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UNITED STATES DEPARTMENT OF THE INTERIOR

THE SOUTHERN ALASKA RANGE

GEOLOGICAL SURVEY BULLETIN 862

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 862

THE SOUTHERN ALASKA RANGE

BY
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THE SOUTHERN ALASKA RANGE

By Stephen R. Capps

ABSTRACT

The southern Alaska Range, as here defined, extends from the Skwentna River and Rainy Pass on the north to Iliamna Lake on the south. It comprises an area of more than 23,000 square miles, of which much was unexplored until 1926, when the surveys here described were begun. Within that area there are still many unsurveyed patches, but the major topographic and geologic features of this great mountain area are now known.

This portion of the Alaska Range, though nowhere reaching the altitude of Mount McKinley, is nevertheless of impressive grandeur, with many peaks reaching heights of 10,000 to 12,000 feet, and includes a labyrinth of ragged mountain crests that nourish great valley glaciers, interspersed with timbered valleys studded with magnificent glacial lakes. In it the wild animals, including moose, caribou, bighorn sheep, and grizzly bears, live in a primitive wilderness almost undisturbed by man.

Geologically the region has a complex history, as represented by rock formations that range in age from Paleozoic to Recent. These formations include ancient gneiss, schist, and crystalline limestone, less highly metamorphosed Mesozoic sediments, cut by tremendous intrusive masses of granitic rocks, little-altered Tertiary coal-bearing beds, extensive deposits of glacial moraines and outwash gravel, and the present stream, lake, and beach deposits. One of the highest mountains of the region, Mount Spurr, was found to be a volcano that still shows signs of mild activity, and other volcanoes, such as Mounts Iliamna and Augustine, lie just east of the region here treated. These mountains are the northern members of that great line of volcanic vents that stretches along the Alaska Peninsula and Aleutian Islands.

So few white men have visited this region that its potential mineral resources have not been determined. A little placer gold has been recovered at several localities, but no large areas of workable ground have yet been found. Lodes carrying promising amounts of copper and silver have been located in the southern part of the region, but lack of transportation has retarded their development. Near the shores of Cook Inlet there are extensive deposits of lignitic coal that may sometime be minable, but at present more accessible and better coals supply the local markets.

In many parts of Alaska valuable lode deposits of the metals have been found near the borders of bodies of granitic rocks. The southern Alaska Range is intricately cut by such intrusive masses, both large and small, and it seems likely that close prospecting in the vicinity of the contacts of sediments with these intrusives will result in the discovery of lode deposits of gold, silver, copper, lead, and zinc.

INTRODUCTION

The southern Alaska Range, as the term is here used, comprises that portion of the Alaska Range that lies between the Skwentna River and Rainy Pass, on the north, and Iliamna Lake and Iliamna Bay, on the south, as well as portions of the piedmont slopes both east and west of the range proper (fig. 1). These limits are chosen arbitrarily, for there is no pronounced break in the range in the region of Rainy Pass, and to the southeast the Alaska Range merges

FIGURE 1.—Index map showing location of the southern Alaska Range.

without topographic break into the Aleutian Range. Indeed, on most maps the name "Aleutian Range" has been applied to the mountains that border the Pacific littoral from the Aleutian Peninsula northward along Cook Inlet to the vicinity of Mount Spurr. Geologically, however, the major features of the Alaska Range differ pronouncedly from those typical of the Aleutian Range, and the region shown on the accompanying maps (pls. 1, 2) falls almost entirely within the province of characteristic Alaska Range geology and geologic history. The region here described is so large that it could not be conveniently shown on a single map of the scale used. Accordingly it is here shown on two sheets. The eastern part, called the "Mount Spurr region", is bounded by latitude 60°20′

and 62°5′ north and longitude 150°30′ and 153°30′ west. The western part, called the "Lake Clark-Mulchatna region", is bounded by latitude 59°35′ and 61°41′ north and longitude 153°20′ and 156° west. (See fig. 1.)

This great region, comprising an area of more than 27,000 square miles, has until recent years remained largely unexplored, in spite of the fact that it lies only a short distance west of the navigable waters of Cook Inlet, and its mountains are in sight from the shores. Only the southern portion of the region, in the vicinity of Iliamna and Clark Lakes, and the shores of Cook Island had been mapped and were fairly well known to white men. The remainder was an unexplored wilderness, entirely uninhabited, much of which had never been visited by white men. About half of the area shown on plates 1 and 2 is still unexplored, including much rugged and difficultly accessible country. In order to carry out continuous areal surveys it is necessary that the surveying parties have available some means of transportation that will enable the supplies to be moved frequently from camp to camp as the work progresses. The most serviceable means of transportation for summer work in this country has proved to be the pack horse. Yet the time required to get horses into the difficultly accessible unmapped parts of this region and to travel back to the coast after the work is done has now become so great that only a very short working field season would remain, and, as a consequence, the cost of the surveys per square mile will be high. The completion of the mapping of this region will therefore be delayed until funds are made available for the work.

PREVIOUS EXPLORATIONS AND SURVEYS

The beginnings of our knowledge of the geography of this part of Alaska date back to the early voyage of discovery of Bering, in 1741, when he caught a glimpse of the coast or of some of the islands, probably near the mouth of Cook Inlet. He was followed by many famous navigators, who eventually charted the shore lines with remarkable accuracy, but their mapping was confined to the coast, and the limitations of space permit here only a brief mention of those expeditions that yielded noteworthy geographic information. The information here used concerning explorations between 1741 and 1911 was obtained from an unpublished manuscript by A. H. Brooks, an abstract of which was made by P. S. Smith,[1] and from Brooks' Mount McKinley report.[2]

[1] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, p. 162, 1917.

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 22–32, 1911.

The first actual charting in this region was done by Capt. James Cook, who, in 1778, entered the inlet which bears his name and mapped its shores, though he mistook Turnagain Arm for the mouth of a great river, failed to discover the Susitna River, and apparently never caught a glimpse of high peaks of the Alaska Range in the region of Mount McKinley. Between Bering's trip of discovery and the exploration of Cook, however, independent Russian fur traders had been prompt to establish themselves in this virgin field and by 1762 had pushed as far eastward as Kodiak Island. Their activities were soon halted by a royal ukase that granted a trading monopoly to a single company, which in 1783 established a trading post at Three Saints Bay, on the southeast shore of Kodiak Island, and from that center controlled the trade of adjoining regions.

In 1786 Dixon and Portlock, both of whom had been officers under Cook, returned to Cook Inlet on a commercial expedition, but they added considerably to the mapping of the region. Between 1778 and 1794 a number of Russians and the Spaniard Fidalgo entered Cook Inlet in quest of furs, but they apparently were not concerned with the problem of mapping this new region.

The next expedition to leave a noteworthy record of achievement was that of George Vancouver, another of Cook's officers, who in 1794 returned to Cook Inlet and completed the mapping of its shores. Vancouver mentions high mountains far to the northwest of the head of the inlet, so no doubt he caught a view of Mount McKinley, and was thus the first to leave a printed record of the presence of this lofty summit. During the 25 years following Vancouver's trip the Russians consolidated their position as dominant factors in the fur trade, but they seem to have been slow in extending their explorations inland, and the records of that period add little to our geographic knowledge of the region here described.

One of the earliest recorded explorations into the interior of this region was that of Korasakorsky, who in 1818 traveled from Iliamna Bay, on Cook Inlet, to Iliamna Lake and thence downstream to Bristol Bay and westward to the Nushagak River, at the mouth of which the trading post of Alexandrovsk was established. He thus journeyed along the entire southern border of the region shown on plates 1 and 2 and indicated the general shape and position of Iliamna Lake. A few years later Vasilief, of the Russian-American Co., together with Lukeen, his interpreter, left Alexandrovsk and, ascending the Nushagak River, portaged over to the Holitna, followed that stream to its mouth, proceeded down the Kuskokwim to Bering Sea, and thence followed the coast back to his starting point. In this trip Vasilief failed to enter the region here described, but his course took him not far from its western border, and his discovery of the Kuskokwim River was considered of so much importance by the

Russians that in 1832 Kolmakof and Lukeen were sent to obtain further information. They followed Vasilief's route from Alexandrovsk to the Kuskokwim and established a post locally known as "Lukeen's Fort" about 100 miles below the mouth of the Holitna. This fort was the important interior trading post of the Russians for a number of years, but when it was partly destroyed by fire in a native uprising in 1841, it was replaced a few miles farther downstream by another, known as "Kolmakof's Redoubt", at the site of the present village of Kolmakof.

In 1834 Glazanof, the discoverer of the Yukon River, visited Lukeen's Fort and thence proceeded up the Kuskokwim to the stream now known as the "Stony River." Deserted here by his Indian guides, he nevertheless pushed on eastward for about 50 miles to about the location of the Lime Hills, in the northwest corner of the area shown on plate 2. He was thus the second white man of record to penetrate into this region, although only a short distance beyond its margin.

From the time of Glazanof's expedition until the transfer of the territory to the United States, in 1867, the Russians maintained their fur-trading posts along the coast and in the Yukon and Kuskokwim Basins, but apparently they were not interested in general exploration of the back country and their records reveal little geographic information of value concerning this region. The transfer to the United States scarcely altered the situation in this part of Alaska, though many prospectors and explorers had penetrated the upper basins of the Yukon and Tanana Rivers.

It was not until 1891 that the next geographic discoveries were made, when A. B. Schanz, of Frank Leslie's Magazine, and J. W. Clark, of the Alaska Commercial Co., entered the region by way of the Nushagak River and its main eastern tributary, the Mulchatna. They crossed the region between the Mulchatna and Lake Clark and confirmed the existence of that lake, which had been indicated on some of the early Russian charts and which had been visited about 1881 by C. L. McKay, of the United States Signal Service.

No systematic land surveys were made in this part of Alaska until 1898, but by that time the discovery of gold placer deposits in the Canadian Yukon region had excited the imagination of thousands of adventurous spirits, and a great demand had arisen for reliable information about this northern wilderness. To supply this demand two Federal agencies were particularly active—the United States Army and the United States Geological Survey. Each of these agencies dispatched several parties to Alaska in 1898; in some areas they acted independently, and in others they cooperated.

Into the region here described the United States Geological Survey sent a combined geologic and topographic party in charge of J. E. Spurr, geologist, with W. S. Post as topographer. This party of six men traveled by canoe from Tyonek, near the head of Cook Inlet, up the Susitna River and its tributaries, the Yentna and Skwentna Rivers, as far as Portage Creek, portaged through a high pass across the crest of the Alaska Range to the Kuskokwim Basin, and descended the Kuskokwim to its mouth. They thence proceeded partly by river and partly along the open coast to Nushagak and across the Alaska Peninsula to the Pacific at Katmai Bay. This expedition, though carrying only a line traverse across the region, acquired a large amount of accurate information concerning the geology and geography of a wide territory on each side of the route of travel, and the published report and maps [3] furnished the first authentic description of a great area that up to that time had been entirely unknown. Their route followed only along the northern edge of the area shown on plate 1, though they traveled entirely around the region here described.

The next expedition to enter this region was led in 1899 by Lt. Joseph S. Herron, of the Army.[4] The party, equipped with pack horses, proceeded by boat up the Yentna and some distance up the Kichatna to cross the range at Simpson Pass. No accurate surveys were made, but Herron's sketch map added considerably to the knowledge of the area he traversed.

Another expedition, to which must be credited a large part of even our present-day knowledge of the Alaska Range, was that of the Geological Survey in 1902, headed by Alfred H. Brooks. This party, including D. L. Reaburn as topographer and L. M. Prindle as assistant geologist, landed with pack horses and supplies at Tyonek, on Cook Inlet, proceeded overland to the Skwentna River at the mouth of Canyon Creek, crossed that river and ascended the Kichatna to its head, discovered a new pass (called by them "Rainy Pass") through which they crossed the summit of the range, and thence proceeded northeastward along the face of the range to the Nenana River. The traverse of this expedition ended that fall at Rampart, on the Yukon. Its results were later published in a monumental report on the Mount McKinley region,[5] which for the first time gave precise information about the Alaska Range between the Skwentna and Nenana Rivers.

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[3] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 31–264, 1900.

[4] Herron, J. S., Exploration in Alaska in 1899 for an all-American route from Cook Inlet, Pacific Ocean, to the Yukon: War Dept., Adjt. General's Office, no. 31, pp. 1–77, with maps, 1901.

[5] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 234 pp., 1911.

In 1903 an expedition of a different sort, organized for the purpose of climbing Mount McKinley, traversed a part of the area here described. This party, in charge of Dr. Frederick A. Cook, landed with pack horses at Tyonek and followed the route traversed the preceding year by the Brooks party. No accurate surveys were conducted by this expedition, and in the region here considered no important additions to our knowledge of the geography were made.

Other expeditions of note into this general region include that of Osgood [6] and Maddren, who in 1902 roughly mapped the route from Cook Inlet to Lake Clark and thence by the Chulitna, Mulchatna, and Nushagak Rivers to Bristol Bay; and the explorations carried on in 1901 and intermittently for several succeeding years for a railroad line from Iliamna Bay to Anvik, on the Yukon. These railroad explorations, so far as known, yielded only crude surveys that extended westward only as far as the Mulchatna River. Apparently the route ran westward from Lake Clark up the valley of the Chulitna River. No construction work was done.

The United States Coast and Geodetic Survey made a detailed chart (no. 8665) of Iliamna Bay in 1907 and has since been engaged in the triangulation and charting of Cook Inlet.

In 1911 the Alaska Road Commission began the establishment of a winter trail from the Susitna Basin to the mining camps at Innoko and Iditarod by way of the Skwentna River and Rainy Pass. This trail was later completed, road houses were established along it at intervals of about 20 miles, and it was the common route of winter travel between the coast and lower Yukon and Kuskokwim points for many years, being abandoned only in 1924 with the opening of a new trail that leaves the Alaska Railroad at Kobe and reaches the Iditarod by way of the Kantishna mining district. Travel over the trail from Susitna station through Rainy Pass was confined almost exclusively to winter by dog sled, as the marshy nature of the route and the large rivers to be crossed made it impracticable in summer, and summer travel by way of the Yukon River and its tributaries was much quicker and easier.

Although the establishment of a winter route up the Skwentna River and across Rainy Pass caused many people to traverse the northern margin of this region, nevertheless it resulted in very little exploration of the area away from the trail. The heavy snows and strong winds that prevail there in winter made the country unattractive to winter prospectors, and in summer it was shunned because of the difficulties of transportation and travel during the period when rivers, lakes, and marshes were unfrozen. Except for

[6] Osgood, W. H., A biological reconnaissance of the base of the Alaska Peninsula: U. S. Dept. Agr. North American Fauna, no. 24, 86 pp., 1904.

trail surveys by the Alaska Road Commission along the route actually followed, no systematic surveys were carried out in the Skwentna Basin between the time of the Brooks expedition in 1902 and the first of the expeditions on which this report is based.

The first systematic surveys to be conducted in this region since the 1902 expedition of Brooks were made in 1909 by D. C. Witherspoon and C. E. Giffin, topographers, and G. C. Martin, F. J. Katz, and Theodore Chapin, geologists, all of the Geological Survey. This expedition, equipped with a pack train and canoes, crossed from Iliamna Bay to Iliamna Lake, traversed the shore lines of Iliamna and Clark Lakes, and mapped both geologically and topographically the area north of Iliamna Lake and east of Lake Clark, as well as such other areas as could be reached from the south shore of Iliamna Lake. As a result of this expedition [7] an area of some 4,000 square miles was accurately mapped for the first time, the precise position, shape, and area of Lakes Iliamna and Clark were determined, and the major features of the geology of a section across this southern portion of the Alaska Range were outlined.

The Iliamna-Clark expedition was followed in 1914 by another Geological Survey exploratory party in charge of R. H. Sargent, topographer, with P. S. Smith as geologist.[8] This party followed the well-established route from Iliamna Bay to the Newhalen portage, crossed to the lower end of Sixmile Lake, and, starting their surveys there, proceeded in a northwestward direction to the Kuskokwim River and thence to Iditarod. They thus traversed the western edge of the region here described, obtained precise geographic and geologic information along the route traveled, and outlined the geography of a great region that had been unexplored or only vaguely known from reports of prospectors or trappers.

In 1920 topographic and geologic mapping was carried out on the Iniskin-Chinitna Peninsula, Cook Inlet, in the extreme southeast corner of the area shown on plate 2, by F. H. Moffit, geologist, and C. P. McKinley, topographer, of the Geological Survey. Their mapping was in greater detail than that of the earlier Survey expeditions and consequently covered a rather small area, but the closer geologic studies yielded valuable information concerning the sequence of the Mesozoic rocks at that locality. Unfortunately for the purposes of this report, the geologic units described by Moffit are apparently present only in a narrow band parallel with the coast and do not occur widely in this region.

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[7] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, 138 pp., 1912.

[8] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, 162 pp., 1917.

PRESENT INVESTIGATION

The geologic and geographic explorations mentioned above, insofar as they affected the region here described, gave information concerning portions of the shores of Cook Inlet, a narrow strip along the northern border in the Skwentna Basin, the region lying south of Lake Clark and including part of the south shore of Lake Iliamna, and a strip extending from Lake Clark northwestward across several tributaries of the Mulchatna River to the basin of the Stony River. There thus remained enclosed within these mapped areas a great region covering many thousand square miles of which nothing was known except that it included a mass of lofty, snow-capped, and glacier-filled mountains, with piedmont areas both to the east and west. This region, though bordering on Cook Inlet, was difficult of access, for it is separated from the coast by marshy lowlands and ridges dense with alder thickets. The streams that drain it are unnavigable torrents fed by glacial streams, and the interior slope lies so far from established lines of travel that it can be reached only by a long and difficult journey.

Plans were under consideration for many years by the Geological Survey to carry topographic and geologic surveys into this area, but other more pressing demands for surveys interfered, or funds were not available. In 1926, however, an opportunity was offered by Mr. William N. Beach, of New York, a sportsman and photographer of game, to cooperate with him in a joint expedition into the headwaters of the Skwentna River and adjacent portions of the Kuskokwim Basin. Under this cooperative arrangement the Survey party, in charge of the writer, with K. W. Trimble as topographer, assembled at Anchorage early in June. The horses and part of the supplies were landed at Beluga and proceeded overland to the Skwentna River, while the major part of the provisions and equipment were taken by launch to the mouth of the Skwentna and thence up that river by small boat as far as the mouth of the Happy River. For that distance an outboard motor was used where practicable, but much of the way the current was too swift for the motor to stem and lining was resorted to. At the Happy River the party was united, and from that time until the completion of the field work they traveled by pack train, returning over the same route in the fall.

As a result of that season's work an area of about 1,200 square miles was mapped geologically and topographically[9] on a scale of 1:180,000, and it was found that feasible passes led from the head of the Skwentna southward and westward into the basins of streams that drained to Cook Inlet.

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[9] Capps, S. R., The Skwentna region, Alaska: U. S. Geol. Survey Bull. 797, pp. 67–98, 1929.

The next year (1927) plans were made to reduce still further the unexplored portion of this part of the Alaska Range and to study its geology and mineral resources. In spite of extended inquiries, no information was obtainable as to the easiest route of approach to the mountainous area or as to the possibility of taking pack horses from Cook Inlet westward to and beyond the face of the forbidding mountain range that could be seen from the coast. There were vague reports that many years ago the natives were accustomed to cross the mountains to the head of the Skwentna to hunt caribou, but the route that they traveled was not known. The only clue as to the location of a route into the range was the break in the mountain front just south of Mount Spurr, which could be seen from a distance and which offered the only possible entry into the mountains, the other valleys all being occupied by vigorous glaciers. There was also considerable doubt as to whether horses could be taken in summer across the wide marshy tract that lies between the shores of Cook Inlet and the mountains.

It was finally decided to attempt an expedition to be started from the west shore of Cook Inlet a few miles south of the native village of Tyonek, as there appeared to be relatively high ground reaching from that point back to the mountains. The hope was entertained that just south of Mount Spurr a valley would be found that could be followed back into the Alaska Range. Accordingly a party was organized at Anchorage early in June 1927, with the writer in charge and R. H. Sargent as topographic engineer, with 4 camp men and 15 pack horses. This party was taken by launch and barge to Trading Bay, on the west shore of Cook Inlet, and on June 10 the laborious journey toward the mountains began. From the first, however, it was evident that the route to be followed was fortunately chosen, for both to the north and south there lay extensive marshes that are utterly impassable for horses in summer. The first 12 to 15 miles of the journey lay along a ridge at an altitude of only 200 to 300 feet above sea level, through spruce, birch, and hemlock timber and around the edges of irregular marshes. Considerable trail cutting was necessary, but forward progress of about 5 miles a day could be made. Still farther west the height of the ridge increased, timber line was approached, at an altitude of about 1,200 feet, and the country became more open and afforded excellent travel through grassy meadows and along mossy ridges.

At a point 24 miles by trail from the beach the ridge followed rises to an altitude of 2,600 feet and swings somewhat to the north. It therefore became necessary in order to ascend the large valley south of Mount Spurr to drop down into the brushy lowlands. There for many miles the expedition encountered dense alder thickets that required laborious trail cutting before horses could be taken through them. In places the efforts of the entire party could open less than a mile of trail a day. The route followed led southwestward toward a large river that could be seen to emerge from an extensive valley that cuts the mountains on the south flank of Mount Spurr. When this river, the Chakachatna, as it is known to the natives, was reached it was found to be a roaring torrent, far too deep and swift to be crossed with horses, and bordered on the north for several miles by rock cliffs several hundred feet high, against the foot of which it flowed. It was therefore necessary to return to the high bench north of the river and cut trail for several miles through dense alders to a point above these rock bluffs. That accomplished, it was found possible to ascend the valley on the north bank of the river, though cut bluffs and thick brush still required much trail building and cutting.

Upon ascending the Chakachatna Valley about 15 miles into the mountains, at a distance of 35 miles from the beach, the party encountered a glacier that descends from the southwest slope of Mount Spurr and pushes entirely across the valley of the Chakachatna, blockading the valley and impounding a superb lake, called "Chakachamna" (pl. 3, *B*). For its lower 3 miles this glacier is generally covered by coarse morainal material from a few feet to several feet thick, though in many places the ice shows through. The edges of the moraine are heavily clothed with large alder bush, and smaller alders have found a footing over the more stable portions of the moraine-covered ice. This glacier offers no serious obstacle to passage on foot, but the cutting and grading of a trail passable for pack horses required the equivalent of 20 days work for one man.

Chakachamna Lake is 15 miles long, and above it in the same deep glacial valley but separated from it by Shamrock Glacier is Kenibuna Lake, some 7 miles long. On both shores of Chakachamna Lake and on the north side of Kenibuna Lake the valley walls rise so abruptly from the water's edge that there is no beach upon which travel is possible except at the mouths of tributary streams, where small deltas have been built out into the lake. Travel with horses along the lakes is impossible, but a route was found around the northeast corner of Chakachamna Lake into the valley of the Nagishlamina River, a stream that flows southeastward into the lake. Up this valley the party proceeded, but only with difficulty, for the brush is heavy and the flat of the stream is so strewn with great boulders that it was barely possible to take horses through. By dint of much trail cutting and some grading a route was opened to a point 6 miles above the lake, where a second glacier from the northeast blocked the valley, and several days of trail work was necessary before it could be crossed. About 4 miles still farther northwest a third glacier crosses the valley, but this was passed with less delay. From the head of the Nagishlamina the party crossed by a high but easy pass into the basin of Chilligan River, and thence southwestward across another pass to the Igitna, where the lateness of the season forced the party to turn back. The return trip to the coast was made over the trail already established.

The route above described is the only one that has been opened from Cook Inlet into the upper basin of the Chakachatna River, and so far as known no horses except those of the 1928 Survey expedition and only a few foot travelers have been over it since it was opened in 1927. At that time it was just passable for hardy mountain horses, and many stretches of soft ground were so badly cut up by the passage of the horses that they could barely flounder through. Future travelers who may contemplate using this route with horses should realize this fact; moreover, much of the trail laboriously cut through alder thickets would soon become overgrown again, and much trail that was graded along cut banks or over moraines has no doubt already been washed out. No doubt anyone able to follow the Survey trail would have much less difficulty in making progress than if no trail had been made, but many stretches should be relocated, and much labor would even now be necessary to take a pack train over that route.

The work of the 1927 expedition [10] resulted in the geologic and topographic mapping of a previously unexplored area of about 2,000 square miles. It determined the relations of the streams that flow to the Skwentna River to those that flow by way of the Chakachatna to Cook Inlet, and opened the possibility that a way could be found by which horses could be taken from Cook Inlet westward across the Alaska Range far south of any pass that had been previously discovered.

The explorations of 1926 and 1927 pointed to the desirability of still further exploring adjacent regions. As soon as the general geographic facts concerning the existence of a great river valley and large lakes back of Mount Spurr had become known, Russell H. Merrill, an aviation pilot of Anchorage, had pioneered that route by plane and was using it frequently in flights between Anchorage and points on the Kuskokwim River. He had also seen a pass across the crest of the range that from the air looked passable for pack horses. Accordingly the third expedition in this series was planned, with the writer in charge and Gerald FitzGerald as topographic engineer. In order to move the necessary supplies and provisions to the point

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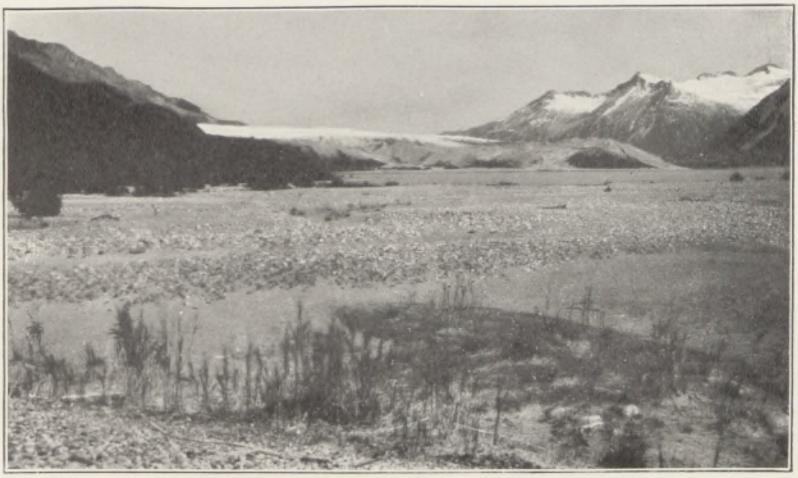
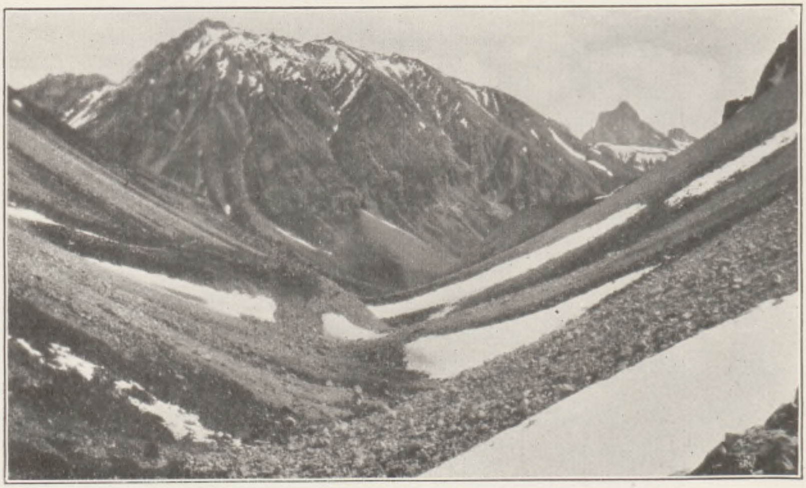
[10] Capps, S. R., The Mount Spurr region, Alaska: U. S. Geol. Survey Bull. 810, pp. 141–172, 1929.

A. LARGE ALDERS IN CHAKACHATNA VALLEY.

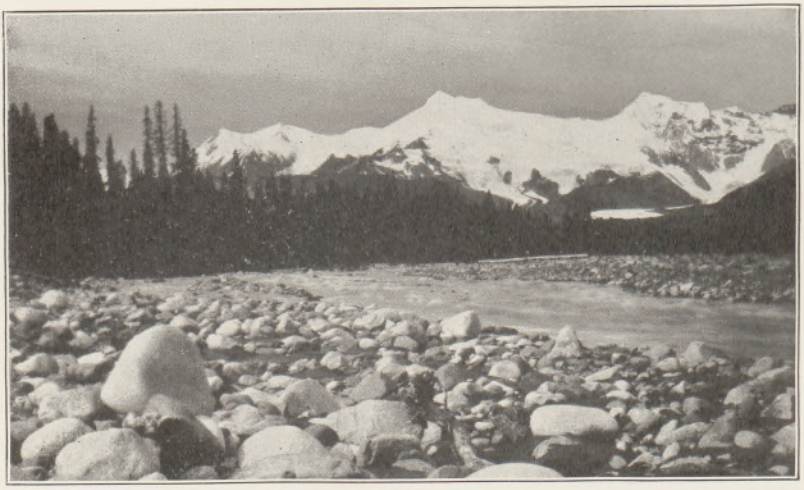


B. BARRIER GLACIER.

Projects across Chakachatna Valley and forms a dam behind which Chakachamna Lake is impounded.



A. GRANITE TALUS SLOPES IN THE SUMMIT OF MERRILL PASS.



B. MOUNT SPURR, AS SEEN FROM UPPER STRAIGHT CREEK.
In 1927 this volcano was mildly active.

of starting the new work it would have been necessary for the pack train to make at least two trips over the difficult trail from Cook Inlet to the head of Kenibuna Lake. To avoid this delay the technical members of the party, together with the greater part of the provisions, were flown by plane to Kenibuna Lake, there to await the arrival of the pack train that was following the trail from Cook Inlet. By air from Anchorage the trip to Kenibuna Lake took a little over 1 hour; the pack train, starting overland from Trading Bay that same day, was 3 weeks in reaching the rendezvous.

After leaving Kenibuna Lake the expedition proceeded westward to the head of Another River, toward Merrill Pass. This pass is low, having an altitude of 3,180 feet, and is approached from both east and west by easy grades. The pass itself, however, is obstructed by coarse granitic talus slides that extend down from the cliffs on both sides and that in three places meet along the valley axis (pl. 4, *A*). In their natural state these accumulations of coarse blocks offered little difficulty to the passage of a man on foot but were entirely impassable for pack horses. Several days' work by all members of the expedition was required to fill in the interstices with fine material and to grade out trail on steep slopes before the horses could be taken through. A part of the trail so constructed will be fairly permanent, but on certain unstable slopes slides are sure to occur, and more trail work will be necessary before horses can again be safely taken across the pass.

Once across the crest of the range the party proceeded westward down a tributary valley to the Necons River and down that river to Two Lakes. From the head of Two Lakes a well-traveled game trail was followed westward across a high ridge to the valley of the Stony River, and that stream was ascended to its head, where an easy pass was discovered leading northward into the basin of some northward-flowing stream, possibly the Hartman River. Unfortunately the lateness of the season prevented the exploration and mapping of this northward-flowing drainage system. From the head of the Stony River the party turned back and returned to Cook Inlet at Trading Bay by the trail followed in the spring. In spite of much trail work and an unusually rainy season, an area of about 1,000 square miles was mapped topographically and geologically, and much information was gained as to the interrelations of the drainage systems that carry the waters from this mountain mass to the sea by way of the Skwentna, Chakachatna, Kuskokwim, and Nushagak Rivers and Lake Clark.

The three expeditions already mentioned had outlined the major geographic features of an extensive area in the Alaska Range south of the Skwentna River and Rainy Pass, but there still remained a large area on the west side of the range between the basins of the Stony River and Lake Clark about which no authentic information was available. A fourth expedition was therefore organized that had as one of its main purposes the connecting of the earlier surveys carried west and northwest from Iliamna Bay with those carried into the region in preceding years by way of the Skwentna River and from Trading Bay on Cook Inlet. This expedition, in charge of the writer, had as topographic engineer Gerald Fitz-Gerald, with 4 camp men and 15 pack horses and necessary supplies and equipment for a summer's work. The party was landed at Iliamna Bay early in June 1929 and proceeded across the pass to Iliamna village, on the Iliamna River some 4 miles above the point where that stream flows into Iliamna Lake. From the village most of the supplies and three of the men traveled by boat to Seversen's trading post, at the foot of the portage to the Newhalen River, while the pack horses were taken around the north shore of Iliamna Lake to the same point. From Seversen's post the reunited party went by pack train to the foot of Sixmile Lake, where the horses swam across the head of the Newhalen River. An old trail was thence followed to the Chulitna River, beyond which field work in an unmapped region began. The general course followed was northeastward through the foothills and along the face of the main range as far as Telaquana Lake, where field work ended with the connection of the mapping with the surveys of the previous season. The journey back to the coast followed an old Indian trail from Telaquana Lake to Lake Clark above the mouth of the Kijik River, thence along the northwest shore of Lake Clark and Sixmile Lake to the head of the Newhalen River, from which the outgoing route was followed to Iliamna Bay.

As a result of the work during 1929 an area of some 1,400 square miles was mapped both topographically and geologically, the position and headward courses of the eastern tributaries of the Mulchatna River were determined, and a connecting link was obtained between the surveys of 1909 and 1914 and those of 1926 to 1928 that were carried westward to the west slope of the Alaska Range by way of the Skwentna, Chakachatna, and Stony Rivers.

In addition to the results obtained during the 4 years 1926–29, a large area in the vicinity of Lakes Iliamna and Clark, mapped in 1909, and another strip extending from Lake Clark to the basin of the Stony River are shown on the accompanying maps. The geology of those areas presents many features that are different from those observed by the writer farther north and east. For the area in the region of Lakes Iliamna and Clark the writer has accepted the mapping and interpretations of Martin and Katz, and for the strip from Lake Clark northward across the Mulchatna, Hoholitna, and Stony Basins those of P. S. Smith. To all these earlier workers in the region the writer is greatly indebted, and he has taken copious excerpts from their published reports.

In the fall of 1933 Ralph Tuck, geologist for the Alaska Railroad, made a short visit into the region west of the lower Susitna River, northwest of Mount Susitna. The information he obtained concerning the areal distribution of the rocks there has been incorporated in plate 1 of this report.

Plates 1 and 2 show the areas surveyed and outline the many areas still unmapped in this great region. The geologic outlines given on these maps are believed to represent the major features of the geology of the region with as great accuracy as the time given to the work warrants. Nevertheless the reader should bear in mind that all this work was done under difficult conditions of travel, when a large amount of the energy of all members of the expedition was devoted to the cutting or grading of trail or to the overcoming of such handicaps to travel as are common to exploration of mountainous countries in high latitudes. Few of the geologic boundaries were actually traced out over long distances, but they have in part been drawn in between disconnected points of observation. Fossils, by which the age of the formations could be accurately determined, are almost completely lacking, only a few collections having been obtained in several seasons of field work. Moreover, many portions of the region are so rugged, so lofty, and so filled with active glaciers that they can be reached only by severe alpine climbing, or not at all. Furthermore, the geologist worked under the handicap of having no topographic map in hand as he worked, for the topographic mapping was carried on concurrently with the geologic mapping, and the map of a given area was frequently available to the geologist only after he had finished his own work there. Nevertheless, reconnaissance work of this type is a necessary precursor of the more detailed work that will sometime be done when funds are available and conditions justify it.

The thin sections of the rocks collected by the writer have been studied microscopically by J. B. Mertie, Jr., and the types of igneous rocks here listed are based upon his determinations.

GEOGRAPHY

DRAINAGE

Some reference has already been made to the major drainage features of the region. Until the expedition of 1927 our knowledge of the physical features of that area that lay south of the Skwentna, west of the shores of Cook Inlet, north of Lake Clark, and east of the strip surveyed in 1914 by R. H. Sargent and P. S. Smith was limited to what could be seen from the coast and to the vague reports of the few prospectors and trappers who had penetrated into it. A few maps had been published on which the supposed position of certain rivers, lakes, and mountains were indicated, but actual surveys proved these earlier maps to be so far in error as to be worse than useless. On the east border of the region, however, the coast line of Cook Inlet had been accurately charted by the Coast and Geodetic Survey, the position and altitude of Mount Spurr and Mount Iliamna and of a few other high points had been determined by triangulation from the coast, and the lower mile or two of each of the larger rivers that drain to the inlet had been mapped. These charts showed a large river, the McArthur, entering Cook Inlet southeast of Mount Spurr. From the coast the view up the great lowland from which that river emerges shows the snout of a great glacier that pushes northeastward to the mountain front, and it was presumed that this glacier was the principal source of the river. Surveys carried inland, however, showed that another large stream, the Chakachatna, drains a great basin within the range and emerges from a valley just south of Mount Spurr to join the McArthur only a few miles from the coast. Although the part of the McArthur River above the Chakachatna was not seen at close range, it is certain, from the size of the drainage basins of the two streams, that the Chakachatna supplies much the greater volume of water. For the lower 25 miles of its course the Chakachatna flows through a marshy lowland with a comparatively low gradient and probably with a current of only moderate swiftness. Within the mountains it has a fall from an altitude of 1,170 feet at its source in Chakachamna Lake to 400 feet at the western or inland edge of the lowland and is a roaring torrent that through considerable distances has a current estimated at 15 miles an hour. The Chakachatna receives several tributaries from the north, all of which carry the drainage from glaciers that radiate from Mount Spurr, and a few short tributaries of moderate size from the south, all of which head in glaciers in the granite mountains south of the river. All these tributaries below the lake are of small volume compared with the size of the stream that flows from the lake itself.

Chakachamna Lake, in which the Chakachatna River has its source, lies in a great east-west glacial valley, the headward portion of which is dammed by Barrier Glacier, a vigorous ice stream that descends the southwest slope of Mount Spurr. To ascend the Chakachatna Valley along the north side of the river to the lake (the south side being impassable for horses), it is necessary to cross the moraine-covered portion of Barrier Glacier, and this can be accomplished with little difficulty on foot, though for horse travel much trail building is necessary. The lake is a superb body of water 15 miles long and on the average 2 miles wide, enclosed to the north and south by steep, rugged, lofty mountains that rise precipitously from the shores. It is separated by the snout of Shamrock Glacier from Kenibuna Lake, which is 7 miles long and occupies a part of the same deep glacial trough. Several glaciers from tributary valleys descend into Chakachamna Lake, or almost to it, and nearly every valley of the surrounding mountains contains a glacier at its head. The water of Chakachamna Lake is slightly turbid in summer for all the streams that flow into it are glacial streams. The steep cliffs that in most places rise from the shores of the lake on its north and south sides render land travel along its shores difficult or impossible, though by boat all points on the lake could be reached with ease.

Several streams of considerable size flow into Chakachamna and Kenibuna Lakes from the north, west, and southwest. The easternmost of these, the Nagishlamina, which joins Chakachamna Lake near its northeast end, was ascended to its source. This river is a large, turbulent stream during the summer, too swift and deep in its lower course to be fordable with horses, and carries boulders so coarse that its bars are difficult to traverse with pack animals. At a point 6 miles above the lake this valley is almost entirely blockaded by Pothole Glacier, which descends from the range north of Mount Spurr and has built a great moraine, in part underlain by ice, across the stream valley. This glacier forms an obstacle to travel along the valley, which, though not so difficult to pass as Barrier Glacier, nevertheless required many days of trail building to construct a passable trail across it. About 4 miles farther upstream a similar glacial obstruction (Harpoon Glacier) is encountered, but this can be largely avoided by fording the river to its northwest side and skirting the edge of the glacier. Beyond Harpoon Glacier travel is easy through a wide-floored glacial trough up to the broad pass that separates this drainage basin from the head of the Skwentna River. The extreme headward tributary of the Nagishlamina from the west may be followed without difficulty to a pass at an altitude of 3,600 feet that leads into the valley of the Chilligan River, 13 miles above the point where that stream flows into Chakachamna Lake.

The Chilligan River is the longest of the northern tributaries of Chakachamna Lake. It heads in the high mountains in which lies the divide between the Skwentna and the South Fork of the Kuskokwim, flows eastward and then southeastward, and empties into the lake near its upper end. Its total length is about 35 miles.

The Igitna River lies southwest of the Chilligan River, receives a number of eastward-flowing tributaries from the main crest of the Alaska Range, and empties into the head of Kenibuna Lake. The stream called "Another River" rises on the crest of the range in Merrill Pass and flows eastward to the head of Kenibuna Lake, a distance of 12 miles. The Neacola River, a tributary of Kenibuna Lake from the southwest, is unexplored in its upper basin, which is said to be connected by a pass with the drainage that flows westward to Lake Telaquana. It is a fairly large stream, is glacier-fed, and for its lower 10 miles flows in many branching channels through a valley floored with sand and silt.

Straight Creek heads on the east flank of Mount Spurr and flows into the lowland to join the Chakachatna 20 miles above its mouth. Nikolai Creek, which flows along the north edge of a swampy flat and receives drainage from the flat itself and from tributaries that drain the rolling ridge north of the flat, is a clear stream and empties into Cook Inlet 11 miles northeast of the mouth of the McArthur River.

Still farther north the east face of the range is drained principally by the Beluga River, which receives the waters of several large glaciers that flow eastward from the high mountains north of Mount Spurr. Streams from these glaciers flow to a lake several miles long, at the base of the range, and the Beluga River from its source in that lake flows eastward through the piedmont country a distance of some 30 miles to Cook Inlet. Much of the upper basin of the Beluga River is still unexplored.

The Skwentna River flows along the northern edge of the area shown on plate 1 and receives the drainage from a large area of that part of the Alaska Range that lies east of the main crest and north of the Chakachatna drainage basin. The Skwentna is a tributary of the Yentna, which joins the Susitna River some 30 miles above the mouth of that stream. The Skwentna is a typical glacial river, much of its water originating in the melting glaciers of the Alaska Range. Like all streams that are supplied mainly by glacial waters, it has a volume largely determined by the rate of melting of the glaciers. The high-water period occurs usually in June or July, when the days are long and warm and when some of the preceding winter's snow still remains in the mountains, or at other times as the result of warm rains on the snowfields. As cold weather approaches in the fall the volume of water diminishes rapidly, and with the decrease of glacial melting the streams become less heavily charged with sand, gravel, and silt. In the winter stream discharge is at a minimum and the waters run clear.

The problem of transporting supplies up the Skwentna River during the summer is a serious one, for the current runs from 5 to 8 miles or more an hour, and the tendency of the heavily loaded stream to split up into many branches makes it difficult to find a continuous channel of sufficient depth for a boat drawing even 1 or 2 feet of water. Power launches drawing about 3 feet of water can be counted upon to ascend only to a point 6 or 7 miles above the mouth of the stream, even in periods of high water. Above that point loads have usually been taken in poling boats or shallow-draft boats equipped with outboard motors. In the expedition of 1926 a poling boat with a capacity of about 1 ton, equipped with a 6-horsepower outboard motor, was employed. Throughout much of the river the current was so swift or the water so shallow that progress with a loaded boat by motor was impossible, and lining was resorted to. Nevertheless, there were many stretches where the motor could be used, and it was invaluable in making crossings from one bar to another and in ascending through the canyons or along brushy banks where towing or poling were especially difficult. Even with the more powerful outboard motors that are now available, there are many stretches of the river where lining will be necessary, and no one who has not spent days wading the icy waters and exerting every ounce of his strength in dragging a heavy boat against the rushing waters can realize the hardships of moving supplies in that way.

Inasmuch as the Skwentna River furnishes the route by which supplies have been taken into the region in summer, a somewhat detailed description of that river may be of value to those who, unfamiliar with the stream, may seek to ascend it. From a point some 13 miles upstream, at Skwentna Crossing, to its mouth, the river flows over a wide gravel flat in many branching channels. Just above Skwentna Crossing is a canyon some 2 miles long, cut into hard rock, with steep bluffs on each side. Above this the river again widens out and is spread over a broad flat of alternating channels and sand and gravel bars. Great quantities of driftwood have accumulated on these bars, and snags and log jams add to the difficulties and dangers of boating. This flat extends upstream to a point about 8 miles above the mouth of the Hayes River. Between the Hayes River and the mouth of the second canyon the Skwentna is for the most part so broken up into numerous shallow channels and the current is so swift that a motor is of little use, and boats must be moved by lining.

In the second canyon, which has a length of about 4 miles, the river is swift but is well confined to a single channel, and much of this stretch can be run in a power boat. Above the second canyon the current is in general swifter than below, and although certain stretches can be run with a motor, an increasing proportion of towing must be done. The third canyon, some 16 miles above the Hayes River, is short but can be traversed by motor. Above this canyon there is little water in which a motor is of use, and the rapid current and coarse boulders render progress upstream increasingly difficult. The highest stretch of river which members of the survey party traveled by boat, between the Happy River and Portage Creek, was considered to be the most difficult portion of all. It is possible that a lightly loaded boat could be towed much farther upstream than the mouth of Portage Creek, but the work would be arduous and the progress slow.

The only large tributaries entering the Skwentna from the south between its mouth and Portage Creek are the Talushulitna River, Canyon Creek, and the Hayes River. The Talushulitna is a clear stream and receives most of its water from the broad lowland that lies between Beluga Mountain and the base of the Alaska Range. Canyon Creek is also a clear stream of only moderate size. Its upper basin is still unmapped. The Hayes River is a large glacial stream that discharges almost as much water as the Skwentna above their junction. The upper basin of the Hayes River is entirely unexplored, but a view up the valley from its mouth shows that a great glacier occupies that basin, some 10 or 15 miles upstream, and it appears certain that the basin as a whole, with an area of 300 to 400 square miles, contains extensive ice fields.

From the north the Happy River is the only important tributary of the Skwentna within this region. It heads near Rainy Pass, but most of its basin lies outside the area here described. Portage Creek, from the west, enters the Skwentna some 8 miles above the Happy River. It is slightly turbid from glacial waters and heads in a high and somewhat difficult pass to Ptarmigan Valley, in the Kuskokwim drainage basin.

Above Portage Creek the Skwentna has a general northward course. It is joined from both east and west by many tributary streams, some of which are so large as to be difficult to ford on foot. At least four of these tributaries are glacial streams, three entering from the east and one from the west. The Skwentna River itself heads in the Twin Glaciers, two large glaciers that lie in adjacent valleys and flow westward to the edge of the main north-south trough in which the Skwentna flows. This trough continues southward across a low, scarcely perceptible divide, into the valley of the Nagishlamina, a tributary of the Chakachatna River.

A small area within the basin of the South Fork of the Kuskokwim River is shown on plate 1, drained by the Styx River and the head of the South Fork itself. Both these streams head back into unexplored and unmapped areas. The Styx is only slightly turbid, indicating that its basin contains only glaciers of small size. The South Fork by contrast is very muddy and heavily charged with sand and gravel and flows in braided channels over a wide valley floor, thus indicating that a considerable portion of its water is derived from melting glaciers, and that the glaciers are of sufficient size to deliver large quantities of debris to the river.

The west slope of the Alaska Range within the region here described drains, except for the small area just mentioned, into the Kuskokwim by way of the Stony River or to Bristol Bay by way of the Nushagak River and its tributaries or through Iliamna and Clark Lakes and the Kvichak River. The northernmost of these streams is the Stony River, which is tributary to the Kuskokwim River at a point about 50 miles above Georgetown. The Stony heads in high, glaciated mountains against divides that separate its basin on the north, northeast, and east from that of tributaries of the South Fork, of the Kuskokwim River, and of the Chakachatna River. Its main head drains from a low, easy pass that leads northward into an unexplored region, probably drained by the Hartman River. From that pass it flows in a southerly direction, not swinging westward until it has emerged from the mountains onto the Kuskokwim lowland. In this area the Stony receives three large tributaries. West Fork, only the lower part of whose basin has been mapped, joins it from the northwest. The Necons River, another tributary, is for most of its course roughly parallel with the Stony and itself receives a tributary from the east that drains from Merrill Pass, a low divide that separates the Chakachatna Basin from that of the Stony. At the face of the mountains the Necons River empties into a large double lake known as " Two Lakes ", below which its course gradually converges with that of the Stony. These streams join in the lowland some 20 miles below Two Lakes. The third important tributary of the Stony from the east is the Telaquana River, a glacial stream that flows northwestward from unmapped mountains, empties into Telaquana Lake, and thence discharges into the Stony River 20 miles or so below the lake. Telaquana Lake is a part of a series of lakes, at least one of which lies near the face of the mountains in the valley of each major stream that drains west from the Alaska Range between Iliamna Lake and the Stony River. All these lakes receive glacial waters, and all are slightly turbid during the summer season.

Below the mouth of the Telaquana River the Stony flows northwestward through the Kuskokwim lowland, a broad area of low relief broken by groups of isolated hills. The air-line distance from the mouth of the Telaquana to the Kuskokwim is 90 miles, but the distance by the river is considerably more. The Stony is said to be navigable by poling boats or by shallow-draft power boats for many miles above its mouth, but it is reported that there are a few canyons through which boats cannot be taken and around which portages several miles long must be made.

Between the Stony Basin and that of Lake Clark all the westward-flowing drainage from the Alaska Range finds its way through the Mulchatna River or one of its several tributaries to the Nushagak, which empties into Bering Sea at the head of Bristol Bay.

The main head of the Mulchatna River rises in glaciers that push down within a few miles of the west face of the Alaska Range in the vicinity of Telaquana Mountain. The waters from these glaciers flow into Turquoise Lake, in which they drop most of their sediment. Below that lake the Mulchatna is only slightly turbid and flows in a southwestward course through broad alluvium-floored lowlands from which isolated groups of hills arise. Its principal tributary from the east is the Chilikandrotna River, which rises in the high mountains of the range but receives much drainage from the ice-free foothills northwest of Lake Clark. As a consequence of the many lakes in its upper basin that serve as traps for the glacial debris the Mulchatna throughout its length is relatively clear and for the most part flows in a single channel between well-defined wooded banks. It is navigable at a good stage of water by shallow-draft boats from its mouth to a point a few miles above the mouth of the Chilikandrotna and by poling boat still farther.

In the northwestern part of the region shown on plate 2 the Hoholitna River, which has its source in Whitefish Lake, drains westward and beyond the region here described turns northwestward to join the Kuskokwim some 20 miles below the mouth of the Stony. The Hoholitna is a clear stream, and though its lower course is little known it is said to be navigable for small boats throughout much of its length.

The basin of the Kvichak River, in which Lakes Clark and Iliamna lie, includes all of the southern portion of the region shown on plate 2 except a small area in its southeast corner, tributary to Iliamna and Iniskin Bays on Cook Inlet. Lake Clark is a magnificent body of water surrounded, except at its lower end, by lofty mountains. It is 44 miles long, averages about 4 miles in width, and is separated by short stretches of river from Sixmile Lake, below, and Little Lake Clark, above. Its surface is 220 feet above sea level, and depths of as much as 606 feet have been sounded. In beauty of setting it deserves a place among the famous mountain lakes of the world, though it has been little visited by white men, and its shores are inhabited by only half a dozen white men and less than a hundred natives.

The largest tributary of Lake Clark is the Tlikakila River, which enters its head from the north. Though the basin of that river is unmapped and little known the stream is said to rise in glaciers and to be bordered by rugged mountains throughout its length. A fairly low pass over a glacier is said to be passable on foot for winter travel from the head of the Tlikakila River to the head of Kustatan River and thus to offer the only route across the range between Mount Spurr and Iliamna Bay.

The Kijik River is tributary to Lake Clark from the north at a point some 17 miles below the head of the lake. The Kijik heads in rugged mountains, and although the extreme head of its basin was not mapped, its cloudy waters show that there are active glaciers at its head. The low pass northeast of Ingersol Lake that gives access to the valley of the Tlikakila River suggests either that the upper part of the Kijik Basin may once have drained to that stream but was diverted to the southeast by a great glacier that once filled the Tlikakila Valley, or that the low pass was excavated to its present level by ice flowing westward from the great glacier that formerly filled the Tlikakila Valley.

The Chulitna River, which enters Lake Clark from the west at the head of Chulitna Bay, is a large clear-water stream that drains a lake-dotted lowland between the Mulchatna and Lake Clark and for most of its length is sluggish and too deep to ford with horses. It is said that the only feasible ford is that used by the Geological Survey party, just south of the center of Long Lake. The Chulitna is navigable for shallow-draft boats for a long distance above Lake Clark and forms a route long used by the natives in crossing to the Nushagak River.

The Koksetna, a northern tributary of the Chulitna, follows a peculiar course, flowing first north, then successively southwest, south, east, and again southwest to join the Chulitna. This unusual drainage pattern is due to former heavy glaciation in the region and the succeeding deposition of thick accumulations of outwash gravel in all the valleys near the ice margin. The scour and fill brought about many drainage changes in the region, and the present stream pattern is no doubt quite different from that of preglacial time.

The region south of Lake Clark and the basin of Iliamna Lake was seen by the writer only in passing, but Martin [11] has given a brief description of the lakes and glaciers there. He reports that Iliamna Lake is 80 miles long, from 8 to 20 miles wide, and the

[11] Martin, G. C., op. cit. (Bull. 485), pp. 13–14.

largest lake in Alaska. Its surface is about 50 feet above tide and it drains through the Kvichak River into Bristol Bay. At its east end soundings have shown depths of many hundreds of feet. Sixmile Lake is at practically the same altitude as Lake Clark, from which it is separated by a short stretch of river. It drains out through the Newhalen River into Iliamna Lake. Kontrashibuna Lake, tributary to Lake Clark from the east through the Tanalian River, is 14 miles long and half a mile to a mile wide and lies 560 feet above sea level. Upper and Lower Tazimina Lakes, which are about 650 feet above sea level, drain through the Tazimina River into Sixmile Lake. Many smaller lakes lie on the various tributaries of Lake Clark.

The Kvichak River, which flows from Iliamna Lake to Bristol Bay, is south of the region shown on plate 2 but carries all the waters from the basins of both Iliamna and Clark Lakes. It is about 62 miles long. For its upper 17 miles it has an average current of probably 6 miles an hour and is much broken up by islands and bars into narrow, relatively shallow channels. The greater part of its fall is in this portion of its course. For the next 13 miles it is somewhat less swift, running about 3 or 4 miles an hour, and is confined to a single deep channel. The lower 32 miles of its course is tidal, the water being of considerable depth even at low tide. The river is navigable for its entire length by boats drawing 3 or 4 feet of water.

The Newhalen River, between Sixmile and Iliamna Lakes, is some 23 miles in length. For the upper 11 miles of its course it is navigable for launches, but rapids and falls render the lower 12 miles entirely unnavigable. These rapids are avoided by a 5-mile portage to Iliamna Lake.

The other large streams tributary to Iliamna Lake within the region mapped are Pile and Iliamna Rivers. Boats drawing several feet of water ascend the Iliamna River as far as Iliamna Village, which is connected with Iliamna Bay by trail and road. The Tazimina and Tanalian Rivers and Currant Creek enter Lake Clark from the southeast, and the Chokotonk River joins Little Lake Clark from the northeast, draining an unsurveyed region.

Many of these streams offer favorable sites for the development of water power whenever a demand for it arises. One of the most promising power sites is on the Tanalian River, which has a fall of 60 feet in a single drop at the outlet of Kontrashibuna Lake. The Tazimina River has a fall of about 430 feet between Lower Tazimina Lake and Sixmile Lake, most of it within a distance of 3 miles. The Newhalen River, a large stream, falls 160 feet in its lower rapids, through a distance of about 6 miles. Other streams also have possibilities for power development, and in many of them the flow is regulated by natural storage in lakes.

GLACIERS

Inasmuch as most of the higher valleys of this region are occupied by active glaciers, no attempt will be made to describe the glaciers in detail. As is to be expected, the largest glaciers cluster around the mountains that lie just west of Cook Inlet, for there peaks reach the greatest altitude, and there the precipitation is heaviest. Apparently the moisture-laden winds that enter the Cook Inlet depression are deprived of much of that moisture as soon as they encounter the lofty enclosing mountains, for the glaciers on the Cook Inlet slope are much larger than those found on the westward-facing valleys. Thus a notable group of glaciers drains to the Beluga River from the high ridge on which Mounts Spurr, Torbert, and Gerdine lie, and another though somewhat smaller group drains to the McArthur and Chakachatna Rivers from the high mountains that lie south of Chakachamna Lake. These glaciers contrast sharply in size with those that drain the same mountain masses but face westward.

Within the region as a whole there are scores of unnamed glaciers from a few hundred yards to 10 or 12 miles long, which on maps of the scale here shown appear small. Many of them are imposing features of the landscape, however, and in any area less abundantly supplied with majestic scenery would be notable.

Some of these glaciers are vigorous and show little evidence of recent retreat. Others are apparently now undergoing shrinkage; their lower portions are moraine-covered, and their whole appearance gives the impression of undernourishment. This region has been so recently explored that there is as yet too little information upon which to base any conclusions as to whether the ice fields as a whole are maintaining themselves, advancing, or retreating.

RELIEF

The southern Alaska Range, as here described, includes a segment entirely across that great range of mountains, together with portions of a piedmont belt both to the east and to the west of the range proper. Within this region the range has an east-west width from flank to flank that ranges from about 100 miles in the latitude of Mount Spurr to about half that distance in the latitude of Iliamna Lake. Within the mountain area the topography is in general extremely rugged and is characteristic of a region that has been severely sculptured by glacial ice. The highest altitudes within the mountain belt are found on the ridge of which Mount Spurr (pl. 4, *B*) forms the southern end. Many points on that ridge attain altitudes of 10,000 feet or more, Mount Spurr rising to 11,050 feet and Mount Gerdine to 12,600 feet. Elsewhere the summit peaks commonly reach altitudes of 6,000 to 7,000 feet, with a few as high as 8,000 feet, but as the main valley floors for the most part have altitudes of only 1,000 to 3,000 feet, the immediate relief is high and the slopes are steep. Practically all the major streams head in glaciers, some of which are large, and the range is of distinctly alpine character. Particularly in those mountains that are carved from granitic rocks the topographic forms are rough, and the crest-line ridges consist of a series of sharp, ragged pinnacles. (See pls. 5 and 6.)

At its eastern margin the face of the Alaska Range is abrupt, with a sharp topographic break between the rolling ridges of the piedmont area and the mountain province. From the Skwentna River southward to Nikolai Creek the mountains give way toward the east to rolling upland ridges of poorly developed drainage, covered by glacial deposits, dotted by scattered lakes and ponds, and trenched by only a few major streams. This piedmont slope, much of which is marshy, slopes down gradually to sea level at the shore of Cook Inlet. It is interrupted, between the mouth of the Susitna River and the lower Skwentna, by a group of rounded granite mountains among which Mount Susitna and Beluga Mountain are prominent.

Between Nikolai Creek and West Foreland is a low marshy plain that extends from tidewater to the mountain front and that is interrupted only by the low ridge of which West Foreland is the southern point and by two or three low hills that rise above the general level of the plain. This plain has apparently been carved from the foothill belt by the vigorous erosion of the McArthur and Chakachatna Rivers, which flow across it in anastomosing courses over an outwash plain of glaciofluvial debris. It is almost impassably marshy in summer, and the rivers are unnavigable, though in winter it offers no serious problems to travel by dog sled.

From West Foreland southward to Iliamna Bay the mountains rise directly from the shore or are separated from it by a piedmont belt only a few miles wide. Throughout the distance from Iliamna Bay northward to the Skwentna River the piedmont area offers serious difficulties to summer travel, presenting a succession of dense thickets of alder bush, marshy tracts, and unfordable rivers. At only a few places has it been found possible to travel in this area with pack horses, and then only after much trail cutting and long detours to avoid marshes and beaver ponds.

From what is known of the west face of the range and the bordering lowlands in this region, conditions there are quite different from those found on the east slope. North of the Stony River the mountain face is unexplored and unmapped, but as seen from a distance the mountains appear to give way abruptly to a lowland region, a part of the great lowland of the upper Kuskokwim Basin. South of the Stony the face of the range is less sharply defined, the high, rugged, glacier-filled mountains gradually giving place to more smoothly rounded foothills that rise from a gravel-filled lowland. This hill-dotted lowland extends from the Alaska Range westward for 100 to 150 miles and includes much of the basins of the Stony, Holitna, and Hoholitna rivers, all tributaries of the Kuskokwim, and of the Nushagak River, which flows southward to Bristol Bay. Throughout that area rounded hills of rock are separated by open basins through which the streams flow with only moderate swiftness. Travel in this belt is possible by pack train in summer, and in that portion between Lake Clark and the upper Stony pack horses may be taken almost anywhere with little difficulty.

CLIMATE

Inasmuch as the region here described is almost uninhabited, no systematic observations of its climate have been recorded. The nearest points at which accurate weather records have been kept are on the coast on the east side of Cook Inlet and at Bristol Bay, and at these points the climate is obviously affected by the influence of the ocean waters and is unlike that in the mountainous region farther inland. Furthermore, the distribution of temperature throughout the year, as well as the amount and distribution of the precipitation, are here, as in any area of highly diversified topography, greatly affected by local relief and by the direction of exposure to the sun and to the prevailing winds. The general statements here given concerning the climate of this region express the experience of the Geological Survey parties during the summers of 1926 to 1929, supplemented by such other information as could be obtained.

The larger size of the glaciers that drain eastward to Cook Inlet, as compared with those on the west slope of the range, indicate plainly that precipitation is heavier on the Cook Inlet slope than on the inland slope. It is also evident that more rain and snow falls on the higher peaks than on the mountains of lesser altitude. Probably the annual precipitation on the east slope of the range averages between 30 and 40 inches, though the part that falls in the summer is distributed as frequent light rains rather than as heavy downpours. Between June 15 and September 15 in each of the years from 1926 to 1929 there were from 40 to 70 days during which some rain fell in the place where the Survey party happened to be, so that the summer climate within the mountains appears to be cool and rainy. The number of rainy days is somewhat less in the Cook Inlet piedmont area and considerably less in the lowland west of the range. Late spring and early summer weather is likely to be clearer than that of middle and late summer. Frost is to be expected in the mountains in any month during the summer, though in the lowlands of Cook Inlet and along the shores of Lakes Iliamna and Clark summer frosts are infrequent, and vegetables, berries, and root crops flourish.

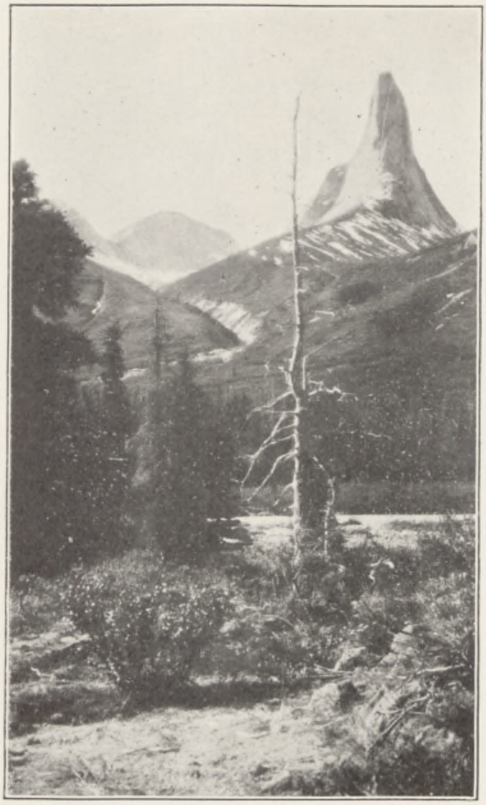
Nothing definite can be said about the climate during the winter further than that it is probably much like that of the other mountain provinces that border Cook Inlet. The attitude of the brush on the Cook Inlet piedmont area indicates a fairly heavy snowfall, whereas within the mountains, particularly on their western slope, and in the vicinity of Lakes Clark and Iliamna, the brush indicates that the snowfall is moderate.

VEGETATION

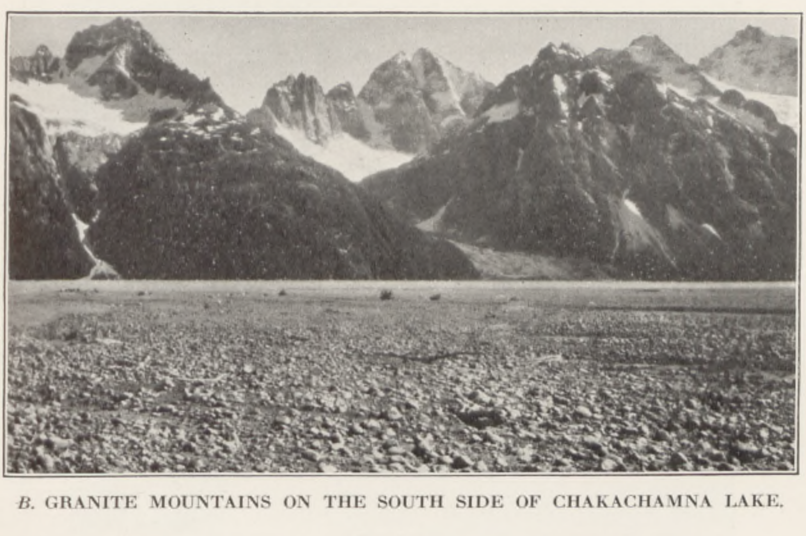
Throughout this region as a whole timber may be found in areas that have an altitude of less than 2,000 feet. At a few places scattered trees grow up to 2,400 or 2,500 feet, but large areas even below 2,000 feet have only scattered trees. The accompanying map (pl. 7) shows the areas within which timber occurs. Spruce trees are most common, with birch on some well-drained slopes and cottonwood and balsam poplar along the coast and on alluvial flats. Little of this timber is large enough or good enough to yield merchantable lumber, and with the possible exception of certain areas of birch near the head of Cook Inlet its value will be only for purely local uses. Some fairly heavy stands of cottonwood along the lower Susitna may also sometime be valuable for pulpwood.

In the Cook Inlet piedmont area there is scattered timber along many of the rivers and on the ridges up to altitudes of 1,200 to 1,500 feet. The trees are mainly spruce, but with a little cottonwood and in one small area a little scrubby hemlock. Large areas below 1,500 feet in altitude between Nikolai Creek and the Skwentna River have only scattered, scrubby trees or none. The wide flat through which the Chakachatna and McArthur Rivers flow is generally marshy and supports timber only in narrow strips bordering the streams or scrubby trees in a few areas that are relatively well drained. The remainder of the flat is clothed only with brush and marsh plants.

The lowland bordering the lower Skwentna and the valley of the Susitna River is generally covered with a fair stand of timber up to an altitude of about 2,000 feet, with scattered trees up to 2,400 feet. The most prevalent tree is the spruce, which in favorable places reaches a diameter of 2 feet, though few clear logs of merchantable size are obtainable. Of recent years the spruce in this region has been seriously attacked by a bark beetle, and over a large area perhaps half of the trees have been killed.

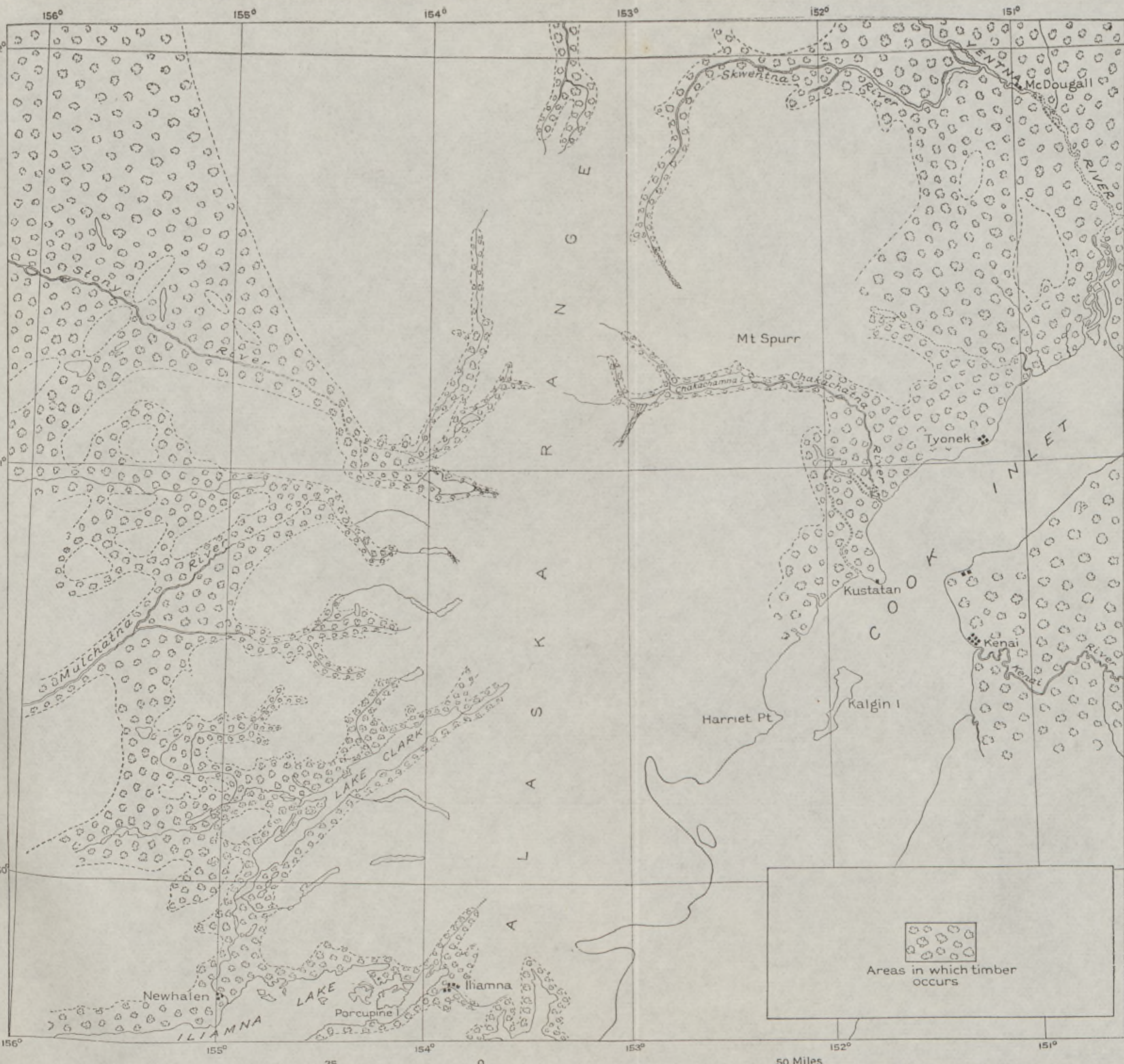


A. THE TUSK, A GLACIATED GRANITE PINNACLE IN THE BASIN OF ANOTHER RIVER



B. GRANITE MOUNTAINS ON THE SOUTH SIDE OF CHAKACHAMNA LAKE.

RUGGED TOPOGRAPHY DEVELOPED FROM GRANITIC ROCKS IN THE UPPER BASIN OF THE STONY RIVER.



MAP SHOWING AREAS IN SOUTHERN ALASKA RANGE IN WHICH TIMBER OCCURS.

Within the higher mountains trees are confined to narrow strips along the valleys below altitudes of 2,000 to 2,600 feet. This is true of the tributaries of the Chakachatna, the Skwentna, the Stony, and the Mulchatna and of Lake Clark. Thus on the Skwentna there are spruce trees within 4 miles of North Twin Glacier, and on the Styx River up to Timber Creek. In the Chakachatna Basin timber occurs sparingly up to Chakachatna Lake and for 4 miles up the Nagishlamina River, 14 miles up the Chilligan River, and 8 miles up the Igitna River above the lakes into which these streams empty. On the west slope of the range there are trees up the Stony River to a point within 11 miles of Sled Pass, up the Necons and Merrill Rivers for 12 miles above Two Lakes, and on the Telaquana to and for some distance above Telaquana Lake. Turquoise Lake is several miles above timber line, but spruce trees grow around and above Twin Lakes. In the lowlands west of the main range timber occurs here and there where the altitude is sufficiently low, especially along the banks of the larger streams and lakes, but elsewhere is generally present in scattered groves, separated by treeless areas.

Within the timbered areas there is nearly everywhere some brushy undergrowth that includes alders (pl. 3, *A.*), willows, and various shrubs, so that some trail cutting is necessary for the passage of pack animals, and in many places on the mountain slopes and above timber line alders grow in such dense stands that they are almost impassable, even for a man on foot. This is especially true of the Cook Inlet slope of the range, where there are areas many square miles in extent in which the alders grow to heights of 15 or 20 feet in unbroken thickets. The general statement may be made that on the east slope of the range much trail cutting is necessary to open up a new route for pack animals, whereas on the west slope the brush is much less dense and much less cutting is required.

In most valley heads alders or willows may be found considerably beyond the last trees, and these supply tent poles and fuel for the camper in places where otherwise he would be without them.

Grass is fairly well distributed throughout the region, though it is necessary to have the question of forage in mind when choosing a camp site, as there are considerable areas in which grass is scanty. The commonest grass is a variety known as " redtop ", which locally grows in lush, luxurious stands. There is also some bunch grass and in places some vetch known as " pea vine." The leaves of certain types of willows are also eagerly sought by horses. The experience of the several seasons spent in this region by the Survey parties indicates that the problem of forage offers no serious difficulty. Most of the forage plants are nutritious only during the growing season, however, so that pack animals can subsist properly on what they can obtain by grazing only from early June to late September.

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WILD ANIMALS

This portion of the Alaska Range is fairly well stocked with large game animals, though in fewer numbers and smaller variety than in some other parts. Except in the area tributary to Lake Clark they have been little hunted and are therefore fairly easy to approach. Both black and grizzly bears are common, from 50 to 100 having been seen each summer by the Survey parties. They are especially abundant in the Chakachatna, Stony, and Skwentna Basins. As these bears have had little experience with man, they show little fear, and the black bears especially are bold and likely to raid any provisions left unguarded. Wolverines also are common, and precaution must be observed to keep them out of caches. Moose are present in the timbered areas throughout the region. East of the range they are hunted by the natives and are not abundant, but in the upper Chakachatna, Skwentna, Stony, and Telaquana Basins they are fairly numerous, and the well-marked moose trails along all the larger valleys are of great assistance to the traveler, as they are relatively free from brush and follow favorable gradients. Caribou range in the Ptarmigan Valley and South Fork of the Kuskokwim area in some numbers and into the head of the Skwentna Basin. They are also found sparingly in the Chakachatna and upper Stony Basins and along the west face of the mountains as far south as Lake Clark. Mountain sheep are abundant in the basin of the South Fork of the Kuskokwim but were seen only in small bands of few individuals in the upper Skwentna and Chakachatna Basins, at the head of the Stony River, and near Telaquana Lake.

The fur-bearing animals that are to be found in this area include beaver, which are widely distributed, mink, fox, lynx, marten, wolverine, ermine, and land otter. Except for beaver, upon the trapping of which there are restrictions from time to time, the mountainous portions of this region are said to offer no exceptional inducements to the trapper.

Among the small game animals rabbits are generally present in large numbers, but of recent years they have decreased greatly and over considerable areas have entirely disappeared. Ptarmigan, like the rabbits, vary greatly in abundance from year to year and were scarce from 1926 to 1929. The dearth of rabbits and ptarmigan, upon which most of the fur-bearing animals rely for food, has resulted in a notable diminution in the annual catch of furs.

As almost all the larger streams that drain the mountains head in glaciers, their waters are muddy during the summer season of melting, and they are unfavorable for fishing. Here and there are clear-water streams and lakes that contain trout of several varieties, grayling, pickerel, and whitefish. Some salmon run up all the streams that empty into Cook Inlet, as well as up the Stony, and Lakes Clark and Iliamna have a heavy run of salmon. These lakes and their tributary streams also offer exceptionally fine fishing for the angler.

ROUTES OF TRAVEL

Although the eastern edge of this region can be easily approached by way of Cook Inlet and boats drawing several feet of water can ascend the Kvichak River from Bristol Bay to all points on Iliamna Lake, nevertheless this region as a whole is difficultly accessible, and considerable areas within it had not been visited by white men until the expeditions of the Geological Survey upon which this report is based. The Survey expeditions of 1926 to 1929 all entered the region from the east, by way of Cook Inlet, and as all of them transported camp equipment and supplies by means of pack horses, it was necessary to establish trails passable for horses from some point on the coast to the areas to be surveyed. It is true that all parts of the region are within a few hours' travel by airplane from Anchorage, and planes can land on open stream bars or on lakes, or in winter almost anywhere on skis, but inasmuch as planes cannot be used in summer in the day by day moving of camp to all parts of the region, irrespective of landing places, the pack horse still remains the most reliable means of transportation for this type of work.

To survey the upper Skwentna Basin pack horses were carried by scow to the mouth of the Beluga River and thence were taken with light loads overland around the head of the Talushulitna River to the Skwentna some 4 miles above the mouth of Canyon Creek. Parts of this route are brushy and required considerable trail chopping, and other stretches are difficult as the result of swamps and lakes caused by beaver dams. From 7 to 10 days should be allowed for traversing the 70 miles from Beluga to the Skwentna.

After arrival at the Skwentna it is necessary to cross that river, which is there too deep to ford. In summer stages of water there are likely to be two or more channels, each at least 100 yards wide, and it would be hazardous to have the horses swim with their loads. It is therefore necessary to have a boat at the crossing to transfer the equipment and members of the party. From the north side of the river the winter trail can be followed westward by pack horses, though in places the ground is boggy.

It is also possible to ascend the Skwentna River in summer by shallow-draft boats as far as the mouth of the Happy River, though many stretches are so swift that lining must be resorted to. In 1926 the Survey party took most of its provisions by way of the Skwentna to the Happy River, from which horses were used exclusively.

Some 4 miles west of the Happy River travelers into the upper Skwentna Basin leave all marked trails behind, but except for some brushy areas, where cutting must be done, pack horses can be taken almost anywhere without unusual difficulty. Numerous well-traveled game trails are of great assistance and with a moderate amount of cutting can be developed into good trails for horses.

For winter travel the old winter dog trail from the Alaska Railroad at Nancy to the Kuskokwim by way of Rainy Pass is still open and may be used to points on the Skwentna as far west as the Happy River. This trail, however, is now rarely used and offers no accommodations to travelers. Anyone now using it would be forced to break his own trail the entire way.

Some account of the route from Cook Inlet, at Trading Bay, into the basin of the Chakachatna River has been given on pages 10–12. Until that trail was opened by the United States Geological Survey party in 1927, no summer route across that part of the piedmont belt was known to be practicable for horses, and no horses had until that time been taken into the Chakachatna and upper Stony Basins. The route actually followed was chosen because, as seen from Cook Inlet, there appeared to be a ridge of high ground extending from the beach to the mountains. The trail as established leaves the shore of Cook Inlet at Trading Bay, at a point just north of the mouth of Nikolai Creek. For several miles it follows the benches just above the great flat there, skirting several open marshes, and gradually ascends the piedmont ridge to and above timber line. Through the timber the trail is blazed, and where brush was encountered much cutting was done. In both 1927 and 1928 Geological Survey pack trains used this trail, and it should be passable for some time, though a new growth of brush and vegetation will obliterate much of it as time goes on. With the exception of the Survey parties no more than half a dozen persons have used it, and no other horses have been taken over it.

After following the south edge of the piedmont ridge for some 22 miles in an air line from the coast and reaching an altitude of 2,600 feet, the trail leaves the high ridge and descends abruptly to the valley of Straight Creek over steep slopes densely overgrown with large alders. It ascends that valley for about 4 miles and then crosses to the Chakachatna River through an extremely brushy country. Through this stretch the traveler will be wise to follow the trail meticulously, for the brush is almost impenetrable unless much trail cutting is done. Above the point at which the Chakachatna River is reached the route followed by the Survey parties (see pl. 1) can be followed without more difficulty than is to be expected in an uninhabited country. To reach Merrill Pass and the Stony Basin it is impossible to follow the shores of Chakachamna and Kenibuna Lakes on foot or with horses, and the only feasible route known is that up the Nagishlamina River to its head, thence across the passes to the Chilligan and Igitna Rivers, down the Igitna to Another River, and up that valley to Merrill Pass. From Merrill Pass one can proceed on foot without difficulty to Two Lakes and thence over the ridge to the Stony, which can be traveled to its head. It should be borne in mind, however, that to take horses over this route from Cook Inlet is a difficult trip. No doubt the brush has already grown sufficiently to require considerable cutting before horses can be taken through. There are many down logs within the first 20 miles from the beach, and many stretches of trail so soft as to be barely passable. Furthermore, much rebuilding of the trail is likely to be necessary across the lower ends of Barrier, Pothole, and Harpoon Glaciers and through Merrill Pass.

The western slope of the range, between Lake Clark and the Stony River, can be most easily approached either by boat to Iliamna Lake from Bristol Bay by way of the Kvichak River, or from Iliamna Bay across a low divide to Iliamna village, on the Iliamna River about 4 miles above the mouth of that stream at Iliamna Lake. A trail, long in use over that portage, a distance of about 12 miles, is now being replaced by a wagon road, not quite completed in 1932. A small pack train has been maintained for the summer transportation of supplies across this trail, but few horses have ever been taken farther west than the east end of Iliamna Lake. The Survey party of 1929, like that of Martin and Katz, in 1909, and of Sargent and Smith, in 1914, landed with horses and supplies at Iliamna Bay, transported the outfit by pack horse to Iliamna village, from which the horses were sent with light loads around the north shore of the lake to the foot of the Newhalen portage, while most of the supplies and part of the personnel traveled to that point by boat. There is no good summer trail along the lake shore, and considerable soft ground and brushy country must be traversed. Practically all travel in this country goes by boat in summer and by dog sled in winter. There are a number of medium-sized gas boats on Iliamna Lake that are available for hire. From Seversen's trading post, at the Iliamna Lake end of the Newhalen portage, there is a trail across to the Newhalen River at a point above the falls. For summer transportation all supplies for the country contiguous to Lake Clark are back-packed across this portage, a distance of about 6 miles. From the head of the portage, and in fact generally throughout the country to the north, there are only faint native trails for land travel. One of these may be followed from Nondalton village northwestward to the Chulitna River, and another follows the north shore of Lake

Clark, for the most part keeping to the beach and so being submerged during periods of high water. Another faint trail, formerly much used by the natives, leaves the shore of Lake Clark at the mouth of the Kijik River and continues northward through the foothills to Telaquana Lake. These are the only trails of consequence on the west face of the mountains, but pack horses can be taken almost everywhere without serious difficulty.

POPULATION

Except for a few small settlements around its margins, this region is entirely uninhabited by either whites or natives. On its eastern edge, according to the census of 1930, there were 78 persons residing at Tyonek, on Cook Inlet, all but a few of whom were natives; 52 persons at Susitna station, on the Susitna River, of whom perhaps a dozen were white; and a few white trappers and fishermen scattered along the shores of Cook Inlet and the Susitna, Yentna, and Skwentna Rivers. At Iliamna village, on the Iliamna River, the records show 100 inhabitants, of whom perhaps a dozen were whites, and many of those actually reside at various places along the shores of Iliamna Lake. The village of Nondalton, on Sixmile Lake, below the mouth of Lake Clark, was credited with 24 inhabitants, all but one or two of whom are natives. A few white trappers and prospectors and a few families of natives live along the shores of Lake Clark. From all these points of settlement trappers maintain trap lines during the winter, and many families have summer fishing camps at some distance from their winter houses, but except for the shores of Cook Inlet and of the larger rivers and lakes there are no permanent habitations in this great region.

There was formerly a considerable native village at the foot of Telaquana Lake, but it is now abandoned. Before the advent of the white man the natives of Tyonek were accustomed to make summer hunting trips into the headwaters of the Chakachatna Basin, and similarly the Susitna natives formerly hunted in the upper Skwentna Basin, but for the last 30 years these expeditions have been given up, for the natives find it easier to gain a living by various employment with white men than to make the difficult journeys of former years.

Although a few prospectors occasionally visit the more accessible parts of the region, and a few mining claims are held near Iliamna Lake and Lake Clark and on Iliamna Bay, there is now no mining in progress, and in the past mining has been confined to the production of small amounts of placer gold from the north shore of Lake Clark. The natives subsist largely upon fish and rely upon their catch of fur and the sale of fish to supply them with money for such purchases as they need to make. The white men of the region are all fishermen, trappers, or traders, some of whom do some prospecting also. As a whole, this region is as undeveloped as it was 30 years ago, and there appears to be no immediate likelihood of any improvement in this condition unless mineral deposits of importance are discovered. During each of the four summers spent by the writer in this region months at a time elapsed without the party seeing any other human being.

GEOLOGY

GENERAL OUTLINE

The general distribution of the rocks of the southern Alaska Range is shown on plates 1 and 2 insofar as the formations have been differentiated. Prior to the expeditions on which this report is based the region was unmapped except for a traverse along its northeastern border by Spurr, a few observations made by Brooks between the Beluga and Skwentna Rivers, the work of Martin and Katz in the Iliamna-Clark region, and the surveys of Smith from lower Lake Clark to the Kuskokwim. All these expeditions were of exploratory or reconnaissance nature, and in all of them only reconnaissance mapping was attempted. Attention is again directed to the fact that on each of these expeditions a serious problem was faced in transporting personnel and supplies from the coast to the field of work through an almost unknown country, and much time and great effort were expended in merely overcoming the physical obstacles to travel with horses in a land where horses had not before been used. Furthermore, the summer season in Alaska during which geologic field work with horses is feasible is short, ordinarily extending from early June to mid-September, or a total of about 100 days. In penetrating to a remote region much of this short season is consumed in merely traveling to and from the chosen field of work, so that a period of 50 to 70 days of productive field work is all that can be expected, and from this must be subtracted days of weather so inclement that field work is impossible. A further handicap to the close mapping of geologic boundaries arose from the fact that on each of these expeditions the topographic mapping was carried on concurrently with the geologic field work, and completed topographic maps as a base for the geology were not available until several months after the end of the field season. As a consequence of these difficulties the geologic boundaries as shown on the accompanying maps are only approximate, but they represent the best information obtainable under the circumstances.

The geologic units shown on plates 1 and 2 include 11 rock groups and 2 groups of relatively young and unconsolidated materials. All these units have been described in one or another of the reports issued after each of the field expeditions was completed. The attempt is here made to compile in a single report the information on this region gathered during eight separate field seasons and by nearly as many geologists and to correlate their work so as to set forth the geologic relationships throughout the region as a whole. The topographic base maps for plates 1 and 2, showing the whole region, insofar as it has been surveyed, represent the work of seven different topographic engineers. Although considerable areas still remain unsurveyed, these maps show the main drainage lines and the principal mountain masses of the region, and it is believed that they will prove to be of great value to anyone who contemplates a visit to this hitherto little-known portion of Alaska.

Although the area here included is part of an unbroken mountain range that, measured along its axis, is many hundreds of miles in length and that throughout that distance comprises alpine peaks and countless mountain glaciers, both large and small, nevertheless the rocks of which the range is composed differ greatly from place to place. So far as is known the growth of the present range began in Tertiary time, and although its most active period of growth was probably completed by the end of the Tertiary, some slow crustal movements have no doubt continued down to the present day. In pre-Tertiary time, however, the geologic history of various provinces now included in the range was quite different, as is shown by the great variety exhibited by the geologic section in different parts of the range. Of the region here described that portion that extends from the Skwentna River southwestward to a line formed by Lake Clark and its prominent tributary from the northeast, the Tlikakila River, has all apparently had a similar orogenic history, at least since early Mesozoic time, and throughout it much the same rocks are represented. South of Lake Clark and the Tlikakila River the history has been quite different. Several groups of rocks, apparently of Paleozoic age, are represented there, and the Mesozoic section differs in many important details from that of the range farther north. The mountains just west of Cook Inlet, referred to in some earlier reports as the Chigmit Mountains, certainly include many rock formations that have not been recognized in other parts of the Alaska Range, but they also include many formations which are typical of the range as far north as Mount McKinley. Between these areas there is no sharp structural or geomorphic break, and as it is impossible to draw any logical boundary between the Alaska Range proper and the Chigmit Mountains, the name "Chigmit" is here discarded, and the whole mountainous area is considered a part of the main Alaska Range.

The region southeast of Lake Clark and the Tlikakila River was seen by the writer only briefly, and that northwest of the Mulchatna River was not visited by him at all. Consequently the descriptions here given of the geologic formations represented in those parts of the region are taken from the published reports by Martin and Katz and by P. S. Smith, already cited, and their age determinations are accepted. Throughout the region fossils are extremely rare or altogether lacking, and the age determinations of the rocks were perforce based upon lithologic and stratigraphic similarities to rocks in adjacent regions whose age could be determined directly.

The rock types shown on plates 1 and 2 include a great variety of materials, among which are normal sediments and their metamorphic equivalents, deep-seated intrusives, and volcanic lavas and tuffs of great diversity. The entire succession is nowhere exposed in a single section, and any ideal geologic column that may be constructed is a composite composed of partial sections at various localities. This fact and the scarcity of fossils have made correlations difficult and have left some doubt as to the correctness of some of the interpretations here presented. The difficulties of correlation in most of this region are made more striking because of the fact that just to the east of it, in the Iniskin-Chinitna Peninsula, and farther south, in the Alaska Peninsula, there is a remarkably thick and complete section of Mesozoic rocks, all of which are abundantly fossiliferous and from which has been established a type section for the Mesozoic of northwestern America. Just why, of two adjacent regions, one region should have been so favorable for the growth of invertebrates and the other so inhospitable is still an unsolved problem.

In the following pages the various geologic units that have been differentiated in the field and that are shown on the accompanying geologic maps are described in some detail. Associated with the sediments throughout the geologic section are large bodies of igneous rocks, some of which were laid down on the surface as lava flows and tuffs, and others were intruded into the sediments and cooled under cover. The lava flows and tuffs, as surface deposits, have a definite place in the stratigraphic section and so are here described in order along with the other bedded materials. The intrusive rocks, cutting bedded deposits of various ages, are discussed in a later section of this report.

PALEOZOIC ROCKS

GNEISS, MICA SCHIST, AND QUARTZITE

Distribution and character.—According to Martin,[12] the oldest rocks of this region are believed to be a group of highly metamor-

[12] Martin, G. C., op. cit. (Bull. 485), p. 30.

phosed sediments now appearing as gneisses, mica schists, and quartzites, that occupy two districts—a southern one in the mountains between Iliamna and Pile Bays and a northern one on both sides of the upper end of Lake Clark, as shown on plate 2. In the southern district these rocks are divided into two detached areas, separated by granitic intrusive rocks. The rocks in the eastern of these two areas are bordered on the east in part by slates, to be described later, and in part by granite. The western area is bounded on the west by Triassic (?) limestone and on the east by granite. In the upper Lake Clark region there are also two areas of quartzite and mica schist, one on each side of the lake. The area on the southeast side of the lake is bounded on the east by crystalline limestone and calcareous schist and on the west and south by Mesozoic volcanic rocks. The area northwest of the lake, probably continuous beneath the lake with the area just mentioned, appears to be bordered on both sides by crystalline limestone.

The gneisses and schists lying nearest Iliamna Bay include coarse-grained light-colored rocks, of gneissic texture, composed of quartz, feldspar, and biotite and in places also hornblende, as well as fine-grained types of darker color, composed of hornblende and feldspar and approaching schists in texture. There are also present quartzitic schists, which are locally abundant. These rocks have a general northeast strike and a steep northwest dip and are probably overthrust or overfolded upon the slate and greenstones that lie east of them.

The rocks just east of Pile Bay include some biotite gneiss but a larger proportion of coarse to fine hornblende gneiss and some chloritic schist. The adjacent limestone to the west is believed to overlie the gneiss unconformably, and the granite on the east is regarded as intrusive into it.

In the neighborhood of Lake Clark the rocks of this group include quartzite, quartzite schist, and mica schist. The quartzite locally shows distinct shearing, and argillaceous quartzites, composed largely of quartz with varying amounts of biotite and accessory magnetite and carbonaceous material, are also present. These quartzites, quartzite schists, and mica schists are of undoubted sedimentary origin and occur as an alternation of moderately thin beds. They are minutely plicated, with the axial planes of the folds and the schistosity standing vertical and striking a little east of north. Some basic dikes invading this formation have been folded with it.

Age.—There is no direct evidence as to the exact age of these rocks, except their degree of metamorphism. They are more highly altered than any other rocks of the region, and as they are apparently not connected with the other rocks by metamorphic gradation facies, it is concluded that they are older. This determines their age as certainly pre-Triassic. As some of the less metamorphosed rocks of the region are also older than the Triassic, it is presumed that the gneisses and schists are probably as old as early Paleozoic, and they may be in part of pre-Cambrian age. No direct correlation can yet be made with other rocks in this part of Alaska, and no more precise age determination is now possible.

CRYSTALLINE LIMESTONE AND CALCAREOUS SCHIST

Distribution and character.—Highly metamorphosed and presumably old calcareous rocks are found in this region in three districts—one near the head of Iliamna and Cottonwood Bays, one adjacent to the upper end of Lake Clark, and a third, shown in the northwest corner of plate 2, stretching from the Hoholitna Basin northeastward across the Stony River. Southeast of the upper Lake Clark area they occur as a continuous belt along the eastern margin of the quartzite schists already described and extend southward for at least 2½ miles beyond Kontrashibuna Lake, beyond which they were not traced. Northwest of upper Lake Clark these rocks are present both east and west of the schist and probably occur there as an anticline, with a portion of what is apparently the west limb of this fold showing on a small island in the center of the lake.

In the area west of Iliamna Bay the crystalline limestone occurs in two small areas—one about 2 miles west of the head of the bay, on the old trail to the village, and the other about 3 miles west of the head of Cottonwood Bay. In the basins of the Hoholitna and Stony Rivers the limestone forms a group of isolated hills having a northeast trend and entirely surrounded by unconsolidated materials, so that the structural relation of the limestone to other hard rocks is concealed.

The limestone and calcareous schist on Lake Clark seem to overlie the mica schists and quartzite already described. They appear to be many hundreds of feet thick, but their complex structure renders any measurement of thickness uncertain. Most of the section is composed of pure limestone, and the associated schists are highly calcareous. Their separation from the presumably older quartzitic rocks is made on the basis of their lime content, as no structural break was observed, and the two groups appear to have suffered equally severe metamorphism.

Southeast of Lake Clark the calcareous rocks are made up of two parts, of which the western part, which is apparently the lower, consists of thin interlaminated bands of schistose material and of fine-grained crystalline limestone. The eastern and upper part is presumably higher and consists of light-colored limestone that in the main is fine-grained, though in places it is coarsely crystalline. On the headland just north of the mouth of Currant Creek the cliffs are composed of calcareous schist that includes sericitic and serpentinous material and calcite, with chlorite and quartz, cut by veinlets of quartz and epidote. This rock, in which secondary parallelism of crystals is well developed, is doubtless a sheared calcareous argillite. Throughout the Lake Clark area these rocks wherever seen are thoroughly recrystallized as the result of regional metamorphism.

In the two small areas west of Iliamna Bay the calcareous rocks are crystalline limestone or marble, the calcite grains ranging from one-eighth to one-fourth inch in diameter. No trace of bedding or of the original unaltered calcareous material remains, and no noncalcareous materials are present except for quartz veins that cut the marble.

These masses of marble may possibly be lenses in the surrounding gneiss but are more probably small detached areas of some larger mass. The limestone of the Lime Hills, in the basins of the Hoholitna and Stony Rivers, is described by Smith,[13] who states that those hills are composed entirely of limestone. They form striking landmarks because they have little vegetation on them and the white color of the limestone is conspicuous. The limestone knobs rise abruptly from the lowlands, like islands above the sea. Their lower slopes are submerged in the great deposits of recent alluvium, so that the relations of the individual hills to one another and to the other hard rocks of the region cannot be determined with certainty. In spite of this difficulty, however, the color of the limestones is so distinctive that the hills they form can be recognized for long distances, and they have been mapped for more than 30 miles along the strike. The width of the limestone belt thus recognized is a little more than 2 miles, but the thick alluvial cover of the lowlands may conceal the true width.

The limestones of the Lime Hills are dominantly gray-white and semicrystalline. At a distance bedding or a laminated structure is distinctly recognizable, but on nearer view such features are much less evident and were noted at only a few outcrops, the recrystallization having obliterated the original bedding in large measure. Locally the limestone has been silicified, and the siliceous portions stand out in relief on weathering.

Although these hills are dominantly calcareous, some dolomites were recognized, and these may have stratigraphic significance, though no such relation was definitely proved.

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[13] Smith, P. S., op. cit. (Bull. 655), pp. 50–57.

The dominant structural trend of the limestones of the Lime Hills in the area visited is about N. 30° E., though local features may diverge considerably from that direction. At one or two places the limestones strike northwest, but these variations are due to deformation and are local. The dip, usually to the southeast, differs in amount from place to place but is nowhere less than 30° and in several localities approaches 90°. Faults parallel to the general trend of the belt were observed, many of them small but some apparently of considerable displacement.

The width of the limestone belt, averaging about 2 miles, and the steepness of the dips indicate a thickness of more than 5,000 feet. There may be some reduplication by faulting, but on the other hand the width of the belt may be greater than is shown by the exposures. It seems likely that more refined measurements would show a thickness greater than 5,000 feet rather than less.

Age.—As these limy metamorphic rocks have yielded no fossils, determination of their age must rest on their stratigraphic relations to associated rocks. It is here presumed that the calcareous metamorphic rocks of the Lake Clark area and those just west of Iliamna Bay are of the same age. On Lake Clark these rocks overlie the mica schists and quartzites, which have been tentatively referred to the early Paleozoic, though on weak evidence. They are overlain unconformably by porphyries and tuffs of presumably Lower Jurassic age and are cut by granitic intrusives that are of late Mesozoic age. Thus the positive evidence merely goes to show that they are of pre-Jurassic age, though their severe metamorphism indicates that they are much older than the Jurassic. Certain limestones on Iliamna Lake are of Triassic age, and Martin[14] believes them to be younger than the calcareous materials here under discussion. He also believes that these calcareous schists and marbles are older and more severely metamorphosed than certain pre-Triassic greenstones and slates on Pile Bay. On this basis he places them somewhere in the Paleozoic and suggests a possible correlation with the Devonian.

The evidence for the age of the limestones of the Lime Hills is equally indefinite. They have yielded no fossils, though a few indistinct markings suggested organic remains. Smith canvassed the possibility that they might be correlative with the Triassic limestones of Cottonwood Bay and southwest of Iliamna Village but discarded it because of differences in color, carbonaceous content, degree of alteration, and thickness and because of the lack of fossils in the rocks of the Lime Hills. He therefore assigned them to the

[14] Martin, G. C., op. cit. (Bull. 485), pp. 34–35.

Paleozoic, on admittedly weak evidence. This evidence includes the presence of a Devonian fossil in a pebble found in the first exposed formation above the limestone and the recognition of Devonian fossils along the west front of the Alaska Range not far north of the Lime Hills. Neither of these bits of evidence is conclusive, but the weight of available information seems to favor a Paleozoic age for these rocks.

PALEOZOIC OR EARLY MESOZOIC ROCKS

SLATE AND CHERT

Distribution and character.—Slates locally associated with cherts and other sediments occur at several localities in the region contiguous to Lakes Iliamna and Clark. They are here grouped under one heading on account of their general lithologic similarity, though that they are all contemporaneous is by no means finally established. One area of these materials lies along the face of the mountains west of Cottonwood Bay and up the valley at its head, though neither end of this belt is known. These rocks are in that locality bordered on the west by gneiss and schist and on the east by greenstone.

Somewhat similar slates with associated chert occur in at least three localities between Kontrashibuna and Iliamna Lakes. Another locality at which similar rocks are associated with altered igneous rocks and thin-bedded limestones is found on both sides of the lower end of Little Lake Clark. There also the north and south extensions of this belt are unknown.

Near Cottonwood Bay the rocks of this group constitute a monotonous succession of hundreds and possibly several thousand feet of black slate without characteristic subdivisions, although a few thin beds of limestone and quartzite are present, and possibly some schist and phyllite along the western margin should be included with them. These rocks have a well-developed slaty cleavage but are less strongly metamorphosed than the groups already described. They are believed to lie unconformably above the gneisses and schists west of them, though the present structure shows the slates apparently dipping below the schists, owing, it is thought, to overturned folding or faulting. Similarly on the east the succession is believed to be inverted, and the slates dip below greenstones that are believed to be younger. Two miles west of Cottonwood Bay there are some schistose rocks, whose origin is not clear, that have well-developed flow cleavage and are interbedded with the slates. It is not certainly known whether or not these schistose materials are of the same age as the slates, or whether they have been faulted or folded into their present relation.

In the three areas of these rocks that have been mapped between Kontrashibuna and Iliamna Lakes the materials consist of fine-grained black slate, argillite, or graywacke, with banded white, gray, or dark-colored chert or very fine grained quartzitic rocks. The cleavage in the slates is only imperfectly developed. The sediments are all minutely crumpled, and nothing definite is known as to their thickness. They are bordered by much younger volcanic rocks, which are much less highly metamorphosed.

In the area near the west end of Little Lake Clark these rocks consist predominantly of chert and slate, with a little thin-bedded limestone and some associated materials that may be altered volcanic rocks. The slate has fairly well developed cleavage; the limestone, although of very fine grain, is somewhat recrystallized; and the chert is apparently unaltered. As a whole the rocks here are less altered than those at Cottonwood Bay and differ also in that they include cherts and igneous rocks.

Age.—The evidence as to the age of the slates and cherts is very indefinite. They have yielded no fossils in any part of this region, and even the age of the rocks with which they are associated is uncertain. Moreover, there is no certainty that all the rocks in the widely separated localities, here grouped under one heading, really belong together. Their correlation depends chiefly upon a general lithologic similarity, although in detail the rocks of each area differ from those in the other areas.

The slates of Cottonwood Bay are certainly younger than the more metamorphosed gneisses and schists west of them and older than the greenstones on the east. They are somewhat more altered than the limestone on Iliamna Bay and on Iliamna Lake and a little more altered than the limestone north of Meadow Lake but definitely less altered than that of Lake Clark.

The slate and chert between Kontrashibuna and Iliamna Lakes are more highly metamorphosed and distinctly older than the volcanic rocks, believed to be of Jurassic age, with which they are associated.

At Little Lake Clark the adjacent rocks are chiefly granite, which is intrusive into the slate. This granite is believed to be of late Mesozoic age.

It may therefore be stated that the slates are all older than late Mesozoic and are older than the volcanic rocks of probable early Jurassic age. Those at Cottonwood Bay are older than the greenstone, which is probably of Triassic age, and are therefore probably as old as some part of the Paleozoic. No more definite age assignment can be made at present.

MESOZOIC ROCKS

GREENSTONES

Distribution and character.—Under the term "greenstones" are here included rocks which occur at several places within this region and exhibit considerable diversity of character but which possess in common certain characteristics, including the presence of original basic igneous material, alteration to such a degree that the original character of the material is obscured, original banding or secondary schistosity or both, and a general similarity in color, texture, and physical appearance.

Rocks that belong in the general category of greenstones have been recognized only in that part of the region that extends northward from Iliamna Bay and upper Iliamna Lake to the head of Lake Clark. They occupy a belt that extends in a northeasterly direction across the heads of Iliamna and Cottonwood Bays and stretches for an unknown distance both northeast and southwest. They are bordered on the east and north by granite and on the west by slate.

A large area of greenstone lies on the southeast side of Pile Bay, just south of the Iliamna River. It is bordered on the southeast by Triassic limestone, on the southwest is faulted against granite, and on the north is intruded by granite. Near the mouth of Pile Bay a small body of schistose amphibolite, here grouped with the greenstones, lies along the contact between granite and rhyolite.

Schistose greenstone occurs on the northwest shore of Lake Clark, opposite the mouth of Currant Creek, but its extent and relation are not known. On both sides of the upper end of Lake Clark there occurs a belt of rocks, the longitudinal extent of which is not known, that are here grouped with the greenstones, though it is possible that they represent a facies of the porphyries and tuffs of probable Lower Jurassic age that have been locally intensely altered by the intrusion of large masses of granite in the neighborhood.

The greenstone of the Iliamna-Cottonwood Bay area consists mainly of dark-green aphanitic rocks, marked in places by whitish and epidote-green bands. They are in general slightly schistose and in places markedly so, though locally they are massive. Under the microscope specimens are seen to be made up largely of epidote, zoisite, and quartz, with lesser amounts of amphibole and feldspar. The structure and composition indicate that the rock is a metamorphosed volcanic rock, possibly a tuff.

The greenstones southeast of Pile Bay consist for the most part of thoroughly recrystallized quartz amphibolites or quartz-epidote amphibolites, whose composition indicates that they were derived from rocks related to diorite or diabase, though one specimen is probably a partly altered pyroxenite. In it augite is altered to fibrous amphibole, besides which there is some epidote, sericitic material, calcite, and limonite. In this area, especially on the shores of Pile Bay, the rocks are in part tuffaceous. On the whole they are not very schistose.

Age.—The greenstone on Cottonwood Bay is in contact with the slates that are considered to be of Paleozoic or early Mesozoic age, and although the slates rest upon the greenstone, this relation is believed to be due to overturned folding or to faulting, and the greenstones are thought to be younger than the slates. On Iliamna, Cottonwood, and Pile Bays the greenstones are cut by granites. Martin [15] considered the granites of this region to be probably of Lower Jurassic age and on this ground placed the greenstones in these localities as older than Lower Jurassic, and therefore Triassic or older. As shown on page 72, more recent field evidence indicates that at least a considerable part of the granite of the southern and central Alaska Range cuts rocks that are certainly as young as Upper Jurassic and may be as young as Cretaceous, and that there is a possibility that some granites are of early Tertiary age. This evidence therefore makes less definite the upper limit of the age range within which the greenstones must fall. The greenstones southeast of Pile Bay are considered to be younger than the adjacent limestone, which on lithologic similarity is correlated with the limestones of Iliamna Bay and of the north shore of Iliamna Lake, which are shown to be of Upper Triassic age. If that correlation is correct, then the greenstone southeast of Pile Bay appears to be definitely younger than the Upper Triassic. The evidence regarding the rocks of upper Lake Clark here grouped with the greenstones is less definite, and it should be borne in mind that the correlation between the various greenstone areas shown on the map is weak and is based only on their somewhat similar lithology.

UPPER TRIASSIC LIMESTONE AND CHERT

Distribution and character.—Limestone of Upper Triassic age is present on the north shore of Iliamna Lake at a point west of Chekok Bay and on the south shore of Iliamna Bay, and another narrow belt of limestone that extends southwestward from Iliamna village is here regarded as identical with this. There is also a possibility that the crystalline limestone of upper Lake Clark, already described, may be its metamorphosed representative. Under this same heading is included a thickness of several hundred feet of chert just south of the head of Cottonwood Bay. These cherts were called by Martin the "Kamishak chert" and were mapped separately by him, but he concluded, with some expressed doubts, that they were of the same

[15] Martin, G. C., op. cit. (Bull. 485), pp. 76–77.

age as the Upper Triassic limestone, so they are shown on the geologic map (pl. 2) in the same pattern. In the region here described there is only a small area of these cherts, but they are extensively developed farther south, along the shore of Kamishak Bay.

On the south side of Iliamna Bay the limestone crops out along the shore for a distance of over a mile, interrupted locally by several masses of igneous rock. Its southward continuation is not known, though what may be an equivalent limestone crops out on the shore of Ursus Cove, 5 or 6 miles to the southwest. On Iliamna Bay the limestone constitutes a large mass so complexly folded that no estimate of its stratigraphic thickness could be made. It is white and blue, fine-grained, much shattered, with the fractures healed with calcite, and is little altered except by this crushing and healing. From it was collected a scanty and poorly preserved fossil fauna.

The limestone on the north shore of Iliamna Lake, just west of Chekok Bay, has a general resemblance in color, lithologic character, and degree of metamorphism to that on Iliamna Bay and like it contains a fauna including corals, although the two limestones cannot be positively correlated.

A limestone occupying a long, narrow belt southwest of Iliamna village is of the same general character as that on Iliamna Bay and Iliamna Lake. It evidently was originally a rather pure, homogeneous rock. This limestone is intricately folded and intensely crushed and shattered but not in general greatly metamorphosed. It is somewhat more metamorphosed than the limestone on the north shore of Iliamna Lake but much less so than that on upper Lake Clark. The character of the folding is such that no estimate of thickness can be made. The limestone is bordered on the east by gneisses and schist and on the west by greenstones. Several masses of schist occur within the limestone belt, but whether they are interbedded with it or were placed in their present position by structural disturbances is not known, though the latter seems more likely. This limestone has yielded no fossils, and the age here assigned to it is based on correlation with the lithologically similar rocks of Iliamna Bay and the north shore of Iliamna Lake. Its relations to adjacent rocks give only indirect evidence of its age, for their age also is somewhat doubtful.

Age.—It is here assumed that the limestones that occur at Iliamna Bay, near Chekok Bay, and southwest of Iliamna village are of the same age. Two of these localities have yielded fossils that appear to be of the same age, and one of them, that near Chekok Bay, has yielded a fauna that has been definitely pronounced to be of Upper Triassic age. Martin [16] has already given the available evidence for this age assignment in some detail, and it will not be repeated here.

[16] Martin, G. C., op. cit. (Bull. 485), pp. 43–47.

The age of the chert beds at the head of Cottonwood Bay called by Martin the "Kamishak chert" is somewhat more in doubt. Martin found interbedded with the cherts at Ursus Cove, just south of this region, certain shales and limestones that carry a fauna of definite Upper Triassic age. He expressed some definite doubt as to whether or not these shales and limestones are actually interbedded with the chert and in the field considered them to be less metamorphosed and probably younger than the limestone of Iliamna Bay. As the fossils they yielded are certainly of Upper Triassic age, however, and among them are the same distinctive species as occur at Iliamna Bay, he concluded that the chert must be of the same general age as that limestone and assigned them both to the Upper Triassic. They are therefore here grouped on plate 2 in a single pattern. The stratigraphic and structural evidence for this assignment and the correlation of these beds with other Upper Triassic materials in other parts of Alaska is fully stated by Martin.[17]

LOWER JURASSIC (?) LAVA FLOWS AND TUFFS

Distribution and character.—Rocks here included in a single group and tentatively assigned to the Lower Jurassic are widely distributed throughout the southern Alaska Range and are especially abundant both south and north of Lake Clark. They are present in the basin of the Skwentna River, near the northern margin of the region, and on the southern shore of Iliamna Lake and at Iliamna Bay, at its southern edge, and occur also well out into the basin of the Mulchatna River, so that their distribution is almost as broad as the region here treated, although many of the areas in which they occur are small. For convenience in mapping and in the written description these rocks are grouped together, though it is by no means certain that all are of the same age. They have yielded no fossils, and their correlation is based upon lithologic similarity and stratigraphic relations. More detailed field work may result in a separation of this group into two or more units of somewhat different age from that here assigned.

The rocks here included in this group have been described by various authors in the field areas where they have worked. No one person has seen them through this entire region. The published descriptions, however, seem to show sufficient agreement to justify their correlation, though there seems to be some uncertainty among them as to the exact age of these rocks. The geologists whose descriptions are used in the present report include Martin and Katz[18] for the region extending from Iliamna Bay and the south shore of

[17] Martin, G. C., op. cit. (Bull. 485), pp. 47–50.
[18] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 50–59.

Iliamna Lake to Lake Clark, Smith[19] for the area west of lower Lake Clark, and Capps[20] for the region extending from Lake Clark north and northeast to the Skwentna River. The most complete of these descriptions is that by Martin and Katz, who found large areas of these rocks in the region around Lakes Iliamna and Clark. They mapped these rocks in an area near Iliamna Bay, on the south shore and the islands of Iliamna Lake, between Iliamna and Clark Lakes, and along the the northwest shore of lower Lake Clark. Smith extended the known distribution of these materials westward from Sixmile Lake and thence northward in the foothills of the Mulchatna Basin. Capps later found rocks in the lower basin of the Skwentna that he correlated with this group and in succeeding explorations mapped scattered areas of similar materials in the basin of the Chakachatna River and thence southwestward to Lake Clark.

Throughout this great region this group consists predominantly of volcanic materials that include tuffs, breccias, and lava flows, many of which are porphyritic. In the lower Skwentna area the rocks are mainly fine-grained tuffs with some associated argillaceous sediments. In the upper basin of the Skwentna considerable amounts of tuff are interbedded with the prevailing Mesozoic clastic sediments, but it was not possible to map these tuff zones separately in the time that was available, and they were grouped with the upper Mesozoic sediments. Farther southwest, in the Chakachatna Basin, the group includes a wide range of materials of which the volcanic rocks are most conspicuous, though there, too, interbedded sediments are present in minor amounts. The most characteristic phase of this predominantly volcanic group of rocks consists of a great variety of tuffs and agglomerates interbedded with porphyritic lava flows. The tuffs range in color from dark gray, or almost black, through lighter gray, pink, and various hues of green, purple, and brown. The included fragments are angular to subangular or rounded and range in size from those of microscopic dimensions to pieces 8 inches or more in diameter. They are composed for the most part of andesite, dacite, rhyolite, and basalt, but there are in places abundant pieces of shale and argillite, and a few pebbles and fragments of granitic rock were seen. These tuffs are interbedded with lava flows that include andesite, rhyolite, dacite, and basalt and with some altered sedimentary materials such as argillite, graywacke, black chert, and a little limestone. Some of the lava beds are finely banded and show flow structure.

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[19] Smith, P. S., op. cit. (Bull. 655), pp. 104–112.

[20] Capps, S. R., The Skwentna region: U. S. Geol. Survey Bull. 797, pp. 82–86, 1929; The Chakachamna-Stony region: U. S. Geol. Survey Bull. 813, pp. 111–113, 1930; The Lake Clark-Mulchatna region: U. S. Geol. Survey Bull. 824, pp. 141–143, 1932.

In the upper basin of the Stony River and in the eastern branch of its tributary the Necons River there are areas of lavas and tuffs that were first ascribed by the writer [21] to the series of Lower Jurassic volcanic rocks. Later studies by the writer in the upper Mulchatna Basin have convinced him that these volcanic rocks are more likely to be the correlative of the Tertiary lavas of the Mulchatna Basin, and in this report they are grouped with the Tertiary volcanic rocks.

In the region between the Stony River and Lake Clark volcanic rocks of this group are present in large areas along the face of the range and in the foothills. That part of the main range is still largely unsurveyed, and the distribution of the rocks is unknown, but in all likelihood these volcanic rocks occur there in considerable amounts. Where mapped these rocks consist of an undifferentiated complex of basic to medium-basic lavas, tuffs, and associated argillite, slate, and graywacke, all more or less metamorphosed. Martin and Katz found the porphyry and tuff of this group to give way on the east to greenstone, chert, slate, crystalline limestone, gneiss, and quartzite schist of probable Paleozoic age, which are cut off farther east by granitic rocks. Apparently the main granitic core of the range, which at the head of Lake Clark has a northeasterly trend, swings westward in the region north of upper Lake Clark and comes to the face of the mountains near Telaquana Lake. It is thought likely that the greater part of the region east of the mountain face and west of the granitic core of the range is composed of rocks of this group of lava, tuff, and metamorphosed sediments. North of Lake Clark this rock group comprises a lower portion that consists almost exclusively of porphyritic lava and tuff and an upper portion that includes increasingly large proportions of argillite, slate, graywacke, and tuff and lesser amounts of lava.

For the southern part of this region, including the area lying between Lake Clark and Iliamna Lake, the south shore and islands of Iliamna Lake, and the vicinity of Iliamna and Cottonwood Bays, the description by Martin and Katz [22] gives considerable detail and will here be briefly summarized. In the area between Iliamna Lake and Lake Clark these rocks range in composition from quartz-feldspar rocks with only small amounts of ferric minerals to augite andesites. Their textures are usually porphyritic, with aphanitic or exceedingly fine granular groundmass, and not infrequently flow structure is evident. Tuffs and agglomerates of like composition are intermingled with these rocks. Some are of coarse and angular grain

[21] Capps, S. R., The Chakachamna-Stony region: U. S. Geol. Survey Bull. 813, pp. 111–113, 1930.

[22] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 50–59.

which distinctly reveals their true nature, but associated with them and in places connected with them by intermediate gradation phases are considerable masses of dense, aphanitic light-colored and banded rocks which appear to be thoroughly indurated pyroclastic rocks of very fine grain.

In general these rocks are not fresh, the feldspar as a rule being more or less completely kaolinized or saussuritized. The hornblendes and biotites are largely altered to chlorites and iron oxides, etc. Epidote, calcite, chlorite, quartz, and limonite are abundant along fractures and in vesicles of the scoriaceous and tuffaceous members, and the tuffs are for the most part thoroughly indurated.

The mountain just north of the lower end of Little Lake Clark is composed of materials that in the field were considered to be conglomeratic arkoses but that under the microscope appear to be tuffs. As they resemble the porphyries and tuff of Lower Tazimina Lake more closely than any other formation of the region they are here grouped with those rocks, though on uncertain grounds.

In the area west of Sixmile Lake and lower Lake Clark and lying between these lakes on the Chulitna River, Smith [23] differentiated two groups of volcanic rocks, one of which, termed by him the "older lavas", is believed to be the correlative of the group of rocks here under discussion. He described them as being probably present over much larger areas than are shown on the geologic map but concealed beneath younger lavas and unconsolidated materials except where recent streams have cut through these materials into them. The streams have not cut deeply enough, however, to expose the rocks upon which they lie. North of the Chulitna River these volcanic rocks appear to lie upon Mesozoic slates.

In lithologic character the volcanic rocks described by Smith correspond closely with the more basic members of the group described by Martin and Katz and consist mainly of dacites and andesites.

Structure.—Although the amount of deformation that these rocks have suffered differs from place to place, in the main it is not large. Apparently the rocks southeast of Lake Clark are not greatly folded, though they are locally faulted and intruded, and the average dip is at low angles. The same lack of severe deformation was noted by Smith in the rocks west of lower Lake Clark, though at one locality he recognized a syncline in which the lavas lay with apparent unconformity upon sedimentary rocks. A similar absence of severe folding is characteristic of these materials along the face of the range north of Lake Clark and in the basin of the Stony River. In

[23] Smith, P. S., op. cit. (Bull. 655), pp. 104–112.

the upper Skwentna Valley tuffs and lavas that are assigned to this group are interbedded with the Mesozoic sediments and were not mapped separately. There the observed structure includes open folds with moderate dips, though there has been considerable faulting. In many places these rocks are cut by granitic masses, which are thus proved to be younger.

Age and correlation.—This group of lavas and tuffs has nowhere in this region been found to contain fossils, and its age determination as here given is based upon lithologic similarity to rocks in adjacent parts of Alaska and upon stratigraphic relations with sediments whose age is more accurately known. The lavas and tuffs exposed on Cottonwood Bay extend southward to Kamishak Bay, where they overlie the Kamishak chert, of Upper Triassic age. At that place there is no apparent stratigraphic break between these two formations, and there appears to be a more or less gradual lithologic gradation from the finer homogenous cherty beds below to the coarser heterogeneous volcanic materials above. The relations indicate that the volcanic rocks at that locality are either very high in the Triassic or low in the Jurassic. At Seldovia Bay, east of Cook Inlet, there is a similar stratigraphic relation between water-laid fragmental igneous material above and some cherty limestone, which has yielded Lower Jurassic fossils, below.

Farther north, in the basins of the Stony and Yentna Rivers, these volcanic rocks are overlain by argillites and slates in which a few fossils, both plant and invertebrate, have been found. A plant found in the upper Skwentna Valley in a bed high in the series of sediments was determined by Arthur Hollick to be a dicotyledonous angiosperm leaf of Cretaceous or Tertiary age. From correlation with other rocks of that region and from evidence that the beds from which the leaf came are older than any known Tertiary beds in this part of Alaska, these overlying sediments are believed to be of Cretaceous rather than Tertiary age. In the Stony Basin a fossil shell identified by T. W. Stanton as an *Inoceramus*, of probable Cretaceous age, was found in shales that are thought to overlie this volcanic group. The positive evidence from this region is, therefore, that these volcanic rocks are younger, though probably not much younger, than the Upper Triassic and are distinctly older than the Cretaceous. Martin classifies them as of probable Lower Jurassic age, and nothing learned in this investigation gives reason for changing that age assignment.

UNDIFFERENTIATED JURASSIC AND CRETACEOUS SEDIMENTS

Distribution and character.—Throughout the southern Alaska Range Mesozoic sediments, believed to be mainly of Jurassic and

Cretaceous age and consisting principally of argillite, slate, and graywacke, are of wide-spread occurrence and constitute one of the major elements of the mountain mass. In this region the central portion of the range includes much granite, and these upper Mesozoic beds form the host rock into which much of the granite was intruded. The complex pattern of the intrusive contact accounts in large measure for the patchy distribution of the sediments within the mountain province, as shown on the geologic maps. In the foothills of the Mulchatna Basin granitic intrusions are less abundant, and the sediments prevail over large areas, in part concealed by unconsolidated materials. Likewise in the Skwentna Basin, at the northern margin of this region, the sediments occupy broad areas to the exclusion of other materials, and this is true still farther north, for there a broad belt of Mesozoic argillite, graywacke, and slate constitutes the most wide-spread rock formation on the east flank of the range.

Plate 2, as drawn, happens to include in its extreme southeast corner a small area of rocks of this group. This is but a small portion of an area of Jurassic beds that are extensively developed along the west shore of Cook Inlet from Snug Harbor southward to Iniskin Bay and thence well out onto the Alaska Peninsula. These rocks constitute one of the notable Jurassic sections of the continent, both in their great thickness and in their remarkably abundant and unique fauna. Their lithologic characteristics, structural relations, and fauna have been described in great detail, by Martin and Katz,[24] by Moffit,[25] and by various other investigators, and the description will not be repeated here, further than to state that they have been subdivided, on the basis of their fossils, into the Tuxedni sandstone, of Middle Jurassic age, and the Chinitna and Naknek formations, of Upper Jurassic age. These rocks, though believed to be of the same general age as the argillite, slate, and graywacke so abundant in the parts of the range to the west and north, must have been deposited under very different conditions, for they are abundantly fossiliferous, whereas the other rocks, here to be described, are almost completely lacking in fossils, and for this reason a close correlation is impossible. The only area in the region here described where these fossiliferous rocks occur is at Iniskin Bay, and as the present writer has done no work there he brings nothing new to the discussion of these formations. For that reason it seems undesirable to include here a detailed description of these rocks, so well described elsewhere, and they are therefore here grouped with the other sediments of Middle and Upper Jurassic and Cretaceous age and mapped with them in a single pat-

[24] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 50–74.

[25] Moffit, F. H., The Iniskin-Chinitna Peninsula and the Snug Harbor district, Alaska: U. S. Geol. Survey Bull. 789, pp. 12–42, 1927.

tern as undifferentiated Mesozoic rocks. The reader is reminded, however, that in the Iniskin Bay area these rocks have been subdivided as the result of detailed study.

Mesozoic sediments that consist primarily of argillite, shale, and impure sandstone or graywacke, which have locally been metamorphosed into quartzite schists, carbonaceous schists, and slates, are widely developed throughout the length of the Alaska Range. In the region covered by this report they appear in a belt that extends from the Chulitna River northward to the Stony Basin and in another wider belt that stretches northward from the vicinity of Telaquana Lake to and beyond the basin of the Skwentna River. Southwest and west of Telaquana Lake the country is still unsurveyed, but it is entirely possible that in that unmapped area similar rocks occur, connecting the two belts. North of the Skwentna River Mesozoic slate, argillite, and graywacke are even more abundant and cover wider areas than in the region here under discussion.

This group of beds comprises a wide range of materials, which, though dominantly of sedimentary origin, nevertheless include locally considerable amounts of tuffaceous material. In degree of metamorphism, also, the beds show a great range. In the outlying hills at the western edge of this region the sediments have been much less altered by the mountain-building movements that have affected the Alaska Range proper and consist prevailingly of shale, argillite, and sandstone, relatively free from igneous material, and have comparatively simple structure. In the basins of the Stony, Chakachatna, and Skwentna Rivers, on the other hand, where they have been intimately intruded by large bodies of granitic rocks, their structure is more complex, and locally they have been altered by dynamic and igneous metamorphism into carbonaceous and micaceous schists, quartzites, and quartzite schists.

These rocks were first described by Spurr,[26] who observed them in his journey up the Skwentna River and down the South Fork of the Kuskokwim. He divided them into the Skwentna " series ", composed mainly of basic volcanic rocks and tuff, and the Tordrillo " series ", composed of shale, arkose, and limestone but without tuffaceous material. Brooks [27] later described these two divisions, adding his own observations to those of Spurr. Both Spurr and Brooks believed that the Skwentna group and Tordrillo formation, as they are now known, were distinct lithologically, the Skwentna being composed predominantly of volcanic materials and the Tordrillo

[26] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 149–155, 1900.

[27] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 85–90, 1911.

almost entirely free from them. In the present investigation, which included a large area visited by neither Spurr nor Brooks, it was found that their observations were accurate for the region they studied, except for the fact that the Skwentna group in places carries more sedimentary material than they had realized and that thick tuff beds recur far up in the Tordrillo. In the entire series fossils are scarce or altogether absent, so that their aid in the determination of the relative age of different parts of the series is lacking. The present writer therefore considers it impossible at this time to make a consistent separation of the rocks of Spurr's Skwentna and Tordrillo " series " and has therefore mapped them as a single group of undifferentiated rocks that can be properly subdivided only after much more detailed study than they have yet received.

In the wider portions of the Skwentna Valley, as far west as the Happy River, there are exposures of bedrock here and there in the river bluffs, and in the three canyons of the Skwentna there are nearly continuous exposures of the rocks of this group. Throughout this distance the rocks are fine-grained, show what seems to be bedding, and closely resemble clastic sediments. In thin sections, however, many of them prove to be composed mainly of tuffaceous material, but this in many places contains a considerable admixture of sand and mud, and some thin sections show mainly graywacke or argillite, with minor amounts of tuffaceous material. Farther west, above the mouth of the Happy River, black argillite, shale, and graywacke, with some limy beds, are more abundant through a vertical range of several thousand feet, but these beds in turn are succeeded, a few miles above the mouth of Muddy Creek, by another thick series of tuff beds that crosses the Skwentna Valley as a syncline striking northeast. Still farther up the Skwentna Valley the argillite and graywacke beds are present, but only in irregular areas partly surrounded or entirely enclosed by masses of granite. Similar isolated patches of these sediments, surrounded by granitic rocks, occur in the head of the Nagishlamina River, a tributary of the Chakachatna.

In the headward valley of the Stony River and of its tributary the Necons River two distinct facies of the Mesozoic sediments may be recognized, though on plate 2 they are shown by a single color. In the basin of the Necons River and extending thence across the divide into the Stony Valley there is a group of undifferentiated rocks that includes some lavas and tuffs, at first thought to belong with the Lower Jurassic (?) lava and tuff group already described but now believed to be Tertiary, and a series of metamorphosed sediments, at least a part of which may eventually be grouped with the Upper Cretaceous sediments here under discussion. They include a great variety of rock types, among which are coarse graywacke, some of it containing more or less rounded fragments of shale or argillite; finely banded and ribboned siliceous graywacke; dense rusty quartzite; and some black chert. All these rocks are cut by large and small siliceous dikes and by the prevailing granitic rocks of the region. Both graywacke and dike rocks contain disseminated pyrite, which, along with the secondary silica, is the result of igneous metamorphism. Over considerable areas the oxidation of the pyrite has given these rocks a rusty color.

In the upper valley of the Stony River and in the Necons Basin near Two Lakes there is a group of black argillite and slate and dark-gray graywacke that appear to be distinct from the metamorphosed sediments and tuffs described above, though they are here mapped in the same pattern with them. They are characterized by their prevailing black color, in contrast to the rusty and brownish shades of the other sedimentary group, and by their comparative freedom from igneous intrusive rocks.

In the vicinity of Two Lakes these rocks comprise black slabby argillite and gray siliceous graywacke. The proportion of argillite to graywacke varies from place to place. In one section 100 feet or so of argillite, with little coarser material, gives place gradually to an intimately banded alternation of argillite and graywacke in layers an inch or less thick, and this in turn, by the increase in thickness of the graywacke bands and a decrease in thickness of the argillite bands, to a massive graywacke, with beds several feet thick separated by only thin partings of argillite. Locally the argillite shows slaty cleavage, and the graywacke is silicified and becomes an impure quartzite. (See pl. 8, *A*.)

On the Stony River above Two Lakes the argillite and graywacke crop out first on one side of the valley and then on the other but occupy only a narrow north-south belt, bordered by granitic intrusive rocks and by volcanic rocks. Apparently they have formed a line of weakness through an area of more resistant rocks and have determined the course of the Stony River.

As the main forks of the Stony are approached from the south, the argillite and graywacke show increasingly the effects of igneous metamorphism from the intrusion of the granitic rocks. Secondary mica and silica become more abundant, and a schistose cleavage appears. Farther north these sediments become very schistose, the coarser phases being altered to impure quartzite schist and the argillite to a black fissile carbonaceous schist characterized by a remarkable development of needlelike andalusite crystals that lie parallel to the planes of schistosity but point in all directions within those planes Secondary pyrite appears as scattered cubes throughout both coarse and fine phases of these rocks. Still farther north, near the bars at the head of the Stony River, these rocks again become less schistose, and normal argillite and graywacke prevail.

In his description of these rocks along the western margin of this region, between the Stony and Chulitna Rivers, Smith [28] separates them into three subdivisions. Of these, one is composed of conglomerate and occupies a narrow belt just north of Hook Creek and including Cairn Mountain; a second is composed dominantly of shale but contains some sandstone; and a third is composed dominantly of sandstone, with some interbedded shale. Smith describes these rocks in considerable detail, but inasmuch as the present writer did not see much of the region visited by Smith and so can add little to his description, the three subdivisions are here shown on plate 2 in a single pattern, and the original description is summarized.

The conglomerate member, occurring at and near Cairn Mountain and occupying an area 5 miles wide and at least 20 miles long, is considered by Smith to be the oldest member of his Mesozoic section. It is a dark-gray rock ranging in texture from coarse sandstone to conglomerate with pebbles a foot or more in maximum diameter but averaging about 3 inches. Most of the pebbles are slate, but some of granite, greenstone, andesite, and other igneous rocks are present, as well as limestone, chert, and quartzite. In one limestone pebble fossils of Middle or Upper Devonian age were found. The matrix consists of a great variety of rock fragments but is generally calcareous.

South of the conglomerate belt the rocks consist of a monotonous succession of shale with a little sandstone, the series containing no distinct horizon markers. The shale differs in texture from place to place and in the vicinity of igneous intrusive masses has been altered by contact metamorphism and contains such secondary minerals as biotite, cordierite, and chiastolite. The shales are for the most part dark gray to black, but in one locality green and red slates were observed. In many areas they are cut by small reticulated quartz veins.

Still farther south, between the Hoholitna and Mulchatna Rivers, sandstones become predominant and shales subordinate in the series. A conglomerate of small pebbles is believed to mark the base of the sandstone.

Structure and thickness.—The degree of complexity of the structure of these beds differs greatly from place to place and seems to depend, in considerable part, upon the size of the areas in which they occur. Although everywhere tilted, folded, and faulted to some extent, the general statement is warranted that where these beds occur in fairly large, continuous areas the folds are open and the

[28] Smith, P. S., op. cit. (Bull. 655), pp. 57–84.

dips moderate, but that in the smaller areas surrounded by granitic intrusions the rocks are more highly metamorphosed, the folds closer, and the dips steeper. Thus in the Skwentna Valley above Portage Creek the beds lie in great open folds, striking parallel with the axis of the range. In the upper Skwentna Basin, however, there is less regularity in the direction and steepness of the folds. In the upper Stony Valley the beds are highly altered and closely folded and dip at high angles. Although many local departures from uniformity may be found, nevertheless the general strike of the Mesozoic sediments within the higher mountains of the main range is northeast, parallel to the axis of the range, whereas in the foothill area to the west of the main range the prevailing strikes are a little north of east, and the rocks have prevailing dips to the south, though the monoclinal structure is interrupted from place to place by folds.

Smith reports that the conglomerate at Cairn Mountain dips at steep angles, generally to the south, and cites evidence of probable overturned folding. He makes no estimate of its thickness but says that Cairn Mountain, which stands 3,000 feet above the adjacent lowland, is composed entirely of this conglomerate. Likewise he gives no figure for the thickness of either the sandstone or the shale member of the Mesozoic sediments, but inasmuch as each of these members occupies a belt from 12 to 16 miles wide, in which the hilltops are from 1,500 to 2,000 feet above the adjacent lowlands, and as the rocks have prevailingly steep dips, it would seem probable that the total thickness of beds involved must be measured in thousands of feet. The writer believes that the Mesozoic sediments in the upper Skwentna Basin must be 4,000 to 5,000 feet thick, and possibly much more, and suggests a minimum thickness of at least 3,000 feet in the upper Stony Basin.

Age and correlation.—One of the most baffling problems that has confronted the geologists working in Alaska is concerned with this great group of sediments that forms so prominent an element in the Alaska Range throughout its length and is widely distributed elsewhere in the Territory. In the Alaska Range, extending from the vicinity of Lake Clark northward and northeastward to and beyond Broad Pass, on the south flank, and almost equally far on the north flank, there is this great group of sediments, consisting mainly of argillite, shale, sandstone, and graywacke, much metamorphosed and almost barren of fossils. Similar rocks form large parts of the coastal mountains of the Gulf of Alaska on Kodiak and Afognak Islands and in the Kenai and Chugach Mountains, as well as in the eastward extension of the Alaska Range from Broad Pass to the international boundary. Wherever present they are characterized by a monotonous alternation of dark argillaceous rocks with almost equally dark impure sandstones or graywackes, locally metamorphosed to slates and quartzite schists; by the absence of distinctive horizons that can be traced for considerable distances; and by their almost complete lack of fossils. These factors, together with the complex folding and faulting of the beds, have made the problem of deciphering the structure of this group as a whole and of subdividing it into stratigraphic units of known age one that is still far from final solution. During more than 30 years a large number of geologists of the Federal Survey have given close attention to these sediments, yet in all that time scarcely more than half a dozen localities have yielded fossils whose age could be definitely determined. The early workers in this field were inclined to the view that these rocks were for the most part of Paleozoic age, basing their judgment on the advanced stage of metamorphism of the sediments. With succeeding years and more extensive study, however, the accumulated evidence indicates more and more definitely that most of them are Mesozoic, and probably of Jurassic and Cretaceous age rather than early Mesozoic. Just why great areas of Jurassic and Cretaceous seas in which sands and muds were being laid down should have been so inhospitable to marine life, while in nearby areas, such as the upper Matanuska Valley and the Pacific littoral of the Alaska Peninsula, a prolific fauna flourished, is hard to understand.

As fossils are so scarce in these beds many other lines of evidence have been used in attempting to place them in their proper position in the geologic column. Areal and structural continuity, lithologic similarity, degree of metamorphism, and relations to other sedimentary formations and to igneous intrusive masses have all given some light, and the few collections of fossil plants and animals have been of greatest value.

In the region here under discussion and in adjoining parts of the Alaska Range to the north these sediments are known definitely to be older than the Eocene coal-bearing beds, which in places they underlie unconformably. They are also older than the Cantwell formation, which has been classified as Eocene but may be Upper Cretaceous. They are younger than the Middle Devonian limestone that occurs in several places along the range. In the present investigation one fossil leaf was found, in the Skwentna Basin—a fragment of a dicotyledonous angiosperm that was determined by Arthur Hollick to be of Cretaceous or Tertiary age. This leaf came from a bed high in the group, though by no means at its top. From the headward basin of the Stony River a single shell collected from these rocks was identified by T. W. Stanton as an *Inoceramus*, which he believed to be Cretaceous and probably Upper Cretaceous. From the Mulchatna Basin Smith collected imprints of fragments of shells, probably *Inoceramus*, of Jurassic or Cretaceous age. These three fossil collections are the only ones that have been obtained within this entire region from this great series of sediments, and although none of them are so characteristic as to give an absolute age determination, nevertheless they all point to a Cretaceous age for the beds in which they occurred.

Additional evidence of the age of this group may be procured by an attempt to correlate it with similar beds elsewhere whose age is more certainly known. The structural trend of these rocks in the Skwentna Basin, at the north edge of the region here described, strikes northeastward from the Skwentna Valley across the Happy River and Kichatna Valley to the Cache Creek district, in the Kahiltna Basin, and thence across the West Fork of the Chulitna River to Broad Pass. The general lithology, stratigraphic position, and structure leave little doubt that these sediments, lying along the flank of the range, are continuous to the southwest with those in the Stony and Mulchatna Basins and constitute a single group. In 1902 Brooks [29] found fossils in this group near Rainy Pass that were determined to be of Middle Jurassic age. In 1917 Mertie [30] found fossils in rocks in the Cache Creek district that belong to this group and that are probably of Upper Cretaceous age. That same year the writer [31] described a section in the upper Chulitna region in which a similar series of argillite, slate, and graywacke was found to occur above a Triassic limestone and below the Cantwell formation (Eocene). In 1930, from this same section, he collected fossils that were determined as "not older than Upper Jurassic and not younger than Lower Cretaceous." [32] Thus all the positive evidence so far obtained indicates that this group is of Mesozoic age and younger than Triassic.

The lowest part of the group on the Skwentna River, in which volcanic tuff is so prevalent, closely resembles a series of rocks in the Matanuska Valley and the Talkeetna Mountains that has been described by Martin [33] as the Talkeetna formation, of Lower Jurassic age. In the Skwentna region the volcanic material consists mainly of fine-grained tuff, whereas in the Talkeetna region volcanic agglomerate and breccia are common. The stratigraphic relations of

[29] Brooks, A. H., op. cit. (Prof. Paper 70), p. 90.

[30] Mertie, J. B., Jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, p. 237, 1919.

[31] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 217–218, 1919.

[32] Capps, S. R., The eastern portion of Mount McKinley National Park: U. S. Geol. Survey Bull. 836, p. 263, 1932.

[33] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, p. 219, 1926.

these volcanic rocks are so similar in the two places, however, that it is likely that in a general way they can be correlated.

From the above paragraphs it is apparent that the argillite, graywacke, and tuff group of the southern Alaska Range probably includes beds ranging in age from Lower Jurassic to Upper Cretaceous. The astonishing fact is that these rocks are so barren of fossils, although they are in many places only moderately or little metamorphosed and should have retained fossils if these had ever been present, whereas the Mesozoic rocks in such neighboring regions as the Talkeetna Mountains and the Alaska Peninsula and Cook Inlet area carry an abundant and characteristic fauna. Until fossils are found in the several parts of this group in the Skwentna, Stony, and Mulchatna Basins, correlation of these parts will remain uncertain, and it seems best for the present to consider the group as of undifferentiated Mesozoic age.

TERTIARY ROCKS

EOCENE COAL-BEARING ROCKS

Distribution and character.—Tertiary coal-bearing rocks are widely distributed in the basins of Cook Inlet and the Susitna River. In the region here described they have been observed along the banks of the Susitna, Yentna, and Skwentna Rivers, on the Beluga and Chuitna Rivers and Straight Creek, and on the shores of Cook Inlet near Tyonek. They have also been reported in the basins of the Talushulitna River and Canyon Creek, tributaries of the Skwentna from the south. So far no occurrences of these rocks have been reported from the west slope of the Alaska Range in the region here under discussion, though they occur on that slope farther north. In all the areas just mentioned the Eocene rocks occur in the piedmont belt between the face of the mountains and the Cook Inlet-Susitna depression and nowhere have been found in the high, rugged mountains of the range proper. Within the piedmont area these beds have only scattered outcrops but are actually of much wider distribution than is shown on plate 1, for they are generally concealed beneath a cover of glacial deposits or of vegetation and muck. Their character, structure, and age have been discussed in considerable detail in other publications [34] dealing with adjacent regions in which these beds are better exposed, and only a brief description is necessary here.

Wherever they occur the Eocene beds are characteristic and easily recognized and consist of unconsolidated to moderately well in-

[34] Martin, G. C., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 67–89, 1915. Brooks, A. H., op. cit. (Prof. Paper 70), pp. 94–103. Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 28–33, 1913

durated clay, sand, and gravel, commonly with some lignitic coal. They are largely confined to the lowlands and are easily eroded compared with older rocks, so that exposures are found mainly in the cut bluffs of streams or in wave cliffs along the shore, the formation being elsewhere concealed beneath a covering of younger unconsolidated materials or of vegetation. The beds are of fresh-water or estuarine origin and contain abundant organic matter as carbonaceous sticks and imprints, as well as coal, but no marine invertebrates. All the fossils that have so far been found are land plants.

Beds of this formation were described by Spurr [35] as the Tyonek "beds", and by Eldridge [36] as the Kenai formation; and their observations and his own were later summarized by Brooks,[37] who also published a cross section of the formation at a locality which was not seen by the writer. Brooks states that Eldridge observed near Tyonek about 1,000 feet of beds consisting of friable sandstone, fine conglomerate, shale, and lignitic coal, striking N. 10°–15° E. and dipping 15°–60° SE. There were 24 coal beds, ranging in thickness from 1 to 15 feet. Farther west, along the shores of Trading Bay for several miles east of the mouth of Nikolai Creek, the bluffs are composed of glacial till, and the Eocene beds are not exposed, though they are probably present beneath the glacial deposits.

Northwest of Trading Bay, in the piedmont belt between Cook Inlet and the mountain front, no outcrops of this formation were seen for a distance of 18 miles from the beach, but in the headward basin of Straight Creek there are many exposures of these beds, and fragments of lignite coal are common along the bars of Straight Creek. The route traveled did not permit a careful study of the Eocene section exposed along the mountain front between the Chakachatna and Skwentna Rivers, though from a distance and from the air several localities in which those beds crop out could be seen. At one locality about a mile west of the point where the trail leaves the high piedmont ridge to descend to the valley of Straight Creek a section of this formation was examined. This section, given below, is far up in the formation and is underlain by many hundreds of feet of beds that from a distance seem to consist mainly of friable sandstone and shale. In general the formation at that place strikes about due north and dips 15° E. The dip is greater than the eastward slope of the piedmont ridge, so that the Eocene outcrops near Tyonek would appear to be higher in the formation than the section given herewith. The thicknesses stated are approximate only.

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[35] Spurr, J. E., op. cit. (20th Ann. Rept., pt. 7), pp. 171–172.

[36] Eldridge, G. H., A reconnaissance in the Sushitna Basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 16–17, 21–22, 1900.

[37] Brooks, A. H., op. cit. (Prof. Paper 70), pp. 94–103.

Section of Eocene beds 19 miles northwest of the mouth of Nikolai Creek

	Feet
Volcanic ash and soil	5
Glacial boulders and lava blocks	5
Glacial till	50
Poorly exposed but mainly sandstone and shale; a thin bed of impure lignite near top	100
Coarse gray sandstone and fine conglomerate	10
Sandstone containing boulders, mainly granitic	15
Gray grit and fine white sandy clay	30
Purple, brown, and gray grit and tuff, with boulders 2 feet or less in diameter; pebbly beds with pebbles mainly of volcanic materials	30
Unconformity.	
Gray, brown, and purple grit and tuff, with beds containing boulders, including lava blocks as much as 3 feet in diameter	50
Gray sandstone and white clayey sandstone	30
Unexposed.	
	360

The unconformity shown in this section is angular, but there is evidence of the presence of coal beds both above and below it. The areal extent and stratigraphic significance of this unconformity are not known, but in a section containing so much coarse material it is likely that the break may be of only local significance and the unconformity only intraformational.

Earlier explorations have shown that beds of this formation extend from Tyonek northward across the Beluga and Skwentna Basins, occupy much of the Susitna Basin, and occur in numerous outcrops almost entirely around the borders of Cook Inlet. There is good reason to suppose that a great part of the Cook Inlet depression, from the Alaska Range on the west to the Kenai Mountains on the east, is underlain by beds of this formation, although in much of that region they are overlain and concealed by deposits of glacial till and glacial outwash gravel. In nearly every place where these beds are extensively exposed they are found to contain lignitic coal, and in many localities coal beds occur at several places in the formation and are fairly thick. At the present time these Cook Inlet coals are of too low grade to command other than local markets, but without doubt the quantity present in this basin is very great, and at some future time the coal will be valuable.

In the basin of the Susitna River the Tertiary coal-bearing beds crop out at a large number of places, many of which occur within the area here under discussion. At Susitna station the bluffs of the Susitna River show well-indurated conglomerate of this age, and a shaft, now caved in, is said to have shown the presence of lignitic coal.

On both banks of the lower course of the Yentna River there are outcrops of the Tertiary coal-bearing formation, and at one locality on the southwest bank some 7 miles above Susitna station an adit was driven many years ago on a coal bed and some coal extracted. The workings are now caved and inaccessible. Other exposures of these beds occur on the south bluffs of the Skwentna at the mouth of Quartz Creek, between Canyon Creek and the Talushulitna, and a few miles above Canyon Creek, though no coal was seen at these localities. It is said that considerable coal crops out along the headward tributaries of the Talushulitna, and abundant lignite float on the bars of Canyon Creek indicates an area of this formation somewhere in that basin.

The most extensive exposures of these rocks seen in the Skwentna Basin occur along the southeast bluff of the Hayes River just above its mouth and on the north bluff of the Skwentna above and below the mouth of the Hayes River. The exposure on the Hayes River shows about half a dozen coal beds, the thickest 12 or 15 feet thick, interbedded with shale and soft sandstone. The bedding is much disturbed, the beds dipping from 10° to 75° or 80° N. There has been considerable crushing of coal and sediments, and one fault displaces the formation for at least 50 feet and possibly much more. On the north bank of the Skwentna the exposure shows one coal bed 10 feet thick and one 2 feet thick dipping gently northward beneath a gravel covering.

Structure and thickness.—Outcrops of these beds are now known at so many localities in the Cook Inlet and Susitna Basins that a study of these occurrences has made it possible to reach rather definite conclusions concerning the distribution and general structure of the beds. First of these is the conclusion that although the formation was formerly more widely distributed than it is now and has been removed by erosion from certain areas, nevertheless it was probably never deposited over the main region now occupied by the higher mountains that surround these basins but was originally laid down in lowland basin areas as stream, lake, swamp, and estuarine deposits, at a time when the surrounding mountains were of milder relief than they are now. Secondly, in post-Eocene time the mountains surrounding the basins of Eocene deposition were uplifted, and in this uplift the Eocene beds were locally warped, mildly folded, and faulted, and around the margins of the basins the beds were generally upturned, in places at high angles. Subsequent erosion by streams and glacial ice removed much material from the upturned edges, as well as from the more gently deformed areas, and the remaining beds were later generally covered by deposits of glacial moraine and outwash gravel. As a result of this history the Eocene beds, as we now find them, are in general moderately to steeply tilted and faulted near the margins of the basins but more gently folded toward the centers of the basins.

The meager exposures of the formation in this region do not permit an accurate estimate of its thickness there, for no exposure shows more than a part of the total thickness. On Straight Creek, just east of Mount Spurr, the beds show a general dip of about 15° E., and this dip continues eastward to the point where these beds pass beneath the glacial deposits. It is possible that gentle monoclinal eastward dips continue to the coast. At the Tyonek exposures the dips are also eastward but steeper, ranging from 25° to 60°. This difference indicates that if the beds at Tyonek extend westward to the mountain front, as is probable, they are either folded or faulted. Otherwise such steep eastward dips, extending over a distance of 25 or 30 miles, would give a section much thicker than has been observed elsewhere in this formation. So much of the area occupied by Eocene rocks in this region is covered by younger deposits, however, and the exposures so far examined are so small in extent that much remains to be learned about the detailed structure of the Tertiary beds. Likewise any estimates of thickness of the formation are of minimum rather than of maximum thickness. Brooks[38] states that the Tyonek section exposes about 1,000 feet of beds. The exposures on upper Straight Creek, as seen from a distance, appear to show as much as 2,000 feet or more of beds that probably belong in this formation and probably also are stratigraphically below the beds exposed near Tyonek. On the Hayes River a section of several hundred feet of the formation, complicated by faulting, is exposed, and in the Fairview district, some 30 miles still farther north, beyond the boundaries of the area here under discussion, a section measured by the writer[39] shows this formation to be more than 1,000 feet thick.

When it is considered that the formation was laid down over a lowland surface of irregular relief, the earliest beds being deposited in the lower parts of the basin but the formation becoming more widespread as the basin filled, it is to be expected that the original thickness of the formation would have varied greatly from place to place, and later differential erosion has no doubt exaggerated that irregularity.

Age and correlation.—The Eocene rocks were laid down in fresh water as estuarine, river flood plain, or marsh and swamp deposits. They have yielded no invertebrate fossils but contain abundant plant remains in the form of coal, carbonized twigs, and leaf imprints, and

[38] Brooks, A. H., op. cit. (Prof. Paper 70), p. 95.
[39] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, p. 31, 1913.

from these a large number of plant forms have been identified. In spite of this abundance of organic material, however, it has been possible to collect determinable fossils only at a relatively few places, for the matrix in which the plants are found is in general poorly indurated and too fragile to stand shipment. All the fossil collections from this formation have been determined to be of Eocene age, and the general aspect of the beds is so characteristic and so distinct from that of other formations with which they are associated that little uncertainty is involved in correlating the scattered exposures throughout the Cook Inlet-Susitna region. From the widespread occurrence of this formation around the Cook Inlet Basin and in the valleys of the Susitna River and its tributaries, it is known that during Eocene time a great lowland that corresponded in general size and shape to the present lowland was in existence and was receiving deposits of sediments from surrounding higher lands. Also during that period there were recurring intervals during which, at many places within this lowland, organic material accumulated as peat or bog deposits, which were later transformed to lignitic coal. From our present knowledge of these coal beds it appears that no single bed is continuous over large areas and that at no one time was coal-forming material laid down over the entire basin. It is more likely that at any particular time vegetation was accumulating over rather local areas while sand and clay were being laid down elsewhere. In other words, the conditions of sedimentation at any one time differed greatly from place to place throughout the basin, and it is therefore difficult to correlate accurately a section exposed at one locality with that at another locality some distance away. The general assignment of the scattered outcrops to a single formation, however, can be made with little uncertainty. The significance of such intraformational unconformities as that shown in the section northwest of the mouth of Nikolai Creek, described above, is not yet determined. So far as is known, therefore, all the exposures of the coal-bearing formation in the area of the Cook Inlet-Susitna lowland are to be correlated with the Kenai formation and are of Eocene age.

VOLCANIC ROCKS

Distribution and character.—At various places in the southwestern and western portions of the region here treated there occur areas of lava flows and tuffs that are definitely younger than the Mesozoic lavas already described. These rocks were observed by Martin and Katz,[40] who state that most of the shores of Iliamna Lake below the large islands at the mouth of Pile Bay are composed of basaltic rocks, including effusive sheets, tuffs, and probably some intrusive dikes

[40] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 78–82.

and sills. They also noted rocks of this same group on the high hills west of the Newhalen River and Sixmile Lake and at several places on both shores of Lake Clark. West of Lake Clark these lavas were studied and mapped by Smith [41] at several localities. In 1929 the writer [42] found an area of over 200 square miles in the foothills of the upper basin of the Chilikandrotna River to be covered by similar lavas and tuffs, the largest single area of these lavas within the region shown on plates 1 and 2. Most of the localities described by Martin and Katz and by Smith were not revisited by the writer, and the descriptions here given are summarized from their published reports.

On the south shore of upper Iliamna Lake the Tertiary lavas are mainly basalts and tuffs, with which a few thin beds of sandstone and shale are interbedded. They have a prevailingly gentle western dip and at most exposures show the vertical columnar jointing typical of basaltic flows. Under the microscope thin sections of these rocks show them to be mostly augite andesites, containing phenocrysts of plagioclase, common augite, magnetite, and ilmenite, and much smaller ones of apatite, embedded in a groundmass of the same minerals.

North of Iliamna Lake, at a point 6 miles north of the mouth of the Chekok River, a mountain is capped by fine-grained diabase or diabase porphyry that apparently occurs as a nearly flat sheet. In composition this rock is much like that on the south side of Iliamna Lake, already described. On the southeast shore of Lake Clark, 7 miles northwest of Tanalian Point, is another occurrence of similar lava, evidently the remnant of a once more extensive flow.

West of Sixmile Lake the Tertiary lavas form the upper parts of hills whose lower parts are presumably formed of older lavas. They are flat-lying or have only gentle dips. Smith divides this series into two portions, one composed of light-colored acidic lavas and the other of dark-colored basic lavas. The acidic lavas are mainly rhyolites, and the basic lavas are basalts. The rhyolites range in color from nearly pure white through tints of light pink to reddish brown. Some tuffaceous beds of colors like those of the rhyolites are associated with them, but the beds are composed mainly of flow rocks rather than of fragmental volcanic materials. All are fresh, and the rhyolites are generally fine-grained and glassy, some being obsidian in which almost no crystallization of minerals appears. Flow structure is distinctly recognizable, and flows with surfaces showing ropy flow structure were seen.

The basaltic flows are composed mainly of plagioclase feldspar, pyroxene, and glass, and no tuff beds were recognized in association

[41] Smith, P. S., op. cit. (Bull. 655), pp. 122–127.

[42] Capp, S. R., The Lake Clark-Mulchatna region: U. S. Geol. Survey Bull. 824, pp. 145–147. 1932.

with them. The flows are generally nearly flat-lying, though in a few places they have been mildly tilted. Their patchy distribution shows that they have been much eroded and that the now isolated areas are probably remnants of what were once extensive flows.

In the upper basin of the Chilikandrotna River there is a large area of Tertiary lavas and tuffs that, like those west of Sixmile Lake, includes rhyolite flows and tuffs as well as basaltic flows. These rocks occur mainly in the foothills and in general form rounded hills or mountains that rise 1,000 to 2,500 feet above the bordering valleys, though just south of the large lakes in the upper reaches of the Chilikandrotna, where the foothills merge into the main range, mountains of these lavas rise 3,000 feet above the lakes.

This volcanic group is composed of lava and tuff of sharply contrasting appearance and composition. The predominant rocks range in color from white through cream-colored to pink, red, and brown, and consist of rhyolite and andesite flows and tuffs. Especially conspicuous are certain areas of nearly white rocks that in the field appear to be well-laminated volcanic glass but under the microscope prove to be very fine grained rhyolite tuff, probably derived from the consolidation of beds of volcanic ash. Elsewhere black obsidian occurs. Associated with these acidic volcanic materials are almost equally conspicuous black diabase and basalt flows, some showing columnar structure. In general the basaltic flows appear to occur near the upper part of the series, though in places basalt flows are overlain by several hundred feet of the more acidic lavas.

In the upper basin of the Stony River and of its tributary the Necons River there are areas occupied by a great variety of volcanic tuffs and agglomerates interbedded with porphyritic lava flows. The tuffs range in color from dark gray or almost black through lighter gray, pink, and various hues of green, purple, and brown. The included fragments are angular to subangular or rounded and range from microscopic particles to pieces 8 inches or more in diameter. They are composed for the most part of andesite, dacite, rhyolite, and basalt, but there are in places abundant pieces of shale and argillite, and a few pebbles and fragments of granite were seen. The tuffs are interbedded with lava flows that include andesite, dacite, rhyolite, and basalt and with some sedimentary materials, such as argillite, graywacke, black chert, and a little limestone. Some of the lava beds are finely banded and show flow structure.

Structure and thickness.—As a rule the Tertiary lavas lie more nearly horizontal and are less deformed than any of the other hard rocks of the region. As stated by Martin, these flows south of Iliamna Lake in general dip gently westward, though at some localities fairly steep dips were observed. Smith likewise noted the general flatness of the flows and tuffs west of Sixmile Lake and stated his belief that the patchy present distribution of these rocks is due to their removal over considerable areas by erosion. In the upper Chilikandrotna Basin these lavas are extensively developed, and though in that area they are in general nearly flat-lying, there is local evidence of steep tilting and of thrust faulting.

The tuffs and lavas in the Stony Basin show various attitudes, but in general they are less deformed than the associated sediments. In many places they are only mildly folded, and their structure is relatively simple. Elsewhere they are closely folded and crumpled and are intricately faulted.

As originally described [43] these lavas and tuffs in the Stony Basin were grouped with somewhat similar rocks that occur in the Chakachatna and Skwentna Basins and that are believed to be, in part, at least, of Lower Jurassic age. Later studies by the writer in the Mulchatna Basin have convinced him that the lavas and tuffs of the Stony Basin are the correlatives of the similar rocks of Tertiary age in the Mulchatna, and they are so shown on plate 2.

As mapped by Martin and Katz, and on the assumption of only mild dips, these lavas south of Iliamna Lake reach a thickness of well over 2,000 feet. West of Sixmile Lake Smith shows the upper 2,000 feet of Hoknede Mountain to be composed of these rocks. Similarly in the upper Chilikandrotna Basin the series is certainly 2,000 to 2,500 feet thick, with a possible maximum of 3,000 feet. How great an area in this region was originally covered by these lavas it is now impossible to estimate, but that area was certainly much larger than it is today.

Age and correlation.—The age of the lavas and tuffs here described as Tertiary is not accurately known, though their assignment to the Tertiary period is probably correct. They are certainly the youngest hard rocks in the area extending from Iliamna Lake northward to the headwaters of the Chilikandrotna River and are older than any recognized glacial deposits in this region. Martin [44] included in the Tertiary lavas mapped only basalts and tuffs that were found lying unconformably upon the series of lavas and tuffs assigned by him to the Lower Jurassic, and he described no acidic volcanic materials in the Tertiary. He considered the rhyolitic rocks that lie below the capping of basalts on the mountains west of Sixmile Lake as belonging to the Jurassic volcanic rocks. Smith,[45] however, after studying that same area, noted a series of lavas of

[43] Capps, S. R., The Chakachamna-Stony region: U. S. Geol. Survey Bull. 813, pp. 111–113, 1930.
[44] Martin, G. C., op. cit. (Bull. 485), pp. 81–82.
[45] Smith, P. S., op. cit. (Bull. 655), pp. 125–127.

which the oldest was a much decomposed andesite, overlain unconformably by rhyolite, which in turn was capped by basalt. Smith therefore found three distinct lavas and concluded that either the lowest of the three must be older than the Lower Jurassic lavas mapped by Martin, or, if that andesite was Lower Jurassic, that the unconformably overlying rhyolite must be younger. Additional information concerning these lavas was obtained by the writer in the upper basin of the Chilikandrotna River, where a section of these rocks some 2,000 to 3,000 feet thick shows both basaltic and acidic phases. In general the basaltic flows appear to occur near the upper part of the series, but localities were seen at which acidic lavas and tuffs occur both above and below the basalts.

The only fossil evidence of the age of this lava series was collected by Martin and Katz from beds of sandstone that are supposed to lie at the base of the lavas on the south shore of Iliamna Bay. These fossils are presumably Tertiary, though the material was fragmentary. Coal-bearing beds of Eocene age occur at numerous localities along the northern and eastern borders of this region, but they are nowhere associated with the lavas here under discussion. The lavas themselves offer abundant structural evidence that they are younger than the underlying series of Lower Jurassic (?) lavas, and as they are much less deformed than the Jurassic and Cretaceous sediments of this region, the presumption seems justified that they are younger than the youngest Mesozoic beds of the region. On the other hand, the pre-Pleistocene age of this lava series is witnessed by the fact that deep glacial valleys are cut into it, and erratic glacial boulders are found at many places upon the eroded surface of the lavas. There is still too little information at hand to justify an assignment of this lava series to any particular part of the Tertiary, but all the known evidence indicates its Tertiary age.

VOLCANIC ROCKS OF MOUNT SPURR

Mount Spurr is a volcanic mass that lies on the east face of the Alaska Range and so far as is known is the northernmost of a long line of volcanoes that extends down the Alaska Peninsula and westward through the Aleutian Islands and includes Mount Spurr, Redoubt Peak, Iliamna Peak, Mount St. Augustine, Mount Katmai, Mount Peulik, Aniakchak Crater, and many others. It is thus one of a conspicuous series of volcanoes that border the Pacific Ocean, and many of these vents are still active. The mass of which the highest peak is called Mount Spurr consists of a great outer crater, now breached by the valleys of several glaciers that flow radially from it, and a central cone within this older crater, the highest peak of the mountain, from vents near the top of which steam sometimes still issues. One small subsidiary crater, now occupied by a small glacier, was recognized on the south rim of the old, outer crater.

As is shown by the presence of abundant volcanic ash and coarser ejectamenta in the coal-bearing Eocene beds nearby, volcanic activity at this place began at least as long ago as Eocene time, the vent having been formed through the somewhat older granitic rocks. It is likely that this mountain, like other volcanoes, has been active intermittently, the active periods alternating with periods of relative quiescence. Volcanic ash is widely scattered in this region and is found immediately beneath the turf, indicating that the last violent explosion, probably from Mount Spurr, took place within the last few centuries. A moderate steam plume, visible at times, is the only indication that was seen that the volcano is at present active.

The rocks of which Mount Spurr is composed include breccia, tuff, and lava flows, together with minor amounts of dikes and sills. They range in composition from diorite porphyry, which occurs in minor amounts, to basalt porphyry, which makes up the bulk of the mountain. A thin section of a pyroxene diorite porphyry showed phenocrysts of plagioclase, basaltic hornblende, and augite in a holocrystalline groundmass of plagioclase, augite, basaltic hornblende, biotite, apatite, and magnetite. The commonest type of basalt porphyry consists of a glassy to microcryptocrystalline matrix containing phenocrysts of plagioclase and augite, with small amounts of apatite and iron oxides. Another type consists of a holocrystalline groundmass of labradorite, titaniferous augite, magnetite, and apatite, with phenocrysts of labradorite and augite.

INTRUSIVE ROCKS

Distribution and character.—The most conspicuous single group of rocks in the southern Alaska Range, on account of its wide-spread distribution and of the rugged topographic forms produced from it by erosion, is that which includes the granitic intrusive rocks. As shown on plates 1 and 2, granitic rocks occupy by far the greatest part of the basin of the Chakachatna River, are abundantly present in the headward basins of the Skwentna and Stony Rivers and along the west front of the range between the Stony River and Lake Clark, and occur in wide areas between Little Lake Clark and the southern margin of the region here described. The mapping of even these extensive areas, however, fails to show the actual prevalence of granitic rocks in this part of the range, for it is known that granitic materials occupy the greater part of those rugged portions of the range that are as yet unmapped, and it is probable that a wide belt of granitic rocks extends continuously from Iliamna Lake to the

Chakachatna Basin. South of the area here treated there are also known to be extensive granitic areas, and similar rocks are abundantly present also in the range north of the Skwentna River.

The facts above set forth indicate clearly that the granitic rocks constitute a great central mass lying parallel to and having its longest dimension along the axis of the range. In the northern part of the region the continuity of the granitic areas is broken by large, irregular patches of the sediments into which the granitic materials were intruded, and along the margins of the main intrusive mass there are many smaller areas entirely separated from it, forming satellites, but probably for the most part of the same age as the main mass.

Throughout this region the prevailing rocks of granitic texture consist of hornblende granite, hornblende granite porphyry, biotite granite, sodic granite, granodiorite, quartz diorite, and diorite, all inclined to a porphyritic habit, with phenocrysts of feldspar. Those nearest the granite end of the series are most abundant, and diorites are present in minor amount. These rocks are of medium to coarse grain, are completely crystalline, and range in color from pink and white through light to dark gray. All these rocks are readily recognized in the field as granitic rocks or as porphyry of the same general composition as the granitic rocks, and in the main they are believed to belong to the same general period of igneous activity.

The granites are cut by many dikes, chiefly of granitic porphyries. Most of these dikes are only a few feet wide, but a few from 25 to 75 feet wide were seen. In addition to the acidic rocks already described, there are also present in this region minor amounts of basic intrusive materials, including augitite or pyroxenite, diabase, basalt, and basalt porphyry, that occur as dikes or sills of moderate size. They are areally unimportant compared with the granitic materials.

Katz [46] reports that diorites composed of andesine feldspar, hornblende, biotite, and some augite are present between Iliamna Bay and Iliamna village and that these range in texture from fine to coarse and from granitic to gneissoid. At the mouth of the Iliamna River, on the margin of the granitic area, are rocks ranging in composition from diorites to hornblendites, composed almost wholly of large hornblende crystals with very small amounts of feldspar, magnetite, and sulphides. Katz also states that west of Iliamna Bay the granite is much more basic than at other points and possesses a rough foliation, and he suggests the possibility that granites of two types and ages are there present.

[46] Katz, F. J., op. cit. (Bull. 485), p. 75.

Near the head of Kenibuna Lake the writer [47] found granular intrusive rocks that have undergone varying amounts of metamorphism. They range from fairly coarse quartz diorite, with incipient foliation, through banded gneiss to finely foliated and fissile biotite schist. Whether these gneissic rocks are merely a locally metamorphosed phase of the prevailing granitic rocks, or whether they represent a much older period of intrusion, followed by metamorphism before the intrusion of the great bulk of the granitic rocks, is not certainly known, but the evidence seems to favor the former of these alternatives. Katz [48] noted a similar situation just west of the head of Iliamna Bay, where gneissic rocks are present, and he too was uncertain as to whether these gneisses represent a locally metamorphosed phase of the prevailing granitic rocks, or whether they are much older. For the present that question must remain unsettled.

Age.—In regard to the age of the granites of the Alaska Range it was long believed that they were definitely younger than part of the Lower Jurrasic rocks and older than the Middle Jurassic. Martin [49] so placed them and correlated them with the granites of the Talkeetna Mountains, also believed to be of lower Middle Jurassic age. This age determination was based upon the fact that quartz diorite of the normal type for this region was intruded into Upper Triassic rocks on Bruin Bay subsequent to their close folding, whereas nearby are broad areas of Upper Jurassic rocks that were not involved in the close folding and are not cut by the granites. Furthermore, he states that nowhere on Cook Inlet are Middle Jurassic rocks known to be cut by granitic rocks and that the Chisik conglomerate, at the base of the recognized Upper Jurassic, contains granitic boulders of the same types as the granites which occur in the mountain areas. Later studies, however, have shown definitely that great areas of granitic rocks within the Alaska Range are much younger than Jurassic and in fact cut sediments containing both plant and invertebrate fossils that are certainly as young as Upper Cretaceous. This relation has been found for the granites at many places along the range, including a locality on the upper Stony River, one on the upper Skwentna, and several places north of the region here described. There can therefore be little doubt that some if not most of the granitic rocks of the southern Alaska Range are as young as Upper Cretaceous, whereas nowhere in this part of Alaska have

[47] Capps, S. R., The Chakachamna-Stony region: U. S. Geol. Survey Bull. 813, pp. 109–110, 1930.

[48] Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 75–76, 1912.

[49] Martin, G. C., op. cit. (Bull. 485), pp. 76–77.

typical rocks of this kind been found to cut the coal-bearing Tertiary beds, generally considered to be of Eocene age. This conclusion that much of the Alaska Range granitic material is as young as Upper Cretaceous does not, however, preclude the possibility that some older granitic rocks may be present. The gneissic rocks near Kenibuna Lake and west of Iliamna Bay suggest an age greater than that of the prevailing granitic rocks, and indeed the presence of granitic boulders in the Chisik conglomerate, the Chinitna shale, and the Tuxedni sandstone, all Jurassic formations, demands a source from some body of granite older than these Jurassic sediments. It is the writer's opinion, however, that by far the greater portion of the granites of the Alaska Range are as young as late Mesozoic and that although older intrusives of this type are present, they are subordinate in amount.

In addition to the large areas of granitic intrusive rocks shown on the accompanying geologic maps, intrusive rocks of a wide variety of types occur as dikes and sills of too small areal extent to be shown on maps of this scale. These intrusives are doubtless of several ages, but in most places it is impossible to determine their age beyond the obvious fact that they are younger than the materials into which they were intruded. The periods of greatest igneous activity in the region occurred during Lower Jurassic time, when the extensive areas of porphyries and tuffs were laid down; near the end of the Mesozoic era, when most of the granitic intrusion took place; and at some undetermined time in the Tertiary period, during which other lava flows and tuffs were laid down. During all three of these periods dikes and sills were unquestionably intruded in various places, and it is likely that there have been other times during which igneous material invaded cracks and bedding planes in preexisting rocks. Intrusion in a minor degree is known also to have continued even into recent geologic time around the volcanic vents such as Mount Spurr and Redoubt, Iliamna, and Augustine Peaks, in or near this region. The close mapping of these smaller intrusive masses, the accurate determination of their ages, and their careful petrographic study must await more detailed geologic studies than have so far been made.

QUATERNARY DEPOSITS AND HISTORY

Quaternary deposits in this region include a wide range of materials, most of which are unconsolidated. The chief event that here marked the transition from Tertiary to Quaternary time was the formation and expansion of glaciers, which first developed in the high mountain valleys and later grew and pushed outward from the mountains onto the surrounding lowlands. This growth of glaciers was repeated several times during the Pleistocene epoch, and by the erosive effects of the ice upon the highlands and by the deposition in the lowlands of the detritus removed from the mountains, the glaciers had a profound effect upon the appearance of the country as we see it today. The Quaternary deposits now present in the region include wide areas of materials deposited directly by the glaciers as morainal material or indirectly by the glacially fed streams as outwash gravel; the present stream gravel, some of which, however, is of glacial origin, being laid down by rivers that head in existing glaciers; lacustrine and marine deposits; volcanic ash; talus accumulations and the results of normal weathering of rock in place; volcanic ash; and organic deposits. These materials vary greatly in their relative abundance, the glacial, glaciofluviatile, and fluviatile deposits forming the great bulk of the unconsolidated materials. A mantle of rock-disintegration products and of organic materials is widespread and in the aggregate forms a great volume of material, but in most places this mantle is so thin that the character of the underlying rock formations can be recognized. As the practice in reconnaissance geologic mapping is to show, insofar as possible, the distribution of the rock formations, the surface covering of rock-disintegration products and of recent organic deposits is not mapped on plates 1 and 2.

PREGLACIAL CONDITIONS

During most if not all of Tertiary time the region now occupied by the southern Alaska Range was a land mass upon which at times and in places great deposits of stream gravel, sand, and silt were laid down, thick deposits of organic materials accumulated, lava flows were poured out, and several volcanoes were intermittently active. This land mass was also subject at intervals to great orogenic movements, during which the surface was elevated to form a great mountain range, and upon this range steep rivers carved their valleys. It is believed that the uplift of the range started first along a relatively narrow belt, but as it proceeded continually wider areas became involved, and the beds were folded and faulted, in some places intricately.

Just how far into Tertiary time the active growth of the range continued is not known, but it seems certain that by the end of the Tertiary the main uplift had been almost completed, and the whole mass had been carved into mature relief by rivers that followed in a general way the courses of the present valleys, so that the drainage pattern roughly resembled the present one.

GLACIAL EPOCH

OLDER GLACIATION

Quaternary time in Alaska was initiated by a change in climate that probably involved both a decrease in the mean annual temperature and an increase in precipitation, so that the high mountain basins received more snow each winter than melted during the following summer. When these conditions are continued for a long period of years the snow fields become enlarged, thicken, and join with one another, and glaciers are formed in the higher and more sheltered mountain valleys. With still further accumulations of snow and ice, however, every high valley head becomes able to support a glacier, and as these grow and lengthen down the valleys many ice tongues converge in the trunk valleys to form great glaciers that push downward to and beyond the flanks of the mountains. Such expanded glaciers will persist as long as conditions of temperature and precipitation are favorable. With lessened snowfall or an increase in the mean annual temperature the glaciers will shrink, and if the weather change is great enough and of long enough duration the glaciers may melt away and largely disappear. Such fluctuations of weather conditions took place several times during the Pleistocene. In the Mississippi Valley, where the most detailed studies of Pleistocene history have been made, there were at least five major periods of long-continued glacial advance, each followed by a long interglacial stage during which the ice melted away and disappeared. For Alaska the evidence is much less complete. It is known, however, that there, too, recurrent glacial advances alternated with periods of ice withdrawal, and as the great climatic changes that made possible such dramatic episodes as the growth of glaciers over the whole northern portion of the continent must have been widespread, it is reasonable to suppose that the Alaskan glaciers waxed and waned at the same time as those continental glaciers. It seems definitely established that the last great stage of glaciation in Alaska was contemporaneous with the last or late Wisconsin continental glaciation,[50] but the earlier stages of Alaska glaciation have not yet been correlated with those that occurred in the central part of the continent. Observations show conclusively that in various parts of the Territory there were Pleistocene glacial advances that preceded the late Wisconsin glaciation. The Alaskan glaciers were of the mountain-glacier type, however, and were confined to mountainous areas and the immediately adjoining lowlands, and the scarcity of observed deposits of pre-Wisconsin glacial materials is due to the

[50] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 620, pp. 69–75, 1916.

vigor of the late Wisconsin glaciers, which scoured out and removed much of the evidence left by their predecessors.

Among the localities in Alaska in which pre-Wisconsin Pleistocene glacial deposits have been observed are two within the Alaska Range. In the valley of the Nenana River many large boulders occur on the surface of the Nenana gravel high above the altitude reached by the glaciers during their last great advance, and other large boulders occur many miles beyond the outermost moraines of Wisconsin age. Similar erratic boulders were seen in the basin of the Savage River.[51] These are believed to be the glacial deposits of an ice tongue that was considerably longer and thicker than the Wisconsin glacier that occupied the same basin.

A further occurrence of older glacial material was found in the upper basin of the Chilikandrotna River (pl. 2),[52] about 2 miles north of the outlet of the lower of the Twin Lakes, where there is an exposure of rounded and subangular boulders and pebbles and of fragments of a wide variety of rocks, embedded in a clayey matrix. The boulders, pebbles, and rock fragments are somewhat decayed, and their original surfaces are lost. No striae were found, but few pebbles were sound enough to have preserved striae, even if they had once been present. The matrix and the included rocks are oxidized to a conspicuous reddish color, in contrast to the blue color and unoxidized and undecayed character of the more recent till by which this deposit is overlain. The fresh overlying till is a part of the lateral moraine left by the last great ice advance, in Wisconsin time. The oxidized and decomposed till beneath is believed to be morainal material left by the ice during a pre-Wisconsin stage of the Pleistocene. There is too little information at hand to justify the correlation of this older glacial deposit with any particular stage of Pleistocene glaciation.

The westward face of the Alaska Range should prove to be a fertile field for study of the problem of successive Pleistocene glaciations, for there each mountain glacier pushed out upon the adjacent lowlands, to spread out in a spatulate piedmont lobe and deposit its load of debris. In the piedmont area glacial deposition was dominant and glacial erosion was of minor importance, so that these conditions should have favored the superposition of younger glacial deposits over the older ones, and interglacial periods should have left their record of soil weathering and oxidation and of organic deposits. In this almost uninhabited region the absence of road cuts and arti-

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[51] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 59–60, 1919.

[52] Capps, S. R., The Lake Clark-Mulchatna region: U. S. Geol. Survey Bull. 824, p. 152, 1921.

A. VERTICALLY DIPPING ARGILLITE AND GRAYWACKE BEDS IN THE CANYON OF THE UPPER STONY RIVER.

B. EXTENSIVELY GLACIATED MOUNTAINS IN CHAKACHATNA BASIN.

ficial excavations, so useful to the glaciologist in settled areas, has delayed the deciphering of the events of Pleistocene time.

ADVANCE AND EXTENT OF THE LAST GREAT GLACIERS

The last great ice advance in this region, in late Wisconsin time, repeated in many ways the chain of events that occurred during each of the earlier glacial stages of the Pleistocene. Since the preceding glacial stage a long time had elapsed during which there were no large glaciers in the main mountain valleys, and the normal processes of weathering and stream erosion were in operation. Perhaps relatively small glaciers had survived in the higher mountain valleys, but on the whole the climate, vegetation, and general character of the country were much as they are today. With a renewal of climatic conditions favorable for ice accumulation, however, the ice tongues began once more to grow and to push down the stream valleys toward the mountain flanks. In advancing over a country long subjected to the ordinary processes of rock weathering and decay, the glaciers found ready at hand great quantities of soil, talus, and stream detritus as abrasive material with which to attack the hard rocks of their beds. By the rasping away of projecting ridges and hills and by the plucking out of great blocks of rock the irregularities of the valley walls and sides were removed, sinuosities in the valleys were straightened, and broad V-shaped troughs were developed. These glacial features, together with others such as steep-walled cirques in the valley heads, mountain lakes in rock-carved basins, truncated spurs, and hanging valleys, are characteristic features of the more rugged portions of this region, whereas on the mountain flanks and in the bordering lowlands depositional features such as lateral and terminal moraines and wide-spread accumulations of stream gravel are more evident.

As the glaciers advanced beyond the mountain front, both east and west of the main range, the ice streams from adjacent valleys spread out and joined to form a continuous piedmont ice sheet. That on the east of the range joined and helped to swell the great glacier that poured down the Susitna Valley and that was also fed by tributary ice streams flowing from the Chugach and Kenai Mountains, to the east. This great glacier filled the upper basin of Cook Inlet, covered the adjacent lowlands both east and west of it, and pushed southward down that depression an unknown distance, but possibly as far as the mouth of the inlet. Certainly all the eastward-moving valley glaciers from the southern Alaska Range flowed into the sea by way of the great glacier in Cook Inlet. That glacier was of vast dimensions, for it drained the entire basin of the Susitna River, parts of the Copper River Basin, a large area on the north slope of the Chugach Mountains, and all the western face of the Kenai Mountains. East of the area shown on plate 1 it had a width of 80 miles. Its thickness in the middle is not known, but the topographic form of Mount Susitna, near the mouth of the Susitna River, indicates that this 4,000-foot granite mountain was overriden by the glacier. Farther southwest, near Mount Spurr, there is definite evidence that the ice along the flank of the range stood at an altitude of 3,000 feet or more, and the glacier must therefore have pushed southward down the lowland a long distance beyond Mount Spurr.

This great Cook Inlet-Susitna glacier was fed by many vigorous tributary ice streams from the region here under discussion. That from the Skwentna Basin was over 80 miles long above the point where it joined the southward-flowing trunk glacier, and near its head the Skwentna Glacier, itself fed by many tributary ice streams from the higher mountains, occupied the main valley to an altitude of about 6,000 feet. Similarly, the surface of the glacier that occupied Ptarmigan Valley and the headward basins of the Styx River and the South Fork of the Kuskokwim, streams which now drain westward but which in Pleistocene time sent their ice to the Skwentna by way of the Happy River, had an altitude at their junction of at least 5,800 feet. Several large glaciers, as yet unstudied, still occupy the headward basin of the Beluga River, and the much larger Pleistocene glaciers from that basin made important contributions to the great Cook Inlet glacier.

Another notable ice stream tributary to the Cook Inlet glacier from the west was that which occupied the basin of the Chakachatna River. This glacier at one time was continuous through a pass at the head of the Nagishlamina with the Skwentna Glacier, the ice surface in the pass having an altitude of 6,000 feet, or 3,000 feet above the pass. No doubt the direction of flow of the glacier through the pass was at times northward into the Skwentna Basin and at other times southeastward into the Nagishlamina, depending upon which basin received the heavier snowfall. Similarly, glacial ice moved through other passes between the Chakachatna Basin and the Skwentna, to the north, and the Stony, to the west. Thus the mountainous part of this region was so heavily glaciated that the valleys were filled with ice to a depth of several thousand feet, and only the high, ragged mountain ridges projected above its surface. The mountainous portion of the Chakachatna Basin has an area of about 1,200 square miles, and at the time of maximum glaciation the area of the glacier that occupied this basin was almost equally large. At the foot of Chakachamna Lake its surface reached a height of about 4,200 feet, or about 3,000 feet above the present level of the lake. (See pl. 8, *B*.) The shrunken remnants of this glacier that still persist include many magnificent ice streams, some 10 to 12 miles long. Between the Chakachatna Valley and Snug Harbor there is an area on the east slope of the Alaska Range that is still unsurveyed, but it is known that every valley along this slope was occupied during late Pleistocene time by a vigorous glacier that pushed eastward beyond the mountain front to join the southward-flowing glacier in Cook Inlet.

On the westward slope of the range the valley glaciers of the late Pleistocene were almost as vigorous as those on the east, but unlike them they pushed out onto an unglaciated lowland. Much of that lowland is still unsurveyed. In his traverse in 1914 across this lowland from Lake Clark to the Kuskokwim River, Smith [53] observed the extent of glaciation there and drew a sketch map showing the glaciated areas. The writer, in his expedition of 1929, passed along the mountain front from Lake Clark to the basin of the Stony River, but his route lay well to the east of the outer border of the glaciated area. These two expeditions and that of Martin and Katz in the Iliamna region [54] leave many details of the glacial history of this region still unsolved, but they have succeeded in pointing out the larger features of the glaciation. Thus it is known that the present basin of Iliamna Lake was once entirely occupied by a great ice tongue that pushed at least 7 miles below the present outlet of the lake and there left a high terminal moraine. The surface of Iliamna Lake is about 50 feet above sea level, and reported soundings at its east end show a depth of several hundred feet, so that the excavation of this great lake basin is an index of the great erosive power of the glacier that occupied the basin. All the mountain valleys tributary to Iliamna Lake contributed ice to this great glacier, which, however, was of alpine type and deployed and ended in the lowlands not far beyond the mountain front. The high interstream areas projected above the glacier surface but served as collecting grounds for the tributary ice streams that occupied every high valley.

The Lake Clark Basin was likewise filled by a vigorous alpine glacier. The forms of the mountain walls indicate a thickness of glacial ice at the upper end of Lake Clark of at least 3,000 feet, and this vigorous glacier, confined in a relatively narrow mountain valley, was able to erode its bed to a depth of 600 feet below the present lake level, or nearly 400 feet below sea level, as is shown by soundings in the lake. It was fed by large tributary glaciers from the valleys of the Tlikakila, Chokotonk, and Kijik Rivers on the north and northeast and the Currant, Kontrashibuna, and Tazimina Valleys on the east. Toward the lower end of the lake the ice decreased

[53] Smith, P. S., op. cit. (Bull. 655), pp. 85–94.
[54] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 82–88.

somewhat in thickness, as the glacier was able to expand in the wider valleys there. A part of its ice flowed southward down the valley of the Newhalen River to join the Iliamna glacier, and a part flowed westward up the Chulitna Valley, that lobe sending its melting waters to the Mulchatna.

North of Lake Clark the glacial pattern was more complex, for the glaciers that originated in the high mountains of the range pushed westward through a belt of foothills, of which some projected above the glacier surface and others were overridden. These foothills, some of which reach altitudes of as much as 4,000 feet, are separated from one another by many broad, low valleys that were filled with ice, so that a network of glaciers, supplied by ice from the headward basins of the Kijik, Little Mulchatna, and Chilikandrotna Rivers, connected these basins with one another. Some of that ice drained by way of the Koksetna Valley to join the Chulitna lobe of the Lake Clark glacier, and some pushed westward down the Chilikandrotna Valley toward the Mulchatna. An exceptionally fine lateral moraine on the north side of the Chilikandrotna Valley stands 2,000 feet above the lower end of the lower Twin Lake, and the ice there was at one time continuous to the north with that in the Mulchatna Valley.

The upper Mulchatna Valley likewise contained a vigorous glacier that north of Turquoise Lake left a lateral moraine 1,600 feet high. The glacier pushed westward well into the lowlands, but its outer limit is not accurately known.

The glacier in the Telaquana Valley left lateral moraines more than 2,500 feet high at the point where it emerged from the mountains and pushed northwestward to join the Stony Glacier. Below the junction this glacier flowed westward down the Stony Valley to and beyond the borders of the region shown on plate 2, thus having at the time of its maximum size a length of about 120 miles.

GLACIAL EROSION AND DEPOSITS

The entire region of the southern Alaska Range bears evidence of the severity of glacial activity during Pleistocene time. Within the high mountains, where the glacial ice was accumulating and the ice streams were confined within narrow, steep-walled valleys, the preponderant effects of glaciation were in the excavation of cirques at the valley heads, in the deepening and broadening of the valley floors, and in the smoothing out of the irregularities of the glacial troughs. These features have become generally recognized as the characteristic effects of severe mountain glaciation. Beyond the mountain fronts, however, where the ice streams could widen out and their ability to transport debris was diminished, erosion gave place to deposition, and the materials scoured and carved from the mountains were laid down in the lowlands. It is a notable fact that within the high mountains such glacial deposits as till and lateral and terminal moraines are rare except near the existing glaciers. No doubt such features were built by the retreating glaciers, but, being left in relatively narrow valleys, they were at once attacked by the vigorous streams from the melting ice and so were for the most part washed away. By contrast, on the flanks of the mountains and in the bordering lowlands glacial deposits are extensively developed. Mention has already been made of the great lateral moraines near Telaquana, Turquoise, and Twin Lakes, on the west slope of the range. Within the foothill belt west of the range the lowland valleys are all paved with morainal material and with gravel deposited by the streams from the wasting glaciers, so that many separate hills or groups of hills rise like islands from an irregular plain of unconsolidated glacial or glaciofluvial materials. These lowlands are covered with tundra or with brush or timber, so that there is little opportunity to determine the thickness of this accumulation of Pleistocene material, but in many places it is no doubt great. The lateral moraines near Telaquana, Turquoise, and Twin Lakes are built upon and against rock valley walls, but locally gulches cut to a depth of 200 feet in some of them fail to show the base of the morainal material. Since the great shrinkage of the ice in late Pleistocene time the streams have been engaged in reforming normal gradients over the Pleistocene deposits. Glacial lakes are being filled, and channels are being excavated into the moraine and outwash materials of the valley floors. In places fine sets of terraces have been cut into the gravel and till, showing the progress so far made by the streams toward adjusting their beds to present conditions by volume, load, and gradient. In other places the bedrock floor had been oversteepened by the ice, or rock ridges lay athwart the valley beneath a covering of unconsolidated material. As the streams at these places lowered their channels they cut canyons through the rock ridges, so that their courses now present a succession of wide stretches cut in gravel, alternating with narrow rock canyons.

On the east side of the range the conditions governing the deposition of glacial materials were somewhat different from those prevailing on the west side, for the eastward-flowing Pleistocene glaciers there joined a great southward-flowing trunk glacier in Cook Inlet, and much of their morainal material was carried by it far to the south. This trunk glacier, however, deposited a heavy sheet of till beneath itself over wide areas. Thus, just north of Trading Bay, on the shore between the mouth of Nikolai Creek and the village of Tyonek, there are bluffs 125 to 150 feet high cut in till that for miles fail to show the base of the glacial deposits, and this till sheet is present over thousands of square miles of the lowlands bordering Cook Inlet and in the lower Susitna Valley and extends up the basins of the Yentna and Skwentna Rivers to the points where these streams leave their narrow mountain valleys to emerge into the lowland.

Within the mountainous portion of the eastward-draining river valleys there are in places also considerable volumes of morainal material and of glacial outwash gravel, but these have been shown on the geologic map only in those places where they are especially thick or have given topographic expression to the land forms. Thus in the Chakachatna Basin there are certain areas where the valley walls of that river or its tributaries are heavily veneered with morainal material, and at the termini of several large, active glaciers, such as Shamrock, Harpoon, Pothole, and Barrier Glaciers, there are well-preserved terminal moraines. The lower end of Shamrock Glacier and its terminal moraine form the obstruction that separates Kenibuna Lake from the upper end of Chakachamna Lake, and Chakachamna Lake itself is impounded behind a dam formed by Barrier Glacier and its terminal moraine. (See pl. 3, *B*.)

During some stage in the retreat of the ice lobe up the Chakachatna Valley the glacier terminated somewhere near the lower end of Chakachamna Lake, and at that time an extensive filling of outwash gravel was laid down along the Chakachatna Valley to and beyond the mountain front. With a further retreat of the main glacier and the formation of Chakachamna Lake behind the dam formed by Barrier Glacier, the load of gravel and sand brought down by the headward tributaries of the Chakachatna was trapped in the lake, and the river below the lake, freed from this burden of sediments, was able to intrench itself into the gravel filling of the valley and locally into bedrock. As a result a fine series of terraces was developed in the valley for many miles below the lake, especially on the north valley slope. The upper and most prominent terrace stands about 100 feet above the river, and in places three or four lower terraces can be seen at intervals of 20 feet or so apart.

Terraces are also extensively developed along the south slope of the piedmont ridge that extends from Cook Inlet back to the mountains just north of Nikolai Creek. These terraces are for the most part thickly covered by timber and brush and are not conspicuous, but one well-developed terrace, 100 to 150 feet above sea level, was traced back for several miles from the beach.

EXISTING GLACIERS

On plates 1 and 2 between 175 and 200 glaciers are shown, and this number might be doubled if the unsurveyed portions of the more rugged parts of the range had been mapped, for in the higher portions of the range nearly all the valley heads harbor glaciers, remnants of those far greater ice streams that flooded this region during Pleistocene time. It seems probable that many of these glaciers have persisted continuously from the first Pleistocene ice invasion, or possibly even earlier times, through the recurring advances and retreats of the glacial epoch, to the present time, and it is even possible that many of them may endure to become the nuclei of the great glaciers of another ice advance.

The size attained by any one of the present glaciers is a response to the interrelation of altitude of the catchment basin, its exposure to the sun, and the amount of snowfall that it receives. Inasmuch as the Cook Inlet slope of the range in this region has a heavier precipitation than the western slope, the eastward-draining glaciers average much larger than those that drain to the west. As would be expected, the largest glaciers of this region are those that flow eastward from the high ridge of which Mount Spurr, 11,050 feet above sea level, is the south end and which extends northward to Mount Gerdine, with an altitude of 12,600 feet. This is the loftiest mountain mass in the region here described. Its eastern front has been only partly surveyed, but from it there descend two great valley glaciers that drain through the Beluga River to Cook Inlet. The southern of these, unnamed, is some 25 miles long and has an area of about 75 square miles, and the northern, Triumvirate Glacier, is formed by four great lobes, each 12 to 20 miles long. Triumvirate Glacier has a maximum length of 28 miles and an area of about 170 square miles. The Hayes River, a tributary of the Skwentna from the south, heads in a large glacier that drains the high ridge north of Mount Gerdine. This glacier is unsurveyed, and its length and area are not known.

The west slope of the high mountain mass between Mount Spurr and Mount Gerdine is drained by several vigorous ice streams, of which Barrier, Pothole, and Harpoon Glaciers drain to the Chakachatna River and North and South Twin Glaciers drain to the Skwentna. These glaciers are from 8 to 11 miles long but are small by comparison with the great ice lobes on the east side of the same ridge.

There are dozens of small valley-head glaciers scattered through the higher mountains of the Skwentna and Chakachatna Basins, and on the south side of Chakachamna Lake many imposing ice streams descend from the granite mountains to or almost to the level of the lake. The largest of these, Shamrock Glacier, has three main lobes, is 14 miles long, and covers an area of about 40 square miles.

South of the Chakachatna River the McArthur River heads in a great many-branched glacier that is at least 20 miles long and is 2½ miles wide at its terminus but that drains a basin still largely unsurveyed. Still other unsurveyed glaciers drain eastward from such lofty mountain masses as Black and Double Peaks, Mounts Redoubt and Iliamna, and other high parts of the range.

The glaciers on the western slope of the range in this region are less well known than those on the east, as the loftier portions of the range on that side are largely unexplored and unmapped. Many small glaciers are present in the high valleys of the upper Stony Basin, but the largest of these are no more than 6 miles long and have areas of only a few square miles, and most of them are less than a square mile in area.

The volume of the Telaquana River above the lake and the heavy load of debris that it carries indicate that this stream heads in a glacier of considerable size. The Mulchatna River has at its head at least two sizable glaciers that drain into Turquoise Lake, and the upper courses of the Chilikandrotna and Kijik Rivers above the lakes through which they flow are characteristic glacial streams, flowing in braided channels over extensive gravel bars. The glaciers at the heads of these streams lie in unexplored territory, and their sizes and exact positions are not known.

It is interesting to note that with the exception of the main Stony River, all the major westward-flowing streams that drain from the high mountains in this region flow through lakes in which their coarse, glacially supplied debris is trapped and below which the streams are only slightly turbid. Streams with this characteristic include the Necons, Telaquana, Mulchatna, Chilikandrotna, Kijik, Tlikakila, Chokotonk, Kontrashibuna, Tazimina, Pile, and Iliamna Rivers.

Only small, valley-head glaciers occur in the mapped portion of the basins of Lakes Clark and Iliamna. Some of these in the upper basin of the Kontrashibuna River and several just south of Little Lake Clark are shown on plate 2. It is reported that both the Tlikakila and Chokotonk Rivers head in large glaciers outside of the area mapped, and the heavy load of gravel and silt carried by the Pile River indicates that this stream also receives much of its water from glacial sources.

PRESENT STREAM GRAVEL

The mapping of the gravel of the present streams, as shown on plates 1 and 2, is not everywhere consistent throughout the region, for in some of the reports by the writer and by other geologists from which these maps are compiled the present stream gravel was not separated from the glacial deposits and older stream gravel but was shown with them as a single pattern. In this report, therefore, an attempt has been made to map the present stream gravel only in those places where the streams have flood plains of considerable width. Wherever the streams flow in single, sharply restricted channels between well-established banks and occupy most of the flood plain, the stream gravel is not shown. Narrow flood plains could not be shown on maps of this scale without great exaggeration. It is probable that so large a stream as the Mulchatna has a well-developed flood plain west and southwest of the Bonanza Hills, but that region was not visited by the writer.

It is a notable characteristic of steep glacially fed streams that they carry great quantities of gravel, sand, and silt supplied by the glaciers and that they tend to deposit this material as soon as the stream gradient becomes more gentle, the coarse material being dropped first and the finer material at a greater distance from the glaciers. By this process wide gravel and sand flats over which the streams flow in many branching channels are built up in stretches of relatively slight gradient, and these alternate with narrow stretches of flood plain in canyons or wherever the current flows more swiftly. As a glacial stream emerges from its steep mountain valley into the lowlands the heavier load of glacial detritus is dropped, and as the distance from the glacier increases the coarseness of the material moved decreases until all but the finer sand and silt is left behind, and the stream flows in a single well-defined channel between banks of sand or silt. In many of the glacial river valleys of this region, however, particularly on the west slope of the mountains, there are large lakes into which the heavily loaded streams discharge. These lakes entrap all the coarser sediments, and below them the waters, though still faintly cloudy with the finest glacial mud, are free of glacially derived sand and gravel and flow in single channels through relatively narrow flood plains. This accounts in large measure for the meager development of present stream gravel on the west slope of the range as shown on plate 2.

On the Cook Inlet slope of the range there is an extensive area floored by gravel of the present streams in the lowland between Nikolai Creek and the Kustatan River. This lowland was first excavated by the great glaciers that flowed out of the Chakachatna and McArthur Valleys and was later aggraded by a great flood of gravel supplied to the McArthur and Chakachatna Rivers and Straight Creek by the glaciers in which they head. Much of that lowland, though still subject to overflow and aggradation by the shifting glacial streams, is now overgrown by marsh plants and low brush and is almost or quite impassable on foot during the summer.

There is a considerable area of glacial outwash gravel flats in the headwaters of the Beluga River, below the great glaciers in which that stream heads. This area was seen only from a distance, but the relations there seem to indicate that the southern of the two large glaciers has thrown out a strong valley train of gravel and so built a dam across the stream draining Triumvirate Glacier, thus impounding Beluga Lake. The basin of the Beluga River has been surveyed only in part, and the size and shape of the deposits of stream gravel are imperfectly known.

The Skwentna River has a flood plain floored by stream gravel throughout its length, though the width of these deposits varies greatly from place to place, wide areas of gravel over which the river anastomoses alternating with canyons in which the river covers most of its flood plain. The Skwentna is fed by glacial tributaries at intervals throughout the upper two-thirds of its length, and from these it constantly receives new supplies of coarse gravel. As a result it is unable to leave its coarser load in its upper reaches and except in the rock canyons is an aggrading stream to its mouth, where it joins the Yentna.

Below the mouth of the Skwentna the Yentna has a relatively narrow flood plain to its mouth, the valley being deeply incised into glacial deposits and in places into the Tertiary sediments. Near its junction with the Susitna, however, its flood plain widens to merge with the extensive flats of the Susitna. The Susitna flats, below Susitna village, increase in width to the south, to merge into the Susitna Delta. That portion of the delta that is above the ordinary reach of the tide is shown on plate 1, but the delta itself extends as broad shallows many miles southward into Cook Inlet, and extensive mud flats are exposed at low tide.

Beach deposits are only meagerly represented in this region. The shores of Cook Inlet are bordered by a narrow strip of beach that at high tide is practically all submerged. At low tide this strip widens greatly, and in shallow places considerable areas of mud flats are bared, particularly during especially low tides, for in upper Cook Inlet the tidal range is from 25 to 30 feet or even more. Except at the margin of the Susitna Delta and at the head of Trading Bay the shores of Cook Inlet are cut by waves into steep bluffs 100 feet or more high, and as a rule the strip of beach deposits at the base of these bluffs is narrow. The beach material, largely derived by erosion from the bluffs of glacial till and from the outwash of glacially fed streams, ranges in coarseness from large glacial boulders to fine silt and includes all the varieties of rock that occur in the Cook Inlet drainage basin.

VOLCANIC ASH

One of the most recent geologic events in this region was a volcanic eruption that resulted in the deposition of a layer of ash over much of it. The ash deposit is in most places inconspicuous, as it was long ago covered by vegetation, but in good exposures it can be detected as a layer from a fraction of an inch to several feet thick, occurring immediately below the surface layer of plant roots and soil. In a few places on the piedmont ridge east of Mount Spurr, above the altitude to which brush grows, persistent snow banks have prevented the growth of moss or heather, and there bare patches occur that show a mixture of volcanic ash and soil. Elsewhere the ash appears only along freshly exposed stream banks or in places where for some reason fresh cuts have been made through the surficial materials.

Along the Skwentna River below the Happy River ash a few inches thick was noted at many places and is a favorite layer for the excavation of burrows by ground squirrels. On a point between the junction of Muddy Creek and the Skwentna, some 3 miles above the mouth of Muddy Creek, a thick section of ash was measured in a freshly dug hole on a moraine-covered bench. It is not known how large an area was covered to this depth or whether the unusual thickness at this place was the result of drifting of the ash by the wind. The surface of the ground was sloping and gave no appearance of there having been a hollow into which the ash could have been carried by water. Mature spruce trees are growing above the ash. The section is as follows:

Section of volcanic ash 3 miles above the junction of Muddy Creek and Skwentna River

	Inches
Vegetation and muck	8
Buff ash, mottled to black by vegetation stains	4.50
Fine tan to buff ash	6.25
Gray ash, as coarse as coarse sand, with pieces as much as half an inch in diameter	2.50
Fine dove-gray ash	.60
Fine gray ash with buff mottling	1.25
Fairly fine dove-gray ash	.75
Medium fine gray ash	4.50
Very fine blue-gray ash	1.75
Very fine rusty-buff ash, mottled with blue-gray	4.50
Fine buff ash	11
Coarse sand and fine gravel.	
Total thickness of ash	37.60

On the southeast side of Straight Creek 3 miles below the glacier the terrace face shows as much as 6 feet of volcanic ash overlain by 12 to 18 inches of vegetal material and soil, on the surface of which stands a forest of large spruce trees. In the valley of the Nagishlamina River, on the surface of the moraine of Harpoon Glacier, volcanic ash ranging from 2 to 4 feet in thickness was seen beneath a foot of turf. Still farther west, in the pass between the Chilligan and Igitna Rivers, 4 feet of pale-buff to brown ash was seen immediately below the turf.

At several places on the west flank of the range, between Lake Clark and the Stony River, a thin layer of volcanic ash was seen just beneath the turf, but nowhere was it observed to reach as great thicknesses as those noted in the Skwentna and Chakachatna Basins. This ash layer is old enough for mature trees to have grown upon it. Neither Martin and Katz in their study of the Iliamna-Lake Clark region nor Smith in his study of the Lake Clark-central Kuskokwim region noted this ash.

From what is now known of the distribution of this ash layer it occurs to the greatest thickness in a region that centers around Mount Spurr. In 1927 evidences of mild activity were noted at that volcano, and it therefore seems probable that this mountain was the vent from which the ash was ejected. Mature spruce trees growing on top of the ash indicate that it fell at least 100 or 200 years ago and possibly several times that.

In June 1912 Katmai Volcano, which stands about 100 miles south of the lower end of Lake Clark, was in violent eruption and cast out ashes that were observed over an area of several hundred thousand square miles. Smith [55] reports that at Iliamna village the layer of ash was 1½ inches thick, but north and west of Lake Clark it was less than a quarter of an inch thick. So thin a layer of very fine ash quickly disappears in the vegetative covering of the ground and could be detected only at exceptionally favorable places. It was not noted by either Smith or the writer north of Lake Clark.

MINERAL RESOURCES

As is to be expected of a region which has been so little visited by white men and so much of which is still unmapped and unexplored, little is known of its potential mineral resources. Until the Geological Survey expedition of 1926 the upper valley of the Skwentna above Portage Creek was unknown, and no record could be obtained of its having been visited by white men. Similarly, the fact that a large eastward-flowing river, the Chakachatna, drained a basin lying west of Mount Spurr and that its basin contained two rather large lakes was the discovery of the Geological Survey expedition of 1927. Possibly one or two white men had entered that

[55] Smith, P. S., op. cit. (Bull. 655), pp. 100–101.

basin, but they left no record of their discoveries. There was almost as great a lack of knowledge regarding the headward basin of the Stony River and of the western front of the Alaska Range between Lake Clark and the Stony River until the expeditions recounted in this report had been made. As a result of the difficulty of access to the region and the ignorance of the routes by which it could be most easily reached, the southern Alaska Range has been neglected by prospectors. Only in the better-known areas around Lakes Iliamna and Clark has any prospecting of consequence been done, and that by only a few men and at scattered localities. Since preliminary maps of the recently surveyed areas have been issued some interest has been noted in the region, and the quick and easy method of reaching it by airplane has been utilized by a number of trappers and prospectors. It may safely be stated, however, that great areas in this part of Alaska have escaped even a casual examination of their mineral possibilities.

So far as is known to the writer, no systematic prospecting for lode deposits has been done in the upper basins of the Skwentna and Stony Rivers, in the Chakachatna Basin, or in the region between the Stony and the Chilikandrotna. Under present conditions of transportation no lodes could be mined at a profit in these areas except those carrying precious metals, and even gold and silver lodes would need to be of high tenor to merit development. No such rich lodes have yet been found, though the general geologic relations, which show sediments cut by granitic intrusive rocks, suggest that lodes carrying gold, silver, and the sulphides of lead, zinc, and iron may well exist in the region. Pyritic mineralization in the argillite and graywacke near granitic intrusive bodies is common in the upper Skwentna Basin, and in many places the sediments near the contact with intrusive rocks are colored a rusty red by the oxidation of the iron pyrite. Specular hematite was observed in altered sediments near the north end of the Twin Glaciers, in which the Skwenta heads. On the lower Styx River, in the basin of the South Fork of the Kuskokwim River, a conglomerate band in the sedimentary group is in places heavily impregnated with pyrite. Disseminated pyrite is commonly found in the sediments near the granite contacts. It can therefore be definitely stated that the region shows considerable mineralization, though throughout most of it sufficient prospecting has not been done to determine whether or not commercially valuable lodes exist there.

As for the possibility of finding gold placer deposits of value, it should be borne in mind that in comparatively recent geologic time this region was subjected to severe glaciation, in which the mountain valleys were filled with moving ice to a depth of several thousand feet, and that this ice completely covered the Cook Inlet lowland and on the western face of the range pushed far out through the foothills to the lower country there. This glacial ice scoured out the mountain valleys and carried away most of the stream gravel that lay in its path. It is quite possible that this gravel in places contained concentrations of placer gold, but most of it was removed by the ice and scattered.

Since the retreat of the glaciers erosion has been active, but its accomplishments are small, and too little erosion of bedrock has taken place for the accumulation of extensive new stream placers from lodes. In a few places local concentrations, either from bedrock sources or by the reconcentration of older gravel, have occurred, and it is always possible that remnants of preglacial placers that through some unusually favorable situation have escaped removal by the glaciers may be found.

The lode deposits of this region that have received attention from prospectors are all in its southern part, near the shores of Iliamna Bay and of Lakes Iliamna and Clark. They include deposits that contain gold, silver, copper, lead, molybdenum, and manganese. Coal occurs in the northeastern part of the region. In the area immediately adjoining this region at its southeastern margin there are petroleum seepages, and not far to the northwest of it there are lodes containing mercury and others containing gold that have been operated on a commercial scale. Within the region here described, however, no lode mine is now or has been in the past actively productive, and the only mineral output has been a small amount of placer gold.

LODE DEPOSITS

Most of the lode deposits of the region in the vicinity of Iliamna Bay and near Lakes Iliamna and Clark were visited in 1909 by Martin and Katz [56] and have not since been examined by a member of the Geological Survey, although several competent mining engineers have examined some of them more recently, and it is known that much development work has been done on several of these properties since the descriptions here summarized were written. The fullest printed description of these properties is that of Martin and Katz, and the following paragraphs are a summary of their description. The names here given to the various prospects are those by which they were known when examined by Martin and Katz, although it is more than likely that the ownership of some of these properties has changed since that time.

[56] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 116–126.

COPPER

Dutton.—The claims of the Dutton Mining & Development Co. are about 9⅗ miles west-northwest of the head of Cottonwood Bay and about 3 miles southeast of the shore of Pile Bay, the eastern arm of Iliamna Lake, at a point 3 miles southwest of the mouth of the Iliamna River. They may be reached from Cottonwood Bay by road and trail, or from Iliamna village by trail. The claims, ranging in altitude from 1,200 to 1,900 feet, lie along the flanks of a peak that rises to a height of over 4,000 feet. They were located in 1902, and considerable development work, including exploration of the lodes and the construction of trails and buildings, was done during 1904 and 1905, but little has been done since.

The lodes are situated along the contact between an intricately plicated and closely appressed limestone of probable Triassic age and an older greenstone that was originally a diabase or diorite. Both these rocks are cut by small dikes composed of a very fine granular porphyritic andesite.

The prospective ore bodies are included within a zone averaging 200 feet wide that lies along the limestone-greenstone contact but is chiefly in the limestone. Within this zone two areas include the lodes that show most promise. There the ore "rock" consists of an aggregate of fibrous epidote and fine granular calcite with some quartz in which there are scattered small crystals of pyrite. This aggregate is interlaced by irregular veinlets, a fraction of an inch to 1 inch in thickness, of quartz and of calcite containing chlorite and chalcopyrite and in places also pyrite. Locally also molybdenite is present in minute scattered particles. There has been no commercial production of ore from these claims.

Copper King.—The Copper King claims lie on a steep mountain slope about 1⅓ miles west of the head of Iliamna Bay and one-third mile south of the road to Iliamna village, at an altitude of 1,000 to 1,500 feet. When last visited by a member of the Geological Survey they were developed only by shallow surface pits and cuts. The prospects lie near the contact between hornblende granite and greenstone. Within the granite there are small areas of crystalline limestone and irregular masses of garnet and of magnetite-bearing rock. The country rock is cut by veins of quartz and epidote. The prospective ore is magnetite-bearing rock impregnated with chalcopyrite. It is reported that although some rich ore has been found, it is irregularly distributed in bodies of small size.

Durand.—The Durand claims are 1 mile from the shore of Pile Bay and about 2½ miles southwest of the mouth of the Iliamna River, at an altitude of 1,000 feet. When examined, in 1909, the developments consisted of two shallow pits opened on a 10-foot quartz vein that strikes N. 80° E. (magnetic) and dips 45° NE. The country rock, a schistose greenstone, is impregnated with pyrite for 4 feet from the vein. The vein contains disseminated masses of chalcopyrite and pyrite, with copper carbonates present in the weathered portions.

Millet.—The Millet claims, on the north shore of Iliamna Lake some 22 miles west of Iliamna village, lie along a zone that strikes N. 35°–40° W. (magnetic) in a fine-grained bluish-white limestone. This zone is parallel to the contact with a dark fine-grained diabase and about 100 to 150 feet from it. Near the lake shore both diabase and limestone are overlain by a thin capping of tuffaceous porphyry. When visited, in 1909, the claims were developed by seven open cuts, each of which crossed the entire width of the mineralized zone. The mineralized zone, the limits of which are sharply defined, is from 22 to 42 feet wide and has been traced for 3,500 feet. Both its walls are crystalline limestone, much shattered and healed by white calcite seams. The mineralized rock is a dark-bluish, more or less coarsely crystalline limestone, traversed at intervals of 1 to 10 feet by fracture zones in which the intricately shattered limestone has been cemented by calcite and sulphides, refractured, slickensided, and recemented. These fracture zones, a fraction of an inch to 1 foot wide, are very irregular, though having a general trend of N. 35°–40° W. (magnetic) and a dip of 75°–90° NE.

The mineralization introduced chalcopyrite, pyrite, calcite, and quartz. The sulphides appear mainly with calcite as vein fillings, though they have impregnated the limestone to some extent. The veins are broken, crumpled, and slickensided, and their contained calcite is coarsely recrystallized, with the fractures refilled by calcite, quartz, and small amounts of sulphides. Picked samples of the ore are said to have assayed 10 percent of copper and to have carried small quantities of precious metals.

Kasna Creek.—Several lode claims have been located about 2 miles above Kontrashibuna Lake on a tributary stream of steep gradient that lies among ragged mountains in a hanging valley. The prospect, which at the time of examination in 1909 was developed only by one small hole, was situated in a belt of limestone about 2,000 feet wide and consisted of a zone some 75 feet wide lying parallel to the strike of the limestone. Within this zone there has been considerable mineralization by hematite, chalcopyrite, pyrite, quartz, calcite, and amphibole, segregated to some extent into several parallel bands. Two of these bands, each 7 to 10 feet wide, consist almost entirely of aggregates of specular hematite with a little quartz. Other bands of similar width contain severely shattered dense gray limestone with bunches of amphibole, hematite, quartz, and chalcopyrite. These bands are cut by irregular stringers of chalcopyrite, pyrite, and quartz. Some stringers of solid chalcopyrite several inches thick were seen. Pyrite is nowhere an abundant constituent of the mineralized zone. No oxidized ores or secondary minerals are present except a thin surface film of limonite and copper carbonates.

SILVER

Duryea.—The only lodes that are known in this district in which silver is the mineral of greatest value are in the same limestone belt in which the Dutton copper prospects, already described, are located. When examined by Martin and Katz, in 1909, the only claims on which any considerable development work had been done were the Duryea claims, about 14 miles by road and trail west of the head of Cottonwood Bay and about 6 miles by trail south-southwest of Iliamna village.

The limestone in which the lodes lie is not continuously exposed but is visible in approximately parallel belts of various widths. It is intricately plicated, with closely appressed minute folds. The strike is parallel to the trend of the limestone belt, here having a northeasterly direction, and the dips are steep. The limestone is cut at nearly right angles by numerous small vertical dikes 3 feet or less in width and by some larger dikes that are parallel to the strike.

Small masses and nodules of black manganiferous iron oxide have been found on the limestone surface at a number of places, and wherever these localities have been explored by test pits bodies of silver-bearing galena and sphalerite have been found along fissures in the limestone. Along the fracture zones, which appear to be vertical, the limestone is brecciated, and sphalerite, galena, and a small amount of pyrite occur in the fractures. The limestone is also impregnated to some extent with these sulphides. At the time of examination the openings failed to penetrate below the zone of weathering, and the sulphides visible were much oxidized and the limestone decayed. It was therefore not known whether or not there had been replacement of the limestone. The abundance of limonite, even with the least-weathered galena and sphalerite, indicated that pyrite would be found in the unoxidized ore at greater depth.

The distribution of manganiferous gossan on the surface and in the various test pits indicated that a fairly persistent mineralized fissure zone striking about N. 20° E. (magnetic) and with a nearly vertical dip lies near the eastern margin of the limestone and has a length of about 1 mile. The owners of the claims on this zone reported assays some of which yielded as much as 196 ounces of silver and $20 in gold to the ton, 35 to 50 percent of lead, and 15 to 20 percent of zinc. No reliable report concerning developments on this property since 1909 is available to the writer.

GOLD

The Duryea claims, described above, are said to have yielded assays sufficiently high in gold to justify mining for their gold content if sufficient ore of the higher tenor could be found. These claims, however, were formerly considered by the owners as valuable chiefly for their silver. A few other claims have been located in this region as gold lode prospects, but none have so far been placed on a productive basis. Martin and Katz [57] mention some gold lode claims near Iliamna Bay, assays from which had shown moderate quantities of gold, also other undeveloped prospects on the south shore of Iliamna Lake, 23 miles above its outlet. Prospectors have from time to time operated in the vicinity of Lakes Clark and Iliamna, and a few men have penetrated into the area north of Lake Clark and into the upper Stony Basin, but so far as is known to the writer no gold lode prospects of demonstrated value have been found.

GOLD PLACERS

The earliest prospecting in any new region is almost always done in the search for placer gold, for rich stream placers can be worked with simple equipment and with small investment of capital, and the product can be easily transported out and sold. The region here described is no exception to that rule, and most of the streams in its more accessible portions have been tested by the prospector's pan. So far the results have been disappointing, though the possibilities have by no means been exhausted. A little placer gold has been found on some northern tributaries of the Chulitna and on several headward tributaries of the Kijik River. The most ambitious attempt to develop the gold placer deposits on any one stream took place in 1910 to 1912 on Portage Creek, which flows into Lake Clark from the northwest some 10 miles northeast of the mouth of the Kijik River. Several men worked for three summers on the lower four claims on that stream, and it is reported that the total value of the gold recovered was about $2,000. Desultory mining has been done at a few other localities near Lake Clark, but the results were discouraging, and during the last few years no placer mining has been in progress there.

It is reported that a small gold-placer stampede took place about 1912 to what was then called the " Stony River country." The focus of interest was at the canyon of Bonanza Creek, a tributary of the

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[57] Martin, G. C., and Katz, F. J., op. cit. (Bull. 485), pp. 125–126.

Mulchatna River that flows westward from the foothills that lie between the Mulchatna and the Chilikandrotna. Some placer gold prospects were found, but only a few dollars' worth of gold was recovered. It is said that there is some ground on Bonanza Creek that might be profitably worked if the region were less remote and the cost of hauling in supplies and equipment were not prohibitive.

It is known that coarse gold exists in small amounts in the lower basin of the Styx River, though a little prospecting there failed to reveal paying ground. Colors of placer gold are also reported at various other places within the region, and it is possible that workable placer ground may yet be found in it, though so far the results of prospecting have been disappointing.

COAL

Within the region here under consideration coal is found only in the sediments of Eocene age, and these occur only in the northeastern part of the area shown on plate 1. The beds of the coal-bearing series, being soft or only moderately hard, have suffered greatly from erosion and now occur for the most part in the lowlands, where they are generally covered by glacial deposits, gravel, soil, and vegetation. Most of the outcrops occur along steep stream banks or in beach cliffs, and the formation, which is doubtless of widespread occurrence throughout the lowlands of the Skwentna, Yentna, and Susitna Rivers and in the piedmont region east of the main range, nevertheless has very meager surface exposure. The geologic map, therefore, that shows only those areas of the coal-bearing formation where it is exposed at the surface by no means gives an adequate idea of the actual distribution of that formation beneath its cover of glacial and alluvial deposits.

At many localities, notably at Susitna station on the lower Yentna, in the upper Talushulitna Basin, on the Skwentna near the mouth of the Hayes River, on the Beluga and Chuitna Rivers, in the beach cliffs west of Tyonek, and in the headwaters of Straight Creek, the formation is known to contain coal beds, and at other places coal float on the stream bars indicates its presence in places not far away. At Susitna station and at a point on the Yentna about 7 miles above its mouth openings were made some years ago on coal beds, and a small amount of coal was mined for local use. The openings are now caved and inaccessible. It is reported that a coal bed about 4 feet thick, with a mild dip to the southwest, occurs on a headward tributary of the Talushulitna. Canyon Creek has coal float on its bars, though the outcrops of the coal formation were not seen. High water and the swift current of the Skwentna at the mouth of the Hayes River prevented a close examination of the coal outcrops there, but a considerable exposure on the southeast bluff of the river disclosed a number of coal beds of varying thickness, and on the north bluff two beds were seen, one about 10 feet thick and the other about 2 feet. Brooks [58] states that Eldridge observed about 1,000 feet of strata of this formation near Tyonek, in which there were 24 coal beds, ranging in thickness from 1 to 15 feet, and coal float was seen on Straight Creek, though no coal was observed in the section examined there.

At all the localities mentioned above the coal is of similar quality to that now known to crop out at a great many places in the Susitna lowlands and around the margins of Cook Inlet. It is a lignite of medium grade and burns readily in an open fire or stove. In the region here under discussion it lies so remote from transportation that it has no present commercial value, especially because there are abundant supplies of equally good or better coal at more accessible points. It may, however, prove of great value for local use at points near the coal beds, either for domestic fuel or for development of power for mines or other industries.

PETROLEUM

So far as is known there are no petroleum-bearing rocks in this region. The sediments of probable Paleozoic age include gneiss, mica schist, quartzite, crystalline limestone, and possibly slate and chert. All these rocks are so highly metamorphosed that they may be dismissed as possible sources of petroleum. The Mesozoic sediments, including crystalline limestone and chert, of Upper Triassic age, and argillite, slate, and graywacke, of Jurassic and Cretaceous age, are also highly metamorphosed and cut by abundant masses of intrusive rock. Although these beds where least metamorphosed might conceivably yield petroleum, they have so far shown no indications of containing it, although abundantly and deeply exposed by erosion. Similar sediments, of probably the same age, are present in wide areas in the Alaska Range north of this region and constitute the prevailing formation over thousands of square miles in Kenai Peninsula and the Chugach Range. Although these rocks have been closely scrutinized by a large number of observers, no trace of petroleum has been found in them. They therefore offer little promise of yielding oil in the southern Alaska Range.

The only Tertiary sediments in this region are the beds of the Eocene coal-bearing formation, which also have nowhere else in Alaska been found to be oil-bearing and are considered by the

[58] Brooks, A. H., op. cit. (Prof. Paper 70), p. 95.

writer a most unlikely source of oil. The other rocks of the region are all either intrusive or extrusive igneous rocks, which can be at once dismissed as possible sources of oil. In short, there seems little likelihood that the region here described will ever be the scene of oil production. To be sure, Jurassic beds, quite different from any described in the foregoing pages, are known to occur on the coast of Cook Inlet just east of the southeast corner of the area shown on plate 2, and these beds contain some oil, as is shown by petroleum seepages and by several shallow wells drilled in them that yielded small amounts of oil and gas. These Jurassic beds are similar in age and lithology to beds farther south along the Alaska Peninsula which also contain oil seepages. They are of much simpler structure than the Jurassic and Cretaceous beds here described, are much less highly metamorphosed, are of more porous texture, and contain fossils that represent an abundant marine fauna, whereas the slates and graywackes of this region are relatively impervious, highly metamorphosed, and almost devoid of evidences of marine life. The conditions under which the upper Mesozoic sediments were deposited were very different in these two areas, and whereas along lower Cook Inlet the Jurassic sediments offer promise in the search for commercial oil fields, those in the Stony and Skwentna Basins are not considered to be probable sources of petroleum.

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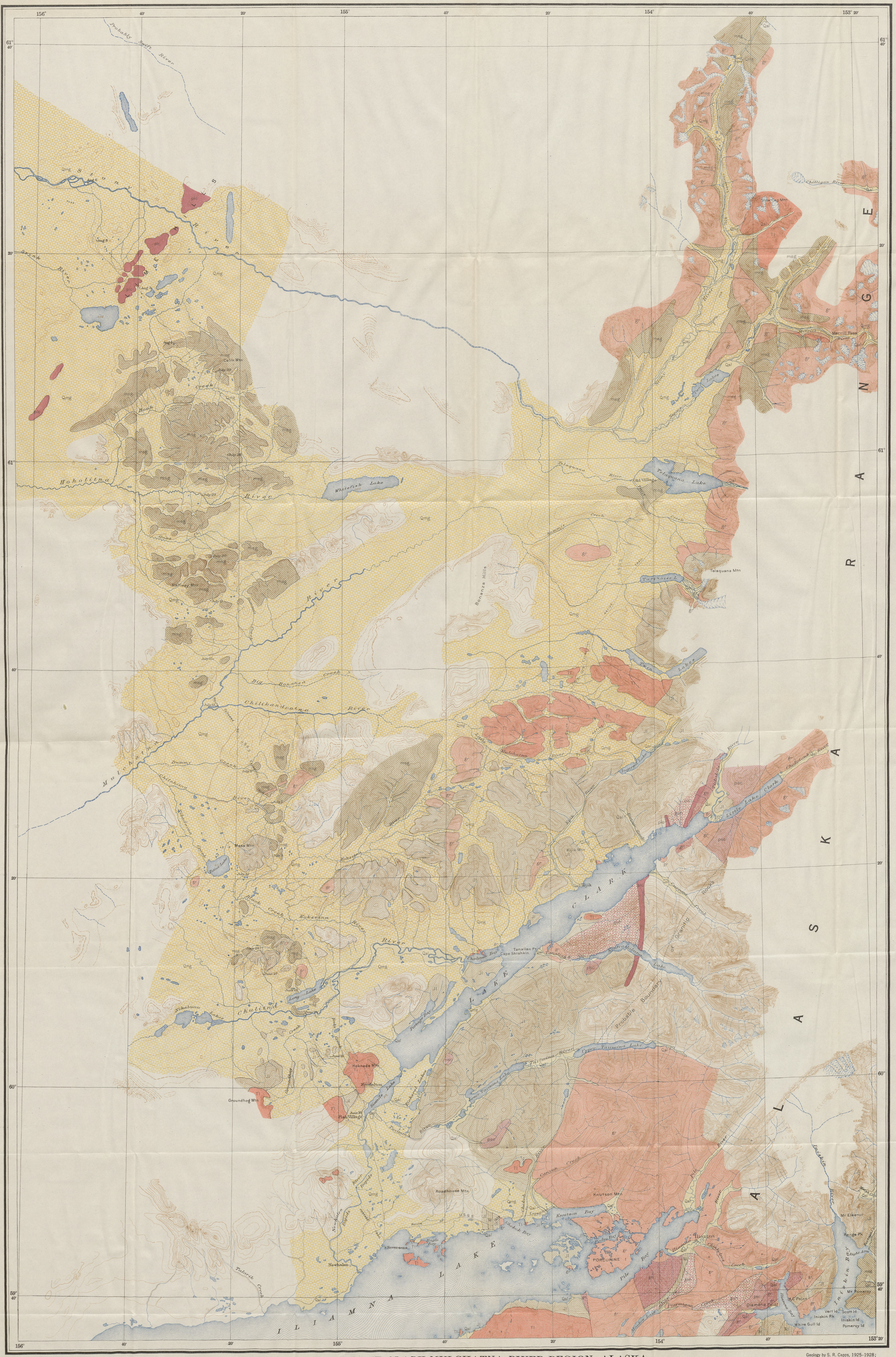


EXPLANATION

Recent

Qal — Present stream gravel, sand, and silt, in part outwash from existing glaciers; delta and beach deposits.

Recent and Pleistocene

Qmg — Morainal deposits and outwash gravel of Pleistocene glaciers; moraines of present glaciers, in part underlain by ice; terrace and beach gravel.

(QUATERNARY)

Tl — Bedded lava and tuff of Mulchatna-Stony River region

(TERTIARY)

UNCONFORMITY

Upper Cretaceous and older

msg — Undifferentiated complex, mainly black argillite, slate, and gray-wacke with some sandstone and conglomerate, and minor amounts of lava and tuff. Probably in part Upper Cretaceous.

UNCONFORMITY

Lower Jurassic to Cretaceous

Jl — Undifferentiated complex, mainly medium basic to basic lava and tuff, but locally containing considerable metamorphosed sediments and some intrusive rocks.

UNCONFORMITY

Triassic or older

Trl — Limestone deformed and recrystallized

(MESOZOIC)

Late Paleozoic or Mesozoic

gn — Greenstone (Triassic?)

UNCONFORMITY

psc — Slate and chert

Later Paleozoic (?)

plc — Crystalline limestone and calcareous chert

Paleozoic (?) and older

gsh — Gneiss, mica schist, and quartzite

(PALEOZOIC)

INTRUSIVE ROCKS

gr — Granitic rocks locally somewhat gneissic

(MESOZOIC)

GEOLOGIC MAP OF LAKE CLARK-MULCHATNA RIVER REGION, ALASKA

BY STEPHEN R. CAPPS

Scale 1/250000

5 0 5 10 15 Miles

5 0 5 10 15 20 Kilometers

APPROXIMATE MEAN DECLINATION, 1929 — TRUE NORTH — MAGNETIC NORTH — 25½°

Contour interval 200 feet

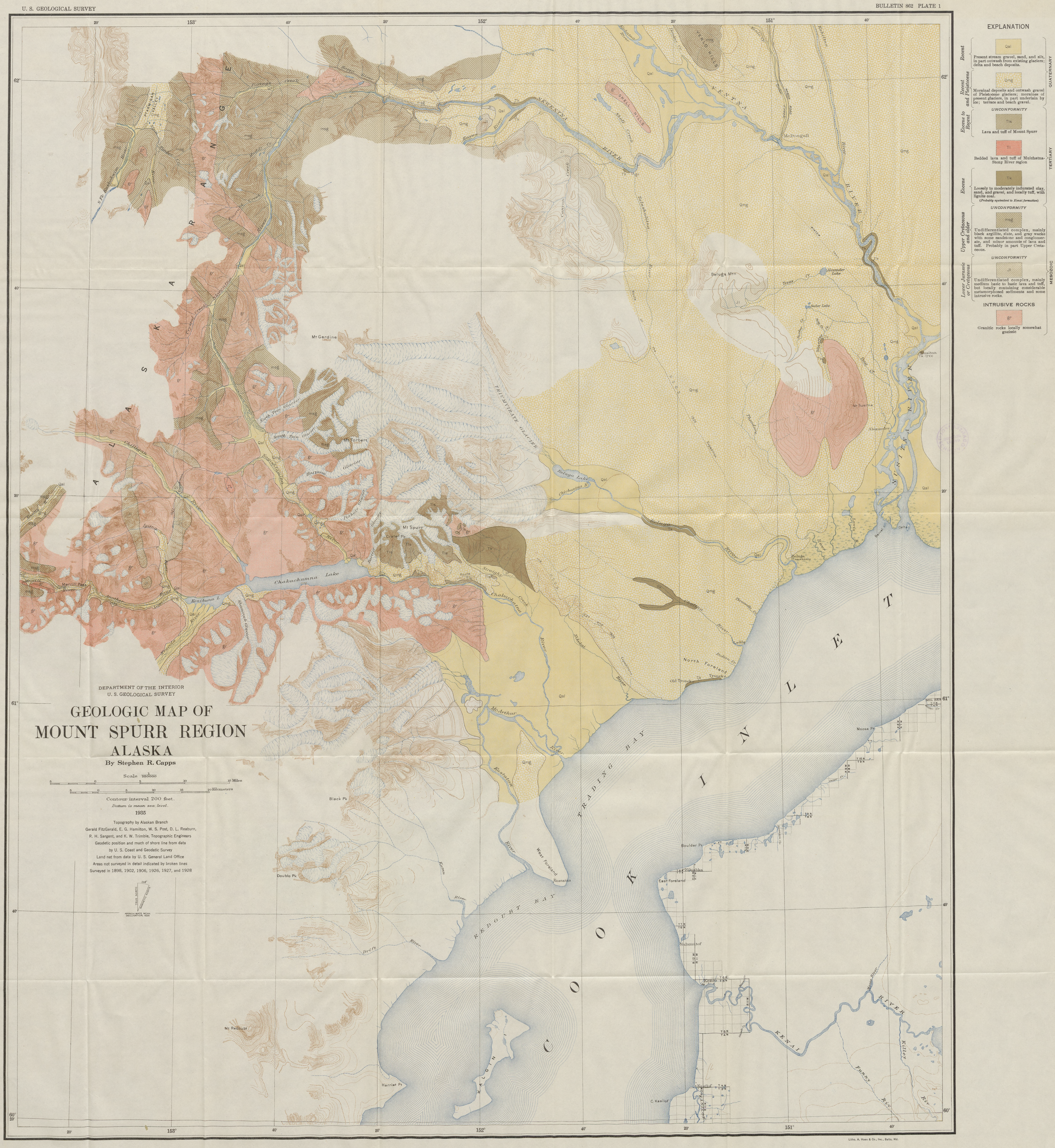
Datum is mean sea level

Broken lines represent probable topography, of unsurveyed areas

1935

Topography by Alaskan Branch
Gerald FitzGerald, C. E. Giffin, C. P. McKinley, R. H. Sargent, and D. C. Witherspoon, Topographic Engineers
Surveyed in 1909, 1914, 1928, 1929
Geodetic position based upon data by U. S. Coast and Geodetic Survey

Geology by S. R. Capps, 1925-1928; P. S. Smith, 1914; G. C. Martin and F. J. Katz, 1909.



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