EOLIAN DEPOSITS OF ALASKA

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EOLIAN deposits of Pleistocene to Recent age are recognized in all major regions of Alaska (see Fig. 1). Lack of economic incentive and of suitable base maps or air photographs have in the past precluded much detailed work on such deposits. Further, complexities produced by growth of vegetation, reworking by streams, and, particularly in areas of permafrost, by frost action and mass wasting processes, tend to mask, assimilate, modify, or remove eolian materials as they accumulate. Consequently at present only a small proportion of the eolian deposits can be shown on a map and relatively few data are available on their morphology, stratigraphy, and genesis. This paper is an attempt to summarize these data, at the request of the U.S. National Research Council Committee for Study of Eolian Deposits in North America.

The writer has visited all the major areas of eolian deposits described here and has incorporated into the text and map his own ideas or interpretations rather than utilizing only those of other workers. He acknowledges gratefully the unpublished information and comments received from each of the persons listed on Fig. 2, who have carried out detailed studies of the areas shown. Many ideas expressed, for which individual acknowledgment is difficult, originated with them. Special mention should be made of the valuable summaries by Clyde Wahrhaftig and David M. Hopkins, parts of which are quoted verbatim. David M. Hopkins, W. A. Rockie, and Troy L. Péwé, in particular, critically reviewed the entire manuscript.

For convenience, the eolian deposits are discussed in three major groups, in each of which the physical setting and types of deposits and their genesis are similar. These groups are: Coastal plain of northern Alaska; Areas associated with glacial streams; and Coastal margins. These groups grade into one another and, obviously in a region as large and as complex as Alaska, many variations exist from one deposit to another. The areas associated with glacial streams have been subdivided because of their diversity, enormous area involved, and lack of information.

The writer believes that only higher parts of mountain ranges and local areas in the lowlands, together comprising less than half the territory, have escaped some eolian deposition. However, eolian materials over a wide area either were very thin and have been removed, or else have been masked or assimilated by other sediments. In southeastern Alaska eolian deposition is confined to the neighbourhood of braided glacial streams.

Fig. 1 shows only those areas in which eolian materials are known to occur; in many districts the extent of the eolian materials is believed to be greater than that shown.

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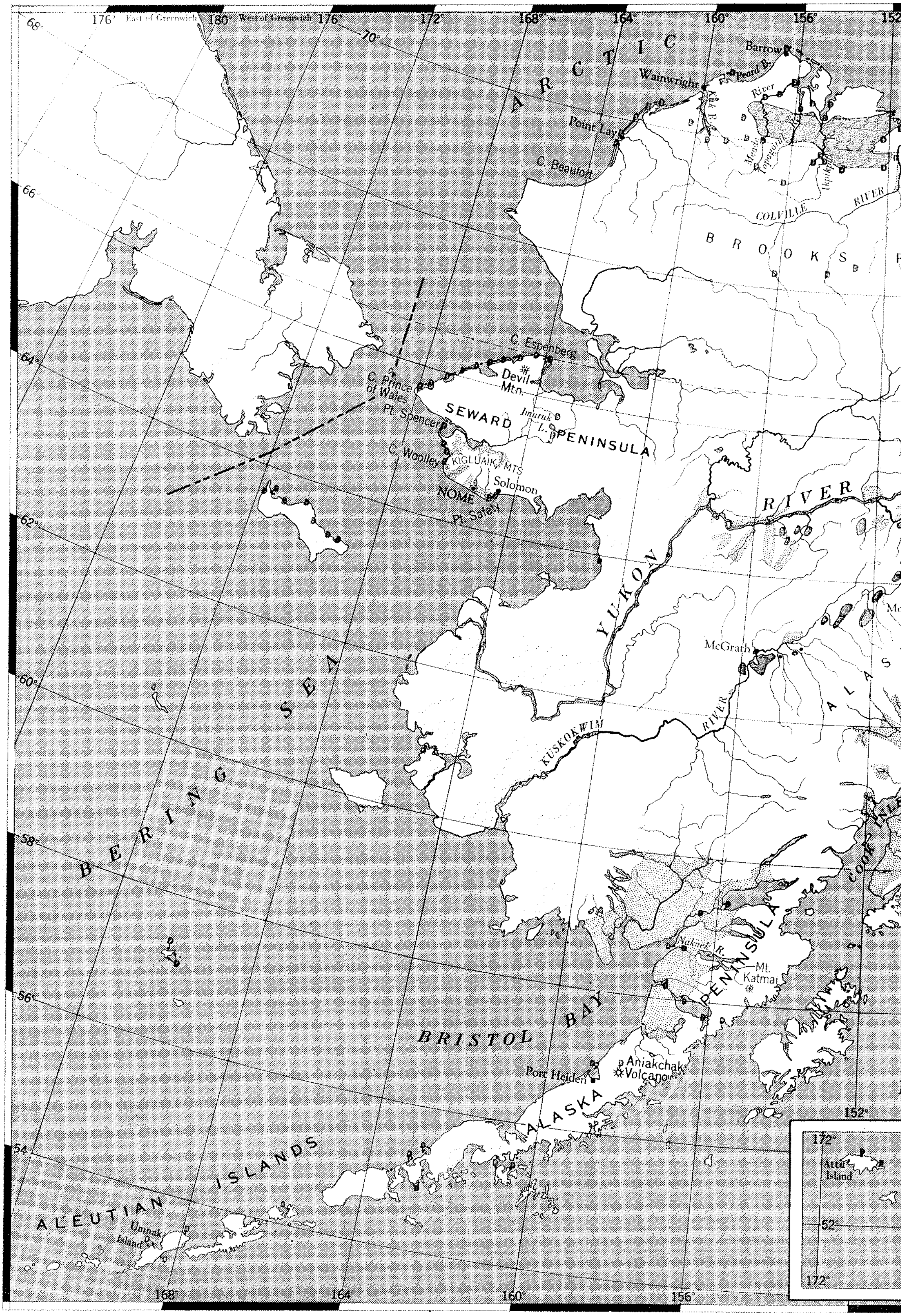

Fig. 1. Eolian deposits of Alaska,

information available in February 1950.

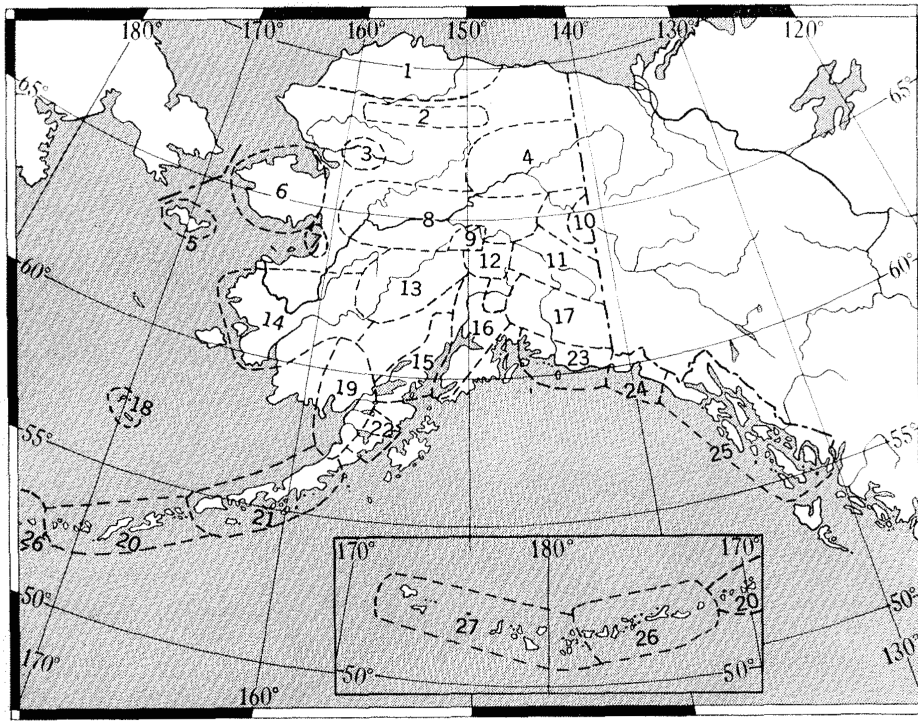

Fig. 2. Areas for which information was provided by the following: (1) R. F. Black; (2) George Gryc; (3) R. R. Coats; (4) W. S. Benninghoff and J. R. Williams; (5) H. B. Allen and J. G. Wells; (6) D. M. Hopkins; (7) W. A. Rockie; (8) T. L. Péwé; (9) W. S. Benninghoff; (10) Helmuth Wedow; (11) T. L. Péwé and R. F. Black; (12) Clyde Wahrhaftig; (13) A. T. Fernald; (14) J. M. Hoare; (15) R. F. Black; (16) T. N. V. Karlstrom, W. A. Rockie, and I. J. Nygard; (17) F. H. Moffit, R. F. Black, and I. J. Nygard; (18) F. M. Byers from notes of T. F. W. Barth and Ray Arnett; (19) E. H. Muller; (20) F. M. Byers and R. E. Wilcox; (21) H. H. Waldron; (22) and (23) D. J. Miller; (24) R. F. Black; (25) W. S. Twenhofel; (26) R. R. Coats; (27) H. A. Powers, R. R. Coats, F. M. Byers, R. E. Wilcox, and Olcott Gates.

Coastal Plain of Northern Alaska

Eolian materials can probably be found at least locally over most of northern Alaska. Stabilized longitudinal, parabolic, and multicyclic dunes, hitherto undescribed, occur over an area of about 5,000 square miles on the coastal plain west of the Colville River (see Fig. 1). Discontinuous and isolated dunes are active along most of the rivers and larger streams, along part of the coast northward from Cape Beaufort, and on the higher banks of many of the larger oriented lakes. Loess, a few inches to several feet thick, is recognized along the west bank of the lower Colville River and is probably ubiquitous in northern Alaska, although it is covered in most places by vegetation and modified by frost action, mass wasting processes, and stream erosion.

The following data and tentative conclusions are based on incidental field observations in 1946-7 by the writer and on interpretation of a small proportion only of the air photographs of northern Alaska. The coastal plain, although not glaciated, is particularly favourable for eolian erosion and deposition because of high winds, lack of topographic obstacles or wind breaks, low precipitation, and abundance of silt and sand that cover the plain to a depth of several tens of feet. But for permafrost, which impedes surface runoff and permits luxuriant vegetation to grow in spite of low precipitation, the coastal plain would be a desert with rapidly shifting sands. "When the wind blows, which seems to be most of the time, a veritable sheet of sand is sent scudding along the beaches above the high-tide level with stinging velocity until the grains lodge in the lee of some obstruction, such as a log or even a piece of shell" Smith and Mertie (1930, p. 249). The U.S. Weather Bureau records east-northeast as the dominant wind direction at Barrow and west-southwest as the secondary maximum. Numerous oriented lakes and dunes (Black and Barksdale, 1949) throughout the coastal plain show that these maximum winds are just as consistent and effective inland and that slightly more erosion is produced by the easterly (65° to 80°) than by the westerly winds (245° to 260°), though local topography may be even more important in determining the position and shape of dunes. High-velocity winds from the northern and southern quadrants are also fairly common and modify the effects of the easterly and westerly winds.

In the large area of stabilized dunes on the coastal plain west of the Colville River, longitudinal and parabolic types are the most abundant, and several varieties of these two types are recognized (see Fig. 3). Many can probably be described as lee-source, windrift, and elongate-blowout dunes; transverse dunes and undifferentiated types are represented; multicyclic dunes are probably present. The area delineated on Fig. 1 shows the approximate distribution of the stabilized dunes. The adjacent individual '*D*'s' mark active blowout areas. Surface materials favourable for the formation of dunes extend westward to the Arctic Ocean between Wainwright and Point Lay. That area is higher, more rolling, and more dissected, and old stabilized dunes, if once present, have been so modified as to be unrecognizable on the available air photographs. None were seen on air reconnaissance during permafrost studies, but from ground studies Karl Stefansson and Marvin Mangus, of the U.S. Geological Survey, report stabilized dunes along the Kuk River. Surface materials east of the Colville River are coarser and are not nearly as favourable for the formation of dunes (Leffingwell, 1919, p. 175).

The stabilized dunes are scattered abundantly in the areas interjacent to lakes and streams (Black and Barksdale, 1949, pl. 3B); they are absent on the river floodplains, on the beds of most, though not all, drained lakes, and on the steeper slopes where soil movements are very rapid. The dunes are most abundant on tops of ridges or other topographic irregularities and are associated commonly with cut banks of large lakes and streams.

The dunes vary considerably in size from place to place although no regional variation was noted. Most longitudinal dunes are less than 3,000 feet long, but the longest is about 8,000 feet. Most appear to be only a few feet thick, although some may be as much as 10 to 20 feet. If they were ever high, geomorphic processes have reduced them. They commonly merge into the tundra and are generally marked by a change in vegetation only,

Photo: U.S. Navy

Fig. 3. Stabilized dunes on the coastal plain of northern Alaska, 70°32N., 153°14W., 5 August 1948.

caused by the slightly greater thickness of the active layer (zone of seasonal freezing and thawing) and better drainage. The parabolic dunes commonly merge into the longitudinal dunes to form complex types and presumably were formed simultaneously. The winds that produced most of the dunes blew from the same direction as the predominant winds of today. Shifting of the winds from easterly to westerly and less commonly to northerly or southerly directions has produced complex varieties of the longitudinal and parabolic types and superimposed one on another to form transverse and complex dunes. Other earlier orientations are believed to exist but none were determined conclusively in the field or from air photographs.

The majority of the stabilized dunes are being destroyed by migrating lakes and streams, by frost heaving, growth of ice-wedge polygons, and other

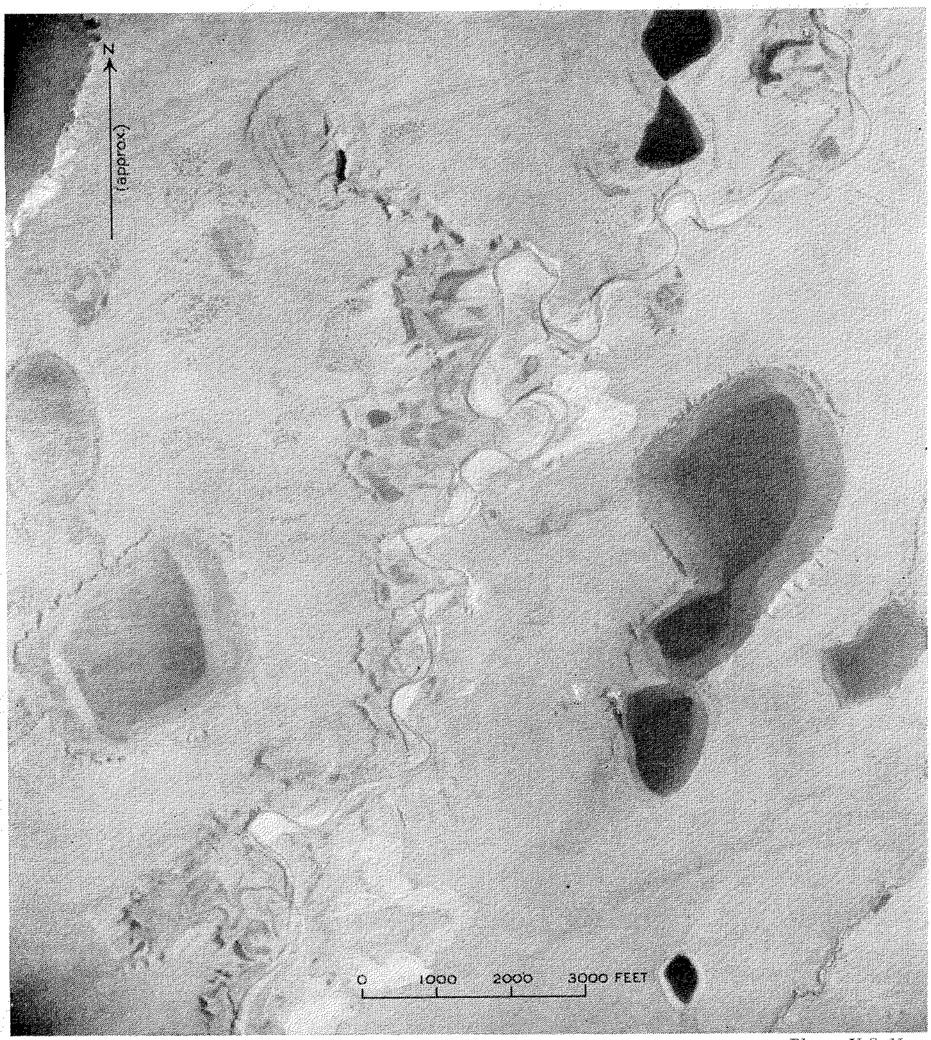

Photo: U.S. Navy

Fig. 4. Active blowouts and stabilized dunes on the coastal plain of northern Alaska, 69°51N., 152°52W., 13 August 1948.

weathering and erosional processes. However, many are still being supplied with additional material from blowouts along lake and river banks. The largest blowouts seen on air photographs are more than a million square feet in area; though most are only a few thousand square feet (see Fig. 4). From air photographs it would seem that the vegetated dunes in these active areas are only slightly higher and more clearly defined than other dunes that are not being supplied with sand. Small active blowouts may appear on the stabilized dunes and produce further complexities.

As the dunes are derived largely from local materials, the sands vary considerably in composition. Near the Colville River the dunes are formed from the Gubik sand, described by Schrader (1904, p. 93). Through the central Ikpikpuk River and Meade River areas the materials are principally medium-grained white to yellow and tan quartz-rich sands (see Fig. 5).

The age of the majority of the dunes is not known. Some are forming slowly today; others are completely inactive and are considerably modified by geomorphic processes. Some seem to be older than the ice-wedge polygons with which they are associated, and some are definitely younger. It is believed that the majority of the dunes were formed in a climate slightly warmer than that of today. The active layer would have been thicker and would therefore

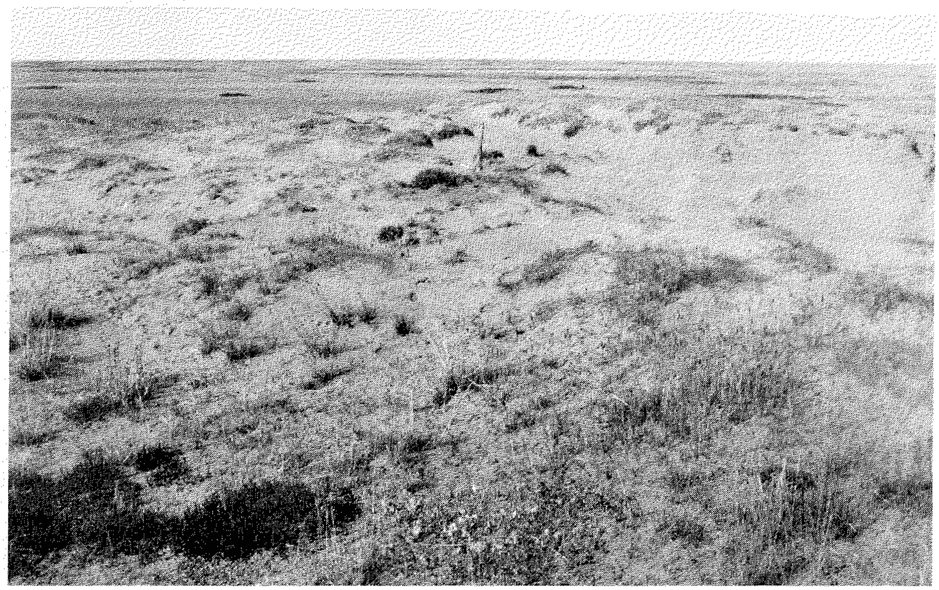

Fig. 5. Blowout dune partly stabilized by vegetation on bank of lake, 70°28N., 157°55W., in northern Alaska, 25 August 1947.

have permitted better soil drainage. Vegetation would probably have been slightly sparser, though some must have been present. Surface soils would have dried out more than they do now. Such a climate could probably have been produced in the post-Pleistocene optimum. What effect the northerly (or southerly) winds, postulated for the origin of the oriented lakes, had on the formation of these or earlier dunes cannot be surmised at this time.

Tops of many polygonal mounds along coastal banks, inland along lake and river banks, and on the open tundra, are frequently stripped by winds. During a period of a few weeks in summer, vegetation and a few inches of clay, silt, and fine sand may be removed. This very slow eolian reworking of the uppermost soil layers in the drier places is continuing each summer and is aided by the exposure of additional material by frost action (see Fig. 6).

Along the braided rivers, such as the lower Colville, Ikpikpuk, Topagoruk, and Meade, the exposed bars are constantly subject to wind action. As pointed out by Smith and Mertie (1930, p. 249), sand and silt are swept up from the bars and piled up 10 to 20 feet high on the river banks. The coarser material is deposited quickly; the silt is probably carried for miles. The soil in many places along the west bluff of the lower Colville River is formed from silt a few inches to several feet thick; one exposure visited contained more than 10 feet of this silt, much of which seemed to be loess.

Even small willow shrubs may impede winds sufficiently to cause a few inches of silt to be deposited around them. Most of the loess is incorporated into the marshy, tundra soil by the growth of vegetation and by frost processes and is not recognizable. It stands out markedly, however, on the drier ridges

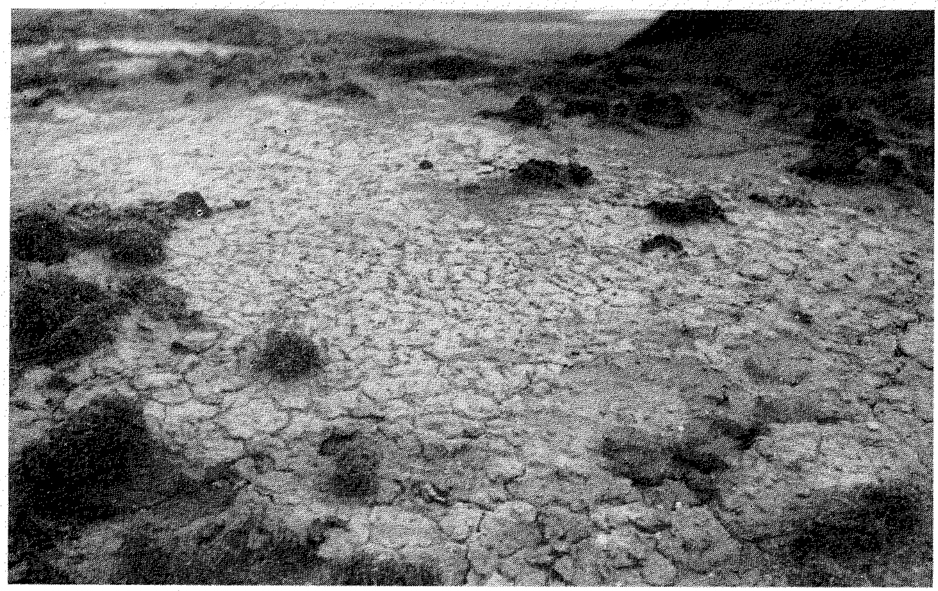

Fig. 6. Frost-stirred and wind-eroded top of silt polygon, Barrow, 7 August 1946.

and banks. It probably is being formed today adjacent to most rivers and lakes with high banks and exposed tundra polygons. The process may well have been more widespread in the past.

Areas Associated with Glacial Streams

Eolian deposits, locally reworked by streams, lakes, and tides, are found in all glacial outwash plains and most glacial stream valleys in Alaska. The dust storms associated with the braided streams of today are familiar to all travellers in Alaska. At present, glaciers cover less than 4 per cent of Alaska (Smith, 1939, p. 67), but possibly a quarter of the territory has been glaciated in the past, and no part of Alaska is more than 225 miles and much is less than 150 miles from a glaciated area. Most major streams traversing the non-glaciated areas have been fed by glacial waters at some time and carry or carried abundant material of silt size. Undoubtedly, former winds, commonly blowing outward from the major mountains, picked up sand and silt from the exposed bars and banks of those streams and redeposited them elsewhere as the winds are doing today. Because of topography, dense vegetation, high rainfall, and

Photo: U.S. Navy

Fig. 7. Stereographic vertical air photograph of compound dunes near the junction of the Alaska Highway and the 40 Mile Road, upper Tanana valley, 13 September 1948.

scarcity of materials, large areas in southeastern Alaska, although glaciated, are far enough from braided streams to be free from eolian materials.

Throughout non-glaciated areas in central Alaska, creek bottoms and even the flanks and tops of low hills may be buried under silt deposits as much as several tens of feet thick on the summits and as much as hundreds of feet thick in the valleys. Over broad areas the silts are similar, though local variations may be pronounced. In particular the silts on the uplands are clean, non-stratified, and largely yellow to light brown. The silts in the valleys are commonly stratified, rich in organic matter, and brown, grey, or black. Local conditions probably varied greatly from valley to valley during glacial times when most of the deposits seem to have been formed.

There is considerable divergence of opinion today on the origin of these tremendous quantities of silt and no attempt can be made here to discuss the problem in detail. Relatively little is known of the distribution of the various silt formations and their character. Taber (1943, pp. 1471-3) has written: "The Alaska silts have been formed and deposited in several different ways, and some have had a very complex origin. They contain material produced by glaciation, volcanic activity, organic processes, and weathering, and the deposits may be classified as residual, aeolian, fluviatile, lacustrine, and marine."

Numerous areas of sand dunes also are associated with the glacial valleys. Only a few of these and some known areas of loess are shown on Fig. 1. It is the writer's opinion that many of the extensive silt blankets known to occur throughout central Alaska will prove to be eolian in origin but modified through frost action and growth of vegetation.

Central Yukon River and lower Tanana River

In central Alaska, in the drainage of the Yukon and Tanana rivers, the origin of the silts and so-called mucks has long been controversial (see for example Eakin, 1916, pp. 55–61, 67, and 69–75; 1918, pp. 35–6 and 43–8; Mertie, 1937, pp. 186–9; Eardley, 1938; Giddings, 1938; Capps, 1940, pp. 164–5; Tuck, 1940, pp. 1295–310; and Taber, 1943, pp. 1471–503). Formerly a lacustrine origin was proposed for much of the silt except that in stream floodplains. Later workers accepted an eolian origin for much of it, except Taber (1943, p. 1473) who advanced . . . "the hypothesis that the creek-valley silts have been formed chiefly by disintegration of local country rock, the products of weathering having been moved down the valley slopes by soil creep and slope wash and distributed over the valley floors by occasional floods." The writer, like Troy L. Péwé (oral communication) and Tuck (1940), favours an eolian origin for much of the original silt, recognizing that considerable movement has taken place from the hillsides to the creek bottoms as quoted from Taber, and that locally frost action has supplied large quantities of material that have been partly mixed with the loess. The thick "muck" deposits cannot be regarded as primary loess deposits. The thickness varies so greatly that no general figures are given, though it may reach as much as 80 feet, for instance, on low hills near Fairbanks. The silts vary considerably in composition and structure and somewhat in size-grade distribution. A great amount of work needs to be done to delimit the horizontal and vertical extent of the loess and to distinguish silts of eolian origin that are also found in central Alaska.

A few stabilized longitudinal and other dunes have been noted by Moffit (1942, pp. 112-3 and 138) and Troy L. Péwé. Those near Big Delta are from 5 to 10 feet high, 100 to 300 feet long, and possibly 50 feet wide.

Upper Yukon River

Silts of possible eolian origin have been recognized along the upper Yukon River by Eakin (1916, pp. 55–61) and Mertie (1933, pp. 434–9; and 1937, pp. 188–9). Their extent is not known. In 1948–9 William S. Benninghoff and John R. Williams found that the superficial soils near the present floodplain of the Yukon River, between Stevens and Circle, are mainly composed of silt. Most of this is alluvial, though winds are constantly reworking it on the exposed bars and dust clouds are common. On a terrace 180 feet high bordering the southern margin, fine tan silts up to several tens of feet in thickness may be eolian. The northern rim of the valley is covered by 1 foot to 2 feet of reddish brown silt, locally mixed with float gravel and fine sand, which is tentatively mapped as eolian.

Upper Tanana River

During glacial times the upper Tanana River, in the Tetling-Northway flats, was occupied by a large lake, which left behind isolated sand and silt terraces as much as 350 feet high (Van Alstine and Black, 1944; and Wallace, 1948, p. 172). The upper surfaces of these terraces have been modified by wind into well-developed longitudinal, parabolic, compound, and undifferentiated dunes, 200 feet high (see Fig. 7). In places along the edge of the valley the dunes encroach on the bedrock hills. Most have been stabilized with vegetation for at least 1,400 years as they are covered by 4 to 8 inches of volcanic ash, believed to be of that age (Capps, 1916, p. 83). The dunes are perennially frozen, commonly as "dry-permafrost" (Wallace, 1946, pp. 16–7). In the vicinity of Northway approximately 85 per cent of the material is tan to black sand, the remainder is silt.

The major dune-forming winds blew from the northwest, but southwest winds have had some effect. These dunes, about which little is known, are among the best developed in Alaska and warrant detailed study because of their large size and peculiar shapes.

Loess a few inches to a few feet thick is essentially continuous along the glacial streams and may extend for considerable distances northward into the Yukon–Tanana Plateau, where centres of local glaciation and thick "muck" deposits are known.

Kuskokwim and Kantishna rivers

The Kuskokwim and Kantishna valleys were not glaciated, but they were traversed during glacial times by many glacial streams. These drained the Alaska Range to the east and south and also many centres of local glaciation to the north and west respectively. Broad outwash fans from the piedmont and valley glaciers (Capps, 1935, p. 76) filled the valleys to depths of possibly several hundred feet, as in the Yukon and Tanana valleys, and were favourable areas for wind action. Because of somewhat different source materials, of higher gradients, and proximity of glaciers, the central and upper Kuskokwim and Kantishna valleys contain more sandy surface material and therefore more sand dunes (see Fig. 1) than the central Yukon and lower Tanana valleys.

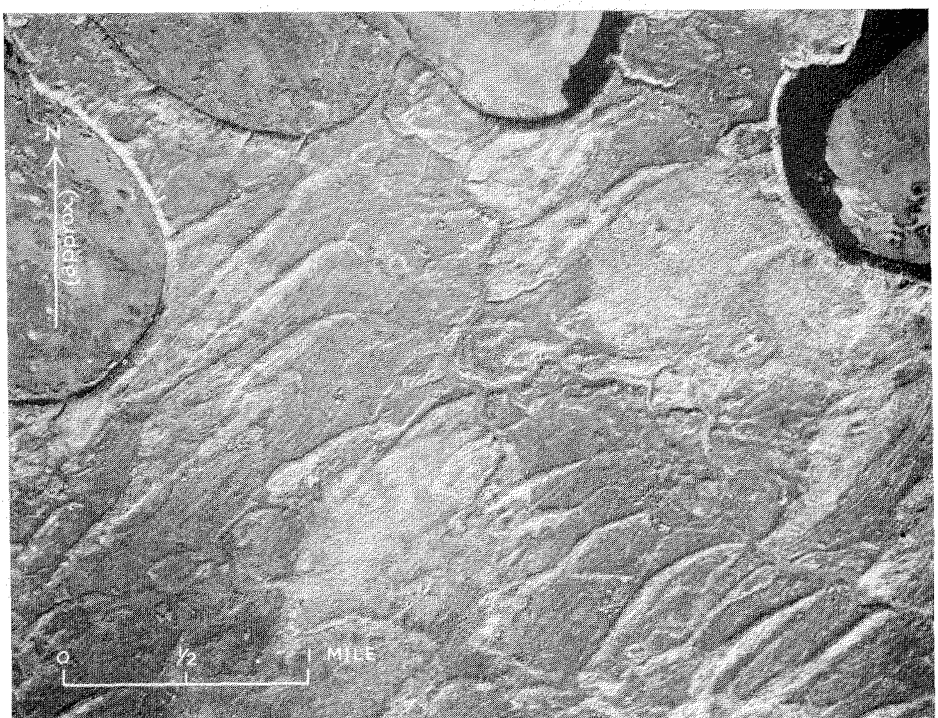

Photo: U.S.A.F.

Fig. 8. Parabolic dune ridges and undifferentiated dunes on a dissected alluvial plain about seven miles east-southeast of McGrath.

Arthur T. Fernald and William H. Drury record (in a letter) that near McGrath parabolic dunes of fine- to medium-grained sand average 25 feet in height and 2,500 feet or more in length (see Fig. 8). In the upper Kuskokwim and Kantishna valleys parabolic, longitudinal(?), and undifferentiated dunes are possibly 10 to 50 feet high and many are more than a mile long. Throughout the valleys compound and undifferentiated types may be found. All are stabilized by vegetation, but rarely small active blowouts may be seen.

Loess deposits 15 to 60 feet thick are recognized at two places (see Fig. 1) and are undoubtedly much more widespread. Extensive silt formations are known in the lower Kuskokwim and may prove to be eolian but are not shown on Fig. 1 because their origin and distribution are not known (Mertie and Harrington, 1924, pp. 44–9). Small active blowouts in silt and fine sand are common in the Kuskokwim delta.

Copper River

During glacial times the Copper River basin was buried under several thousand feet of ice that left behind hundreds of feet of unconsolidated sediments (Moffit, 1938, p. 113). These are being dissected by streams and have been exposed to wind action for centuries.

In 1901 Schrader and Spencer (p. 61) wrote of the Copper River region: "Besides wind-blown deposits in the forms of dunes, the surface soil is frequently composed of fine sand, doubtless of similar origin, and careful investigation would probably show that eolian deposits are rather generally distributed over the Copper Basin." This statement was supported by Tarr and Martin (1913, p. 295–300) and by Moffit (1914, pp. 31–2; 1918, p. 46; 1938, p. 100; and 1941, p. 144) and it seems that a considerable proportion of the present soil adjacent to the major glacial streams in the Copper River region is wind-blown silt from the bare floodplains. The limits of these materials have yet to be determined. Probably they encroach on the foothills of the Wrangell Mountains, and extend farther down the Copper River into much of the Hanagita Peak and Bremner River areas (Moffit, 1914, p. 31–2) and northward up the Chistochina, Gakona, and Gulkana rivers. However, the glacial streams flowing south from the Alaska Range seem to be less important as producers of loess than the streams flowing north.

The wind-blown silts vary from grey, yellow, buff, tan through brown. The fineness of the particles increases with distance from the streams. These silts are described in some detail by Tarr and Martin (1913, pp. 295–300; see also Bennett and Rice, 1919, pp. 227–8).

Sand and silt dunes are outstandingly developed along the banks of the Tonsina and Chetaslina rivers, and locally along the Copper River (Schrader and Spencer, 1901, p. 61; Mendenhall, 1905, p. 72). Smaller dunes are to be found locally along most glacial streams.

Cook Inlet

As the great Susitna–Cook Inlet glacier retreated northward during the waning stages of the Pleistocene epoch, conditions for silt deposition were probably at least as good as they are at present. Today the strong winds and frequent dust storms in the lowlands are well known (Tuck, 1938, pp. 652–3; Rockie, 1946, pp. 2, 6, 10, 23, 31–2). A considerable part, if not all, of the lowlands and lower flanks of the adjoining hills of Cook Inlet were probably covered with a blanket of eolian materials. On the alluvial bottoms and tidal flats the loess has been reworked, in swampy areas it has mingled with the organic deposits, and in the lakes it has been deposited as a lacustrine formation.

Sand dunes are relatively scarce because of abundant vegetation over most of the lowland. They occur along bluffs that are being eroded by water. Most are stabilized and are irregular in shape. Locally they may be as much as 50 feet high, but most are less than 20 feet (Rockie, 1946, p. 23).

The loess in the Matanuska Valley has been described by Tuck (1938) and Rockie (1946). Thor N. V. Karlstrom found that the thickness ranges from a few inches to 10 feet or more. Possibly the thickness depends on conditions of deposition rather than on later erosion and may be correlated with the position and duration of static fronts during glacial retreat. Without doubt its source has been the broad braided streams issuing from the numerous glaciers in or adjacent to the lowland. Two distinct ash horizons in the loess and in glacio-fluvial deposits may prove useful as time indicators.

Bristol Bay

In the Bristol Bay area, Ernest H. Muller found that loess, containing two or more distinct ash layers, mantles the coastal lowland to a depth of 1 foot to 3 feet, except where it has been removed by streams or where, as one

Photo: E. H. Muller, U.S. Geol. Surv.

Fig. 9. Coastal dune belt at Port Heiden, Bristol Bay, looking southwest from a point near Reindeer Creek, August 1949.

exposed morainic knolls, it has accumulated too slowly to maintain its identity. The loess generally lies on fluvioglacial sands and gravels from which it is clearly distinguished by texture, and was derived from the braided glacial streams that crossed the lowland and drained glaciers that almost surrounded the area.

Sand dunes up to 60 feet in height are found along sea bluffs, river bluffs, and past and present shorelines of the larger lakes (see Fig. 9). Active and stabilized fore dunes, commonly scarred with blowouts, are predominant. In places along the major streams the dunes form an "eolian levee" system 5 to 20 feet high. From the Naknek River to the northeast they are commonly covered with a spruce-parkland type of vegetation. The sand is medium-grained and well-sorted, passing into fine-grained sand and typical silt-loess within a few thousand feet from the river bank.

Small dunes are found in ash deposits on Aniakchak Volcano (Knappen, 1929, p. 206), and on the flanks of other volcanoes in the area (Howard

Waldron). Thick ash deposits on the flanks of volcanoes grade into thin ash layers of loess-like structure.

Spots of bared soil and blowout scars are abundant in the lowland wherever subsurface drainage permits seasonal drying of the soil.

Alaska Range

Eolian deposits are probably abundant throughout the Alaska Range though they have been mapped in the vicinity of the Alaska Railroad only. Clyde Wahrhaftig has provided the following information.

Sand dunes are restricted to the immediate vicinity of cliff-heads and lee-sides of "badland" areas, where they accumulate as true cliff-head dunes. They are present along the tops of all south-facing "badland" bluffs, but have not been observed along the tops of north-facing bluffs. The sand composing the dunes has been derived from sandstones or conglomerates of the adjacent "badlands", which are in the Tertiary coal-bearing formation and overlying Nenana gravel. The dunes range from 10 to 40 feet thick and may extend several hundred feet to the lee of the cliff-head. Cliff-head dunes show all gradations of stability, from bare, active, rapidly growing dunes, in places of perfect sigmoid shape, to completely stabilized dunes, overgrown with dense spruce forest. Where they have been dissected by wind, water erosion, or railroad cuts, up to three peat and forest layers are visible. One dune to the lee of a large outcrop of coal consists largely of coal fragments.

Angular platy fragments of schist, ½ inch thick and as much as 3 to 4 inches across, may be found in dune deposits at the tops of cliffs in the canyons of the Nenana and Totatlanika rivers. These must have been blown, rolled, or ricochetted by the wind for a distance of several tens of feet from their source in outcrops of schist to reach their present lodging places on top of, and interbedded with, thick turf, and in the branches of low bushes. They indicate extreme velocities of south winds.

Deposits of wind-blown silt mantle the slopes and tops of terraces along the Nenana River. The silt is 3 to 8 feet thick on bluffs overlooking the river, but thins away from the river. It thickens northward, increasing from 3 feet at Healy to 8 feet at Browne, 20 miles to the north. Commonly the silt is in two layers, a lower layer in which the bedding has been convoluted by frost action and the contained plant material is black, and an upper layer in which the bedding is undisturbed and the contained plant material is still brown and woody. Up to three peat layers may be present, and the boundary between the two types of silt is marked by a prominent peat layer. The median grain size of the upper silt layer is about 0.15 mm., whereas the median grain size of the lower silt layer, which has been affected by frost action, is 0.015 mm. The silt profiles on the higher and older terraces were not found to be thicker or more complex than those on the lower terraces.

The separate stratigraphic units of the silt mantle can be traced in many exposures from one terrace level to the next. The silt must therefore have been deposited following the development of all terraces. Inasmuch as the terraces can be traced upstream to glacial stages late in the Wisconsin, the silt deposits are all late Wisconsin or later.

Evidence on the rate of accumulation of the silt was obtained at two places. In the canyon between McKinley Park Station and Healy buried willow branches indicated an accumulation of 1 foot in about 50 years. At Healy a metal container buried under 8 inches of silt and exposed on the edge of the river bluff indicated a rate not less than 1 foot in 60 years.

Other areas

David M. Hopkins reports that very small dunes are active on recent beaches of several lakes in the interior of Seward Peninsula. The dunes are mostly blowouts and are generally less than 5 feet high and 10 to 20 feet long. Fine silts, believed to be largely wind-deposited, are widespread in the southwestern part of Seward Peninsula adjacent to the Kigluaik Mountains. The silts overlie glacial outwash deposits in valley bottoms and are locally present on the adjacent bedrock slopes. The deposits are 1 foot to 10 feet thick. The silts are believed to have been deposited during ice advances of several ages but present data are insufficient to subdivide either the glacial deposits or the associated silts.

George Gryc reports that poorly developed longitudinal dunes and active blowouts are common in north-facing valleys above 2,000 feet in the Brooks Range. All valleys have been extensively glaciated and filled with glacial debris, the source of the eolian material. Some terraces are reported to be covered with silt of possible eolian origin.

Ray (1935, Fig. 12) shows a photograph of a ripple-marked sand dune in the outwash plain of the Mendenhall Glacier, southeastern Alaska. It is now believed to be destroyed, but it is thought that sand dunes have existed on the outwash plains of many of the larger glaciers in southeastern Alaska and that silt has been picked up by the wind and deposited near the glacial streams. However, the torrential rainfall and the meandering streams tend to destroy all such deposits almost as soon as formed, and if any survive they are soon covered by luxuriant vegetation.

Dunes and loess are reported from many other glacial valleys but are not shown on Fig. 1 as their locations are not known.

Coastal Margins

Coastal margins along the Gulf of Alaska, the Aleutians, the Bering Sea and Bering Sea islands, and Seward Peninsula northward along northern Alaska, are characterized by fore dunes and irregular small blowouts. Isolated or continuous dunes of various types are common. The location and size of isolated dunes or dune belts are determined by the direction and velocities of seasonal winds, the degree of protection from marine erosion, and the supply of sand. Though precipitation and other climatic factors and local geology vary widely, at least a limited amount of sand is available locally to seasonal winds in exposed bars and beaches. At most places heavy rainfall, or persistent light rains, fog, high humidity, clouds, and vegetation discourage wind transportation. Hence, most dunes extend inland only a few hundred feet though some form belts a mile wide (see Fig. 9).

In the Gulf of Alaska, especially between Cape Suckling and Icy Bay and adjacent to the Malaspina Glacier, there may be three or more ancient beach ridges, topped by dunes, behind the present beach (Don J. Miller). The ridges, being better drained, are covered with timber; the intervening areas of lagoon deposits are swampy. The dunes may extend for many miles but cover a very small area. The average thickness measured from sea level to the top of the dunes is 20 feet, and the maximum thickness about 80 feet. Only part of such beach-dune ridges is wind-transported material. The wind produces fore dunes, blowouts, and transverse dunes. Those along the present beach are active; those on the ancient beach ridges are stabilized.

Locally on some islands in the Copper River distributary (Tarr and Martin, 1914, p. 466) and on the coast east of Cape Suckling, longitudinal and other types of dunes are several tens of feet high. Most are partly active though vegetation is abundant.

Isolated areas of wind-blown sand and small dunes just above high tide are found on many of the Aleutian Islands and the Alaska Peninsula (Smith and Baker, 1924, p. 188; Knappen, 1929, p. 206; Griggs, 1936, pp. 389–90; Byers, *et al.*, 1947, p. 35; Simons and Matheson, 1947, p. 64; Coats, 1947a, p. 83; 1947b, p. 102). Judson (1946) has studied in some detail an area of dunes on Adak. Single fore dunes and dune belts, modified by blowouts, are most common (Howard A. Powers, *et al.*). Their composition and form vary widely. Frank M. Byers writes that a dune belt 3 miles long and 600 feet wide lies on glacio-fluvial material on the north coast of Shemya. Robert R. Coats mentions that loess composed of reworked ash is absent or very scarce on most Aleutian Islands, but is 5 to 6 feet thick in stream valleys on Kiska Island. Coats also mentions that small dune ridges similar to those on Seward Peninsula (see below) in a few places in the Aleutians, for example on Tanaga Island.

Isolated fore dunes and occasional longitudinal dunes are found on the wet, wind-swept Bering Sea islands, but little is known about them. Most are built in vegetation and actually encroach on the tundra as much as one mile from the shore. Blowouts are numerous.

David M. Hopkins has made detailed notes of eolian deposits on Seward Peninsula, and the following account is largely quoted verbatim from his unpublished summary.

Much of the coastline of Seward Peninsula is smooth and straight, with broad sandy beaches. Active eolian formations are present everywhere along these beaches, and are especially well developed in the areas between Solomon and Point Spencer and between Cape Prince of Wales and Cape Espenberg.

The most common dunes, consisting of crescent-shaped hillocks of sand, 3 to 10 feet high and 8 to 20 feet long, should probably be termed parabolic. These are found at the top edge of escarpments carved in overgrown beach ridges by recent storm waves. They are generally elongate parallel to the shore and slightly convex towards the sea. The shoreward slopes of bare sand are steep and undergoing active deflation. The landward depositional slopes are gentler, with generally a fairly complete cover of wild rye

(*Elymus sp.*). All the dunes observed appear to be formed by onshore winds and do not reflect any constant regional wind direction.

Small barchans, 1 to 1½ foot high, and small "climbing" or "cliff" dunes are present locally on exceptionally wide beaches composed of very fine sand. They are found between the level of normal high tide and the ridge or escarpment carved by the highest storm tides, and are especially well developed at Port Safety, east of Nome.

Oval blowout areas undergoing active deflation are conspicuous on the Bering coast about a mile north of Cape Woolley. They are about 200 feet wide and 500 to 1,000 feet long. One area is indented about 8 feet below the general level of the surrounding terrain, but others only a few inches. The long axes of the blowouts trend north-northeast to south-southwest at an angle of about 50 degrees to the present coastline, which therefore truncates each of the oval areas.

A few small rounded dunes several feet high, which support a sparse cover of *Elymus*, are scattered over the surface of the blowouts. The remainder of the surface area is covered with small "dunes" of a type not previously encountered by Hopkins. They consist of broadly sinuous asymmetrical ridges extending discontinuously across the width of the blowouts. The ridges are 6 to 24 inches high and spaced at intervals of about 5 feet. The south sides have an average slope of 12 degrees but range in slope from 3 to 20 degrees, and are covered by a dense mat of *Dryas-Arenaria* turf. The north slopes range from nearly vertical to slightly overhanging and consist of bare sand apparently undergoing active deflation. The roots of the plants composing the turf are exposed in the escarpments and several buried turf layers may also be exposed in the underlying sand. Areas of bare sand are present in the hollows separating the dunes. The orientation of the turf dunes indicates that they are carved by winds blowing from N.5°E. to N.15°E.

The surface material in the vicinity of the deflated areas at Cape Woolley consists of coastal plain sediments. Silt containing varying quantities of organic matter is the dominant constituent but linear bodies of sand, probably representing elevated beach deposits, are common. The deflated areas appear to coincide with the areas of surface sands, and the orientation of the blowouts may be determined by the orientation of the linear sand bodies, rather than by the direction of strong winds. The orientation of the turf dunes is slightly oblique to the trend of the blowouts and is believed to reflect the direction of strong winds more accurately. Silt is also being distributed from bare floodplains of small streams near the coast.

Along the Bering and Arctic coasts of Seward Peninsula, stabilized dunes have been recognized on ancient beach ridges only. Ancient strand lines with stabilized dunes have been recognized at Solomon, Point Safety, between Cape Woolley and Point Spencer, and at many localities between Cape Prince of Wales and Cape Espenberg. Nondescript oval dunes are the most common form, but parabolic dunes are fairly common along the Arctic coast, particularly near Cape Espenberg. The larger stabilized dunes at Cape Espenberg are pockmarked with small active blowouts and appear to be undergoing destruction by recent winds.

On the offshore bars and beaches northward from Seward Peninsula to Barrow, plants, predominantly *Elymus mollis,* catch the drifting sand and build irregular to oval mounds a few inches to many feet high (see Fig. 10), but the quantity of sand is limited and no large coastal dunes form. Typical "desert pavements" are developed locally. The larger exposed rock fragments, commonly chert, are wind-polished and -faceted. Blowouts are abundant in

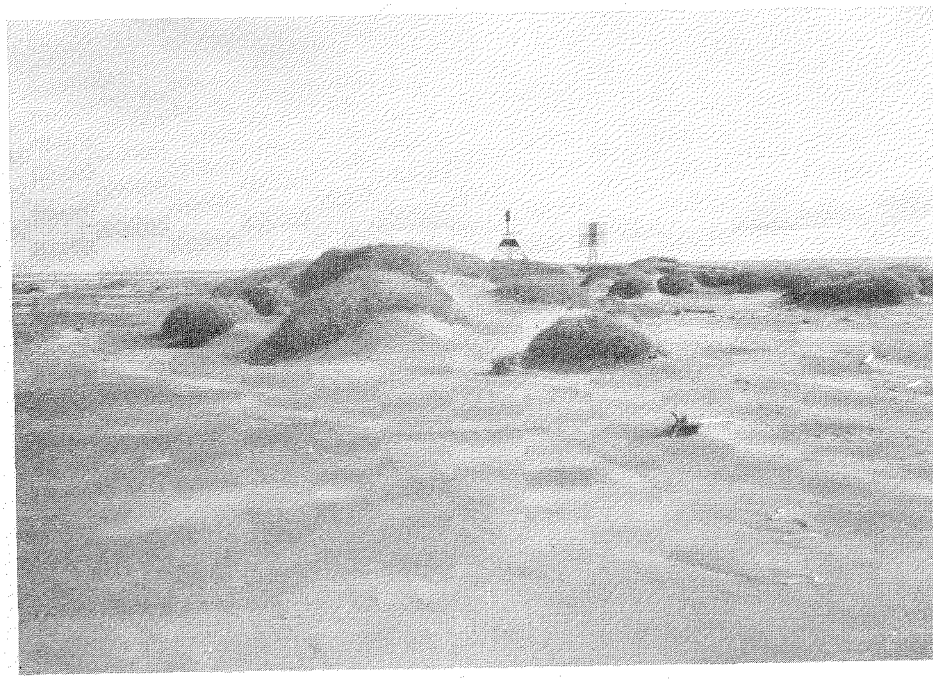

Fig. 10. Rounded and irregular dunes formed by *Elymus mollis* on an offshore bar at Peard Bay, northern Alaska, 4 August 1947.

the dunes on the bars and along the coastal bluffs. From Cape Beaufort to Peard Bay the unconsolidated superficial deposits are predominantly sands. Fine sand and silt become increasingly abundant in the bluffs to the north, and are commonly exposed along the tops of the bluffs where vegetation has been removed by wind action. Small blowouts a few feet to several tens of feet in diameter and generally a few inches deep occur during dry summers.

Ventifacts

Troy L. Péwé notes ventifacts cut by sand-blast action, in the valley of the Delta River in central Alaska. They were formed, and apparently are still forming, on ridges exposed to strong south winds. Those in younger moraines are less well developed than those in older moraines. Ernest H. Muller mentions that in the Bristol Bay coastal lowland ventifacts are buried in glacial outwash and can be found on the top of moraines. Clyde Wahrhaftig reports that wind-polished and -faceted pebbles and boulders are common in exposures of old till on terraces above Healy and on some south-facing slopes in adjacent "badland" areas in the Alaska Range.

Earlier workers have probably observed ventifacts in numerous other areas in Alaska, for example Smith and Mertie (1930, p. 249) in northern Alaska. However, such observations are generally not recorded and ventifacts are probably more widespread than published references suggest. It is likely that ventifacts occur in many of the mountainous areas, as Péwé and Wahrhaftig have reported for their areas, for high winds are common in the passes. Similarly, high winds are characteristic of the coastal margins and no doubt future investigators will find many places where wind-faceted pebbles and boulders are common.

Ash Deposits

Ash deposits are known in most major regions of Alaska, except northern Alaska. However, only in the Alaska Peninsula and adjacent islands, in the Aleutians, and in parts of the upper Tanana and White rivers do they make up an appreciable proportion of the soil. Their distribution, character, and genesis are only partly known, yet numerous references to them exist in the literature. As the ash falls have no known close climatic significance or correlation with the present eolian deposits, except as age indicators, they are not described in detail. Smith (1939, pp. 79-88) summarizes vulcanism during Tertiary to Recent time and describes the main ash falls in Alaska. Robinson (1947) gives more recent information for the Aleutians, where one to two volcanic eruptions are expected each year, and where most surface material is ash. It is apparent that the light pumiceous ash of andesite in the upper White and Yukon rivers, described in detail by Capps (1915), and the ash from the eruption of Mount Katmai in the Alaska Peninsula described by Griggs (1922), are by far the most outstanding ash falls known in Alaska. The former is estimated to cover more than 140,000 square miles and has a total volume of ash of about 10 cubic miles; it took place possibly 1,400 years ago. The latter occurred in 1912, and about 4¾ cubic miles of ash was ejected.

Thor N. V. Karlstrom has found that two ash layers buried to a depth of a few inches to several feet in the superficial deposits in many parts of the Cook Inlet area, are ½ to 1 foot apart in loess and peat. Two thin ash layers are found in the Bristol Bay lowland (Ernest H. Muller), one at the base of the litter[1] and the other 3 to 6 inches lower. These may prove to be potential horizon markers and, with those in Cook Inlet, may possibly be correlated with explosions from Mount Katmai and other volcanoes.

Reed and Coats (1941, pp. 47–8) describe a widespread ash fall from Mount Edgecumbe, near Sitka, in southeastern Alaska, which blankets recent morainic deposits but has been removed by erosion from many exposed places.

David M. Hopkins mentions that, throughout the eastern part of the coastal plain of northern Seward Peninsula, ash from Devil Mountain is probably interbedded with or overlies the coastal plain sediments. In central Seward Peninsula there are several small cinder cones which have thin, discontinuous layers of ash at the surface. Thick peat sections within a radius

[1]The upper, only slightly decomposed part of the forest floor.

of 10 miles from Imuruk Lake generally include a zone exceptionally rich in silt, which ranges from 3 to 18 inches thick and lies at a depth of 6 to 18 inches. The inorganic material consists almost entirely of shards of colourless volcanic glass, but includes a small percentage of broken crystals. The zone is believed to have originated from an ash fall but may possibly represent loess.

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