft and spaced 1 to 3 mi apart. The streams appear to occupy valleys at the base of rather steep, west-facing lee slopes. Most of the east-flowing gullies draining into these streams are longer than those on the western slopes, and many of the interstream divides are closer to the western stream than to the eastern one. Streams in T. 9 to 10 S., R. 28 and 29 E. (K. R. M.) are perpendicular to the west-southwest trend of the sand mass and probably are boundaries of transverse dunes; streams between these and the Tanana River flow more nearly north or south, following depressions at an approximate 45° angle to the axes of the parabolic dunes. The streams thus outline what are probably sand ridges on which the much smaller parabolic and longitudinal dunes are superimposed; the latter are most common on the flanks of the dune field.

The north edge of the east half of this tract extends west-southwest from the junction of the Yukon and Tanana Rivers; the southern boundary is formed by lake-bed deposits that occupy the basin of the Chitanana River just southeast of the dunes (Chapman and others, 1975). A shallow pit in a low ridge on the southwest side of Redlands Lake (T. 3 S., R. 24 W.), 20 ft above the lake but within the lake-bed area as mapped by Chapman, Yeend, and Patton (1975), disclosed 0.2 ft of humus, 0.4 ft of medium-gray mineral soil, and 1.7 ft of very slightly silty, medium-gray clay. A 50-ft cutbank of the Chitanana River, less than 0.5 mi northwest of the lake, exposes light-buff, horizontally bedded clayey silt.

The undulating surface and subparallel streams are absent west of R. 28 E. (K. R. M.), and the dune field is composed entirely of parabolic and longitudinal dunes. Hills in the area commonly have dunes mounting their eastern slopes to a variable height that averages 1,150 ft; the hills cast a "wind shadow" to the west in which dunes are lacking. The northern and southern boundaries of this part of the field are abrupt and depositional and were evidently determined by the effect of the topography on the wind—both the edge of the tract and the edge of the lowland that contains it have the same west-southwest trend. The western boundary is formed by old cutbanks marking the east edge of the Nowitna River flood plain, which, at an elevation of about 250 ft, is at least 200 ft lower than the gently rolling, lake-dotted surface underlying the dunes. As seen from a small plane, two cutbanks on Grand Creek (T. 10 S., R. 27 E., K. R. M., and T. 10 S., R. 28 E., K. R. M.) and one on the Big Mud River (T. 11 S., R. 29 E., K. R. M.) have the color, angle of repose, and texture of loose sand.

OTHER QUATERNARY DEPOSITS

Alluvium

For most of the Northwestern Tract, no evidence is now

available to determine the type of material underlying the dunes. The eastern part of the dune field, however, appears to be largely underlain by alluvium. Material underlying the dune sand is exposed only in a few cutbanks of the Kantishna River, where unconsolidated alluvium occurs in lenticular or horizontal beds of silt, sand, and gravel. Some of the sections above the junction with the Toklat River have horizontal or steeply north-dipping gravel beds at the base. Details of these sites are shown in tables 1, 2, 4, and 5. Elsewhere in the Southeastern Tract other indications that the dunes lie on alluvium are:

1. On a small peninsula on the southwest side of Black Bear Lake gravel was found in a dug hole at a depth of 2 ft (F. R. Weber, oral commun., February 1981).
2. A dry hole west of Nenana (Union Oil of California Nenana No. 1) drilled into gravel at a depth of 140 ft.
3. Northwest of Bearpaw Mountain, in the central area, there are a few small patches of polygonal ground in the interdune areas. A 2.4-ft pit in the interdune area beside Pass Lake (T. 9 S., R. 20 W.) penetrated frozen, slightly sandy, silty mud. These data suggest that in the vicinity of Bearpaw Mountain and Pass Lake underlying material is fine grained or poorly sorted and is now permanently frozen.
4. A 30-ft cutbank along the Foraker River 0.25 mi north of Foraker Pond exposed muck containing plant material at the base. The top of the muck rises from about 2 ft to about 15 ft above the river at the north end. The sand that overlies it is slightly finer than that from the Foraker Pond sample and in turn is overlain, at the north end of the cut, by flatlying beds of sand, silt, and clay that contain tree branches.

The only site where dune sand was seen to directly overlie bedrock is on the west shore of West Twin Lake.

Outside of the dune field, three localities provide additional information:

1. Along the Foraker River, south (upstream) from the dune field toward the Alaska Range, river banks are low and contain silt. However, southward (upstream) from the vicinity of Castle Rocks (T. 17 S., R. 24 W.), gravel, probably outwash, appears below the dark silt, making a sharp contact that rises gradually as the exposed thickness of gravel increases. Whether or not these sediments continue far enough north to underlie the dunes is unknown.
2. A pit on a small ridge just north of the dunes, on the west shore of North Snohomish Lake (T. 13 S., R. 26 W.), penetrated about 4 ft of poorly sorted, coarse to very fine, silty, clayey sand.
3. Lake sediments in the flats near the Chitanana River, south of the Northwestern Tract, are topographically lower than the dune field.

The contact between underlying material and the dune sand is hard to distinguish in the few places it is exposed. The crossbedded sand at site 6 and at Toklat Bluff is certainly windlaid, and the horizontal beds there may also be dune sand. Underlying alluvium may be exposed at site 6 and certainly is exposed at sites 3, 4, and 7. At site 7, horizontally bedded sand is separated from the sandy silt below by a sharply defined, horizontal 1-in. stratum of medium-dark-gray clay that may mark the base of windblown sediments.

Sandy silt

Rising against the northeastern flanks of Bearpaw Mountain and Castle Rocks are areas of irregular lake-dotted, spruce-covered terrain that are 150 to 200 ft higher than the

nearby dunes. The deposit near Bearpaw Mountain is southwest of the eastern area of the dune field, and the one near Castle Rocks is southwest of part of the southwestern area. These silty deposits are, therefore, downwind from sand dunes and upwind from sizeable obstructions, relative to the wind that moved the dunes.

Both areas rise above the adjacent dune field with abrupt, straight northwestern boundaries; their surfaces have a northeast-trending grain, expressed in part by poorly developed, generally northeast- or southwest-flowing streams. In the few spots where deposits underlying the surfaces were sampled, they consisted of unconsolidated very fine sand and silt that differed in color and grain size, as well as location and topographic expression, from the dunes and from the overlying loess blanket.

Samples taken near Mucha Lake (T. 8 S., R. 17 W.) along the northwest side of the Bearpaw Mountain area consist of about 50 percent very fine sand and nearly equal parts of coarse silt and fine-silt-and-clay. The surface northwest of Castle Rocks is underlain by more variable sediments; very fine sand dominates two samples from Big Long Lake (T. 16 S., R. 25 W.), but the one from nearby Little Long Lake has 56.9 percent fine silt and clay. Both of these lakes are near the northwest edge of the terrain; the sample from Live Trap Lake, near the northeast edge, has about one third each of very fine sand, coarse silt, and fine silt and clay (details are given in table 6). Southwest of Castle Rocks, however, a ridge along the south side of Burnt Lake (T. 18 S., R. 2° W.) contains silty clay, indicating that the silt did not extend into the wind shadow of the hills. Permafrost, lacking at Mucha Lake, was present at depths of 20 to 30 in. in the Castle Rocks area, and lakes are mostly the smaller, more numerous, and steeper walled thaw lakes typical of thermokarst terrain.

The only other locality where similar sediments were penetrated by pit or auger is the peninsula between the Beaverlog Lakes (T. 11 S., R. 22 W.), where 6.5 ft of clayey silt overlies sand (see table 3). Chapman and Yeend (1931, p. B30) report "silt more than 5 ft thick conceals bedrock on the lower hills between the Cosna and Kantishna Rivers."

Loess

All of the dunes visited (except the blowout at Dune Lake) were covered with buff-colored, silty and clayey, noncalcareous, unconsolidated loess ranging from one inch to nearly 2 ft in thickness. No bedding was seen, and although the deposits are commonly too thin to show the vertical cleavage typical of loess, they are coherent enough to form vertical or slightly overhanging faces in cutbank exposures. The upper inch or so is commonly darkened by the addition of a little humus and the incipient soil profile. Roots of living plants penetrate the loess, and dark-brown root-shaped markings are evidence of plants now dead. In many cases, forest fires have left a residue of ash between the loess and the present vegetation. Except for these minor changes, the material seems little altered, and no other weathering is apparent.

The loess also occurs on bedrock—1 ft or less coats the western slopes of the Roosevelt Hills and the upper two thirds of Sevenmile Hill (T. 12 S., R. 23 W.). Apparently the only surfaces that lack loess are very recent flood plains and lake shores. The available measurements suggest that this blanket deposit is thickest in the northeast, thinning gradually and irregularly to the west and south.

South of the dune field, loess occupies the slightly higher ground along the northwest slope of the Kantishna Hills, an area of typical thermokarst topography. It contains many deep-set ponds whose vertical banks are commonly sealed by undercut and overhanging mats of roots and other vegetation. Samples from exposures at several lakes, ranging from lake 581 (at the boundary of T. 8 and 9 S., R. 15 W.) to Lonely Lake, (T. 16 S., R. 20 W.), are all typical loess; details are given in table 7. An alluvial fan of the Toklat River, its apex located where the river emerges from the Kantishna Hills, forms the eastern boundary of this widespread deposit. The loess is also interrupted by alluvial fans of Moose Creek and the McKinley River to the west. In each case, the fan is lower in elevation than the adjacent loess.

Southwest of the silt deposit around Castle Rocks, the silty clay at Burnt Lake may be loess, but it is gray, water-soaked, and close to permafrost and is probably muck.

Other exposures large enough to be seen from a small airplane have the vertical banks, color, and presence of swallow nest holes typical of loess. Such holes are present in various places outside the dune field; some are listed in table 7.

ANCIENT ENVIRONMENTS

Pre-dune conditions

In the central Kantishna River valley and probably elsewhere, the dunes were deposited on alluvium derived from the Alaska Range. Along the lower Kantishna River the contact between gravel and alluvial sand seems to dip a bit more steeply northward than the present grade of the river; the alluvium in this vicinity may be a continuation of an inactive alluvial fan that extends north from the point where the Toklat River emerges from the Kantishna Hills. The best exposure of this underlying material is located at site 1; here the sediments become finer upward in the section. Organic material is rare, but a small carbonaceous parting in the upper part of the cutbank indicates that vegetation was near enough to be washed in, and Estella Leopold has identified a probable tundra assemblage (85 percent *Betula* sp, probably dwarf birch) and abundant algae, suggesting a productive lake (written commun., 1972). The willow *Salix* cf. *S. glauca* was identified from Kantishna River site 3 (see table 1) by Robert Nelson. A 1.2-in. layer of olive-gray clay at site 7A may mark the location of a pond or backwater, and a few sand-size fragments of mollusks and one of an insect were found in the overlying massive sand (see table 4). These bits of data hint at enough water to support sufficient vegetation to keep the silty, sandy material in place.

Source of sand

When a change in climate resulted in diminishing vegetation, the winds began to move sand southwest across the alluvial deposit. The sand, brought down to the Tanana River by the ancestral Nenana, Kantishna, and other streams, overwhelmed any remaining vegetation and built the massive dunes that lie immediately to the southwest. This was especially true near the northwest-flowing stretches of the Tanana River, indicating that the river was in much the same position as it is now. Farther to the southwest, a diminishing sand supply permitted vegetation to anchor the dunes, resulting in the parabolic and longitudinal dune forms typical of areas that have discontinuous plant cover (Melton, 1940; McKee, 1979).

It seems significant that the dune field does not extend eastward up the Tanana River beyond its junction with the Nenana River. The Nenana River occupies the only large glaciated valley in the Alaska Range between the Delta River valley, 100 mi to the east, and the Muldrow-Foraker complex, a similar distance to the west. Its location relative to the dune field suggests that it was the source of sand for the eastern area. The Kantishna River and its glacially fed tributaries furnished additional sediment to the central area and the Northwestern Tract. The massive deposits west of the lower Kantishna suggest that this river too, "maintained its course during the time of dune activity" (written commun., D. M. Hopkins, 1983).

The northwestern boundary of the dune field strikes west-southwest (downwind) from the junction of the Tanana and Yukon Rivers. Two factors may have caused this relationship: (1) the Yukon River is a large stream and is a few hundred miles distant from possible glacier-fed tributaries, so its flow of water may have increased enough below the junction to carry remaining sand on downstream; (2) downstream from this junction the Yukon River hugs the southern base of a range of hills that could have deflected the northeast wind from the river and its sandbars.

The southwestern dune area is separated from the other parts of the field by a few miles of sandless terrain. The glaciers draining the Mount McKinley region (the ancestral

Muldrow, Peters, Foraker, and Straightaway Glaciers) could well be the source of sand for this comparatively small dune area, via the equivalents of the present McKinley, Foraker, and Herron Rivers. This relatively close source could account for the comparatively coarse grain size in many of these dunes, and for the large size of the dunes compared to the dunes at the southwest end of the central area.

Climate during dune deposition

No direct evidence exists as yet to show whether the formation of the dune field was accompanied by warmer or colder climates. A warming climate, by destroying permafrost that now underlies much of the region, would destroy the swamps, muskeg, and possibly the spruce forests, which are more sensitive to aridity than to cold. It would also be associated with retreating glaciers, which would presumably increase the discharge of both water and sediments into glacial streams. A colder climate, especially if accompanied by the emergence of the Bering land bridge, would probably cause an increase in wind from the northeast (see below). It would also cause a decrease in stream flow and, hence, less alluvium to supply sand; a probable decrease in vegetation, however, would permit sand to blow. In either case, aridity and a large supply of loose sand were undoubtedly present.

If the vegetative and loess cover now anchoring the sand were removed, the present wind regime would probably be adequate to build a similar dune field. Alaska weather is now largely determined by low pressure systems moving from the northwest Pacific Ocean and by high pressure systems from northeastern Siberia. In summer the lows, which have counter-clockwise winds, tend to move north through the Bering Sea and bring wet southwesterlies to central Alaska. In winter the lows are more likely to move east, south of the Alaska Peninsula, bringing precipitation to southern Alaska and easterlies, dried by crossing the Alaska Range, to the dune-field region. The summer pattern of the highs parallels the Arctic coast far to the north; in winter the highs move eastward across northern Alaska, and their clockwise winds bring cold, dry northeast winds that often blow more than 20 mi per hour and occasionally reach 60 mi per hour. These patterns would be accentuated by the presence of a continuous land mass across the present northern Bering Sea.

Sediment still is blown from sand bars on the Tanana River near Old Minto (T. 1 N., R. 8 W. and designated as Minto on the map sheet) to as far as 50 mi to the southwest, when the wind is strong. At Lake Minchumina, the wind first strips several inches of snow from the sandy silt of the Foraker delta flat and then blows the sediment, at altitudes as much as 60 or more ft above the surface, to a hill a mile or more away. It has deposited as much as 2 in. there in a single wind storm, killing the underlying low vegetation. Sample + (fig. 3), for instance, was blown in suspension for more than 0.25 mi and then deposited on the deck of a boat as a 0.5-in. layer interbedded with snow, the result of alternating wind and snowfall. This sediment is slightly coarser than samples from the silty deposits near Bearpaw Mountain and Castle Rocks, but finer than the dune sand. By contrast, southwest winds are usually accompanied by rain or snow and generally do not cause either snow to drift or sand and silt to blow appreciably, although they are responsible for the small blowout dunes at Dune Lake and near Spirit Lake (T. 14 S., R. 28 W.). Winds from other quadrants are uncommon and usually not strong.

Finer material, probably carried as a suspension load, was dropped as the northeast winds rose over the isolated hills and was banked against the northeast slopes of Bearpaw Mountain and Castle Rocks, the former downwind from the eastern area of the dunes and the latter downwind from the southwestern area. Similar silty material rising above the dunes in the central area was probably deposited on the eastern flanks of the Kuskokwim Mountains to form the colluvium and silt identified on many lower slopes by Chapman, Yeend, and Patton (1975) and Chapman and Yeend (1981). Any silt blowing above the dunes of the Northwestern Tract would presumably have been dropped in the wide Nowitna River flood plain or perhaps carried to the hills

several miles west of the Nowitna River. Like the dunes, the few silt-deposit samples are lacking in organic material.

Postdune changes

Another change, either in climate or in quantity of available sand, must have occurred because sand movement ceased comparatively abruptly, and the dunes and most other exposed surfaces were blanketed by loess. That the loess also blew from the northeast is suggested by the irregular thinning from northeast to southwest across the dune field. Small steep gullies, typical of loess deposits, are present on the east slopes of hills near Lake Minchumina, but are lacking on west-facing slopes. Loess deposition is probably still in progress, although at a much slower pace than in the past. A cloud of dust—future loess—that rose to a height of 5,000 ft over the country between Minchumina, Tanana, and Nenana was observed in April 1965, an unusual but not unique event that undoubtedly resembled loess clouds of the past. Because single loess deposits were probably thin, they, in contrast to the heavier silt and sand deposits, may not have damaged or killed the underlying vegetation. Once deposited, the loess is more coherent than sand or silt; when frozen, it is rock hard even on dune crests, whereas the sand is loose and easily moved at the coldest temperatures.

AGE

Radiocarbon dating

The dune field cannot be dated directly because no radiocarbon dates are available that come with certainty from material within the dune deposits. However, three dates are probably relevant to the dunes. One sample, which has a date of $20,240 \pm 460$ years B.P., is from a lake-shore deposit about 8 ft above the present Lake Minchumina, and the other two samples are from cutbanks of the Kantishna River. Of the latter, one sample (1J, USGS-1489) dates a small carbonaceous parting in alluvial deposits at site 1 (point j, table 5) as $19,850 \pm 150$ years B.P. This site is 12 mi southwest of the nearest large group of dunes in the eastern area and about 10 mi southeast of the nearest dunes in the central area. The deposits appear to be part of the alluvial surface on which the dunes in the eastern area were deposited. The third date, from sample 60AWr14 (I-12927), is more than 40,000 years B.P. It came from site 4, a cutbank about 80 ft high and 1 mi long that intersects the edge of the central area of the dune field. Florence R. Weber, who collected the sample, described it as "reddish stained wood which appears to be in place in humus filled layer 20 ft above water level... the lowest 20 ft of the cut is quite full of humus which has a brownish tan color." (F. R. Weber, written commun., 1960). Twenty-one years later the south half of the site 4 bluff was covered with slumped vegetation, and the north half exposed only sandy and silty sediments (see table 2) and no organic-rich beds were visible. Therefore, the specific relationship of the sample to the dune sands is uncertain, although it is reasonable to assume that it predates them.

Topography

The dunes and the underlying alluvium as it is exposed in the Kantishna River banks are not cemented or consolidated. Drainage in the dune field is poorly developed, and streams and lakes circumnavigate or parallel the ridges. Dune ends protrude into several lakes, and dune sides form many lake shores, but little erosion of dune forms is visible. Their slopes approach the angle of repose of sand, and the lower slopes end abruptly at the junction with the flat terrain. Nevertheless, streams like the Chitanana, Zitziana, Kantishna, and Foraker have cut meander scars in the dunes, leaving sharply scalloped bluffs edging the flood plains; alluvial fan distributaries of streams such as the McKinley River have left uneroded patches of dune-covered higher ground here and there (such as the one in T. 13 S., R. 21 W.).

The superposition of parabolic and longitudinal dunes on the large dune ridges in the east half of the Northwest Tract

and the north half of the central area implies a changing environment, but not necessarily two separate episodes of dune building. The nearly unaltered topography described in the paragraph above applies to dune-covered terrain whether massive dune ridges are present or not; the change in size and shape could be the result of decreasing sand supply and increasing vegetation.

Relation to former lakes

Two former lakes may have been confined by the dunes. One is represented by lake-bed deposits in the Chitanana River valley just west of Redlands Lake, and the other is represented by the present Lake Minchumina.

The lake deposits near Redlands Lake are about 200 ft lower in elevation than the dunes that border them to the north. The present Chitanana River drains the lake beds through a narrow valley that is cut between dunes and bedrock in T. 1 S., R. 22 W. and thence between two areas of dunes to the Tanana River valley. The Chitanana changes course from north-northeastward to east-northeast in doing so, which suggests that the dunes may have blocked its original course and caused a lake to form. This was later drained when another outlet was found. Unfortunately, no present means exist to date these lake-bed deposits.

Ancestral Lake Minchumina, on the other hand, laid down a beach deposit containing charcoal fragments that have been given a radiocarbon date of $20,250 \pm 460$ years B.P. (Charles E. Holmes, written commun., 1982; sample WSU 2585). The deposit consists of 6 to 8 in. of rounded gravel 0.04 to 3 in. in diameter that is derived from the local dark-gray argillite. This is overlain by 3 to 5 in. of yellowish-gray clay and 0 to 2 in. of dark reddish-brown organic material that contained the charcoal. The sequence rests on bedrock and is overlain by colluvium composed mostly of loess and small angular fragments of bedrock. The deposit marks a lake level of 650 ft, 8 ft above the highest level of recent times, and may correspond in age to a "slightly more mesic interval" in the otherwise cold and dry Duvanny Yar interval (Hopkins, 1982).

This high level, however, is lower than any part of the southwestern area of dunes. The ancestral Lake Minchumina probably occupied the flats between the present dune field and the Kuskokwim Mountains and may have extended around the northeast end of the dunes as well. The ancestral Foraker, McKinley, and Herron Rivers could have emptied into such a lake and deposited alluvium there. If the dunes in the southwestern area were fed from such a source, dunes and lake could have been contemporaneous. No indications of a shoreline have been found between the dunes and the ancestral lake. In the lowland east of Lake Minchumina (northeast part of T. 12 S. and southeast part of T. 11 S., R. 21 W.), two small patches of northeast-trending dune-like ridges occur below the 650-ft contour (from the 1:63,360-scale McKinley D-4 quadrangle) close to the lower Muddy River. They are 2.5 to 4 mi from the nearest parts of the dune field, but if they are a remnant of the dune field, and if the ancestral lake did extend that far southeast, they are presumably resting on the lake bed and hence postdate it.

Younger and older dunes

The similarities in dune shape and erosional features described above show that the dune field is mainly of one age. However, there are three small groups of north-striking dunes that may be younger than the rest of the field. Two of them are located on the west side of the Kantishna River on remnants of river terraces that are about 30 ft above the flood plain, but about 100 ft below the dunes (T. 7 and 8 S., R. 16 W., and T. 4 S., R. 13 W.). The third group occupies a similar position between the Nenana River and the edge of the eastern area of dunes (T. 5 S., R. 10 W.). Sediments underlying the northern group near the Kantishna River are described in table 4.

An older generation of dunes may be represented by topography that has a vaguely northeast orientation of swales

west of Lake Minchumina. Similar terrain lies south of the dunes in T. 8 S., R. 15 W. These have not been visited on the ground, and the nature of the surficial deposits is not known.

Conclusions

Dune fields that have comparable topographic expression elsewhere in Alaska have been active during the late Wisconsin glacial interval (Fernald, 1960, 1964; Péwé, 1975; Carter, 1981; Hopkins, 1982). Although the central Alaska dunes may have been emplaced earlier, it is reasonable to suppose they were at least reworked at approximately the same time, when "the seasonal round of weather in periglacial Beringia consisted of short summers, warmer and drier than at present, and long winters, evidently colder but with snow cover thinner than at present" (Hopkins, 1979, p. 23). A change in climate beginning about 14,000 years ago (Ager, 1975) brought increasing vegetation and, presumably, an end to major dune deposition in this region.

AGRICULTURE

Parts of T. 4 S., R. 10 and 11 W. west of Nenana have recently been surveyed for development as an agricultural area. This acreage is part of the eastern area of the dune field; it is underlain by "Nenana silt loam", which is a shallow, well-drained soil, although increasing amounts of "Tuklanika loamy fine sand" have developed on dune ridges toward the west (Forbush and others, 1980). The presence of dunes suggests that any major disturbance of the vegetation and topsoil could easily result in blowing sand, rapid deflation, and deposition of sand downwind.

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Table 1.--Stratigraphic sections and sieve analyses of sand from dunes in the eastern area
(Tr, trace; Ø, phi grain-size scale)

Location	Depth (ft)	Description	Sample interval	Weight of sample (gm)	Sieve analyses											
					Cumulative Weight (% of whole sample)											
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 fine sand	0.125-0.0625 mm very fine sand	0.0625-0.044 mm silt	0.044 mm- pan silt, clay					
Pit samples																
Nenana T. 5 S., R. 8 W. Pit 25 ft above road	0-0.1 0.1-0.8	Vegetation Clay, slightly silty, moderate reddish brown (soil profile on loess). Base irregular with 0.2 ft of relief, marked by 0.2 in. of slightly darker clay	1.3-1.7 ft	100.7	---	0.1	3.2	46.8	96.1	98.3	100					
	0.8-2.2 2.2-2.6	Clay, silty, moderate yellowish brown (loess) Sand, yellowish gray.	2.3-2.6 ft	100	---	Tr	5.4	62.5	97.7	99.4	100					
	0-0.1 0.1-0.9 0.9-1.2 1.2-5	Vegetation Clay, silty, moderate yellowish brown (loess) Silt, very clayey, slightly grayer than above Sand, moderate yellowish brown; uniform, massive	2.3-2.7 ft 14.5-5 ft	100.7 100.8	---	Tr Tr	7.4 7.2	71.6 78.7	98.0 98.6	99.4 99.4	100 100					
	0-0.1 0.1-0.2 0.2-0.7 0.7-0.9 0.9-1.2 1.2-4.1	Vegetation Humus, dark brown, clayey Clay, silty, light yellowish brown, modern roots (newer loess?) Clay, silty as above containing few streaks of moderate reddish-brown silty clay (old soil profile?) Silt, clayey, moderate yellowish brown (old loess?), upper and lower contacts sharp Sand, grayish yellowish brown; roots to 2 ft	1.7-2 ft 13.8-4.1 ft	99.2 99.7	---	Tr ---	1.2 1.0	32.2 52.9	93.2 99.4	93.8 99.6	100 100					
Cabin Lake T. 1 S., R. 9 W. Pit 5 ft above lake	0-0.1 0.1-0.5 0.5-1.3 1.3-5.0	Vegetation Clay, silty, moderate reddish brown (soil profile) Clay, silty, moderate yellowish brown (loess) Sand, light yellowish gray, uniform, massive	1.8 ft 1.24, 5-5 ft	98.2 100.6	---	Tr ---	2.0 10.4	40.6 53.2	92.7 96.6	96.5 99.1	100 100					
	---	Sample from 5 ft below highest point of dune in small active blowout about 150+ ft above lake and about 1+ ft below surface of blowout. Sand is grayish yellow	1----	100.8	---	.2	30.1	94.5	100	Tr	Tr					

Table 1.--Stratigraphic sections and sieve analyses of sand from dunes in the eastern area--Continued

Location	Description	Sample Interval	Weight of sample (gm)	Sieve analyses									
				Cumulative weight (% of whole sample)									
				1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.04 mm silt	0.04 mm-pan silt, clay			
				0 Ø	0.5 Ø	1 Ø	1.5 Ø	2 Ø	2.5 Ø	3. Ø	3.5 Ø	4 Ø	>4 Ø
Cutbank samples													
Toklat River Bluffs T. 5 S., R. 14 W. sampled bluff is about 150 ft and 1 mi long, concave to the west; has exposed beds about 0.3 mi from northwest end; rest of bluff vegetation covered		B:	227.23	---	0.82	1.75	5.73	25.76	48.25	80.55	94.27	98.29	100
		C:	212.87	---	---	.93	2.02	7.02	25.62	74.70	92.70	97.82	100
		A:	222.39	---	---	.82	2.31	9.59	26.49	71.82	92.67	98.32	100
Site 3, Kantishna River bluff, T. 7 S., R. 15 W. Bluff is 60 ft high and about 0.25 mi long and is mostly vegetation-covered. Exposed bedding is even and horizontal. Swallow-nest holes mark material fine-grained enough to hold its shape when penetrated by holes about 0.3 ft across and 2 ft or more deep. Thin lenticular beds of gravel interbedded with coarse sand occur as high as 8 ft above river level; pebbles are 0.4-3 in. in diameter, mostly 1-2 in. composed primarily of well-rounded quartz and chert in a coarse sand matrix		D:	69.78	---	---	---	1.61	6.07	19.45	55.72	84.14	94.61	100
		C:	110.54	1.99	1.99	4.91	8.61	14.04	22.75	60.64	88.43	96.62	100
		E:	191.92	---	---	---	1.01	2.24	6.74	22.49	61.42	86.08	100
		A:	84.24	2.93	2.93	8.05	17.58	41.45	75.27	90.80	94.84	97.60	100

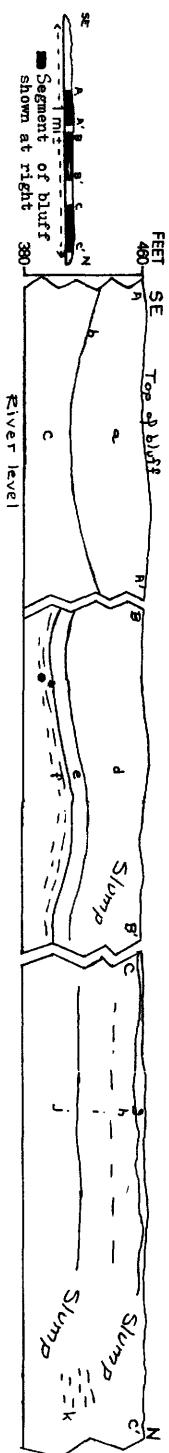
1 Sample used in cumulative curve, figure 3

2 Auger sample

Table 2.--Stratigraphic sections and sieve analyses of sand from dunes in the central area

(Tr, trace; Ø, phi grain-size scale)

Sieve analyses													
Cumulative Weight (% of whole sample)													
Location	Depth (ft)	Description	Sample Interval (ft)	Weight of sample (gm)									
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.044 mm silt	0.044 mm-pan silt, clay		
Kindarina Lake T. 2 S., R. 15 W. Pit 50 ft above lake	0-0.2	Vegetation											
	0.2-1.8	Clay, silty, moderate yellowish brown, uniform											
	1.8-5.0	Sand that has streaks of medium to coarse sand and rare granules; light yellowish gray	2.3-2.7 13.3-3.5 14.5-5.0	98.6 49.5 100.5	1.1 3.4 1.4	6.0 9.6 8.5	40.3 51.6 53.8	88.8 89.8 90.4	98.1 98.4 98.0	98.8 98.8 98.7	100 100 100		
Issigita Lake T. 2 S., R. 13 W. Pit 50 ft above lake	0-0.2	Vegetation.											
	0.2-1.8	Clay, silty, moderate yellowish brown, uniform											
	1.8-5.0	Sand, light yellowish gray, uniform, massive	2.3-2.5 1.24-5.5-0	100.8 99.8	--- ---	.1 .1	13.2	64.3 71.4	96.6 98.7	98.4 99.6	100 100		
Kantishna River site 6 T. 2 S., R. 12 W. Bluff, 0.5 mi long, 200+ ft high. Uppermost beds dip as much as 10° south; horizontal contact with underlying beds, which dip 30° south Lower part badly slumped; has swallow holes (see site 3, table 1); horizontal bedding(?)	500	Top of bluff											
	280	Vegetation											
		Sandy silt? Slump, sandy?											
Wilderness Lake T. 4 S., R. 18 W. Pit 35 ft above lake	0-0.1	Vegetation											
	0.1-0.5	Clay, silty, moderate reddish brown; sharp but irregular base 0.1-0.4 ft below top of bed											
	0.5-0.9	Clay, silty, 0.1-0.4 ft thick, has sharp contacts above and below.											
East Twin Lake T. 6 S., R. 16 W. 30 ft above lake	0-0.2	Vegetation											
	0.2-2.0	Clay, silty, yellowish gray, has irregular streaks of moderate reddish brown near top. Siltier toward base											
	2.0-5.0	Sand, slightly darker than overlying clay	2.2-2.8 1.24-5.5-0	99.8 98.1	Tr 1.9	.6 3.5	11.7 18.5	68.6 70.7	99.4 99.6	99.7 99.8	100 100		



Southern part of bluff is vegetated but seems to have horizontal bedding. No samples were taken

a Horizontal bedding in sand
b Contact sharp where exposed
c Siltier, grayer than overlying sand
d Silty sand, gray, thin, continuous beds
e Yellowish fine- to medium-grained sand; bedding parallel gray beds

g Organic material
h Silt?
i Coarser than h; approximately horizontal bedding; 2-4 in. beds of sand
j Horizontal, slightly wavy beds 0.5-2 in. thick; sand
k Beds horizontal or with slight dip to north and 0.5-2 in. thick

Table 2.--Stratigraphic sections and sieve analyses of sand from dunes in the central area--Continued

Location	Depth (ft)	Description	Sample interval (ft)	Weight of sample (gm)	Sieve analyses									
					Cumulative Weight (% of whole sample)									
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.044 mm silt	0.044 mm- pan silt, clay			
					0 #	0.5 #	1 #	1.5 #	2 #	2.5 #	3 #	3.5 #	4 #	> 4 #
Wien Lake T. 6 S., R. 19 W. Samples from steep (340-380°) slope on east side of lake	---	Sand, yellowish gray, has modern rootlets	3 ft above lake 25 ft above lake 50 ft above lake	100.2 99.5 100.0	Tr ---	0.1 1.3 .8	12.7 38.9 13.3	70.9 79.6 64.2	98.9 98.8 98.4	99.0 99.0 98.5	100 100 100			
Pit on flat ridge top, 80 ft above lake. Ridge slopes gently to north- east, then rises steeply to 165 ft above lake	0-0.2 0.2-0.5 0.5-1.0	Vegetation Sand, clayey, moderate yellowish brown Sand, moderate yellowish brown	1	99.5	---	.4	16.9	73.6	98.7	98.8	100			
Pit on ridge top, 165 ft above lake	0-0.2 0.2-0.5 0.5-1.0	Vegetation Clay, silty, moderate reddish brown; finer grained than 0.2-0.5 ft interval in pit described above Sand, moderate yellowish brown	1.2	97.5	---	.2	4.4	48.3	76.0	78.2	100			
Duck Lake T. 8 S., R. 18 W. Test pits on southwest slope of dune abutting lake; slope dips 320° southwest. Pit 15 ft above lake	0-0.2 0.2-0.3 0.3-0.5	Vegetation Clay, sandy, silty Sand, silty, moderate yellowish brown	.5	98.0	0.1	.8	20.2	73.1	89.8	91.7	100			
Pit 65 ft above lake at top of dune	0-0.1 0.1-0.4 0.4-0.6 0.6-1.0	Vegetation Sand, silty, clayey, reddish brown Silt, sandy, clayey, yellowish gray Sand, slightly darker than silt above	.4-0.6 2.6-1.0	53.7 98.0	.2 Tr	1.4 .4	11.2 19.3	49.7 81.4	68.4 95.8	73.1 96.5	100 100			
Pass Lake T. 9 S., R. 20 W. Pit 20 ft above lake. Slope of dune, 290° west. Bedding approx- imately horizontal; samples both contain sand from alternating beds of fine and very fine sand	0-0.3 0.3-0.4 0.4-0.6 0.6-0.9 0.9-2.0	Humus Clayey soil, moderate brown; upper and lower boundaries moderately sharp Soil, clayey, moderate yellow- ish brown (part of soil pro- file on loess) Loess, silty, grayish yellow Sand in 1/2 to 1-in. beds, alternating and grading from fine to very fine sand	1.0-1.5 2.1-2.0	100.8 100.3	.3 .1	3.6 2.9	24.4 25.8	70.8 74.4	95.5 98.9	96.7 99.1	100 100			

1 Auger sample

2 Sample used in cumulative curve, figure 3

Table 3.--Stratigraphic section and sieve analyses of sand from dunes in the southwest area

(Tr, trace; ϕ , phi grain-size scale)												
Location	Depth (ft)	Description	Sample interval (ft)	Weight of sample (gm)	Sieve analyses Cumulative weight (% of whole sample)							
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.044 mm silt	0.044 mm- pan silt, clay	>4 ϕ
					0 ϕ	1 ϕ	2 ϕ	3 ϕ	4 ϕ			
Beaverlog Lakes T. 11 S., R. 22 W. Pit on west side of East Beaverlog Lake, 25 ft above lake	0-0.2 0.2-0.3 0.3-0.6 0.6-1.0 1.0-7.4	Humus Ash, light gray, clayey (from fire) Silt, clayey (loess), dark yellowish orange, noncalcareous (part of soil profile) Silt as above, yellowish gray Silt, clayey, mottled medium light gray and moderate yellowish brown; browner in top 6 in.										
Pit on east side West Beaverlog Lake 15 ft above lake	0-0.3 0.3-1.3 1.3-4.8	Humus, with ash layer at base Silt, clayey (loess), yellowish gray, noncalcareous Silt, clayey, mottled medium light gray and moderate yellowish brown										
Pit on southwest side of East Beaverlog Lake, 25 ft above flats (in group of small pits dug in the 1920's)	0-0.1 0.1-0.5 0.5-5.0 5.0-7.3	Humus Soil, dusky brown at top grading to dark yellowish brown. Contact with underlying clayey silt is sharp, slightly irregular Silt, clayey, grayish yellow. Slight mottling with dark yellowish orange near top Sand, silty, yellowish gray, mottled with moderate yellowish brown. Slightly coarser with depth	1,2,5,2 16,8-7.3	15.4 100	---	Tr 0.3	Tr 7.1	10.6 41.5	92.2 94.9	96.1 97.0	100 100	
Auger hole at corner of ridge southwest of Beaverlog Lake, 25 ft above flats	0-0.2 0.2-5.0	Soil, dark yellowish brown Loess to bottom; slightly coarser at base										
Pit 50 ft southeast and 25 ft below auger hole	0-0.1 1.0-2.0 2.0-3.0	Clay, very slightly silty, grayish yellow Silt, clayey, yellowish gray, slightly mottled with yellowish brown Sand, very fine grained, yellowish gray										
Billberg Lake T. 12 S., R. 22 W. Pit in dune forming peninsula in north- west part of lake	0-0.1 0.1-0.4 0.4-6.0	Vegetation Silt, clayey, moderate yellowish brown Sand, yellowish gray	8-1.0 2.0-3.0 1,2,4,5-6.0	99.8 100.1 97.4	Tr .5 ---	.3 .8 Tr	11.9 10.4 6.7	80.5 76.6 73.2	98.7 97.8 98.2	98.9 97.8 98.2	100 100 100	
Gosling Lake T. 12 S., R. 22 W. Pit 48 ft above lake	0-0.1 0.1-0.2 0.2-0.3 0.3-0.8 0.8-5.0	Vegetation Soil, medium dark brown Clay, silty, moderate reddish brown (loess) Clay, silty, moderate yellowish brown (loess) Sand, yellowish gray	1,2-1.4 1,2,4,0-5.0	98.9 100.9	---	.1 Tr	1.0 1.1	39.8 38.9	93.3 96.0	96.4 98.9	100 100	
Carlson Lake T. 13 S., R. 23 W. Pit 25 ft above lake, in dune at southwest shore of lake	0-0.3 0.3-0.6 0.6-1.3 1.3-4.1	Vegetation Clay, silty, moderate yellowish brown Silt, clayey, slightly grayer than above. Grades within an inch to Sand, moderate yellowish brown, but grayer than silt	1,3-1.4 1,8-2.1 2,8-3.1	98.9 98.2 99.0	Tr .1 Tr	.2 .3 .1	12.3 8.5 5.2	57.2 59.6 56.6	78.9 81.9 90.9	86.9 89.9 96.9	100 100 100	
Corner Lake T. 14 S., R. 22 W. Pit 30 ft above lake, on knoll 100-ft square	0-0.7 0.7-0.8 0.8-1.3 1.3-2.0 2.0-2.7	Horizontal 0.25 in layer of very coarse sand Sand as at 1.3-4.0 ft Vegetation Sand, clayey, silty, very fine to fine grained, moderate reddish brown Sand, moderate yellowish brown Clay, sandy, silty, moderate yellowish brown, light yellow gray Sand as above, frozen	24,1-4.3	100.9 100.9	.3	1.9	46.2 10.1	76.8 55.7	77.3 56.3	99.2 92.9	100 100	
	4.1-4.3											
	0-0.7 0.7-0.8											
	0.8-1.3		1	99.2	1.6	6.7	28.3	58.7	71.2	75.6	100	
	1.3-2.0		2.3	100.1	.1	1.7	34.1	83.0	94.1	94.9	100	

Table 3.--Stratigraphic section and sieve analyses of sand from dunes in the southwest area--Continued

Location	Depth (ft)	Description	Sample interval (ft)	Weight of sample (gm)	Sieve analyses						
					Cumulative weight (% of whole sample)						
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.044 mm silt	0.044 mm-pan silt, clay
					0 ϕ	1 ϕ	2 ϕ	3 ϕ	4 ϕ	>4 ϕ	
Foraker Pond T. 14 S., R. 24 W. Lake-bottom sediment from 10 ft in northwest of southeast corner of lake. Pit 0.25 mi east of pond	0-0.2 0.2-0.4 0.4-0.6 0.6-1.2 1.2-4.2	Vegetation, some blackened by fire Clay, very slightly silty, moderate brown, noncalcareous; sharp contact with Clay, very silty, moderate yellowish brown Sand, yellowish gray; granule layer at 0.9 ft Sand, yellowish gray, no granules, uniform	--- 0.6-0.9 0.8-1.0 1.2, 3.9-4.2	100.7 100.1 99.6 100.0	0.5 0.3 5.7 0.2	3.5 0.4 6.7 0.6	24.4 10.3 16.1 8.8	82.7 77.8 69.4 68.2	97.8 99.8 98.9 99.0	99.0 99.9 99.1 99.4	100 100 100 100
Foraker River, T. 14 S., R. 24 W. Cutbank on west side of river 0.25 mi east of Foraker Pond; top 5 ft of cut exposed	0-1.0 1.0-2.0 2.0-2.1 2.1-5.0	Vegetation Muck, dark grayish brown, very slightly silty Sand, very fine grained, yellow stained. Sharp contact with muck Sand in lenses 1/8-2 in. thick, 2 in. to 5 ft long. No crossbedding	--- 0.6-0.9 0.8-1.0 2.5 3.0-3.5	100.7 100.1 99.6 26.5 99.6	0.5 0.3 5.7 31.0 0.2	3.5 0.4 6.7 77.9 2.5	24.4 10.3 16.1 84.0 30.1	82.7 77.8 69.4 95.8 81.4	97.8 99.8 98.9 100.0 98.9	99.0 99.9 99.1 100.0 99.1	100 100 100 100 100
Cutbank on west bank of river; 0.25 mi north of cutbank described above	0-0.2 0.2-0.4 0.4-0.8 0.8-1.2 1.2-4.7	Vegetation and humus Burned layer, sand and ash Sand, light brown at top, grading to moderate yellowish brown at base Sand, grayish yellow Sand as above, uniform	0.4-0.8 1.2-1.5 1.2-4.0-4.7	98.5 49.3 99.2	2.0 0.2 0.5	9.5 9.7 5.8	38.2 45.2 45.6	75.9 82.5 85.5	90.3 96.0 98.8	91.1 96.6 98.9	100 100 100
Lake Spohnish T. 13 S., R. 26 W. (pit 40 ft above lake)	0-0.7 0.7-1.2 1.2-5.0	Vegetation Clay, silty, moderate yellowish brown, grading to Sand (silt and a little clay in upper 1 ft), mottled medium yellowish gray	1.6-1.8 1.2-3.5 1.45-5.0	98.3 99.0 58.7	0.4 2.3 1.5	4.4 10.3 8.3	17.3 37.2 44.7	32.2 74.8 77.2	47.3 97.0 90.5	49.9 97.6 90.8	100 100 100
20 ft above lake, on slope below pit	---	Irregular, horizontal, lenticular bedding. Finer grained strata slightly grayer or yellower than others	---	100.4	0.1	1.8	10.2	36.5	92.5	95.0	100
Cranberry Lake T. 14 S., R. 26 W. (pit 10 ft above lake)	0-0.3 0.3-1.0 1.0-1.7 1.7-1.8 1.8-3.5 3.5-4.5	Vegetation Sand, light brown, mottled with clay Sand, moderate yellowish brown, grading to Sand, moderate yellowish brown, lenticular, apparent southward dip Sand, very fine grained, silty Sand, fine to medium Sand, fine to coarse	0.5-0.7 1.3-1.5 1.2, 3.8-4.5	99.1 98.2 99.5	Tr 11.9 3.0	2.8 45.5 15.1	29.8 65.7 51.1	85.2 80.8 83.8	98.9 86.7 98.5	99.0 87.4 98.5	100 100 100
Beaver Lake T. 15 S., R. 26 W. Pit 10 ft above lake; cutbank below pit is sand to water's edge	0-0.2 0.2-0.4 0.4-0.8 0.8-1.2	Vegetation Sand, clayey, dark grayish brown (soil) Sand, clayey, moderate yellowish-brown Sand, yellowish gray	1.0-1.2	98.0	---	0.4	13.9	66.1	87.9	89.0	100

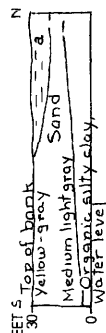


Table 3.--Stratigraphic section and analyses of sand from dunes in the southwest area--Continued

Location	Depth (ft)	Description	Sample interval (ft)	Weight of sample (gm)	Sieve analyses						
					Cumulative weight (% of whole sample)						
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.04 mm silt	0.04 mm- pan silt, clay
					0 \emptyset	1 \emptyset	2 \emptyset	3 \emptyset	4 \emptyset	>4 \emptyset	
Carls Cache Lake T. 16 S., R. 26 W. 30 ft above lake	0-0.2 0.2-0.5	Vegetation Sand, yellowish gray. Sand continues, in a cutbank, to lake level 30 ft below	0.5	100.7	Tr	0.6	12.8	69.4	99.3	99.7	100
Fish Lake T. 16 S., R. 26 W.	---	Estimated 30 ft sand exposed in cutbank									
Shisona Lake T. 17 S., R. 28 W. Pit 30 ft above lake	0-0.1 0.1-0.6	Lichens Sand, very clayey, yellowish brown, grading down to slightly clayey and lighter color (soil profile?)	0.3-0.5	100.0	Tr	1.2	3.3	19.8	62.2	69.1	100
	0.6-5.0	Sand, yellowish gray	1-0-1.2 1-24.5-5.0	100.1 100.4	- Tr	Tr 2.2	.3 8.0	16.7 43.5	95.2 96.7	98.3 98.9	100 100

1 Auger sample

2 Sample used in cumulative curve, figure 3

Table 5A.--Stratigraphic sections of cutbanks along the Kantishna River outside of the dune field

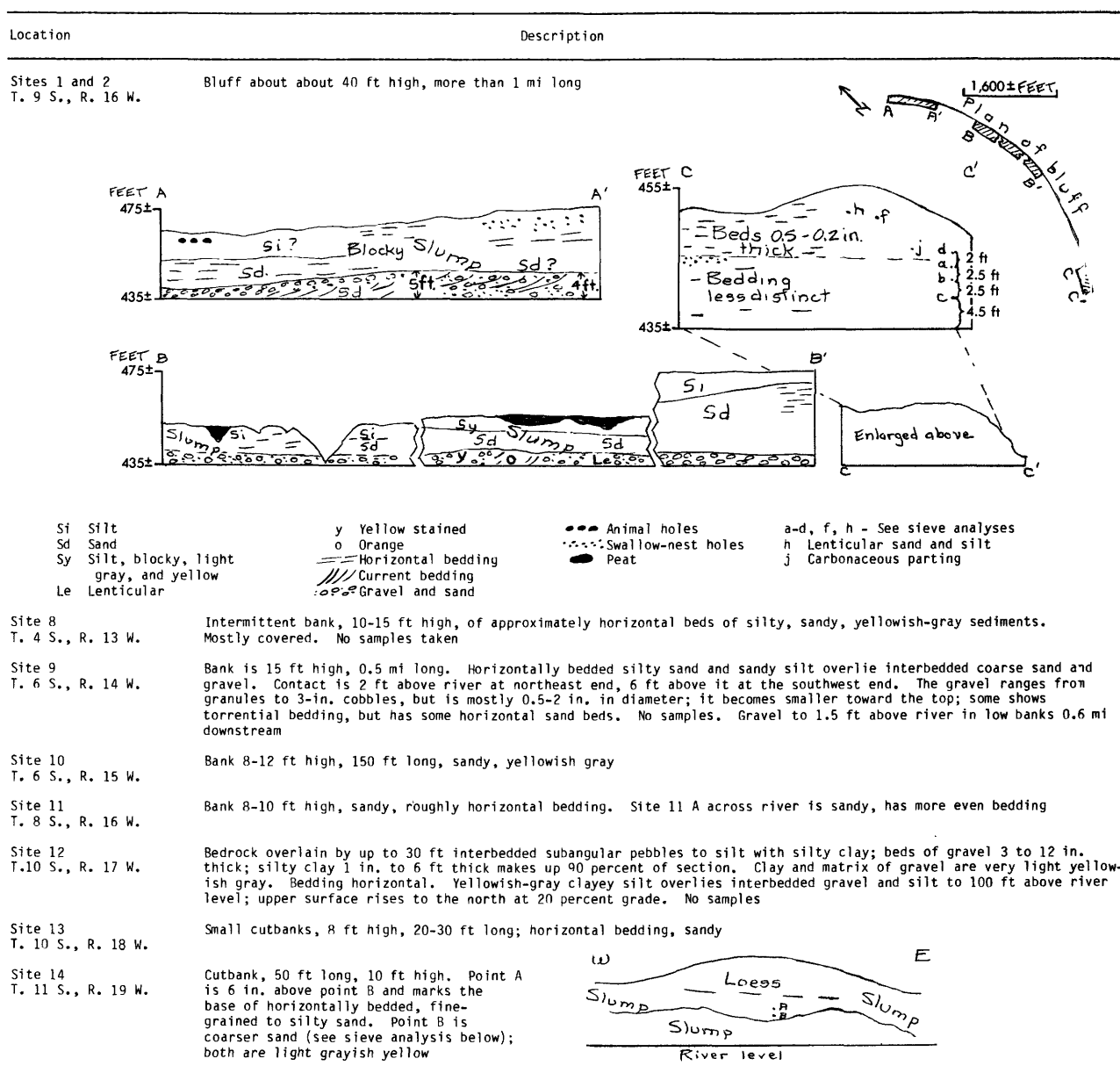


Table 5B.--Sieve analyses of samples from cutbanks in table 5A

(φ, phi grain-size scale)

Sample number		Sieve analyses									
		Cumulative weight (% of whole sample)									
		1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625 mm- pan silt, clay				
	Weight of sample (gm)	0 φ	0.5 φ	1 φ	1.5 φ	2 φ	1.5 φ	3 φ	3.5 φ	4 φ	>4 φ
Site 1											
a	215.81	---	1.14	2.66	5.04	9.52	15.78	27.96	51.70	71.95	100
b	213.43	1.00	2.27	4.13	9.30	20.09	34.56	54.93	73.19	85.94	100
c	202.98	---	1.09	3.10	9.38	24.48	42.00	58.88	74.96	86.02	100
d	149.87	---	1.55	3.32	6.00	10.90	17.59	28.68	46.44	67.45	100
f	174.63	1.93	3.51	5.54	9.75	17.88	30.33	50.51	70.96	84.74	100
h	80.90	3.09	3.09	7.10	13.55	25.91	41.12	59.95	72.87	83.36	100
Site 14B	88.98	---	2.23	5.08	12.56	29.41	48.42	69.43	85.19	94.31	100

Table 6.--Stratigraphic sections and sieve analyses of silt deposits
(Tr, trace; Ø, phi grain-size scale)

Location	Depth (ft)	Description	Sample interval (ft)	Weight of sample (gm)	Sieve analyses							
					Cumulative weight (% of whole sample)							
					1 mm	1-0.5 mm coarse sand	0.5-0.25 mm medium sand	0.25-0.125 mm fine sand	0.125-0.0625 mm very fine sand	0.0625-0.04 mm silt	0.04 mm- pan silt, clay	
					0 Ø	1 Ø	2 Ø	3 Ø	4 Ø	>4 Ø		
Mucha Lake T. 8 S., R. 17 W. Pit 0.25 mi south-southwest of small delta on south shore of lake, 40 ft above lake on sharp east-west ridge	0-0.2 0.2-0.3 0.3-0.8 0.8-5.0	Vegetation, humus, grading to Soil, brown, clayey Clay, silty, moderate yellowish brown, noncalcareous Sand, very silty, light olive gray	3.0-3.3 1.24-8-5.0	77.1 99.2	Tr ---	Tr ---	0.1 .1	0.9 1.0	49.7 57.0	72.4 79.2	100 100	
Hill 0.5 mi south-southwest of delta described above, 200 ft above lake.	0-1.0 1-?	Loess Sand and silt, yellowish gray; faint, irregular bedding shown by yellow or gray tinge and very slight changes in grain size. Beds lenticular, 0.25-1.0 in. thick, 2 in.-2 ft long	---	99.3	---	---	.2	2.7	58.3	76.5	100	
Live Trap Lake T. 16 S., R. 23 W. The south shore of a small thaw pond 100 ft north of the lake has a silty-clay bank that may be loess; the test pit is about 10 ft south of this bank. A neighboring cutbank is composed of silt. Pit is 5 ft above the lake.	0-0.7 0.7-1.3 1.3-2.3	Vegetation Humus, clayey, dark gray Silt, clayey, dark brownish gray; permafrost at 2.3 ft	21.8	98.2	---	Tr	.2	1.3	35.1	67.5	100	
Big Long Lake T. 16 S., R. 25 W. Pit 80 ft above the lake	0-0.3 0.3-0.4	Vegetation Thin discontinuous layers of silty clay, moderate reddish brown, grading to moderate yellowish- brown clayey silt										
	0.4-2.5 2.5-2.8	Silt, sandy, yellowish gray Silt as above, frozen	0.5-0.6 2.5-2.8	98.2 54.9	Tr ---	.4 .2	3.3 2.0	14.3 13.8	52.2 62.7	73.6 81.2	100 100	
Little Long Lake T. 16 S., R. 25 W. Pit 35 ft above lake	0-0.2 0.2 0.2-1.5	Vegetation Ash layer (from fire) Silt, clayey, moderate yellow- ish brown. Permafrost at 1.5 ft	21.0-1.5	97.7	---	1.1	5.7	9.6	36.7	43.1	100	

1 Auger sample

2 Sample used in cumulative curve, figure 3

Table 7.--Loess deposits identified south of the dune field

(Loess is present at every dune-crest pit, and the details of thickness at those locations are shown in the sections described in tables 1-6)

Location	Depth (ft)	Description
Lake 581 Sec. 3, 4, and 34 T. 8 and 9 S., R. 15 W. Pit on peninsula on northwest side of lake	3.5	Loess, with mica; slightly siltier than at hill 527 (described below)
Kantishna River Site 12 T. 10 S., R. 17 W.	---	Nearly vertical cutbank, 80 to 100 ft high, about 300 ft long. Loess, light buff gray, no bedding, numerous swallow holes
Hill 527 South of Kantishna River Sec. 14, T. 10 S., R. 17 W.	---	Loess on sides and top, exposed in two pits 2 ft deep
Sandless Lake T. 11 S., R. 16 W. 30-ft-high bank	---	Silty clay, medium light gray, no bedding, irregular vertical fracture. Contains modern plant roots and is overhung by a 1- to 2-in. mat of vegetation
Lake 1.25 mi east-southeast of Diamond Sec. 10, T. 12 S., R. 17 W. Pit in steep bank 5 ft above lake level	0-0.2 0.2-1.5	Humus Clay, silty, buff, uniform, no bedding; loess
Lonely Lake Sec. 16, T. 16 S., R. 20 W. Bank, vertical to overhanging, on north shore of lake	1.0 8.0	Roots and soil Loess, buff, uniform, no bedding