PHYSIOGRAPHIC DIVISIONS OF ALASKA

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Physiographic Divisions of Alaska

By CLYDE WAHRHAFTIG

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A classification and brief description with a discussion of high-latitude physiographic processes

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PHYSIOGRAPHIC DIVISIONS OF ALASKA

By Clyde Wahrhaftig

ABSTRACT

Alaska occupies the great northwestern peninsula of North America, which slopes and drains westward to the Bering and Chukchi Seas. Most of the State is mountainous or hilly although plains 20–100 miles wide abound. The central part, which slopes westward, consists of interspersed plains, plateaus, and rounded mountains, extending from beyond the Canadian border to the west coast; this part is bordered on the north and south by high rugged ranges which effectively cut off the bulk of the peninsula from the Arctic and Pacific Oceans. The northern range is the Arctic Mountains province of the Rocky Mountain System, dominated by the Brooks Range whose summit altitudes are 6,000–8,000 feet. North of this province are the Arctic Foothills, also part of the Rocky Mountain System, and the Arctic Coastal Plain, the northwestern extension of the Interior Plains. The southern mountain barrier, part of the Pacific Mountain System, is a pair of ridges separated by a line of discontinuous depressions, the Coastal Trough province. The northern ridge of the pair is the Alaska-Aleutian province; and the southern, the Pacific Border Ranges province. The highest peaks of North America, rising to an altitude of more than 20,000 feet, are here; and mountains 8,000–12,000 feet in altitude are common.

The part between the Arctic Mountains and the Pacific Mountain System is a disordered assemblage of flat plains and rolling uplands, surmounted here and there by groups of low mountains; the whole region declines in relief and altitude westward. It is divided from east to west into five provinces: the Northern Plateaus province, having uplands at altitudes of 3,000–5,000 feet, formed on Paleozoic and crystalline rocks; the Western Alaska province, having uplands at altitudes of 1,500–3,000 feet, formed on late Mesozoic sedimentary and volcanic rocks; Seward Peninsula and the Ahklun Mountains, two distinctive relatively mountainous provinces; and the Bering Shelf, a nearly featureless plain, which is mostly submerged but has mountainous islands. Southeastern Alaska includes parts of the Coast Mountains, Coastal Trough, and Pacific Border Ranges; all are provinces of the Pacific Mountain System.

By far the largest river is the Yukon, which, together with the Kuskokwim and other rivers that flow to the Bering and Chukchi Seas, drains all the Intermontane Plateaus and parts of the two mountain systems. The Bering-Chukchi-Arctic Ocean Divide is in the Arctic Mountains province; and the Bering Sea-Pacific Ocean Divide is partly on the crest of the Alaska-Aleutian province but for long stretches is in the lowlands of the Coastal Trough where in places it follows eskers.

Each of the provinces is divided for purposes of description into sections, 60 in all; and some of the sections are broken into subsections. The general topography, drainage, lakes, glaciers, permafrost conditions, and geology of each section are briefly described.

The Rocky Mountain System, Intermontane Plateaus, and Pacific Mountain System together constitute the North American Cordillera, one of the major physiographic features of the continent. Throughout most of its history the North American Cordillera has been the site of geosynclinal sedimentation, dominantly miogeosynclinal with interbedded carbonate and well-sorted clastic rocks in the Rocky Mountain System and northern part of the Intermontane Plateaus and dominantly eugeosynclinal with interbedded volcanic and poorly sorted clastic rocks in the Pacific Mountain System and southern part of the Intermontane Plateaus. Orogenic activity, accompanied by the invasion of immense granitic batholiths in the Pacific Mountain System and Intermontane Plateaus, has affected the North American Cordillera almost continuously since early Jurassic time. Near the end of Cretaceous time, orogenic activity reached its climax; and most of Alaska was converted to dry land, which has remained ever since. In Cenozoic time Alaska has been subjected to faulting, warping, and local folding. These processes formed highlands, whose erosion produced large quantities of poorly consolidated sediments, and basins, in which these sediments were deposited and are now preserved. Deformation continues and is particularly strong along the Pacific Coast. Active volcanoes are in the Aleutian Islands, Alaska Peninsula, and Wrangell Mountains.

Alaska has bedrock structure of great variety and complexity, which is reflected in the number and types of its mountainlands, uplands, and lowlands. Structural trends are predominantly parallel to the Pacific Coast; they swing from northeastward in the southwestern part to eastward in central and northern Alaska and southeastward in southeastern Alaska.

For the last 2 or 3 million years, frost climates have prevailed in Alaska, and the geomorphic processes have been predominantly either glacial or periglacial. Most of Alaska north of the Pacific coastal belt is underlain by permafrost. The firn line today ranges from 3,000 feet on the south coast to 6,000 feet on the north coast and is 8,000 feet in the eastern interior; during the glacial stages of the Pleistocene, it probably averaged 1,000–2,000 feet lower; thus, the Pacific Mountain System, which even today has extensive glaciers and mountain icecaps, was covered almost completely by the vast cordilleran ice sheet. The Arctic Mountains province, Ahklun Mountains, and southern Seward Peninsula were also intensely glaciated, whereas, in contrast, most of the Intermontane Plateaus, Arctic Foothills, and Arctic Coastal Plain were never glaciated.

Glaciated uplands that were buried by icecaps were eroded into blocklike groups of mountains having rounded hummocky

summits, isolated by networks of broad steep-sided U-shaped valleys and low passes. Ridges and peaks that rose above the level of the icecaps are jagged and knifelike. Ranges dominated by such ridges have extreme relief, and their valleys head in steep-walled glacier-filled cirques.

Glaciated lowlands are irregular and consist of end and ground moraines, drumlins, chaotic assemblages of irregular hills and hollows (stagnant ice topography), kames, eskers, and glacial-lake plains. Rock-basin and moraine-dammed lakes of great size, depth, and beauty are common around the margins of the glaciated lowlands.

Unglaciated uplands have been sculptured largely by creep and solifluction under an arctic permafrost climate, as the abundance of patterned ground, solifluction sheets and lobes, and altiplanation terraces attests. Ridges of the unglaciated uplands have broad rounded summits and gentle convex sides which are commonly mantled in their lower parts by windborne silt. The uplands are cut by narrow flat-floored valleys which have V-shaped tributary gulches.

Unglaciated lowlands are generally broad silt plains which have meander belts along the wildly meandering axial streams. Near the meander belts are flat plains dotted with thaw lakes (in places making up more than 50 percent of the area) and sporadic pingos. Toward the surrounding uplands are rolling silt-covered benches pocked by thaw sinks. Near the margins of the Pleistocene ice sheets, the lowlands have extensive outwash fans and aprons, commonly trenched by shallow terraced valleys; the streams are commonly braided. Fields of stabilized and active sand dunes are present locally.

INTRODUCTION

Alaska, the 49th State of the United States of America, occupies the great peninsula at the northwest corner of the North American continent and is separated from the conterminous United States by part of western Canada. It is one of the last regions of North America to be explored, and maps adequate for delimiting its physiographic divisions did not exist before the last 20 years. In this paper the State is divided into 12 physiographic provinces and 60 smaller divisions (pl. 1), all but two of which are described briefly.

Almost the entire State of Alaska is included in the North American Cordillera, the great mountainous backbone of western North America. Mountain-building activity has been recurrent throughout the geologic history of Alaska and has continued to the present time. The great variety of structures produced by the mountain-building activity and the differential movements of the recent geologic past have combined to give the State its extreme topographic diversity. Alaska's position at the northwestern corner of North America, close to the Eurasian landmass, has caused it to play a major part in the biologic, as well as geologic, history of the earth. At various times in the geologic past Alaska has been connected with Siberia and has served as a migration route for plants, animals, and men between the Eastern and Western Hemispheres (Hopkins, 1959a).

Although Alaska had long been inhabited by peoples of American Indian and Eskimo stock, the first Europeans to see it were Russian explorers under the captainship of Vitus Bering in 1741. The Russians conquered it and explored its southern coastal areas but did not penetrate deeply into the interior. It was part of the Russian Empire until 1867, when it was sold to the United States for $7,200,000. Systematic exploration of Alaska by expeditions of the United States Government began in 1883 (Brooks, 1906, p. 121–123). The first expeditions were sent by the Army and the Revenue-Marine Service; they generally had with them a geologist who prepared a report on and map of the region traversed. About 1898 the task of exploring the geology and geography of Alaska, except for the coastline, was taken over almost exclusively by the U.S. Geological Survey.

The early exploring parties were searching for routes of travel and commerce—navigable rivers and passes over the high mountain ranges that border the Pacific Ocean. They were in Alaska for the summer only, when the swampy lowlands are largely impassable. They therefore traveled by boat along the rivers, and later by horse across plateaus and low mountains. They mapped the country topographically as far as it could be seen on either side of their route, in part by instrumental observation on the spot and in part by panoramic photographs from which the topography could be determined by careful measurements in the office the following winter (Bagley, 1917). The narratives of their explorations—for example, Spurr's (1900) account of the exploration of southwestern Alaska—are stories of high adventure, full of danger and hardship. Their discoveries were summarized in two reports of the Geological Survey: that by Brooks in 1906 on the geography and geology of Alaska and that by P. S. Smith in 1939 on the areal geology of Alaska.

Brooks recognized that Alaska has two great mountain systems and an intermontane plateau region between them, and he saw that these are the northern continuations of the mountain ranges of the United States and Canada. He also recognized most of the subdivisions of the southern mountain system that we use today, but the Intermontane Plateaus seemed to be a chaotic jumble of hills and lowlands, which he did not attempt to classify.

As late as 1940 most of Alaska was still unmapped, topographically and geologically. The application of aerial photography to topographic mapping, and particularly the invention of the metrogon lens which permitted horizon-to-horizon photography from a single airplane flight, greatly accelerated mapping in Alaska. By 1946, in response to wartime needs, a crude map of the then territory had been prepared on a scale of 1 : 1,000,000, with a contour interval of 1,000 feet. Since that time the topographic mapping of Alaska has been progressing rapidly under the programs of the U.S. Geological Survey, the U.S. Coast and Geodetic Survey, and the U.S. Army Map Service. By 1970 nearly all the State will be covered by topographic maps of excellent quality having a scale of 1 : 250,000 and a contour interval of 200 feet (see fig. 1); and the greater part of it will be covered also by maps having a scale of 1 : 63,360 and a contour interval of 50 or 100 feet; all maps will be prepared by photogrammetric methods from vertical or near-vertical aerial photographs.

Geologic mapping, which is not amenable to accurate surveys from the air, has necessarily proceeded much more slowly. Nevertheless, in the last 15 years geologic maps on a scale of 1 : 250,000 have been made for all northern Alaska and much of western Alaska, the Brooks Range and southwestern Alaska.

ACKNOWLEDGMENTS

This wealth of new geographic and geologic information has made desirable a new classification of the State into physiographic divisions. The classification in this report was prepared intermittently between 1949 and 1959; most of the work was done between 1956 and 1959. The physiographic units and their boundaries were determined with the advice and assistance of the following geologists of the U.S. Geological Survey: Robert S. Bickel, Earl Brabb, William P. Brosgé, Robert L. Detterman, Arthur Grantz, J. M. Hoare, David M. Hopkins, E. H. Lathram, Marvin D. Mangus, Don J. Miller, William W. Patton, C. L. Sainsbury, and John R. Williams. It is hoped that the publication of this classification will bring about a clearer understanding of the geography of Alaska and will stimulate research into the history of the formation of the Alaskan landscape.

In addition to advice and assistance, the geologists named above also contributed unpublished information on the geology and physiography of Alaska. Arthur H. Lachenbruch provided information on the formation of ice-wedge polygons. A. R. Tagg and G. W. Holmes provided photographs of microrelief features.

Especial thanks are due Bradford Washburn, Director of the Boston Museum of Science, for permission to use his excellent aerial photographs of Alaska. Other aerial photographs were provided by the U.S. Navy and U.S. Air Force.

The work was done under the supervision of George O. Gates and G. D. Eberlein, and their encouragement and advice are gratefully acknowledged.

THE BASIS FOR THE CLASSIFICATION

The purpose of a physiographic classification of a region as large and diversified as Alaska is to divide it into areas that are so homogeneous topographically and distinct from the areas around them that the physical appearance of the region can be easily apprehended and described. The boundaries of the physiographic divisions are therefore drawn where the topography changes in character. The physical divisions must be such that one can describe them accurately in short, general statements. If the units are too large, they cannot be described in general terms without doing violence to the facts about their parts; and if they are too small, major relations of topography, geology, and drainage cannot be described because the units do not include them.

Although the basis for selecting the units is largely topographical, a major use of the classification is to deduce the history of the topography in order to understand why there are mountains in one place and valleys in another. Such a history is necessarily geologic, and the geologic structure must be considered in determining which areas shall be designated physiographic units. For example, the Upper Matanuska Valley and the Broad Pass Depression are shown as physiographic units because they are structurally controlled troughs, although many valleys that are just as wide are not considered physiographic units because they bear no relation to the structure.

The terminology follows the scheme used for the physical divisions of the conterminous United States by Fenneman and others (1946), in which the great physiographic features of North America were broken into major divisions, each major division, into provinces, and each province into sections. In addition, in the classification of Alaska, some division of sections into subsections has been necessary. As far as possible, the boundary lines were drawn to correspond with those of Bostock (1948) for the Canadian Cordillera so that the physiographic units would match across the international boundary. Bostock's names were used for the units unless Alaskan names had already appeared in the literature or seemed more appropriate. Bostock's grouping into units corresponding to provinces and major divisions could not be adhered to in all details.

The major divisions and their boundaries are shown on plate 1. These in turn have been divided into 12 provinces, which are shown on plate 1. The provinces have been divided into 60 sections, whose descriptions begin on page 18. The number in parentheses follow-

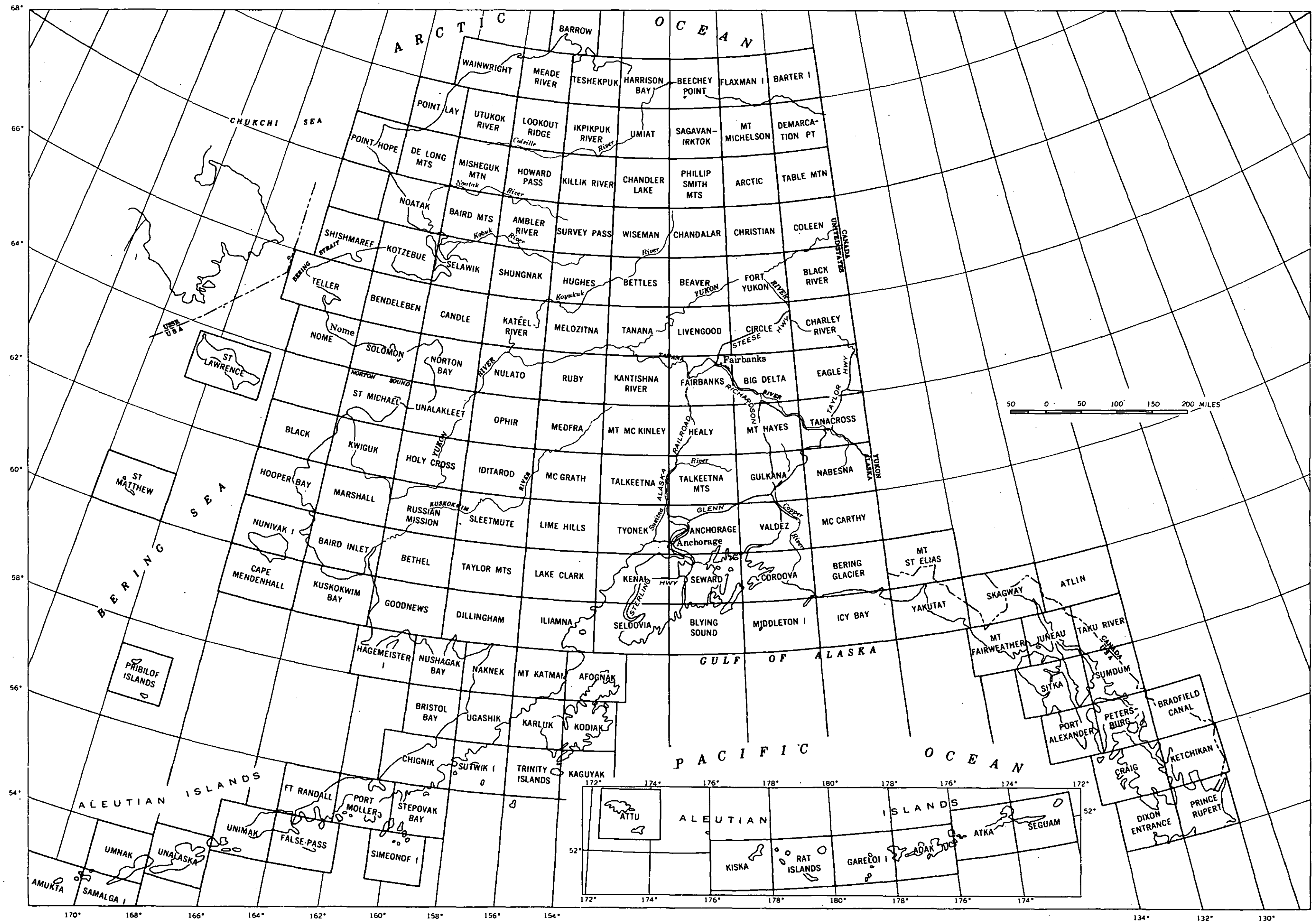

FIGURE 1.—Location of 1:250,000 topographic maps.

ing the title of each province or section or the first mention in the text of each subsection corresponds to the numbering of that area on plate 1.

The descriptions of the individual provinces and sections include: a brief sketch of the topography; some salient features of the drainage; statements on the lakes, glaciers, and permafrost; and a condensed account of the geology as it affects physiographic development. These statements are based on the literature dealing with the geology and geography of Alaska, chiefly publications of the U.S. Geological Survey; on topographic maps and aerial photographs; and to a very large extent, especially for the geology, on unpublished information given freely by my colleagues of the Geological Survey and listed on plate 1.

Two sections shown on plate 1, the Old Crow Plain (8) and the Duke Depression (50), are not described in text. These lie largely in Canada and have very small prongs that extend into Alaska. Descriptions for these areas were given by Bostock (1948, p. 76, 96–97).

SUMMARY OF THE GEOLOGIC HISTORY OF ALASKA

Alaska has already been indicated to be a region of intense orogenic (mountain-building) activity. Any understanding of its present topography depends, therefore, on some knowledge of its geologic history. A brief account of the geologic history is given in this section and summarized in table 1.

Most of Alaska has been studied geologically only in an exploratory manner. In his cross-country travels the geological explorer attempted to interpret, on the basis of a single traverse, the geology for many miles on either side. Only in recent years has there been much geologic mapping that attempted to cover uniformly the geology of a large area. Despite the speed at which the early Alaskan geologists worked, the extrapolations they had to make from rock outcrops near at hand to mountains miles away, and the lack of accurate maps on which to plot their observations, few of their interpretations of the geology have been found to be in serious error. Nevertheless, our knowledge of the geologic history of the State is still fragmentary and hypothetical. The most recent general summary of the geology of Alaska, on which this brief account is based, is that of Miller and others (1959). The geology of Alaska, at the same scale as plate 1, is shown on the map by Dutro and Payne (1957).

The oldest rock unit in Alaska is the schist of the Yukon-Tanana Upland and the Alaska Range—called the Birch Creek Schist from outcrops along Birch Creek. This schist was originally sand and mud deposited in ancient seas and is thought to have been tightly folded and metamorphosed in early Precambrian time.

Apparently most, if not all, of Alaska was under water during much of the Paleozoic Era, for thick deposits of this age are found throughout the State. The Paleozoic rocks of the Brooks Range consist largely of limestone, sandstone, and shale, or of their metamorphic equivalents. In the central part of Alaska, the rocks also consist largely of limestone, sandstone, and shale; chert, volcanic rock, and graywacke as old as Ordovician in age are interbedded with the other rocks. In southern and southeastern Alaska, graywacke and volcanic rock—the rocks of orogenic belts—are common throughout the Paleozoic sequence, interbedded with great thicknesses of limestone, slate, schist, and nonmarine red beds.

Even in the early Paleozoic rocks there are fragmentary records of mountain-building activity, for angular unconformities exist between rocks of Ordovician, Silurian, and Devonian age in southeastern Alaska and similar unconformities in central and northern Alaska record a period of mountain building at the beginning of Devonian time. Whatever the nature of these orogenies, they have had practically no effect on the present topography of Alaska.

In Mississippian time extensive submarine volcanic eruptions occurred in various parts of Alaska, and during part of the Permian and Triassic most of Alaska south of the Yukon River was a great submarine volcanic field. The ancient basalt flows of this age constitute the greenstone formations common in Alaska; the most famous of these is the Nikolai Greenstone of the Kennicott Copper district. After the eruption of the greenstone, more limestone and shale were deposited over the sea floor.

A new period of orogenic activity began in Jurassic time. It was heralded by the eruption, in southern Alaska, of andesite flows and tuffs. These were intruded in mid-Jurassic time by an enormous granitic batholith that stretched from the Talkeetna Mountains through the southern Alaska Range to the Aleutian Range. From this time on, parts of Alaska were rapidly uplifted to form mountains, from which sediments were eroded and deposited in adjacent basins that were as rapidly subsiding. These sediments became the great thicknesses of graywacke, argillite, and conglomerate that make up great parts of the mountain ranges of southern and central Alaska. Not only were the blocks of land uplifted and depressed, but they were also squeezed together and slid over and past each other; therefore, throughout large parts of Alaska the consolidated bedrock is tightly folded, broken by numerous faults, and slightly metamorphosed. The deformation was not continuous but was probably of a pulsating nature. Periods of rapid change alternated

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TABLE 1.—*Geologic time scale*

Time of beginning, in years before present[1]	Era	Period		Typical fossils	Events in Alaska and elsewhere
8,700 years	Cenozoic	Quaternary	Recent	Civilized man.	Retreat of the glaciers; rise of sea to present level.
About 2 million			Pleistocene	Mammoth, giant beaver.	Growth of vast ice sheets and glaciers;[2] cold climates; growth of mountains to their present height.
About 63 million		Tertiary		Various kinds of horses, camels, saber-toothed tigers, and other mammals. In sea, mollusks (clams and snails) and echinoderms (sea urchins and sand dollars).	Most of Alaska probably dry land. Accumulation of gravels in many low areas. Accumulation of coal in swamps to form Nenana, Matanuska, and Bering River coal fields. A period of waning mountain-building activity except in the Aleutians and the Gulf of Alaska coastal belt.
About 135 million	Mesozoic	Cretaceous		Age of dinosaurs on land; in sea, age of complicated nautilus-like animals called ammonites.	Period of culmination of great mountain-building period in Alaska. Intrusion of Coast Range batholith and other batholiths. Accumulation of vast thicknesses of sand, shale, and impure sandy muds in basins where Kenai-Chugach Mountains, Kuskokwim Mountains, and Nulato Hills now stand, as well as north of Brooks Range. Folding and thrusting of rocks of Brooks Range and elsewhere.
About 230 million		Jurassic			Period of growing mountain-building activity in Alaska. Volcanic deposits in the Talkeetna Mountains and intrusion of the Talkeetna batholith. Sand and shale in Cook Inlet.
		Triassic		Small dinosaurs, amphibians.	End of period of outflow of submarine lavas over much of southern Alaska.
About 345 million	Paleozoic	Permian		Amphibians, clubmoss and fern forests on land. Trilobites, early corals, and primitive fishes in sea.	Early part of period of outflow of submarine lavas over much of southern Alaska.
		Carboniferous	Pennsylvanian		Submarine lavas and dark sedimentary rocks in southern Alaska.
			Mississippian		Chert in central Alaska. Limestone in northern Alaska.
About 600 million		Devonian		Most primitive fishes. First forests on land.	Sandstone and shale in northern Alaska; limestone and other sedimentary rocks deposited in central and southern Alaska. Apparently a period of mountain-building in Alaska, in which the mountains may have trended northeast or north.
		Silurian		Chiefly trilobites and brachiopods (lampshells).	In southeastern Alaska accumulation of pure limestone in reefs associated with volcanic rocks.
		Ordovician			Little record in Alaska. Limestone in Seward Peninsula.
		Cambrian		Earliest trilobites.	Little record in Alaska.
Oldest age determined from rocks by radioactivity: 3300 million	Precambrian	Precambrian		No fossil record.	Formation of Birch Creek Schist of central Alaska (Fairbanks area, Yukon-Tanana Upland, and Alaska Range).

[1] Date of Pleistocene-Recent boundary is based on Charlesworth (1957, v. 2, p. 1525–1526); date of boundary between Tertiary and Quaternary is based on Leakey and others (1961) and on J. F. Evernden and G. H. Curtis, quoted in Hay (1963); other dates from Kulp (1961).

[2] It has been determined that ice advanced and then melted away at least 4 times in Central United States and probably also in Alaska. The last such advance and the one that left the clearest mark on the topography is called the Wisconsin Glaciation.

with periods of relative stability, and a block that was uplifted at one time might be depressed at another.

Orogenic activity reached its climax in late Early and Late Cretaceous time. At that time, the rocks were tightly folded and had a cleavage; and great batholiths were intruded in the Alaska Range, in the Interior Plateaus, in the Kodiak and Chugach Mountains, and throughout southeastern Alaska and adjacent British Columbia. The Paleozoic rocks of the Brooks Range were thrust northward and folded into great flat folds overturned to the north. By the end of Cretaceous time, most of Alaska was dry land—a segment of the great mountain belt that borders the Pacific Ocean on the east, north, and west. The part of that belt in North America is called the North American Cordillera. In Alaska the structures produced by this orogeny are great arcuate belts roughly parallel to the shore of the Gulf of Alaska, and structural trends are generally northwestward in southeastern Alaska, roughly due west throughout most of central and northern Alaska, and southwestward in western and southwestern Alaska.

The structures characteristic of the North American Cordillera in Alaska have their counterparts farther south in Canada and the conterminous United States. Thus the bedded rocks of the Pacific Mountain System consist largely of great thicknesses of tightly folded graywacke, argillite, conglomerate, and basalt and andesite flows and tuffs. Rocks of the Rocky Mountain System are mainly limestone, quartzite, slate, and shale that were folded and thrust northward or eastward, away from the Pacific. The greatest intrusive and volcanic activity has been in the Pacific Mountain System, which contains an almost continuous belt of granitic batholiths from Mexico to the Aleutian Islands as well as a chain of active and recently active volcanoes. The evidence of igneous activity decreases across the cordillera away from the Pacific, and relatively little igneous activity occurred in the north front of the Brooks Range.

Orogenic activity continued in the North American Cordillera throughout the Tertiary. The belt immediately adjacent to the Pacific Ocean has been the most active. Tertiary rocks along the coast of the Gulf of Alaska have been tightly folded, thrust, and raised to great heights. The great chain of volcanoes in the Aleutians suggests the presence of magma at depth. Both the Aleutians and the Gulf of Alaska coast have experienced many strong earthquakes in recent years.

In the remainder of Alaska, the orogenic activity of Cenozoic time was much less intense than that of the Cretaceous. It has consisted mainly of block faulting and, in late Cenozoic time, of broad gentle warping and uplift. In the Alaska Range and elsewhere, bodies of coarse poorly consolidated conglomerate and sandstone which are folded and faulted indicate at least one period of intensive mountain building in central Alaska in Tertiary time.

Cenozoic time (the last 60 million years) has probably been largely an era of erosion in Alaska, interspersed at times by local depression of the ground surface which caused continental sediments to accumulate in basinlike areas of relatively small extent. It is the period of the formation of the physiography of Alaska. It is much more difficult to reconstruct the history of the formation of this landscape than it is to unravel the history of the rocks on which it is formed, even though the landscape is younger than the rocks. The advantage to a geologist of a sequence of sedimentary rocks is that the rocks themselves contain the record of the history of their deposition, stacked in order like the pages of a book. The landscape, however, does not generally retain the record of its formation. The record of erosion is like messages on a blackboard, for each stage of the erosional process destroys most of the product of the stage before it, and to work out the successive stages we must rely on undestroyed relics of the old topographies, which are hard to find and even harder to interpret.

Many hypotheses have been proposed for the evolution of the drainage of Alaska and for the distribution of its mountains and lowlands. Information on the later geologic history of Alaska is as yet insufficient to eliminate any but a few of these hypotheses or to give a history of the development of drainage that explains all known features. Therefore, no account is given here of the development of the major physiographic features or of the development of the drainage.

Certain facts of the physiography of Alaska, however, must be taken into account in formulating any history of its physiographic development. Although the mountain systems broadly parallel the major belts of internal structure of the cordillera, there are significant local differences, particularly in southwestern Alaska, where the north front of the Pacific Mountain System trends diagonally across several structural belts. The Western Alaska province of the Intermontane Plateaus is underlain largely by folded and faulted marine and continental sedimentary rocks of Cretaceous age. The Northern Plateaus province, on the other hand, is underlain chiefly by metamorphic rocks of Paleozoic and Precambrian age, including the oldest rocks in Alaska, and by large granitoid batholiths. There is no break in the structure of the under-lying rocks at the boundaries of this province with the mountain system to the north and south. Many of the lowlands are underlain, beneath a thin cover of soft Tertiary or Quaternary sedimentary deposits, by the same kinds of rock—crystalline or partly metamorphosed—that make up the mountains that surround them. It seems, therefore, that the present topography neither can be explained as being an immediate product of the main period of rock deformation and igneous activity in the North American Cordillera, nor can it be explained entirely by differential erosion of the rocks deformed in that period. Folding and faulting of more recent age, probably during late Tertiary or Quaternary time, were at least partly responsible for the topography.

The drainage similarly shows many anomalies. The major drainage divides do not generally coincide with major mountain axes but lie for long distances in lowlands to the north or south of them; and a large number of rivers cross mountain ranges through deep canyons from one lowland to another, even though the lowlands join around the ends of these ranges.

DETAILS OF SCULPTURE—PHYSIOGRAPHIC EVOLUTION IN THE LAST MILLION YEARS

Although the drainage and the larger physiographic features of Alaska may have originated far back in the Tertiary and possibly even earlier, the erosion and deposition that was responsible for the detailed form of mountainsides and valley floors has probably taken place throughout Quaternary time, when the present climate in Alaska was being established. Quaternary climatic patterns are unusual in the history of the earth in that extreme cold prevails in the polar regions. Much work has been done in Alaska and elsewhere on the erosional processes prevailing in these cold climates, and we have some idea about how the details of topography were formed.

The Quaternary has been a period when vast sheets of ice, compacted from snow, covered large parts of North America, Europe, Asia, Patagonia, and Antarctica and pack ice covered the polar seas. Several periods of growth of these ice sheets, accompanied by cooler and wetter conditions around the world, have alternated with periods having climates similar to, or even warmer and drier than, those of today. We know that much, though not all, of Alaska was covered with ice during the Pleistocene glacial advances; large parts are still ice covered. Furthermore, north of the southern coastal areas, Alaska is a region of permafrost—that is, a region where large areas of the ground a few feet below the surface are frozen the year around. A climate in which glaciers or permafrost can form is called a frost climate and is generally characterized by an average annual temperature that is below freezing. Figures 2, 3, and 4 indicate in a general way the climate of Alaska by showing the average January minimum and July maximum temperatures and the annual precipitation.

The layer of permafrost has profoundly affected the weathering and erosion of the rocks and produced a characteristic topography over much of interior and northern Alaska. Figure 5 shows the extent of the permafrost areas and the extent of Pleistocene and modern glaciation in Alaska.

In addition to its direct effect in the formation of glaciers and permafrost, the arctic and subarctic climate of Alaska has an indirect effect on the processes of erosion by its control on vegetation. Much of Alaska is above or beyond timberline and is covered by a dense mat of low bushes, herbs, grasses, and moss; parts are so high and cold that they are barren rock deserts. The distribution of the major types of vegetation in Alaska is given by Sigafoos (1958), and some of the climatic factors controlling the distribution of vegetation are discussed by Hopkins (1959c).

The physiographic sections of Alaska that are shown on plate 1 can be conveniently divided into four groups, in each of which a fairly uniform topography prevails: (a) glaciated highlands and mountains, (b) glaciated lowlands, (c) unglaciated highlands, and (d) unglaciated lowlands. The physiographic processes that prevail in each of these groups are discussed in the following four sections. The boundaries between the glaciated and unglaciated regions are not everywhere sharp, for in places where the older glacial advances were much more extensive than the younger glacial advances the glaciated topography produced by the older advances has been greatly modified by nonglacial erosional processes.

The material in the following four sections is based in large part on the following books and articles: Black (1951, 1954); Bostock (1948); Coats (1950); Eakin (1916, p. 76–92); Eardley (1938b); Eckel (1958); Flint (1957); Hopkins (1949); Hopkins and Sigafoos (1951); Hopkins, Karlstrom, and others (1955); Lachenbruch (1960a, 1960b, 1962); Leffingwell (1919, p. 179–214); Livingston (1954); Muller (1947); Péwé (1954, 1955a); Péwé and others (1953); Plafker and Miller (1958); Porsild (1938); Sharp (1947, 1958); Taber (1943); Tarr and Martin (1914); Trainer (1953); Twenhofel (1952); Wahrhaftig (1949, 1958a); Wahrhaftig and Cox (1959); Wallace (1948); Washburn (1956); and Williams (1958).

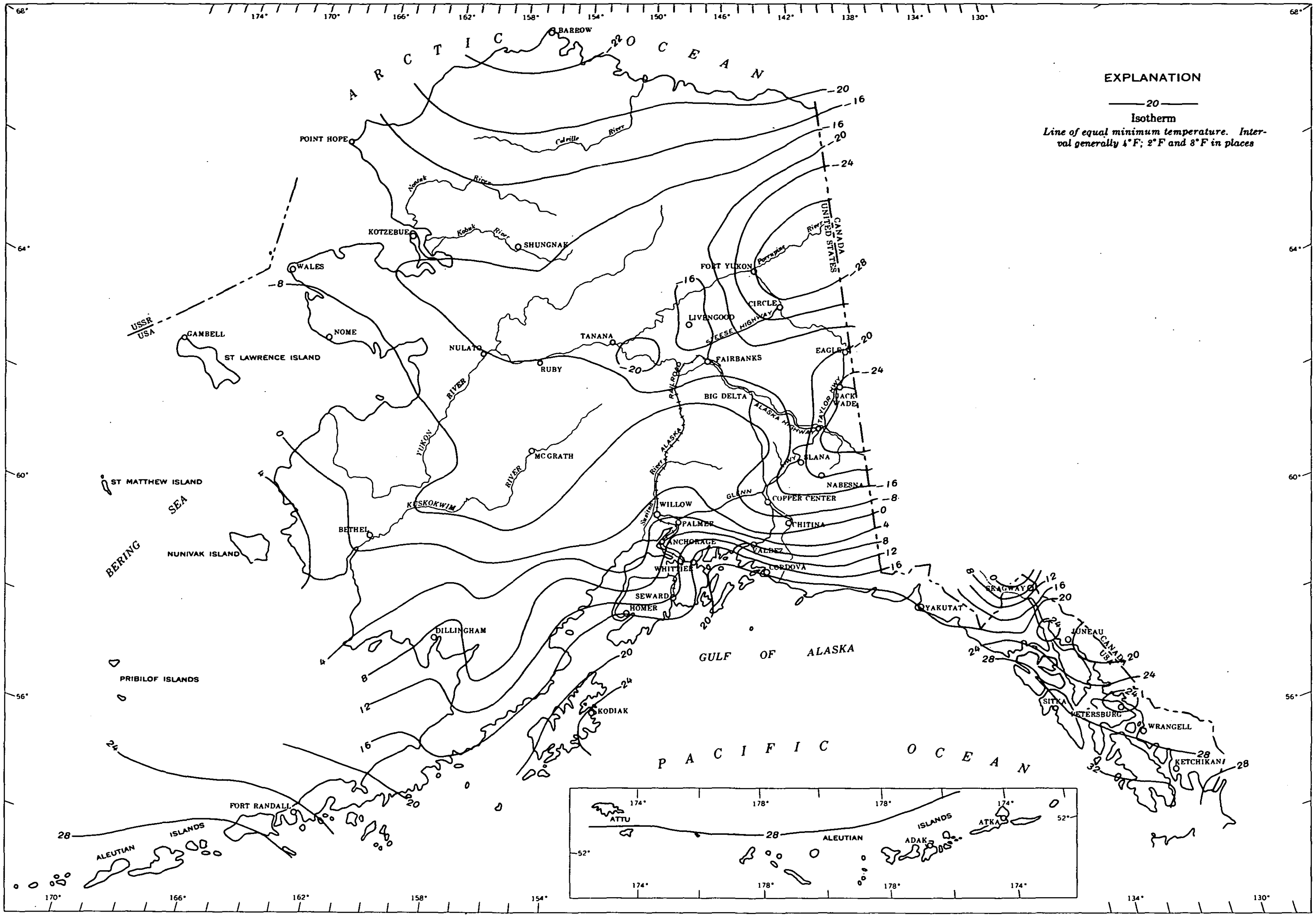

Figure 2.—Mean daily minimum temperature (degrees Fahrenheit) in Alaska in January (January mean daily maximums are generally 10° higher). From Watson (1959, p. 21).

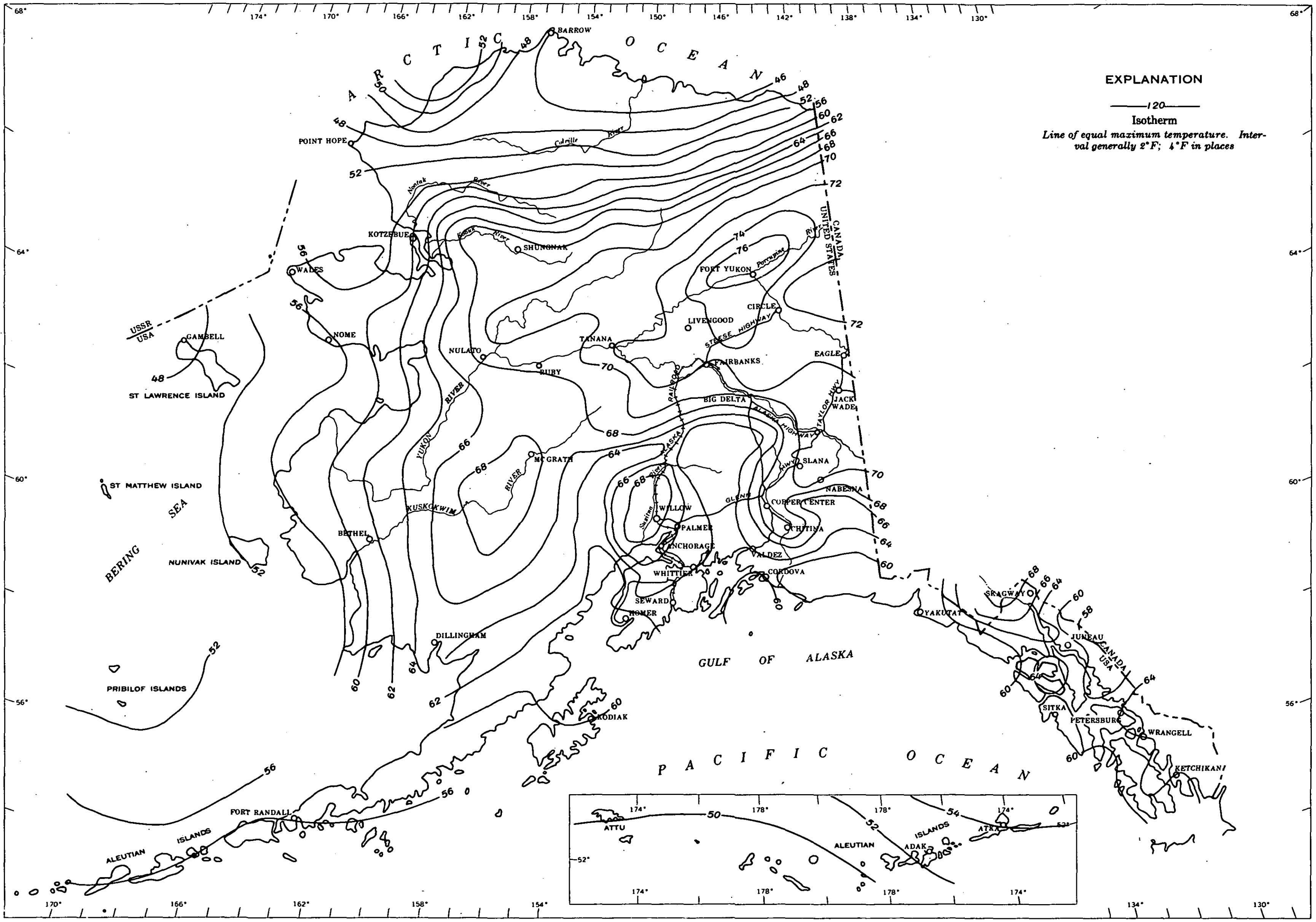

FIGURE 3.—Mean daily maximum temperatures (degrees Fahrenheit) in July (July mean daily minimums are generally 10° lower in coastal areas and 20°–25° cooler in the interior). Modified from Watson (1959, p. 22).

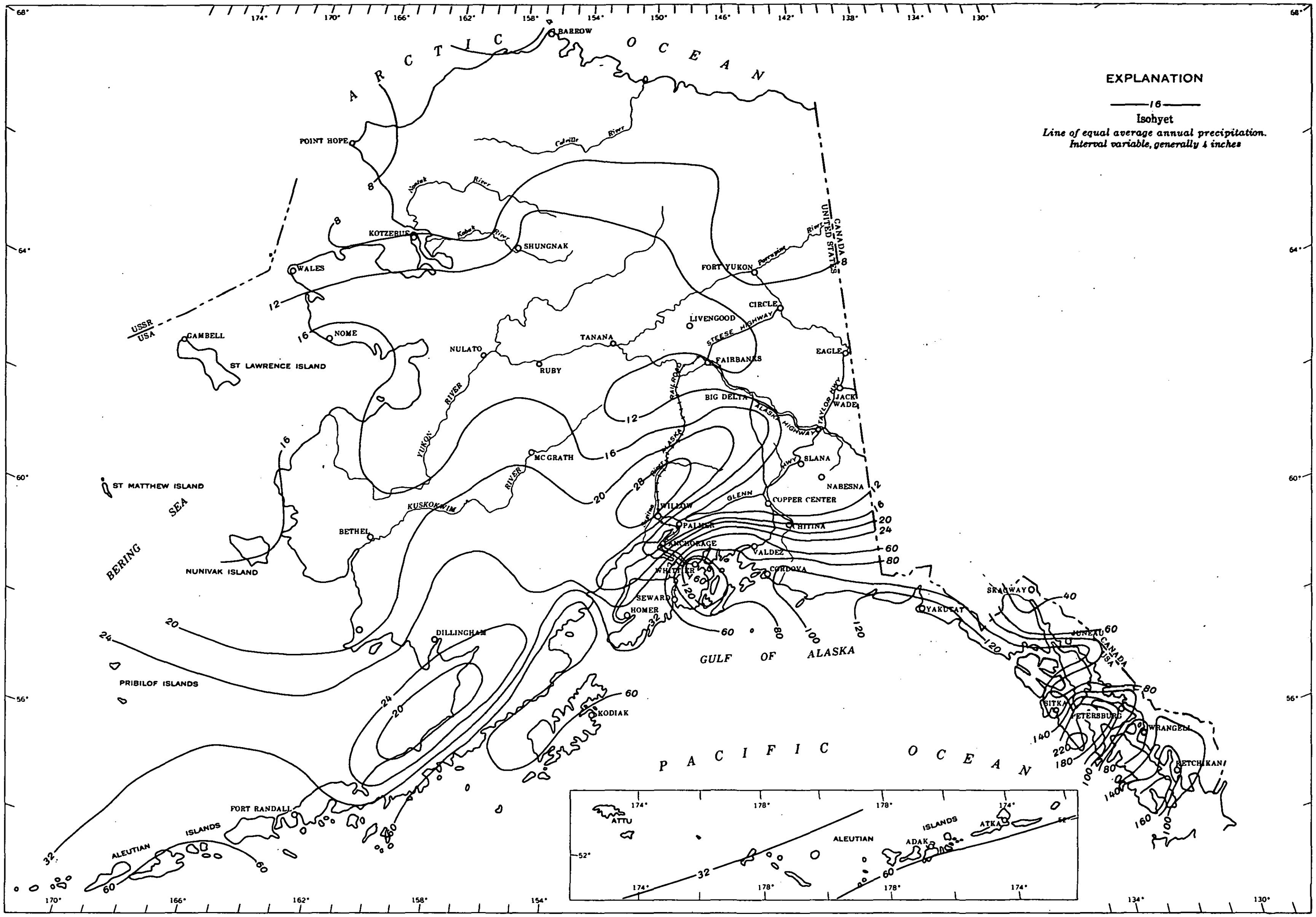

FIGURE 4.—Average annual precipitation, in inches. From Watson (1959, p. 19).

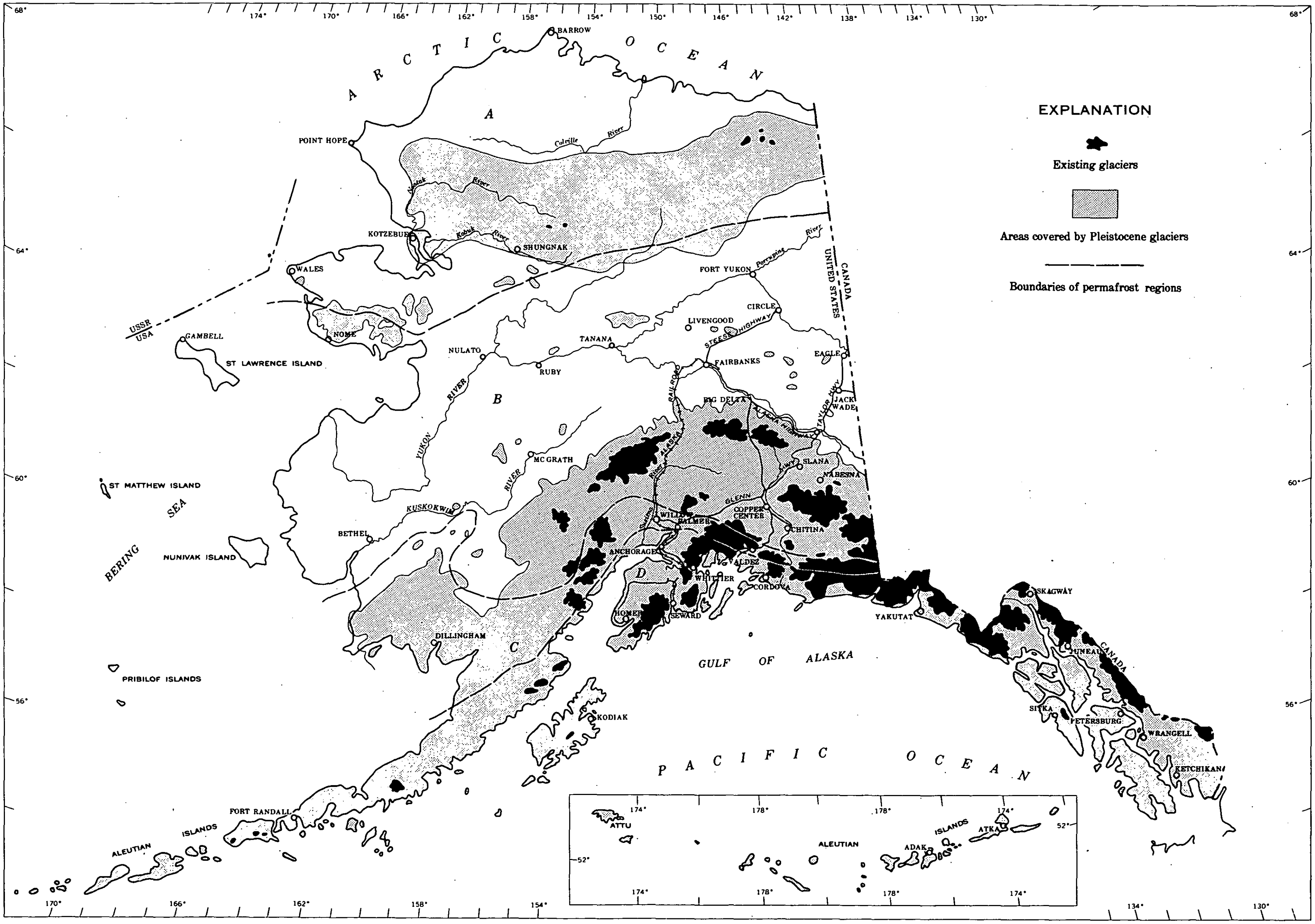

FIGURE 5.—Extent of existing glaciers, Pleistocene glaciers, and permafrost regions in Alaska. *A*, continuous permafrost. *B*, discontinuous permafrost. *C*, sporadic permafrost. *D*, no permafrost. (Modified from Hopkins, Karlstrom, and others, 1955, fig. 11, and Williams, 1958, fig. 2.)

GLACIATED HIGHLANDS AND MOUNTAINS

During the glacial expansions of the Pleistocene, snow accumulated on the mountains and avalanched into the heads of valleys, where it compacted into ice and flowed down the valleys as glaciers, just as it does on a smaller scale in the higher mountains of Alaska today. Eventually, most parts of the Pacific Mountain System and the Brooks Range were buried beneath a great network of glaciers and icefields; and smaller ice sheets existed on the Ahklun Mountains, on many mountains in the Intermontane Plateaus, and on the Seward Peninsula.

The grinding and quarrying action of the glaciers enlarged the heads of the valleys into steep-walled flat-floored theaterlike basins or cirques and steepened or undermined the surrounding mountainsides (pl. 5, figs. 9 and 10; pl. 6, figs. 6 and 7). Freezing of water in joint cracks in the mountains that stood above the ice split out blocks that fell to the glaciers below to be carried away by the ice. As a result these mountains were left as jagged knife-edge ridges (arêtes) and mountain spires (horns) with steep craggy cliffs that are commonly accessible only to experienced mountaineers (pl. 6, figs. 1, 4, and 6). In the glaciated regions, the upper limit that was reached by the most recent ice sheet can be recognized as the lowest level at which these jagged cliffs occur.

The cliffs and pinnacles are higher and steeper in areas of widely jointed rocks such as granitic intrusions and are less steep in closely jointed or slabby rocks such as schist and shale. Mountains formed of gently dipping sedimentary rocks have a cliff-and-bench topography (pl. 3, fig. 2); the cliffs are made of resistant widely jointed rocks such as limestone and quartzite and the benches are formed on soft marls and shales.

The ice generally flowed in the direction that its upper surface sloped whether or not this coincided with the slope of the buried landscape. As it flowed, the ice—using as tools the rock fragments embedded in it—quarried, ground, and polished the buried land and carried away all weathered and broken material. Hilltops overridden by the ice were rounded and flattened. Layers of soft rock and cracks and planes of weakness such as joints and faults were etched out by the ice, and the intervening masses were left as rounded knobs. Such glaciated country, free of all soil and most loose material, presents magnificent fresh outcrops for geologic study (pl. 6, figs. 7 and 11; pl. 5, fig. 11).

Glacial erosion widened valleys so that they now have U-shaped cross profiles with steep bounding walls and broad gentle floors; it straightened them by planing off projecting spurs; and it gave them irregular longitudinal profiles, eroding parts into deep rock basins (now filled by lakes) and in other parts forming giant steps by quarrying action. In mountainous areas almost completely buried by ice, the movement of the glaciers tended to lower the passes between the former drainage systems; and such areas eventually came to consist of blocklike mountains separated by a network of valleys and low passes (pl. 5, fig. 4).

In most of their erosion the ice sheets merely modified a pattern of valleys that already existed; they did not entirely destroy old drainage systems, nor did they create new valleys. The material removed was carried to the lower margins—where melting and evaporation balanced the inflow of ice—and was deposited there as heaped-up lines of ridges or end moraines. Melt water flowing along the sides of the glaciers carved notches and valleys that are now one-sided (the former other side was ice) and deposited plains of sand and gravel that now stand as benches (pl. 2, fig. 10). Beyond these lines of marginal deposits the topography of the unglaciated parts of the mountains is usually markedly different (pl. 5, fig. 7); however, this distinct margin is visible only around the later great glacial advances. Where ancient glaciation was more extensive than later advances, its forms can be recognized in subdued sharp-crested mountains and open cirquelike valleys without steep headwalls or lakes (pl. 5, fig. 6), but in most places the older morainal deposits have largely been removed by erosion (pl. 3, fig. 7).

GLACIATED LOWLANDS

Glaciated lowlands are largely regions in which material was deposited by ice. The material deposited directly from ice (till) is generally a very poorly sorted mixture of boulders, sand, and clay. The few basins eroded by the glaciers in the lowlands, generally where the glaciers flowed out of the bordering mountains, are now filled by lakes many miles across.

As a glacier advances it may push up a ridge of debris at its front. This ridge, or moraine—generally an arc enclosing the mouth of the valley from which the glacier flowed—remains when the glacier melts. There may be many parallel ridges, each pushed up by a short advance that punctuated a general period of glacier retreat. Few of the arcuate ridges enclosing the mouths of glacial valleys are of such simple ice-push origin, however. The debris scraped up by the glacier tended to be concentrated near the glacier front. When the glacier melted away, this debris was left as a belt of hilly country somewhat higher than the ground it encloses (pl. 3, fig. 10; pl. 4, fig. 13).

Some till was plastered directly on the ground from the lower part of the moving ice. If the resulting sheet of till is thin, it merely subdues the topography that existed before it was deposited. If it is thick, the preglacial topography may be obliterated, and a new topography imposed, which generally has smooth streamlined hills (drumlins) and hollows elongated in the direction of ice flow. Such sheets of till, whether thick or thin, are known as ground moraine.

As the glaciers melted away, the ice that was protected from sunlight by a covering of moraine did not melt as rapidly as the bare ice on either side of it. Rapid lowering of the bare ice surface left the moraine-covered ice standing as steep-sided ridges. The moraine slid off these ridges onto the bare ice, and the formerly protected ice melted down in turn. The repeated inversion of topography that this process produced caused the debris to slide back and forth and resulted eventually in accumulation of the debris as great piles of open bouldery till (pl. 2, fig. 10). In the last stages of this process the glacier was too thin to flow, and the ice became stagnant. The last blocks of ice to melt—half buried by accumulations of till around them—left hollows that are now commonly filled by irregular ponds and lakes. Large areas of the glaciated lowlands are marked by this chaotic stagnant ice topography (pl. 3, fig. 10; pl. 4, fig. 13).

Melt water from the glaciers circulated through and between the blocks of stagnant ice, sorting and reworking much of the morainal material. Gravel deposited by water flowing in tubes within and beneath the ice stands as narrow sinuous ridges (eskers) now that the ice has melted away (pl. 2, fig. 13). Elsewhere, the water deposited the gravel to form plains bounded by walls of stagnant ice. The ice later melted, leaving these plains as flat-topped ridges and hills (kames). Some of these flat ridges coalesce downstream to form outwash plains—plains made of the sand and gravel washed out of the ice by glacial melt water (pl. 5, fig. 3; pl. 6, fig. 5).

Much glacial melt water and water trapped from surrounding uplands flowed along the margin of the ice sheet; in many places its channel would have one wall of ice; some segments of its channel would be entirely in ice; and other segments would be cut across low spurs of the surrounding uplands. The remains of such channelways form benches and notches on the gently sloping valley walls or are narrow flat-floored steep-sided winding valleys that end abruptly downstream and upstream where the water formerly passed over ice. The streams, if any, that flow in these valleys today are too small to have cut them; at many places their direction of flow is the reverse of that of the melt water (pl. 5, fig. 2; pl. 6, fig. 9).

Large parts of some lowlands, the Copper River Lowland, for example, were flooded by lakes made when the rivers draining them were dammed by glaciers from the surrounding mountains. Finely ground rock debris that was washed into these lakes from the surrounding glaciers accumulated as layers of clay on the lake floors; today these floors are flat plains (pl. 6, fig. 3).

The result of this variety of processes of deposition and erosion accompanying the advance and retreat of the glaciers is that the glaciated lowlands are much more irregular and more diversified topographically than are the lowlands of unglaciated regions.

UNGLACIATED UPLANDS

The slopes of the unglaciated uplands of Alaska are modeled through the freezing and thawing of the thin surface layer above the permafrost. This thin layer of debris is formed by the freezing of water in joints and cracks that shatters the bedrock into small fragments. During freezing the ground heaves outward perpendicular to the slope. This heaving is caused partly by the expansion that water undergoes when it turns to ice and partly by the growth of ice crystals as water is drawn to them through capillary openings in the soil. When the ground thaws it tends to settle vertically downward under the influence of gravity. The small displacements that result shift the surface layer downslope, and over the years their cumulative effect is considerable. This slow, almost imperceptible motion is called creep.

The layer of repeatedly frozen and thawed material is kept close to saturation by ice melting in the frozen soil beneath it. In its saturated condition during the spring thaw it flows downslope as a thick sludge, a type of motion known as solifluction. Both creep and solifluction can take place on very slight slopes.

Freezing and thawing not only transport the surface layer, they also rearrange the soil and sort the soil constituents. The manner in which this rearrangement and sorting are accomplished is not yet completely understood and what is known is too complex to be told in this short review. However, the products are striking and are easily recognized. On nearly level surfaces the coarse fragments in the soil are sorted from the fine constituents and are arranged into polygonal networks of stones about centers of silt or clay (pl. 2, fig. 12). The silt and clay centers of the polygons are commonly raised into low mounds. This is one type of patterned ground (pl. 2, fig. 11). On some sloping surfaces the polygons are elongated downslope through creep and solifluction and pass into stripes of stones and fine earth extending down the slope (pl. 2, fig. 6). On other slopes the soil is arranged into small benches or terraces having steep banks of stones or turf. In some parts of Alaska, notably the Alaska Range, the stripes occur on south-facing slopes and the terraces on north-facing slopes.

The rate at which hills are eroded by creep and solifluction and the forms of the hills that are produced depend to a very large extent upon the rate at which the material is moved down the slope by these processes. The rate of movement, in turn, depends upon many factors—among which are the steepness of the slope, the depth of thaw, the amount of water in the soil, the size of the soil fragments, and the extent of vegetation. These factors vary not only from place to place but from year to year. In general, one may assume that, other things being equal, the rate of movement increases with steepness of slope and with increase in water content of the soil. Large blocks move more slowly than fine soil, and vegetation inhibits movement by decreasing the depth of penetration of the thaw and by holding the soil fast with its roots.

If the rate of movement on the upper part of the slope is greater than that on the lower part, material will pile up at midslope. Lobelike masses (solifluction lobes), particularly common near the upper limit of vegetation, show that this piling up of material is common (pl. 2, fig. 5). If the rate of transport is constant throughout the slope, erosion can take place only near the top of the slope, for the layer of material moving down the slope protects the lower parts from frost penetration and erosion. The tops of the hills will be flattened, whereas the lower parts of the slopes will retain their steepness and will be eroded only where the rate of transport increases at least in proportion to the distance from the top of the slope. Hence, where the rate of transport increases with the steepness of the slope, erosion of the lower part of the slope takes place only where the steepness increases downslope. The tendency of erosion by creep and solifluction, therefore, is to produce hills with broad gently rounded or flat summits and convex side slopes. Such hills are characteristic of the uplands throughout the unglaciated parts of Alaska (pl. 3, figs. 5, 6, and 9; pl. 4, figs. 5, 10, and 11).

If the downslope increase in the rate of transport is greater than the increase necessary to erode the slope evenly, the lower part of the slope is degraded more rapidly than the upper part. The part of the slope where degradation increases downslope must be growing steeper, because its base is being lowered more rapidly than its top. This part of the slope may grow into a craggy outcrop or a cliff (pl. 3, fig. 4). Common manifestations of this downslope increase in rate of degradation are tors, or bosses; these are resistant masses of unjointed bedrock a few tens of feet across and as high as a hundred feet, left standing on hilltops as the material around them moves downslope by creep and solifluction (pl. 2, fig. 3).

An extreme example of downslope mass movement is a landslide. Where saturated with water, poorly consolidated or badly shattered rock may suddenly or slowly move downhill over surfaces of slipping. Contrary to popular impression, the water does not act as a lubricant; its effect is much more complicated. In part it breaks down the soil structures, such as clods, that hold the mineral and rock fragments together or dissolves salts or other chemicals binding or cementing the rock; thus the rock is weakened for sliding. Its greatest influence, however, is its buoyancy. The rock is buoyed up by the weight of water filling its pores much as a stone is easier to lift when it is submerged in water, because the weight of the water it displaces acts against the weight of the stone. This buoyant weight counteracts the component of weight directed against the slope, which is the component that maintains the frictional resistance against sliding. At the same time the weight of the water is added to the component directed along the slope—the component that causes the sliding. Permafrost provides abundant ground water that keeps the ground saturated during the summer; because the permafrost is impervious (its pores are clogged with ice) this water cannot drain away. Hence, permafrost areas have frequent landslides (pl. 2, fig. 7).

A major factor in the landslide hazard is the steepness of the slope. Saturated silt and clay will slide or flow on slopes of 10° or less, but more massive material will stand on much steeper slopes, even in vertical cliffs, although it may contain much water. Anything that undercuts or steepens a slope is likely to cause landslides. The outer banks of meanders and the walls of canyons that are being deepened by streams are likely places for landslides.

Landslides are characterized by hummocky topography and irregular hillocks and depressions. At the upper end is a bowl-shaped hollow, bounded by steep scarps that mark the limits of the area of landslide subsidence. The lower end of some landslides is a bulging prominence, which may dam a stream to form a lake. The rocks of a landslide area are displaced, broken, and disturbed; characteristically, blocks are rotated backward toward the mountain as they move downslope.

Poorly consolidated rocks are generally protected from the erosional activity of rainwash by a blanket of vegetation. Areas laid bare by landslides lack this protection, and rainwash quickly carves exposures of sand and clay and of poorly consolidated sandstone and claystone into intricate patterns of steep-walled gullies. In Alaska the activity of rainwash alternates with freezing and thawing, and this alternation produces in the poorly consolidated rocks erosional forms of great beauty and regularity. The finest of these are the exposures of coal-bearing rocks in the Nenana coal field, in the Northern Foothills of the Alaska Range (pl. 2, fig. 8). On exposures of conglomerate, pebbles and cobbles are loosened by freezing and thawing and bounce down the slopes, loosening other pebbles in their paths; the faint hollows formed by the first-falling pebbles channel other pebbles to fall their way so that an initially smooth cliff is gradually transformed into many closely spaced ravines which have rounded floors and are separated by knifelike ridges (pl. 2, fig. 9).

The higher ridge crests and mountain tops in the unglaciated parts of Alaska are notched into giant steps or terraces several hundred to a thousand feet wide, whose banks of coarse rubble are 50–200 feet high (pl. 2, fig. 1). The material on the upper surfaces of these terraces is progressively finer and more saturated with water toward the back of the terrace. The origin of these altiplanation terraces is not clearly understood, for they have not been studied in detail. They are probably an example of erosion produced by solifluction and creep acting with the frost-sorting process.

The lower slopes of the upland hills are mantled with loess (wind-deposited silt) blown from the flood plains of the glacial streams. Part of this loess mantle is moved to the adjacent valley bottoms by torrents, mudflows, or landslides; so, the lower slopes of the hills are marked by a fine tracery of shallow gullies (pl. 3, fig. 9). In its transport to the valley bottoms, the reworked loess carries down and buries great quantities of vegetable material and even animal remains. Subsequently the whole mass freezes. The placer gravels of interior Alaska are commonly covered with several tens to a few hundred feet of this frozen muck.

Transitional in character between the forms of glaciated uplands and those of unglaciated uplands are rock glaciers; these are tonguelike or lobelike masses of coarse blocky rubble 50–250 feet high, resembling glaciers or lava flows, that move through the flow of their interstitial ice. They move outward at a rate of a few feet per year from the lower ends of talus cones, and hence are found only at the bases of steep cliffs in areas of frequent rockfalls. The interstitial ice is necessary for the movement of rock glaciers, and the accumulation of boulders is necessary for the protection of the ice, which would otherwise melt. They are common in cirques and along the walls of glaciated valleys a few hundred to 2,000 feet below the firn line.

The many cycles of glaciation in the glaciated parts of Alaska were matched by alterations of intense and mild frost action, creep, and solifluction in the unglaciated parts. In general, during the cold and wet glacial periods the level at which the more alpine forms of erosion were active was lowered, and the accumulation of loess was more rapid. During the warmer interglacial periods the silt tended to slide into the valleys to form muck, and the hillsides were moderately gullied. From a study of these deposits one can work out a succession of alternately severe and mild climates in interior Alaska that corresponds with at least the later stages of glacial advance and retreat in the adjoining glaciated areas.

UNGLACIATED LOWLANDS

The topography of the unglaciated lowlands of Alaska has been formed by the deposition of material brought in from adjacent highlands and glaciated areas by rivers and wind and by the action on this material of processes involving freezing and thawing that take place in permafrost areas. Most of the great rivers that flow through these lowlands had their sources in ice sheets during the Pleistocene Epoch, and many of them still head in glaciers. They brought and are still bringing great quantities of sand and gravel and finely ground rock flour from the glaciers. Where the rivers enter the lowlands, this coarse material was deposited in the form of broad, low fan-shaped deposits (outwash fans) that are crossed by the bare flood plains of the braided rivers (pl. 3, fig. 8). The gravel deposits raise the beds of the rivers and cause them to overspill their banks and change their courses to flow through adjacent lower areas. Such a shift of the Nenana River in 1921 destroyed a segment of the newly built Alaska Railroad. This shifting of the streams builds the outwash fans. Most of the fans were built during the Pleistocene ice advances, when the rivers were much more heavily laden than they are now. Because they have less material to carry from the glaciers, the rivers have removed some of the gravel they formerly deposited and now flow through the upper parts of their outwash fans in terraced valleys a few feet to a few hundred feet deep and ¼–4 miles wide. The outwash terraces can be traced for miles upstream into the surrounding mountains, where they generally end at the end moraines of the ice advances of the time they were deposited (pl. 4, fig. 13; pl. 6, fig. 2).

Downstream from the fans the rivers carry silt and clay. Banks of these compact sticky materials are not as easily eroded as are the loose banks of gravel and sand. Consequently, the rivers cannot spread freely over their flood plains in networks of small channels but instead concentrate in one or two large channels, which meander across the silt-covered plains (pl. 4, figs. 6 and 7).

Many of the streams rise in unglaciated regions. Some of these are provided with abundant debris by frost action in highland source areas and behave much as glacial streams do. Others carry very little inorganic debris and meander sluggishly over flat marshy lake-dotted plains. Peat accumulates in the lowland flats along these sluggish streams and extensive logjams occur in their courses.

The glacial rivers are subjected to daily and annual floods. The major annual flood occurs during the spring ice breakup, which progresses from the headwaters downstream. The ice floes form great jams and back up the rivers, which then flood the lowlands and deposit silt and clay in the vegetation of their flood plains. Freezing of this mixture of silt, clay, and slowly decaying vegetation keeps pace with accumulation. Generally the percentage of ice in this type of permafrost is as great as or greater than the combined percent of inorganic silt and organic matter.

During periods of low water the wind blows great clouds of dried mud and sand from the beds of the glacial streams. The fine material settles out of the air to mantle the plains and lower slopes of the surrounding hills as loess, which has accumulated to great thickness. The great dust storms that blow across the Alaska and Richardson Highways from the beds of the Delta, Donjek, and White Rivers are examples of the loess-forming process in action. Such storms must have been much more common and extensive during the glacial advances of the Pleistocene.

The sand that was blown from the river flats accumulates as dunes. Some dunes form long low ridges parallel to the direction of the wind. Others are great wavelike ridges at right angles to the wind and have gentle windward slopes and steep lee slopes (pl. 4, fig. 12). Most of these are now stable and overgrown with vegetation, but active dune deserts, barren as any in the Sahara, cover parts of the Koyukuk Flats and Kobuk Valley.

Ice accumulates in the silt in the form of interstitial cement, thin horizontal sheets, and thick vertical wedges that form polygonal networks, another type of polygonal ground (pl. 2, fig. 2). The ice wedges start from tension cracks that open during winter periods of rapid and profound drop in temperature. Later, water trickles into these cracks and freezes, adding to the permafrost. The cracks open during cold spells of following winters, and the ice wedges gradually thicken. The ice wedges are marked at the surface by shallow troughs bordered by low ridges of material thrust aside when the ground warmed and expanded in spring and summer after the contraction crack had filled with ice. Generally, the vegetation growing in these troughs is different from that growing in the intertrough areas. When the climate warms or the vegetation cover is removed, the ice wedges melt and the ground above them settles. Fields cleared in such ice-wedge terrain have to be abandoned after a few years.

The meandering rivers rapidly erode the frozen silty outer banks of their meanders at the same time that silt and sand bars are built in the slack water at the insides of the meanders. The rate of migration of the channels by this process has been estimated to be as much as 75 feet per year. The pattern of delicate alternation of bars and swales (known as meander-scroll pattern) left behind as the rivers migrate laterally is slowly buried by silt and vegetation, which is added to the body of permafrost (pl. 4, figs. 6 and 7).

The permafrost beneath the great silt-covered flats, 50 percent or more ice by volume, is in delicate equilibrium with the prevailing temperature and is generally protected from thawing by an insulating layer of moss, grass, and other low plants. If this vegetation layer is broken, the soil beneath it thaws and collapses, forming a pit which is filled with water. This water, in turn, thaws the banks of the pit, which is thus enlarged to a pond or lake called a thaw or thermokarst lake; the lake grows by collapse of the walls of the pit until the water has an opportunity to drain off. Silt and vegetation again cover the hollow and ice forms in the soil once more. The cycle may then repeat itself (pl. 4, fig. 3).

Loess and muck on hillsides, also frozen, can thaw and collapse by this process. Generally, much of the water drains out of the pits so formed, and an irregular topography of steep-walled flat-bottomed thaw sinks, which are a few feet to a few tens of feet deep and some of which contain lakes, forms on rolling silt-covered lowlands and terraces (pl. 4, fig. 7). Such topography is easily mistaken for morainal topography.

Pingos, rounded or conical ice-covered turf mounds a few feet to 100 feet high, are characteristic features of the lowlands of the northern parts of Alaska and in valleys in central Alaska (pl. 2, fig. 4). Pingos form when water trapped under great pressure in layers within the permafrost (between the permafrost and newly frozen ground) or beneath permafrost breaks through the confining frozen ground and forms a great blister of ice just beneath the turf—for water kept liquid at subfreezing temperatures only by high confining pressure freezes instantly when the pressure is released.

The processes that affect the unglaciated lowlands are for the most part depositional processes that reduce or erase irregularities on the lowland surface. The permafrost prevents downward percolation of ground water, and summer melting of ice at the top of the permafrost keeps the vegetation on these relatively smooth plains saturated. Consequently, large parts of the unglaciated lowlands are marshy flats, impassable to overland travel except in winter (pl. 4, figs. 1, 3, and 7).

DESCRIPTION OF THE PHYSIOGRAPHIC DIVISIONS

Two of the major physiographic features of North America extend into Alaska—the Interior Plains and the North America Cordillera. The Arctic Coastal Plain is the only continuation of the Interior Plains in Alaska. The North American Cordillera, which includes most of Alaska, consists of three of the major divisions of Fenneman's (1946) classification—the Rocky Mountain System, the Intermontane Plateaus, and the Pacific Mountain System, which form three parallel belts from the conterminous United States through Canada to Alaska (pl. 1). In Bostock's (1948) terminology, the Rocky Mountain System is the Eastern System and the Pacific Mountain System, the Western System. The names used by Fenneman had been applied to Alaska by Brooks in 1906, and there seems to be no reason for abandoning them here in favor of Bostock's terms.

The Rocky Mountain System in Alaska is represented by the Brooks Range—a mountainland 80 miles wide and 600 miles long that rises to altitudes of 4,000–9,000 feet—and by the Arctic Foothills—a rolling upland about 80–100 miles wide on the north side of the Brooks Range. The Brooks Range faces the Arctic Foothills with an abrupt scarp, and similarly rises abruptly above lowlands and low plateaus on the south (pl. 1).

The Intermontane Plateaus system in Alaska consists of a heterogeneous assemblage of low mountain ranges, rolling uplands, and alluvium-floored lowlands that decline in average altitude and relief westward from the Canadian border to the Bering and Chukchi Seas. Altitudes of uplands and mountains rarely exceed 6,000 feet in the east and 4,000 feet in the west, and are generally below 3,000 feet.

The Pacific Mountain System is an arcuate belt of high mountains that borders the Pacific Ocean. Generally, the system consists of two ranges of mountains and a belt of intervening lowlands. The northern range is represented in Alaska by the Aleutian Range, the Alaska Range, and the Coast Mountains; and the southern range, by the Kodiak, Kenai-Chugach, Baranof, and Prince of Wales Mountains. Intervening lowlands include the Cook Inlet-Susitna Lowland, the Copper River Lowland, and the Kupreanof Lowland. The northern and southern ranges come together and culminate in the St. Elias Mountains. Relief in the Pacific Mountain System is extreme: the lowlands lie near or even below sea level and the mountains rise to altitudes of 10,000–20,000 feet.

The Intermontane Plateaus are drained by the Yukon River, the largest river in Alaska, and by other streams flowing to the Bering and Chukchi Seas. The divide between the Bering and Pacific drainages follows in part the northern ridge of the Pacific Mountain System and is in part in the depressions south of that ridge. The divide between the Bering-Chukchi and Arctic Ocean drainage lies mostly in the Brooks Range, the main part of the Rocky Mountain System in Alaska. The major rivers and their drainage basins are shown in figure 6.

INTERIOR PLAINS

ARCTIC COASTAL PLAIN (1)

General topography.—The Arctic Coastal Plain is a smooth plain rising imperceptibly from the Arctic Ocean to a maximum altitude of 600 feet at its southern margin. The coastline makes little break in the profile of the coastal plain and shelf, and the shore is generally only 1–10 feet above the ocean; the highest coastal cliffs are only 50 feet high. The Arctic Coastal Plain province is divided into the Teshekpuk (1a) and White Hills (1b) sections. Scattered groups of low hills rise above the plain in the White Hills section; the Teshekpuk section is flat. Locally, an abrupt scarp 50–200 feet high separates the coastal plain from the Arctic Foothills. Locally pingos are sufficiently abundant to give an undulatory skyline. The part of the coastal plain between the Kuk and Colville Rivers has scattered longitudinal sand dunes 10–20 feet high trending N. 55°–75° E.

Drainage.—The Arctic Coastal Plain is very poorly drained and consequently is very marshy in summer. It is crossed by rivers which head in highlands to the south. Rivers west of the Colville River meander sluggishly in valleys incised 50–300 feet; those east of the Colville cross the plain in braided channels and are building deltas into the Arctic Ocean.

Lakes.—The Teshekpuk Lake section of the Arctic Coastal Plain province is covered by elongated thaw lakes oriented N. 15° W.; these range from a few feet to 9 miles long, are from 2 to 20 feet deep, and are oval or rectangular in shape (pl. 4, fig. 3). The lakes expand about 1 meter per year in places, and several generations of drained lake basins may be seen.

Glaciers and permafrost.—There are no glaciers. The entire land area is underlain by permafrost at least 1,000 feet thick. The permafrost table (base of zone of summer thaw) is ½–4 feet below the surface. A network of ice-wedge polygons covers the coastal plain (pl. 2, fig. 2). These are oriented parallel and perpendicular to receding shorelines because of stress differences set up by horizontal temperature gradients. Random polygons form in areas of more uniform stress.

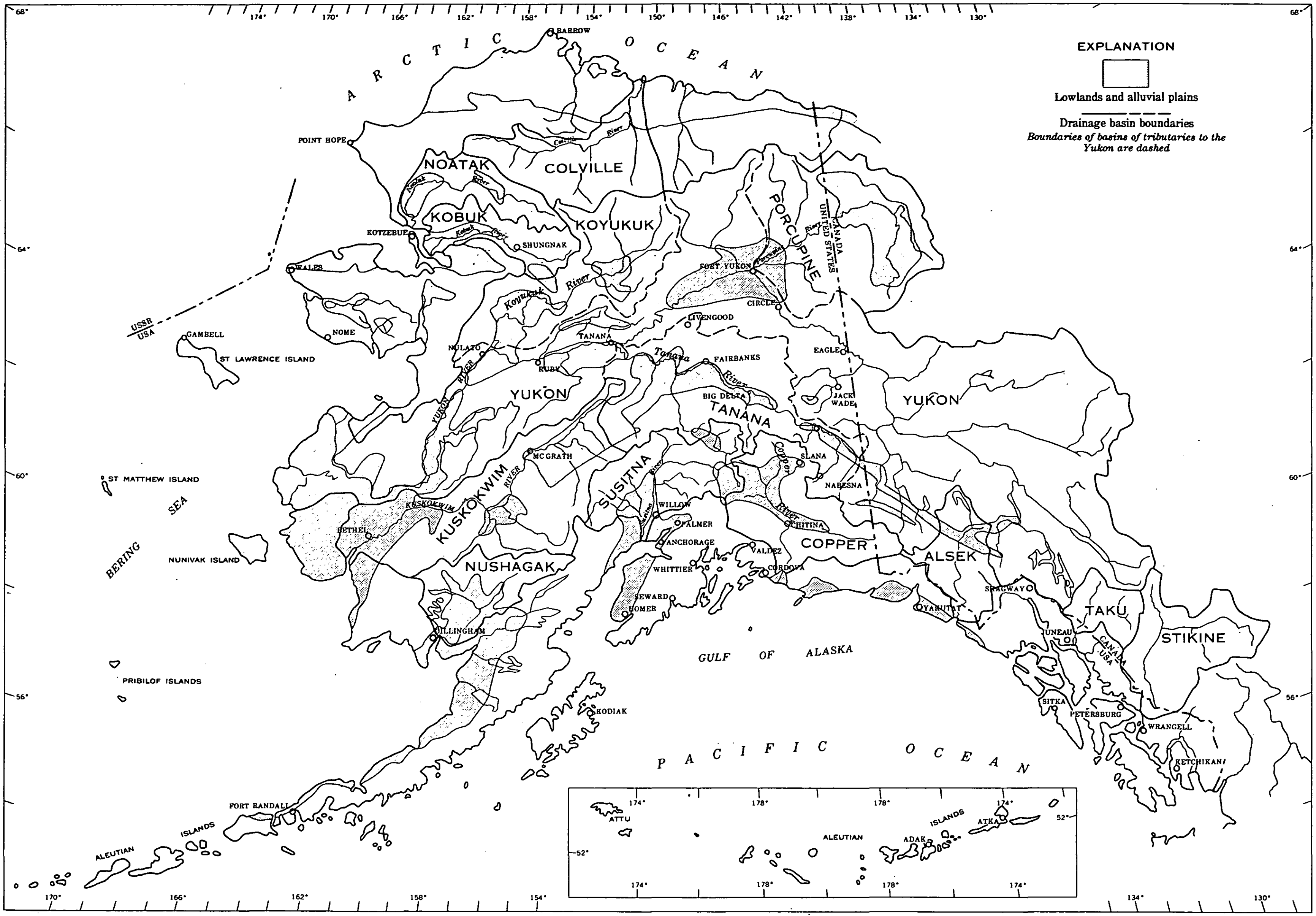

FIGURE 6.—Drainage basins of major rivers of Alaska.

Geology.—The Teshekpuk Lake section is underlain by 10–150 feet of unconsolidated Quaternary marine sediments resting on nearly flat Cretaceous sedimentary rocks containing coal. The White Hills section contains, in addition, lower Tertiary sedimentary deposits.

References.—Black (1952, 1955); Black and Barksdale (1949); W. P. Brosgé (oral commun., 1959); Chapman and Sable (1960); Coulter and others (1960); Lachenbruch (1960a, 1960b, 1962); A. H. Lachenbruch (oral commun., 1962); Leffingwell (1919, p. 150–155, 211); W. W. Patton, Jr. (oral commun., 1959); Porsild (1938); Smith and Mertie (1930); I. L. Tailleur (oral commun., 1959).

The Arctic Coastal Plain is covered by the following 1:250,000 topographic maps: Barrow, Barter Island, Flaxman Island, Beechy Point, Harrison Bay, Teshekpuk, Meade River, Wainwright, Demarcation Point, Mount Michelson, Sagavanirktok, Umiat, Ikpikpuk River, Lookout Ridge, Utukok River, and Point Lay.

ROCKY MOUNTAIN SYSTEM

ARCTIC FOOTHILLS (2)

General topography.—The Arctic Foothills consist of rolling plateaus and low linear mountains; they are divided into two sections. The northern section (2a) rises from an altitude of 600 feet on the north to 1,200 feet on the south and has broad east-trending ridges, dominated locally by mesalike mountains. The southern section (2b) is 1,200–3,500 feet in altitude, has local relief of as much as 2,500 feet, and is characterized by irregular buttes, knobs, mesas, east-trending ridges and intervening gently undulating tundra plains (pl. 3, figs. 3 and 4).

Drainage.—The Arctic Foothills are crossed by north-flowing rivers from sources in the Brooks Range. The Colville River, the largest stream, has an anomalous east-trending course for more than 220 miles along the boundary between the northern and southern sections. Most streams have swift, braided courses across broad gravel flats that are locally covered in winter with extensive sheets of aufeis, or anchor ice, that freezes to the riverbeds; this filling of the channels causes the streams to flood their gravel flats.

Lakes.—A few thaw lakes are present in the river valleys and on some divides. The upper valleys of major rivers from the Brooks Range contain many morainal lakes.

Glaciers and permafrost.—There are no glaciers. The entire province is underlain by permafrost. Ice wedges, stone stripes, polygonal ground, and other features of a frost climate are common.

Geology.—The northern section is underlain by Cretaceous sedimentary rocks deformed into long linear folds of the Appalachian type. Unequal erosion of layers of rock that differ in hardness has produced the linear-ridge topography. The southern section is underlain by diverse sedimentary rocks of Devonian to Cretaceous age together with mafic intrusions, all tightly folded and overthrust to the north. A preglacial gravel-covered pediment surface is preserved on some divides between north-flowing rivers. Hummocky morainal ridges border most valleys issuing from the central Brooks Range.

References.—Chapman and Sable (1960); J. T. Dutro (oral commun., 1959); Keller and others (1961); W. W. Patton, Jr. (written commun., 1959); Payne and others (1951); Schrader (1904, p. 45–46); Smith and Mertie (1930); I. L. Tailleur (written commun., 1959).

The Arctic Foothills are covered by the following 1:250,000 topographic maps: Meade River, Wainwright, Demarcation Point, Mount Michelson, Sagavanirktok, Umiat, Ikpikpuk River, Lookout Ridge, Utukok River, Point Lay, Philip Smith Mountains, Chandler Lake, Killik River, Howard Pass, Misheguk Mountain, De Long Mountains, Point Hope, and Noatak.

ARCTIC MOUNTAINS PROVINCE

The Arctic Mountains province consists of mountains and hills carved chiefly from folded and overthrust Paleozoic and Mesozoic sedimentary rocks. It is divided into the following sections: De Long Mountains (3), Noatak Lowlands (4), Baird Mountains (5), central and eastern Brooks Range (6), and Ambler-Chandalar Ridge and Lowland section (7).

DE LONG MOUNTAINS (3)

General topography.—The central part of the De Long Mountains consists of rugged glaciated ridges that are 4,000–4,900 feet in altitude and have a local relief of 1,500–3,000 feet. Narrow even-crested ridges in the lower eastern and western parts rise to 3,000–4,000 feet. Many passes about 3,500 feet in altitude cross the range. The north boundary with the Arctic Foothills is irregular and indistinct, but the south front is abrupt.

Drainage.—Streams from the De Long Mountains flow south and west to the Noatak River and the Chukchi Sea and north to the Arctic Ocean. The drainage divide is at the north edge of the mountains. Asymmetry of passes, barbed drainage, wind gaps, perched tributaries, and abandoned valley systems suggest that the divide has moved northward by stream capture.

Lakes, glaciers, and permafrost.—There are no lakes or glaciers in the De Long Mountains. The entire section is underlain by permafrost.

Geology.—The De Long Mountains consist of folded and faulted sedimentary rocks of Devonian to Cretaceous age, intruded by massive diabase sills that are the chief cliff-forming units; structural trends are westward in the eastern and northern mountains and change to southwestward in the southwestern part. The eastern and northern De Long Mountains are a great sheet thrust north over the rocks of the Artic Foothills.

References.—Mangus and others (1950); Smith and Mertie (1930); I. L. Tailleur (written commun., 1959).

The De Long Mountains are covered by the following 1:250,000 topographic maps: Howard Pass, Misheguk Mountain, and De Long Mountains.

NOATAK LOWLANDS (4)

General topography.—Two broad lowlands surrounded by hills and separated by a rolling upland lie along the Noatak River. The Mission Lowland (4a) is a broad tundra flat, containing thaw lakes and pingos 25–300 feet high and crossed by the forested flood plain of the Noatak River; it merges with the surrounding foothills by silt uplands intricately dissected by thaw sinks. The Aniuk Lowland (4b) is an irregular rolling plain that slopes gradually upward on the south to merge with a subsummit upland in the Baird Mountains. The intervening upland is the Cutler River Upland (4c).

Drainage.—The two lowlands and the Cutler River Upland are drained entirely by the Noatak River, which rises in the western part of the Schwatka Mountains. The Noatak crosses the Cutler River Upland and the Igichuk Hills south of the Mission Lowland by narrow cliffed gorges a few hundred feet deep.

Lakes.—The Mission Lowland has numerous thaw lakes. There are scattered morainal and thaw lakes in the Aniuk Lowland.

Glaciers and permafrost.—There are no glaciers. The entire section is underlain by permafrost, and pingos abound in the Mission Lowland.

Geology.—Bedrock geology beneath the lowlands is probably similar to that of surrounding uplands and mountains. The entire valley of the Noatak was probably glaciated in pre-Wisconsin time, but glaciers of Wisconsin time occupied only part of the Aniuk Lowland and reached only the north edge of the Mission Lowland. The depth of alluvial fill in the lowlands is unknown. Rounded gravel is reported 850 feet above the Noatak in the Cutler River Upland, and the course of the Noatak across the upland may be superposed.

References.—Smith (1913, p. 27–33, 92–93); Smith and Mertie (1930); I. L. Tailleur (written commun., 1949).

The Noatak Lowlands are covered by the following 1:250,000 topographic maps: Howard Pass, Misheguk Mountain, De Long Mountains, Ambler River, Baird Mountains, and Noatak.

BAIRD MOUNTAINS (5)

General topography.—Moderately rugged mountains having rounded to sharp summits 2,500–3,000 feet in altitude rise abruptly from lowlands on the south and west to a subsummit upland along the crest of the Baird Mountains. This subsummit upland slopes gently northward and merges with the Aniuk Lowland and Cutler River Upland. Scattered groups of higher mountains (3,500–4,500 feet in altitude) rise above the subsummit upland; they were centers of glaciation in Pleistocene time. The indistinct boundary with the Schwatka Mountains on the east is drawn where the relief increases abruptly eastward.

Drainage.—The Baird Mountains are drained by streams that flow north to the Noatak River and south to the Kobuk River. The south-flowing streams head in narrow ravines having steep headwalls, several hundred feet high, incised in broad flat passes that are the beheaded parts of north-draining valleys. This relationship indicates that the divide is migrating to the north by headward erosion.

Lakes and glaciers.—There are no lakes or glaciers in the Baird Mountains.

Geology.—Schist, quartzite, and limestone of Paleozoic age make up most of the Baird Mountains. Structural trends are eastward and the internal structure is probably anticlinorial. Differential erosion involving limestone and volcanic rocks of a northeast-trending anticline along the northwest border of the mountains has produced prominent northeast-trending ridges.

References.—Smith and Mertie (1930); I. L. Tailleur (written commun., 1959).

The Baird Mountains are covered by the following 1:250,000 topographic maps: Ambler River, Baird Mountains, and Noatak.

CENTRAL AND EASTERN BROOKS RANGE (6)

General topography.—The central and eastern Brooks Range is a wilderness of rugged glaciated east-trending ridges that rise to generally accordant summits 7,000–8,000 feet in altitude in the northern part and 4,000–6,000 feet in altitude in the southern part. The easterly grain of the topography is due to belts of hard and soft sedimentary and volcanic rocks. The mountains have cliff-and-bench slopes characteristic of glacially eroded bedded rocks. Abrupt mountain fronts face foothills and lowlands on the north (pl. 3, figs. 1, 2, and 3, pl. 4, fig. 4).

Drainage.—The drainage divide between the Bering Sea and Arctic Ocean drainages is near the north edge of the range west of long. 149° W. and in the center of the range east of long. 149° W. The major rivers flow north to the Arctic Ocean and south to the Yukon, Koyukuk, and Kobuk Rivers in flat-floored glaciated valleys ½–2 miles wide; they have a broad dendritic pattern. Minor tributaries flow east and west parallel to the structure, superposing a trellised pattern on the dendritic pattern of the major drainage.

Lakes.—Large rock-basin lakes lie at the mouths of several large glaciated valleys on the north and south sides of the range. The Brooks Range in general is characterized by a paucity of lakes for a glaciated area.

Glaciers.—Small cirque glaciers are common in the higher parts of the range, in the Schwatka Mountains (6a), and in mountains around Mount Doonerak. The firn line is at an altitude of about 6,000 feet in north-facing cirques and about 8,000 feet in south-facing cirques. Valley glaciers 6 miles long are fed from cirques and small icecaps in the Romanzof Mountains (6b).

Geology.—The central and eastern Brooks Range is composed chiefly of Paleozoic limestone, shale, quartzite, slate, and schist. Northeast of the Sagavanirktok River the Paleozoic rocks are in faulted folds overturned to the north. Elsewhere, they are in giant plates or nappes thrust to the north. The deformation is of Laramide age. The north front of the range is made of light-colored cliff-forming Mississippian limestone (see pl. 3, figs. 2 and 3). Rocks south of lat. 68° N. are metamorphosed and generally equivalent in age to those farther north. Granitic intrusions underlie the higher parts of the Schwatka Mountains (6a) and Romanzof Mountains (6b), both of which rise to 8,500–9,000 feet in altitude.

References.—Brosgé (1960; oral commun., 1959); Brosgé and others (1952); Chapman and Eberlein (1951); R. L. Detterman (oral commun., 1959); Detterman and others (1958); Keller and Detterman (1951); Keller and Morris (1952); Keller and others (1961); Mangus (1953); Mangus and others (1950); W. W. Patton, Jr. (oral commun., 1959); Patton and others (1951); Payne and others (1951); Schrader (1904); Smith (1913, p. 32–35); Smith and Mertie (1930); I. L. Tailleur (oral commun., 1959).

The central and eastern Brooks Range is covered by the following 1:250,000 topographic maps: Demarcation Point, Mount Michelson, Sagavanirktok, Table Mountain, Arctic, Philip Smith Mountains, Chandler Lake, Killik River, Howard Pass, Christian, Chandalar, Wiseman, Survey Pass, and Ambler River.

AMBLER-CHANDALAR RIDGE AND LOWLAND SECTION (7)

General topography.—This section consists of one or two east-trending lines of lowlands and low passes 3–10 miles wide and 200–2,000 feet above sea level, bordered on the north by the abrupt front of the Brooks Range. Along the south side is a discontinuous line of rolling to rugged ridges, 25–75 miles long and 5–10 miles wide, rising to 3,000–4,500 feet in altitude. Some of these ridges were intensely glaciated. Within the lowlands are east-trending ridges 5–10 miles long.

Drainage.—The western part of the section is drained by tributaries of the Kobuk River; the central part, by the Koyukuk River and its tributaries; and the eastern part, by the Chandalar River. Most streams flow south out of the Brooks Range across both the lowlands and the ridges to lowlands farther south. The drainage was probably superposed but may have been disoriented later by glaciers. The Chandalar River flows east along the eastern part of the trough.

Lakes.—Several large lakes fill ice-carved rock basins in deep narrow canyons across the southern ridge. Areas of ground and end moraines contain many ponds. The flood plains of the major streams have thaw lakes and oxbow lakes.

Glaciers and permafrost.—The section contains no glaciers but is underlain by continuous permafrost.

Geology.—The ridges are composed in part of resistant massive greenstone (metamorphosed basalt) of Mesozoic(?) age. The lowlands are underlain largely by Cretaceous sedimentary rocks, folded into synclines. Pleistocene glaciers from the Brooks Range extended across the lowland and through passes in the line of ridges.

References.—Brosgé (1960; oral commun., 1959); W. W. Patton, Jr., (oral commun., 1959); I. L. Tailleur, (oral commun., 1959); Smith and Mertie, (1930).

The Ambler-Chandalar Ridge and Lowland section is covered by the following 1:250,000 topographic maps: Chandalar, Wiseman, Survey Pass, Ambler River, Bettles, Hughes, and Shungnak.

INTERMONTANE PLATEAUS

NORTHERN PLATEAUS PROVINCE

The Northern Plateaus province consists of uplands and lowlands carved chiefly in Paleozoic and Precambrian(?) rocks. It is divided into the following sections: Porcupine Plateau (8), Old Crow Plain (9), (not described), Ogilvie Mountains (10), Tintina Valley (Eagle Trough) (11), Yukon-Tanana Upland (12), Northway-Tanacross Lowland (13), Yukon Flats section (14), Rampart Trough (15), and Kokrine-Hodzana Highlands (16).

PORCUPINE PLATEAU (8)

General topography.—Low ridges having gentle slopes and rounded to flat summits 1,500–2,500 feet in altitude dominate the topography of the Porcupine Plateau; a few domes and mountains rise to 3,500 feet. Valley floors are broad; and valley patterns, irregular, having many imperceptible divides. Thazzik Mountain

(8a) in the extreme west, a rugged glaciated mountain group, rises to 5,800 feet.

Drainage.—The entire plateau, except the extreme northeastern part, is drained by tributaries of the Yukon River. The Chandalar, Sheenjek, and Coleen Rivers rise in the Brooks Range and flow south across the plateau in broad valleys floored with moraines and outwash terraces. The Porcupine River crosses the plateau in a narrow cliff-lined canyon 50–500 feet deep. The Black and Little Black Rivers, which drain the southeastern part of the area, meander through broad irregular flats.

Lakes.—A few moraine-dammed lakes lie in glaciated passes and valleys along the north margin of the plateau. The largest of these is Old John Lake, 5 miles long and 2 miles wide. Scattered thaw lakes occur in lowlands and low passes.

Glaciers and permafrost.—There are no glaciers. The entire section is underlain by continuous permafrost.

Geology.—The northern part is underlain by crystalline schist, granite, quartzite, slate, and mafic rocks, probably mostly Paleozoic in age; the southeastern part is underlain by moderately deformed Paleozoic and Mesozoic sedimentary rocks. Basinlike areas of Tertiary rocks and flat-lying Cenozoic flows occur along the Porcupine River.

References.—Bostock (1948); W. P. Brosgé (oral commun., 1959); FitzGerald (1944); Kindle (1908); Mertie (1930a).

The Porcupine Plateau is covered by the following 1:250,000 topographic maps: Table Mountain, Arctic, Coleen, Christian, Chandalar, Black River, and Charley River.

OGILVIE MOUNTAINS (10)

General Topography.—The Ogilvie Mountains have sharp crestlines, precipitous slopes, and deep narrow valleys; they rise to 5,000 feet in altitude, and local relief is as much as 4,000 feet. The ridges are interconnected and passes are few. The narrow valleys are interrupted by gorges where rivers cross cliff-forming layers of rock.

Drainage.—The Ogilvie Mountains are drained by the Kandik, Nation, and Tatonduk Rivers, all tributaries of the Yukon River.

Lakes.—Small thaw lakes and oxbow lakes are along the Yukon River in the southern part of the mountains.

Glaciers and permafrost.—There are no glaciers. Most of the section is underlain by permafrost, and pingos are common.

Geology.—Moderately folded and faulted sedimentary and volcanic rocks ranging in age from late Precambrian to Cretaceous make up the mountains. Some formations of limestone, dolomite, quartzite, and greenstone are in massive cliff-forming beds. Continental sandstone and conglomerate of Late Cretaceous and early Tertiary (?) age underlie a lowland on the upper Nation River.

References.—Bostock (1948, p. 59); Brabb (1962, oral commun., 1962); Mertie (1932).

The Ogilvie Mountains are covered by the following 1:250,000 topographic maps: Charley River and Eagle.

TINTINA VALLEY (11)

General topography.—The Tintina Valley is a narrow belt of low country consisting of low rounded ridges and open valleys, which pass northwest into loess-covered terraces and a lake-dotted plain that connects with the Yukon Flats section. Relief in the southeastern part (southeast of Woodchopper Creek) is 1,000–1,500 feet, and ridges rise to 2,000–2,500 feet in altitude. Discontinuous low hills on the north separate this part from the Yukon River, and the mountains of the Yukon-Tanana Upland rise gradually above it on the southwest.

The northwestern part, around Circle Hot Springs and Birch Creek, is a lake-dotted plain that slopes gradually upward to the base of surrounding hills, and that is separated from the Yukon River by a flat-topped gravel ridge about 400 feet high and 3–4 miles wide.

Drainage.—The southeastern part in Alaska is drained chiefly by small north-flowing streams that rise in the upland to the south and have superposed courses to the Yukon River in narrow valleys across hills of resistant rocks on the north. The northwestern part is drained largely by Birch Creek, which flows parallel to the Yukon into the Yukon Flats.

Lakes.—There are no large lakes in the southeastern part. The plain of the northwestern part has several thaw lakes; the largest, Medicine Lake, is nearly 2 miles across.

Glaciers and permafrost.—The section contains no glaciers but is generally underlain by permafrost.

Geology.—The Tintina Valley is underlain by a synclinal belt of highly deformed, easily eroded continental sedimentary rocks of Cretaceous and Tertiary age that are probably in sedimentary contact with the metamorphic and granitic rocks of the Yukon-Tanana Upland on the south and with the well-consolidated Paleozoic and Mesozoic sedimentary rocks of the Ogilvie Mountains on the north. Northwest of Woodchopper Creek, loess mantles flat-topped ridges and hides most bedrock outcrops. The geology beneath the plain near Circle Hot Springs is unknown.

References.—Brabb (1962; oral commun., 1962); Mertie (1930b, 1937, and 1942).

The Tintina Valley is covered by the following 1:250,000 topographic maps: Charley River, Eagle, and Circle.

YUKON-TANANA UPLAND (12)

General topography.—The Yukon-Tanana Upland is the Alaskan equivalent of the Klondike Plateau in Yukon Territory. Rounded even-topped ridges with gentle side slopes characterize this section of broad undulating divides and flat-topped spurs (pl. 3, figs. 6 and 9). In the western part (12a) these rounded ridges trend northeast to east; they have ridge-crest altitudes of 1,500–3,000 feet and rise 500–1,500 feet above adjacent valley floors. The ridges are surmounted by compact rugged mountains 4,000–5,000 feet in altitude. Ridges in the eastern part (12b) have no preferred direction, are 3,000–5,000 feet in altitude but have some domes as high as 6,800 feet, and rise 1,500–3,000 feet above adjacent valleys (pl. 3, fig. 6). In the extreme northeast the ridges rival the Ogilvie Mountains in ruggedness. Valleys in the western part are generally flat, alluvium floored, and ¼–½ mile wide to within a few miles of headwaters. Streams in the eastern part that drain to the Yukon flow in narrow V-shaped terraced canyons, but the headwaters of the Fortymile and Ladue Rivers are broad alluvium-floored basins.

Drainage.—The entire section is in the Yukon drainage basin. Streams flow south to the Tanana River and north to the Yukon River. Most streams in the western part follow courses parallel to the structural trends of bedrock, and several streams have sharp bends involving reversal of direction around the ends of ridges of hard rock. Drainage divides are very irregular. Small streams tend to migrate laterally southward (pl. 4, fig. 5).

Lakes.—The few lakes in this section are mainly thaw lakes in valley floors and low passes.

Glaciers and permafrost.—There are no glaciers. The entire section is underlain by discontinuous permafrost. Periglacial mass-wasting is active at high altitudes, and ice wedges lace the frozen muck of valley bottoms.

Geology.—A belt of highly deformed Paleozoic sedimentary and volcanic rocks containing conspicuous limestone units, overthrust and overturned to the north, extends along the north side of the upland. The rest of the upland is chiefly Precambrian(?) schist and gneiss but has scattered small elliptical granitic intrusions in the northwestern part; large irregular batholiths make up much of the southeastern part. In the western part a thick mantle of windborne silt lies on the lower slopes of hills, and thick accumulations of muck overlie deep stream gravels in the valleys. Alluvial deposits of gold and other metals abound throughout the upland. Pingos are common in valleys and on lower hill slopes (pl. 2, fig. 4).

References.—Bostock (1948, p. 59–73); Holmes and others (1965); D. M. Hopkins (oral commun., 1959); Mertie (1937); Péwé (1955a, 1955b, 1958); Prindle (1905, p. 17); Williams (1959); Williams and others (1959).

The Yukon-Tanana Upland is covered by the following 1:250,000 topographic maps: Charley River, Circle, Livengood, Tanana, Eagle, Big Delta, Fairbanks, Kantishna River, Tanacross, and Mount Hayes.

NORTHWAY-TANACROSS LOWLAND (13)

General topography.—The Northway-Tanacross Lowland consists of three small basins, separated by screens of low rolling hills. The two basins along the north side of the lowland are nearly level plains, broadly oval in plan. Scattered longitudinal dunes mark the floor of the eastern one of these two basins. The third basin, on the southeast, is a gently rolling moraine-covered plain.

Drainage.—The entire lowland is drained by the Tanana River, which may have captured the lowland in early Pleistocene time, for the drainage divide with the Yukon River is only 2–5 miles north of the Tanana and the north tributaries of the Tanana are steep barbed streams. The headwaters of the Yukon drainage north of the divide are underfit streams in broad valleys that head in wind gaps.

The main tributaries of the Tanana rise in glaciers in mountains to the south, and their deposits of outwash have pushed the Tanana against the north side of the lowland. The upper courses of these streams are swift and braided; their lower courses and the course of the Tanana are sluggish and meandering.

Lakes.—Large lakes in reentrants in the surrounding hills may be caused by alluviation of the lowland. Thaw lakes abound in areas of fine alluvium, which are as much as 70 percent lake surface. Oxbow lakes and morainal ponds are also present.

Glaciers and permafrost.—The lowland has no glaciers; it is in the area of discontinuous permafrost.

Geology.—The basins are mantled with outwash gravel, silt, and morainal deposits. The two northern basins were probably occupied by a lake dammed by a glacier at Cathedral Rapids. Tertiary rocks have been reported on the north side and may extend beneath the Quaternary deposits. Bedrock hills are Precambrian(?) schist and Mesozoic granitic intrusions. The Taylor Highway immediately north of Tetlin Junction passes through a field of stabilized sand dunes.

References.—D. F. Barnes (oral commun., 1956); Black (1951, p. 98–100); Mertie (1937, pl. 1); Moffit (1954a, pl. 6); Wallace (1946).

The Northway-Tanacross Lowland is covered by the following 1:250,000 topographic maps: Tanacross, Mount Hayes, and Nabesna.

YUKON FLATS SECTION (14)

General topography.—The central part of the Yukon Flats section consists of marshy lake-dotted flats rising from 300 feet in altitude on the west to 600–900 feet on the north and east. The northern part of the flats is made up of gently sloping outwash fans of the Chandalar, Christian, and Sheenjek Rivers; the southeastern part of the flats is the broad gentle outwash fan of the Yukon River. Other areas are nearly flat flood plains. Rolling silt- and gravel-covered marginal terraces having sharp escarpments 150–600 feet high rise above the flats and slope gradually upward to altitudes of about 1,500 feet at the base of surrounding uplands and mountains. Their boundaries with surrounding uplands and mountains are gradational.

Drainage.—The Yukon Flats section is drained by the Yukon River, which has a braided course southeast of the bend at Fort Yukon and a meandering course, containing many sloughs, southwest of the bend at Fort Yukon. Most tributaries rise in surrounding uplands and mountains and have meandering courses through the flats.

Lakes.—Thaw lakes are abundant throughout the flats. Thaw lakes and thaw sinks are common on the marginal terraces.

Glaciers and permafrost.—There are no glaciers. Permafrost probably underlies most of the section except rivers, recently abandoned meander belts, and large thaw lakes.

Geology.—Escarpments bounding the Yukon Flats expose well-consolidated or crystalline rocks of Paleozoic and possibly Mesozoic age. The marginal terraces are capped with gravel on which rests a layer of windborne silt. A well drilled at Fort Yukon in 1954 disclosed 48 feet of aeolian sand of late Pleistocene or Recent age, underlain by 100 feet of sandy gravel of Pleistocene age, underlain in turn by at least 292 feet of fine lake sediments of late Pliocene or early Pleistocene age. On the basis of this well it is thought that the Yukon Flats are the site of a late Tertiary lake that occupied a downwarped basin.

References.—Williams (1955, p. 124–125; 1960; written communs., 1955–1959).

The Yukon Flats section is covered by the following 1:250,000 topographic maps: Coleen, Christian, Black River, Fort Yukon, Beaver, Charley River, Circle, and Livengood.

RAMPART TROUGH (15)

General topography.—The Rampart Trough is a structurally controlled depression having gently rolling topography 500–1,500 feet in altitude; it is incised 500–2,500 feet below highlands on either side. Terraces on tributaries of the Yukon River near Rampart are 20 feet, 100 feet, 150 feet, 250 feet, and 500 feet above stream level.

Drainage.—The Yukon River enters the east end of the trough through a narrow rocky gorge and swings in broad bends from one side of the trough to the other within a narrow flood plain. Near the southwest end, a ridge of hard rock separates the Yukon River from the trough. Short tributaries rise in hills to the south, and flow across the trough and through the bedrock ridge on its north side to the Yukon. The Yukon and its tributaries appear to be superposed from a surface at least 1,500 feet in altitude.

Lakes.—Scattered thaw lakes lie on the Yukon flood plain and elsewhere in the trough.

Glaciers and permafrost.—The Rampart Trough contains no glaciers. Permafrost underlies all the lowland except the Yukon flood plain.

Geology.—The Rampart Trough was eroded along a tightly folded belt of soft continental coal-bearing rocks of Tertiary age. Hard rock hills and the surrounding uplands are partly metamorphosed sedimentary and volcanic rocks of Mississippian age that strike about N. 60° E. and are cut by granitic intrusions.

References.—D. M. Hopkins (oral commun., 1959); Mertie (1937, p. 174–185); R. A. Paige (written commun., 1958).

The Rampart Trough is covered by the following 1:250,000 topographic maps: Livengood and Tanana.

KOKRINE-HODZANA HIGHLANDS (16)

General topography.—The Kokrine-Hodzana Highlands consist of even-topped rounded ridges rising to 2,000–4,000 feet in altitude surmounted by isolated areas of more rugged mountains. A rugged compact highland in the northeastern part has many peaks between 4,500 and 5,700 feet in altitude. The Ray Mountains (16a), rising to 5,500 feet, have cirques and glaciated valleys and craggy cliffed tors that rise abruptly from broad granite ridgetops. Valleys have alluviated floors to within a few miles of their heads.

Drainage.—The irregular drainage divide between the Yukon River and its large tributary, the Koyukuk River, passes through these highlands. Drainage to the Yukon is by way of the Hodzana, Tozitna, Melozitna and Dall Rivers and many shorter streams. Drainage to the Koyukuk is by the Kanuti River and the South Fork of the Koyukuk.

Lakes. There are a few thaw lakes in the lowland areas and a few lakes in north-facing cirques in the Kokrine Hills (16b) and the Ray Mountains.

Glaciers and permafrost.—There are no glaciers. The entire section is probably underlain by permafrost. This section contains classic examples of altiplanation terraces, stone polygons, and other periglacial phenomena.

Geology.—The highlands are underlain chiefly by Paleozoic and Precambrian(?) schist and gneiss having a northeast-trending structural grain, cut by several granitic intrusions, the largest of which is the granite batholith that upholds the Ray Mountains. Small placers of tin and gold occur in the southern part of the highlands.

References.—Eakin (1916); Maddren (1913); J. R. Williams (written commun., 1959).

The Kokrine-Hodzana Highlands are covered by the following 1:250,000 topographic maps: Chandalar, Wiseman, Beaver, Bettles, Livengood, Tanana, Melozitna and Ruby.

WESTERN ALASKA PROVINCE

The Western Alaska province consists of uplands and lowlands underlain chiefly by folded and faulted Cretaceous rocks. It is divided into the following sections: Kanuti Flats (17), Tozitna-Melozitna Lowland (18), Indian River Upland (19), Pah River section (20), Koyukuk Flats (21), Kobuk-Selawik Lowland (22), Selawik Hills (23), Buckland River Lowland (24), Nulato Hills (25), Tanana-Kuskokwim Lowland (26), Nowitna Lowland (27), Kuskokwim Mountains (28), Innoko Lowlands (29), Nushagak-Big River Hills (30), Holitna Lowland (31), and Nushagak-Bristol Bay Lowland (32).

KANUTI FLATS (17)

General topography.—The Kanuti Flats form an irregular shaped lake-dotted plain 400–1,000 feet in altitude that merges with low surrounding hills. Scattered low irregular hills rise in the central part of the plain, which is crossed by the forest-covered meander belts of the Koyukuk and Kanuti Rivers.

Drainage.—The Kanuti Flats are drained by the Koyukuk River and its tributaries. The Kanuti River, which drains the southern part of the plain, flows through a narrow canyon in the Indian River Upland before joining the Koyukuk River.

Lakes.—There are numerous thaw lakes, some as large as 2 miles across. Some parts of the flats are more than 50 percent lake surface.

Glaciers and permafrost.—The flats contain no glaciers. The section is underlain by permafrost except beneath large lakes, rivers, and recently formed flood plains.

Geology.—The geology of the Kanuti Flats is unknown.

References.—None.

The Kanuti Flats are shown on Bettles 1:250,000 topographic map.

TOZITNA-MELOZITNA LOWLAND (18)

General topography.— The Tozitna-Melozitna Lowland is a long, narrow rolling plain, 5–10 miles wide, at the heads of the Tozitna and Melozitna Rivers. The pass between these streams is less than 1,000 feet in altitude.

Drainage.—The lowland is drained by the Tozitna and Melozitna Rivers, which flow south from the lowland in narrow gorges across the Kokrine-Hodzana Highlands to the Yukon River.

Lakes.—The lowland contains numerous thaw lakes. Oxbow lakes are common along the Melozitna River.

Glaciers and permafrost.—The section has no glaciers; it is in the area of discontinuous permafrost.

Geology.—Nothing is known of the geology of this lowland.

References.—None.

The Tozitna-Melozitna Lowland is covered by the following 1:250,000 topographic maps: Tanana and Melozitna.

INDIAN RIVER UPLAND (19)

General topography.—Groups of low gentle ridges having rounded accordant summits at 1,500–2,000 feet altitude are interspersed with irregular lowlands and broad flat divides. The ridges in the southeastern part are generally parallel and trend northeastward; ridges in the northwestern part have irregular trends. A few mountains rise to 4,000 feet in altitude. The Koyukuk and Kanuti Rivers cross the upland in narrow canyons a few hundred feet deep.

Drainage.—Most of the Indian River Upland is drained by the Koyukuk River and its tributaries. The northwest corner drains to the Kobuk River and the southeastern part drains by the Melozitna River to the Yukon. Many of the streams have extremely irregular courses.

Lakes.—Numerous thaw lakes, the largest 2½ miles across, are in the lowlands, valleys, and broad passes.

Glaciers and permafrost.—There are no glaciers. The entire land area, except recent flood plains, is underlain by permafrost, and periglacial processes predominate. Altiplanation terraces are common at high altitudes.

Geology.—The Indian River Upland is underlain chiefly by folded sedimentary and volcanic rocks of Mesozoic age, in which sandstone, shale, and conglomerate predominate. These rocks are intruded by small granitic stocks, and are overlain by remnants of flatlying lavas of Tertiary or Quaternary age. Structural trends are northeastward in the southeastern part but are poorly defined in the northern part.

References.—Cass (1959e); W. W. Patton, Jr. (oral commun., 1959).

The Indian River Upland is covered by the following 1:250,000 topographic maps: Bettles, Hughes, Tanana, Melozitna, Kateel River, Ruby, and Nulato.

PAH RIVER SECTION (20)

General topography.—The Pah River section is an area of diversified topography. Compact groups of hills and low mountains 20–40 miles long and rising to 4,000 feet in altitude are surrounded by rolling plateaus 500–1,500 feet in altitude and broad lowland flats 5–10 miles across. The lower parts of the mountain groups consist of gently rounded ridges; their higher glaciated parts contain broad, shallow cirques having flaring walls (pl. 3, fig. 7).

Drainage.—The northern and western parts of the Pah River section drain to the Selawik and Kobuk Rivers. The southern and eastern parts drain via the Huslia and Hogatza Rivers to the Koyukuk River. The major streams meander sluggishly through the broad lowlands. The Pah River, which drains the Pah River flats (20b), flows north to the Kobuk through a narrow canyon across the Lockwood Hills (20a).

Lakes.—Numerous thaw lakes lie in the lowland flats. The central part of the Pah River flats is probably 50 percent lake surface. (See pl. 3, fig. 7.) A few small cirque lakes occur in the higher glaciated parts of the Lockwood Hills and the Zane Hills (20c).

Glaciers and permafrost.—There are no glaciers. The entire section is underlain by permafrost, and periglacial erosional processes predominate. Altiplanation terraces are common below the level of glaciation in the Zane Hills and the Purcell Mountains (20d).

Geology.—The Pah River section is underlain by Mesozoic volcanic and sedimentary rocks that are intensely deformed and locally contact metamorphosed, without strong persistent structural grain, and by Mesozoic granitic stocks and batholiths.

References.—W. W. Patton, Jr. (oral commun., 1959); I. L. Tailleur (oral commun., 1959).

The Pah River section is covered by the following 1:250,000 topographic maps: Hughes and Shungnak.

KOYUKUK FLATS (21)

General topography.—The Koyukuk Flats form an extensive lowland of irregular outline at the junction of the Yukon and Koyukuk Rivers. The central parts of the Koyukuk Flats are flat plains 5–20 miles wide, along the major rivers. The parts immediately adjacent to the rivers are meander belts 5–10 miles wide; the parts farther away are dotted by thaw lakes. Broad rolling silt plains, in part mantled by dunes and in part pocked by thaw sinks, stand 100–200 feet above these central plains and merge imperceptibly with the surrounding uplands. Several low bedrock hills rise from the center of the lowland (pl. 4, fig. 7).

Drainage.—The Koyukuk Flats are drained by the Yukon River and its tributaries. Streams meander wildly across the lowland and have numerous meandering side sloughs. Lateral migration of meanders is as much as 75 feet per year, and elaborate patterns of bars and swales (meander-scroll pattern) are left behind (pl. 4, figs. 6 and 7).

Lakes.—The meander belt has innumerable narrow meander-scroll lakes and some oxbow lakes; these are generally silted by floods, and the newly formed ground freezes perennially. Subsequently, thaw lakes form in the frozen ground and pass through a complicated cycle of enlargement, coalescence, and destruction by infilling or drainage. These thaw lakes are abundant away from the rivers (pl. 4, fig. 7).

Glaciers and permafrost.—No glaciers exist in the flats. All the land area except recently formed flood plains is underlain by permafrost.

Geology.—The bedrock hills and surrounding uplands are chiefly Cretaceous sedimentary rocks, older Mesozoic volcanic rocks, and some intrusions. Low basalt hills rise from the central part of the lowland. The plains are underlain by water-laid and windborne silt. Sand dunes are common; a large barren area of active sand dunes lies in the northwestern part. Northeast-trending scarplets and low rises that cross the lowland presumably mark active faults.

References.—Cass (1957, 1959e, 1959f); Eardley (1938a, 1938b); Elias and Vosburgh (1946); W. W. Patton, Jr. (oral commun., 1959); Péwé (1948).

The Koyukuk Flats are covered by the following 1:250,000 topographic maps: Hughes, Shungnak, Melozitna, Kateel River, Ruby, and Nulato.

KOBUK-SELAWIK LOWLAND (22)

General topography.—The Kobuk-Selawik Lowland consists chiefly of broad river flood plains and lake-dotted lowlands that pass at their seaward margins into deltas. The Baldwin Peninsula, which separates Hotham Inlet from Kotzebue Sound, is a rolling lake-dotted lowland containing hills as high as 350 feet in altitude, bordered by bluffs. The Waring Mountains (22a) are an east-trending group of low rounded hills less than 2,000 feet in altitude. The upper valley of the Kobuk River is bordered by gravel and sand terraces 100–200 feet above river level that are dotted with thaw lakes and thaw sinks and, on the south side of the river, have large areas of both stabilized and active sand dunes.

Drainage.—The lowland is drained mainly by the Kobuk and Selawik Rivers. Most streams are sluggish, meandering, of low gradient, and have numerous side sloughs.

Lakes.—The area around the Selawik River, in particular, has numerous large thaw lakes. Hotham Inlet and Selawik Lake are large bodies of water at sea level that are kept nearly fresh by the great outflow of the Selawik, Kobuk, and Noatak Rivers.

Glaciers and permafrost.—Glaciers are absent. Most land area is underlain by permafrost. Pingos are abundant in the lowland around the Selawik River.

Geology.—Most of the lowland areas are underlain by morainal deposits and by stream and lake deposits of unknown thickness. Baldwin Peninsula is probably the end moraine of a pre-Wisconsin glacial advance. In Wisconsin time glaciers from the Brooks Range sent tongues into the upper valley of the Kobuk but did not advance farther. The Waring Hills are underlain by Cretaceous sedimentary rocks.

References.—A. L. Fernald (written commun., 1958); D. M. Hopkins (oral commun., 1959); W. W. Patton, Jr. (oral commun., 1959); Smith (1913); Smith and Mertie (1930); I. L. Tailleur (oral commun., 1959).

The Kobuk-Selawik Lowland is covered by the following 1:250,000 topographic maps: Ambler River, Baird Mountains, Noatak, Shungnak, Selawik, and Kotzebue.

SELAWIK HILLS (23)

General topography.—The Selawik Hills are gentle hills having rounded to flat summits as much as 3,300 feet in altitude. The hills rise fairly abruptly, with a relatively straight scarp, from the Kobuk-Selawik Lowland on the north and decline gently to the Buckland River Lowland on the south. Altiplanation terraces are common on the higher summits (pl. 2, fig. 1).

Drainage.—The hills are drained by short streams that flow south and west to the Buckland River or north to the Kauk River, Selawik River, and Selawik Lake.

Lakes, glaciers, and permafrost.—There are no lakes or glaciers. The entire section is underlain by permafrost.

Geology.—The Selawik Hills are underlain chiefly by Paleozoic and Mesozoic metamorphosed volcanic rocks and granitic intrusive rocks. Quaternary volcanic rocks lie on the flanks.

References.—W. W. Patton (oral commun., 1959).

The Selawik Hills are covered by the following 1:250,000 topographic maps: Selawik and Candle.

BUCKLAND RIVER LOWLAND (24)

General topography.—The Buckland River Lowland is a rolling lowland having slopes of a few feet to a few hundred feet per mile and consisting largely of the original surfaces of lava flows.

Drainage.—The lowland is drained mostly by the Buckland River. The Tagagawik River drains the extreme eastern part, and the Koyuk River the southern prong.

Lakes.—Small thaw and oxbow lakes are common along the Buckland River and in other flat valleys. A few thaw lakes lie on some flat interfluves.

Glaciers and permafrost.—There are no glaciers. The entire section is probably underlain by permafrost.

Geology.—The lowland is underlain chiefly by flat-lying lava flows of Quaternary age, mantled by a thick layer of windborne silt.

References.—D. M. Hopkins (oral commun., 1959); W. W. Patton, Jr. (oral commun., 1959).

The Buckland River Lowland is shown on the 1:250,000 topographic map of Candle quadrangle.

NULATO HILLS (25)

General topography.—The Nulato Hills consist, in general, of northeast-trending even-crested ridges, 1,000–2,000 feet in altitude, having rounded summits and gentle slopes. Valleys are narrow and have flat floors that are generally trenched in their upstream parts to depths of about 30 feet. Local relief is 500–1,500 feet. The topography is relatively fine textured; gullies are spaced 500–1,500 feet apart and second-order tributaries are ½–1 mile apart (pl. 4, fig. 10). Three highland areas of steeper ridges rise to about 4,000 feet in altitude.

Drainage.—Streams on the east side of the section flow to the Yukon River and those on the west side to Norton Sound. Major streams are markedly parallel, flowing either northeast or southwest, and their courses are eroded along northeast-trending fault zones. Valley heads are generally connected by low passes along the faults.

Lakes.—There are a few thaw lakes in the valleys.

Glaciers and permafrost.—There are no glaciers. The entire section is probably underlain by permafrost.

Geology.—Almost all the hills are composed of tightly folded sandstone, conglomerate, and shale of Cretaceous age. The folds trend about N. 45° E. but bend around to northward in the northern part. The rocks are cut by northeast- and north-trending faults. A few mountains are underlain by post-Cretaceous intrusive and volcanic rocks. Older rocks, chiefly of volcanic origin, make up the hills in the extreme northern part and extreme southern part.

References.—R. S. Bickel (oral commun., 1958); Cass (1957, 1959a, 1959b, 1959c, 1959f); Harrington (1918); Hoare and Coonrad (1959b); Patton and Bickel (1956a, 1956b); Smith and Eakin (1911).

The Nulato Hills are covered by the following 1:250,000 topographic maps: Shungnak, Kateel River, Candle, Nulato, Norton Bay, Unalakleet, St. Michael, Holy Cross, Kwiguk, Russian Mission, and Marshall.

TANANA-KUSKOKWIM LOWLAND (26)

General topography.—The Tanana-Kuskokwim Lowland is a broad depression bordering the Alaska Range on the north; its surfaces are of diversified origin. Coalescing outwash fans from the Alaska Range slope 20–50 feet per mile northward to flood plains along the axial streams of the lowland. Rivers from the range flow for a few miles at the heads of the fans in broad terraced valleys 50–200 feet deep. Semicircular belts of morainal topography lie on the upper ends of some fans. (See pl. 3, fig. 10 and pl. 4, fig. 13.) The flood plains of the Kuskokwim and Kantishna Rivers and of the Tanana River west of Tolovana are incised 50–200 feet below the level of the lowland. Several nearly level projections of the lowland extend into uplands on the north. Large fields of stabilized dunes cover the northern part of the lowland and lower slopes of adjacent hills between Nenana and McGrath (pl. 4, fig. 12).

Drainage.—The central and eastern parts of the lowland are drained by the Tanana River, and the southwestern part is drained by the Kuskokwim River. Braided glacial streams rising in the Alaska Range (pl. 3, fig. 8) flow north across the lowland at intervals of 5–20 miles. Outwash has pushed the axial streams—the Tanana, Kuskokwim, and Kantishna Rivers—against the base of hills on the north side. Tightly meandering tributaries of low gradient flow into the section from the north.

Lakes.—Thaw lakes abound in areas of fine alluvium. Thaw sinks are abundant in areas of thick loess cover.

Glaciers and permafrost.—The lowland contains no glaciers. The entire section is an area of permafrost. Porous gravel at the heads of the outwash fans, however, has a deep water table and dry permafrost (ground perennially at temperatures below freezing but having no ice).

Geology.—The outwash fans grade from coarse gravel near the Alaska Range to sand and silt along the axial streams. Areas north of the axial streams are underlain by thick deposits of "muck," a mixture of frozen organic matter and silt. Parts of the southwestern part of the lowland have thick loess cover, but the central and eastern parts are free of loess south of the Tanana River. Scattered low hills of granite, ultramafic rocks, and Precambrian(?) schist rise above the outwash. Tertiary conglomerate in the foothills of the Alaska Range plunges beneath the lowland in a monocline, and the heads of the outwash fans may rest on a pediment cut across this conglomerate. The base of the alluvial fill near Fairbanks is at or below sea level.

References.—D. F. Barnes (oral commun., 1956); Barnes and McCarthy (unpub. data, 1954); Drury (1956); Fernald (1955, 1960); Holmes and Benninghoff (1957); Kachadoorian (1956); Péwé (1954, 1955b, 1958); Péwé and others (1953); Reed (1961); Wahrhaftig (1958a); Williams and others (1959); Andreasen and others (1964).

The Tanana-Kuskokwim Lowland is covered by the following 1:250,000 topographic maps: Livengood, Big Delta, Fairbanks, Kantishna River, Mount McKinley, Medfra, Talkeetna, and McGrath.

NOWITNA LOWLAND (27)

General topography.—The Nowitna Lowland is a rolling silt-covered tableland ranging from 250 to 900 feet in altitude and having a local relief of 50–250 feet and slopes of 100–150 feet per mile into which the flat flood plains of the major rivers (valleys 1½–10 miles wide) have been incised 150–300 feet. A line of gentle bedrock hills in the center rises to 1,500 feet. The tableland is pocked with thaw sinks. The part of the tableland south of the line of hills is covered with longitudinal and sigmoid dunes and has been dissected by steep-walled gullied canyons (pl. 4, fig. 8).

Drainage.—The entire lowland is drained by the Yukon River, which follows the north boundary. The confluence of the Yukon with the Tanana River is in the eastern part of the lowland. The southern part of the lowland is drained by the Nowitna River, a tributary of the Yukon, and its tributaries. Parallel drainage of small tributaries of the Chitinana River and other streams in silt uplands of the eastern part may be consequent upon the flanks of a recent upwarp (pl. 4, fig. 9).

Lakes.—Oxbow lakes are common in the central parts of the meander belts. Thaw lakes abound in the marginal areas and throughout the silt- and dune-covered uplands.

Glaciers and permafrost.—The lowland contains no glaciers; it is underlain by permafrost, except in recently abandoned flood plains.

Geology.—Bedrock in the hills is similar to that of surrounding highlands—schist and gneiss on the west and Cretaceous sedimentary rocks on the east, all cut by granitic intrusions. Tilted and faulted Tertiary and possibly Quaternary sedimentary deposits are exposed on the south bank of the Yukon. Most of the lowland is covered by windborne silt and sand of unknown thickness. Depth of alluvium is at least 180 feet.

References.—Cass (1959d, 1959e); Eakin (1914, 1918); Eardley (1938, 1938b).

The Nowitna Lowland is covered by the following 1:250,000 topographic maps: Tanana, Melozitna, Kantishna River, and Ruby.

KUSKOKWIM MOUNTAINS (28)

General topography.—The Kuskokwim Mountains are a monotonous succession of northeast-trending ridges having rounded to flat summits 1,500–2,000 feet in altitude and broad gentle slopes (pl. 4, fig. 11). Ridge crests north of the Kuskokwim River are accordant at about 2,000 feet and are surmounted at intervals of 10–30 miles by isolated circular groups of rugged glaciated mountains 3,000–4,400 feet in altitude. Valleys have flat floors 1–5 miles wide.

Drainage.—The Kuskokwim Mountains are drained by tributaries of the Yukon and Kuskokwim Rivers. Major streams generally flow northeast to southwest along valleys that are probably controlled by faults; streams are fast and meandering and generally lie near the northwest walls of their valleys. The Kuskokwim River crosses the mountains in a gorge 100–400 feet deep incised in an older valley about 1,000 feet deep and 2–8 miles wide.

Lakes.—Lakes are few. There are oxbow and thaw lakes in the valleys and a few cirque lakes in the glaciated mountains.

Glaciers and permafrost.—There are no glaciers. Permafrost underlies most of the section, and periglacial erosional processes predominate.

Geology.—Most of the Kuskokwim Mountains are made of tightly folded Cretaceous rocks that strike northeast. Graywacke upholds the ridges, and argillite underlies the valleys. The northeastern and northwestern parts are underlain by Paleozoic sedimentary rocks and Precambrian(?) schist. The isolated circular groups of high mountains are underlain by monzonitic intrusions and their surrounding hornfels aureoles. Flat-lying basalt caps the remnants of a mid-Tertiary erosion surface. Pleistocene and Recent block faulting has occurred south of the Kuskokwim River.

References.—Brown (1926a, 1926b); Cady and others (1955); Eakin (1918); Hoare and Coonrad (1959a, and 1959b); Mertie and Harrington (1924).

The Kuskokwim Mountains are covered by the following 1:250,000 topographic maps: Kantishna River, Ruby, Nulato, Mount McKinley, Medfra, Ophir, Unalakleet, McGrath, Iditarod, Holy Cross, Sleetmute, Russian Mission, Taylor Mountains, and Bethel.

INNOKO LOWLANDS (29)

General topography.—The Innoko Lowlands are a group of flat river flood plains, dendritic in pattern, whose bounding slopes are generally steep banks cut into the surrounding hills; in places, however, gentle silt-covered slopes merge with the surrounding hills.

Drainage.—The Yukon River and a large tributary, the Innoko River, cross the lowlands. The main part of the lowlands has a complex intersecting network of meandering sloughs of these two streams.

Lakes.—Oxbow and meander-scroll lakes are abundant in recently abandoned flood plains and partly silted sloughs. Thaw lakes abound in old flood plains and on gentle silt-covered slopes. The lower parts of many tributaries from surrounding hills are dammed by alluvium from the Yukon and form narrow dendritic lakes.

Glaciers and permafrost.—No glaciers exist in the lowlands. Much of the section is underlain by permafrost.

Geology.—Bedrock geology is probably the same as that of the surrounding hills. The plains are mantled by river-flood-plain deposits and by windborne silt, which also extends up the slopes of the surrounding hills.

References.—None.

The Innoko Lowlands are covered by the following 1:250,000 topographic maps: Ophir, Unalakleet, Iditarod, Holy Cross, and Russian Mission.

NUSHAGAK-BIG RIVER HILLS (30)

General topography.—The Nushagak-Big River Hills are largely rounded, flat-topped ridges rising to an altitude of 1,500 feet on the west and 2,500 feet on the east; the hills have broad gentle slopes and broad flat or gently sloping valleys. Local relief is 1,000–2,500 feet. Mountains in the northeastern part rise to an altitude of 4,200 feet. Ridges trend northeastward in the eastern part but have no preferred trend in the southwestern part.

Drainage.—The northern part of the hills drains to the Kuskokwim River via the Big, Stony, Swift, and Holitna Rivers; the southern part is drained by the Mulchatna and Nushagak Rivers. The rivers that rise from glaciers in the Alaska Range and flow across the hills, like the Stony and Swift, are braided muddy streams. Others, like the Holitna, are clear and meandering.

Lakes.—A few thaw lakes are in some valleys. Ponds are abundant in the moraine-mantled eastern part of the hills.

Glaciers and permafrost.—There are no glaciers. Most of the section is underlain by permafrost, and periglacial erosional processes predominate.

Geology.—Most of the hills consist of tightly folded Mesozoic graywacke, argillite, conglomerate, and greenstone flows. There is a central northeast-trending belt of Paleozoic rocks, including steep isolated ridges of limestone. Early Tertiary intrusions and their metamorphic aureoles uphold two small circular groups of high mountains in the southwestern part.

References.—Capps (1935); J. M. Hoare (written commun., 1958); C. L. Sainsbury (oral commun., 1959); Smith (1917).

The Nushagak-Big River Hills are covered by the following 1:250,000 topographic maps: McGrath, Iditarod, Lime Hills, Sleetmute, Lake Clark, Taylor Mountains, Iliamna, and Dillingham.

HOLITNA LOWLAND (31)

General topography.—The Holitna Lowland is largely a moraine-covered plain 300–800 feet in altitude and is crossed by several low arcuate hummocky ridges marking the end moraines of glacial advances and by broad outwash and meander plains along rivers. The Lime Hills, conspicuous isolated steep-sided ridges in the southern part of the lowland, rise to an altitude of 1,000–2,300 feet.

Drainage.—The Holitna Lowland is drained by the Kuskokwim River and three of its tributaries, the Stony and Swift Rivers, which are glacial streams from the Alaska Range that have braided gravelly courses, and the Holitna River, a clear meandering stream that rises in uplands to the south.

Lakes.—There are numerous morainal and thaw lakes throughout the lowland.

Glaciers and permafrost.—There are no glaciers. This section is probably one of discontinuous permafrost.

Geology.—The bedrock hills are of Mesozoic graywacke, argillite, and conglomerate and early Paleozoic limestone. Most of the lowland is underlain by moraine and outwash together with thick accumulations of windborne silt.

References.—J. M. Hoare (oral commun., 1959); J. N. Platt (written commun., 1956); Smith (1917).

The Holitna Lowland is covered by the following 1:250,000 topographic maps: McGrath, Iditarod, Lime Hills, Sleetmute, and Taylor Mountains.

NUSHAGAK-BRISTOL BAY LOWLAND (32)

General topography.—The Nushagak-Bristol Bay Lowland is a moraine- and outwash-mantled lowland having local relief of 50–250 feet and rising from sea level to an altitude of 300–500 feet at its inner margins. High steep-sided outliers of the Ahklun Mountains rise from the western part. Arcuate belts of morainal topography, 100–300 feet high and 1–5 miles wide, enclose large deep glacial lakes on the southeast margin and cross parts of the lowland west of the Nushagak River.

Drainage.—The lowland is drained by the Nushagak and other large rivers that flow into Bristol Bay. Most streams rise in large lakes in ice-carved basins bordering the surrounding mountains and flow into tidal estuaries that appear to be drowned river mouths.

Lakes.—The lowland is dotted with morainal and thaw lakes. Large lakes occupy ice-scoured basins along the margins of the lowland. The largest of these, Lake Iliamna, is 80 miles long and 20 miles wide.

Glaciers and permafrost.—There are no glaciers in this section, and permafrost is sporadic or absent.

Geology.—The lowland is underlain by several hundred feet of outwash and morainal deposits that are mantled in part by silt and peat. Outwash deposits are coarse near the mountains and grade to fine sand along the coast. Quarternary deposits thin to a featheredge along the base of surrounding mountains. A small area of low stabilized and active dunes lies east of the Nushagak River.

References.—Muller (1952, 1953, 1955, 1956).

The Nushagak-Bristol Bay Lowland is covered by the following 1:250,000 topographic maps: Taylor Mountains, Iliamna, Dillingham, Naknek, Nushagak Bay, Ugashik, Bristol Bay, Chignik, Port Moller, Fort Randall, False Pass, and Unimak.

SEWARD PENINSULA (33)

General topography.—The Seward Peninsula contains: extensive uplands of broad convex hills and flat divides that are 500–2,000 feet in altitude and are indented by sharp V-shaped valleys (pl. 3, fig. 5); isolated groups of rugged glaciated mountains, 20–60 miles long and 10 miles wide, having peaks 2,500–4,700 feet in altitude (pl. 4, fig. 2); and coastal lowland and interior basins.

Drainage.—Many small rivers, whose lower courses are sluggish and meandering, drain the peninsula. Some of these build deltas into the heads of protected lagoons and bays. The interior basins are drained through narrow canyons across intervening uplands.

Lakes.—The lowlands have numerous thaw lakes. There are several rock-basin and morainal lakes in the glaciated Bendeleben (33a) and Kigluaik (33b) Mountains. Lakes fill several large shallow volcanic craters in the northern part of the peninsula and several depressions between lava flows in the central upland; some of the depressions were accentuated by faulting and warping.

Glaciers and permafrost.—The Seward Peninsula has no glaciers. The entire peninsula is underlain by permafrost; periglacial erosional processes predominate (pl. 2, fig. 5) and ice-wedge polygons are common.

Geology.—The bedrock of the peninsula is chiefly Paleozoic schist, gneiss, marble, and metamorphosed volcanic rocks, all of which are cut by granitic intrusive masses. Structural trends in the metamorphic rocks are chiefly northward. The York Mountains (33c) are carved in a mass of resistant marble (pl. 4, fig. 2). The Kigluaik, Bendeleben, and Darby Mountains have recent scarplets along their bases and may be Cenozoic uplifts. A Quaternary lava plateau lies in the north-central part. The southern and western mountains are extensively glaciated. In exposures of beach placer deposits along the south coast, layers of till are interbedded with beach and shore deposits that are both above and below sea level; it is therefore possible to correlate glacial advances in the Seward Peninsula with the history of rise and fall of sea level in late Cenozoic time.

References.—Collier (1902); Collier and others (1908); Hopkins (1949, 1955, 1959a, 1959b, 1963; written communs., 1956, 1959); Hopkins and Hopkins (1958); Hopkins and others (1960); Moffit (1913, pl. 1); Smith (1910); A. R. Tagg (oral commun., 1962).

Seward Peninsula is covered by the following 1:250,000 topographic maps: Selawik, Kotzebue, Shishmaref, Candle, Bendeleben, Teller, Norton Bay, Solomon, and Nome.

BERING SHELF

The Bering Shelf is the largely submerged, nearly level plain close to sea level that joins Alaska with the Chukotsk Peninsula of Siberia. It contains two sections, the Yukon-Kuskokwim Coastal Lowland, a largely emerged area, and the Bering Platform, a largely submerged area.

YUKON-KUSKOKWIM COASTAL LOWLAND (34)

General topography.—The Yukon-Kuskokwim Coastal Lowland is a triangular lake-dotted marshy plain rising from sea level on its west margin to 100–300 feet at its east end. Many low hills of basalt surmounted by cinder cones and broad shallow volcanic craters and a few craggy mountains of older rocks 2,300–2,450 feet high, rise from the western part of the plain. Low beach ridges, marked by lines of thaw lakes, lie along part of the west coast.

The Norton Bay Lowland (34a) is a lake-dotted coastal plain on the east side of Norton Bay, similar to the northern end of the Yukon-Kuskokwim Coastal Lowland. At its western extremity is an isolated range of hills, the Denbigh Hills.

Drainage.—The lowland is crossed by meandering streams of extremely low gradiant, many of them distributaries or former channels of the Yukon River; these flow to the Bering Sea. The Yukon River flows along the base of hills on the north side of the lowland and is building a delta into the Bering Sea. The Kuskokwim River on the southeast side ends in a marine estuary that appears to be a drowned river mouth.

Lakes.—The lowland is dotted with innumerable thaw lakes, many of them 10 or more miles long. Some have scalloped shorelines and probably formed through the coalescence of several smaller lakes. Probably 30–50 percent of the lowland is lake surface.

Glaciers and permafrost.—The area contains no glaciers; it is underlain by discontinuous permafrost.

Geology.—The lowland is underlain by Quarternary sand and silt to unknown depth. Basalt flows and cinder cones are of Tertiary and Quarternary age. Other bedrock hills consist of Cretaceous sedimentary rocks, cut by early Tertiary intrusions, and of crystalline rocks of unknown age.

References.—Coonrad (1957).

The Yukon-Kuskokwim Coastal Lowland is covered by the following 1:250,000 topographic maps: Unalakleet, Saint Michael, Holy Cross, Kwiguk, Black, Russian Misson, Marshall, Hooper Bay, Bethel, Baird Inlet, Nunivak Island, Goodnews, and Kuskokwim Bay.

BERING PLATFORM (35)

General topography.—The Bering Platform is a montonously smooth submarine plain 100–500 feet deep bordered on the southwest by a submarine scarp several thousand feet deep. A coastal lowland at the head of Norton Sound is included in the platform. Several islands rise abruptly from the plain. Most of the islands are rolling uplands a few hundred to 1,000 feet high bordered by wave-cut cliffs. St. Lawrence Island (35a), the largest, is about 100 miles long and 20 miles wide. It is chiefly a lake-dotted bedrock plain less than 100 feet in altitude above which isolated mountain groups bordered by old sea cliffs rise to altitudes of 1,000–1,500 feet (pl. 4, fig. 1). A large shield volcano with many vents is on the north coast of St. Lawrence Island. St. Paul and Nunivak Islands consist largely of undissected volcanic topography.

Drainage.—Many small rivers drain St. Lawrence Island and Nunivak Island; most small islands have no permanent streams.

Lakes.—Thaw lakes abound on the lowlands of St. Lawrence Island and the lower parts of Nunivak Island; there are small crater lakes on Nunivak and the Pribilof Islands.

Glaciers and permafrost.—There are no glaciers. Part of St. Lawrence Island and possibly Nunivak Island may be underlain by permafrost.

Geology.—The Pribilof Islands (35b), St. Matthew Island (35c), Nunivak Island (35d), and north-central St. Lawrence Island are made of Cenozoic basalt flows and pyroclastic debris interbedded with some sediments. Cinder cones are present on the Pribilofs and Nunivak Island. St. Lawrence, Diomede, and King Islands are underlain largely by intensely deformed Paleozoic and Mesozoic sedimentary and volcanic rocks and granitic intrusions.

References.—Barth (1956); Dutro and Payne (1957); Flint (1958); Hopkins (1959a).

Land areas of the Bering Platform are covered by the following 1:250,000 topographic maps: Norton Bay, St. Lawrence, St. Matthew, Nunivak Island, Cape Mendenhall, and Pribilof.

AHKLUN MOUNTAINS (36)

General topography.—Groups of rugged steep-walled mountains, having sharp summits 2,000–5,000 feet in altitude, separated by broad flat valleys and lowlands, rise abruptly above the lowlands and low hills on the north and east. Mountains in the southwestern part have rounded summits 1,500–2,500 feet in altitude.

Drainage.—The Ahklun Mountains are drained by shallow, clear streams that flow directly to the Bering Sea on the south and west, to the Nushagak River via the Nuyakuk River on the northeast, and to the Kuskokwim River on the northwest. Most rivers are incised in bedrock gorges 20–50 feet deep in the downstream parts of their valleys. Drainage is roughly radial, and several streams in the northwestern part flow through canyons that cut directly across structurally controlled ridges.

Lakes.—This province is outstanding for the number and beauty of its glacial lakes, which are long narrow bodies of water in U-shaped canyons. The largest, Lake Nerka, is 29 miles long, and at least 40 lakes are more than 2 miles long. Lake depths as great as 900 feet have been reported.

Glaciers and permafrost.—A few small cirque glaciers are found in the highest parts of the mountains from Mount Waskey northward. Permafrost occurs sporadically.

Geology.—The mountains are made of strongly deformed sedimentary and volcanic rocks of late Paleozoic and Mesozoic age together with some bodies of older schist. These rocks are cut by great northeast-trending faults along which many of the valleys have been eroded. Structural trends control many ridges. Small granitic masses surrounded by more resistant hornfels have formed many ringlike mountain groups. Late Cenozoic basalts lie on the floor of Togiak valley. The entire province was intensely glaciated.

References.—Harrington (1921); J. M. Hoare (written commun., 1958); Hoare and Coonrad (1959a, 1959b, 1961a, 1961b); Mertie (1938, 1940).

The Ahklun Mountains are covered by the following 1:250,000 topographic maps: Taylor Mountains, Bethel, Dillingham, Goodnews, Nushagak Bay, and Hagemeister Island.

PACIFIC MOUNTAIN SYSTEM

ALASKA-ALEUTIAN PROVINCE

The Alaska-Aleutian province consists of an arcuate belt of mountain ranges along the north side of the Pacific Mountain System in Alaska. It is divided into the following sections: Aleutian Islands (37), Aleutian Range (38), Alaska Range (southern part) (39), Alaska Range (central and eastern parts) (40), and Northern Foothills of the Alaska Range (41).

ALEUTIAN ISLANDS (37)

General topography.—The Aleutian Islands are a chain of islands surmounting the crest of a submarine ridge 1,400 miles long, 20–60 miles wide, and 12,000 feet high above the sea floor on either side. An arcuate line of 57 volcanoes of Quaternary age, 27 reported active, rise 2,000–9,000 feet above sea level along the north side of the Aleutian Islands. Other topography in the Aleutian Islands is of two types: (a) wave-cut platforms less than 600 feet above sea level, bordered by low sea cliffs, and (b) intensely glaciated mountainous islands 600–3,000 feet above sea level, indented with fiords and bordered by cliffs as high as 2,000 feet (pl. 5, fig. 12). Broad level intertidal platforms border some islands; they were probably produced by frost weathering.

Drainage.—Streams in the Aleutian Islands are short and swift. Many plunge into the sea over waterfalls. Volcanoes of porous rock have widely spaced stream courses that are filled with water only during exceptionally heavy rains.

Lakes.—Many small lakes occupy irregular ice-carved basins in rolling topography on the glaciated islands. Numerous ponds were enlarged when ice, expanding by freezing, shoved the banks aside to form ramparts of soil and turf. Lakes fill a few volcanic craters and calderas.

Glaciers and permafrost.—The firn line is at an altitude of about 3,000 feet east of Unimak Pass and about 4,500 feet west of it. Most high volcanoes bear icecaps or small glaciers, and there are a few cirque glaciers on the mountainous islands. There is probably no permafrost in the Aleutian Islands, but periglacial erosional processes are active because of the cold, wet climate.

Geology.—The linear chain of volcanoes on the north side of the islands is of constructional origin and late Cenozoic age; it includes many calderas. The remaining islands appear to be emerged parts of tilted fault blocks consisting chiefly of faulted and folded Cenozoic volcanic rocks, locally mildly metamorphosed; granitic intrusions of Cenozoic age are present on Sedanka, Unalaska, Ilak, and other islands. Submarine topography of the Aleutian ridge shows it to be complexly blockfaulted along its crest.

References.—Bradley (1948); Byers (1959); Coats (1950, 1953, 1956a, 1956b, 1956c, 1959a, 1959b); Coats and others (1961); Drewes and others (1961); Fraser and Barnett (1959); Fraser and Snyder (1959); Gates and Gibson (1956); J. P. Schafer (unpub. data, 1956); Gibson and Nichols (1953); Kennedy and Waldron (1955); Murray (1945); Nelson (1959); Powers and others (1960); P. C. Scruton (unpub. data, 1953); Sharp (1946); Simons and Mathewson (1955); Snyder (1957, 1959).

The Aleutian Islands are covered by the following 1:250,000 topographic maps: Port Moller, Fort Randall, False Pass, Unimak, Unalaska, Umnak, Samalga Island, Amukta, Seguam, Atka, Adak, Gareloi Island, Rat Islands, Kiska, and Attu.

ALEUTIAN RANGE (38)

General topography.—The Aleutian Range consists of rounded east-trending ridges 1,000–4,000 feet in altitude, surmounted at intervals of 5–85 miles by volcanoes 4,500–8,500 feet in altitude (pl. 6, fig. 8). It merges northward with the Bristol Bay-Nushagak Lowland and has an abrupt and rugged south coast. The range is extensively glaciated as shown by the U-shaped valleys, cirques, and other features of glacial erosion. Most of the volcanoes reached their final growth after the extensive glaciation of the range.

Drainage.—The drainage divide between the Bering Sea and the Pacific Ocean is generally along the highest ridges, within 10 miles of the south coast. Streams to the Pacific are short and steep; those flowing to Bering Sea are longer and have braided channels.

Lakes.—Along the north side of the range are many large lakes, partly held in by end moraines. Most of them extend well below sea level. The largest is Lake Iliamna.

Glaciers and permafrost.—The firn line is at an altitude of about 3,000–3,500 feet along the axis of the range and rises northward across the range to 4,000–5,000 feet in the northwestern part. Most volcanoes have glaciers on all sides and some have summit icefields. There is probably no permafrost, but periglacial erosional processes are active in the cold, wet climate.

Geology.—Most of the range is composed of mildly deformed folded and faulted Mesozoic and Cenozoic sedimentary rocks, locally intruded by granitic stocks and surmounted at intervals by volcanic piles of late Tertiary to Recent age. Many volcanoes are calderas (pl. 5, fig. 5). A major fault extends along the north side of the eastern part of the range, separating the sedimentary rocks from a large Mesozoic granitic batholith on the north.

References.—Atwood (1911); Coats (1950); Curtis and others (1954); Griggs (1922); Keller and Reiser (1959); Knappen (1929); Mather (1925); Muller and others (1954); Smith (1925a); Smith and Baker (1924); Wilcox (1959).

The Aleutian Range is covered by the following 1:250,000 topographic maps: Iliamna, Afognak, Mount Katmai, Naknek, Karluk, Ugashik, Bristol Bay, Sutwik Island, Chignik, Stepovak Bay, Port Moller, and Semeonof Island.

ALASKA RANGE (SOUTHERN PART) (39)

General topography.—Between Rainy Pass and Lake Chakachamna the Alaska Range consists of many parallel rugged glaciated north-trending ridges 7,000–12,000 feet in altitude; south of Lake Chakachamna the ridges trend northeast and are 4,000–6,000 feet in altitude. Between the ridges lie broad glaciated valleys which have floors less than 3,000 feet in altitude. Local relief is between 4,000 and 9,000 feet. Many spirelike mountains rise in the central part of the range.

Drainage.—Large braided glacial streams follow the north- and northeast-trending valleys; they flow north or south to the Kuskokwim River, southwest to the Nushagak or Kvichak Rivers, and east to the Susitna River and Cook Inlet.

Lakes.—Many large lakes occupy glaciated valleys within and on the margins of the range; the largest of these is Lake Clark, 49 miles long and 1–4 miles wide.

Glaciers and permafrost.—Extensive systems of valley glaciers radiate from the higher mountains. The firn line is lower and the glaciers are larger on the southeast side of the range than on the northwest and west side of the range. The extent of permafrost is unknown.

Geology.—Most of the range is underlain by large granitic batholiths, intrusive into moderately metamorphosed and highly deformed Paleozoic and Mesozoic volcanic and sedimentary rocks, which form scattered areas of lower mountains. Structural trends are generally northerly, but change abruptly to northeasterly and easterly northward across Rainy Pass. Mount Spurr, Mount Iliamna, and Mount Redoubt are large active volcanoes. Well-bedded Jurassic sedimentary rocks form prominent hogbacks and cuestas dipping southward off the south flank of the range toward Cook Inlet (pl. 2, fig. 10).

References.—Capps (1935, 1940); Juhle (1955); Juhle and Coulter (1955); Moffit (1927); Spurr (1900).

The southern part of the Alaska Range is covered by the following 1:250,000 topographic maps: Talkeetna, McGrath, Tyonek, Lime Hills, Kenai, Lake Clark, Seldovia, and Iliamna.

ALASKA RANGE (CENTRAL AND EASTERN PART) (40)

General topography.—The central and eastern part of the Alaska Range consists of two or three parallel rugged glaciated ridges, 6,000–9,000 feet in altitude, surmounted by groups of extremely rugged snow-capped mountains more than 9,500 feet in altitude (pl. 6, fig. 1). The Mentasta-Nutzotin Mountain segment (40a) at the east end of the Alaska Range has a single axial ridge. The ridges are broken at intervals of 10–50 miles by cross-drainage or low passes; most of the drainage appears superposed (pl. 5, fig. 1 and pl. 6, fig. 2). The range rises abruptly from lower country on either side, and its longitudinal profile, seen from a distance, is irregular. Mount McKinley, 20,269 feet high and the highest mountain in North America, is in this part of the Alaska Range. (pl. 6, fig. 2).

Drainage.—The central and eastern part of the Alaska Range is crossed at places 25–100 miles apart by north-flowing tributaries of the Tanana and Yukon Rivers. Most of the range drains to the Tanana. The western part drains to the Kuskokwim River and parts of the south flank drain to the Susitna and Copper Rivers. Streams are swift and braided, and most rivers head in glaciers.

Lakes.—There are a few rock-basin lakes and many small ponds in areas of ground moraine. Lakes are rare for a glaciated area.

Glaciers and permafrost.—The firn line on the south side of the range is 5,000–7,000 feet in altitude and on the north side is 6,000–8,000 feet in altitude; this change reflects the northward decrease in cloudiness and precipitation as one passes from the Gulf of Alaska coast to the interior. The high mountains are sheathed in ice, and valley glaciers as much as 40 miles long and 5 miles wide radiate from them. For some glaciers (for example, Black Rapids Glacier and Muldrow Glacier) short periods of rapid advance have alternated with long periods of stagnation. Short valley glaciers lie in north-facing valleys in the lower parts of the range. Rock glaciers are common. Permafrost is extensive and solifluction features are well developed.

Geology.—The internal structure of the Alaska Range is a complex synclinorium having Cretaceous rocks in the center and Paleozoic and Precambrian(?) rocks on the flanks. This synclinorium is cut by great longitudinal faults that trend approximately parallel to the length of the range and are marked by lines of valleys and low passes. The synclinorium was probably formed near the close of the Mesozoic Era. Many roughly oval granitic stocks and batholiths support groups of high mountains that have cliffs as high as 5,000 feet (pl. 6, fig. 1).

Synclinal areas of Tertiary rocks underlie lowlands that trend parallel to the length of the range. Much of the major topography of the range was probably produced from mid-Tertiary structures by removal of easily eroded Tertiary rocks to form lowlands. Recently formed scarplets as high as 30 feet can be seen on several longitudinal faults. At least four periods of glaciation have been recognized; the earliest is indicated only by scattered giant granite erratics on uplands in the foothills to the north.

References.—Brooks (1911); Capps (1912, 1913, 1916a, 1932, 1940); Maddren (1917); Moffit (1912, 1914, 1954a); Wahrhaftig (1958a, 1958b); Wahrhaftig and Cox (1959).

The central and eastern Alaska Range is covered by the following 1:250,000 topographic maps; Tanacross, Mount Hayes, Healy, Mount McKinley, Nabesna, Gulkana, Talkeetna Mountains, Talkeetna, McGrath, and Tyonek.

NORTHERN FOOTHILLS OF THE ALASKA RANGE (41)

General topography.—The Northern Foothills of the Alaska Range are flat-topped east-trending ridges 2,000–4,500 feet in altitude, 3–7 miles wide, and 5–20 miles long that are separated by rolling lowlands 700–1,500 feet in altitude and 2–10 miles wide. The foothills are largely unglaciated, but some valleys were widened during the Pleistocene Epoch by glaciers from the Alaska Range. Colorful badlands abound in areas of rapid erosion in soft Tertiary rocks (pl. 2, figs. 8 and 9).

Drainage.—The major streams of the foothills are superimposed across the topography. Most streams are nearly parallel, rise for the most part in the Alaska Range, and flow north to N. 20° W. across the ridges in rugged impassable V-shaped canyons and across the lowlands in broad terraced valleys. The entire section drains to the Tanana River.

Lakes.—A few small lakes of thaw origin lie in the lowland passes, and morainal areas have shallow irregular ponds.

Glaciers and permafrost.—The entire section is below the firn line, and there are no local glaciers, although a few glaciers from the Alaska Range terminate in the foothills. Permafrost is extensive, and polygonal ground and solifluction features are well developed (pl. 2, figs. 6 and 11).

Geology.—Crystalline schist and granitic intrusive rocks make up most of the ridges, which are anticlinal. Poorly consolidated Tertiary rocks underlie the lowlands; thick coarse conglomerate near the top of the Tertiary section forms cuestas and ridges where it dips 20°–60°, and broad dissected plateaus where it is flat lying. The topography reflects closely the structure of monoclines and short, broad flat-topped anticlines having steep north flanks. Flights of tilted terraces on north-flowing streams indicate Quaternary tilting and uplift of the Alaska Range. The Tertiary rocks contain thick beds of subbituminous coal.

References.—Capps (1912, 1919, 1940); Holmes and Benninghoff (1957); Maddren (1917); Wahrhaftig (1951, 1958a, 1958b); Wahrhaftig and Hickcox (1955); Wahrhaftig and others (1951).

The Northern Foothills of the Alaska Range are covered by the following 1:250,000 topographic maps: Big Delta, Fairbanks, Kantishna River, Mount Hayes, Healy, and Mount McKinley.

COASTAL TROUGH PROVINCE

The Coastal Trough province is a belt of lowlands extending the length of the Pacific Mountain System, interrupted at intervals by oval mountain groups. It is divided into the following sections: Cook Inlet-Susitna Lowland (42), Broad Pass Depression (43), Talkeetna Mountains (44), Upper Matanuska Valley (45), Clearwater Mountains (46), Gulkana Upland (47), Copper River Lowland (48), Wrangell Mountains (49), Duke Depression (50) (not described), Chatham Trough (51), and Kupreanof Lowland (52).

COOK INLET-SUSITNA LOWLAND (42)

General topography.—The Cook Inlet-Susitna Lowland is a glaciated lowland containing areas of ground moraine and stagnant ice topography, drumlin fields, eskers, and outwash plains (pl. 6, figs. 5 and 9). Most of the lowland is less than 500 feet above sea level and has a local relief of 50–250 feet. Rolling upland areas near the bordering mountain ranges rise to about 3,000 feet in altitude, and isolated mountains as high as 4,800 feet rise from the central part of the lowland. The Cook Inlet-Susitna Lowland is the major population center of Alaska and contains most of the developed agricultural land.

Drainage.—The lowland is drained by the Susitna River and other streams that flow into Cook Inlet. Most of these streams head in glaciers in the surrounding mountains. The shores of Cook Inlet are for the most part gently curving steep bluffs 50–250 feet high.

Lakes.—Three large lakes—Tustumena, Skilak, and Beluga—fill ice-carved basins at the margins of surrounding mountains. Lake Tustumena, the largest, is 23 miles long and 7 miles wide. Hundreds of small irregular lakes and ponds occur in areas of stagnant ice topography and on ground moraines. Strängemoore ponds are common in marshes.

Glaciers and permafrost.—The section is almost ice-free, although one glacier reaches the lowland from the Alaska Range on the west, and sporadic permafrost is present in the northern part.

Geology.—Bedrock beneath the lowland consists mainly of poorly consolidated coal-bearing rocks of Tertiary age, generally mildly deformed or flat lying; this rock is mantled by glacial moraine and outwash and marine and lake deposits. Sequences of moraines record successive glacial advances. The boundaries of the lowlands are of two kinds: (a) abrupt straight mountain fronts that are probably faultline scarps, and (b) uplands of hard pre-Tertiary rocks that slope gently toward the lowland. The uplands are probably uplifted parts of the surface on which the Tertiary rocks were deposited; the edge of the lowland generally marks the edge of the Tertiary cover, which dips gently away from the mountains. The isolated mountains in the center of the lowland generally consist of metamorphic and granitic rocks of Mesozoic age.

References.—Barnes and Cobb (1959); Barnes and Payne (1956); Barnes and Sokol (1959); Brooks (1911); Capps (1940); T. N. V. Karlstrom (written commun., 1957); Karlstrom (1955, 1960); Martin and others (1915); Miller and Dobrovolny (1959); Trainer (1953, 1960).

The Cook Inlet-Susitna Lowland is covered by the following 1:250,000 topographic maps: Talkeetna Mountains, Talkeetna, Anchorage, Tyonek, Kenai, and Seldovia.

BROAD PASS DEPRESSION (43)

General topography.—The Broad Pass Depression, 1,000–2,500 feet in altitude and 5 miles wide, is a trough having a glaciated floor; it opens on the east to a broad glaciated lowland with rolling morainal topography and central outwash flats. The bounding mountain walls of the trough are several thousand feet high. Long, narrow drumlinlike hills on the floor of the trough trend parallel to its axis, and the main streams in the trough are incised in rock-walled gorges a few hundred feet deep. The trough opens on its south end to the Cook Inlet-Susitna Lowland.

Drainage.—The divide between the Bering Sea and Pacific Ocean drainages crosses this depression in two places and is marked by nearly imperceptible passes. The southwestern part drains by the Chulitna River to the Susitna River; the central part, by the Nenana River north to the Yukon River; and the eastern part, by the headwaters of the Susitna. Most streams head in glaciers in the surrounding mountains and are swift, turbid, and braided.

Lakes.—Many long, narrow lakes lie in morainal depressions in the central part of the trough. Morainal and thaw lakes are common in the eastern part.

Glaciers and permafrost.—There are no glaciers. Most of the depression is underlain by permafrost.

Geology.—Patches of poorly consolidated Tertiary coal-bearing rocks, in fault contact with older rocks of the surrounding mountains, show that this depression marks a graben of Tertiary age. Most of the bedrock consists of highly deformed slightly metamorphosed Paleozoic and Mesozoic rocks that are also exposed in the surrounding mountains. Ground moraine mantles the lowland.

References.—Capps (1940); Hopkins (1951); Wahrhaftig (1944, 1958a).

The Broad Pass Depression is covered by the following 1:250,000 topographic maps: Healy, Talkeetna Mountains, and Talkeetna.

TALKEETNA MOUNTAINS (44)

General topography.—The Talkeetna Mountains are an oval highland of diversified topography that interrupts the belt of lowlands of the Coastal Trough province. The central Talkeetna Mountains (44c) are a compact group of extremely rugged radial ridges 6,000–8,800 feet in altitude, having only few low passes, that isolate steep-walled U-shaped valleys. Accordant flat ridge crests in the western and eastern parts of the central Talkeetna Mountains suggest a warped peneplain that plunges beneath Tertiary rocks in the adjacent lowlands (pl. 6, fig. 5). The glaciated Chulitna Mountains (44a), a compact group of mountain blocks separated by low passes, are isolated from the central Talkeetna Mountains by the Fog Lakes Upland (44b), a northeast-trending area of broad rolling summits, 3,000–4,500 feet in altitude, which has a glacially sculptured mammillated surface in its southwestern part but is unglaciated in the northeastern part. A similar upland (the Clarence Lake Upland, 44d) borders the mountains on the east.

Drainage.—The central Talkeetna Mountains have a radial drainage of large braided glacial streams that are tributary to the Susitna, Matanuska, and Copper Rivers. The extreme northern part drains to the Yukon River via the Nenana River. The Susitna River flows west across the Talkeetna Mountains in a narrow steep-walled gorge that in places is more than 1,000 feet deep. West-flowing streams in the southwestern Talkeetna Mountains have many long southern tributaries and few or no northern tributaries; low slanting solar rays from the south, favoring the growth of glaciers in shaded north-facing valley heads and inhibiting their growth on sunny south-facing slopes, probably caused this asymmetry.

Lakes.—There are few lakes in the southern part of the Talkeetna Mountains. Many lakes, some 5 miles long, occupy ice-carved and moraine-dammed basins in the northern part.

Glaciers and permafrost.—The firn line is between altitudes of 6,500 and 7,000 feet. Glaciers 5–15 miles long lie at the heads of most valleys in the central Talkeetna Mountains. A few cirque-glaciers occupy north-facing valley heads in the northeastern Talkeetna Mountains and Chulitna Mountains. Rock glaciers are common in the southeastern Talkeetna Mountains and in the Chulitna Mountains. Permafrost probably underlies most of the section; altiplanation terraces are present in unglaciated parts of the northeastern Talkeetna Mountains.

Geology.—A large mid-Jurassic batholith in the central and western Talkeetna Mountains intrudes Jurassic volcanic rocks and older rocks and is eroded into cliffs and spires. The southeastern Talkeetna foothills (44e) are composed of soft sandstone and shale of Jurassic and Cretaceous age, capped by flat-lying cliff-forming Tertiary basalt flows aggregating several thousand feet in thickness. The northern part of the Talkeetna Mountains consists of Paleozoic and Mesozoic greenstone, graywacke, and argillite in northeast-trending belts. The greenstone forms rugged mountains.

References.—Barnes (1962); Capps (1927, 1940); Chapin (1918); Grantz (1953, 1960a, 1960b, 1961a, 1961b, oral commun., 1957); Moffit (1915); Paige and Knopf (1907); J. R. Williams, oral commun. 1957).

The Talkeetna Mountains are covered by the following 1:250,000 topographic maps: Healy, Talkeetna Mountains, Talkeetna, and Anchorage.

UPPER MATANUSKA VALLEY (45)

General topography.—The Upper Matanuska Valley is a glaciated trough 2–5 miles wide containing longitudinal bedrock hills 500–1,000 feet high and having steep bounding walls several thousand feet high. Altitude of its floor ranges from 800 feet on the west to 2,000 feet on the east.

Drainage.—The Upper Matanuska Valley is drained entirely by the Matanuska River, which flows westward along the trough.

Lakes.—Many small narrow lakes occupy ice-carved bedrock basins, and ponds are common in morainal areas.

Glaciers and permafrost.—The terminus of the Matanuska Glacier reaches the east end of the trough. Permafrost is present in the eastern part of the trough, but its extent is unknown.

Geology.—The Upper Matanuska Valley is a structurally controlled trough bounded on the north by a major fault, the Castle Mountain fault, and on the south by a steep unconformity and faults. It is underlain by easily eroded rocks of Cretaceous and Tertiary age, which are highly deformed and were intruded by gabbro sills and stocks. It contains several coal fields. The bordering mountains are of older and more resistant rocks.

References.—Barnes (1962); Barnes and Payne (1956); Capps (1927); Grantz (1953, 1960b, 1961a; oral commun., 1959); Grantz and Jones (1960); Martin and Katz (1912).

The Upper Matanuska Valley is shown on the 1:250,000 topographic map of Anchorage quadrangle.

CLEARWATER MOUNTAINS (46)

General topography.—The Clearwater Mountains consist of two or three steep, rugged east-trending ridges rising to altitudes of 5,500–6,500 feet, separated by U-shaped valleys 3,000–3,500 feet in altitude. They are intensely glaciated. The ridges are asymmetrical; long spurs on their north sides separate large compound cirques; their south sides are relatively smooth mountain walls grooved by short steep canyons.

Drainage.—The entire section is tributary to the Susitna River.

Lakes.—There are a few rock-basin lakes in cirques and passes. The largest lake is less than 1 mile long.

Glaciers.—The north slopes of the highest peaks have a few cirque-glaciers.

Geology.—The Clearwater Mountains are underlain chiefly by Triassic greenstone and Mesozoic argillite and graywacke. The rocks are highly deformed, strike generally east, and dip steeply.

References. Kachadoorian and others (1954); Moffit (1912); Ross (1933).

The Clearwater Mountains are covered by the following 1:250,000 topographic maps: Mount Hayes and Healy.

GULKANA UPLAND (47)

General topography.—The Gulkana Upland consists of rounded east-trending ridges separated by lowlands 2–10 miles wide. The ridge crests, 3,500–5,500 feet in altitude, are 4–15 miles apart and are cut at intervals of 5–15 miles by notches and gaps that were eroded by glaciers or glacial melt water (pl. 5, fig. 2). The lowlands are floored by glacial deposits showing morainal and stagnant-ice topography and contain large esker systems (pl. 5, fig. 3).

Drainage.—The southeastern and eastern part drains south to the Copper River; the western part drains southwest to the Susitna River; and the north-central part drains north via the Delta River to the Tanana and Yukon. The drainage divide between the Pacific Ocean and Bering Sea has an irregular course through this section and is in part along eskers (pl. 5, fig. 3).

Lakes.—Many long, narrow lakes occupy rock-cut basins in notches through the ridges. Irregular lakes abound in some areas of morainal topography.

Glaciers and permafrost.—A few cirque glaciers lie on the north sides of the highest ridges. The lower ends of a few glaciers from the Alaska Range are in this section. The upland is underlain by permafrost and contains ice-wedges, pingos, and altiplanation terraces.

Geology.—Bedrock is chiefly greenstone and of late Paleozoic and Mesozoic age; structure trends eastward. Areas of relatively low relief in the northern part are underlain by poorly consolidated Tertiary sedimentary rocks.

References.—Kachadoorian and others (1954); Kachadoorian and Péwé (1955); Moffit (1912, 1954a).

The Gulkana Upland is covered by the following 1:250,000 topographic maps: Mount Hayes, Healy, Gulkana, and Talkeetna Mountains.

COPPER RIVER LOWLAND (48)

General topography.—The eastern part of the Copper River Lowland (48a) is a relatively smooth plain, 1,000–2,000 feet in altitude trenched by the valleys of the Copper River and its tributaries, which have steep walls 100–500 feet high (pl. 6, fig. 3). The Copper and Chitina valleys, eastward prongs of this lowland, contain longitudinal morainal and ice-scoured bedrock ridges that rise above axial outwash plains. The western part of the Copper River Lowland, the Lake Louise Plateau (48b), is a rolling upland, 2,200–3,500 feet in altitude, and has morainal and stagnant-ice topography; the broad valley of the Nelchina and Tazlina Rivers separates this upland from the Chugach Mountains.

Drainage.—The eastern and southern parts of the Copper River Lowland are drained by the Copper River and its tributaries. The northwestern part is drained by the Susitna River. Low passes lead to the heads of the Delta, Tok, and Matanuska Rivers. Most rivers head in glaciers in surrounding mountains and have braided upper courses. Salty ground water has formed salt springs and mud volcanoes.

Lakes.—Large lakes occupy deep basins in the mountain fronts. Thaw lakes are abundant in the eastern plain. Lakes occupy abandoned melt-water channels; those in morainal depressions in the western upland are as much as 6 miles across. Beaches and wave-cut cliffs border lakes more than 2 miles wide whereas irregular muskeg marshes encroach on smaller lakes.

Glaciers and permafrost.—There are no glaciers. The entire lowland is underlain by permafrost. The permafrost table is within 5 feet of the surface and permafrost is at least 100 feet thick.

Geology.—Bedrock beneath the southern part of the lowland is chiefly easily eroded sandstone and shale of Mesozoic age; bedrock beneath the northern part is chiefly resistant late Paleozoic and Mesozoic metamorphosed volcanic rocks. Tertiary gravels cap some hills. Ground and end moraine and stagnant ice deposits mantle much of the lowland. The eastern plain is underlain by glaciolacustrine and glaciofluvial deposits at least 500 feet thick.

References.—Andreasen and others (1958); Grantz (1961b; oral commun., 1959); Grantz and others (1962); Mendenhall (1905); Moffit (1938, 1954a); D. R. Nichols (written commun., 1960); J. R. Williams (written commun., 1957).

The Copper River Lowland is covered by the following 1:250,000 topographic maps: Nabesna, Gulkana, Talkeetna Mountains, McCarthy, Valdez, and Anchorage.

WRANGELL MOUNTAINS (49)

General topography.—The Wrangell Mountains are an oval group of great shield and composite volcanoes (Mount Wrangell, 14,005 feet in altitude, is still active) that rises above a low plain on the north and west and above heavily glaciated cliffed and castellated ridges on the south and east (pl. 6, fig. 3). Six volcanoes at altitudes higher than 12,000 feet—the highest is Mount Blackburn, 16,523 feet—make up the greater part of the mountains.

Drainage.—Seventy-five percent of the section drains to the Copper River, which encircles the mountains on the west. The remainder drains to the Tanana River via the Nabesna and Chisana Rivers and to the Yukon River via the White River.

Lakes.—There are a few rock-basin lakes in the extreme northern part. Several ice-marginal lakes lie in Skolai Pass at the east end of the mountains.

Glaciers and permafrost.—The firn line is at an altitude of about 7,000 feet. A large icecap covers most of the high mountains and feeds large valley glaciers. Rock glaciers are common in the southeastern Wrangell Mountains. Permafrost is probably present in the glacier-free areas, but its extent is unknown.

Geology.—The Wrangell Mountains are a great pile of Cenozoic volcanic rocks that rests on deformed Paleozoic and Mesozoic sedimentary and volcanic rocks, among which are cliff-forming units of limestone and greenstone. Some granitic masses intrude the Mesozoic rocks. An important belt of copper deposits, including the Kennicott Mine, lies on the south side of the Wrangell Mountains.

References.—Capps (1915, 1916a); Mendenhall (1905); Moffit (1938, 1954a).

The Wrangell Mountains are covered by the following 1:250,000 topographic maps: Nabesna, Gulkana, McCarthy, and Valdez.

CHATHAM TROUGH (51)

General topography.—The Chatham Trough is a deep, straight trench, 4–15 miles wide, which is entirely below the sea except for its north end. Average depth of water in the trough is more than 1,900 feet, and its maximum depth is 2,900 feet. Mountains on either side rise to 2,500–5,000 feet above sea level.

Geology.—The Chatham Trough probably marks a major fault line. Rocks on opposite sides of the trough do not match across the trough, either in their structure or in their age. It probably owes its greater depth to glacial erosion of relatively soft rocks.

References.—Lathram and others (1959).

The Chatham Trough is covered by the following 1:250,000 topographic maps: Skagway, Juneau, Sitka, and Port Alexander.

KUPREANOF LOWLAND (52)

General topography.—The Kupreanof Lowland consists of islands and channels. Islands of rolling heavily glaciated terrain having a local relief of 300–500 feet and a maximum relief of 1,000–1,500 feet are separated by an intricate network of waterways. (See northeast part of fig. 11, pl. 5.) Scattered blocklike mountains having rounded hummocky summits 2,000–3,000 feet in altitude rise above the general level of the lowland. Parts of some islands are plains which are a few feet above sea level and are cut across rocks of varying hardness.

Drainage.—The islands of the lowland are drained by many short clear streams that generally follow linear depressions etched by the Pleistocene ice sheets along joints, faults, bedding, and schistosity.

Lakes.—There are abundant lakes in glacially scoured basins. Parts of some islands are almost 50 percent lake surface.

Glaciers and permafrost.—There are no glaciers or permafrost.

Geology.—The lowland is underlain mainly by well-consolidated faulted and folded Paleozoic and Mesozoic sedimentary rocks, locally metamorphosed. Small elliptical granitic and ultramafic masses underlie most of the high mountains. The northern part of the lowland has an extensive Cenozoic basalt field. Small patches of Tertiary sedimentary rocks have been found.

References.—Buddington and Chapin (1929); G. D. Eberlein (oral commun., 1957); Sainsbury (1961); Sainsbury and Twenhofel (1954).

The Kupreanof Lowland is covered by the following 1:250,000 topographic maps: Sumdum, Sitka, Petersburg, Port Alexander, Ketchikan, Craig, and Prince Rupert.

PACIFIC BORDER RANGES PROVINCE

The Pacific Border Ranges province consists of several mountain ranges bordering the Pacific Coast and a coastal shelf that is present in places between them and the ocean. It is divided into the following sections: Kodiak Mountains (53), Kenai-Chugach

Mountains (54), St. Elias Mountains (55), Fairweather Range (55a), Gulf of Alaska coastal section (56), Chilkat-Baranof Mountains (57), and Prince of Wales Mountains (58).

KODIAK MOUNTAINS (53)

General topography.—The Kodiak Mountains include a group of mountainous islands that are the structural continuation of the Kenai-Chugach Mountains (54) but whose topography is more finely textured and on a smaller scale than that of the Kenai-Chugach Mountains. The Kodiak Mountains section is mostly glaciated, but the glaciation of western Kodiak Island was very early. Summit altitudes are between 2,000 and 4,000 feet. Kodiak Island has a rugged northeast-trending divide having horns and arêtes from which broad smooth ridges extend northwestward. The topography southeast of the divide has a strong northeasterly grain normal to the drainage (pl. 5, fig. 7). The coastline is extremely irregular, having many fiords and islands. The northern part of Afognak Island is a hilly lowland, and the western part of Kodiak Island has many broad valleys.

Drainage.—The islands of the Kodiak Mountains are drained mostly by swift, clear streams that are less than 10 miles long. Two rivers, each about 25 miles long, drain much of southwestern Kodiak Island.

Lakes.—There are several lakes more than a mile long in the southwestern part of Kodiak Island and on Afognak Island. Small ponds are scattered over the glacially sculptured topography. The glaciated valleys heading in the main divide have chains of paternoster lakes.

Glaciers and permafrost.—The firn line is between altitudes of 3,000 and 3,500 feet along the main divide of Kodiak Island, which has 40 cirque glaciers, all less than 2 miles long; the firn line rises to much more than 4,000 feet in the northwestern part of Kodiak Island. Permafrost is probably absent.

Geology.—The Kodiak Mountains are underlain mostly by Mesozoic argillite and graywacke. Older rocks, chiefly greenstone and schist, lie along the northwest coast. The main divide of Kodiak Island is underlain by a granitic batholith. Northeast-trending belts of downfaulted and easily eroded Tertiary rocks lie on the southeast side of Kodiak Island and also make up the Trinity Islands. Lateral moraines, ice-marginal drainage channels through the ends of ridges, and old greatly modified cirques half buried in alluvium (pl. 5, fig. 6) indicate that western Kodiak Island was not covered by ice of the last glaciation and that ice from the Aleutian Range banked against its western shore.

References.—Capps (1937); Maddren (1919).

The Kodiak Mountains are covered by the following 1:250,000 topographic maps: Afognak, Kodiak, Karluk, Kaguyak, and Trinity Islands.

KENAI-CHUGACH MOUNTAINS (54)

General topography.—The Kenai-Chugach Mountains form a rugged barrier along the north coast of the Gulf of Alaska. High segments of the mountains are dominated by extremely rugged east-trending ridges 7,000–13,000 feet in altitude. Low segments consist of discrete massive mountains 5–10 miles across and 3,000–6,000 feet in altitude, separated by a reticulate system of through valleys and passes ½–1 mile wide that are eroded along joints and cleavage (pl. 5, fig. 4). The entire range has been heavily glaciated, and the topography is characterized by horns, arêtes, cirques, U-shaped valleys and passes, rock-basin lakes, and grooved and mammillated topography. The south coast is deeply indented by fiords and sounds, and ridges extend southward as chains of islands (pl. 5, fig. 8). The north front is an abrupt mountain wall.

Drainage.—The drainage divide, generally an ice divide, is along the highest ridges, and is commonly only a few miles from the Pacific Ocean. Streams are short and swift; most head in glaciers. The Copper River crosses the eastern part of the Chugach Mountains in a canyon 6,000–7,000 feet deep.

Lakes.—Large lakes fill many ice-carved basins along the north margin of the Chugach Mountains and throughout the northern Kenai Mountains. Lake George is an ice-margin lake dammed by the Knik Glacier; it empties in an annual flood.

Glaciers and permafrost.—The firn line rises from an altitude of 2,500–3,500 feet on the south side of the mountains to 7,000–8,000 feet on the north side of the central Chugach Mountains. All higher parts of the range are buried in great icefields, from which valley and piedmont glaciers radiate. Many of the glaciers on the south side of the mountains end in tidewater. The extent of permafrost is unknown.

Geology.—The Kenai-Chugach Mountains are composed chiefly of dark-gray argillite and graywacke of Mesozoic age that are mildly metamorphosed and have a pronounced vertical cleavage that strikes parallel to the trend of the range. In the Prince William Sound area large bodies of greenstone are associated with the argillite and graywacke. A belt of Paleozoic and Mesozoic schist, greenstone, chert, and limestone lies along the north edge of the Kenai and Chugach Mountains. All these rocks are cut by granitic intrusions.

References.—Barnes (1943); Capps (1916b, 1940); Capps and Johnson (1915); Grant and Higgins (1910, 1913); Grantz (1961a, 1961b; oral commun., 1957); Landes (1927); Martin and others (1915); Miller

(1958; oral commun., 1959); Moffit (1914, 1935, 1954b); Park (1933); Plafker (1955); Tarr and Martin (1914, p. 232–450); Tuck (1933); J. R. Williams (oral commun., 1957).

The Kenai-Chugach Mountains are covered by the following 1:250,000 topographic maps: McCarthy, Valdez, Anchorage, Bering Glacier, Cordova, Seward, Kenai, Blying Sound, and Seldovia.

ST. ELIAS MOUNTAINS (55)

General topography.—The St. Elias Mountains are probably the most spectacular mountains of North America. Massive isolated blocklike mountains 14,000–19,000 feet in altitude rise at intervals of 5–30 miles from a myriad of narrow ridges and sharp peaks 8,000–10,000 feet in altitude that, seen from a distance, gives the impression of a broad ice dome. The average altitude of icefields in the interconnected valley system is 3,000–7,000 feet. Local relief is extreme and jagged cliffs abound (pl. 6, fig. 4).

Drainage.—Drainage is almost entirely by glaciers. The ice divides between drainages of the Yukon, Copper, and Alsek Rivers and the Pacific Ocean meet in this range. The Alsek River flows west to the Pacific across this range from lowlands on the northeast side and separates the Fairweather Range subsection from the rest of the mountains.

Lakes.—There are no lakes.

Glaciers and permafrost.—All parts of the range gentle enough to hold snow are sheathed in glacial ice. A continuous network of icefields and glaciers 4–15 miles wide and as much as 80 miles long penetrates the range and feeds piedmont glaciers to the south. The extent of permafrost is unknown.

Geology.—The high mountains are probably underlain by crystalline schist and granitic intrusive masses. A belt of Permian and Triassic volcanic and sedimentary rocks extend along the north side of the range. Lower Cretaceous sedimentary rocks lie in downfaulted basins in the center of the range and probably underlie ice-filled valleys. The entire sequence is thrust southward against Cretaceous and Cenozoic rocks; thrusting may be active today. Cenozoic volcanoes are present in the northern part of the range; some of these may still be active.

References.—Blackwelder (1907a, 1907b); Bostock (1948, p. 92–101, 1952, p. 6–8); Capps (1961a); Filippi (1900); Kindle (1953); Miller (1958); Moffit (1938); Muller (1954); Odell (1950); Plafker and Miller (1957, 1958); Russell (1893); Sharp (1943, 1947); Sharp and Rigsby (1956); Tarr and Butler (1909); Tarr and Martin (1912, 1914, p. 23–231); Washburn (1936).

The St. Elias Mountains are covered by the following 1:250,000 topographic maps: McCarthy, Bering Glacier, Mount St. Elias, and Yakutat.

FAIRWEATHER RANGE (55a)

(Subsection of the St. Elias Mountains)

General topography.—The Fairweather Range is an exceedingly steep and high unbroken barrier between the Pacific Ocean and Glacier Bay; mountains rise to 12,000–15,000 feet in altitude only 15 miles from tidewater (pl. 6, fig. 6). Peaks are high ice-clad pyramids having steep-cliffed walls, sharp ridges, and spirelike summits. There are a few subsummit ice plateaus but no passes across the range.

Drainage.—The Fairweather Range is drained entirely by glaciers; most of these discharge into the Pacific Ocean or Glacier Bay.

Lakes.—There are no lakes.

Glaciers and permafrost.—Most of the range is above firn line (4,000 ft) and supports vigorous glaciers that descend to tidewater. Glaciers on the west side have not advanced or retreated in recent years; those on the east side have retreated in the last 60 years and expose fiords having walls nearly 6,000 feet high. Permafrost is probably absent.

Geology.—The Fairweather Range is underlain mainly by crystalline schist that has northwesterly structural trends parallel to the length of the range. Many large granitic stocks and three large elliptical layered mafic bodies have intruded the schist. The range is bounded on its southwest side by a major fault, the Fairweather fault, on which a lateral displacement of 21 feet took place in July 1958.

References.—Mertie (1931); Miller (1953b, 1960); Rossman (1963a, 1963b); Tocher and Miller (1959).

The Fairweather Range is covered by the following 1:250,000 topographic maps: Skagway and Mount Fairweather.

GULF OF ALASKA COASTAL SECTION (56)

General topography.—The Gulf of Alaska coastal section has a diversified topography carved in Tertiary rocks. A coastal plain marked by longitudinal beach and dune ridges, crossed in places by outwash plains and by belts of morainal topography, is backed by marine terraces as high as 800 feet in altitude and by rugged intricately gullied mountain ridges as high as 12,000 feet. The straight exposed coastline is broken at intervals of 50–100 miles by large fiords (pl. 6, fig. 10).

Drainage.—Short melt-water streams of large volume cross the lowland. Bars built by coastal currents cause the river mouths to go through cycles of westward migration followed by breakthrough at their original sites during periods of high runoff.

Lakes.—There are many ephemeral lakes along the margins of the piedmont glaciers. A few large lakes occupy ice-carved basins.

Glaciers and permafrost.—The firn line is at an altitude of 2,000–4,000 feet. Icefields on higher mountains and valley glaciers in most of the valleys coming from the St. Elias and Chugach Mountains feed enormous piedmont glaciers, of which the Malaspina Glacier (pl. 6, fig. 4) is the largest. Glacial advances within the last thousand years are greater than any advance recorded in the Pleistocene. Permafrost is absent.

Geology.—The Cenozoic rocks are intensely deformed yet easily eroded claystone, sandstone, and conglomeratic sandy mudstone, all tightly folded and thrust to the south. Large thrust faults separate this section from mountains to the north and northeast. Marine terraces show that the area has been uplifted rapidly. The conglomeratic sandy mudstone interbedded in the Cenozoic section is interpreted to be marine tillite; it indicates recurrent tidewater glaciation on this coast as far back as Pliocene time or earlier. An earthquake-induced landslide on July 9, 1958, created a flood wave on Lituya Bay that splashed to a height of 1,700 feet on the side of a mountain, sweeping the forest in its path into the bay.

References.—Mertie (1931); Miller (1953a, 1953b, 1957, 1958, 1960; written commun., 1957); Plafker and Miller (1957, 1958); Twenhofel (1952).

The Gulf of Alaska coastal section is covered by the following 1:250,000 topographic maps: Mount St. Elias, Bering Glacier, Cordova, Yakutat, Icy Bay, Middleton Island, and Mount Fairweather.

CHILKAT-BARANOF MOUNTAINS (57)

General topography.—The Chilkat-Baranof Mountains are a highland of diversified topography, which is divided into four subsections: the Alsek Ranges (57a), a subsection of rugged glaciated mountains 4,000–7,500 feet altitude, containing horns and arêtes (pl. 6, fig. 6); the Glacier Bay subsection (57b), a lowland, largely drowned, that contains isolated rounded mountains; the Chichagof Highland (57c), consisting mainly of northwest-trending ridges whose summits are accordant, rounded, and 3,000–3,500 feet in altitude and of long fiords and through valleys; and the Baranof Mountains (57d), a rugged asymmetric chain 3,000–5,300 feet in altitude, having a steep eastern slope (pl. 5, fig. 10) and a more gentle southwest slope deeply indented by fiords. The southern two-thirds of the Chilkat-Baranof Mountains consists of islands. A narrow strandflat lies on the west coast of Chichagof and Baranof Islands.

Drainage.—The Chilkat-Baranof Mountains are drained by short, swift streams that flow directly to the ocean. Chains of cascades are common on the east side of Baranof Island (pl. 5, fig. 10).

Lakes.—Lakes abound in ice-carved basins in Baranof and southwestern Chichagof Islands (pl. 5, fig. 10). Elsewhere lakes are few.

Glaciers and permafrost.—The Alsek Ranges have large icefields containing tidal glaciers; Glacier Bay was filled with ice at least 2,000 feet thick as late as 1750, and glaciers have retreated more than 50 miles since then to expose the bay. Mountains on Baranof Island higher than 4,500 feet support cirque glaciers and small icefields (pl. 5, fig. 10). Permafrost is probably absent.

Geology.—Northwest-trending belts of Paleozoic and Mesozoic sedimentary and volcanic rocks underlie the Alsek Ranges and Glacier Bay subsections; northwest-trending belts of crystalline schist and gneiss and large areas of migmatitic and granitic rocks underlie the Chichagof Highland and the northeastern part of the Baranof Mountains and are bordered on the west by a belt of Mesozoic graywacke and greenstone. The rocks are cut by many northwest-trending faults. Quaternary volcanoes make up southern Kruzof Island.

References.—Buddington and Chapin (1929); Guild and Balsley (1942); Knopf (1912); Lathram and others (1959); Reed and Coats (1942); Rossman (1963b; oral commun., 1956); Sainsbury and Twenhofel (1954); Seitz (1959).

The Chilkat-Baranof Mountains are covered by the following 1:250,000 topographic maps: Skagway, Juneau, Mount Fairweather, Sitka, and Port Alexander.

PRINCE OF WALES MOUNTAINS (58)

General topography.—The Prince of Wales Mountains are moderately rugged glaciated mountains having rounded hummocky summits 2,000–3,500 feet in altitude and some spirelike arêtes as much as 3,800 feet in altitude. They are dissected by steep-walled U-shaped valleys and by fiords 600–1,000 feet deep. (See pl. 5, fig. 11.) Several passes less than 500 feet in altitude cross the range. The northeast front is abrupt, and the northwest boundary is indistinct. Karst topography is found in areas of marble on Dall and Long Islands in the southwest Prince of Wales Mountains.

Drainage.—Short, swift streams, having many lakes and waterfalls, drain the mountains and generally follow trenches eroded by Pleistocene glaciers along joints, faults, and bedding.

Lakes.—There are many rock-basin and cirque lakes, a few as much as 2,000 feet above sea level. The largest lake is 7 miles long and 1 mile wide.

Glaciers and permafrost.—One or two very small glaciers lie on the protected north sides of the highest peaks. There is no permafrost.

Geology.—The Prince of Wales Mountains are underlain in part by well-consolidated slightly metamorphosed Paleozoic sedimentary and volcanic rocks and in part by crystalline schist and marble. Several small granitic stocks cut these rocks. The mountains were entirely covered by the Pleistocene cordilleran ice sheet, which was fed partly from local centers but mainly from the Coast Mountains to the east.

References.—Buddington and Chapin (1929); Condon (1961); G. D. Eberlein (oral commun., 1959).

The Prince of Wales Mountains are covered by the following 1:250,000 topographic maps: Ketchikan, Craig, Prince Rupert, and Dixon Entrance.

COAST MOUNTAINS

The Coast Mountains form a massive mountain barrier underlain by the Coast Range batholith. The province can be divided into the Boundary Ranges (59) and the Coastal Foothills (60).

BOUNDARY RANGES (59)

General topography.—The Boundary Ranges are a glacier-covered upland 5,000–7,000 feet in altitude dissected by a dendritic pattern of deep steep-walled U-shaped valleys. The ridges have rounded accordant summits and are surmounted by arêtes and horns rising to 8,000–10,000 feet. Many of the valleys are drowned and form fiords. Passes are scarce, and valley heads are isolated. The mountains give an impression of great bulk and are bordered largely by cliffs that plunge several thousand feet to tidewater. (See pl. 5, fig. 9; pl. 6, fig. 7.)

Drainage.—The summit of the Coast Mountains coincides approximately with the international boundary; most of the range in Alaska is drained by glacial streams less than 20 miles long. Large braided rivers flow southwestward across the range at intervals of 30–120 miles from low-lying areas in northwestern British Columbia.

Lakes.—A few small lakes lie in rock basins on valley floors and in mountainside hollows in the western, glacier-free part of the range.

Glaciers and permafrost.—The firn line is about 4,500–5,000 feet in altitude. Extensive mountain icecaps, the largest 90 miles long, feed many valley glaciers, some of which descend to tidewater. Extent of permafrost is unknown.

Geology.—The Boundary Ranges are underlain mostly by the massive granitic rocks of the Coast Range batholith; a belt of schist and phyllite along its western margin and migmatized roof pendants within the batholith give a strong northwesterly grain to the topography.

References.—Buddington (1929); Buddington and Chapin (1929); Lathram and others (1959); Sainsbury and Twenhofel (1954); Twenhofel (1952).

The Boundary Ranges are covered by the following 1:250,000 topographic maps: Atlin, Skagway, Taku River, Juneau, Sumdum, Bradfield Canal, Petersburg, Ketchikan, and Prince Rupert.

COASTAL FOOTHILLS (60)

General topography.—The Coastal Foothills consist of blocks of high mountains 3–30 miles across separated by flat-floored valleys and straits ½–10 miles wide; they include closely spaced mountainous islands and peninsulas 1,000–4,500 feet in altitude. Mountains less than 3,500 feet in altitude were glacially overridden and have rounded hummocky summits (pl. 6, fig. 11). Higher mountains are generally sharp crested. The boundaries with bordering sections are indistinct.

Drainage.—Few streams are more than 10 miles long. The lower parts of most valleys are drowned, forming inlets and harbors.

Lakes.—There are many rock-basin lakes, the largest 8 miles long and 1 mile wide.

Glaciers and permafrost.—The Coastal Foothills are almost entirely ice free. A few small glaciers lie on the north sides of the high peaks on Admiralty Island. There is no permafrost.

Geology.—Northwest-trending belts of metamorphic rocks, cut by many faults parallel to the northwesterly trend of the rocks, give the topography a pronounced northwest grain. Small granitic and ultramafic bodies and westerly projections of the Coast Range batholith cut the metamorphic rocks. Southwest Admiralty Island is a high Tertiary basalt plateau.

References.—Buddington and Chapin (1929); Lathram and others (1959); Sainsbury and Twenhofel (1954).

The Coastal Foothills section is covered by the following 1:250,000 topographic maps: Taku River, Juneau, Sumdum, Sitka, Bradfield Canal, Petersburg, Ketchikan, Craig, and Prince Rupert.

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